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Course Code : CC04

Unit-I
Forest Ecosystem

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STRUCTURE AND FUNCTION OF FOREST ECOSYSTEM(TERRESTRIAL ECOSYSTEM)

- A forest is an area with a high density of trees.
- World's total land area is 13,076 million hectares - (Source: FAO; 1989). Of which total forests account for about 31% of the world's land area.
- In India, the forest cover is roughly 19% of the total land area.
- The forest ecosystems are of great concern from the environmental point of view.
- It provides numerous environmental services like; Nutrient cycling, Maintaining biodiversity, Providing wildlife habitat, Affecting rainfall patterns, Regulating stream flow, Storing water, Reducing flooding, Preventing soil erosion, Reclaiming degraded land & many more….
- Apart from environmental values, forest ecosystems have some traditional values as well.
- Examples are: Fire Wood & Timber. Fruits. Gums. Herbs & drugs.

Structure and Function of Forest Ecosystem

- **Forests Ecosystem**
- Forests are extensive, self-sustained, wooden tracts with biotic community predominated by trees forming a sort of canopy. Forests cover about 40% of the land. In a forest, the tree canopy makes the underneath shadier and humid. This helps in the growth of shade tolerant short trees, shrubs, herbs, vines, ferns and mosses. The latter produce layers or strata of vegetation. The phenomenon of having two or more layers of vegetation in a forest is called forest stratification. Major forest types of the world are north coniferous, temperate deciduous, temperate evergreen, temperate rain, sclerophyllous, tropical scrub and tropical deciduous and tropical rain forests.

Characteristic features

The forest environment is less variable. The upper most level i.e., tree tops forms the canopy, which is exposed to sunlight and wind fury, but it does not permit them to the ground. This result in

a. Passing diffused sunlight to the ground

b. The moisture content of the soil remains more or less stable and is maintained for longer periods because of the absence of evaporation.

c. There is no loss of water by transpiration below the forest canopy, because the tree tops act as wind breakers.

d. Temperature is generally lower in summer and is higher in winter. Also the days are cooler and nights are warmer than the surroundings.

e. The forest floor is thickly carpeted with lichens and mosses along with several herbs.

- **Abiotic components**: These are the inorganic as well as organic substances present in the soil- and atmosphere. In addition to the minerals present in forests, the dead organic debris - the litter accumulation is also found chiefly in temperate climate. Moreover, the light conditions are different due to complex stratification of the plant communities.
- **Abiotic components of a forest ecosystem include soil, water, inorganic carbon, solar energy, temperature, humidity, pH, acidity, topography, oxygen, and nutrients.**
- They are collectively defined as all components or factors that are non-living or inorganic in nature.
- Forest abiotic components can be categorized into features and conditions.
- The features include soil, water, nutrients, minerals, oxygen, topography, and solar energy. These abiotic components are relatively constant and do not easily change from one form to another.
- Conditions include humidity, temperature, *intensity* of solar radiation, acidity, turbidity, and biological oxygen demand. These components are easily changed, compared to the abiotic features.
- *Solar energy* from sunlight is the primary form of energy in a forest ecosystem. It is captured by green plants, algae and cyanobacteria, and used to produce biomass. The competition for sunlight among plants leads to the typical growth pattern of forest canopies and ground vegetation

- *Soil* is a very important abiotic component of forest ecosystems. It provides support to vegetation, and serves as a storage medium for nutrients, water and carbon. Forests soils are usually well-developed as a result of the growth of roots through them. They are also usually rich in organic matter, that includes plant and animal remains.
- *Water* is another essential resource in forest ecosystems. It is stored in various media, including soil, underground aquifers, rivers, and biomass. The natural cycling of water in the hydrological cycle is a basic process required for organic continuity and survival.
- *Oxygen* is released by plants as a byproduct of photosynthesis. This component is needed for respiration and survival of animals.
- *Inorganic* carbon in a forest ecosystem, commonly occurs in the form of carbon dioxide, which is stored in soil through carbon sequestration. Biomass also contains carbon, which is stored through photosynthesis.
- Temperature and Humidity, determine the effectiveness and trend of various important processes in a forest ecosystem, such as evaporation, respiration, and biodegradation.
- Forest topography may vary widely from flat to mountainous. Landscape modification is not very active here because vegetation protects the land from heavy wind, rainfall and floods. The topography of a forest ecosystem affects water flow, vegetation growth patterns, and nutrient distribution.
- Ezoic Nutrient concentration, pH, turbidity, solar intensity, and biological oxygen demand (BOD) are all physicochemical parameters that determine the quality and productivity of soil and water in the forest ecosystem.

- **Biotic components**: The living organisms present in the food chain occur in the following order:
- Producers. These are mainly trees that show much species diversity and greater degree of stratification especially in tropical moist deciduous forests. The trees are of different kinds depending upon the kind of the forest formation developing in that climate. Besides trees, there are also present shrubs and ground vegetation. In these forests, dominant members of the flora, the producers, are trees such as *Tectona grandis, Butea frondosa, Shorea rubusta* and *Lagerstroemia parvifiora*. In temperate coniferous forests, shrubs and ground flora are insignificant. In temperate deciduous forests the dominant trees are species of *Quercus rubra, Acer rubrum, Betula, Thuja orientalis, Picea orientalis* etc., whereas in a temperate coniferous forests, the producer trees are species of *Abies, Picea, Pinus, Cedrus; Juniperus, Rhododendron* etc.
- Consumers, these are as follows:
- Primary consumers: These eat the herbivores that include the animals feeding on tree leaves such as ants, flies, beetles, leafhoppers, bugs and spiders etc., and larger animals grazing on shoots and/or fruits of the producers, the elephants, deer, motes, squirrels, flying foxes, fruit bats, mongooses etc.
- Secondary consumers: These are the carnivores like snakes, birds, lizards, fox etc. feeding on the herbivores.
- Tertiary consumers: These are the higher level carnivores like lion, tiger etc. that eat carnivores of secondary consumer's level.
- 3. Decomposers: These are wide variety of microrganisms including fungi (species of *Aspergillus, Coprinus, Polyporus, Ganoderma, Fusarium, Altemaria, Trichoderma* etc.), bacteria (species of *Bacillus, Clostridium, Pseudomonas, Angiococcus* etc.), and actinomycetes, like species of *Streptomyces* etc. Rate of decomposition in tropical and subtropical forests is more rapid than that in the temperate ones.

Tectona grandis

Butea frondosa

Shorea rubusta

Lagerstroemia parvifiora

Quercus rubra *Acer rubrum* *Thuja orientalis* *Picea orientalis*

Producers: Different tree species

Consumers in a Forest Ecosystem

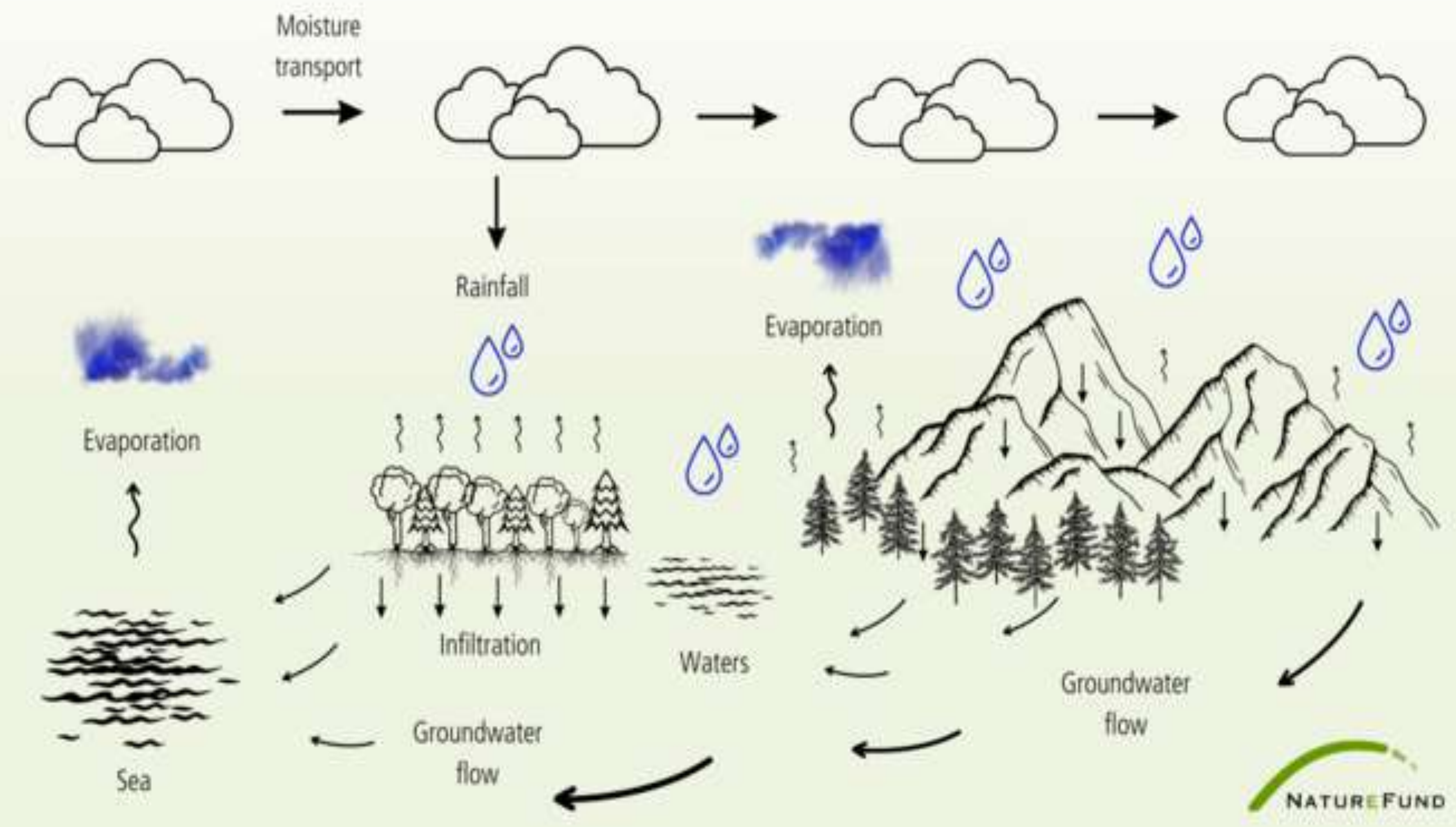
Decomposers in a Forest ecosystem

Fig.1.4 Forest Ecosystem

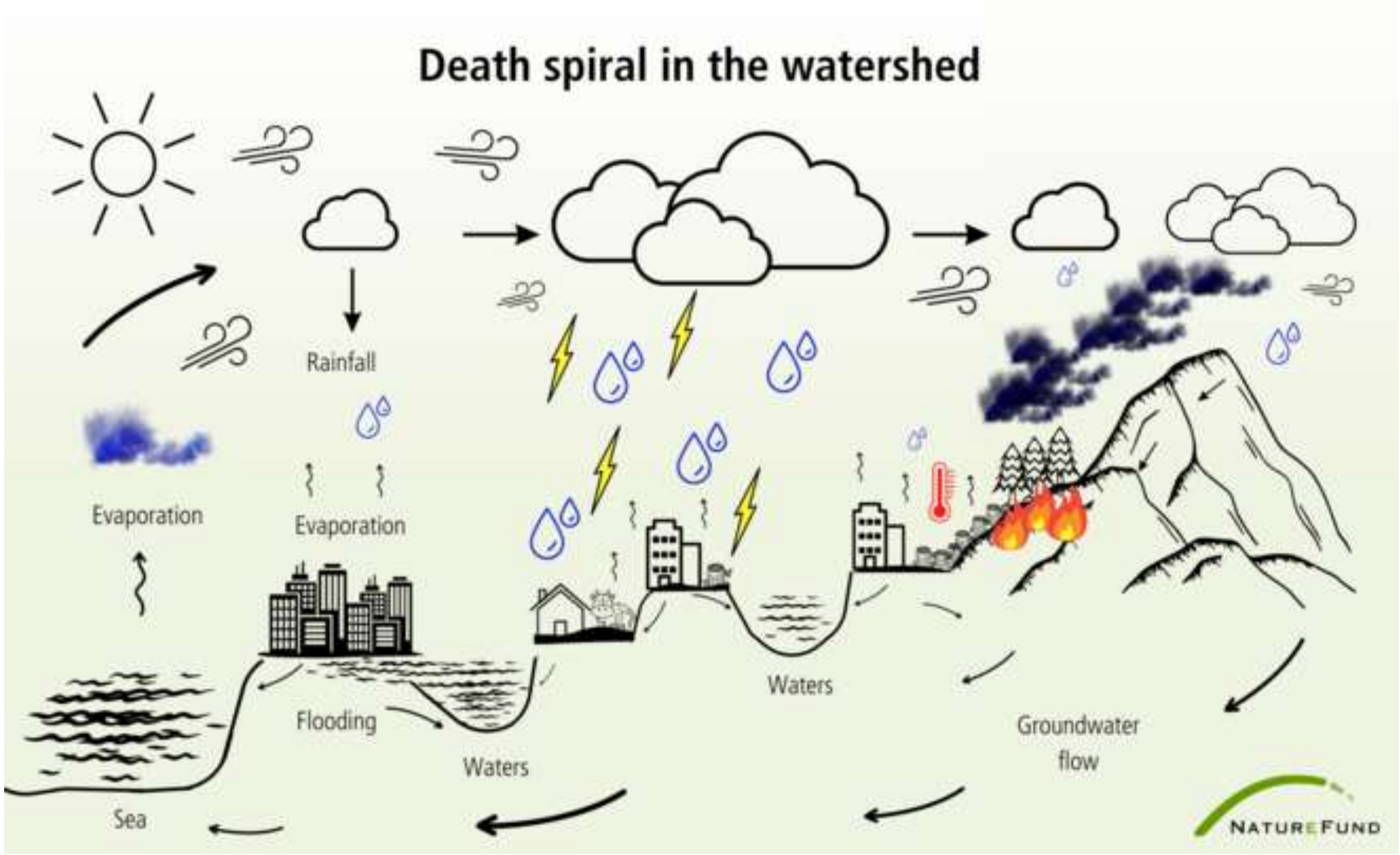
FOREST MICROCLIMATE

- Forests provide shade, which reduces direct sunlight and lowers temperatures in the understory. The dense canopy of trees blocks a portion of the incoming solar radiation, preventing excessive heating. This shading effect can create a cooler microclimate within and near the forest.
- What are the 5 factors of microclimate?
- The microclimates of a region are defined by the moisture, temperature, and winds of the atmosphere near the ground, the vegetation, soil, and the latitude, elevation, and season. Weather is also influenced by microclimatic conditions. Wet ground, for example, promotes evaporation and increases atmospheric humidity.
- **Forests and their importance for a functioning water cycle**
- The forest and the water cycle are closely interrelated. For example, the amount of annual precipitation determines whether forests can grow and remain healthy. While the forest as a landscape form has a considerable influence on where and how much precipitation falls and is absorbed.

Intact water cycle over land areas



- Water is present in the atmosphere in the form of water vapour, which is continuously regenerated by evaporation processes. As a result, water droplets or ice crystals condense at high altitudes and remain suspended in the atmosphere up to a certain size in the form of clouds or near the ground as fog.
- The wind can transport these over long distances. After reaching a certain size, the water droplets or ice crystals return to the land surfaces in the form of precipitation. The rain initially falls on the vegetation if there are no buildings, other sealing or bare soil. Part of the precipitation is retained by the vegetation and evaporates directly from there (evaporation). The remaining part of the precipitation penetrates the soil (infiltration).
- The amount of this infiltration depends on the water absorption capacity, the permeability of the soil and the local vegetation. If the intensity of the precipitation is higher than that of the water absorption capacity, the rain will run off superficially. This follows the path of the greatest gradient and flows to the nearest stream or river. The greater the amount and duration of precipitation, the greater the slope and the lower the infiltration capacity of the soil, the greater the surface runoff. The forest delays rapid runoff of precipitation into streams or rivers.
- In the forest, only a small part of the precipitation hits the ground directly through the gaps in the vegetation. Most of the rain falls first on the treetops and evaporates directly there, or drips onto shrubs or mosses before it seeps into the ground. A healthy forest soil also has countless interstitial spaces and thus a high infiltration capacity. Much of the rainwater seeps into deeper areas and enriches the groundwater. Only a small part runs off above ground. Thus, forest stands can reduce floods and soil erosion.


Death spiral in the watershed
Rainfall
Evaporation
Evaporation
Flooding
Waters
Waters
Groundwater flow
Sea
NATUREFUND

- However, the water cycle looks different in our increasingly densely populated and sealed landscape with strongly decreasing natural areas and constantly growing agricultural areas. A warmer climate, dying forests and drying up streams are the result.
- According to science, it is predicted that current water use, combined with climate change and land use change, could create a water crisis for billions of people worldwide and countless natural areas.
- For example, water is diverted from the natural cycle to feed billions of livestock, irrigate vast fields and supply households and the economy.
- Climate change is also already taking its toll: as temperatures rise, the atmosphere can absorb more moisture, leading to increased heavy rainfall events. According to climate impact research, the following scenario could therefore occur in the future: Many dry regions could become drier and drier, while other regions could have to struggle with floods.
- At the same time, forests, wetlands and other ecosystems that are extremely important for the functioning water cycle are being destroyed at an alarming rate worldwide.
- For example, deforestation means that less water evaporates in the respective region, so that fewer rain clouds are formed and as a result the amount of precipitation also decreases in other regions.

- The disappearance of forests also has other negative consequences for the water cycle. If a formerly forested area is used as farmland, for example, the soil quickly becomes compacted due to cultivation with large machines and thus absorbs less water. When it rains, the rainwater reaches the soil unchecked. Due to the lack of infiltration capacity, only a small part of the water seeps into the soil. Most of it is carried away via surface runoff to the nearest watercourse. This leads to increased soil erosion and may result in more floods. At the same time, less groundwater is stored, as the forest soil plays a major role in infiltrating rainwater into the soil and thus contributing to groundwater formation. Without forests, soils dry out more quickly and are often no longer able to fully withstand drought stress during periods of drought.
- Forest protection for an intact water cycle
- If we look at the current consequences of our unsustainable land use - heavy precipitation events and the associated floods, dry farmland where the seeds dry up and the sharply falling groundwater level - it becomes clear that more efforts must be made to protect our ecosystems. Politicians certainly have a duty to do this, but every individual can also contribute something to the protection of nature. Discover our holistic tree projects, with which we protect forests worldwide and reforest degraded areas.

FOREST PRODUCTIVITY

ROLE OF FORESTS

- **Forests serve two roles viz.,**
- **a) Productive role and   B) Protective role**
- **a) Productive role**
- 1. Food
- 2. Fuel
- 3. Shelter
- 4. Clothing
- 5. Timber
- 6. Industrial wood
- **b) Protective role**
- 1. Climate amelioration
- 2. Soil and water Conservation
- 3. Wildlife habitats

- **a) Productive role**
- It is estimated that the forest products contribute about 1% of world gross domestic product (GDP). The annual turnover of timber and other wood products from forests is valued at more than US$200 billion. The demand for commercial timber and other products is ever increasing, and expected to rise by 50% by 2010. Apart from that, non-timber products like rubber, cotton, medicinal products, food and so on represent significant economic value.
- **1. Food**
- a) Rhizome : *Amarphous campanulatum*, *Cyprus rotandus*
- b) Root and aerial : *Dioscorea* , *Moringa oleifera Caryota urens*, *Bauhinia variegata*
- c) Buds : *Dillenia pentagyna*, *Phoenix sp*
- d) Sap, and latex, : *Borassus flabellifer*, *Cissus rapanda* Bark
- e) Stems : *Cycas pectinata*, *Dendrocalamus strictus*
- f) Leaves : *Tamarindus indica*, *Moringa oleifera*
- g) Flowers : *Ficus glomerata*, *Madhuca indica*, *Bambax ceiba*, *Tamarindus indica*
- h) Fruits : *Aegle marmelos*, *Anacardium occidentale*, *Anona squamosal*, *Artocarpus heterophyllus*,*Borassus flabellifer*, *Capparis decidua*, *Diospyros melanoxylon*, *Emblica officinalis*, *Ferronia elephantum*, *Morus alba*, *Zizyphus spp*
- i) Seeds : *Anacardium occidentale* , *Juglans regia*, *Prunus amygdalus*, *Tamarindus indica*, *Dendrocalamus strictus*

- **2. Fuel**
- Wood is used as fuel for thousands of years, until the advent of coal, oil, gas, electricity, etc. Wood constitutes as chief source of fuel. Even today more than half of the total world consumption of wood is for fuel-wood. Wood remains the major source of domestic fuel in India. Approximately 175 mm3 of wood is used as fuel in the country. It is estimated that by 2010, most of the 3 billion people who depend on it for their daily living will find it hard to obtain. Already, rural families spend precious hours in collecting firewood instead of other productive work, something that causes losses to the tune of US$ 50 billion to the world economy.
- *Eg., Acacia spp, Casuarina equisetifolia, Prosopis, Neem, Leucaena leucocephala, etc.,*
- **3. Shelter**
- Wood is used for construction of buildings.
- Eg., Palmyra, Teak, Jack, etc.,
- **4. Clothing**
- Rayon cloth eg., Eucalyptus spp
- **5. Timber**
- Timber is a major forest produce and is used extensively for various purposes. In India most of the wood produced is used for construction of houses, agricultural implements, bridges, sleepers etc., In India 12 mm3 of timber is produced from our forests.More than 1500 species of trees are commercially exploited for timber in different parts of India. It is used in timber-based industries such as plywood, saw milling, paper and pulp, and particle boards.
- Many species like teak, sal, deodar, babul, sissoo, chirpine, adina, axlewood, rosewood, dipterocarpus, and etc.yield valuable timber.

- **6. Industrial wood**
- 1) Forest provide raw material to large number of industries eg: paper and pulp, plywood and other boards, packing cases, matches, toys etc.,
- Paper and pulp : Bamboos, Eucalyptus, casuarina
- Plywood : Teak, Rose wood, Terminalia etc.,.
- Packing cases : Pinus sp, Silver oak, Fir,
- Matchwood : Ailanthus, Simaruba, Bombax
- Toys : Adina, Redsanders, rose wood
- **7.Others**
- **i) Fibre and flosses**
- Fibres are obtained from tissue of certain woody plants, which are used for making ropes. Flosses are obtained from certain fruits and are used for stuffing pillows, mattresses, etc Flosses are obtained from *Ceiba pentandra* and fibres are obtained from *Agave sisalana*, *Sterculia urens*

- **ii) Grasses and bamboos**
- A large variety of grasses are found in the forests. About 30% of the 416 million livestock population graze in the forests. Among valuable grasses eg: Sabai (*Eulaliopsis binata*) is harvested annually 6.5 million tones and 80,000 tonnes of bamboo are harvested from forest every year.
- **iii) Essential oil**
- India produced about 1500 tonnes of essential oils during 1980, which was utilized in making soaps, detergents and chemicals eg. Eucalyptus, Bursera, Cymbopogan, *Santalum album* etc.,
- **iv) Oil seeds**
- Many tree species of *Madhuca indica*, *Pongamia pinnata*, *Shorea robusta*, *Azadirachta indica*, *Schleichera oleosa*, *Vateria indica* etc., produce oil-bearing seeds, which are commercially important. Presently these seeds are used in the soap industry. There is a potential production of about 1 million tonnes of oil every year from forests tree seeds.
- **v) Tans and dyes**
- Important tannins are extracted from myrobolan nuts, bark of wattles (*A.mearnsii*, *A.decurrens*, *A.dealbata*) and *Cassia auriculata* , leaves of *Embelica officinalis* and *Anogeissus latifolia*, bark of *Cleistanthus collinus*, fruits of *Zizphus xylophora*, *Cassia fistula*, *Terminalia alata*, *T.arjuna* etc., katha and cutch are obtained from *Acacia catechu.*
- **vi) Gums and resins**
- Gums and resins are exuded by trees as a result of injury to the bark or wood. Gums –eg: *Sterculia urens*, *Anogeissus latifolia*, *Lannea coromandalica*, *Acacia nilotica*, *Ptercapus marsupium*, *Butea monosperma* etc.,
- Resin is obtained from *Pinus roxburghii*

- **vii) Drugs, Spices and Insecticides**
- Important spices yielding drugs are *Rauvolfia serpentina*, *Hemidesmus indicus*, *Dioscorea spp*, *Atropa spp*, *Datura innoxia* etc,
- **Spices :** Seeds of *Carum carvi*, barks of *Cinnomomum zeylanicum*, dried capsules of *Elletaria cardomomum.*
- **Insecticides :** Pyrethrum and neem
- **viii) Tendu and other leaves**
- Tendu leaves (bidi leaves) (*Diopyrus melanoxylon*) and leaves of bauhinia spp, *Butea spp*, plates, dona etc.,
- **ix) Lac and other products**
- Lac is a resinous secretion of insects which feed on forest trees eg ; *Butea monosperma*. Silkworm is feed on *Morus alba* or *Terminalia alata*. Honey is produced from forests.
- **x) Fodder and grazing**
- About 30% of 416 million livestock population depend up on forest grazing and leaf fodder supply.**Eg;** *Luecaena leucocephala*, *Albizzia lebbeck*, *Hardwickia binata*
- **xi) Cane**
- Canes or rattans are the stems of a climber plant and are used for a large number of household items. It is used to make walking sticks, polo sticks, baskets, picture frames, screens, and mats.

B) PROTECTIVE ROLE

- **1. Forests as Earth's air purifiers**
- Forests form an effective sink for the carbon dioxide produced as a result of animal respiration, burning of fossil fuels, volcanoes and other natural and human-induced phenomenon. And if that is not all, a by-product of photosynthesis is oxygen. Thus, the Amazon forests are the Earth's air purifiers, given the large amounts of carbon dioxide they absorb from the atmosphere.
- Forests play a significant role in maintaining the CO_2 balance in the atmosphere without sufficient forest cover all the co_2 released in the atmosphere will not be utilised, resulting in a higher per cent of co_2 in the atmosphere.
- According to scientists, this will result in warming of the world temperature; disturbance in the climate etc., The CO_2 percent in the atmosphere has already reached 0.042 per cent against the normal of 0.03%. If this increases continuously higher temperature and other disturbances on the earth may bring unimaginaste miseries to mankind.
- **2. Climate amelioration**
- Forest increase local precipitation by about 5 to 10% due to their arographic and microclimatic effect and create conditions favourable for the condensation of clouds Forest reduce temperature and increase humidity. It also reduces evaporation losses.

- **3. Soil and water conservation**
- Forests maintain the productivity of the soil through adding a large quantity of organic matter and recycling of nutrients. The leaves are used as manure.
- Tree crowns reduce the violence of rain and check splash erosion. Forests increase the infiltration and water holding capacity of the soil, resulting in much lower surface runoff. This inturn results in checking of soil erosion.
- Forest checks floods. Forests intercept 15 to 30% of the caused due to siltation of river channels caused due to erosion. Forests and trees reduce wind velocity considerably. Reduction of wind velocity causes considerable reduction in wind erosion, checks shifting of sand dumes and halts the process of desertification. Forests by reducing erosion check the siltation of irrigation and hydel resources. Rapid siltation of various reservoirs in the country is the result of deforestation in the catchment areas of these reservoirs.
- Forest protect us from physical, chemical and noise pollution, dust and other particulates and gaseous pollutants cause serious health problems. Forests protect as from these pollutants. Forest and trees provide shelter and wind break effect which is beneficial to agricultural crops, particularly in arid and semiarid areas and increase agricultural production.
- **4. Wildlife habitats**
- Trees act as a habitat for wildlife.

Animals and Their Roles in Forest Ecosystem

- Most species in tropical forests are animals and most of these animals are invertebrates, particularly insects. Vertebrates are much less diverse, but dominate some key ecological roles. Almost all plants in tropical lowland forests are pollinated by animals, with bees, followed by beetles and flies, most important. Most seeds are also dispersed by animals, except in the upper canopy, with birds, fruit bats, primates, and a variety of terrestrial mammals most important.
- Maximum routine movement distances for both pollen and seeds are most often in the range 100–1000 m. Seeds are predated before dispersal by colobine monkeys, squirrels, birds, and insects and after dispersal by rodents, birds, ants, and other insects. After germination, the dominant herbivores are insects, and insects also dominate the consumption of dead plant material. Carnivorous animals have indirect impacts on plants through their effects on the abundances and behaviors of other animals.
- Few forest animals survive deforestation, while hunting is the major threat to vertebrates in intact and logged forests. Failures of seed dispersal are currently the most obvious impacts of animal losses, but more subtle impacts would be easily overlooked. Restoration of seed dispersal services is potentially one of the most effective ways of enhancing forest recovery after logging and increasing resilience to climate change.

- **Protection against climate change**
- Protecting wildlife could significantly reduce the frequency and intensity of destructive forest wildfires. Plant-eating wild animals reduce the amount of grass that can fuel fires through grazing. In Hluhluwe-iMfolozi Park in South Africa, for example, one of the world's largest grazers, the white rhinoceros, has been known to reduce the spread and intensity of fire, especially after high rainfall when grass grows more rapidly.

  Furthermore, large wild grass-eaters such as elephants, zebras, rhinos and camels do not produce so much methane, a potent greenhouse gas, as domestic livestock. This is because they digest grass in a different way than livestock – using a large, single stomach rather than regurgitating their food.

  But that's not all. Wildlife can also help forests to store carbon more efficiently. Many tree species in tropical rainforests rely on animals like elephants and toucans to eat their large, fleshy fruits – and so help disperse their seeds. Trees with large fruits can grow taller than those with small fruits, making them more effective in trapping carbon. Studies show that the loss of such trees results in as much as a 10 per cent drop in the carbon storage potential of tropical forests.

- **Nutrient-rich food source**
- Wild animals serve as a critical food source, rich in proteins and minerals for billions of people around the world. The UN Food and Agriculture Organization (FAO) reports that 34 million people rely on fishing for a living; providing protein to over 3 billion people. In tropical countries, people harvest over six million tons of medium-to-large-sized mammals, birds, and reptiles for their meat annually which serve as a rich source of important minerals. The proportion of children suffering from anemia is projected to increase by 29 per cent if they lose access to meat from wildlife, with a much greater impact on lower income households. Wildlife ranching could also have major advantages for human health, since game meat contains higher proportions of unsaturated fatty acids. Consuming wild meat also helps cut down on food miles and the carbon footprint of food production making it a win-win for us and the planet.
- **Nature's medicine cabinet**
- Chemicals from nature have been a part of human civilization ever since our early ancestors began using them to improve and enrich their own lives. Today, they continue to provide valuable knowledge to researchers and medical practitioners with crucial implications for medical sciences. Amphibians are especially important for modern medicine with compounds extracted from frogs alone used for treating depression, seizures, strokes and memory loss. We also rely on animals for a range of novel compounds including "frog glue," a flexible adhesive obtained from the glands of Australian holy cross frog species used to treat human knee injuries; lanolin and Vitamin D3 derived from sheep's wool; and Premarin, prepared from mare's urine and used to treat menopausal symptoms.

- **Cultural significance**
- Non-material benefits, ranging from spiritual enrichment to leisure pursuits, while difficult to measure and value, are amongst the least recognized yet most important contributions of wildlife to human well-being.

  Wildlife offers numerous therapeutic benefits. Research has shown that people are most drawn to landscapes that are tranquil, aesthetically appealing, have a historic significance and contain wildlife. Natural habitats and landscapes which support thriving wildlife populations also serve as valuable spaces for people to interact with wildlife, ranging from photographing wildlife to watching wildlife films. Not surprisingly, international travel to wildlife destinations has tripled over the past 20 years, with visits to protected areas rising in most developing countries and generating an estimated revenue of 600 US billion dollars a year.

  Wildlife also provides us important spiritual benefits, with sacred places and species playing an important role in many people's lives. The snake temple in Penang, Malaysia and the Galtaji Temple in Jaipur, India, dedicated to monkeys, are just two examples of wildlife forming the basis of religious practices and rituals.

- **Improving soil health and fertility**
- Wild animals play a key role in enhancing the health and fertility of soil by improving its nutrients. Their dung and urine helps replenish the nutrient content of the soil by providing it with enriching minerals. Wildlife, which range widely, can also move nutrients around – for example, the hippo's night-time grazing in grasslands brings nutrients back to the river through their dung, increasing fish productivity.
- **Maintaining ecological connectivity and keeping ecological corridors open**
- *Bison bonasus*, the largest land mammal in Europe, is a key species for preserving wilderness strongholds. The bison's browsing ability in the search of food helps maintain a mosaic of forested areas and grasslands, a landscape which is highly valuable from for its biodiversity and natural resilience in the face of climate challenges. Moreover, the bison is a species that, if successfully re-introduced and its habitat actively preserved across the entire Carpathian Mountains, will help maintain ecological corridors on a large scale, allowing for species migration, be it the bison itself or other large carnivores such as the brown bear, the wolf or lynx. The European bison is one of the most threatened large mammals in the world, and it is protected at the European level. WWF Central and Eastern Europe's and Rewilding Europe's Life Bison Project aims to establish a wild bison population that is demographically and genetically viable, by reintroducing 100 individuals in the Țarcu Mountains and Poiana Ruscă Natura 2000 sites in south-western Romania, where one of the largest wilderness areas in Europe survives.

- **Importance of Wildlife**
- Wildlife is important for a number of reasons. Here are just a few:
- Ecological balance: Wildlife plays a vital role in maintaining the balance of the ecosystem. For example, predators help to control the population of their prey, which can prevent overgrazing and other imbalances.
- Biodiversity: Wildlife helps to maintain biodiversity, which is the variety of different species living within an ecosystem. Biodiversity is important because it helps to ensure the survival of different species and makes ecosystems more resilient to change.
- Economic value: Many species of wildlife have economic value, either directly (e.g., through hunting, fishing, or ecotourism) or indirectly (e.g., through the ecosystem services they provide, such as pollination or water filtration).
- Cultural value: Wildlife has cultural value for many people around the world, who may see certain species as important symbols or hold spiritual beliefs about the natural world.
- Scientific value: Wildlife is a source of scientific knowledge and can be studied to better understand the natural world and to develop conservation strategies.

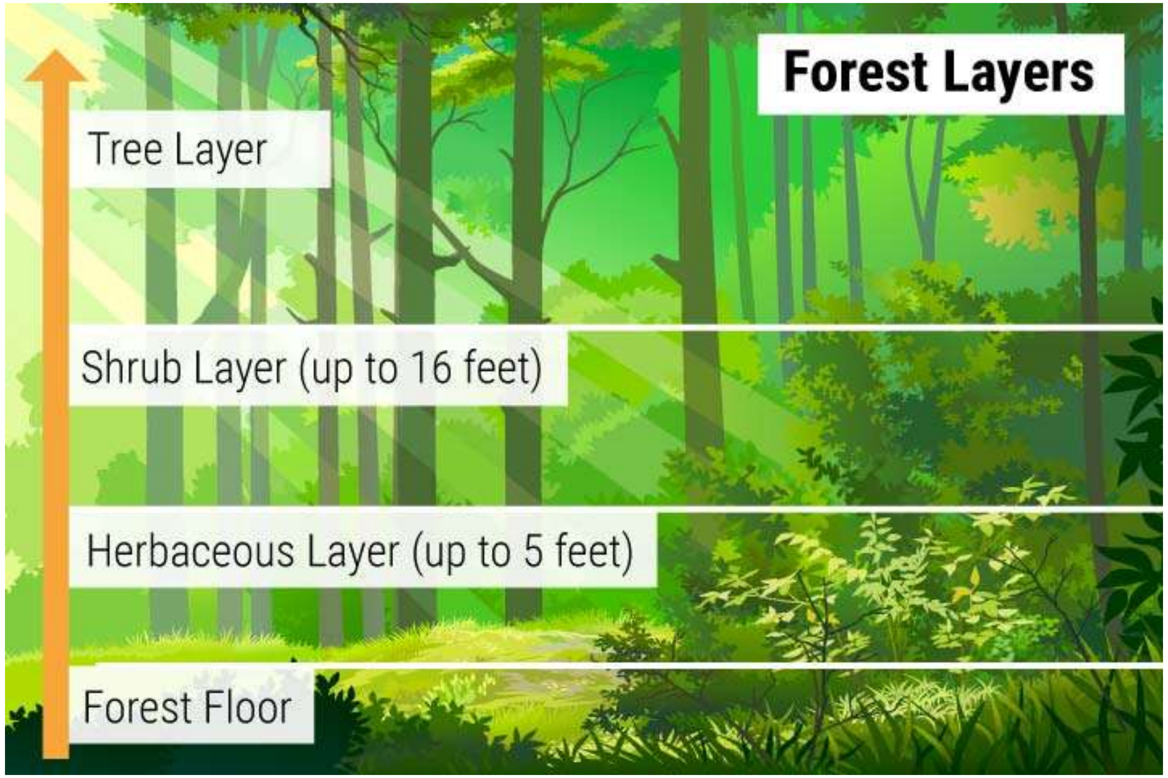
ANIMALS OF THE FOREST

- Discover the fascinating world of forest animals and their habitat, and learn about the vital role of forests.
- The forest provides a habitat for many animals. Here they find food and shelter at the same time. Each animal occupies its own space – in the crown of a tree, in shrubs and bushes or on the ground. Hedges and meadows are often located near the edge of forests.

- RedFox

- **Forest Fact File**
- Forests contain 60,000 different tree species, 80 percent of amphibian species, 75 percent of bird species, and 68 percent of the world's mammal species.(www.unep-wcmc.org)
- **A forest provides animals with:**
- spots for breeding and nesting
- protection against the weather and animals of prey
- food
- ambush for animals of prey
- **A forest provides the environment with:**
- water reservoirs
- protection for the soil
- climate protection, “air filter”
- oxygen production

- **Forests Are Divided into Layers**
- A forest is just like a **building with four floors** or so-called "layers": **forest floor, herbaceous layer, shrub layer and tree layer**. The more sunlight falls through the canopy of the tree layer, the more distinct are the shrub and soil layers. In each layer lives different animals.



- **1. Forest floor (directly on the ground)**
- Mosses, lichens, mushrooms and foliage cover the ground of the forest. Insects, spiders and reptiles can be found there, but also mammals such as mice and hedgehogs. The nutritious soil provides food for many animals. For animals that dig little holes and tunnels into the ground, it also offers some hide-away.
- Animals in the forest floor:
- Beetles
- Hedgehog
- Insects
- Lizards
- Mouse
- Salamanders
- Snails
- Spiders

Fire Salamander

- **2. Herbaceous layer (up to 5 feet / 1.5 meters)**
- Mainly insects live between the grasses and ferns of the herbaceous layer. The plants provide protection and food as well. The more sunlight reaches the layer through the canopy of leaves, the more plants grow and thrive in the herbaceous layer. If there is not much sunlight, the vegetation is also rather sparse.
- Animals in the herbaceous layer:
- Badgers
- Bees
- Beetles
- Butterflies
- Hare
- Firefly
- Fox
- Lynx
- Wasps

Badger

- **3. Shrub layer**
- Shrubs protect deer from bad weather and animals of prey. Birds use shrubs to hide in them, build nests and pick tasty fruits (such as rowan berries, sloes, raspberries). Many shrubs have thorns, which protect the birds from animals of prey.
- Animals in the shrub layer:
- Blackbirds
- Deer
- Edible Dormouse
- Hazel Dormouse
- Robins
- Squirrel
- Thrushs

White-Tailed Deer

- **4. Tree layer (up to 16 feet / 5 meters)**
- Mainly birds live in the tree layer and have their nesting and breeding places there. In this area they are optimally protected against animals of prey that are living on the ground. Yet, also mammals such as the squirrel or the pine marten climb up that high. The squirrel even builds its nest up there, which is called “drey”.
- Animals in the tree layer:
- Bat
- Eurasian Jay
- Owl
- Squirrel
- Woodpecker

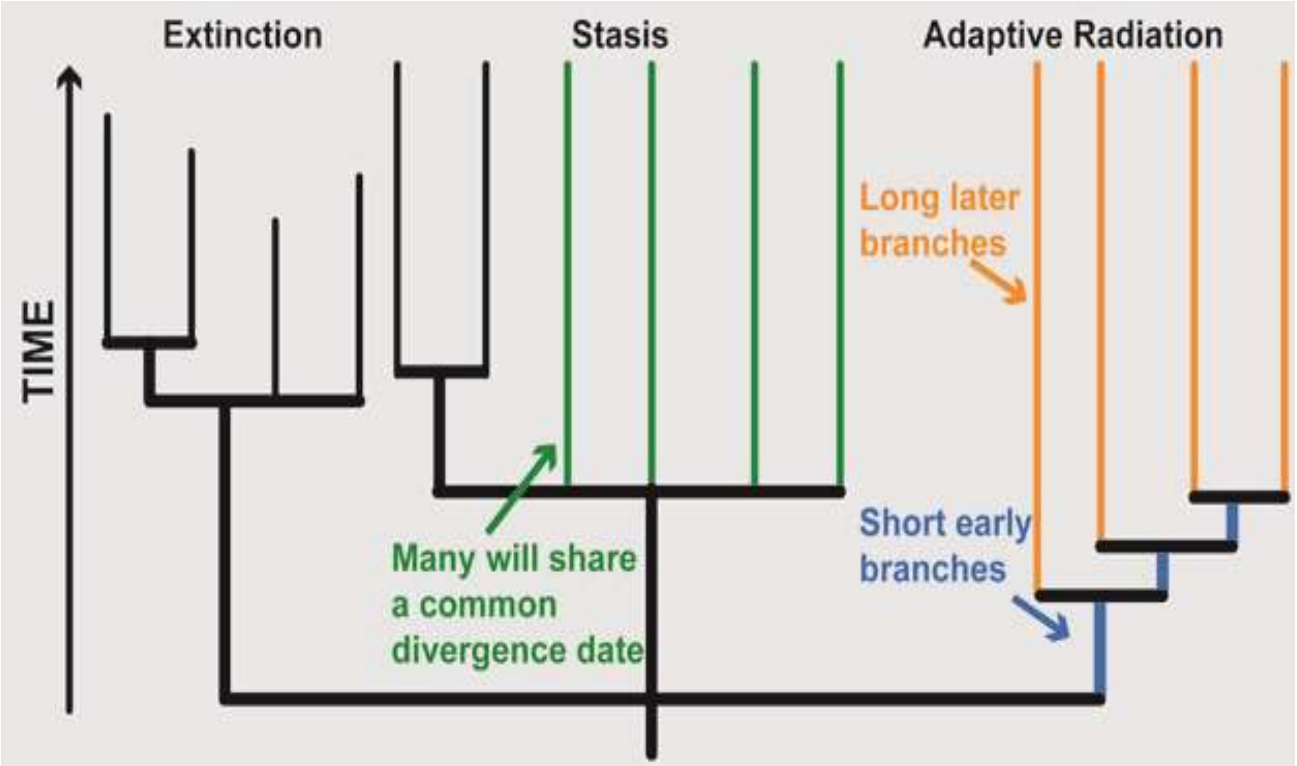
Squirrel

- Forests are usually named after their types of trees, e.g.:
- Broadleaf forest: elms, willows, alder trees, birches
- Conifer forest: pines, spruces
- Mixed forest: mix of broadleaf and conifer forest
- Forests are also named according to their geographic location, climate or composition. The mountain forest is obviously located in mountain regions. The swamp forest is rather wet and humid and can be found in swamp areas. The South-American rain forest is known for its particularly humid climate. A forest that is not cultivated by humans is called primary forest or old-growth forest. An alluvial forest is located next to creeks and rivers.

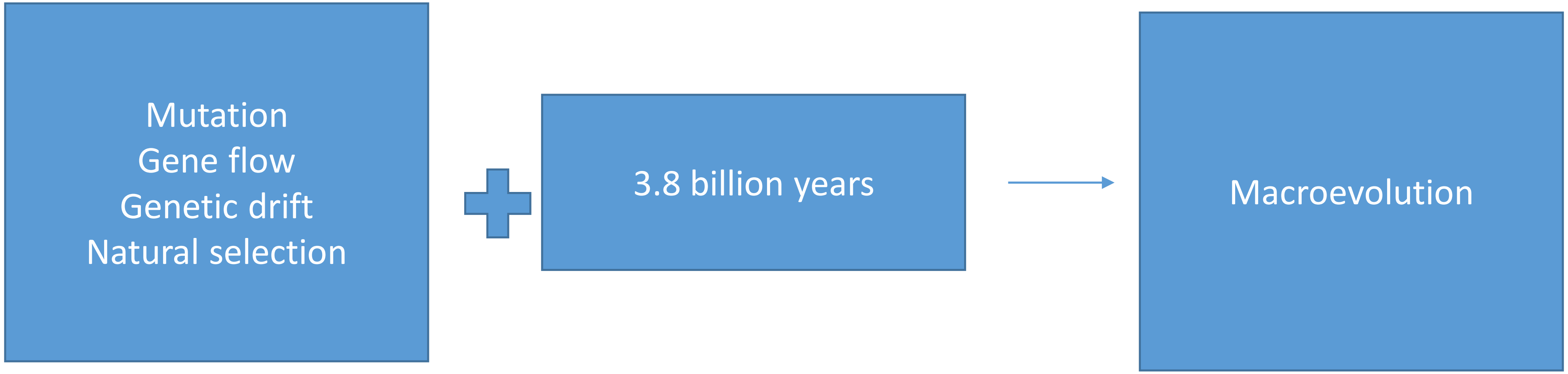
MACRO EVOLUTION

- The tree of life has many branches that all connect to a common ancestor, and the diversity of life on the tree results from evolutionary processes.
- Many scientists propose that evolution can be divided into two distinct hierarchical processes -- microevolution and macroevolution -- although the distinction between them is somewhat artificial.
- Microevolution describes mechanisms that alter the frequencies of alleles in gene pools within species (Rexnick & Ricklefs 2009). These mechanisms include mutation, migration, genetic drift, and natural selection. Theory suggests that the effects of these processes accumulate over time and can sometimes result in the divergence of populations and the birth of new species.
- In contrast, macroevolution describes patterns on the tree of life at a grand scale across vast time periods. Many different patterns can be observed across the tree of life at a grand scale (Figure 1), including stability, gradual change, rapid change, **adaptive radiations**, extinctions, the **co-evolution** of two or more species, and **convergent evolution** in traits between species - just to name a few.

Figure 1
Example of macroevolutionary patterns as they would appear in a phylogenetic tree, including extinctions, adaptive radiations, and stasis.



Process of Macroevolution: The basic evolutionary mechanisms — mutation, migration, genetic drift, and natural selection — can produce major evolutionary change if given enough time.

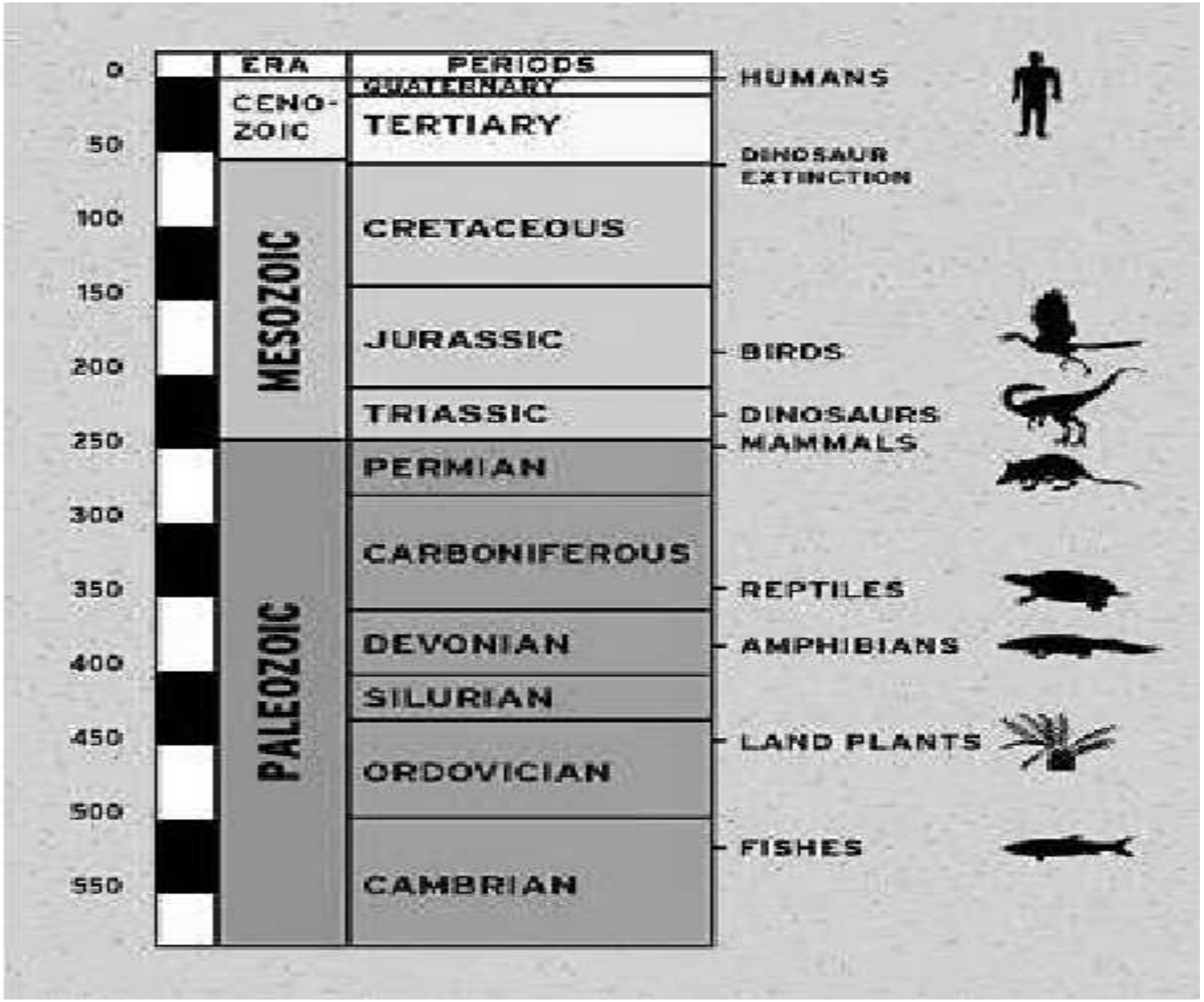


Microevolution	Macroevolution
Definition	
A change that occurs in a population due to changes in allelic frequencies is known as microevolution.	Large-scale and visible changes that occur above the level of species are known as macroevolution.
Level of Evolution	
The change occurs at an intraspecific level.	The change occurs at an interspecific level.
Cause	
There are four causes of microevolution: genetic drift, mutation, selection and gene flow.	Extended microevolution causes macroevolution.
Time	
It takes relatively shorter time as compared to macroevolution.	It takes millions of years.
Visibility	
The changes are very minute and hence cannot be viewed by a casual observer. It can be observed by Hardy-Weinberg equilibrium, mathematically.	The changes are large and occur over a span of million years, hence specific methods such as fossil studies have to be employed to observe the evolution.
Example	
Bacterial strains that have acquired antibiotic resistance.	Evolution of bat wings and loss of limbs in snakes and lizards.

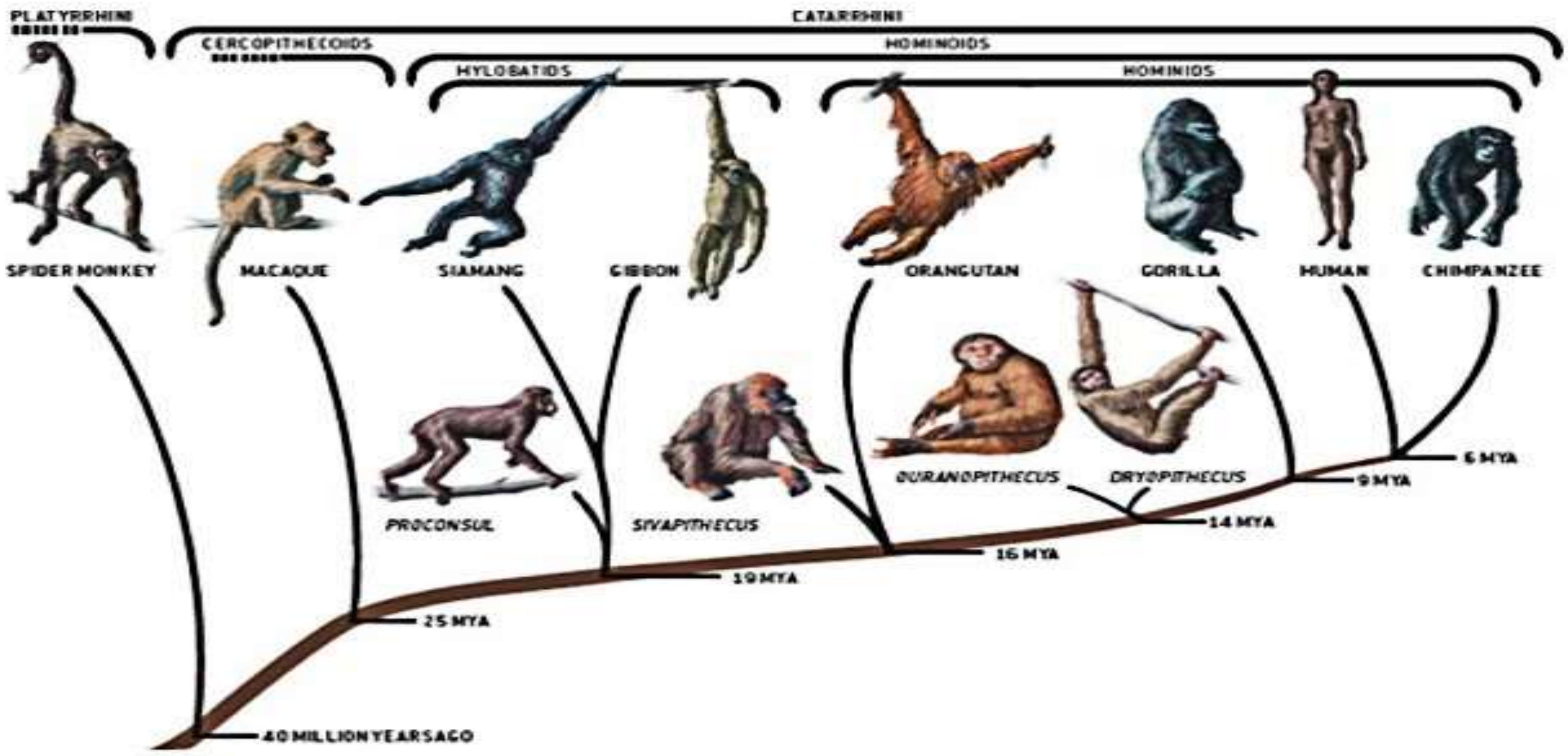
- Understanding macroevolution is important because it explains both the diversity of life and the pace of evolutionary change(Eldredge & Gould 1972, Eldredge *et al.* 2005).
- One group holds that microevolutionary processes alone can sufficiently explain grand patterns and radical changes on the tree of life. In other words, mutation, migration, genetic drift, and natural selection can produce major evolutionary changes given enough time. The key element is vast amounts of time -- on a scale that is difficult for most people to imagine. This model of macroevolution is called **phyletic gradualism**. It proposes that most speciation events are the result of a gradual and uniform transformation of one species into a new one through a process called **anagenesis**.
- Patterns of macroevolution are easy to spot on the tree of life when one considers big events like the abrupt appearance of tetrapods in the fossil record, long periods of stasis like that observed in sharks and crocodiles, and adaptive radiations including the recent diversification of mammals that began about 70 million years ago (mya). As one moves out along the branches of the tree of life, the processes that produced the rich patterns of biodiversity along a particular twig can be harder to understand and interpret.
- Yet, there are many examples of macroevolutionary phenomena found in the order Primates, including stasis, adaptive radiations, extinctions of entire lineages, co-evolution, and convergent evolution.

- *Adaptive radiations and extinctions* -- *The rise and fall of Miocene Apes*
- Phylogenetic trees based on genetic data cannot reveal much about what might have caused adaptive radiations or extinctions. Careful examination of fossils combined with an understanding about what Earth's environment was like when these fossils were living can be used to infer what might have precipitated different macroevolutionary events. For example, during the Miocene the ancestors of Old World monkeys and apes experienced both radiations and extinctions that have been linked to climate change (Harrison 2010).
- In the early Miocene, primates found in Africa and the Arabian Peninsula were a diverse group that occupied tropical forests and woodlands. During the mid-Miocene, Africa reconnected with Eurasia and a major period of global warming caused the expansion of tropical habitats northward.
- These developments allowed the nascent hominoid lineage to branch off and colonize newly available Eurasian habitats, leading to a major proliferation of ape species across much of Eurasia. However, around 9.6 mya, a major shift to drier climates created more open habitats that led to a decline of hominoid taxa in Eurasia. By 5 mya, most ape species were extinct, except for a few that eventually led to modern-day orangutans and gibbons (Moyà-Solà *et al.* 2009, Harrison 2010).

Geological time scale



The family tree of extant hominoids includes only a small fraction of the diversity of apes that have lived on this planet. During the Miocene, up to 100 ape species once lived throughout much of Europe and Asia, but ultimately went extinct. *Proconsul* may have been the last common ancestor of extant hominoids. *Sivapithecus* was probably an ancestor to orangutans. *Ouranopithecus* or *Dryopithecus* appeared in the fossil record later in the Miocene than *Proconsul* and *Sivapithecus*. Both have been proposed as ancestors shared by all living hominoids. Source: Planet of the Apes. David Begun and John Gurche, *Scientific American*, **16**, 4-13 (2006) doi: 10.1038/scientificamerican0606-4sp



RECIPROCAL ADAPTATIONS

- Adaptation is the biological mechanism by which organisms adjust to new environments or to changes in their current environment.
- An adaptation can also be behavioral, affecting the way an organism responds to its environment. An example of a structural adaptation is the way some plants have adapted to life in dry, hot deserts. Plants called succulents have adapted to this climate by storing water in their short, thick stems and leaves.
- Structural adaptations - These are special body parts of an organism that help them to survive in their natural habitat (e.g., skin colour, shape, and body covering).
- Behavioural adaptations - These are special ways in which a particular organism behaves to survive in its natural habitat.
- **Two examples of adaptation are:**
- To prevent water loss from leaves by transpiration in the hot climates of deserts, cacti have leaves modified into spines.
- Animals living in extremely cold climates, such as polar bears have thick coats of fur and large deposits of fat to insulate them against the cold.

- Contemporary forest management and forest policies often serve multiple purposes and can incorporate measures to adapt to climate change, even if they are not primarily designed to do so. In many situations measures to tackle habitat destruction, forest fragmentation and forest degradation are compatible with efforts to adapt to climate change and to mitigate greenhouse gas emissions in the forest sector.
- Adaptation measures are needed to ensure that the ecosystem services provided by forests are maintained under future climates. The scientific basis for such measures varies across major forest types, as does their potential effectiveness. In particular, the measures chosen for any given forest will depend on the local situation and the expected nature of future climate change. As a result, there are no universally applicable solutions.
- The choice of adaptation measures will be determined not only by the likely changes occurring in a forest, but also by the management objectives for the forest (which might change in light of climate change), its past management history, and a range of other factors.

- A critical aspect of any adaptation framework will be to ensure that local managers have sufficient flexibility to choose the most appropriate suite of management measures for their conditions.
- Forest management actions taken to adapt to climate change can be consistent with sustainable forest management (SFM). SFM is a continuously evolving concept designed to ensure that forests continue to provide a range of ecosystem services. Forests are social-ecological systems that involve both nature and society. Sustainable forest management, therefore, serves both forest ecosystems and the people and societies that benefit from the provision of forest ecosystem services.
- Adaptation should not be viewed independently of mitigation. Large reductions in fossil-fuel emissions and halt to deforestation are needed to curb climate change and to ensure that forests retain their adaptive capacities.

COMPETITION AND SURVIVAL

- Competition for water and nutrients between trees and other vegetation is discussed using examples from the interactions between tree and weeds in production forests, and trees and pasture in agroforestry systems. Production and economic viability of plantation forests are dependent upon sound weed management practices. Competition for water and nutrients by a plant is registered as a water deficit or a nutrient deficit.
- Plant responses to competition are similar to those for coping with water and nutrient deficiency in the soil. One species may have a competitive advantage over another for water and nutrients by
- (*i*) acquiring a greater proportion of available soil water and (or) nutrients,
- (*ii*) using water and nutrients more efficiently in producing biomass, and (or)
- (*iii*) allocating assimilate in ways that maximize survival and growth.

- However, a tree must not outperform its neighbours in relation to all traits to be a successful competitor. For example, the native beech tends to grow rather slowly and does not reach a particularly impressive height; it has, however, a high wood density and shade-tolerance, which gives it a major advantage in the ecological competition during the second phase of forest colonization after around 50-100 years. With its traits, it comes very close to a combination identified by the study as being very successful in the long-term competition for survival in global forests. Therefore, from a long-term perspective, shade-tolerant high-growing trees with medium to high wood density enjoy competitive advantages all over the world.
- It also emerged from the study that the competitive pressure within one and the same species is always greater than that between trees of different species. This is also rather obvious, as trees from the same species have more or less identical traits. They thus occupy the same ecological niche and compete for the same resources in a location. The fact that one of two trees will ultimately prevail is above all due to the fact that even trees of the same species will not have identical locations and traits.
- Furthermore, the fact that the role played by chance in the ecological competition is far from insignificant, should not be forgotten here – irrespective of whether the competitors are from the same species or not. For example, plants can be damaged by disease or wild animals and this impairs their chances of survival in the battle with their competitors.

FOREST SUCCESSION

- The simple definition is the predictably and orderly progression of change in the plant species that dominate an area. The classic image is of grassy fields, followed by brush, then small trees, and finally forest. The cycle of succession starts with the response of a plant community to a disturbance of previously vegetated lands. Because plants occupied the site before the disturbance, this type of succession is known as secondary succession. Succession on land that did not previously have plants, such as soil exposed as a glacier retreats or a new sand bar in a river is called primary succession.

- Forest succession is simply the succession or the orderly and predictable change in the dominant species of forest plants. The change in dominance occurs because the plants that dominate early often die early, allowing longer lived plants dominance.
- **The 5 Stages of Succession are Nudation, Invasion, Competition and Co-action, Reaction, and Climax or Stabilization**. At the same location, a succession of biotic communities naturally emerges one after another until the Climax stage is reached. In their early stages, biotic communities develop slowly. But as it progresses, the speed gradually picks up.

- **Ecological Succession is the process by which the mix of species** and habitats changes over time in 5 stages. The stages of Ecological Succession are as follows:
- **Nudation**: Nudation is the first stage of succession. It is the formation of a nude or a bare area. It might result from flooding, erosion, landslide, volcanic eruption, or other artificial or natural reasons.
- **Invasion**: Invasion is the arrival of the propagules or the reproductive bodies of different organisms that can settle on the bare area.
- **Competition and Co-action**: Competition and Co-action mean that the population of the invasive species increases in number within a limited space.
- **Reaction**: Since the organisms grow in a place, the environment molds itself under the organism's influence. It means that the area's temperature, land, water, and soil change.
- **Stabilization or Climax**: The Climax or Stabilized stage is the final or terminal stage of ecological succession. **The terminal or final communities referred to as the climate community**, reach this stage and become more stable and stay there for a longer time. For instance, grasslands, forests, and coral reefs.

ECOLOGICAL SUCCESSION

- Ecological succession is the steady and gradual change in a species of a given area with respect to the changing environment. It is a predictable change and is an inevitable process of nature as all the biotic components have to keep up with the changes in **our environment**.
- The ultimate aim of this process is to reach equilibrium in the ecosystem. The community that achieves this aim is called a climax community. In an attempt to reach this equilibrium, some species increase in number while some others decrease.
- In an area, the sequence of communities that undergo changes is called sere. Thus, each community that changes is called a seral stage or seral community.
- All the communities that we observe today around us have undergone succession over a period of time since their existence. Thus, we can say that evolution is a process that has taken place simultaneously with that of ecological succession. Also, the initiation of life on earth can be considered to be a result of this succession process.
- If we consider an area where life starts from scratch through the process of succession, it is known as primary succession. However, if life starts at a place after the area has lost all the life forms existing there, the process is called secondary succession.
- It is obvious that primary succession is a rather slow process as life has to start from nothing whereas secondary succession is faster because it starts at a place which had already supported life before. Moreover, the first species that comes into existence during primary succession is known as the pioneer species.

- **Types of Ecological Succession**
- These are the following types of ecological succession:
- **Primary Succession**
- Primary succession is the succession that starts in lifeless areas such as the regions devoid of soil or the areas where the soil is unable to sustain life.
- When the planet was first formed there was no soil on earth. The earth was only made up of rocks. These rocks were broken down by microorganisms and eroded to form soil. The soil then becomes the foundation of plant life. These plants help in the survival of different animals and progress from primary succession to the climax community.
- If this primary ecosystem is destroyed, secondary succession takes place.
- A climax forest is a good place to start an argument with an ecologist. To some, it is a nice name for forests that have escaped disturbance by outside forces like storms or diseases or logging long enough to have settled into a condition of relative stability. That is, the composition and structure of the forest don’t change much over long periods of time.
- Trees and other plants grow, mature, reproduce, age, and die. Soils build and erode. Weather changes daily, and climate varies over long periods. Animal populations come and go. With time, these sorts of changes bring still other changes that go beyond the sizes of the trees to involve shifts in the kinds (species) and mixes of trees growing in the forest.

- Eventually, if these forests escape major disturbance long enough, they become dominated by trees of species such as sugar maple, American beech, or eastern hemlock. Although these species may be present in the early going, they tend to become dominant later in the succession of change. They are capable of living a very long time – hundreds of years – without being replaced by other mixes of species. In fact, unlike their fast growing, short-lived, early successional counterparts – called “pioneer” species – whose seedlings tend to die in the understory, the seedlings and saplings of these “climax” species are very tolerant of shade.
- This is key. Climax species’ seedlings are capable of surviving in the understory and can therefore grow up to replace overstory parent trees that die. When this happens, the forest’s mix of species remains relatively constant for extended periods. This is what some have called the climax forest.
- Example:

Warren Woods in Michigan, USA, is an example of a beech-maple climax forest. Beech (center) and sugar maple (bottom left) dominate the forest due to their towering height and tolerance of shade.

FOREST FIRE

- The most common hazard in forests is forests fire. Forests fires are as old as the forests themselves. They pose a threat not only to the forest wealth but also to the entire regime to fauna and flora seriously disturbing the bio-diversity and the ecology and environment of a region.
- During summer, when there is no rain for months, the forests become littered with dry senescent leaves and twinges, which could burst into flames ignited by the slightest spark. The Himalayan forests, particularly, Garhwal Himalayas have been burning regularly during the last few summers, with colossal loss of vegetation cover of that region.
- Forest fire causes imbalances in nature and endangers biodiversity by reducing faunal and floral wealth. Traditional methods of fire prevention are not proving effective and it is now essential to raise public awareness on the matter, particularly among those people who live close to or in forested areas.

CAUSES OF FOREST FIRE

- Forest fires are caused by Natural causes as well as Man made causes
- Natural causes- Many forest fires start from natural causes such as lightning which set trees on fire. However, rain extinguishes such fires without causing much damage. High atmospheric temperatures and dryness (low humidity) offer favorable circumstance for a fire to start.
- Man made causes- Fire is caused when a source of fire like naked flame, cigarette or bidi, electric spark or any source of ignition comes into contact with inflammable material.
- Traditionally Indian forests have been affected by fires. Themenace has been aggravated with rising human and cattle population and the consequent increase in demand for Forest products by individuals and communities. Causes of forest fires can be divided into two broad categories: environmental (which are beyond control) and human related (which are controllable).
- Environmental causesare largely related to climatic conditions such as temperature, wind speed and direction, level of moisture in soil and atmosphere and duration of dry spells. Other natural causes are the friction of bamboos swaying due to high wind velocity and rolling stones that result in sparks setting off fires in highly inflammable leaf litter on the forest floor.

- **Human related causes** result from human activity as well as methods of forest management. These can be intentional or unintentional, for example:
- graziers and gatherers of various forest products starting small fires to obtain good grazing grass as well as to facilitate gathering of minor forest produce like flowers of *Madhuca indica* and leaves of *Diospyros melanoxylon*
- the centuries old practice of shifting cultivation (especially in the North-Eastern region of India and inparts of the States of Orissa and Andhra Pradesh).
- the use of fires by villagers to ward off wild animals
- fires lit intentionally by people living around forests for recreation
- fires started accidentally by careless visitors to forests who discard cigarette butts.
- The causes of forest fire have been increasing rapidly. The problem has been accentuated by the growing human and cattle population. People enter forests ever more frequently to graze cattle, collect fuelwood, timber and other minorforest produce. It has been estimated that 90% of forest fires in India are man-made

- **Classification of Forest Fire**
  Forest fire can broadly be classified into three categories;
- Natural or controlled forest fire.
- Forest fires caused by heat generated in the litter and other biomes in summer through carelessness of people (human neglect) and
- Forest fires purposely caused by local inhabitants.
- **Types of Forest Fire**
  There are two types of forest fire i) Surface Fire and ii) Crown Fire
- **Surface Fire-**
  A forest fire may burn primarily as a surface fire, spreading along the ground as the surface litter (senescent leaves and twigs and dry grasses etc) on the forest floor and is engulfed by the spreading flames.
- **Crown Fire-**
  The other type of forest fire is a crown fire in which the crown of trees and shrubs burn, often sustained by a surface fire. A crown fire is particularly very dangerous in a coniferous forest because resinous material given off burning logs burn furiously. On hill slopes, if the fire starts downhill, it spreads up fast as heated air adjacent to a slope tends to flow up the slope spreading flames along with it. If the fire starts uphill, there is less likelihood of it spreading downwards.

- **EFFECTS OF FOREST FIRE**
- Fires are a major cause of forest degradation and have wide ranging adverse ecological, economic and social impacts, including:
- loss of valuable timber resources
- degradation of catchment areas
- loss of biodiversity and extinction of plants and animals
- loss of wildlife habitat and depletion of wildlife
- loss of natural regeneration and reduction in forest cover
- global warming

- loss of carbon sink resource and increase in percentage of CO_2 in atmosphere
- change in the microclimate of the area with unhealthy living conditions
- soil erosion affecting productivity of soils and production
- ozone layer depletion
- health problems leading to diseases
- loss of livelihood for tribal people and the rural poor, as approximately 300 million people are directly dependent upon collection of non-timber forest products from forest areas for their livelihood.

- **The need of the fire management**
- The incidence of forest fires in the country is on the increase and more area is burned each year. The major cause of this failure is the piecemeal approach to the problem.
- Both the national focus and the technical resources required for sustaining a systematic forest fire management programme are lacking in the country. Important forest fire management elements like strategic fire centres, coordination among Ministries, funding, human resource development, fire research, fire management, and extension programmes are missing.
  Taking into consideration the serious nature of the problem, it is necessary to make some major improvements in the forest fire management strategy for the country. The Ministry of Environment and Forests, Government of India, has prepared a National Master Plan for Forest Fire Control. This plan proposes to introduce a well-coordinated and integrated fire-management programme that includes the following components:
- Prevention of human-caused fires through education and environmental modification. It will include silvicultural activities, engineering works, people participation, and education and enforcement. It is proposed that more emphasis be given to people participation through Joint Forest Fire Management for fire prevention.

- Prompt detection of fires through a well coordinated network of observation points, efficient ground patrolling, and communication networks. Remote sensing technology is to be given due importance in fire detection. For successful fire management and administration, a National Fire Danger Rating System (NFDRS) and Fire Forecasting System are to be developed in the country.
- Fast initial attack measures.
- Vigorous follow up action.
- Introducing a forest fuel modification system at strategic points.
- Firefighting resources.
- Each of the above components plays an important role in the success of the entire system of fire management. Special emphasis is to be given to research, training, and development.
- **Integrated forest protection**
- The main objective of this scheme to control forest fires and strengthen the forest protection in Tamilnadu. The works like fireline clearing, assistance to Joint Forest Management committees, creating water bodies, purchase of vehicles and communication equipments, purchase of fire fighting tools, etc., are being undertaken.

ECOLOGICAL EFFECTS

- Windthrow is common in all forested parts of the world that experience storms or high wind speeds. The risk of windthrow to a tree is related to the tree's size (height and diameter), the 'sail area' presented by its crown, the anchorage provided by its roots, its exposure to the wind, and the local wind climate.
- A common way of quantifying the risk of windthrow to a forest area is to model the probability or 'return time' of a wind speed that would damage those trees at that location. Another potential method is the detection of scattered windthrow based on satellite images. Tree senescence can also be a factor, where multiple factors contributing to the declining health of a tree reduce its anchorage and therefore increase its susceptibility to windthrow. The resulting damage can be a significant factor in the development of a forest.
- Windthrow can also increase following logging, especially in young forests managed specifically for timber. The removal of trees at a forest's edge increases the exposure of the remaining trees to the wind.
- Windthrow is all too often looked at as an exceptional, catastrophic phenomenon rather than a recurrent driver of ecosystem patterns and processes that falls within the spectrum of chronic and acute effects of wind on forests. Windthrow disturbance patterns are complex and it is often difficult to see order in the aftermath of an individual storm.
- While individual windthrow events have immediate impacts, the long-term and cumulative impacts of recurrent windthrow are often overlooked by scientists and managers. Furthermore, the study of windthrow and the management of windthrow-prone landscapes encompasses many scientific and professional disciplines.

- **Windthrow mechanics, stand-level instability**
- Windthrow results when the wind-induced drag force on the tree crown, multiplied over the lever-arm of the stem, results in a turning moment that exceeds the bending resistance of the stem, or the root anchorage. Tree design appears to balance core rigidity with peripheral flexibility. The bending and reconfiguration of branches, and consequently tree crowns, during high winds streamlines foliage and reduces the frontal area. Over the range of wind speeds at which this reconfiguration occurs, drag on tree crowns is directly proportional to wind speed rather than to the square of wind speed, as is the case for solid bodies.

- **Factors contributing to windthrow**
- **Recurrent extreme winds**

- The severity of damage to forests during extreme weather events depends on the duration of the event, the maximum sustained wind speed and precipitation immediately prior to and during the event – in other words, on the intensity of the event.[3] The role of wind as a driver of ecosystem processes also depends on how frequently intense weather events recur within a region. Extreme winds are traditionally ranked according to increasing intensity as gales (62–88 km h^{-1}), storms (89–117 km h^{-1}) and hurricanes (≥118 km h^{-1}) according to the Beaufort scale.[57] Hurricanes/typhoons and tornadoes are associated with specific synoptic conditions and are ranked according to the Saffir–Simpson and Fujita scales, respectively.[58,59] Gale-force and storm-force winds can be produced by a variety of synoptic conditions. In mid-latitude temperate zones, extra-tropical cyclones are a major source of recurrent gale and storm force winds, and consequently forest disturbance. Extra-tropical cyclones develop over the Pacific and Atlantic oceans in response to temperature gradients between tropical and polar climates. These are very large-scale systems that are most intense during the winter months, and are often accompanied by high rainfall.

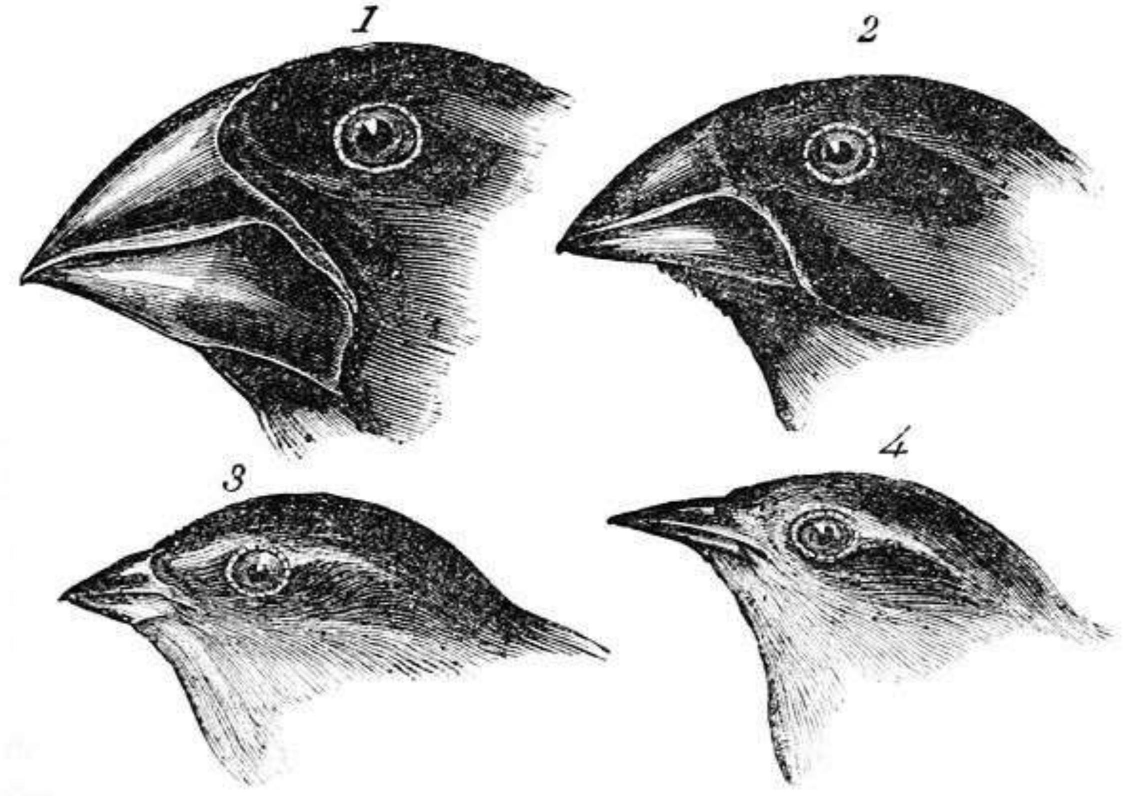
Macroevolution in forests

- Macroevolution in a forest ecosystem refers to large-scale evolutionary changes that occur over extended periods, leading to the emergence of new species, genera, families, or even higher taxonomic groups. These changes can significantly alter the composition and dynamics of the forest ecosystem.
- **Key Aspects of Macroevolution in Forest Ecosystems:**
- **Speciation**:
  - Over long periods, populations of organisms within a forest may become isolated due to geographical barriers (like rivers, mountains, or climatic changes), leading to speciation. For example, a population of trees might diverge into two distinct species due to differences in climate or soil conditions.

- **Adaptive Radiation:**When new ecological niches become available, such as after a mass extinction event or the formation of a new habitat (like an island), species can rapidly diversify to fill these niches. This can lead to a burst of speciation, resulting in a wide variety of species adapted to different parts of the forest.
- According to Darwin's Theory of Evolution, living organisms change their physical and anatomical structures over a long period of time for better adaptations to the changing environment.
- The initiation of the point of evolution was when organisms wanted to exploit a niche and they were not able to do so with their existing body design or structural component. Organisms started to split and adapt various versions for better survival.

- Adaptive radiation is the evolutionary process by which many species originate from one species in an area and radiate to different species.
- The phenomenon of adaptive radiation was first observed by Darwin when he travelled to a place called Galapagos Island. There he observed that there were finches with different types of beaks. So, he concluded that all of these finches radiated on the same island from a single ancestor Finch.
- All of these finches developed beaks according to the kind of food available to them. Hence, they evolved from the conventional seed-eating finches to vegetarian and insectivorous finches. They later came to be known as Darwin’s finches.

Adaptive radiation-Darwin’s finches



1. Geospiza magnirostris.
2. Geospiza fortis.
3. Geospiza parvula.
4. Certhidea olivacea.

- **Co-evolution**:Species in a forest ecosystem often evolve in response to each other. For example, the evolution of flowering plants (angiosperms) and their pollinators (such as insects or birds) is a classic example of co-evolution. As plants develop new flower forms or chemical defenses, pollinators may evolve new behaviors or adaptations in response.
- **Extinction and Replacement:** Over millions of years, species may go extinct due to changes in the environment, competition, or other factors. These extinctions can lead to the rise of new species that take over the ecological roles of the extinct species. For instance, the extinction of large herbivores in a forest might lead to the rise of smaller herbivores or even changes in plant species composition.

- **Long-term Ecosystem Changes**:Macroevolution can lead to significant changes in the structure and function of forest ecosystems. As new species evolve, they may alter the way energy flows through the ecosystem, the cycling of nutrients, or the overall biodiversity. For example, the evolution of nitrogen-fixing plants can change soil chemistry, which in turn affects other plant species and the animals that depend on them.
- **Examples in a Forest Ecosystem**:
- Angiosperm Evolution: The rise of flowering plants around 100 million years ago led to profound changes in forest ecosystems. These plants often formed new forest types and provided new food sources for evolving animal species.
- Mammalian Diversification: After the extinction of dinosaurs, mammals diversified and filled various niches in forest ecosystems, leading to the evolution of primates, and other forest-dwelling animals.
- Insect Diversification: The evolution of insects, especially those that interact with plants (like pollinators and herbivores), has greatly influenced forest ecosystems by driving plant diversification and shaping plant communities.

- Macroevolutionary changes in forest ecosystems are ongoing, driven by environmental changes, genetic variation, and the interactions between species. These processes contribute to the rich biodiversity and complexity observed in forests around the world.

Reciprocal adaptation

- Reciprocal adaptation in forests, often referred to as co-evolution, occurs when two or more species in close ecological relationships influence each other’s evolution. This process leads to adaptations that are mutually beneficial, antagonistic, or neutral, depending on the nature of their interaction. Reciprocal adaptation is a key factor in the dynamic balance of forest ecosystems, influencing species diversity, community structure, and ecosystem function.
- **Examples of Reciprocal Adaptation in Forests:**
- **Plant-Pollinator Interactions**:
  - **Example**: Many flowering plants in forests have evolved specific traits, such as flower color, shape, and scent, to attract certain pollinators (bees, birds, bats). In turn, these pollinators have evolved physical adaptations like long proboscises or specialized feeding behaviors that allow them to access nectar or pollen efficiently. This reciprocal adaptation increases the reproductive success of both plants and pollinators. The plants benefit from more effective pollination, while the pollinators gain reliable food sources.

- **Herbivore-Plant Defense Mechanisms**:Example: Some forest plants produce toxic chemicals, tough leaves, or spines to deter herbivores. In response, certain herbivores have evolved resistance to these chemicals or behaviors to avoid the plant defenses. For instance, monarch caterpillars can feed on toxic milkweed plants because they have developed a resistance to the plant’s toxins. This leads to a continuous evolutionary "arms race," where plants and herbivores keep evolving new strategies and counter-strategies, maintaining a balance between plant survival and herbivore feeding.

Predator-Prey Relationships

- **Predator-Prey Relationships:Example**: Predators like wolves or big cats and their prey (deer, rabbits) in forest ecosystems often undergo reciprocal adaptations. Prey species might evolve faster speeds, better camouflage, or heightened senses, while predators may develop sharper claws, better stalking techniques, or enhanced coordination in hunting packs. These adaptations help maintain population control and balance within the ecosystem, ensuring neither predator nor prey populations become too dominant.

- **Symbiotic Relationships: Example**: Mycorrhizal fungi and forest trees engage in a mutualistic relationship where the fungi colonize the roots of trees. The fungi receive carbohydrates produced by the tree through photosynthesis, while the tree benefits from the fungi's ability to absorb water and nutrients like phosphorus from the soil more efficiently. This relationship enhances tree growth and resilience, which in turn supports a diverse forest structure. The fungi also benefit by having a stable and nutrient-rich environment.
- **Seed Dispersal Mechanisms:Example**: Many forest trees and plants have evolved fruits that are specifically attractive to certain animals. Birds, mammals, and even insects may eat these fruits and later disperse the seeds over wide areas. In response, the animals have evolved traits like beak shapes or digestive systems optimized for consuming and processing these fruits. This reciprocal adaptation ensures the wide distribution of the plant species, while providing the animals with a reliable food source. It contributes to the spread and genetic diversity of forest plants.

Competition and survival

- Competition and survival are fundamental aspects of life in forest ecosystems. Forests, being rich in resources and biodiversity, are also environments where various species—plants, animals, fungi, and microorganisms—compete for limited resources like light, water, nutrients, space, and even mates.
- This competition drives natural selection, influencing the survival and reproductive success of species and ultimately shaping the structure and dynamics of the forest ecosystem.

- **Types of Competition in Forests:**
- **Intraspecific Competition**:
  - **Definition**: Competition among individuals of the same species for the same resources.
  - **Examples**:**Trees**: In dense forests, trees of the same species compete for sunlight, water, and nutrients. Young saplings often struggle to survive under the canopy of mature trees because the larger trees capture most of the available sunlight.
  - **Animals**: Territorial animals, like deer or wolves, compete for mates, territory, and food. This can lead to aggressive behaviors, dominance hierarchies, and even physical confrontations.
- **Interspecific Competition**:
- **Definition**: Competition between different species for the same resources within an ecosystem.
- **Examples**:
  - **Plants**: Different tree species may compete for sunlight by growing taller or spreading their branches wider to capture more light. For example, fast-growing species like poplars may outcompete slower-growing species like oaks in the early stages of forest succession.
  - **Predators**: Carnivores like wolves and bears may compete for prey such as deer. If one predator is more efficient or has access to a broader range of prey, it may outcompete others.

Survival Strategies in Forests:

- **Niche Differentiation**:
  - **Definition**: The process by which competing species use the environment differently in a way that helps them to coexist.
  - **Examples**:
    - **Canopy Layers**: In forests, plants may occupy different layers of the canopy. Tall trees dominate the upper canopy, while smaller trees, shrubs, and ground plants occupy lower layers, each adapted to varying levels of light.
    - **Feeding Strategies**: Different species of birds may feed at different heights in trees or specialize in different types of food (insects, seeds, nectar), reducing direct competition.
- **Adaptations for Competition**:
- **Physical Adaptations**: Plants may develop broad leaves to capture more sunlight, deep roots to access water, or thorns and toxins to deter herbivores. Animals may evolve sharp claws, fast running speeds, or camouflaged fur to better compete for food and avoid predators.
- **Behavioral Adaptations**: Some animals adopt specific behaviors, like nocturnal activity, to reduce competition. For instance, some species of rodents might forage at night to avoid daytime predators and competition with diurnal species.

Ecological Consequences of Competition and Survival:

- **Succession**:
  - Forests undergo ecological succession, where different species dominate at various stages of development. Early-successional species are often fast-growing and competitively dominant, but as the forest matures, they are often replaced by slower-growing, more shade-tolerant species.
- **Biodiversity**:
  - Competition contributes to high biodiversity in forests by driving the evolution of a wide range of adaptations. This, in turn, supports complex food webs and ecological processes, enhancing the overall resilience of the ecosystem.
- **Population Control**:
  - Competition naturally regulates population sizes, preventing any one species from becoming too dominant. This balance is crucial for maintaining the health and stability of forest ecosystems.

Forest succession

- **Forest succession** is the natural process through which a forest ecosystem changes over time, transitioning through a series of stages from a disturbed, often bare or minimally vegetated area to a mature, stable forest. This process can take decades, centuries, or even millennia, depending on various factors such as climate, soil conditions, and the type of disturbance that initiated the succession.
- **Types of Forest Succession:**
- **Primary Succession**:
  - **Definition**: Primary succession occurs in areas where there was previously no soil or vegetation, such as on bare rock after a volcanic eruption, glacial retreat, or on a newly formed sand dune.
  - **Process**:
    - **Pioneer Species**: The first organisms to colonize the area are often hardy pioneer species like lichens, mosses, and certain grasses that can survive in harsh, nutrient-poor conditions. These species help to break down the rock and contribute organic material as they die and decompose, slowly forming soil.
    - **Early Successional Species**: As soil depth and quality improve, grasses, herbs, and small shrubs establish themselves. These plants further modify the environment by adding organic matter to the soil and providing habitat for insects and small animals.

- **Intermediate Species**: Over time, small trees and shrubs begin to grow, shading out the earlier species that require more sunlight. Species like pines or birches may dominate during this stage.
- **Climax Community**: Eventually, a stable, mature forest develops, consisting of larger, long-lived trees like oaks, maples, or conifers, depending on the climate and soil. This stage is known as the climax community, and it represents a relatively stable ecosystem that can persist for centuries unless disturbed.

- **Secondary Succession**:
- **Definition**: Secondary succession occurs in areas where an existing forest has been disturbed or destroyed by events such as fire, logging, windstorms, or agricultural activities, but where soil remains intact.
- **Process**:
  - **Disturbance**: The process begins after a disturbance that removes the existing vegetation but leaves the soil, seeds, and some organisms intact.
  - **Pioneer Species**: Fast-growing, light-demanding plants, such as grasses, herbs, and shrubs, quickly colonize the disturbed area. These pioneer species stabilize the soil, reduce erosion, and provide habitat for animals.
  - **Intermediate Species**: As the area stabilizes, early successional trees like pines, willows, or aspen may grow, gradually shading out the pioneer species. These trees often create conditions that allow shade-tolerant species to establish.
  - **Climax Community**: Over time, the area may develop into a mature forest, similar to the climax community of primary succession, though the exact composition of species may differ depending on the local environment and the nature of the disturbance.

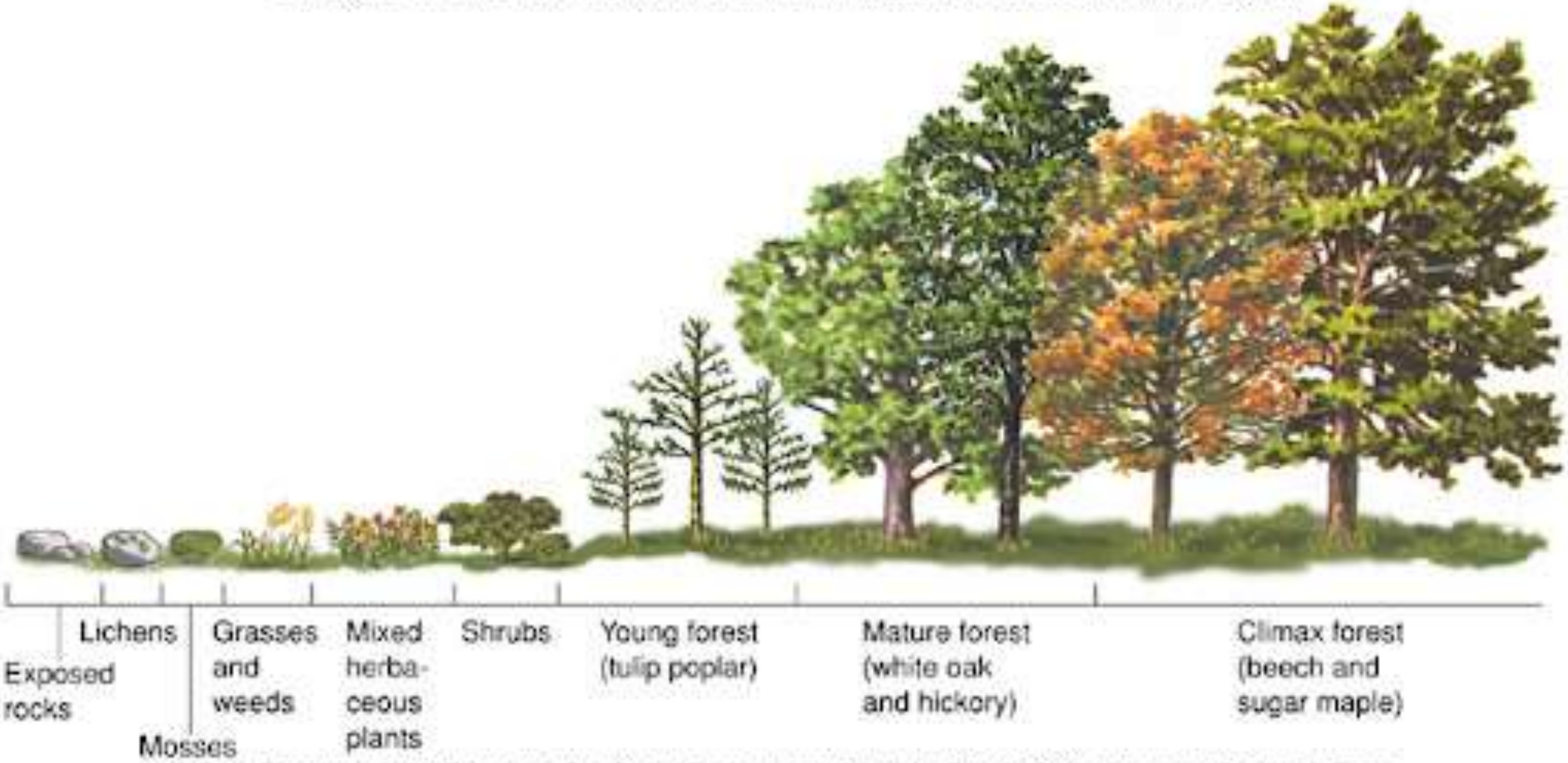
Factors Influencing Forest Succession:

- **Climate**: Temperature, precipitation, and seasonal patterns influence the types of species that can thrive at each stage of succession.
- **Soil**: Soil composition, fertility, and depth affect plant growth and the rate of succession.
- **Disturbance**: The type, frequency, and intensity of disturbances (natural or human-induced) can reset succession or alter its trajectory.
- **Species Interactions**: Competition, herbivory, and mutualistic relationships (e.g., mycorrhizal fungi with trees) play significant roles in shaping the successional pathway.

Stages of Forest Succession:

- **Pioneer Stage**:
  - Dominated by fast-growing, opportunistic species that are the first to colonize a disturbed area. These species are typically hardy, with seeds that can disperse over long distances and germinate quickly.
  - Examples: Grasses, annuals, and small shrubs.
- **Establishment Stage**:
  - Early successional species begin to take root, grow, and reproduce, further stabilizing the soil and modifying the microenvironment.
  - Examples: Small shrubs, fast-growing trees like birch or poplar.
- **Intermediate Stage**:
  - Larger, longer-lived species start to dominate as conditions become more stable and the environment becomes less favorable for pioneer species.
  - Examples: Pine forests, young hardwood forests.
- **Climax Stage**:
  - The ecosystem reaches a stable state with a complex structure, including a variety of species in different layers (canopy, understory, ground layer). The species composition is relatively stable, and the forest can persist for long periods unless disrupted.
  - Examples: Old-growth forests with mature trees like oaks, beech, spruce, or fir, depending on the region.

Succession



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Windthrow

- **Windthrow**, also known as **blowdown** or **windfall**, refers to the uprooting or breaking of trees due to strong winds. This phenomenon is a common occurrence in forests and can have significant ecological and economic impacts. Windthrow can occur during storms, hurricanes, or other severe weather events, and its effects can range from isolated tree falls to large-scale destruction across vast forest areas.

- **Causes of Windthrow:**
- **High Wind Speeds**:
  - The primary cause of windthrow is strong winds, which exert force on the trees. The intensity and duration of these winds determine the likelihood and extent of tree damage.
  - **Storms and Hurricanes**: Extreme weather events, such as hurricanes, tornadoes, and intense storms, can generate wind speeds that are sufficient to uproot or break even large trees.
- **Soil Conditions**:
  - **Waterlogged Soil**: Saturated soils after heavy rainfall can reduce the soil's ability to anchor tree roots, making trees more susceptible to being uprooted by strong winds.
  - **Shallow or Poorly Developed Roots**: Trees growing in shallow soils, rocky terrain, or areas with a high water table may have less stable root systems, increasing the risk of windthrow.
- **Tree Characteristics**:
  - **Height and Canopy Structure**: Taller trees with large, dense canopies are more prone to windthrow because they catch more wind and experience greater force.
  - **Root Structure**: Trees with shallow root systems (e.g., spruce and fir) are more likely to be uprooted than those with deep or extensive root systems (e.g., oak).
  - **Health and Stability**: Diseased, damaged, or weakened trees are more vulnerable to windthrow. For example, trees affected by root rot or those with previous structural damage are at higher risk.

- **Forest Stand Characteristics:**
- **Edge Effects**: Trees on the edges of forests or clearings are more exposed to wind and are therefore more likely to experience windthrow than those within the interior of a dense forest.
- **Forest Composition and Density**: Monoculture forests or those with a high density of similar species may be more susceptible to widespread windthrow. Mixed forests with a variety of species and ages tend to be more resilient.
- **Topography**:
- **Exposed Ridges and Slopes**: Trees on ridges or slopes that are exposed to prevailing winds are more susceptible to windthrow.
- **Valleys and Depressions**: While valleys can provide some protection, wind funneling through narrow depressions can also increase wind speeds and the likelihood of windthrow.

Ecological Impacts of Windthrow:

- **Habitat Creation**:
  - **New Microhabitats**: Uprooted trees and the resulting gaps in the forest canopy create new microhabitats. These gaps allow sunlight to reach the forest floor, encouraging the growth of understory plants, shrubs, and young trees.
  - **Wildlife Habitat**: Fallen trees provide habitat for various species, including insects, fungi, birds, and small mammals. The decaying wood becomes a critical resource for detritivores and plays a role in nutrient cycling.
- **Forest Dynamics and Succession**:
  - **Natural Disturbance**: Windthrow is a natural disturbance that contributes to forest succession. It can accelerate the process by creating openings for new species to establish, leading to increased biodiversity and forest regeneration.
  - **Species Composition**: Windthrow can influence species composition by favoring species that are more resilient to wind damage or those that thrive in open, sunlit conditions.
- **Soil and Hydrology**:
  - **Erosion and Soil Disturbance**: Uprooted trees can disturb the soil, leading to erosion, particularly on slopes. However, the exposed soil can also create opportunities for colonization by pioneer species.
  - **Water Dynamics**: Windthrow can alter local hydrology by changing the flow of water and nutrients through the forest floor. The removal of trees may also affect groundwater recharge and surface water flow patterns.

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