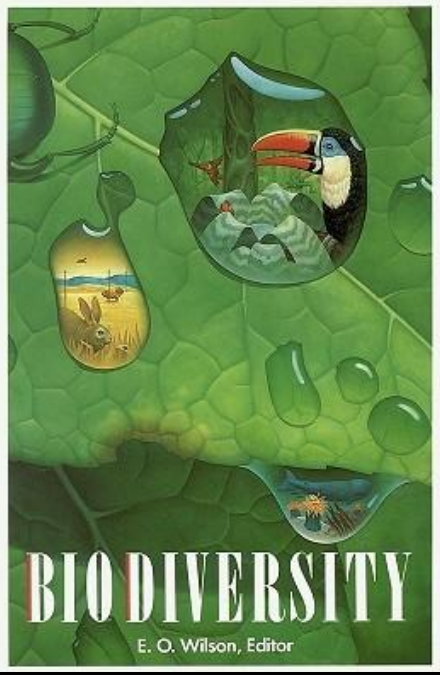
EVOLUTION AND BIODIVERSITY

- **Biological Diversity**

Biodiversity

- **Biodiversity** refers to the variety of life-forms, commonly expressed as the *number of species* or the number of genetic types in an area.
- The term "***Biological Diversity***" in its current sense began in 1980; and coined in 1985 in a conference proceedings of which were published as the book "**Biodiversity**" edited by E. O. Wilson



Definition

- Biodiversity is the variety of flora and fauna on this planet earth. It includes all life forms-from the unicellular fungi, protozoa and bacteria to complex multicellular organisms such as plants, birds, fishes and animals.
- As defined in convention on Biological diversity singed at Rio De Jenerio (Brazil) in 1992 by 154 countries, the Biodiversity defined as "***the variability among living organisms from all sources including, terrestrial, marine and other aquatic eco-systems and the ecological complexes of which the area part- this include diversity with in species, between species and of ecosystem***."
- According to IUCN in 1998, Biodiversity defined as "***the variety and variability of species of their population, the variety of species of their life forms, the diversity of the complex association with species with their interaction and their ecological process which influences perform***."
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Why Biodiversity is important?

It is important to **sustain human life**:

1. **Biodiversity providing free ecosystem services**:
   - Microorganisms, plants, and animals play a critical role in balancing ecosystem
2. **Diversity has provided humanity with the wide variety of products**:
   - Crops, domestic animals, medicines, etc.). 90% of the calories consumed by human beings come from 80 plant species. An estimated 4.5 billion people (~80% of the world population) use plants as their primary source of medicine.
3. **Biodiversity is the nature**:
   - Loss of biodiversity is a cutoff of our connection to nature and to history.
   - Inspiration and cultural heritages: Species inspire songs, stories, dances, poetry, myths, arts, cuisine, rituals, festivals… Nature is an unsurpassed source of relaxation, wonderment, rejuvenation, beauty and peace.

Biodiversity

- **Biodiversity** is defined as "the variability among living organisms from all sources including terrestrial and aquatic systems and the ecological complexes of which they are a part".
  - It is the diversity within species, among species, and of ecosystems; interactions at all levels among organisms
- **There are primarily three concepts of Biological diversity:**
  1. **Genetic diversity**
  2. **Species diversity**
  3. **Ecosystem diversity and services**
- *In effect, these levels cannot be separated. Each is important, interacting with and influencing the others. A change at one level can cause changes at the other levels*

First: Genetic diversity

- Genetic is the variety of genotypes (Genetic variations)
  - It is the total number of genetic characteristics of a specific species, subspecies, or group of species.
- In terms of genetic engineering and our new understanding of DNA, this could mean the total **base pair sequences** in DNA; the total number of genes, active or not; or the total number of active genes
- Genetic variation, responsible for different traits of individuals, interacts with local environmental conditions to determine the extent to which population can adapt to environmental changes and survive exposure to new diseases.
- Genetic variation is extremely important to the survival of populations.
  - ***Isolated populations (e.g., on a small island) tend to have less genetic variations, therefore, are more susceptible to extinction.***

Second: Species diversity

- **Species diversity** is the variety among the species or distinct types of living organisms found in different habitats of the planet
- It has three qualities:

1. Species richness (R): the total number of species
2. Species evenness (*p*i): the relative abundance of species
3. Species dominance: the most abundant species

- The widely used biodiversity index is **"Shannon diversity index (H')"** :

$$H' = -\left[\Sigma\left(pi * \ln pi\right)\right]$$

Where: *p*i = the relative abundance of each species, ***P*i=** ni/N
ni = number of individuals in species I,
N = total number of individuals of all species combined)
In = the natural logarithm

Known Species (evolved over 3.8 billion years)

Virus	5,000
Bacteria	4,000
Fungi	70,000
Plants	270,000
Invertebrates (excluding insects)	400,000
Insects (of which 600,00 are beetles)	**960,000**
Fishes	22,000
Birds	10,000
Amphibians and reptiles	12,000
Mammals	4,500
Total	**1.8 million**

Source: *A. Alonso, F. Dallmeier, E. Granek and P. Raven. 2001. Biodiversity: connecting with the tapestry of life. Smithsonian Institution/Monitoring & Assessment of Biodiversity Program and President's Committee of Advisors on Science and Technology, Washington, D.C*

Theory of Speciation

Speciation is the source of the diversity of life. It is the origin of new species

Speciation

- **A theory of speciation** is essential to link poorly understood macro-evolutionary processes, such as the origin of biodiversity and adaptive radiation, to well understood micro-evolutionary processes, such as allele frequency change due to natural or sexual selection.
  - An important question is whether, and to what extent, the process of speciation is 'adaptive', i.e., driven by natural and/or sexual selection.
- Here, we discuss two main modeling approaches in adaptive speciation theory:
  1. *Ecological speciation models*
  2. *Sexual selection models of speciation*

Ecological speciation models

- A variety of **Ecological Speciation Models** has been developed that show Darwin's intuitive notion of competitive speciation can be given a theoretical underpinning.
- These models are based on **a dynamic view of natural selection**, allowing selection to **switch from stabilizing to disruptive** in the same coherent framework**.**
- The realization that Darwinian fitness is highly context dependent and dynamic, and that in a diversity of settings, natural selection can drive a population toward a regime of ongoing disruptive selection, **makes selection-driven speciation more plausible than in traditional model**s.

Sexual selection models of speciation

- Various **Sexual Selection Models Of Speciation** give disruptive sexual selection a prominent place in the speciation process.
- Several studies demonstrate that, under specific circumstances, **sexual selection may lead to the divergence of female preferences within a single population**, eventually leading to reproductive isolation.

The biological concept of the SPECIES

- **A biological species** is the largest set of populations in which ***genetic exchange is possible*** and ***is genetically isolated from other populations.***

- ***Species*** is a Latin word meaning "kind" or "appearance".
  - Traditionally morphological differences have been used to distinguish species.
  - Differences in body function, biochemistry, behavior, and genetic makeup are also used to differentiate species.
- Groups of actually or potentially interbreeding natural populations genetically isolated from other such groups by one or more reproductive isolating mechanisms.

Species: A Working Definition

- A **species** is commonly defined as a population of organisms whose members have the potential to interbreed naturally to produce viable, fertile offspring, for several generations; but *do not interbreed* with other groups.

There are two key ideas within this definition:

First, **a species is a population of organisms**.

- The human species, *Homo sapiens,* consists of over 7 billion individuals, whereas the endangered California condor species, *Gymnogyps californianus*, consists of about 160 individuals.

Second, the definition involves the ability of individuals within the group to produce fertile offspring.

- Individuals within the group have potentially the capability of interbreeding to produce fertile offspring (**gene flow)**.
  - Two or more populations that demonstrate gene flow between them constitute a single species.
  - Conversely, two or more populations that do not demonstrate gene flow between them are generally considered to be different species.

Some examples will clarify this working definition

- The mating of a male donkey and a female horse produces young that grow to be adult mules, incapable of reproduction . Because mules are nearly always sterile, there can be no gene flow between horses and donkeys and they are considered to be separate species.
- Similarly, lions and tigers can be mated in zoos to produce offspring (**Ligor**).
  - However, this does not happen in nature and so gene flow does not occur naturally; thus they are considered to be two separate species.




Some Examples

Species are based on inter-fertility, not physical similarity.

- For example, the eastern and western meadowlarks may have similar shapes and coloration, but differences in song help prevent interbreeding between the two species.
- In contrast, humans have considerable diversity, but we all belong to the same species because of our capacity to interbreed.

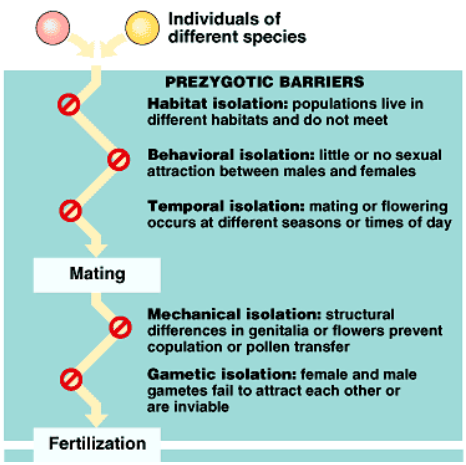
Reproductive isolation

- So the biological species concept emphasizes **reproductive isolation**
- Reproductive barriers can be categorized as
  - prezygotic or postzygotic, depending on whether they function before or after the formation of zygotes
- No single barrier may be completely impenetrable to genetic exchange, but many species are genetically sequestered by multiple barriers.
  - Typically, these barriers are intrinsic to the organisms, not simple geographic separation.
  - Reproductive isolation prevents populations belonging to different species from interbreeding, even if their ranges overlap.

Prezygotic barriers

- Prezygotic barriers impede mating between species or hinder fertilization of ova if members of different species attempt to mate.

- ***These barriers include*** :
  1. habitat isolation,
  2. behavioral isolation,
  3. temporal isolation,
  4. mechanical isolation,
  5. gametic isolation.



Prezygotic barriers

- **Habitat isolation.** Two organisms that use different habitats even in the same geographic area are unlikely to encounter each other to even attempt mating.
  - This is exemplified by the two species of garter snakes, in the genus *Thamnophis*, that occur in the same areas but because one lives mainly in water and the other is primarily terrestrial, they rarely encounter each other.

Prezygotic barriers

- **Behavioral isolation**. Many species use elaborate behaviors unique to a species to attract mates.
  - For example, female fireflies only flash back and attract males who first signaled to them with a species-specific rhythm of light signals.
- In many species, elaborate courtship displays identify potential mates of the correct species and synchronize gonadal maturation

Prezygotic barriers

- **Temporal isolation**. Two species that breed during different times of day, different seasons, or different years cannot mix gametes.
  - For example, while the geographic ranges of the western spotted skunk and the eastern spotted skunk overlap, they do not interbreed because the former mates in late summer and the latter in late winter.

Prezygotic barriers

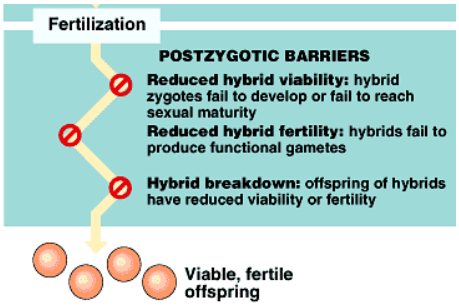
- **Mechanical isolation**. Closely related species may attempt to mate but fail because they are anatomically incompatible and transfer of sperm is not possible.
  - To illustrate, mechanical barriers contribute to the reproductive isolation of flowering plants that are pollinated by insects or other animals.
  - With many insects the male and female copulatory organs of closely related species do not fit together, preventing sperm transfer.

Prezygotic barriers

- **Gametic isolation** occurs when gametes of two species do not form a zygote because of incompatibilities preventing fusion or other mechanisms.
  - In species with internal fertilization, the environment of the female reproductive tract may not be conducive to the survival of sperm from other species.
  - 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.
  - A similar molecular recognition mechanism enables a flower to discriminate between pollen of the same species and pollen of a different species.

Postzygotic barriers

- If a sperm from one species does fertilize the ovum of another, postzygotic barriers prevent the hybrid zygote from developing into a viable, fertile adult. These barriers include :
  - reduced hybrid viability,
  - reduced hybrid fertility,
  - and hybrid breakdown.



Postzygotic barriers

- **Reduced hybrid viability**. Genetic incompatibility between the two species may abort the development of the hybrid at some embryonic stage or produce frail offspring.
  - This is true for the occasional hybrids between frogs in the genus *Rana*, which do not complete development and those that do are frail.

Postzygotic barriers

- **Reduced hybrid fertility**. Even if the hybrid offspring are vigorous, the hybrids may be infertile and the hybrid cannot backbreed with either parental species.
  - This infertility may be due to problems in meiosis because of differences in chromosome number or structure.
  - For example, while a mule, the hybrid product of mating between a horse and donkey, is a robust organism, it cannot mate (except very rarely) with either horses or donkeys.

Postzygotic barriers

- **Hybrid breakdown**. In some cases, first generation hybrids are viable and fertile.
  - However, when they mate with either parent species or with each other, the next generation are feeble or sterile.
  - To illustrate this, we know that different cotton species can produce fertile hybrids, but breakdown occurs in the next generation when offspring of hybrids die as seeds or grow into weak and defective plants.

Modes of Speciation

Two general modes of speciation are distinguished by the mechanism by which gene flow among populations is initially interrupted.

1. **Allopatric speciation**:
   - Geographic barriers can lead to the origin of species
   - Geographic separation of populations restricts gene flow
2. **Sympatric speciation**:
   - A new species can originate in the geographic midst of the parent species
   - speciation occurs in geographically overlapping populations when biological factors, such as chromosomal changes and nonrandom mating, reduce gene flow.

Allopatric Speciation

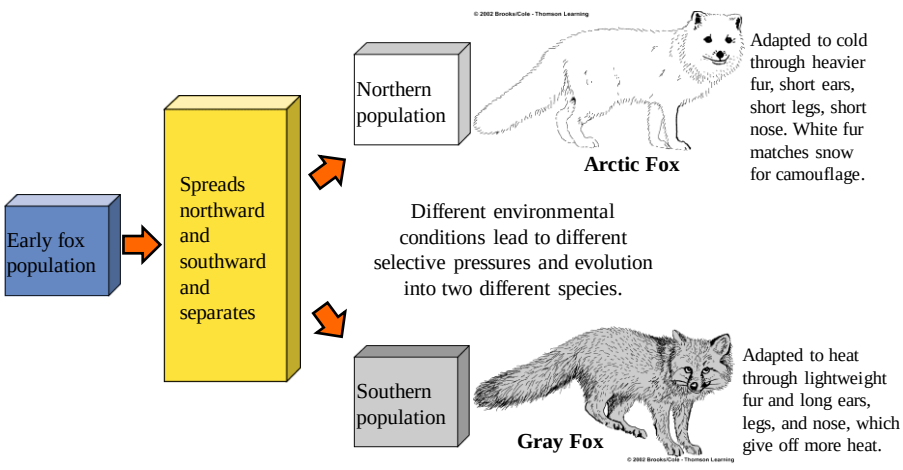
- Geographic barriers can lead to the origin of species
- Several geological processes can fragment a population into two or more isolated populations.
  - Mountain ranges, glaciers, land bridges, or splintering of lakes may divide one population into isolated groups.
  - Alternatively, some individuals may colonize a new, geographically remote area and become isolated from the parent population.
    - For example, mainland organisms that colonized the Galapagos Islands were isolated from mainland populations.

Allopatric Speciation

How significant a barrier must be to limit gene exchange

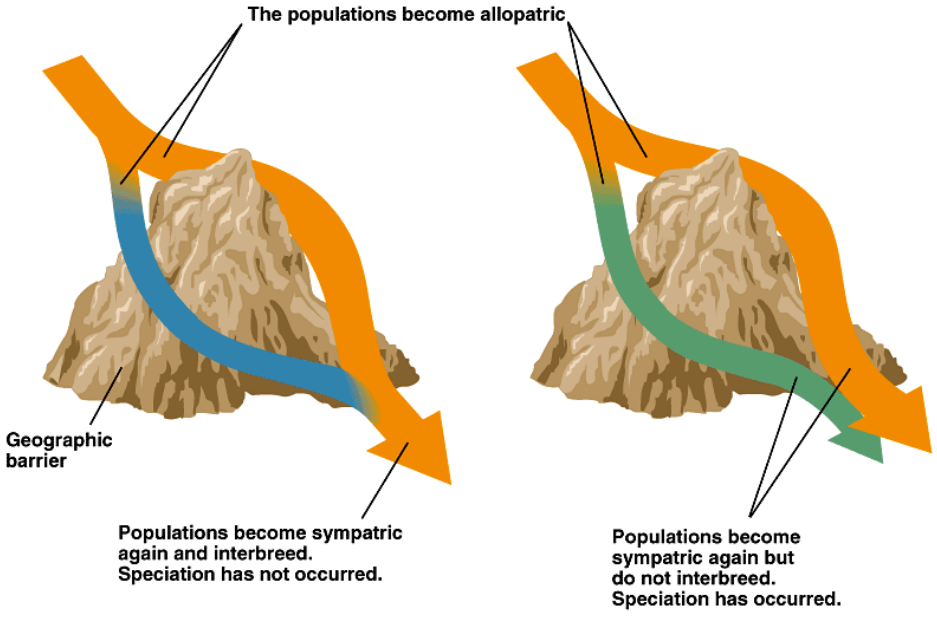
- This depends on the ability of organisms to move about.
  - A geological feature that is only a minor hindrance to one species may be an impassible barrier to another.
  - i.e. The valley of the Grand Canyon is a significant barrier for ground squirrels which have speciated on opposite sides, but birds which can move freely have no barrier.

Speciation



Allopatric Speciation

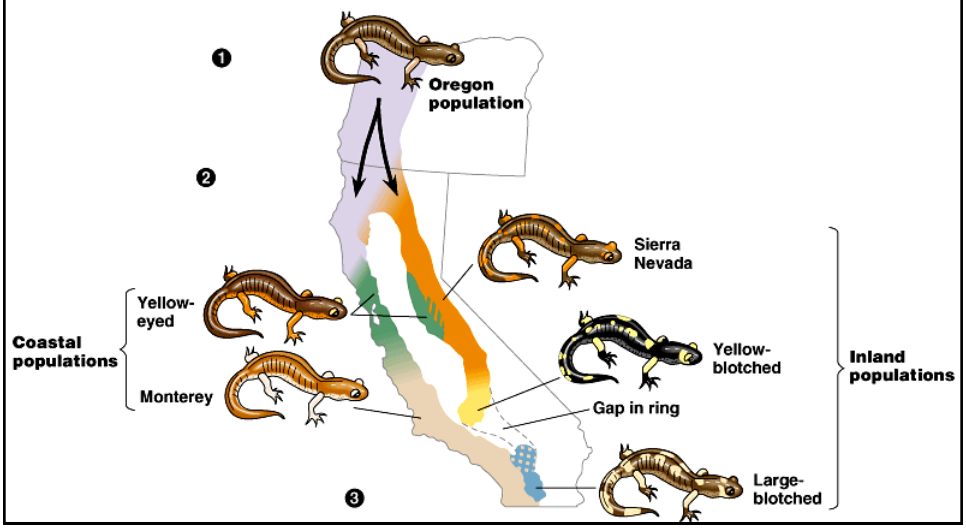
- The likelihood of allopatric speciation increases when a population is both small and isolated. A small, isolated population is more likely to have its gene pool changed substantially by genetic drift and natural selection.
  - However, very few small, isolated populations will develop into new species; most will simply perish in their new environment.
- A question about allopatric speciation is whether the separated populations have become different enough that they can no longer interbreed and produce fertile offspring when they come back in contact.



Allopatric Speciation- Summary

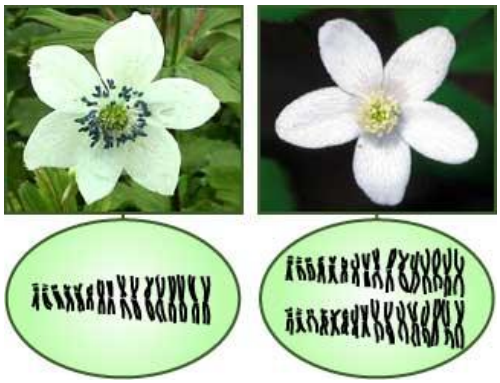
- In summary, in allopatric speciation, new species form when geographically isolated populations evolve reproductive barriers as a byproduct of genetic drift and natural selection to its new environment.
  - These barriers prevent interbreeding even if populations come back into contact.
  - These barriers include prezygotic barriers that reduce the likelihood of fertilization and postzygotic barriers that reduce the fitness of hybrids.

- At the northern end of the ring, the coastal and inland populations interbreed and produce viable offspring. In this area they appear to be a single biological species.
- At the southern end of the ring, the coastal and inland populations do not interbreed even when they overlap. In this area they appear to be two separate species.



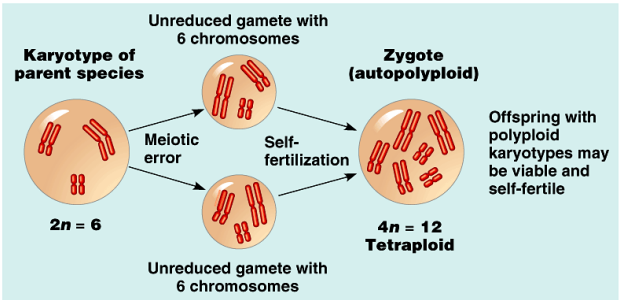
Sympatric Speciation

- In sympatric speciation, new species arise within the range of the parent populations.
- Here reproductive barriers must evolve between sympatric populations



Sympatric Speciation- Autopolyploid

- An individual can have more that two sets of chromosomes from a single species if a failure in meiosis results in a tetraploid (4*n*) individual.
- This **autopolyploid** mutant can reproduce with itself (self-pollination) or with other tetraploids.
- It cannot mate with diploids from the original
- population, because of
- abnormal meiosis by the triploid hybrids.



Sympatric Speciation

- In the early 1900s, botanist *Hugo de Vries* **produced a new primrose species**, the tetraploid *Oenotheria gigas*, from the diploid *Oenothera lamarckiana*.
  - This plant could not interbreed with the diploid species.

Sympatric Speciation

- Plants for example have a special way of generating new species by increasing their chromosome numbers as a result of abnormal mitosis or meiosis (**Polyploidy**).
  - In plants it can be resulted accidentally during cell division; while in animals, it may be resulted from gene-based shifts in habitat or mate preference.
- Many plants important for agriculture are the products of polyploidy.
  - For example, oats, cotton, potatoes, tobacco, and wheat are polyploid.
  - Plant geneticists now hybridize plants and use chemicals that induce meiotic and mitotic errors to create new polyploids with special qualities.
    - Example: artificial hybrids combine the high yield of wheat with the ability of rye to resist disease.

Some other examples:

Plant	Probable ancestral haploid number	Chromosome number	Ploidy level
domestic oat	7	42	**6n**
peanut	10	40	**4n**
sugar cane	10	80	**8n**
banana	11	22, 33	**2n**, **3n**
white potato	12	48	**4n**
tobacco	12	48	**4n**
cotton	13	52	**4n**
apple	17	34, 51	**2n**, **3n**

Polyploidy in plants

- Polyploidy is very common in plants, especially in angiosperms. From 30% to 70% of today's angiosperms are thought to be polyploid.
  - Species of coffee plant with 22, 44, 66, and 88 chromosomes are known. This suggests that the ancestral condition was a plant with a haploid (**n**) number of 11 and a diploid (**2n**) number of 22, from which evolved the different polyploid descendants.
- In fact, the chromosome content of most plant groups suggests that the basic angiosperm genome consists of the genes on 7–11 chromosomes.
  - Domestic wheat, with its 42 chromosomes, is probably hexaploid (**6n**), where **n** (the ancestral haploid number) was 7.
- Polyploid plants not only have larger cells but the plants themselves are often larger.
  - This has led to the deliberate creation of polyploid varieties of such plants as watermelons, and snapdragons.

Sympatric Speciation- in Animals

- While polyploid speciation does occur in animals, other mechanisms also contribute to sympatric speciation in animals.
  - Sympatric speciation can result when genetic factors cause individuals to be fixed on resources not used by the parent.
  - These may include genetic switches from one breeding habitat to another or that produce different mate preferences.
- Sympatric speciation is one mechanism that has been proposed for the explosive adaptive radiation of almost 200 species of cichlid fishes in Lake Victoria, Africa.
  - While these species clearly are specialized for exploiting different food resources and other resources, non-random mating in which females select males based on a certain appearance has probably contributed too.

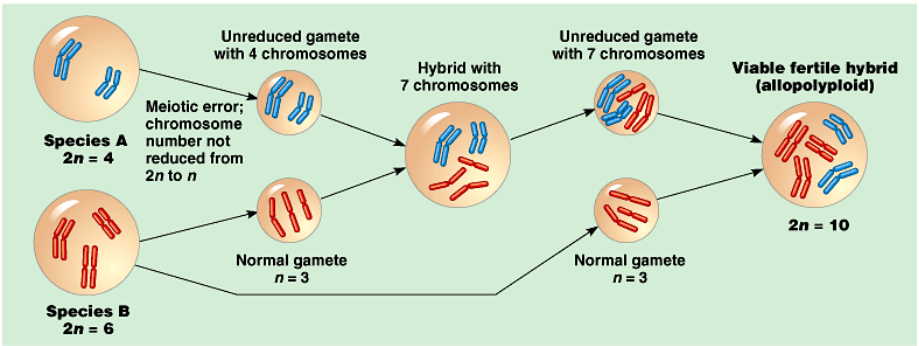
- **Polyploidy** is a condition in which there are more than two complete sets of chromosomes in an organism
- Polyploidy is much rarer in animals. It is found in some insects, fishes, amphibians, and reptiles. Until recently, no polyploid **mammal** was known. However, the 23 September 1999 issue of **Nature** reports that a polyploid (tetraploid; **4n** = 102) rat has been found in Argentina.

Sympatric Speciation- Allopolyploid

- Another mechanism of producing polyploid individuals occurs when individuals are produced by the *mating of two different species,* **an allopolyploid**.
- While the hybrids are usually sterile, they may be quite vigorous and propagate asexually.
- Various mechanisms can **transform a sterile hybrid into a fertile polyploid.**
  - These polyploid hybrids are fertile with each other but cannot interbreed with either parent species.

Sympatric Speciation- Allopolyploid

- One mechanism for **allopolyploid** speciation in plants involves several cross-pollination events between two species of their offspring and perhaps a failure of meiotic disjunction to a viable fertile hybrid whose chromosome number is the sum of the chromosomes in the two parent species.



Alterations Of Chromosome Number or structure cause some genetic disorders

- Large-scale chromosomal alterations often lead to spontaneous abortions or cause a variety of developmental disorders
- *Abnormal Chromosome Number* when nondisjunction occurs
  - Pairs of homologous chromosomes do not separate normally during meiosis
  - Gametes contain two copies or no copies of a particular chromosome
- **Aneuploidy**
  - Results from the fertilization of gametes in which nondisjunction occurred
  - It is a condition in which offspring have an abnormal number of a particular chromosome
    - If a zygote is *trisomic* it has three copies of a particular chromosome
    - If a zygote is *monosomic* it has only one copy of a particular chromosome

Sympatric Speciation- in Animals

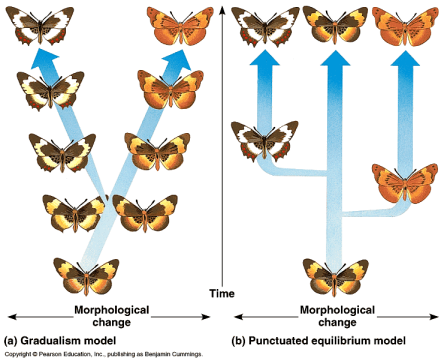
- Individuals of two closely related sympatric cichlid species will not mate under normal light because females have specific color preferences and males differ in color.
  - However, under light conditions that de-emphasize color differences, females will mate with males of the other species and this results in viable, fertile offspring.
  - The lack of postzygotic barriers would indicate that speciation occurred relatively recently.

Sympatric Speciation- Summary

- Sympatric speciation requires the emergence of some reproductive barrier that isolates a subset of the population without geographic separation from the parent population.
  - In plants, the most common mechanism is hybridization between species or errors in cell division that lead to polyploid individuals.
  - In animals, sympatric speciation may occur when a subset of the population is reproductively isolated by a switch in resources or mating preferences.

The punctuated equilibrium model has stimulated research on the tempo of speciation

- Traditional evolutionary trees diagram the diversification of species as a gradual divergence over long spans of time.
  - These trees assume that big changes occur as the accumulation of many small one, the gradualism model.



The Biological Species Concept Has Some Major Limitations

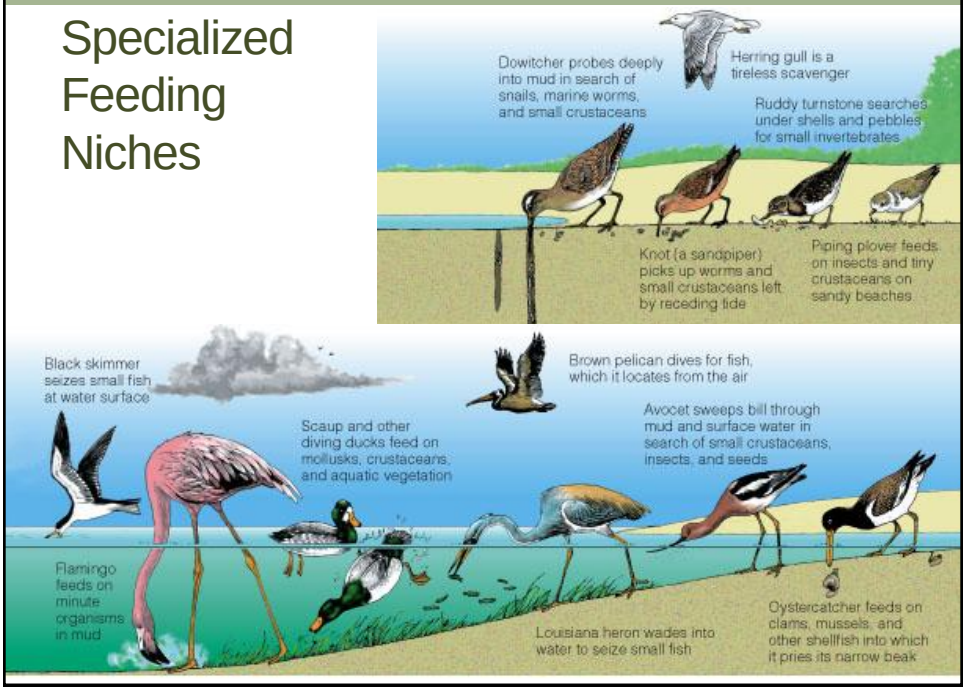
- While the biological species concept has had important impacts on evolutionary theory, it is limited when applied to species in nature.
  1. Cannot test the reproductive isolation of morphologically-similar fossils, which are separated into species based on morphology.
  2. Lack the information on interbreeding to apply to every living species.
  3. Many species (e.g., bacteria) reproduce entirely asexually and are assigned to species based mainly on structural and biochemical characteristics.

Evolutionary Biologists Have Proposed Several Alternative Concepts Of Species

- The ecological species concept: defines a species in terms of its **ecological NICHE**, the set of environmental resources that a species uses and its role in a biological community.
  - As an example, a species that is a parasite may be defined in part by its adaptations to a specific organism.

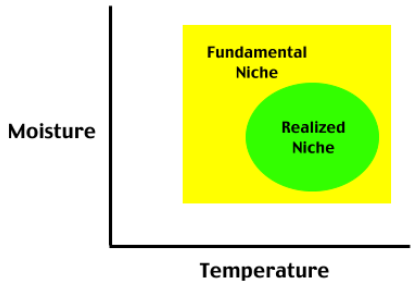
- **Niche**: is a species detailed functional role in an ecosystem; involves everything that affects its survival and reproduction includes:
  1. Range of tolerance of all abiotic factors
  2. Trophic characteristics
  3. How it interacts with biotic and abiotic factors
  4. Role it plays in energy flow and matter cycling

Specialized Feeding Niches

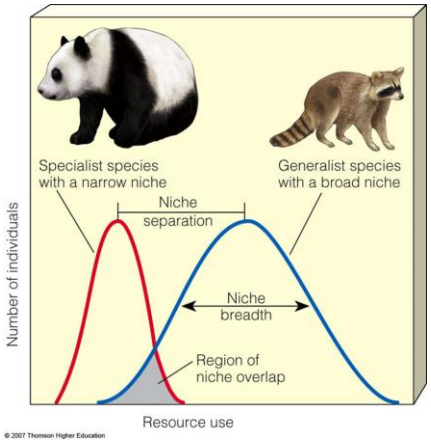


Competition Shrinks Niches

- **Fundamental Niche**
  - Full potential range of physical chemical and biological conditions and resources it could theoretically use if there was no direct competition from other species
- **Realized Niche**
  - Part of its niche actually occupied

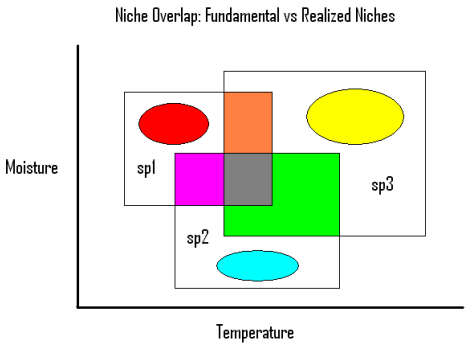


Generalist vs. Specialist



- **Generalist species** tolerate a wide range of conditions.
  - Lives many different places, eat many foods, tolerate a wide range of conditions vs few, few, intolerant…
- **Specialist species** can only tolerate a narrow range of conditions.
- ***Which strategy is better in a stable environment vs unstable?***

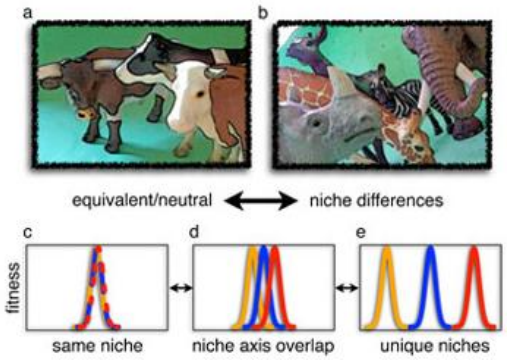
Competition and Community Diversity



- Species evolve to minimize competition and niche overlap
- Results in a diverse matrix of differing species within a community

What's this niche stuff got to do with evolution and biodiversity?

- Let's think about three key points….
  - The more niches you have in an ecosystem…
    - The more of a generalist species you are…
      - The more of a specialist species you are…



Third: Ecological diversity and services

- **Ecological diversity** is a type of biodiversity that deals with variation in the **ecosystems** found in a region or the variation in **ecosystems** over the whole planet.
- The enormous range of terrestrial and aquatic environments on earth has been classified into a number of ecosystems.
  - Major habitat types (**Biomes**) include tropical rain forests, grasslands, wetlands, coral reefs and mangroves.
- Measuring changes in the extent of ecosystems is difficult, because there is no globally agreed classification of ecosystems, and boundaries are often variable and elusive.
  - Species contained within a given ecosystem also vary over time

Ecological diversity concept of Biological diversity

- Studies of ecosystem diversity are carried out on different scales:
  - from one ecosystem to an entire region containing many different ecosystems.
- Regions containing a great variety of ecosystems are rich in biodiversity, but individual ecosystems containing *endemic species* also make a significant contribution to global biodiversity.
- Some of the world's richest habitats are **tropical moist forests**.
  - Although they cover only 7 percent of the world's surface, these areas contain at least 50 percent, and possibly up to 90 percent of all plant and animal species.
- Isolated islands are often rich in endemic species.

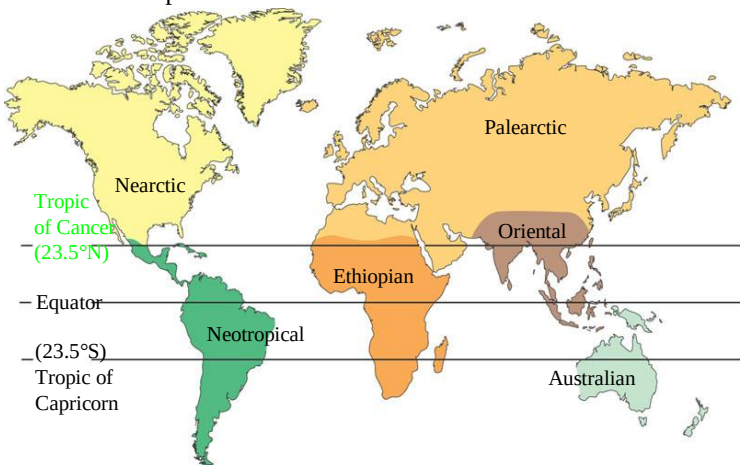
Ecological services

- **Ecosystem services** encompass all the processes through which natural ecosystems and the species they contain help sustain human life on Earth.
- Ecosystem services include
  1. Purification of air and water
  2. Detoxification and decomposition of wastes
  3. Cycling of nutrients
  4. Moderation of weather extremes
  5. others

Interactions between organisms and the environment limit the distribution of species

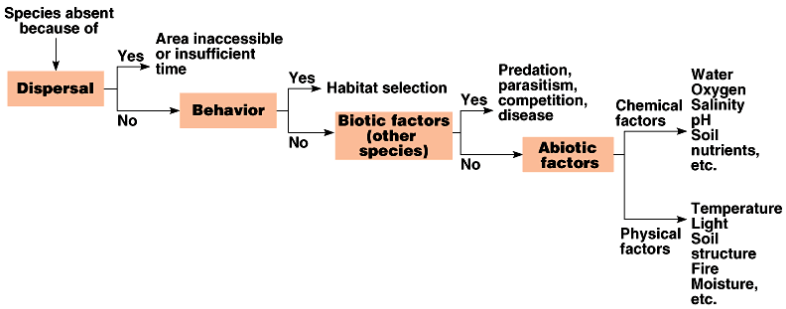
- Ecologists have long recognized global and regional patterns of **distribution** of organisms within the biosphere

Many naturalists Began to identify broad patterns of distribution by naming **biogeographic realms**



Biogeography

- It is interactions between organisms and the environment limit the distribution of species
- It is studying the Factors affecting the distribution of organisms
- It is the study of the geographic distribution of organisms throughout the landscape
- It provides a good starting point for understanding what <u>limits</u> the geographic distribution of species



(a) Species Dispersal

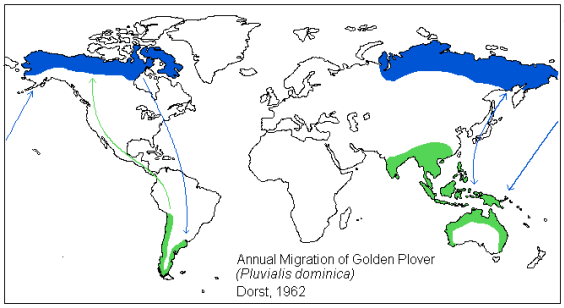
- Dispersal refers to the process of distribution of individuals within geographic population boundaries
- Ecological (Adaptive) Dispersal: "why it happens"
  - Movement to new, unused resources (away from parents)
    - Within same habitat
    - Across barrier to new habitat (within range)
- Successful Dispersal depends on "long distance" transport
  - withstanding unfavorable conditions during travel and upon early arrival
  - establishing a viable population

Kinds of Dispersal

Three kinds of dispersal leading to range expansion

1. **Jump Dispersal**: long distances over inhospitable habitat
   - Oceanic islands mostly by volant organisms (flight) ex.: Galapagos Islands
2. **Diffusion movement**: into adjacent habitats as population expands
   - Plants: purple loosestrife, halogeton, storksbill
   - Birds: cattle egret, starlings, house sparrows
   - muskrat, armadillo, nutria (Myocastor coypus)
3. **Secular Migration**: geological times scale
   - Plants: diversification and spread of flowering plants
   - Animals: spread of camels from North America to S. America and Asia

Dispersal Mechanisms



1) Active Dispersal

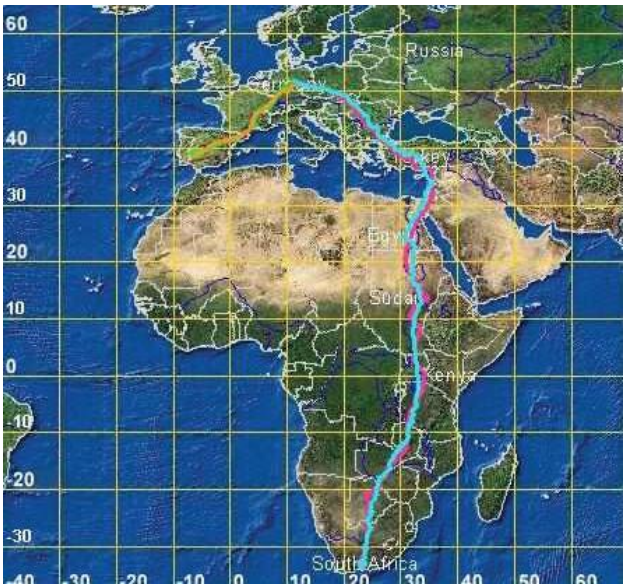
- strong fliers
- annual migrators
  - examples: golden plover (is a shore bird that breeds during the Arctic summer, and then flies to the southern hemisphere during its summer.

2) Passive Dispersal :

- Plants

Active Dispersal

- The route of the stork (طائر اللقلق)"Frente" (blue) from Germany to South Africa and its return (in violet)
- This was recorded by the satellite through a transmitter attached to its body. [Her husband "Yunus" emigrated to southern Spain (In yellow)].

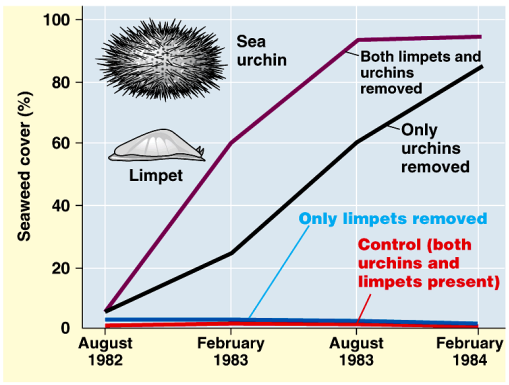


(b) Behavior

- *Why Organisms may not occupy all potentially suitable habitat ?*
- This is may be referred to:
  - Evolution doesn't lead to perfect organisms.
  - Evolution is an ongoing process.
  - Environments change, but it takes a while for organisms to respond.

(c) Biotic factors

- Did organisms required for potential community members to colonize may be lacking?
  - Pollinators, prey, predators that limit competition



*(d) Abiotic factors-*Physical Environment

- The nature of the physical environment in large measure determines what organisms live in a place. **Key elements include**:
  - **Temperature.**
    - Most organisms are adapted to live within a relatively narrow range of temperatures and will not thrive if temperatures are colder or warmer. The growing season of plants, for example, is importantly influenced by temperature.
  - **Water**.
    - Plants and all other organisms require water. On land, water is often scarce, so patterns of rainfall have a major influence on life.
  - **Sunlight**.
    - Almost all ecosystems rely on energy captured by photosynthesis; the availability of sunlight influences the amount of life an ecosystem can support, particularly below the surface in marine communities.
  - **Soil**.
    - The physical consistency, pH, and mineral composition of soil often severely limit plant growth, particularly the availability of nitrogen and phosphorus.

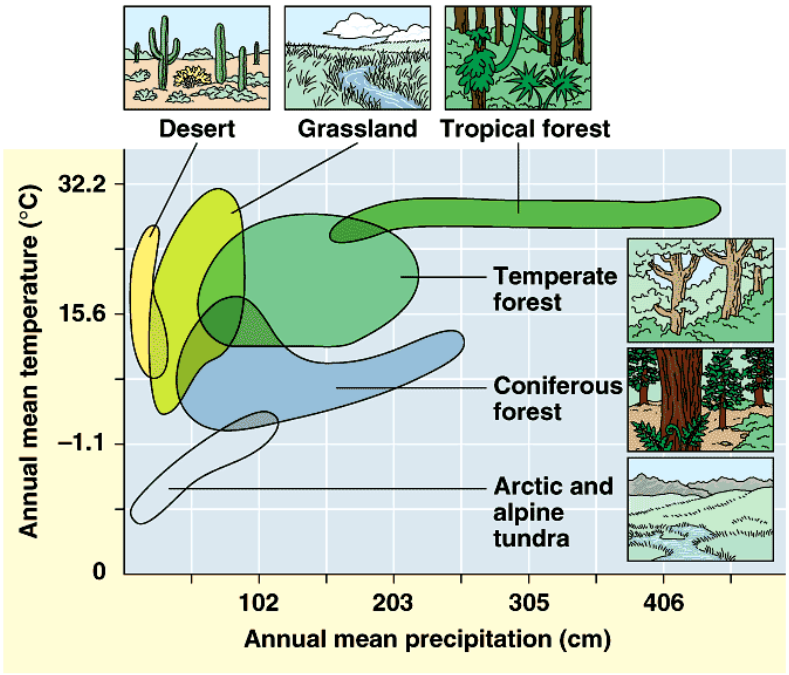
Climate shapes the character of ecosystems

- The distribution of biomes results from the interaction of the features of the earth itself, such as different soil types or the occurrence of mountains and valleys, with two key physical factors:

  (1) the amount of solar heat that reaches different parts of the earth and seasonal variations in that heat; and

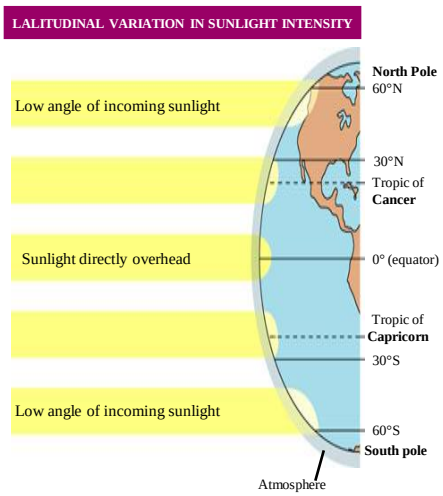
  (2) global atmospheric circulation and the resulting patterns of oceanic circulation.

- Together these factors dictate local climate, and so determine the amounts and distribution of precipitation.



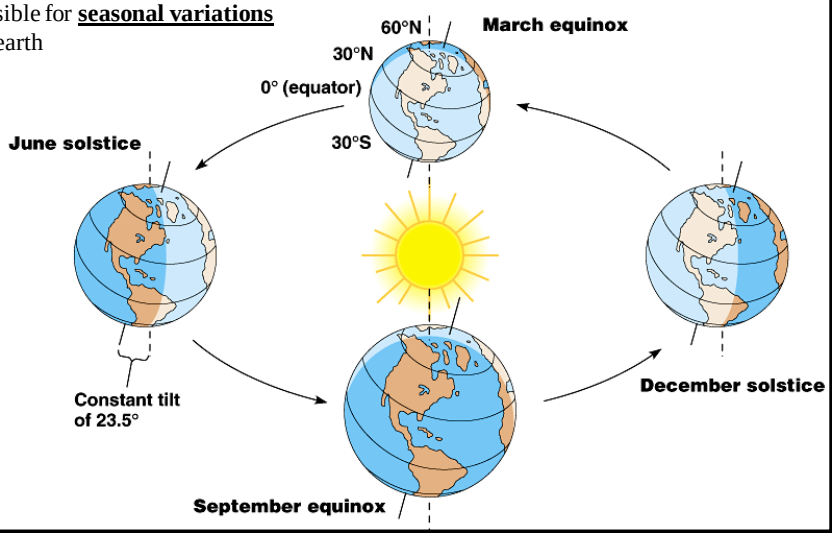
Earth's global climate

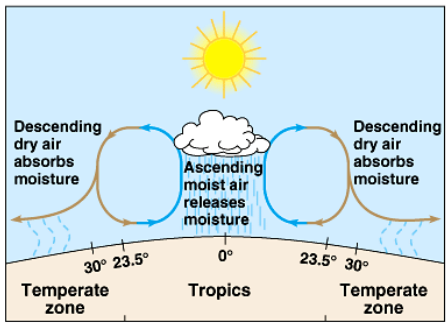
- Earth's global climate patterns are determined largely by
  - the input of solar energy
  - the planet's movement in space.
- Sunlight intensity plays a major part in determining the Earth's climate patterns.



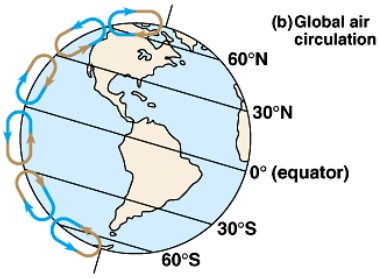
The Sun and Atmospheric Circulation

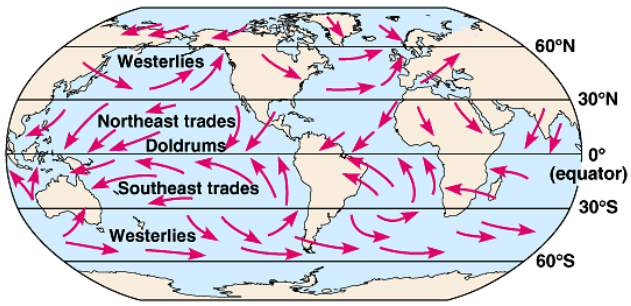
The angle of the earth's axis is responsible for **<u>seasonal variations</u>** on the earth





(a) Air circulation and precipitation near the equator



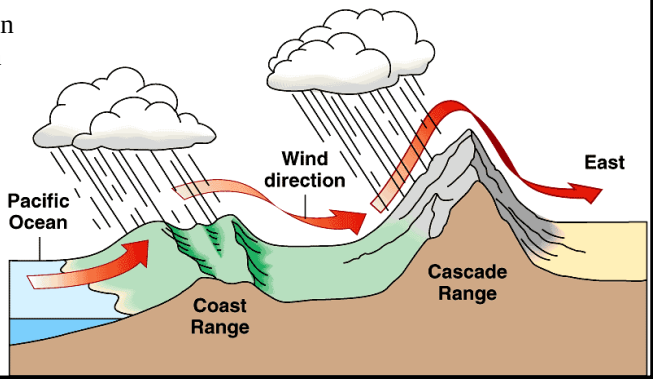


(c) Global wind patterns

Regional, Local, and Seasonal Effects on Climate

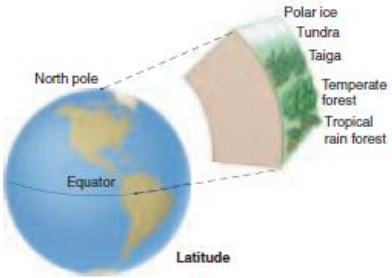
- Various features of the landscape contribute to local variations in climate
- **Bodies of water** and **topographic features** such as mountain ranges create regional climatic variations

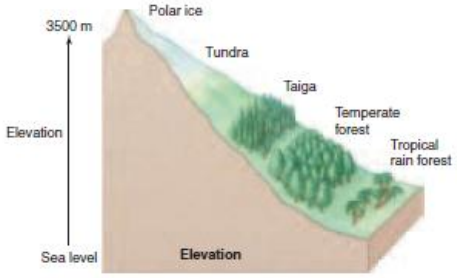
  - **Ocean** currents can influence climate in coastal areas.
  - **Mountains** affect rainfall greatly.



Regional Climates

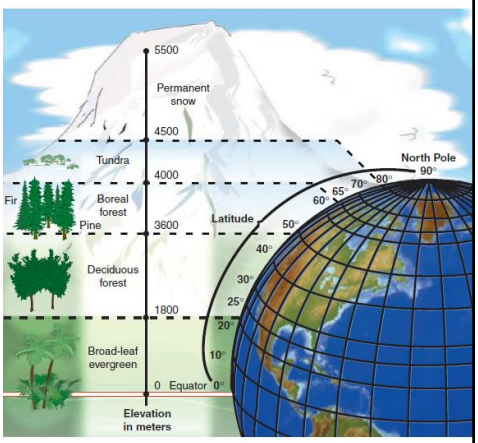
- **Elevation** affects the distribution of biomes much as latitude does.
- Biomes that normally occur far north and far south of the equator at sea level also occur in the tropics at high mountain elevations.
  - Thus, on a tall mountain in southern Mexico or Guatemala, one might see a sequence of biomes like the one illustrated





Distribution of biodiversity

- The pattern of having lots of species at the equator with diversity dwindling off towards the poles is known as the **Latitudinal Diversity Gradient** "latitudinal" meaning how far north or south of the equator, "diversity" meaning the number of species, "gradient" meaning the transition between high and low.
- Mountains climate change with elevation (**Altitude**) such as latitude. Thus flora and fauna decreases with elevation.



The Biomes

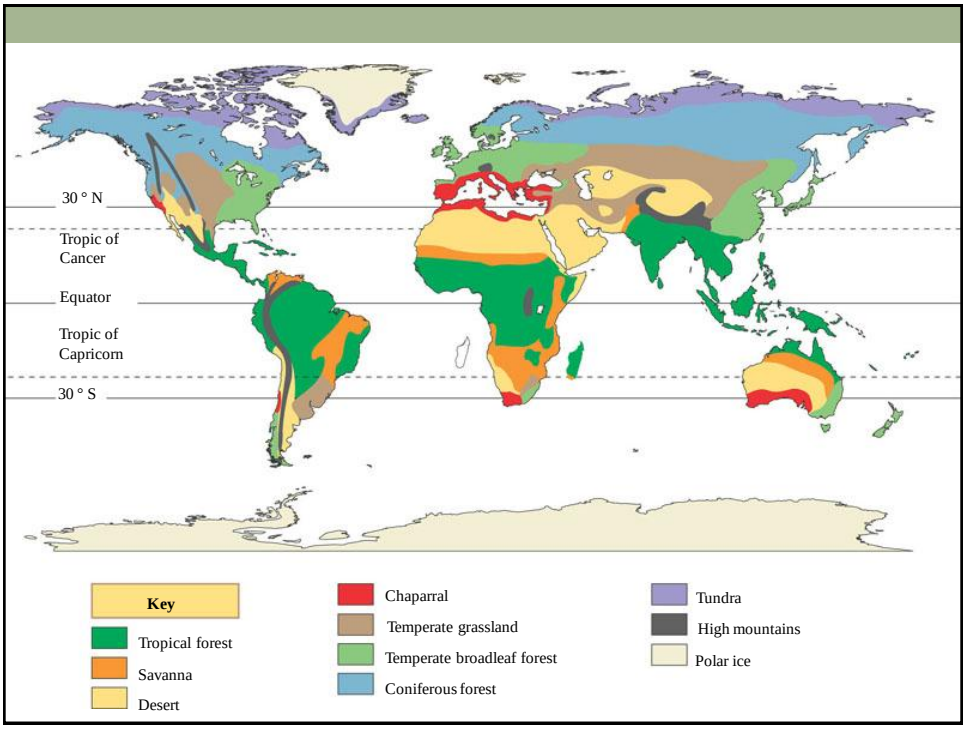
- Climate determines the makeup of biomes. Four major abiotic components make up climate: Temperature, water, sunlight, and wind
  - The primary climatic factors that determine the kinds of organisms that can live in an area are the **amount and pattern of precipitation** and **the temperature ranges** typical for the region.
- Climate patterns can be described on two scales:
  - ***Macroclimate***, patterns on the global, regional, and local level
  - ***Microclimate***, very fine patterns, such as those encountered by the community of organisms underneath a fallen log.

Biomes definition

- Biome is described as the major type of ecosystem in a defined region; including the particular communities of organisms that are adapted to such climate conditions.
- Biomes are described as the major communities of organisms that have a characteristic appearance and that are distributed over a wide land area defined largely by regional variations in climate.
  - As you might imagine from such a broad definition, there are many ways to classify biomes, and different ecologists may assign the same community to different biomes.
  - There is little disagreement, however, about the reality of biomes as major biological communities—only about how to best describe them

Terrestrial Biomes

- Biomes are distinguished primarily by their predominant plants and are associated with particular climates.
  - Geographic and seasonal variations in temperature and precipitation are fundamental components.
  - Climate has a great impact on the distribution of organisms
- Terrestrial biomes are often named for major physical or climatic factors and for their predominant vegetation
- ***Stratification*** is an important feature of terrestrial biomes
  - The *canopy* of the tropical rain forest is the top layer, covering the layers below.
  - The *permafrost* in the tundra is a permanently frozen stratum that lies under ground.
- The species composition of any biome differs from location to location.



The major seven types of terrestrial biomes

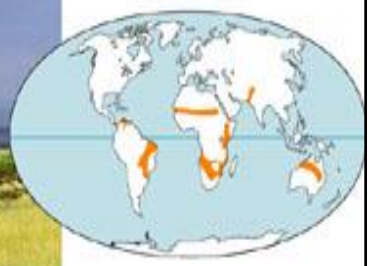
1. Tropical rain forest
2. Savanna
3. Desert
4. Temperate grassland
   - *Chaparral*
5. Temperate deciduous forest
   - *Temperate broadleaf (deciduous) forest*
6. Coniferous forest
7. Tundra

Tropical Rain Forest

- Receive 140 to 450 centimeters of rain a year
- These are the richest ecosystems on earth, as they contain at least half of the earth's species of terrestrial plants and animals
- Vertical stratification with trees in canopy blocking light to bottom strata. Many trees covered by epiphytes (plants that grow on other plants).

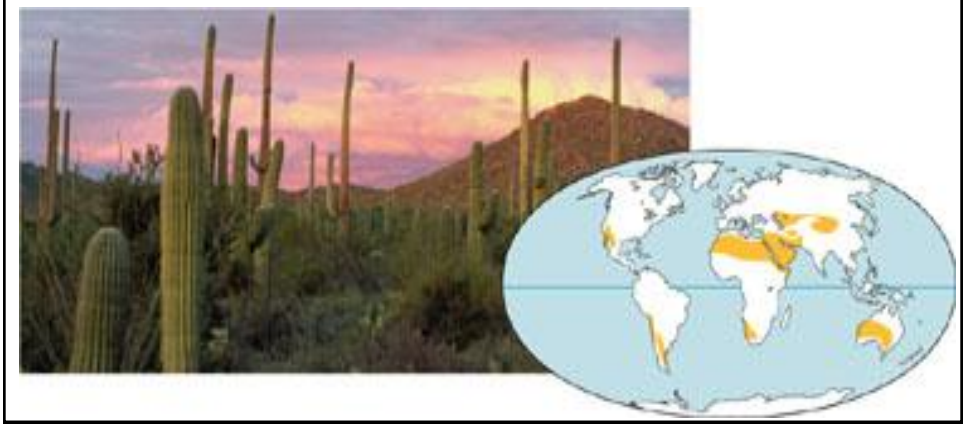
Savanna

- Receive seasonal rainfall (75 to 125 centimeters annually) .
- Savanna is grassland with scattered individual trees. Savanna landscapes are open, often with widely spaced trees
- Many of the animals and plants are active only during the rainy season.



Desert

- Deserts are dry places where less than 25 centimeters of rain falls in a year, an amount so low that vegetation is sparse and survival depends on water conservation.
- Plants and animals may restrict their activity to favorable times of the year, when water is present. Can be either very hot, or very cold



Temperate grassland

- Halfway between the equator and the poles are temperate regions where rich grasslands grow.
- *Prairies*, another name for temperate grasslands.
- Temperate grasslands are often populated by herds of grazing mammals
- Marked by seasonal drought and *fires*, and grazing by large animals.
- Rich habitat for agriculture.

Chaparral

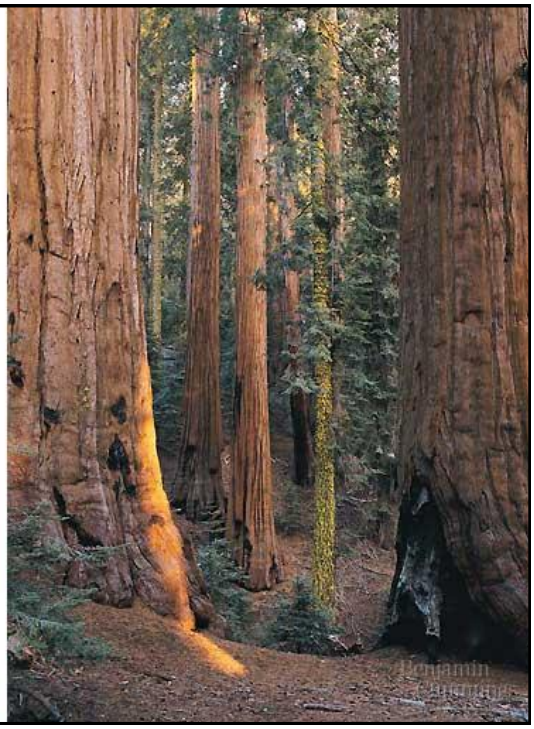
- From the word chaparro (Spanish word means both small and dwarf evergreen oak).
- It is shaped by a Mediterranean climate (mild, wet winters and hot dry summers) and wildfire. Periodic fires (some plants require fire for seeds to germinate)
- Found primarily in the U.S. state of California and in the northern portion of Mexico.
- Similar plant communities (Dense, spiny, evergreen shrubs) are found in the four regions around the world: the Mediterranean Basin, central Chile, South African Cape Region, and in Western and Southern Australia.

Temperate broadleaf (deciduous) forest

- Most of these areas receive 200 centimeters (80 inches) or more precipitation per year.
- This abundance of water, along with fertile soil and mild temperatures, results in a lush growth of plants.
- Mid-latitudes with moderate amounts of moisture, distinct vertical strata: trees, understory shrubs, herbaceous sub-stratum.
- Loss of leaves in cold, many animals hibernate or migrate then.
- Original forests lost from North America by logging and clearing.

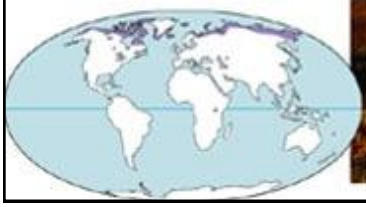
Coniferous Forest

- The evergreen trees are especially adapted to withstand long, cold winters with abundant snowfall.
- Typically the growing season is less than 120 days and rainfall ranges between 40 and 100 centimeters per year
- Coniferous forest: Largest terrestrial biome on earth, old growth forests rapidly disappearing, usually receives lots of moisture as rain or snow.

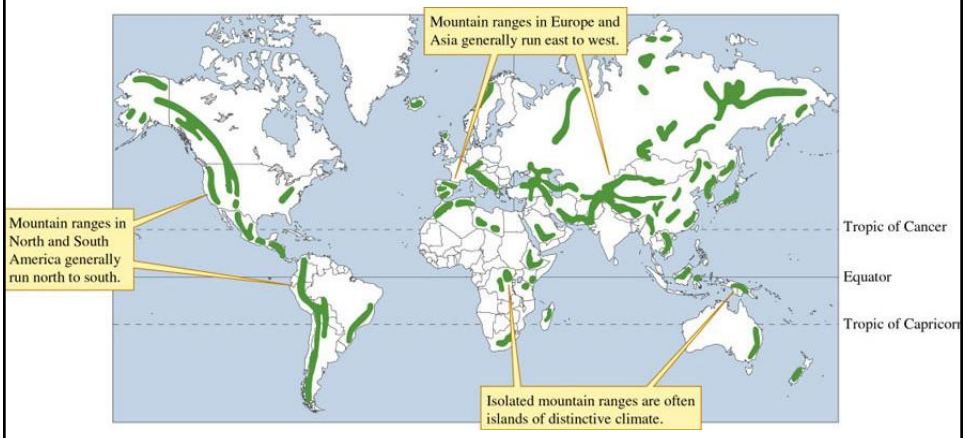


Tundra

- Tundra is the coldest of all the biomes.
- *Permafrost* (Permanent frozen ground), bitter cold, high winds and thus no trees.
- Tundra comes from the Finnish word *tunturia*, meaning treeless plain.
- It is noted for its frost-molded landscapes, extremely low temperatures, little precipitation, poor nutrients, and short growing seasons.
- Dead organic material functions as a nutrient pool.
- Has 20% of land surface on earth.

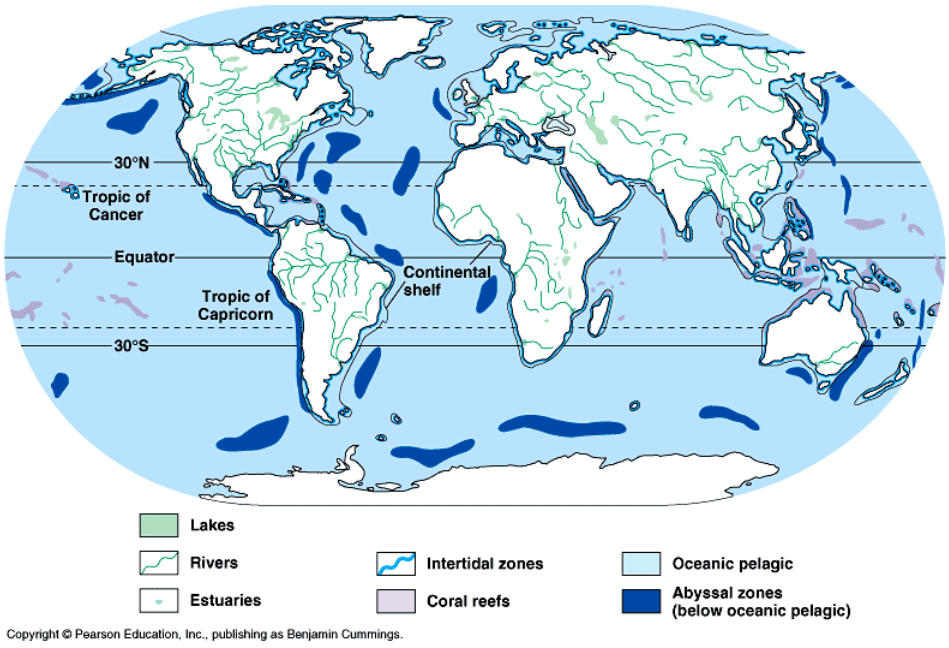


Mountains as islands of distinctive climate



Aquatic biomes

- Aquatic biomes
  - Account for the largest part of the biosphere in terms of area
  - Can contain fresh (1% salt) or salt water (3% salt)
  - Cover about 75% of Earth's surface
  - Have an enormous impact on the biosphere
- Many of aquatic biomes are stratified into **zones** or layers defined by *light penetration*, *temperature*, and *depth*



The major aquatic biomes

1. Lakes
2. Wetlands
3. Rivers, streams
4. Estuaries
5. Oceanic (Marine) zones:
   - Intertidal zone
   - Coral reefs
   - Pelagic biome
   - Benthos

Lakes

- Over long periods of time, oligotrophic lakes may become mesotrophic as runoff brings in nutrients.
  - **Oligotrophic lakes** are deep, nutrient-poor and do not contain much life; water is clear, oxygen rich; little productivity by algae, relatively deep with little surface area.
  - **Eutrophic lakes** are shallower; nutrient rich, lots of algal productivity so it's oxygen poor at times, water is murkier; often a result of input of agricultural fertilizers
  - **Mesotrophic** have a moderate amount of nutrients and phytoplankton productivity.

An **oligotrophic** lake

A **eutrophic** lake

Wetlands

- They are areas covered with water that supports many types of plants.
- They can be saturated or flooded and include areas known as marshes, bogs, seasonal ponds and swamps.
- They are home to many different types of organisms, from herbivores to crustaceans.
- Among richest biomes with respect to biodiversity and productivity.
- Very few now exist as they are thought of often as wastelands.

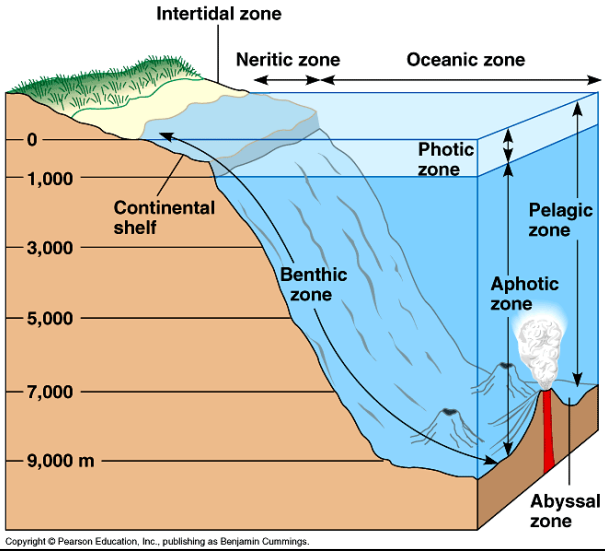
Streams and Rivers

- The are bodies of water moving continuously in one direction
- Rivers and Streams: Organisms need adaptations so that they are not swept away by moving water; heavily affected by man changing the course of flow (E.g. dams and channel-straightening) and by using rivers to dispose of waste.
- Headwaters are cold and clear and carry little sediment and relatively few mineral nutrients.
- As the stream travels down, it picks up O2 and nutrients on the way.
- Nutrient content is largely determined by the terrain and vegetation of the area.

Estuaries

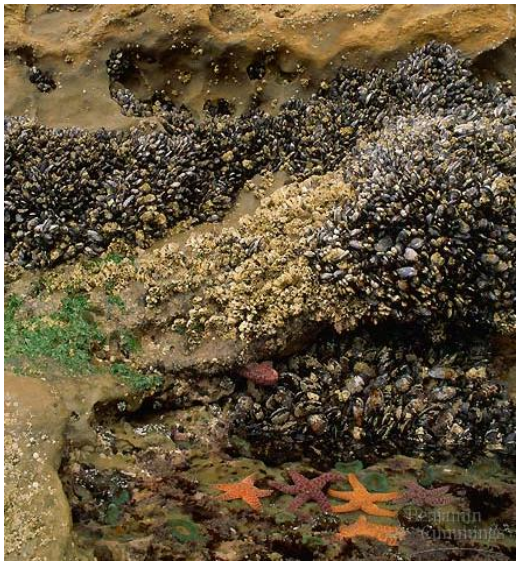
- Estuaries are areas where freshwater streams or rivers merge with the ocean.
- Highly productive biome; important for fisheries and feeding places for water fowl.
- Often heavily polluted from river input so many fisheries are now lost.
- This mixing of waters with such different salt concentrations creates a very interesting and unique ecosystem.
- Microflora like algae, and macroflora, such as seaweeds, can be found here.
- Estuaries support a diverse fauna, including a variety of worms, oysters, crabs, and waterfowl.

Marine environment with zonation



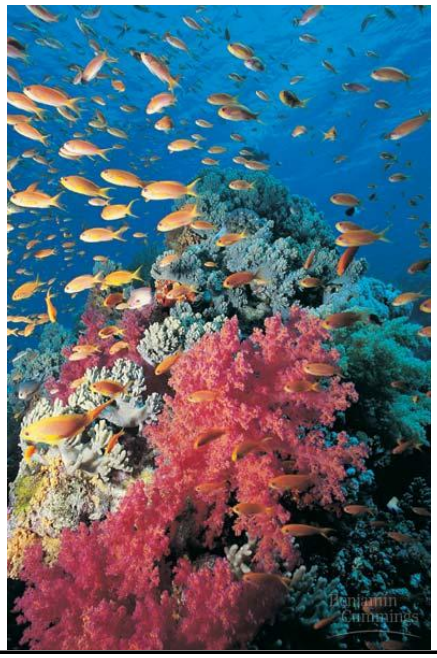
Intertidal zones

- The intertidal zone is where the land meets the water.
- They are alternately submerged and exposed by the twice-daily cycle of tides
  - Many types of organisms inhabit these areas, such as suspension-feeding worms, crustaceans, mollusks and others.
- Intertidal Zone often polluted by oil that decreases biodiversity.



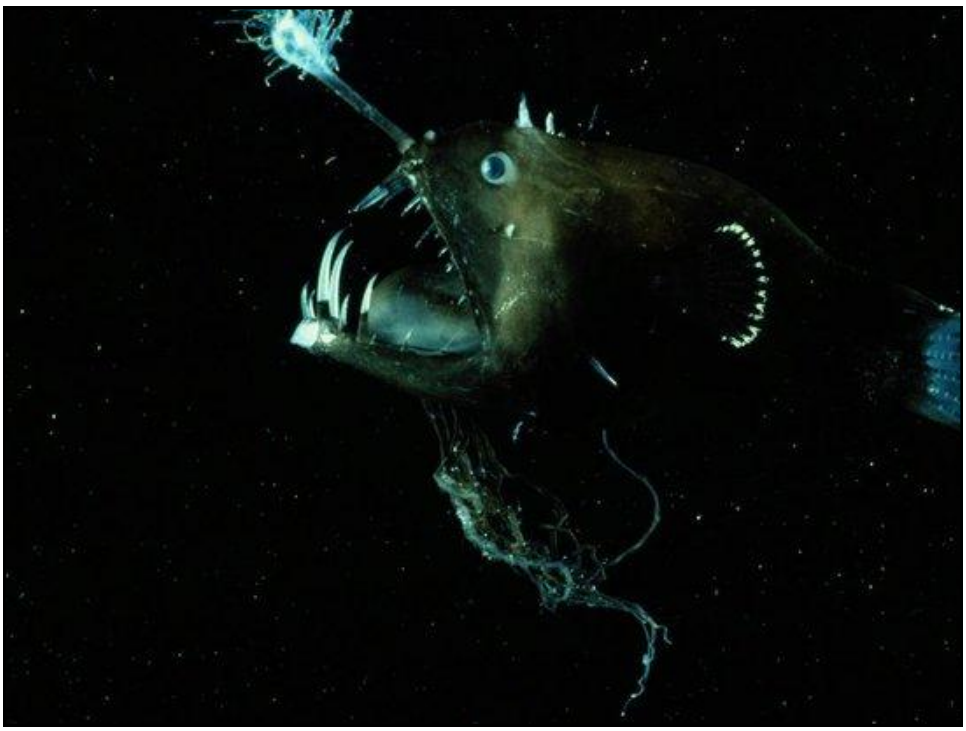
Coral reefs

- Coral Reefs occur in neritic zones of warm, tropical water, dominated by cnidarians (corals); very productive, protect land from storms; most are now dying from rise in global temperatures
- The neritic zone includes the shallow regions over the continental shelves.
- They constitute a conspicuous and distinctive biome.
- They are dominated by coral and include a very diverse assortment of vertebrates and invertebrates.



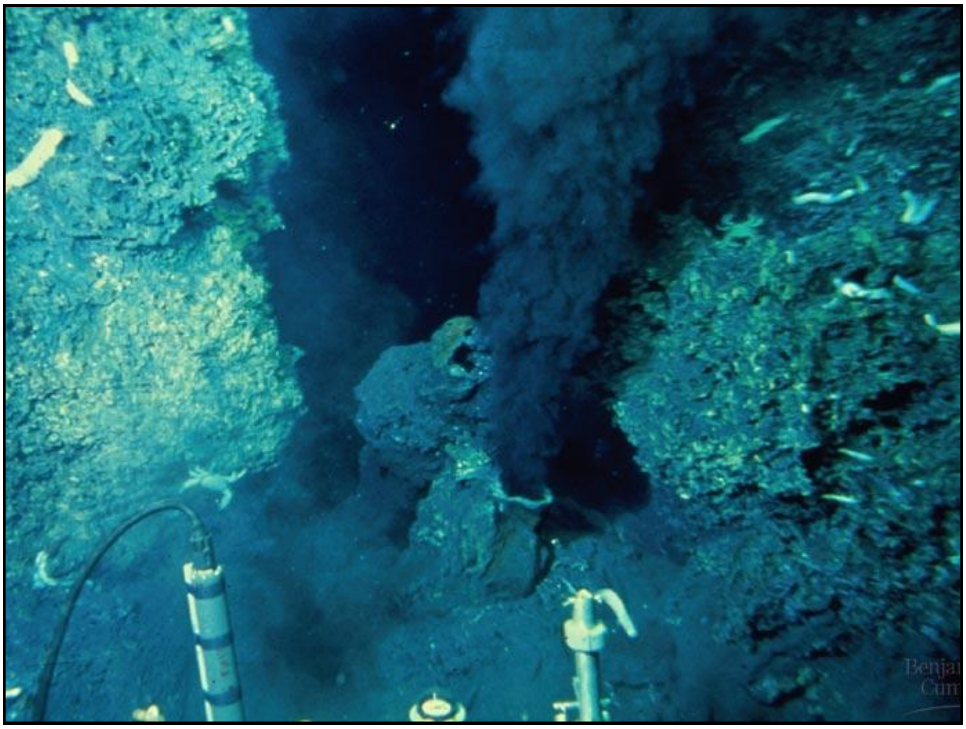
Oceanic Pelagic Zone

- The oceanic zone extends past the continental shelves, and can be very deep.
- The pelagic zone is the open water.
- Includes most of the ocean's water.
- The water is constantly mixed by ocean currents.
- Plankton live in the photic zone and are the producers for this biome.
- This biome also includes a great variety of free swimming fish and mammals.



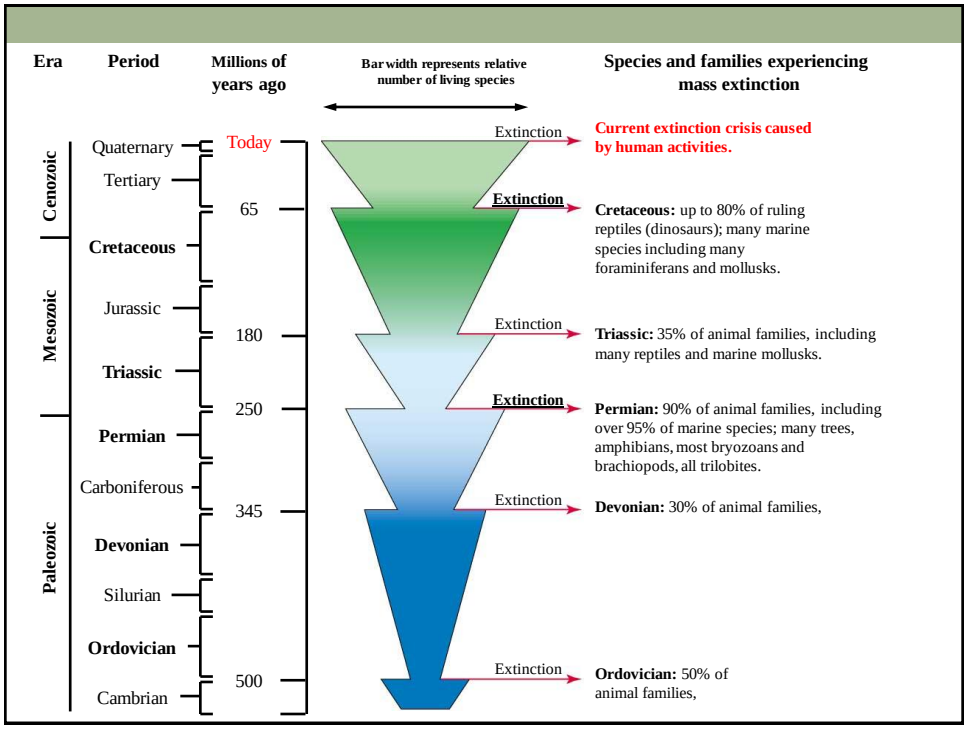
Marine benthic zone

- The benthic zone is the seafloor.
- Benthos is the ocean bottom below the neritic and pelagic zones.
- This area is extremely productive due to the great amount of nutrients found. Benthic communities consist of bacteria, fungi, seaweed and filamentous algae, numerous invertebrates, and fish.
- Deep-sea vent occurs in benthic zone; diverse, unusual organisms; energy comes not from light but from chemicals released from the magma
- The very deep communities lie in the abyssal zone.
  - Organisms here are adapted to continuous cold.
  - Deep-sea thermal hydrothermal vents of volcanic origin are found here.



Extinction

- **Extinction**: The death of all individuals of a species
- The **99.9%** of all the species that have ever existed are now extinct
  - To a very close approximation, all species are extinct
- Mass Extinction
  - Five great mass extinctions in which numerous new species (including mammals) evolved to fill new or vacated niches in changed environments
  - 10 million years or more for adaptive radiations to rebuild biological diversity following a mass extinction
- *Extinctions open up new opportunities for speciation* and adaptive radiation…



Factors Affecting Extinction Rates

These are the main factors contributing to the loss of biodiversity:

A. Natural causes

1. Climate change
2. Cataclysmic event (volcano, earthquake; fire;…etc)
3. Invasive species (outcompete native species, 35-45% of endangered or threatened species in US is caused by invasive species)

B. Human Activities

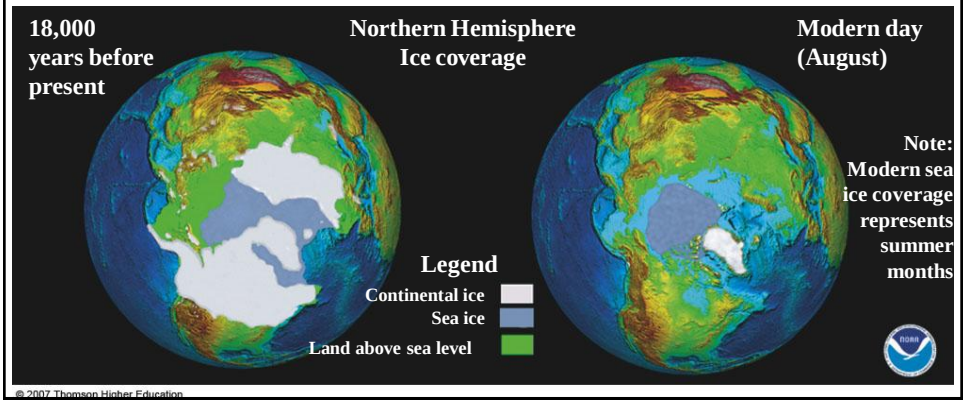
1. **Exponential growth of human population**
2. **Changes in land-use** cause habitat destruction and fragmentation leading to inbreeding, loss of genetic diversity and local extinction)
3. **Increase of atmospheric carbon dioxide** which blamed to be thr cause of global warming, raising sea level, changes in climate patterns, prolonged droughts.
4. **Invasive species** that outcompete native species (i.e. 35-45% of endangered or threatened species in US is caused by invasive species)
5. **Overuse of resources** (populations cannot sustain if exploitation rate is greater than growth rates. Nine of world's major ocean fisheries are declining because of over fishing as well as water pollution and habitat destruction.)
6. **Pollution** (i.e. oil spill, acid precipitation, toxic chemicals in fertilizers and pesticides, urban sewage runoff, etc.)

Natural Extinction
Density-Independent Factors

- A density-independent factor is a population-limiting factor whose intensity is unrelated to population density.
  - Examples include abiotic factors like unfavorable changes in the weather (i.e., freeze in the fall) and/or abrupt environmental trauma such as fire, floods, storms, and habitat disruption by human activity.
- In many natural populations, density-independent factors limit population size before density-dependent factors become important.
  - E.g.: Weather change as a density-independent factor limiting growth of an aphid population

Climate Change and Natural Selection

- Changes in climate throughout the earth's history have shifted where plants and animals can live.



Major Causes of Climate Change

Natural Causes

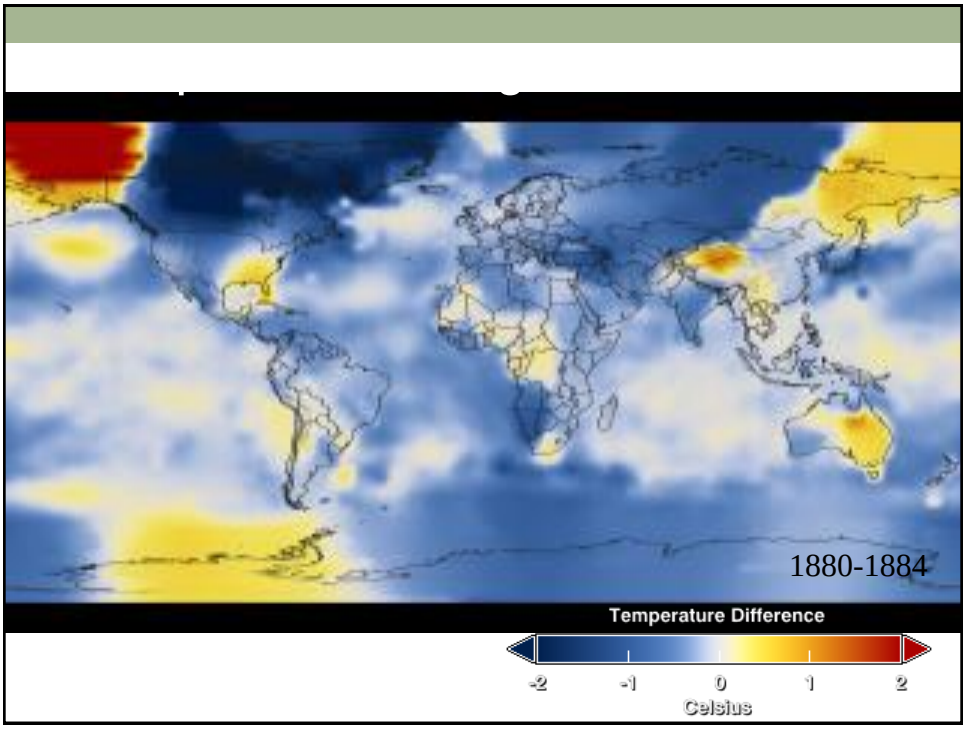
1. The arctic tundra and wetlands release **methane**, a greenhouse gas
2. Earth naturally has a **cycle** of climate change that occurs every 40,000 years
3. the sun's solar energy output is changing and naturally increases Earth's average temperature by about **1°C every century**
4. Earth's **orbit and tilt** alter in relation to the sun, which changes solar energy output

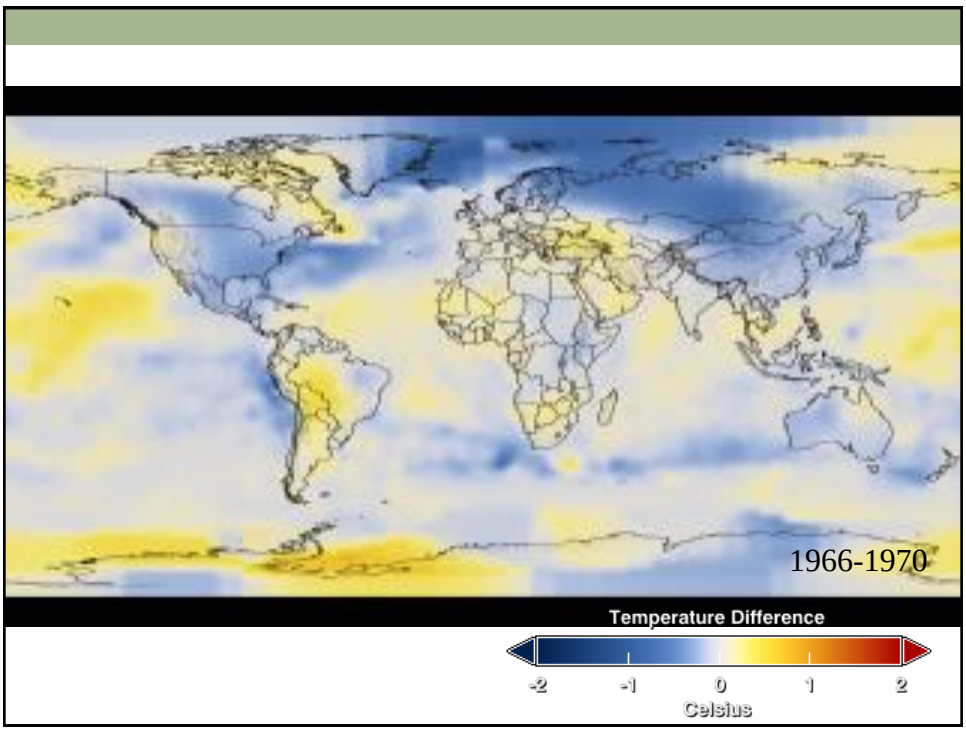
Human Causes

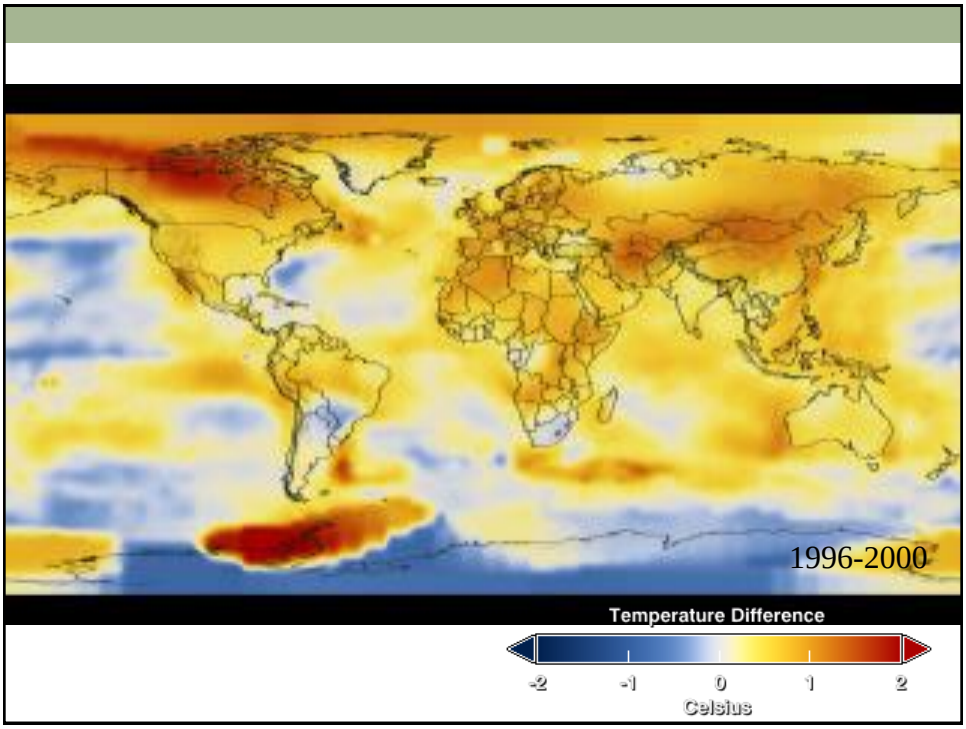
1. Increasing green house gas emissions from **burning fossil fuels-oil,** coal, gas
2. **Pollution**, smog from factories
3. Large forests have been cut down (trees absorb CO_2 and pollution, **deforestation** creates about 6 billion tons of CO_2 per year)
4. **Increasing world population-more** people requires more food, energy, transportation, etc. Farms animals release methane from their wastes.
   - More people also means more CO_2 production from respiration and less trees to make room for human population

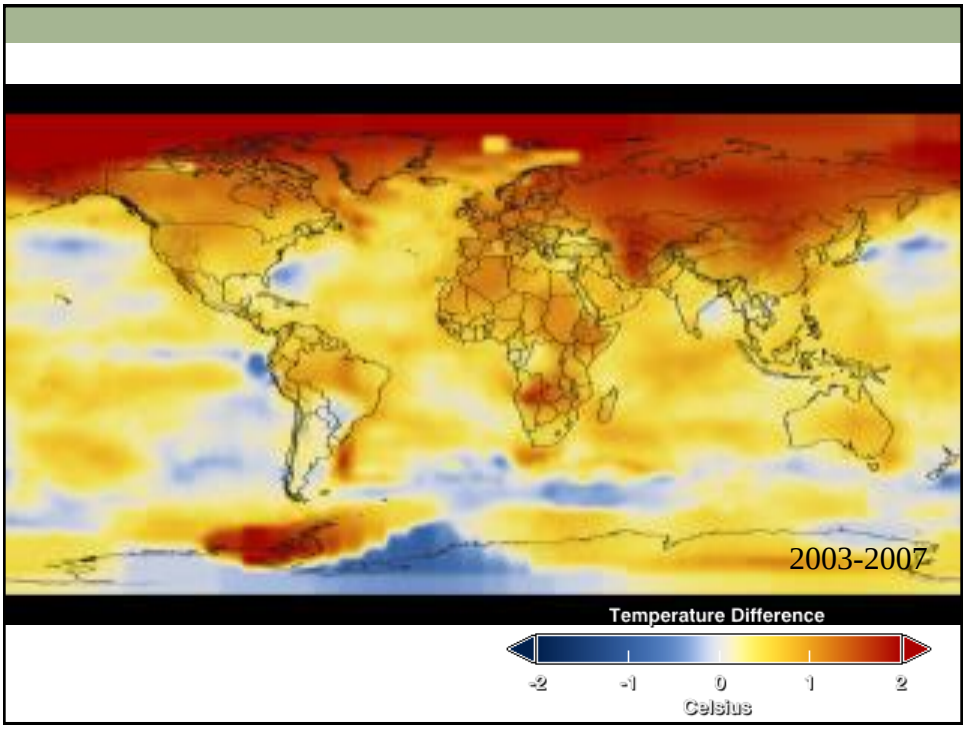
Effects of Climate Change on Earth

1. An average **increase in Earth's temperature during the last century**
2. **Melting of polar ice -** polar bears and other animals are drowning
3. **Migrating birds** are forced to change their time and place of migration
   - Longer summers can **disrupt animal habitation**
4. Melting of glaciers will lead to **higher sea level**, which will cause floods and put many low-elevation regions at risk of disappearing under water
5. **New and widespread diseases** because of warm climate
6. Damaged crops due to sudden climate change and floods
7. **Average precipitation increase around the world**
8. **Droughts, heat waves, extreme winters** and storms, hurricanes, typhoons;..etc
9. More **wildfires**


1880-1884
Temperature Difference
-2
-1
0
1
2
Celsius


1966-1970
Temperature Difference
-2
-1
0
1
2
Celsius


1996-2000
Temperature Difference
-2
-1
0
1
2
Celsius


2003-2007
Temperature Difference
-2
-1
0
1
2
Celsius

What's the difference between "global warming" and "climate change"?

GLOBAL WARMING

- It is the increase of the Earth's average surface temperature due to a build-up of greenhouse gases in the atmosphere.

CLIMATE CHANGE

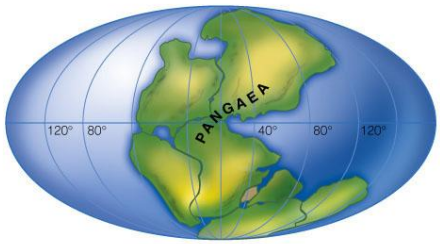
- It is a broader term that refers to long-term changes in climate, including average temperature and precipitation

Cataclysmic event

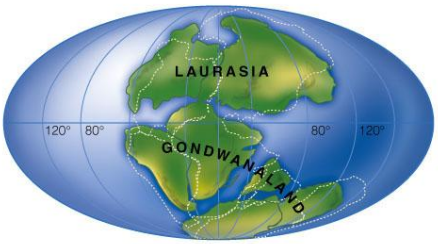
Volcano and Earthquake

- The movement of solid (tectonic) plates making up the earth's surface, volcanic eruptions, and earthquakes can wipe out existing species and help form new ones.
  - The locations of continents and oceanic basins influence climate.
  - The movement of continents have allowed species to move.

Geological processes and biological evolution



225 million years ago

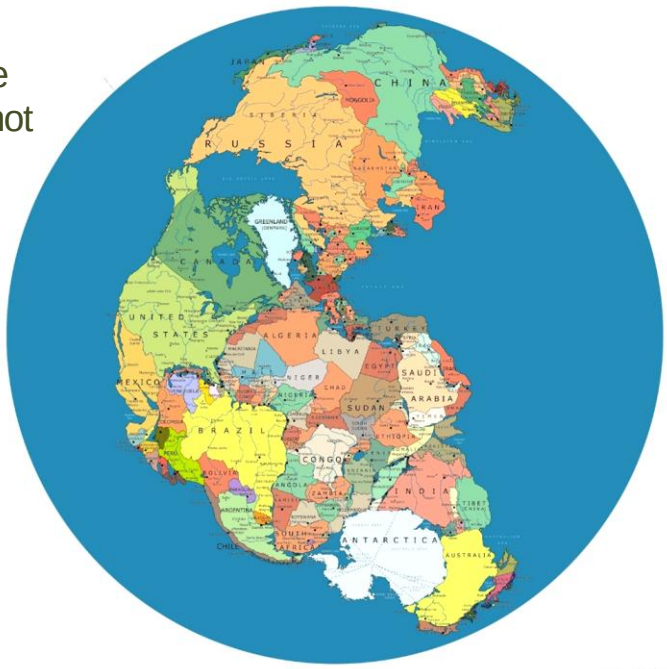


135 million years ago

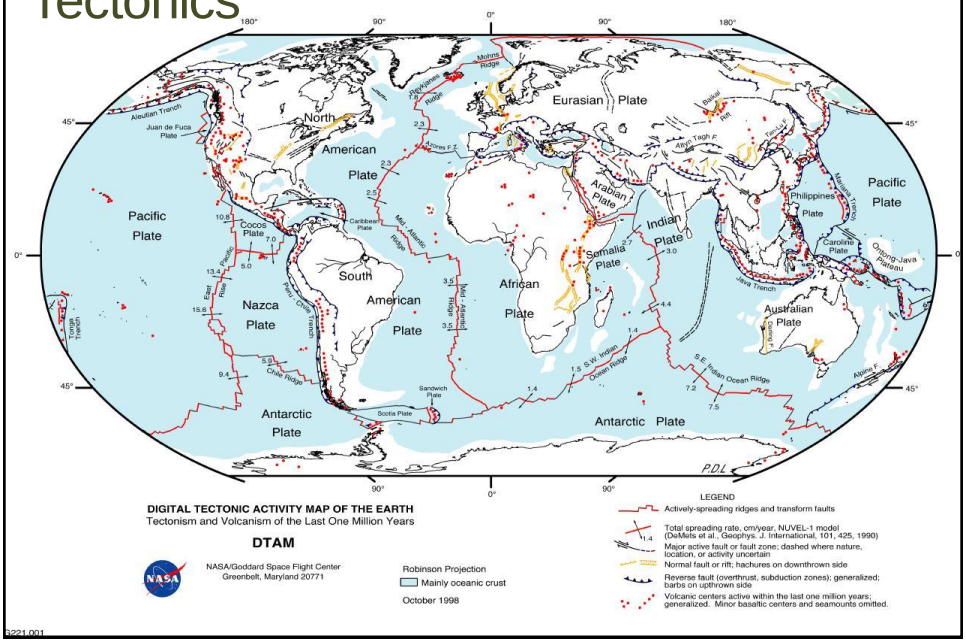
65 million years ago

Present

How countries should be if the **Pangaea** did not separate

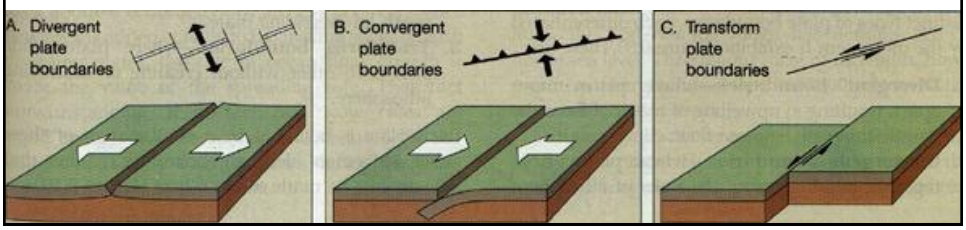


Tectonics'



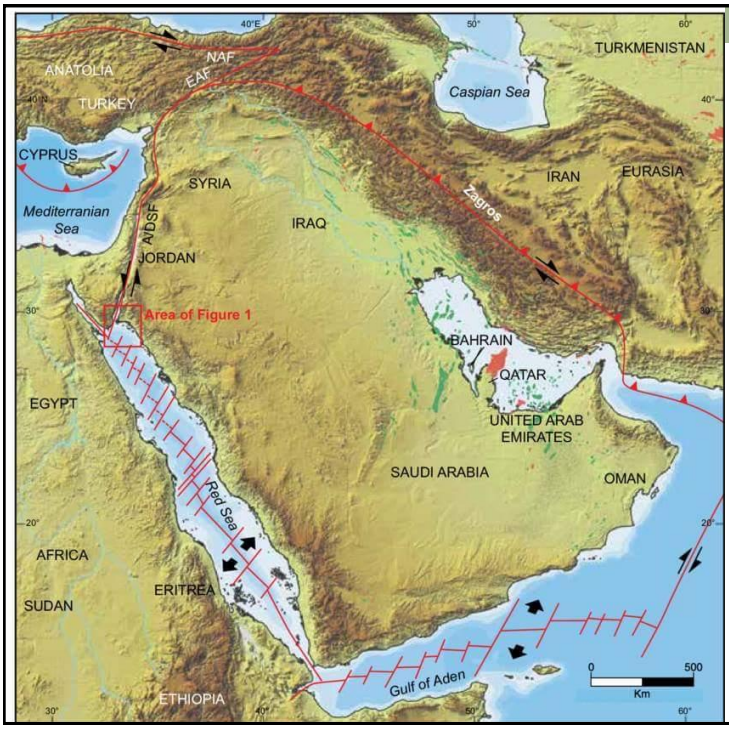
Tectonic theory

- Plate interactions are complex. Plate tectonic theory describes three basic end members:
  - A) **Divergent** plate
  - B) **Convergent** plate
  - C) **Transform** plate



Tectonic theory

- **A divergent plate boundary**:
  - occurs at a spreading ocean ridge where plates are moving away from one another and new lithosphere is produced. This process, known as *seafloor spreading*, produces ocean basins.
- **A convergent plate boundary**:
  - occurs when plates collide when a plate composed of relatively heavy ocean-basin rocks dives (subducts) beneath the leading edge of a plate composed of lighter continental rocks, a subduction zone is present.
    - Such a convergence may produce linear coastal mountain ranges, such as the Andes in South America. When two plates that are both composed of lighter continental rocks collide, a continental mountain range may form, such as the Himalayas in Asia.
- **A transform fault boundary** :
  - occurs where one plate slides past another.
    - An example is the San Andreas Fault in California, which is the boundary between the North American and Pacific plates. The Pacific plate is moving north, relative to the North American plate, at about 5 cm/year (2 in./year). As a result, Los Angeles is moving slowly toward San Francisco, about 500 km (300 mi) north. If this continues, in about 10 million years San Francisco will be a suburb of Los Angeles.



Volcanic eruptions

Earthquake

Flooding

Other Catastrophes

- Asteroids
  - *E.g. Meteor; Shehab; Luminary*
- Fires
- Lightning strikes / severe fires
- Cyclones
  - *E.g. Indian ocean islands*

Asteroids

Fire

Lightening

Cyclones

Factors Affecting Extinction Rates

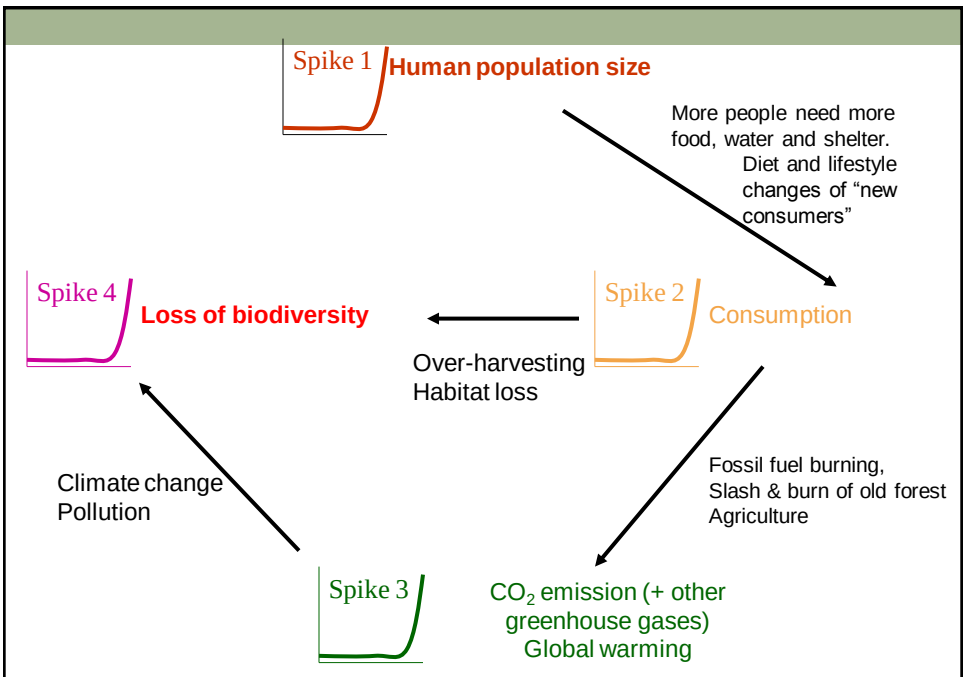
These are the main factors contributing to the loss of biodiversity:

A. **Natural causes**

1. Climate change
2. Cataclysmic event (volcano, earthquake; fire;…etc)
3. Invasive species (outcompete native species, 35-45% of endangered or threatened species in US is caused by invasive species)

B. Human Activities

1. **Exponential growth of human population**
2. **Overuse of resources** (populations cannot sustain if exploitation rate is greater than growth rates. Nine of world's major ocean fisheries are declining because of over fishing as well as water pollution and habitat destruction.)
3. **Changes in land-use** cause habitat destruction and fragmentation leading to inbreeding, loss of genetic diversity and local extinction)
4. **Increase of atmospheric carbon dioxide** which blamed to be the main cause of global warming, raising sea level, changes in climate patterns, prolonged droughts.
5. **Invasive species** that outcompete native species (i.e. 35-45% of endangered or threatened species in US is caused by invasive species)
6. **Pollution** (i.e. oil spill, acid precipitation, toxic chemicals in fertilizers and pesticides, urban sewage runoff, etc.)



Exponential growth of human population

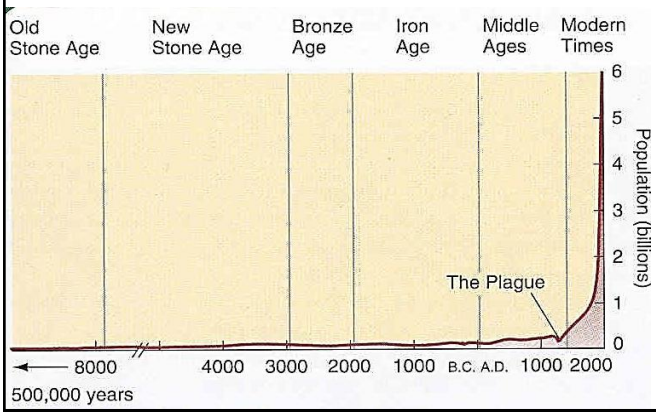
- Humans are the major force in the premature extinction of species.
- Extinction rate increased by 100-1000 times the natural background rate.
- As we grow in population over next 50 years, we are expected to take over more of the earth's surface and productivity.
  - This may cause the premature extinction of up to a QUARTER of the earth's current species and constitute a SIXTH mass extinction
  - Genetic engineering won't solve this problem
  - Only takes existing genes and moves them around
- Know why this is so important and what we are losing as it disappears….

History of Human Populations

- Prior to ca. 10,000 years ago human population growth was very slow (*similar to the hummingbird*).
- Now it is almost 7 billion humans living on this planet
- So what….??????

Then about 10 – 8 thousands years ago, human population growth increased

https://www.worldometers.info/world-population/

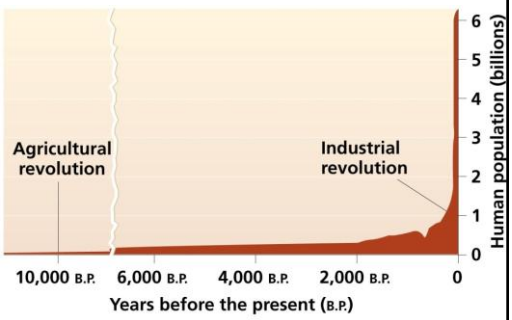


Note: the last 100 years have witnessed the greatest increase in human populations

(Chiras, 2001. Environmental Science: Creating a sustainable future, 6th Edition, Jones and Bartlett, Sudbury, MD, pg 150.

Why so many humans?

- More than 7 billion humans
- Why so many humans?
  - Industrial revolution
    - Urbanized society powered by fossil fuels
  - Agricultural revolution
    - Stable food supplies
    - More food
  - Sanitation and medicines
  - Transportation and communication

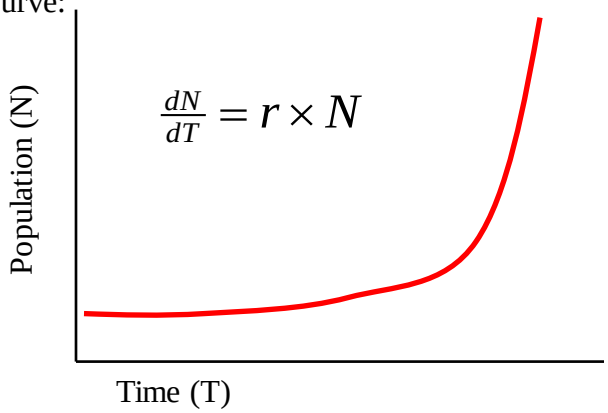


(a) World population growth

Human Population Growth is Exponential

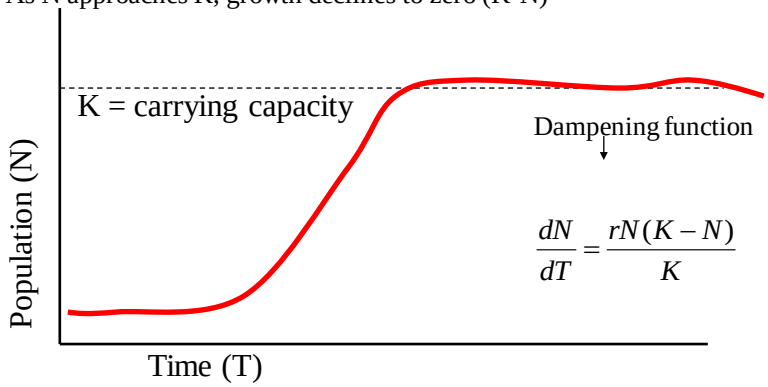
r = intrinsic growth curve
- based on individual species growth potential

- Standard exponential growth curve:



Carrying Capacity

- **Carrying Capacity**: "the maximum number of individuals that the environment can support"
  - Usually set by the amount of available resources
- The carrying capacity has a "dampening" function that limits a population once numbers grow to a certain value.
- As N approaches K, growth declines to zero (K-N)



Human Population Growth and The Environment

- **The increase in human populations is an environmental concern for several reasons; these are just a few**:
  1) more waste
  2) use more resources
  3) increased land development for both agriculture and habitation
  4) more energy demands
  5) greater pressure on wildlife and greater pressure on marine life

- It is suggested, that human population growth is the biggest threat to the environment
  - Human population growth may possibly be the greatest threat to humans themselves !!!!

Overuse of resources

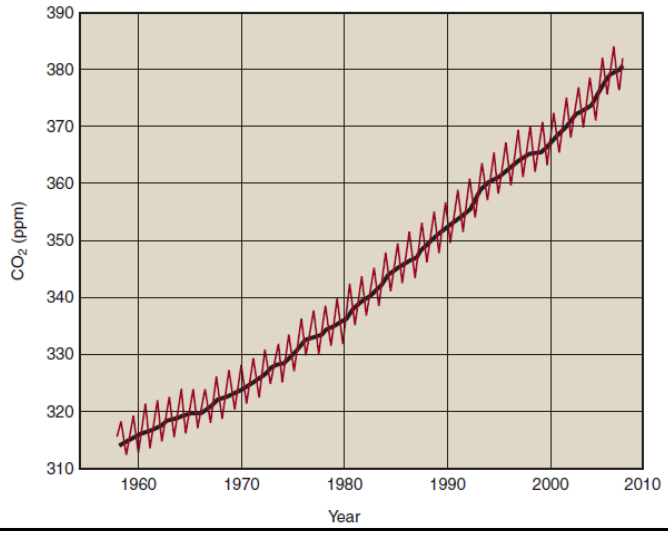
Overexploitation

- Overexploitation refers generally to the human harvesting of wild plants or animals at rates exceeding the ability of populations of those species to rebound
- The fishing industry has caused significant reduction in populations of certain game fish
- The extermination of keystone species by humans can lead to major changes in the structure of communities

Changes in land-use -Habitat Destruction

- Human alteration of habitat is the single greatest threat to biodiversity throughout the biosphere
  - Massive destruction of habitat has been brought about by many types of human activity
  - Many natural landscapes have been broken up fragmenting habitat into small patches
- In almost all cases habitat fragmentation and destruction leads to loss of biodiversity

Increase of atmospheric carbon dioxide



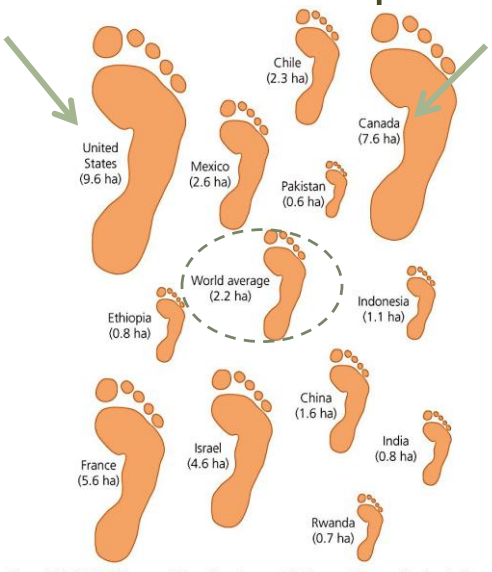
Ecological footprint

- The "Ecological Footprint" is the environmental impact of a person or population or country . It is measured based on
  - The amount of **biologically productive land** & **water**
  - The **raw materials used**
  - The raw materials to dispose or **recycle waste**
  - **The CO2 emission**
- ***Overshoot***: humans have surpassed the Earth's capacity

We are using 30% more of the planet's resources than are available on a sustainable basis!

Ecological footprints are not all equal

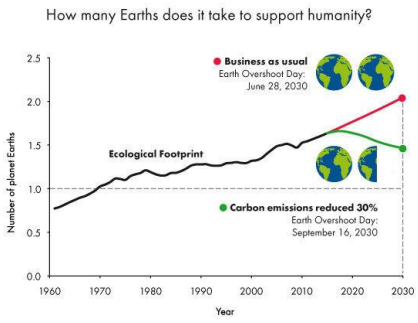
- The ecological footprints of countries <u>vary greatly</u>
  - The U.S. footprint is almost 5 times greater than the world's average
  - Developing countries have much smaller footprints than developed countries



Population & consumption

- Human population growth exacerbates all environmental problems
  - The growth rate has slowed, but we still add more than 200,000 people to the planet each day
- Our consumption of resources has risen even faster than our population growth.
  - Life has become more pleasant for us so far
  - However, rising consumption amplifies the demands we make on our environment.

Overshoot



- The world's ecological deficit is referred to as global ecological overshoot. Since the 1970s, humanity has been in ecological overshoot, with annual demand on resources exceeding what Earth can regenerate each year.
- Today humanity uses the equivalent of 1.6 Earths to provide the resources we use and absorb our waste, according to Global Footprint Network.
- This means it now takes the Earth one year and six months to regenerate what we use in a year.
- We use more ecological resources and services than nature can regenerate through overfishing, overharvesting forests, and emitting more carbon dioxide into the atmosphere than forests can sequester.

- In 2008, the Earth's total biocapacity was 12.0 billion gha, or 1.8 gha per person, while humanity's Ecological Footprint was 18.2 billion gha, or 2.7 gha per person.
- This discrepancy means it would take 1.5 years for the Earth to fully regenerate the renewable resources that people used in one year, or in other words, we used the equivalent of 1.5 Earths to support our consumption.

Introduced Invasive species

- Introduced species are those that humans move from the species' native locations to new geographic regions
- Introduced species that gain a foothold in a new habitat usually disrupt their adopted community

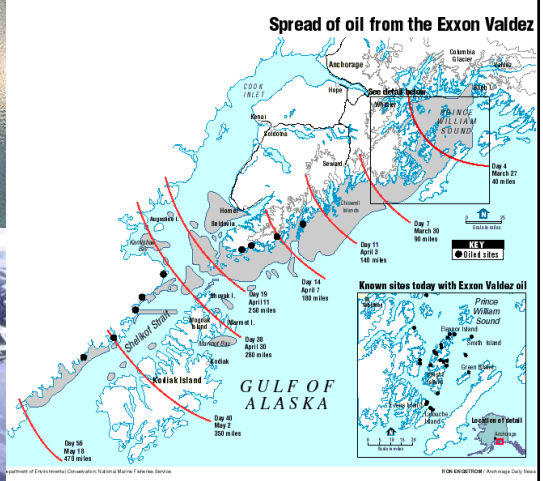
(a) Brown tree snake, introduced to Guam in cargo

(b) Introduced kudzu thriving in South Carolina

Pollutions

- Pollution can be referred to man-made production and spreading of waste materials, usually harm to many livings including human being himself.
- Pollutants could be categorized as:
  1. Environmentally Transmitted Infectious Disease (Pathogens and microbial)
  2. Toxic inorganic chemicals (Heavy Metals and pharmaceutical drugs ; Acids)
  3. Organic Compounds (sewage water; pesticides; Nutrients fertilizers,)
  4. Nuclear Radiation (Radioactive matters
  5. Thermal Pollution
  6. Particulates and Asbestos (Sediments
  7. Light and Electromagnetic Fields
  8. Noise Pollution
  9. …etc

Garbage Dump



1989 – Exxon Valdez oil spill

Exxon Valdez oil spill