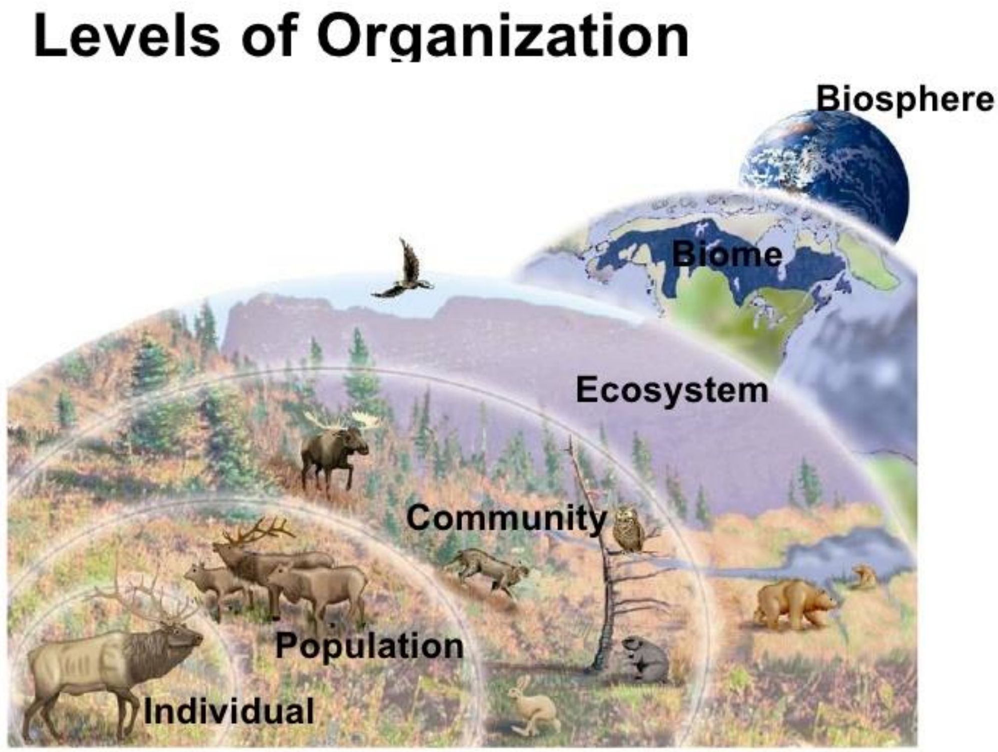
Part I: General Principles of Ecology

General Principles of Ecology:

- **Ecology and the abiotic environment**
  - ecology – introduction and terms
    - **ecology** = how organisms interact with one another and with their environment
    - **environment** = biotic (other organisms) and abiotic (physical factors)
  - natural selection – adaptation
  - soils and nutrients
  - climate
- **Ecology of individual organisms**
  - physiological ecology
  - temperature and water balance
  - light and biological cycles
  - conservation
- **Ecology of populations**
  - properties of populations
  - patterns of distribution and density
  - intraspecific competition
  - population dynamics
  - population growth and regulation
  - altering population growth
  - human impact
- **Ecological interactions among species**
  - interactions
  - competitive interactions - interspecific competition, competitive exclusion, resource partitioning
  - predation
  - exploitation
  - symbiosis – mutualism, parasitism, commensalism, amensalism
- **Ecology of communities**
  - closed vs. open communities
  - species abundance and diversity
  - concept of the ecosystem
  - trophic structure of communities – food webs and food chains
- **Ecology of ecosystems**
  - energy flow within ecosystems – energy flow and biomass pyramids
  - community succession and stability
  - nutrient recycling – biogeochemical cycles
- **Biomes –** weather and climate
  - terrestrial biomes – tundra, taiga, temperate forest, grassland, desert, tropical forest
  - aquatic biomes – marine, freshwater
- **Biosphere**

Ecology and the Abiotic Environment

- **Four levels of ecological organization:**
  - **Population** - group of individuals of the same species occupying a common geographical area
  - **Community** - two or more populations of different species occupying the same geographical area
    - Populations and communities include only biotic factors
  - **Ecosystem** - a community plus its abiotic factors, e.g., soil, rain, temperatures, etc.
  - **Biosphere** - the portion of the earth that contains living species. It includes the atmosphere, oceans, soils and the physical and biological cycles that affect them

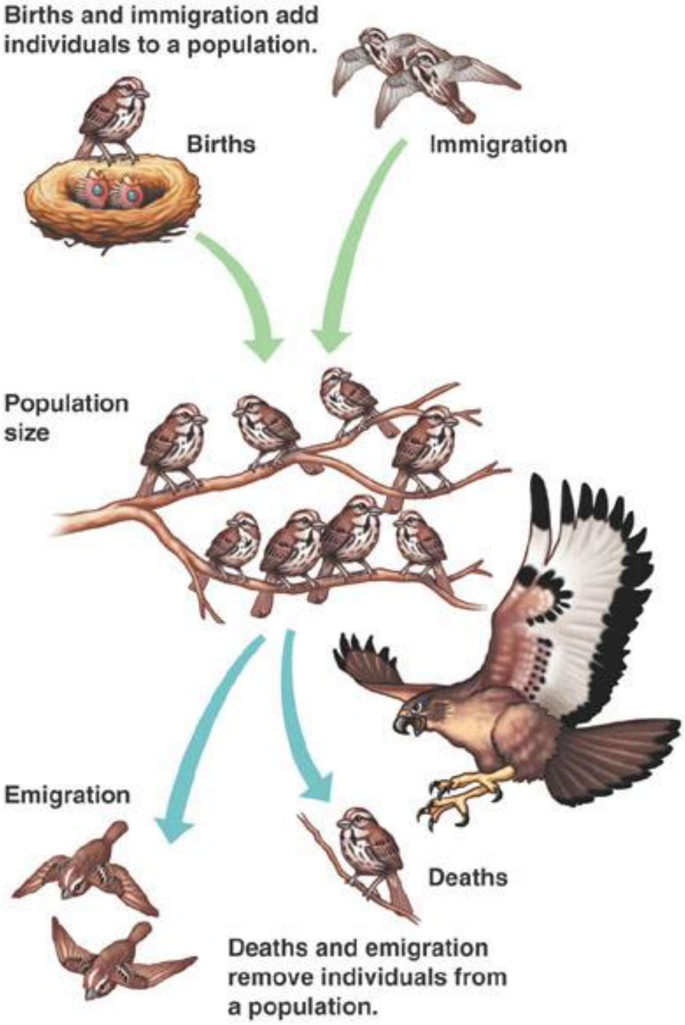


Ecology of Populations

- **Population Ecology** = the study of how populations interact with their environment
- **Population** = group of individuals of the same species occupying a common geographical area
- **Habitat** = where a species normally lives

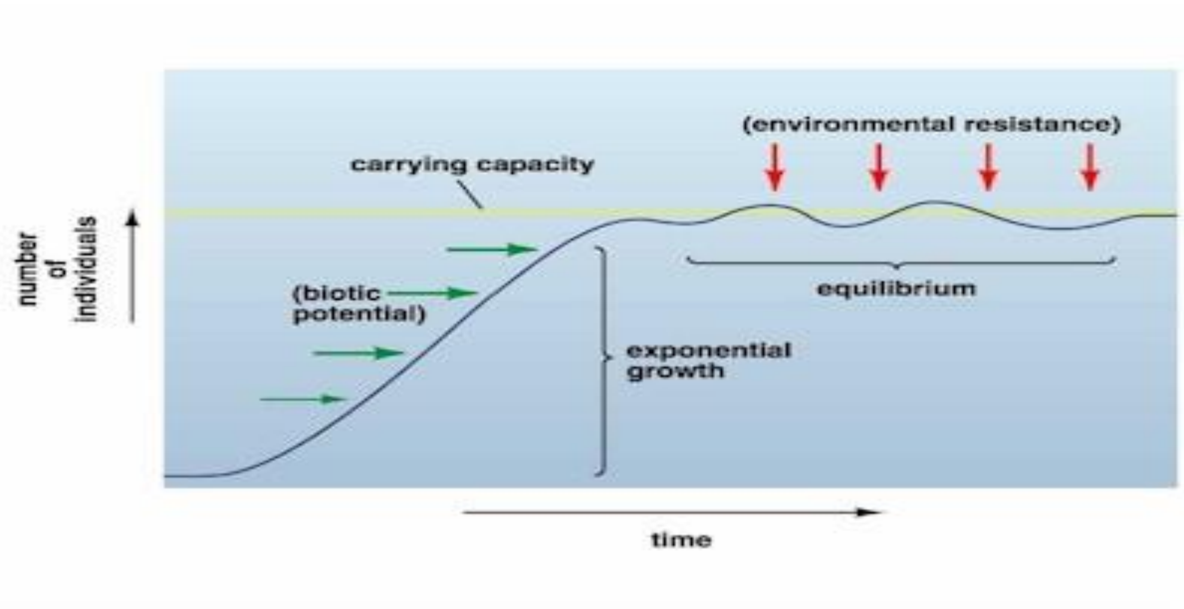
Characteristics of populations - Each population has certain characteristics:

- **Population size** = number of individuals making up its gene pool
- **Population density** = number of individuals per unit of area or volume, e.g., persons/square mile
- **Population distribution** = the general pattern in which the population members are dispersed through its habitat, may be:
  - ***Clumped*** (most common)
  - ***Uniformly*** dispersed (rare)
  - ***Randomly*** dispersed
- **Age structure** defines the relative proportions of individuals of each age
  - ***Pre-reproductive***
  - ***Reproductive***
  - ***Post-reproductive***
- **Population size and growth**



Population size is dependent on births, immigration, deaths, and emigration

- **Zero population growth** designates a near balance of births and deaths
- **Exponential growth:** If birth and death rates of a population remain constant, they can be combined into one variable ***r*** = net reproduction per individual per unit time (rate of increase)
- **Population growth may be represented mathematically as: $G = rN$** where G = population growth per unit time, r = rate of increase, and N= the number of individuals. When plotted against time, a graph in the shape of a J denotes **exponential growth**, i.e., one variable increases much faster than the other
- As long as per capita birth rates remain even slightly above per capita death rates, a population will grow exponentially - with ever-increasing rates and shortened "doubling times"
- It took 2 million years for the world's human population to reach 1 billion, yet it took only 12 years to reach the fifth billion
- If a population lives under ideal conditions, it may display its **biotic potential** - the maximum rate of increase under ideal conditions. Few populations live under ideal conditions because a number of factors limit their growth
- **Limiting factor =**- any resource that is in short supply, e.g., food, minerals, light, living space, refuge from predators, etc.
- **Carrying capacity** = maximum number of individuals of a species or population that a given environment can sustain. Each habitat or area can only support so many individuals
- Because of limiting factors, populations rarely exhibit J-shaped growth curves
- **Logistic growth:** Early on populations will exhibit very rapid growth, but as they near the carrying capacity, they will level off. This type of growth produces an **S-shaped curve**
- Logistic growth is **density dependent**, i.e., the growth is affected by the density of individuals.
- *For example* - 26 reindeer were introduced onto an island off the coast of Alaska in 1910. Within 30 years the herd increased to 2,000. However, overgrazing reduced the food supply and the population crashed to 8 animals by 1950
- *High density and overcrowding* put individuals at greater risk of being killed, e.g., predators, parasites and pathogens have greater numbers of prey and hosts in a smaller area to interact
- ***Bubonic plague*** swept through Europe in the 14th century, killing at least 25 million. The disease spread rapidly in overcrowded cities where sanitary conditions were poor and rats were abundant
- Population size and growth may also be controlled by **density-independent factors,** e.g., adverse weather, floods, droughts, cold temperatures



Life history patterns

- Not all individuals in a population are the same age.
- Different populations may have very different **age structures** and these will determine their growth patterns
- Age structure refers to the proportions of pre-reproductive, reproductive and post- reproductive age individuals in a population. The age structure of a population will determine its future
- Each species has a characteristic life span and the probability of dying increases with age
- Population ecologists, as well as insurance companies track **cohorts** and construct **life tables** for populations
- **Cohort =** a group of individuals born at the same time, e.g., Baby Boomers are a large group of individuals born just after World War II
- A **life table** is an age-specific death schedule. Such a schedule is often converted to a survivorship schedule. For each age interval there is a predicted life expectancy or survivorship
- Ecologists divide populations into age classes and assign birth rates and mortality risks to each class. Absolute population numbers mean very little unless their age structure is known
- For example, population A might have many more members than population B. However, all the members of A might be post-reproductive, whereas B might consist of mostly pre-reproductive and reproductive age individuals. Therefore, population A might be in danger of extinction.

Life history strategies (Division C Only)

- **r-selected organisms** - put most of their energy into rapid growth and reproduction. This is common of organisms that occupy unpredictable environments, e.g., weeds are usually annuals with rapid growth and early reproduction. They produce large number of seeds containing few stored nutrients
- **K-selected** organisms - put most of their energy into growth. They are common in stable environments near carrying capacity, e.g., long-lived trees such as redwoods take many years of growth to reach reproductive age

Ecology of Communities

Community = two or more populations of different species occupying the same geographical area

- **Community Ecology** = the study of how different species interact within communities
- **Habitat** = the physical place where an organism lives, e.g., a pine forest or freshwater lake
- Some organisms, particularly migratory birds, require more than one habitat
- **Niche** = the functional role of an organism in a community; its job or position
- Each species has a **potential niche** - what they could do with no competitors or resource limitations but due to competition and/or resource limitations, most organisms occupy a **realized niche**. The realized niche is the part of the fundamental niche that a species actually occupies in nature

Species interactions

- **Neutral** - two species that don't interact at all
- **Commensalism** - beneficial to one species but neutral to another, e.g., birds that nest in trees, epiphytes (plants that grow on other plants) such as tropical orchids
- **Mutualism** - an interaction that is beneficial to both species, e.g., plants and their pollinators, plants and animals that disperse their seeds, certain fungi and plant roots
- **Parasitism** - an interaction that benefits one species and is detrimental to another. Note that the host is generally not killed.

- **Predation** - an interaction beneficial to one species and detrimental to another. In this case the prey is killed. Predators are those that kill and eat other animals. Although many organisms eat plants, they usually don't kill them because they are a constant supply of food. Prey are killed and eaten.
- **Amensalism** - an interaction that is neutral to one species and is detrimental to another, e.g., cattle that tramples on grass—the grass is harmed while cattle are unaffected.

Competitive interactions

- Competition has negative effects on both organisms competing for a resource
- Because resources are limited in nature, there will always be competition for them
- Competition is the driving force of evolution. Those that win leave more offspring

- Types of competition:
  - **Intraspecific** - competition among individuals of the same species, e.g., humans compete against other humans
  - **Interspecific** - competition between different species, e.g., humans compete against a wide variety of species seeking to utilize our food resources
  - The theory of **competitive exclusion** maintains that species who utilize the same resources cannot coexist indefinitely - the "one niche, one species" concept
  - **Resource partitioning -** the resources are divided, permitting species with similar requirements to use the same resources in different areas, ways, and/or times

Community stability

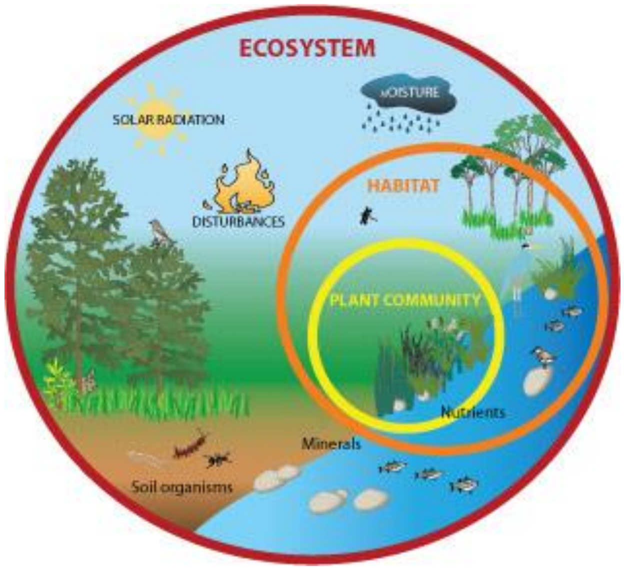
- Communities are assemblages of many different species occupying the same geographical area
- Communities are not static. Rather, they gradually change over time because the environment changes and species themselves tend to also change their habitats

Ecology of Ecosystems

Ecosystem = a community of organisms interacting within a particular physical environment or an ecosystem is a community plus its abiotic factors, e.g., soil, rain, temperatures, etc. Virtually all energy on earth comes from the sun, via **photoautotrophs** (primarily plants), and it is ultimately distributed throughout ecosystems.

- **Primary producers** are the autotrophs
- All other organisms are **consumers**
  - Consumers which eat plants are called **herbivores**
  - Consumers which eat animals are called **carnivores**
  - Organisms such as humans, which eat both plants and animals, are called **omnivores**
- **Decomposers,** which includes fungi and bacteria, obtain their energy by breaking down the remains or products of organisms
- **Detritivores** are decomposers which eat **detritus** - organic wastes and dead organisms

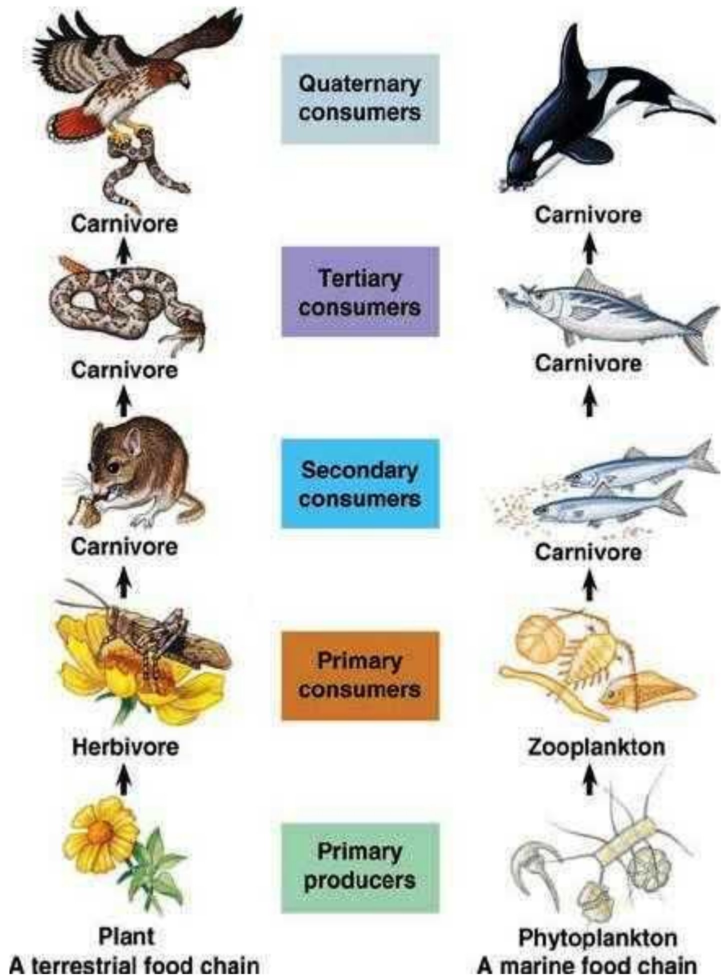
Structure of ecosystems



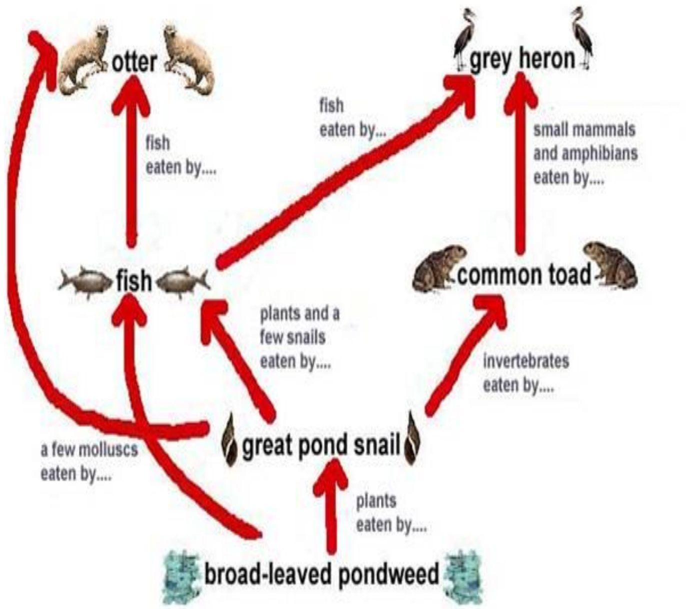
- Energy flows through ecosystems via **food webs**, intricate pathways of energy flow and material cycling
- It is possible for an organism to fulfill multiple roles, e.g., be a secondary consumer in one food chain and a tertiary consumer in another.
- Ecosystems are arranged by **trophic** (feeding) levels between various producers (the autotrophs) and consumers (the heterotrophs)
- **First trophic level**
  - Contains the autotrophs which build energy containing molecules
  - They also absorb nitrogen, phosphorous, sulfur and other molecules necessary for life
  - They provide both an **energy-fixation** base as well as the **nutrient-concentration** base for ecosystems
  - Two types of autotrophs:
    - Photoautotrophs - plants and some Protista
    - Chemoautotrophs - bacteria
- **Second trophic level -** contains the primary consumers which eat the primary producers including herbivores, decomposers and detritivores, e.g., insects, grasshoppers, deer and wildebeest
- **Third trophic level** - contains the secondary consumers, primary carnivores which eat the herbivores, e.g., mice, spiders and many birds
- **Fourth trophic level** - contains the tertiary consumers, secondary carnivores who eat the primary carnivores, e.g., weasel, owl, sharks and wolves.
- Linear **food chains** as described above are probably rare in nature because the same food source may be part of several interwoven food chains and many organisms have several food sources
- Decomposers play a key role in ecosystems but are often not represented on food chains

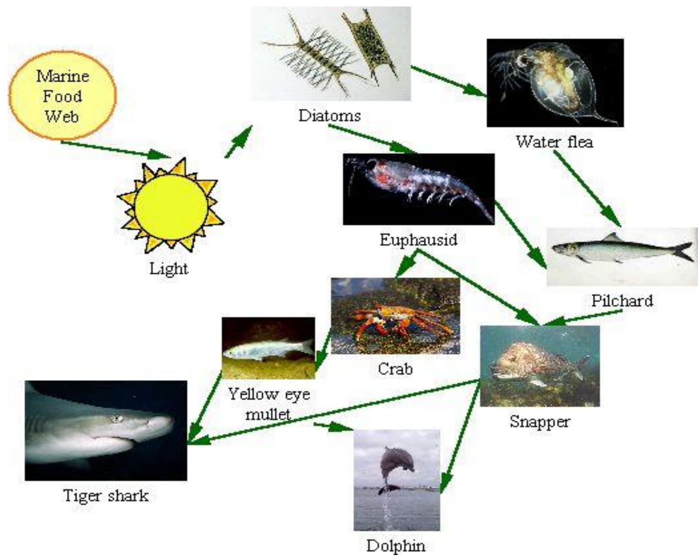
Food Chains

- **Producer**
- **1st order Consumer or Herbivore**
- **2nd order Consumer or 1st order Carnivore**
- **3rd order Consumer or 2nd order Carnivore**
- **4th order Consumer or 3rd order Carnivore**
- **Decomposers – consume dead and decaying matter as bacteria**



Food Web – many food chains in relation to each other



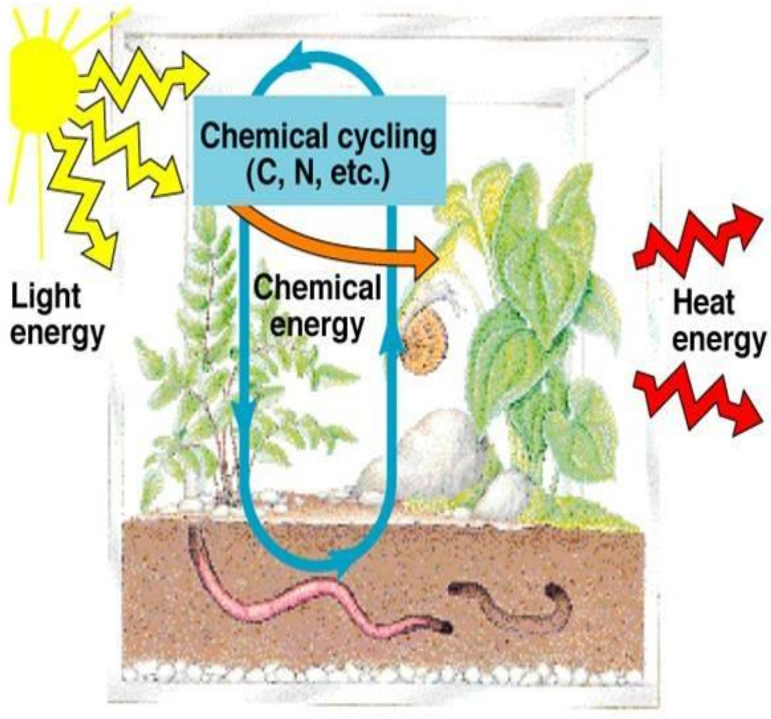


Energy flow through ecosystems

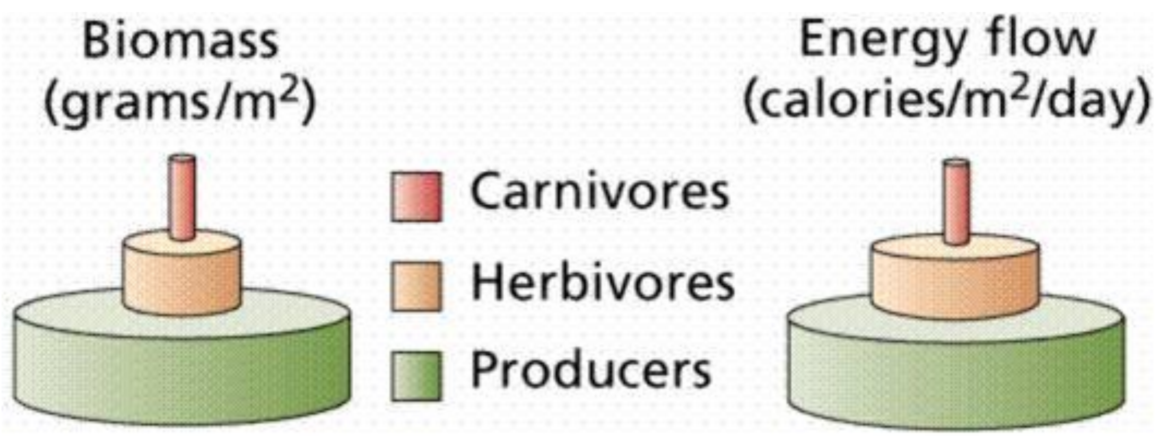
- **Gross primary productivity** = the rate at which the primary producers capture and store energy per unit time. Since the primary producers expend energy during respiration the **net primary productivity** is considerably lower than the gross productivity, NPP = GPP - R
- Productivity is usually measured as biomass (dry weight of organic matter) per unit area per a specified time interval, e.g., ***$kg/m^2/yr$***
- The trophic structure of an ecosystem is often represented by an **ecological pyramid**, with the primary producers at the base and the other levels above
- Most of the food eaten by organisms is converted to biomass, or used to maintain metabolic functions, or lost as heat. Only about **10% of the energy** makes it to the next level
- This massive energy loss between trophic levels explains why food chains can't contain more than a few levels. It takes billions of primary producers (plants) to support millions of primary consumers, which support a few secondary consumers. This is why there are so few large carnivores on Earth
- An **energy pyramid** is a more useful way to depict an ecosystem's trophic structure
- Each block of the pyramid is proportional to the amount of energy it contains
- Pyramids may also represent biomass or numbers of individuals
- The energy pyramid concept helps explain the phenomenon of **biological magnification** - the tendency for toxic substances to increase in concentration at progressively higher levels of the food chain

Energy vs. Nutrients

- Nutrients are **cyclic** – biogeochemical cycles
- Energy flow is **one way**



Biomass and Energy Pyramids



Ecological succession = a directional, cumulative change in the species that occupy a given area, through time

- **Primary succession -** starts from barren ground, e.g., new islands or de-glaciated areas
- **Secondary succession -** starts from disturbed areas, e.g., abandoned farm land or storm ravaged land
- Succession starts with a **pioneer community**, the first organisms to occupy an area
- Several **transitional communities** may come and go
- Eventually, a **climax community**, a stable, self-perpetuating array of species in equilibrium with one another and their habitat, will form.

Biodiversity - Biodiversity, the number of different species within an area, is greatest in tropical areas near the equator and it decreases towards the poles

- Tropical areas have more sunlight and of greater intensity, more rainfall and longer growing seasons for plants
- This environment is quite stable and contains many vertical "layers" which provide more microhabitats
- These areas can support more species, e.g., the number of bird species is directly correlated with latitude

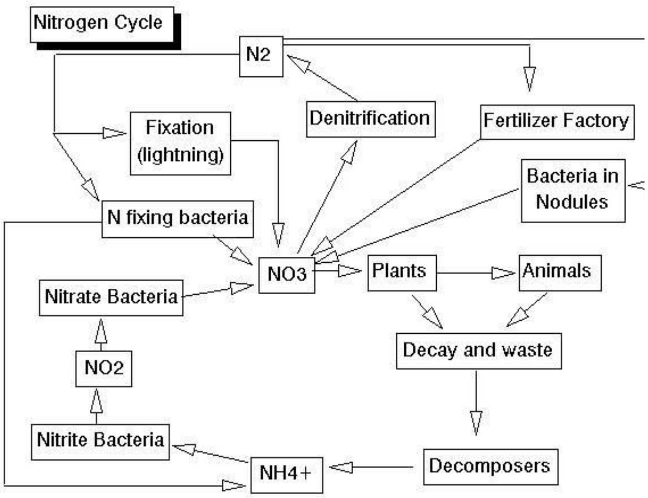
Weather and climate

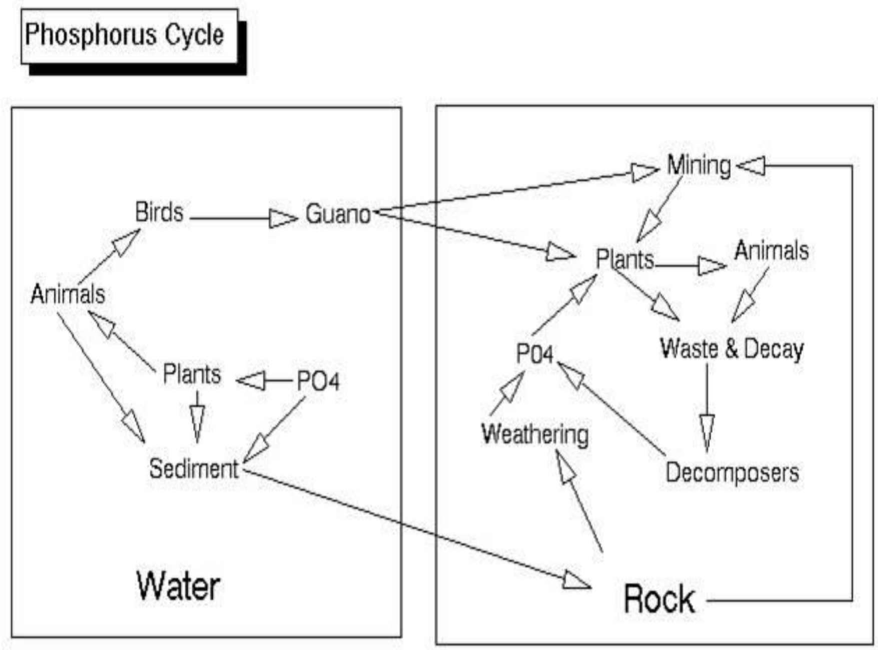
- **Biome** = a large region of land characterized by the climax vegetation of the ecosystems within its boundaries
- The distribution and key features of biomes are the outcome of temperatures, soils, and moisture levels (which vary with latitude and altitude), as well as evolutionary history
- **Weather** = the condition of the atmosphere at any given time
- **Climate** = the accumulation of weather events over a long period of time (temperatures, humidity, wind, cloud cover, rainfall)
- Climate is dependent upon several factors:
  - Solar radiation
  - The Earth's daily rotation
  - The Earth's rotation around the sun
  - The distributions of continents and oceans

Elevation or Depth of Light Penetration

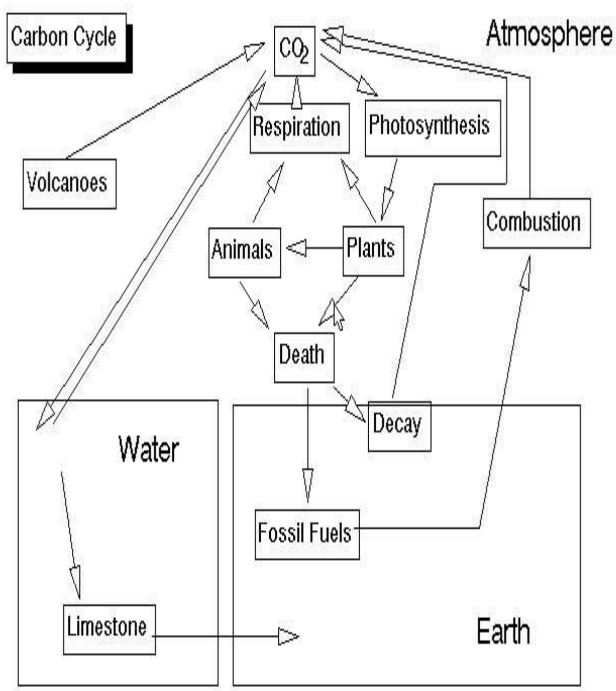
- Heat energy from the **sun** drives the Earth's weather systems, which ultimately determine the composition of ecosystems
- In aquatic environments it is often the depth of light penetration that is the key factor.

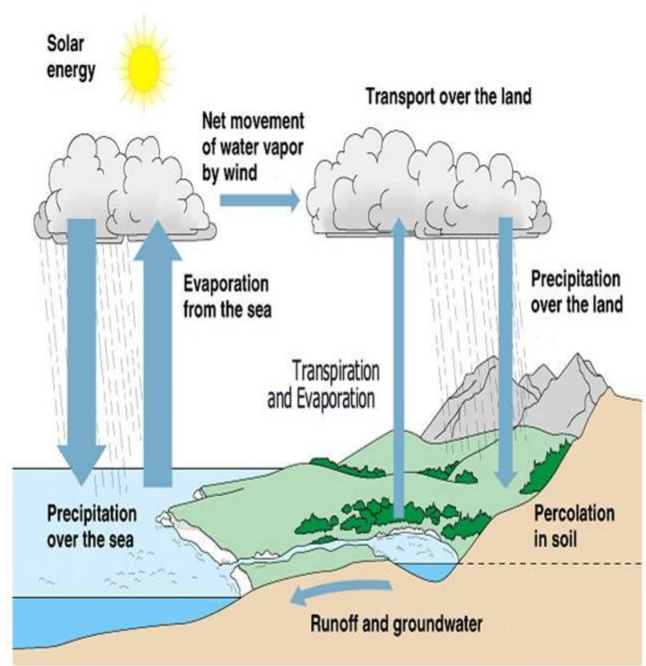
Nutrient Recycling – Biogeochemical Cycles





Hydrologic (Water) Cycle





Watershed

A **watershed or drainage basin** is an area of land where water from rain and melting snow or ice drains downhill into a body of water, such as a river, lake, reservoir, wetland. All of the major terrestrial and aquatic ecosystems are impacted by what happens in a watershed.

The rivers will eventually flow into large rivers which become estuaries and flow into the oceans.

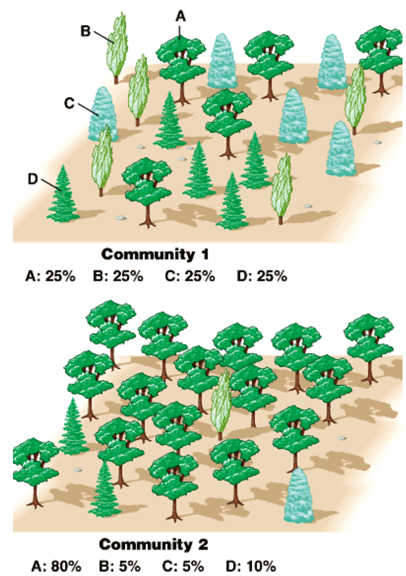
- Watershed surface water management plans are implemented to reduce flooding, improve water quality, and enhance stream and wetland habitat.
- Land usage and water treatment methods are important in maintaining water quality in the watershed
- Sources of water pollution may include **point source pollution** from a clearly identifiable location or **nonpoint source pollution** that comes from many different places.
- Sources of pollution usually fall into four main categories – industrial, residential, commercial, and environmental
- Some types of pollution may include
    - **organic pollution** – decomposition of living organisms and their bi-products
    - **inorganic pollution** – dissolved and suspended solids as silt, salts, and minerals
    - **toxic pollution** – heavy medals and other chemical compounds that are lethal to organisms
    - **thermal pollution** – waste heat from industrial and power generation processes

Ecosystem Stability and Resilience

Biological Diversity

- Ecosystem stability and the response of ecosystems to disturbance are of crucial importance
- Biological diversity acts to stabilize ecosystem functioning in the face of environmental fluctuation.
- Variation among species in their response to such fluctuation is an essential requirement for ecosystem stability
- ***Climate change and other human-driven (anthropogenic) environmental changes will continue to cause biodiversity loss in the coming decades***

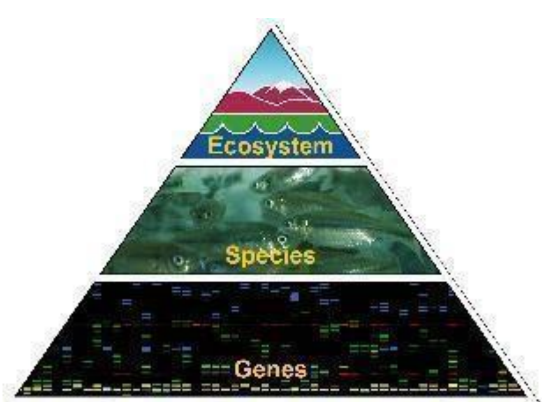
Kinds of Biological Diversity

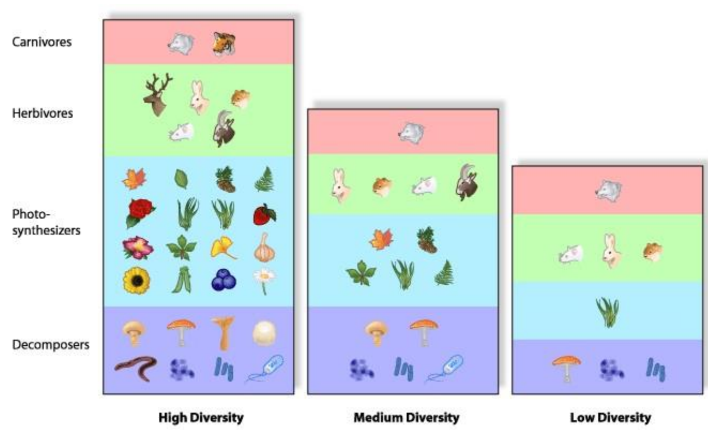


- **Habitat/ecosystem diversity -** the different kinds of habitats in a given unit area
- **Species diversity -** the different kinds of species in a given unit area, further divided into species richness, species evenness, and species dominance.
    - **species richness -** the total number of species
    - **species evenness -** the relative abundance of species
    - **species dominance -** the most abundant

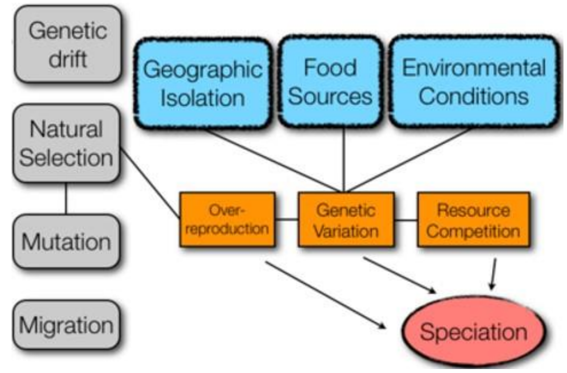
Aspects of Biological Diversity

- Number of different species
- Relative abundance of different species
- Ecological distinctiveness of different species, e.g., functional differentiation
- Evolutionary distinctiveness of different species
- Biodiversity is accomplished through mutation and natural selection



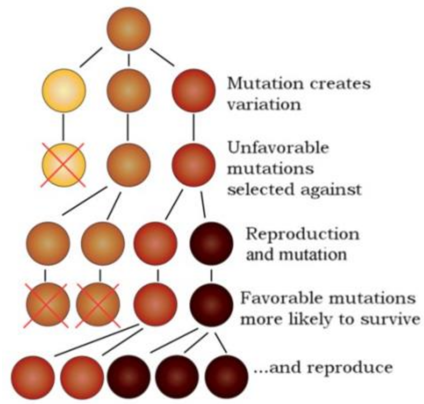


Adaption



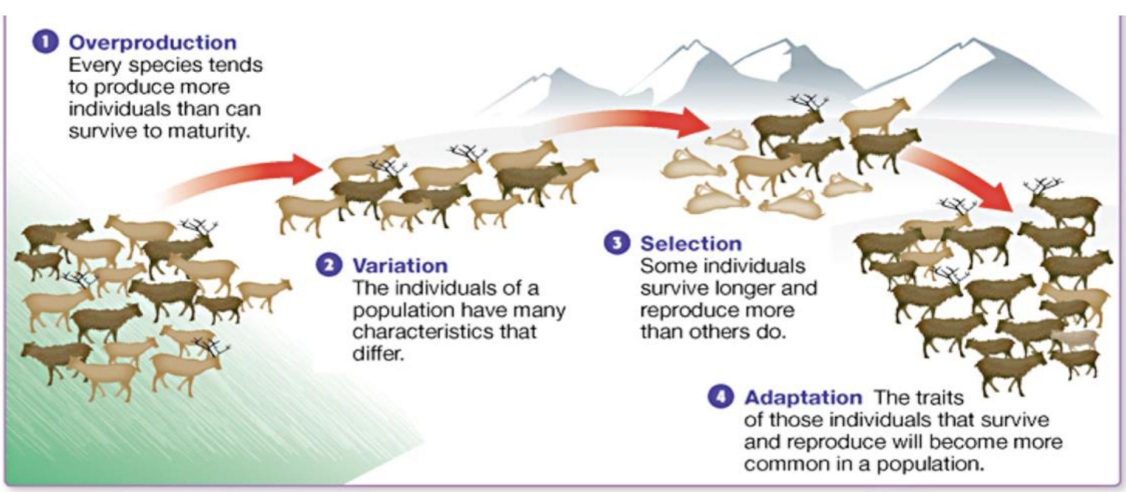
- If their environment changes in a way that organisms can no longer survive, they will have to adapt or cease to exist – **extinction**
- ***Biological Evolution*** (adaption) is the change in inherited characteristics of a population from generation to generation – it can result in a new species

Four Processes Lead to Biological Evolution



1. **Mutation -** when DNA is changed, it has undergone mutation – causes of mutations include:
   - error in replication
   - external agent coming in contact with DNA and changing it
   - radiation breaking DNA apart or changing its chemical structure
   - chemicals and viruses

2. **Natural Selection**
   - ***Natural Selection* -** when there is variation within a species, the individuals with the most useful traits tend to survive and pass on their traits to the next generation - making their trait more common or even a general characteristic of the species
   - ***Genetic Variability***- inheritance of traits from one generation to the next and some variation in these traits
   - Environmental variability
   - Differential reproduction that varies with the environment



3. Migration

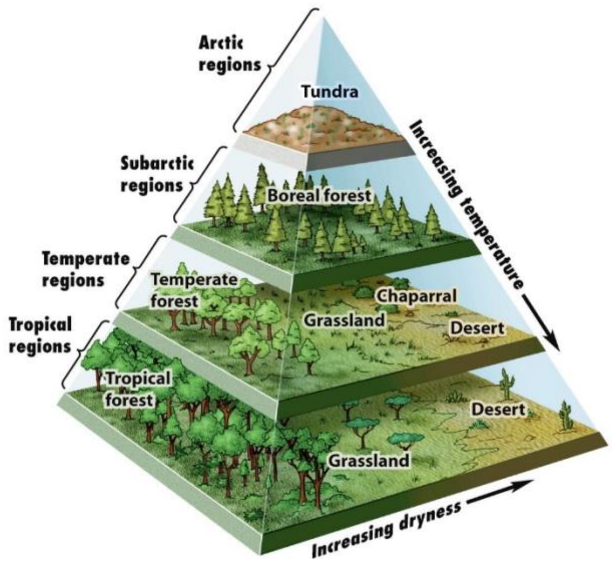
- Migration can play a large role in the development of a new species
- When two populations of a species migrate to different areas and are then kept isolated for whatever reason (usually changes in climate or physical barriers) for a long enough time, the two populations can develop differently to the point where they are no longer the same species.

4. Genetic drift – random chance change

- Genetic drift is changes in the frequency of a gene in a given population not due to mutation, selection, or migration, but simply change or random chance
- Change can be anything, such as a smaller group being isolated from a large population--suddenly the gene pool has changed and certain genes may be by chance, more common or rare.
- Genetic drift is not necessarily beneficial to a species
- Influence of the environment on survival and reproduction

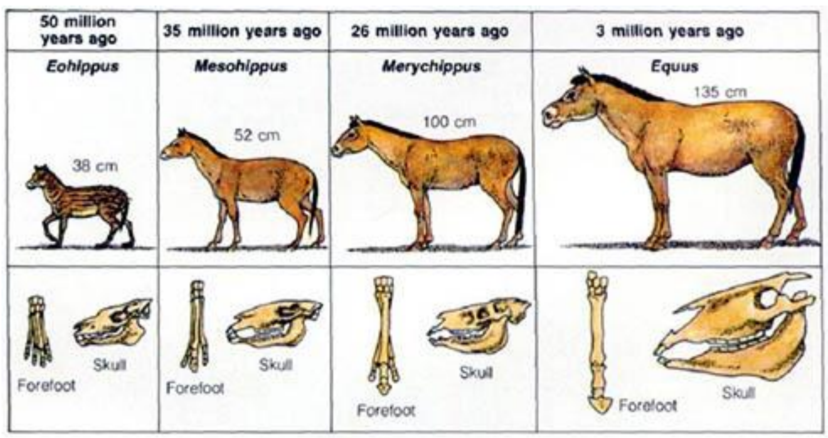
Types of Adaptations – most organisms have combinations of all these types

- ***Structural***– based upon an organism's physical body
  - Desert foxes have large ears for heat radiation
  - Arctic foxes have small ears to retain body heat.
  - Seals have flippers to navigate water
  - Raccoons have separate, flexible digits to manipulate food.
  - White polar bears blend into ice floes
  - Trees may have corky bark to protect from wildfires
- ***Physiological*** – based upon body chemistry and metabolism
  - More efficient kidneys for desert animals like kangaroo rats
  - Compounds that prevent blood coagulation in mosquito saliva
  - Presence of toxins in plant leaves to repel herbivores
- ***Behavioral* –** something an animal does in response to a stimulus
  - Bears hibernate to escape cold;
  - Birds and whales migrate to warmer winter climates.
  - Desert animals are active at night during hot summer weather.
  - Lizards seek a sunny spot in the morning to warm up to operating temperatures more quickly
  - A nesting killdeer will pretend to be injured to lure a predator away from her young.



Extinction

- The disappearance of a species of living organisms
- It usually occurs as a result of changed conditions to which is species is not suited.
- If no member of the affected species survives and reproduces, the entire line dies out.
- A species may become extinct through gradual evolution into a new species as a result of natural selection for characteristics suited for new environmental conditions. This is a natural process
  An example of the is the evolution of horses



Extinctions Today

- There are natural causes for extinctions as well as human causes.
- Human causes have accelerated the rate of species extinctions
- Since the 1600s, scientists have documented 784 extinctions - about half were direct result of human activities