3. Population Biology

Principles of Ecology

1- Energy Flow & Productivity in Ecosystems
2- Biogeochemical Cycles
3- Population Growth & Regulation
4- Community Structure, Growth, Regulation
5- Habitat
6- Concept of Niche
7- Island Biogeography
8- Evolutionary Ecology

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7- Classification of Living Organisms
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Principles of Behavior

1- Stereotyped, Learned Social Behavior
2- Societies

Social Biology

1- Human Population Growth
2- Human Intervention in Natural World
3- Biomedical Progress

3.1 Principles of Ecology

Principles of Ecology

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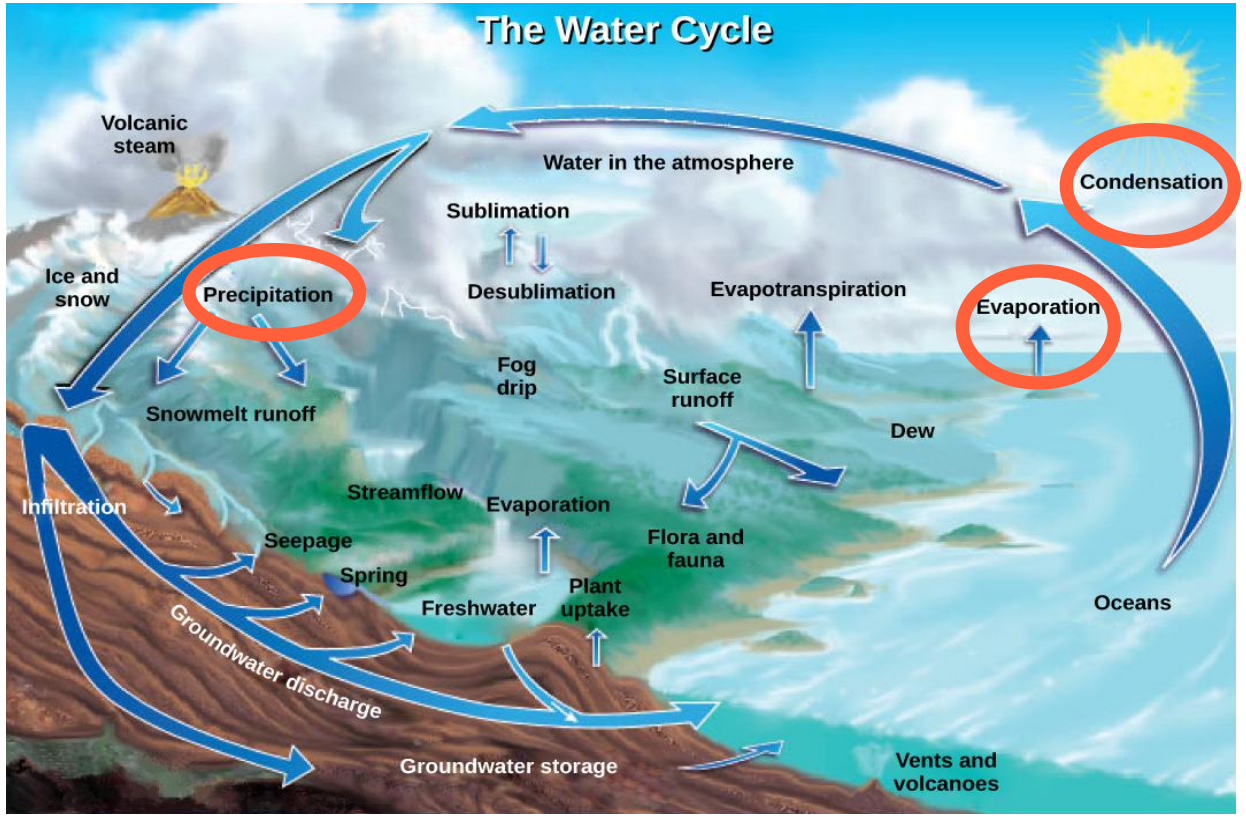
Energy Flow & Productivity in Ecosystems

- Energy Flow
- Trophic Levels
- Trophic Categories
- Ecological Roles
- Transfer of Energy

Biogeochemical Cycles

- Introduction
- Water
- Carbon
- Nitrogen
- Phosphorous



Population Growth & Regulation

- Introduction
- Limiting Biotic Factors
- Limiting Abiotic Factors
- Density
- Demography & Growth

Community Structure, Growth, Regulation

- Introduction
- Competition
- Symbiosis
- Succession

Habitat

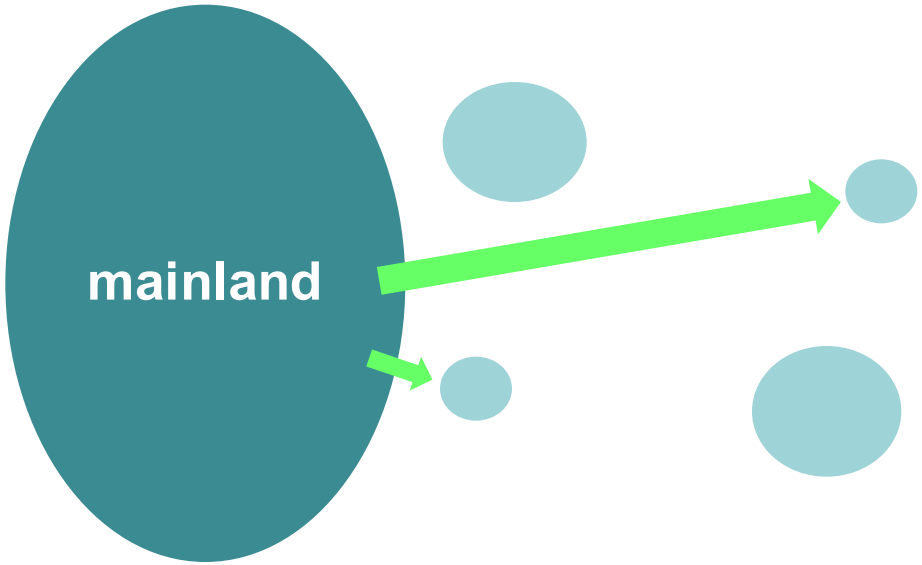
- **Definition & examples**

Concept of Niche

- **Definition & examples**

Island Biogeography

- Introduction
- Dispersal
- Species Diversity
- Immigration & Extinction
- Area Effects
- Distance Effects
- Age Effects



Evolutionary Ecology

- Introduction & Example
- Interactions
- One-way Interactions
- Reciprocal Interactions

3.1.1 Energy Flow & Productivity in Ecosystems

Energy Cycle

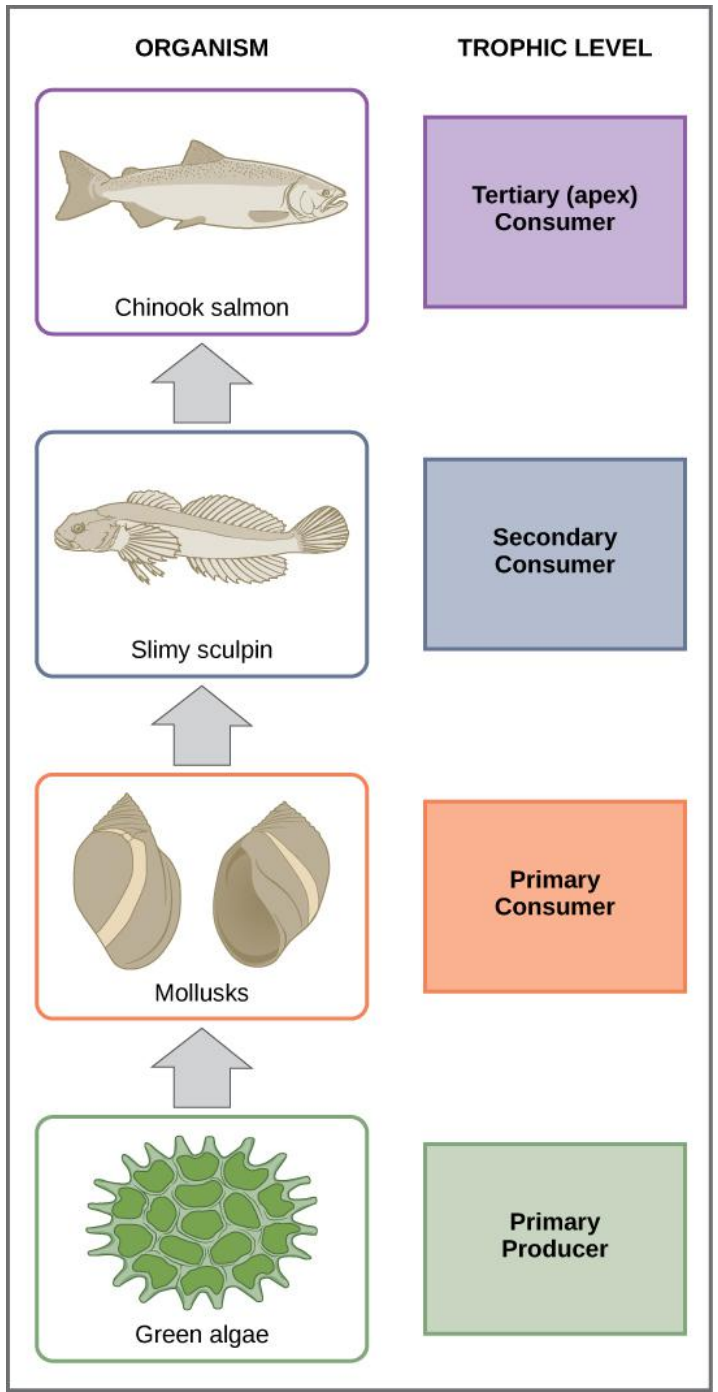
Also ‘Food Chain’ and ‘Food Web’

- represent flow of energy (matter)
- show how energy enters & leaves

Trophic Levels

Producers: make energy accessible to ecosystems via photosynthesis

Consumers: eat producers or other consumers


ORGANISM
TROPHIC LEVEL
Chinook salmon
Tertiary (apex) Consumer
Slimy sculpin
Secondary Consumer
Mollusks
Primary Consumer
Green algae
Primary Producer

Trophic Categories

Autotrophs: self-feeders, producers, make food molecules from sun

Heterotrophs: other-feeders, consumers, get food molecules from eating other

Ecological Roles

Herbivores: eat plants

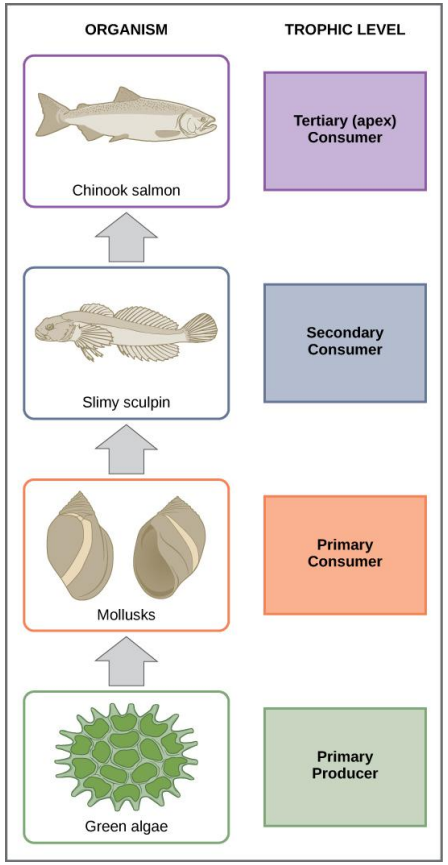
Carnivores: eat animals

Omnivores: eat plants & animals

Transfer of Energy

Very inefficient due to heat loss

Each higher level gets 10% of previous



1J

10J

100J

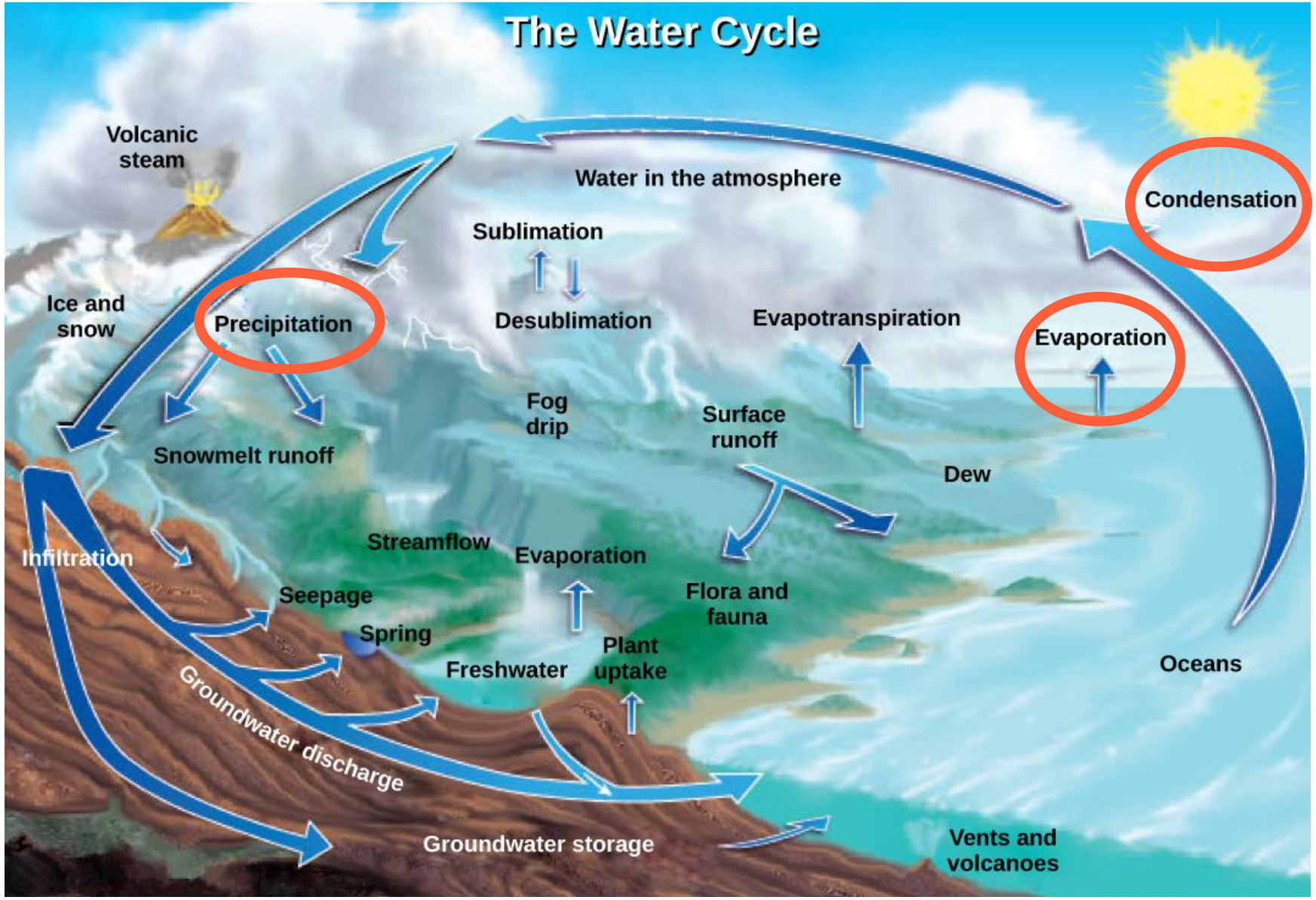
1000J

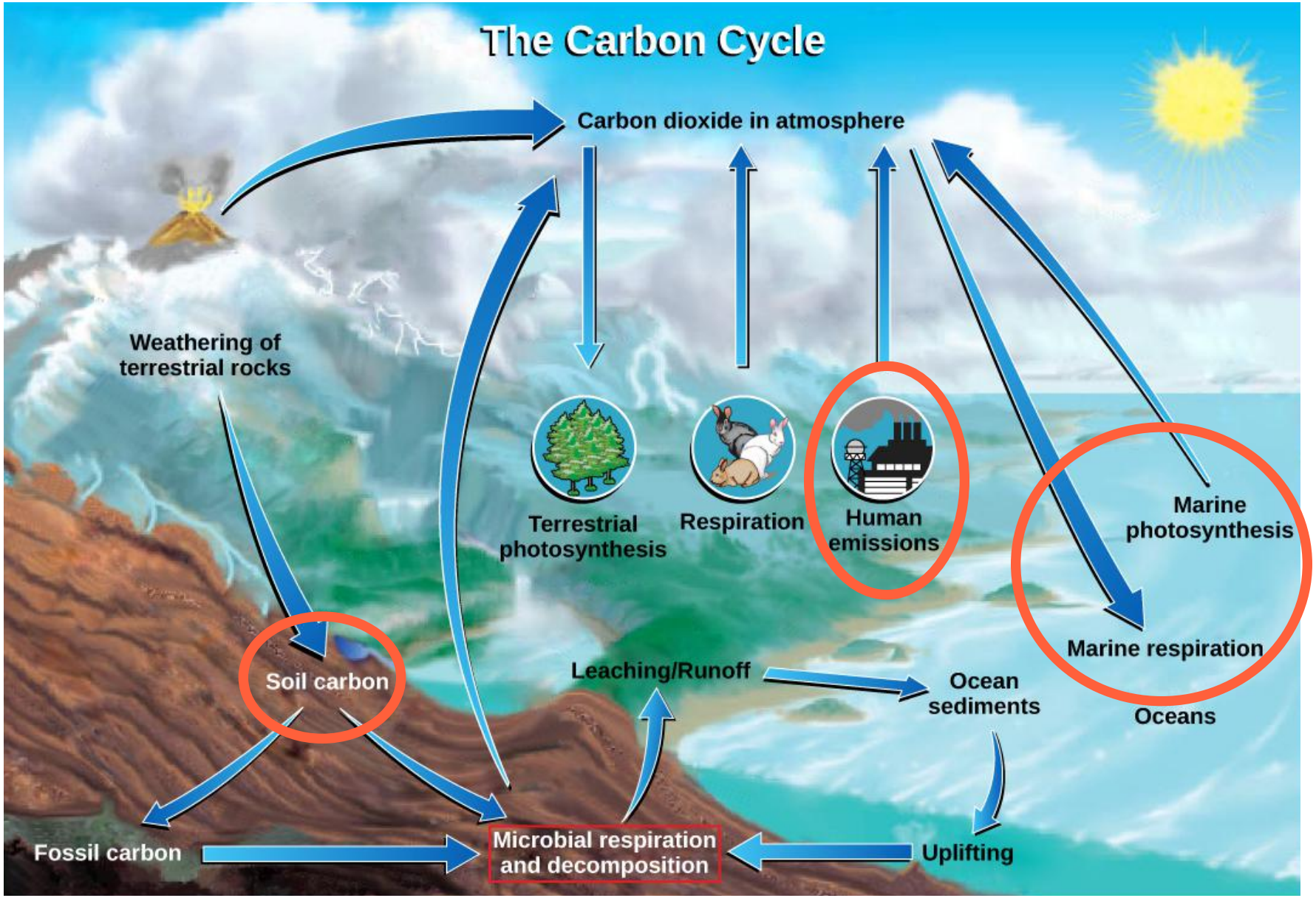
3.1.2 Biogeochemical Cycles

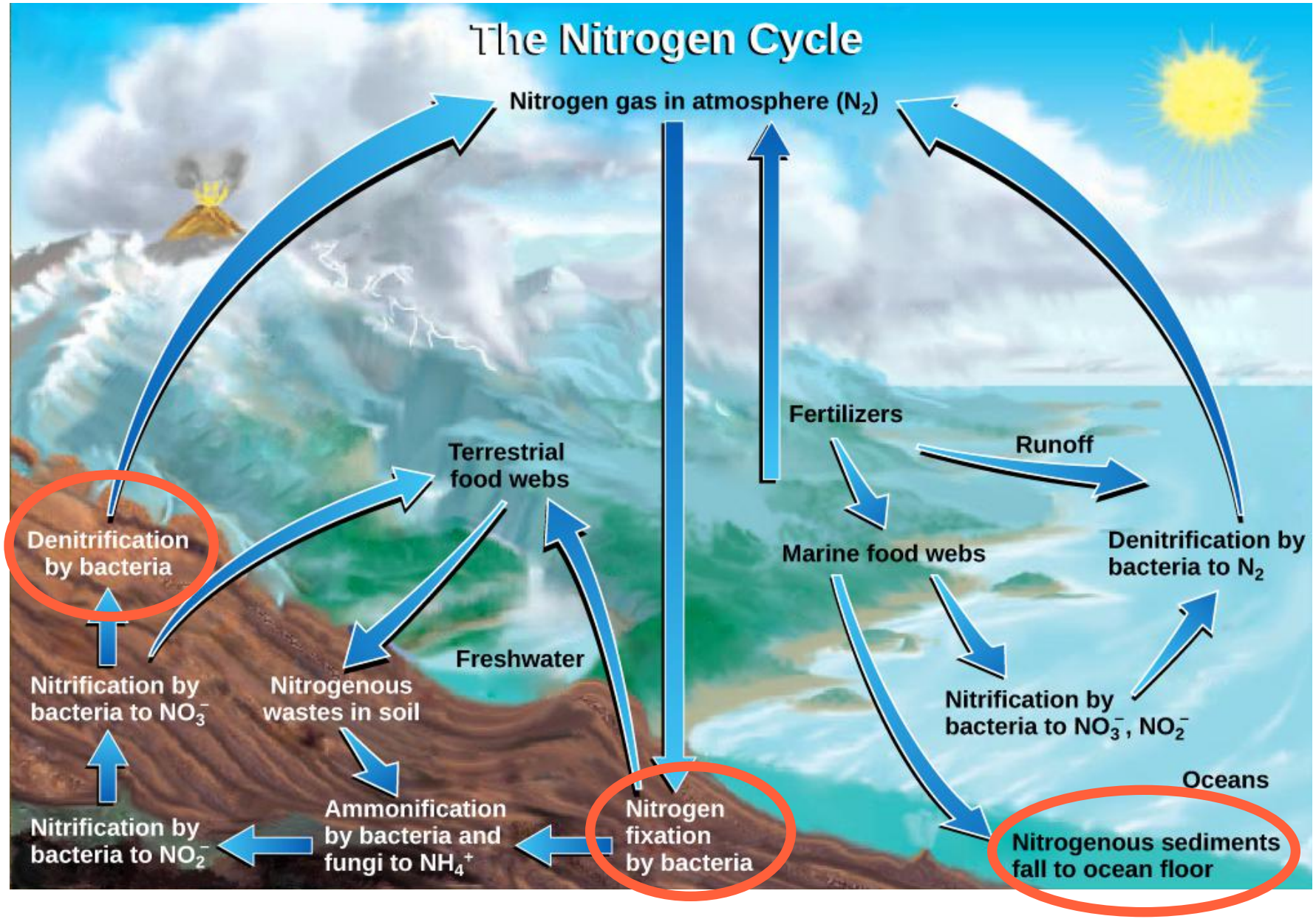
Biogeochemical Cycle?

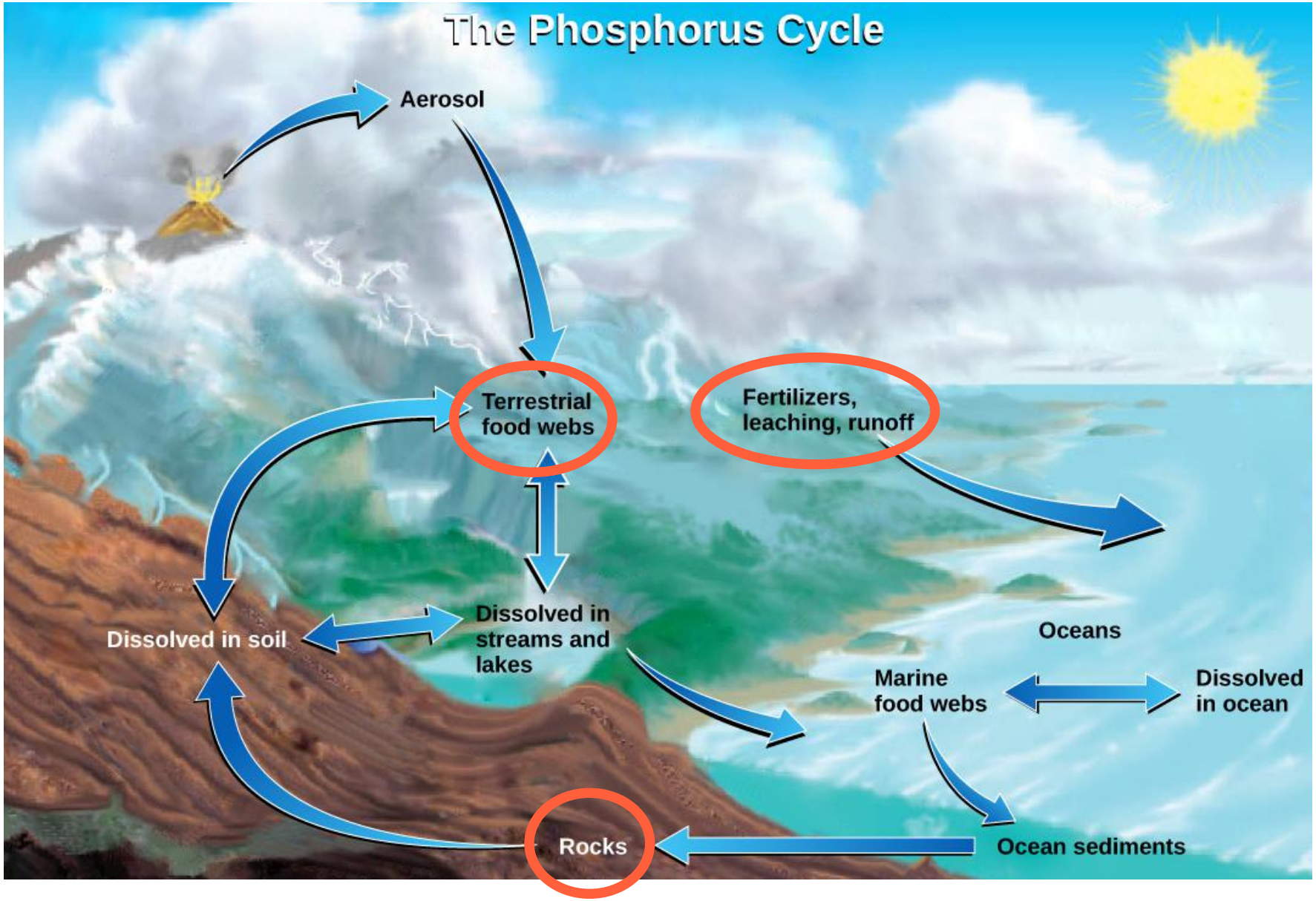
Bio: living things
Geo: sediments/ rocks
Chemical: molecules
Cycles: circular movement

Circular movement of molecules through an ecosystem's living and non-living things


The Water Cycle
Volcanic steam
Water in the atmosphere
Condensation
Sublimation
Ice and snow
Precipitation
Desublimation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Snowmelt runoff
Dew
Streamflow
Evaporation
Infiltration
Seepage
Flora and fauna
Spring
Plant uptake
Freshwater
Oceans
Groundwater discharge
Groundwater storage
Vents and volcanoes


The Carbon Cycle
Carbon dioxide in atmosphere
Weathering of terrestrial rocks
Terrestrial photosynthesis
Respiration
Human emissions
Marine photosynthesis
Marine respiration
Oceans
Soil carbon
Leaching/Runoff
Ocean sediments
Fossil carbon
Microbial respiration and decomposition
Uplifting


The Nitrogen Cycle
Nitrogen gas in atmosphere (N_2)
Fertilizers
Runoff
Terrestrial food webs
Denitrification by bacteria
Marine food webs
Denitrification by bacteria to N_2
Freshwater
Nitrification by bacteria to NO_3^-
Nitrogenous wastes in soil
Nitrification by bacteria to NO_3^-, NO_2^-
Oceans
Nitrification by bacteria to NO_2^-
Ammonification by bacteria and fungi to NH_4^+
Nitrogen fixation by bacteria
Nitrogenous sediments fall to ocean floor


The Phosphorus Cycle
Aerosol
Terrestrial food webs
Fertilizers, leaching, runoff
Dissolved in soil
Dissolved in streams and lakes
Oceans
Marine food webs
Dissolved in ocean
Rocks
Ocean sediments

3.1.3 Population Growth & Regulation

What is it?

Study of groups of organisms of one species living together (population)

- limiting factors
- birth rate
- death rate
- growth rate

Limiting Biotic Factors

- Dispersal: movement away from center
- Competition
- Predators
- Lack of prey/ food
- Parasites

Limiting Abiotic Factors

- Climate
- Landscape
- Soil
- Water salinity
- Sunlight

Density

Density: # individuals per unit area

Density-dependent regulators:

- **competition**
- **predation**
- **disease**

Density

Density-independent regulators:

- **climate**
- **disturbance (fire, flood, etc.)**
- **pollution**

Demography & Growth

Demography: vital statistics like birth & death rate, age at maturity

Growth rate: how fast is population getting larger or smaller? Rate of growth (r) equals births (b) minus deaths (mortality, m)

$$r = b - m$$

3.1.4 Community Structure, Growth, Regulation

What is it?

Study of interactions among different species in the same area

- **competition**
- **predation**
- **symbiosis**
- **succession**

Competition

More than one species in community attempts to use the same limited resource

Competition

Competitive Exclusion Principle: no two species can occupy same niche indefinitely; one will be a better competitor, other will go extinct locally

Niche partitioning allows coexistence

Symbiosis

Close interaction b/w two species

1. Mutualism: both benefit
2. Commensalism: one benefits, other neutral
3. Parasitism: one benefits, other harmed

Succession

Process through which community recovers from disturbance

1. Primary: no soil
   (ex: lava flows, glacial moraine)
2. Secondary: soil present
   (ex: abandoned fields)

3.1.5 Habitat

Habitat

Species' physical location, including all biotic & abiotic factors it needs to survive

- pond
- forest
- river
- grassland

3.1.6 Concept of Niche

Ecological Niche

Species' role in community

- time of day/ year
- parts of habitat
- prey size
- temperature
- trophic level

3.1.7 Island Biogeography

Biogeography

Study of distribution of organisms in space, historically & currently

Island Biogeography

Biogeography specific to islands & their species

- dispersal
- species diversity
  - area effects
  - distance effects
  - age effects

Dispersal

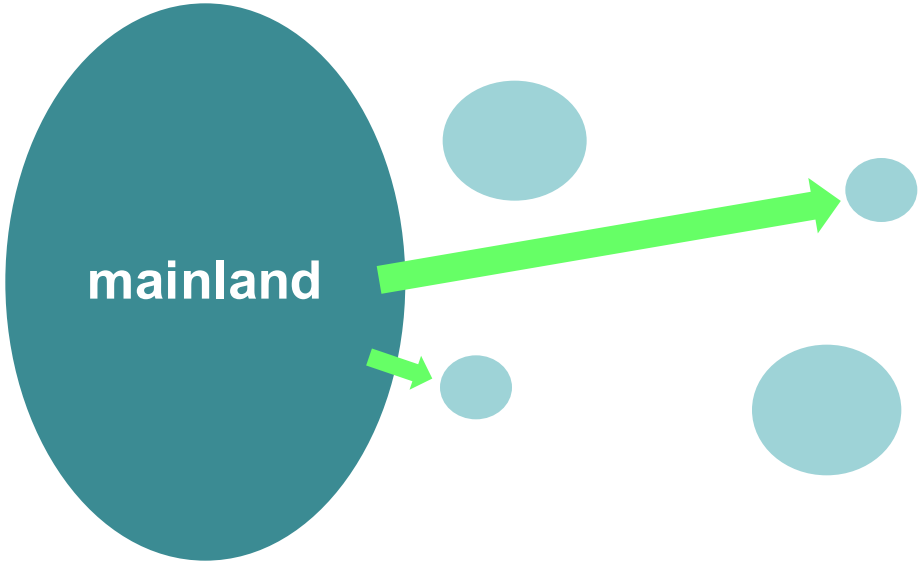
Species reach islands by dispersal methods

- flying
- blown by wind
- floating on water

Species Diversity

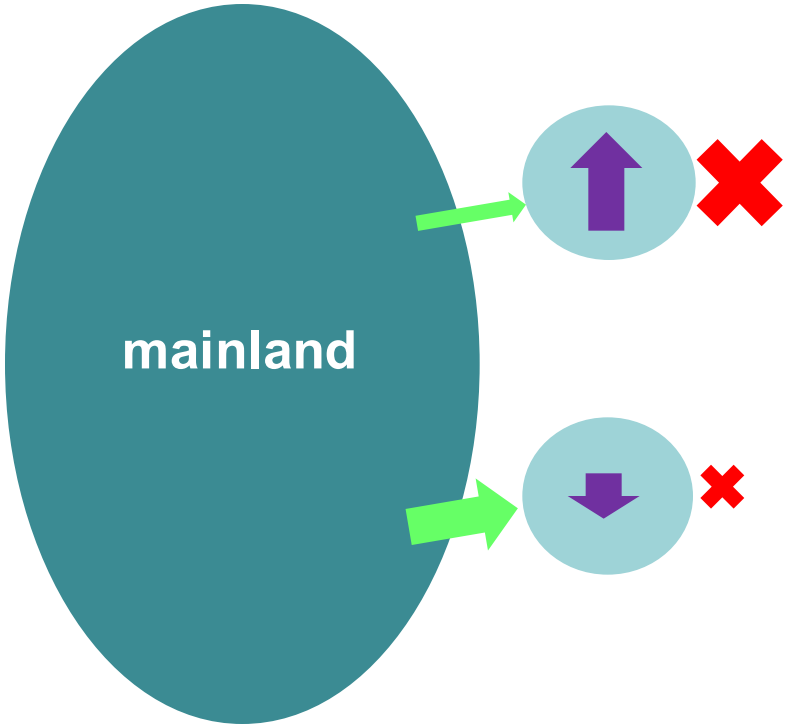
Number of species on island determined by:

- immigration & extinction rates
- size
- distance
- age



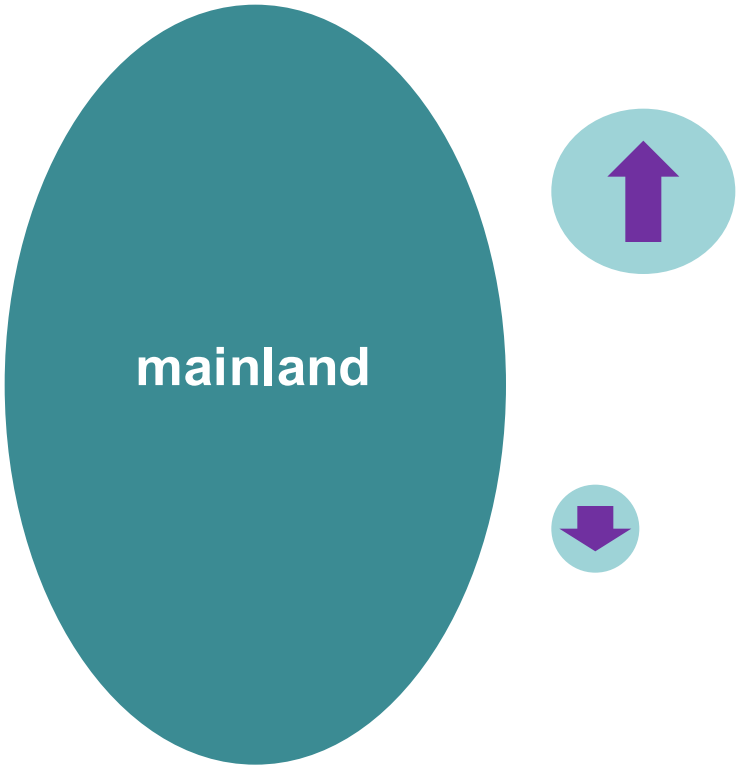
Immigration & Extinction

As diversity increases, immigration rate decreases and extinction rate increases



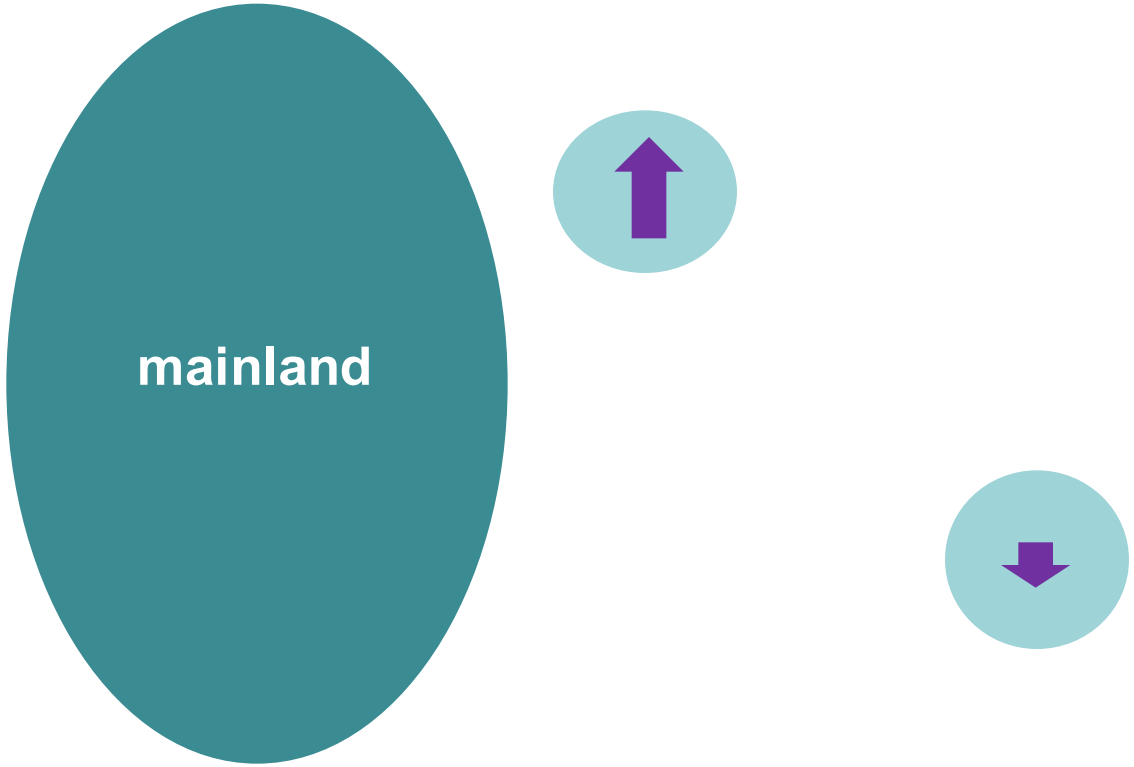
Area Effects

Diversity highest on larger islands



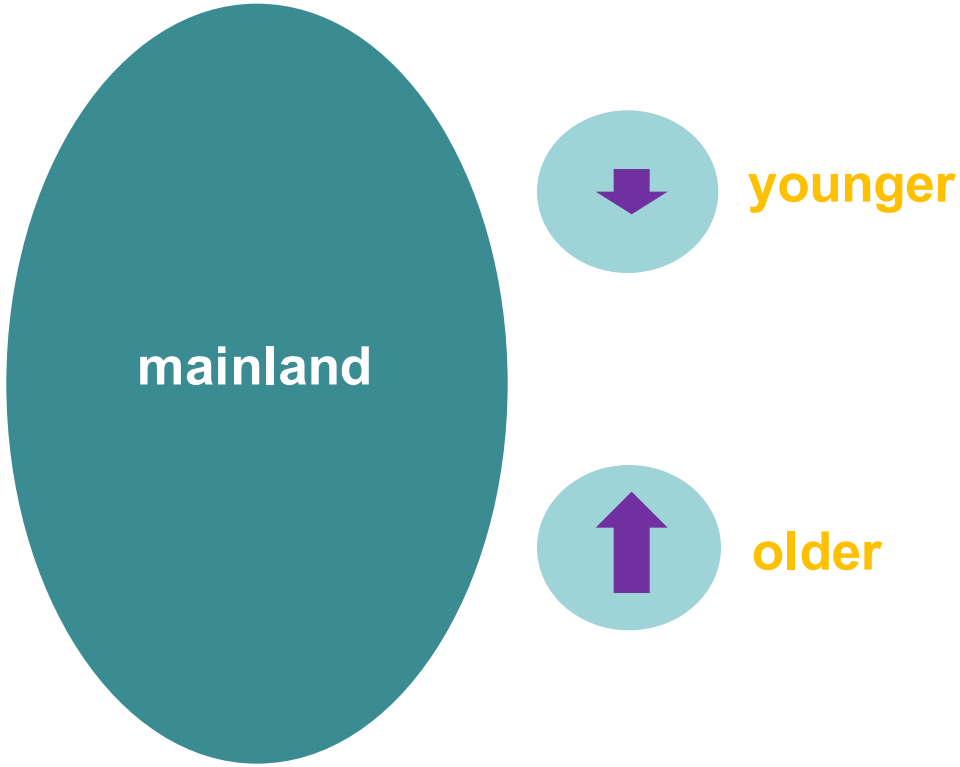
Distance Effects

Diversity highest on near islands



Age Effects

Diversity is highest on older islands



3.1.8 Evolutionary Ecology

What is it?

Study evolution of interactions between & among species and with their environment

- **competitors**
- **mutualists**
- **predators**
- **prey**
- **pathogens**

Example: Research on the origin of the mutualism b/w termites and protozoa

Interactions

Two types studied:

1. with physical environment
2. with other species
   a. one-way
   b. reciprocal

One-way Interactions

One species affects another, but not vice versa

- **commensalism**

Reciprocal Interactions

Two species affect each other

- **predator-prey**
- **parasite-host**
- **competitors**

3.2 Principles of Evolution

Principles of Evolution

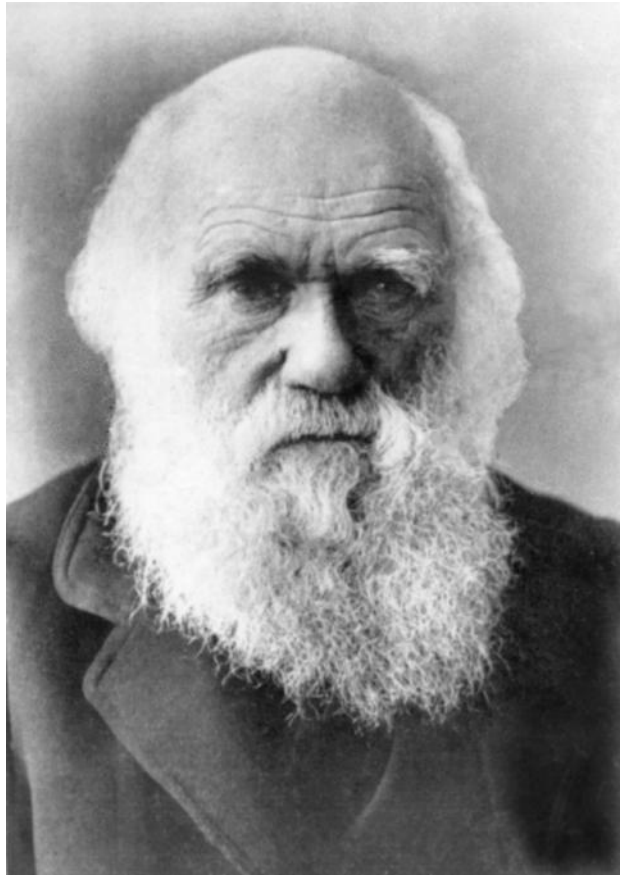
1- History of Evolutionary Concepts
2- Concepts of Natural Selection
3- Adaptive Radiation
4- Major Features of Plant & Animal Evolution
5- Concepts of Homology & Analogy
6- Convergence, Extinction, Balanced Polymorphisms, Genetic Drift
7- Classification of Living Organisms
8- Evolutionary History of Humans

History of Evolutionary Concepts

- Evolution
- Carolus Linnaeus
- Lamarck

Concepts of Natural Selection

- Darwinian Concept
- Modern Synthesis



Adaptive Radiation

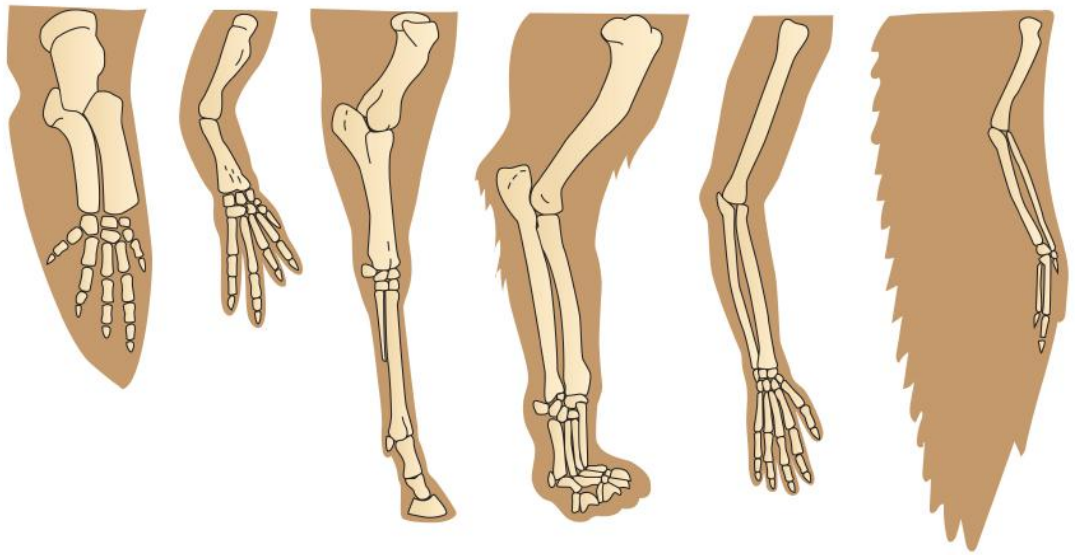
- Adaptations
- Species
- Resource Partitioning

Major Features of Plant & Animal Evolution

- Plant Evolution
- Animal Evolution
- Explosions

Concepts of Homology & Analogy

- Homology
- Analogy



Convergence, Extinction, Balanced Polymorphisms, Genetic Drift

- Convergence
- Extinction
- Balanced Polymorphisms
- Genetic Drift

Classification of Living Organisms

- Taxonomy
- Taxa
- The Domain
- Classification of Domestic Cat
- Eukaryote Kingdoms
- Animal Phyla

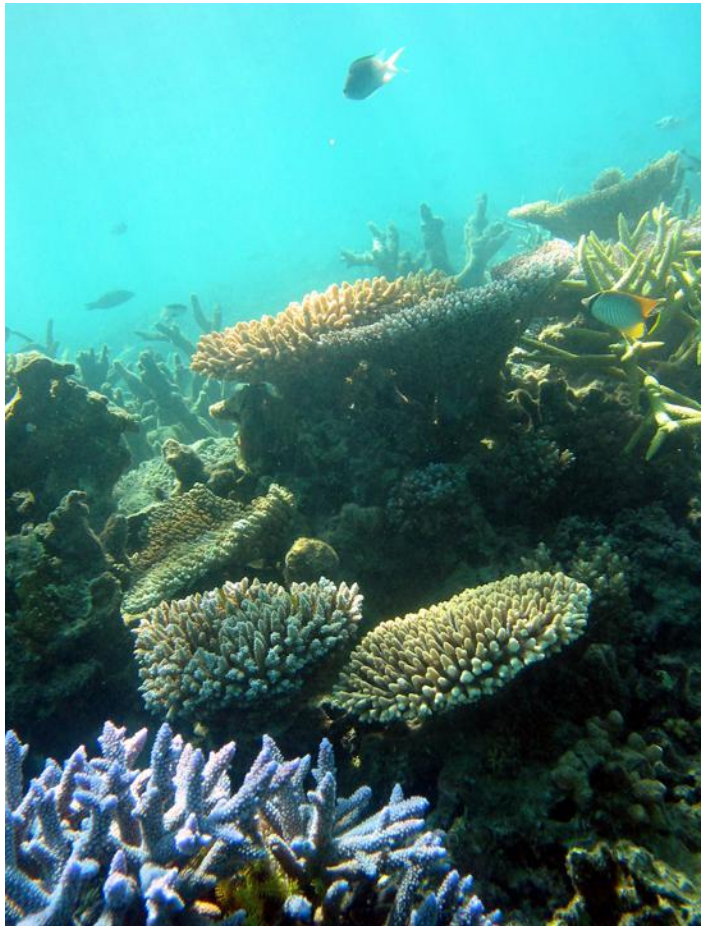
Evolutionary History of Humans

- Order Primates
- Great Apes
- Hominid Fossils
- Location

3.2.1 History of Evolutionary Concepts

Evolution

Genetic change in a population over time



Carolus Linnaeus

Invented binomial nomenclature

Wrote about origins & relationships b/w organisms (1700s)

Lamarck

Proposed that organisms acquire traits throughout lifespan & pass these on (proven false)

3.2.2 Concepts of Natural Selection

Darwinian Concept

Natural Selection is driving force behind evolution

- more offspring produced than can survive
- variation in characteristics among individuals of population
- some individuals better competitors
- these have more offspring
- frequency of characteristic increases in population
- population smallest unit that can evolve

Modern Synthesis

Darwin's theory still supported, but we know more details now:

- **characteristics result from genes**
- **variations in characteristics result from alleles**
- **evolution can take thousands of years**

3.2.3 Adaptive Radiation

Adaptations

Inherited characteristics that provide survival/ reproductive advantages

- speed
- camouflage
- armour
- hearing

Species

Population of interbreeding individuals, common gene pool, viable offspring, don't interbreed w/ other populations

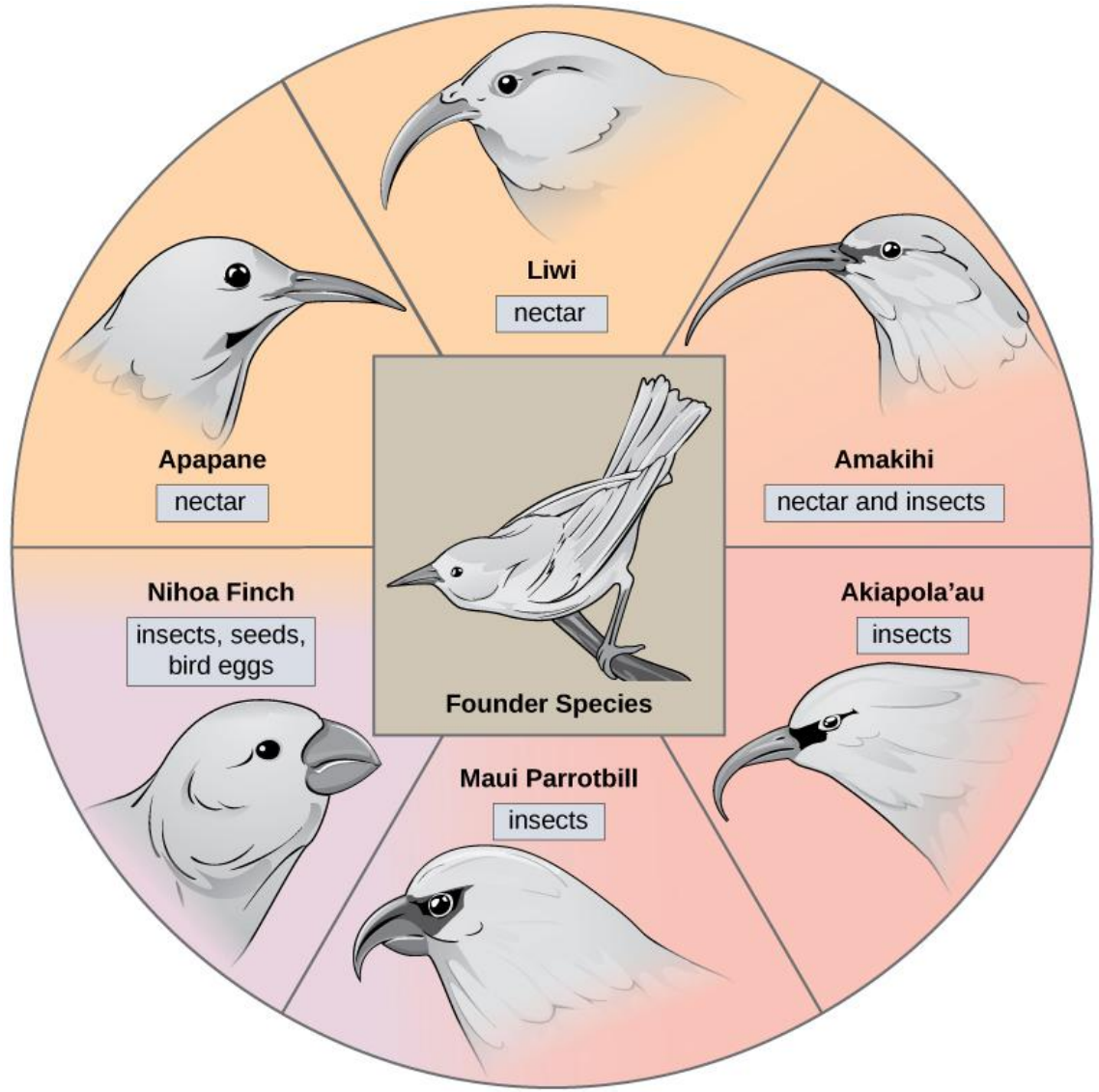
A new species forms when two populations no longer interbreed

Resource Partitioning

Decreases competition b/w species by utilizing more specialized niches

Adaptive radiation occurs as result of resource partitioning:

- alleles that allow individuals to use resources differently are adaptive
- over time, many new species evolve as result of benefits of using new niches


Liwi
nectar
Apapane
nectar
Amakihi
nectar and insects
Nihoa Finch
insects, seeds, bird eggs
Founder Species
Akiapola'au
insects
Maui Parrotbill
insects

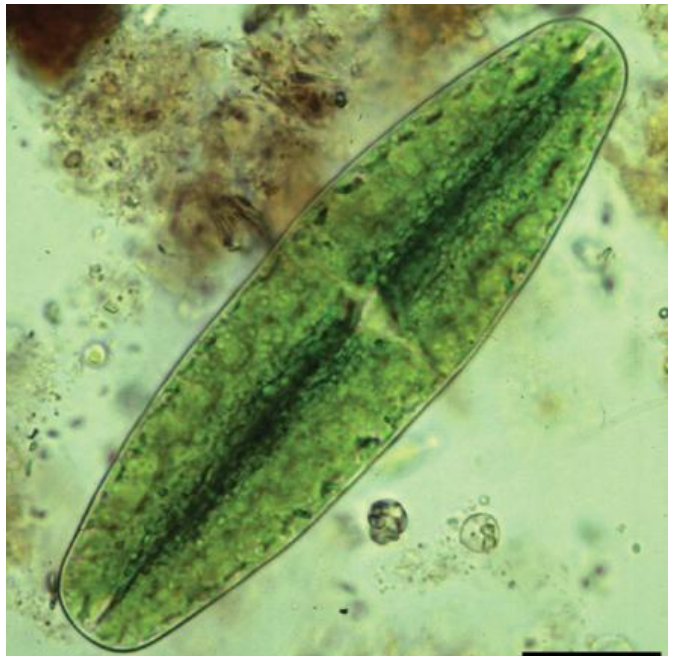
3.2.4 Major Features of Plant & Animal Evolution

Plant Evolution

Endosymbiont Theory explains evolution of autotrophs from heterotrophs

Early plants were aquatic, asexual

Movement to land accompanied by adaptations for water storage, increased gravitational pull



Plant Evolution

Separate sexes allowed for greater genetic diversity

First land plants didn't have seeds

Evolution of seeds allowed colonization of more habitats

Evolution of flowers allowed animal attraction for pollination & seed dispersal

Animal Evolution

First animals were aquatic, unicellular, soft-bodied

Multicellularity & hard structures appeared (spicules, exoskeletons)

Invertebrates first on land

Animal Evolution

Fish were first w/ backbones

Adaptations for conserving water & dealing with higher gravitational pull appeared with land colonization

Explosions

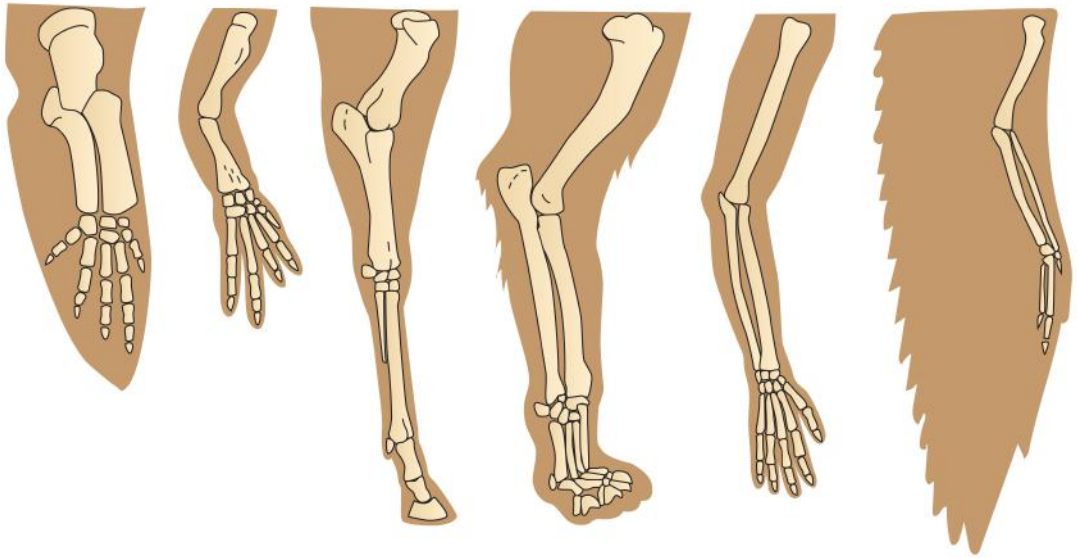
Cambrian explosion: rapid increase in multicellular organisms

- **aquatic plants appeared**
- **most major animal phyla appeared**
- **new niches evident: active hunting, burrowing into sediment, making branching burrows**

3.2.5 Concepts of Homology & Analogy

Homology

Similar structures resulting from common ancestry, could have different functions.



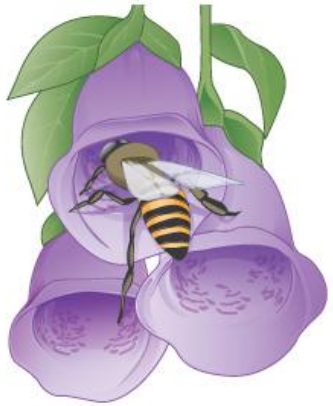
Analogy

Similar structures resulting from common function but not common ancestry

3.2.6 Convergence, Extinction, Balanced Polymorphism, Genetic Drift

Convergence

Convergent evolution: unrelated species evolve similar characteristics due to similar environments



Extinction

When a species disappears from planet forever

Permian extinction (250mya): 96% species lost

Balanced Polymorphism

Polymorphism: genetic diversity within a species for a particular trait

Balanced Polymorphism: natural selection tends to keep number of forms stable; when one is scarce, its fitness increases

Genetic Drift

Random change in allele frequency for a particular trait in a single population

Ex: Storm randomly causes death of most squirrels carrying alleles for light coat color

3.2.7 Classification of Living Organisms

Taxonomy

Organizes living things into groups based on appearance, genetics, evolutionary history

Carolus Linnaeus invented binomial nomenclature, using genus & species "Scientific name" ***Borrelia burgdorferi***

Taxa

Taxon: level of classification of living things

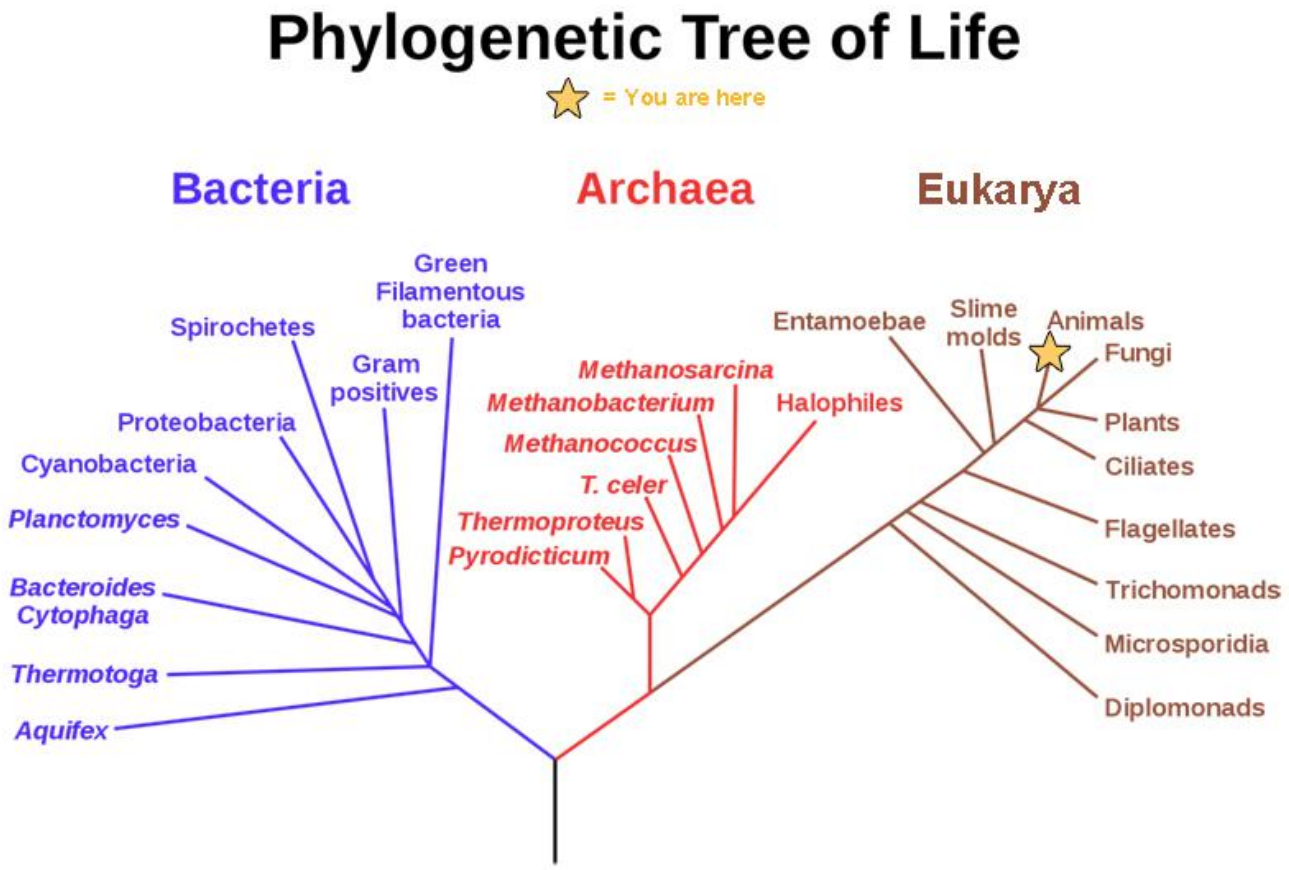
Kingdom
Phylum
Class
Order
Family
Genus
Species

The Domain

Recent addition to taxonomy

3 Domains, encompass all other taxa

- Archaea
- Eubacteria
- Eukaryota



Classification of Domestic Cat

Domain: Eukarya (eukaryotes)
Kingdom: Animalia (heterotrophs)
Phylum: Chordata (backbones)
Class: Mammalia (milk)
Order: Carnivora (meat)
Family: Felidae (hypercarnivore, claws)
Genus: *Felis* (small)
Species: *catus* (domesticated)

Scientific Name: *Felis catus*

Eukaryote Kingdoms

1. Animalia- animals
2. Plantae- plants
3. Monera- fungi
4. Protista- unicellular, animal-like or plant-like

Animal Phyla

1. Porifera- sponges
2. Cnidaria- jellies
3. Platyhelminthes- flatworms
4. Nematoda- roundworms
5. Mollusca- clams, snails, squid
6. Annelida- earthworms
7. Arthropoda- crabs, insects, spiders
8. Echinodermata- starfish, sea urchins
9. Chordata- fish, mammals, birds, reptiles, amphibians

3.2.8 Evolutionary History of Humans

Order Primates

Prosimians: lemurs, lorises

More recent:

- **tarsiers**
- **new world monkeys**
- **old world monkeys**
- **apes- gorilla, chimpanzee, orangutan, human**

Great Apes

Humans, gorillas, chimpanzees, bonobos, and orangutans have recent common ancestor

First true hominids 4.5mya, larger brains & bipedal locomotion

Hominid Fossils

1. ***Australopithecus afarensis*** **(Lucy)- 4.5mya, head smaller, long arms**
2. ***Homo erectus*****- first from same genus, 1.8mya, head larger, facial features**
3. **First *Homo sapiens* (Cro-Magnon Man)- 100,000 years ago, looked like us**

Location

Oldest human fossils from Africa

Fossils suggest we evolved in Africa 100,000 years ago, migrated throughout Europe, Asia, the Americas

Crossed Bering Land Bridge into North America, then to Central & South America

3.3 Principles of Behavior

Principles of Behavior

1- Stereotyped, Learned Social Behavior
2- Societies

Stereotyped, Learned Social Behavior

- Stereotyped Behaviors
- Fixed Action Patterns
- Learned Behaviors
- Conditioning
- Habituation
- Imprinting

Societies

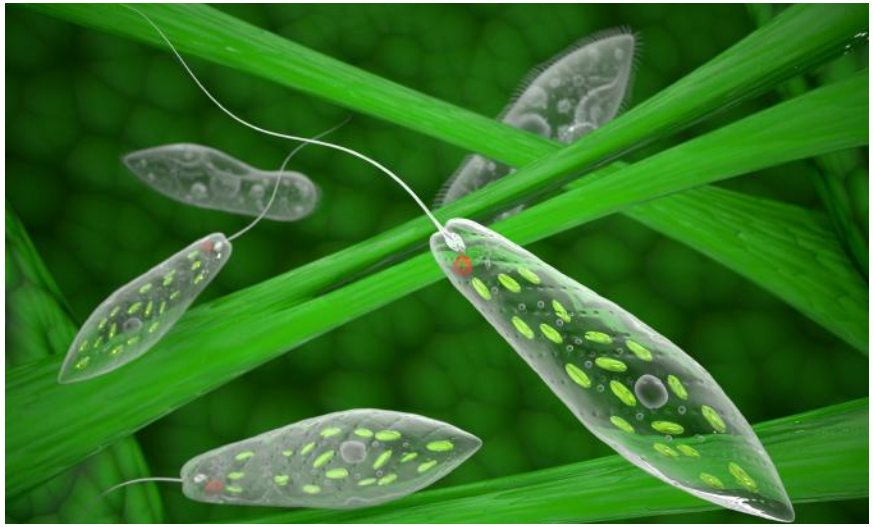
- Society
- Insect Societies
- Primate Societies

3.3.1 Stereotyped, Learned Social Behavior

Stereotyped Behaviors

Instinctive, performed the same way by all individuals of species, in response to a stimulus

1. **taxis- directional**
2. **kinesis- speed change**
3. **reflex- automatic movement of body part**
4. **fixed action pattern- more complex series of behaviors**



Fixed Action Pattern (FAP)

Behavior sequence continues, even when stimulus removed

- courtship behaviors
- feeding young
- circadian rhythms

Learned Behaviors

Not instinctive, must be seen & practiced, can be stopped mid-behavior, based on life experience

- **conditioning**
- **habituation**
- **imprinting**

Conditioning

Behavioral response to one stimulus is applied also to different stimulus

- **dogs drool when they smell food**
- **ring a bell when food presented**
- **dogs eventually drool BOTH when they smell food and hear bell**

Habituation

Response decreases with exposure to stimulus if no positive or negative result

- cat cries at night for attention
- you ignore cat, so nothing good or bad happens
- cat eventually stops crying at night

Imprinting

Attachment to another animal or object during critical period (usually shortly after birth/ hatching)

- **crane hatchlings see a person right after hatching, instead of another crane**
- **hatchlings imprint on person, following around to learn**

3.3.2 Societies

Society

Organization of individuals in population, tasks divided so group works together

Insect Societies

Bees, ants, some wasps

- only queen breeds
- workers are her daughters
- different jobs, depending on age
  - nursery
  - cleaner
  - queen care
  - guard
  - forager

Primate Societies

Built around concept of dominance

- more dominant individuals get best access to mates, resources
- individuals compete for status, often when sexual maturity reached by young
- altruistic behavior common when members related

3.4 Social Biology

Social Biology

1- Human Population Growth
2- Human Intervention in Natural World
3- Biomedical Progress

Human Population Growth

- Human Populations
- Life Span
- Growth Rate
- Demographic Transition

Human Intervention in Natural World

- Human Population Size
- Pollution
- Resource Management

Biomedical Progress

- Nutrition
- Medical Advances
- Treatments
- Other Advances

3.4.1 Human Population Growth

Human Populations

Grow by same means as other populations

births – deaths = growth

Complex, b/c we reason around resource limitations, technology, think about reproductive behavior

Life Span

Better nutrition & medicine have increased human life span

Infant mortality greatly decreased

Birth rate decreased due to contraception

Growth Rate

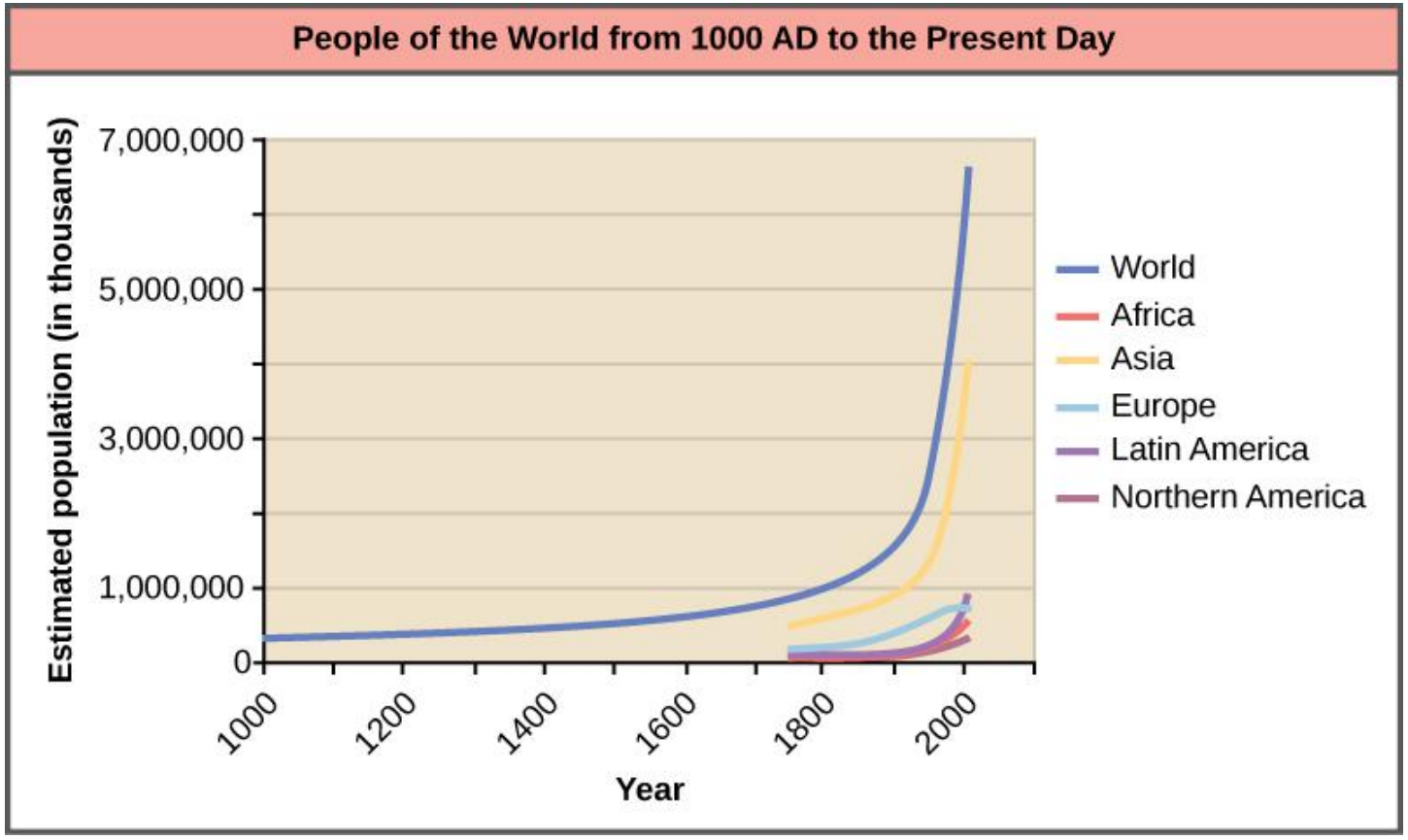
Over 7 billion people in 2016

Doubling time decreased

Technology increased food production, but starvation happens due to distribution

Demographic Transition

Theory proposes progressive demographic time periods of human population growth



Demographic Transition

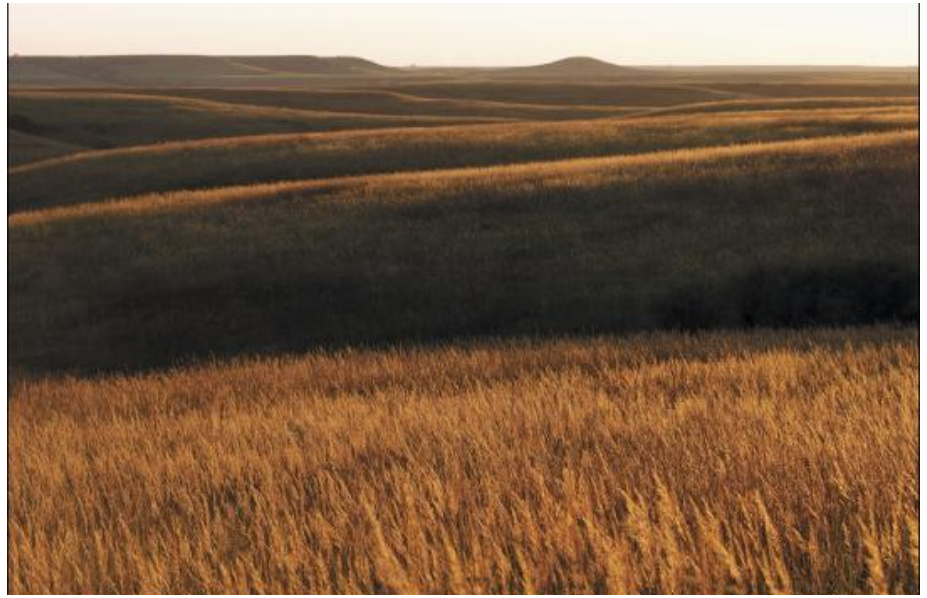
1- At first, birth & death rates equal, population in equilibrium w/ environment

2- Societal developments of medicine & food production allow birth rate to overtake death rate, population increases rapidly

Demographic Transition

3- Agrarian lifestyles (many children for labor) become less common, children liability in urban society

4- medical advancement decreases infant mortality, urban populations increase rapidly



Demographic Transition

5- Industrialized countries lower birth rate using contraceptives

6- Increasing population strains environment, resources

3.4.2 Human Intervention in Natural World

Human Population Size

Profound effects on environment

- pollution
- habitat loss
- overharvesting
- introduced species
- climate change


1938
T. J. Hileman photo
Courtesy of GNP Archives
1981
Carl Key photo
USGS
1998
D. Fagre photo
USGS
2009
Lindsey Bengtson photo
USGS

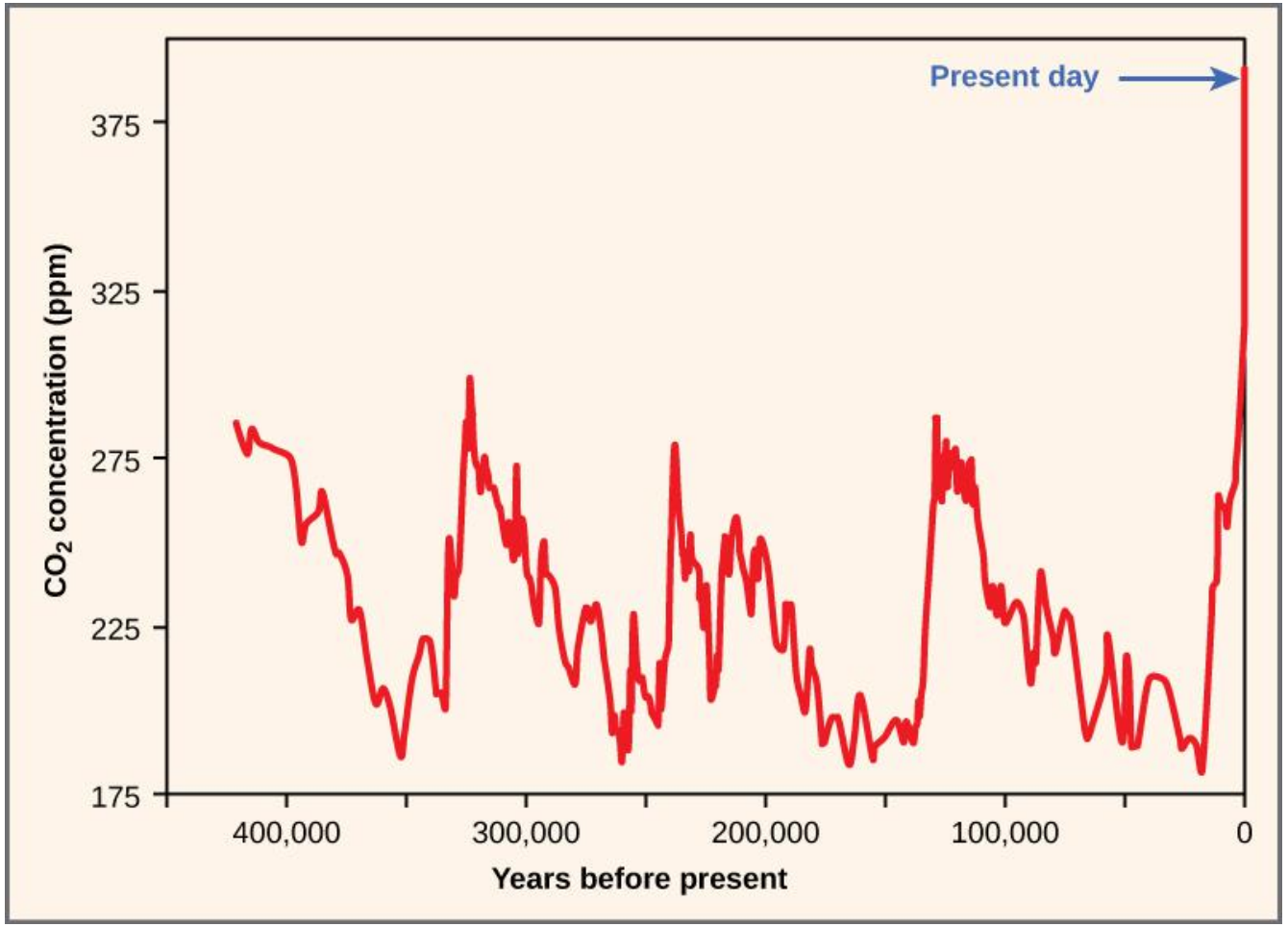
Pollution

Started as result of ignorance during Industrial Revolution

Addition of foreign substances to air, water, soil, etc.

- **fertilizers, pesticides, herbicides**
- **industrial cleaners**
- **carbon emissions**
- **trash**

Pollution


Present day
375
325
275
225
175
CO_2 concentration (ppm)
400,000
300,000
200,000
100,000
0
Years before present

Resource Management

We've had success repairing damaged ecosystems

We've learned ways to protect threatened species & ecosystems

"Reduce, reuse, recycle" works

3.4.3 Biomedical Progress

Nutrition

We've learned importance of essential nutrients, allowing healthier, longer lives

Decreases sickness due to malnutrition

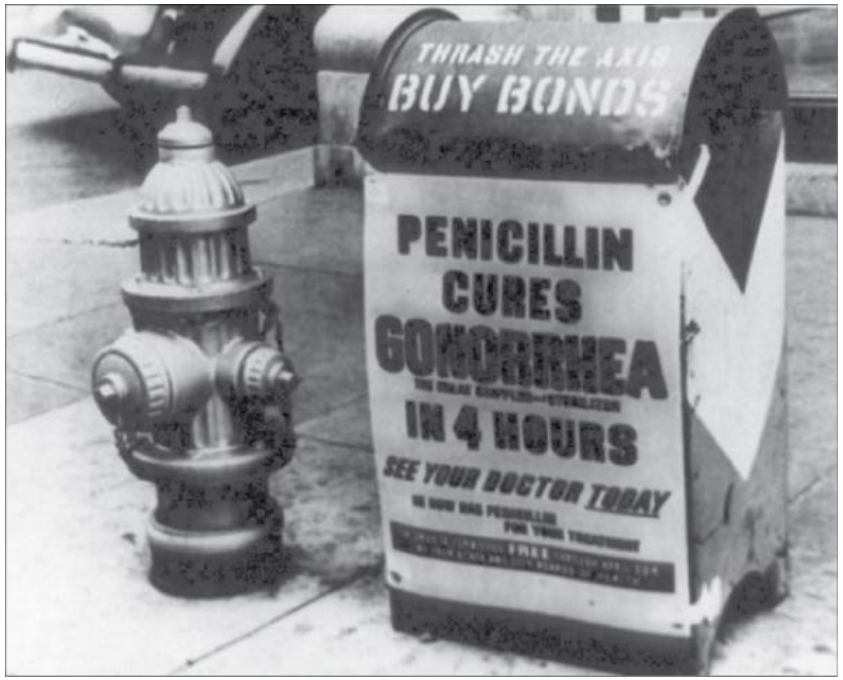
- scurvy
- goiter
- anemia

Medical Advances

Development of antibiotics in 1920s decreased deaths from infection

Vaccines protect from previously lethal diseases (flu, smallpox, rabies, etc.)

Antiviral treatments decrease sickness after viral infection (AIDS)



Treatments

Improvements in managing illness, synthesizing molecules have allowed people to live longer & more comfortably

- heart disease
- osteoporosis
- arthritis
- cancer
- diabetes

Other Advances

Genetically Modified Organisms have increased agricultural output

Use bacteria to make:

- **human insulin**
- **vaccines**
- **cancer treatments**

Investigating stem cells for organ transplantation