Evolution & Biodiversity: Origins, Niches, & Adaptation

tutorial by Paul Rich

Outline

1. Life on Earth
   prokaryotes vs. eukaryotes; six kingdoms
2. Origins of Life
   chemical evolution, early life, fossils
3. Evolution & Adaptation
   mechanism of evolution, coevolution, niches
4. Speciation, Extinction, & Biodiversity
   origin of new species, extinction as accelerated by humans, significance for biodiversity
5. Sustainability & Evolution
   How does our time frame influence our thinking?

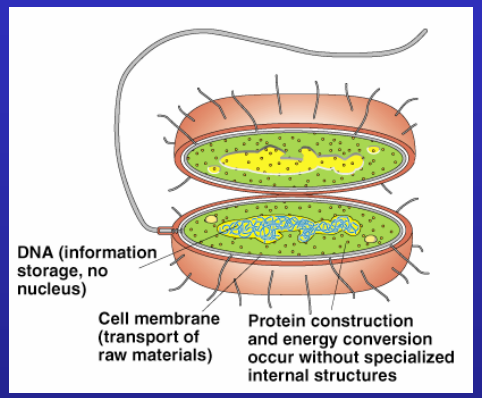
1. Life on Earth

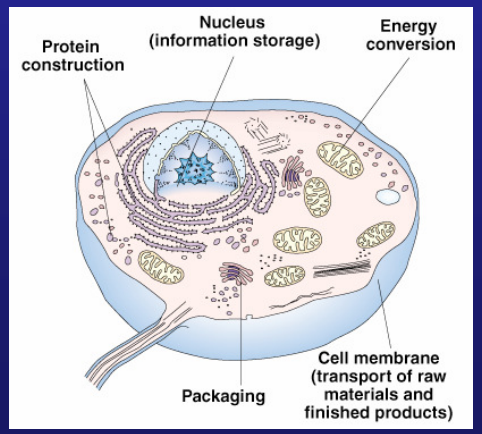
biodiversity: (=biological diversity) variety of different species, genes, or ecosystems.

types main types of life:

- **prokaryotes:** (means "before nucleus") *organisms (bacteria) whose cells do not have a distinct nucleus or other internal parts enclosed in membranes.*
- **eukaryotes:** (means "true nucleus") *organisms whose cells have a distinct nucleus and various internal parts enclosed in membranes.*

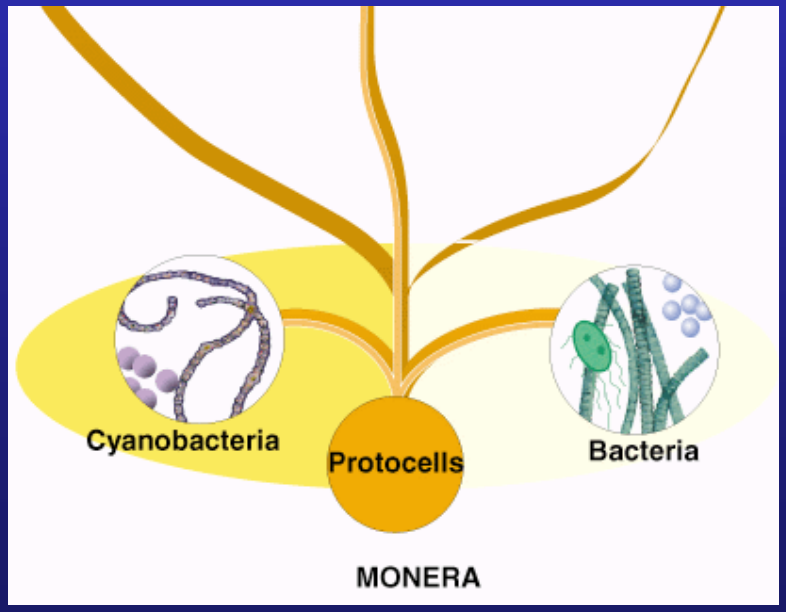
Fig. 6–2





Six Kingdoms

- **archaebacteria & eubacteria (formerly monera):** single–celled, microscopic prokaryotic organisms, in particular bacteria & cyanobacteria.
- **protista (protists):** mostly single–celled eukaryotic organisms, such as diatoms, dinoflagellates, amoebas, golden–brown & yellow–green algae, & protozoans.



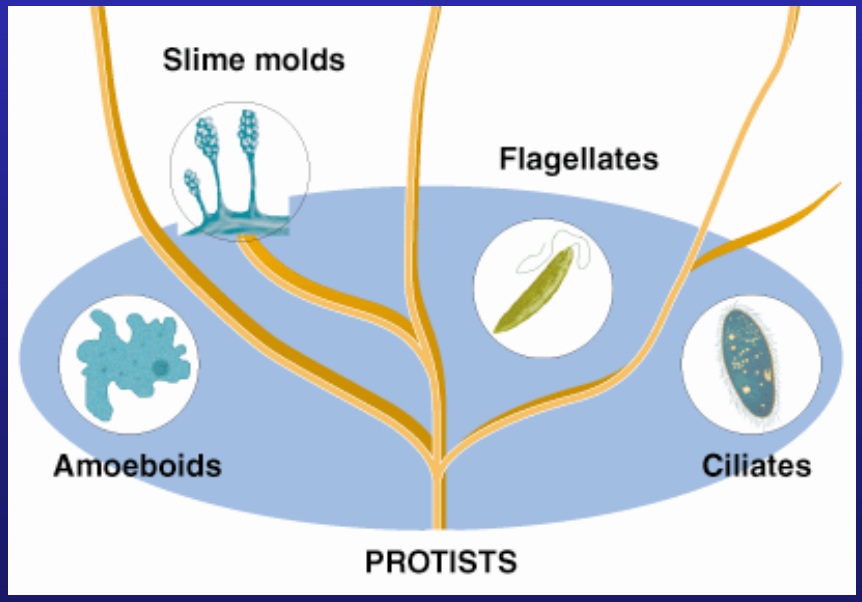
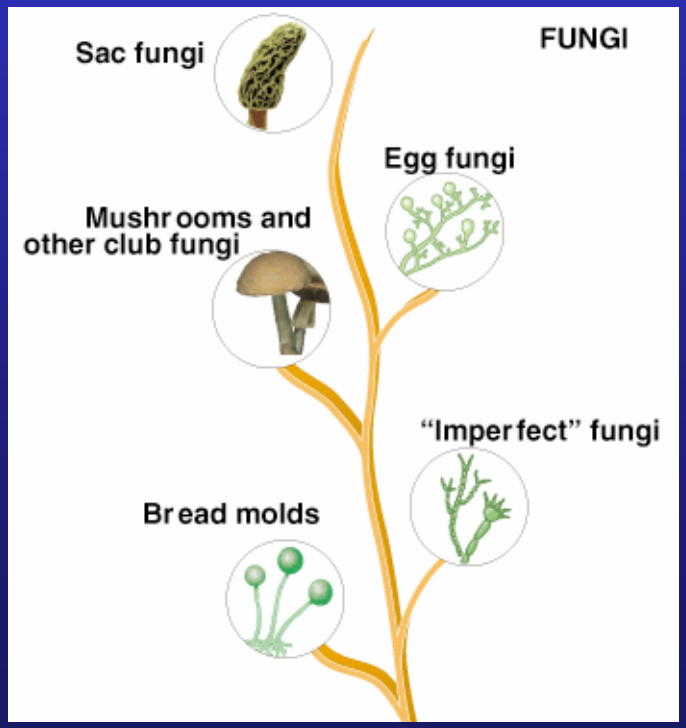


Fig. 6–3 a & b

Six Kingdoms

- **fungi:** mostly many–celled (some single–celled) eukaryotic organisms, such as mushrooms, molds, mildews, & yeasts.
- **plantae (plants):** mostly many–celled eukaryotic organisms, such as red, brown, & green algae, mosses, ferns, conifers, & flowering plants.



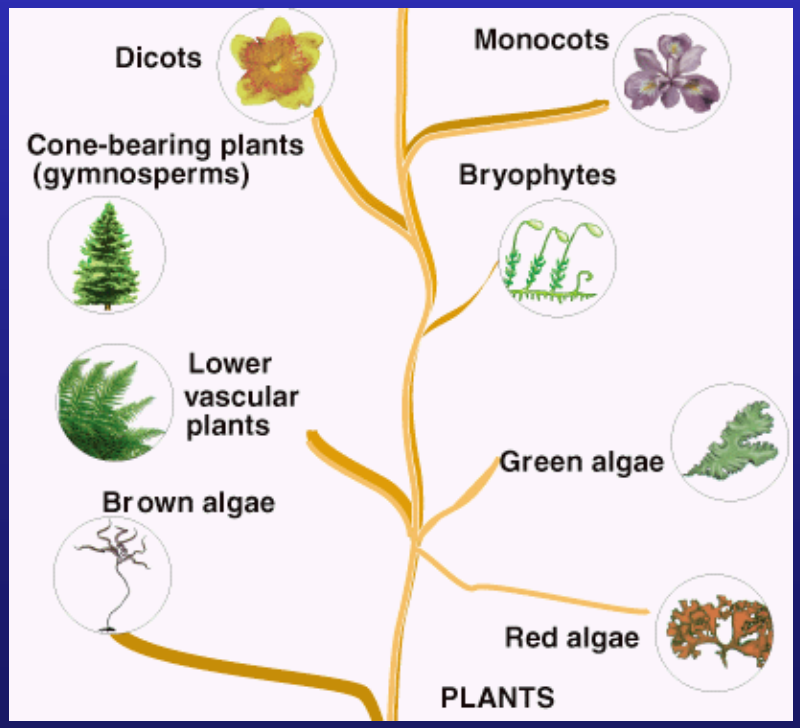


Fig. 6–3 c & d

Six Kingdoms

- **animalia (animals):** many–celled eukaryotic organisms, including **invertebrates** (e.g., sponges, jellyfish, sponges, mollusks, worms, arthropods) & **vertebrates** (e.g., fish, amphibians, reptiles, birds, & mammals).

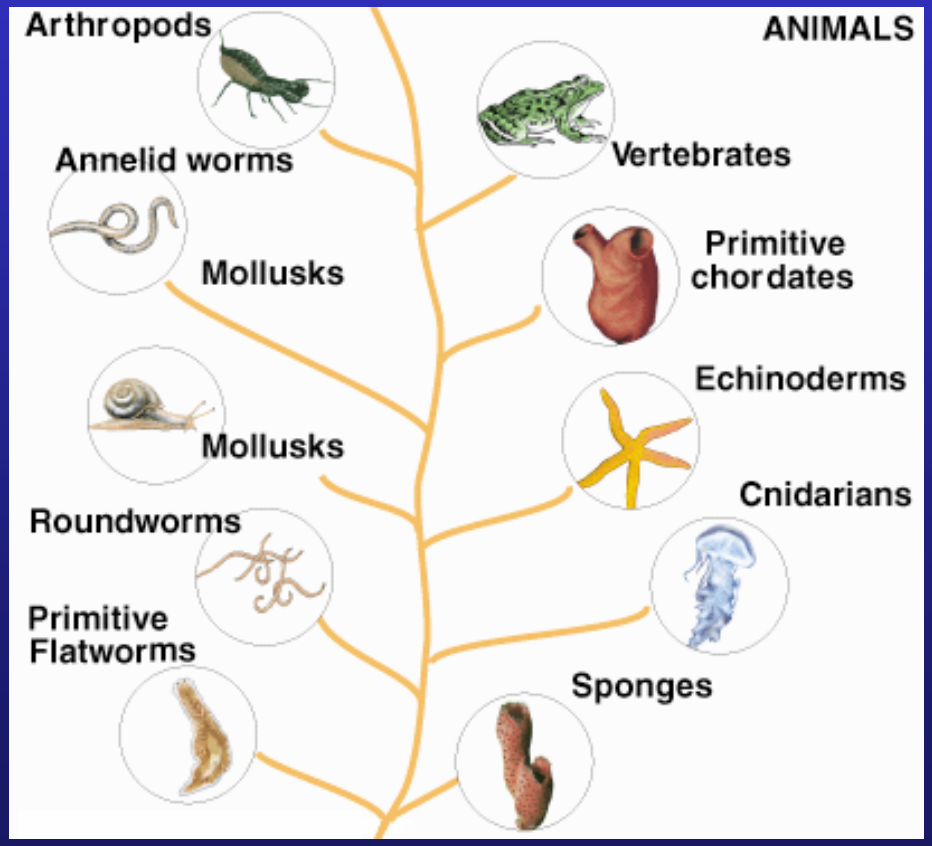


Fig. 6–3 e

What is a Species?

species: a distinct kind of organism; groups of organisms that resemble each other, &, in cases of sexually reproducing organisms, can potentially interbreed.

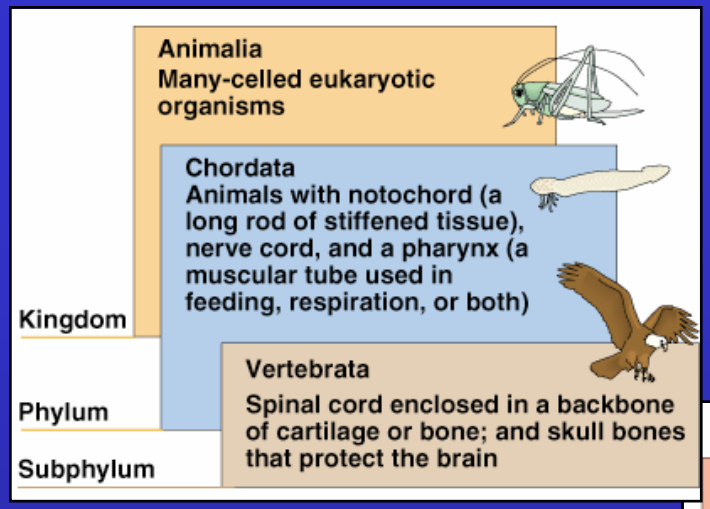
- each known species is assigned a **scientific name** (derived from Latin), consisting of two parts (genus + specific epithet), always written in italics or underlined.

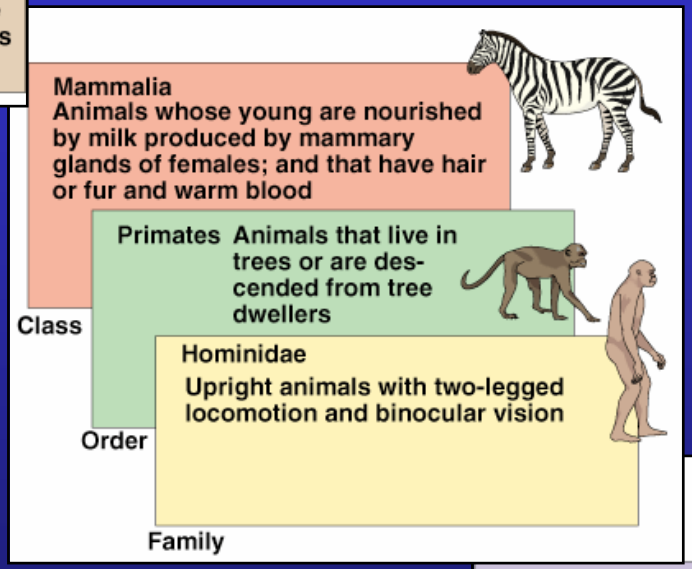
  examples: *Ursus horribilis* is the grizzly bear
  Taraxacum officinale is the dandelion

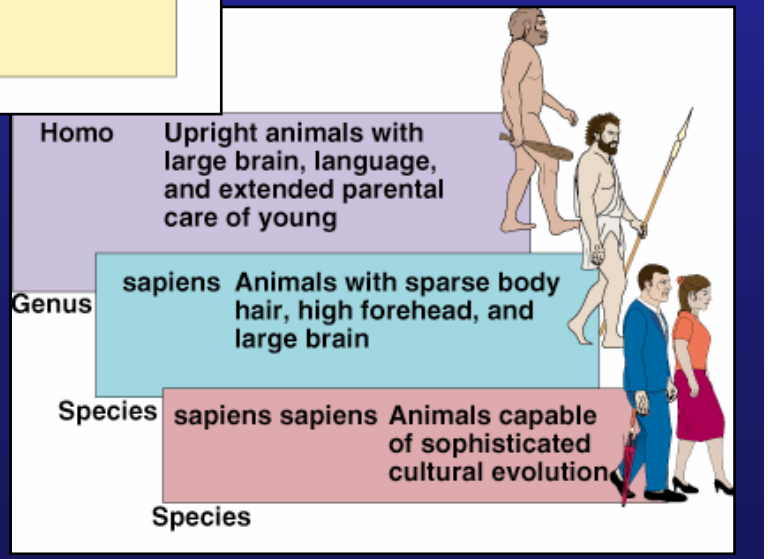
- each species is classified in a **hierarchical taxonomic classification**:

  kingdom, phylum, class, order, family, genus, species

Classification of Organisms







Example of the classification of human beings.

Fig. 6–4a~c

2. Origins of Life

Summary of the evolution of the earth & its life over the past 4.7 to 4.8 billion years.

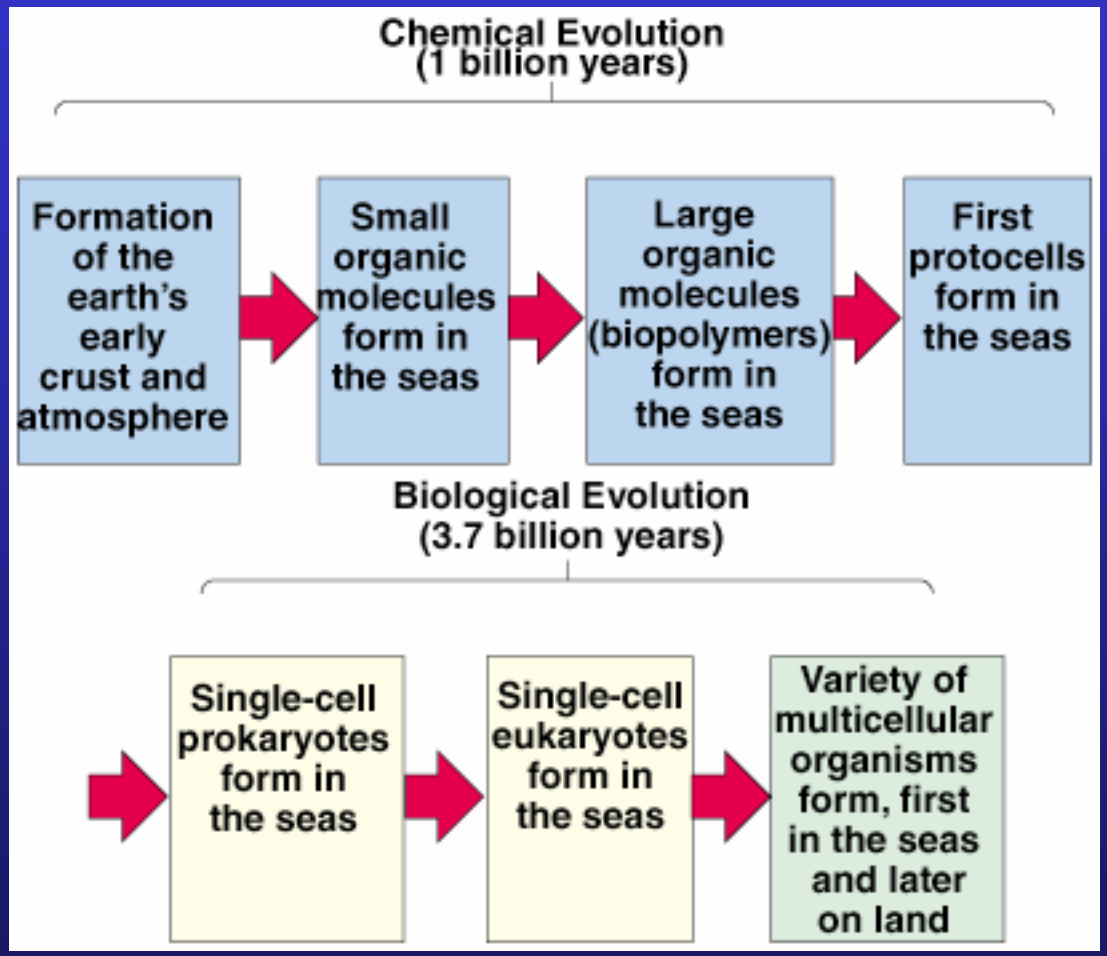


Fig. 6–5

Why is Earth "just right" for life?

- distance from sun: leads to a temperature range favorable to life (between freezing & boiling point of water); energy flow from sun sufficient to drive weather & supply energy for life;
- size: enough gravitational mass to hold its atmosphere of light molecules (N_2, O_2, CO_2, and H_2O) and to keep its core molten;
- rotation: leads to daily patterns (night & day);
- orbit around sun: leads to seasonal patterns;
- atmospheric evolution: accumulation of O_2 in lower atmosphere; formation of ozone shield to screen harmful ultraviolet (UV) radiation.

3. Evolution & Adaptation

evolution: the change in a population's genetic makeup through successive generations.

- **microevolution**: change in gene frequency within a population (short–term evolutionary changes);
- **macroevolution**: the formation of new species from ancestral species (long–term evolutionary changes).

Microevolution

four processes drive microevolution:

- **gene flow**: the movement of genes between populations;
- **genetic drift**: change in genetic composition that results by chance, especially in small populations.
- **mutation**: random changes in the structure of DNA molecules that serve as the ultimate source of genetic variation;
- **natural selection**: the process by which some individuals of a population have genetically based characteristics that cause them to survive & produce more offspring than other individuals;

Natural Selection

three conditions required for natural selection:

- **variability**: there must be natural variability for a trait within a population;
- **heritability**: the trait must be inheritable, meaning that it has a genetic basis such that it can be passed from generation to generation;
- **differential reproduction**: the trait must enable individuals with the trait to leave more offspring than other members of the population.

adaptation: a heritable trait that enables organisms to better survive & reproduce within a given set of environmental conditions.

Natural Selection

Example: peppered moth (*Biston betularia*)

- **variability**: two color forms, one dark & one light; light form originally more common because it blended in with lichens on trees & was not easily eaten by birds;
- **heritability**: color form was genetically based;
- **differential reproduction**: during the industrial revolution of the mid–1800s in England soot coated trees; dark form became more common because light individuals became easier for birds to find & dark form blended in.

Classic example of microevolution – change in gene frequency in a population.

(see Fig. 6–8)

Natural Selection

Directional selection favors individuals with traits that are at one end of a distribution (such as the peppered moth example).

"It pays to be different."

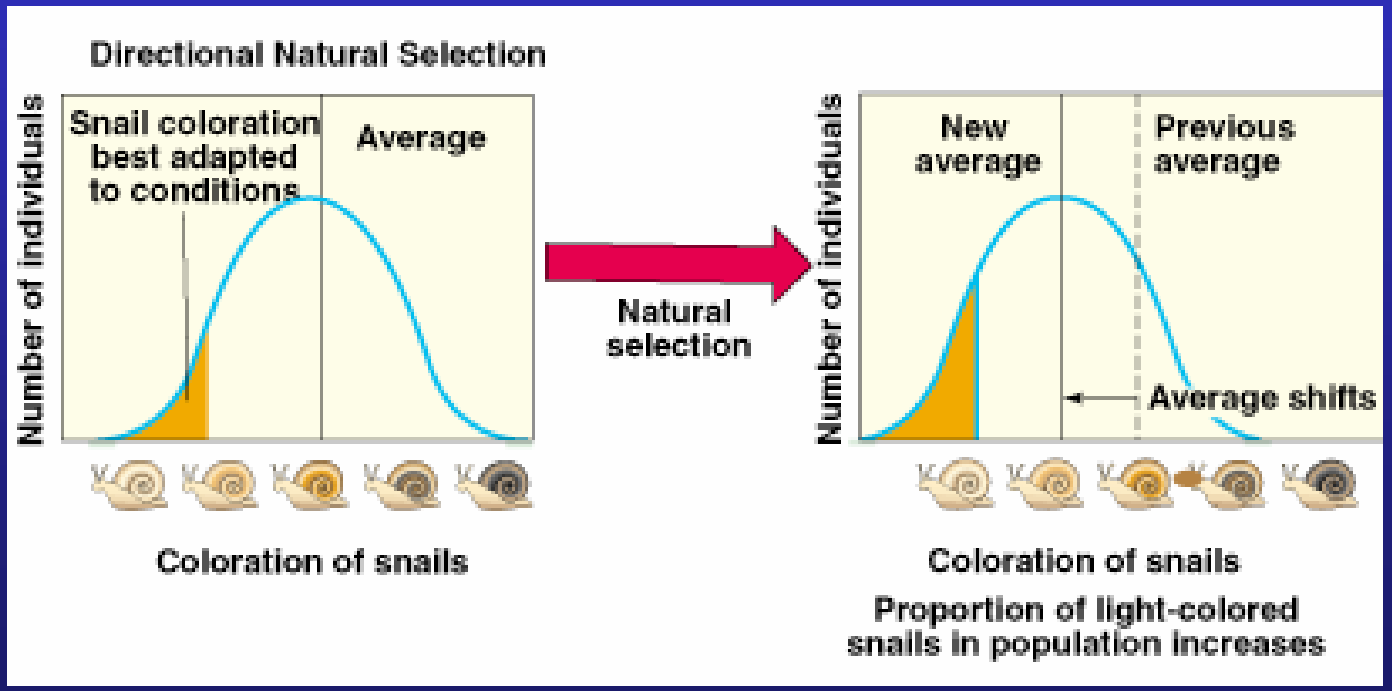


Fig. 6–9a

Natural Selection

Stabilizing selection eliminates individuals at both in of the spectrum of variation; the average remains the same.

"It pays to be average."

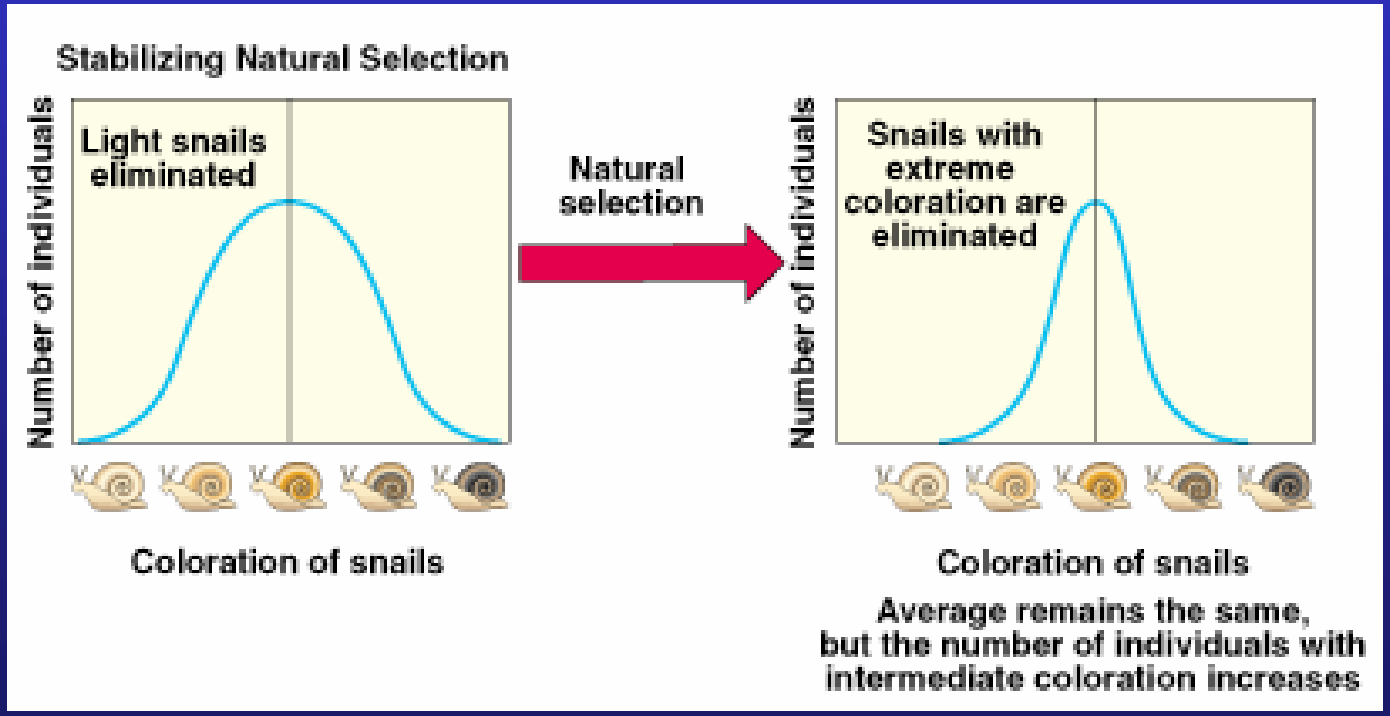


Fig. 6–9b

Natural Selection

Diversifying selection eliminates average individuals, but favors individuals at either extreme of the spectrum of variation.

"It doesn't pay to be normal."

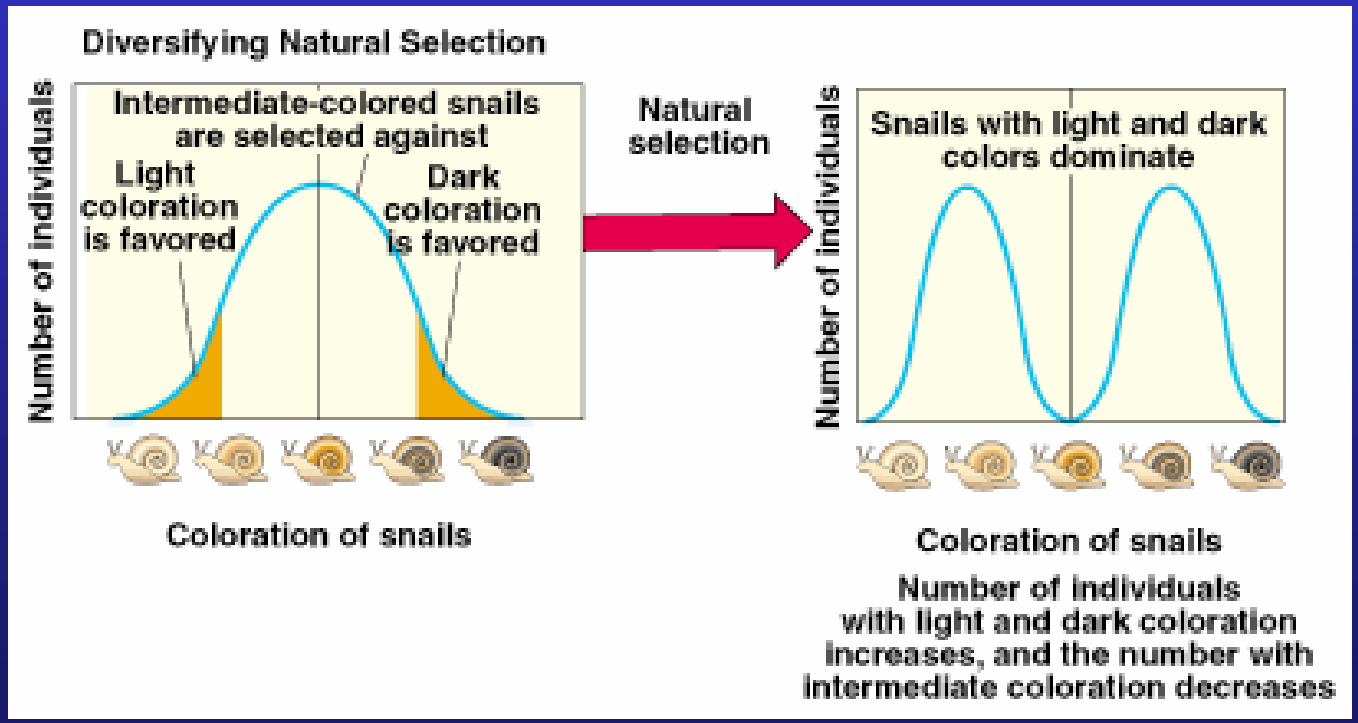


Fig. 6–9c

Coevolution

coevolution involves interactions between two species that result in ongoing evolutionary changes in each of the species.

examples:

- flowering plants & their pollinators; flowers attract pollinators & provide "reward" for food in the form of nectar or pollen; pollinators perform "service" of moving pollen between flowers;
- plants with defenses against herbivores (thorns, camouflage, toxins) & the herbivores' ability to deal with plants' defenses.

Ecological Niche vs. Habitat

niche: the functional role of a species in an ecosystem.

includes:

- conditions (physical & chemical);
- resources (such as nutrients or food);
- interactions with living (biotic) & nonliving (abiotic) components of ecosystem;
- role in flow of energy cycling of matter.
- *niche* is different than *habitat*;

habitat: the actual location where an organism lives.

- habitat is like "address" of an organism;
- Niche is like "occupation of an organism.

Adaptation & Ecological Niche

adaptation: any genetically controlled trait that helps an organism survive & reproduce in a given set of environmental conditions.

relationship between ecological niche & adaptation:

- species with similar niches tend to evolve similar sets of traits;
- the resemblance of different species with similar niches is called **convergence**;
- examples of convergence:
  - desert shrubs of different parts of world have deep roots, small leaves, & high tolerance to hot, dry conditions.
  - herbivores of different parts of world have traits to forage & digest plant material, escape predators, & migrate or become dormant when food is scarce.

4. Speciation, Extinction, & Biodiversity

Macroevolution involves changes in an evolutionary lineage over much longer periods than *microevolution*.

involves three processes:

- evolutionary change of lineage through time**;**
- **speciation**: formation of new species;
- **extinction**: loss of species:

new species typically evolve by two steps:

- **geographic isolation** – separation into distinct populations with different evolutionary pressures;
- **reproductive isolation** – evolutionary changes in each population that prevent interbreeding when populations come into contact.

Speciation

Geographic isolation can lead to reproductive isolation, divergence, and speciation.

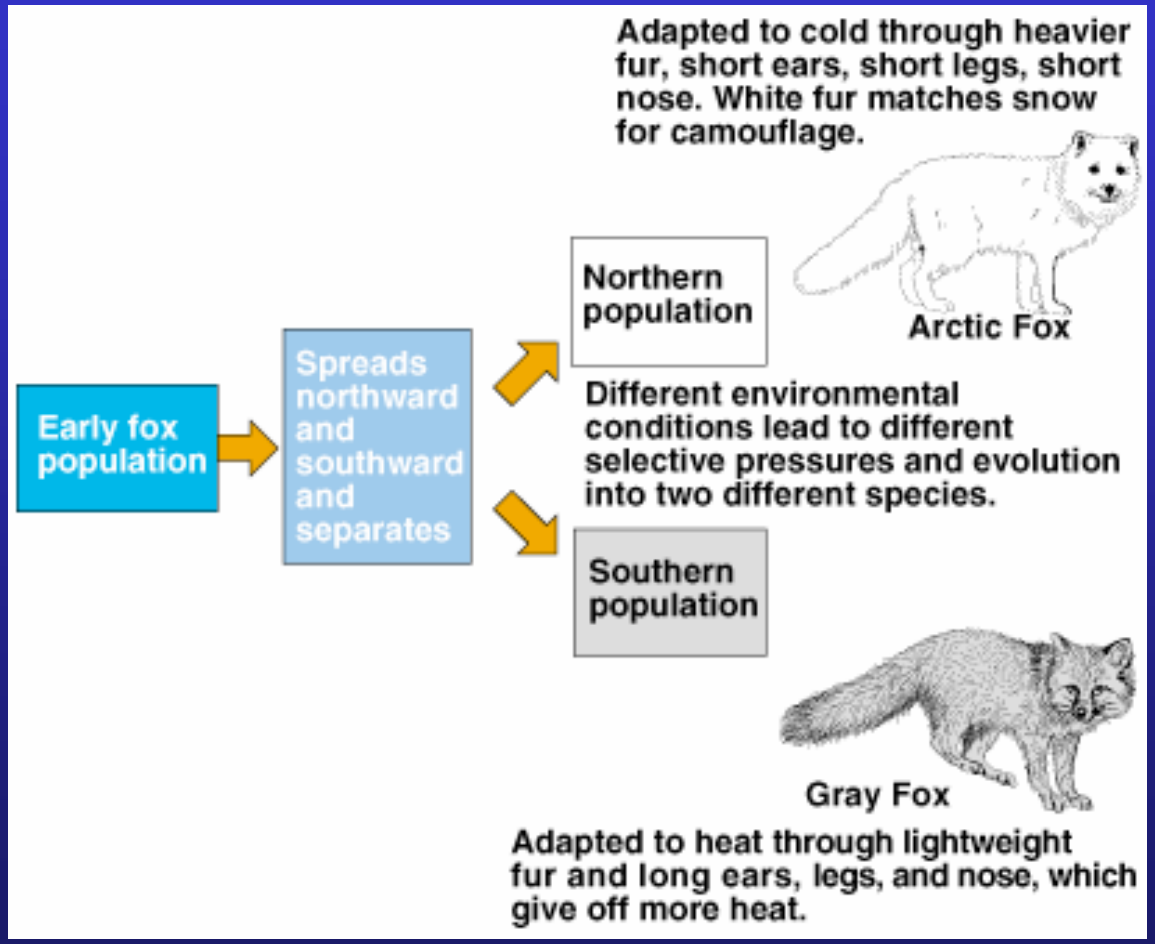


Fig. 6–11

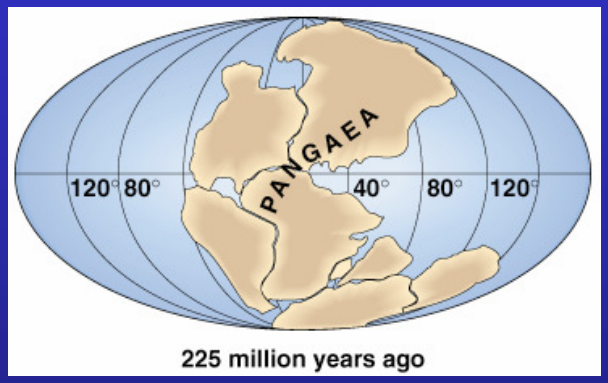
Extinction

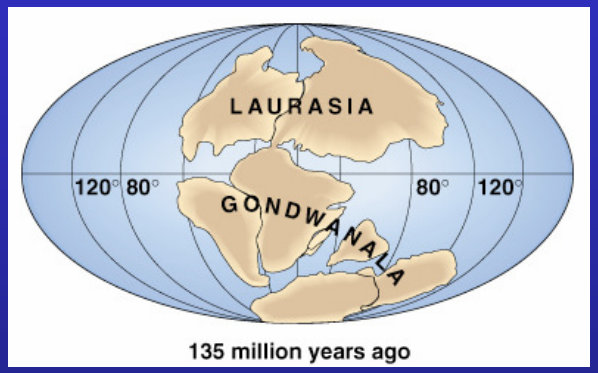
Fossil record shows evidence of extinction as a natural process:

- **background extinction**: loss of species at a relatively low rate, often due to changes in local conditions;
- **mass extinction**: abrupt increases in extinction rates above the background level.
- mass extinctions believed to result from global climate changes;
- five great mass extinction during past 500 million years;
- recent extinctions caused by humans at exceptionally high rates.

Continental Drift

Continental drift, slow movement of continents, has played a major role in both speciation and extinction.





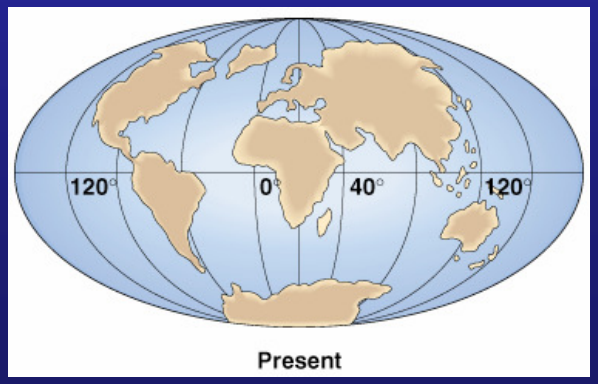


Fig. 6–12

Adaptive Radiation

Adaptive radiation *involves splitting of a lineage to form many species with different ecological niches. The adaptive radiation of mammals began about 65 million years ago.*

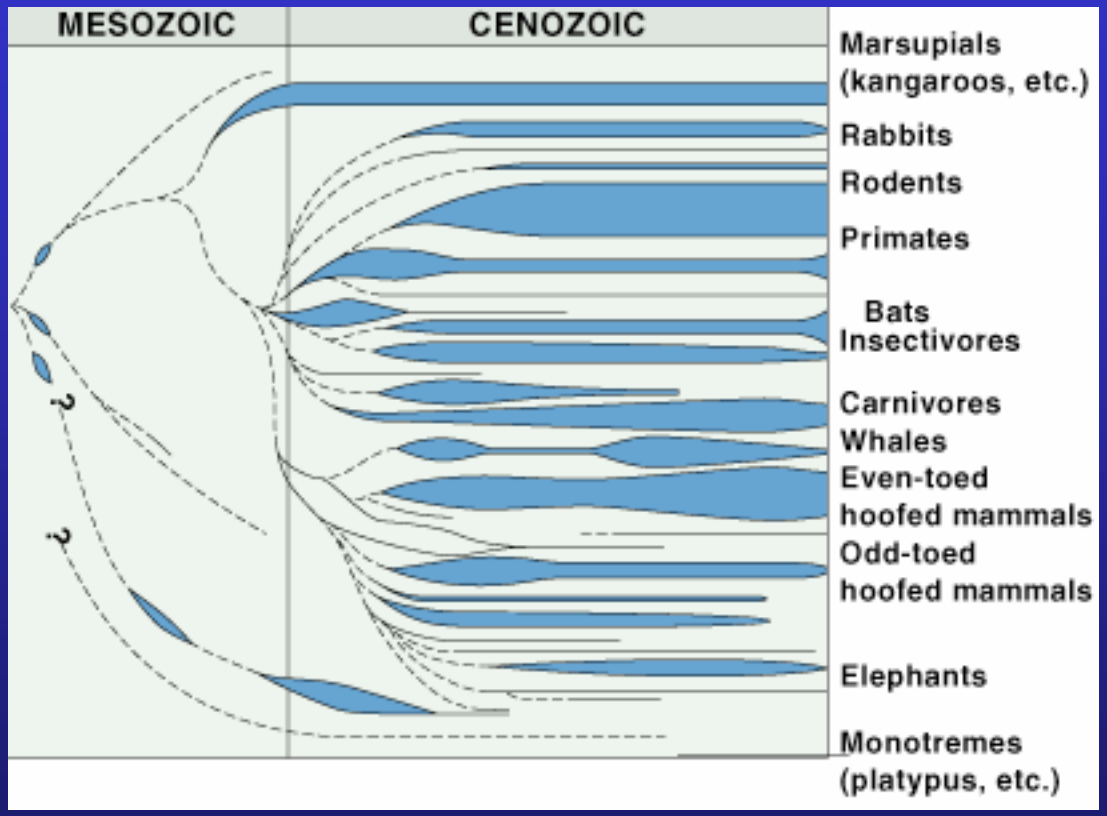


Fig. 6–14

5. Sustainability & Evolution

What is the appropriate time frame for thinking about environmental problems?

- humans have existed on a tiny fraction of geological or evolutionary time scales;
- earth's biodiversity has taken millions of years to evolve & is not replaceable in human time scale;
- extinction is natural process, but human–induced extinction is occurring at unprecedented rates.

Can we heal the earth?

- requires lots of time & money;
- better to prevent environmental degradation & loss of biodiversity.