

Phylogeny

(CH. 25)

Summary

- Paleontology
(study of fossils)
 - Sedimentary rocks
 - Dating fossils
 - Rare events
 - Continental drift
 - Mass extinctions → Adaptive radiation
- Phylogeny
 - Taxonomy
 - DNA sequence homologies
- Systematics
 - Phenetics
 - Cladistics

History of Life

- Origin of novel designs (wings)
- Evolutionary trends (↑ brain size)
- Explosive diversification (flowering plants)
- Mass extinctions (dinosaurs)
- Adaptive radiation (mammals)
- Phylogeny: evolutionary history of a species
- Systematics: study of biological diversity in an evolutionary context

Sedimentary Rock

Sedimentary Rock

- Formation
 - Sand and silt erode from land
 - Particles are carried to seas and settle to bottom
 - Deposits pile up and compress layers underneath
 - Sand → sandstone
 - Mud → shale
 - Few of dead animals that settle to bottom are preserved
 - Different periods (wet/dry) of sedimentation form strata
- Fossil: preserved remnants or impression of an organism
- Fossil record: ordered array of fossils in strata of sedimentary rock that marks passing of time

Types of Fossils

- mold fossils
 - fossilized impression
- cast fossils
 - formed when a mold is filled in
- bone fossils
 - fossils of the actual animal bones, shells (may be mineralized turning animal to stone)
- trace fossils = ichnofossils
 - fossilized nests, burrows, footprints
- preserved organisms
 - entire body in ice, amber, or acid bog
 - thin films of organic material (leaves)

Fossil Formation

Fossil Dating

(relative)

- Younger sediments are superimposed on older (indicate order)
- Index fossils: identify specific strata around the world
- Geological time scale: distinct ages in world history marked by boundaries of explosive radiations or mass extinctions
 - Eras: precambrian, paleozoic, mesozoic, cenozoic (vary in length)
 - Eras → periods → epochs

Example of

Geological Time Scale

Fossil Dating

(absolute)

- Age of fossils in years
- Radiometric dating: amount of left-over isotope
 - Half-life: fixed years when half of isotope to decays
 - Carbon-14 (5600 years): dating of specimen <50,000yrs
 - Uranium-238 (4.5 billion years): dating of cambrian era
- Racemization of amino acid isomers
 - Organisms synthesize only L-amino acids (aa)
 - L-aa are converted to D-aa at predictable rates

Fossil formation is rare

- Improbable coincidences
 - Animal dies at the right place and time
 - Sedimentary rock escapes geological processes (erosion, pressure, melting)
 - River carving a canyon exposes strata
 - Someone must find the site
- Fossil record is incomplete
 - Few organisms left fossils
 - Existed long time, were most abundant, had shells/skeletons
 - Those that did were destroyed
 - Only fraction of existing fossils have been discovered

Biogeographical history

(Tectonic plates)

Sections of crust (continents) float on hot, liquid mantle

Biogeographical history

(continental drift)

Plates collide or separate forming mountains or trenches

Pangea (all land)

→ Laurasia (north) + Gondwana (south)

→ Current continents

Biogeographical history

(Drastic Events)

- Formation of Pangea (250 million yrs ago)
 - Paleozoic era (end)
 - Extinctions
 - Collision reduced coastal areas
 - More competition among previously separated species
 - New opportunities
 - Larger expanses of land
- Continental separation (180 million yrs ago)
 - Mesozoic era
 - Isolation lead to divergent evolution

- Australia: pouched mammals (marsupials)
- Other continents: placental mammals

Extinction vs. Speciation

History of Life

(adaptive radiations)

- Adaptive zone: set of new living conditions and resources presents new opportunities (wings)
- Cambrian explosion
(between Precambrian and Paleozoic eras)
 - ↑ diversity of sea animals
 - Origin of hard body parts (shells, skeletons, claws)
- Mammalian diversification (Cenezoic era)
 - Opening of adaptive zones
 - Changes in environment cause extinctions and allow those species that are adapted to new conditions to survive

History of Life

(mass extinctions)

- Destroyed habitats and changes in environment (organisms)
- Permian extinctions (250 million yrs ago)
 - Boundary between Paleozoic and Mesozoic eras
 - 90% of marine species
 - Continents merged to form Pangea
(↑ volcanoes → CO₂ → global warming → ↓ Temperature differences between equator and poles → ↓ Ocean water mixing → ↓ O₂)
- Cretaceous extinctions (65 million yrs ago)
 - Boundary between Mesozoic and Cenozoic eras
 - 50% of marine species
 - Potentially due to a comet or asteroid colliding with Earth
(Chicxulub crater: 180 km diameter)
 - Impact was at low angle → white-hot debris sent over North America
 - Cloud cover, blocked sunlight, ↓ temperatures, ↓ photosynthesis, acid precipitation
 - Possibly caused by changes in Earth's climate and volcanic activity
 - Most likely both happened

Phylogenetic Trees

(genealogy of organisms)

Taxonomy

(identification and classification of species)

- Linnaeus (18th century)
 - Binomial: *Genus species* (specific epithet)
 - Filing system: progressively broader categories
 - Taxon: named taxonomic unit at any of following levels
Species, Genus, Family, Order, Class, Phylum, Kingdom, Domain

Systematics

(main goal)

- Create a classification that reflects evolutionary history of organisms and their relatedness
- Ancestors in phylogenetic trees are also first members of specific taxa
 - Kingdom Plantae arose 450 million yrs ago
(with one ancestor)
 - Division Anthophyta arose 100 million yrs ago
(with first ancestral member)
 - Species is the most specific and youngest taxa

Phylogeny of Drosophila

Types of Taxa

- Monophyletic:

- includes all descendants of a single ancestor
- Polyphyletic: includes descendants of multiple ancestors
- Paraphyletic: includes some descendants of a single ancestor

Homology vs. Analogy

- Similarity due to common ancestry: Homology
- Similarity due to convergent evolution: Analogy
- Recognizing homology:
 - Greater number of homologous parts between species the more closely they are related
 - The more complex two similar structures are, the less likely they evolved independently (skulls)

Molecular Biology

- ↑ similar species = ↑ similar DNA and amino acid sequences
- Molecular tools are objective and quantitative
- Compare very similar and very diverse species (hard to classify otherwise)
- Internet databases and software (BLAST)

Molecular Biology

(tool of systematics)

- Protein comparisons
 - Identical regions
 - Similar regions
 - Example
 - hemoglobin
 - Drawback
 - Uses only small part of genome (2%)

- Myosin

Molecular Biology

(tool of systematics)

- DNA-DNA hybridization

(overall similarity, not specific)
- Restriction maps

(digestion and electrophoresis, only small fragments can be compared)
- DNA sequence analysis

(mt: quickly changing; and nuclear: more data)

 - Automation (capillary system; pyro-sequencing)
 - Bioinformatics (databases)
 - Analysis of homology (BLAST software; pg. 480)
 - Fossils
- rRNA
 - Very slowly changing
 - Compare organisms that diverged a long time ago

Phylogenetic Systematics

- Phenetics
- Cladistic analysis: developed to objectively compare phenotypic characteristics and molecules (DNA, RNA, protein sequences)
 - Clade: an evolutionary branch
 - Outgroup comparison
 - Synapomorphies: shared derived characteristics
 - Parsimony: simplest explanation is probably right
 - Monophyletic taxa only (Pg. 483)