

## I. THE "TREE OF LIFE"

### • The unity and diversity of life

evolution: unity and diversity are the dual faces of life on earth: unitary origin of life: evolutionary trees (fossil, anatomical, developmental, and molecular data): niche: species: adaptation: coevolution: prokaryote: eukaryote: brief overview of history of life on earth (earth forms, first prokaryotes, first eukaryotes, first animals, Paleozoic era, Mesozoic era, Cenozoic era)

- Describe how evolution explains the dual faces of life on earth—unity and diversity, and how the unitary origin of life allows us to draw a "tree of life".
- Give examples of evidence of the unitary origin of life, e.g., universal use of DNA as the genetic material, common molecular features of all life forms, the fossil record, molecular trees.
- Describe the concepts of niche, adaptation, and coevolution, and how these lead to diversity of life.
- Give examples of coevolution and how these illustrate selective pressures.
- Describe the broad features of the history of life on earth.

### • Systematics

Linnaean classification: taxonomy: taxon (taxa): systematics: phylogeny: anagenesis: cladogenesis: The 5 Kingdom system—Monera (prokaryotes): Protists: Plants (non vascular plants, vascular plants (seedless, seed plants—gymnosperms, angiosperms): Fungi: Animals (invertebrates, chordates, vertebrates, tetrapods, amniotes -jawless fish, cartilaginous fish, bony fish, Class Amphibia, Class Reptilia, Class Aves, Class Mammalia—monotremes, marsupials, placentals): The 3 Domain system—bacteria, archae, eukaryotes: The 8 Kingdom system: endosymbiotic theory: homologous: analogous

- Contrast the common and distinguishing features of life on earth and understand classification schemes based on 5 Kingdoms, 3 Domains, and 8 Kingdoms.
- Describe the broad features of the branching relationships of life on earth.
- Describe how the processes of anagenesis and cladogenesis, combined with extinctions, have produced the diversity of organisms living today, and how this can all be traced back to a most recent common ancestor
- Contrast homologous and analogous traits and their role in drawing evolutionary relationships.

### • Tempo and mode of evolution

Eras: Periods: Epochs: adaptive radiation: exaptation: convergent evolution (convergence): reversion (reversal): homoplasy: George Gaylord Simpson: living fossils: Eldredge and Gould: punctuated equilibria: gradualism: macroevolution: microevolution

- Give examples of how convergent evolution shows the action of selection on organisms that are not closely related but have a shared way of life.
- Give examples of how adaptive radiations lead to diversity within an evolutionary lineage.
- Contrast punctuated equilibria and gradualism.
- Describe broad patterns in the fossil record.

- **Cladistics**

clade: common ancestor: node: cladogram: sister groups (or taxa): plesiomorphic: symplesiomorphic: apomorphic: synapomorphies: autapomorphy: monophyletic group: paraphyletic group: polyphyletic group: outgroup: stem group: crown group

- Contrast ancestral and derived traits.
- Explain the weaknesses of the hierarchical Linnaean classification system (Kingdom, phylum or division, class, order, family, genus, species).
- Describe and apply the basic methodology of cladistics.

## II. MICROEVOLUTION

- **Overview of Mendelian genetics**

Gregor Mendel, 1865: gene: allele: genotype: phenotype: homozygote: heterozygote: dominant: recessive: Mendel's law of segregation (first law): test cross: incomplete dominance: codominance: multiple alleles: polymorphic: autosomes: sex-linked inheritance: Mendel's law of independent assortment (second law): sexual vs. asexual reproduction: gene (allele) counting with incomplete dominance or codominance

- Describe the experiments of Mendel and use Mendel's principles to solve novel problems, e.g., predict genotypes and phenotypes resulting from a given cross.
- Apply Mendel's principles to examples with incomplete dominance and codominance relationships of alleles, multiple alleles, and sex-linked cases.
- Describe gene linkage and crossing over, and their relationship to Mendel's law of independent assortment.
- Contrast sexual and asexual reproduction in terms of the generation of genetic variability.
- Use the method of gene (allele) counting to determine allele frequencies when heterozygotes can be distinguished from the homozygote state.

- **Hardy Weinberg (HW)**

HW assumptions: HW equilibrium (2 alleles): HW equilibrium for multiple alleles and for an X linked trait: estimation of allele frequency for recessive trait (the square-root formula): deviations from HW assumptions—non-random mating: inbreeding: mutation: migration (and see below)

- Describe the HW law, explain the conditions that must be met for it to hold true, and determine if a population is in HW proportions (including multiple alleles and sex-linked cases).
- Use the HW expectations to calculate allele frequencies for recessive/dominant cases, estimate the frequency of heterozygous carriers for a recessive trait, and explain why the majority of mutant alleles are carried in heterozygous individuals for rare recessive traits.
- Explain the consequences of violating each of the assumptions of the HW law.

- **Genetic drift**

genetic drift: short term genetic drift effects: long term genetic drift effects: common ancestor: founder effect: bottleneck

- Distinguish between the short term and long term effects of genetic drift on the genetic structure of populations and the relationship to population size.
- Explain the long term consequences of genetic drift on populations and how this applies to drawing molecular phylogenies (see below).

**All Biology texts teach that genetic drift is only important in small populations, this is incorrect - the short term consequences of genetic drift are more dramatic in small populations, but the long term effects are important in all populations- leading to molecular evolution even in the absence of selection.**

### • Selection

relative fitness: natural selection: balancing selection (heterozygote advantage, frequency dependent selection): sickle cell anemia: directional selection: Industrial melanism: lead tolerance: quantitative traits (stabilizing selection, directional selection, disruptive selection): artificial selection: sexual selection: Batesian and Mullerian mimicry: sociobiology: kin selection: inclusive fitness: altruism: group selection: the genetics of behavior

- Distinguish between single gene traits and quantitative traits.
- Contrast the short and long term effects of balancing versus directional selection on the genetic structure of a population for Mendelian and quantitative traits.
- Describe examples of heterozygote advantage, disruptive selection, etc.
- Contrast Mullerian and Batesian mimicry.
- Relate observations on artificial selection to natural selection.
- Describe the concept of inclusive fitness and how it relates to Darwinian selection.
- Relate evolution and ecology via the evolution of e.g., life history strategies, behavior, etc.

### • Molecular evolution and Molecular genetic variation

overview of molecular genetics: construction of evolutionary trees from nucleotide or amino acid data: substitution times: molecular clock: overview of different types of genetic variation: ancient DNA: neutral school: balance school: evolutionary lag school

- Describe why phylogenetic trees drawn from molecular data should show the same broad patterns as those drawn from fossil data.
- Use the molecular clock principle to draw phylogenetic trees and estimate divergence times between groups.
- Be aware of the extent of genetic variation in populations and that there are different types of genetic variation.
- Contrast the three schools of thought (neutral, balance, and evolutionary lag) to explain the observed levels of variation in populations.

### • Speciation

species: intergrade: reproductive isolating mechanisms: allopatric speciation: sympatric speciation: ring species: polyploid: species clusters

- Describe the biological species concept and be aware of other species concepts.
- Contrast allopatric and sympatric speciation.
- Describe examples of species clusters, and relate to concepts of niche, adaptive radiation, convergent evolution.

### III. MACROEVOLUTION

#### • Fossils, Continental drift, and Early life on earth

fossil: Principle of Superposition, Steno's Law: index fossils: radioactive dating: continental drift: Gondwanaland: Pangaea: Wegener: plate tectonics: geological consequences of plate tectonics: major features of continental drift over time: Paleontological evidence of continental drift: endemic: vicariance : Stanley Miller: early atmosphere of earth: Miller's experimental results

- Give examples of fossils.
- Describe the Law of Superposition.
- Relate broad patterns in the fossil record to major geological events and plate tectonic movement.
- Give examples of vicariance.
- Explain how life may have originated on this planet.

#### • Major features of the fossil record

cyanobacteria: stromatolites: mass extinctions: PRECAMBRIAN—4.5 billion to 544 Myr ago (first prokaryotes, first eukaryotes, marine invertebrates): PALEOZOIC—544 to 245 Myr ago (all major phyla appear, colonization of land, gymnosperms, anapsid, euryapsid, diapsid, synapsid): MESOZOIC—245 to 65 Myr ago (ichthyosaurs, plesiosaurs, pterosaurs, dinosaurs, archaeopteryx, mammals, flowering plants): Luis Alvarez: CENOZOIC—65 Myr to present (Tertiary, Quaternary) (major radiation of mammals, birds, pollinating insects, angiosperms): anthropoid primates: hominoids: hominids: hominid genera

- Describe the major patterns in the fossil record.
- Describe the relationship of the overall features of the fossil record to phylogenetic trees and cladistics.
- Give examples of transitional and intermediate fossils.
- Describe possible causes of mass extinctions and their major features.
- Give examples of major features in hominid evolution.

#### • Darwin and Evidence for evolution

Pre-Darwinian views on evolution: Lamarck: inheritance of acquired characteristics: observations on the voyage of the HMS Beagle that influenced Darwin's views: Lyell—'Principles of Geology': Malthus—'Essay on the Principles of Populations': natural selection (survival of the fittest): Wallace: 1859: Darwin's main points: vestigial: ontogeny recapitulates phylogeny: allometric growth: paedomorphosis: heterochrony: Hox genes

- Describe the views on evolution pre-Darwin/Wallace.
- Describe the principle of natural selection and how this can lead to speciation.
- Explain how vestigial structures, the imperfection of adaptations, the patterns of distribution of animals etc. are all compatible with Darwin's theory.
- Describe how Lyell and Malthus influenced Darwin.
- Describe the features of developmental changes which can lead to evolution.

