EVOLUTION OF LIFE

INTRODUCTION: KEY CONCEPTS OF EVOLUTIONARY BIOLOGY

PART 1. FACTS ABOUT PAST EVOLUTION (100 Subsections)

Chapter 1.1. Evolutionary Inferences from Modern Life

Section 1.1.3. Reconstructing the course of past evolution

1. Phylogenetic trees
2. Reconstructing exclusively-divergent evolution
3. Reconstructing constant-rate evolution
4. Dealing with real-life problems
5. Phylogenies that are not trees
6. Importance of phylogenetic reconstructions

History and perspectives

Chapter 1.2. Past Environments and Direct Data on Past Evolution

Section 1.2.1. Key properties of the Earth

1. The Earth's orbit
2. Structure of the Earth
3. Plate tectonics
4. Types of rocks and the rock cycle

Section 1.2.2. Studying history of the Earth

1. Geochronology
2. Stratigraphy
3. Continental drift
4. Paleoenvironments
5. Drastic events

Section 1.2.3. Direct evidence of past life and its evolution

1. Fossilization
2. Fossils
3. Fossil record
4. Evolutionary inferences from fossils

Section 1.2.4. History of abiotic conditions on Earth

1. Climate
2. Geography
3. Oceans
4. Atmosphere
5. Geological time scale

History and perspectives

Chapter 1.3. Long History of Life on Earth

Section 1.3.1. The first 3 billion years of life

1. Origin of habitable Earth and of life

2. Prokaryotes
3. Eukaryotes
4. Animals

Section 1.3.2. Phanerozoic eon

1. Cambrian biota
2. Vertebrates
3. Land plants
4. Insects
5. Tetrapods
6. Mammals
7. Birds
8. Mass extinctions

Section 1.3.3. Contemporary life

1. Biodiversity
2. Biogeography
3. Environments and ecosystems
4. Ongoing mass extinction

History and perspectives

Chapter 1.4. Origin of *Homo sapiens*

Section 1.4.1. Primates

1. Phylogeny and diversity of primates
2. Modern hominids
3. The human-chimpanzee clade

Section 1.4.2. The last 7 Ma of the human lineage

1. *Ardipithecus*
2. *Australopithecus*
3. *Homo*
4. Origin of modern human diversity
5. Factors of human evolution

Section 1.4.3. Our extinct close relatives

1. *Paranthropus*
2. Non-African *Homo erectus*
3. *Homo neanderthalensis*

History and perspectives

Chapter 1.5. Generalizations Emerging from Past Evolution

Section 1.5.1. Level-specific generalizations

1. Sequences
2. Molecules
3. Cells
4. Organisms
5. Populations
6. Ecosystems

Section 1.5.2. Generalizations concerned with diversity

1. Diversity of extant life
2. Evolution of a lineage
3. Birth and death of lineages
4. Independent evolution in multiple lineages
5. Coevolution
6. Diversity in space

Section 1.5.3. Generalizations concerned with complexity and adaptation

1. Genetical aspects of adaptive evolution
2. Phenotypic aspects of adaptive evolution
3. Origin of novelties
4. Optimality of the outcomes of evolution
5. Dynamics of complexity
6. Was evolution a purely natural phenomenon?

History and perspectives

Chapter 1.6. Evolution While You Are Watching

Section 1.6.1. Observations of evolution in nature

1. Continuous fossil records
2. Local adaptation
3. Rapid evolution in undisturbed environments
4. Adaptation to recent changes of the environment

Section 1.6.2. Evolution of domesticated plants and animals

1. Phenomenon of domestication
2. Evolution of new phenotypes in domesticated species
3. Evolution of diversity within domesticated species
4. Cost of domestication

Section 1.6.3. Evolution in experiments

1. Evolution of captive populations
2. Long-term artificial selection
3. Evolution under relaxed selection
4. Experimental speciation

2. Variation of sequence-level traits
3. Associations betwen sequence-level traits
4. Phenotypic effects of sequence-level traits

Section 2.2.2. Multifactorial Variation

1. Multifactorial traits and their distributions
2. Inheritance at the level of phenotypes and breeding values
3. Components of the phenotypic variance
4. Variation, evolvability and heritability in natural populations

Section 2.2.3. Genotype > phenotype maps

1. Quantitative trait loci
2. Finding quantitative trait loci
3. Genetic basis of multifactorial variation
4. Epistasis in genotype > phenotype maps

History and perspectives

Chapter 2.3. Factors of Microevolution

Section 2.3.1. Mutation

1. Phenomenon of mutation
2. Mutation rates and effects
3. Mutational equilibrium
4. Waiting for a mutation

Section 2.3.2. Selection

1. Phenomenon of selection
2. Measuring selection
3. Genetic load and variance of relative fitness
4. Evolution under selection acting alone
5. Selection acting on a quantitative trait

Section 2.3.3. Mode of reproduction

1. Phenomenon of reproduction
2. Mendelian segregation and Hardy-Weinberg law
3. Recombination and interlocus associations
4. Non-random assortment of gametes

Section 2.3.4. Population structure

1. Phenomenon of population structure
2. Impact of spatial structure
3. Impact of age structure

Section 2.3.5. Drift

1. Phenomenon of drift

2. Effective population size
3. Effective sizes of natural populations
4. Factors determining intensity of drift
5. Allele genealogies and coalescence
6. Relationships between drift and selection

History and perspectives

Chapter 2.4. Theory of Microevolution

Section 2.4.1. Selection that promotes changes
1. A complete allele replacement
2. Hitch-hiking
3. Simultaneous allele replacements under amphimixis
4. Lag load and possible rates of adaptive evolution
5. Allele replacements in space
6. Phenotypical approach: breeder's equation and Lande's equation

Section 2.4.2. Selection that prevents changes
1. Mutation-selection balance
2. Balancing selection
3. Maintenance of multifactorial variance

Section 2.4.3. Weak or absent selection
1. Fate of a weakly selected mutation
2. Mutation-selection-drift equilibrium at a site
3. Weak selection at multiple sites

Section 2.4.4. Inverse problems
1. Positive selection
2. Negative selection
3. Balancing selection
4. Other factors of Microevolution

History and perspectives

Chapter 2.5. Microevolution of Natural Populations

Section 2.5.1. Variation and Natural Selection
1. Overall strength of selection and kinds of variation
2. Positive selection and ongoing allele replacements
3. Negative selection against unconditionally deleterious alleles
4. Inbreeding depression and recessivity of deleterious alleles
5. Epistasis in selection against unconditionally deleterious alleles
6. Sign epistasis and selection on multifactorial traits

7. Balancing selection
8. Weak selection on near-neutral variation

Section 2.5.2. Patterns in Allele Replacement

1. Parameters of adaptive allele replacements
2. Epistasis in adaptive evolution
3. Genetical basis and rates of phenotypic evolution
4. Near-neutral evolution

Section 2.5.3. Microevolutionary Foundations of Macroevolution

1. Limitations on the course of Macroevolution
2. Limitations on the rate of Macroevolution
3. Role of inadaptive evolution
4. Microevolution of extinction

History and perspectives

Chapter 2.6. Species and Speciation

Section 2.6.1. Species and incompatibility

1. Defining species
2. Fitness landscapes and evolution of incompatibility
3. Genetics of incompatibility
4. Ecology of incompatibility
5. Data on incompatibility

Section 2.6.2. Mechanisms of speciation

1. Phyletic, allopatric, sympatric, parapatric, and hybrid speciation
2. Allopatric speciation: Orr's snowball
3. Sympatric speciation: disruptive and incompatibility selection
4. Sympatric speciation: evolution of reproductive isolation
5. Parapatric speciation: spread of incompatible alleles and reinforcement
6. Hybrid speciation: reaching a remote fitness peak

Section 2.6.3. Data on speciation

1. Rates of allopatric and phyletic speciation
2. Examples and prevalence of sympatric speciation
3. Parapatric speciation, hybrid zones and other long paths
4. Hybrid speciation

History and perspectives

PART 3. UNDERSTANDING MACROEVOLUTION (51 Subsections)

Chapter 3.1. Evolution of Sequences

Section 3.1.1. Reconstructing past evolution of sequences
1. Evolutionary distance between sequences
2. Common ancestry of individual sites
3. Common ancestry of sequence segments

Section 3.1.2. Evolution of sequences due to fixations of small-scale mutations
1. Evolution of a segment
2. Divergence of sequences
3. Degeneration of non-recombining sequences
4. Evolution of simple sequences

Section 3.1.3. Evolution of sequences due to fixations of large-scale mutations
1. Origin of paralogous genes
2. Evolution of multigene families
3. Evolution of families of transposable elements

History and perspectives

Chapter 3.2. Evolution of Complex Phenotypes: Molecules, Cells, and Organisms

Section 3.2.1. Studying adaptation
1. Recognizing adaptations
2. Trade-offs
3. Experimental studies of adaptation
4. Comparative studies of adaptation

Section 3.2.1. Macroscopic properties of fitness landscapes
1. Phase spaces of complex phenotypes
2. Ruggedness and random fitness landscapes
3. Modularity, robustness, and degeneracy
4. Possible large-scale features of realistic fitness landscapes

Section 3.2.2. Evolution of function
1. Non-biological evolution by selection
2. Evolution of molecules
3. Origin of life
4. Evolution of living objects

History and perspectives

Chapter 3.3. Evolution of Simple Phenotypes: Individuals and Populations

Section 3.3.1. Independent phenotypes
1. Phenotypic plasticity

2. Non-interactive behavior
3. Semelparity and iteroparity
4. Clutch size and viviparity
5. Dormancy
6. Aging

Section 3.3.2. Gene transmission

1. Mutation
2. Maintenance of amphimixis
3. Crossing-over
4. Systems of mating
5. Origin of amphimixis
6. Genetic conflicts

Section 3.3.3. Interactions between individuals

1. Warning coloration and other ecological interactions
2. Dispersal
3. Aggression
5. Cooperation and altruism
4. Group selection.

Section 3.3.4. Complex population-level phenomena

1. Evolution of fitness landscapes
2. Origins of multicellularity and coloniality
3. Anisogamy and sex allocation
4. Mate choice
5. Coevolution of female preferences and male display
6. Conflicts between gametes and sexes
7. Parent-offspring conflicts
8. Eusociality

History and perspectives

Chapter 3.4. Evolution of Ecosystems

Section 3.4.1. Coevolution of interacting populations

1. Red Queen dynamics
2. Coevolution in space
3. Darwinian extinction

Section 3.4.2. Evolution of communities

1. Invadability
2. Species assembly
3. Trophic chains and food webs

History and perspectives

EPILOGUE: EVOLUTION OF LIFE AND HUMAN CONDITION

1. Human imperfection
2. Human variation
3. Human diseases
4. Psychology
5. Traditional beliefs
6. Eternal questions