

Contents

■ PART I SCIENCE AND EVOLUTION AS SCIENCE1

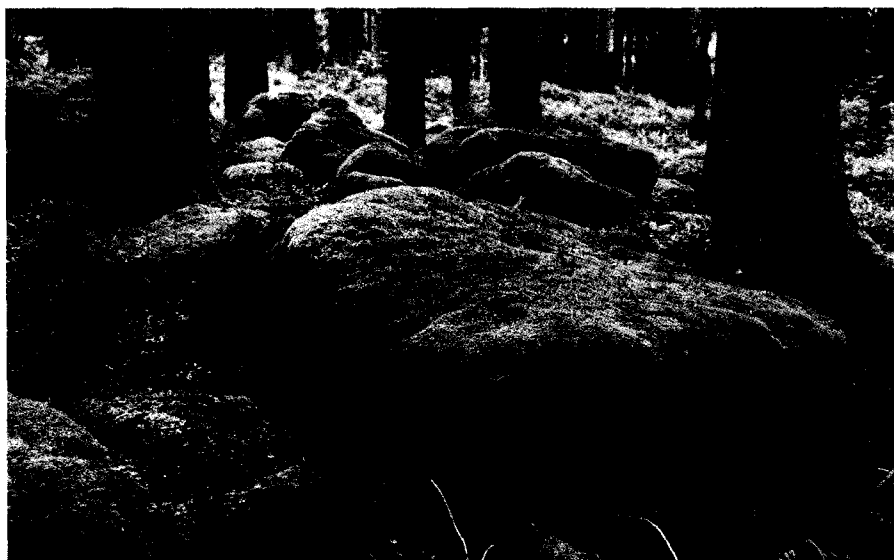
CHAPTER 1	The Nature of Science and Evolution, and Evolution as Science	2
	Overview	2
	The Scientific Method.	3
	Science and Events in the Past	5
	Evolution as a Science	6
	Evolution as Only a Theory.	7
	Evolution: an Overview of the Term and the Concept	8
	Evolution as the Development of an Individual	
	Evolution as the Transformation of Populations between	
	Generations	
	Transformation and Descent with Modification: 1859–Now	
	Individuals, Populations and Evolution	13
	Recommended Reading	16
	Box 1.1 Environment–Organism Interactions	
	Box 1.2 What Is a Gene?	
	Box 1.3 What Is a Niche?	

■ PART II ORIGINS17

CHAPTER 2	The Origin of Matter, the Universe and Earth . .	18
	Overview	19
	What Makes Earth So Special?	19
	The First 380,000 Years	19
	The Universe Evolves	21
	The Future of the Universe	23
	Origin of the Solar System	23
	Earth's Structure and the Origin of the Moon.	23
	Earth Evolves	26
	Earth's Atmospheres	
	Dating Earth's Rocks and Fossils	27
	Fossils and the Nature of Geological Change	31
	Continental Drift	34
	Paleomagnetism	
	Sea-Floor-Spreading	
	Plate Tectonics	



Recommended Reading	39
<i>Box 2.1</i> Some Early Attempts to Determine Earth's Age	
<i>Box 2.2</i> Darwin and the Age of Earth	
<i>Box 2.3</i> Radiometric Dating	
CHAPTER 3 The Origin of Molecules and the Nature of Life .	40
Overview	41
Prerequisites for the Origin of Molecules.	41
Our Sun and Earth's Orbit	
Chemical Elements	
Water	
Replicating the Production of the First Molecules	
in the Laboratory	43
Possible Sites for the Origin of the First Molecules	
on Earth	43
Hydrothermal Vents	
Volcanoes	
Clays	
Molecules in Meteorites	44
DNA, RNA and Proteins	45
Which of These Molecules Evolved First: DNA,	
RNA or Protein?	48
DNA First	
Proteins First	
RNA First	
First RNA, Then DNA.	48
The Genetic Code	51
Enzymes and Energy Transfer	
Molecules and Life.	52
Recommended Reading	52
<i>Box 3.1</i> Molecules in Meteorites	
<i>Box 3.2</i> Ribonucleic Acids (RNAs)	
<i>Box 3.3</i> The Genetic Code	



CHAPTER 4	From Molecules to Cells and the Origin of Selection	53
	Overview	54
	Earth's Atmosphere(s) and the First Cells/Organisms	54
	Oxygen and Cyanobacteria	55
	Membranes → Protocells	56
	Membranes	
	Protocells	
	Laboratory Studies	
	Selection	61
	The Origin of Selection	
	Selection and Inheritance	
	Selection and the Cellular Basis of Life	
	Chromosomes and Cell Division	62
	Life Without Cells?	64
	Prions	
	Viruses	
	Life.	65
	Recommended Reading.	67
	Box 4.1 What Is Life?	

PART III DARWIN, WALLACE, NATURAL SELECTION AND INHERITANCE 68

CHAPTER 5	Darwin and the Voyage of the <i>Beagle</i>	69
	Overview	70
	Defining Species.	75
	Species Concepts	75
	Charles Darwin	77
	Voyage of the <i>Beagle</i>	81
	Lamarckian Inheritance	84
	Recommended Reading of Books by and on Darwin	87
	Box 5.1 Fossils	
	Box 5.2 Plato, Idealism, and the Concept of Species	
	Box 5.3 The Great Chain of Being	
	Box 5.4 Darwin's Finches	

CHAPTER 6	Darwin and Wallace's Evolution by Natural Selection	88
	Overview	89
	Natural Selection	89
	Artificial and Natural Selection	92
	Variation and Initiating Change	95
	Small Continuous Variations	
	Getting Selection Started	
	Evolving from Something	

Malthus and Darwin.	99
Vestiges of the Natural History of Creation and Darwin's Delay	
Alfred Russel Wallace	102
Aspects of the Natural World Explained by the Theory of Evolution by Natural Selection.	104
Fossils	
Geographical Distribution and Classification	
Wider Impacts of <i>On the Origin of Species</i>	112
Arguments Raised Against the Theory of Evolution by Natural Selection	114
Geographical Isolation	
Recommended Reading	116
Box 6.1 Spontaneous Generation	
Box 6.2 Selection, Randomness and Chance	
Box 6.3 Eye Evolution	
Box 6.4 Classification	
Box 6.5 Cladistics	
Box 6.6 The Real Father of Geographical Isolation	

CHAPTER 7	Darwin, Mendel and Theories of Inheritance. . .	117
	Overview	118
	Seeking a Mechanism of Heredity	118
	Lamarckian Inheritance	
	Blending Inheritance	
	Pangenesi s	
	Constancy and Variation	121
	Mendel's Experiments	121
	Principle of Segregation	
	Principle of Independent Assortment	
	Deviations from Mendelian Genetics.	126
	Extranuclear Inheritance	
	Sex-Linked Genes and Sexual Reproduction	
	Sex Determination	127
	Sex Chromosomes	
	Autosomes and Sex Determination	
	Environmentally Induced Sex Determination	
	Recommended Reading	135
	Box 7.1 Styles in Science; Mendel and Darwin	
	Box 7.2 Preformation	
	Box 7.3 Modes of Sex Determination	
	Box 7.4 Environmental Sex Determination	

PART IV THE UNIVERSAL TREE OF LIFE136

CHAPTER 8	From Single-Celled Organisms to Kingdoms . .	137
	Overview	138
	Kingdoms of Organisms	138
	Two	
	Two Became Five	

Early Fossilized Cells/Unicellular Organisms	143
Cyanobacteria and Stromatolites	
The Ancestral Organism and the Universal Tree of Life . .	146
Horizontal Gene Transfer and the Tree of Life	147
Between Unicellular Organisms	
To or Between Multicellular Organisms	
Recommended Reading	149
Box 8.1 Using Genes and Gene Products to	
Construct Phylogenetic Trees	

CHAPTER 9	Eukaryotic Cells and Multicellular Organisms . .	150
	Overview	151
	Evolution of Eukaryotic Organization	151
	Single-Celled Eukaryotes: Protistans	152
	Origin and Evolution of Mitochondria and Chloroplasts . .	158
	Mitochondrial DNA	
	Transfer of Genes between Organelles and Nucleus	
	Recommended Reading	164
	Box 9.1 Five or Six Supergroups in the Eukaryote Tree of Life	
	Box 9.2 Ancient DNA	

CHAPTER 10	Plants and Fungi as Branches of the	
	Tree of Life	165
	Overview	166
	An Abominable Mystery	166
	An Algal Ancestry	168
	Bryophytes	170
	Early Vascular Plants	173
	Ferns	
	Origins of Leaves	176
	Moving onto Land	177
	Relationships of Flowering Plants	
	Fungi	185
	Recommended Reading	187
	Box 10.1 Multicellularity	
	Box 10.2 Alternation of Generations	
	Box 10.3 Coevolution of Plants and Insects	

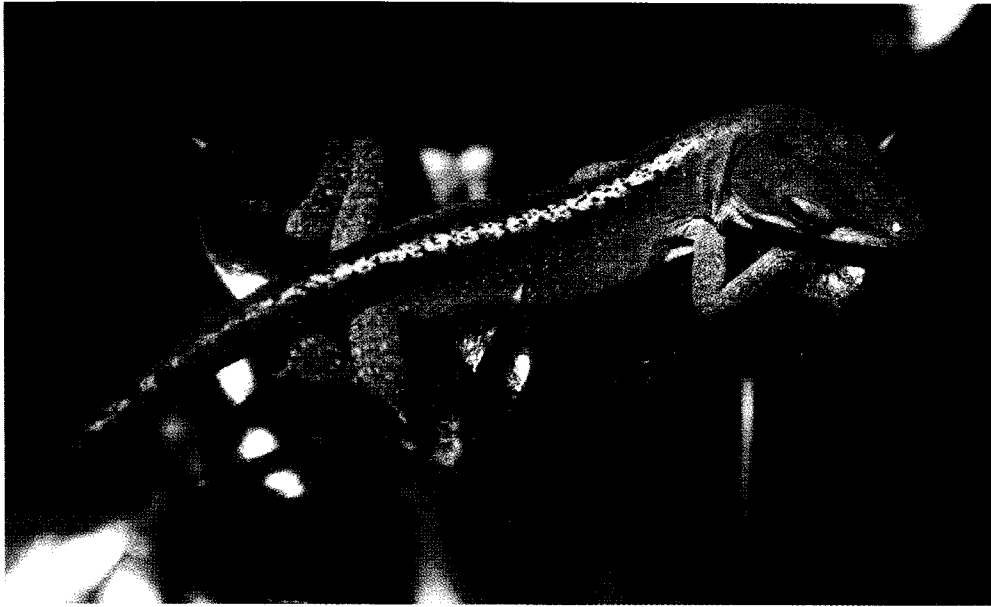
CHAPTER 11	Animals as a Branch of the Tree of Life	188
	Overview	189
	Animal Origins	189
	The Ediacaran Biota	190
	Animals Arise	192
	Burgess Shale Fauna	
	Assessing Morphology	
	A Cambrian "Explosion?"	195
	Causes of the Cambrian Radiation	197
	Geological Conditions	
	Rising Oxygen Levels	



Predator-Prey Relationships	
Shared Embryonic Development and Body Plan Specification	
Homeobox Genes	
Developmental Change and Evolution	203
Recommended Reading	208
Box 11.1 Snowball Earth	
Box 11.2 Evolutionary Molecular Clocks	
Box 11.3 Hox Genes and Vertebrate Origins	
Box 11.4 Gene Duplication and Divergence	

PART V PRINCIPLES AND PROCESSES OF EVOLUTION.210

CHAPTER 12 Individual Genetic Variation and	
Gene Regulation	211
Overview	212
Variation: Five Central Questions	212
Variation in Chromosome Number	213
The Evolution of Wheat	
Breeding the Evil Weed in the Laboratory	
Other Changes in the Phenotype of Chromosomes	215
Chromosomal Evolution in <i>Drosophila</i> and Primates . . .	219
Mutations as a Source of Genetic Variation	219
Sickle Cell Anemia	
Gene Regulation	222
Gene Regulation as a Source of Variation	222
Gene Regulation in the Bacterium <i>Escherichia coli</i>	
Gene Regulation in Eukaryotic Cells	
Gene Regulation and Evolution	227
Transposons	
Recommended Reading	234
Box 12.1 Major Mechanisms of Gene Regulation in	
Eukaryotic Cells	
Box 12.2 Barbara McClintock and the	
Discovery of Transposons	
CHAPTER 13 Genetic Variation in Populations	236
Overview	237
Mutation	237
Mutation Rates	239
Neo-Darwinism and Genetic Polymorphism	239
Continuous Variation	241
Quantitative Trait Loci	
Population Genetics and Gene (Allele) Frequencies	
in Populations	244
Populations, Allele Frequencies and the Gene Pool	
Measuring Allele Frequencies	
Additional Sources of Variation in Populations	249
Gene Flow	
Genetic Drift	



Selection, Variation and Increased Fitness	252
Phylogeography: Reconstructing the Geographical History of a Lineage Using Genetics	254
Spread of Wheat	
Recommended Reading	256
Box 13.1 Demes: Reproductive Units Within Populations	
Box 13.2 The Shifting Balance Theory Proposed by Sewall Wright	

CHAPTER 14	The Biology of Populations	257
	Overview	258
	Biological Interactions Within Populations	258
	Competition	260
	Resource Partitioning	
	Character Displacement	
	Competitive Exclusion	
	Predation	266
	Coevolution	267
	Parasitism	
	Insects and Host Plants	
	Extent of Coevolution	
	Phenotypic Plasticity	269
	Population Growth	271
	Recommended Reading	274
	Box 14.1 Can Individuals Exist Outside a Population?	
	Box 14.2 Darwin's Finches and the Jaws of Fish	
CHAPTER 15	Natural Selection	275
	Overview	276
	Survival of the Fittest	277

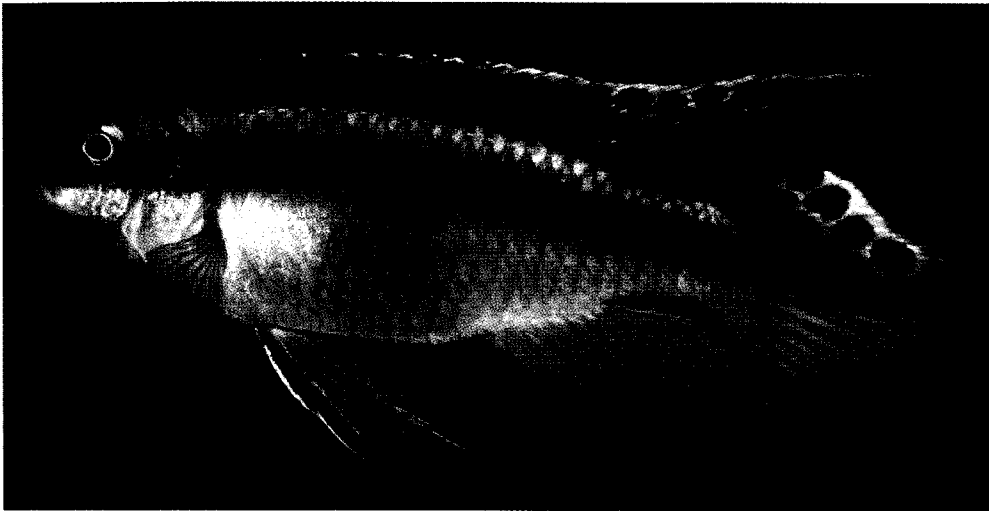
Kinds of Selection	278
Stabilizing Selection	
Directional Selection	
Disruptive Selection	
Sexual Selection	
Selection on One Species Affects Other Species	285
Selection and Developmental Constraint	285
Reaction Norms, Canalization and Genetic Assimilation	
Selection and Fitness	287
Adaptive Landscapes and the Shifting Balance Theory	288
Group Selection	
Evolutionarily Stable Strategies	292
Selection and Balanced Polymorphism	293
Selection and Mimicry	
Selection and Industrial Melanism	
Recommended Reading	298
Box 15.1 Altruism, Kin Selection and Reciprocal Altruism	

PART VI ON THE NATURE AND ORIGIN OF SPECIES. .299

CHAPTER 16 Species and Similarity: On Being the Same Yet Different	300
Overview	301
Classification and the Reality of Species	301
Classification and Phylogenetic Relationships	303
Species Identification and Species Concepts	308
Morphological Species	
Biological Species	
Evolutionary Species	
Similarity: Knowing When Characters Are the Same or Different	317
Homology	320
A Brief History	
Homology Statements	
Parallelism	323
Convergence	323
Recommended Reading	324
Box 16.1 Horse Evolution	
Box 16.2 Vestigial Organs	
Box 16.3 Living Fossils	

CHAPTER 17 Origin of Species	325
Overview	326
Species Can Change Without Speciation Being Initiated	326
Adaptation and Differentiation	327
Speciation Initiated by Geographical Isolation	327
Forms of Geographical Isolation	
Speciation without Geographical Isolation	329
Cichlid Fishes	





Mechanisms Facilitating Reproductive Isolation	336
Reproductive Incompatibility	338
Hybrids	
Sexual Isolation in Sympatric and Allopatric Populations	
Speciation and Hybridization Zones.	340
Plants	
Animals	
Frequency and Impact of Hybridization in Nature	
Genes and Speciation.	342
Recommended Reading	344
Box 17.1 Speciation of Fruit Flies in Hawaii	
Box 17.2 Pharyngeal Jaws in Cichlid Fish	

CHAPTER 18	Mass Extinctions, Opportunities and Adaptive Radiations	345
	Overview	346
	Extinction	346
	Extraterrestrial Impacts	347
	Mass Extinctions	348
	Dinosaurs and Late Cretaceous Mass Extinctions.	349
	Collision with an Asteroid	
	Chicxulub Crater	
	Radiations of Mammals	351
	Radiation into South America	
	Invading the Air: Flying Reptiles	356
	Pterosaurs and Pterodactyls	
	Avian Dinosaurs: Birds	359
	<i>Archaeopteryx</i>	
	Bird Evolution	
	Origin of Feathers	
	Flightlessness	
	Insects Conquer Land and Air	364
	Social Organization	

Complexity	370
Measuring Complexity	
Increase in Numbers of Types of Cells	
Increase in Organismal Size	
Life Style	
Recommended Reading	372
Box 18.1 Fragmentation of Pangaea	
Box 18.2 Moving Continents and South American	
Mammalian Radiations	
Box 18.3 Modularity	
Box 18.4 Kin Selection in Social Insects	

PART VII HUMAN ORIGINS AND EVOLUTION374

CHAPTER 19 Human Origins and Evolution 375

Overview	376
Primates: A Rapid Survey	376
Monkeys	
Apes and Humans: Hominoids	
Australopithecines: The Southern Apes of Africa	381
<i>Australopithecus africanus</i>	
Origins of Humans (Hominins)	383
Bipedalism and Brain Size: Hypotheses about	
Early Human Evolution	
Origins of <i>Homo</i>	387
<i>Homo rudolfensis</i> and <i>Homo habilis</i>	
<i>Homo ergaster</i> and <i>Homo erectus</i>	
<i>Homo sapiens</i>	
<i>Homo heidelbergensis</i>	
Neanderthals: Another Species of <i>Homo</i>	
Tool Use by Species of <i>Homo</i>	391
<i>Homo sapiens</i> (Humans)	392
MtDNA and Human Migration	
Out of Africa	393
Mitochondrial Eve	
Y-Chromosome Adam	
Autosomal Human	
Humans as Hunter-Gatherers	396
The Rise of Agriculture	397
Humans as Genetic Engineers	398
Food Crops and Animals	
Concerns About GM Technology	
Recommended Reading	402
Box 19.1 What's in a Name? Hominids and Hominins	
Box 19.2 Piltdown Man	
Box 19.3 Diversity of the Southern Apes of Africa	
Box 19.4 <i>Pithecanthropus erectus</i>	
Box 19.5 Tool Use by Chimpanzees and Monkeys	
Box 19.6 Dwarf Hominins on the Island of Flores	
Box 19.7 Stages in the Manufacture and Use of Tools	
by Species of <i>Homo</i>	



CHAPTER 20	Cultural and Social Evolution	403
	Overview	404
	Instincts.	405
	Learning, Society and Culture	406
	Cultural Evolution Outpaces Biological Evolution.	409
	Social Darwinism.	411
	Sociobiology	412
	Human Control over Our Own Evolution.	413
	Deleterious Alleles.	416
	Eugenics	418
	Eugenics Policies	
	Reproductive Technology and Eugenics	
	Genetic Technology	
	Gene Therapy	
	Clones and Cloning	422
	Our Influence on the Evolution of Other Species	
	and on Their (and Our) Environment	425
	Recommended Reading	426
	Box 20.1 Speech and Language	
	Box 20.2 Evolution of the Human Brain	
	Box 20.3 Population Explosion	
	Box 20.4 Regulating Risk and Safety	
CHAPTER 21	Culture, Religion and Evolution	427
	Overview	428
	Charles Darwin and Society.	429
	Science and Culture.	429
	Science and Religion	432
	Bases of Religious Belief.	433
	Darwinism and Religion	435
	The Question of Design	436
	Creationism and Intelligent Design	438
	Last Words	442
	Recommended Reading	442
	Box 21.1 Printing, Gunpowder and the Compass in China	
	Box 21.2 Accounts of the Origin of the World from	
	Ten Different Cultures	
	Box 21.3 Evidence Refuting Common Claims	
	Made by Creationists	
	Glossary.	G-1
	Lexicon	L-1
	Additional Reading	A-1
	Index	I-1
	Photo Acknowledgments.	P-1