

CONTENTS IN BRIEF

INTRODUCTION

The nature of biology and science	1
-----------------------------------	---

PART 1 CELL BIOLOGY AND ENERGETICS

Chapter 1	The nature of molecules	15
Chapter 2	Biological molecules	16
Chapter 3	The chemistry of life	32
Chapter 4	Functioning cells	61
Chapter 5	Movement across membranes	82
Chapter 6	Harvesting energy	110
Chapter 7	Cells, tissues and signals	125
Chapter 8	Cell division	149
		178

PART 2 GENETICS AND MOLECULAR BIOLOGY

Chapter 9	Inheritance	197
Chapter 10	Genes, chromosomes and DNA	198
Chapter 11	The genetic code	226
Chapter 12	Gene expression	242
Chapter 13	Genomes, mutation and cancer	262
Chapter 14	Viruses	275
Chapter 15	Genetic engineering and biotechnology	297
		314

PART 3 PLANT FORM AND FUNCTION

Chapter 16	Reproduction and development of flowering plants	343
Chapter 17	Structure of plants	344
Chapter 18	Plant nutrition, transport and adaptation to stress	370
Chapter 19	Plant hormones and growth responses	402
		428

PART 4 ANIMAL FORM AND FUNCTION

Chapter 20	Animal reproduction	451
Chapter 21	Animal development	452
		477

Chapter 22	Homeostasis of water and solutes	511
Chapter 23	Gas exchange in animals	538
Chapter 24	Circulation	566
Chapter 25	Metabolism, temperature regulation and environmental stress	594
Chapter 26	Animal and human nutrition	618
Chapter 27	The immune system: innate and acquired defences	646
Chapter 28	Hormonal control in animals	680
Chapter 29	Nervous systems	705
Chapter 30	Animal movement	736
Chapter 31	Animal behaviour	765

PART 5 EVOLUTION AND BIODIVERSITY

Chapter 32	Evolving life	787
Chapter 33	Evolving earth	788
Chapter 34	Mechanisms of evolution	809
Chapter 35	Prokaryotes: Bacteria and Archaea	833
Chapter 36	The protists	861
Chapter 37	Plants	888
Chapter 38	Fungi	922
Chapter 39	Simple animals: sponges to flatworms	961
Chapter 40	Annelids, molluscs, nematodes and arthropods	989
Chapter 41	Echinoderms and chordates	1013
		1044

PART 6 ECOLOGY

Chapter 42	Australian biota	1077
Chapter 43	Population ecology	1078
Chapter 44	Living in communities	1111
Chapter 45	Ecosystems	1132
Chapter 46	Human impacts	1161
		1184

CONTENTS IN FULL

<i>Case guide</i>	<i>xviii</i>
<i>The editors</i>	<i>xxii</i>
<i>Contributing authors</i>	<i>xxiii</i>
<i>Reviewers and acknowledgments</i>	<i>xxiv</i>
<i>Digital resources</i>	<i>xxvi</i>
<i>How to use this book</i>	<i>xxviii</i>
<i>Highlights of this edition</i>	<i>xxxii</i>
<i>Interviews</i>	<i>xxxiv</i>

INTRODUCTION	The nature of biology and science	1
Biology today		2
Unifying themes in biology		2
Living organisms are made of cells		2
Origin of life		3
Life's raw ingredients		3
Were RNA polymers the first molecules to store information and reproduce?		4
Concentration and containment of molecules in cell-like compartments		5
DNA is the basis of life		5
Life evolves: the theory of natural selection		6
The evolutionary tree of life		6
Phylogenies are the basis of classification		6
The practice of science		7
Scientific method		7
Making observations		7
Testing hypotheses by experiments		8
Experimental design		8
Scientific publication		8
Ethics, social responsibility and limitations in science		9

PART 1 CELL BIOLOGY AND ENERGETICS

15

CHAPTER 1	The nature of molecules	16
All life is composed of the same few elements		17
Elements are made of atoms		19
Electrons are in orbit around a nucleus		19
Chemical bonding of atoms makes molecules		19
Covalent bonds are created by sharing electrons between two atoms		20
Non-covalent bonds between atoms or molecules		21
Water is the medium of life		23
Properties of water		23
Water as a solvent		26

Non-polar molecules and hydrophobic interactions	26
Carbon is the atom on which biomolecules are constructed	27
Properties of carbon	27
Why is carbon unique?	27
Acids, bases and buffers	27
pH	28
Buffers	28

CHAPTER 2	Biological molecules	32
Biomolecules		33
Organic molecules		33
Synthesising macromolecules		33
Nucleic acids		35
DNA		36
RNA		36
Proteins		37
Protein structure and function		37
Primary structure of proteins		38
Secondary structure of proteins		38
Tertiary structure of proteins		40
Quaternary structure of proteins		40
Types of proteins		43
Carbohydrates		46
Monosaccharides		46
Disaccharides		48
Polysaccharides		48
Lipids		53
Simple lipids		53
Complex lipids		55

CHAPTER 3	The chemistry of life	61
Chemical reactions and life processes depend on energy		62
Energy and entropy		62
Laws of thermodynamics		62
Free energy		63
The equilibrium state of a reaction determines its available energy		63
Free energy and the equilibrium constant		65
Spontaneous chemical reactions and free energy		65
Rates of chemical reactions, activation energy and catalysis		66
Enzymes are biological catalysts		67
How enzymes are specific in their action		68
Models of enzyme action		69
Factors affecting enzyme activity		70
Cofactors and coenzymes		72
Chemical reactions drive events in cells		73
Metabolism		73
ATP is an energy carrier		74
Electron transport pathways		75

Oxidation and reduction reactions	76	Voltage differences across membranes: a dynamic feature of all cells	116
Biological electron carriers	77	Osmosis: passive movement of water	116
Energy in fuel molecules	77	Water has free energy	116
		Water moves in response to differences in water potential	117
		Osmosis and cells	117
CHAPTER 4 Functioning cells	82	Transport of large molecules across membranes	119
The cellular basis of life	83	Endocytosis	119
Prokaryotic cells	83	Exocytosis	120
Eukaryotic cells	85		
Studying the structure of cells	85		
Membranes: boundaries and barriers	88	CHAPTER 6 Harvesting energy	125
Fluidity of membranes	90	Harvesting chemical energy	126
Permeability of membranes	90	Glycolysis: the initial processing of glucose	128
The nucleus	91	β -oxidation: the initial processing of lipids	128
Chromosomes	92	The citric acid cycle: completing the oxidation of fuels	129
Nucleolus	92	Recycling electron carriers	130
Ribosomes	93	The electron transport system generates ATP	130
Endomembrane system	93	Evolution of oxidative respiration led to greater ATP production	131
Endoplasmic reticulum	93	Fermentation produces ATP without oxygen	131
The Golgi apparatus	95	Harvesting light energy: photosynthesis	133
Intracellular sorting and transport	95	Light energy	135
Mitochondria	97	Pigments: molecules that absorb light	135
Plastids	98	Light-dependent reactions of photosynthesis	136
Chloroplasts	99	Chloroplasts trap photons	136
Amyloplasts, chromoplasts and other plastid types	100	Photosystems I and II	136
Microbodies	100	Photosynthetic prokaryotes	139
The cytoskeleton	101	Light-independent reactions of photosynthesis	140
Microfilaments	102	Carbon fixation and the Calvin-Benson cycle	140
Microtubules	102	Photorespiration: competition between carbon dioxide and oxygen	142
Intermediate filaments	104	Plants have adapted to different environments	142
Cilia and flagella: driving cell motility	105	The C_4 pathway of photosynthesis	142
The cell wall: a major difference between plant and animal cells	106	Crassulacean acid metabolism	144
CHAPTER 5 Movement across membranes	110	CHAPTER 7 Cells, tissues and signals	149
The plasma membrane: the interface between a cell and its environment	111	Animal tissues	150
Why are membranes necessary?	111	The extracellular matrix	151
Permeability of membranes	111	Components of the extracellular matrix	151
Diffusion	111	Intercellular connections	152
Diffusion of solutes in water	111	Tight junctions	152
Diffusion across membranes	112	Anchoring junctions	152
Ions diffuse along an electrochemical gradient	112	Communicating (gap) junctions	153
Membrane transporters	113	Principal animal tissues	154
Diffusion through the lipid bilayer may be slow	113	Epithelia	154
Facilitated diffusion through channels and carriers	113	Connective tissue	156
Diffusion through channels is controlled by 'gating' mechanisms	113	Muscle tissue	158
Aquaporins	114	Nervous tissue	159
Active transport	114		

CONTENTS IN FULL *continued*

Plant cells: the importance of the cell wall	160	Monohybrid cross	200
Cell wall structure	160	Pleiotropy: multiple effects of single genes	203
Development of plant cell walls	161	Incomplete dominance	203
Plasmodesmata: links between plant cells	162	Blood groups, codominance and multiple alleles	204
Plant tissue systems	162	Inheritance of combinations of genes	205
Dermal tissue	162	Dihybrid cross	205
Ground tissue	163	Backcrosses and testcrosses	207
Vascular tissue	163	Mendelian inheritance in humans	208
Cell signals	163	Extending Mendel's ideas	210
Types of signals	164	Sex linkage and chromosomes	210
Responses to signals	164	Sex-linked genes	210
Physical stimuli	164	Genes are on chromosomes	210
Chemical stimuli	168	X-linked traits in humans	212
Signal processing	169	Y-linkage and male sex determination	212
Direct receptor-mediated responses	169	Linkage on autosomes	213
G-protein-linked receptors	170	Linkage and recombination	213
Protein phosphorylation and receptor tyrosine kinases	173	Chromosome mapping	215

CHAPTER 8 Cell division

Cell division and the cell cycle	179
Cell division in prokaryotes	179
The cell cycle in eukaryotes	179
The cell cycle: an outline	180
Mitosis	181
Mitosis in animal cells	182
Cytokinesis in animal cells	185
Mitosis and cytokinesis in plant cells	186
The control of cell division in eukaryotes	187
Control of cell cycle progression	187
Cyclin-CDKs regulate cell cycle progression	188
Checkpoint control of the cell cycle	188
Meiosis and the formation of haploid cells	190
The cell cycle and DNA content	190
Meiosis I	193
Meiosis II	193
Genetic consequences of meiosis	193

PART 2 GENETICS AND MOLECULAR BIOLOGY 197

CHAPTER 9 Inheritance

Genetics: the science of biological information	199
The foundation for understanding genetics	199
Inheritance of a single gene	200
Mendel's experiments	200

More variations on Mendel's observations	216
Recombination generates novel phenotypes	216
Phenotypes and environment	216
Penetrance and expressivity	217
Epistasis	218
Epigenetic regulation	218
X chromosome inactivation	218
Imprinting	219
Quantitative characters	220
Understanding genetics as the study of biological information	222

CHAPTER 10 Genes, chromosomes and DNA

Tracking the genetic material	227
Chromosome behaviour accounts for patterns of inheritance	227
Chromosome structure	227
Chromosomes consist of protein and DNA and are assembled into nucleosomes	228
Genetic information is stored in DNA and not protein	229
The structure of DNA explains its capacity to store biological information	230
DNA synthesis: an overview	231
DNA replication in prokaryotes	233
Replication in eukaryotes	237

CHAPTER 11 The genetic code

The one gene-one polypeptide hypothesis	243
Inborn errors of metabolism	243
The one gene-one enzyme hypothesis	243
The one gene-one polypeptide hypothesis	243

The central dogma	244
Transcription	244
Initiation of transcription	246
Prokaryotes: transcription in the cytoplasm	247
Eukaryotes: transcription in the nucleus	248
Cutting, splicing and adding to eukaryotic mRNA	248
Translation and the genetic code	250
The genetic code	250
Translation	252
Protein synthesis	254
Ribosomes	254
Polypeptide synthesis	255
Initiation	255
Elongation	257
Termination	257
Protein targeting and processing	258

CHAPTER 12 Gene expression 262

An introduction to regulation of gene expression	263
Constitutive and differentially regulated genes	263
Control points for gene expression	263
Regulation of gene expression in prokaryotes	263
Structure of bacterial operons	263
Regulation of the lactose (<i>lac</i>) operon	263
Regulation of the tryptophan biosynthesis operon	266
Regulation of gene expression in eukaryotes	267
DNA-binding regulatory proteins	267
DNA-binding domains	268
How do sequence-specific DNA-binding proteins repress transcription in eukaryotes?	268
Yeast <i>GAL</i> regulation	269
Combinations of enhancers and silencers	269
Histones, nucleosomes and eukaryotic gene regulation	270
Gene regulatory cascades in eukaryotes	270
RNA-mediated regulation of gene expression	271

CHAPTER 13 Genomes, mutation and cancer 275

Genomes	276
Genomes and phenotypes	276
Genome evolution	276
Genome organisation: an overview	276
The relative sizes of genomes	276
Gene numbers in genomes	276
Organelle genomes	278
Types of DNA sequences	278
Gene families	282
Genome maps	284

Genes and genetic programs

Sets of genes respond to various situations	2
Sets of related genes regulate equivalent biological processes in different species	2
Essential and non-essential genes	2
Mutation, genetic variation and genome instability	2
Genomes and genetic variation	2
Mutation: the source of genetic variation	2
DNA synthesis errors and spontaneous mutation	2
Environmental mutagens	2
DNA repair mechanisms	2
Genomes, mutation and cancer	2
Cancer cells have modified growth and survival characteristics	2
Tumours are clonal in origin	2
Cancer is a genetic disease	2
Dominant oncogenes	2
Tumour suppressor genes and cell cycle regulation	2
Tumour suppressor genes and the integrity of the genome	2
The genome, mutation and cancer: an unfolding story	2

CHAPTER 14 Viruses 297

The discovery of viruses	298
Viruses are subcellular organisms	301
Features distinguishing viruses from cellular organisms	301
Virions are the transmission phase	301
Viral genomes	303
Replication	303
Ecology and spread of viruses	305
Evolution of viruses	306
Other virus-like 'agents'	309
Satellite viruses	309
Retrotransposons and similar agents	309
Viroids and prions: virus-like infections agents	310
Virus control	310

CHAPTER 15 Genetic engineering and biotechnology 314

An overview of recombinant DNA	315
Cutting and joining DNA	315
Genetic transformation	315
Designer genes	315
Recombinant DNA technology	316
DNA-modifying enzymes	316
Analysis of DNA fragments by electrophoresis	317
Joining DNA molecules	317
Propagating recombinant DNA using plasmids and bacteriophage vectors	318

CONTENTS IN FULL *continued*

Identifying and isolating individual genes	321
Characterising cloned DNA sequences	325
Applications of recombinant DNA technology	330
Analysing genetic variation	330
DNA technology in forensic science	330
Determining paternity	331
Mapping genes	332
Biotechnology	333
Making pharmaceutical products	333
Genetically modified crops	333
Cloning farm animals	338
Gene and cell therapy	339
RNA interference in agriculture and disease	339

PART 3 PLANT FORM AND FUNCTION

343

CHAPTER 16 Reproduction and development of flowering plants

Sexual life cycle of a flowering plant	344
Gametes of plants are not the direct result of meiosis	345
The flower is the site of sexual reproduction	346
The anther is the male reproductive organ	347
The carpel is the female reproductive organ	350
Double fertilisation	351
Reproduction without fertilisation: the unusual case of apomixis	353
Pollination in flowering plants: choose your partner carefully	353
The stigma and style recognise pollen	353
Cross-pollination	354
Self-incompatibility is a genetically controlled recognition system	355
Self-pollination	355
Major events in the formation of seeds	356
Development of the embryonic plant	356
Endosperm formation	356
Seed and fruit development	356
Seed maturation, dormancy and germination	358
Organogenesis: making leaves, roots and flowers	360
The shoot apex	361
The root apex	361
Asexual reproduction in flowering plants	364
Vegetative reproduction	364
Tissue culture: generating a whole plant from a single cell	365

CHAPTER 17 Structure of plants

Plant cell walls	370
Middle lamella	371
Primary wall	371
Secondary wall	372

Plant tissue systems

Dermal tissue	373
Ground tissue	373
Vascular tissue	375

Stem structure

Primary growth	377
Secondary growth	377
Special functions of stems	381

Root structure

Primary growth	385
Secondary growth	386
Special functions of roots	389
Root adaptations and nutrient supply	389

Leaf structure

Leaf arrangement and life span	392
Leaf shape and orientation	392
Leaf structure and organisation	393
Modifications of leaf structure	394
	396

CHAPTER 18 Plant nutrition, transport and adaptation to stress

Nutrition of plants	402
Essential minerals	403
Pathways and mechanisms of transport	406
Water transport	407
Factors that affect water potential	408
Water uptake by plant cells	408
Transpiration	410
Water movement in xylem	410
Water movement from leaves	412
Translocation of assimilates	416
Pathway of assimilate transport	416
What substances are transported in phloem?	417
Rate of phloem transport	417
Mass-flow mechanism of transport	418
Adaptations to stress	419
Water stress	419
Ways that plants cope with drought	421
Salinity and mineral stress	423
Lack of oxygen around roots	424
Temperature stress	424

CHAPTER 19 Plant hormones and growth responses

Auxins promote growth	428
Phototropism	429
Indole-3-acetic acid and other auxins	429
Auxin and cell elongation	430
Apical dominance	431
	431

Auxin and shade intolerance	432
Gravitropism	432
Auxin-binding proteins	433
Gibberellins play several roles	433
Stem elongation	434
Mobilisation of seed protein and carbohydrate reserves	434
Gibberellic acid receptor	435
Cytokinins promote cell division	436
Absciscic acid is a growth inhibitor	438
Drought resistance	438
Frost tolerance	439
Seed dormancy	439
ABA receptors	440
Ethylene is a gaseous hormone	440
Signal transduction	440
Fruit ripening	441
Shoot growth and flowering	441
Karrikins and ecosystem renewal	443
Brassinosteroids switch on genes	443
Control of flowering by photoperiodism	444
Short-day and long-day plants	444
Vernalisation and flowering	446

PART 4 ANIMAL FORM AND FUNCTION

451

CHAPTER 20 Animal reproduction	452
Asexual reproduction	453
Regeneration	453
Budding	453
Parthenogenesis	454
Sexual reproduction	454
Hermaphroditism	455
Reproductive strategies	456
Human reproduction	459
The costs of sexual reproduction	461
Parental care	464
Gametogenesis and fertilisation	465
The formation of gametes: gametogenesis	465
Fertilisation: cellular events	470

CHAPTER 21 Animal development	477
Features of animal development	478
Animal development: an overview	478
Cleavage	479
Gastrulation	481

Mechanisms of morphogenesis	485
Organogenesis	487
Vertebrate neurulation	487
Limb formation	489
Genetic regulation of development	490
Cytoplasmic determinants and intercellular signalling in the central nervous system of <i>Drosophila</i>	492
Cytoplasmic specification in sea squirts	492
Primary induction and mesoderm induction in amphibia	494
The notochord is an inducer of neural tube patterning	494
The molecular genetics of segmentation in <i>Drosophila</i>	496
Early embryonic development in <i>Drosophila</i>	496
Specifying the anterior-posterior axis	497
Zygotic segmentation genes	499
Homeotic (<i>Hox</i>) genes	499
Cell lineages and the maintenance of animal tissues	504
Cell lineages	504
Stem cells	504
Tissue maintenance	504
Blood cell formation	504

CHAPTER 22 Homeostasis of water and solutes	511
Water and solutes	512
Homeostasis	512
Passive homeostasis	513
Negative feedback regulation	514
Positive feedback destabilisation	515
Patterns of ionic and osmotic balance	515
Intracellular and extracellular environments	515
Exchange with the environment	516
Living in water	516
Living on land	521
Nitrogenous wastes	524
Ammonia, urea and uric acid	524
Environmental and phylogenetic patterns	525
Excretion	526
Excretory organs	526
Epithelial salt pumps	526
Tubular excretory organs	526
Invertebrates	528
Vertebrates	530

CHAPTER 23 Gas exchange in animals	538
Air and water as respiratory media	539
Exchanging gases	540
Surface area and volume	540
Ventilation and convection	542
Gas-exchange organs	543
Water breathers	543

CONTENTS IN FULL *continued*

The transition from water to air breathing	547
Air breathing: lungs	549
Air breathing: tracheae	556
Transporting gases	558
Transport of oxygen	558
Oxygen-carrying capacity	559
Oxygen affinity	560
Transport of carbon dioxide	560
Control of ventilation	562

CHAPTER 24 Circulation 566

Pumps	567
How the heart works	572
Electrical activity	573
The electrocardiogram	576
Open and closed circulatory systems	577
Circulatory systems of vertebrates	577
Structure and function of blood vessels	578
The microcirculation	580
Capillary exchange	580
The lymphatics	582
Regulation of blood flow and pressure	583
Regulation of blood flow to tissues	583
Cardiovascular regulation in vertebrates	585
Blood	586
Erythrocytes	587
Blood clotting	589

CHAPTER 25 Metabolism, temperature regulation and environmental stress 594

Energy requirements of animals	595
Factors affecting metabolic rate	596
Body temperature	597
Heat exchange between animals and their environment	597
Temperature coefficient (Q_{10})	598
Patterns of body temperature regulation	599
Ectotherms	599
Endotherms	602
Responding to environmental challenges	604
Acclimatisation and acclimation	604
Metabolic depression	604
Hypothermia and torpor	605
Hypoxia	607
Animals in extreme environments	608
Burrowing	608
Animals at high altitude	609
Diving	610
Animals in the cold	611
Animals in deserts	612

CHAPTER 26 Animal and human nutrition 618

What nutrients do animals need?	619
Nutrient composition of foods	621
Plant tissues	621
Animal tissues	623
How much food do animals require?	623
The digestive process	624
Physical digestion	624
Enzymatic digestion	624
Control of digestive secretion in humans	624
Evolution and diversity of digestive systems	628
Intracellular and extracellular digestion	628
Simple digestive cavities	629
Two openings: one-way movement of food	630
Muscular gut wall: coelomates	630
Chitinous mouthparts: arthropods	630
Jaws and teeth: vertebrates	631
Mammals	632
Filter feeding: eating tiny particles	633
Dealing with plant cell walls	634
Digesting cellulose	634
Foregut fermentation	634
Ruminant foregut fermenters	634
Hindgut fermentation	636
Body weight regulation in humans	639
Body composition and the myth of fast and slow metabolism	639
Where does our body fat come from?	640
Fuel for our bodies to meet our energy needs	640
Mechanisms for regulating appetite and body fat: evidence for a genetic basis to body mass	640

CHAPTER 27 The immune system: innate and acquired defences 646

Evolution of immune responses	647
Self-recognition	647
Toll-like receptors	647
Antimicrobial proteins	648
Cells of the immune system	648
Antigens, antibodies, T-cell receptors and specific acquired immunity	648
Resistance in plants	650
Mammalian immune system	650
Innate defence mechanisms	650
Specific acquired immunity	653
Cells of the immune system	654
Molecules of the immune system	660
Nature of immune responses	665
Secondary lymphoid tissues and the lymphatic network	665
Humoral responses	667
Cellular responses	667
Immunity to infection	668

Defence against tumours	671
Allergies, hypersensitivity and immunopathology	672
Tissue transplantation	673
Contribution of immunology to modern medicine	676

CHAPTER 28 Hormonal control in animals 680

General functions of hormones	681
Mechanisms of hormone action	682
Hormonal control systems	684
Neurosecretion	684
Endocrine secretion	684
Feedback control	685
Hormones in vertebrates	686
Hypothalamus and pituitary gland	686
Adrenal gland and hypothalamo-pituitary-adrenal axis	688
Thyroid gland and hypothalamo-pituitary-thyroid axis	691
Parathyroid and ultimobranchial glands	693
Gonads and the hypothalamo-pituitary-gonadal axis	693
Pineal gland	695
Digestive system	697
Hormones in insects	699

CHAPTER 29 Nervous systems 705

Neurons: the functional units of nervous systems	706
Functional classes of neurons	707
The resting membrane potential of neurons	707
Neurons transfer information as electrical signals	707
Neurons carry electrical signals over long distances using action potentials	708
How are action potentials conducted?	710
Neurons communicate with other cells across synapses	712
What are synaptic potentials?	713
How do neurons integrate information?	716
The evolution of nervous systems	716
Complex nervous systems: vertebrates	718
The mammalian brain	718
Higher functions of brains	721
How do neural circuits produce behaviour?	722
The functional divisions of nervous systems	723
Controlling muscles and movements	723
Monitoring the external world	723
Visceral control	728

CHAPTER 30 Animal movement 736

Locomotion as a key to animal life	737
Living in water	737
Buoyancy	737

Non-muscular locomotion	738
Muscular locomotion	739
Travelling through air	742
Unpowered (gliding) flight	742
Powered flight	743
Moving on land	745
Locomotion without legs	745
Locomotion with legs	746
Muscles and skeletons working together	749
Skeletons	749
Joints	752
Size and the skeleton	755
Muscle	755

CHAPTER 31 Animal behaviour 765

Genetics and the evolution of behaviour	766
Genetic markers	767
Selection experiments	767
Populations with genetic differences	767
Learning and the development of behaviour	767
Understanding complex behaviour	769
Obtaining food	770
Avoiding being eaten	772
Living in groups	772
Competition and territorial behaviour	773
Territorial behaviour	773
Animal contests	774
Courtship and mating behaviour	776
Courtship	776
Parental care	778
Social organisation and co-operative behaviour	780
Co-operative breeding in birds and mammals	780
Insect societies	781
Evolution of co-operation	782

PART 5 EVOLUTION AND BIODIVERSITY

787

CHAPTER 32 Evolving life 788

Recording the diversity of life	789
Australia's biodiversity	789
Discovering phylogeny and the evolutionary tree of life	791
How to discover a phylogenetic tree by cladistic analysis	791
Comparing morphology	791

CONTENTS IN FULL *continued*

Homologous features are evidence of relationships between divergent forms	793
Analogous features are evidence of convergence	793
Comparing molecules	794
Comparing amino acid sequences of proteins	794
Comparing nucleotide sequences of DNA	795
Molecular clocks and measuring evolutionary time	797
Classification is based on phylogenetic relationships	798
Purposes of classification	798
Taxonomy and naming the hierarchy of life	800
The binomial system	802
Species are the basic taxonomic units	803
Kingdoms of life	805

CHAPTER 33 Evolving earth 809

Fossils are a record in rocks of past life	810
How do fossils form and where are they found?	810
Dating rocks provides a time scale of evolution	811
Evolving earth influences life	814
Plate tectonics explains how continents drift	814
Ancient positions of continents	815
Rodinia is the oldest known supercontinent	815
Supercontinents Gondwana, Laurasia and Pangaea	815
Geological eras mark major events in evolution	816
Precambrian life	816
Ediacaran fauna: evidence of multicellular organisms	819
Palaeozoic life: ancient life	819
Mesozoic life: the age of reptiles	823
Cenozoic life: the beginning of modern life	825
Biogeographic regions of the modern earth reflect evolutionary history	825
Continental biogeographic regions	825
Marine biogeographic zones	828

CHAPTER 34 Mechanisms of evolution 833

What is evolution?	834
Evidence for evolution	835
Selection and the environment	837
Evolution does not produce perfect adaptation	837
Genetic diversity arises by mutation and recombination	839
Mutation	839
Recombination	839
Stability and change in the genetic structure of populations	840
Random mating and the Hardy-Weinberg principle	840
Deviation from the Hardy-Weinberg equilibrium	841
Natural selection	844
Directional selection	844
Balancing selection	844
Disruptive selection	845

Sexual selection	845
Adaptation to environments and trade-offs	845
Inclusive fitness and co-operation	846
Speciation	847
Species concepts	848
Speciation in progress	850
Mechanisms of speciation	852
Geographic isolation and speciation	852
Sexual selection and speciation	854
Temporal and ecological isolation	856

CHAPTER 35 Prokaryotes: Bacteria and Archaea 861

Prokaryotes are single-celled organisms that lack a true nucleus	862
Evolution and diversity of bacteria	862
Prokaryotes were the first cellular life on earth	862
Early photosynthetic bacteria	862
Two major evolutionary lineages: Bacteria and Archaea	862
Classifying and identifying bacteria	866
Bacterial structure and function	871
Growth and reproduction of bacterial populations	872
Nutritional and metabolic diversity of bacteria	872
Genetic systems of bacteria	877
Transformation: gene transfer by free molecules of DNA	878
Conjugation: gene transfer by plasmids	878
Transduction: gene transfer by bacteriophages	878
Bacterial interactions with humans	880
Beneficial interactions in the maintenance of good health	880
Harmful interactions leading to disease	881
Remarkable features of bacteria	883
Bacterial communication	883
Bacterial adaptation to adverse environments and stress	884
Biofilm formation by bacteria	884
Bacteria as cellular compasses	884

CHAPTER 36 The protists 888

Protists are a diverse group of eukaryotes	889
Where did eukaryotic cells come from?	889
Origin of the nucleus	889
The endomembrane system: extension of the nuclear envelope	889
Mitochondria and plastids arose by endosymbiosis	890
Cilia and flagella: extensions of the cytoskeleton	892
Are simple protists ancient eukaryotes?	892
Sponge-like protists	893
'Collar' flagellates: choanoflagellates	893
Slime moulds	893
Cellular slime moulds	893
Acellular slime moulds: myxomycetes	895
Parasitic flagellates that contaminate water supplies: diplomonads	896

Symbionts and parasites: parabasalids	897	Origin and evolution of the flower	950
Amoebae	897	In the life cycle of flowering plants fertilisation is a 'double' event	951
Rhizopods are amoebae that can alter their shape	897	The agents of pollination are often animals	952
Actinopods are radially symmetrical unicells	897	Fruits protect seeds and aid their dispersal	954
Protists with plastids	898	Coevolution of flowering plants and animals	956
Protists with primary plastids: the 'primary lineage'	899		
Missing links in endosymbiosis: glaucophytes	899		
Red algae: rhodophytes	900		
Green algae: chlorophytes	900		
Protists with secondary plastids	903		
Chromist protists: the 'brown lineage'	903		
Flagellates with secondary plastids: cryptomonads	903		
Golden flagellates: chrysophytes	904		
Chalk comes from dead algae: haptophytes	904		
Algae in glass houses: diatoms	905		
Brown algae: phaeophytes	906		
Water moulds and downy mildews: oomycetes	907		
Alveolates: dinoflagellates, ciliates and parasites	909		
Dinoflagellates: whirling algae	910		
Small but deadly: apicomplexans	911		
Ciliates: eukaryotes with two different nuclei	912		
Euglenoids and kinetoplasts	915		
Euglenoid flagellates	915		
Flagellate parasites: kinetoplasts	915		
Cercozoa and forams	917		
Amoebae with secondary plastids: chlorarachniophytes	917		
More chalky protists: forams	917		
CHAPTER 37 Plants	922		
Evolution of plants	923		
Green algae and the origin of land plants	924		
Adaptations to living on land	925		
Specialisation of vegetative features	925		
Alternating generations and sexual reproduction	927		
Non-vascular plants: liverworts, hornworts and mosses	928		
Gametophytes are the haploid generation	928		
Sporophytes are the diploid generation	931		
Vascular plants evolved conducting tissues	933		
Lycophytes: clubmosses and quillworts	935		
Ferns and their relatives	935		
Evolution of seed plants was a major event	940		
Seeds develop from ovules	940		
Pollen transports male gametes	941		
Secondary growth allows plants to become large	941		
Cycadophytes: ancient seed plants	942		
Ginkgophytes: retain flagellate sperm	943		
Coniferophytes: successful non-flowering seed plants	943		
Gnetophytes: are they related to conifers or flowering plants?	946		
Magnoliophytes: flowering plants	947		
The flower	949		
		CHAPTER 38 Fungi	961
		The diversity and evolution of fungi	962
		What is a fungus?	963
		Fungal growth	964
		Hyphae are for feeding	964
		Specialised hyphae	965
		Fungal nuclei are different	967
		Fungal nutrition	968
		Fungi digest nearly any form of organic carbon	968
		Fungi are found in a wide range of environments	969
		Fungal reproduction	970
		Spores for travel and survival	970
		Life without sex	971
		Fungal phyla	971
		Early branches: microsporidians and chytrids	971
		Moulds: phylum Zygomycota	973
		Arbuscular mycorrhizas: phylum Glomeromycota	975
		The Dikarya have cells with paired nuclei: phyla Ascomycota and Basidiomycota	975
		Fungi without sex: anamorphs	979
		Fungal mutualisms	979
		Lichens	979
		Mycorrhiza: a fungus associated with plant roots	981
		Endophytes	982
		Fungi and animals	982
		Fungi and humans	983
		Eating and drinking fungi	983
		Poisonous fungi	984
		Allergens and fungal diseases	984
		Agriculture	985
		Biological control	985
		Fungi and biotechnology	985
		CHAPTER 39 Simple animals: sponges to flatworms	989
		Animals are multicellular, heterotrophic organisms	990
		What do we know of the origin and early evolution of animals?	990
		The origin of multicellularity	990
		Fossil faunas and what they tell us about the history of animals	990
		The phylogeny of modern groups of animals	992
		Protostomes and deuterostomes: two modes of development	992
		Parazoa: sponges (phylum Porifera) are an early lineage	993
		Sponges are aquatic filter feeders	994
		Eumetazoa: animals with true tissues	995

CONTENTS IN FULL *continued*

Radially symmetrical animals	995
Polyps and medusae: phylum Cnidaria	995
Jellyfish: class Scyphozoa	997
Box jellyfish: class Cubozoa	998
Hydras: class Hydrozoa	999
Sea anemones and corals: class Anthozoa	1000
Comb jellies: phylum Ctenophora	1002
Bilaterally symmetrical animals: simple protostomes	1002
Flatworms: phylum Platyhelminthes	1002
Free-living flatworms: class Turbellaria	1004
Ectoparasitic flukes: class Monogenea	1005
Endoparasitic flukes: class Trematoda	1005
Tapeworms: class Cestoda	1007
Proboscis worms: phylum Nemertea	1008

CHAPTER 40 Annelids, molluscs, nematodes and arthropods 1013

Increasing complexity among the protostomes	1014
Segmented worms: phylum Annelida	1014
The annelid body	1015
Functional implications of segmentation and a coelom	1015
Marine bristle worms: class Polychaeta	1017
Annelids with a clitellum: class Clitellata	1019
Chitons, oysters, snails and octopuses: phylum Mollusca	1020
Molluscan body plan	1021
Chitons have eight shell plates: class Polyplacophora	1022
Molluscs with a single shell plate: class Monoplacophora	1022
Filter feeding and the class Bivalvia	1023
Torsion and the class Gastropoda	1024
Squid and octopuses: class Cephalopoda	1025
The Cuticulata are the most species-rich clade of animals	1028
Roundworms: phylum Nematoda	1028
Joint-limbed animals with an exoskeleton: phylum Arthropoda	1030
Features of the arthropod body	1031
Chelicerate arthropods include spiders and scorpions	1032
Mandibulate arthropods: myriapods, crustaceans and insects	1033

CHAPTER 41 Echinoderms and chordates 1044

Echinoderms are a phylum of marine deuterostomes	1045
The echinoderm skeleton	1045
The water vascular system	1046
Reproduction, development and regeneration	1047
Echinoderms include five classes of marine animals with five-rayed symmetry	1048
Pharyngotremata are deuterostomes with pharyngeal slits	1049
Hemichordates: acorn worms and pterobranchs	1049

Chordates	1050
Tunicates: urochordates	1050
Lancelets: cephalochordates	1051
Craniates: chordates that evolved a head	1052
Jawless craniates: hagfishes and lampreys	1052
Jawed craniates: gnathostomes	1053
Cartilaginous fishes: chimaeras, sharks, skates and rays	1054
Ray-finned fishes have true bone and a swim bladder	1054
Tetrapods and their relatives are the Sarcopterygii	1056
Coelacanth and lungfishes: fleshy-finned fishes	1056
Amphibians: living on land and in water	1057
Amniotes have embryos with ponds of their own	1058
Turtles, terrapins and tortoises	1058
Snakes, lizards and the tuatara	1058
Archosaurians: crocodiles, dinosaurs and birds	1060
Mammals	1062
Primates	1066
The great apes	1068
Human evolution	1068
Walking upright: the first fossil hominins	1068
Robust fossil forms	1070
<i>Homo</i> : increase in brain size	1071
Multiple migrations out of Africa	1071

PART 6 ECOLOGY 1077

CHAPTER 42 Australian biota 1078

The Australian biota: southern connections	1079
Australia in Gondwana	1080
Evolution of Australian environments through the Cenozoic	1081
Changing climate and increased aridity	1081
Changing landforms and weathering of soils	1082
Increasing frequency of fire	1083
Quaternary ice ages: cool, arid periods	1084
Arrival of humans	1085
Modern Australian environments	1087
Terrestrial environments	1087
Marine environments	1087
Australian flora	1089
Dominance of sclerophylls ('hard' leaves)	1090
Succulent survivors	1091
Characteristics of some Australian flowering plants	1093
A unique southern fauna	1097
Insects with southern connections	1098
Biogeographic patterns of terrestrial vertebrates	1099
Adaptive radiation of frogs	1100

Australian reptiles	1101
Adaptive radiation in mammals	1102
CHAPTER 43 Population ecology	1111
What is a population?	1112
Distribution and abundance of populations	1112
Potential and realised distributions	1113
Density-independent population dynamics	1116
Exponential population growth in discrete time	1116
Modelling density-independent growth	1116
Environmental variability and exponential growth	1117
Exponential population growth in continuous time	1117
Density-dependent population dynamics	1119
Space-limited populations	1121
Age- and size-structured population dynamics	1122
Bioeconomics: managing exploited populations	1125
Viable population sizes for conservation	1126
CHAPTER 44 Living in communities	1132
Species coexist and interact in communities	1133
Community structure	1133
Species diversity	1133
Structural diversity of plant communities	1135
Interactions within communities	1136
Symbiosis	1137
Commensalism	1137
Mutualism	1138
Parasitism	1140
Predation	1140
Abundance of predators and prey	1140
Fruit eaters aid seed dispersal	1141
Predation and biological control	1142
Plant defences	1142
Animal defences	1143
Keystone predators	1144
Competition	1145
Ecological niche	1147
Niche overlap and character displacement	1148
Communities are not constant	1149
Succession is the replacement of one community by another	1149
Alternative pathways of change	1149
Disturbance affects many communities	1150
Fire promotes habitat variability	1150
Disturbance can promote diversity	1151
Humans can act as novel disturbances	1152
Communities are the result of many different interactions	1153
Biomes: communities on a global scale	1154
Gradients and ecotones	1154

CHAPTER 45 Ecosystems	1161
Feeding relationships shape ecosystems	1162
Food chains and food webs	1163
Ecological pyramids	1166
Pyramids of numbers	1166
Pyramids of biomass	1166
Pyramids of energy	1167
Why food chains are short	1168
Productivity of different ecosystems	1169
Productivity in ecosystems may change through time	1170
Biogeochemical cycles	1171
The water cycle	1171
Carbon cycle	1175
Nitrogen cycle	1177
Phosphorus cycle	1179
CHAPTER 46 Human impacts	1184
Humans in Australia	1185
Changing Australian environments	1185
Losing biodiversity	1185
Biodiversity hotspots	1188
Why conserve biodiversity?	1188
Land clearance and habitat fragmentation	1191
Introducing new species	1192
Impact of introduced animals	1192
Integrated pest management	1193
Impact of weeds	1194
Land and water degradation	1196
Fresh water is the key to life	1197
Holding on to soil	1197
Salinity	1198
Global pollution of the atmosphere: depleting ozone	1200
CFCs deplete ozone	1200
The ozone 'hole' over Antarctica	1201
Human impacts and global climate change	1201
The greenhouse effect and carbon dioxide as a major greenhouse gas	1201
Global temperature change	1202
Towards sustainability	1203
Illegal trade in endangered species	1204
Legislative and policy framework	1204
Managing natural communities for conservation	1204
Restoration ecology: resetting the clock	1205
Ecologically sustainable development	1206
Appendix: Classification of cellular organisms	1210
Glossary	1213
Credits	1269
Index	1273