

CONTENTS

<i>Preface</i>	xiii
Chapter 1 INTRODUCTION	1
Biology as a Science	2
THE SCIENTIFIC METHOD	2
The Rise of Modern Biological Science	4
Darwin's Theory	6
THE CONCEPT OF EVOLUTIONARY CHANGE	6
THE CONCEPT OF NATURAL SELECTION	8
The Variety of Organisms	11
MONERA	11
PROTISTA	12
PLANTAE	13
FUNGI	16
ANIMALIA	16
<i>Concepts in Brief</i>	21

PART I The Chemical and Cellular Basis of Life

Chapter 2 SOME SIMPLE INORGANIC CHEMISTRY	25
The Elements	26
ATOMIC STRUCTURE	26
Chemical Bonds	30
IONIC BONDS	30
COVALENT BONDS	32
BIOLOGICALLY IMPORTANT WEAK BONDS	35
Some Important Inorganic Molecules	36
WATER	36
CARBON DIOXIDE	39
OXYGEN	39
<i>Concepts in Brief</i>	40

Chapter 3 SOME SIMPLE ORGANIC CHEMISTRY

Hydrocarbons	41
Carbohydrates	42
SIMPLE SUGARS	42
DISACCHARIDES	43
POLYSACCHARIDES	44
<i>Cellulose Digestion in Ruminants</i>	46
Lipids	45
FATS	45
<i>Atherosclerosis and the Diet-Heart Hypothesis</i>	48
PHOSPHOLIPIDS	49
STEROIDS	49
Proteins	50
THE BUILDING BLOCKS AND PRIMARY STRUCTURE OF PROTEINS	50
<i>Determining the Primary Structure of a Protein</i>	51
THE SPATIAL CONFORMATION OF PROTEINS	52
CONJUGATED PROTEINS	56
Nucleic Acids	57
DEOXYRIBONUCLEIC ACID	57
RIBONUCLEIC ACID	58
Chemical Reactions	58
GENERAL CONDITIONS FOR CHEMICAL REACTIONS	58
FACTORS THAT INFLUENCE THE RATE OF CHEMICAL REACTIONS	59
Enzymes	61
ENZYMES AS HIGHLY SPECIFIC CATALYSTS	61
<i>Concepts in Brief</i>	64

Chapter 4 CELLS: UNITS OF STRUCTURE AND FUNCTION

The Cell Theory	66
MICROSCOPES AND THE STUDY OF CELLS	67
CELL SIZE	68
The Outer Boundaries of Cells	69
THE STRUCTURE OF THE CELL MEMBRANE	69
FUNCTION OF THE CELL MEMBRANE	72
CELL WALLS AND COATS	78
The Internal Structure of Cells	80
THE NUCLEUS	80
THE ENDOPLASMIC RETICULUM AND RIBOSOMES	82

THE GOLGI APPARATUS	84
MITOCHONDRIA	85
LYSOSOMES	86
MICROBODIES	86
PLASTIDS	86
VACUOLES	88
MICROFILAMENTS	88
MICROTUBULES	89
CENTRIOLES	90
CILIA AND FLAGELLA	90

Eucaryotic vs. Procaryotic Cells	91
"TYPICAL" EUKARYOTIC CELLS	91
PROCARYOTIC CELLS	94
<i>Concepts in Brief</i>	95

Chapter 5 MULTICELLULAR ORGANIZATION

Plant Tissues	97
MERISTEMATIC TISSUE	98
SURFACE TISSUE	99
FUNDAMENTAL TISSUE	100
VASCULAR TISSUE	101
Plant Organs and Organ Systems	102
Animal Tissues	102
EPITHELIUM	103
CONNECTIVE TISSUE	105
MUSCLE	106
NERVE	106
Animal Organs and Organ Systems	107
<i>Concepts in Brief</i>	108

Chapter 6 ENERGY TRANSFORMATIONS: PHOTOSYNTHESIS

Characteristics of Energy	110
Photosynthesis	110
HISTORICAL DEVELOPMENT	111
THE CHEMICAL NATURE OF PHOTOSYNTHESIS	112
LIGHT AND CHLOROPHYLL	113
CYCLIC PHOTOPHOSPHORYLATION	113
NONCYCLIC PHOTOPHOSPHORYLATION	116
CARBOHYDRATE SYNTHESIS BY THE CALVIN CYCLE	118
THE LEAF AS AN ORGAN OF PHOTOSYNTHESIS	120

Chemosynthesis	122	NUTRIENT PROCUREMENT BY FLATWORMS	160
<i>Concepts in Brief</i>	122	ANIMALS WITH COMPLETE DIGESTIVE TRACTS	160
 Chapter 7 ENERGY TRANSFORMATIONS: CELLULAR METABOLISM	124	THE DIGESTIVE SYSTEM OF HUMANS AND OTHER VERTEBRATES	162
Anaerobic Metabolism	125	ENZYMATIC DIGESTION IN HUMANS	166
GLYCOLYSIS	125	<i>The Digestion of Lactose by Human Adults</i>	169
FERMENTATION	127	<i>Concepts in Brief</i>	170
 Aerobic Metabolism (Respiration)	128	 Chapter 10 GAS EXCHANGE	171
OXIDATION OF PYRUVIC ACID TO ACETYL-COA	128	The Problem	171
THE KREBS CITRIC ACID CYCLE	128	Solutions in Terrestrial Plants	173
THE RESPIRATORY ELECTRON-TRANSPORT CHAIN	129	LEAVES	173
SUMMARY OF THE ATP YIELD OF THE RESPIRATION OF GLUCOSE	132	STEMS AND ROOTS	175
RESPIRATION OF FATS AND PROTEINS	132	Solutions in Aquatic Animals	176
MITOCHONDRIA AS ORGANELLES OF CELLULAR RESPIRATION	133	GILLS	177
BODY TEMPERATURE AND METABOLIC RATE	134	Solutions in Terrestrial Animals	180
<i>Concepts in Brief</i>	135	LUNGS	180
 PART II The Biology of Organisms		TRACHEAL SYSTEMS	183
 Chapter 8 NUTRIENT PROCUREMENT IN PLANTS	139	<i>Concepts in Brief</i>	184
Nutrient Requirements of Green Plants	140	 Chapter 11 INTERNAL TRANSPORT IN PLANTS	185
RAW MATERIALS FOR PHOTOSYNTHESIS	140	Organisms without Special Transport Systems	186
MINERAL NUTRITION	140	Vascular Plants	186
Nutrient Procurement by Green Plants	142	STRUCTURE OF STEMS	187
ROOTS AS ORGANS OF PROCUREMENT	142	THE ASCENT OF SAP	194
INSECTIVOROUS GREEN PLANTS	149	TRANSLOCATION OF SOLUTES	197
<i>Concepts in Brief</i>	150	<i>Concepts in Brief</i>	200
 Chapter 9 NUTRIENT PROCUREMENT IN HETEROTROPHIC ORGANISMS	151	 Chapter 12 INTERNAL TRANSPORT IN ANIMALS	201
Nutrients Required	152	The Insect Circulatory System	202
VITAMINS AND MINERALS	153	The Human Circulatory System	203
<i>Vitamin Deficiency and Its Treatment</i>	154	THE BLOOD CIRCUIT	204
Nutrient Procurement by Fungi	156	THE HEART	206
Nutrient Procurement by Protozoans and Animals	157	BLOOD PRESSURE	207
NUTRIENT PROCUREMENT BY PROTOZOANS	157	<i>Measuring Blood Pressure</i>	208
NUTRIENT PROCUREMENT BY COELENTERATES	159	CAPILLARY FUNCTION	209
		<i>Thromboembolic and Hypertensive Disease in Human Beings</i>	212
		THE LYMPHATIC SYSTEM	213

Blood	214	Chapter 15 CHEMICAL CONTROL IN ANIMALS	249
COMPOSITION OF THE BLOOD	214	Hormones in Mammals	249
BLOOD CLOTTING	215	THE PANCREAS AS AN ENDOCRINE ORGAN	250
ERYTHROCYTES AND THEIR FUNCTION	216	THE ADRENALS	254
HEMOGLOBIN AND ITS ROLE IN THE TRANSPORT OF OXYGEN	217	<i>Medical Use of Cortical Hormones</i>	256
THE ROLE OF HEMOGLOBIN IN TRANSPORT OF CARBON DIOXIDE	217	THE THYROID	256
LEUKOCYTES AND THEIR FUNCTIONS	218	THE PARATHYROIDS	258
<i>Concepts in Brief</i>	219	THE PITUITARY AND THE HYPOTHALAMUS	259
		THE PINEAL	262
Chapter 13 REGULATION OF BODY FLUIDS	220	The Mechanism of Hormonal Action	263
The Extracellular Fluids of Plants	221	THE ROLE OF CYCLIC AMP	263
The Vertebrate Liver	223	PROSTAGLANDINS	265
THE LIVER'S ROLE IN REGULATION OF THE BLOOD-SUGAR LEVEL	223	<i>Concepts in Brief</i>	266
THE LIVER'S ROLE IN THE METABOLISM OF LIPIDS AND AMINO ACIDS	224	Chapter 16 HORMONAL CONTROL OF VERTEBRATE REPRODUCTION	267
The Problem of Excretion and Salt and Water Balance in Animals	225	The Process of Sexual Reproduction	267
THE PROBLEM IN AQUATIC ANIMALS	225	The Human and Other Mammalian Reproductive Systems	270
THE PROBLEM IN TERRESTRIAL ANIMALS	227	THE GENITAL SYSTEM OF THE HUMAN MALE	270
Excretory Mechanisms in Animals	228	HORMONAL CONTROL OF SEXUAL DEVELOPMENT IN THE MALE	272
CONTRACTILE VACUOLES	228	THE GENITAL SYSTEM OF THE HUMAN FEMALE	273
FLAME-CELL SYSTEMS	228	HORMONAL CONTROL OF THE FEMALE REPRODUCTIVE CYCLE	276
NEPHRIDIA OF EARTHWORMS	229	HORMONAL CONTROL OF PREGNANCY	280
THE VERTEBRATE KIDNEY	230	HORMONAL CONTROL OF PARTURITION AND LACTATION	281
<i>The Kidneys as a Factor in High Blood Pressure</i>	232	<i>Concepts in Brief</i>	282
MALPIGHIAN TUBULES	233	Chapter 17 NERVOUS CONTROL	284
<i>Concepts in Brief</i>	234	Evolution of Nervous Systems	285
Chapter 14 CHEMICAL CONTROL IN PLANTS	236	IRRITABILITY	285
Plant Hormones	237	SIMPLE NERVOUS PATHWAYS	285
AUXINS	237	NERVE NETS AND RADIAL SYSTEMS	287
GIBBERELLINS	242	EVOLUTIONARY TRENDS IN BILATERAL NERVOUS SYSTEMS	287
CYTOKININS	243	Nervous Pathways in Vertebrates	289
INHIBITORS	243	NEURONS OF VERTEBRATES	291
ETHYLENE	243	REFLEX ARCS	292
CONTROL OF FLOWERING	244	THE AUTONOMIC NERVOUS SYSTEM	294
<i>Concepts in Brief</i>	248	Transmission of Nerve Impulses	296
		CONDUCTION ALONG NEURONS	296

TRANSMISSION ACROSS SYNAPSES	300
TRANSMISSION BETWEEN THE MOTOR AXON AND THE EFFECTOR	303
<i>Concepts in Brief</i>	305

Chapter 18 SENSORY RECEPTION AND PROCESSING 306

The Major Senses	306
MECHANISM OF RECEPTOR FUNCTION	306
SENSATIONS	307
SENSORY RECEPTORS OF THE SKIN, SKELETAL MUSCLES, AND VISCERA	308
THE SENSES OF TASTE AND SMELL	309
THE SENSE OF VISION	311
THE SENSE OF HEARING	317
THE SENSES OF EQUILIBRIUM AND ACCELERATION	320
The Brain	320
EVOLUTION OF THE VERTEBRATE BRAIN	321
THE MAMMALIAN FOREBRAIN	323
<i>Concepts in Brief</i>	327

Chapter 19 EFFECTORS AND ANIMAL LOCOMOTION 329

The Structural Arrangements of Muscles and Skeletons	330
ANIMALS WITH HYDROSTATIC SKELETONS	330
ANIMALS WITH HARD JOINTED SKELETONS	331
<i>Red and White Muscle</i>	334

The Physiology of Muscle Activity	336
THE GENERAL FEATURES OF SKELETAL-MUSCLE CONTRACTION	336
THE MOLECULAR BASIS OF CONTRACTION	338
THE CONTROL OF CONTRACTION	342
<i>Concepts in Brief</i>	345

Chapter 20 ANIMAL BEHAVIOR 346

Analysis of Behavior	346
FUNDAMENTAL ELEMENTS OF BEHAVIOR	347
INHERITANCE AND LEARNING IN BEHAVIOR	349
MOTIVATION	354
THE CONCEPT OF SIGN STIMULI	356

Animal Communication	358
COMMUNICATION BY SOUND	358
COMMUNICATION BY CHEMICALS	361
COMMUNICATION BY VISUAL DISPLAYS	363
COMMUNICATION IN HONEYBEES	367
SYMBOLISM IN COMMUNICATION	368

Biological Clocks 369

Orientation Behavior	371
ORIENTATION BY VISUAL LANDMARKS	371
ORIENTATION BY ECHOLOCATION	371
AVIAN ORIENTATION AND NAVIGATION	372

Social Behavior (Sociobiology)	374
SPATIAL FACTORS THAT INFLUENCE SOCIALITY	375
INSECT SOCIETIES	376
VERTEBRATE SOCIETIES	378

The Evolution of Behavior	381
THE DERIVATION OF BEHAVIOR PATTERNS	381
THE GENETICS OF BEHAVIOR	385
<i>Concepts in Brief</i>	386

PART III The Perpetuation of Life

Chapter 21 CELLULAR REPRODUCTION 391

Mitotic Cell Division	393
MITOSIS	393
CYTOKINESIS	398
Meiotic Cell Division	400
THE PROCESS OF MEIOSIS	401
THE TIMING OF MEIOSIS IN THE LIFE CYCLE	404
THE ADAPTIVE SIGNIFICANCE OF SEXUAL REPRODUCTION	406
<i>Concepts in Brief</i>	407

Chapter 22 PATTERNS OF INHERITANCE 409

Monohybrid Inheritance	409
EXPERIMENTS BY MENDEL	409
THE TEST CROSS	414
INTERMEDIATE INHERITANCE	415
Dihybrid and Trihybrid Inheritance	416
THE BASIC DIHYBRID RATIO	416
GENE INTERACTIONS	418

Penetrance and Expressivity	419	Post-transcriptional Control	466
Multiple Alleles	420	Cancer: A Failure of Normal Cellular Controls	467
Mutations and Deleterious Genes	423	The Immune Response	470
Sex and Inheritance	424	<i>Concepts in Brief</i>	475
SEX DETERMINATION	424		
SEX-LINKED CHARACTERS	425		
GENES ON THE Y CHROMOSOME	428		
SEX-INFLUENCED CHARACTERS	428		
Linkage	428	Chapter 25 DEVELOPMENT: FROM EGG TO ORGANISM	477
Chromosomal Alterations	432	Development of a Multicellular Animal	477
STRUCTURAL ALTERATIONS	432	FERTILIZATION	477
CHANGES IN CHROMOSOME NUMBER	432	EMBRYONIC DEVELOPMENT	478
<i>Trisomy in Humans</i>	433	<i>Development of the Human Embryo</i>	484
		POSTEMBRYONIC DEVELOPMENT	485
Genetics Problems	433	Development of a Flowering Plant	489
<i>Concepts in Brief</i>	437	THE SEED AND ITS GERMINATION	489
		GROWTH AND DIFFERENTIATION OF THE PLANT BODY	492
		Differentiation in Plants and Animals	496
Chapter 23 THE NATURE OF THE GENE AND ITS ACTION	438	THE EFFECTS OF CLEAVAGE ON DIFFERENTIATION	496
The Chemical Nature of the Genetic Material	438	TISSUE INTERACTIONS IN DEVELOPMENT	497
THE MOLECULAR STRUCTURE OF DNA	441	THE GRADUALNESS OF DIFFERENTIATION	501
The Replication of DNA	443	IS DIFFERENTIATION REVERSIBLE?	502
THE THEORY OF WATSON AND CRICK	443	<i>Concepts in Brief</i>	503
The Mechanism of Gene Action	444		
THE ONE GENE-ONE ENZYME HYPOTHESIS	444	PART IV The Biology of Populations and Communities	
THE SYNTHESIS OF PROTEINS	445		
THE GENETIC CODE	447	Chapter 26 EVOLUTION	509
TRANSFER RNA AND ITS ROLE IN TRANSLATION		Evolution as Change in the Genetic Makeup of Populations	509
OF MESSENGER RNA	449	GENETIC VARIATION AS THE RAW MATERIAL FOR	
THE READING OF THE CODE BY THE RIBOSOMES	450	EVOLUTION	509
A SUMMARY OF THE MODEL	451	THE GENE POOL AND FACTORS THAT AFFECT ITS	
Mutations	452	EQUILIBRIUM	511
Now What Is a Gene?	453	<i>The Hardy-Weinberg Equilibrium</i>	514
Extrachromosomal Inheritance	455	THE ROLE OF NATURAL SELECTION	516
CYTOPLASMIC ORGANELLES	455		
PLASMIDS AND RECOMBINANT DNA	455	Adaptation	522
<i>Concepts in Brief</i>	458	ADAPTATIONS FOR POLLINATION IN FLOWERING PLANTS	523
		DEFENSIVE ADAPTATIONS OF ANIMALS	525
Chapter 24 DEVELOPMENT: ASPECTS OF CELLULAR CONTROL	459	SYMBIOTIC ADAPTATIONS	530
The Control of Gene Transcription	459	ALTRUISTIC BEHAVIOR	532
CONTROL OF GENE TRANSCRIPTION IN BACTERIA	460	Species and Speciation	534
CONTROL OF GENE EXPRESSION IN EUCARYOTIC CELLS	462	UNITS OF POPULATION	534
		SPECIATION	537

The Concept of Phylogeny	546	CYANOBACTERIA	628
DETERMINING PHYLOGENETIC RELATIONSHIPS	546	PROCHLOROPHYTA	630
PHYLOGENY AND CLASSIFICATION	549	<i>Concepts in Brief</i>	631
<i>Concepts in Brief</i>	551		
 Chapter 27 ECOLOGY	553	 Chapter 30 THE PROTISTAN KINGDOM	632
Populations as Units of Structure and Function	554	Animal-like Protista	632
POPULATION SIZE AND DISTRIBUTION	554	THE FLAGELLATES (MASTIGOPHORA)	633
POPULATION GROWTH	555	THE AMOEBOID PROTOZOA (SARCODINA)	633
POPULATION REGULATION	559	THE PARASITIC PROTOZOA (SPOROZOA)	634
		THE CILIATE PROTOZOA (CILIATA)	636
The Economy of Ecosystems	563	Funguslike Protista	637
THE FLOW OF ENERGY	563	THE SLIME MOLDS (GYMNOMYCOTA)	637
CYCLES OF MATERIALS	566	Plantlike Protista	639
THE ROLE OF SOILS	573	THE EUGLENOIDS (EUGLENOPHYTA)	639
		THE YELLOW-GREEN ALGAE, THE GOLDEN-BROWN ALGAE, AND THE DIATOMS (CHRYSTOPHYTA)	639
The Biotic Community	576	THE DINOFLAGELLATES (PYRRROPHYTA)	640
DOMINANCE, DIVERSITY, AND COMMUNITY STABILITY	576	<i>Concepts in Brief</i>	641
ECOLOGICAL SUCCESSION	578		
BIOMES	582		
Biogeography	588	 Chapter 31 THE PLANT KINGDOM	642
BIOGEOGRAPHIC REGIONS OF THE WORLD	589	The Green Algae (Chlorophyta)	643
<i>Concepts in Brief</i>	594	THE EVOLUTION OF MULTICELLULARITY IN PLANTS	645
 PART V The Genesis and Diversity of Organisms		The Brown Algae (Phaeophyta)	648
		The Red Algae (Rhodophyta)	650
 Chapter 28 THE ORIGIN AND EARLY EVOLUTION OF LIFE	599	The Movement onto Land	651
The Origin of Life	599	The Liverworts, Hornworts, and Mosses (Bryophyta)	652
<i>The Possibility of Life on Other Planets</i>	607	The Vascular Plants (Tracheophyta)	654
Precambrian Evolution	610	PSILOPSIDA	654
THE FOSSIL RECORD	610	THE CLUB MOSSES (LYCOPSIDA)	655
THE ORIGIN OF EUCARYOTIC CELLS	611	THE HORSETAILS (SPHENOPSIDA)	656
The Kingdoms of Life	613	THE FERNS (PTEROPSIDA)	656
<i>Concepts in Brief</i>	615	<i>The Evolution of Sporophyte Dominance</i>	656
		THE SEED PLANTS (SPERMOPSIDA)	659
 Chapter 29 VIRUSES AND MONERA	617	Summary of Evolutionary Trends	666
Viruses	617	<i>Concepts in Brief</i>	667
Monera	621	 Chapter 32 THE FUNGAL KINGDOM	668
BACTERIA (SCHIZOMYCETES)	621	The Water Molds (Oomycota)	670
		The Conjugation Fungi (Zygomycota)	670

The Sac Fungi (Ascomycota)	672	The Coelomate Protostomia	688
The Club Fungi (Basidiomycota)	673	MOLLUSCA	688
Fungi Imperfecti	674	THE SEGMENTED WORMS (ANNELIDA)	692
<i>Concepts in Brief</i>	674	ARTHROPODA	693
 Chapter 33 THE ANIMAL KINGDOM	675	The Deuterostomia	699
The Sponges (Porifera)	675	ECHINODERMATA	699
The Radiate Phyla	676	HEMICHORDATA	702
COELENTERATA, OR CNIDARIA	677	THE RELATIONSHIPS BETWEEN ECHINODERMS, HEMICHORDATES, AND CHORDATES	703
The Origin of Multicellularity	679	INVERTEBRATE CHORDATA	705
The Acoelomate Bilateria	680	VERTEBRATE CHORDATA	707
THE FLATWORMS (PLATYHELMINTHES)	680	EVOLUTION OF THE PRIMATES	717
THE PROBOSCIS WORMS (NEMERTINA)	684	THE EVOLUTION OF HUMAN BEINGS	720
Divergence of the Protostomia and Deuterostomia	684	<i>Concepts in Brief</i>	727
The Pseudocoelomate Protostomia	686	 Appendix: A Classification of Living Things	A1
ASCHELMINTHES	686	Glossary	A7
		Index	A23