

Contents

CHAPTER 1 INTRODUCING BIOLOGY 1 The different branches of biology What is life? Methods of investigation in biology Conducting biological experiments
Organisms Some basic concepts

CHAPTER 2 STRUCTURE AND FUNCTION IN CELLS 13 The cell theory An animal cell as seen with the light microscope A plant cell as seen with the light microscope The electron microscope **Fine Structure of the Cell 17** Endoplasmic reticulum Golgi body Mitochondria Lysosomes Plasma membrane Microvilli Cilia and flagella Other structures with the same organization as cilia Microtubules Fine structure of plant cells Analysis of function of cell organelles The reality of cell structures **Molecular Structure of the Plasma Membrane 27** The fluid—mosaic model Pores in the cell membrane **The Diversity of cells 30**

CHAPTER 3 TISSUES, ORGANS AND ORGANIZATION 32 Classification of tissues Epithelium: a simple animal tissue Connective tissue Skeletal tissue Other animal tissues Plant tissues The differences between animal and plant tissues Organs and organ systems Levels of organization Colonial organization The advantages of the multicellular state

CHAPTER 4 MOVEMENT IN AND OUT OF CELLS 47 **Diffusion 47** Diffusion and the structure of organisms **Osmosis 49** Cells as osmometers Osmotic potential Water potential Osmosis and plant cells Plant water relations Wilting **Active Transport 55 Phagocytosis 56 Pinocytosis 57**

CHAPTER 5 THE CHEMICALS OF LIFE 58 **Water 58** Water as a solvent Water's thermal properties Surface tension Water's freezing properties **Acids and Bases 60 Salts 61 Organic Compounds 63** The construction of organic molecules **Carbohydrates 63** The hexose sugars Building up complex carbohydrates Starch and glycogen Cellulose Lignification The commercial importance of cellulose Interconversion of carbohydrates Other sugar compounds **Lipids 69** The building up of a lipid The functions of lipids Lipids and the diet Steroids **Proteins 73** The building up of proteins The functions of proteins Proteins and the diet The analysis of proteins Working out the shape of a protein molecule The α helix Haemoglobin and myoglobin Porphyrins The general functions of proteins **Vitamins 79**

CHAPTER 6 CHEMICAL REACTIONS IN CELLS 81 Analysing metabolic pathways Types of chemical reactions in cells **Energy 85** Energy conversions Activation energy The speed of biological reactions **Enzymes 87** Naming and classifying enzymes The properties of enzymes How enzymes work Enzyme inhibitors Allosteric enzymes Cofactors and prosthetic groups

Part I Organization in Cells and Organisms

Part II

The Maintenance of Life

CHAPTER 7 THE RELEASE OF ENERGY 95 The general nature of respiration The composition of inspired and expired air Studying the pattern of respiration Measuring the oxygen consumption of a small organism Respiratory quotient Measuring the energy output of the body The metabolic rate in different circumstances Food and energy Man's energy requirements The vital link: ATP Energy from sugar The hydrogen carrier system The pathway by which sugar is broken down Glycolysis The citric acid cycle Respiration without oxygen Energy from fat Energy from protein The rôle of ATP The control of sugar breakdown

CHAPTER 8 GASEOUS EXCHANGE IN ANIMALS 112 Specialized respiratory surfaces **Gaseous Exchange in Man 114** Structure of the lungs The respiratory cycle Exchanges across the alveolar surface **Gaseous Exchange in Fishes 117** Structure of the dogfish's gills Counterflow and parallel flow Gaseous exchange in teleost fishes Ventilation of the gills **Gaseous Exchange in Insects 122** **The Nervous Control of Breathing 123**

CHAPTER 9 HETEROTROPHIC NUTRITION 124 **General Considerations 124** Physical and chemical digestion How digestive enzymes work Absorption and assimilation The site of digestion **Feeding and Digestion in Man 127** In the buccal cavity Down to the stomach Into the duodenum Absorption **Nutrition in Other Heterotrophs 133** Herbivores Carnivorous animals Carnivorous plants Liquid feeders Microphagous feeders

CHAPTER 10 AUTOTROPHIC NUTRITION 140 Different types of autotrophic nutrition The importance of photosynthesis The raw materials of photosynthesis The products of photosynthesis **The Conditions required for Photosynthesis 142** Carbon dioxide Water Light Temperature Chlorophyll Interaction of factors controlling photosynthesis Photosynthesis and the environment **The Site of Photosynthesis 146** The chloroplast pigments Structure of the chloroplast Structure of the leaf The leaf as an organ of photosynthesis **The Chemistry of Photosynthesis 153** Photosynthesis as a two-stage process The light stage The dark stage The exact sites of the light and dark stages C_3 and C_4 plants Photorespiration **Autotrophic Bacteria 159** Photosynthetic bacteria Chemosynthetic bacteria Fixation of nitrogen

CHAPTER 11 TRANSPORT IN ANIMALS 162 **Blood 162** Plasma Red blood cells Carriage of oxygen Myoglobin and other blood pigments Carriage of carbon dioxide The haemoglobin molecule as a carrier **The Mammalian Circulation 167** The heart The beating of the heart Innervation of the heart Blood flow through the arteries and veins The capillaries **Single and Double Circulations 174** **Open and Closed Circulations 175**

CHAPTER 12 UPTAKE AND TRANSPORT IN PLANTS 177 **Uptake of Carbon Dioxide 177** The stomata The mechanism of stomatal opening and closure **Uptake and Transport of Water 180** Transpiration Measuring the rate of transpiration The evaporating surface Factors affecting the rate of transpiration Water movement in the leaf Structure of the root Uptake of water by the roots Into the vascular tissues of the root From root to leaf Structure of the stem Xylem tissue The xylem and water transport The ascent of water up the stem The functions of transpiration Water stress **Uptake of Mineral Salts 192** Special methods of obtaining essential elements **Transport of Organic Substances 193** Phloem tissue Establishing the site of translocation The mechanism of translocation

CHAPTER 13 THE PRINCIPLES OF HOMEOSTASIS 200 The meaning of internal environment The formation of intercellular fluid What factors must be kept constant? The homeostatic control of sugar The rôle of insulin Diabetes What controls the secretion of insulin? Some generalizations about homeostasis **The Mammalian Liver 206** Functions of the liver Structure of the liver

CHAPTER 14 EXCRETION AND OSMOREGULATION 210 **The Mammalian Kidney 210** Structure of the nephron Filtration in Bowman's capsule Reabsorption in the tubules Fine structure of the tubule cells The rôle of the loop of Henle The kidney as a regulator **Excretion and Osmoregulation in Other Animals 220** Marine invertebrates From sea to fresh water Contractile vacuole Antennal glands Fresh water fishes From fresh water back to the sea Marine elasmobranchs Migratory fishes From fresh water to land **Osmoregulation in Plants 228** **Control of Ions 230**

CHAPTER 15 TEMPERATURE REGULATION 232 How heat is lost and gained Response to cold by an endothermic animal Response to heat by an endothermic animal The rôle of the brain in temperature regulation The effect of lowering and raising the environmental temperature Temperature regulation and the environment Behavioural control of body temperature Temperature and hibernation Temperature tolerance Temperature control in plants

CHAPTER 16 CONTROL OF RESPIRATORY GASES 243 The rôle of breathing and the circulation The effects of fluctuations in oxygen and carbon dioxide Carbon dioxide as the stimulus in the control process The rôle of the brain The control of blood pressure Cerebral control of respiration and circulation Adjustment to high altitudes Adjustments during exercise Response to total oxygen deprivation

CHAPTER 17 DEFENCE AGAINST DISEASE 250 Preventing entry Phagocytosis Antibody formation Lymph nodes The immune response The rôle of the thymus gland Allergy and stress Blood groups How are antibodies produced? Rejection of grafts Transplantation surgery Interferon Chemotherapy and antibiotics

Part III

Adjustment and Control

Part IV

Response and Coordination

CHAPTER 18 NERVOUS AND HORMONAL COMMUNICATION 262 **The Nerve Cell and its Impulse 262** Structure of nerve cells Investigating the nerve impulse The electrical nature of the nerve impulse Ionic basis of the nerve impulse **Properties of Nerves and Nerve Impulses 267** Stimulation The all-or-nothing law Refractory period Transmission speed Myelin sheath Axon diameter **The Synapse 271** Structure of the synapse Transmission across the synapse The transmitter substance The nerve-muscle junction The action of drugs and poisons Noradrenaline Summation and facilitation Inhibition Accommodation The rôle of synapses in the nervous system **Reflex Action 275** Structure of a generalized reflex arc The vertebrate reflex arc **Organization of the Nervous System 277** The vertebrate CNS The peripheral nerves The autonomic nervous system Functions of the vertebrate brain in general Functions of the main parts of the brain in a fish Functions of the main parts of the brain in mammals Localization in the cortex **The Primitive Nervous System 289** Interneural and neuromuscular facilitation Through-conduction The rôle of the brain in lower animals Cephalization **Hormonal Communication 294** Hormonal compared with nervous communication Principles of hormone action illustrated by the thyroid gland Control of thyroxine production The rôle of the pituitary gland Neurosecretion How hormones control cells

CHAPTER 19 RECEPTION OF STIMULI 298 **Sensory Cells 299** Functioning of a sensory cell How does a receptor cell work? Frequency of discharge Adaptation Fusion of stimuli The initial events in the reception of stimuli Mutual inhibition Inhibition through efferent nerves Sensitivity Precision **Sense Organs 305** The mammalian eye The retina Colour vision The compound eye The mammalian ear Hearing Balance

CHAPTER 20 EFFECTORS 314 Different types of muscle **Properties of Skeletal Muscle 315** The single twitch Summation Tetanus Fatigue Electrical activity in muscle **How Muscle Contracts 317** The light microscope structure of muscle The fine structure of muscle The chemistry of muscle The sliding filament hypothesis What propels the filaments? Muscle spindles Tendon organs **Other Effectors 324** Chromatophores Electric organs Light-producing organs The nematoblast: an independent effector

CHAPTER 21 LOCOMOTION 326 Skeleton and muscles **Movement in Water 327** Propulsion in fishes Support in fishes Buoyancy in bony fishes Stability in fishes The action of cilia and flagella **Movement on Land 332** The musculo-skeletal basis of locomotion in tetrapods Propulsion in tetrapods Support in tetrapods Stability in tetrapods **Movement in Air 337** Flight in birds Flight in insects **Amoeboid Movement 341**

CHAPTER 22 BEHAVIOUR 343 A word about techniques Types of behaviour **Reflex Action 344** Escape responses Analysis of the earthworm's escape response Escape response of the squid **Orientation 347** Kinesis Taxis **Analysis of Species-characteristic Behaviour 349** The rôle of stimuli Releasers Stimulus selection The function of releasers Synchronization in sexual behaviour Motivation Pheromones The rôle of hormones The hypothalamus and behaviour Displacement activity Vacuum activity **Learning 357** Habituation Associative learning The conditioned reflex Trial and error learning Learning and the octopus brain A neural theory of learning A biochemical theory of learning Exploratory learning Imprinting Insight learning

Part V

Reproduction, Development and Heredity

CHAPTER 23 CELL DIVISION 366 **Mitosis 366** Observing mitosis Interphase Prophase Metaphase Anaphase Telophase The essential principle underlying mitosis The rôle of mitosis **Meiosis 372** The rôle of meiosis The essential principle underlying meiosis Prophase I Metaphase I Anaphase I Telophase I The second meiotic division The importance of meiosis in variation Chiasmata Observing meiosis The differences between mitosis and meiosis

CHAPTER 24 REPRODUCTION 378 The genetic importance of sex: bacterial conjugation Evolutionary development of gametes The spermatozoon The egg cell Fertilization Evolution of reproductive methods **Sexual Reproduction in Man 384** Gametogenesis Histology of the testis Histology of the ovary What brings sperm and eggs together? Development of the zygote The sexual cycle In the event of pregnancy The sexual cycle in other mammals Sexual activity in the human male **Sexual Reproduction in the Flowering Plant 393** Structure of the flower Inside the stamen Inside the carpel Transfer of pollen Growth of the pollen tube and fertilization After fertilization The flowering plant compared with other organisms **Self Versus Cross Fertilization 398** **Parthenogenesis 400** **Asexual Reproduction 401** Fission Spore formation Budding Fragmentation Vegetative propagation **Dispersal 404**

CHAPTER 25 THE LIFE CYCLE 406 The life cycle of man Alternation of generations The life cycles of moss and fern Reduction of the sporophyte or gametophyte Club mosses and horsetails Flowering plants and conifers Alternation of generations in animals?

CHAPTER 26 PATTERNS OF GROWTH AND DEVELOPMENT 412 **Growth 412** Measuring growth The growth curve Rate of growth Percentage growth Intermittent growth in arthropods **Animal Development 415** Cleavage Gastrulation Formation of neural tube and notochord Formation of mesoderm Origin of the coelom Further development of mesoderm and coelom Development of birds and mammals: the extra-embryonic membranes Larval forms Metamorphosis **Development in the Flowering Plant 423** Types of germination The physiology of germination Growth and development of the shoot and root Secondary growth

CHAPTER 27 THE CONTROL OF GROWTH 430 **The Control of Plant Growth 431** Evidence for involvement of a hormone Auxins Response to gravity Response to light Other responses Mode of action of auxins Other auxin effects Gibberellins Kinins Abscisin Ethylene Temperature and plant growth Light and plant growth Photoperiodism **Control of Growth in Animals 442** Action of a growth hormone illustrated by insects Metamorphosis **Dormancy and Suspended Growth 444** Survival during dormancy The mechanism of dormancy

CHAPTER 28 MENDEL AND THE LAWS OF HEREDITY 448 Mendel **Monohybrid Inheritance 449** Conclusions from the monohybrid cross Genes and their transmission In terms of probability The rôle of chance Mendel's first law: the law of segregation Explanation of Mendel's first law Breeding true Test cross Monohybrid inheritance in man **Dihybrid Inheritance 456** Conclusions from the dihybrid cross Mendel's second law: the law of independent assortment In terms of probability Relationship between genotype and phenotype Test cross Explanation of Mendel's second law Independent assortment in the fruit fly **Mendel in Retrospect 461**

CHAPTER 29 CHROMOSOMES AND GENES 462 Linkage Linkage groups and chromosomes Sex determination Sex linkage Sex linkage and the Y chromosome Crossing-over Explanation of crossing-over Locating genes on chromosomes Can genes be seen? Multiple alleles Genetics and the law Degrees of dominance The sickle-cell allele Gene action Lethal alleles Interaction of genes

CHAPTER 30 THE NATURE OF THE GENE 480 Evidence that nucleic acid is involved The structure of nucleic acids The Watson-Crick hypothesis Replication of the DNA molecule Conservative versus semi-conservative replication DNA replica-

tion and mitosis The essential rôle of DNA DNA and protein synthesis DNA as a code for proteins How does DNA communicate with the cytoplasm? Formation of messenger RNA The assembly of a protein The rôle of the ribosomes Evidence for DNA's control of protein synthesis Is the code overlapping or non-overlapping? Transcription and translation of the genetic code DNA's control over the cell

CHAPTER 31 GENES AND DEVELOPMENT 502 The importance of the nucleus The problem of multicellular organisms The rôle of the cytoplasm The fate of cells in the blastula Tissue culture and grafting Spemann and Mangold's experiment Organizers The chemical nature of organizers The rôle of DNA in development Chromosome puffs Gene switching The Jacob-Monod hypothesis of gene action The possibility of cytoplasmic control The rôle of the environment The formation of ribosomes: the rôle of the nucleolus Senescence

CHAPTER 32 THE ORGANISM AND ITS ENVIRONMENT 520 From biosphere to ecological niche The physical environment The biotic environment The concept of the ecosystem Population growth Environmental resistance Maintenance of populations Sudden changes in populations Control of the human population Succession The cycling of matter and flow of energy The carbon, oxygen and nitrogen cycles Food chains and food webs Pyramids of biomass and numbers Autecology Rhythms and the environment Exploitation and conservation The effect of man on the ecosystem Pollution

CHAPTER 33 ASSOCIATIONS BETWEEN ORGANISMS 544 Parasitism Adjustment between parasite and host Parasitic adaptations Parasites and man Commensalism Symbiosis Some questions concerning these associations Social animals Interaction between individuals

CHAPTER 34 EVOLUTION IN EVIDENCE 560 Darwin and the theory of evolution What did Darwin do? **Distribution Studies 561** Continental distribution Explanation of continental distribution Evidence for migration and isolation The Australian fauna Continental drift Oceanic islands The Galapagos islands Darwin's finches Isolating barriers **Comparative Anatomy 569** The pentadactyl limb Divergent evolution Reconstructing an evolutionary pathway: the vertebrate heart and arterial arches Convergent evolution **Taxonomy – the Classification of Organisms 574** The basis of a natural classification Classification of the chordates **Embryology 577** The tadpole larva of sea squirts The connection between annelids and molluscs Evolution and embryology: a warning **Cell Biology 578** Distribution of phosphagens Distribution of blood pigments Serological tests **Palaeontology 580** How fossils are formed Reconstructing evolutionary pathways from the fossil record Dating fossil remains The evolution of horses Evolution of the vertebrate ear ossicles

CHAPTER 35 THE MECHANISM OF EVOLUTION 588 Summary of Darwin's theory Lamarck's theory The Darwinian and Lamarckian theories compared **Variation 590** The causes of genetic variation Reshuffling of genes The rôle of reshuffling of genes in evolution What are mutations? The spread of mutations through a population The types of mutation Chromosome mutations Polyploidy Gene mutations Different kinds of gene mutation The importance of mutations in evolution **The Struggle for Existence 601** Populations and evolution **Natural Selection 602** The action of natural selection on genes Natural selection as an agent of constancy as well as change Natural selection in action Polymorphism Natural selection and population genetics The effect of isolation on gene frequency Application of the Hardy-Weinberg principle **The Origin of Species 611** The importance of isolation Isolating mechanisms The emergence of new species Evolution in retrospect Artificial selection

CHAPTER 36 SOME MAJOR STEPS IN EVOLUTION 617 Reflections on the origin of life Synthesis of organic molecules The first organisms Development of autotrophs Aerobic respiration and the development of secondary heterotrophs The divergence of animals and plants The problem of bacteria and viruses Origin of multicellular organisms Larval forms and evolution The colonization of dry land Evolutionary trends in animals and plants The emergence of man Alternatives to evolution

Part VI

Ecology and Evolution

Appendixes

I	Outline Classification of the Animal Kingdom	630
II	Outline Classification of the Plant Kingdom	631
III	Alternative Classifications	631
IV	Size Scale	632
V	Conversions to S.I. Units	632
VI	Formulae of the Naturally Occurring Amino Acids	633
VII	Glycolysis and the Krebs Cycle	634
VIII	Vitamins Required by Man	636
	SUGGESTIONS FOR FURTHER READING	637
	INDEX	647