

An environmental perspective

Patrick J. Butler

University of Birmingham, UK

J. Anne Brown

University of Exeter, and Aquatonics Ltd, UK

D. George Stephenson

La Trobe University, Australia

John R. Speakman

University of Aberdeen, UK, and Chinese Academy of Sciences, PR China



Contents

Part 1 Animals and their environment 3 1 The diversity of animals and their interactions with natural environments 1.1 What is environmental animal physiology? 1.2 Natural environments: where and under 9 what conditions do animals live? 1.3 How animal groups are related to each other 19 1.4 Animal diversity 25 1.5 Environmental change and animal diversity 36 2 Energy metabolism: generating energy from food 45 2.1 What is energy? 45 48 2.2 Metabolism, energy metabolism and metabolic rates 2.3 Energy intake from food 66 2.4 Intermediary metabolism involved in extracting energy 81 from foodstuff Cells and organisms, and their interactions with 3 91 their environment 3.1 Physical principles govern the flow of heat and the movement of ions and molecules in animals 91 3.2 General properties of animal cells 99 3.3 Interactions of animals with their environments 113

Part 2 Water and salts 123

4	Bod	ly fluid regulation: principles and processes	124
	4.1	Animal body fluids	124
	4.2	Transepithelial transport	131
	4.3	Regulation of cell volume	141
5	Osm	notic and ionic regulation in aquatic animals	149
	5.1	Marine animals	149
	5.2	Animals living in freshwater habitats	170
	5.3	Osmoregulation in changing salinities	185
6	Water balance of land animals		195
	6.1	Water loss from animals living on land	195
	6.2	Balancing water loss	226
7	Kidneys and excretion		243
	7.1	Production of the primary urine	243
	7.2	Kidney tubules and their functions	256
	7.3	Invertebrate nephridia	275
	7.4	Nitrogenous excretion	286

Part 3 Temperature

4 5

303

437

8	Temperature and the principles of heat exchange		304
	8.1	The effect of temperature on chemical reactions	304
	8.2	The effect of temperature on biological processes	307
	8,3	Environmental temperature variation	313
	8.4	General processes of heat exchange	315
	8.5	How do we describe different	
		thermoregulatory strategies?	323
9	Temperature regulation in ectotherms		326
	9.1	Thermal relations of ectotherms with their	
		environments	326
	9.2	Surviving cold or subzero conditions	344
	9.3	Temperature change over three timeframes:	
		implications for tissue functioning in ectotherms	364
10	Temperature regulation in endotherms		382
	10.1	Heat requirements of endotherms	382
	10,2	How endotherms regulate their body	
		temperature	385
	10.3	Endothermic fish, reptiles and insects	422

Part 4 Oxygen

11	The respiratory gases, gas exchange and transport	438
	11.1 The respiratory gases	438
	11.2 Principles of gas exchange and transport	449
12	Respiratory systems	456
	12.1 Types of gas exchanger	456
	12.2 Gas exchange in water	457
	12.3 Gas exchange in air	469
	12.4 Tracheal system of insects	498
13	Transport in respiratory systems	
	and acid-base balance	511
	13.1 Transport of oxygen and carbon dioxide	511
	13.2 Transport and storage of metabolic substrates	536
	13.3 Acid-base balance	542
14	Cardiovascular systems	553
	14.1 General characteristics of circulatory systems	553
	14.2 Fluid dynamics	571
	14.3 Circulatory systems of invertebrates	577
	14.4 Circulatory systems of vertebrates	583

Contents	vii

15	Environmental and behavioural influences on the	
	cardiorespiratory system	604
	15.1 Responding to a change in oxygen demand and supply	604
	15.2 Responding to an increase in demand for oxygen	605
	15.3 Responding to a decrease in oxygen supply	636
	15.4 Responding to a decrease in oxygen	
	demand—hibernation	655

Part 5 Coordination and integration 663

16	Neurons, nerves and nervous systems	664
	16.1 Nervous systems in animals	664
	16.2 The ionic basis of electrical activity in neurons	683
	16.3 How neurons communicate with one another	704
17	How animals sense their environments	725
	17.1 Principles of sensory processing	725
	17.2 Photoreception	731
	17.3 Chemoreception	750
	17.4 Mechanoreception	759
	17.5 Thermoreception	771
	17.6 Nociception	772
	17.7 Electroreception	773
	17.8 Magnetoreception	777
18	Muscles and animal movement	783
	18.1 Muscle form and function	783
	18.2 Voluntary muscle fibres: trusted followers of	
	the nervous system	795
	18.3 Cardiac myocytes: muscle cells that never	
	pause to rest	806
	18.4 Smooth muscle fibres: the 'invisible' achievers	811
	18.5 The muscular system is the engine that provides the	
	power for an animal's movements and behaviour	816
	18.6 Animal locomotion	824

19	Hormones	842
	19.1 Dynamics of hormonal processes	842
	19.2 Central control processes of vertebrates—the	
	hypothalamus, pituitary gland and pineal gland	854
	19.3 The vertebrate adrenal gland and stress	864
	19.4 The vertebrate thyroid gland	874
	19.5 Invertebrate hormones	887
20	Reproduction	899
	20.1 Characteristics of sexual reproduction	899
	20.2 Sex determination and sexual differentiation	915
	20.3 Vertebrate male reproductive systems	922
	20.4 Female reproductive systems of vertebrates	928
	20.5 Fertilization and subsequent events	934
	20.6 Asexual reproduction	941
21	Control of sodium, water and calcium balance	946
	21.1 Control of sodium and water balance	
	among vertebrates	946
	21.2 Calcium balance	975
22	Integration of the respiratory and circulatory systems	997
	22.1 Generation of the respiratory rhythm	997
	22.2 Control of the respiratory system	1009
	22.3 Generation of the cardiac rhythm	1024
	22.4 Control of the cardiovascular system	1029
	22.5 Central terminations of respiratory and	
	cardiovascular sense organs and their	
	interactions in vertebrates	1037
	Appendix	1045
	Index	1047