

# CONTENTS

Preface	ix
Note to the reader	xiii
Glossary	xv
<b>1 CHEMIOSMOTIC ENERGY TRANSDUCTION</b>	<b>3</b>
1.1 Introduction	3
1.2 The chemiosmotic theory: fundamentals	3
1.3 The basic morphology of energy-transducing membranes	7
1.4 Overview	14
<b>2 ION TRANSPORT ACROSS ENERGY-CONSERVING MEMBRANES</b>	<b>17</b>
2.1 Introduction	17
2.2 The classification of ion transport	17
2.3 Bilayer-mediated transport	21
2.4 Protein-catalysed transport	25
2.5 Swelling and the co-ordinate movement of ions across membranes	26
<b>3 QUANTITATIVE BIOENERGETICS: THE MEASUREMENT OF DRIVING FORCES</b>	<b>31</b>
3.1 Introduction	31
3.2 Gibbs energy and displacement from equilibrium	33
3.3 Oxidation–reduction (redox) potentials	40
3.4 Ion electrochemical potential differences	46
3.5 Photons	47
3.6 Bioenergetic interconversions and thermodynamic constraints on their stoichiometries	48



3.7	The equilibrium distributions of ions, weak acids and weak bases	50
3.8	Membrane potentials, diffusion potentials, Donnan potentials and surface potentials	52
<b>4</b>	<b>THE CHEMIOSMOTIC PROTON CIRCUIT</b>	<b>57</b>
4.1	Introduction	57
4.2	The measurement of protonmotive force	59
4.3	The stoichiometry of proton extrusion by the respiratory chain	66
4.4	The stoichiometry of proton uptake by the ATP synthase	68
4.5	Proton current and respiratory control	69
4.6	Proton conductance	73
4.7	Mitochondrial respiration rate and metabolic control analysis	77
4.8	Overall parameters of energy transduction	81
4.9	Reversed electron transfer and the proton circuit driven by ATP hydrolysis	83
4.10	ATP synthesis driven by an artificial protonmotive force	85
4.11	Kinetic competence of $\Delta p$ in the proton circuit	86
4.12	Light-dependent ATP synthesis by bovine heart ATP synthase	87
<b>5</b>	<b>RESPIRATORY CHAINS</b>	<b>89</b>
5.1	Introduction	89
5.2	Components of the mitochondrial respiratory chain	89
5.3	The sequence of redox carriers in the respiratory chain	95
5.4	The mechanism of electron transfer	99
5.5	Proton translocation by the respiratory chain: 'loops', 'conformational pumps' or both?	105
5.6	Complex I (NADH-UQ oxidoreductase)	107
5.7	Delivering electrons to ubiquinone without proton translocation	111
5.8	Ubiquinone and complex III ( $bc_1$ or UQ-cyt $c$ oxidoreductase)	114
5.9	Cytochrome $c$ and complex IV (cytochrome $c$ oxidase; ferrocycytochrome $c$ : $O_2$ oxidoreductase)	119
5.10	Overall proton and charge movements catalysed by the respiratory chain: correlation with the P/O ratio	126
5.11	Superoxide production by complexes I and III	127
5.12	Oxidative stress	129
5.13	The nicotinamide nucleotide transhydrogenase	130
5.14	Electron transport in mitochondria of non-mammalian cells	131
5.15	Bacterial respiratory chains	134
<b>6</b>	<b>PHOTOSYNTHETIC GENERATORS OF PROTONMOTIVE FORCE</b>	<b>157</b>
6.1	Introduction	157
6.2	The light reaction of photosynthesis in <i>Rhodobacter sphaeroides</i> and related organisms	159



6.3	The generation by illumination or respiration of $\Delta p$ in photosynthetic bacteria	168
6.4	The electron-transfer and light-capture pathway in green plants and algae	171
6.5	Bacteriorhodopsin and halorhodopsin	186

## **7 THE ATP SYNTHASE** **195**

7.1	Introduction	195
7.2	$F_1$ and $F_o$	195
7.3	The subunits of the $F_1.F_o$ -ATPase	198
7.4	The structure of $F_1.F_o$	199
7.5	Enzymology of ATP synthase	204
7.6	Relating the structure to function for ATP synthase	210
7.7	Non-thermodynamic regulation of the ATP synthase	216
7.8	Proton translocation by other ATPases and pyrophosphatases	216

## **8 METABOLITE AND ION TRANSPORT** **219**

8.1	Introduction	219
8.2	Mitochondrial cation transporters	220
8.3	Mitochondrial metabolite transporters	225
8.4	The transfer of electrons from cytoplasmic NADH to the respiratory chain	229
8.5	The phosphate and adenine nucleotide transporters	230
8.6	The uncoupling protein family	232
8.7	Bacterial transport	234
8.8	Transport (movement) of bacterial cells	246
8.9	Transport of macromolecules across bacterial membranes	247

## **9 MITOCHONDRIA IN THE CELL** **249**

9.1	Introduction	249
9.2	Monitoring $\Delta\psi_m$ and ATP synthesis in intact cells	251
9.3	Mitochondria and cellular $Ca^{2+}$ homeostasis	255
9.4	Mitochondria and programmed cell death	258
9.5	Mitochondria and necrotic cell death	261
9.6	The mitochondrial genome	263
9.7	Import and assembly of mitochondrial proteins	264
9.8	Mitochondrial genetic diseases	266
9.9	Mitochondrial involvement in neurodegenerative diseases	268

References	271
------------	-----

Appendix: Protein structures	283
------------------------------	-----

Index	287
-------	-----

Colour plates of selected molecular structures are located between pages 126 and 127.