

Contents

Preface *xi*

1	Biological Membranes	1
1.1	Introduction	1
1.2	The Biological Membranes	2
1.2.1	The Lipids and the Lipid Bilayer	4
1.2.2	The Membranes of Cells and Organelles	9
1.3	The Proteins	12
1.4	The Membrane Functions	14
1.4.1	Transport	15
1.4.2	Signal Transduction	17
1.4.3	Cell–Cell Recognition	17
1.4.4	Enzymatic Activity	18
1.4.5	Intercellular Joining	18
	References	19
2	Electrostatics of Biomembranes	21
2.1	The Electric Field	21
2.2	Electric Field Created by a Uniform, Infinitely Extended Planar Charge Distribution	23
2.3	The Parallel-plate Capacitor	27
2.4	The Dielectric Constant	28
2.5	The Electric Potential Across a Membrane	30
2.6	Poisson–Boltzmann Equation and Gouy–Chapman Theory	33
2.7	Measurement of the Charge Density of the Polar Heads of a Charged Lipid	40
2.8	Electropermeabilization of Lipid Bilayers	44
	References	51
3	Thermodynamics	53
3.1	Some Concepts of Chemical Thermodynamics	53
3.2	The Electrochemical Potential	59
3.3	Thermodynamics of Irreversible Processes	61

3.4	Coupling of Primary and Secondary Active Transport in Biomembranes	68
3.4.1	Plasma Membranes of Animal Cells	70
3.4.2	Inner Mitochondrial Membrane, Thylakoid Membrane, and Bacterial Plasma Membrane	71
3.4.3	Membranes of Plant and Fungal Cells	74
3.4.4	Membranes of the Vesicular System	76
	References	76
4	Passive Transport	79
4.1	How do Ion Channels Look Like?	79
4.2	The Nernst Equation and the Resting Potential	84
4.3	A First Approach to the Action Potential	89
4.4	Single-channel Open Probability	94
4.4.1	The Variance	98
4.5	The Goldman–Hodgkin–Katz Equation	100
4.6	Open Probability and Gating Charge of Ion Channels	108
4.6.1	The Gap Junction	112
4.7	Rate Theory of Membrane Transport	115
4.8	Action Potential Revisited	117
4.8.1	The Shape of the Action Potential	124
4.8.2	The Gating Current of the Potassium Channel	125
	References	127
5	Active Transport	129
5.1	The Ion Pumps	129
5.2	Electromotive Force and Inversion Potential of Ion Pumps	136
5.3	Energy Levels of the Enzymatic Cycle of Ion Pumps	138
5.4	Kinetics of Ion Pumps Under Steady-State Conditions	144
5.5	Electrogenicity of the Ion Pumps	147
5.6	Kinetics of Ion Pumps Under Pre-Steady-State Conditions	150
5.6.1	Ca^{2+} -ATPase of the Sarcoplasmic Reticulum	161
5.6.2	Na^+, K^+ -ATPase	166
5.7	Transporters	168
5.7.1	Cotransporters	168
5.7.2	Countertransporters	170
	References	172
6	Biomimetic Membranes	175
6.1	The Various Types of Biomimetic Membranes	175
6.2	Electrochemical Techniques for the Investigation of Biomimetic Membranes	177
6.2.1	Electrochemical Impedance Spectroscopy	177
6.2.2	Potential-Step Chronoamperometry (Current–Time Curves)	185
6.2.3	Potential-Step Chronocoulometry	193

6.2.4	Cyclic Voltammetry	198
6.2.5	AC Voltammetry	216
6.3	Lipid Bilayers Interposed Between Two Aqueous Phases	218
6.4	Biomimetic Membranes Noncovalently Supported by Metals	224
6.4.1	Lipid Monolayers Self-Assembled on Mercury	224
6.4.2	Solid-Supported Bilayer Lipid Membranes (sBLMs)	227
6.4.3	S-Layer Stabilized Bilayer Lipid Membranes (ssBLMs)	232
6.5	Biomimetic Membranes Covalently Supported by Metals	233
6.5.1	Alkanethiol/Lipid Hybrid Bilayers	233
6.5.2	Tethered Bilayer Lipid Membranes (tBLMs)	236
6.5.3	Polymer-Cushioned Bilayer Lipid Membranes (pBLMs)	242
6.5.4	Protein-Tethered Bilayer Lipid Membranes (ptBLMs)	242
6.6	Conclusions	244
	References	248
7	Auxiliary Techniques	255
7.1	Physical Properties of Electromagnetic Waves	255
7.2	Surface Plasmon Resonance	262
7.3	Infrared Spectroscopy	272
7.4	Neutron Reflectivity	279
7.5	Fluorescence Microscopy	286
7.6	Scanning Probe Microscopy	296
7.6.1	Atomic Force Microscopy	297
7.6.2	Scanning Tunneling Microscopy	302
7.7	Langmuir–Blodgett and Langmuir–Schaefer Transfers	305
7.8	Quartz-Crystal Microbalance	310
	References	314
	Index	317