

---

## Contents

<i>Preface to the second edition</i>	<i>page xi</i>
<hr/>	
<b>Chapter 1</b>   Energy transformation	1
A. Introduction	1
B. Distribution of energy	7
C. System and surroundings	11
D. Animal energy consumption	13
E. Carbon, energy, and life	18
F. References and further reading	19
G. Exercises	21
<hr/>	
<b>Chapter 2</b>   The First Law of Thermodynamics	25
A. Introduction	25
B. Internal energy	29
C. Work	31
D. The First Law in operation	35
E. Enthalpy	38
F. Standard state	41
G. Some examples from biochemistry	42
H. Heat capacity	47
I. Energy conservation in the living organism	51
J. References and further reading	51
K. Exercises	53
<hr/>	
<b>Chapter 3</b>   The Second Law of Thermodynamics	58
A. Introduction	58
B. Entropy	61
C. Heat engines	66
D. Entropy of the universe	69
E. Isothermal systems	70
F. Protein denaturation	72
G. The Third Law and biology	74
H. Irreversibility and life	75
I. References and further reading	78
J. Exercises	80
<hr/>	
<b>Chapter 4</b>   Gibbs free energy – theory	85
A. Introduction	85
B. Equilibrium	88
C. Reversible processes	93
D. Phase transitions	95

E. Chemical potential	98
F. Effect of solutes on boiling points and freezing points	102
G. Ionic solutions	104
H. Equilibrium constant	108
I. Standard state in biochemistry	110
J. Effect of temperature on $K_{eq}$	113
K. Acids and bases	115
L. Chemical coupling	117
M. Redox reactions	120
N. References and further reading	124
O. Exercises	126
<hr/>	
<b>Chapter 5</b>   Gibbs free energy – applications	134
A. Introduction	134
B. Photosynthesis, glycolysis, and the citric acid cycle	134
C. Oxidative phosphorylation and ATP hydrolysis	139
D. Substrate cycling	146
E. Osmosis	147
F. Dialysis	154
G. Donnan equilibrium	157
H. Membrane transport	158
I. Enzyme-substrate interaction	162
J. Molecular pharmacology	165
K. Hemoglobin	170
L. Enzyme-linked immunosorbent assay (ELISA)	172
M. DNA	174
N. Polymerase chain reaction (PCR)	178
O. Free energy of transfer of amino acids	180
P. Protein solubility	182
Q. Protein stability	184
R. Protein dynamics	191
S. Non-equilibrium thermodynamics and life	193
T. References and further reading	195
U. Exercises	199
<hr/>	
<b>Chapter 6</b>   Statistical thermodynamics	207
A. Introduction	207
B. Diffusion	211
C. Boltzmann distribution	215
D. Partition function	222
E. Analysis of thermodynamic data	223
F. Multi-state equilibria	228
G. Protein heat capacity functions	235
H. Cooperative transitions	236
I. “Interaction” free energy	238

J. Helix-coil transition theory	240
K. References and further reading	243
L. Exercises	246
<hr/>	
<b>Chapter 7</b>   Binding equilibria	250
A. Introduction	250
B. Single-site model	253
C. Multiple independent sites	255
D. Oxygen transport	261
E. Scatchard plots and Hill plots	265
F. Allosteric regulation	269
G. Proton binding	272
H. References and further reading	275
I. Exercises	277
<hr/>	
<b>Chapter 8</b>   Reaction kinetics	281
A. Introduction	281
B. Rate of reaction	284
C. Rate constant and order of reaction	286
D. First-order and second-order reactions	287
E. Temperature effects	290
F. Collision theory	291
G. Transition state theory	294
H. Electron transfer kinetics	297
I. Enzyme kinetics	299
J. Inhibition	304
K. Reaction mechanism of lysozyme	306
L. Hydrogen exchange	307
M. Protein folding and pathological misfolding	311
N. Polymerization	314
O. Muscle contraction and molecular motors	317
P. References and further reading	320
Q. Exercises	322
<hr/>	
<b>Chapter 9</b>   The frontier of biological thermodynamics	326
A. Introduction	326
B. What is energy?	326
C. The laws of thermodynamics and our universe	329
D. Thermodynamics of (very) small systems	331
E. Formation of the first biological macromolecules	332
F. Bacteria	337
G. Energy, information, and life	339
H. Biology and complexity	349
I. The Second Law and evolution	355

J. References and further reading	359
K. Exercises	366
<b>Appendices</b>	369
A. General references	369
B. Biocalorimetry	372
C. Useful tables	378
D. BASIC program for computing the intrinsic rate of amide hydrogen exchange from the backbone of a polypeptide	385
<i>Glossary</i>	400
<i>Index of names</i>	411
<i>Subject index</i>	413