

# Contents

<b>List of Abbreviations</b> . . . . .	XXIII
--	-------

## Introduction

<b>A. TREBST and M. AVRON (With 1 Figure)</b> . . . . .	1
---	---

## I. History

### Photosynthesis 1950–75: Changing Concepts and Perspectives

#### D.I. ARNON (With 16 Figures)

A. Introduction . . . . .	7
B. Photosynthesis Research at Midcentury . . . . .	7
C. Research Past Midcentury: Some Major Advances . . . . .	10
D. CO <sub>2</sub> Assimilation: Experiments with Whole Cells . . . . .	10
E. Evidence for CO <sub>2</sub> Assimilation by Isolated Chloroplasts . . . . .	13
F. Investigations of Light Reactions of Photosynthesis: Experimental Advantages of Chloroplasts Over Whole Cells . . . . .	15
G. Discovery of Photosynthetic Phosphorylation . . . . .	16
H. The Concept of a Light-Induced Electron Flow . . . . .	18
I. Noncyclic Photophosphorylation . . . . .	19
J. Role of Cyclic Photophosphorylation: Early Views . . . . .	20
K. Physical Separation of Light and Dark Phases of Photosynthesis in Chloroplasts . . . . .	22
L. Ferredoxins in Chloroplasts and Bacteria . . . . .	22
M. Role of Ferredoxin in Noncyclic Photophosphorylation . . . . .	27
N. Ferredoxin as the Physiological Catalyst of Cyclic Photophosphorylation . . . . .	30
O. Stoichiometry and Regulation of Ferredoxin-Catalyzed Photophosphorylations . . . . .	31
P. Other Ferredoxin-Dependent Reactions in Photosynthetic Cells . . . . .	39
Q. Multiple Ferredoxins: Soluble and Bound . . . . .	40
R. Photosynthetic Electron Carriers . . . . .	43
S. Two Photosystems in Plant Photosynthesis: Origins of a Concept . . . . .	44
T. Two Photosystems: Facts, Hypotheses, and Dogma . . . . .	46
U. Concluding Remarks . . . . .	50
References . . . . .	51

## II. Electron Transport

### I. General

#### 1a. Physical Aspects of Light Harvesting, Electron Transport and Electrochemical Potential Generation in Photosynthesis of Green Plants

##### W. JUNGE (With 11 Figures)

A. Introduction . . . . .	59
B. Antennae . . . . .	60
I. Physically Different Types of Chlorophylls in Chloroplasts . . . . .	62
II. Resonant Energy Transfer . . . . .	65

III. Distinctive Properties of Antennae Systems I and II . . . . .	66
IV. Size and Interaction of the Antennae Systems . . . . .	68
V. Protective Reactions . . . . .	70
VI. Structure . . . . .	70
C. Electron Transport . . . . .	72
I. Photochemical Reactions . . . . .	75
II. Non-Photochemical Components . . . . .	77
D. Electrochemical Potential Generation . . . . .	80
I. The Generation of an Electric Potential . . . . .	82
II. Proton Translocation . . . . .	84
References . . . . .	88

### **1b. Electron Transport in Chloroplasts**

**J.H. GOLBECK, S. LIEN, and A. SAN PIETRO (With 4 Figures)**

A. General . . . . .	94
B. Photosystem II . . . . .	95
I. The Oxidizing Side of PS II . . . . .	97
II. The Reaction Center Complex of PS II . . . . .	100
III. The Reducing Side of PS II . . . . .	101
C. Photosystem I . . . . .	102
I. The Primary Acceptor of PS I . . . . .	103
II. The Reducing Side of PS I . . . . .	110
III. The Oxidizing Side of PS I . . . . .	113
References . . . . .	114

### **2. Porphyrins, Chlorophyll, and Photosynthesis**

**D. MAUZERALL (With 2 Figures)**

A. Introduction . . . . .	117
B. Structure . . . . .	117
C. Function . . . . .	121
D. Evolution . . . . .	122
E. Summary . . . . .	123
References . . . . .	124

### **3. Light Conversion Efficiency in Photosynthesis**

**R.J. RADMER and B. KOK (With 3 Figures)**

A. Basic Principles . . . . .	125
B. The Maximum Efficiency of Photosynthesis: Quantum Yields Under Optimum Conditions . . . . .	126
C. ATP Production and Utilization . . . . .	130
D. Quantum Yields of Growing Cells and Photosynthetic Productivity Under Natural Conditions . . . . .	131
References . . . . .	134

### **4. P-700**

**G.E. HOCH (With 2 Figures)**

A. General . . . . .	136
B. Optical Properties . . . . .	137
C. Oxidation-Reduction . . . . .	139
D. Models . . . . .	140
E. Localization of P-700 . . . . .	141

F. Orientation of P-700 . . . . .	142
G. Oxidation of P-700 . . . . .	142
H. Reduction of P-700 . . . . .	142
References . . . . .	146

## **5. Chlorophyll Fluorescence: A Probe for Electron Transfer and Energy Transfer** **W.L. BUTLER (With 2 Figures)**

A. Introduction . . . . .	149
B. Fluorescence Yield and Electron Transport . . . . .	149
I. A (Q) . . . . .	149
II. C-550 . . . . .	151
III. P-680 . . . . .	153
IV. The Back-Reaction . . . . .	154
C. The Photochemical Model . . . . .	154
I. Photosystem II . . . . .	154
II. Photosystem I . . . . .	157
III. The Photochemical Apparatus . . . . .	157
IV. Energy Distribution Between PS I and PS II . . . . .	159
D. Appendix . . . . .	162
References . . . . .	166

## **6. Electron Paramagnetic Resonance Spectroscopy** **E.C. WEAVER and G.A. CORKER (With 1 Figure)**

A. Introduction . . . . .	168
B. EPR Techniques . . . . .	169
C. EPR Studies in Photosynthesis . . . . .	172
I. Bacterial Photosynthesis . . . . .	172
II. Signals in Photosystem II (PS II) . . . . .	173
III. Signals in Photosystem I (PS I) . . . . .	174
IV. Spin Labels . . . . .	176
D. Conclusion . . . . .	177
References . . . . .	177

## **7. Primary Electron Acceptors** **R. MALKIN (With 4 Figures)**

A. Chloroplast Photosystem I . . . . .	179
I. Background . . . . .	179
II. Electron Paramagnetic Resonance (EPR) Studies of Bound Iron-Sulfur Proteins . . . . .	179
III. Flash Kinetic Spectroscopy of P-430 . . . . .	181
IV. Relationship of P-430 to Bound Iron-Sulfur Protein . . . . .	182
B. Chloroplast Photosystem II . . . . .	183
I. X-320 . . . . .	183
II. C-550 . . . . .	184
III. On the Chemical Identity of the Photosystem II Primary Electron Acceptor . . . . .	185
References . . . . .	185

## **8. Oxygen Evolution and Manganese** **B.A. DINER and P. JOLIOT (With 2 Figures)**

A. Introduction . . . . .	187
B. Photosystem II . . . . .	188
C. Kinetic Model of O <sub>2</sub> Production . . . . .	191

D. Interconversion of S-States in the Dark . . . . .	193
E. Turnover Reactions of Photosystem II . . . . .	195
F. Phenomena Related to the S-States . . . . .	197
G. Chemical Treatments that Reversibly Affect the O <sub>2</sub> Evolving Site . . . . .	198
H. Localization of the Oxygen-Evolving Site . . . . .	201
References . . . . .	203

## 9. Ferredoxin

**D.O. HALL and K.K. RAO (With 3 Figures)**

A. Introduction . . . . .	206
B. Extraction and Purification . . . . .	206
C. Assay . . . . .	207
D. Occurrence and Biosynthesis . . . . .	208
E. Properties . . . . .	208
F. Nature of the Active Center . . . . .	211
G. Stability . . . . .	213
H. Biological Function . . . . .	213
I. Immunological Studies . . . . .	214
J. Homology in the Primary Structures . . . . .	214
References . . . . .	215

## 10. Flavodoxin

**H. BOTHE**

A. Biological Properties . . . . .	217
B. Chemical Properties . . . . .	219
References . . . . .	220

## 11. Flavoproteins

**G. FORTI**

A. Introduction . . . . .	222
B. Isolation and Physico-Chemical Properties of the Chloroplast Flavoprotein, Ferredoxin-NADP <sup>+</sup> Reductase . . . . .	222
C. Kinetic Properties of Ferredoxin-NADP <sup>+</sup> Reductase . . . . .	224
D. Multiple Forms of the Chloroplast Flavoprotein . . . . .	226
References . . . . .	226

## 12. Cytochromes

**W.A. CRAMER (With 2 Figures)**

A. Introduction . . . . .	227
B. Isolated Higher Plant Cytochromes . . . . .	227
C. Isolated Algal Cytochromes . . . . .	230
D. Cytochrome Function in Electron Transport . . . . .	230
References . . . . .	236

## 13. Plastoquinone

**J. AMESZ (With 5 Figures)**

A. Introduction and Properties . . . . .	238
B. Experiments with Extracted Chloroplasts . . . . .	240
C. Reactions of Endogenous Plastoquinone as Secondary Electron Acceptor . . . . .	240

D. Identity of the Primary Electron Acceptor of Photosystem II . . . . . 242  
 E. Specific Inhibitors of Plastoquinone . . . . . 244  
 References . . . . . 245

**14. Plastocyanin**

**S. KATOH (With 1 Figure)**

A. Distribution and Localization . . . . . 247  
 B. Extraction and Purification . . . . . 247  
 C. Molecular Properties . . . . . 248  
 D. Function in Photosynthetic Electron Transport System . . . . . 250  
 References . . . . . 252

**15. Artificial Acceptors and Donors**

**G. HAUSKA (With 1 Figure)**

A. Introduction . . . . . 253  
 B. General Aspects . . . . . 253  
 C. Electron Acceptors . . . . . 255  
 D. Electron Donors . . . . . 257  
 E. Compounds Accepting and Donating Electrons—Cyclic Electron Transport and By-passes . . . . . 260  
 F. The Topography of the Chloroplast Membrane and Artificial Energy Conservation . . . . . 261  
 References . . . . . 263

**16. Inhibitors of Electron Transport**

**S. IZAWA (With 1 Figure)**

A. Introduction . . . . . 266  
 B. Description of Inhibitors . . . . . 267  
     I. Inhibitors that Act on Water-Oxidizing Side of Photosystem II . . . . . 267  
     II. Inhibitors that Block Exit of Electrons from Photosystem II . . . . . 270  
     III. Plastoquinone Antagonists . . . . . 274  
     IV. Inhibitors of Electron Transfer Between Plastoquinone and cytochrome f . . . . . 275  
     V. Inhibitors of Plastocyanin . . . . . 276  
     VI. Inhibitors of Reactions in Ferredoxin-NADP<sup>+</sup> Region . . . . . 278  
 References . . . . . 279

**17. Antibodies**

**R. J. BERZBORN and W. LOCKAU**

A. Introduction . . . . . 283  
 B. General Considerations on the Application of Antibodies to Studies of Membrane Function . . . . . 283  
     I. Properties of Antibodies . . . . . 283  
     II. Usefulness of Antibodies . . . . . 284  
 C. Results and Conclusions from Experiments with Antisera Against Individual Chloroplast Antigens . . . . . 287  
 D. Summary and Outlook . . . . . 294  
 References . . . . . 294

**18. Chemical Modification of Chloroplast Membranes**

**R. GIAQUINTA and R. A. DILLEY**

A. Introduction . . . . . 297  
 B. N-ethylmaleimide (NEM) . . . . . 297

C. Carbodiimides . . . . .	298
D. Lactoperoxidase-Catalyzed Iodination . . . . .	300
E. Trypsin . . . . .	300
F. Diazoniumbenzenesulfonic Acid (DABS) . . . . .	301
References . . . . .	303

### III. Energy Conservation

#### 1. Photophosphorylation

##### A.T. JAGENDORF (With 7 Figures)

A. Relation of Electron Transport to Phosphorylation . . . . .	307
I. Electron Transport Patterns . . . . .	307
II. Coupling Between Electron Transport and Phosphorylation . . . . .	308
III. Energy Conservation Sites . . . . .	310
B. Chemiosmotic Principles of Coupled Electron Flow and ATP Synthesis . . . . .	311
I. The Chemiosmotic Hypothesis; and Others . . . . .	311
C. Evidence Relating to Operation of Chemiosmotic Principles in Chloroplasts . . . . .	317
I. Light-Driven Proton Uptake . . . . .	317
II. The Membrane Potential . . . . .	319
III. ATP-Driven Proton Uptake . . . . .	321
IV. Post-Illumination ATP Synthesis ("X <sub>E</sub> ") . . . . .	322
V. Acid to Base Transition . . . . .	322
VI. Stoichiometrics and Thermodynamics . . . . .	323
D. Role of the Coupling Factor in Phosphorylation . . . . .	326
I. CF <sub>1</sub> Enzymatic Activities . . . . .	326
II. Nature, Visualization, Location of the Protein . . . . .	327
III. Uncoupling, Recoupling, and Function in Proton Translocation . . . . .	328
IV. Function in Phosphorylation: Conformational Changes and Ligand Binding . . . . .	329
References . . . . .	334

#### 2. Proton and Ion Transport Across the Thylakoid Membranes

##### H. ROTTENBERG (With 3 Figures)

A. Introduction . . . . .	338
B. The Mechanism of Light-Induced Proton Transport . . . . .	338
C. Secondary Ion Transport . . . . .	340
D. Electrochemical Potential of Protons Across the Thylakoid Membranes . . . . .	342
E. Ion Transport and the Mechanism of Uncoupling in Chloroplasts . . . . .	345
F. ATP-Induced Proton Transport . . . . .	346
G. Proton Transport in Subchloroplast Particles and Chromatophores . . . . .	347
References . . . . .	348

#### 3. Bound Nucleotides and Conformational Changes in Photophosphorylation

##### N. SHAVIT (With 1 Figure)

A. Introduction . . . . .	350
B. Tightly Bound Nucleotides on Isolated and Membrane-Bound CF <sub>1</sub> . . . . .	351
C. Nucleotide and Nucleotide Analogs: Binding and Activity . . . . .	352
D. Antisera to CF <sub>1</sub> . . . . .	354
E. Conformational Coupling in Thylakoid Membranes . . . . .	354
References . . . . .	356

**4. The High Energy State****B.A. MELANDRI**

A. Coupling Mechanism Hypotheses . . . . .	358
B. Experimental Evidence for the Existence of a High Energy State . . . . .	361
C. The Energy Level and the Energy Capacity of the High Energy State . . . . .	363
References . . . . .	366

**5. ATPase****T. BAKKER-GRUNWALD (With 2 Figures)**

A. Introduction . . . . .	369
B. History of ATPase . . . . .	369
C. Feedback in ATPase . . . . .	370
D. Conformational Changes Relevant for ATPase . . . . .	371
E. Component Requirements of Membrane-Bound ATPase in General . . . . .	372
F. Relations of ATPase with Other Topics in Bioenergetics . . . . .	372
References . . . . .	373

**6. Post-Illumination ATP Formation****J.M. GALMICHE**

A. Introduction . . . . .	374
B. Materials and Methods . . . . .	375
C. General Conditions for Post-Illumination ATP Formation . . . . .	376
I. Two-Stage ATP Synthesis . . . . .	376
II. Delayed ATP Synthesis in Flashing Light . . . . .	378
D. High Energy State Intermediate . . . . .	378
I. Chemical High Energy State Intermediate . . . . .	379
II. High Energy State and Membrane Property Changes . . . . .	380
E. Hypotheses on the Nature of the High Energy State Intermediate $X_e$ . . . . .	386
F. Conclusions . . . . .	389
References . . . . .	390

**7. Chloroplast Coupling Factor****N. NELSON (With 2 Figures)**

A. Introduction . . . . .	393
B. Reconstitution of $CF_1$ Depleted Chloroplasts . . . . .	393
C. Preparation of $CF_1$ . . . . .	394
D. Physical Properties of $CF_1$ . . . . .	395
E. Catalytic Properties of Activated $CF_1$ . . . . .	396
F. Subunit Structure of $CF_1$ . . . . .	397
G. Chemical Modification of $CF_1$ and the Nature of its Active Site . . . . .	399
H. Nucleotide Binding and the Mechanism of ATP Formation . . . . .	401
References . . . . .	403

**8. Field Changes****B. RUMBERG (With 3 Figures)**

A. Introduction . . . . .	405
B. Quantitative Results on Changes of Membrane Potential . . . . .	407
C. Concept of Ion Transport Phenomena . . . . .	409
D. Relationship Between Membrane Potential and ATP Formation . . . . .	413
E. Summary . . . . .	414
References . . . . .	415

**9. Acid Base ATP Synthesis in Chloroplasts****S. SCHULDINER (With 2 Figures)**

A. Introduction . . . . .	416
B. General Properties of the System . . . . .	416
C. Dicarboxylic Acid Requirement . . . . .	417
D. The Electrochemical Gradient of Protons and ATP Synthesis . . . . .	419
E. Kinetics . . . . .	420
F. Activation of ATP Hydrolysis . . . . .	420
References . . . . .	422

**10. Energy-Dependent Conformational Changes****R. KRAAYENHOF (With 1 Figure)**

A. Introduction . . . . .	423
B. Conformational Mechanism of Energy Transduction . . . . .	423
C. Energy-Dependent Structural Changes in the Thylakoid Membrane . . . . .	424
D. Energy-Dependent Conformational Changes in Chloroplast ATPase . . . . .	426
References . . . . .	428

**11. Uncoupling of Electron Transport from Phosphorylation in Chloroplasts****N.E. GOOD (With 1 Figure)**

A. The Concept of Uncoupling . . . . .	429
B. Criteria of Uncoupling . . . . .	430
C. Types of Uncoupling by Typical Uncouplers . . . . .	431
I. Malfunctions of the Coupling Factor . . . . .	431
II. Malfunctions of the Membrane . . . . .	433
III. Uncoupling by Unknown Mechanisms . . . . .	434
D. A General Consideration of Mechanisms of Uncoupling . . . . .	435
References . . . . .	436

**12. Energy Transfer Inhibitors of Photophosphorylation in Chloroplasts****R.E. MCCARTY (With 2 Figures)**

A. Definition of Energy Transfer Inhibitors . . . . .	437
B. Energy Transfer Inhibitors Which Probably Exert Their Effects on Coupling Factor I . . . . .	438
C. Energy Transfer Inhibitors Whose Site of Action is Unknown . . . . .	442
D. Some Observations and Conclusions . . . . .	445
References . . . . .	446

**13. Photophosphorylation in vivo****H. GIMMLER**

A. Introduction . . . . .	448
B. Methods . . . . .	452
C. Cyclic Photophosphorylation in vivo . . . . .	456
D. Pseudocyclic Photophosphorylation in vivo . . . . .	460
E. Noncyclic Photophosphorylation in vivo . . . . .	463
F. Regulation of Photophosphorylation in vivo . . . . .	465
G. Photophosphorylation in vivo and CO <sub>2</sub> Fixation . . . . .	466
H. Concluding Remarks . . . . .	467
References . . . . .	468



**14. Delayed Luminescence****S. MALKIN (With 7 Figures)**

A. General . . . . .	473
B. Methods . . . . .	474
C. Phenomenology . . . . .	476
I. Emission and Excitation Spectrum . . . . .	476
II. Decay of Delayed Luminescence . . . . .	476
III. Activation of Delayed Luminescence . . . . .	478
IV. Delayed Luminescence and the S-States . . . . .	483
D. Origin of Delayed Luminescence in Photosynthetic Systems . . . . .	484
I. Delayed Luminescence from Plants . . . . .	484
II. Models for the Mechanism of Delayed Luminescence in Photosynthetic Systems . . . . .	487
References . . . . .	489

**15. Exchange Reactions****C. CARMELI**

A. Introduction . . . . .	492
B. The Development of the Study of Exchange Reactions in Photophosphorylation . . . . .	492
C. Mechanisms of Exchange Reactions . . . . .	494
D. Requirement for Substrates . . . . .	495
E. The Relations Between Exchange Reactions and the Mechanism of Photophosphorylation . . . . .	496
F. Energy Requirements . . . . .	498
G. Reconstitution of Vesicles Catalyzing $P_i$ -ATP Exchange . . . . .	498
References . . . . .	499

**IV. Structure and Function****1. Introduction to Structure and Function of the Photosynthesis Apparatus****K. MÜHLETHALER (With 9 Figures)**

A. The Membrane Components . . . . .	503
B. Ultrastructure of Thylakoid Membranes . . . . .	505
I. General Aspects . . . . .	505
II. The Outer (Matrix Side) Surface (OS) . . . . .	508
III. The Inner (Lumen Side) Surface (IS) . . . . .	509
IV. The Inner Zone of the Thylakoid Membrane . . . . .	510
C. The Relations Between Peripheral and Integral Particles . . . . .	512
D. Mobility of Membrane Particles . . . . .	513
E. The Identification of Membrane Constituents . . . . .	513
F. Correlation Between Ultrastructural and Serological Studies . . . . .	516
G. The Relationship Between Structure and Function . . . . .	518
H. Conclusions . . . . .	518
I. Freeze-Fracture Nomenclature Used for Studies of the Thylakoid Membrane . . . . .	519
References . . . . .	519

**2. The Topography of the Thylakoid Membrane of the Chloroplast****P.V. SANE (With 4 Figures)**

A. Introduction . . . . .	522
B. The Distribution of Photosystems in the Chloroplast Lamellar Structure . . . . .	522
I. The Model . . . . .	522
II. The Supporting Evidence . . . . .	524
III. The Contradictions . . . . .	525

C. Reactivity in the Partition and Nonpartition Regions . . . . .	526
I. The Localization of NADP <sup>+</sup> Reductase . . . . .	527
II. The Localization of ATPase . . . . .	527
III. The Consequences of the Model . . . . .	530
IV. The Role of Grana . . . . .	532
D. The Asymmetry of the Membrane . . . . .	533
I. The Morphological Evidence for the Asymmetry of the Membrane . . . . .	533
II. The Topography Across the Membrane . . . . .	535
III. The Topography Along the Membrane . . . . .	538
E. Concluding Remarks . . . . .	539
References . . . . .	540

### 3. Subchloroplast Preparations

#### G. JACOBI (With 3 Figures)

A. Introduction . . . . .	543
B. The Fractionation Pattern . . . . .	544
C. The Distribution of Photosystems in the Grana and in the Intergrana Region of Chloroplasts from Higher Plants . . . . .	547
D. The Fractionation of Grana Stacks . . . . .	550
E. The Alteration of Reaction Properties and the Diversity of Chloroplast Fragments . . . . .	552
F. The Disorientation of Electron Carriers and the Effect of Plastocyanin . . . . .	555
G. Prospect . . . . .	558
References . . . . .	559

### 4. Fragmentation

#### J.S.C. WESSELS (With 2 Figures)

A. Introduction . . . . .	563
B. Differentiation of the Photosystems . . . . .	564
C. Fragmentation of Chloroplasts . . . . .	565
D. Digitonin Subchloroplast Particles . . . . .	566
E. Triton Subchloroplast Particles . . . . .	569
F. Protein Composition of Subchloroplast Particles . . . . .	571
References . . . . .	572

### 5. The Organization of Chlorophyll *in vivo*

#### J.P. THORNBER and R.S. ALBERTE (With 2 Figures)

A. Introduction . . . . .	574
B. Existence of Multiple Chlorophyll-Proteins in Higher Plants . . . . .	574
C. P-700-Chlorophyll a-Protein . . . . .	575
D. The Light Harvesting Chlorophyll a/b-Protein . . . . .	577
E. Other Chlorophyll-Proteins in the Plant Kingdom . . . . .	579
F. Content of Chlorophyll-Proteins in Higher Plants . . . . .	580
G. Summary and Concluding Remarks . . . . .	580
References . . . . .	582

### 6. Development of Chloroplast Structure and Function

#### N.K. BOARDMAN (With 14 Figures)

A. Ultrastructural Changes During Greening . . . . .	583
B. Spectroscopic Changes During Greening . . . . .	586
C. Chlorophyll Formation in Relation to Ultrastructural and Spectroscopic Changes . . . . .	588
D. Composition of Developing Thylakoids . . . . .	590

E. Development of Photochemical Activity . . . . .	591
F. Cytochrome and P-700 Redox Changes in Developing Plastids . . . . .	595
G. Correlation of Ultrastructural Changes with Function . . . . .	596
References . . . . .	597

## V. Algal and Bacterial Photosynthesis

### 1. Eukaryotic Algae

W. URBACH

A. Introduction . . . . .	603
B. Objects . . . . .	604
C. Pigments and Pigment Systems . . . . .	605
D. Electron Transport and Photophosphorylation . . . . .	608
I. General Aspects . . . . .	608
II. Photosystems . . . . .	611
III. Noncyclic Electron Transport . . . . .	611
IV. Cyclic Electron Transport . . . . .	614
V. Pseudocyclic Electron Transport . . . . .	615
VI. Regulation of Electron Transport Systems . . . . .	616
VII. Special Electron Acceptors . . . . .	616
VIII. Photophosphorylation . . . . .	617
References . . . . .	617

### 2. Blue-Green Algae

D.W. KROGMANN (With 1 Figure)

A. Introduction . . . . .	625
B. Membrane Structure . . . . .	626
C. Major Accessory Pigments . . . . .	627
D. Photosystem II Reaction Centers . . . . .	630
E. Photosystem I . . . . .	631
F. Electron Transport from Photosystem I to NADP <sup>+</sup> . . . . .	631
G. Reactants Linking the Photosystems . . . . .	633
H. Water Splitting, Integrated Function and Phosphorylation . . . . .	634
References . . . . .	635

### 3. Electron Transport and Photophosphorylation in Photosynthetic Bacteria

Z. GROMET-ELHANAN (With 1 Figures)

A. Introduction . . . . .	637
B. Photosynthetic Electron Transport . . . . .	638
I. General . . . . .	638
II. Reaction Centers and Primary Events . . . . .	639
III. Components of the Electron Transport Chain . . . . .	641
IV. Sites of Coupled Phosphorylation . . . . .	644
V. Photoreduction of NAD <sup>+</sup> . . . . .	648
C. Energy Conservation . . . . .	650
I. General . . . . .	650
II. Proton Uptake, pH Gradient and Membrane Potential . . . . .	650
III. Quantitative Estimation of the Light-Induced Electrochemical Proton Gradient in Relation to the Phosphate Potential . . . . .	652
IV. The High Energy State and its Utilization (Postillumination and Acid-Base Phosphorylation) . . . . .	653

V. ATPase, Pyrophosphatase and Exchange Reactions . . . . .	
VI. Coupling Factors . . . . .	
D. Concluding Remarks . . . . .	
References . . . . .	
<b>Author Index</b> . . . . .	
<b>Subject Index</b> . . . . .	