

Index

- Absolute temperature, 24–26
Absorbance, 130, 131
 changes in, 183–186
Absorption, coefficient, 129
 mechanism of, 131–136
Absorption bands, 132, 133
 of chlorophyll *a*, 99, 119–123
 difference, 186
 overlap with fluorescence bands, 135, 155
Soret, 113, 114
Absorption spectra, of algae, 120, 121
 of allophycocyanin, 107
 of bacteriochlorophyll *a* (and *b*), 106, 114
 of bacterioviridin (*Chlorobium chlorophyll*), 106, 114
 of carotenes (*α*, *β* and *γ*), 107
 of carotenoids, 113, 118
 of *Chlorobium chlorophyll* (bacterio-viridin), 106, 114
 of chlorophyll *a*, 106, 113, 114, 119–123
 of chlorophyll *b*, *c*, and *d*, 106, 114
 derivative, 121
 effect of adaptation on, 117
 of fucoxanthol (fucoxanthin), 107
 of luteol, 107
 of phycocyanin, 107, 113, 117
 of phycoerythrin, 107, 113, 117
 of spirilloxanthol (spirilloxanthin), 107
 of two pigment systems, 178
 of violaxanthol (violaxanthin), 107
Accessory pigments, 105–109
 role in photosynthesis, 141–143, 157
Acetic acid, 112
Acid-base transformation, 48, 49
Actinic light, 183–185
Action (excitation) spectra, 143–145, 210
 of chlorophyll *a* fluorescence, 153, 203
 of Emerson (enhancement) effect, 173–175
 of photosynthesis, 145–147
Adenosine triphosphate (ATP), 14, 30, 76, 93, 187, 188, 190, 220, 222, 223, 232, 234, 238, 239, 241–249
 hydrolysis energy of, 31, 241
 need in photosynthesis, 244–246
 site of formation of, 188, 190, 222, 223, 247
 structure of, 243
 use in photosynthesis, 234, 238, 239
Air, improvement by plants, 3
 role in plant nutrition, 1
Alcohol, phosphate, 243
 reduction level of, 45
Aldehyde group, 228, 235
Aldolase, 235, 236
Aldose, 228, 229
Algae, 58
 blue-green (*Cyanophyceae*), 59, 78, 84, 86, 107, 108, 117, 145, 174, 192, 200, 201, 204, 214, 223
 brown, (*Phaeophyceae*), 106–108, 115, 118
 diatoms (*Bacillariophyceae*), 59, 105–108, 118, 145, 147, 151, 157, 174, 175
 green (*Chlorophyceae*), 59, 107, 120, 141, 145, 149–151, 153, 169, 173–175, 177, 178, 181, 191, 192, 198, 200, 203, 205–210, 213, 226
 red (*Rhodophyceae*), 59, 89, 100, 101, 106–108, 117, 145, 146, 148, 169, 174, 179, 189, 200, 204, 211–213
Allen, M. B., 217, 246, 259
Allophycocyanin, occurrence and spectrum of, 107
Amesz, J., 186, 189, 194, 252, 261
Anacystis nidulans, 59, 174, 192, 194, 204

- action spectrum of Emerson effect in, 174
 action spectrum of fluorescence of, 201
 red drop in fluorescence in, 204
 two-light effect on fluorescence of, 214
 Anderson, J. M., 206, 217, 218, 255
 Anthocyanin, 108
 Anthracene, 103, 104
 Army, T. J., 260
 Arnold, W., 67–69, 166, 215, 250
 Arnon, D. I., 76, 77, 246, 247, 262
 Ascorbic acid, 80, 81
Aspidistra elatior, 87
 Assimilation time, 71
 Autoradiography, 224, 225
 Autotrophic organisms, 19
 Avogadro's law, 9
 Avron, M., 182, 261
- Bacillariophyceae* (diatoms), *see Algae*
 Bacteria, 59
 absorbancy changes in, 194, 195
 chemosynthetic, 19
 green, 59, 106, 107
 photosynthetic, 20, 59, 86, 105
 photosynthetic unit in, 69
 purple, 59, 106, 107, 247
 Bacterial photosynthesis, 19, 33, 55, 128, 182
 energetics, 33
 energy traps, 194, 195
 light reactions, 182
 Bacteriochlorophyll *a*, 106, 110
 occurrence and spectrum of, 106, 108, 114
 structure of, 110
 Bacteriochlorophyll *b*, occurrence and spectrum of, 106, 114
 Bacterioviridin (Chlorobium chlorophyll), occurrence and spectrum of, 106, 114
 Baeyer, A. von., 57
 Bailey, J., 192, 193
 Bartsch, R. G., 182
 Bassham, J., 77, 150, 223, 238, 257, 258, 262
 Beer's law, 119–121, 161
 Bendall, D. S., 261
 Bendall, F., 188, 252
 Benson, A. A., 223, 229, 238, 250
 Benzene, 103, 104
 Benzoquinone, 77
 Biggins, J., 89, 91
 Bilan, structure of, 116
 Bioluminescence, 32
 Bisalputra, T., 84
 Bishop, N. I., 261
 Black, C. C., 261
 Blackman, F. F., 60, 250
 Blackman reaction, 60, 61
 Blue-green Algae, *see Algae*
 Boardman, N. K., 206, 217, 218, 255, 261
 Bohr's theory, 132, 139
 Boltzman constant, 165
 Bond energy, 43
 comparison with energy of quanta, 128
 Boussingault, T. B., 9
 Bowen, E. J., 259
 Branton, D., 88
 Bredig, G., 75
 Briantais, J. M., 219
 Brody, M., 89, 146, 148, 169
 Brody, S. S., 158, 171, 200, 206, 207
 Brown, A., 78, 258
 Brown, R., 258
 Brown algae, *see Algae*
 Buchmann, B., 259
 Butler, W. L., 204, 213, 249
- C700, 204
 Calorie, definition of, 15
 Calvin, M., 188, 223, 224, 226, 228, 230, 232, 238, 250, 253, 257, 258
 Calvin-Benson-Bassham cycle, 231–233, 237, 238, 240, 245, 246
 Carbohydrates, 57, 228, 236
 energy content of, 15
 heat of combustion of, 45
 reduction level of, 45
 transformation of, 235, 236
 Carbon, assimilation, 1
 path in photosynthesis, 223–240
 valency of, 103
 Carbon dioxide (fixed air), 3, 5, 57, 71
 acceptor, 229
 annual fixation of, 17
 assimilation, 71
 cycle, 16–18
 heat of combustion of, 45
 participation in photosynthesis, 5, 6
 reduction cycle in photosynthesis, *see* Calvin-Benson-Bassham cycle

- reduction level of, 45
Carbon isotopes (^{11}C , ^{12}C , ^{14}C), 223, 224
Carboxy-dismutase, 230
Carboxylation, 230, 238, 245, 246
Carboxyl group, 224, 242
Carboxylic acid, 224, 238, 242
Carboxyl phosphate, 242, 243
Carotenes (α , β and γ), 107, 108, 218
Carotenoids, 104, 105, 107, 108, 146
absorption spectra of, 113, 118
effectiveness in photosynthesis of, 147
energy transfer to chlorophyll a , 157, 158
solubility of, 109
structure of, 118
Carotenol, 107, 108, 218
Catalase, 94
Cavendish, H., 2
Cederstrand, C. N., 120–122, 169, 216,
 251
Chalmers, R. V., 169, 251
Chemical energy, sources of, 18
Chemosmotic theory of ATP formation,
 244
Chemoautotrophic organisms, 19
Chemoluminescence, 215
Chemosynthesis, 19
Chlorella pyrenoidosa, 59, 149, 240
absorption changes in, 191, 192, 194
absorption spectrum of, 120
action spectrum of fluorescence in, 153,
 209
action spectrum of photosynthesis in, 145
assimilation time, 71
chloroplast in, 83
Emerson (enhancement) effect in, 173–
 175
fluorescence at low temperatures, 206–
 209
fluorescence induction in, 205
fluorescence spectrum of, 198, 200, 207,
 208
oxygen yield in flashing light, 67
quantum yield of photosynthesis of, 149
red drop in fluorescence of, 203, 204
red drop in photosynthesis of, 151
two pigment systems in, 178
Chlorella vulgaris, 84
Chloride ions, 221
Chlorobium chlorophyll (bacterioviridin),
 occurrence and spectrum of, 106, 114
Chlorobium thiosulfatophilum, 59
Chlorophyll, 6, 160, 161
absorption spectrum of, 113, 114
distribution in two pigment systems, 177
layers, 96, 99
location of in vivo, 98, 99
as photocatalyst, 81
photochemistry in solution, 79
photooxidation (and photoreduction) of,
 80, 81
in photosynthetic unit, 69, 70
protein complexes, 94
solubility of, 105, 109
Soret band of, 113
structure, 109, 112
synthesis of, 112
transition (energy level) diagram of, 154
triplet state of, 137, 138
Chlorophyll a , 105, 106, 111
absorption bands of, 99, 106, 113, 114,
 119
active and inactive forms of, 168–171
dimers, 171
fluorescence in cells, 197, 198
fluorescence induction in cells, 205
fluorescence lifetime, 201, 202
homocyclic ring V in, 110, 111
long wave forms of, 119–123, 176–178
in photosynthetic unit, 89, 100
quantum yield of fluorescence of, 139, 196,
 197, 202, 203
several forms of, 119–123, 200, 216
structure, 109–111
in two pigment systems, 177
Chlorophyll a 670, 119–123, 172, 175–
 178, 204, 217
Chlorophyll a 680, 119–123, 172, 176–178, 204
Chlorophyll a 695, 119–123, 176–178, 216
Chlorophyll a fluorescence, action (excitation)
 spectrum of, 203
bands in cells, 198
depolarization of, 164, 204
induction of, 205
lifetime of, 201, 202
origin, 198
two-light effect in, 213–215
Chlorophyll b , 113, 120, 206
absorption spectrum of, 114
occurrence and spectrum of, 106
role in Emerson effect, 174, 175, 177

- structure of, 109, 111, 113
in two pigment systems, 178, 217
- Chlorophyll c**, occurrence and spectrum of, 106
role in Emerson effect, 174, 175
- Chlorophyll d**, occurrence and spectrum of, 106
- Chlorophyll e**, 106
- Chloroplast pigments**, 105
absorption spectra of, 113
function of, 141
location of, 95
- Chloroplasts**, 73, 82, 216, 246
in algae, 83, 84, 89, 100, 101
carbon dioxide fixation by, 77
components of, 92–95
fractionation of two pigment systems in, 216–219
grana in, 84
in higher plants, 85–88
Hill reaction in, 73–78
lamellae in, 86
in leaves, 83
production of ATP in, 246
quantosomes in, 91
thylakoids in, 88, 90
- Chloropseudomonas ethylicum*, 59
- Cho**, F., 206, 208–210
- Christensen**, B. Chr., 259
- Chromatic adaptation**, 114, 115, 117
- Chromatography**, 225
- Chroococcus*, 145
- Clayton**, R. K., 258, 260, 261
- Compensation point**, 148
- Conductance levels**, 165
- Conjugated bonds**, 103, 104
- Conservation of energy**, law of, 22
- Conservation of matter**, law of, 2, 6
- Conti**, S. F., 100, 101
- Corn (maize; *Zea mays*)**, 85, 86, 88, 239
- Coulomb interaction**, 156
- Cramer**, W. A., 249
- Cussanovich**, M. A., 182
- Cyanide**, effect on photosynthesis, 61, 65
- Cyanophyceae*, *see Algae*
- Cyclic phosphorylation**, 189, 247
- Cytochromes**, 49, 79, 185–190, 218
as catalysts, 94
function of, 255
two-light effect on, 188, 189
- Cytochrome *b*₃**, 189, 190
- Cytochrome *b*₆**, 187–189, 218, 247
- Cytochrome *f***, 187–191, 218
- Daniel cell (galvanic)**, 49, 50
- Danielli**, J. F., 258
- Daniels**, F., 37, 149, 259
- Das**, M., 203
- Dehydroascorbic acid**, 80
- Dehydrogenation of water**, 76
- Delayed fluorescence**, 138
- De Saussure**, N. Th., 6
- Detour effect**, 121
- Diatoms**, *see Algae*
- Dichlorophenol indophenol**, (DCPIP), 218, 219, 221
- Dichlorophenyl dimethyl urea** (DCMU), 189, 212, 215, 247, 248
- Difference spectroscopy**, 183–186, 189
- Dihydroorphin**, 110
- Dihydroxyacetone phosphate** (DHAP), 233, 235, 236
- Diphosphoglyceric acid**, 232–234, 238
- Dipole-dipole interaction**, 156
- Dismutation**, 45, 230
- Disorder (entropy)**, 23
- Döring**, G., 192, 193
- Duggar**, B. M., 157
- Dutton**, H. J., 142, 157
- Duysens**, L. N. M., 147, 158, 176, 177, 181, 184, 186–189, 198, 200, 203, 213, 214, 252, 260, 261
- Dyes**, fluorescence of, 210
in Hill reaction, 74
photochemistry of, 79, 80
- E'_o** (normal oxidation reduction potential at pH 7.0), 50
of carbonyl/alcohol, 245
of carboxyl/carboxyl, 223, 245
of CO₂/CH₂O+H₂O, 52, 54
of Cyt *b*/reduced Cyt *b*, 223
of Cyt *f*/reduced Cyt *f*, 223
of Fd/reduced Fd, 222
of H⁺/½H₂, 52, 55
of H₂S/S, 55
of Mn³⁺/Mn²⁺, 221
of NADP⁺/NADPH, 222
of ½O₂/H₂O, 52, 54, 55
of P700⁺/P700, 192

- of Q/QH, 215, 249
 of X/XH, 222
Einstein (mole of photons), 32, 39
Einstein's first law of photochemistry, 64
Einstein's quantum theory of light, 64
Electronic (excited and ground) states, 132, 170
Electronic transitions, 131–140
Electron microscope, resolving power, 82
Electron migration, 164–167, 215
 in conductor, photoconductor, and semiconductor, 164, 165
 in photosynthesis, 166, 215
Electron spin, 137
Electron transfer, 48, 49, 140, 190
Electron volt, 53
Emerson, R., 67–70, 142, 144, 145, 148–151, 169, 172–174, 181, 250, 251, 260
Emerson (enhancement) effect, 172–175, 178, 179
 in blue-green algae, 174
 in diatoms, 174, 175
 in green algae, 173–175
 in NADP⁺ reduction in chloroplasts, 182
 in red algae, 174
Emission bands of pigments, 132, 133
 at low temperature, 206–208
 at room temperature, 198
Endothermal reaction, 25, 26
Energy, 22
 of bond, 43
 content of carbohydrates, 15
 conversion cycle, 40
 different forms (and interconversion) of, 22
 flow in nature, 13, 14, 41
 free, 24–28, 81
 income of the earth, 36
 law of conservation of, 22
 light, total storage, and utilization on earth, 40
 molecular origin of photosynthetic, 42–46
 thermonuclear, 36
 use by mankind, 36–38
Energy levels, of Chl *a* and Chl *b*, 154
 diagram of, 132
 splitting in excited state, 104
Energy migration, 152–164
Energy quantum, 64, 126
 comparison with bond energy, 128
Energy-rich phosphate, 241–244
Energy storage, annual on earth, 40
 discovery of, in photosynthesis, 7, 8
Energy transfer, 152–164
 in bacteria, 158
 efficiency, 158
 heterogeneous (from accessory pigments to Chl *a*), 154–159, 197
 homogeneous (among Chl *a* molecules), 159–164
 probability of, 157
Engelmann, Th. W., 141
Enhancement effect, *see* Emerson effect
Enthalpy (total energy), 24–27
Entropy (disorder), 22–27
Enzymes, 30, 62, 94, 222, 230–240
 Emerson-Arnold, 71
 mechanism of action of, 62
 in path of carbon in photosynthesis, 230–240
 rate limitation of photosynthesis due to, 66
 working time of, 70
Eosinophyll, 80
Erg, 53
Erythrose (and erythrose 4-phosphate), 233, 236
Euglena gracilis, 59, 200
Evolution of life, 20, 255
Excitation energy, fate in cells, 135–140
Excitation spectrum, of Chl fluorescence at low temperature, 209, 210
 of Chl fluorescence at room temperature, 153
Excited state, lifetime of, 133, 202
Exciton migration, 162, 163, 166, 167
Extinction coefficient, *see* Absorption coefficient
Exothermal reaction, 25
Exponential decay, 129–131
 F685–689, 199, 200, 206, 210, 212
 F695–698, 206, 208, 210
 F720–725, 200, 206, 207, 210, 212
Fats, heat of combustion of, 45
Fermentation, 45
Ferredoxin, 76, 190, 222
Ferredoxin-NADP-reductase, 76, 222
Ferric (and ferro) salts, 66, 73, 74
Fisher, H., 110
Flashing light experiments, 60, 66–72

- Flavins, 223
 Flavodoxin, 223
 Fluorescence in plants, 132–140, 152–158, 164, 196–215
 action spectrum in algae, 153, 203, 209
 concentration quenching of, 164
 delayed, 216
 dependence on light intensity, 211–213
 depolarization of, 164
 Franck's theory of, 211
 induction of, 205, 206
 lifetime of, 201, 202
 at low temperature, 206–210, 217
 of phycobilins, 157, 197
 polarization of, 204
 quantum yield of, 139, 196, 197, 202, 203
 quenching of, 213, 214
 red drop in, 122, 203
 sensitized, 152, 158
 spectrum, 198
 Stoke's shift, 134, 135
 transients, *see* Fluorescence, induction
 two-light effect in, 213, 214
 from the two pigment systems, 218
 yield *in vivo*, 196, 203
- Fogg, G. E., 258
 Forbidden (prohibited) transitions, 137, 138
 Fork, D. C., 186, 194
 Formaldehyde, 57
 Förster, Th., 155, 251
 Fortoul, J., 201
 Fossil fuels, 15, 35
 Franck, J., 71, 199, 211, 212, 258, 260
 Franck-Condon principle, 133–135
 Free energy, 24–26, 47, 51
 change in photosynthesis, 27
 consumption in life, 27, 28
 storage of, 80, 81
 French, C. S., 121, 178, 179, 200, 204, 216, 258, 260
 Frenkel, A., 247
 Frequency of light, 125
 Fructose, 229, 235
 Fructose diphosphate (FDP), 233, 236
 Fucoxanthol, 107, 108, 115, 118, 174, 175
 absorption bands of, 146
 effectiveness in photosynthesis, 147
 occurrence and spectrum of, 107
 role in Emerson effect, 174, 175
 Fucus, 108
 Fuller, R. C., 258, 260
 Gaffron, H., 69, 250, 257, 258
 Galvanic potential, 49, 50
 Gantt, E., 100, 101
 Gaussian curve, 122
 Gest, H., 259
 Gibbs, M., 261
 Giese, A. C., 258
 Glass, B., 259
 Glucolipids, 92
 Glucose (and glucose monophosphate), 229, 233, 236
 Glyceraldehyde (and glyceraldehyde phosphate, GAP), 233, 235, 236
 Glycerol, 228
 Glycine, 112
 Glycolic acid, 239
 Glycol phosphate, 230
 Godnev, T. H., 123
 Goedheer, J. H. C., 259
 Good, N., 77
 Goodwin, T. W., 259
 Govindjee, 120, 175, 177, 198, 200, 201, 203, 205, 208, 211, 213, 261, 262
 Govindjee, R., 150, 181, 182
 Grana, 82, 84, 85, 86, 88
 Green algae, *see* Algae
 Green bacteria, *see* Photosynthetic bacteria
 Greer, F. A., 260
 Guldberg and Waage's law, 64, 65
 Haldane, J. B. S., 20
 Hales, S., 1
 Hatch, M. D., 239, 248, 254
 Hatch-Slack pathway, 239
 Heat of combustion, 45
 Heidt, L. J., 259
 Heisenberg's uncertainty principle, 125
 Heller-Marcus mechanism for electron migration, 163
 Heterocyclic (and homocyclic) rings, 103
 Heterotrophic organisms, 19
 Hexose (and hexose phosphate), 229, 235
 High energy phosphate, 241–244
 Hill, R., 73, 187–189, 252, 257, 261
 Hill-Bendall's scheme of photosynthesis, 189, 190

- Hill oxidants, 74
Hill reaction, 73–75, 182, 217, 221
Hind, G., 261
Hoch, G., 260
Hole (electron vacancy) migration, 165
Hydrogen, acceptors and donors, 47
discovery, 3
uphill transfer in photosynthesis, 54
Hydrogen ion gradient and ATP formation,
244
Hydrolysis, 241, 242
Hydrophilic and hydrophobic compounds,
96–98
Hydroquinones, 46, 47
Hydrosphere, 38

Ingenhouse, J., 4–8, 102
Inorganic phosphate (P_i or $(P)OH$), 228
Integrating sphere, 121
Internal conversion, 133, 137
Ionone ring, 118
Isomerase, 235, 236
Isothermal reactions, 24, 25

Jagendorf, A. T., 244, 248, 259, 260
Jensen, R. G., 77
Joliot, P., 214, 221
Joule (unit of energy), 53

Kamen, M., 76, 182, 224, 250, 258
Kamp, B. M., 252
Kandler, O., 246
Katoh, S., 194
Kautsky, H., 199, 213, 214
Keto group, 228
Ketose, 228, 229
Kinase, 232, 234
Kok, B., 72, 184, 186, 191, 192, 214, 222,
249, 252, 259, 260
Krasnovsky, A. A., 80, 81, 171, 216
Krasnovsky reaction, 80
Kreutz, W., 192, 193
Krey, A., 211, 213
Kroghman, D. W., 259

Lamellae, 82, 84–89
Latimer, P., 121
Lavoisier, A., 2
Lavorel, J., 206, 214
Leucodyes, 79, 80

Lewis, C., 145, 251
Leyon, H., 87
Life, origin and evolution of, 20
Lifetime, of excitation, 201, 202
Light, absorption by molecules, 161
discovery of role in photosynthesis, 4, 5
dual nature (particle and wave) of, 125
Einstein's quantum theory of, 64
frequency, velocity, wavelength, and wave-
number of, 64, 125, 126
infrared, visible and ultraviolet, 127
irreversible injury by, 60
saturation of photosynthesis by, 60–62,
68
scattering by algal suspensions, 119, 121
Light absorption, 125–127
mechanism of, 131–135
Light energy, conversion into other forms
of energy, 14, 35
Lipoids (and lipids), 92–94
function of, 93
solubility of, 112
Lithosphere, 38
Livingston, R., 258, 259
Lomonosov, M. V., 2
London, F., 96
Loomis, W. E., 258
Lumry, R., 201
Luteol, occurrence and absorption of, 107

McElroy, W. D., 259
Magnesium, 112
Malic acid, 238, 239
Malic acid dehydrogenase, 239
Manganese, requirement in O_2 evolution, 218,
221
Manning, W. M., 142, 149, 157
Manometry, 58, 149
Mass action law, 64, 65
Matrix analysis, 200
Mayer, J. R., 7, 8, 28
Membranes, 86, 92, 244
function of, 93, 94
Menke, W., 86, 90
Metabolic processes, 56, 243
Metastable state, 136, 137, 211, 212
Methane, heat of combustion of, 45
Methanol, solvent for chlorophyll, 80
Methylene blue, in a model reaction, 79
Metzner, H., 260

- Michaelis, L., 62
 Micron (unit of size), 83
 Mitchell, P., 93, 244
 Mitochondrion, 57, 58, 94
 Molar absorption coefficient, 129
 Molecules, absorption by, 132–135
 cross section of, 161
 dimeric forms of, 171
 Montfort, C., 142
 Morita, S., 182
 Moudrianakis, E. N., 92
 Munday, J. C., Jr., 205
 Myers, J., 179, 181

 NAD⁺ (nicotinamide adenine dinucleotide)/
 NADH couple, 95, 239, 244
 NADP⁺ (nicotinamide adenine dinucleotide
 phosphate)/NADPH couple, 51, 76, 95,
 190, 238, 249
 in Calvin cycle, 232, 234, 245
 Emerson effect in reduction of, 182
 reactions in the two pigment systems, 218,
 219, 221
 structure of, 222
 Naphthalene, 103
Navicula minima, 59, 145, 147, 151, 174,
 175
 Negelein, E., 149
 Negentropy (order), 23, 28
 Neuman, J., 261
 Nicholson, W. J., 201
 Noncyclic photophosphorylation, 190, 247,
 248
 Norrish, R. G. W., 184

 Ochoa, S., 76
 Olson, J. M., 260, 261
 Oparin, A. I., 20
 Optical density (absorbance), 130, 131
 Organic matter, production on earth, 11–
 13, 17
 Organisms, autotrophic, chemoautotrophic,
 heterotrophic, and photoautotrophic, 19
 Osmic acid, 96
 Oxalacetic acid, 224, 239
 Oxidation, 46, 47
 Oxidation-reduction potentials, 46–51
 Oxidation-reduction reaction in photo-
 synthesis, 75, 251
 Oxygen, cycle and annual liberation into
 air, 17, 18
 Oxygen evolution, in chloroplasts, 73–78
 mechanism of, 220, 221, 255
 methods for measuring, 59
 site of, 74

 P (Pigment) 690, 190–193
 P (Pigment) 700, 186, 190–192
 identification with "trap," 192
 oxidation-reduction potential of, 192
 two-light effect on, 192
 Paolillo, D. J., 83
 Papageorgiou, G., 177, 201, 205, 261
 Park, R. B., 88, 89, 91, 92
 Pentose (and pentose phosphate), 229–233,
 236, 237
 pH, 50
Phaeophyceae, *see* Algae
 Phosphatase, 236
 Phosphate bond, 242, 243
 Phosphoenol pyruvate carboxylase, 239
 Phosphoenol pyruvic acid, 239
 Phosphoglyceraldehyde (triose phosphate),
 234–236
 Phosphoglyceric acid (PGA), 226–235, 238
 effect of lowering CO₂ and removal of
 light on, 231
 reduction of, 232–234, 238, 245
 Phospholipids, 92, 97
 Phorescence, 137, 138
 Phosphoric acid, 228, 242
 Phosphorylation, of phosphoglyceric acid
 (and of ribulose monophosphate), 233,
 234, 238; *see also* Photophosphorylation
 Photocatalyst, 79, 81
 Photochemical steps in photosynthesis, 54,
 63, 64, 66, 180, 190
 Photochemistry, 64, 79–81
 Photoconductivity, 165
 Photon (quantum), 39, 64, 125, 126
 Photooxidation of chlorophyll, 80, 81
 Photophosphorylation, 241–249
 chemiosmotic theory of, 248
 cyclic and noncyclic, 247, 248
 discovery in chloroplasts (and chromato-
 phores), 247
 quantum requirement of, 249
 Photoreduction of chlorophyll, 80, 81
 Photorespiration, 78
 Photosynthesis, action spectra of, 143–147

- bacterial, 19, 33, 55, 182
carbon dioxide reduction in, 232–240
compensation point, 148
definition of, 1, 28, 45–47; 53
discovery of, 1–10
effectiveness of pigments in, 147, 158
effect of poisons on, 65
effect of temperature on, 65
efficiency of, 39, 148–150
energetics of, 42, 43, 52–54
enzymatic stage in, 54, 60, 61, 232–240
equations of, 6, 7, 9, 10, 15, 19
evolution of, 255
in flashing light, 66–72
imitation of, 80, 255
“light curve” of, 61, 62
as oxidation-reduction reaction, 139, 140
oxygen evolution in, 220, 221
overall reaction of, 15
phosphorylation in, 241–249
photochemical stage of, 54, 58, 60, 61,
 124, 131–140
primary reaction of, 139, 140, 191–193
products of, 9, 10, 238–240
quantum yield of, 61, 143–150
red drop in, 151, 168–172
saturation of, 61, 63
schemes of, 54, 140, 154, 157, 177, 180,
 190, 232, 233
Photosynthetic bacteria, 20, 59, 86, 90,
 106, 107
Photosynthetic phosphorylation, 246–249
Photosynthetic pigments, 102, 105–109
Photosynthetic units, 68–70, 89–92, 100
Phycobilins, 107, 109, 117
 distribution in two pigment systems, 177
 structure of, 115, 116
Phycobilisomes, 100, 101
Phycocyanin, 109, 115, 117, 157, 174
 occurrence and absorption of, 107, 113
Phycoerythrin, 107, 109, 115, 117, 157,
 174
 occurrence and absorption of, 107, 113
Phytochrome, 102, 116
Phytol, 109, 112
Pigments, *see* Photosynthetic pigments
Pigment systems, I and II, 176–178
 carotenol/carotene ratio in, 218, 219
Chl *a*/Chl *b* ratio in, 218, 219
cytochromes in, 218, 219
differential extraction of, 217
fluorescence of, 200, 201, 204, 210, 213,
 218, 219
iron content of, 218, 219
Mn content of, 218, 219
P690 in, 192, 193, 207
P700/Chl *a* ratio of, 218
photochemical activity of, 218, 219
reconstruction, 219
Pike, S. T., 12
Planck's constant, 64, 126
Plastocyanin (PC), 94, 186, 190, 194, 215
Plastoquinone (PQ), 95, 186, 190, 193, 194,
 215
Polarization of Chl *a* fluorescence, 204
Porphin and porphyrins, 109, 110
Porphyridium cruentum, 59, 89, 100, 145,
 146, 174, 189, 204, 212
Porter, G., 184
Powers, W. H., 259
Priestly, J., 2–4
Pringle, J., 4
Proteins, 92–96
Purple bacteria, *see* Photosynthetic bacteria
Pyridine, 103
Pyridine nucleotides, 95
Pyrrol ring, 109, 110
Pyruvate synthetase, 239
Pyruvic acid, 238, 239
Q, 214, 215, 249
Quanta, 39, 64, 125, 126, 128
Quantosomes, 91, 92
Quantum requirement, *see* Quantum yield
Quantum yield (efficiency), 64
 of fluorescence, 139, 196, 197, 202, 203
 of NADP⁺ reduction, 182
 of photosynthesis, 143–150
Quenching, of Chl *a* fluorescence, 213, 214
Quinone, 46, 47, 74, 95
Rabinowitch, E., 80, 120, 174, 175, 177, 257,
 258, 259, 261
Reaction (enzymatic) centers, 69, 139, 166,
 191–193
Red algae, *see* Algae
Red drop, in fluorescence, 203, 204
 in photosynthesis, 151, 168, 169, 176
Redox couple, 47, 51
Redox potential, 49–55

- Reduction, 46–49
 Reduction level, *R*, 44–46
 Reinke, J., 60
 Resonance, energy transfer, *see* Energy transfer
 stabilization, 242, 243
 Respiration, 14, 28–32, 43, 44
Rhodophyceae, *see* Algae, red
Rhodopseudomonas sphaeroides, 59, 90, 106
Rhodospirillum rubrum, 59
 Riboflavin, 81
 Ribulose diphosphate (RDP), 229–231, 235–239
 Ribulose monophosphate, 233, 238
 Riley, G. A., 12
 Robinson, G. W., 260
 Rosenberg, J., 221, 258, 260
 Rotational states, 132
 Ruben, S., 76, 224, 250
 Ruhland, W., 257
 Sachs, J., 10
 Sanadi, D. R., 258
 San Pietro, A., 76, 259, 260
 Scattering, selective, 121
Scenedesmus, 59, 226
 Scheele, 2
 Schroeder, H., 12
 Sedoheptulose (and sedoheptulose phosphate), 233, 236
 Seely, G. R., 258
 Semiconductor, 165
 Senebier, J., 5
 "Separate packages," hypothesis, 181
 Shibata, K., 260
 Shlyk, A. A., 123
 Shumway, L. K., 88
 Sieve effect, 121, 122
 Singhal, G. S., 201
 Singlet state, 137, 211
 Slack, C. R., 239, 248, 254
 Smith, J. H. C., 10, 123, 260
 Solar constant, 34
 Solar energy, annual storage and flux of, 39
 supply on earth, 34
 Solar radiation, properties of, 127–129
 Soret band, 113, 114
 Spectrofluorometer, 197
 Spectrophotometer, derivative, 121
 difference, 185
 Spencer, J., 208
 Spilhaus, A., 12
 "Spillover," hypothesis, 181
 Spirilloxanthol, occurrence and spectrum of, 107
 Steeman-Nielsen, A., 12
 Steinmann, E., 89
 Stiehl, H. H., 192
 Stocking, C. R., 88
 Stokes' shift, 134, 135
 Stoll, A., 71, 141
 Strain, H., 106
 Strehler, B., 215, 246, 258
 Stroma, 92
 Sucrose, 229
 Sunlight, 34–41, 127, 128
 Sweers, H. E., 213, 214
 Sybesma, C., 182
 System I (PSI) and System II (PSII), 176–178, 216–219
 composition of, 177
 fluorescence of, 206
 Takamiya, A., 260
 Tamiya, H., 71, 259
 Tanada, T., 147
 Temperature, effect on photosynthesis, 61, 65
 Tetrahydroporphin, 110
 Thermal energy, 22
 Thermodynamics, first law of, 22
 second law of, 23–26
 Thiamine (vitamin B_1), 236, 237
 Thomas, J. B., 216, 258, 259
 Thylakoid, 88, 90
 Tolbert, N. E., 258
 Tomita, G., 158
 Transaldolization, 237
 Transketolization, 237
 Traps, absorption changes in, 191–193
 fluorescence of, 207, 208
 Trichlorophenol indophenol, (TCPPIP), 218, 219
 Triose dehydrogenase, 245
 Triose phosphate (TP), 233–235, 238, 244, 245
 Triose phosphate dehydrogenase, 234
 Triplet state, 137, 211
 Two-light effect, in fluorescence, 213

- in photosynthesis, 173, 189, 190, 192
Ulva, 194
Uncertainty principle, 125

Van der Waals forces, 96
Van Helmont, J. B., 1
Van Niel, C. B., 19, 33, 76, 260
Vatter, A. E., 85, 86, 88, 89
Vernon, L. P., 219, 258–261
Vibrational state, 132–134
Vinogradsky, S., 19
Violaxanthol, occurrence and absorption
of, 107
Vishniac, W., 76

Walker, D., 77
Wannier mechanism of exciton migration,
163
Warburg, O., 74, 149, 150
Wassink, E. C., 199
Water, role in photosynthesis, 6, 54, 190

Wavelength, frequency, wave number, 125,
126
Weber, G., 200
Weier, T. W., 88
Weiss, J., 80
Weller, S., 71
Whatley, F. R., 246
Whittingham, C. P., 257
Williams, P., 153
Willstätter, R., 71, 110, 141, 142
Witt, H. T., 185, 186, 191–194, 252
Wohl, K., 69, 250
Woodward, R. B., 110
Wurmser, M. R., 259

X/XH couple, 54, 190, 220, 222
Xanthophyll, 107, 108
Xylulose monophosphate, 233

Y/YH couple, 190, 214

Z/ZH couple, 54, 190, 220