Appendix: How to View the Stereograms

There are more than twenty stereograms of crystal structure of macromolecules or molecular assemblies in this book*. These stereopictures not only contain important three-dimensional, structural information, they are also joy to view. It is also quite easy to view these stereograms with unaided naked eyes. For those who may not be familiar with the viewing method, I believe just a few minutes of practice, by following the steps below, the reader should be able to acquire and retain the ability to view them. A number of articles have appeared in the literature that provide instructions on how to view the stereograms with naked eyes. I have adapted the recent TIBS article by McKeon and Gaffield**, adding a little of my own preference, as an exercise.

Preliminary exercise: Point the left and right index fingers toward each other, leaving a gap of ~1 cm [see Fig. 1 (a)]. It is best to face a plain background, such as a white wall. The fingers are held at the eye level, about 25-30 cm from the eyes, with the eyes focused at and beyond the point between the finger tips. The fingers appear to fuse, forming a short "sausage" floating between the finger tips [see Fig. 1 (b)].

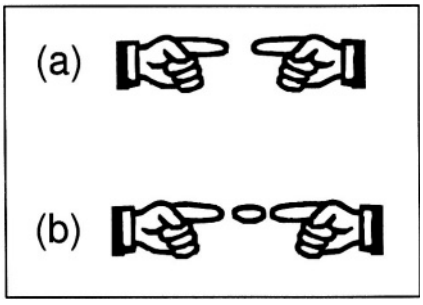

Figure 1

Viewing exercise: Figure 2 shows the stereogram of the crystal structure of a toxaphene component, 2,2,5-endo,6-exo,8,9,10-heptachloroborane. I would suggest to place this book flat on a desk. The reader may bend forward to view the picture at a comfortable distance. This arrangement would keep the picture stationary, better than by raising the book for viewing. Again, by focusing on the gap between the two figures, the left figure appears to move toward the right and fuse with the right figure, and a fascinating, stereopicture appears, in a matter of seconds. In this case, the whole, three-dimensional molecule appears to jump out of the page toward the viewer, and the $C(CH_2Cl)_2$ bridge appears particularly prominent. The individual C- and Cl-atoms, because of the way they are drawn, are particularly intriguing.

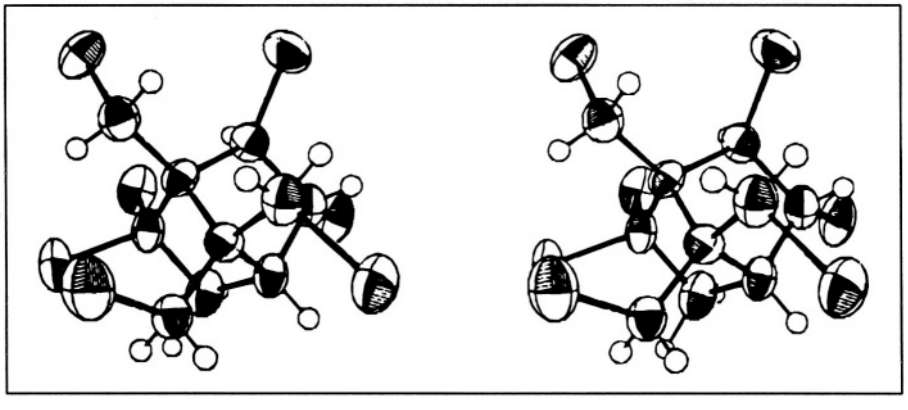
Figure 2

* Stereograms can be found on the following pages: 61, 87, 156, 222, 235, 258, 259, 422, 454, 456, 463, 494, 607, 608, 621, 629 and 630, as well as Color Plate-7.

** TA McKeon and W Gaffield (1990) *Viewing stereopictures in three dimensions with naked eyes.* Trends Biochem Sci 15: 412-413.

Abbreviations

A

Amino acids:
- Ala /A - alanine
- Arg / R - arginine
- Asp / D - aspartic acid
- Asn / N - asparagine
- Cys / C -cysteine
- Gln / Q - glutamine
- Glu / E - glutamic acid
- Gly / G - glycine
- His / H -histidine
- Ile /I - isoleucine
- Leu / L - leucine
- Lys / K - lysine
- Met / M - methionine
- Phe / F - phenylalanine
- Pro / P - proline
- Ser / S - serine
- Thr / T - threonine
- Trp / W - tryptophan
- Tyr / Y - tyrosine
- Val / V - valine

α – misses *see* oxygen evolution

$[\alpha\beta]_O$, $[\alpha\beta]_L$, $[\alpha\beta]_T$ – αβ subcomplex of CF_1 with open, loose or tight affinity for ADP and P_i

α^{APC} - α subunit of APC (allophycocyanin)

1^1A_g (2^1A_g, 1^1B_u, *etc.*) - electronic-state notations for polyenes

Å- Ångstrom unit, 10^{-10} meter

A_0 - the primary (first) electron acceptor of the PS-I reaction center

A_1 - the second electron acceptor of the PS-I reaction center; *see* A_0

A_i - (hyperfine) interaction constant

A_L - absorption of left-handed circularly polarized light

A_R - absorption of right-handed circularly polarized light

AA - amino acids

ACP - accessory chlorophyll proteins

ADMR - absorption-detected magnetic resonance

ADP - adenosine diphosphate

ADRY (agent) - acceleration of the deactivation reaction of the water splitting enzyme Y (agent)

AMD - adenosine monophosphate

AMP-PNP- adenyl-β,γ-imidodiphosphate

ANT2a - 2-(4-chloro-anilino)-3,5-dinitrothiophene

ANT2p - 2-(3-chloro-4-trifluoromethyl-anilino)-3,5-dinitrothiophene

A. nidulans - *Anacystis nidulans*

AP-B - allophycocyanin-B

APC - allophycocyanin

Asc - ascorbate

ATP - adenosine triphosphate

ATPase - adenosine triphosphatase

B

β^{APC} - β subunit of APC (allophycocyanin)

β-OG - octyl-β-glucopyranoside

B - stands for bulk in, *e.g.,* B850 to designate a light-harvesting BChl-protein complex

B - monomeric bacteriochlorophyll

b_6f - cytochrome b_6f

B_A - A-side BChl monomer

B_B - B-side BChl monomer

B_L - L-side BChl monomer; same as B_A

B_M - M-side BChl monomer: same as B_B

β - double hits *see* oxygen evolution

BBY - a PS II-enriched thylakoid membrane named after Berthold, Babcock and Yocum

BChl - bacteriochlorophyll

$[BChl]_2$ - bacteriochlorophyll special pair

bipy - 2,2′-bipyridine

Bpheo - bacteriopheophytin, same as BΦ

BΦ - bacteriopheophytin

$B\Phi_A$ - A-side bacteriopheophytin

$B\Phi_B$ - B-side bacteriopheophytin

$B\Phi_L$ - L-side bacteriopheophytin; same as $B\Phi_A$

$B\Phi_M$ - M-side bacteriopheophytin; same as $B\Phi_B$

BR - bacteriorhodopsin

C

χ - magnetic susceptibility
c - for chloroplast gene; *see* "n"
C (or *c*) - alternative abbreviation for Cyt
C-subunit - cytochrome subunit
$_{CA}$-Chl - core-antenna chlorophyll
CAB - chlorophyll a/b-binding protein
Car - carotenoid
Cb. - Chlorobium
CC - core complex
CChl - Chlorobium chlorophyll
CCI - core complex of photosystem I
CCCP - carbonyl cyanide *m*-chlorophenylhydrazone
CCD - charge coupled device
CD - circular dichroism
Cf. aurantiacus - Chloroflexus aurantiacus
CF - coupling factor
CF_1 / CF_O - major subunit assemblies of chloroplast ATPase
Chl - chlorophyll
Chl *a'* - epimer of Chl *a*
Chl a_I - alternative designation for P700
Chl a_{II} - alternative designation for P680
CM - core membrane
Cm. - Chromatium
Cp. - Chloropseudomonas
CP -chlorophyll protein
C-PC - C-phycocyanin
CPI - chlorophyll protein of photosystem I
CP43 / CP47 - 43- / 47-kDa chlorophyll *a*-binding core-antenna proteins of PS-II
C-P430 - P430 of Chlorobium origin
Cyt - cytochrome
Cyt *b559* - cytochrome *b559*
[Cyt *b559* (LP or HP) refers to the low-potential or high-potential form of cytochrome *b559*]
Cyt b_6f - cytochrome b_6f
Cyt/- cytochrome/

D

$\Delta\mu_{H^+}$ -electrochemical potential
ΔpH - difference in pH across the membrane
ΔΨ - membrane potential difference
ΔA - absorbance difference
ΔCD - difference in circular dichroism
ΔG^0 - standard free energy
Δε - differential extinction coefficient
ΔH - EPR signal linewidth
ΔT/T - relative change in transmission
D - electron donor, or secondary electron donor
D - alternative designation for the primary electron donor; *cf.* "P"
D - stands for diffuse; refers to the diffuse bands D1 and D2 on the SDS-PAGE gel
D1- the 32-kDa polypeptide subunit of Photosystem II encoded by the chloroplast *psbA* gene
D2- the 34-kDa polypeptide subunit of Photosystem II encoded by the chloroplast *psbD* gene
Da - daltons
DABS - diazonium benzene sulfonate
DAD - diaminodurene (C_2,C_3,C_5,C_6-tetramethyl-*p*-phenylenediamine)
DADS - decay associated difference spectrum
DBMIB - 2,5-dibromo-3-methyl-6-isopropylbenzoquinone
DCBQ - dichloro-p-benzoquinone
DCCD - N,N'-dicyclohexylcarbdiimide
DCIP - 2,6-dichlorophenol-indophenol
DCMU - 3-(3,4-dichlorophenyl)-1,1-dimethylurea
DEAE - diethylaminoethyl (cellulose)
DELSEED - an amino-acid segment
DGDG - digalactosyldiacylglycerol
DMBQ-2,6-dimethyl-*p*-benzoquinone
DMSO - dimethyl sulfoxide
DMF-dimethylformamide
DNP - dinitrophenol
DPC - diphenyl carbazide
DPQ - decylplastoquinone
DTNB - 5,5'-dithiobis-(2-nitrobenzoate)
DTT - dithiothreitol

E

ε_M - molar absorption coefficient
e^- - electron
[e^-] - reducing environment
$E_{½}$ - polarographic halfwave potential
e5m - eosin-5-maleimide
E_h - potential relative to the hydrogen electrode
EcF_1 - coupling factor 1 from *Escherichia coli*
EcF_O - coupling factor o from *Escherichia coli*
EDC - 1-ethyl-3-[3-(dimethylamino)-propyl] carbodiimide
EDTA - ethylenediamine-tetraacetic acid

EF_S - exoplasmic fracture face of stacked membrane
EF_U - exoplasmic fracture face of unstacked membrane
E_m - midpoint potential
EM - electron microscopy
ENDOR - electron nuclear double resonance
EPR - electron paramagnetc resonance
erg - energy unit, equals 10^{-7} Joule
ESE - electron spin echo
ESEEM - electron spin echo envelope modulation
ESP-EPR - electron spin polarized EPR
Et - ethyl
eV - electron volt
EXAFS - extended X-ray absorption fine structure

F

$\mathcal{F}$ - Faraday constant
Φ - pheophytin
Φ_D - quantum yield of donor emission
Φ_f - quantum yield of fluorescence
ΦQ - phylloquinone
F - level of fluorescence
F_O - coupling factor o of ATP synthase
F_0 - fluorescence of open reaction centers; or initial fluorescence level
F680 - a fluorescent species emitting at 680 nm
F_1 - coupling factor 1 of ATP synthase
F_1, F_2 - nonspecific designation for FeS-A and FeS-B
F_A, F_B - alternative designations for FeS-A and FeS-B
F_S - steady-state fluorescence level
F_{max} - maximum fluorescence level (of closed reaction centers)
FAD - flavin adenine dinucleotide
FCCP - carbonyl cyanide *p*-trifluoromethoxyphenylhydrazone
FCPA - fucoxanthin-chlorophyll protein assembly
FCPC - fucoxanthin chlorophyll *alc* protein complex
Fd - ferredoxin
FeCy - ferricyanide
Fe•Q - iron-quinone complex
FeS - iron-sulfur (cluster) *see* ISP
FeS-A / FeS-B - iron-sulfur centers A / B
FeS-X - iron-sulfur center X
FIAC - field-induced absorption change
fMet (or fM) - formylmethionine
FMN - flavin mononucleotide
FMO (BChl-*a*) protein - Fenna-Mathews-Olson protein
FNR - ferredoxin-NADP$^+$-reductase
Fp - flavoprotein
FRS - ferredoxin reducing substance
fs - femtosecond, 10^{-15} second

G

γ^{PE} - γ-subunit of PE (phycoerythrin)
g - *g*-value of an EPR signal
G - Gauss
gmcd - gramicidin

H

H-subunit - heavy (molecular-weight) subunit
H - alternative designation for $B\Phi_A$
H^+/ATP - protons translocated per ATP synthesized by the electron-transport chain
H^+/e^- - protons translocated per electron transferred by the electron-transport chain
H_2A - a general designation for a reduced compound, *e.g.*, H_2O, H_2S, *etc.*
Hb. - Heliobacterium
Hc. - Heliobacillus
hfs - hyperfine (line) splitting
HiPIP - High-potential iron protein
HP - high-potential
HP - (subscript) horizontally polarized
HP700 - a PS-I complex with high P700 content
HPLC - high-performance liquid chromatography
hv - photon

I

i - inner (or bound) *see* "o"
I - (transient) intermediate electron acceptor
ISP - iron-sulfur protein, *see* FeS
ICM - Intracytoplasmic membrane

K

K - degree Kelvin
$k_{AB(1)}$ - rate constant for electron-transfer from $Q_A^{\cdot-}$ to Q_B
$k_{AB(2)}$ - rate constant for electron-transfer from $Q_A^{\cdot-}$ to $Q_B^{\cdot-}$
$k(P^{\cdot}Q_B)$ - rate constant for charge recombination between P^+ and $Q_B^{\cdot-}$

kDa - kilodalton
kcal - kilocalorie

L

λ^A - wavelength of absorption
λ^F - wavelength of fluorescence
L - light (weight)
L - linker polypeptide [in PBS (phycobilisome)]
L_C - core linker polypeptide
L_{CM} - core-to-(thylakoid) membrane linker polypeptide
L_R - rod linker polypeptide
L_{RC} - rod-to-core linker polypeptide
LB - Langmuir-Blodgett (technique for preparing multiple monolayers)
L-subunit - light (molecular-weight) subunit
LD - linear dichroism
LDAO - lauryl dimethylamine-N-oxide
LDS - lithium dodecyl sulfate
LHC - light-harvesting complex
LHCP - light-harvesting chlorophyll protein
LH1 (or LHI) - the core (or inner, or proximal) light-harvesting complex of photosynthetic bacteria (B875, B890, *etc.*)
LH2 (or LHII) - the peripheral (or distal) light-harvesting complex of photosynthetic bacteria (B800-850)
LHC I - light-harvesting complex of photosystem I
LHC II - light-harvesting complex of photosystem II
LHCP - light-harvesting chlorophyll-protein
LM-complex - complex consisting of the L- and M-subunit
LP (or LPP) - linker polypeptide
LP - low-potential

M

μE - microeinstein (one micromole of photons)
μm - micrometer (or μ, micron)
μM - micromolar
ms - millisecond, or 10^{-3} second
mV - millivolt
μs - microsecond, or 10^{-6} second
μV - microvolt
M-subunit - medium (molecular-weight) subunit
MES - 2-(N-morpholino)-ethanesulfonic acid
MF_1 / MF_0 - mitochondrial coupling factor l/o
MGDG - monogalactosyldiacylglycerol
MQ - menaquinone (vitamin K_2)
MV -methyl viologen
MW - molecular weight

N

n - for nuclear gene; *see* "c"
n(-side) - negative side of a membrane (also n-phase)
N - normal (for concentration)
NAD^+ - nicotinamide adenine dinucleotide (the oxidized form)
NADH -nicotinamide adenine dinucleotide (the reduced form)
$NADP^+$ - nicotinamide adenine dicucleotide phosphate (the oxidized form)
NADPH - nicotinamide adenine dicucleotide phosphate (the reduced form)
NEM - N-methylmaleimide
NHE - normal hydrogen electrode
NMR - nuclear magnetic resonance
ns - nanosecond, 10^{-9} second

O

o - outer (or mobile) *see* "i"
$^1O_2$ - singlet oxygen
$^3O_2$ - triplet oxygen
OEC - oxygen-evolving complex
OP - *ortho*-phenanthroline
ox - oxidized

P

P - pigment
P - the primary electron donor
P - phosphate group (as in LHC II-P)
P* - excited singlet state of P (the primary donor)
P^+ - cation of P
p(-side) - positive side of a membrane (also p-phase)
2′-P-AMP - 2′-phospho-5′-AMP
P^E (state) - the $[P^{+}\cdot B^{-}]$; (E for early)
P^F (state) - the] $[P^{+}\cdot I^{-}]$ or $[P^{+}\cdot B\Phi^{-}]$ state; (F for fast)
P^R (state) - the $[^TP^{+}\cdot I]$ state; (R for radical-pair triplet)
^TP - reaction-center chlorophyll triplet; *e.g.*, $^TP700$
P/2*e* - the ratio of ATP formed per two electrons transferred

P430 - a secondary electron acceptor of photosystem I
P680 - primary electron donor (chlorophyll special pair) of photoystem II; *see* Chl a_{II}
P700 - primary electron donor (chlorophyll special pair) of photoystem I; *see* Chl a_{I}
P798 (or P800) - primary electron donor of Heliobacteria
P840 - primary electron donor of green-sulfur bacteria
P870 - primary electron donor of *Rb. sphaeroides*
P960 - primary electron donor of *Rp. viridis*
PAGE - polyacrylamide gel electrophoresis
PARAP - polarized absorption relaxation after photobleaching
PB - phycobilin
PBP - phycobiliprotein
PBS - phycobilisome
PBV - phycobiliviolin
PC - plastocyanin
PC - phycocyanin
PC - phosphatidylcholine
Pc. - Prosthecochloris
PCB - phycocyanobilin (chromophore)
PCP - peridinin-chlorophyll *a*-protein
PDG - phosphatidyl diglyceride
PE - phosphatidyl ethanolamine
PE - phycoerythrin
PEB - phycoerythrobilin (chromophore)
PEC - phycoerythrocyanin
PEG - polyethylene glycol
PEWY - an amino-acid segment (Pro-Glu-Trp-Tyr)
PF_S - protoplasmic fracture face of stacked membrane
PF_U - protoplasmic fracture face of unstacked membrane
PG - phosphatidylglycerol
pI - isoelectric point
PL - phospholipid
PM-8 - a mutant of *Rb. sphaeroides* (photosynthetically incompetent)
PMS - *N*-methylphenazonim methosulfate
PP - polypeptide
PP - photosystem pigment (of green sulfur bacteria)
PPBQ - paraphenyl benzoquinione
PQ - plastoquinone
P. aestuarii - Prosthecochloris aestuarii
ps - picosecond, or 10^{-12} second
PsaA-N - the polypeptide subunits of photosystem I (see Chapter 1, Table 1 to 6)
psaA-N - genes encoding the PsaA-N polypeptide subunits of photosystem I (see Chapter 1, Table 1 to 6)
PS - photosystem (also for photosynthetic)
PS I, II - photosystem I, II
PSU - photosynthetic unit
pt_s - -log of time in seconds
PUB - phycourobilin (chromophore)
PXB - cryptoviolin chromophore (of PEC)
PYC - pyocyanine

Q

Q - quinone
Q_0 - 2,3-dimethoxy-5-methyl-1,4-benzoquinone
Q_A - primary quinone acceptor
Q_B - secondary quinone acceptor
Q·Fe - quinone-iron complex
QH_2 - dihydroquinone or quinol
Q_o - oxidizing quinone binding site; also called Q_p
Q_r - reducing quinone binding site; also called Q_n
Q_x, Q_y - electronic transition moments

R

R-26 - a carotenoidless mutant of *Rb. sphaeroides*
Rb. - Rhodobacter
RC - reaction center
RCPP - reaction-center pigment protein (a protein complex of green sulfur bacteria)
red - reduced
R-ISP -Rieske iron-sulfur protein
Rp. - Rhodopseudomonas
R-PC - R-phycocyanin
Rs. - Rhodospirillum

S

s - second
S - singlet state (S_1, S_2, *etc.*)
$S_2O_4^{=}$ - dithionite
S-S - singlet-singlet (energy transfer)
SDS - sodium dodecyl sulfate
SDS-PAGE - sodium dodecyl sulfate polyacrylamide gel electrophoresis
SiMo - silicomolybdate
SI - signal I; EPR signal of photosystem I
SII - signal II; EPR signal of photosystem II
SII_f - fast-decaying PS-II EPR signal
SII_s - slow-decaying PS-II EPR signal
SII_{vf} - very fast-decaying PS-II EPR signal
SL - sulfolipid
S/N - signal-to-noise ratio

S_n (n=0,1,2,3,4) - the redox state of the oxygen-evolving complex (n corresponds to the number of stored oxidizing equivalents)
SQDG - sulfoquinovosyldiacylglycerol
ss - steady state
ST - safranine-T
STM - scanning tunneling microscopy
STS - scanning tunneling spectroscopy

T

τ - time
T - triplet state
Tb. - *Thiobacillus*
T-T - triplet-triplet (energy transfer)
$t_{½}$ (or $\tau_{½}$) - half-decay time
t_d - dark interval
t_D - delay time
TERB - terbutryn (2-thiomethyl-4-ethylamino-6-*t*-butylamino-*s*-triazine)
TLC - thin-layer chromatography
TMPD - *N*,*N*,*N*′,*N*′-tetramethyl-*p*-phenylenediamine
TNBS - 2,4,6-trinitrobenzene sulfonate
Triton X-100 - octylphenoxypolyethoxyethanol
Tris - tris(hydroxymethyl)aminomethane
TSF1 - Triton-fractionated subchloroplast fragment of photosystem I (1)
TSF2 - Triton-fractionated subchloroplast fragment of photosystem II (2)
TSF2a - Triton-fractionated subchloroplast fragment of photosystem II (2), with a high Chl-*a* content
TyrD - tyrosine-160 of the PS-II D2 subunit (or Y_D)
TyrZ - tyrosine-161 of the PS-II D1 subunit (or Y_Z)

U

vp - vertically polarized
UQ - ubiquinone
UV - ultraviolet

V

V - volt
V - violaxanthin
vmc - valinomycin
vp - (subscript) vertically polarized

W

wt - wild-type

X

X - an unkown electron acceptor
X320 - an electron acceptor of photosystem II; equivalent to Q_A
XAES - X-ray absorption edge spectroscopy
XANES - X-ray absorption near edge structure
XAS - X-ray absorption spectroscopy
X_E - a high-energy intermediate

Y

Y - (oxygen) yield
Y_D - tyrosine-160 of the PS-II D2 subunit *see* TyrD
Y_Z - tyrosine-161 of the PS-II D1 subunit *see* TyrZ

Z

Z - a secondary electron donor of photosystem II; same as Y_Z or TyrZ
Z - zeaxanthin

Index

A

B

C

D

E

F

G

H

I

K

L

M

N

O

P

Advances in Photosynthesis

Series editor: Govindjee, University of Illinois, Urbana, Illinois, U.S.A.

1. D.A. Bryant (ed.): *The Molecular Biology of Cyanobacteria.* 1994 ISBN Hb: 0-7923-3222-9; Pb: 0-7923-3273-3
2. R.E. Blankenship, M.T. Madigan and C.E. Bauer (eds.): *Anoxygenic Photosynthetic Bacteria.* 1995 ISBN Hb: 0-7923-3681 -X; Pb: 0-7923-3682-8
3. J. Amesz and A.J. Hoff (eds.): *Biophysical Techniques in Photosynthesis.* 1996 ISBN 0-7923-3642-9
4. D.R. Ort and C.F. Yocum (eds.): *Oxygenic Photosynthesis: The Light Reactions.* 1996 ISBN Hb: 0-7923-3683-6; Pb: 0-7923-3684-4
5. N.R. Baker (ed.): *Photosynthesis and the Environment.* 1996 ISBN 0-7923-4316-6
6. P.1-A. Siegenthaler and N. Murata (eds.): *Lipids in Photosynthesis: Structure, Function and Genetics.* 1998 ISBN 0-7923-5173-8
7. J.-D. Rochaix, M. Goldschmidt-Clermont and S. Merchant (eds.): *The Molecular Biology of Chloroplasts and Mitochondria in Chlamydomonas.* 1998 ISBN 0-7923-5174-6
8. H.A. Frank, A.J. Young, G. Britton and R.J. Cogdell (eds.): *The Photochemistry of Carotenoids.* 1999 ISBN 0-7923-5942-9
9. R.C. Leegood, T.D. Sharkey and S. von Caemmerer (eds.): *Photosynthesis: Physiology and Metabolism.* 2000 ISBN 0-7923-6143-1
10. B. Ke: *Photosynthesis: Photobiochemistry and Photobiophysics.* 2001 ISBN 0-7923-6334-5

For further information about the series and how to order please visit our Website
http://www.wkap.nl/series.htm/AIPH

KLUWER ACADEMIC PUBLISHERS DORDRECHT / BOSTON / LONDON