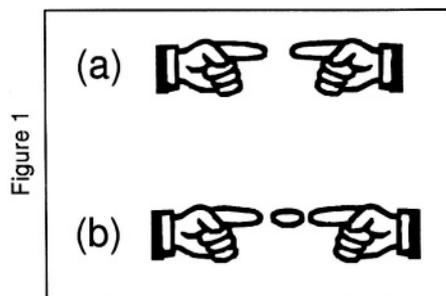


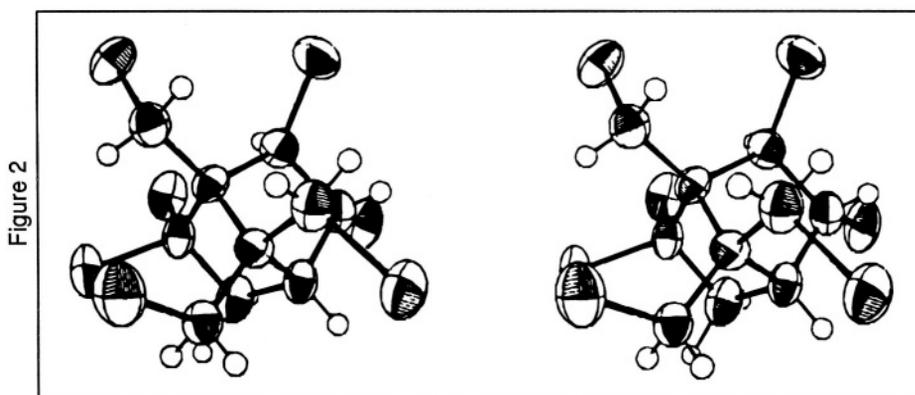
## Appendix: How to View the Stereograms

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)].



*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.



\* 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

$\alpha$  - misses *see* oxygen evolution

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

$\alpha^{APC}$  -  $\alpha$  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  $\underline{Y}$  (agent)

AMD - adenosine monophosphate

AMP-PNP- **adenyl- $\beta$ , $\gamma$ -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

$\beta^{APC}$  -  $\beta$  subunit of APC (allophycocyanin)

$\beta$ -OG - **octyl- $\beta$ -glucopyranoside**

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

B - monomeric bacteriochlorophyll

*b<sub>f</sub>* - **cytochrome *b<sub>f</sub>***

$B_A$  - 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  $B_B$

$\beta$  - 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

Bphea - bacteriopheophytin, same as  $B\Phi$

$B\Phi$  - 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

- $\chi$  - 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<sub>I</sub> / CF<sub>O</sub> - major subunit assemblies of chloroplast ATPase  
 Chl - chlorophyll  
 Chl *a'* - epimer of Chl *a*  
 Chl  $\alpha_1$  - alternative designation for P700  
 Chl  $\alpha_{II}$  - alternative designation for P680  
 CM - core membrane  
*Cm.* - *Chromatium*  
*Cp.* - *Chloropseudomonas*  
 CP - chlorophyll protein  
 C-PC - C-phycoyanin  
 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<sub>6</sub>f* - cytochrome *b<sub>6</sub>f*  
 Cyt/- cytochrome/

## D

- $\Delta\mu_{H^+}$  - electrochemical potential  
 $\Delta pH$  - difference in pH across the membrane  
 $\Delta\Psi$  - membrane potential difference  
 $\Delta A$  - absorbance difference  
 $\Delta CD$  - difference in circular dichroism  
 $\Delta G^0$  - standard free energy  
 $\Delta\epsilon$  - differential extinction coefficient

- $\Delta H$  - EPR signal linewidth  
 $\Delta T/T$  - 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*<sub>2</sub>,*C*<sub>3</sub>,*C*<sub>5</sub>,*C*<sub>6</sub>-tetramethyl-*p*-phenylenediamine)  
 DADS - decay associated difference spectrum  
 DBMIB - 2,5-dibromo-3-methyl-6-isopropylbenzoquinone  
 DCBQ - dichloro-*p*-benzoquinone  
 DCCD - N,N'-dicyclohexylcarbodiimide  
 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

- $\epsilon_M$  - molar absorption coefficient  
 $e^-$  - electron  
 $[e^-]$  - reducing environment  
 $E_{1/2}$  - polarographic halfwave potential  
 e5m - eosin-5-maleimide  
 $E_h$  - potential relative to the hydrogen electrode  
 EcF<sub>1</sub> - coupling factor 1 from *Escherichia coli*  
 EcF<sub>0</sub> - coupling factor 0 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 paramagnetic 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  
 $\Phi$  - pheophytin  
 $\Phi_D$  - quantum yield of donor emission  
 $\Phi_f$  - quantum yield of fluorescence  
 $\Phi_Q$  - phylloquinone  
 F - level of fluorescence  
 $F_o$  - coupling factor 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*-trifluoromethoxyphenylhydrazine  
 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<sup>+</sup>-reductase  
 Fp - flavoprotein  
 FRS - ferredoxin reducing substance  
 fs - femtosecond,  $10^{-15}$  second

## G

$\gamma^{PE}$  -  $\gamma$ -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  
*hν*- 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  $Q_A^-$  to  $Q_B^-$   
 $k_{AB(2)}$  - rate constant for electron-transfer from  $Q_A^-$  to  $Q_B^-$   
 $k(P\cdot Q_B)$  - rate constant for charge recombination between  $P^+$  and  $Q_B^-$

kDa - kilodalton  
kcal - kilocalorie

## L

$\lambda^A$  - wavelength of absorption  
 $\lambda^F$  - 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

$\mu E$  - microeinstein (one micromole of photons)  
 $\mu m$  - micrometer (or  $\mu$ , micron)  
 $\mu M$  - micromolar  
*ms* - millisecond, or  $10^{-3}$  second  
mV - millivolt  
 $\mu s$  - microsecond, or  $10^{-6}$  second  
 $\mu V$  - microvolt  
M-subunit - medium (molecular-weight) subunit  
MES - 2-(N-morpholino)-ethanesulfonic acid  
 $MF_1 / MF_0$  - mitochondrial coupling factor 1/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 dinucleotide phosphate  
(the oxidized form)  
NADPH - nicotinamide adenine dinucleotide 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 [ $P^+B^-$ ]; (E for early)  
 $P^F$  (state) - the [ $P^+I^-$ ] or [ $P^+B\Phi^-$ ] state;  
(F for fast)  
 $P^R$  (state) - the [ $TP^+I$ ] state; (R for radical-pair triplet)  
 $TP$  - reaction-center chlorophyll triplet; *e.g.*,  $TP700$   
*P/2e* - 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 photosystem II; *see* Chl  $a_{II}$   
 P700 - primary electron donor (chlorophyll special pair) of photosystem 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<sub>s</sub> - protoplasmic fracture face of stacked membrane  
 PF<sub>u</sub> - 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 benzoquinone  
 PQ - plastoquinone  
*P. aestuarii* - *Prosthecochloris aestuarii*  
 ps - picosecond, or 10<sup>-12</sup> 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<sub>s</sub> - -log of time in seconds  
 PUB - phycourobilin (chromophore)  
 PXB - cryptoviolin chromophore (of PEC)  
 PYC - pyocyanine

## Q

Q - quinone  
 Q<sub>0</sub> - 2,3-dimethoxy-5-methyl-1,4-benzoquinone  
 Q<sub>A</sub> - primary quinone acceptor  
 Q<sub>B</sub> - secondary quinone acceptor  
 Q·Fe - quinone-iron complex  
 QH<sub>2</sub> - dihydroquinone or quinol  
 Q<sub>a</sub> - oxidizing quinone binding site; also called Q<sub>p</sub>  
 Q<sub>r</sub> - reducing quinone binding site; also called Q<sub>n</sub>  
 Q<sub>x</sub>, Q<sub>y</sub> - 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<sub>1</sub>, S<sub>2</sub>, etc.)  
 S<sub>2</sub>O<sub>4</sub><sup>=</sup> - 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<sub>r</sub> - fast-decaying PS-II EPR signal  
 SII<sub>s</sub> - slow-decaying PS-II EPR signal  
 SII<sub>vf</sub> - 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

$\tau$  - time

T - triplet state

*Tb.* - *Thiobacillus*

T-T - triplet-triplet (energy transfer)

$t_{1/2}$  (or  $\tau_{1/2}$ )- 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 - octylphenoxy polyethoxyethanol

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 unknown 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

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