STRUCTURE AND FUNCTION OF THE PHOTOSYNTHETIC APPARATUS
From molecular to global scale

(from Jeffrey and Mantoura 1997)
Importance

• Phytoplankton photosynthesis is a fundamental process because of its role in trophic webs, and biogeochemical cycles in the ocean.

• A practical way of obtaining instantaneous and synoptic estimation of phytoplankton biomass is through the use of remote-sensing techniques.

• Satellite estimation of chlorophyll is based on the optical properties of phytoplankton.

• The structure and physiology of the photosynthetic apparatus regulate the optical characteristics of phytoplankton, and determine its photosynthetic capacity.
Influence of phytoplankton absorption on reflectance

\[ R(\lambda) = f \frac{b_b(\lambda)}{a(\lambda)} \]

- \( R(\lambda) \): reflectance at wavelength \( \lambda \)
- \( b_b(\lambda) \): backscattering coefficient at \( \lambda \)
- \( a(\lambda) \): absorption coefficient at \( \lambda \)
Components absorbing light in the ocean

\[ a(\lambda) = a_w(\lambda) + Ca_{ph}(\lambda) + Da_d(\lambda) + Ya_y(\lambda) \]

- \( a(\lambda) \): total absorption coefficient of seawater (m\(^{-1}\))
- \( a_w(\lambda) \): absorption coefficient of pure seawater (m\(^{-1}\))
- \( C \): concentration of chlorophyll-\(a\) (mg m\(^{-3}\))
- \( a_{ph}^*(\lambda) \): specific absorption coefficient of phytoplankton [m\(^{-1}\) (mg m\(^{-3}\))\(^{-1}\)]
- \( Y \): concentration of yellow substances (expressed in absorption m\(^{-1}\))
- \( a_y^*(\lambda) \): specific absorption coefficient of yellow substances (dimensionless)
- \( D \): concentration of detritus (mg m\(^{-3}\))
- \( a_d^*(\lambda) \): specific absorption coefficient of detritus [m\(^{-1}\) (mg m\(^{-3}\))\(^{-1}\)]
Spectral composition of underwater light

(from Prézelin et al. 1991)
Distribution of different sizes of phytoplankton

From Yentsch and Spinrad (1987).
Chloroplasts distribution inside the cell

(from Van Den Hoek et al. 1995)
Organisation of thylakoids inside the chloroplasts

(from Staehelin and Arntzen 1986)
Organisation of thylakoids inside the cells

cyanophyte

prochlorophyte

(from Van Den Hoek et al. 1995)
Organisation of the photosynthetic system

• Photosynthetic Unit (PSU):
  – Photosystem-I (PS-I)
  – Photosystem-II (PS-II)
  – Light-harvesting-complexes (LHC)

• Photosystem:
  – Reaction Center (RC)
  – Subantennae
Organisation of the PSUs inside the thylakoids

(from Staheelin and Arntzen 1979)
Organisation of the PSUs inside the thylakoids

(from Larkum and Barrett 1983)
Structure parts of PSU: RC photosynthetic bacteria

(From Deisenhofer and Michel 1989)
Structure parts of PSU:
LHC-II photosynthetic bacteria

(from McDermott et al. 1995)
Structure parts of PSU: PS-I Cyanophyte

(from Jordan et al. 2001)
Structure parts of PSU:
Subantenna PS-I Prochlorophyte

(from Bibby et al. 2001)
Structure parts of PSU: LHC-II plants

(from Kühlbrandt et al. 1994)
Structure parts of PSU:
LHC dinoflagellates (PCP)

(from Hofman et al. 1996)
Structure parts of PSU: Phicobilisomes

(from Porra et al. 1997)
Distribution of energy within the PSU

(from Larkum and Barrett 1983)
Energy flow through phytoplankton

(from Prézelin et al. 1991)
Energy transfer within the PSU

(from Butler 1978)

(from Clayton 1980)
Energy transfer within the PSU

LHCs: light-harvesting-complexes
LHCI and LHCI: light-harvesting-complex I and II
PBS: phycobilisomes (special type LHCI)
PSI and PSII: photosystem I and II
Subant. I and II: subantenna I and II
RCI and RCII: reaction center I and II
TM: thylakoid membrane

(from Lutz 1999)
Physical basis for fluorescence

(from Clayton, 1980)
Photosynthesis equations

**General equation**

\[ 6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow{\text{light}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]

**General equation for “light reactions”**

\[ \text{H}_2\text{O} + \text{NADP}^+ + \text{ADP} \xrightarrow{\text{light}} \text{O}_2 + \text{NADPH} + \text{H}^+ + \text{ATP} \]

**General equation for “dark reactions”**

\[ \text{CO}_2 + \text{NADPH} + \text{H}^+ + \text{ATP} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{NADP}^+ + \text{ADP} + \text{Pi} \]
Z scheme of Photosynthesis

(from Porra et al. 1997)
PSU location and function within the thylakoids

(from Porra et al. 1997)
PSU structure, location, function and regulation in photosynthetic bacteria

(from Bauer and Bird 1996)


Packaging effect

\[ \rho' \text{ is a function of the cell size and the intracellular concentration of pigments} \]

(from Platt and Sathyendranath, 2002)
Variations in the absorption characteristics with cell-size and photoacclimation

(from Lutz et al., 2001)
From molecular to global scale

(from Jeffrey and Mantoura 1997)