Habitats of Photosynthetic Life Forms

purple bacterium

Photosynthetic Apparatus of Purple Bacteria

RC - Photosynthetic Reaction Center
LH – Light Harvesting Complex
Cross-section of a photosynthetic purple bacterium obtained by EM tomography (data from Lena Kourkoutis & Wolfgang Baumeister).

The Whole Photosynthetic Chromatophore

Chromatophore vesicle of purple bacterium containing the antenna proteins LH2 (green) & LH1 (red) reaction centers (RC; blue), bc1 complexes (purple), ATP synthases (orange), and lipids (yellow).
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Light Absorption and First Energy Storage

LH2 complex with the bacteriochlorophyll porphyrin rings. Bacteriochlorophylls convert solar radiation to “long lived” (nanoseconds) electronic excitation.

Bacteriochlorophylls and Carotenoids

Bacteriochlorophylls and carotenoids of LH2. Carotenoids provide additional absorption cross-section and protection against photodamage.
Absorption spectrum of LH2 contains bacteriochlorophyll and carotenoid bands.

Excitation Transferred to Reaction Center and Used to Charge Membrane

LH1-RC-PufX (red-blue-green) dimeric complex. The RC converts electronic excitation absorbed by bacteriochlorophylls into charge separation, releasing membrane-diffusible electron carriers called quinones (orange).
LH2 (green), LH1 (red), reaction center (RC; blue) complexes and their bacteriochlorophylls. LH2 is the main light absorber, that turns single chlorophyll excitation into multi-chlorophyll excitations (excitons). The excitons migrate through so-called energy transfer between LH2s and then become LH1 excitons. The latter transfer their energy to an RC that uses it for charging electronically the chromatophore membrane (inside positive, outside negative).

The bc1 complex turns the electronic membrane voltage into a proton gradient as the latter is a more stable form of energy.

The dimeric bc1 complex an electron-based voltage across the membrane into a proton gradient across the membrane. A key trick to get 150% protein voltage from 100% electronic voltage requires bifurcation of electron flow.
ATP Synthase Utilizes the Resulting Proton Gradient for ATP Synthesis

A minimal photosynthetic unit consisting of 3 LH2, 1 dimeric LH1-RC complex, 1 dimeric bc1 complex, and 1 ATP synthase, embedded in the chromatophore. Not included here is a protein called cytochrome c2 needed to shuttle electrons back from bc1 to RC.
**Components of a chromatophore**

**LH2 (60-100)**
- **Protein components:**
  - 9 α-subunits
  - 9 β-subunits
- **Cofactors:**
  - 27 bacteriochlorophylls
  - 9 carotenoids

**LH1 (20-40)**
- **Protein components:**
  - 16 α-subunits
  - 16 β-subunits
- **Cofactors:**
  - 32 bacteriochlorophylls
  - 16 carotenoids

**RC (10-20)**
- **Protein components:**
  - 1 L-subunit
  - 1 M-subunit
  - 1 H-subunit
- **Cofactors:**
  - 4 bacteriochlorophylls
  - 2 bacteriopheophytins
  - 1 carotenoid
  - 2 quinones

**ATP-synthase (1)**
- **Protein components:**
  - 3 α-subunits
  - 3 β-subunits
  - 1 γ-subunit
  - 1 δ-subunit
  - 1 ε-subunit
  - 1 α-subunit
  - 1 β-subunit
  - 10-11 γ-subunits

**bcl (5-10)**
- **Protein components:**
  - 2 Cytochrome b
  - 2 Cytochrome c₁
  - 2 Rieske-subunits
- **Cofactors:**
  - 4 Fe-S centers
  - 6 hemes

*Numbers in parentheses give approximate number of the complexes in the chromatophore.*
Energy Conversion in Photosynthetic Chromatophore

1. Solar Energy
3. Multi-Molecule Excitons
4. Multi-Molecule Excitons
5. Membrane Electronic Voltage
6. Membrane Proton Gradient
7. Adenosin Triphosphate (ATP)

Mainly Quantum Processes:
1. Light Absorption
2. Exciton Formation
3. Excitation Energy Transf.
4. Electron Transfer
5. Proton Transfer
6. Mechanically Driven Chemical Synthesis

The light-harvesting apparatus in purple photosynthetic bacteria, introduction to a quantum biological device.

Johan Strümpfer, Jen Hsin, Melih Sener, Danielle Chandler, and Klaus Schulten.


The chromatophore vesicle of purple bacteria is a quantum biological device consisting of about 200 protein complexes that cooperate to harvest sunlight. It is a biological solar cell at its simplest. A combination of decades of experimental and theoretical efforts provided an atomic level description of the chromatophore and the light harvesting process that it carries out. The architecture and function of the constituent proteins complexes and their integration into the chromatophore is described with a focus on the initial steps of light-harvesting. These steps involve the capture of sunlight in the form of electronic excitation of a chlorophyll and the subsequent migration of the electronic excitation energy across the chromatophore until its energy is stored first as a transmembrane potential and then in the form of chemical energy.