PHOTOSYNTHESIS – Autotrophic Metabolism

GREEN MEN  - Why do metazoan cells not photosynthesize?
chlorophyll vs. hemoglobin   (leghemoglobins)
mutants = hemoglobins that capture light energy

plant photosynthetic rates = 20 mg hexose/dm²/ hr
average human surface area = 170 dm²
hexose productivity = 40.8 gm/d
    1 mole glucose = 183 gm = 686Kc/mol
          41 gm = 153 Kc/mol
BMR = 2,000 Kc/d = about 8.5 % of need

they evolve, i.e., increased surface area, remain sessile,
peristalsis becomes vestigial, circulation replaced
... "We are a plant"

PHOTOSYNTHESIS ... is a light driven phosphorylation
...it is AUTOTROPHIC Metabolism, and occurs in
organisms, which produce all their organic nutrients
from inorganic materials thru conversion of light energy
into covalent bonds.

a. Chemotrophic...
    oxidation of small inorganics
b. phototrophic...
    use light energy to make organics
What is PHOTOSYNTHE...S ...?

it is a cellular process - requires a living cell
it occurs in prokaryotes - bacteria, blue-green, and eukaryotes - cells w chloroplasts
it captures light energy via pigments - chlorophylls and accessory pigments (carotenes & phycobilins)
it is a REDOX reaction -
produces oxidizing power = O₂ via PHOTOLYSIS
it captures e- into coenzymes, as in cell respiration produces reducing power = NADPH
it produces ATP via photophosphorylation
it couples e⁻ transfer to H⁺ gradients & ATP synthase
it reduces CO₂ to CH₂O

$$6\text{CO}_2 + 12\text{H}_2\text{O}^* \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O} + 6\text{O}_2$$

$$\text{CO}_2 + 2\text{H}_2\text{A} \rightarrow \text{CH}_2\text{O} + \text{H}_2\text{O} + 2\text{A}$$

Source C + e donor organic C oxidized donor
2 Fundamental Reaction Mechanisms of Photosynthesis:

**LIGHT Reactions** - photochemical reactions
molecular excitation of chl by light = charge separation
generation of proton motive force (gradient)
reduction of NADP via an ETS

**DARK Reactions** - thermochemical reactions
CO$_2$ fixation (reduction) stages
  - carboxylation: CO$_2$ + RuBP --> 2 PGA
  - reduction: PGAL + NADPH --> PGAL
  - regeneration: HMP path ---> --> RuBP

**Morphological Basis of Photosynthesis**

**PLASTIDS** - double unit membrane bound organelles
classified by pigment content (functional)

**PROPLASTIDS** ... plastid in MERISTEMATIC cells
gives rise to all other plastids

**LEUCOPLASTS** - *amyloplasts* - synthesize & store starch
*aleuoplasts* - contain stored protein (crystals)
*elaioplasts* contain oil-fat globules – fat synthesis

**CHROMOPLASTS** - found in flower petals, ripe fruit, senescent leaves
Morphological basis of chloroplasts...

**CHLOROPLAST** - ubiquitous to all green plants

**SHAPE** - variable (elipsoid to ovoid; & lenticular or stellate)
**SIZE** - 2 to 3 um dia by 5 to 10 um long
**NUMBER** - 15 to 20 per mesophyll cell  [400,000/cc]
**VOLUME** - often much larger than mitochondria

**CHLOROPLASM** - (Stroma)
- pyrenoids - which are starch coated protein granules
- 70s (procaryotic ribosomes)
- naked DNA - 2 to 10 fentograms of DNA/chlp
  - about equal to bacterial cell DNA
  - highly supercoiled & repetitive (6 copies)
- enzymes of CO₂ fixation and lipid droplets
LIGHT ABSORPTION

PIGMENTS

Accessory Pigments

Carotenoids - carotenes, xanthophylls
Phycobilins - chromophore + a protein
phycoerythrin & phycocyanin
Chlorophylls - a,b,c,d, etc... [side chain differences]

ABSORPTION SPECTRA - is a graphical plot of
amount light absorbed vs. wavelength

ACTION SPECTRA - (by Engelman) is a plot of physiological
activity [O₂ released] vs. wavelength

MOLECULAR EXCITATION of CHLOROPHYLL

FATES of Absorbed Energy,
  i.e., blue light and red light
1. re-radiates as vibrational heat
2. reradiated as fluorescence (red light)
3. reradiated as phosphorescence (far red)
4. induced resonance - vibrational e excitation transfer
5. photoionization - photochemical reactions...
  chlorophyll loses an electron to acceptor = ionized chl⁺
THYLAKOIDS MEMBRANES & ELECTRON FLOW

the Photosystems

complexes of chlorophylls, reaction centers, and primary acceptors

**PS 1** and **PS 2**

release of O₂ by *oxygenase* in photolysis
capture of e- into coenzyme NADP⁺ → NADPH

path of e- flow (*cyclic* vs. *non-cyclic*)

*chemiosmosis* (location in chloroplasts)

**ATP synthase** makes ATP (just like mitochondria)
**DARK REACTIONS**

occur in stroma (chloroplasm)
consume ATP and NADPH mad in light reactions
reduces (fixes) CO$_2$ into CH$_2$O (sugars)

Three (3) different pathways to make sugar

**C3 - CALVIN cycle**

1 CO$_2$ + 5C RuBP $\rightarrow$ (2) 3C sugars (PGA)
(2) 3C sugars $\rightarrow$ 1 net glucose
RuBP carboxylase
Photorespiration - inhibition by O$_2$

**C4 - Hatch & Slack pathway**

1 CO$_2$ + 3C PGA $\rightarrow$ 4C acid (mesophyll cells)
4C acid $\rightarrow$ 3C + CO$_2$ in bundle sheath
CO$_2$ into Calvin cycle (as above)
**spatial** separation of acid & sugar production

**C4 - CAM Pathway**

same as C4, but within the same cell
**temporal** separation of acid & sugar production,
not **spatial** differences.
C₃ Leaf

C₄ Leaf

bundle sheath cell

(a) C₄ leaf anatomy

(b) The C₄ pathway

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