Photosystems & Chemiosmosis

The Mechanism of ATP Synthesis in Chloroplasts

The thylakoid membrane is composed of a phospholipid bilayer (color phospholipids "B" light blue) and photosystem I and photosystem II. The first and most important event in either system is the capturing of light energy (color "E" orange) by the pigments associated with each photosystem. Color the pigments of Photosystem II (P2) dark green and the pigments of Photosystem I (P1) light green. Pigment 680 (color dark green) is associated with Photosystem II, and Pigment 700 (color light green) is associated with Photosystem I. The numbers 680 and 700 refer to the wavelengths of light absorbed by the pigments. Remember R.O.Y.G.B.I.V?

Although they both work simultaneously, it is best to look at them one at a time, usually starting with photosystem II. When a photon of light strikes the reaction center of Photosystem II, it excites an electron. Two water molecules bind to an enzyme that splits water into hydrogen ions (aka protons) and releases an oxygen atom. Color the protons (H+) yellow and the oxygen atoms (O2) red. This process is called **PHOTOLYSIS** and is illustrated by the arrows labeled "L", which you should color pink. Two electrons are released in this process, and these electrons can be traced through photosystem II and photosystem I. Color the electrons (e) grey. Two oxygen atoms will join together to create an oxygen molecule which is released from the plant as a byproduct of the entire reaction.

The primary electron acceptor for the light-energized electrons leaving photosystem II is plastoquinone (color PQ purple). The reduced plastoquinone passes the excited electrons to a proton pump embedded in the membrane called the b6-f complex (color dark blue). This proton pump moves protons (H+) atoms across the membrane against their concentration gradients, which eventually causes a build-up of protons in the thylakoid space. This will be important later. The thylakoid membrane is NOT permeable to protons, so they may only cross the membrane via transport proteins. The protons will exit the thylakoid space via a special channel provided by ATP Synthase (color "S" pink). The protons move through the ATP synthase with the concentration gradient, which allows them to do work-namely drive ATP synthesis. As protons pass through the ATP synthase, ADP is phosphorylated to ATP and released into the stroma. The process of making ATP is called **PHOTOPHOSPHORYLATION**. The arrow labeled "Z" represents photophosphorylation - color orange. This ATP (color orange) is now on its way to the Calvin Cycle where it will be used to generate glucose.

But wait, there's more! The electron that was used in Photosystem II is just sitting around, all de-energized but its story is not finished. A small protein called plastocyanin (color brown) carries the electron to Photosystem I. Light absorbed by photosystem I energizes this electron and passes it to another primary electron acceptor called ferredoxin (color "Fd" turquoise). The enzyme NADP Reductase (color "R" dark purple) transfers these electrons to NADP to fom NADPH. The electron is now on its way to the Calvin Cycle as part of an NADPH molecule (color light purple). Electrons lost from photosystem I are replaced by electrons generated from photosystem II.

Remember you colored the electrons grey, now color the path they take through both systems grey also (represented by the arrow labeled "X")

Remember you colored the protons yellow, now color the path they take through the systems in yellow also (represented by arrows labeled "Y")

Name:

COLORS		
Phospholipids - light blue	Proton path (Y)- yellow	ATP Synthase - pink
Light energy - orange	Oxygen - red	Photophosphorylation (Z) - orange
Photosystem II - dark green	Photolysis - pink	ATP - orange
P680 - dark green	Electrons - grey	Plastocyanin - brown
Photosystem I - light green	Electron path (X) - grey	Ferredoxin - turquoise
P700 - light green	Plastoquinone - purple	NADP Reductase - dark purple
Protons - yellow	b6-f complex - dark blue	NADPH - light purple

Questions:

1. Explain(or list) in words the path that electrons take through the thylakoid.

2. Explain the role of each of the following:

---- P680

---- P700

---- Plastocyanin

---- Plastoquinone

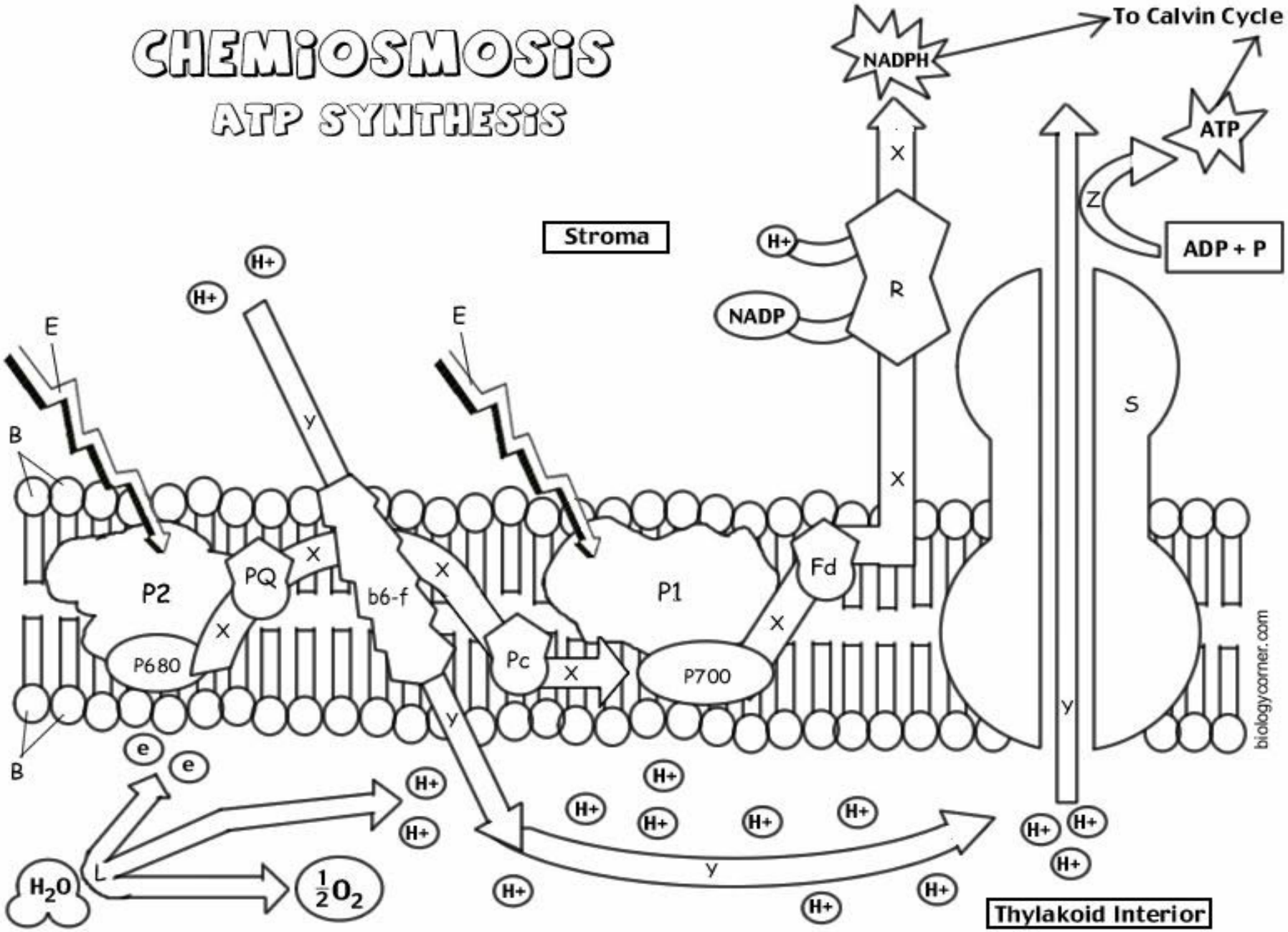
---- Ferredoxin

---- NADP Reductase

---- ATP Synthase

3. Explain how the concentration gradient affects the process of ATP synthesis.

4. Summarize what goes into the photosystems and what comes out of the systems. Where will these products go?


CHEMIOSMOSIS
ATP SYNTHESIS
To Calvin Cycle
NADPH
ATP
X
Z
ADP + P
Stroma
H+
R
NADP
E
B
y
P2
PQ
X
b6-f
P1
Fd
S
P680
Pc
P700
e
H_2O
L
$\frac{1}{2}O_2$
Thylakoid Interior
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