Photosynthesis: The Light Reactions

View it at www.sciencemusicvideos.com

Glenn Wolkenfeld © 2007

Introduction
Boys and Girls, tell me what you think of this?
Time for a lesson 'bout photosynthesis
Cells use light to combine water with carbon dioxide
'Gonna see electrons going for a wild ride.

Making sugar, making sweet O_2
But why should photosynthesis matter to you?
Food on your table, O_2-rich atmosphere
Without photosynthesis you simply wouldn't be here!

The Big Picture
Photosynthesis is a redox reaction,
Powered by light using enzymatic action.
Water's oxidized; CO_2's reduced
The sugar that results you drink in orange juice.

The overall reaction has two phases.
First is the light reactions which has its basis,
Light powered production of ATP.
O_2 is the by-product, and you will see,

Production of electron carrier NADPH
Which provides reducing power needed in the second phase.
'Cause NADPH, during phase II
Provides what's needed for reducing CO_2.

NADPH is made by a reduction
Of $NADP^+$ whose function
Is to absorb electrons (and pick up "H")
Gaining energy, making NADPH.

Phase II is the Calvin cycle, makes carbohydrates
Like sugars and starches and fibers on your lunch plates,
It's how plants make foods animals eat,
Photosynthesis it's so sweet!

Chloroplasts, Thylakoids, Light, and Chlorophyll
In a leaf, there's mesophyllic tissue,
And cells with chloroplasts key to the issue,
Chloroplasts are almost like cells in every way,
With their own ribosomes and their own DNA.

They even reproduce themselves, splitting into half
A clue for this organelle's independent past,
This theory has a name ---endosymbiosis
Developed in the 60s by Lynn Margullis.

Inside a chloroplast is the fluid stroma
It's true in Tokyo. It's true in Roma!
Stroma surrounds little thylakoids,
Each one has a hollow space inside.

The thylakoid's membrane is loaded with protein.
'Cause it's the light reactions' scene.
It's all about using light for powering electrons
All about grabbing the power in photons.

The photons needed, are those from light
Which has the energy to make the world bright
The highest frequency that we can see
Is violet light with wavelength 380.

380 nanometers, sounds small,
But next to gamma rays it's rather tall.
Red light shines at 750.
Isn't the visible spectrum nifty?

Photons are packets, of light energy
Both a wave and a particle you see,
Photons get absorbed by pigments
It's real, it's true it ain´t no figment!

Most important are green chlorophylls
Orange carotenoids and yellow xanthophylls
Together they absorb light mostly red and blue
The green is not absorbed it reflects back to you.

In chlorophyll see the porphyrin ring
See the magnesium which makes you want to sing,
Magnesium, metal with valence two
You'll see those electrons rocketing through.

Notice the tail -- a hydrocarbon chain
Which anchors chlorophyll into the thylakoid membrane.
A molecule with style, so pretty,
In the thylakoid, it makes electricity.

Action v. Absorption Spectrum, Photoexcitation, Photosystems
Engelmann showed us the action spectrum
Used a prism to break the sun's
Light into its frequencies
Shone it on Spirogyra, filamentous algae.

The O_2 algae makes can stimulate bacteria
Which will grow in any oxygen rich area
Bacteria loved it over blue and red
But hardly grew over green, they might as well be dead!

The line of growth, is a reflection,
Of photosynthesis's action spectrum
Note this won't match exactly
The absorption spectra of chlorophyll *a* or *b.*

'Cause the carotenoids and xanthophylls we´ve met
Absorb light frequencies the chlorophylls can´t get
And in the thylakoid, they all cooperate!
In using light to synthesize carbohydrate

Consider chlorophyll in isolation
Shine some light upon it (call it photoexcitation)
The valence electrons in magnesium
Jump to an excited state, it's so fun.

But once up at that level, they can only fall
Back to where they started, like a bouncing ball
These falling electrons release energy
Fluorescing as a red light as you see.

But in thylakoids chlorophyll's not alone,
Instead a photosystem is chlorophyll's home
The photosystem's parts, can take photons
And use their energy to move electrons.

The system's antenna complex does the first capture
Changing photon energy into electron rapture
The energized electrons bounce like a ball,
At the reaction center, they jump but do not fall.

A primary electron acceptor grabs them from on top
And yanks them with a force reaction center cannot stop
To this oxidized reaction center we'll return
But the details of electron flow it now is time to learn.

ATP Synthesis in Non-cylic electron flow
Non-cyclic flow is the main pathway
Much confusion relates to the way
Photosystem II precedes Photosystem I
It's a fact to memorize, just get it done!

PS II's antenna captures a photon
Generates a flow of electrons,
All around the world, even in Haiti
They flow to reaction center P680.

There electrons do not hover,
Electron acceptor passes them over,
To the electron transport chain
In the thylakoid membrane.

This chain's like a bucket brigade
Each molecule has a similar trade,
They take energized electrons,
And use their energy for pumping protons.

From stroma to the thylakoid space
Packing protons into that place.
This makes a gradient 'cross the thylakoid membrane
The protons want out or they'll go insane!

But the protons can't permeate
The membrane won't allow escape,
There's only one port through which they travel
It's the ATP synthase channel.

The "ase" tells you this is an enzyme,
Which makes ATP all the time,
It has binding sites for ADP and P
And channels for diffusing protons whose kinetic energy

Changes the binding site's conformation
Fusing ADP with P, which for your information
Is how thylakoids make ATP
Life's key form of energy.

From respiration this might feel familiar
ATP is made this way in mitochondria
Chemiosmosis is the name,
ATP production is the game.

NADPH Synthesis in Non-Cyclic Electron Flow
Now back to our electrons, moved by the sun
Flowing from Photosystem II to system I,
They get to PS I like a used-up battery
The transport chain used up their energy.

But when light hits PS I's antenna
Electrons bounce to reaction center
This one's P700 [say "P-seven-Oh-Oh"],
That wavelength makes electrons go.

PS I's electron acceptor grabs them away
Leaving P700 [P-seven-Oh-Oh] in an oxidized way
And P-seven-Oh-Oh with its oxidized blues
Accepts the electron from PS II.

Back to electron from PS I
It now goes for a ride having its own fun,
But powering proton pumps ain't its fate
It travels to NADP plus reductase.

An enzyme plant cells count upon
To pass to pass some H and electrons
To $NADP^+$ which gets reduced
It's how NADPH gets produced.

Oxygen Production in Non-Cyclic Electron Flow.
The by-product of these light reactions,
Is oxygen-- here's how it happens.
Back in PS II it came to arise
P680 got oxidized.

To replace lost electrons P680 liberates
Electrons from water which dissociates
Into one oxygen and protons two
The single O will meet another forming O_2.

These protons are formed in the thylakoid space,
Increasing proton concentration in that place.
So we see a side effect of water's oxidation
Is enhancement of ATP creation!