Sept 13 lecture notes – light independent reactions

Review:
We started todays lecture by briefly reviewing the light reactions of photosynthesis. This included a diagram of the thylakoid membrane and the participant proteins and e- shuttles of the electron transport chain. We then broadened our review by identifying two herbicides that kill plants by interrupting the e- transport chain of the light reactions.

Herbicides that interrupt electron transport of the light reactions:
Herbicide : A type of pesticide used to kill unwanted plants.
Pesticide: A compound used to prevent, kill or mitigate any unwanted pest.
Pest: any organism detrimental to human interests.

The movement of electrons from one molecule to the next is known as an electron transport chain. The flow of electrons in the light reactions is an electron transport chain.
In lecture, we discussed two herbicides that act on plants by interrupting the flow of electrons through the transport chain of the light reactions: 1) atrazine, and 2) paraquat.

1) Atrazine: Disables plastiquinone (PQ) such that electrons do not leave PS II, and therefore arrests the light reactions. A VERY common herbicide because it is cheap and effective (e.g., increases corn yields by 1-6%). Recent controversy has arisen because atrazine has been shown to affect hormone levels in some animals (especially amphibians) and cause male frogs to develop female reproductive characteristics. Chemicals that interfere with hormone levels are called endocrine disruptors. Subsequent attempts to duplicate the results of these studies have been "unsuccessful" (e.g., atrazine exposure did not interfere with hormone levels). Many government agencies have effectively dismissed the notion that atrazine is an endocrine disruptor at levels currently encountered in the environment. The debate rages – keep your eyes peeled. Atrazine is also suspected as a carcinogen. Atrazine does not kill crop plants because it is sprayed before crop seeds germinate (a "pre-emergence" herbicide) or because plants like corn are able to degrade it more quickly than weeds.

Video RE: atrazine (from Huffington Post)
http://www.youtube.com/watch?v=9iJQvrEOIjU
(stopped at 3:17)

2) Paraquat: Accepts (more accurately: "steals"!) high energy electrons from PS I before they can be used to drive the formation of NADPH. This arrests photosynthesis. Paraquat is a widely used and very effective herbicide. It is toxic to animals and some research links it to the development of Parkinson's disease in farmworkers and others with high exposure to paraquat. It has been used as a murder poison, and as a suicide agent in poor countries where access is easy. Gained prominence in the 1970's due to "paraquat pot", which was marijuana grown in Mexico and smuggled into the US, but that had been sprayed with paraquat by the US drug authorities in an attempt to eradicate the fields.

<u>Light-independent reactions</u> <u>(aka Calvin cycle, C_3 cycle)</u>

Unlike the light reactions, the light-independent reactions do not require sunlight. Therefore, the Calvin cycle can take place during the day or night.

Steps you need to know:

1) CO_2 is "fixed" (covalently bonded) to the molecule **RuBP** (ribulose 1,5-bisphosphate; you do NOT need to know the full name). The enzyme that catalyzes the bonding of CO_2 and RuBP is called **Rubisco** (full name = RuBP carboxylase/oxygenase; you do NOT need to know the full name! However, note that full the full name ends in –ase…)
   (By the way: Rubisco is the most abundant protein on Earth, and according to Raven's *Biology of Plants* it makes up 40% of protein in leaves!)

2) The molecule formed by the bonding of RuBP + CO_2 is converted into glucose through a series of chemical reactions in plant cells.

These two steps are the only biochemical steps you need to know…
…but just in case you are curious:

The first stable molecule that is formed when CO_2 and RuBP are bonded together is a 3-carbon sugar precursor called **PGA** (3-phosphoglycerate; again, you do NOT need to know PGA or the full name). Because PGA contains 3 carbon atoms, the Calvin cycle is also called the C_3 cycle. (PGA undergoes a series of chemical reactions and ultimately is converted into glucose.)

<u>Variations on the C_3 cycle</u>**<u>: C_4 and CAM metabolism</u>**:

So, Rubisco is a weird enzyme because it not only catalyzes the reaction of CO_2 + RuBP (the result is that PGA is formed), but it will also bind with O_2 and bond it to RuBP if there is no CO_2 available (that's why Rubisco's full name is *RuBP carboxylase/oxygenase*). When Rubisco bonds O_2 to RuBP, it is an "undesirable" outcome for the plant because the result is a molecule (*phosphoglycolate* – you don't need to know this name) that plants must tear apart in a process that burns ATP. This process is called photorespiration (we won't go into the details – and you do not need to know it), and it costs plants energy (ATP).

Plants are better off if they can avoid bonding O_2 to RuBP and therefore avoid photorespiration. Two important adaptations have evolved in plants that help them avoid having Rubisco bond O_2 to RuBP:

1) **C_4 pathway** (plants that do this are known as C_4 plants), and;
2) **CAM metabolism**.

We won't learn the chemical details of these two adaptations, but I do want you to know the following:

The C_4 pathway:

- C_4 plants arrange their tissues such that Rubisco is *physically isolated* from regions of high O_2 concentrations but is surrounded by high concentrations of CO_2. They do this by delivering CO_2 to rubisco on shuttle molecules that have 4 carbons (hence the name C_4 metabolism).
- Only ~ 3% (~8000 species) of all plants use C_4 metabolism. C_4 plants are better adapted than C_3 plants for growth in locations or circumstances where growth is limited by low CO_2, frequent drought, or extreme heat (often, this means tropical locations...).
- About 50% of all grasses are C_4 plants. Important C_4 crop plants include corn and sugarcane.
- C_4 pathway evolved relatively recently: ~27 million years ago – it is an adaptation that modifies the much older C_3 pathway.

CAM

- Like C_4 plants, CAM plants deliver CO_2 to Rubisco on shuttle molecules that have 4 carbons.
- Unlike C_4 plants, CAM plants store or "stockpile" CO_2 that has been bonded to the 4-carbon shuttle molecule that later delivers CO_2 to Rubisco. Why do they do this? Well, they stockpile the CO_2 during the night when temperatures are coolest and they lose the least amount of water out of their stomata. Then, when the sun comes up and temperatures increase, CAM plants <u>close their stomata</u> to minimize H_2O loss, and they fire up their light reaction machinery in the thylakoid membrane. As ATP and NADPH are produced by the light reactions, they mobilize the stockpiled CO_2 (stored on 4-carbon shuttle molecules) and Rubisco catalyzes the production of PGA from CO_2 and RuBP (just like all other plants). This *temporal isolation* of Rubisco from O_2 avoids photorespiration and also minimizes water loss through stomata. (Where do you think CAM plants store the 4 carbon shuttle molecules? If you said "vacuole", you were right!)
- CAM metabolism is common in succulent plants (plants with fleshy leaves and stems) that live in areas with low precipitations and extremely high daytime temperatures.
- CAM metabolism was discovered in members of the family Crassulaceae, and the name CAM is short for <u>C</u>rassulacean <u>A</u>cid <u>M</u>etabolism.
- CAM is more widespread than C_4 photosynthesis, well known CAM plants include cacti, bromeliads, orchids, and succulents. About 7% of all terrestrial plants have CAM.

OK, the last two lectures provide a LOT of information – <u>do not panic</u>! Your study guide will clearly indicate what you need to know for exams! (Also a <u>very</u> good idea to attend review sessions….)

<u>Here comes Midterm #1:</u>
Study alone, study in groups, study actively, and study OFTEN!