28/02/13

Lecture 2: Photosynthesis:

Two types of chlorophyll in plants (green pigments in the thylakoids that are responsible for the absorption of Photosynthetically active radiation (PAR):

1. Chl a
2. Chl b

A and b absorb differed spectrum and allows more light overall to be absorbed. How can we account for the difference?

1. The chemical environment of Chlorophyll affects it absorption spectrum – complexing proteins. Proteins in the leaf mould and change the structure of Chlorophyll so that it broadens the spectrum of light that they can absorb.
2. There is spectrum between 500nm and 600nm that both don't absorb. But photosynthesis still occurs when just this spectrum is applied. Accessory pigments (carotenes) absorb light and donate it to chlorophyll so Photosynthesis can occur. Carotenoids also have a function in protection at high irradiance levels (such as in xanthophylls)
3. Light scattering inside the leaf - less absorbance of light when scattering is reduced – more light is abseobed when light scattering is occurring.

Sun and shade leaves have difference in light scattering:
Thinner leaves in shade have less overall Chlorophyll because of the reduced light conditions. It would be a waste to invest in more light capturing organelles when there isn't enough light for them to capture.

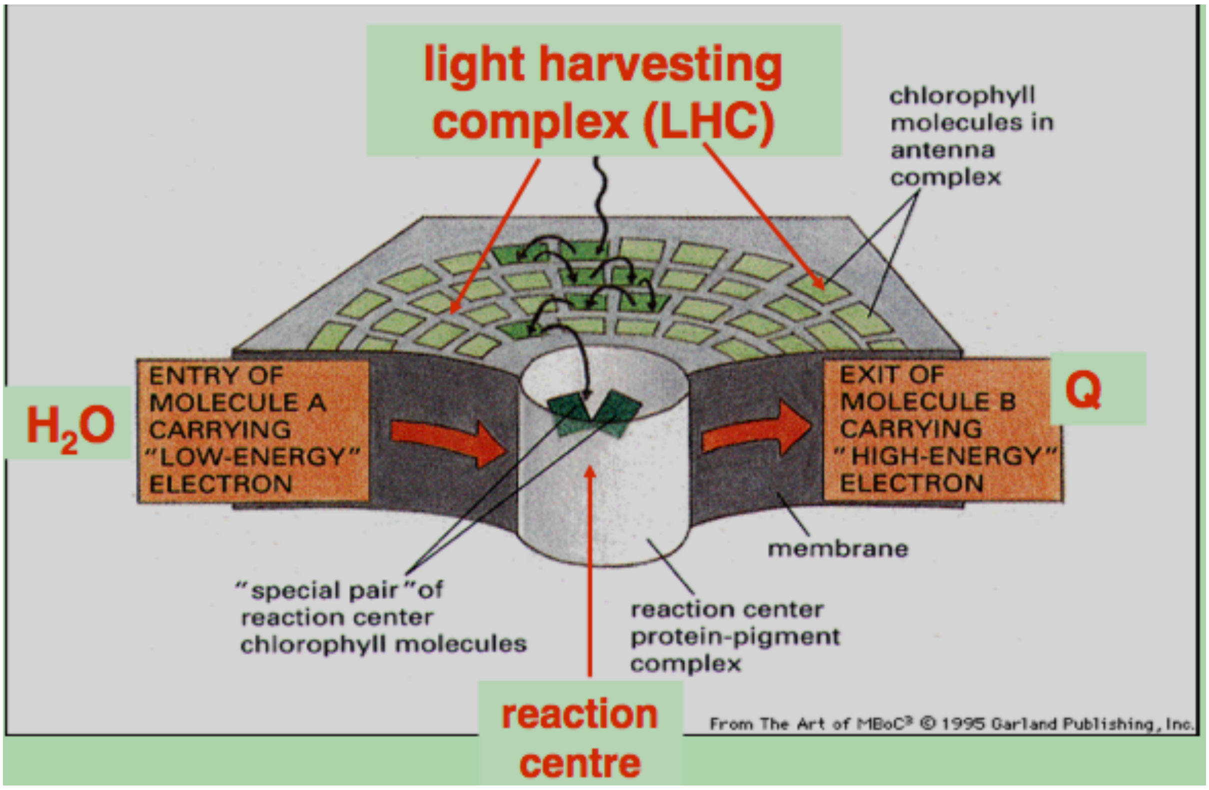
- Shade leaves have less palisade mesophyll
- Scattering occurs predominantly in the spongy mesophyll

Incident light (that hits the surface of the leaf) is either reflected, absorbed or transmitted - Leaves can reduce absorbance by having hairs. Waxes do the same.

When a pigment absorbs light energy, one of three things can occur:

1. Energy is dissipated as heat
2. The energy may be emitted immediately as a longer wavelength (fluorescence)
3. Energy may trigger a chemical reaction, as in photosynthesis - absorption of light energy increase the energy state of a Chlorophyll molecule.

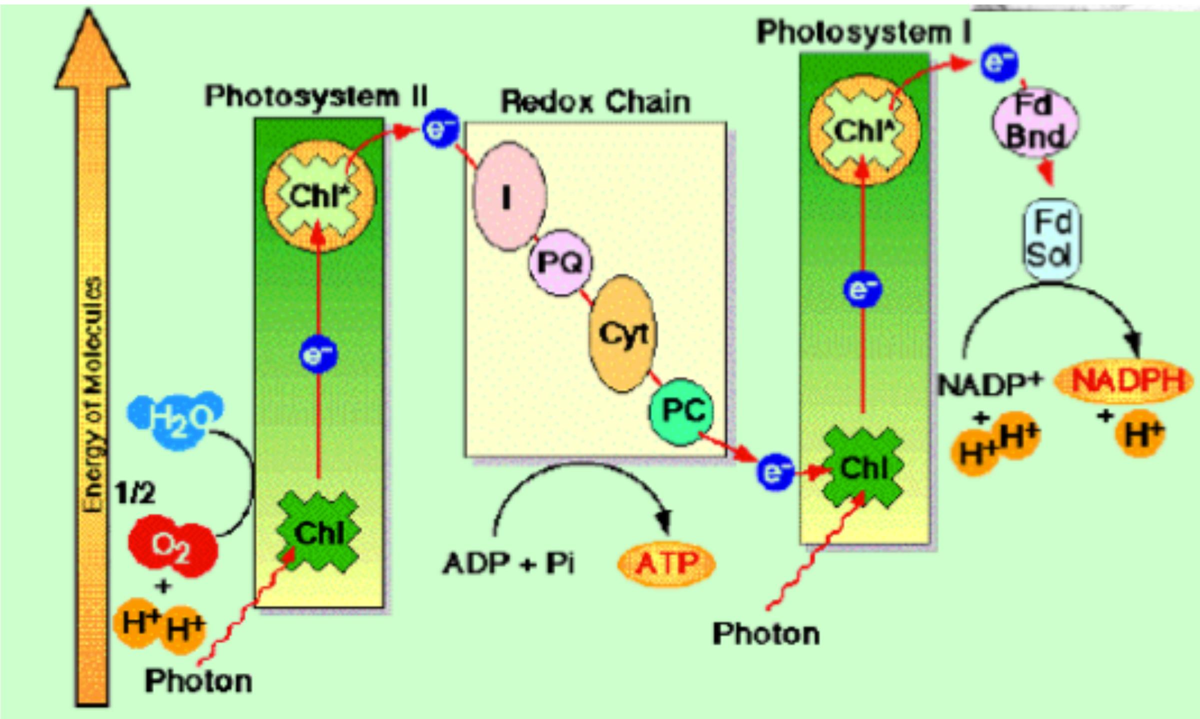
Fluorescence can be measured on intact plants to test their efficiency



• Light is absorbed by antenna chlorophylls and excites an electron to a higher orbital
• This energy is transmitted to a reaction center chlorophyll
• The reaction center reduces an acceptor molecule

The combination of light-harvesting complex, reaction centre, acceptor molecules and associated proteins, together form a photosystem

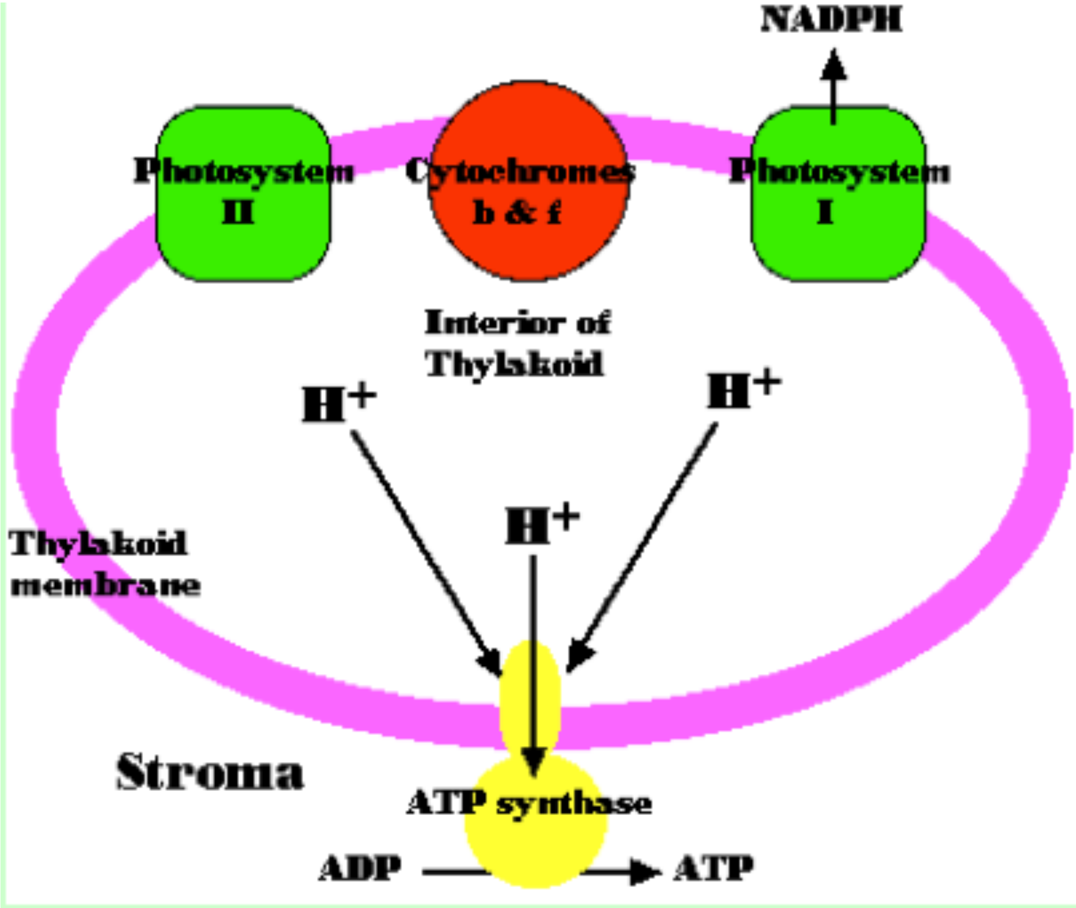
Photosynthetic electron transport – noncyclic phosphorylation



Chlorophyll in the PS2 is struck by a photon and reduced as an electron is passed from the breakdown of water into $2H^+$ and an O_2 molecule. This electron is transferred to the reaction center and passed down the redox chain. This brings with it the transfer of H^+ from the stroma (outside thylakoid) to the lumen (inside thylakoid). The electron makes it way to Chlorophyll in PS1 and is struck by a photon again and makes its way to the reaction center again. there it is transferred through complexes and eventually reduced $NADP^+$ tp NADPH. The buildup of h^+ in the lumen creates a gradient that then passes through ATP synthase complex. This energy is used to create ATP.

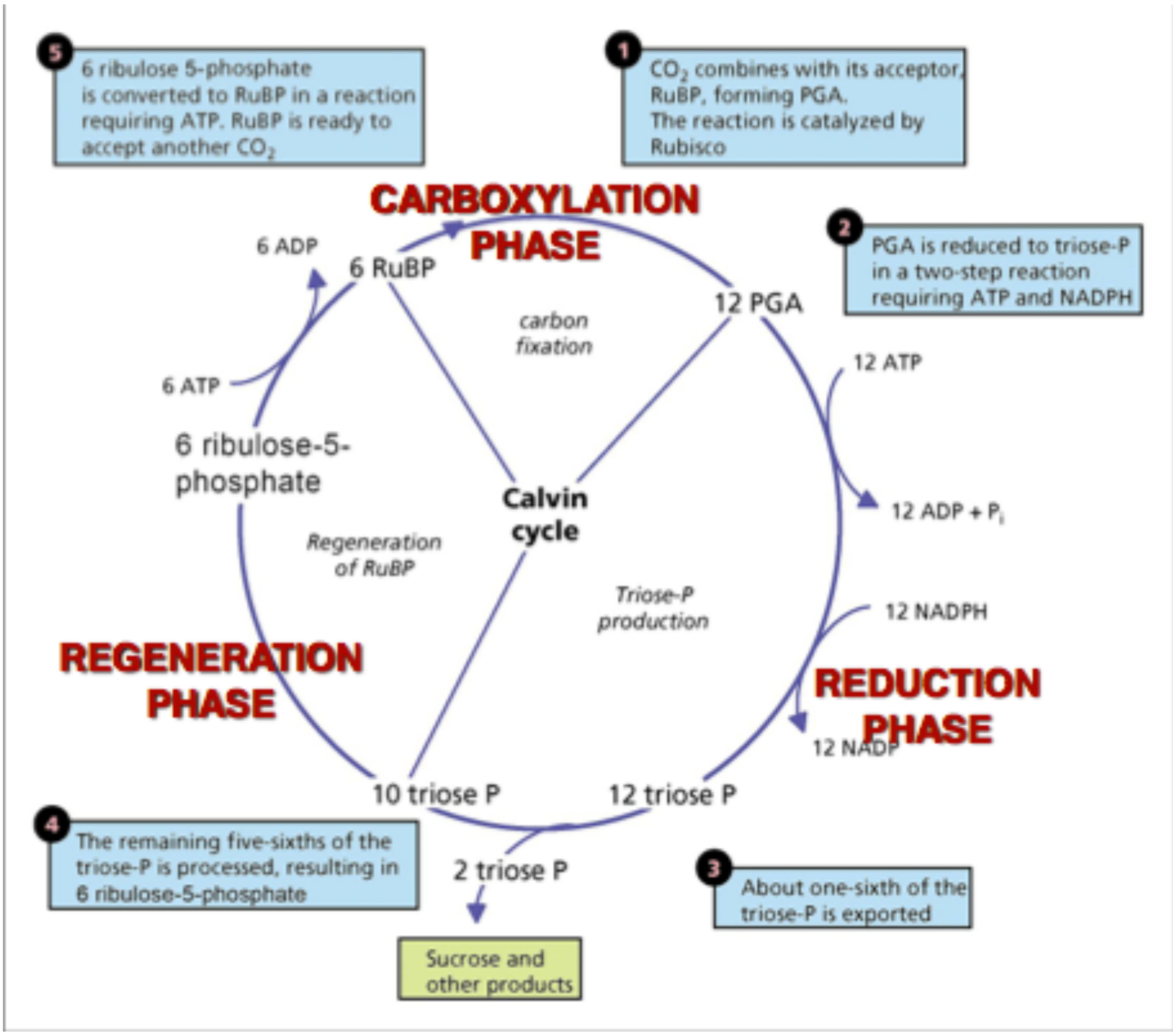
Rather than giving electrons to $NADP^+$, we can cycle the electron down PS1 to make ATP. This is called cyclic phosphorylation.

Summary: production of NADPH and ATP in the light reactions of Photosynthesis



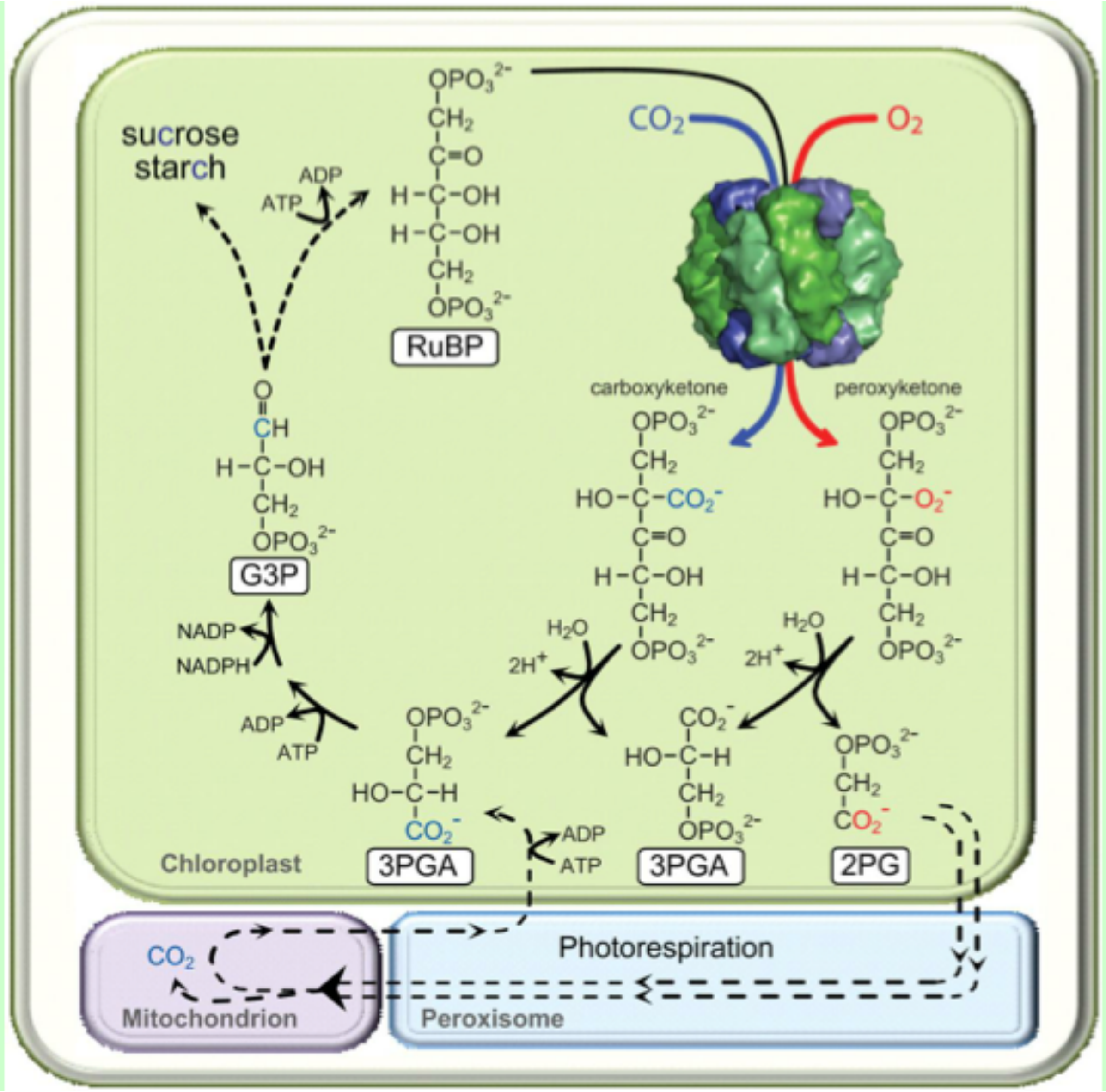
Calvin cycle:

The NADPH and ATP created from photosynthesis, is used in the calvin cycle

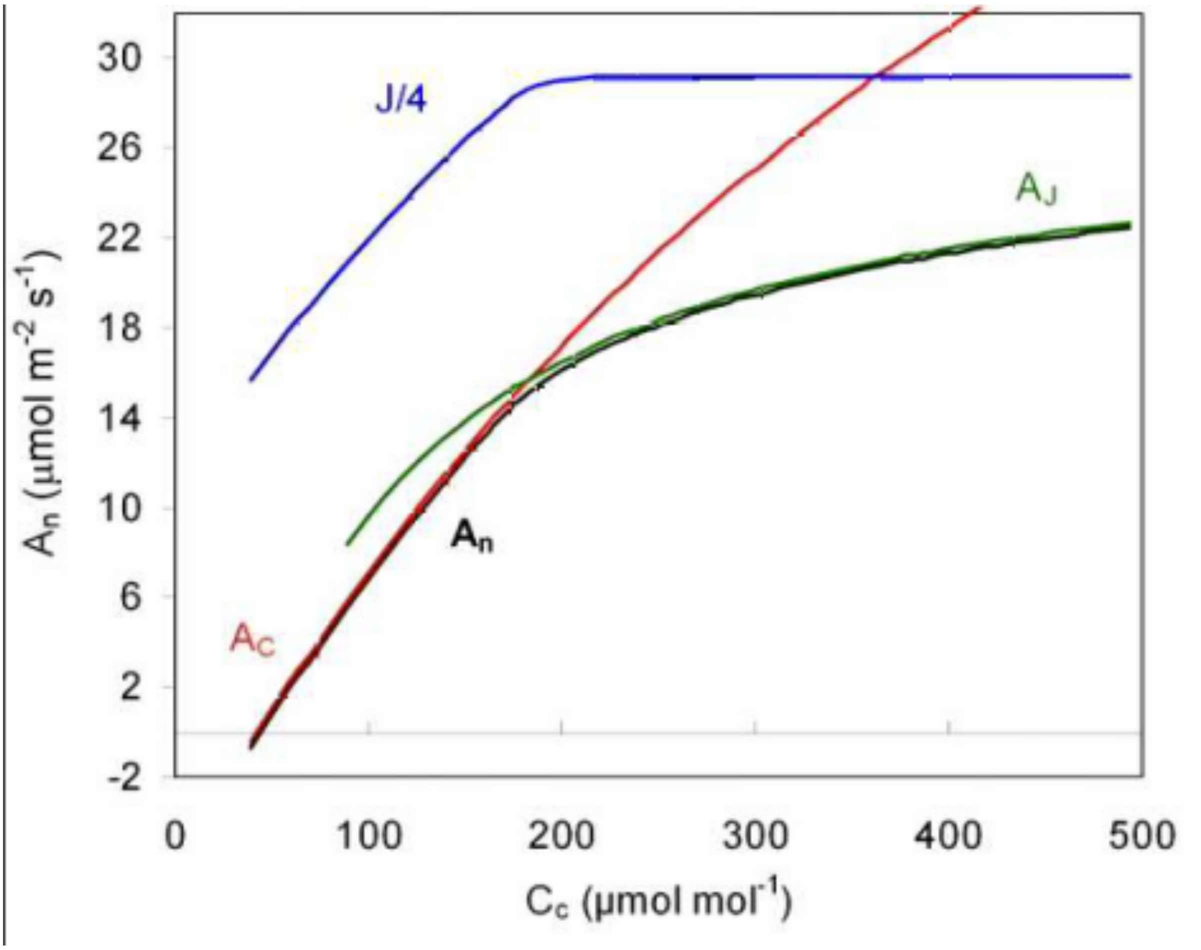


Higher plants have the rubisco enzyme:

- Has 8 small and 8 large subunits each. The larger of the subunits are catalytically active.
- Has both a carboxylase and oxygenase reaction pathways.



- Carboxylase: CO2 fixed to RuBP by RuBisCO is distributed among the resulting two molecules of 3PGA that feed into the photosynthetic Calvin cycle to produce triose phosphates for carbohydrate synthesis or RuBP regeneration
- Oxygenase: also called Photorespiration. Leads to the formation of phosphoglycolate which must go through many chemical reactions in perioxosomes and mitochondrion to create PGA molecules. It is an energetically expensive process.



C02 concentration at the site of RuBisCO (Cc), vs net CO_2 assimilation (An).

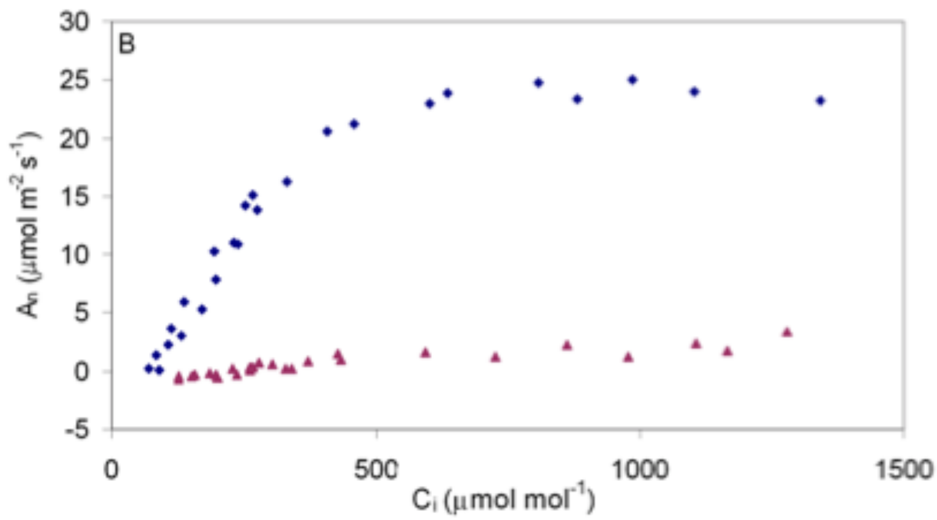
The rate of photosynthesis (redline) increases with increasing CO_2 at the site of RuBisCO. It is not infinitely increasing as there are other limiting factors. J/4 the blue line represents the the electrons transferred in the thylakoid membrane which are required to assimilate one molecule of CO_2. These can become limiting and so effect the net CO_2 assimilation (An). The difference between j/4 and An is due to donation of electrons to other acceptors such as O_2. The real rate of Photosynthesis is the black line.

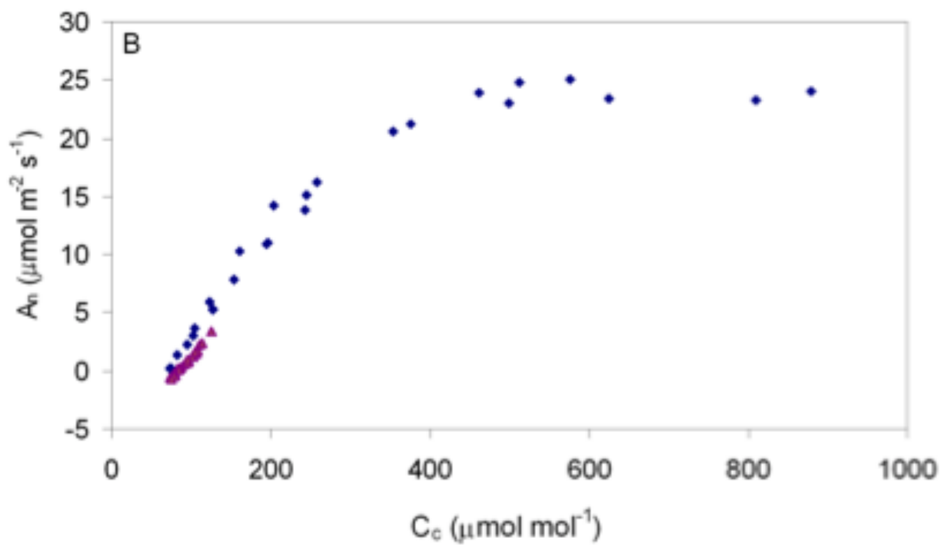
There are limitations on the rate of photosynthesis due to the diffusional differences cuased by mesophyll conductance (See below) and also from the stomata. The stomata can close somewhat during the day and effects the rate of CO_2 entering the mesophyll.

Mesophyll conductance (gm):

- occurs when a difference exists between the partial pressure of CO2 in the intercellular space (ci) and at the site of carboxylation (where RuBisCO is present)(cc). It has been shown that mesophyll conductance plays an important role in determining the rate of photosynthesis in C3 leaves, and should not be left out of leaf photosynthesis models
- During photosynthesis, CO2 moves from the atmosphere (C(a)) surrounding the leaf to the sub-stomatal internal cavities (C(i)) through stomata, and from there to the site of carboxylation inside the chloroplast stroma (C(c)) through the leaf mesophyll. The latter CO2 diffusion component is called mesophyll conductance (g(m)). A large body of evidence has accumulated in the past two decades indicating that g(m) is sufficiently small as to significantly decrease C(c) relative to C(i), therefore limiting photosynthesis

We plot photosynthesis as a function of the CO_2 concentration at the site of RuBisCO, rather than that in intracellular spaces to discriminate between environmental effects on stomatal conductance and effects on the mesophyll conductance.





The decreased CO_2 assimilation in heat stressed vs non stressed plants was thought to be due to the limitation of stomata closing. This was because the CO_2 concentrations were being measured in the intracellular spaces. When its measured at the cite of CO_2 assimilation however, the rate of assimilation was the same regardless if the plant was stressed or not. This is because plants can vary their mesophyll conductance.

To determine Cc, we need to know leaf conductance/resistance:
Leaf conductance:
E=gw (wi-wa) where gw is a coeffieicnt of water consictance, and wi is the water pressure in the intracellular space and wa is the water pressure in the air.

$gc = gw / 1.6$

Fick's first law: The rate of diffusion is determined by the gradient in CO_2 concentration in the air (Ca) and at the site of CO_2 assimilation (Cc). this is multiplied by a coefficient (gc) conductance of CO_2 transfer.
$An = gc (Ca - Cc)$

1. Transpiration: $E = gw (wi - wa)$
2. Leaf temperature - wi
3. $gc = gw / 1.6$
4. Photosynthesis: $An = gc (Ca - Ci)$