Mean = 78.3% (69.6%)
Median = 80% (73%)
Range = 102.5 –36 (97.5 - 27)

The definition of insanity is doing the same thing over and over and expecting different results.

Benjamin Franklin/Mark Twain/Albert Einstein
Photosynthesis Overview

Stages of Photosynthesis

i) Absorption of light
ii) Electron transport
iii) Generation of ATP
iv) CO₂ Fixation

(b) Localization of photosynthesis within the chloroplast
Melvin Calvin
Nobel Prize, 1961

Calvin Cycle

- found in all oxygenic/anoxygenic phototrophs

- in plants and algae Calvin Cycle is confined to the stroma

- CO₂ enters plant leaf through stomata (stoma – singular)

- CO₂ diffuses into photosynthetic cells and enters chloroplasts
The Calvin Cycle

**Conceptual Divisions**

**Phase 1:**
- RuBP (5C) is carboxylated
- Ribulose 1,5 bisphosphate carboxylase/oxygenase = RUBISCO

*Most abundant protein on earth!*
- RUBISCO fixes: 2x10^{11} tons of CO_2 on earth/day

Carboxylation is followed by hydrolysis to form 2 molecules of 3-PG per RuBP

**Phase 2:**
- Reduction of 3-PG
- NADPH from???

**Phase 3:**
- Regeneration of RubP
For a plant to synthesize two molecules of glucose, the Calvin cycle uses ________ molecules of CO₂, ________ molecules of ATP, and ________ molecules of NADPH.
For each CO$_2$ consumed by the Calvin Cycle

3 ATP/ 2 NADPH

But consider:

2H$_2$O $\rightarrow$ O$_2$ + 4e$^-$ $\rightarrow$ 2 NADPH

4H$^+$ 4H$^+$

Assume: 3H$^+$ pass through cF$_0$cF$_1$:

8H$^+$ 3H$^+$

2.7 ATP

Yikes, a thermodynamic conundrum!

Need 3 ATP, but making ‘2.7’
Cyclic Electron Flow

• Allows organism to regulate the ratio of NADPH/ATP within photosynthetic cells

• e⁻ move from PS I to Fd then through cytochrome complex
  • proton pumping → H⁺ gradient → ATP
Ribulose Bisphosphate Carboxylase/Oxygenase (RUBISCO)
Photosynthesis Overview

Stages of Photosynthesis

i) Absorption of light
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iv) CO₂ Fixation

Photophosphorylation

(b) Localization of photosynthesis within the chloroplast
When plants grow, where does the new tissue come from? From water? From the dirt? From thin air?
Photosynthesis Summary

Light reactions:
- Are carried out by molecules in the thylakoid membranes
- Convert light energy to the chemical energy of ATP and NADPH
- Split $H_2O$ and release $O_2$ to the atmosphere

Calvin cycle reactions:
- Take place in the stroma
- Use ATP and NADPH to convert $CO_2$ to the sugar G3P
- Return ADP, inorganic phosphate, and NADP$^+$ to the light reactions

Light reactions:
- Chlorophyll absorbs light
- $H_2O$ is broken down, releasing $O_2$
- Electrons are passed down a chain to create ATP and NADPH

Calvin cycle:
- $CO_2$ is fixed into 3-PG
- 3-PG is reduced to G3P using NADPH and ATP
- G3P is converted back into $CO_2$ and used to make sucrose
Ribulose Bisphosphate Carboxylase/Oxygenase (RUBISCO)

Catalyzes the addition of:

\[
\begin{align*}
&O=\overset{\text{C}}{\text{C}}\overset{\text{O}}{\text{O}} \\
&O=\overset{\text{O}}{\text{O}}
\end{align*}
\]

Carboxylase activity:

\[
\text{RuBP} + \text{CO}_2 \rightarrow 2 \text{(3-PG)}
\]

\[
\begin{array}{ccc}
5\text{C} & 1\text{C} & 3\text{C}
\end{array}
\]

Oxygenase activity:

\[
\text{RuBP} + \text{O}_2 \rightarrow 1 \text{(3-PG)} + 1\text{-phosphoglycolate}
\]

\[
\begin{array}{ccc}
5\text{C} & 3\text{C} & 2\text{C}
\end{array}
\]

Photorespiration:

3-PG = 3-phosphoglycerate

Problems:

- toxic (inhibits triose phosphate isomerase)
- energetically wasteful
  - RuBP contains previously fixed CO\(_2\)
  - under certain conditions some crop plants can lose 50\% of their fixed CO\(_2\)
Ribulose Bisphosphate Carboxylase/Oxygenase (RUBISCO)

**Photorespiration:** Problems/Solutions

1) Atmospheric [ ]’s of O\(_2\) and CO\(_2\):

\[
600:1
\]

2) Plants exposed to high temps; high intensity of light are susceptible to oxygenase activity

- as temp increases; solubility of gas decreases
- solubility of CO\(_2\) decreases faster than O\(_2\)
- plants close stomates at high temps to prevent water loss
  - can not take in CO\(_2\) from the atmosphere!

At high light intensity, the light reactions are producing O\(_2\)!

What’s an autotroph to do?

1) C4 Plants (Hatch-Slack Cycle)
2) CAM plants