I. **Overview of Photosynthesis:** 4 STAGES:

1. Light Absorption: Electrons are pulled from water, and O_2 is evolved. (LIGHT RX)
2. Electron Transport : NADPH is formed. (LIGHT RX)
3. Generation of ATP. (LIGHT RX)
4. Conversion of CO_2 into Carbohydrates. (Carbon Rx)

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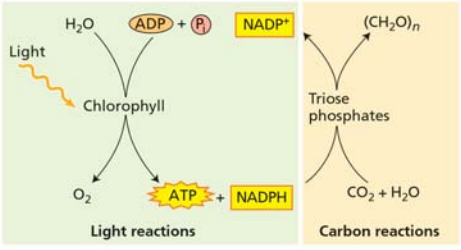


8-1 Taiz

Outline- CO_2 Fixation: Different strategies

1. All plants use C3 pathway to fix CO_2 to make sugars.

   C3 reduction: or Calvin cycle

   CO_2 --> C3 ---> C6

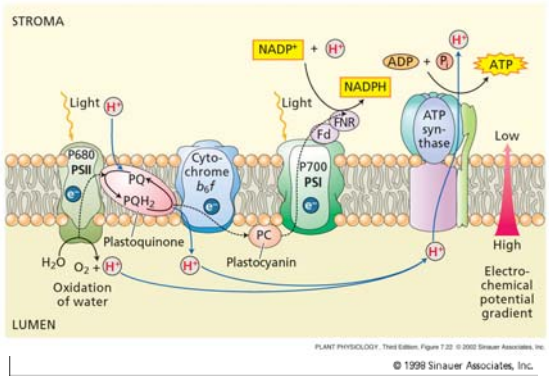
2. Key enzymes are regulated by light.

3. Many plants have photorespiration

4. C4 plants maximize CO_2 fixation using a C4 pathway that increase [CO_2] conc.

5. CAM plants minimize water loss by fixing CO_2 at night.

7-22. Taiz



Concepts of Biosynthetic pathways:

1. Biosynthesis is an uphill process that requires energy in the form of ATP.

2. Biosynthesis requires reducing power in the form of NADPH to convert more oxidized precursors to the more reduced state characteristic of cellular components.

3. Pathways for breakdown and synthesis are always distinct, so degradation and synthesis are independently controlled in response to the cell's need.

4. The first enzyme unique to a biosynthetic pathway is a regulatory enzyme

$C_6H_{12}O_6$

↑

↑ **NADPH**

↑ **ATP**

CO_2

How?

THREE STAGES OF C3 REDUCTION PATHWAY:
3 CO_2 + 3 RuBP + [6NADPH + 9ATP] ---> 1 G3P + 3 RuBP

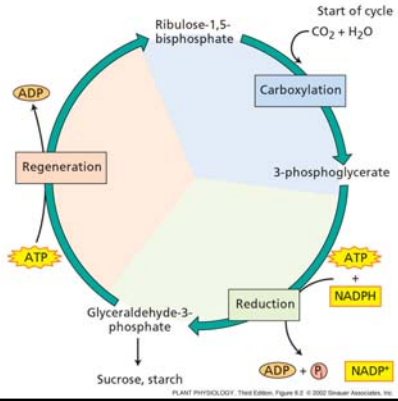
6 CO_2 + 6 RuBP + [12NADPH + 18ATP] ---> 1 Glu + 6 RuBP

1. CARBOXYLATION:
3 RuBP (5C-P) + 3 CO_2 --> 6 PG Acid (3 C-P)

2. REDUCTION OF P-GLYCERATE:
6 PG Acid --> 6 G3P --> 5 G3P + 1 G3P (Glyceraldehyde 3-P)
6NADPH, 6ATP

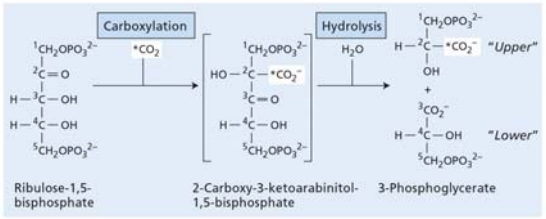
3. REGENERATION OF CO_2 ACCEPTOR:
5 G3P + 3ATP --> 3 RubP
CO_2 acceptor

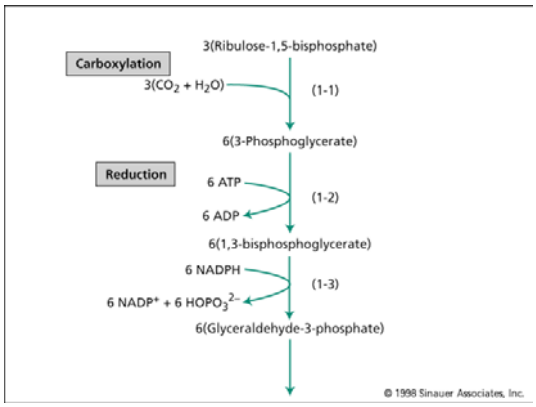
8-2 Taiz. Calvin cycle has 3 stages



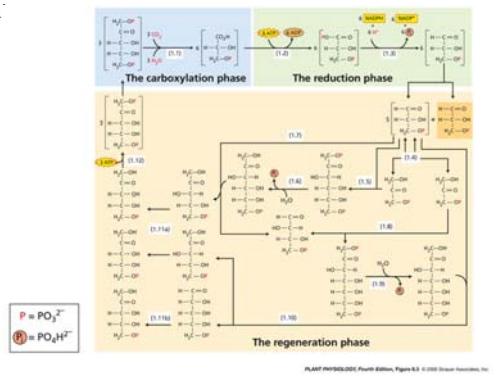
8-4. Taiz. The CO_2 fixation reaction by RuBP Carboxylase,

Rubisco- the most abundant enzyme in the world!





8-3 Ta



How was this pathway determined?

Calvin & Benson 1947-48. Science

Calvin cycle is regulated by light

A. Activity decrease in the Night and increase in the light.

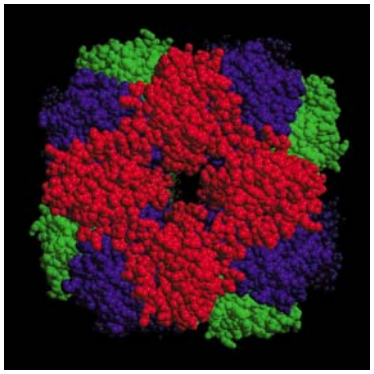
Enzyme is modified: Active form <-----> Inactive form

1. Light causes pH and ionic changes. [Mg] increase
2. Light activates rubisco
3. Light reduces certain enzymes via Fd-thioredoxin. Reduced enzymes are activated.
4. Light affects membrane transport of triose-P & Pi. Low [Pi] levels in cytosol affect ATP in chloroplast. Decrease C fix.

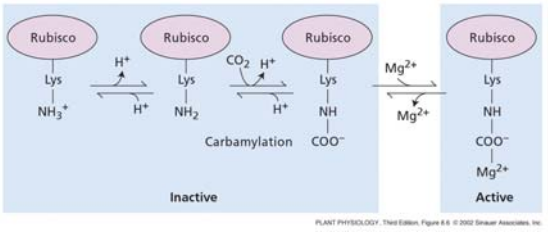
B. **Synthesis and repression of enzyme**

gene ---> mRNA ---> protein [short life-time]

12-39 Buchanan. Rubisco L8S8. SS-Red; LS-green, blue

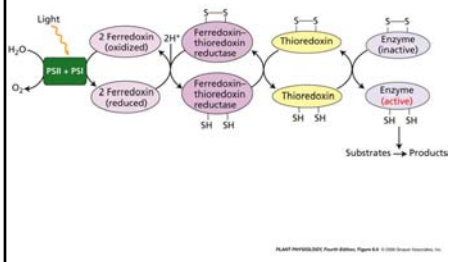


8-7 Taiz Light-dependent pH and [Mg] changes activate rubisco



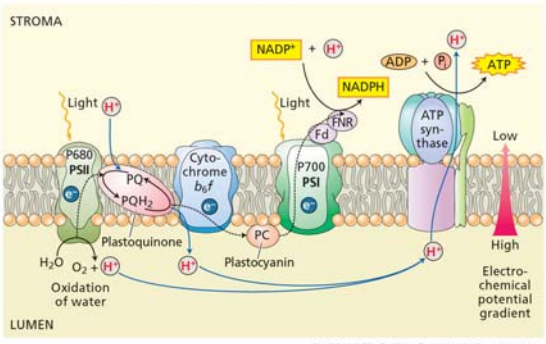
pH 7 Dark	pH 8 Light	[Mg] increase

8-6 Taiz



Light-dependent reduction of Ferredoxin [Fd] activate enzymes via reduced Thioredoxin. E.g. NADP:G3P DH, Ru5P Kinase

7-22. Light reactions: generate NADPH and ATP



[Pi] conc in cytosol regulate rate of PS.

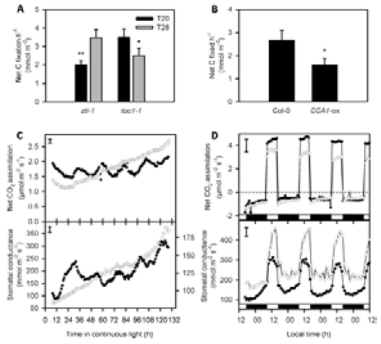
Pi uptake tied to G3P export.

Summary of Calvin cycle

1. $3CO_2$ --> G3P
All steps take place in one chloroplast in one cell type.
All steps take place at one time, I.e. in the day.

2. Enzyme activities of C3 reduction pathway are light-dependent.

The circadian clock enhances photosynthetic carbon fixation



(A) Mean C fixation per hour in *zti-1* and *toc1-1* grown in T20 and T28. (**B**) Mean C fixation per hour in Col-0 wild type and arrhythmic *CCA1*-ox, in T24. (**C**) *CCA1* overexpression (open circles) abolishes the circadian rhythms of CO_2 fixation and stomatal opening that occur in Col-0 wild type (filled circles). (**D**) CO_2 assimilation and stomatal conductance in *CCA1*-ox (open circles) and Col-0 wild type (filled circles) under light-dark cycles (indicated by bars on the *x* axis.

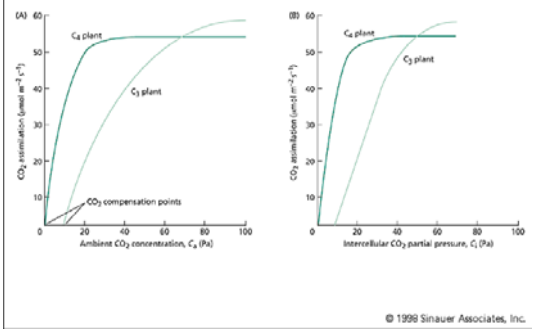
Overexpressor of molecular oscillator component *CCA1* (*CCA1*-ox).

Fig. 3. Environmentally matched clock period enhances vegetative growth.

Dodd AN et al. 2005 Science

9-20. Taiz. Plants differ in their ability to fix ambient CO_2

Photorespiration: light-dependent O_2 uptake and CO_2 release



PHOTORESPIRATION: A process where O_2 is consumed and CO_2 is given off in light by photosynthetic tissues.

C4 METABOLISM: A mechanism to concentrate CO_2 in the chloroplasts to reduce RUBP oxygenase activity.
C4 PLANTS: e.g. Corn, sugar cane, many weeds

1. Carboxylation: in **MESOPHYLL CELL**
   CO_2 + PEP (3c)---> OAA (c4) ---> MAL (c4)
Mal is transported to **BUNDLE SHEATH** cells
2. Decarboxylation : MAL (c4) ---> CO_2 + PVA
3. Calvin cycle: $3CO_2$ --> G3P
Transport of PVA back to **MESOPHYLL**
4. Regeneration of PEP: pva ---> pep