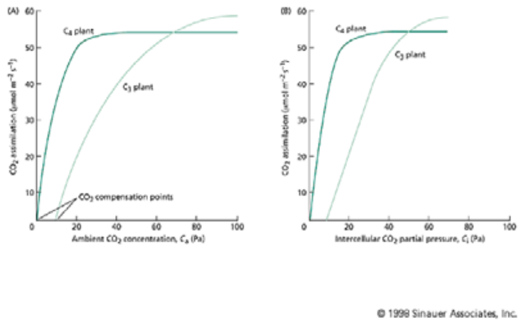
9-18. Taiz. Plants differ in their ability to fix ambient $CO_2$

Photorespiration: light-dependent $O_2$ uptake and $CO_2$ release

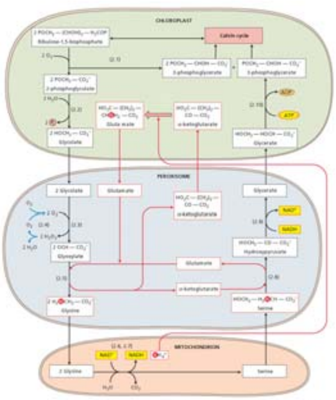



**PHOTORESPIRATION:** A process where $O_2$ is consumed and $CO_2$ is given off in light by photosynthetic tissues (leaf).
*Why?* $O_2$ consumption by RuBP Case/oxygenase

**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. C3 reduction: $3CO_2$ --> G3P
Transport of PVA back to **MESOPHYLL**
4. Regeneration of PEP: pva ---> pep

8-9 taiz. Photoresipration: net loss of C




*RubP carboxylase/ oxygenase*

2RuBP + $2O_2$ -->

2PGA + 2 p-Glycolate -->

2PGA + 1PGA + $CO_2$

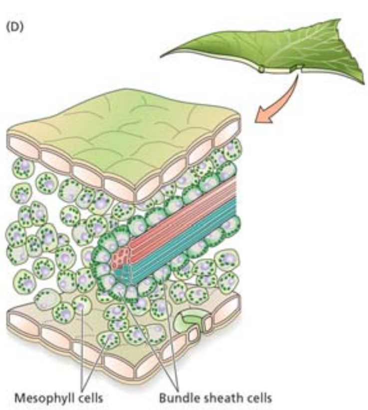
C4-Sorghum & Atriplex

8-9 Taiz

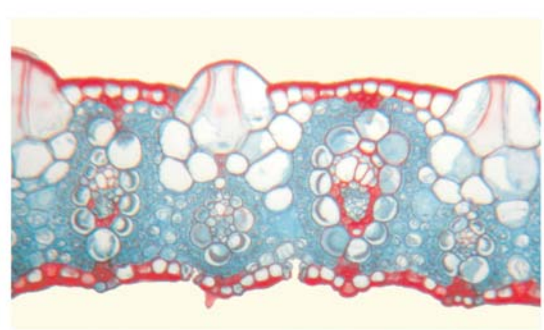
Anatomy of C4 leaf

C4 Plants:

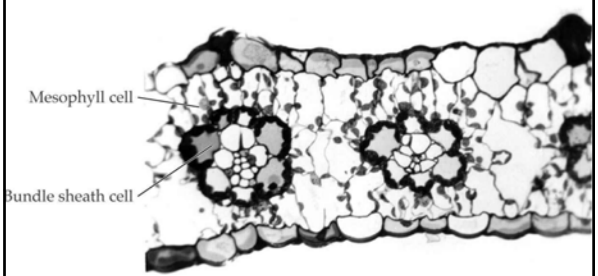
corn,
sugar cane,
sorghum,
weeds:
crabgrass




(A) 8-9A. Sugar cane- C4 monocot

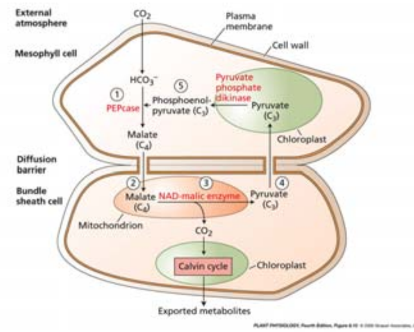


**12-45 Buchanan. C4 plant maize shows Krantz anatomy.**




8-10 Taiz

C4 Carbon cycle



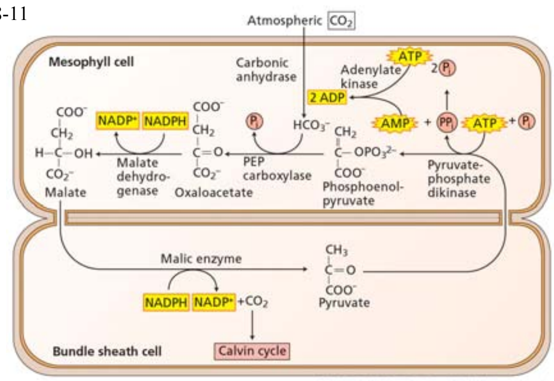

Hatch & Slack 1966-1971

1. Carboxylation: in **MESOPHYLL CELL**
   $CO_2$ + PEP (3C)---> OAA (c4) ---> MAL (c4)

2. Mal is transported to **BUNDLE SHEATH** cells
   Decarboxylation : MAL (c4) ---> $CO_2$ + PVA
   C3 reduction: $3CO_2$ --> G3P
   Carboxylation- rubisco
   reduction
   regeneration

3. Transport of PVA back to **MESOPHYLL**
   Regeneration of PEP: pva ---> pep

8-11




**Ecological significance of C4 plants**

1. C4 plants have low $CO_2$ compensation conc.

2. C3 plants have high transpiration ratio : water loss/$CO_2$ uptake

3. Quantum yield: $CO_2$ fixed/mol quantum

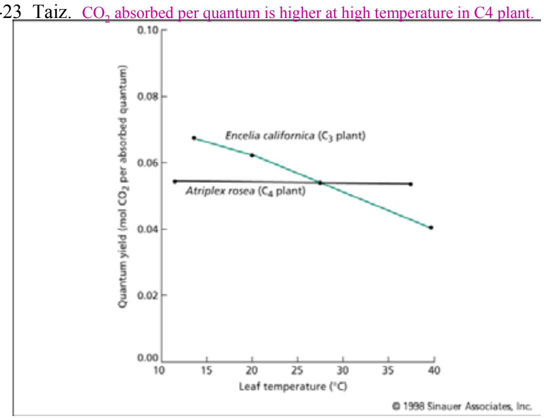
   is higher in C4 plants at high temp and high light

Conclusion:

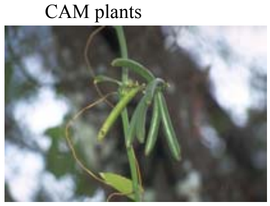
C4 plants are not always more competitive than C3 plants.

C4 have an advantage at high temp, high light, and low water conditions.

9-23 Taiz. $CO_2$ absorbed per quantum is higher at high temperature in C4 plant.



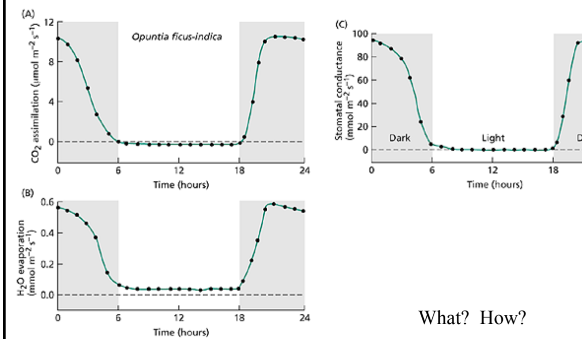
CAM plants



Agave

Vanilla

9-19 Taiz: CAM plants take up $CO_2$ at night




What? How?

Why?

**CAM (Crassulacean Acid Metabolism) plants fix $CO_2$ at night**

**NIGHT:** **PEP Case**

1. Carboxylation: PEP + $CO_2$ ---> OAA --> MAL
2. Mal is stored in the vacuole

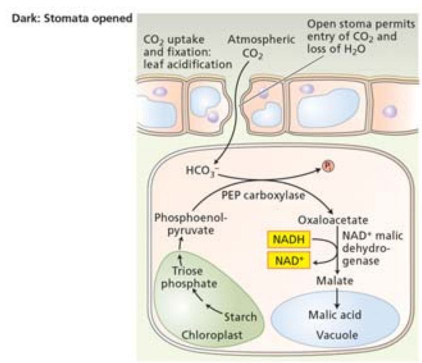
**DAY**

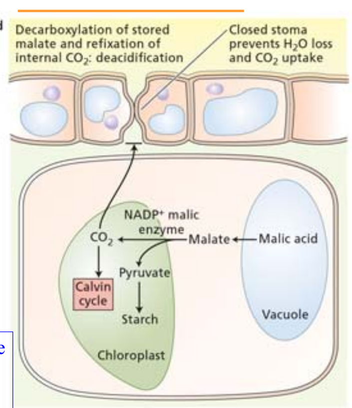
3. Mal is transported back to the cytoplasm
4. Decarboxylation:
   MAL + NADP+ -(*NADP MALIC ENZYME*) ->
   PVA + $CO_2$ + NADPH

5. Carbon Reduction Cycle: $CO_2$ -> PGA -> HEXOSE

6. Regeneration of PEP:
PVA + ATP + Pi-(*PYRUVATE DIKINASE*)-> PEP +AMP + PPi

8-12 Taiz. CAM pathway

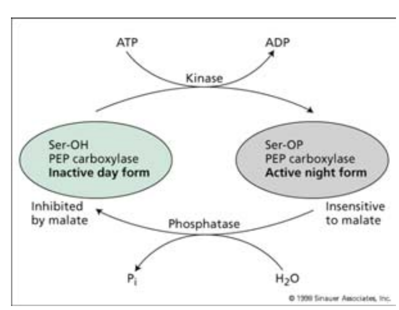



How do plants regulate this?
Prevent futile cycling of malate.

8-15 Taiz. CAM PEP Case is active at night

PEP Case is activated by phosphorylation.




P- enzyme is active.

**Regulation of CAM**

1. PEP Case: is active at night and shuts down in the day.
2. Mal product inhibits PEP Case in the day
3. Malic enzyme is active in the day (Decarboxylation).

**Summary**

CAM reduce water loss by separating reactions in time.

CAM plants are suited to dry habitats.

**Sucrose and starch synthesis**

Sugar cane from web site
Yama……..

Rice from website
of Yama…….

**Synthesis, Export and Storage of Photosynthetic Products**
(or increasing starch in potato chips)

**Synthesis**:

a. Starch synthesis in the chloroplast: G3P--> starch
b. Sucrose synthesis in the cytoplasm of mesophyll cells
G3P moves into the cytoplasm. G3P--> --> SUC
c. Cellulose synthesis

**Transport**

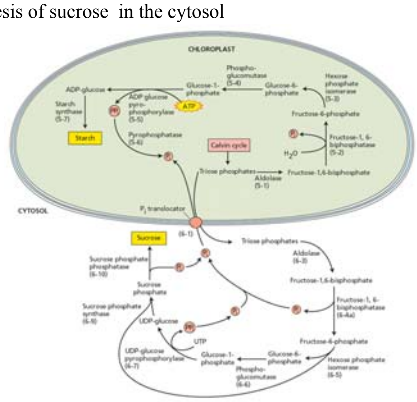
Suc is exported to sinks via the phloem.

**Fate of sucrose in sinks** :

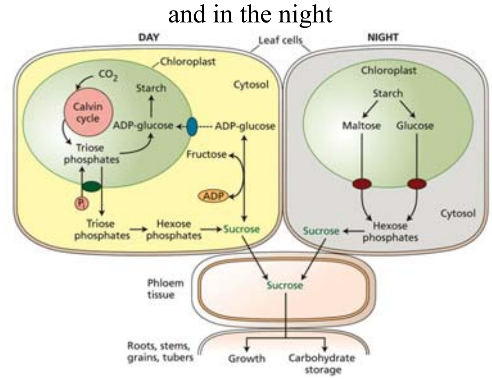
a. -Suc. --> Hexose --> Respiration & Synthesis
b. -Suc. --> Hexose --> Starch for storage

**Regulation of sucrose or starch synthesis** depends on how G3P is distributed.
Photosynthate partitioning determines the harvest index.

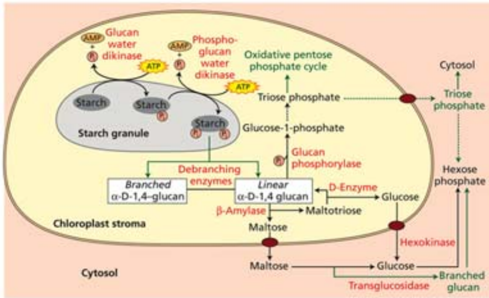
8-14 Taiz. Synthesis of starch in the chloroplast & synthesis of sucrose in the cytosol



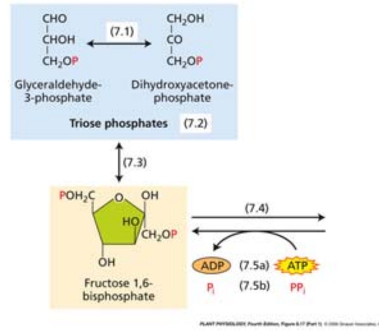

## C metabolism and transport in the day and in the night



## Starch degradation at night

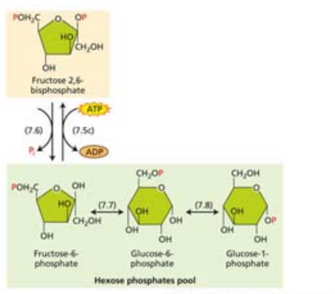



## 2 triose-p condense to make a fructose-1,6-P and produce hexose-p pool

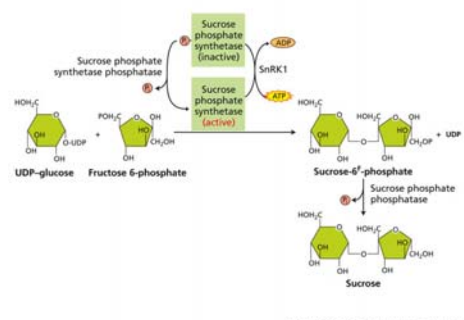



## hexose-P pool

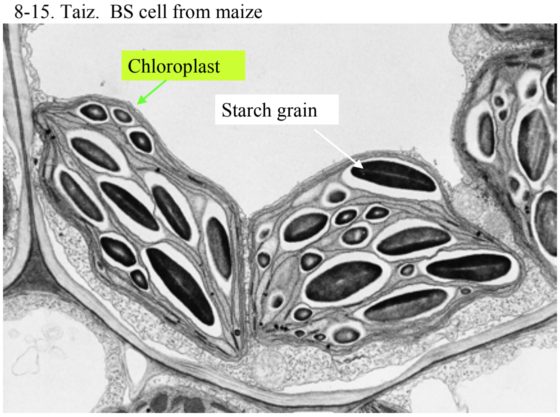
Fructose-1,6-P →




## Sucrose synthesis:
adding glucose (in UDPG) to fructose-6-P

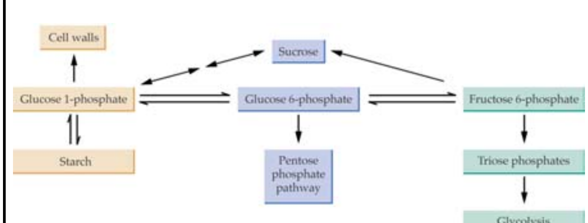



8-15. Taiz. BS cell from maize




Review

13-8 Buchanan. Hexose-P pool contributes intermediates to glycolysis and biosynthesis



# Genetic engineering:
# Increase starch content in potato chips

How?

Increase enzyme forming ADPG

Overexpress enzyme in potato

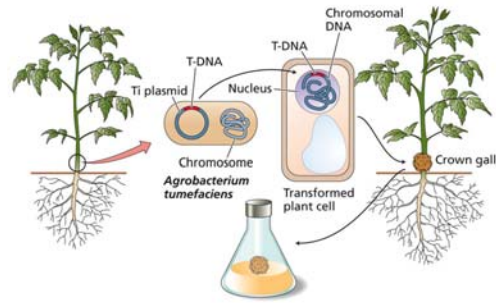
Method

1. Plasmid containing gene ADPG Ppase
2. Introduce into *Agrobacterium tumefaciens*
3. Transform plants with bacteria carrying gene
4. Gene integrates into plant chromosome.

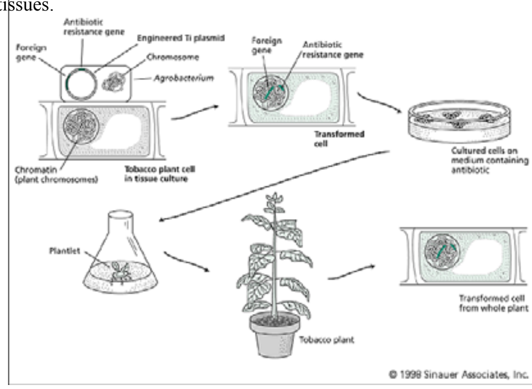
J Preiss

21-4 Taiz. Tumour induction by cytokinin.

Agrobacterium-mediated transformation- introducing new gene into plants




Box 21-1 Taiz. Regenerating whole plants from transgenic cells or tissues.




# Concerns of GM-modified crops

- Antibiotic resistance markers used for selection --> lead to antibiotic-resistance bacteria
- Allergens or toxins introduced

Diurnal regulation of PS protein gene expression

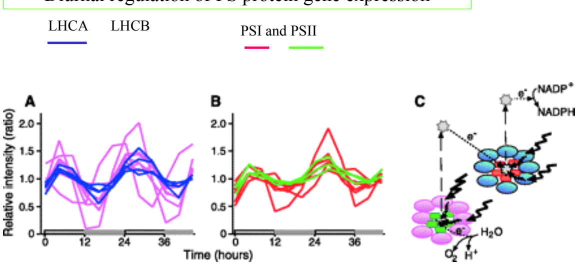
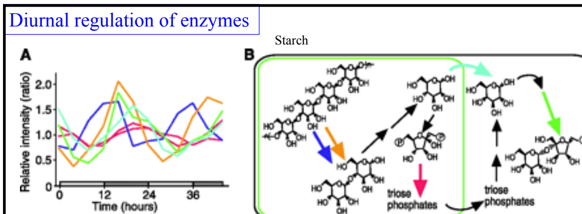



Figure 1. Photosynthesis gene expression peak near the middle of the subjective day.

Harmer SL et al 2000. Science. 0 h = 6 a.m.

Diurnal regulation of enzymes




**Genes encoding starch-mobilizing enzymes peak during the subjective night.** (A) Cycling genes encode a putative starch kinase (accession number AAD31337) that is related to potato R1 protein (38) (dark blue); a -amylase (AJ250341) (gold); putative fructose-bisphosphate aldolase, plastidic form (AAD14543), and putative fructose-bisphosphate aldolase, predicted to be plastidic (AAD23681) (red); a putative sugar transporter (AAD03450) (light blue); and a sucrose-phosphate synthase homolog (T04062) (green). (B) Model for the enzymatic functions of these gene products in the mobilization of starch. Colored arrows indicate the function of the corresponding gene indicated in (A). The chloroplast is bounded by a green box and the cytoplasm by a black box.

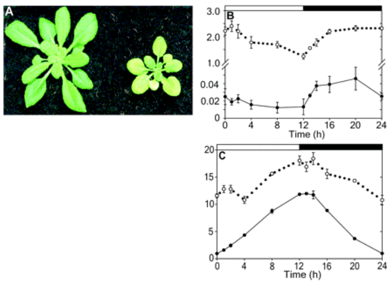
Harmer et al 2000 Science

## Is maltose exported?

Not known until recently.

A mutant with high maltose

WT mutant




mutant

maltose

Wt

mutant

starch

Niittyla et al 2004. Science

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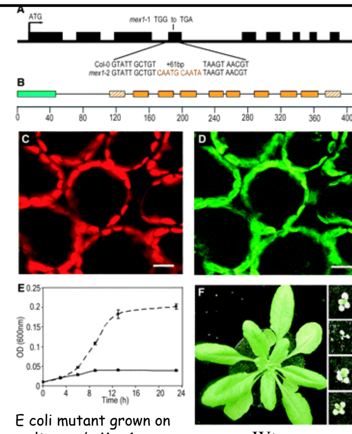


Mex1 transports maltose out of chloroplast

??

MEX1-YFP localized to chloroplast (I.E)

Double mutant of mex1/dpe gluc exporter

E coli mutant grown on maltose +/- Mex1

Wt

---

## Maltose and glucose are exported