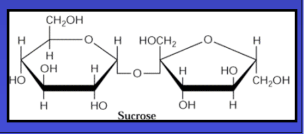
Lect. 9: Allocation, Translocation & Partitioning

- Photosynthates (i.e., starch & sucrose)
- Movement of photosynthates
- Phloem loading, transport and unloading
- Distribution of sugars

Reading: Chapter 6



Export and Short-term Storage of Photosynthates

Photosynthates = Reduced-carbon products of photosynthesis

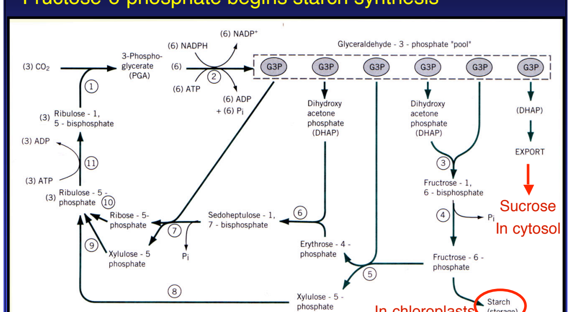
In light, excess photosynthates are stored in different chemical forms and cellular locations

1. Dicotyledenous plants (potatoes, etc…) tend to make and store starch in plastids
2. Monocotyledenous plants (corn, sugarcane, etc…) tend to make sucrose to be stored in vacuoles

At night, photosynthates can be metabolism via respiration to form ATP needed for cellular energy

Review of Products from PCR Cycle (Fig. 5.11)

- Trios phosphate (DHAP) is exported from chloroplasts
- Fructose-6-phosphate begins starch synthesis



Two Forms of Starch in Chloroplasts

- α-Amylose (non-branched), α-(1-4) glucan
- Amylopectin (branched), amylose with periodic α-(1-6) links

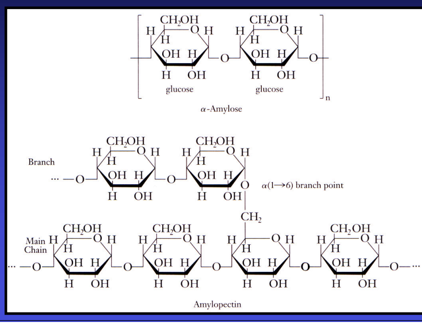


Fig. 6.1

Starch Synthesized in Chloroplasts

Triose-Phosphates from Calvin cycle enter "hexose phosphate pool" and is used to synthesize starch

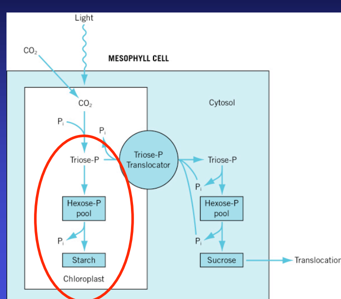
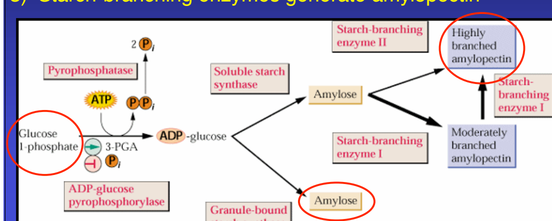


Fig. 6.2

Starch synthesis in Chloroplasts (section 6.1.1 in text)

1) glucose-1-phosphate is "charged" with ADP (increased potential energy)
2) It is covalently linked to growing starch (amylose or amylopectin) chain by Starch Synthase Enzyme
3) Starch-branching enzymes generate amylopectin



Sucrose is Synthesized in Cytoplasm and is Regulated!

- glucose is charged with UDP in hexose phosphate pool
- UDP-glucose + fructose-6-phosphate ⟶ sucrose + UDP
- Catalyzed by Sucrose Phosphate Synthase enzyme

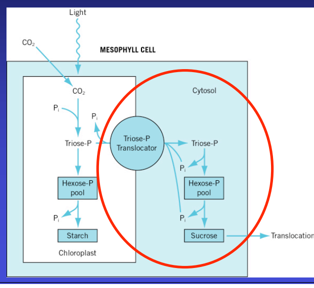
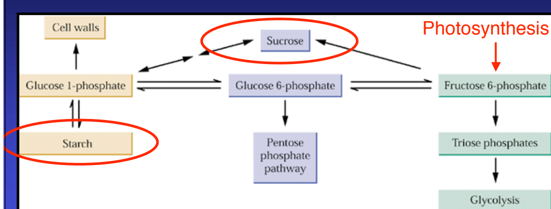


Fig. 6.2

Starch and Sucrose Synthesis are Partly Competitive

Both use sugars from Hexose Phosphate Pool

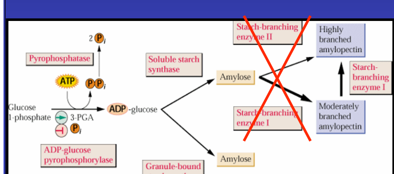


Note, Cellulose (beta 1-4 glucose) also pulls from this pool.

Remember Mendel's Round versus Wrinkled Peas?

The starch synthesis is blocked in "wrinkled" pea seeds

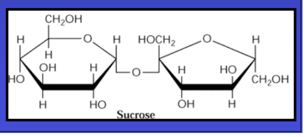
- mutation in starch branching gene, loss of function
- 30% reduction in starch leads to wrinkled seeds
- Excess sucrose, with a strong osmotic pressure increases water in developing fruit that later dry up "wrinkled"



Lect. 9: Allocation, Translocation & Partitioning

- Photosynthates (i.e., starch & sucrose)
- Movement of photosynthates
- Phloem loading, transport and unloading
- Distribution of sugars

Reading: Chapter 6



Sugars Quickly Translocated into Phloem Tissue

- Add C^{14} via CO_2 and follow radioisotope for 10 minutes
- Ends up in petiole phloem tissue within a few minutes

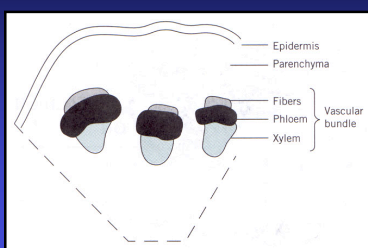
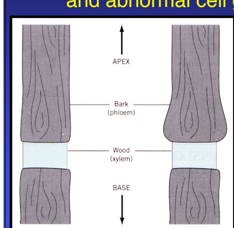


Fig. 6.6 (sugarbeet petiole)

Translocation of Photosynthates Within Trees

- Girdling a tree removes phloem tissues
- Tree lives for only a short time, until roots die.
- Phloem above girdle thickens due to excess photosynthates and abnormal cell growth



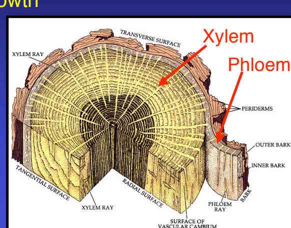
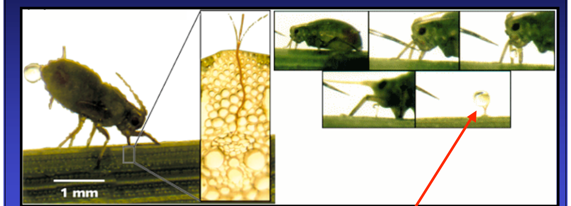


Fig. 6.5

Aphids Able to Find Phloem Tissue and when styles are cut, the positive phloem pressure pushes out Sap



Phloem Sap – test for components

Chemical Composition of Phloem Sap (Table 11.1)

- Sucrose is a major component of phloem sap
- Proteins (namely P-protein) present in phloem

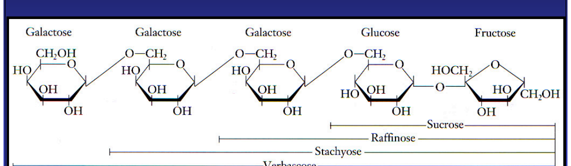
TABLE 6.1 The chemical composition of phloem exudate from stems of actively growing castor bean (*Ricinus communis*).

Organic	$mg\ l^{-1}$
Sucrose	80–106
Protein	1.45–2.20
Amino acids	5.2
Malic acid	2.0–3.2
Inorganic	$meq\ l^{-1}$
Anions (Inorganic)	20–30
Cations (Inorganic)	74–138
Total dry matter	100–125 $mg\ l^{-1}$

Data from Hall and Baker, 1972.

Different types of sugars in phloem

- Although sucrose is the most common transport sugar, other sucrose-related sugars occur in phloem
- For example, "raffinose series" present in some plants

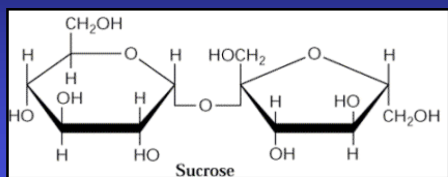


- sucrose is by far the most common!

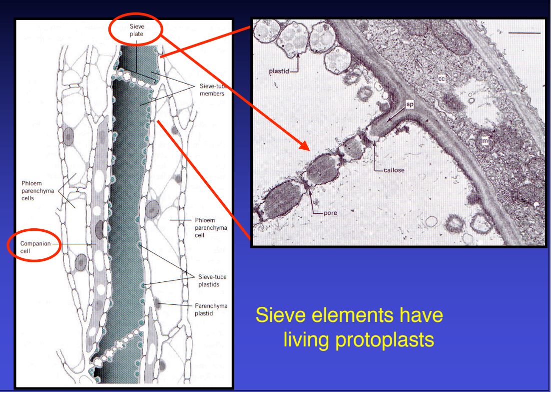
Fig. 6.7

Why Sucrose?

- Why is sucrose the preferred transported sugar?
- Chemical stability and small size
- "non-reducing" sugar (lacks reactive free aldehyde or ketone group)



Phloem Structure and Sieve element (Fig. 6.8 & 6.9)



Sieve elements have living protoplasts

P-protein & Collose protect plant from damaged phloem

- P-protein stands for phloem protein
- very high concentration in sieve elements
- P-protein gels when exposed to air, plugs sieve elements when phloem tubes are damaged (cut/chewed)
- Blocks the loss of valuable sugars

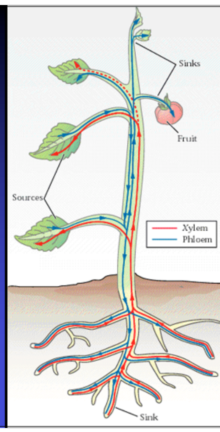
Callose (a □–(1-3) glucan, similar to cellulose)

- rapidly synthesized near wounded sieve plates
- Helps "plug" the sieve tube holes to prevent loss of sap

Source-Sink Relations

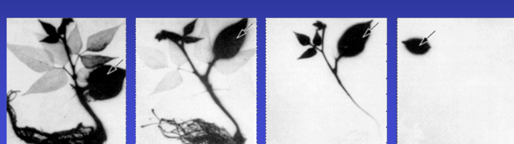
- Source = location where photosynthates are made and loaded into phloem (leaves)
- Sink = location where photosynthates are rapidly reduced for energy (actively growing) and/or loaded into phloem
- These can change over time and plant development

Source-Sink Relations



Radiolabeled Photosynthates in Phloem

-Time course over 24 hr
- Newly fixed radiolabelled carbon ends up in “growing” tissues and not in older organs
- Series of progressively younger leaves from soybeans



Older ← Younger

Movement of Phloem Sap – Pressure Flow

- from sources
- towards sinks
  - respire
  - storage
- moves via pressure flow

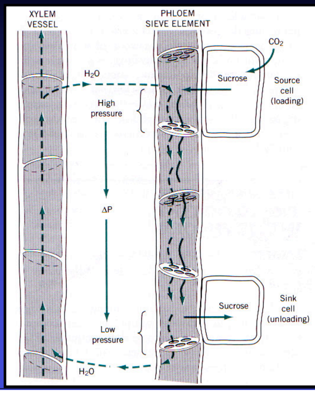


Fig. 6.10

Loading Photosynthates into Phloem from Leaf Cells

- via plasmodesmata (symplast)
- via cell wall (apoplast)

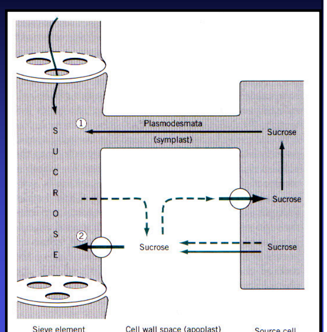


Fig. 6.12

Unloading from Phloem at Sink Tissue

- opposite of loading
- symplastic (plasmodesmata)
- apoplastic (cell wall)
- moved into companion cell

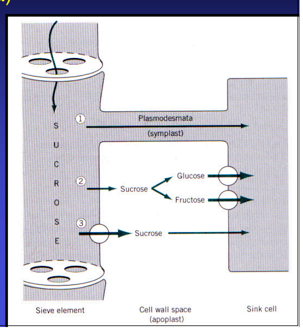


Fig. 6.14

Allocation of Carbon to Different Metabolic Fates

Metabolic fate of carbon

1. Leaf metabolism/biomass
2. Short-term storage
   - sucrose in vacuole
   - starch in chloroplast
3. Export from leaf

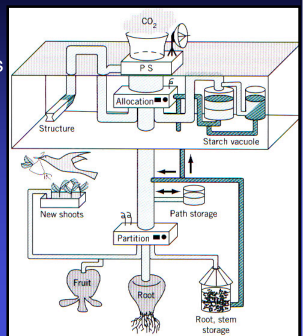


Fig. 6.16

Partitioning of Carbon to Different Sinks Over Life Span

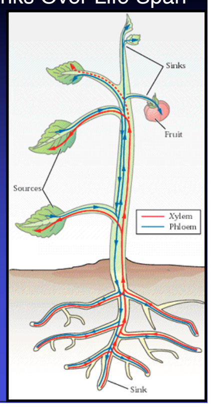
Developmental stages

1. Young herbaceous
   - meristems and leaves
2. Reproduction stage
   - Flowers, fruit & seed
   - starch in chloroplast

Sinks compete for sugars

Few sinks means each receives more

Reason that pruning helps fruit trees!



Sink Strength Greatly Influences Sugar Unloading

Sink strength = capacity to accumulate metabolites

- Sinks tend to draw from close sources
- Developing seeds/grain often strongest sink (table 6.2)
- Grain/Fruit preferentially “fills” at the detriment of other sinks