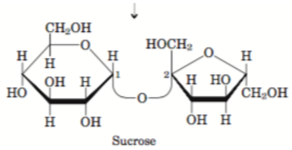
Sucrose and Other Sugars

1. Sucrose is a key product of photosynthesis ("default")

- note dissaccharide structure: glucose (1**a ->** 2ß) fructose (recall the two anomers of monosaccharides)
- sucrose is a **non-reducing** sugar, and key transport form of carbon (energy) in plants (source to sink)
- sucrose and related sugars also for long-term storage



Biosynthesis of sucrose

- in cytoplasm, not the plastids
- source of triose-P is the chloroplast (via **triose-P phosphate translocator),** a channel protein which exchanges triose for *Pi*

=> this connects sucrose & starch pathways

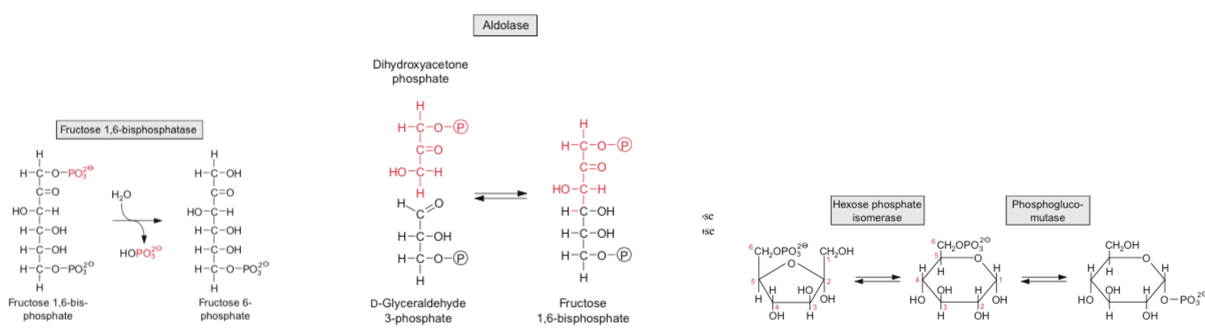
Overall: 4x triose-P ==> 1 glucose + 1 fructose ==> 1 sucrose

<u>Step 1:</u> [*make glucose-1-P*]

2x triose-P ---> fructose-1,6-P_2 ---> fructose-6-P ---> glucose-6-P ---> glucose-1-P

<u>Enzymes:</u> *aldolase, fructose-1,6 bisphosphatase, hexose phosphate isomerase, phosphoglucomutase*

NB: these enzymes are cytosolic isoenzymes, and are not targetted to plastids like for starch



<u>Step 2.</u> (activation step)

glucose-1-P + UTP --> UDP-glucose + PP_i.

[UDP-glucose pyrophosporylase]

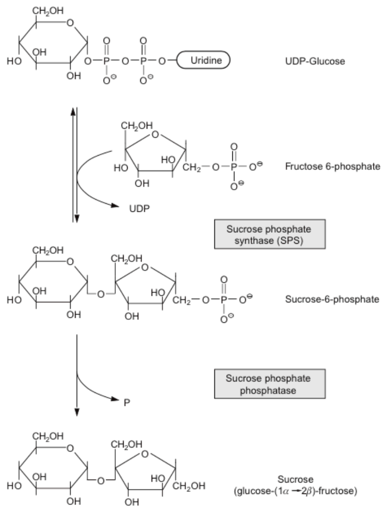
<u>Step 3.</u> (synthesis of sucrose)

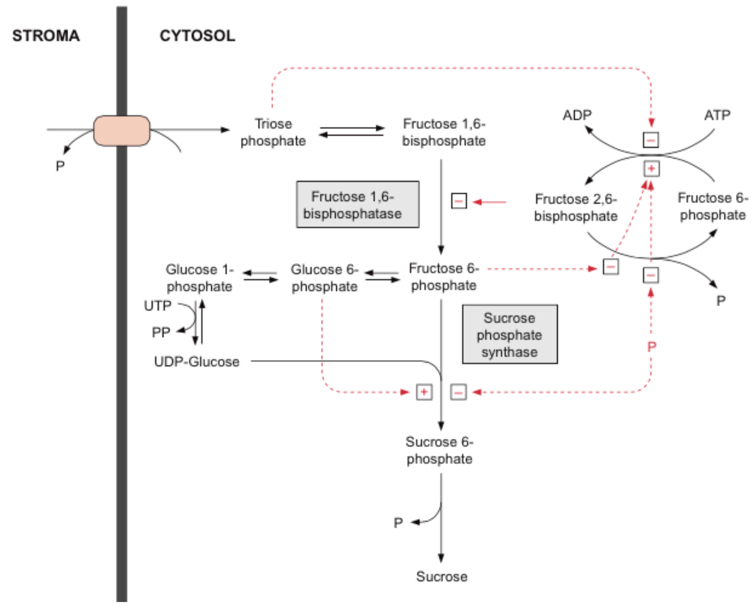
UDP-glucose + fructose-6-P ---> sucrose-6-P

*[Sucrose-phosphate synthase] (*regulatory enzyme*)*

sucrose-6-P --> sucrose + P*i*

[Sucrose-phosphate phosphatase] (irreversible step*)*





2. Regulation of sucrose synthesis is important and needs to balance with Calvin cycle and starch synthesis

Key regulatory enzymes

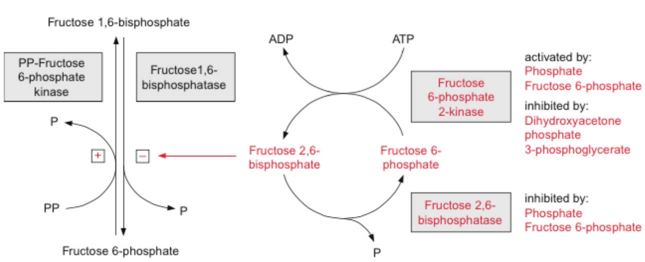
i. Fructose-1,6-bisphosphatase:

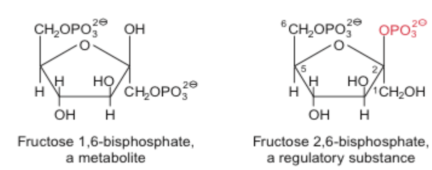
- inhibited by fructose-2,6-P_2 (key regulatory molecule), which exists in a dynamic pool (competing kinase and phosphatase reactions)
    - "senses" triose-P, fructose-6-P, P_i levels

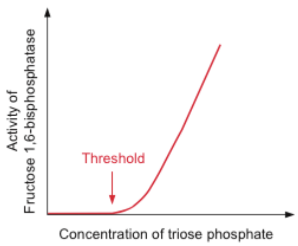
ii. Sucrose-phosphate synthase:

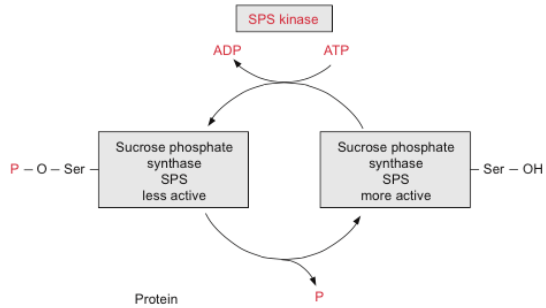
i) **allosteric** mechanisms:
- stimulated by glucose-6-P
- inhibited by P_i, sucrose (?)

ii) inactivated by **phosphorylation**
- balance of kinase and phosphatase (NB: ser residue)
- light stimulates phosphatase









Complex regulation of the whole pathway (see Figure 9.14)

i) light on -> (triose-P up, *Pi*, down) = sucrose synthesis

ii) midday (export saturated) -> sucrose synthesis slowed (via **SPS**, ***Pi***, feedbacks)

iii) inhibit starch synthesis via **triose-P-phosphate translocator (TPT)**.

NB: TPT *connects starch & sucrose, but maintain enough starch for night*

4. Enzymes of sucrose breakdown:

- has to be rapid, to maintain gradient for <u>phloem transport</u>.
- two biochemical routes, depends on species and tissues

i) catalysed by **invertase**:

sucrose + H_2O --> glucose + fructose [a hydrolytic reaction]

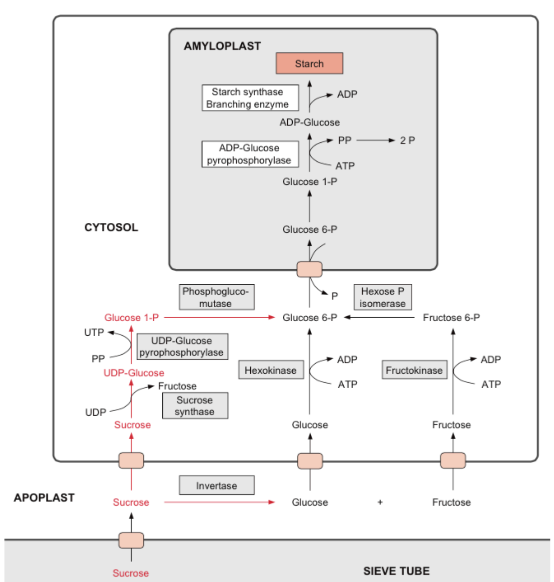
- vacuolar or cell wall (**apoplastic** phloem unloading)
- in cereal grains and other storage organs

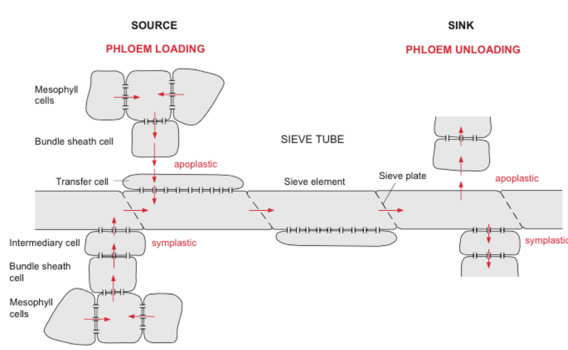
ii) catalysed by '**sucrose synthase' (**note the confusing name...):

sucrose + UDP <----> UDP-glucose + fructose

Note: UDP-glucose can be used directly for cell wall synthesis, etc.

- energetically more efficient than hydrolysis, used in **symplastic** unloading
- typically in growing roots and shoots, potato tubers





5. Other Storage/Transport Sugars

- plants make other interesting and unique types of sugars

i. Raffinose-type oligosaccharides

Structure: sucrose + one or more 1,6 linked galactose units
E.g.: raffinose Gal-(1a ->6)-Glc-(1a->2ß)-Fru
stachyose: Gal-(1a ->6)-Gal-(1a ->6)-Glc-(1a->2ß)-Fru

<u>Synthesis</u>: Requires a *<u>UDP-glucose epimerase</u>)*
[<u>Epimer</u>: isomer differing at one asymmetric center]

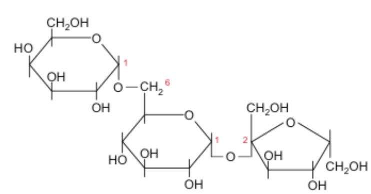
- common in lime, olive and other trees (<u>transport</u> function)
- important for phloem transport via "<u>polymer trapping</u>"
- in peas, beans (<u>storage</u> function, and can act as a <u>cold protectant</u>)
- difficult to digest when in the diet

*ii. Fructans (*soluble, ß-linked polyfructose sugars, DPM >200)

6-kestose type (**levan**-type) (6->ß2) linkage
1-kestose type (**inulin**-type) (1->ß2) linkage

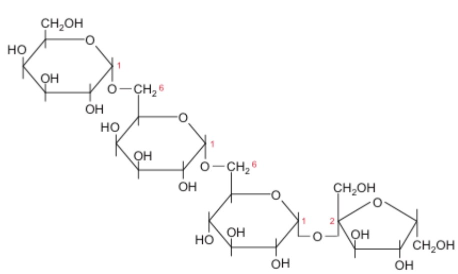
- energy storage in many bulbs (dahlias, onion, some lilies)
- additional storage in stem and leaves of grasses
- vacuolar, synthesized from sucrose
- advantages of accumulating fructans for plant: frost hardiness
- in the human diet: promote probiotic bacteria (chicory, artichoke, leek, onion)
- for First Nations **Camas Lily** was a major carbohydrate (rich in fructans)

Raffinose



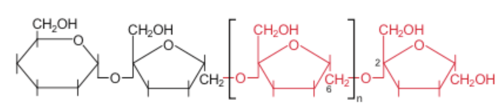
Gal-(1α→6)-Glc-(1α→2β)-Fru

Stachyose



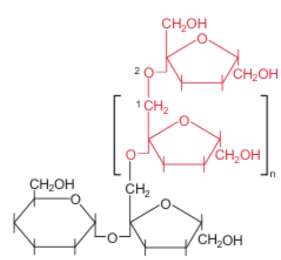
Gal-(1α→6)-Gal-(1α→6)-Glc-(1α→2β)-Fru

6-Kestose type



Sucrose Fru-(6→2β)-Fru

1-Kestose type



Fru-(1→2β)-Fru