Metabolismo Energético

2018/19

T4 a T6

Sumário

Metabolismo Energético Fotossintético

3. Síntese do amido no cloroplasto, a partir das trioses-fosfato (TP) do Ciclo de Calvin.

Partição da síntese do amido no cloroplasto e de sacarose no citosol

Degradação do amido no cloroplasto e síntese de sacarose.

Transporte para o vacúolo e transporte intercelular de açúcares solúveis.

Na aula passada vimos que…

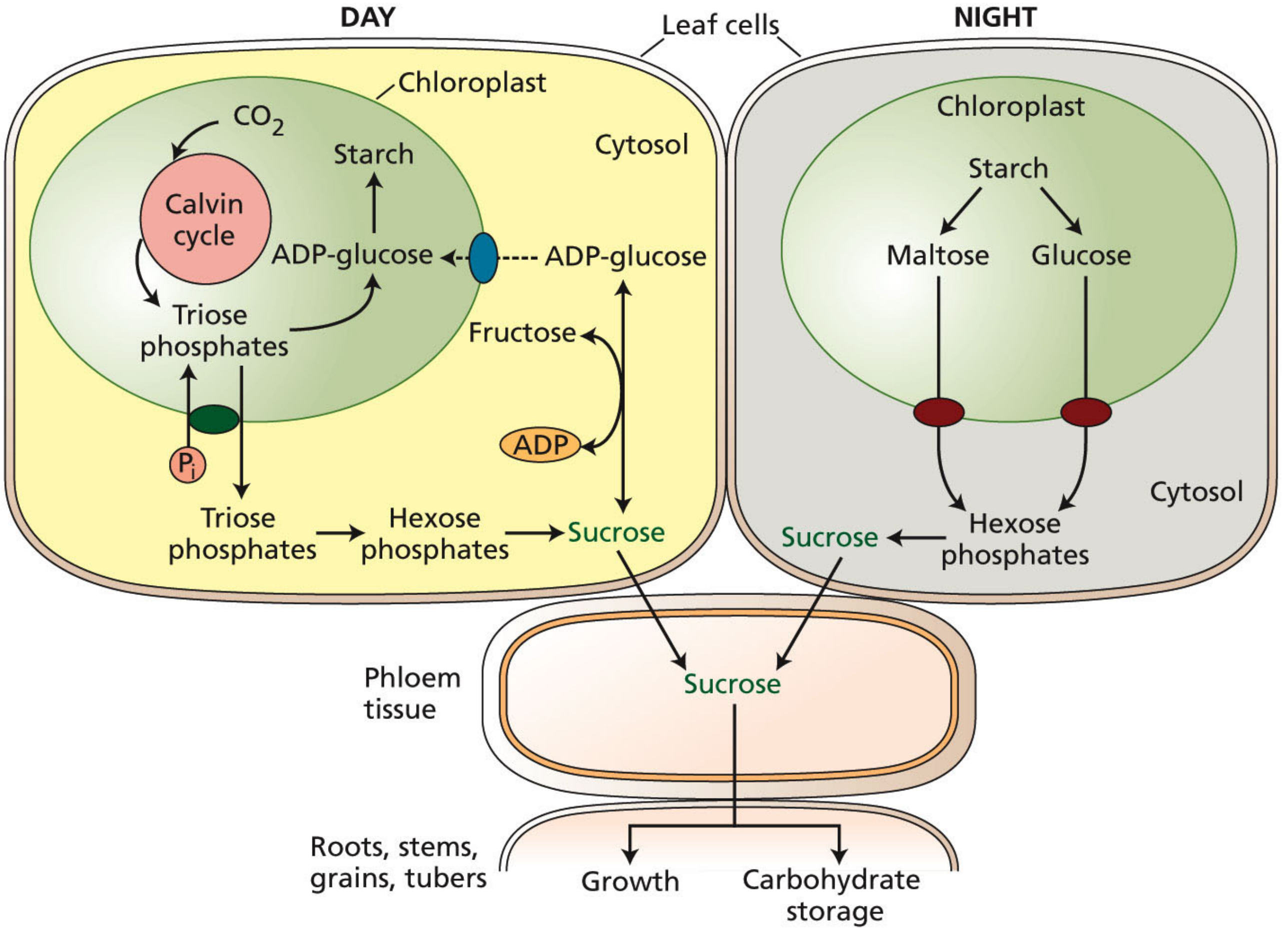
A síntese de sacarose a partir do pool de hexoses-P é regulada pela actividade da SPS

A actividade da SPS é regulada de modo diferente pela [Pi] e [G6P] dependendo do estado de fosforilação/desfosforilação do enzima

A luz regula o nível de fosforilação da SPS

A SPP também regula a síntese de sacarose

Mobilização de carbono em plantas



PLANT PHYSIOLOGY, Fourth Edition, **Figure 8.15** © 2006 Sinauer Associates, Inc.

Proporção amido/sacarose na folha:

- pode ser aprox. constante durante o dia (*e. g.* arabidopsis, soja, beterraba sacarina)
- aumentar quando a sacarose acumulada excede a capacidade de armazenamento da folha ou a necessidade de outros tecidos não fotossintéticos (*e. g.* espinafres)

Constituição do amido, um homopolímero de glucose

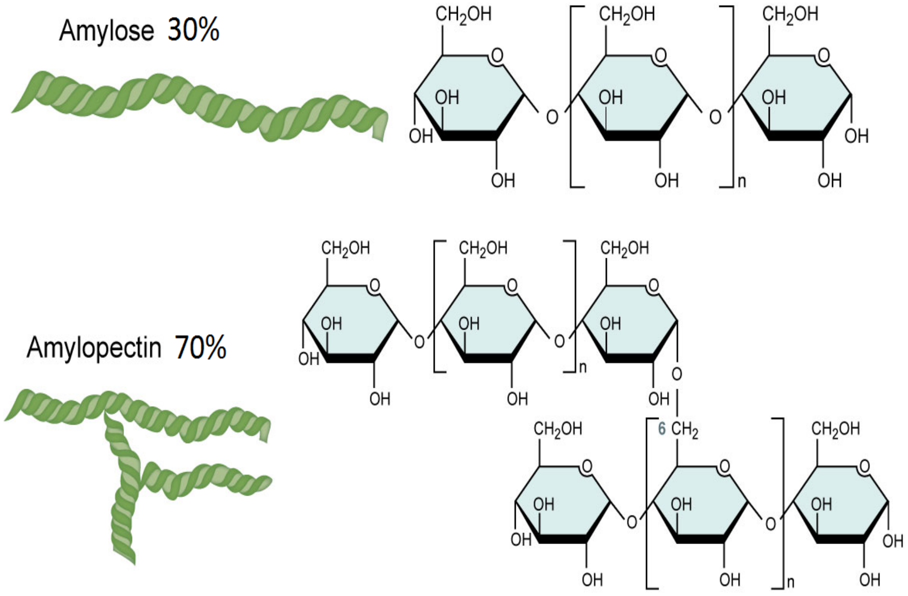
Amido

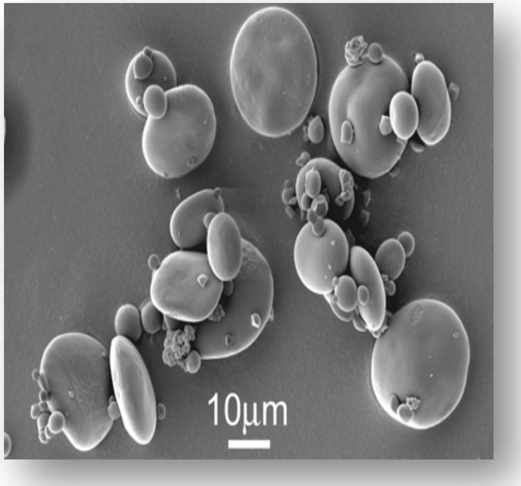
glucose

Amilose → 0,5-20 x 10^3 unidades

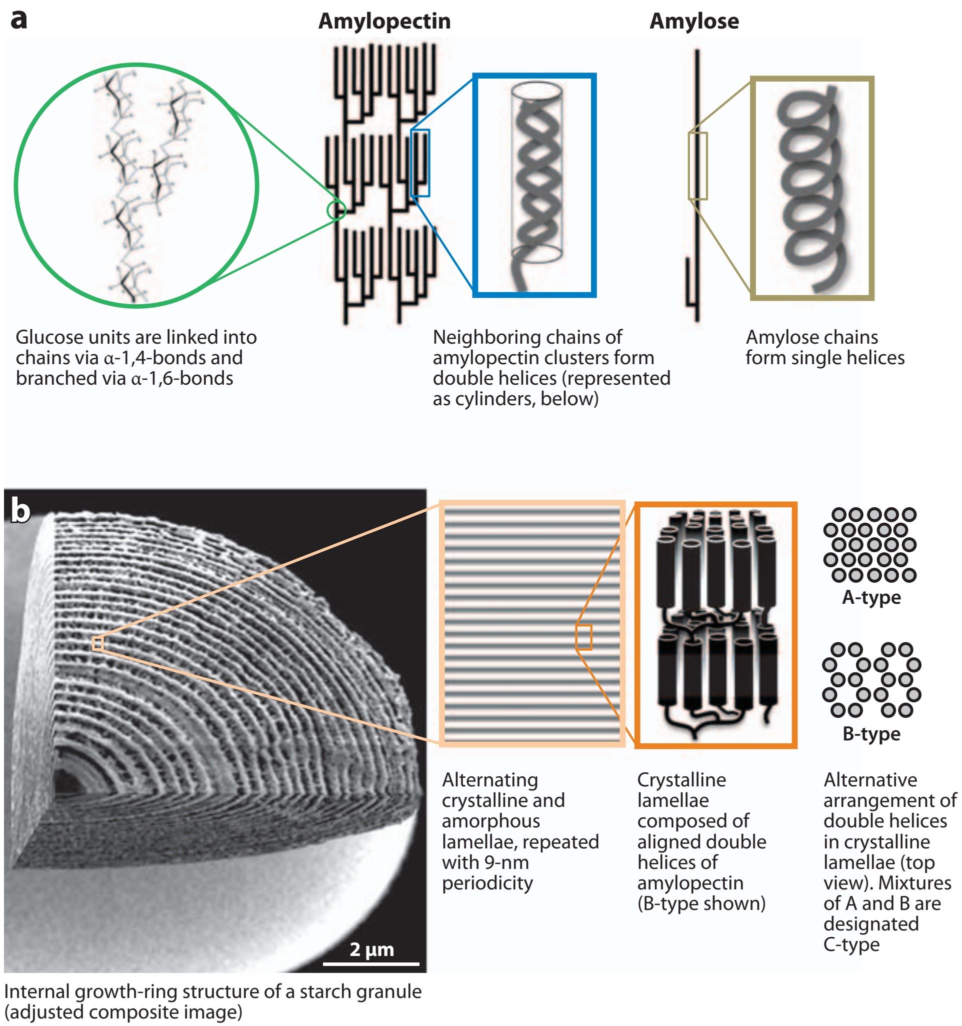
glucose

Amilopectina → *ca*. 10^6 unidades





Nas plantas, a estrutura, tamanho e proporção relativa de amilose e amilopectina variam



Glucose units are linked into chains via α-1,4-bonds and branched via α-1,6-bonds

Neighboring chains of amylopectin clusters form double helices (represented as cylinders, below)

Amylose chains form single helices

Internal growth-ring structure of a starch granule (adjusted composite image)

Alternating crystalline and amorphous lamellae, repeated with 9-nm periodicity

Crystalline lamellae composed of aligned double helices of amylopectin (B-type shown)

Alternative arrangement of double helices in crystalline lamellae (top view). Mixtures of A and B are designated C-type

The composition and structure of starch granules. (*a*) A schematic representation of amylose and amylopectin, and the structures adopted by the constituent chains. (*b*) The relationship between the starch granule (composite image of potato granules, *left*) and amylopectin structure. Crystalline and amorphous lamellae arrange to form blocklets (*not shown; see text*) that make up the growth rings.

Estrutura da amilose -> hélice simples

Estrutura da amilopectina -> hélice dupla

Estrutura cristalina da amilopectina:

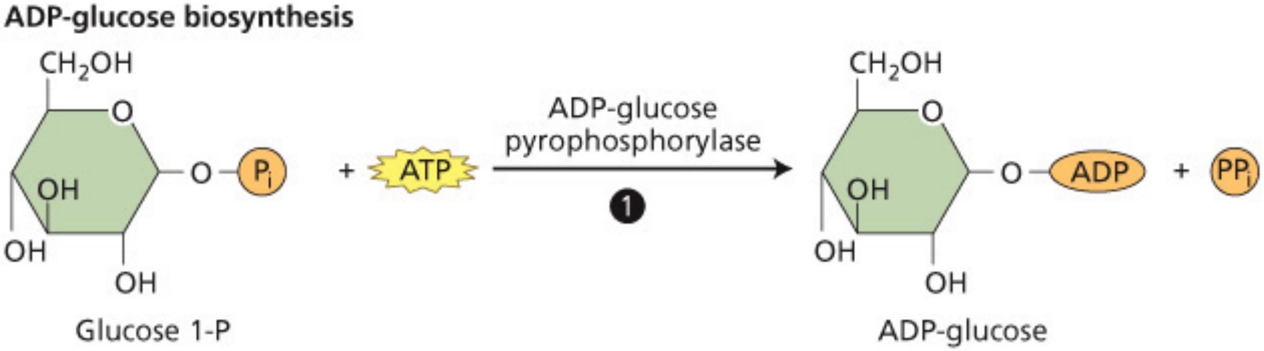
Tipo A

Tipo B

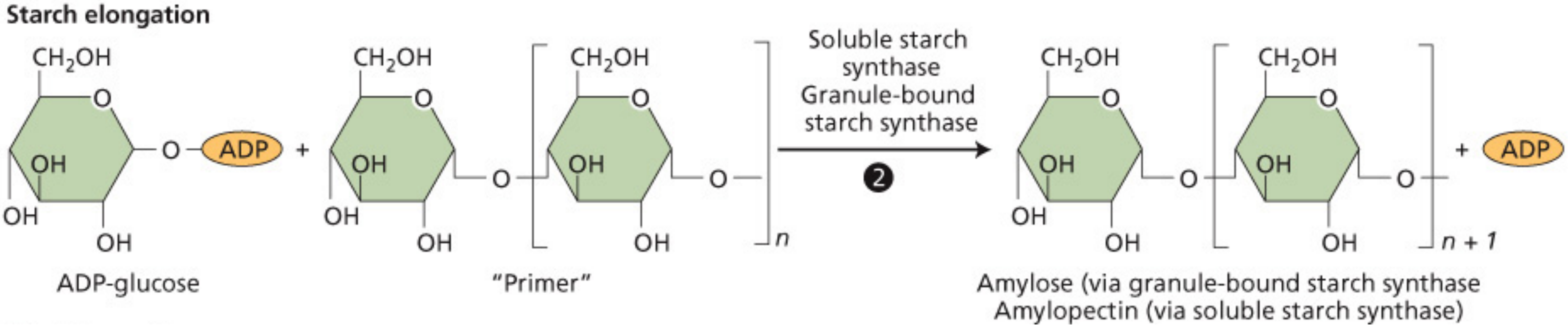
Tipo C = A+B

Annu. Rev. Plant Biol. 2010.61:209-234.

Síntese de amido: biossíntese de ADP-glucose; formação de "primer"; alongamento da cadeia linear…



ADP-glucose pirofosforilase (1) do cloroplasto catalise a síntese de ADP-glucose a partir de glucose-1-P



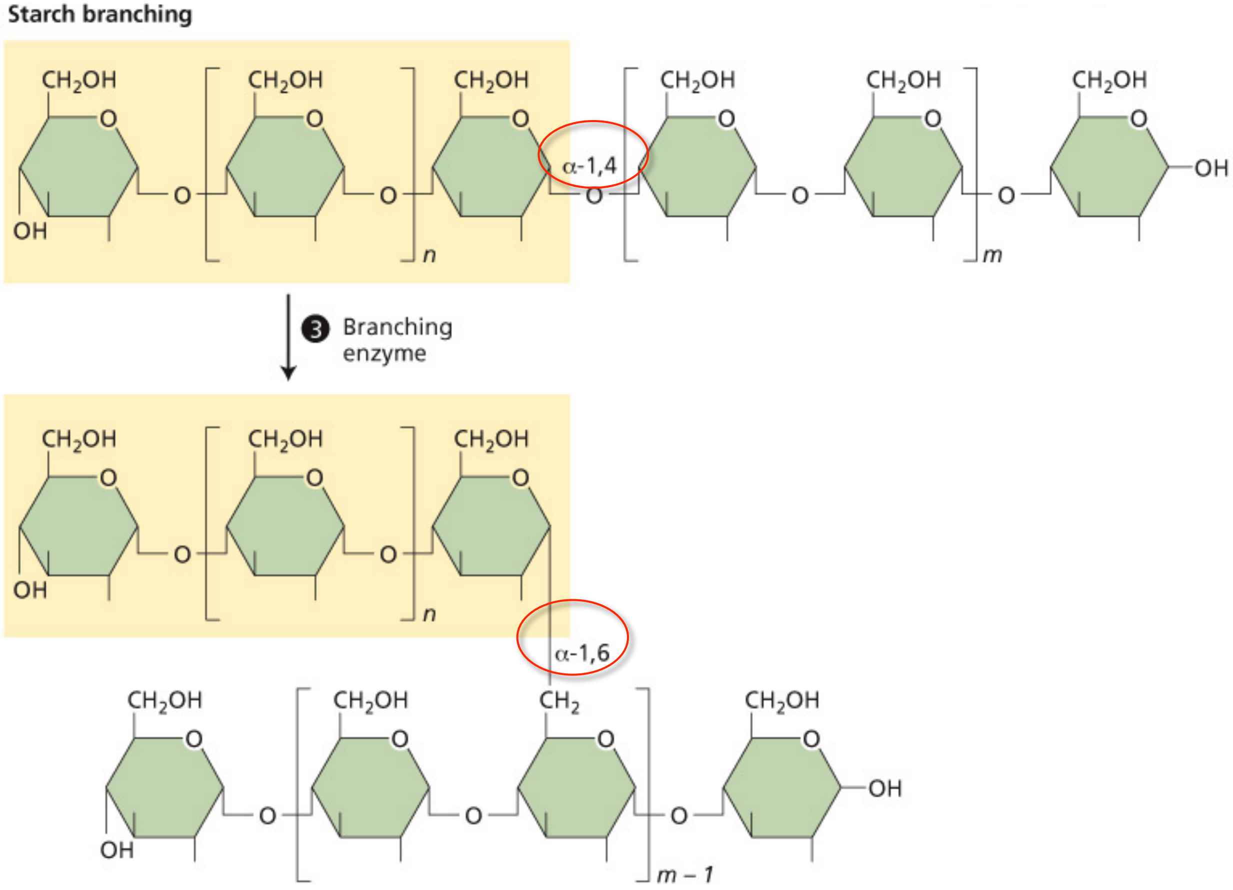
As múltiplas isoformas de **amido sintase (2)** das plantas podem estar:

- associada aos granulos de amido -> síntese de amilose
- em solução -> síntese de amilopectina

A partição destes dois tipos de isoformas variam entre tecidos, espécies e estadios de desenvolvimento

Síntese de amido (cont.)

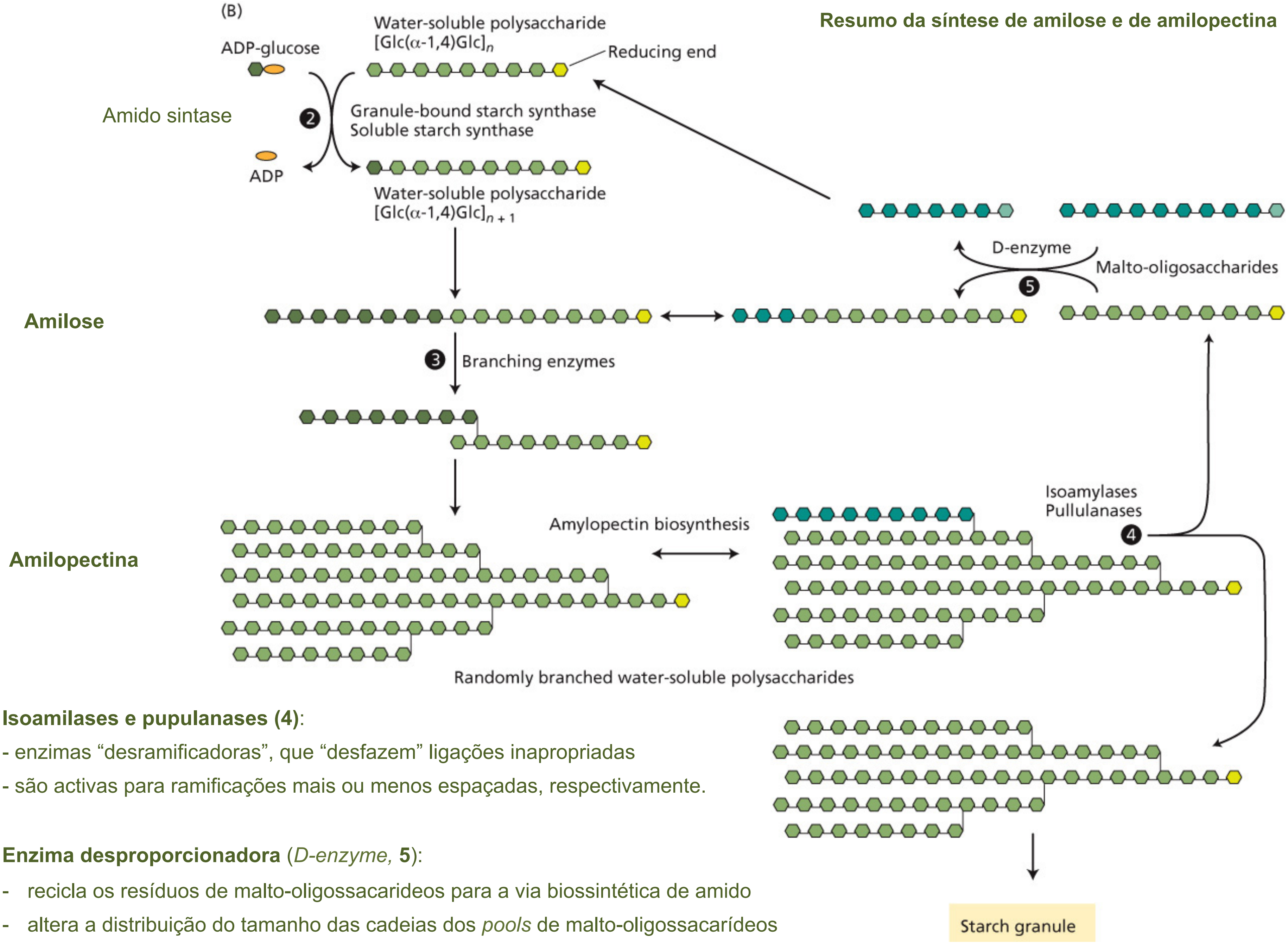
… ramificação



Formação de amilopectina **enzimas ramificadoras do amido (3)**

Existem várias isoformas, que diferem no tamanho da cadeia de glucano transferida e na sua localização

Resumo da síntese de amilose e de amilopectina



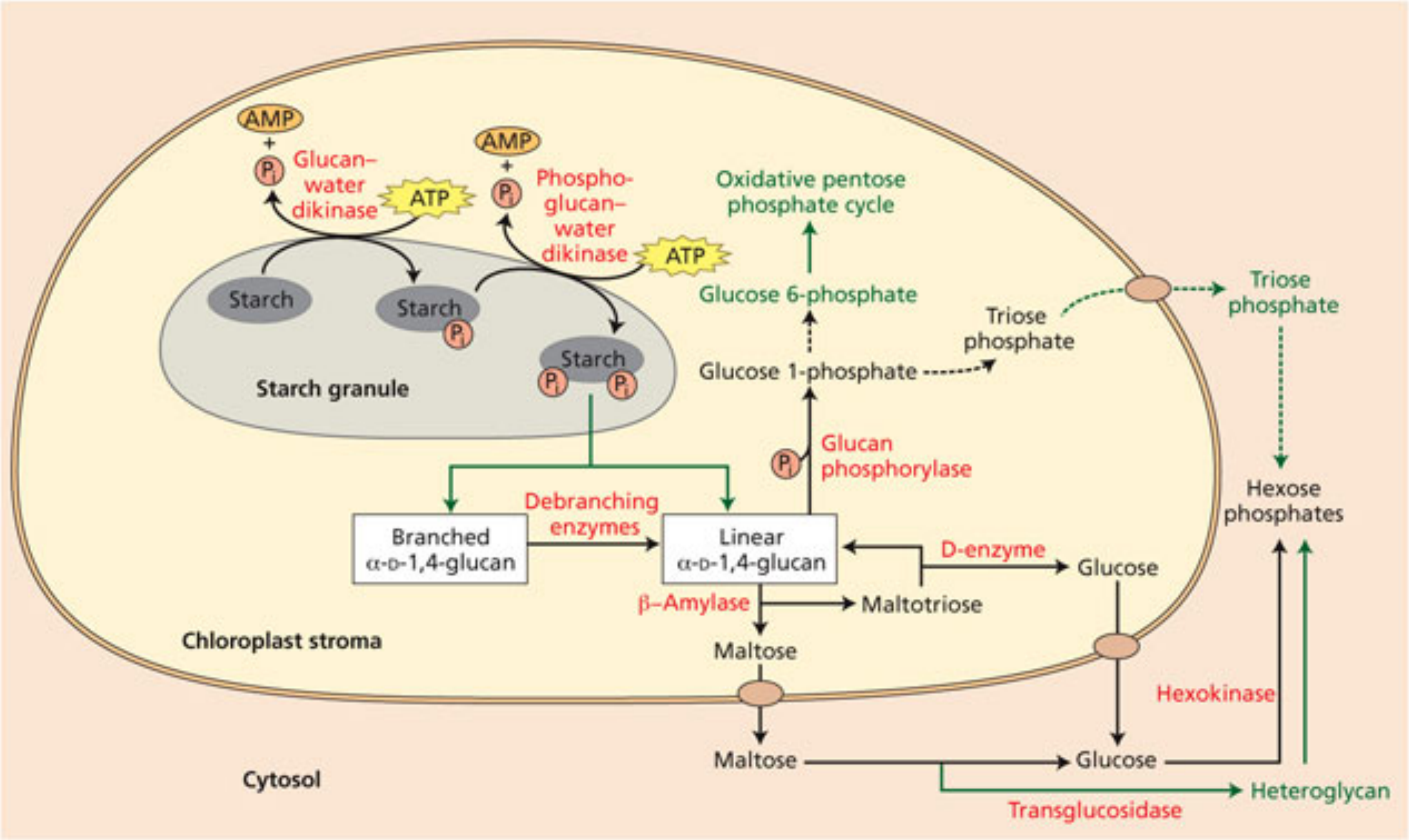
Isoamilases e pupulanases (4):

- enzimas "desramificadoras", que "desfazem" ligações inapropriadas
- são activas para ramificações mais ou menos espaçadas, respectivamente.

Enzima desproporcionadora (*D-enzyme,* **5**):

- recicla os resíduos de malto-oligossacarideos para a via biossintética de amido
- altera a distribuição do tamanho das cadeias dos *pools* de malto-oligossacarídeos

Degradação de amido no periodo nocturno ou em stress, em folhas de *A. thaliana*



PLANT PHYSIOLOGY AND DEVELOPMENT 6e, Figure 8.17

Partição dos produtos do ciclo de Calvin

A ("upper phase")

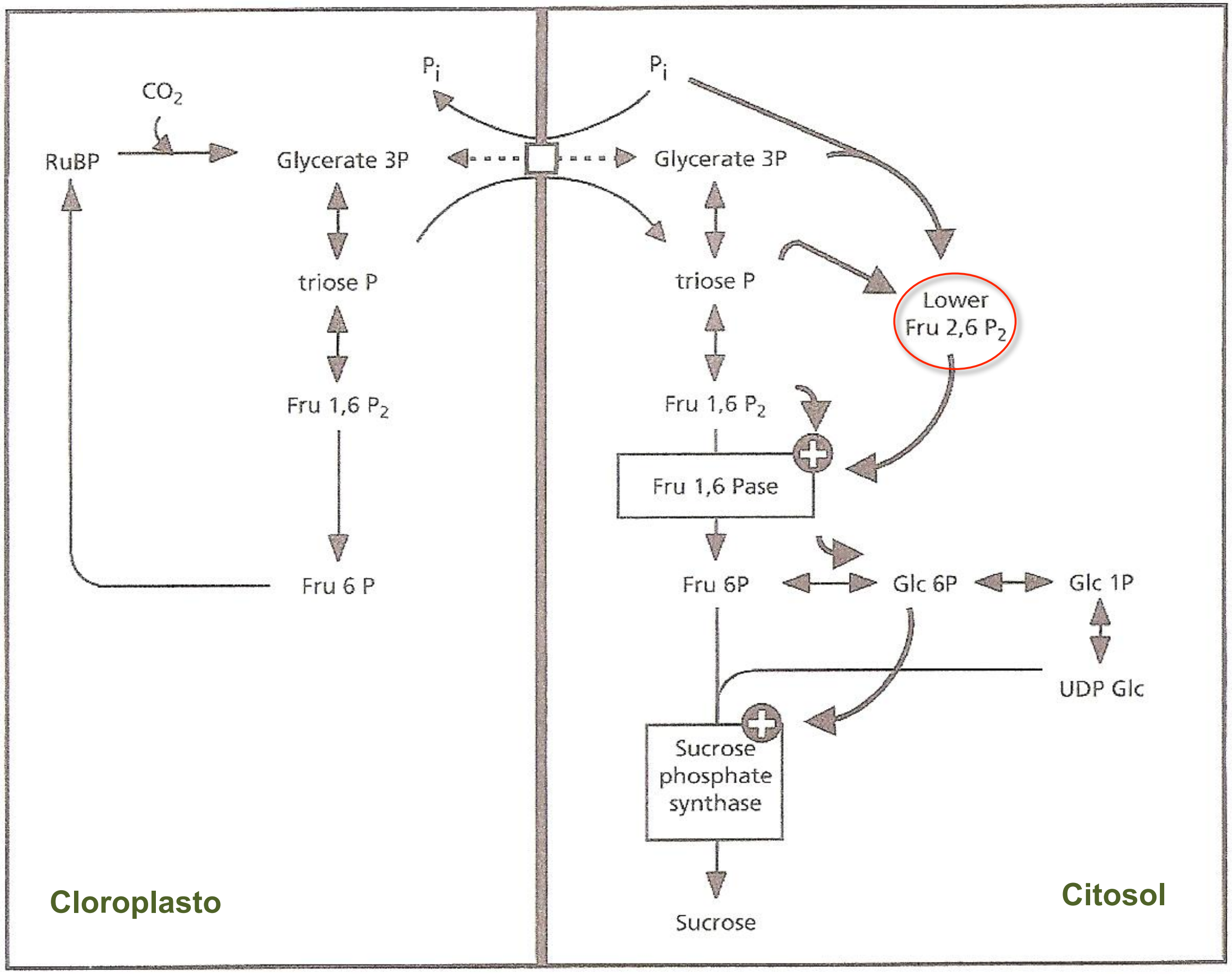


FIGURE 25. The formation of triose-phosphate in the Calvin cycle. Triose-P is exported to the cytosol, in exchange for P_i (upper part), or used as a substrate for the synthesis of starch in the chloroplast (lower graph), when export of triose phosphate stagnates. Fructose 2,6 bis phosphate is a regulatory molecule, and not an intermediate of glycolysis. The − and + signs refer to inhibition and stimulation of enzyme activities, respectively (after Stitt 1997).

Cont.

B ("lower phase")

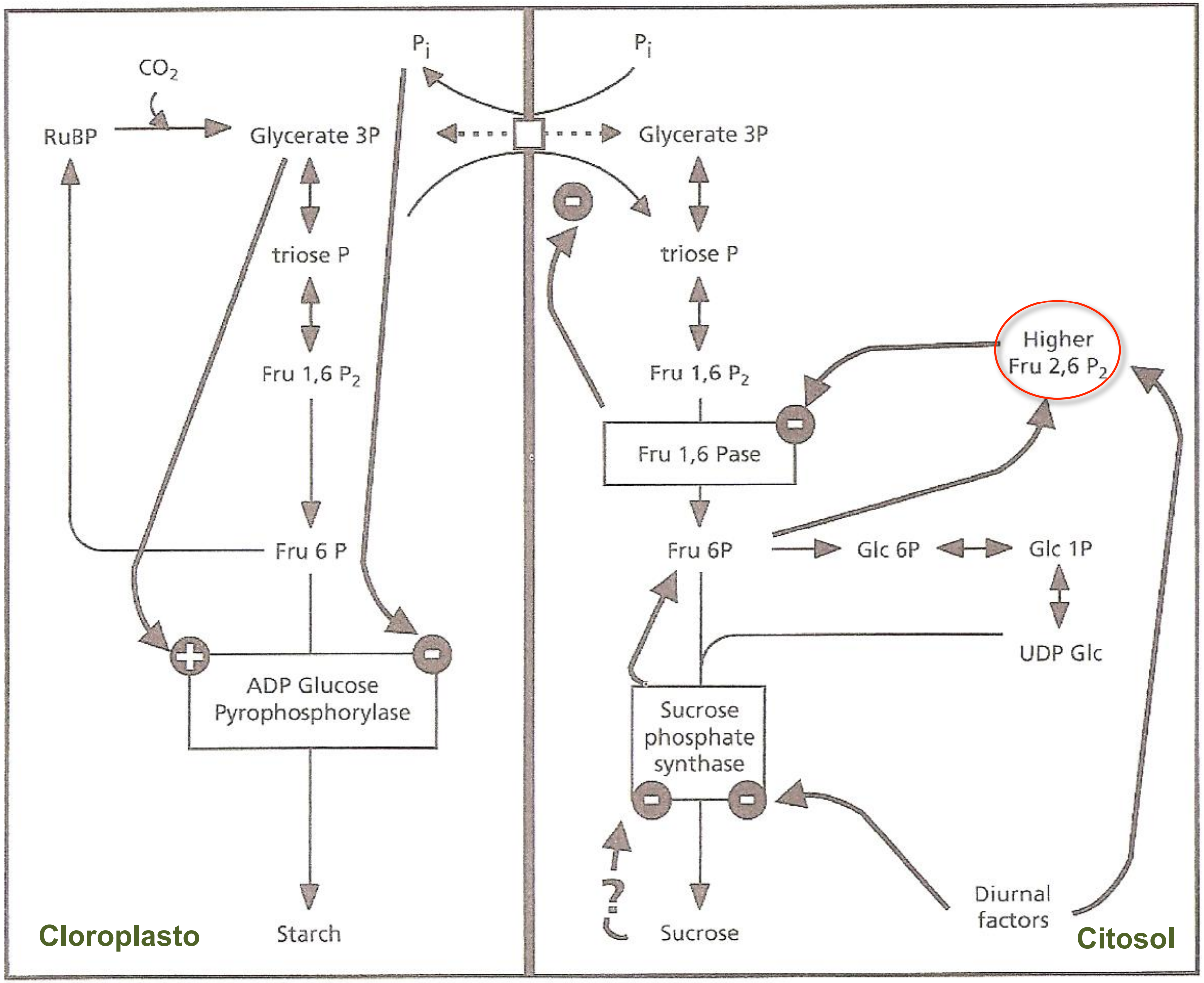


FIGURE 25. The formation of triose-phosphate in the Calvin cycle. Triose-P is exported to the cytosol, in exchange for P_i (upper part), or used as a substrate for the synthesis of starch in the chloroplast (lower graph), when export of triose phosphate stagnates. Fructose 2,6 bis phosphate is a regulatory molecule, and not an intermediate of glycolysis. The − and + signs refer to inhibition and stimulation of enzyme activities, respectively (after Stitt 1997).

Sugestões de leitura

Starch: Its Metabolism, Evolution, and Biotechnological Modification in Plants

Samuel C. Zeeman,[1] Jens Kossmann,[2] and Alison M. Smith[3]

Annu. Rev. Plant Biol. 2010. 61:209–34

Opinion

Cell PRESS

The relocation of starch metabolism to chloroplasts: when, why and how

Philippe Deschamps[1], Ilka Haferkamp[2], Christophe d'Hulst[1], H. Ekkehard Neuhaus[2] and Steven G. Ball[1]

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SYNOPSIS

It Takes Two to Tango: A New Partner in Amylose Synthesis

Caitlin Sedwick*

Freelance Science Writer, San Diego, California, United States of America

PLOS | BIOLOGY

PROTEIN TARGETING TO STARCH Is Required for Localising GRANULE-BOUND STARCH SYNTHASE to Starch Granules and for Normal Amylose Synthesis in Arabidopsis

David Seung, Sebastian Soyk, Mario Coiro, Benjamin A. Maier, Simona Eicke, Samuel C. Zeeman

Published: February 24, 2015 • DOI: 10.1371/journal.pbio.1002080 • Featured in PLOS Collections

Plant, Cell and Environment (2007) **30**, 1126–1149

doi: 10.1111/j.1365-3040.2007.01708.x

Coordination of carbon supply and plant growth

ALISON M. SMITH[1] & MARK STITT[2]

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[2] *Max-Planck-Institute of Molecular Plant Physiology, Am Mühlenberg 1, 14476 Golm, Germany*

Nas aulas passadas vimos que…

Amido e sacarose são os principais produtos da fotossíntese nas plantas

Durante o dia, a maior parte da sacarose formada é exportada e o amido acumula-se nas folhas

Durante a noite, é a partir do amido que se produzem substratos para a respiração e para a síntese de sacarose, permitindo que a sacarose continue a ser exportada

Açúcares solúveis

Fonte de esqueletos de carbono

Armazenamento transiente de energia

Moléculas de transporte

Osmólitos

Sinalizadores

Distribuição dos fotossintetizados

Alocação: regulação da distibuição do carbono fixado em várias vias metabólicas

Partição: distribuição diferencial dos fotossintetizados na planta

Como ocorre o transporte de açúcares solúveis nas plantas?

Revendo os mecanismos de transporte em eucariótas…

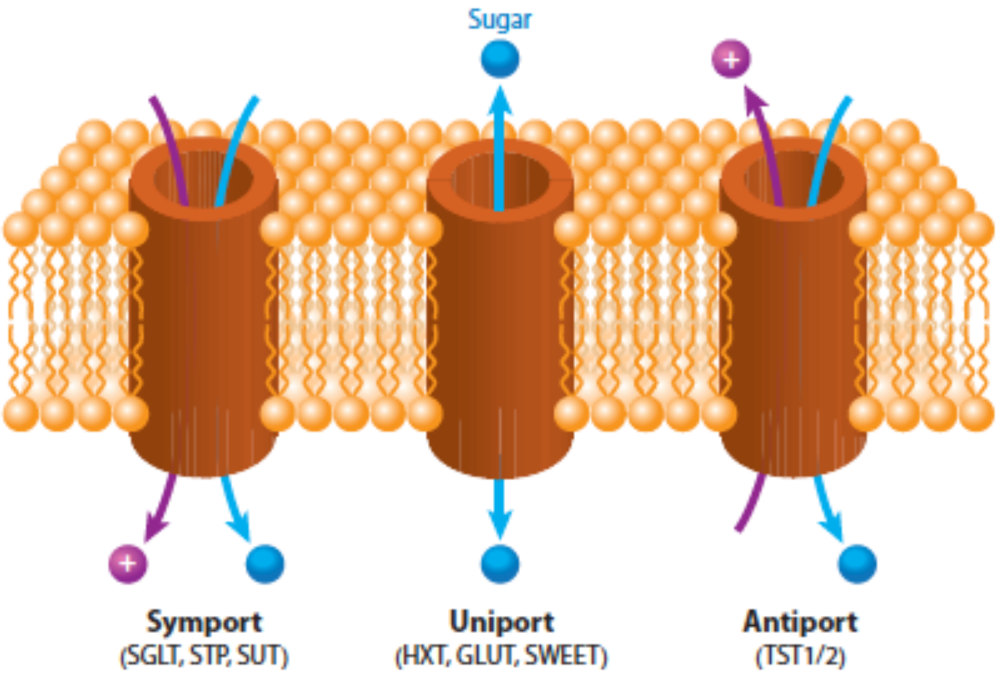

Figure 1

Transport mechanisms in eukaryotes. Cotransporters (76) can be divided into symporters (here a purple cation coupled to transport of a sugar; examples are SGLTs, STPs, and SUTs) and antiporters (shown here is the vacuolar H^{+}/glucose antiporter). Uniporters facilitate sugar transport along the sugar gradient (examples include HXTs, GLUTs, and SWEETs). Abbreviations: GLUT, glucose transporter; HXT, hexose transporter; SGLT, sodium-glucose symporter; STP, sucrose/H^{+} cotransporter; SUT, sugar transporter in plants; TST, tonoplast sugar transporter.

Annu. Rev. Biochem. 2015. 84:865–94

Exemplos de famílias de transportadores de açúcares

Simportes

Transporte depende do potencial de membrana e do pH

SGLTs glucose/Na^{+}, nos humanos

STPs sacarose/H^{+} em plantas

SUTs (*sugar transporters*) hexoses/H^{+} em plantas

Antiportes

TSTs transportadoes de açúcares do tonoplasto

Uniportes

Facilitam o transporte ao longo de um gradiente

Dependem pouco do pH

HXTs transportadores de hexoses, em leveduras

GLUTs transportadores de glucose nos humanos

SWEETs (*hexoses and sucrose transports*),

Bactérias, algas, briófitos, plantas, animais (humanos)

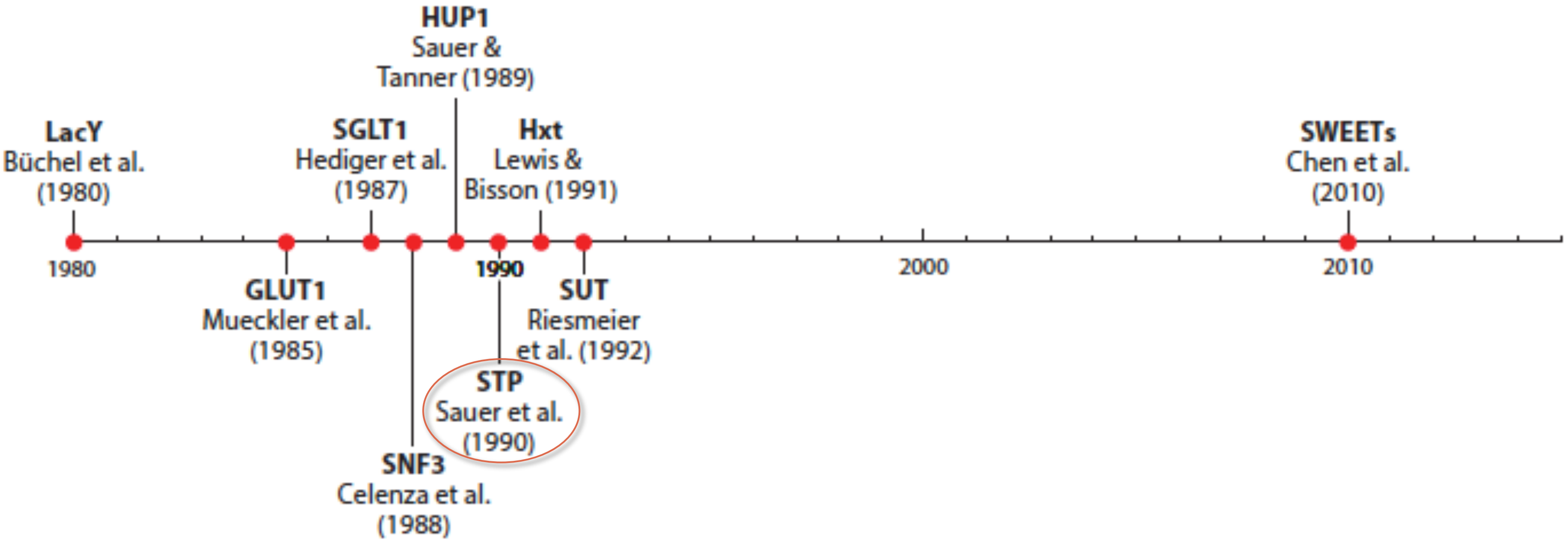

Figure 2

Timeline of the identification of sugar transporters. Details of the transport mechanism classification and associated references are provided in **Supplemental Table 1**. Abbreviations: GLUT, human glucose transporter; HUP, hexose uptake protein of *Chlorella*; Hxt, yeast hexose transporter; SGLT, human sodium-glucose symporter; SNF, sucrose nonfermenting; STP, plant sugar transporter; SUT, plant sucrose/H^+ cotransporter.

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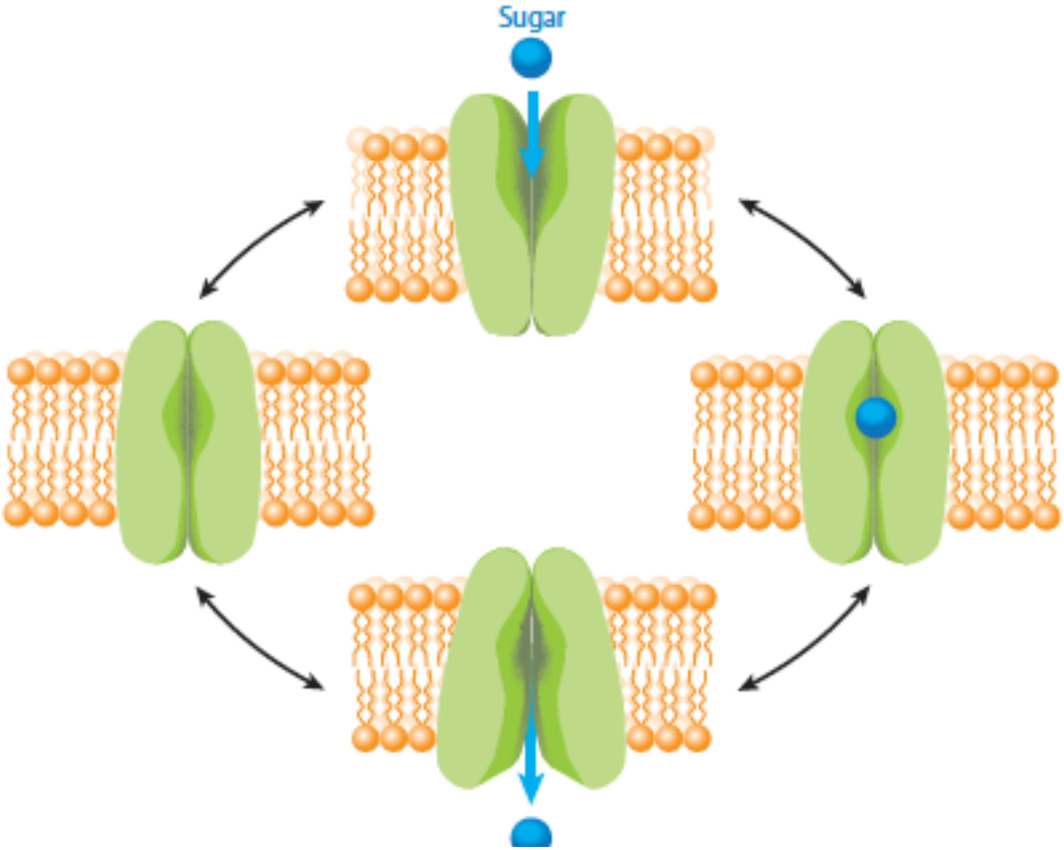


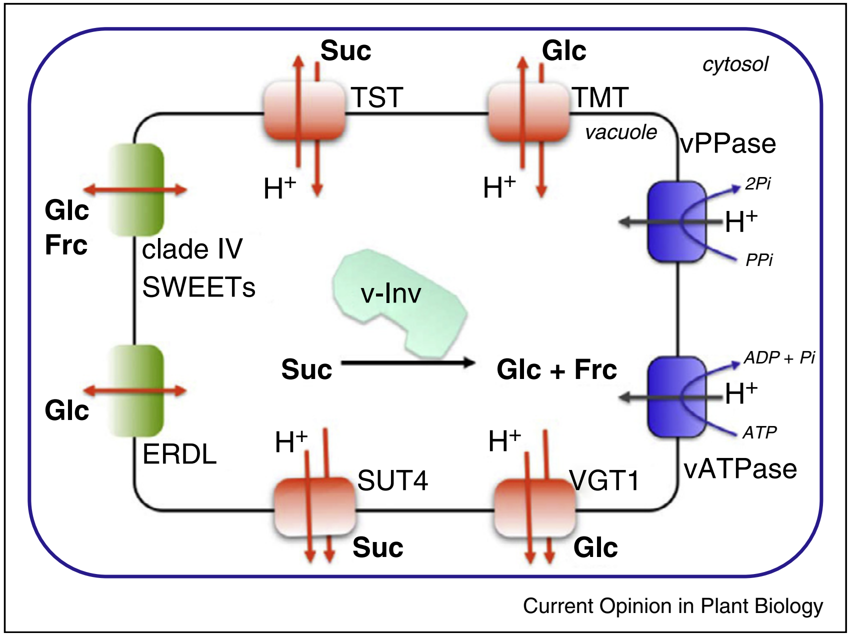
Figure 4

Predicted model of the transport cycle of SWEETs. If SWEETs function as uniporters, a glucose molecule present on the extracellular side of the membrane could bind to the open outward state of the SWEET. In this model, the transporter undergoes a conformational rearrangement, creating an occluded, substrate-bound state that, in turn, triggers a second conversion to an inward open state followed by release of the glucose. The transporter then returns to the outward open state. Alternatively, when the molecule is bound on the inside, the transporter exports the sugar in a series of similar steps.

Annu. Rev. Biochem. 2015. 84:865–94

Transporte de hexoses e sacarose para o vacúolo (simplificado)

"The world's sugar supply comes from the vacuoles of sugarcane stems and sugar beet taproots "



Current Opinion in Plant Biology 2015, **25**:53–62

Transporters for vacuolar uptake and efflux of hexoses and sucrose. Three types of sugar transporters have been identified on the tonoplast: proton symporters (SUT4 for sucrose and VGT1 for hexoses), proton antiporters (TMT for monosaccharides and TST for sucrose) and potential uniporters (ERD-like transporters and SWEETs) for hexoses.

Relembrando as famílias de transportadores …

Simportes

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SGLTs glucose/Na^{+}, nos humanos

STPs sacarose/H^{+} em plantas

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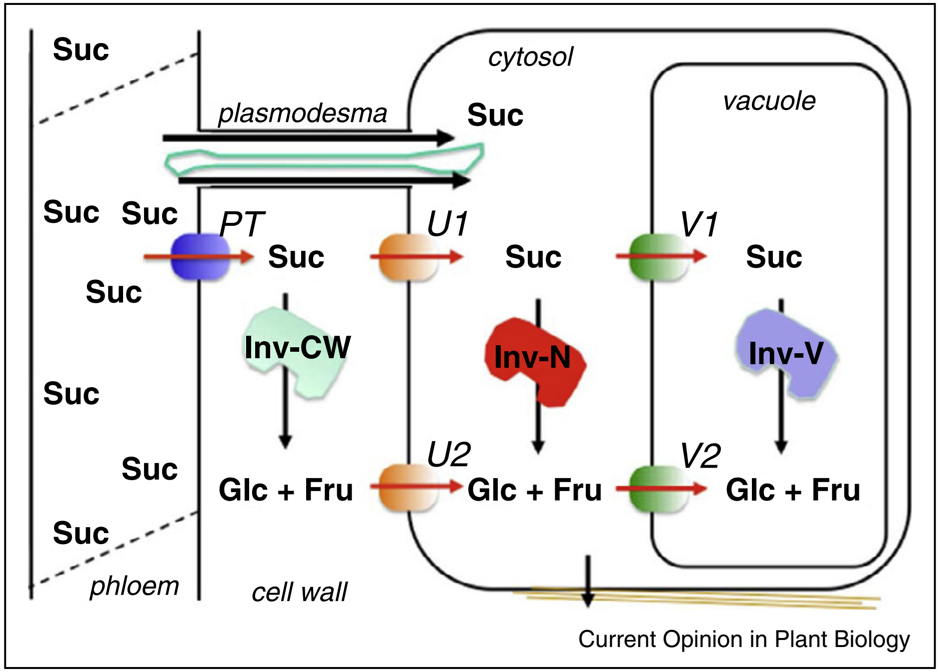
GLUTs transportadores de glucose nos humanos

SWEETs (*hexoses and sucrose transports*),

Bactérias, algas, briófitos, plantas, animais (humanos)

"Despite this massive gain in knowledge, it remains a mystery how this complex suite of transporters is coordinated and how it supports transient accumulation of sugars, and what the key differences are between vacuoles that store low and high levels of sugars"

Modelo geral de transporte de sacarose do floema para vários tecidos (simplificado)



Current Opinion in Plant Biology

Legenda

PT transportador do floema

Inv-CW Invertase extracelular, da parede celular

Inv-N invertase do citosol (neutra)

U1 importador de sacarose

U2 importador de hexoses

V1 transportador de sacarose para o vacúolo

V2 transportador de hexoses para o vacúolo

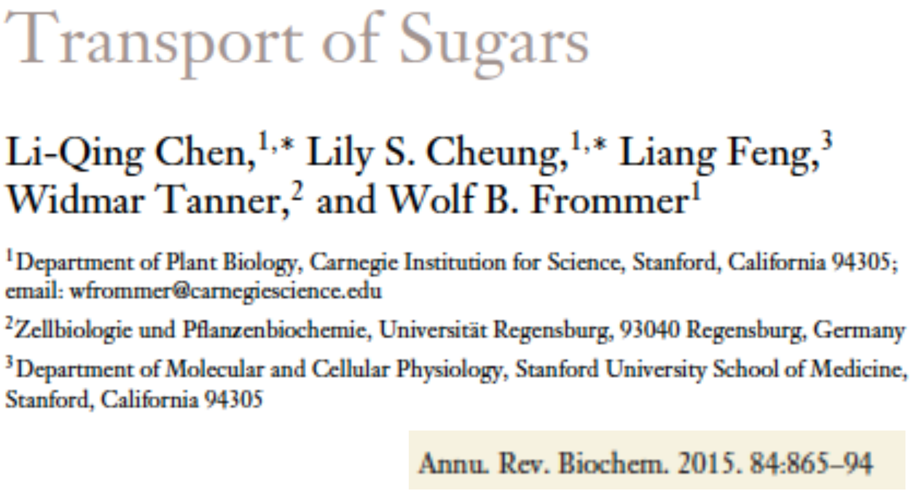
Generic model for principal transport steps and pathways for phloem unloading in various tissues. Sucrose arriving at the phloem endings is either moving symplasmically via plasmodesmata or unloaded (from phloem or after moving symplasmically from post-phloem cells) via a transporter (PT); it can be taken up by sink cells using either a sucrose importer (U1), or by a hexose importer (U2) after cleavage by an extracellular invertase (Inv-CW). Imported sucrose can be catabolized to hexoses by a cytosolic invertase (Inv-N) or sucrose synthetase. Subsequently sucrose or hexoses can be transferred to the vacuole by sucrose or hexose transporters on the tonoplast (V1, V2). The model represents a simplification of the phloem and postphloem unloading pathways.

Current Opinion in Plant Biology 2015, **25**:53–62

SWEETs têm sido implicados em doenças de plantas.
Bactérias patogénicas podem produzir efectores que
directmente induzem os SWEETs nas células infectadas

Homólogos de SWEETs têm sido
encontrados em todos os metazoa ,
incluindo humanos.

Actualmente conhecem-se mais de 50 transportadores de açúcares em plantas



Transport of Sugars

Li-Qing Chen,[1,*] Lily S. Cheung,[1,*] Liang Feng,[3]
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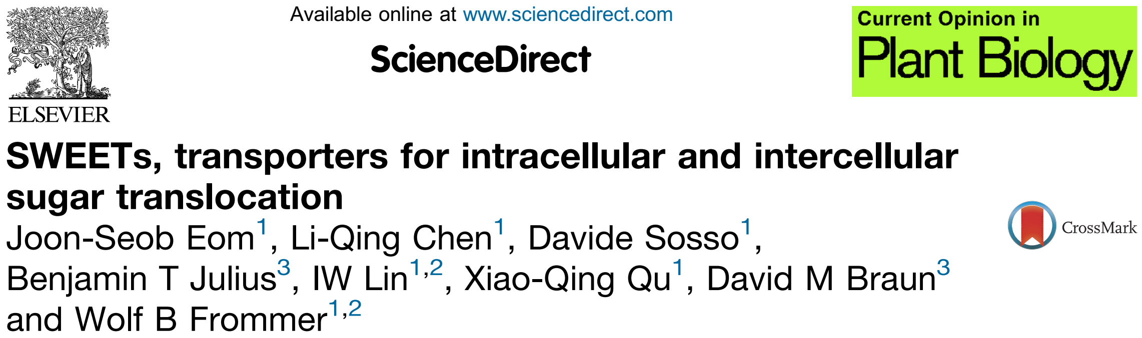

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SWEETs, transporters for intracellular and intercellular sugar translocation

CrossMark

Joon-Seob Eom[1], Li-Qing Chen[1], Davide Sosso[1],
Benjamin T Julius[3], IW Lin[1,2], Xiao-Qing Qu[1], David M Braun[3]
and Wolf B Frommer[1,2]