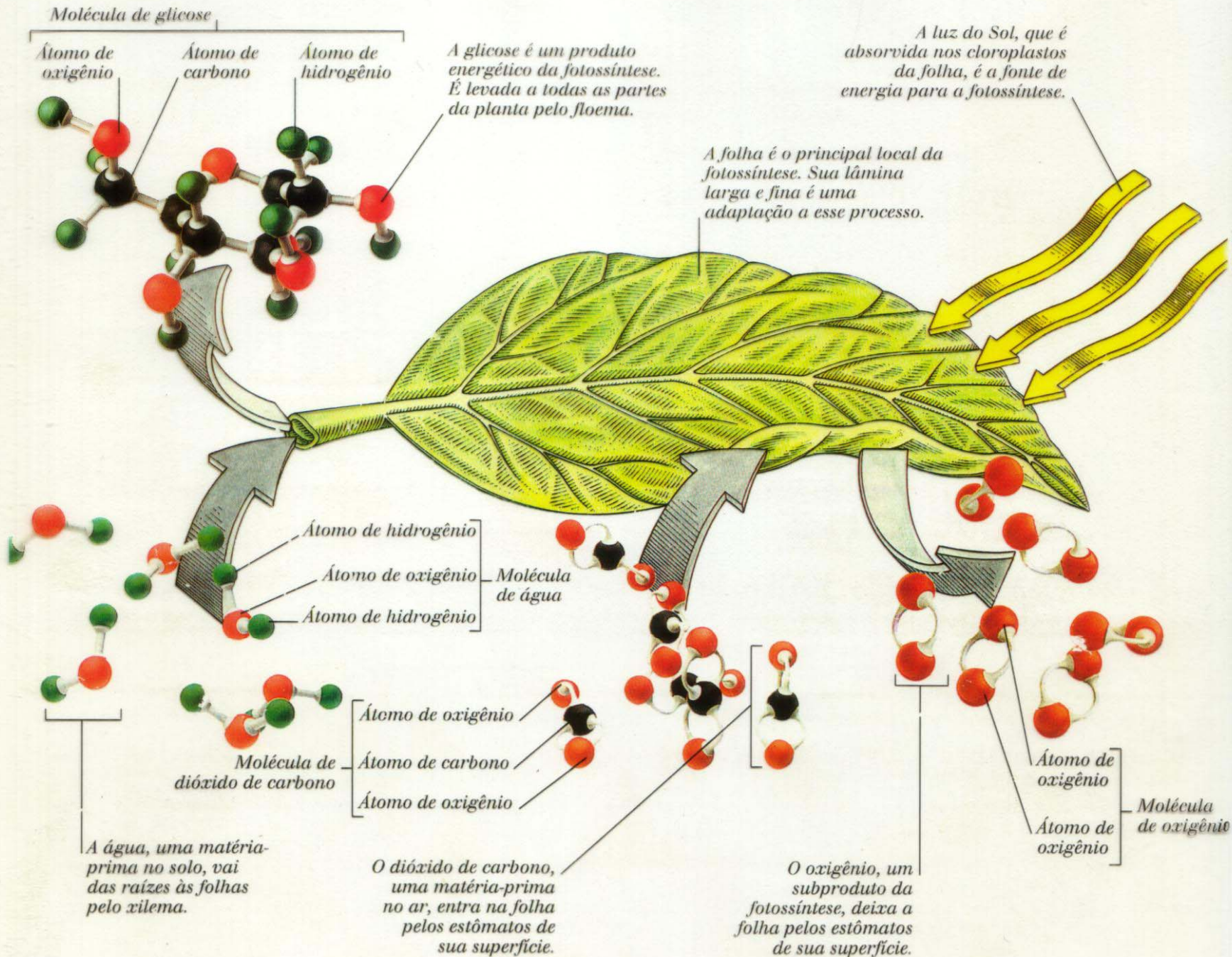




FOTOSSÍNTESE

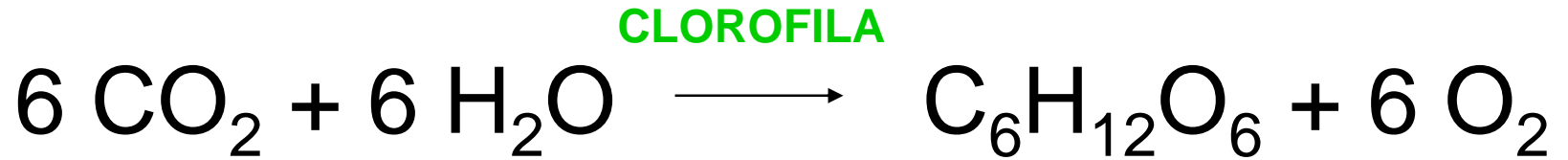
Katia Christina Zuffellato-Ribas

PROCESSO DA FOTOSÍNTESE

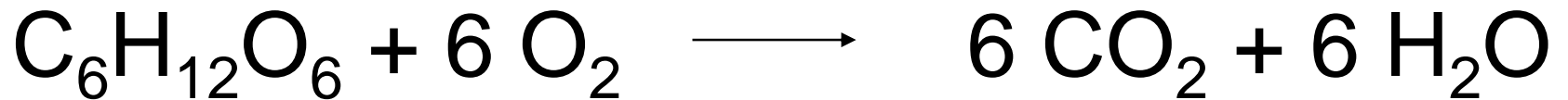


REAÇÃO DA FOTOSÍNTESE

LUZ

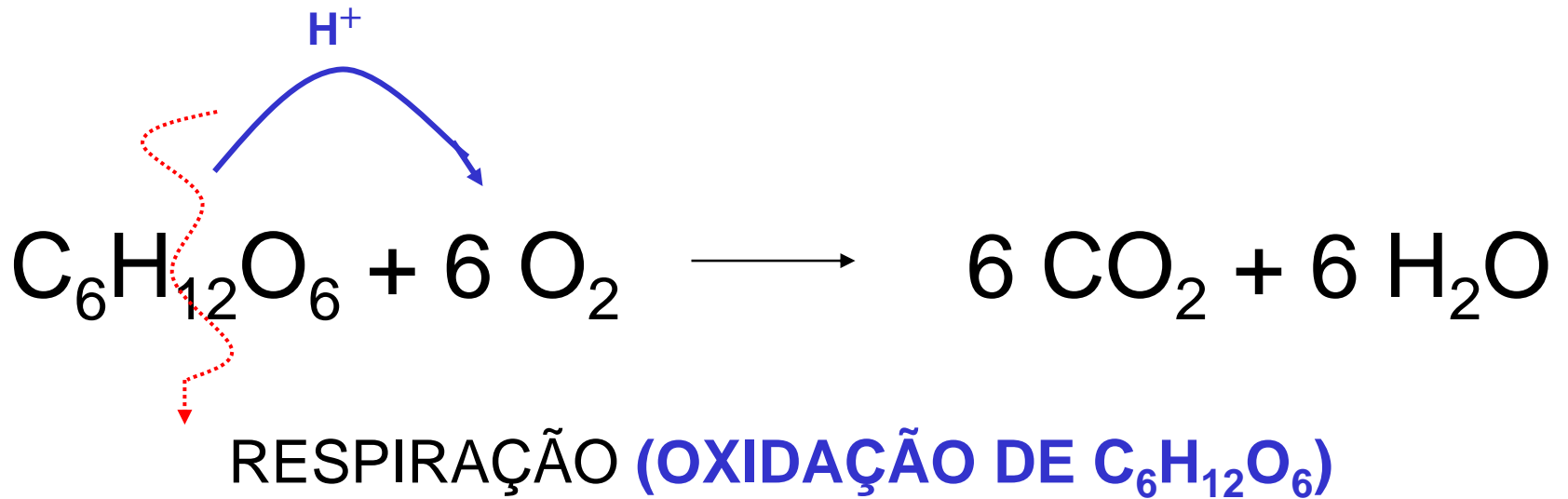
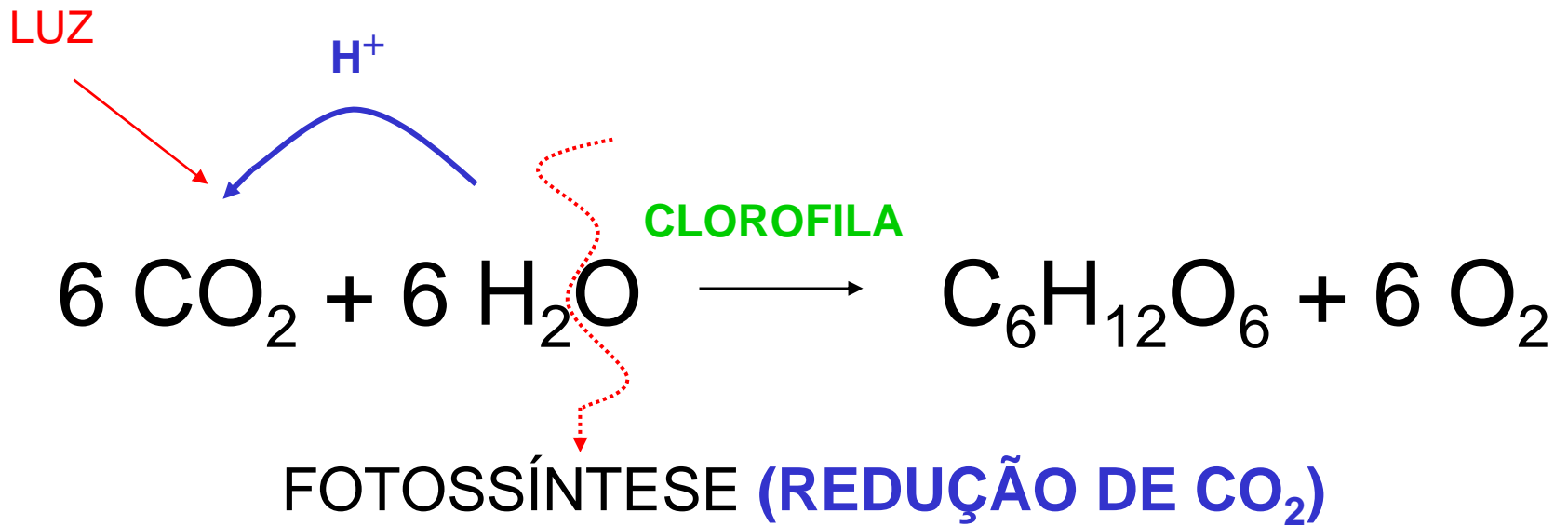


FOTOSÍNTESE (REDUÇÃO DE CO_2)



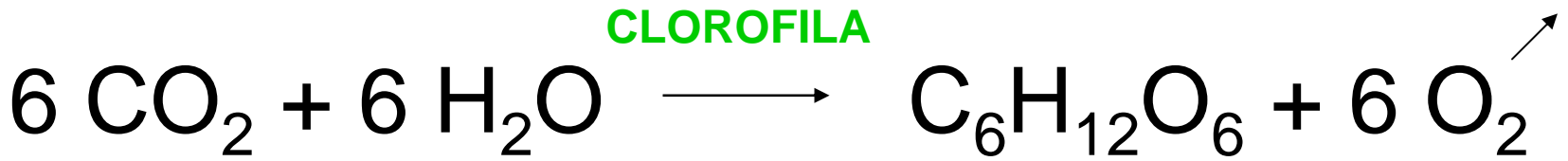
RESPIRAÇÃO (OXIDAÇÃO DE $\text{C}_6\text{H}_{12}\text{O}_6$)

REAÇÃO DA FOTOSÍNTESE

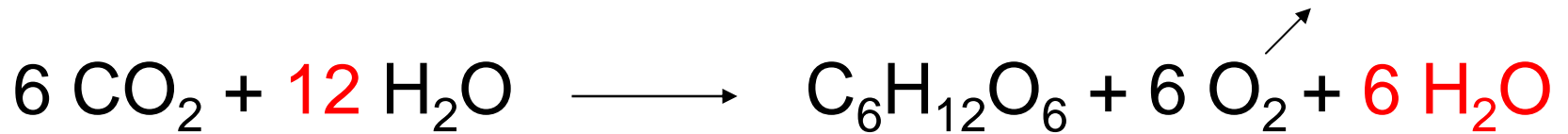


REAÇÃO DA FOTOSSÍNTESE

LUZ



FOTOSSÍNTESE (REDUÇÃO DE CO_2)

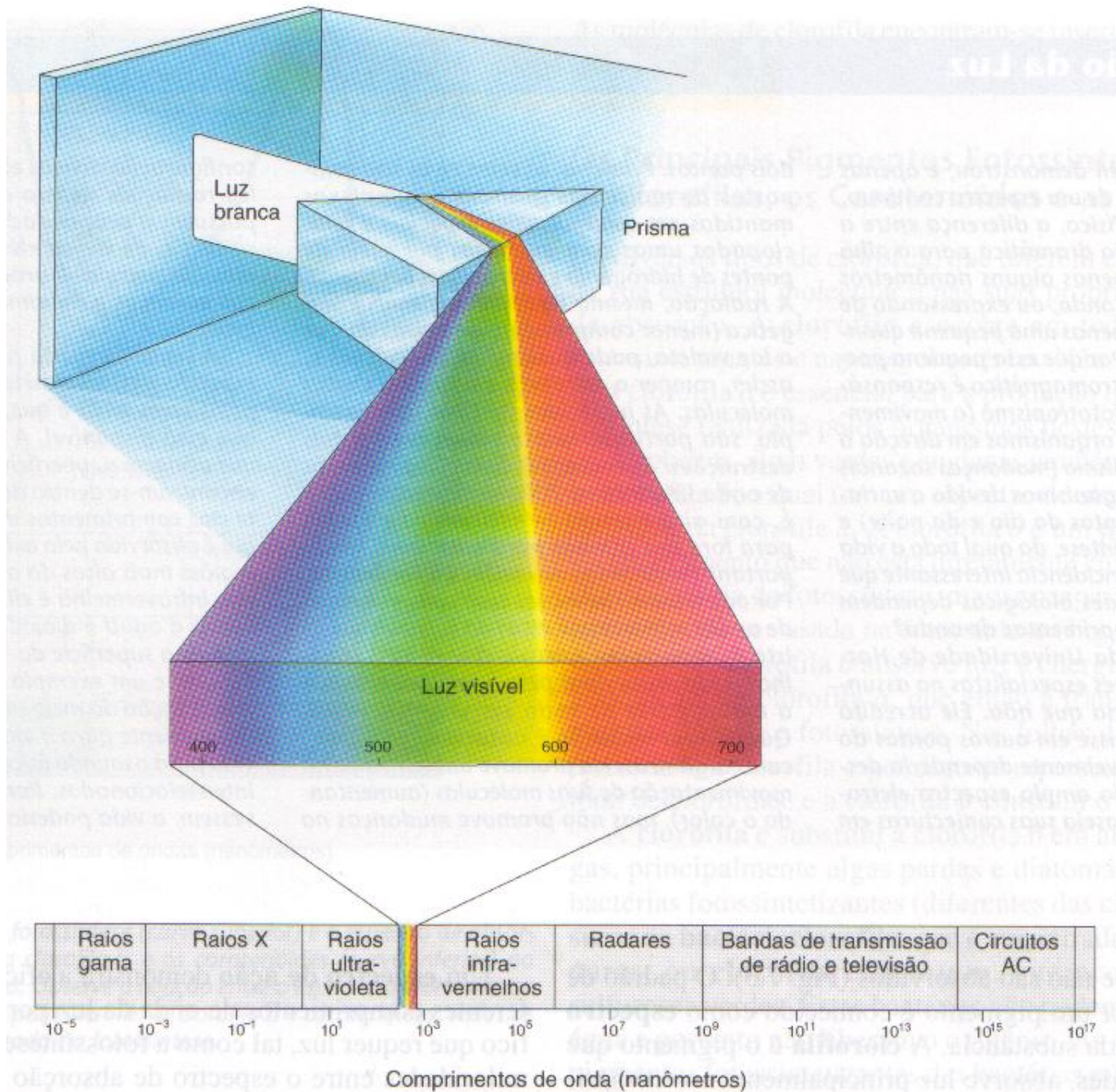


BACTÉRIAS SULFUROSAS VERDES





**PRODUÇÃO DE O_2 DURANTE A FOTOSSÍNTESE EM
FOLHAS DE *Elodea***





Comprimento de onda, λ (nm)

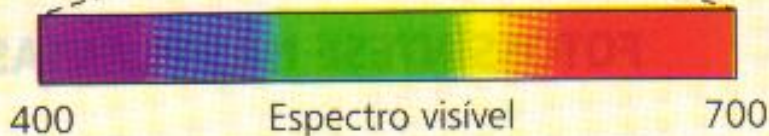
10^{-3} 10^{-1} 10 10^3 10^5 10^7 10^9 10^{11} 10^{13} 10^{15}

Frequência, ν (Hz)

10^{20} 10^{18} 10^{16} 10^{14} 10^{12} 10^{10} 10^8 10^6 10^4 10^2

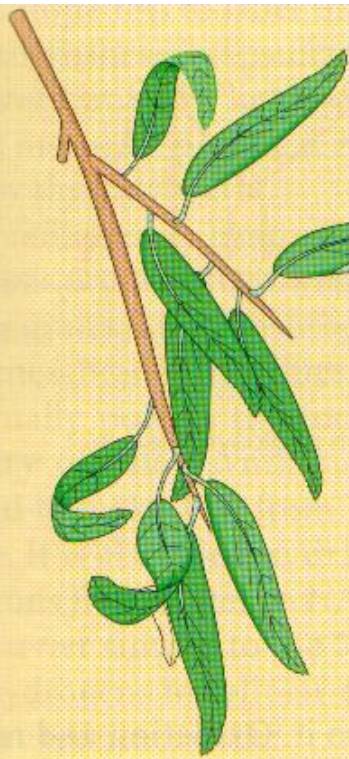
Tipo de radiação

Raios gama Raios X Ultra-violeta Infravermelho Microondas Ondas de rádio

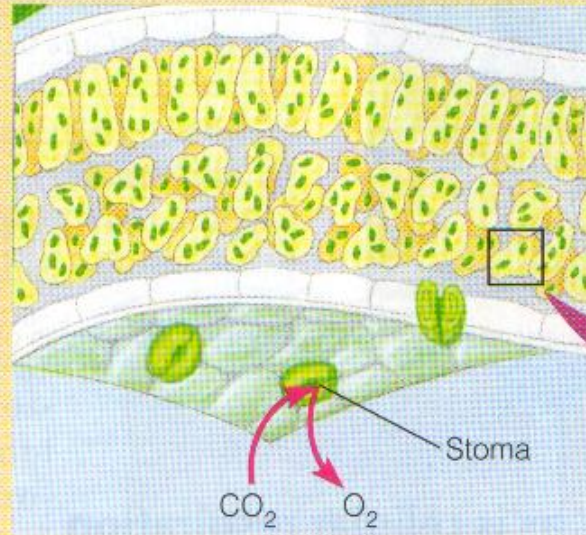


Alta energia ←

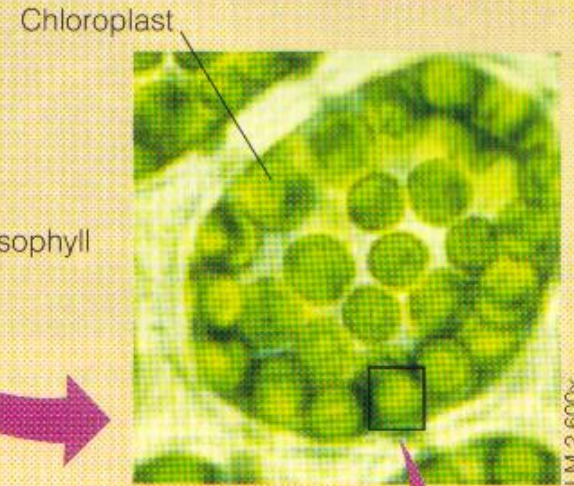
→ Baixa energia



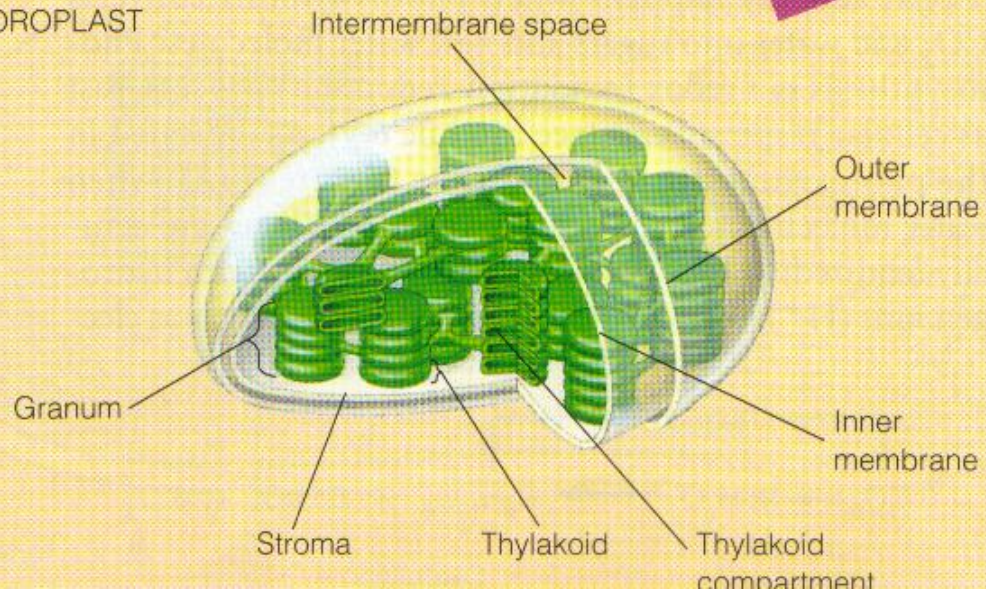
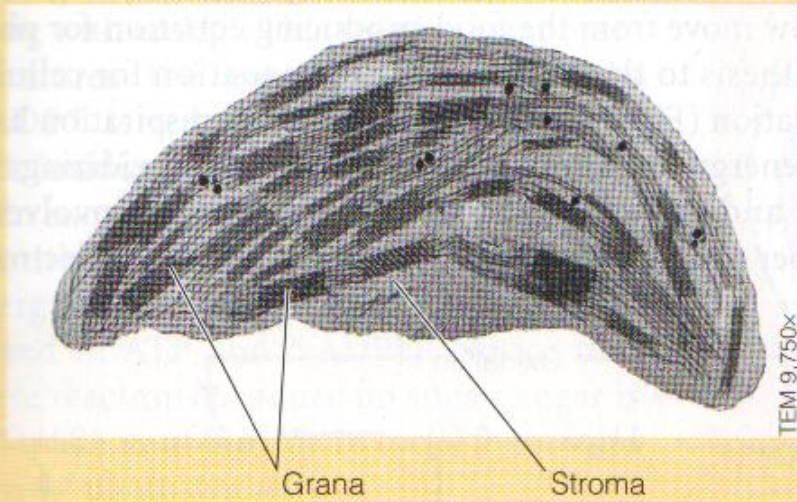
LEAF CROSS SECTION



MESOPHYLL CELL



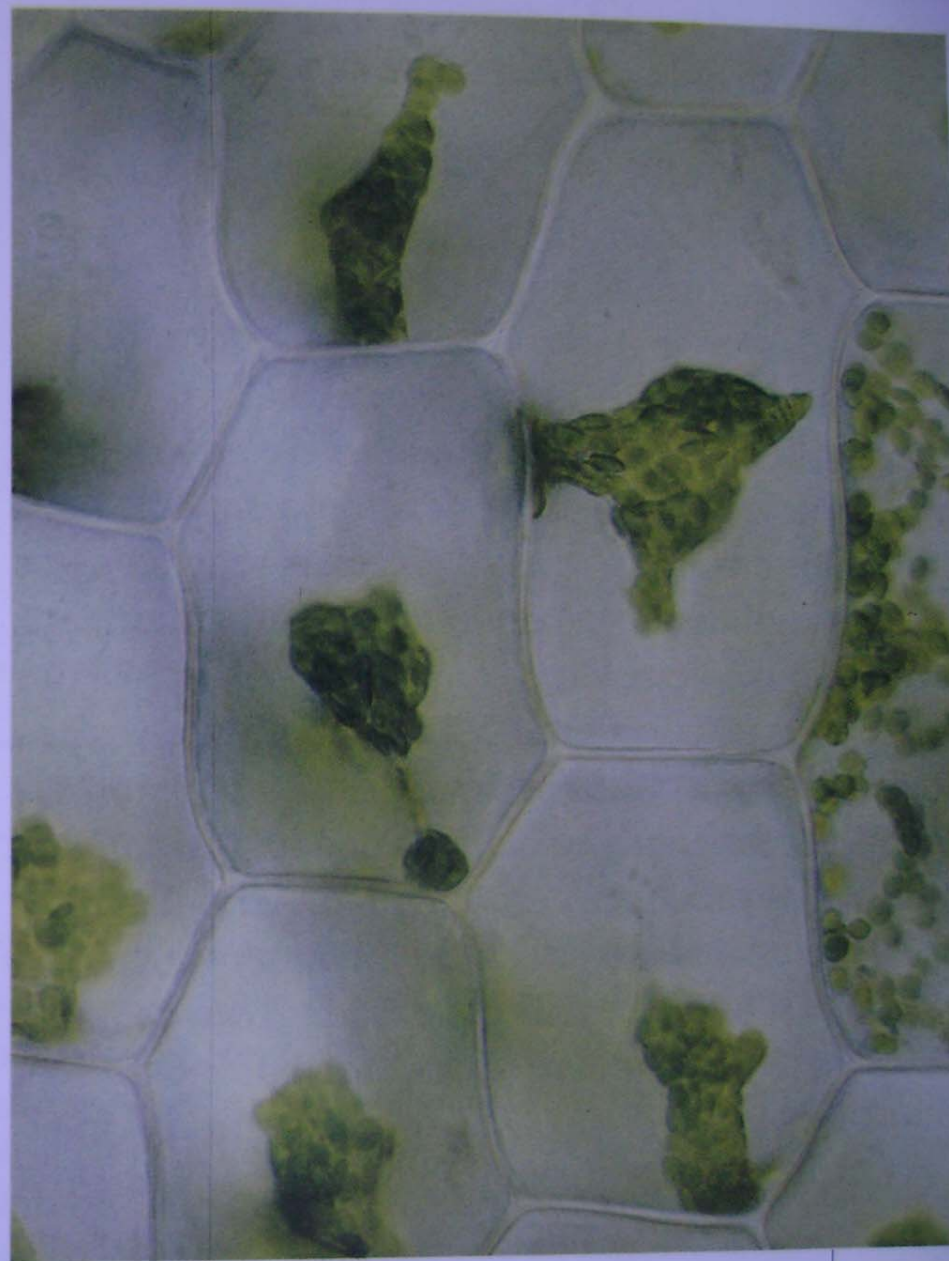
CHLOROPLAST





(a)

CÉLULA TÚRGIDA



(b)

CÉLULA PLASMOLISADA

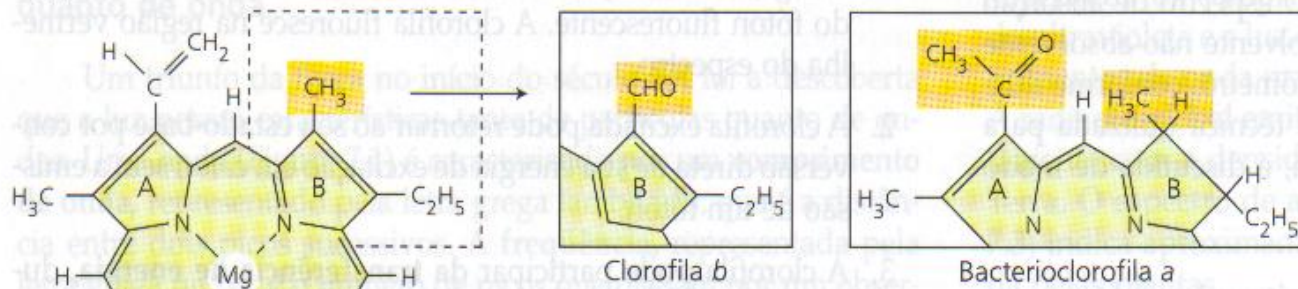
25 μm

PIGMENTOS FOTOSSINTÉTICOS

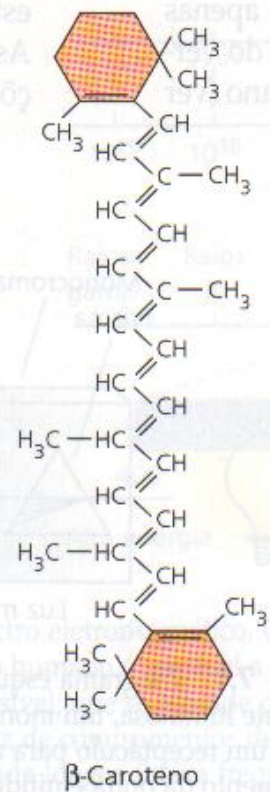
1. PIGMENTOS CLOROFILIANOS

2. PIGMENTOS CAROTENÓIDES

(A) **Clorofilas**



(B) **Carotenóides**



(C) **Pigmentos bilinas**

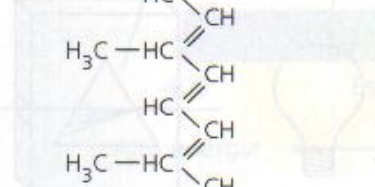
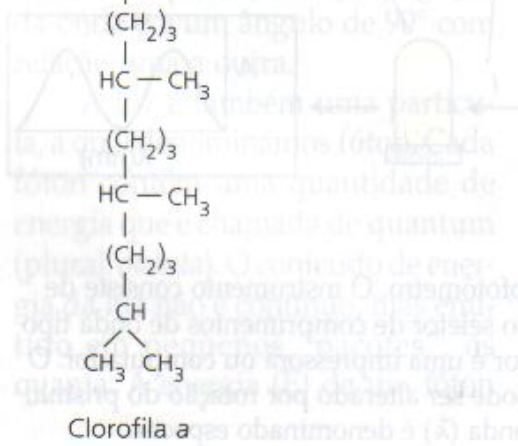
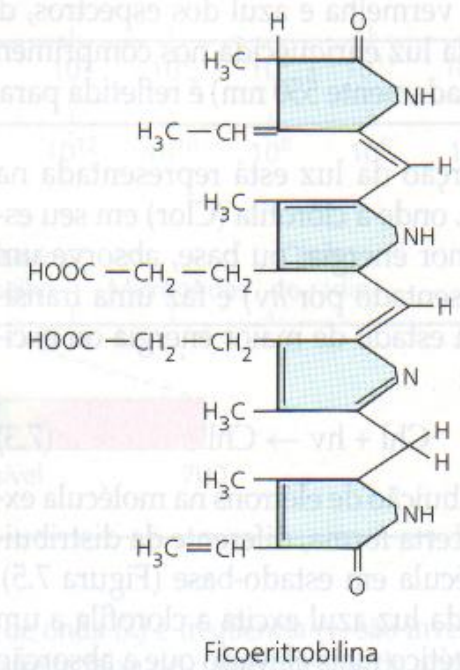
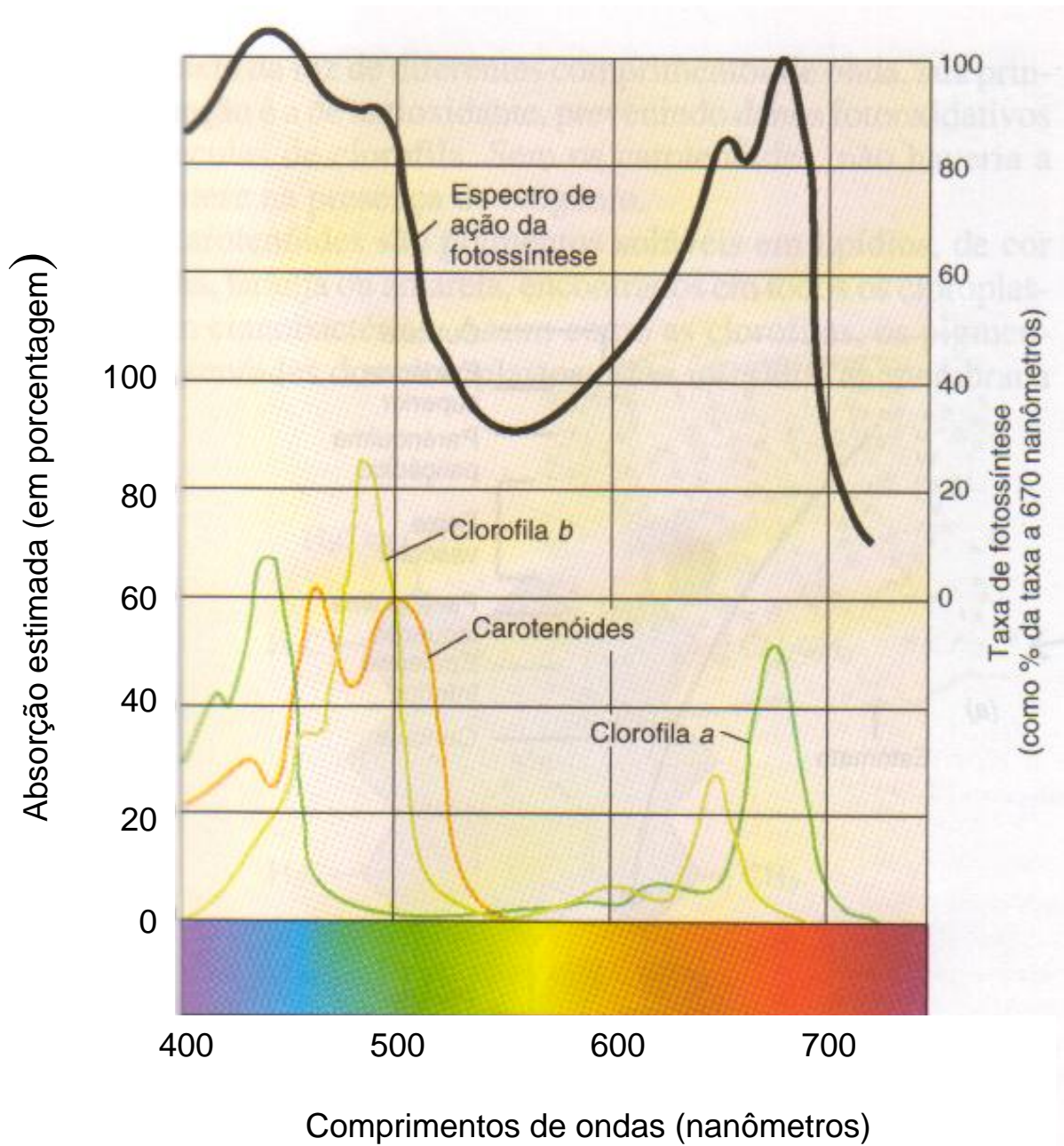
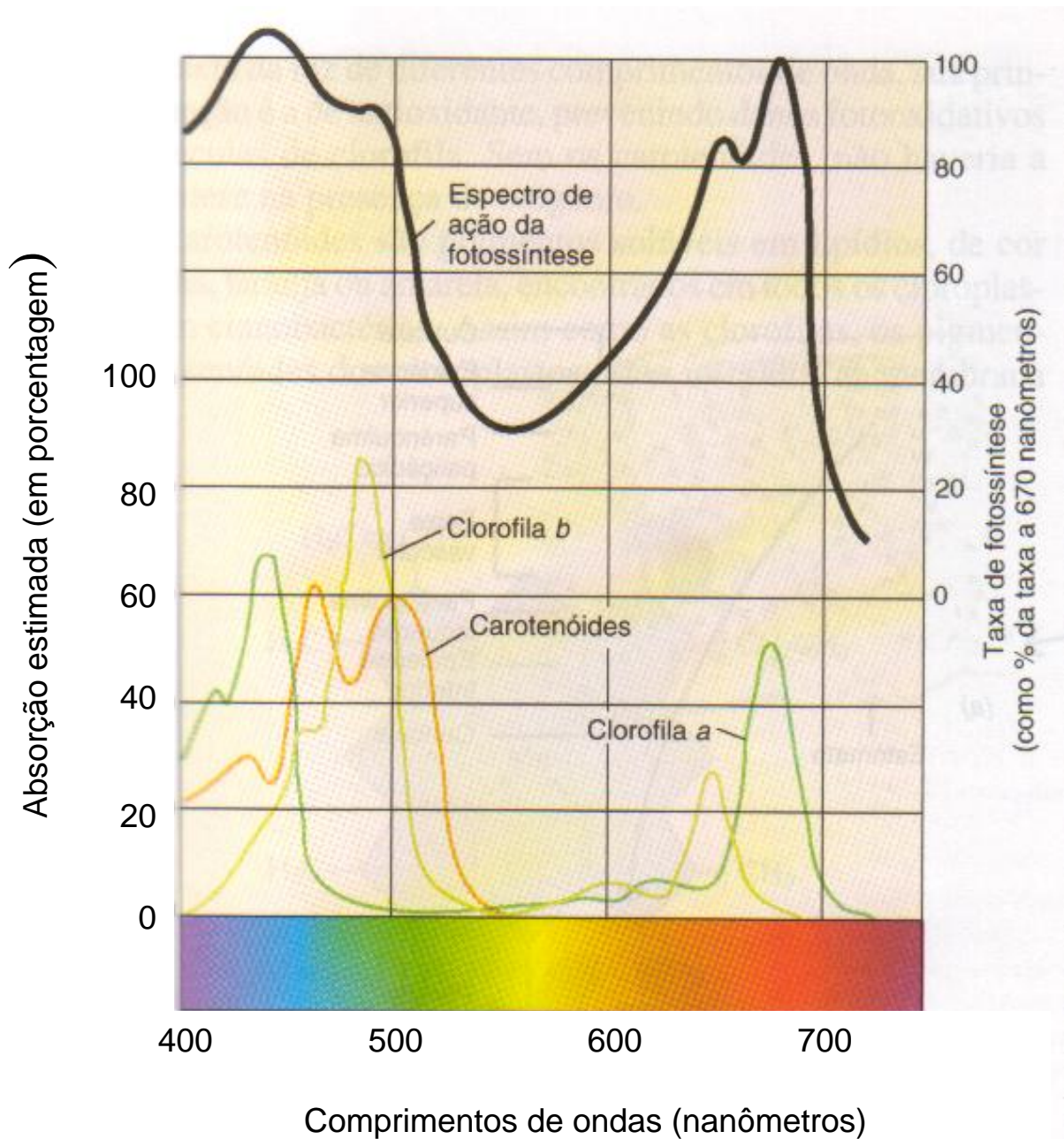


FIGURA 7.2



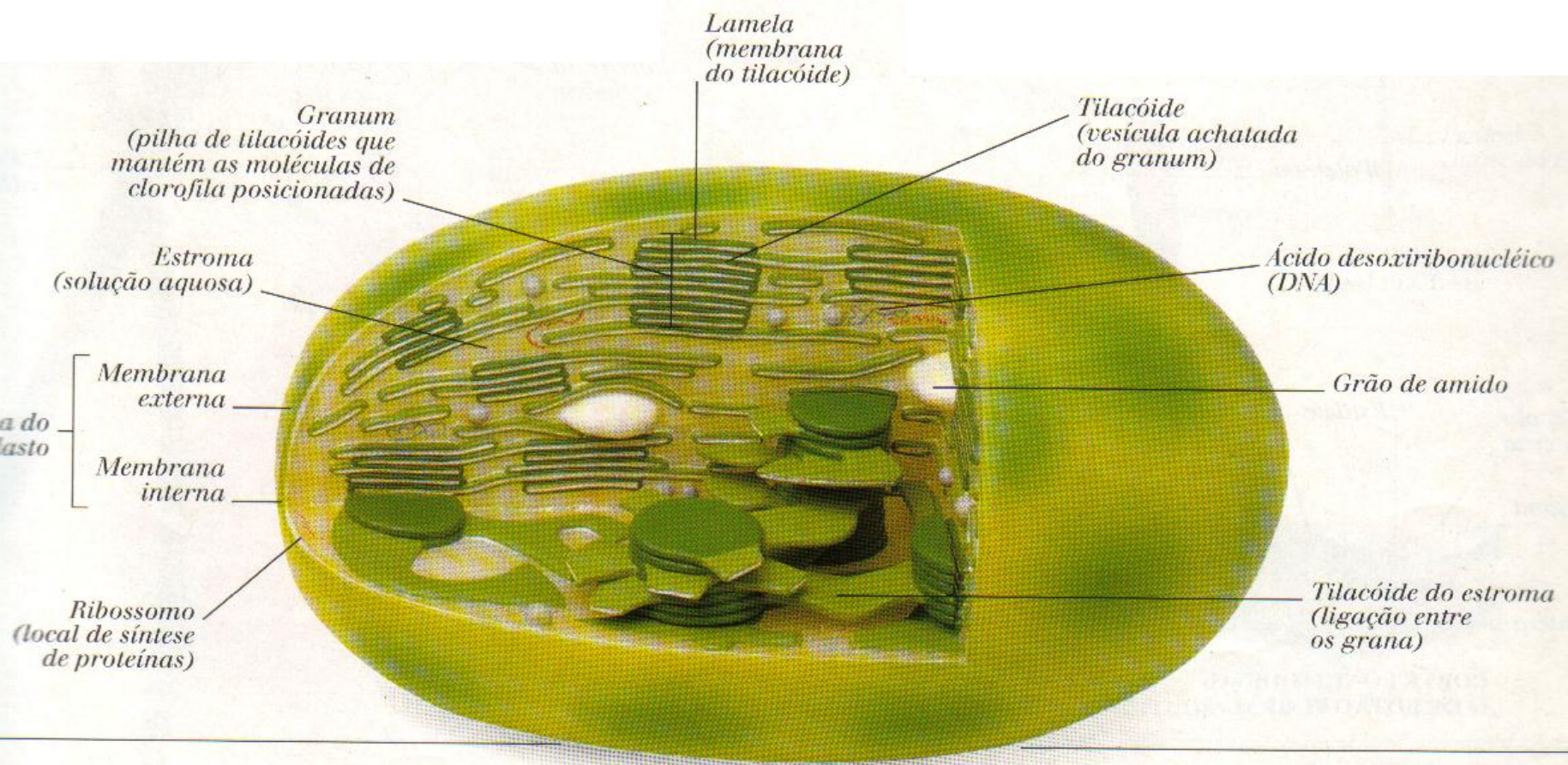


CLOROFILA A:
 VERDE-AZULADA
 AC – VL

CLOROFILA B:
 VERDE-AMARELADA
 AL – VC

CAROTENOS:
 ALARANJADOS
 AZUL - VERDE

COLORPLASTO



PIGMENTOS FOTOSSINTÉTICOS

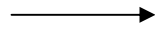
1. PIGMENTOS CLOROFILIANOS

CLOROFILA A: PIGMENTO ESSENCIAL

CLOROFILA B: PIGMENTO ACESSÓRIO

SÍNTESE DE CLOROFILA

ÁCIDO GLUTÂMICO



ÁCIDO 5-AMINOLEVULÍNICO

+

ÁCIDO 5-AMINOLEVULÍNICO



PROTOCLOROFILIDEO *a*



LUZ

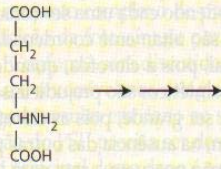
CLOROFILIDEO *a*



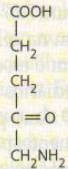
CLOROFILASE

CLOROFILA *a*

Fase I

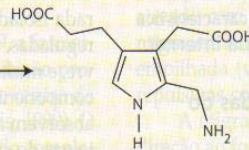


Ácido glutâmico



Ácido 5-aminolevulinico

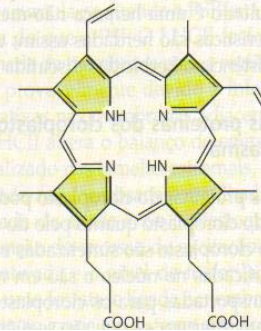
(x 2)



Profobilinogênio

(x 4)

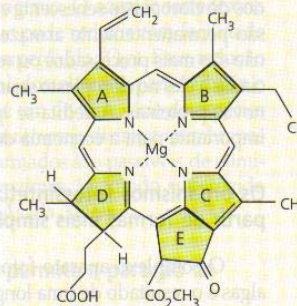
Fase II



Protoporfirina IX

Mg²⁺

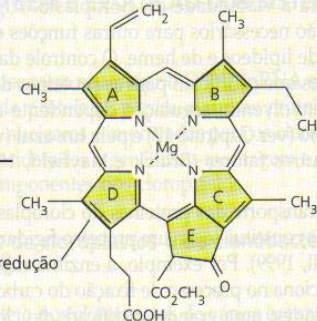
Fase III



Clorofilídeo a

LUZ

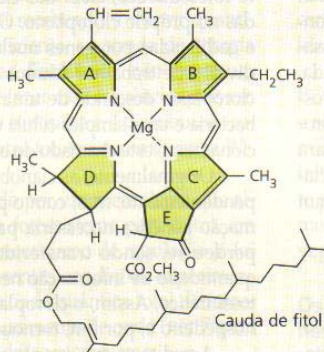
NADPH, luz
Protoclorofilídeo oxirredutase



Protoclorofilídeo a monovinílico

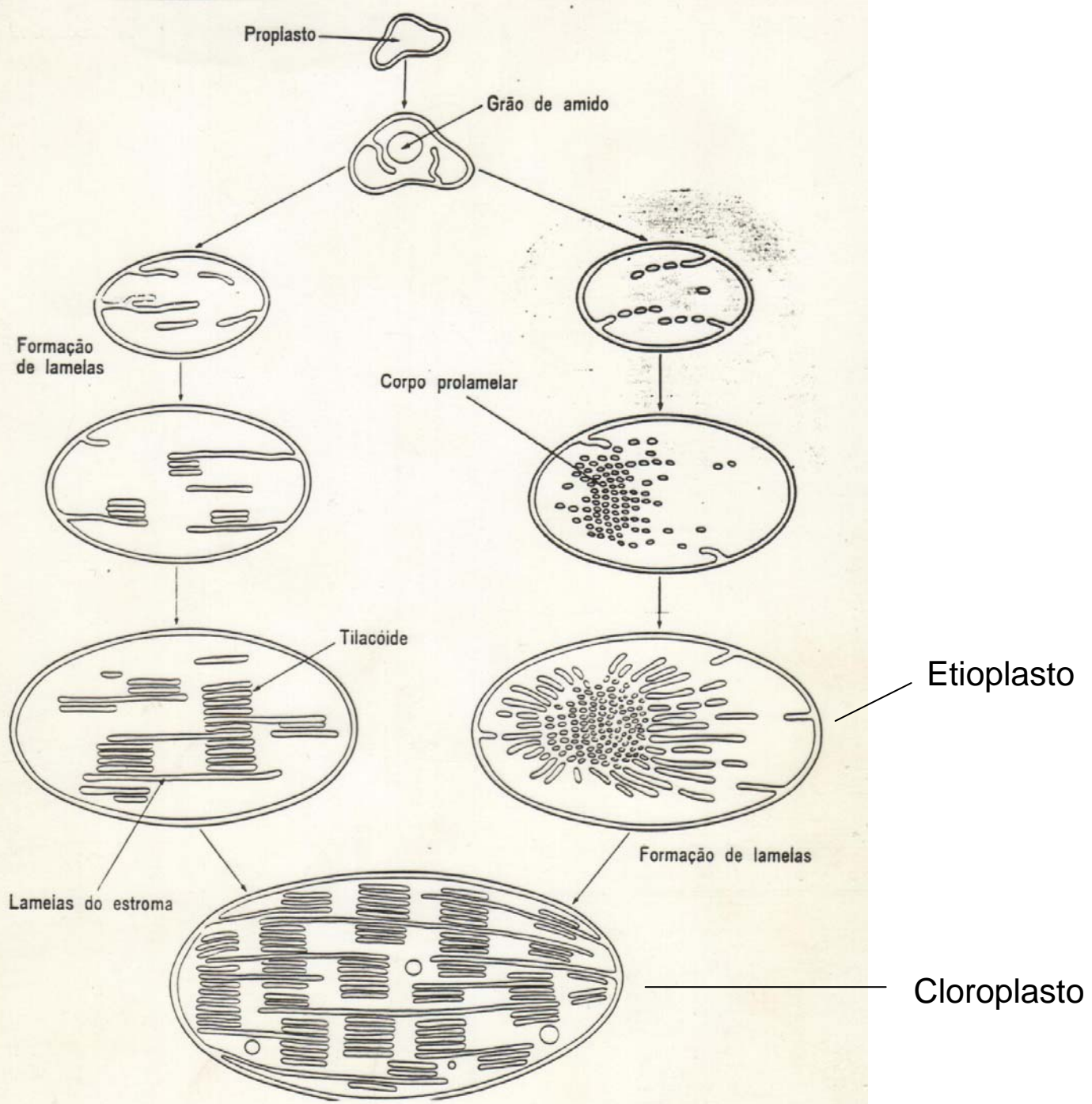
Fase IV

Cauda de fitol



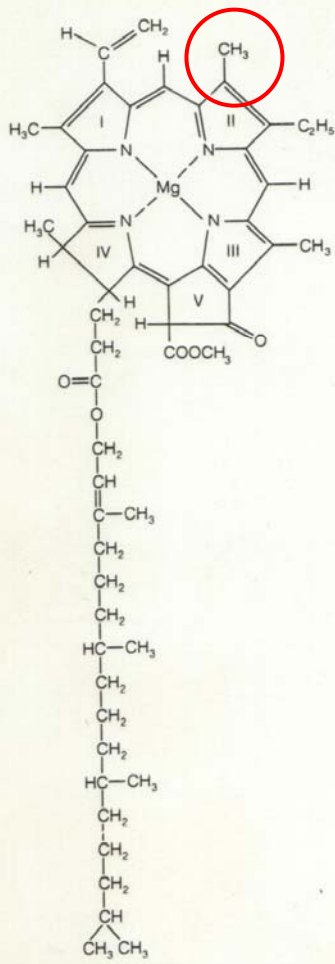
Clorofila a

Cauda de fitol

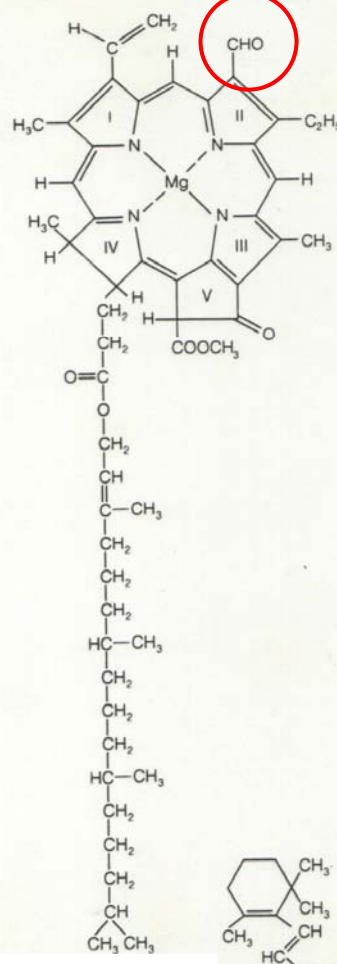


PRINCIPAIS DIFERENÇAS ENTRE CLOROFILAS A e B

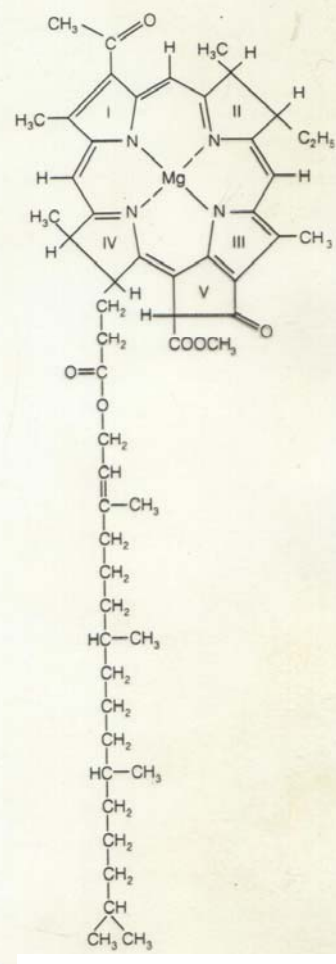
DIFERENÇAS	CLOROFILA A	CLOROFILA B
RADICAIS	METIL LIGADO NO C ₃	ALDEÍDO LIGADO NO C ₃
COR	VERDE-AZULADA	VERDE-AMARELADA
SOLUBILIDADE	ÉTER DE PETRÓLEO	ÁLCOOL METÍLICO
ABSORÇÃO LUMINOSA	AZUL CURTO (420-430 nm) VERMELHO LONGO (> DE 700 nm)	AZUL LONGO (470-490 nm) VERMELHO CURTO (640-680 nm)



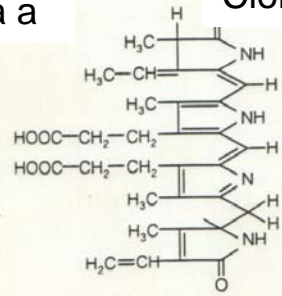
Clorofila a



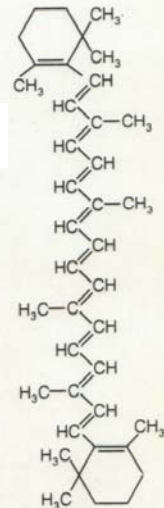
Clorofila b



Bacterioclorofila a



Ficoeritrobilina



β Caroteno

PIGMENTOS FOTOSSINTÉTICOS

2. PIGMENTOS CAROTENÓIDES

CAROTENOS (alaranjados): CONSTITUÍDOS DE C e H

XANTOFILAS (AMARELADAS): CONSTITUÍDAS DE C, H e O

PIGMENTOS FOTOSSINTÉTICOS

2. PIGMENTOS CAROTENÓIDES

PRECURSOR: LICOPENO (COR VERMELHA)

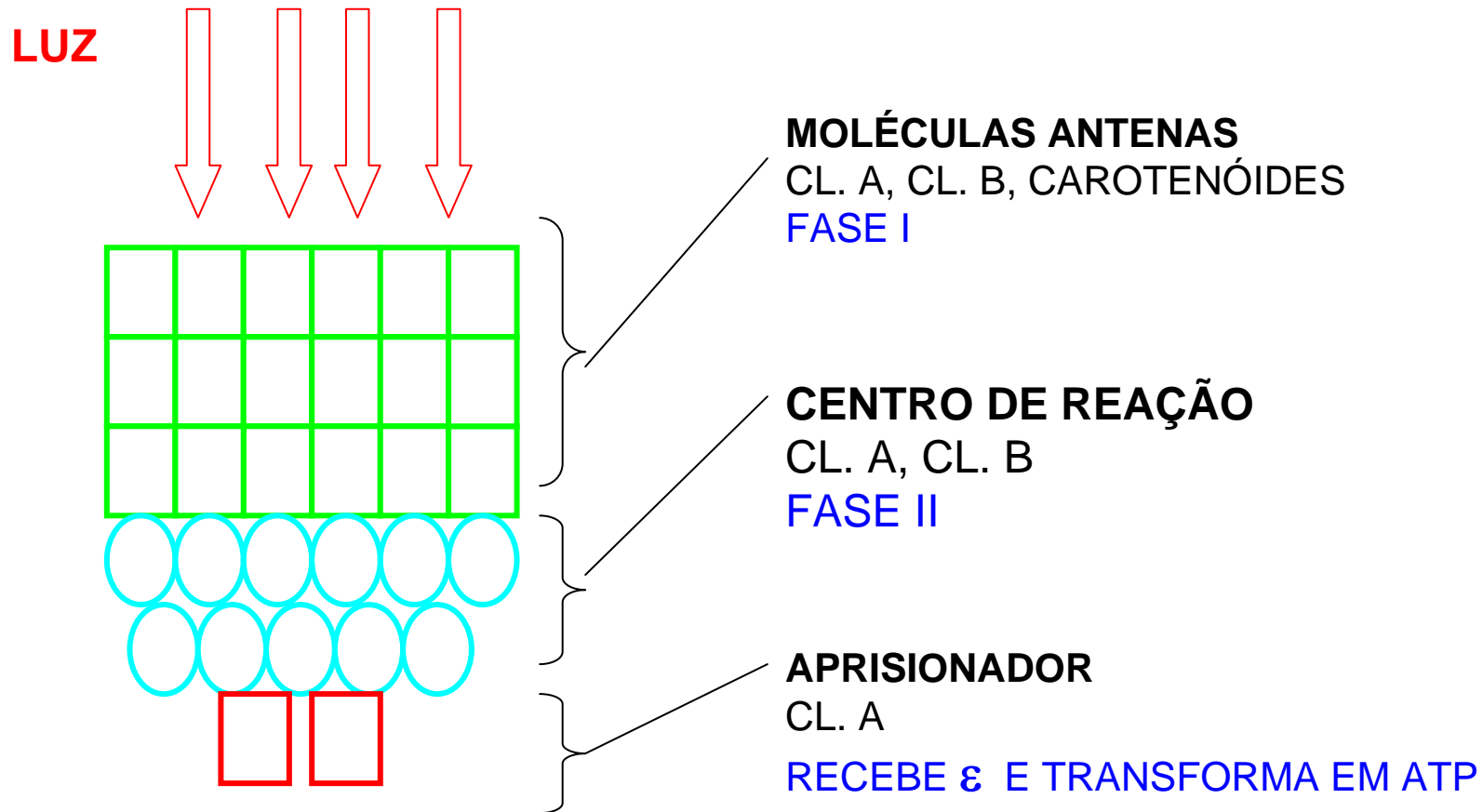
CAROTENOS (alaranjados): CONSTITUÍDOS DE C e H

XANTOFILAS (AMARELADAS): CONSTITUÍDAS DE C, H e O

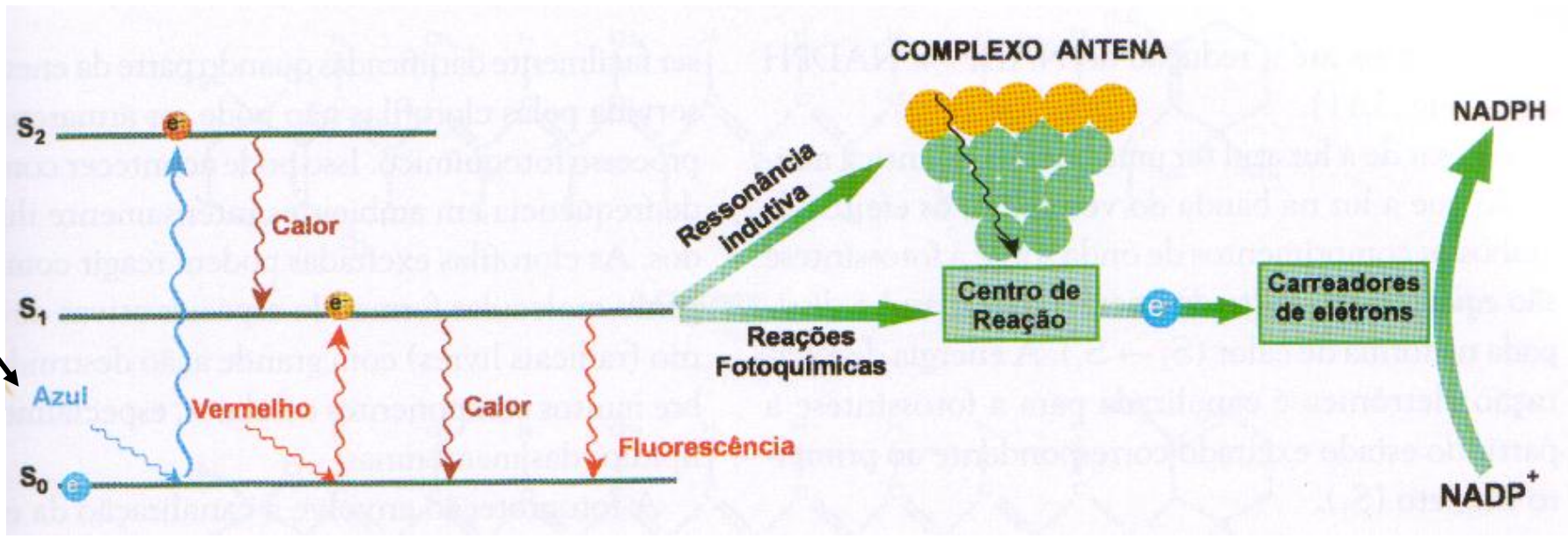
FUNÇÃO DOS CAROTENÓIDES:

ABSORVER LUZ TRANSFERINDO-A PARA A CLOROFILA *a*

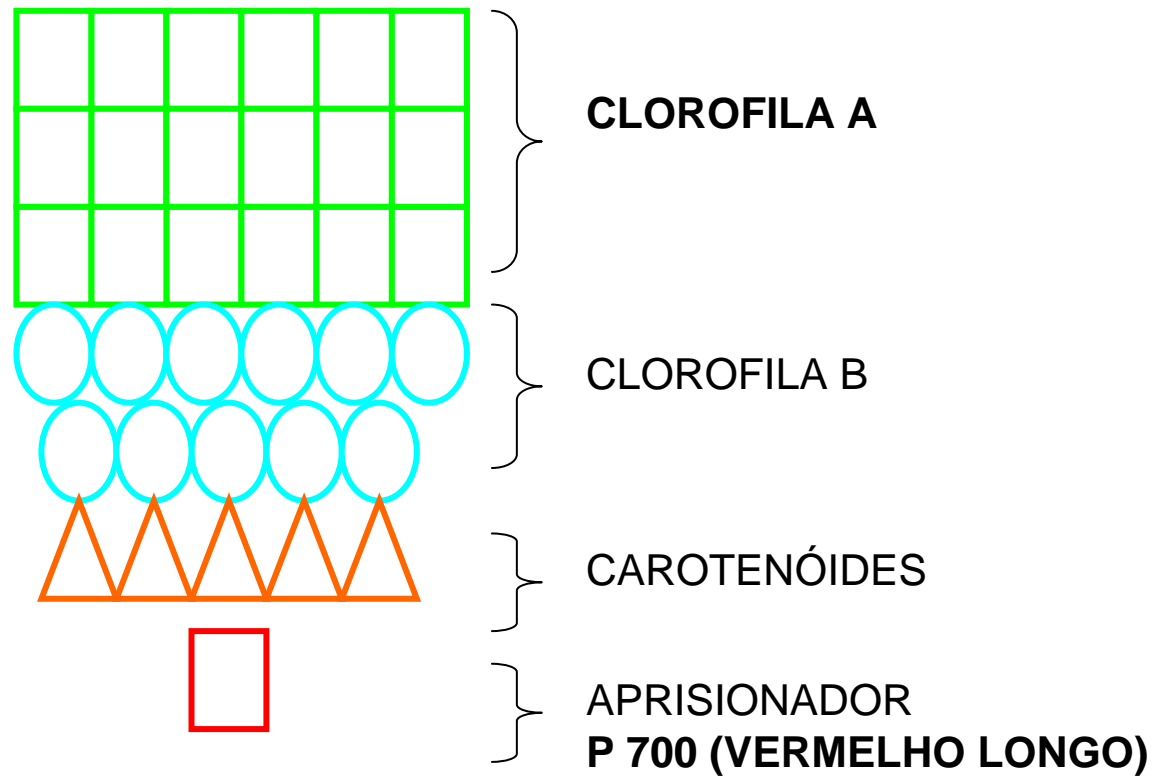
UNIDADE FOTOSSINTÉTICA (QUANTOSSOMOS)



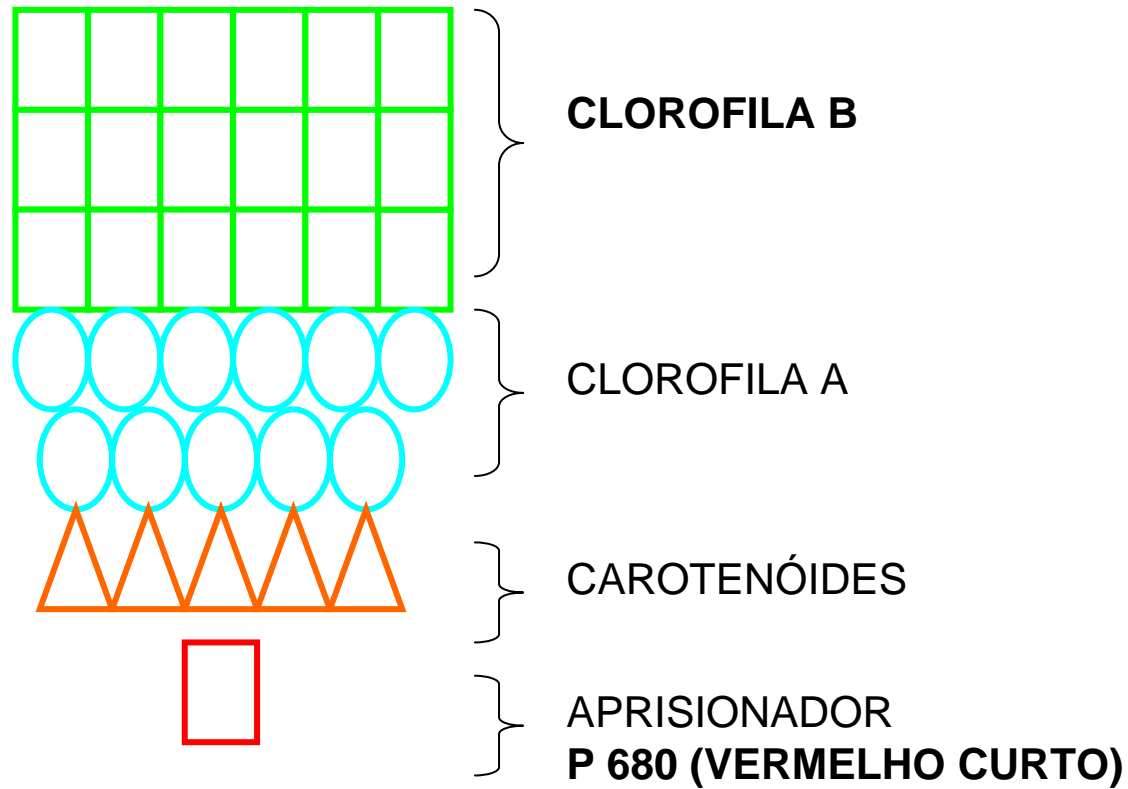
L
U
Z



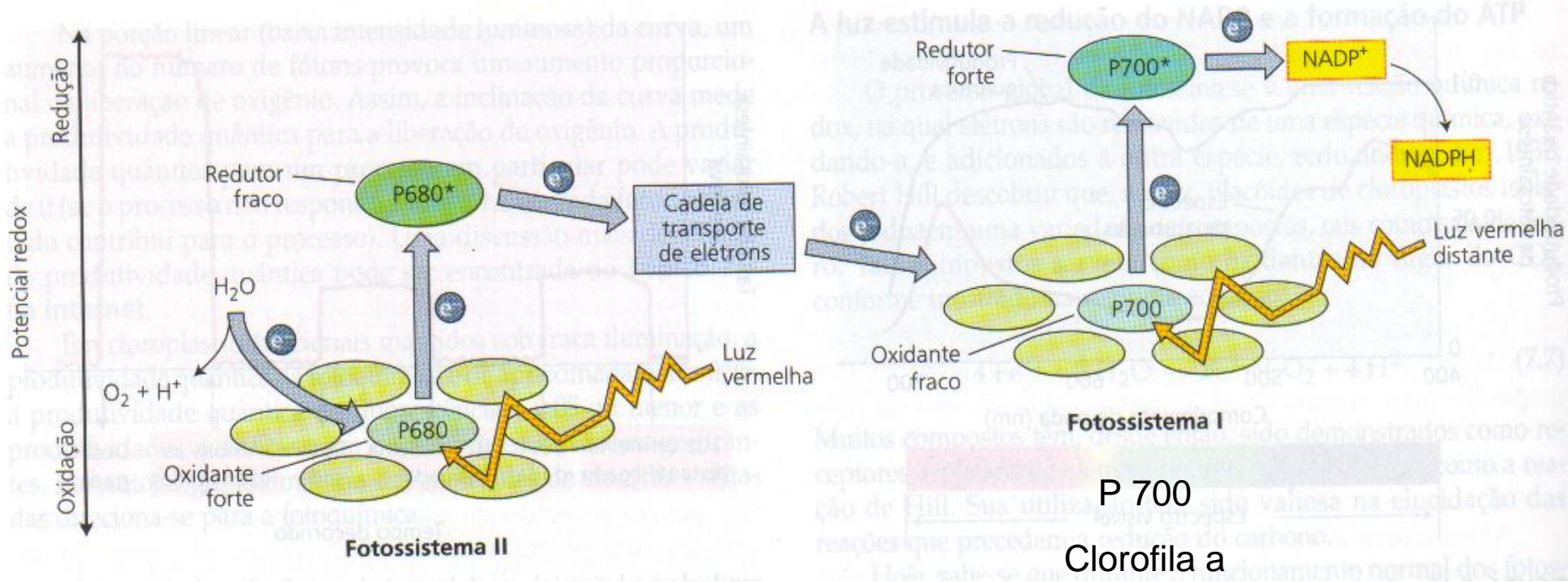
FOTOSSISTEMA I



FOTOSSISTEMA II



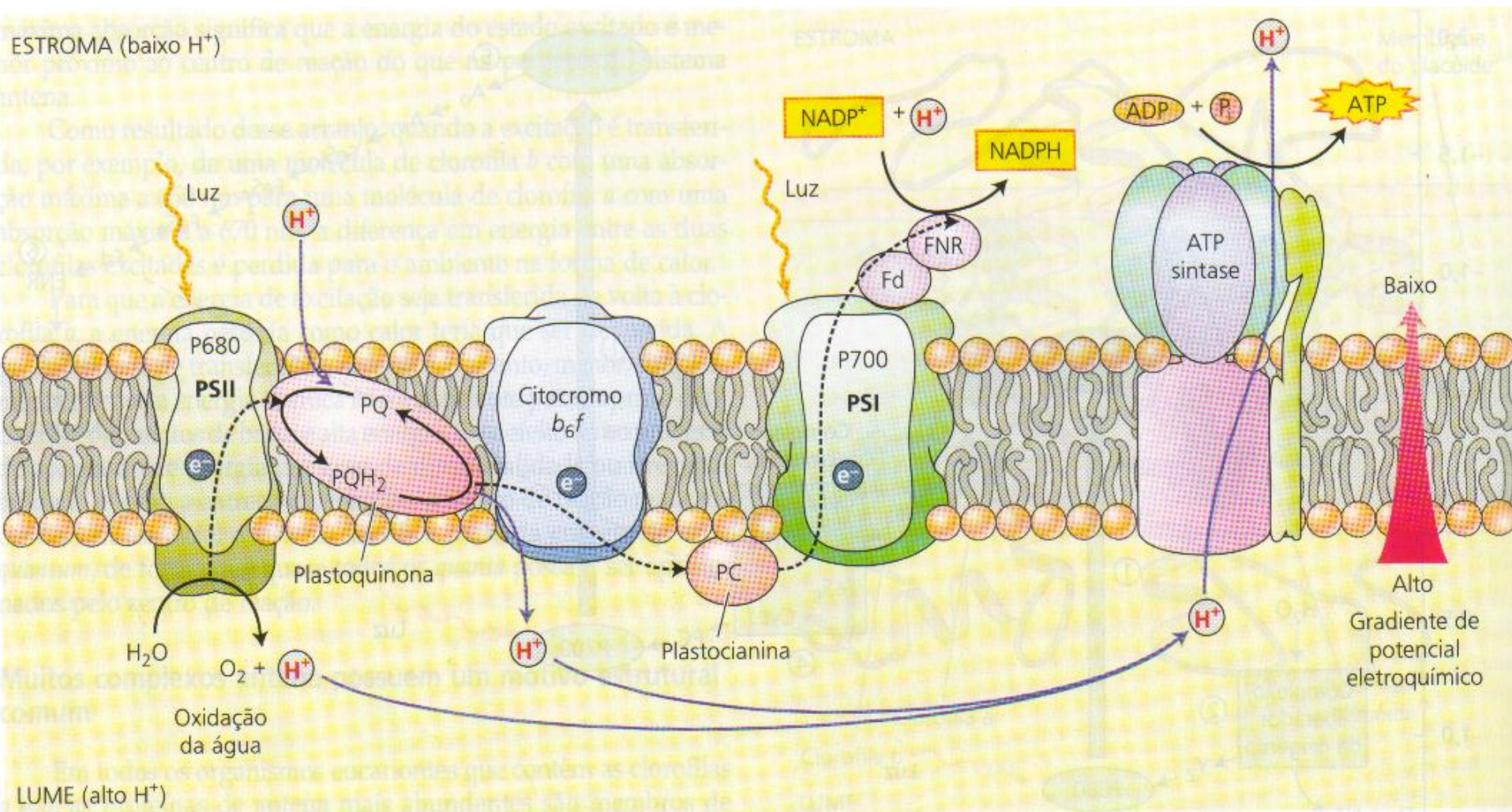
FOTOFOSFORILAÇÃO

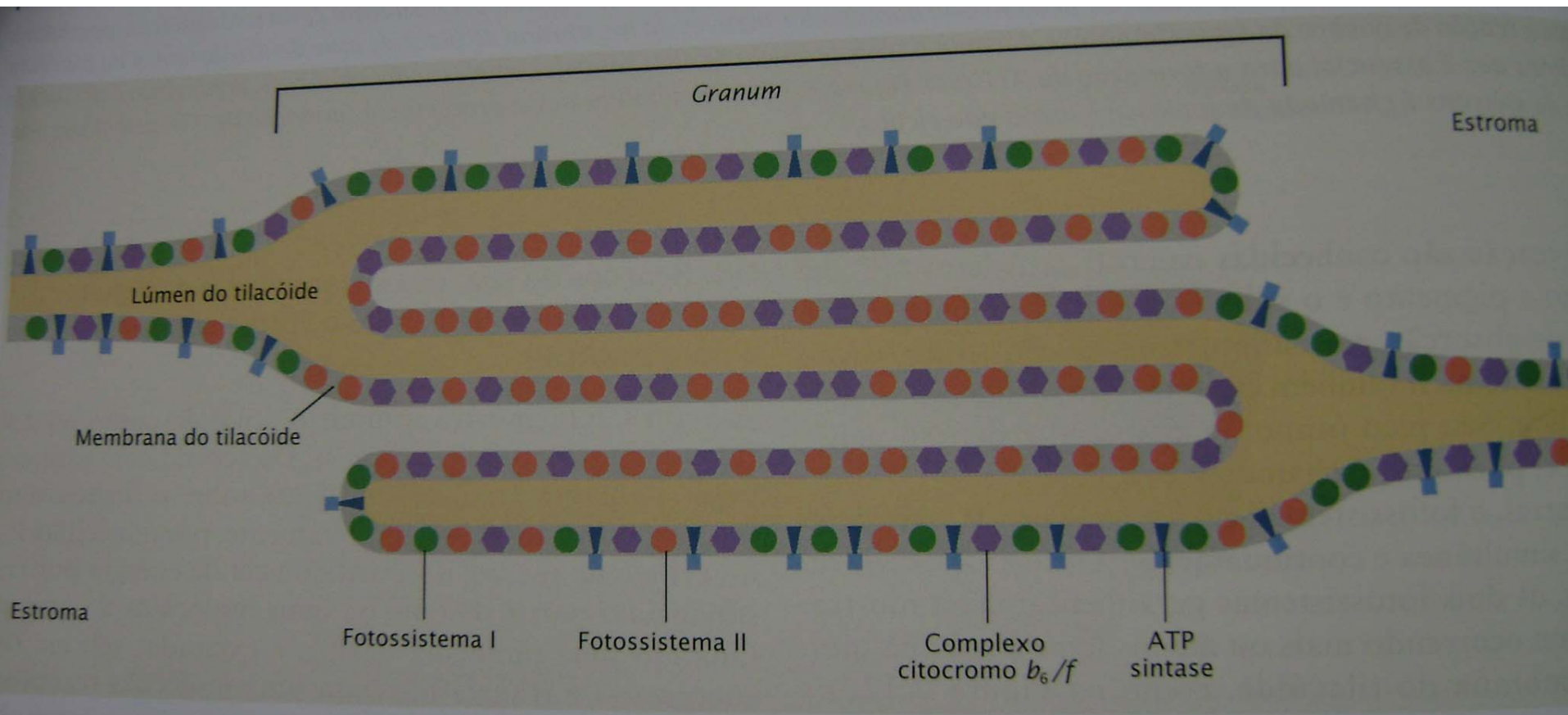


P680
Clorofila b
AL - VC

P 700
Clorofila a
AC - VL

FOTOFOSFORILAÇÃO



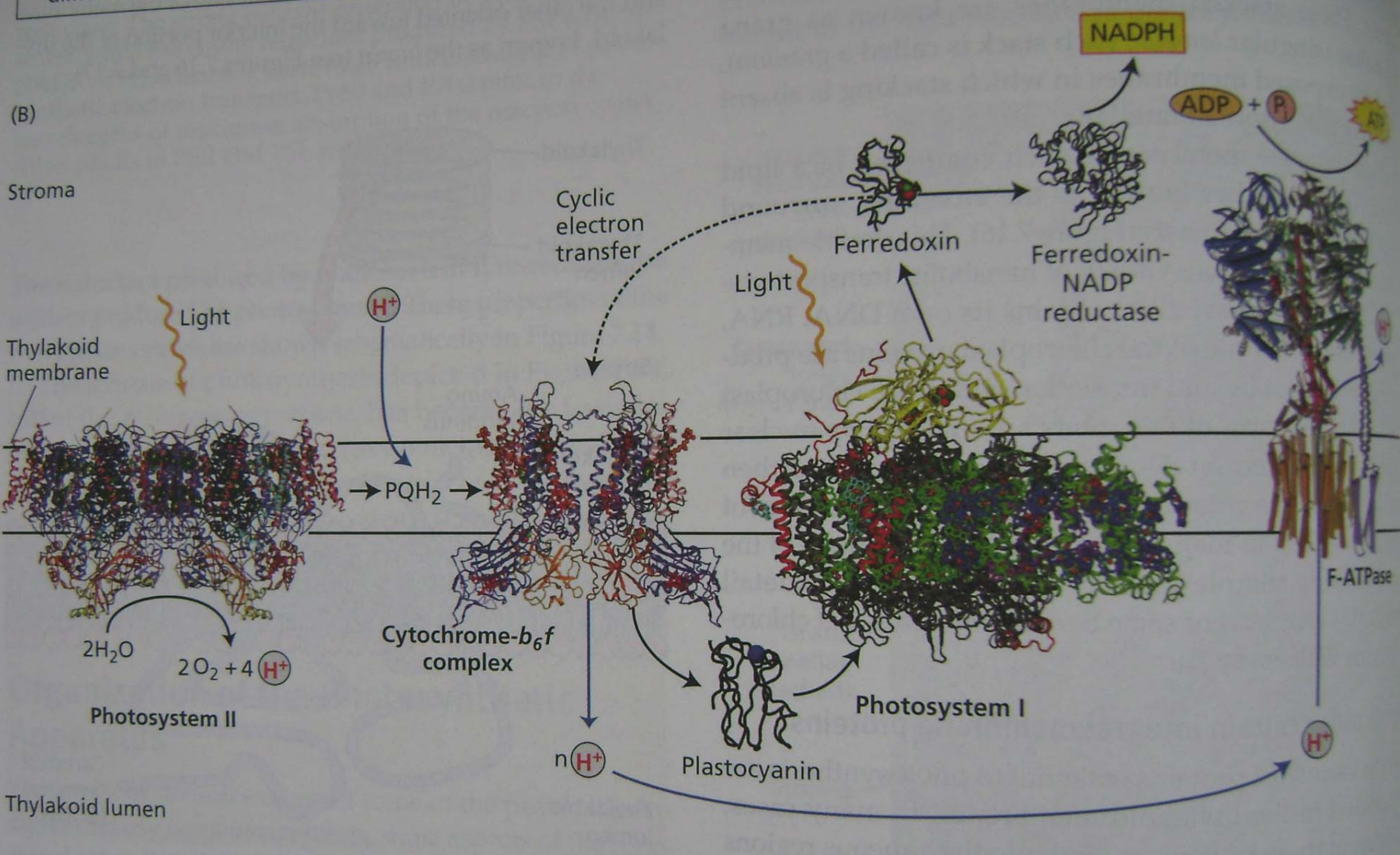


ORGANIZAÇÃO DOS FOTOSSISTEMAS NOS TILACÓIDES

F II nos grana dos tilacóides

F I e Complexo ATP sintase nos tilacóides do estroma e partes externas dos grana

ORGANIZAÇÃO E ESTRUTURA DOS 4 MAIORES COMPLEXOS PROTÉICOS DAS MEMBRANAS DOS TILACÓIDES

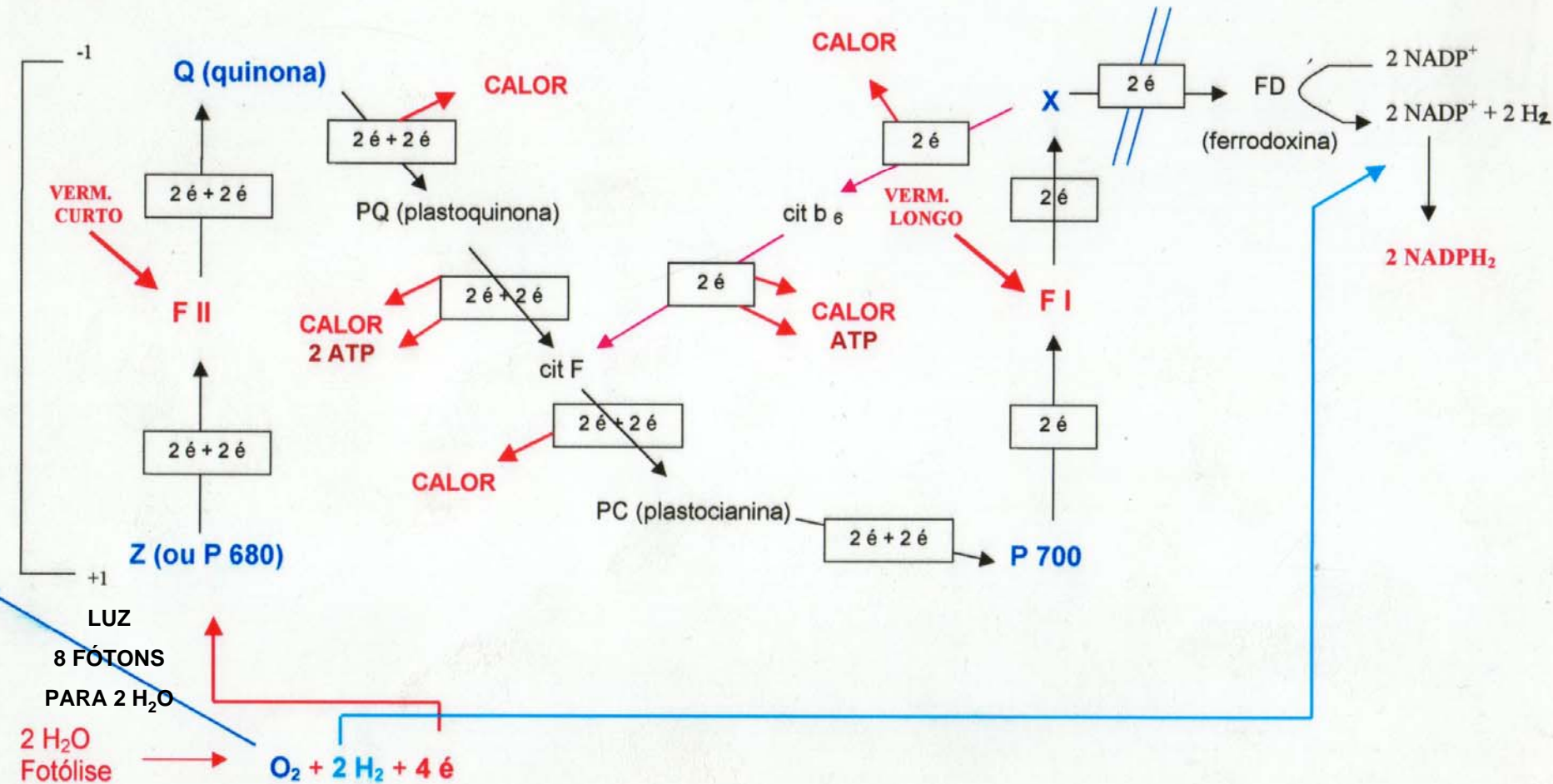


FOTOFOSFORILAÇÃO

FOTOFOSFORILAÇÃO

FOTOSSISTEMAS I E II OCORREM SIMULTANEAMENTE NO SISTEMA LAMELAR DO CLOROPLASTO
FASE CLARA DA FOTOSÍNTESE

Pot Redox



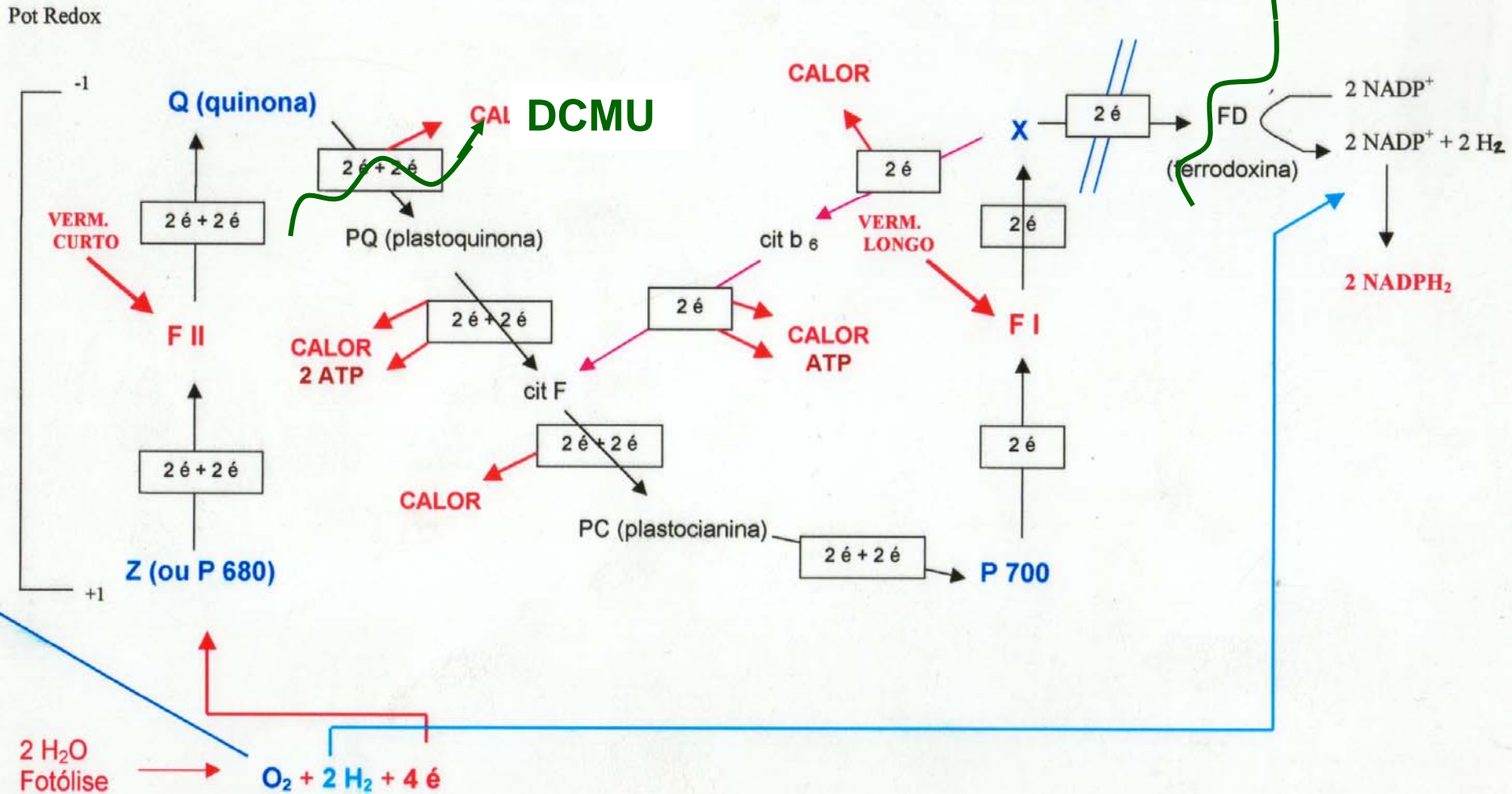
FOTOFOSFORILAÇÃO

FOTOFOSFORILAÇÃO

FOTOSSISTEMAS I E II OCORREM SIMULTANEAMENTE NO SISTEMA LAMELAR DO CLOROPLASTO

FASE CLARA DA FOTOSÍNTESE

PARAQUAT



CONDIÇÕES PARA A QUEBRA DA MOLÉCULA DE ÁGUA:

1. ALTA INSTABILIDADE ELÉTRICA DE Z
2. FRACA ESTRUTURA MOLECULAR DA ÁGUA
3. PRESENÇA DA RADIAÇÃO VERMELHO CURTO (ALTO NÍVEL ENERGÉTICO)
4. PRESENÇA DE Cl^- E Mn^{+2} PARA A FOTÓLISE DA ÁGUA

BALANÇO ENERGÉTICO DA FOTOFOSFORILAÇÃO:

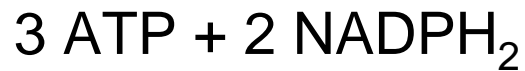
FOTOFOSFORILAÇÃO ACÍCLICA:



FOTOFOSFORILAÇÃO CÍCLICA:



PRODUTO FINAL DAS 2 FOTOFOSFORILAÇÕES:



BALANÇO ENERGÉTICO DA FOTOFOSFORILAÇÃO:

PLANTAS C₃: 3 ATP + 2 NADPH₂

PLANTAS C₄: 5 ATP + 2 NADPH₂



**Olá pessoal!!!
Sou a Fiorella!
Minha mãe não
pára de falar, né!!!**

**Eu sou a Nina... E já
estou enlouquecendo
com essa história de
FOTOSSÍNTESE...**

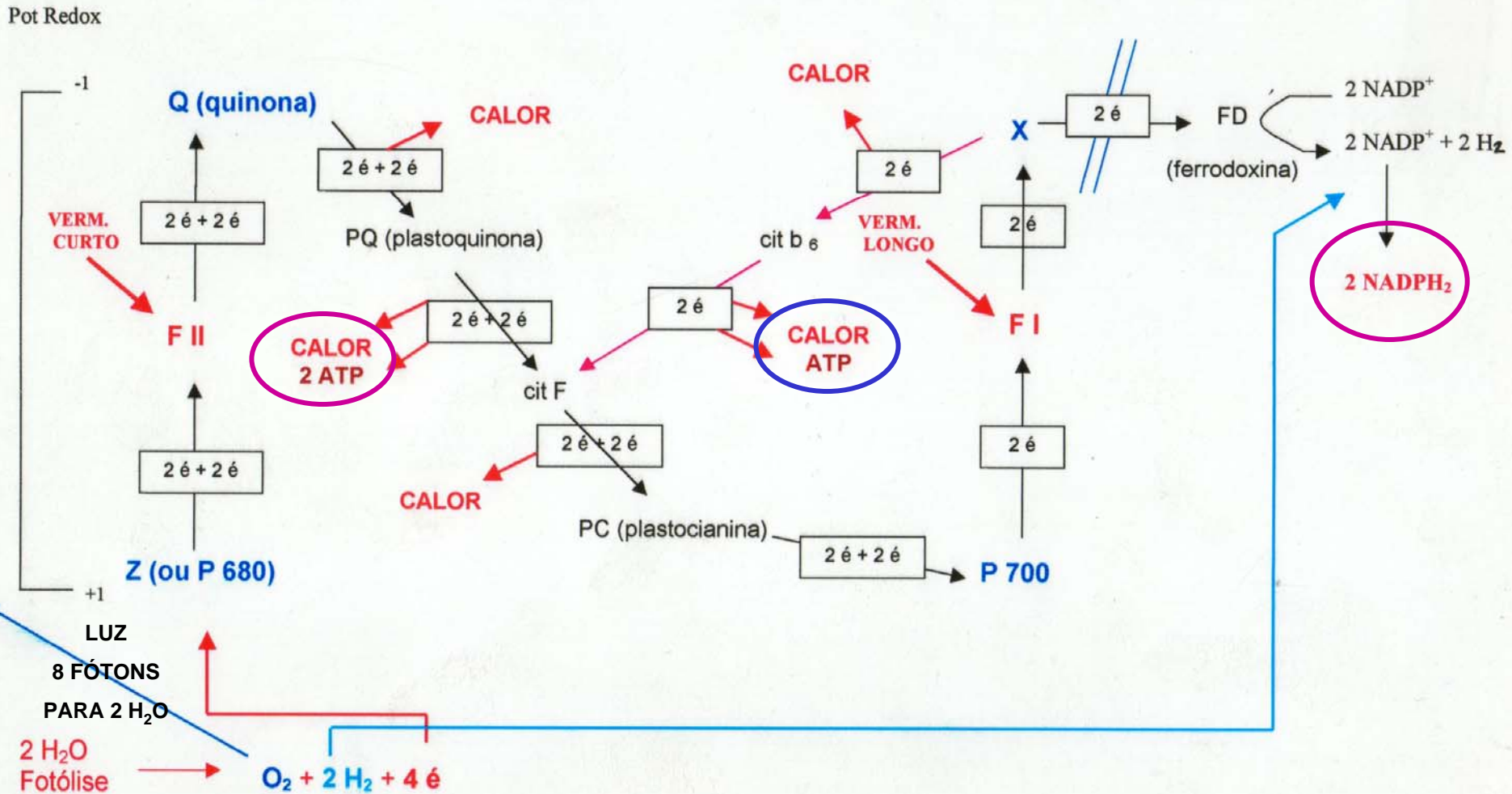


INTERVALO!!!!

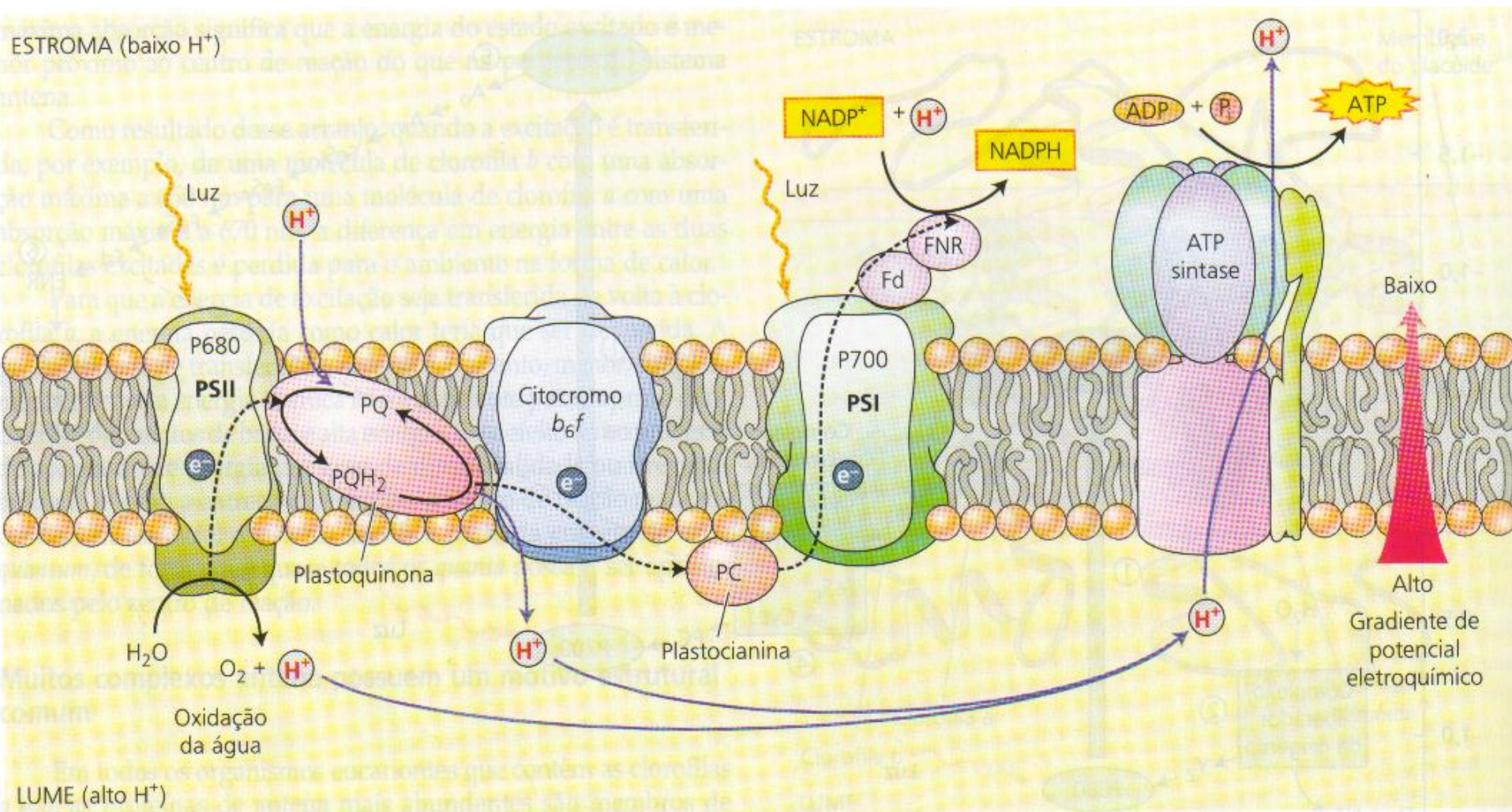
FOTOFOSFORILAÇÃO

FOTOFOSFORILAÇÃO

FOTOSSISTEMAS I E II OCORREM SIMULTANEAMENTE NO SISTEMA LAMELAR DO CLOROPLASTO
FASE CLARA DA FOTOSÍNTESE



FOTOFOSFORILAÇÃO



BALANÇO ENERGÉTICO DA FOTOFOSFORILAÇÃO:

PLANTAS C₃: 3 ATP + 2 NADPH₂

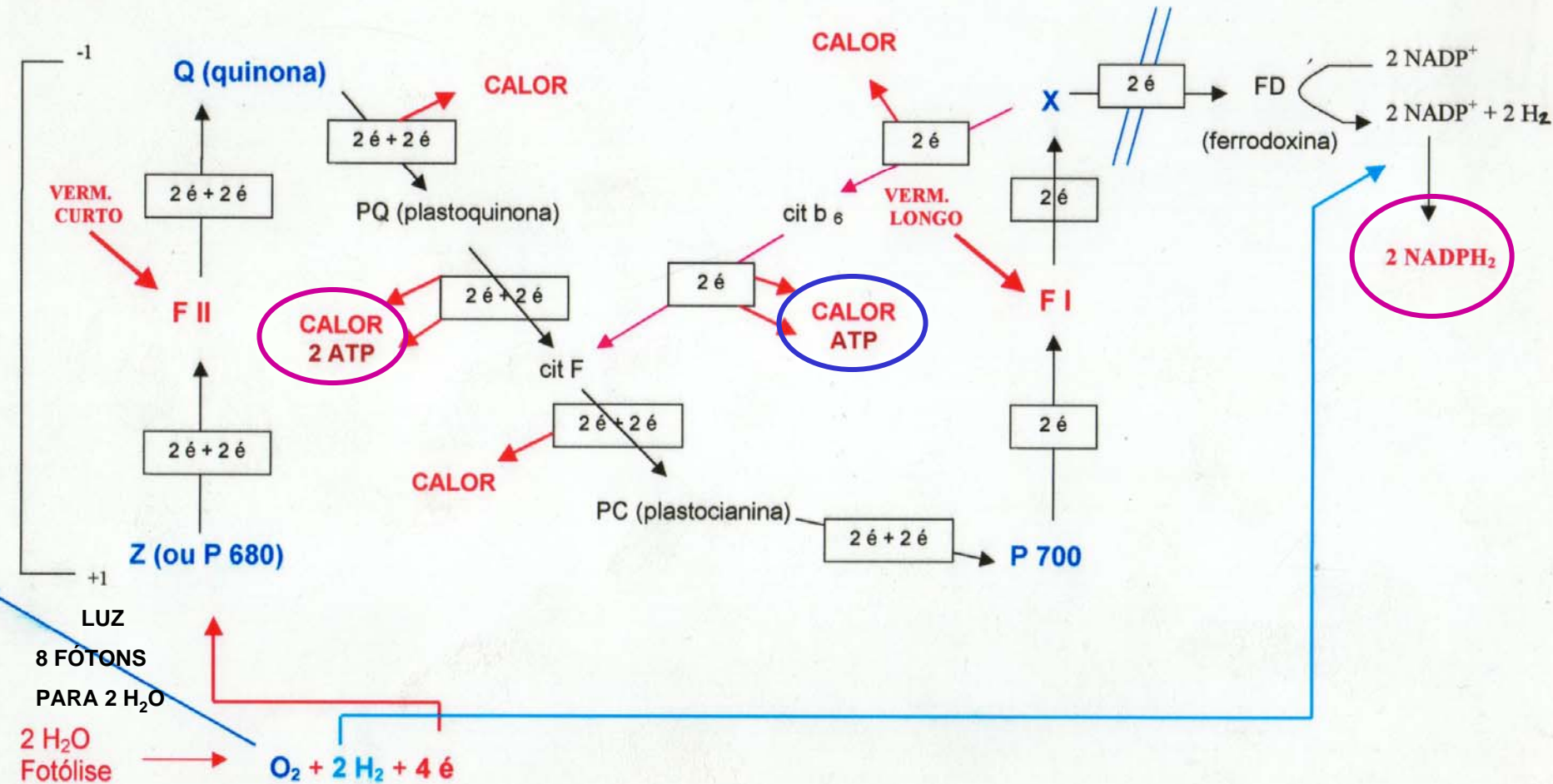
PLANTAS C₄: 5 ATP + 2 NADPH₂

FOTOFOSFORILAÇÃO

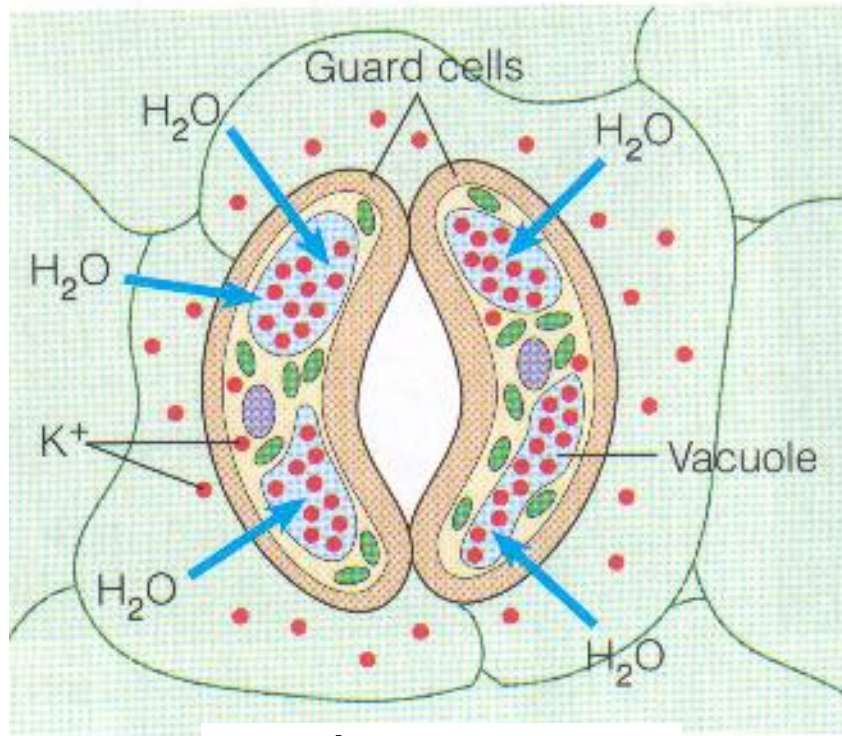
FOTOFOSFORILAÇÃO

FOTOSSISTEMAS I E II OCORREM SIMULTANEAMENTE NO SISTEMA LAMELAR DO CLOROPLASTO
FASE CLARA DA FOTOSÍNTESE

Pot Redox



FIXAÇÃO DE CO₂



ESTÔMATO ABERTO

LUZ PRESENTE

↓ [CO₂]

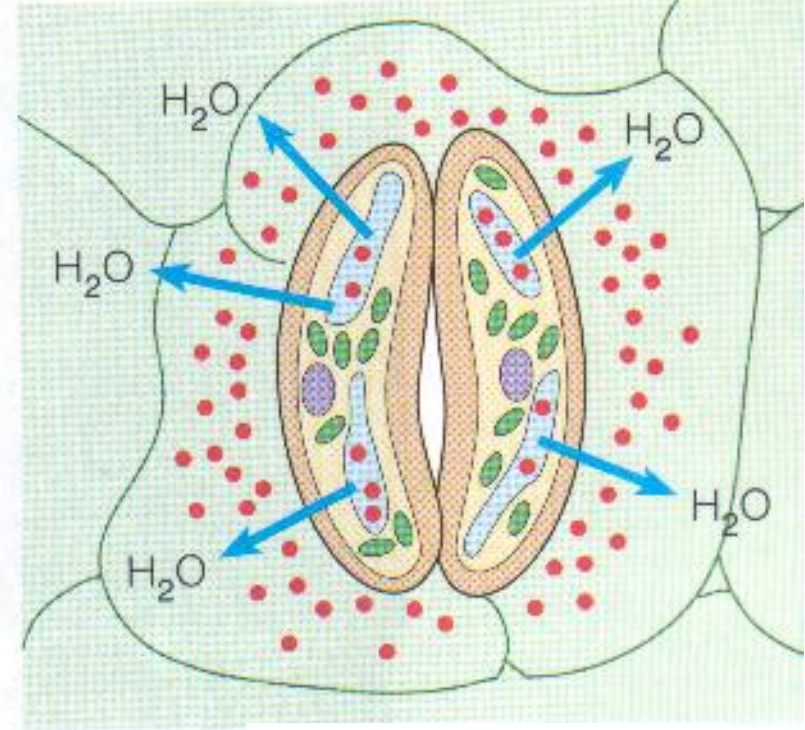
ÁGUA DISPONÍVEL

TEMPERATURAS AMENAS

↓ [AMIDO]

↑ [K⁺]

↑ pH (6-7)



ESTÔMATO FECHADO

LUZ AUSENTE

↑ [CO₂]

SEM ÁGUA

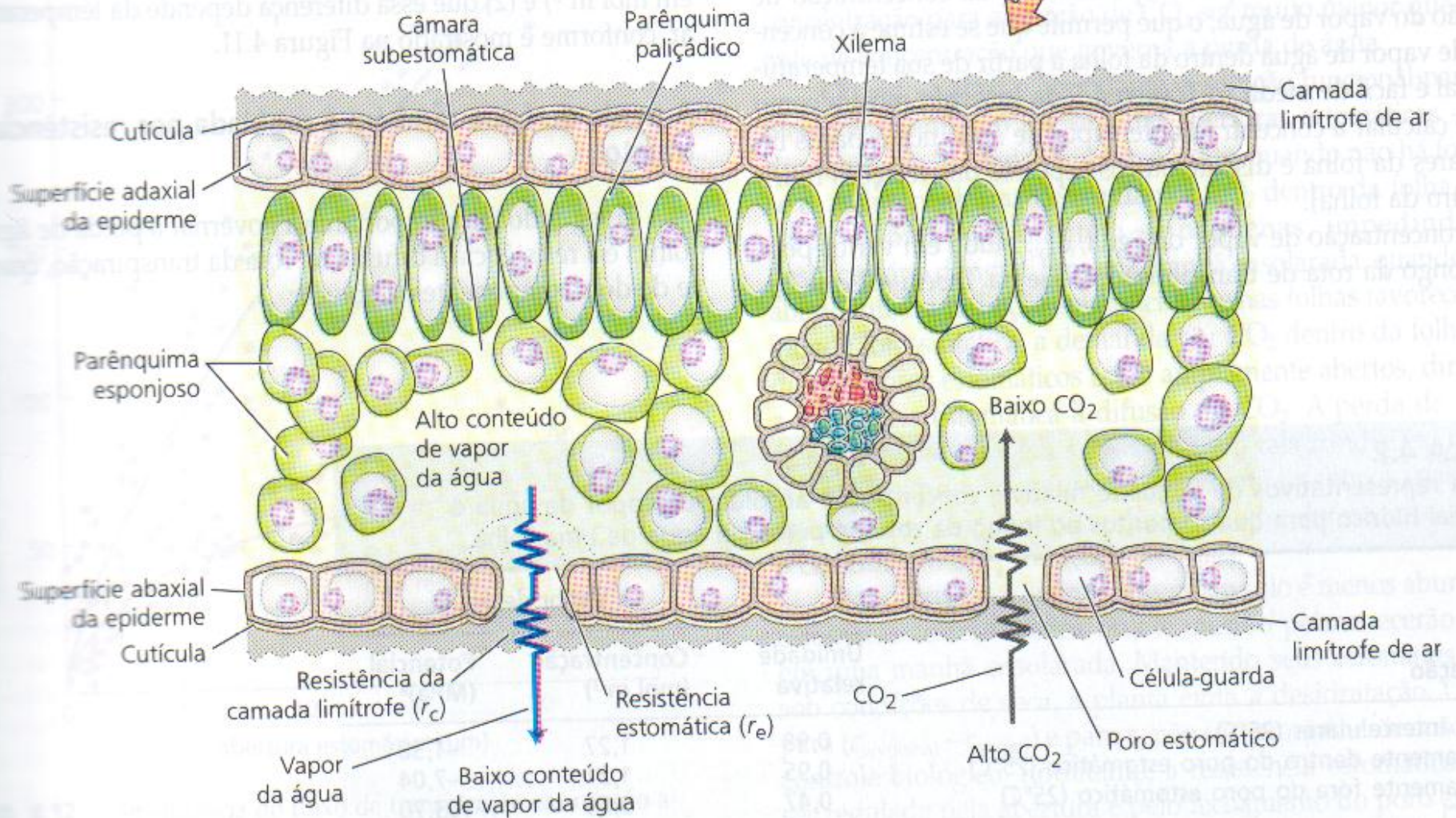
TEMPERATURAS EXTREMAS

↑ [AMIDO]

↓ [K⁺]

↓ pH (4-5)

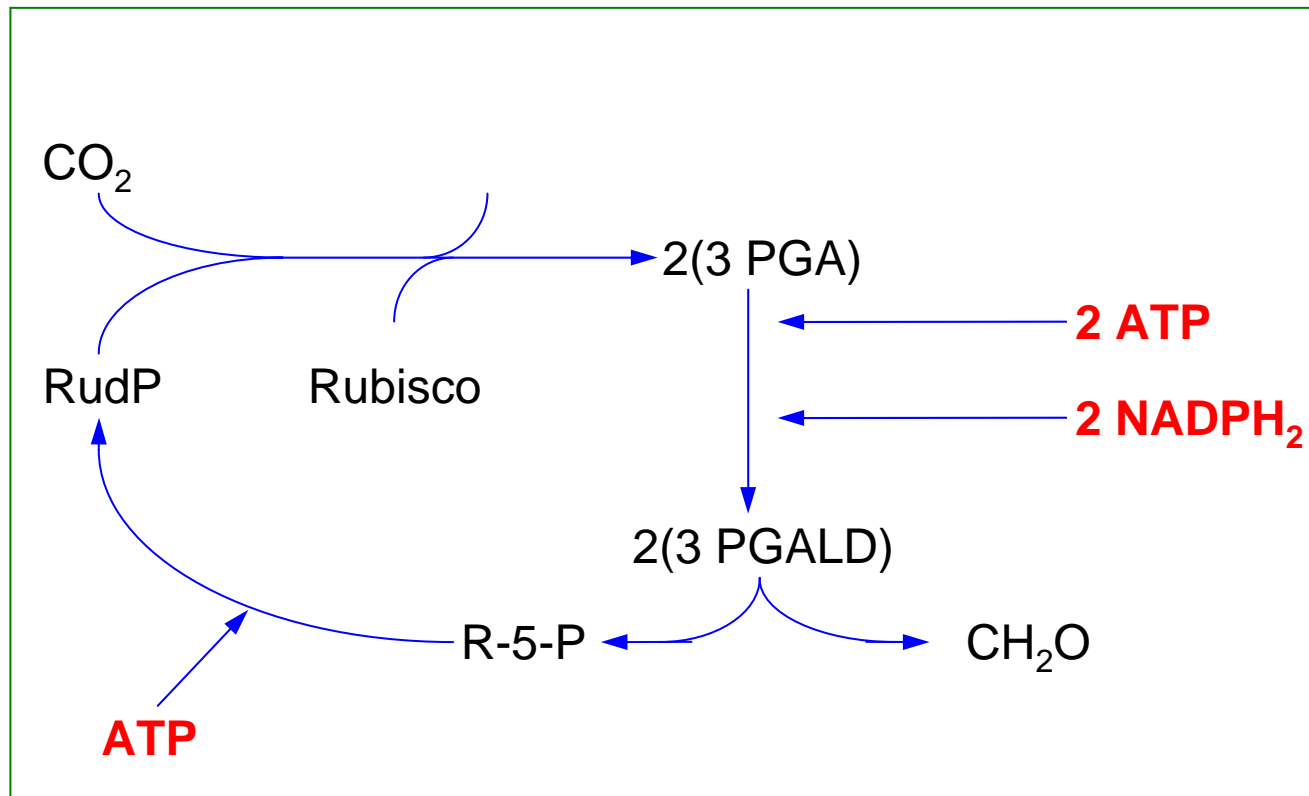
FIXAÇÃO DE CO₂ CUTÍCULA



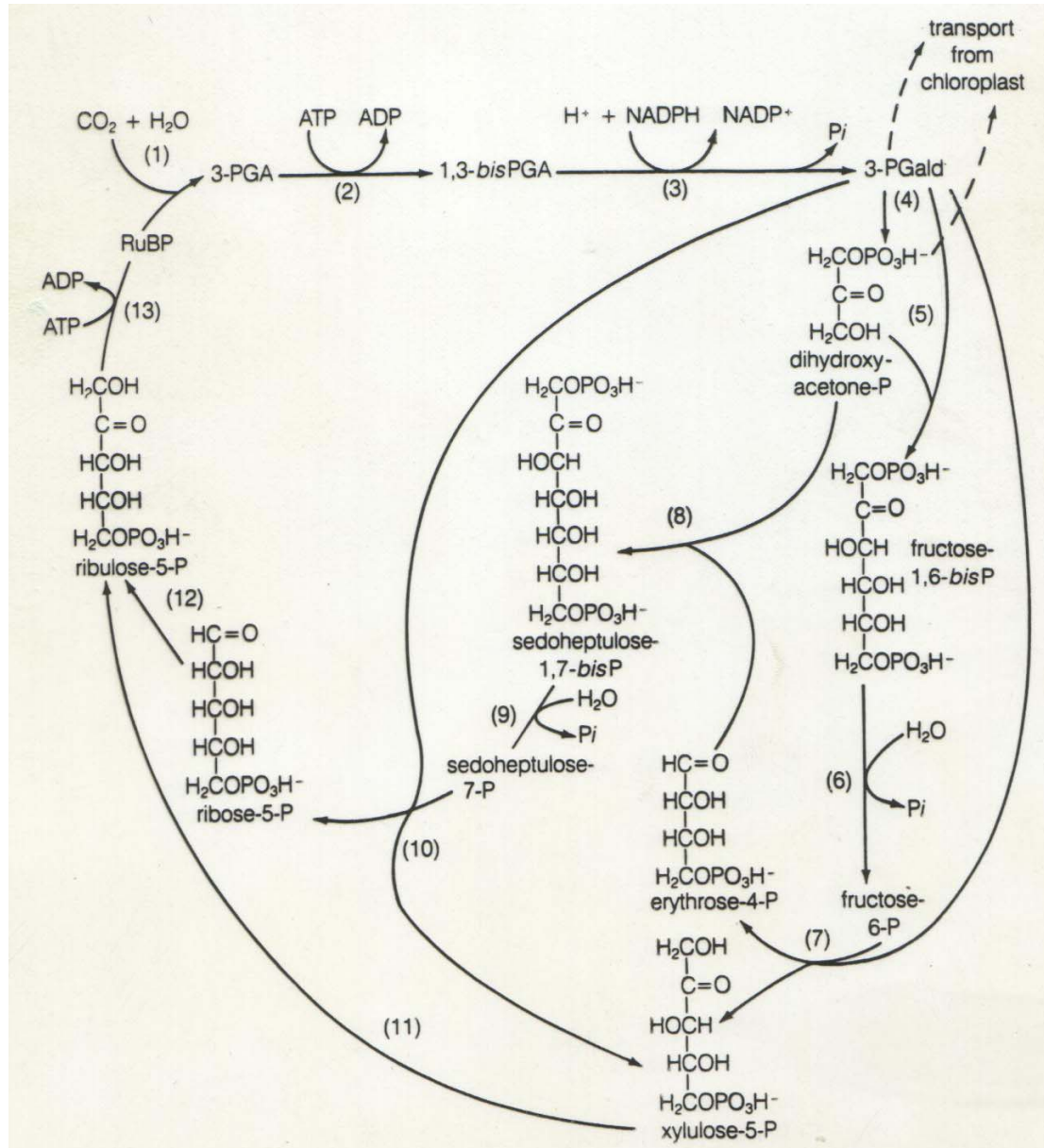
CICLO DE CALVIN-BENSON

Melvin Calvin et al. – Prêmio Nobel em 1961

Melvin Calvin – James Bassham – Andrew Benson (Universidade da Califórnia)



CICLO DE CALVIN-BENSON



CICLO DE CALVIN-BENSON

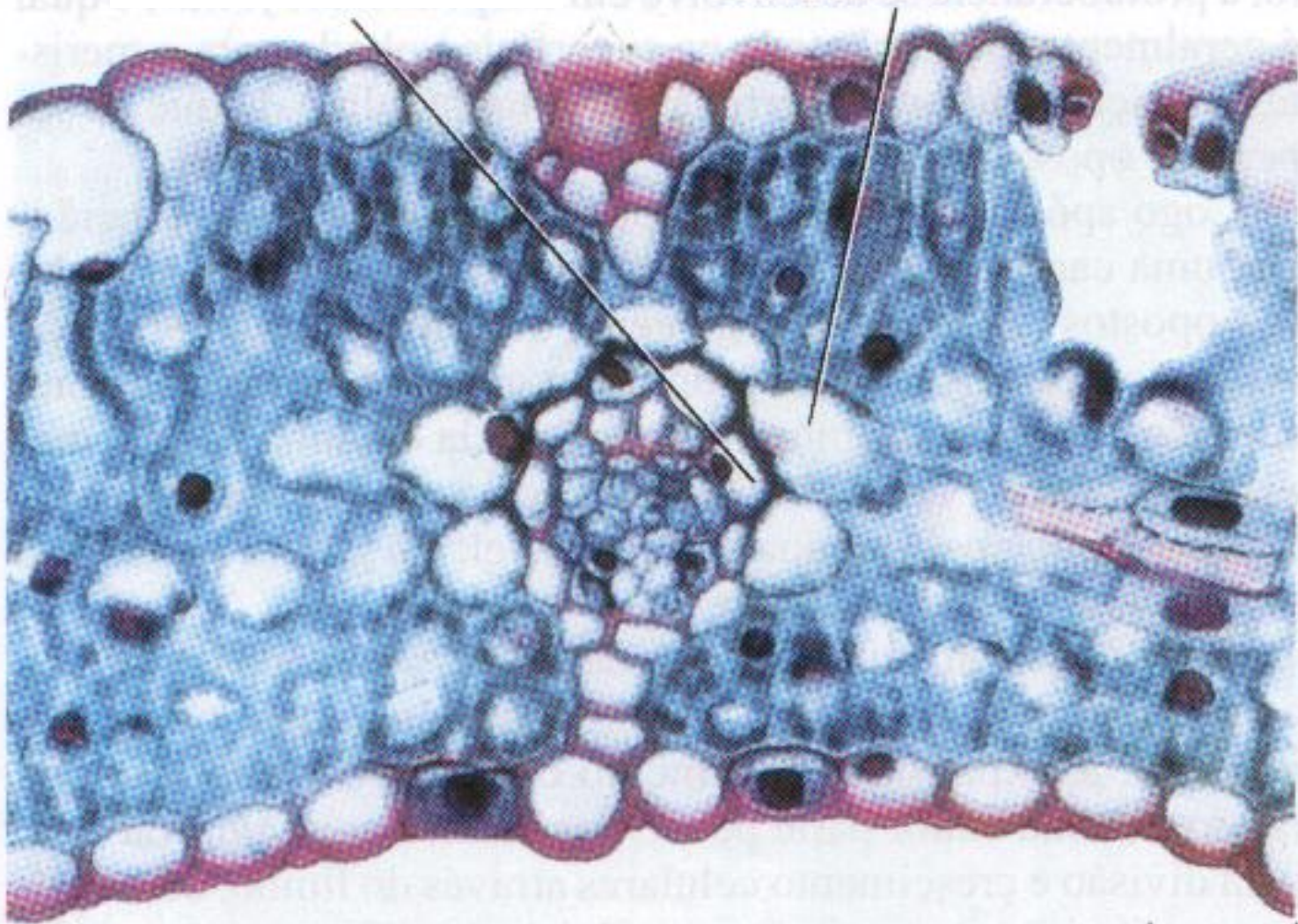
ESTÁGIO 1: FIXAÇÃO DE CO₂

ESTÁGIO 2: REDUÇÃO DE 2(3PGA) A 2 (3PGALD)

ESTÁGIO 3: REGENERAÇÃO DO RECEPTOR DE CO₂ (RuDP)

Bainha interna do feixe

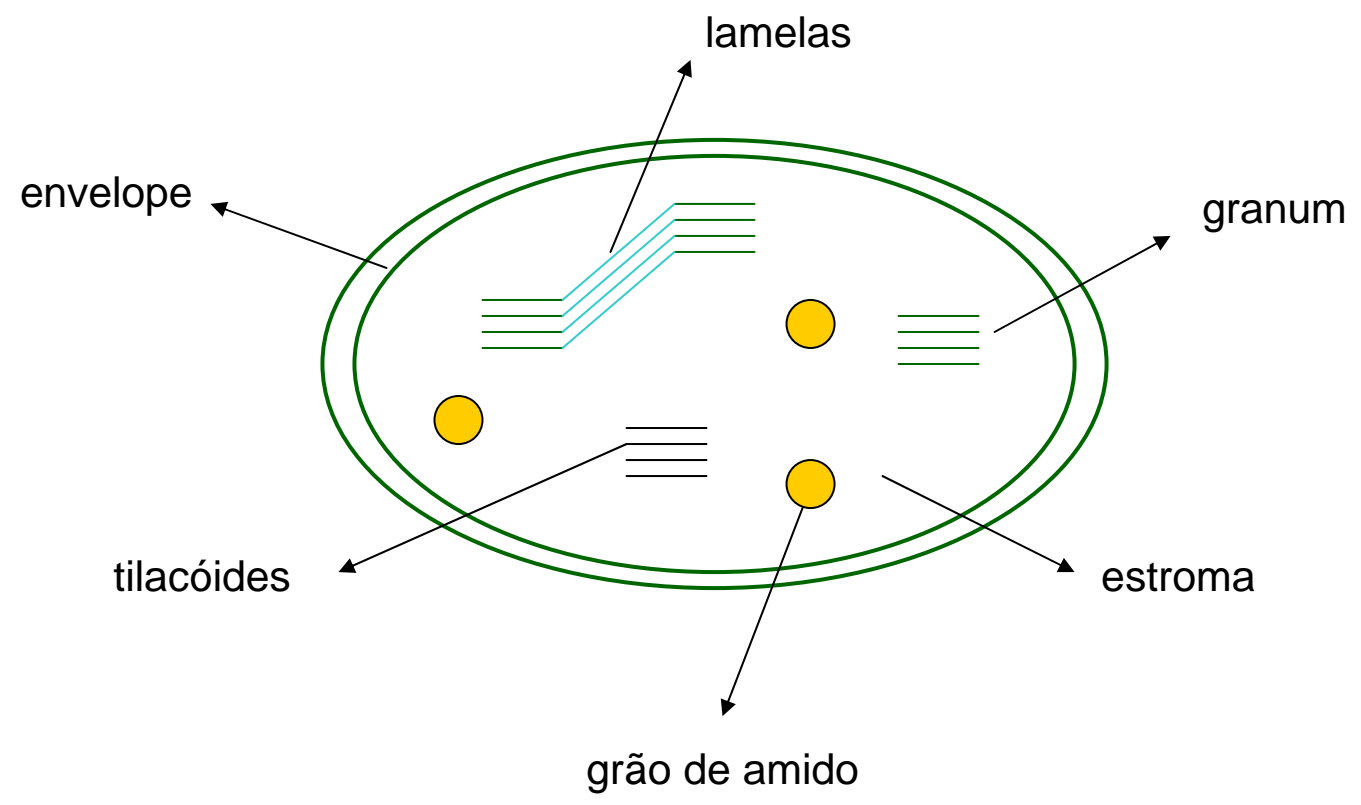
Bainha externa do feixe



25 μm

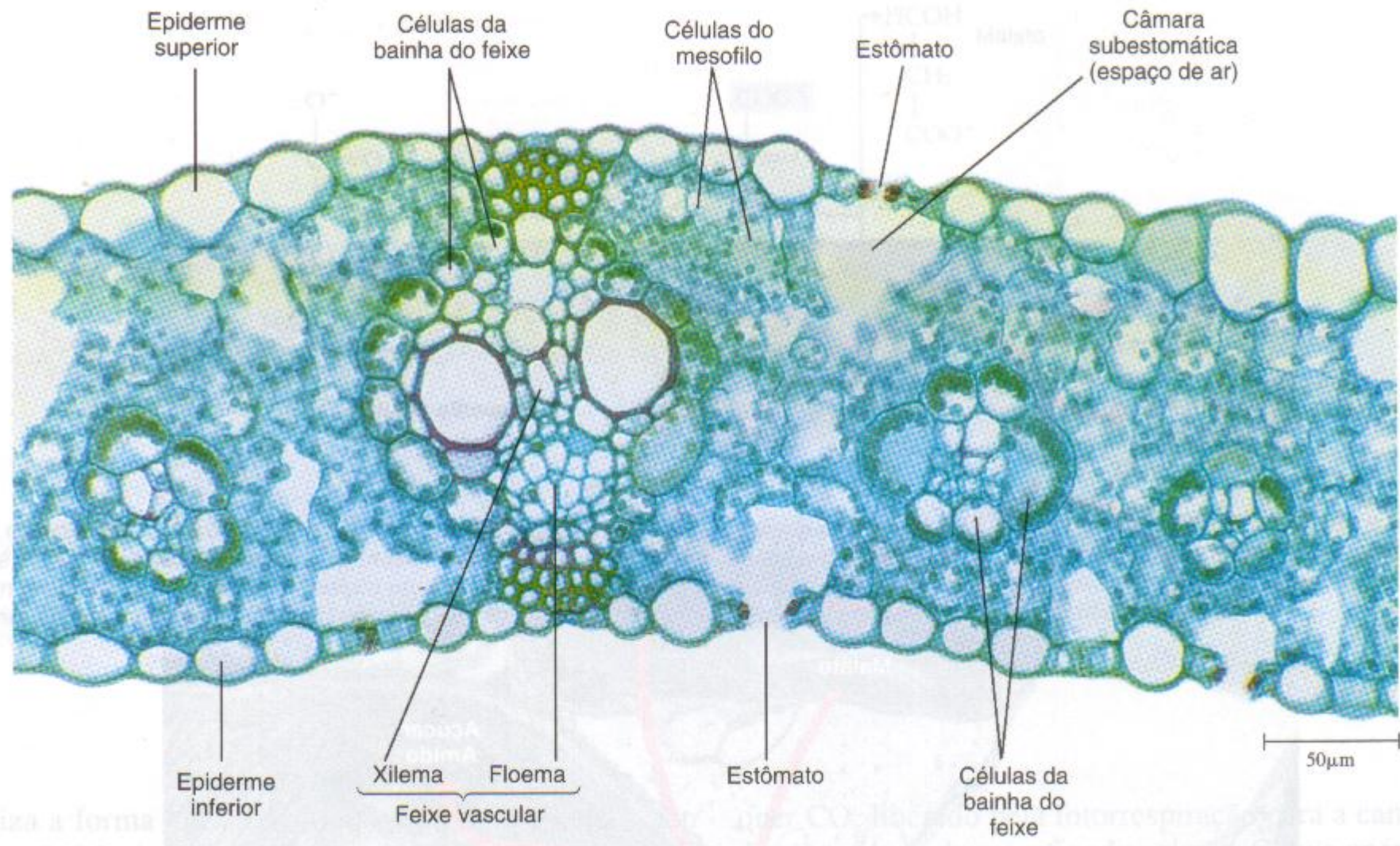
Seção transversal de folha de trigo (*Triticum aestivum*) C₃

CLOROPLASTO DO MESOFILO:



PLANTA C₄

ANATOMIA KRANZ

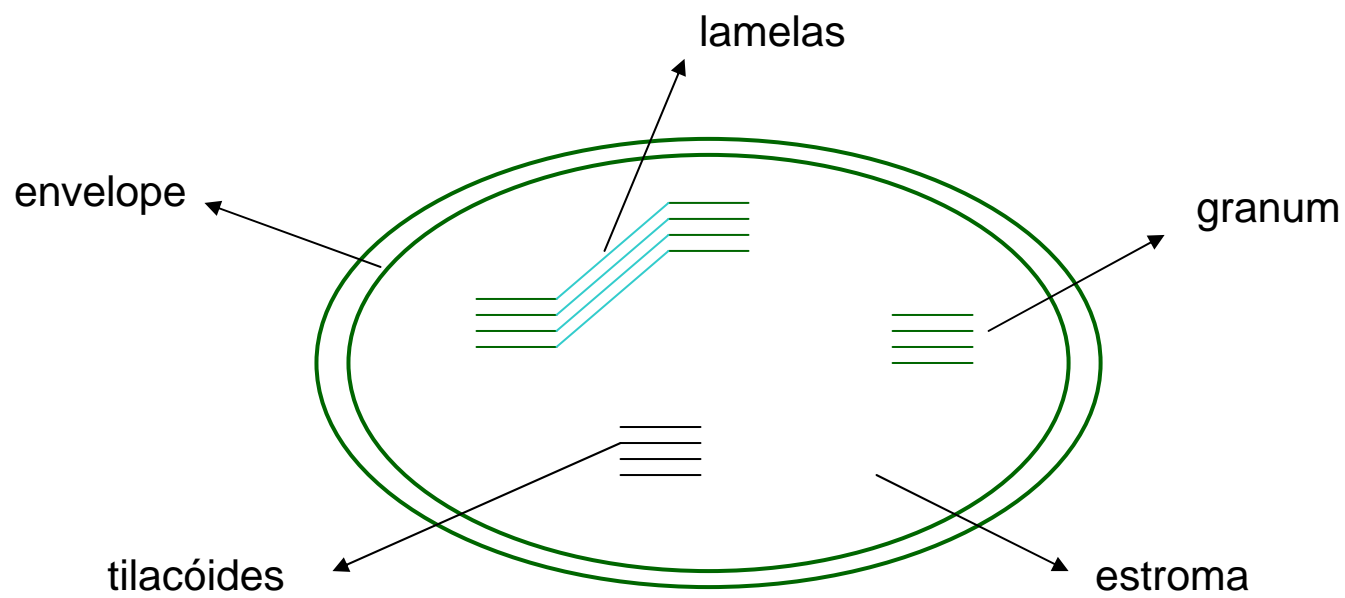


Seção transversal de folha de milho (*Zea mays*) C₄

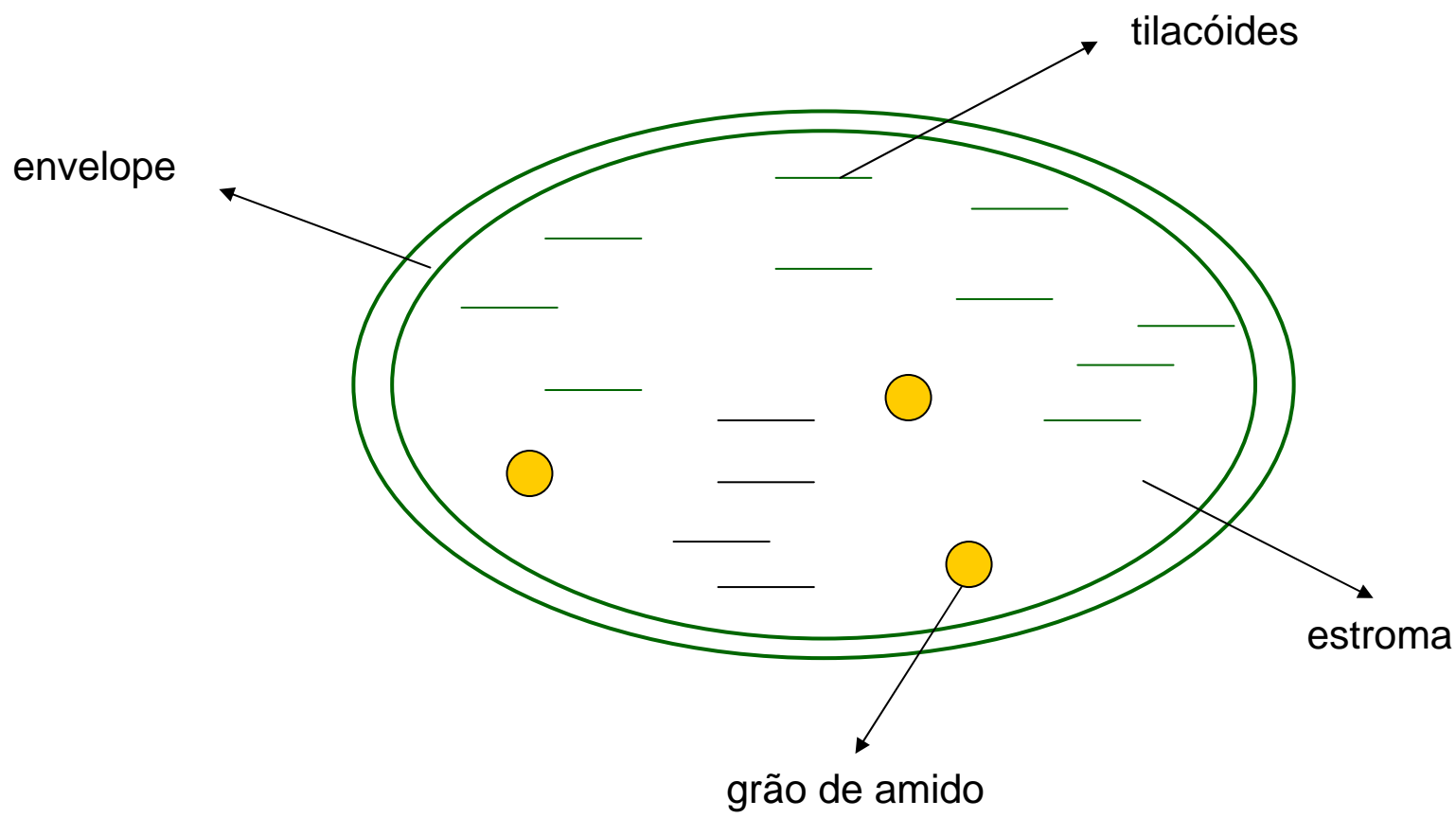
1. CLOROPLASTO DO MESOFILO

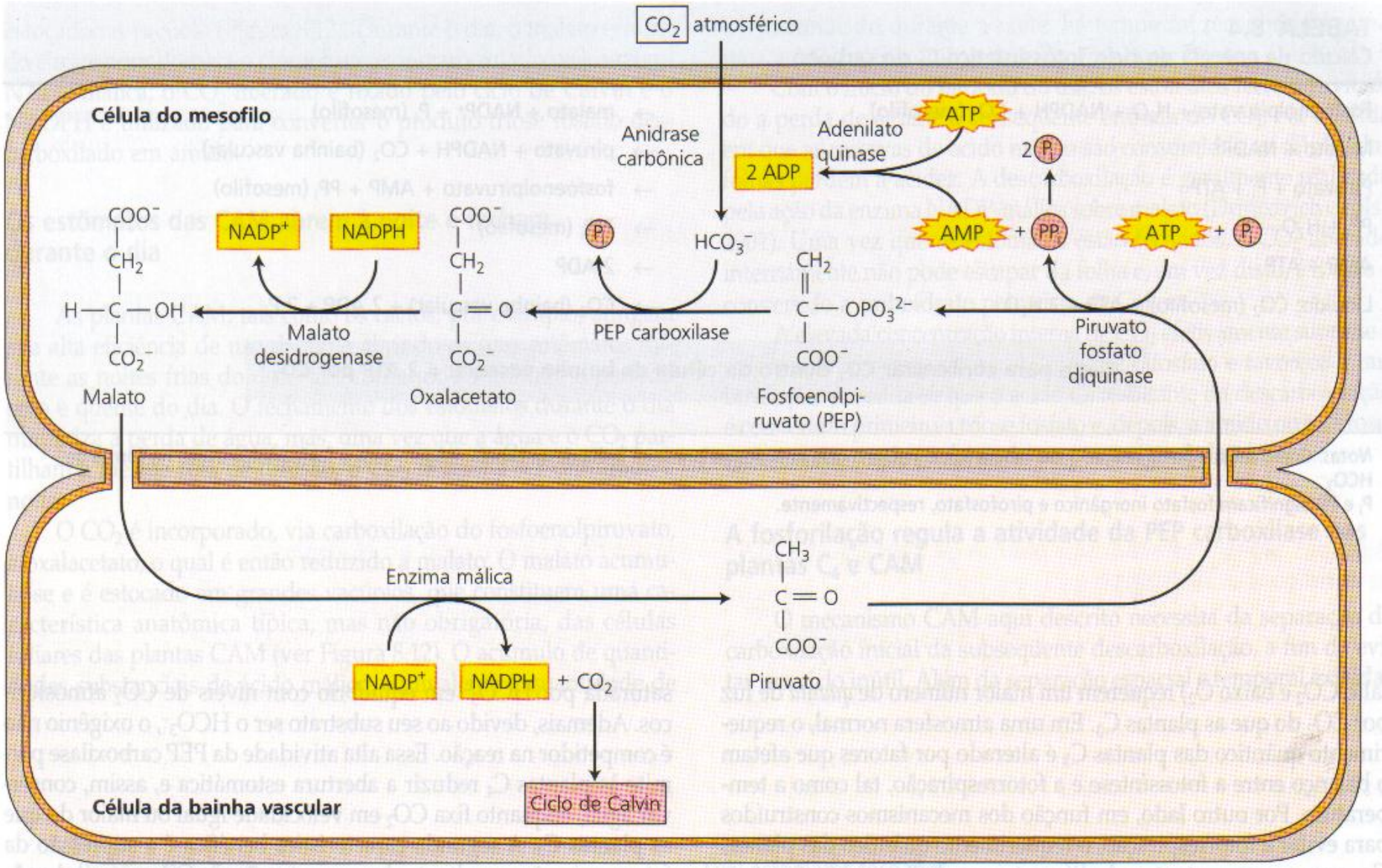
2. CLOROPLASTO DA BAINHA

CLOROPLASTO DO MESOFILO:



CLOROPLASTO DA BAINHA:



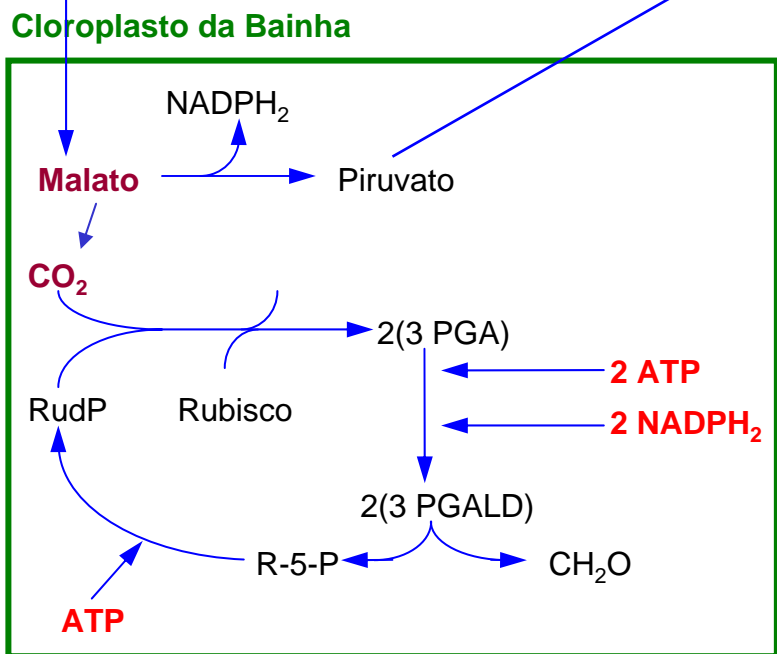
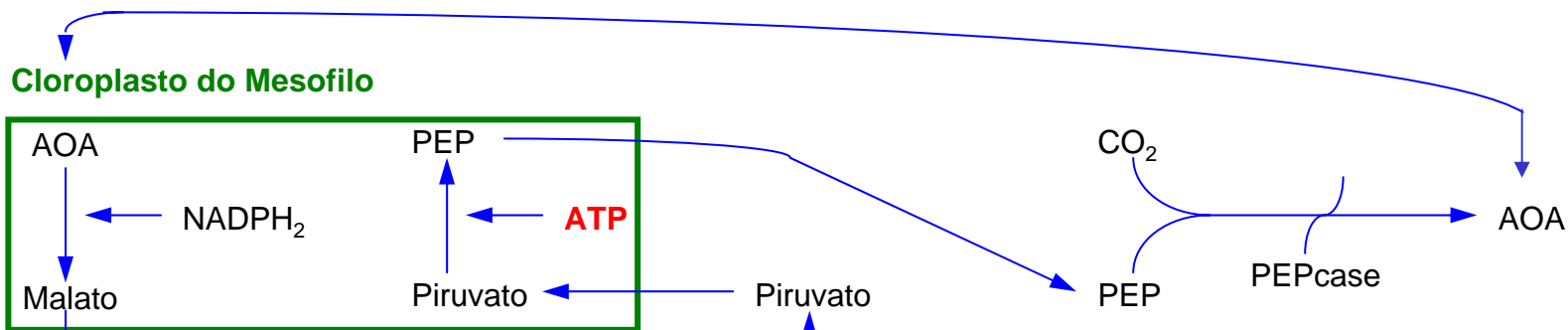


KORTSHACK et al. (1965) ¹⁴CO₂ EM CANA-DE-AÇÚCAR

CO₂ marcado + luz → 70 a 80% do marcador era recuperado em
malato e aspartato (C₄)

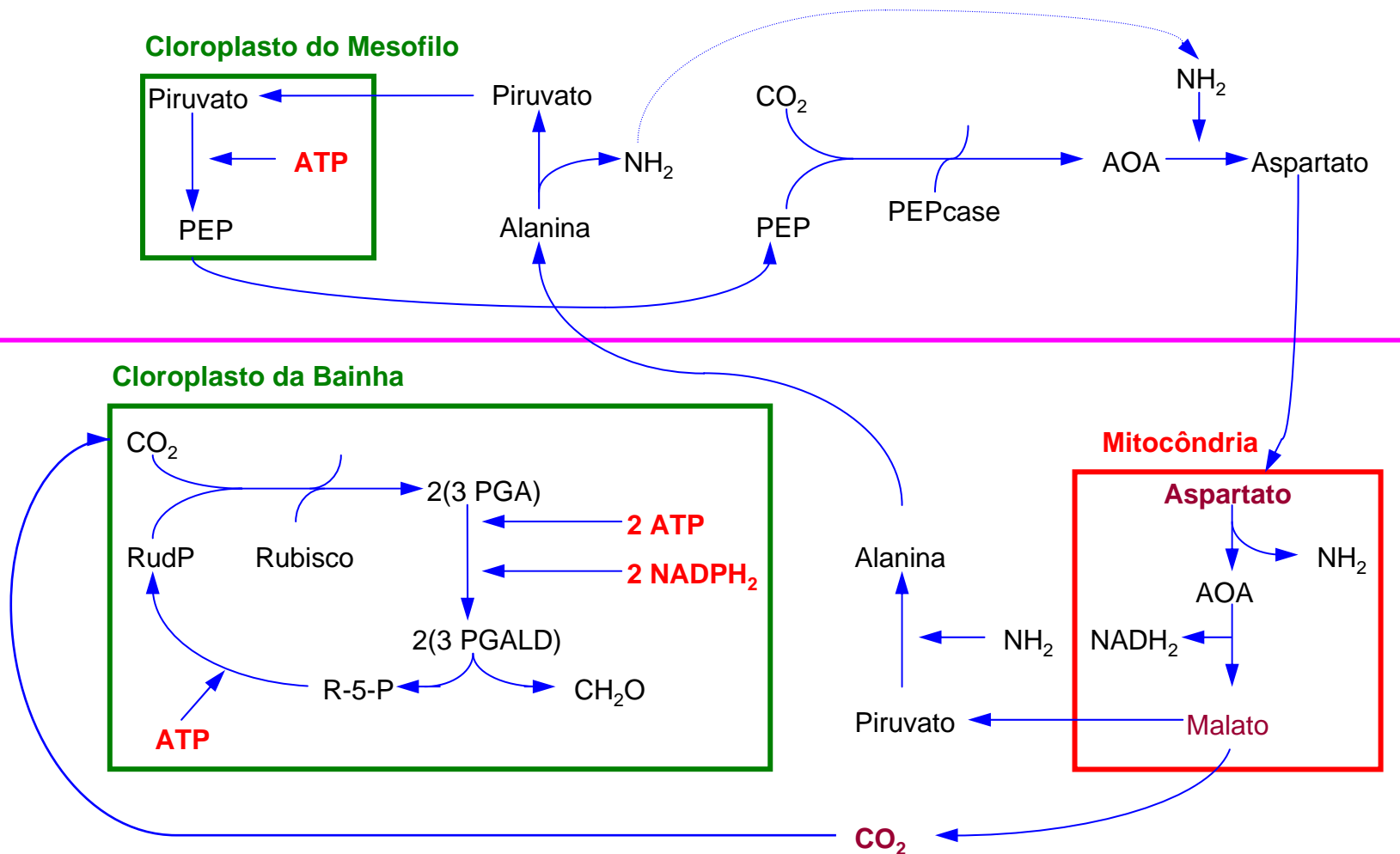
HATCH & SLACK (1966) elucidaram o ciclo C₄

Transporte de CO₂ em Plantas C₄ - Via Malato



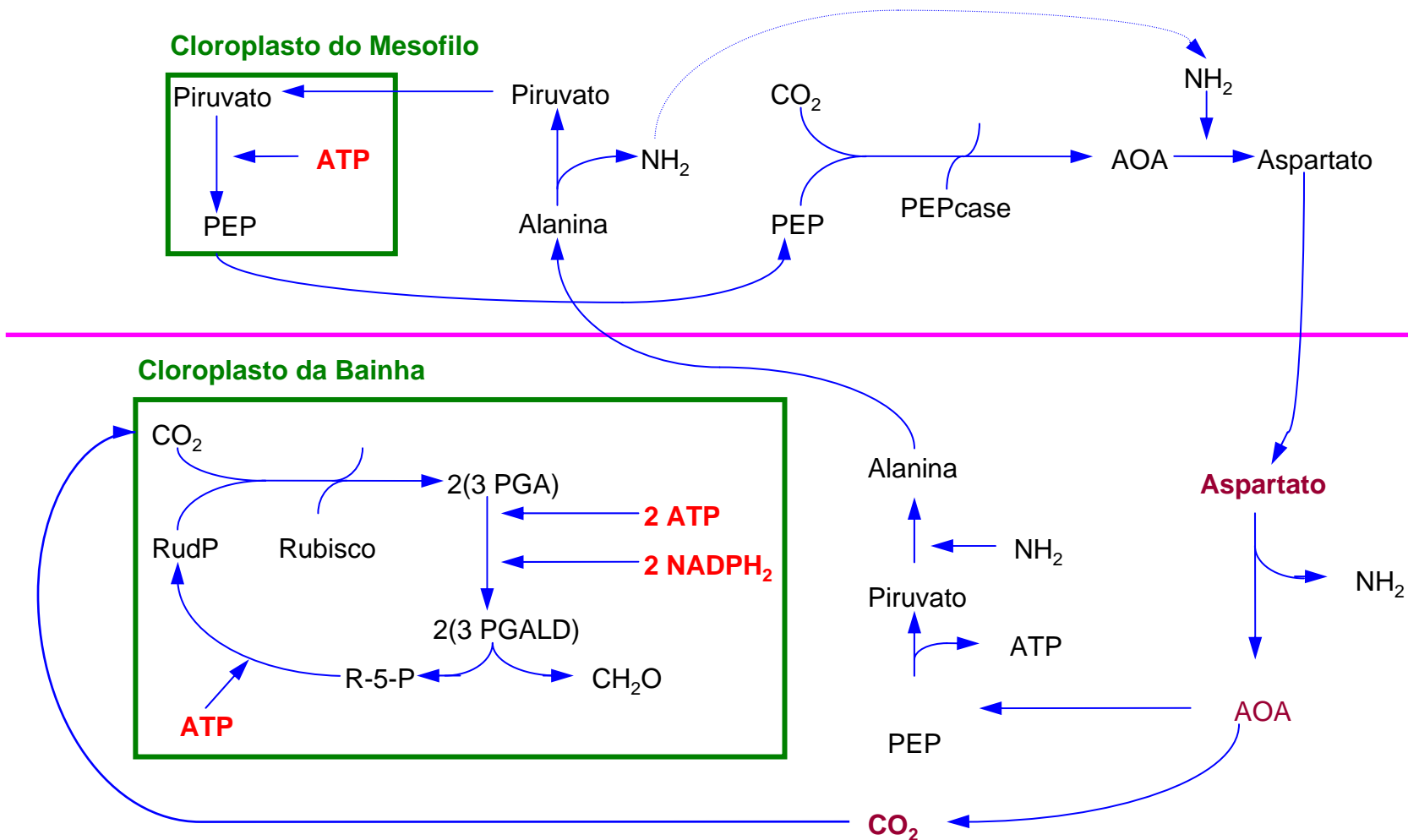
1 CO₂: 5 ATP: 2 NADPH₂

Transporte de CO₂ em Plantas C₄ - Via Aspartato 1



1 CO₂: 5 ATP: 2 NADPH₂

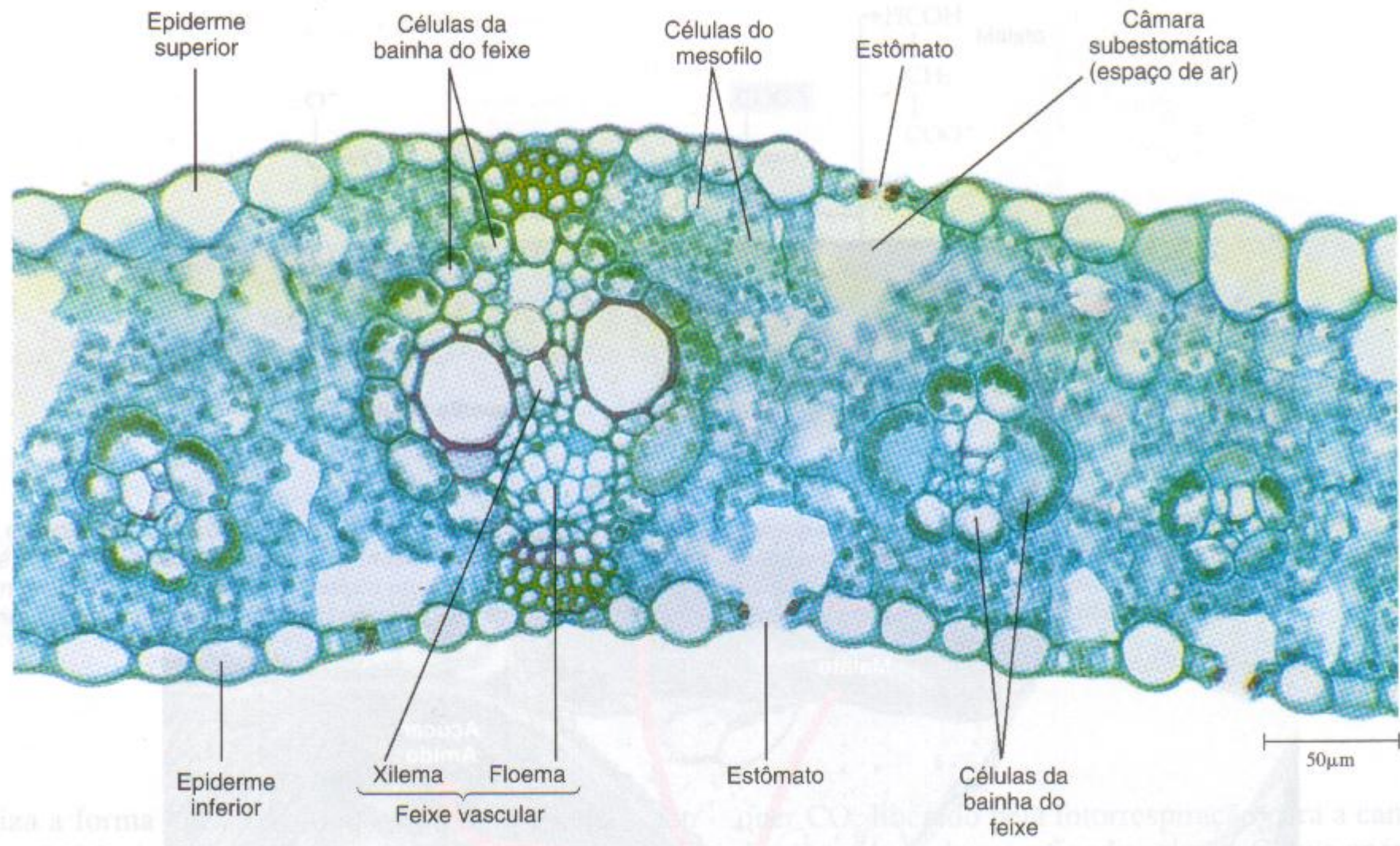
Transporte de CO₂ em Plantas C₄ - Via Aspartato 2



1 CO₂: 5 ATP: 2 NADPH₂

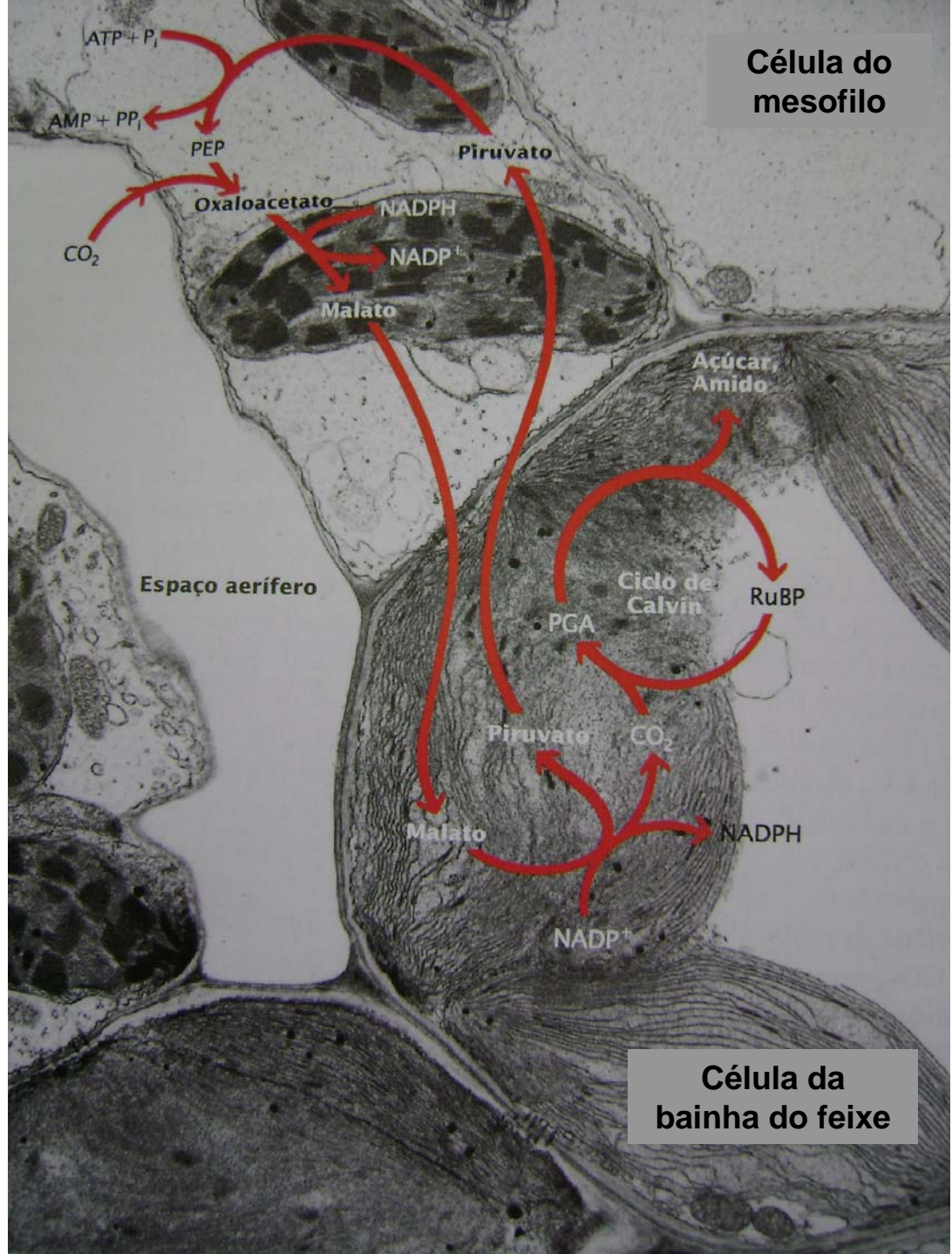
PLANTA C₄

ANATOMIA KRANZ



Seção transversal de folha de milho (*Zea mays*) C₄

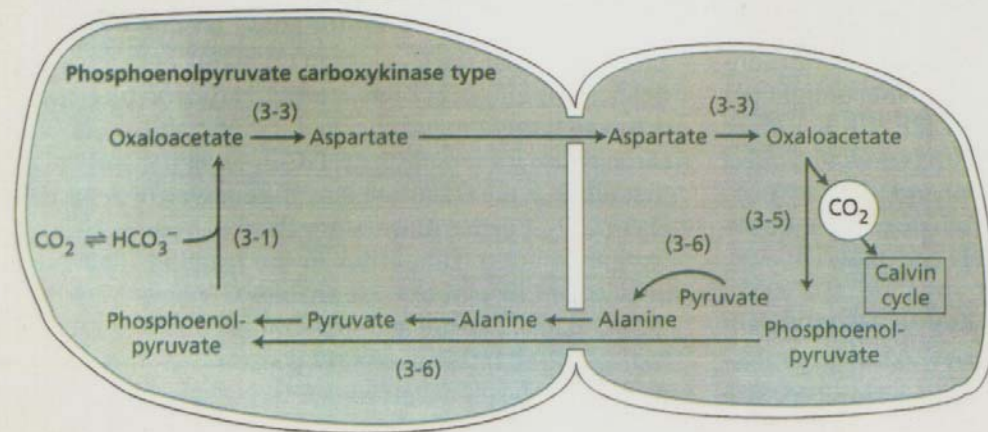
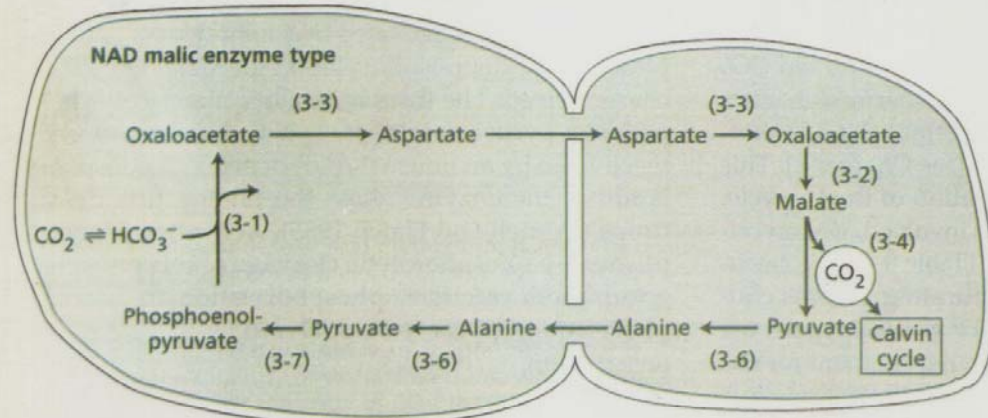
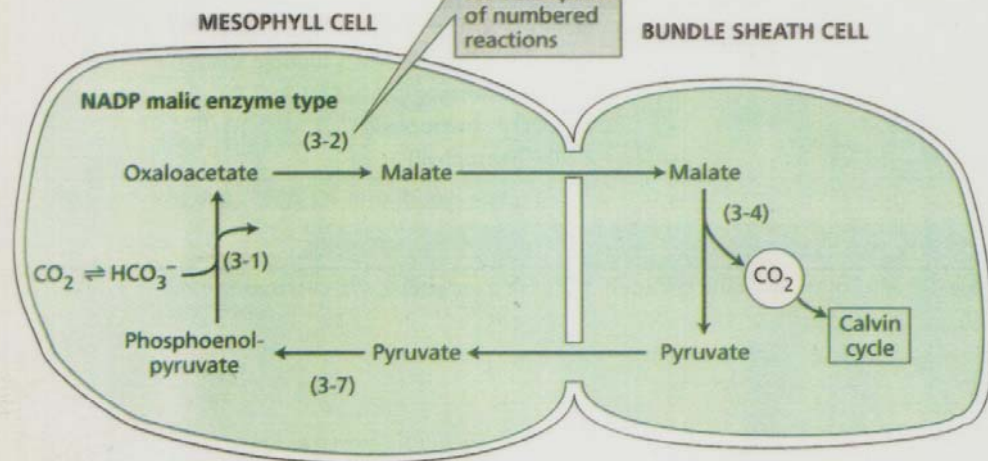
PLANTA C₄



Célula do mesofilo

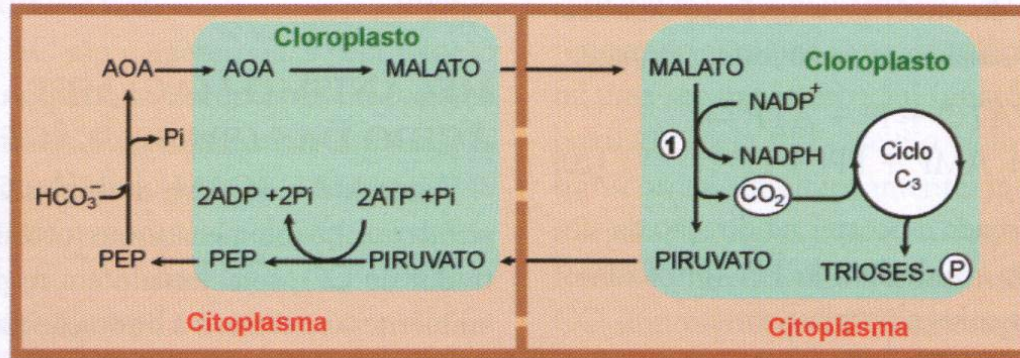
Célula da bainha do feixe

See Table 8.3 for description of numbered reactions

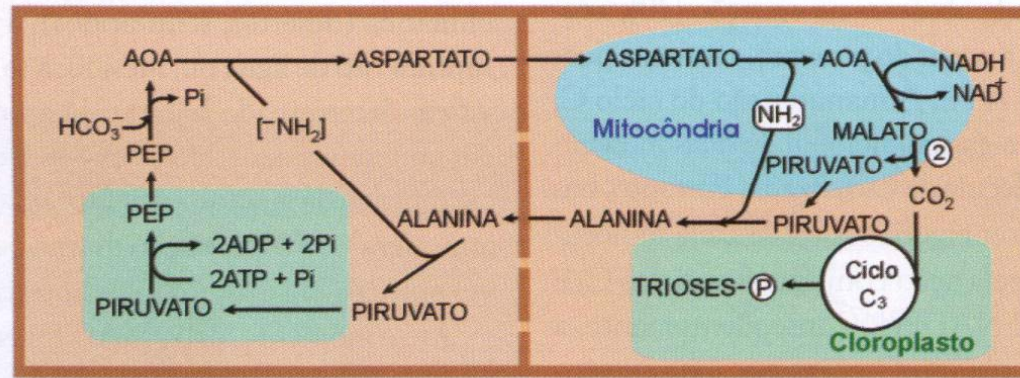


CÉLULA DO MESÓFILO

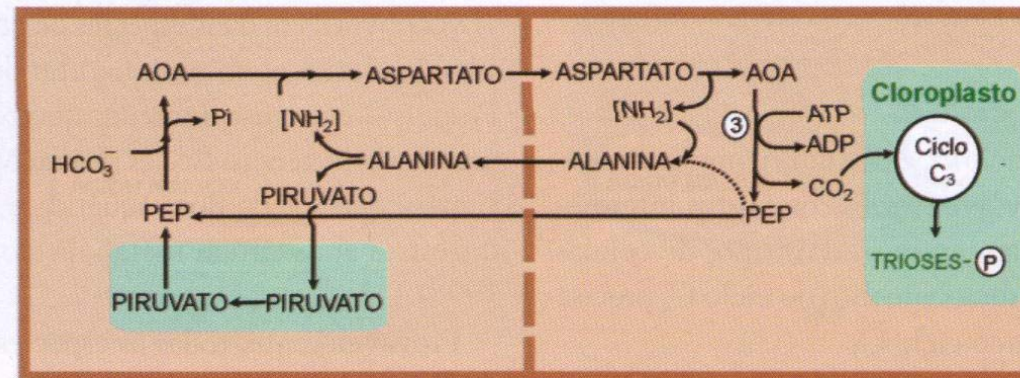
BAINHA PERIVASCULAR



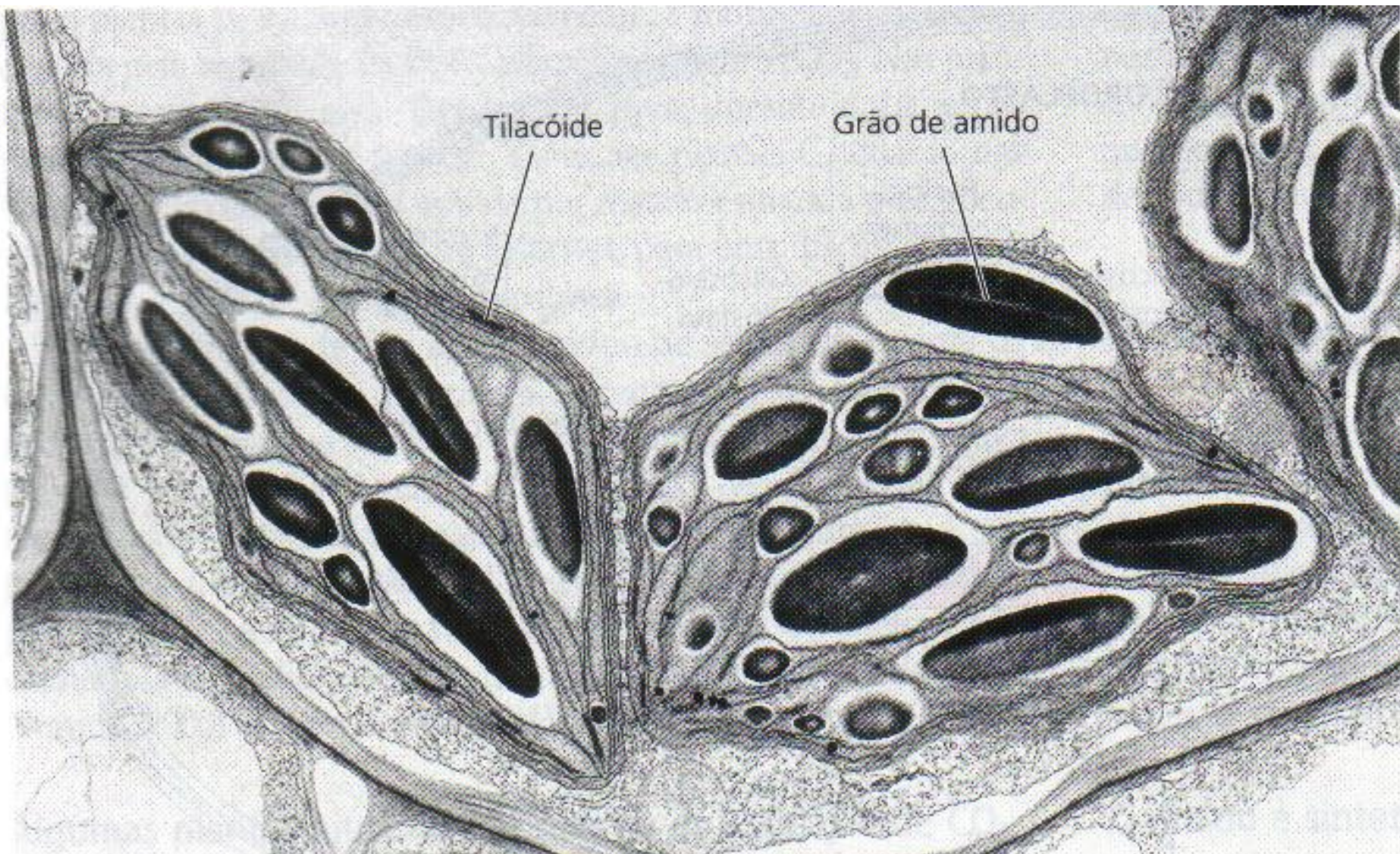
① ENZIMA MÁLICA DEPENDE DE NADP



② ENZIMA MÁLICA DEPENDE DE NAD

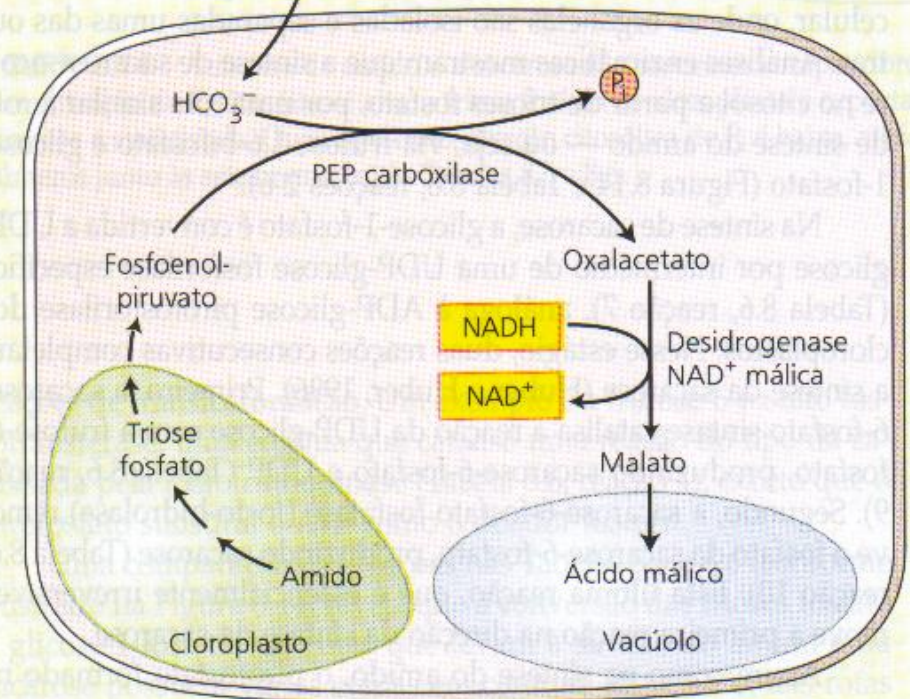
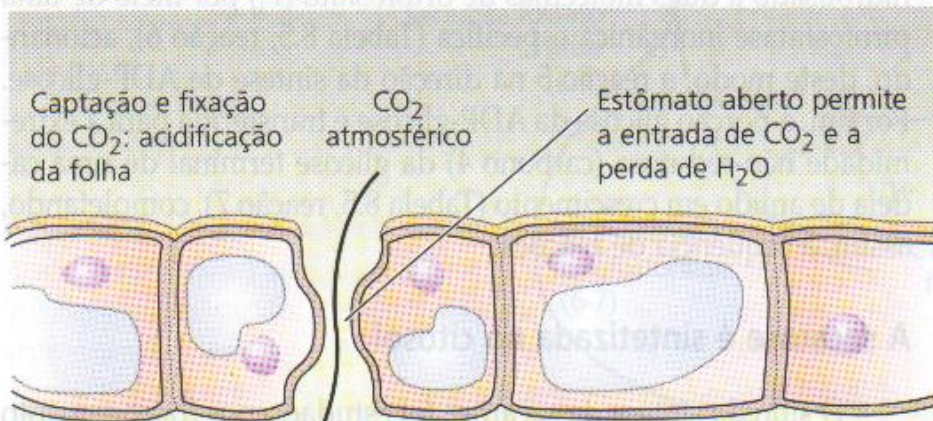


③ FOSFOENOLPIRUVATO CARBOXICINASE

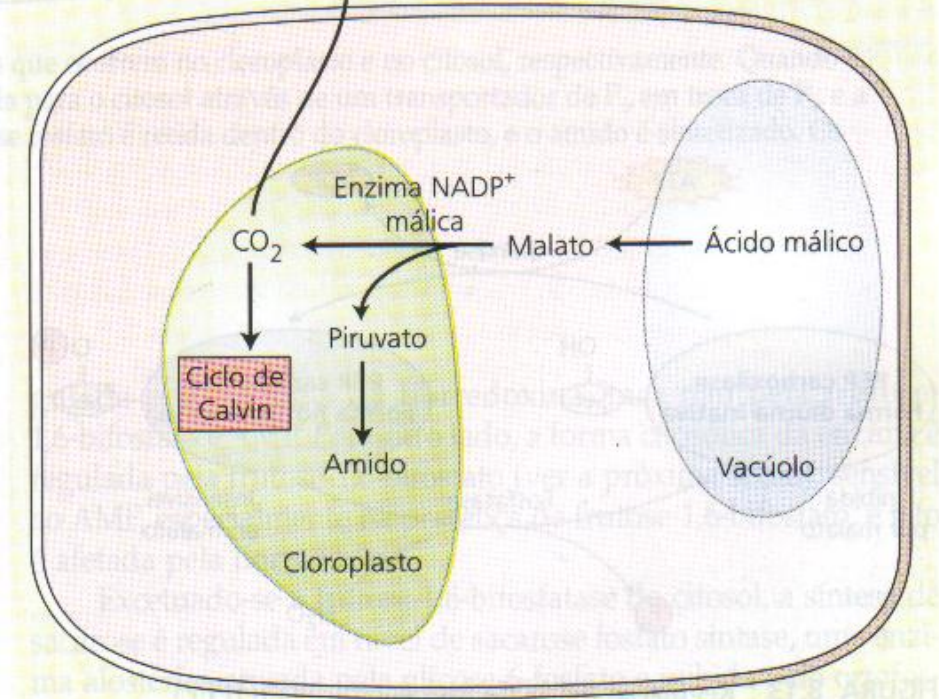
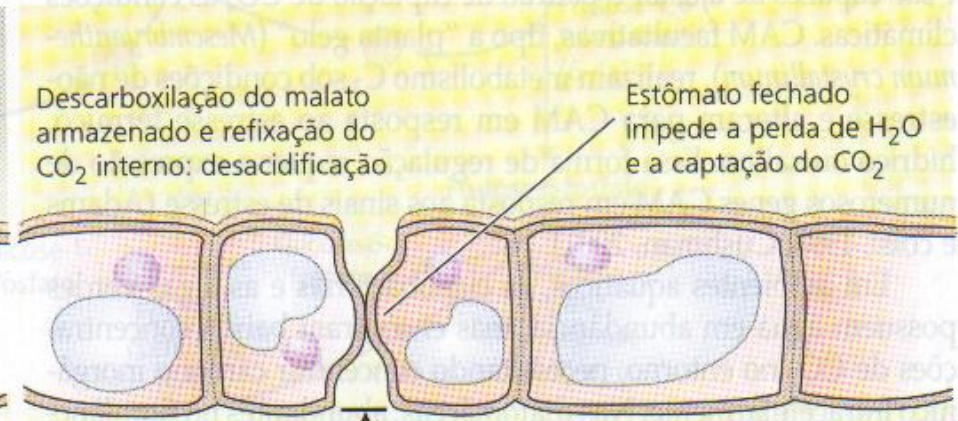


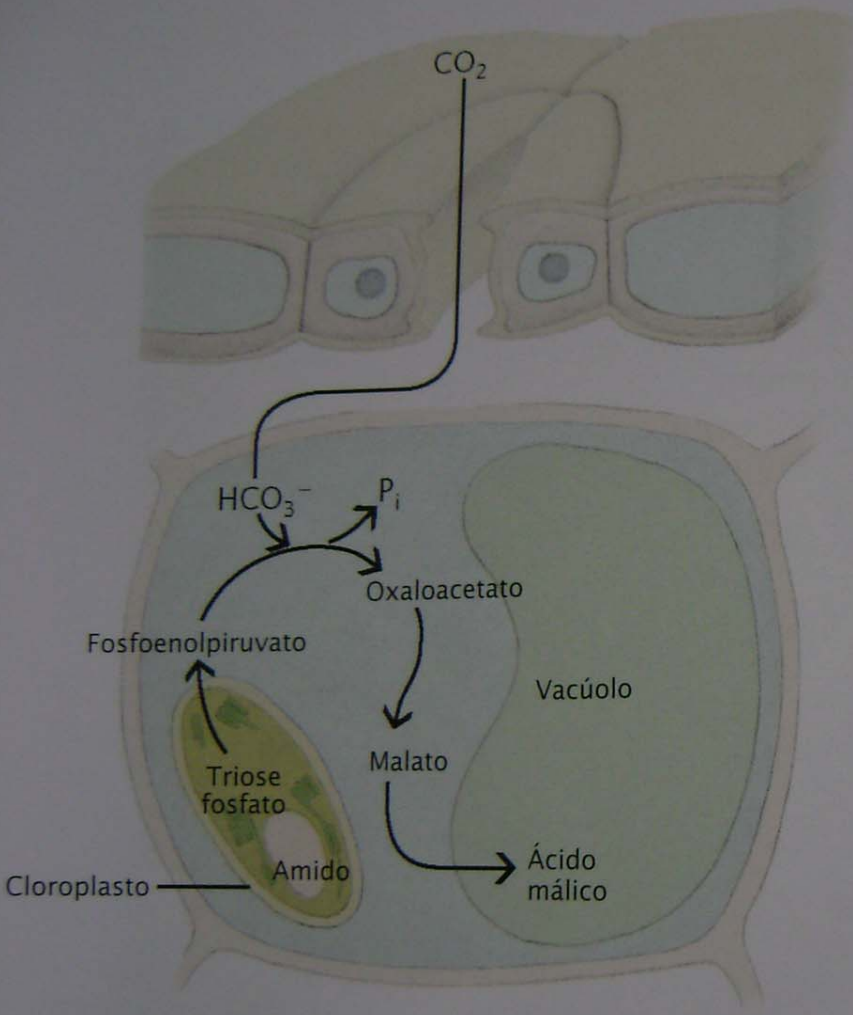
Electromicrografia de uma célula da bainha vascular de milho (C₄) mostrando grãos de amido nos cloroplastos 15.800 x

Escuro: estômatos abertos

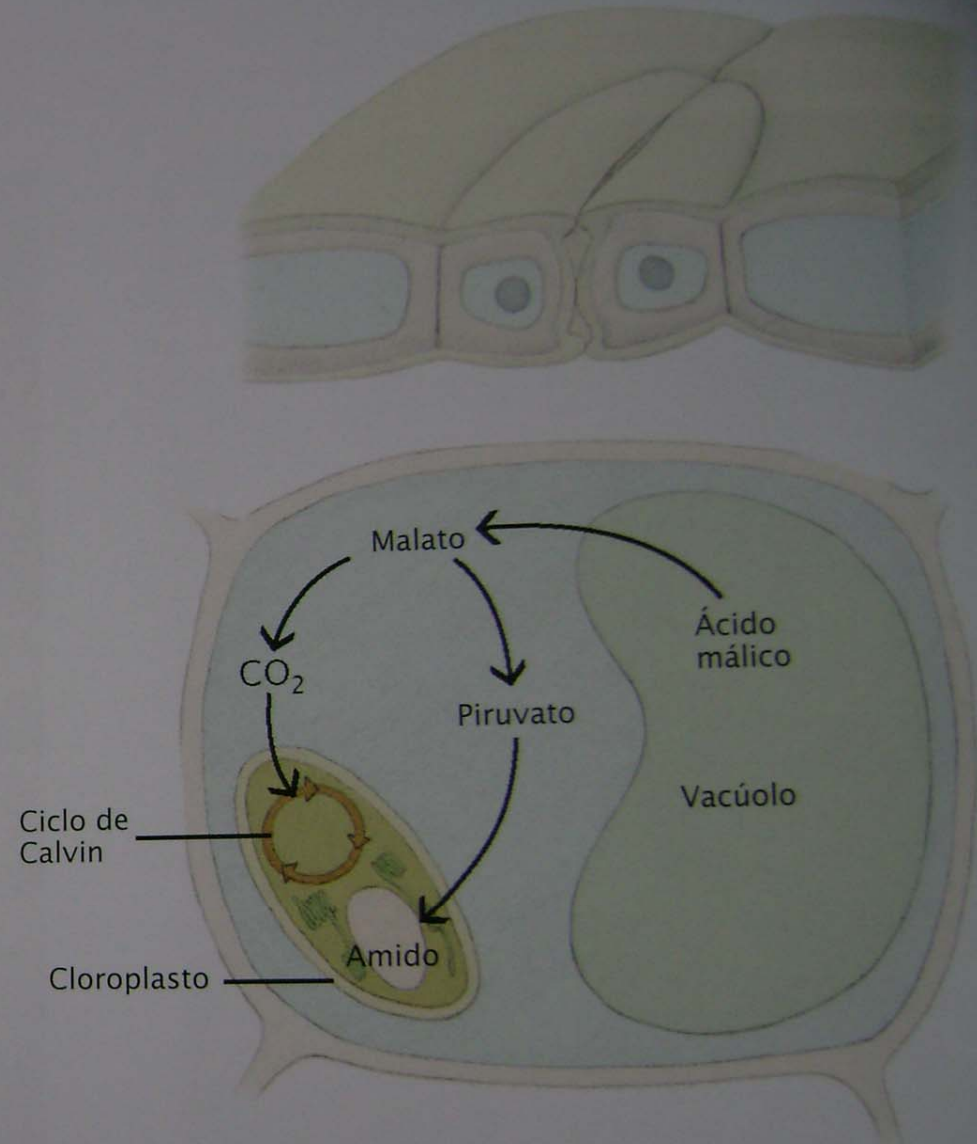


Luz: estômatos fechados





(a) Noite: estômatos abertos



(b) Dia: estômatos fechados

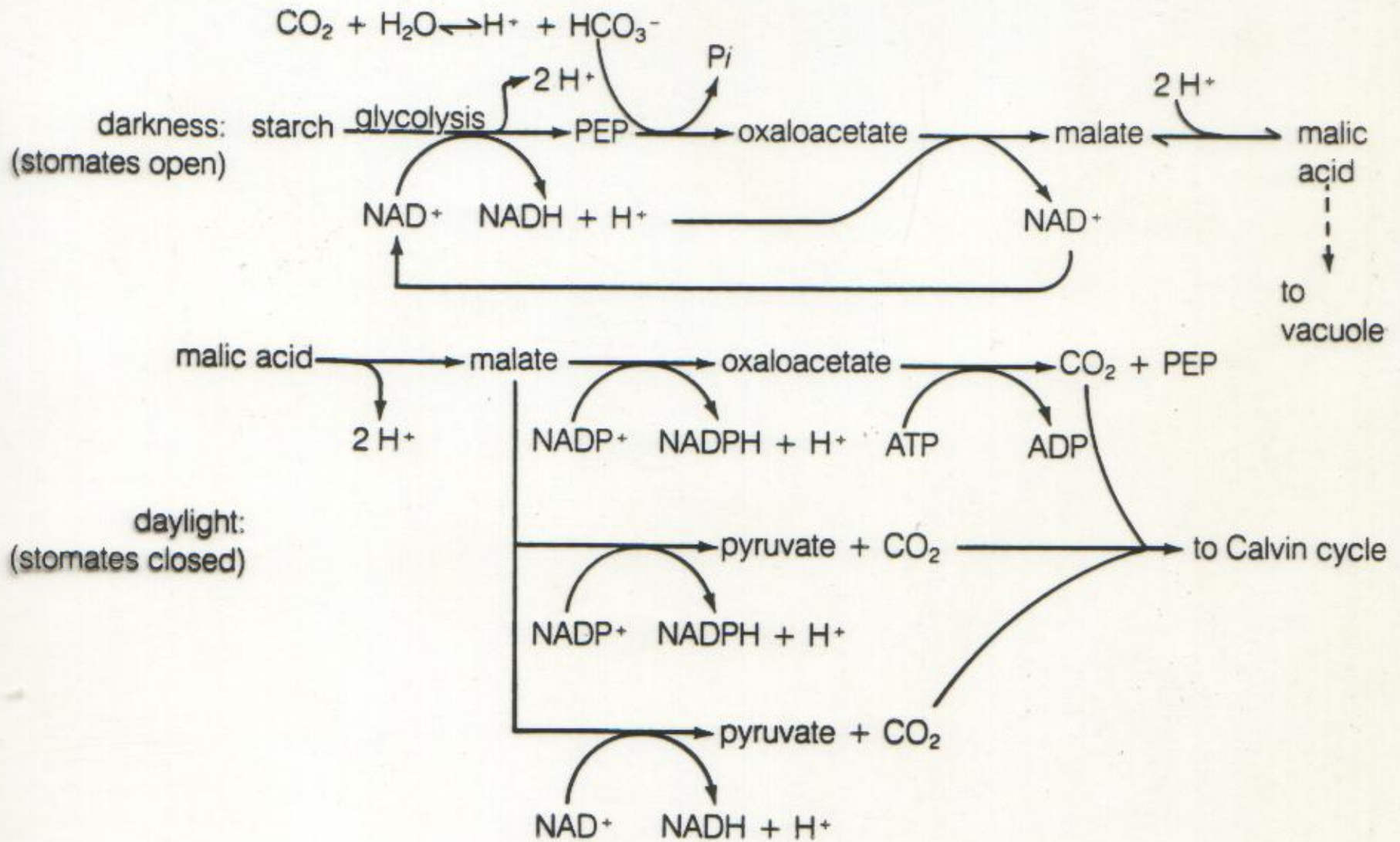
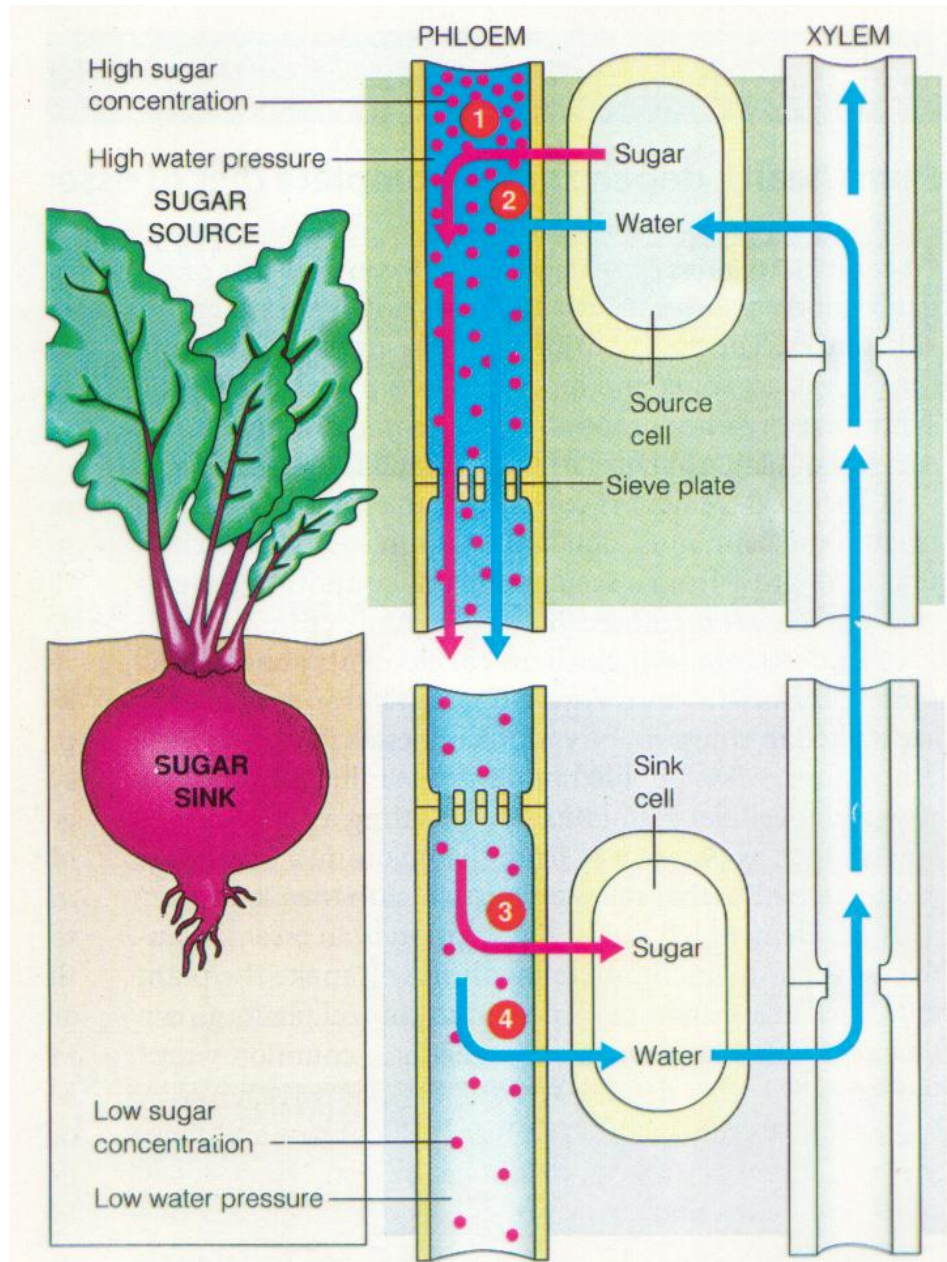


Figure 11-14 A summary of CO_2 fixation in CAM plants.

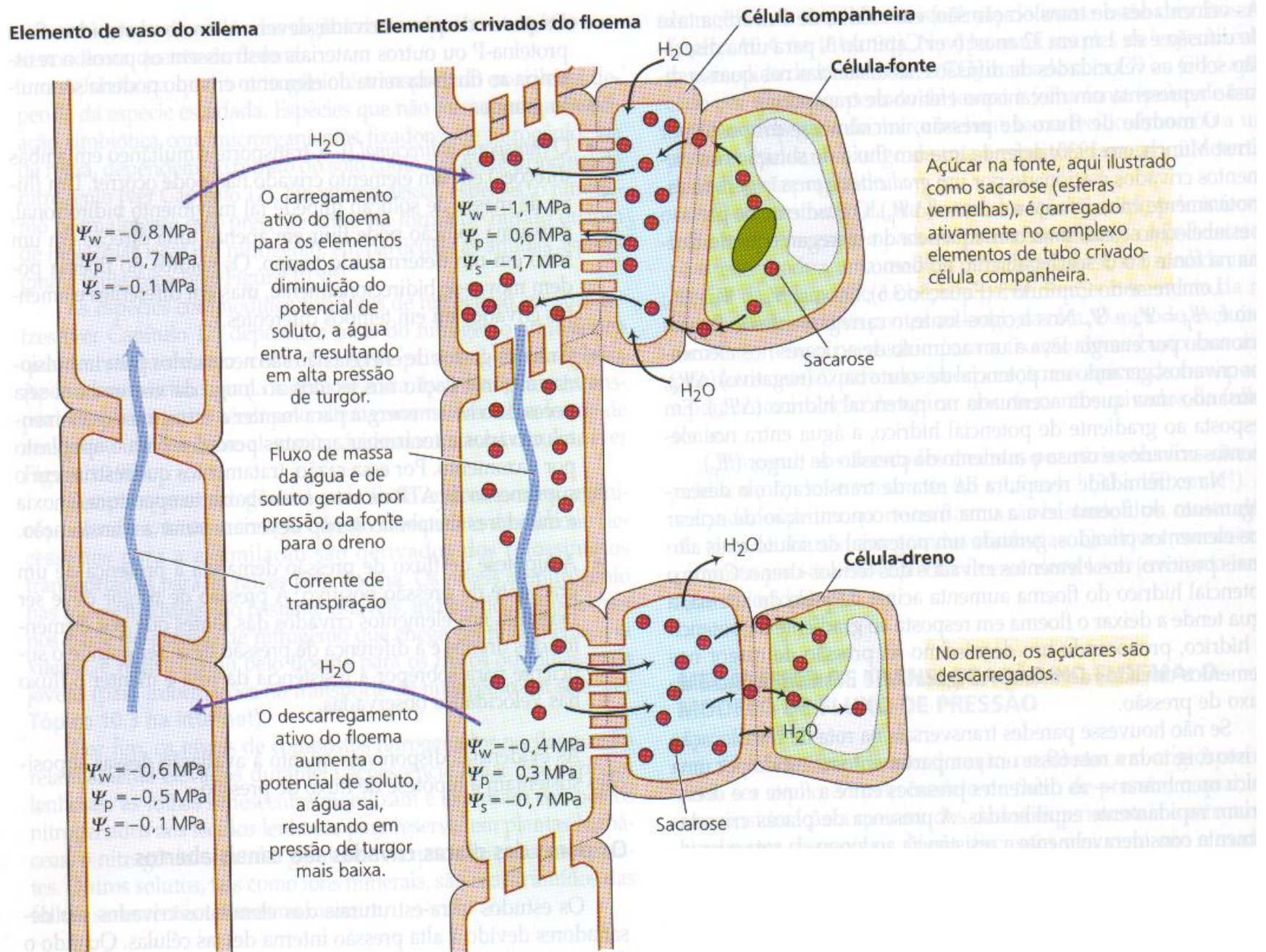
1 CO_2 : 6 ATP ou 5 ATP : 2 NADPH_2

CARREGAMENTO E DESCARREGAMENTO DO FLOEMA

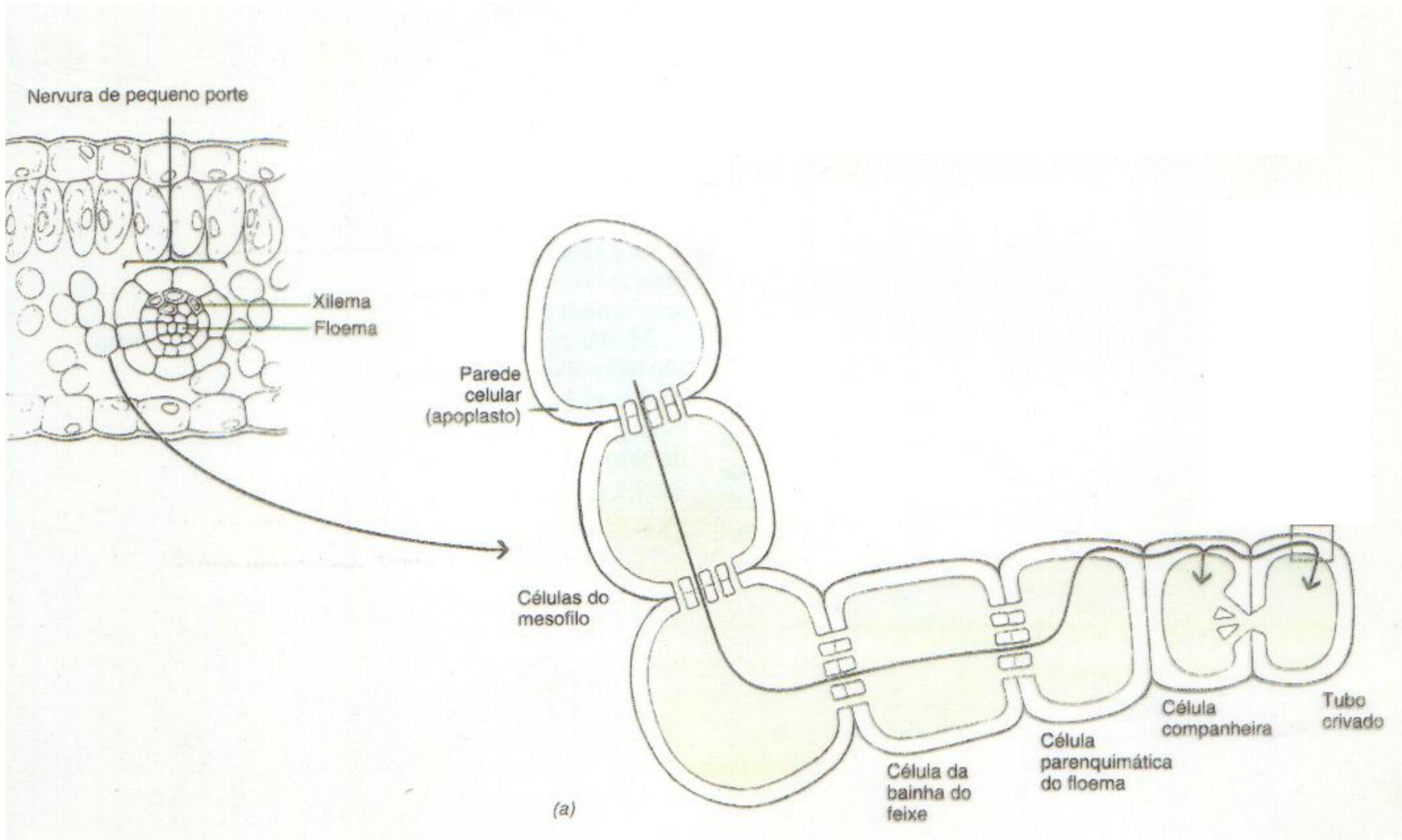


PRESSÃO DO FLOEMA DE UMA FONTE DE AÇÚCAR PARA UM DRENO

CARREGAMENTO E DESCARREGAMENTO DO FLOEMA



CARREGAMENTO E DESCARREGAMENTO DO FLOEMA



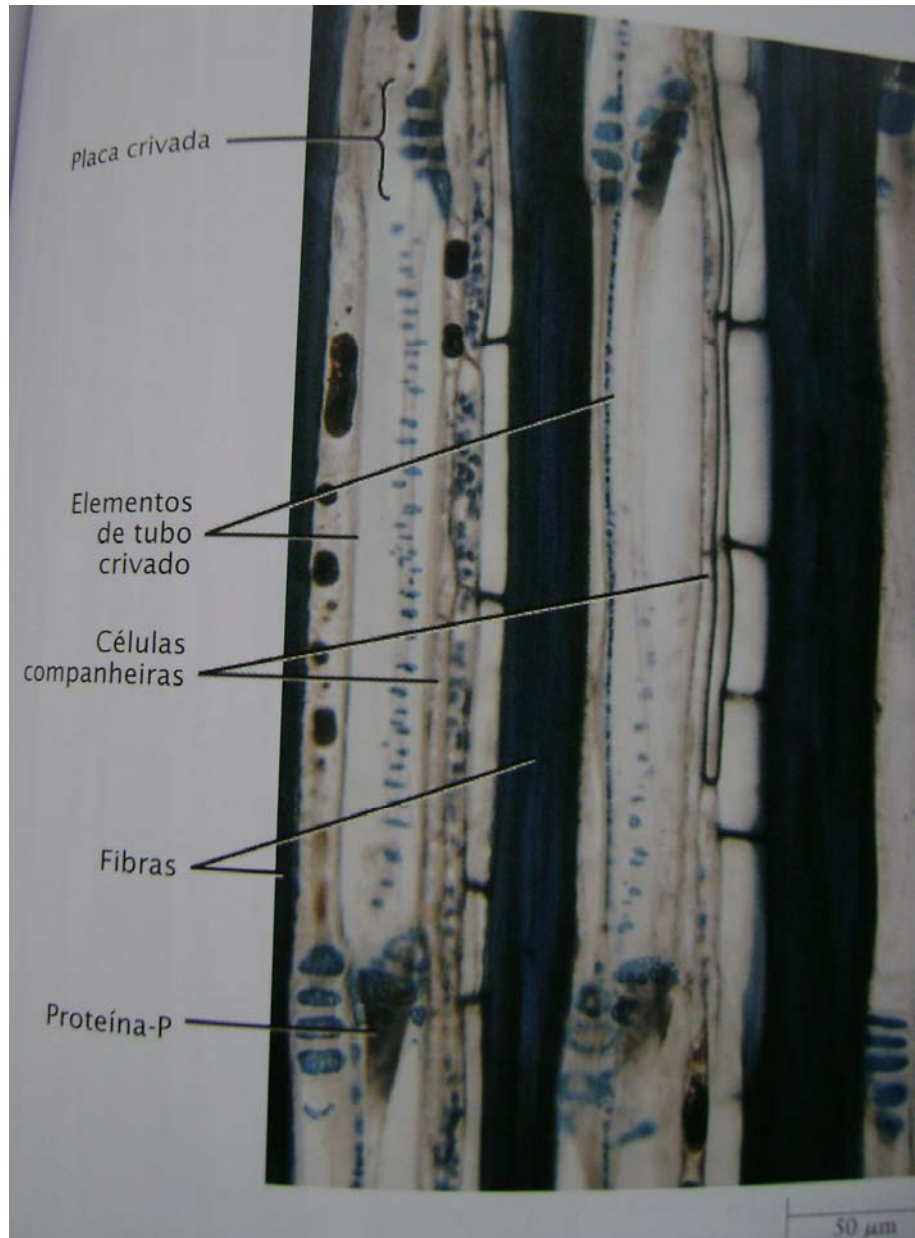
CARREGAMENTO DO FLOEMA A PARTIR DO APOPLASTO OU PAREDE CELULAR

EXUDAÇÃO DO FLOEMA



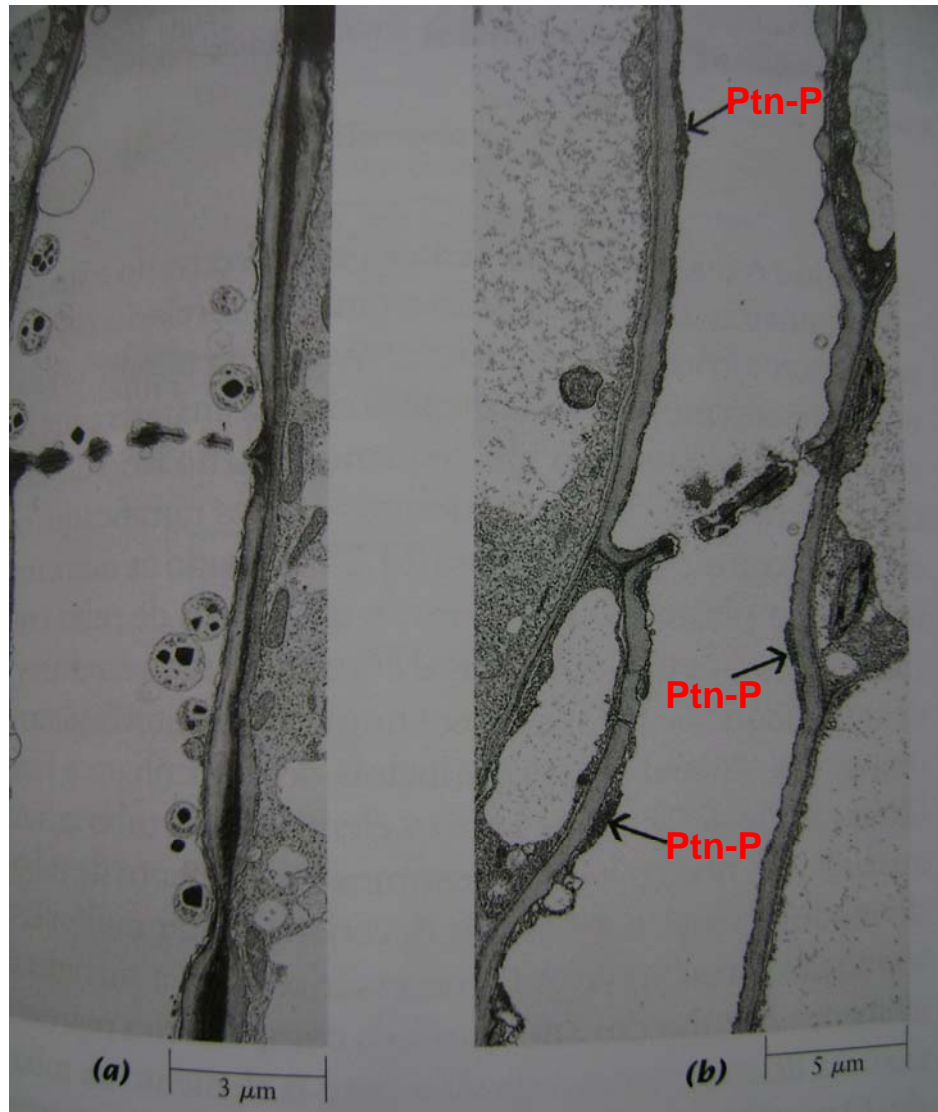
DÓLAR / HERA-SUECA (*Plectranthus mummularius* – LABIATAE)

ELEMENTOS DE TUBO CRIVADO



Seção longitudinal do floema secundário de *Tilia americana*

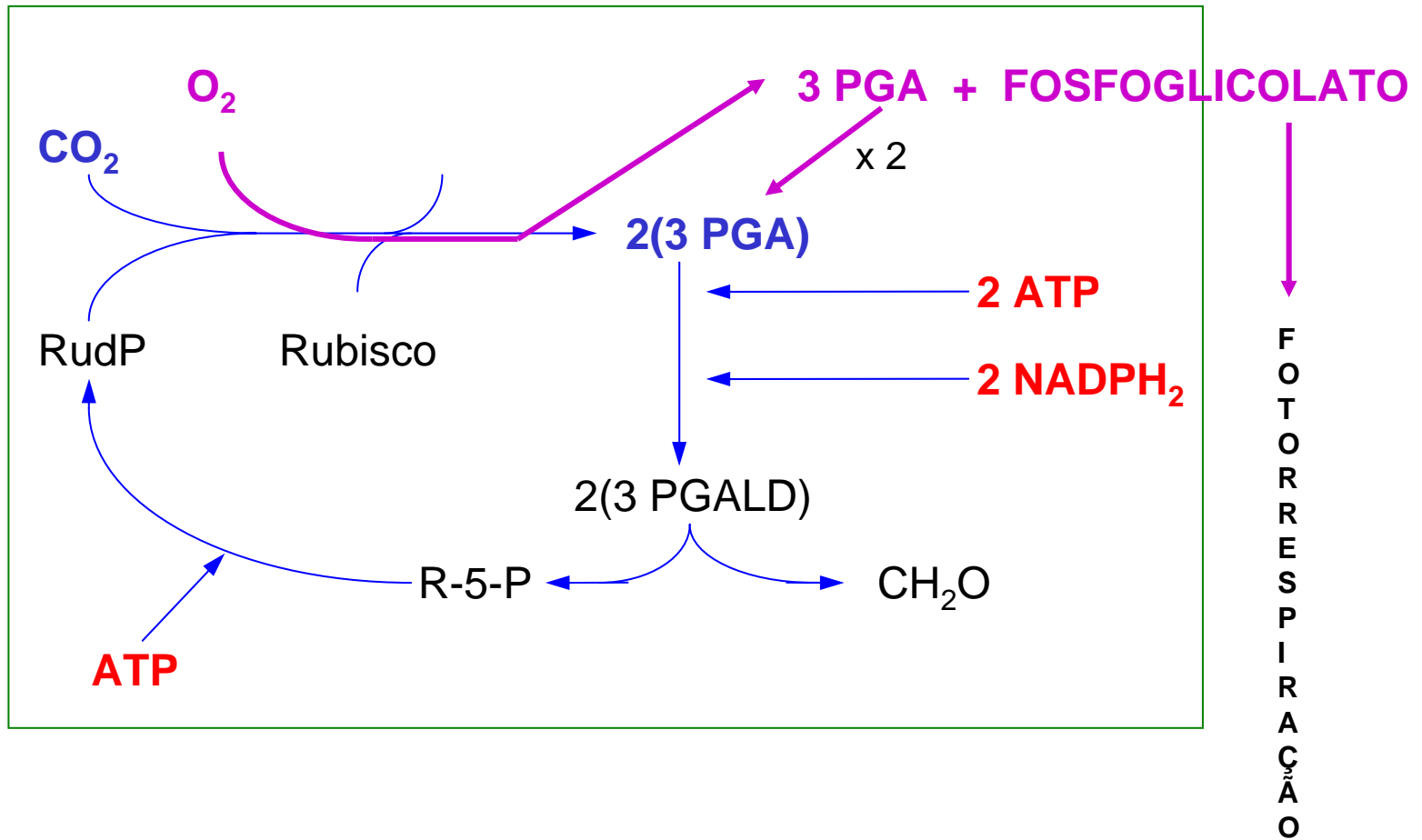
ELEMENTOS DE TUBO CRIVADO



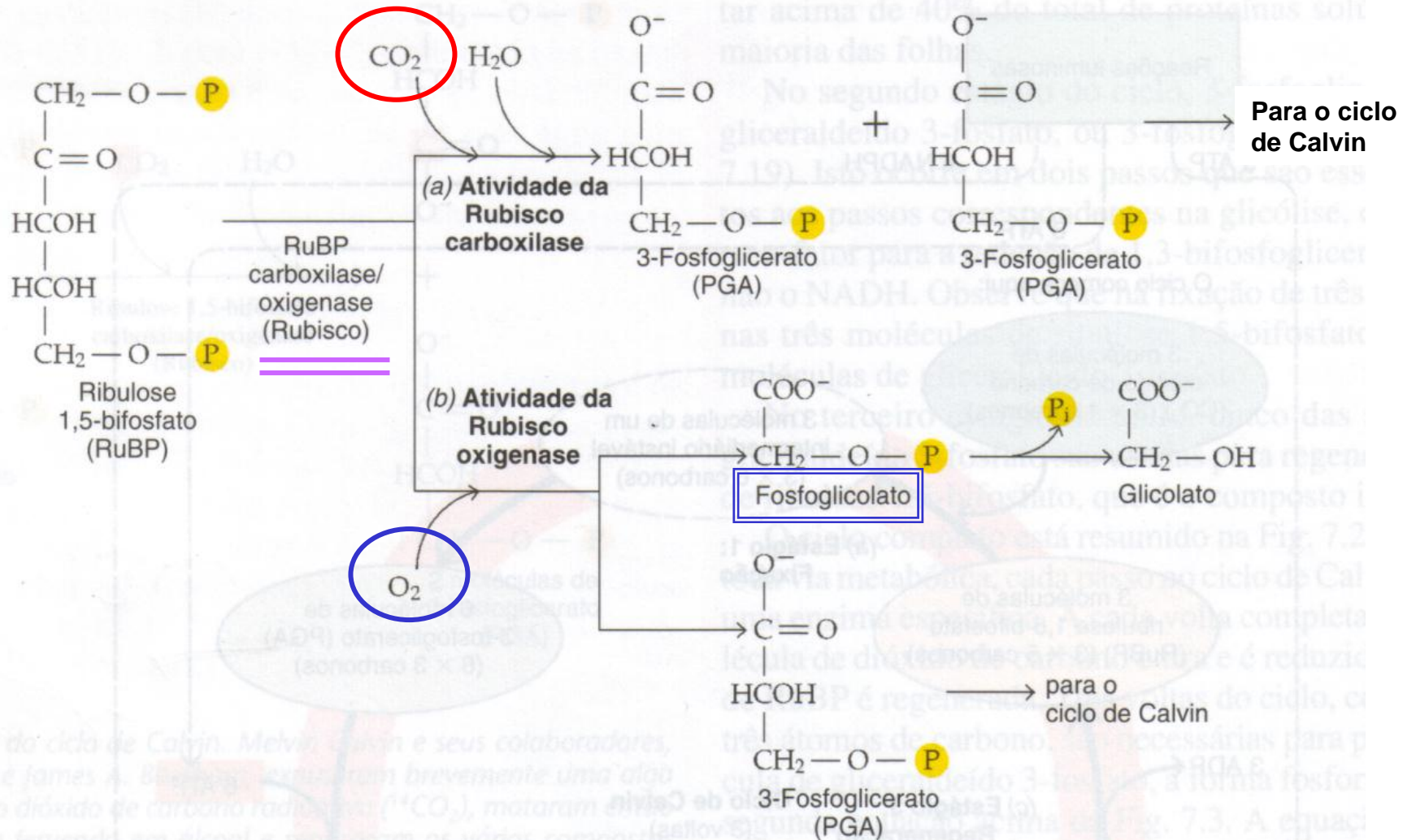
Electromicrografia de transmissão

- a) Floema de caule de milho (monocotiledônea – sem Proteína-P)
- b) Floema do caule de abóboreira (maioria das angiospermas - com Proteína-P)

CICLO DE CALVIN-BENSON



CICLO FOTOSSINTÉTICO OXIDATIVO C₂ DO CARBONO



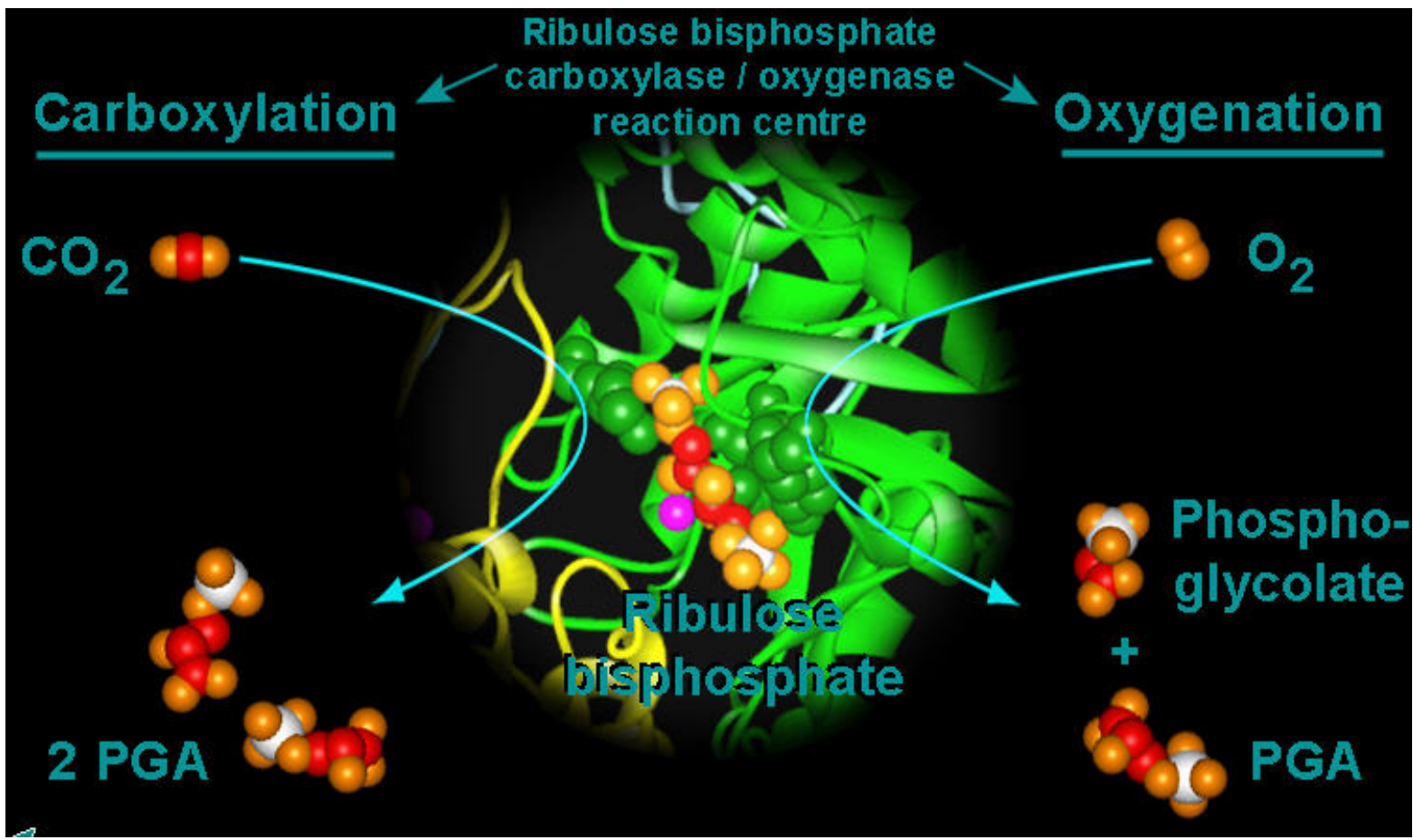
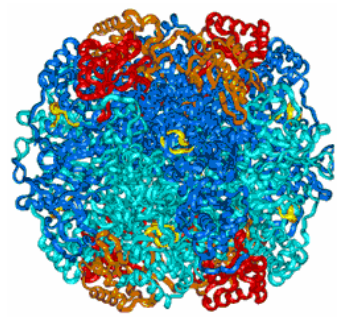
RUBISCO

Proteína mais abundante do planeta.

Elevado peso molecular, constituída de 2 subunidades:
grande (L) e pequena (S)

L é sintetizada nos cloroplastos

S é sintetizada no citoplasma

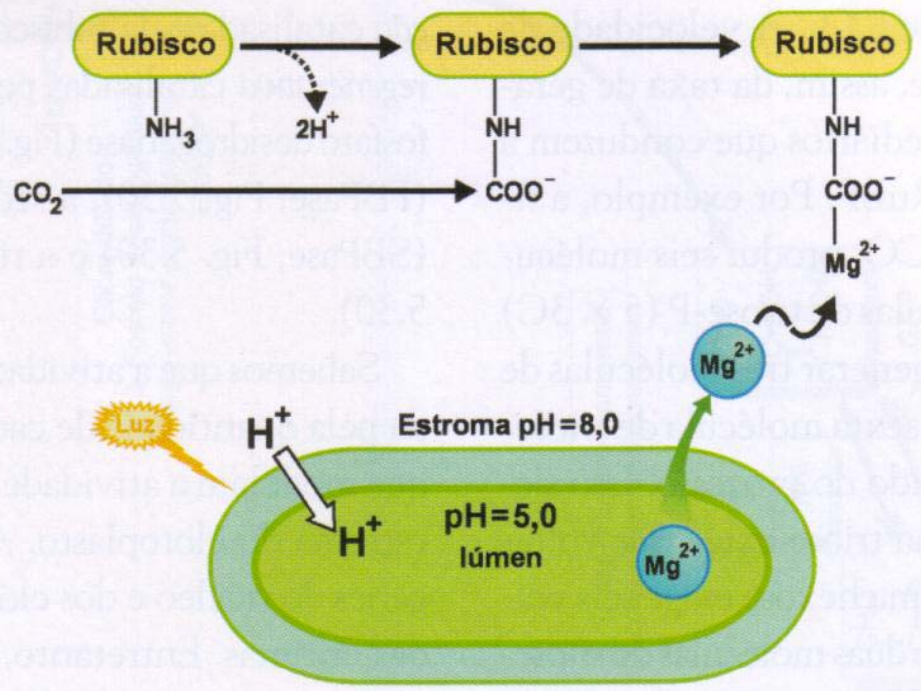


RUBISCO

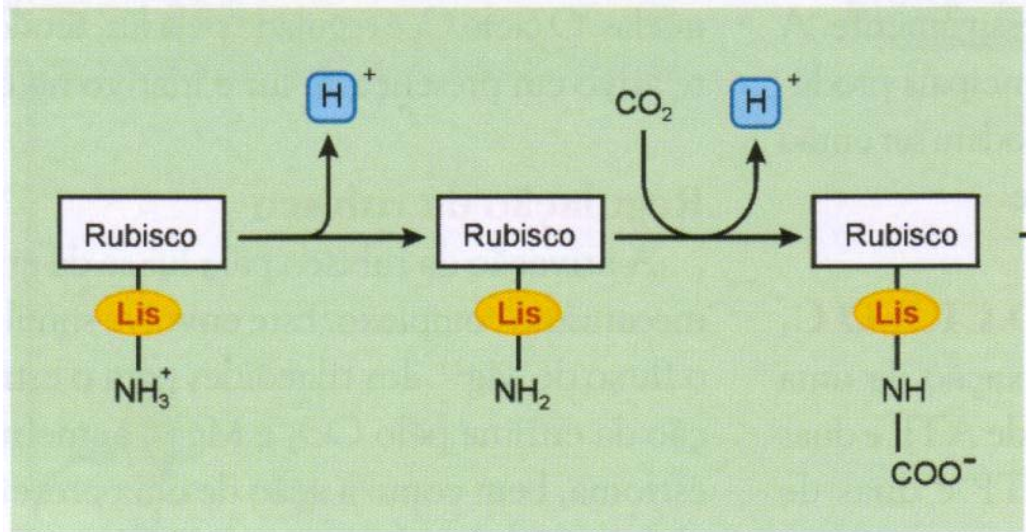
É ativada pela **LUZ**.

Na LUZ → fluxo de Mg^{+2} dos tilacóides para o estroma
ativação da RUBISCO pelo CO_2 e Mg^{+2}
aumento do pH do estroma (pH= 8)
ação da *rubisco ativase*
COMPLEXO ENZIMA - CO_2 - Mg^{+2}
COMPLEXO se liga a RudP

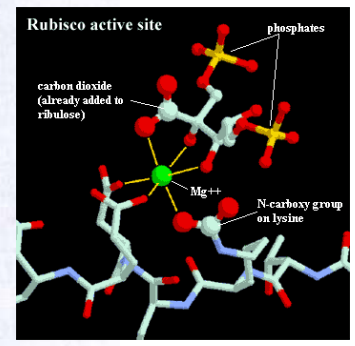
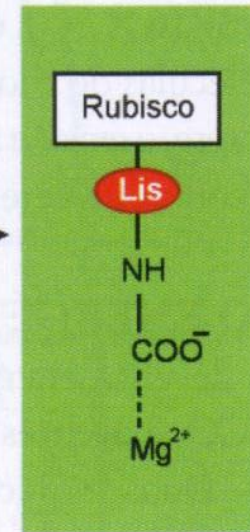
RUBISCO



INATIVA



ATIVA



RUBISCO COM CO₂

NO ESCURO:

↑ afinidade da RUBISCO por CO₂

↓ afinidade da RUBISCO por O₂

70% CO₂

30% O₂

t°C moderadas (↓ t°C)

↑ afinidade da RUBISCO por CO₂

↓ RESPIRAÇÃO

RUBISCO COM O₂

NA LUZ:

↑ afinidade da RUBISCO por O₂

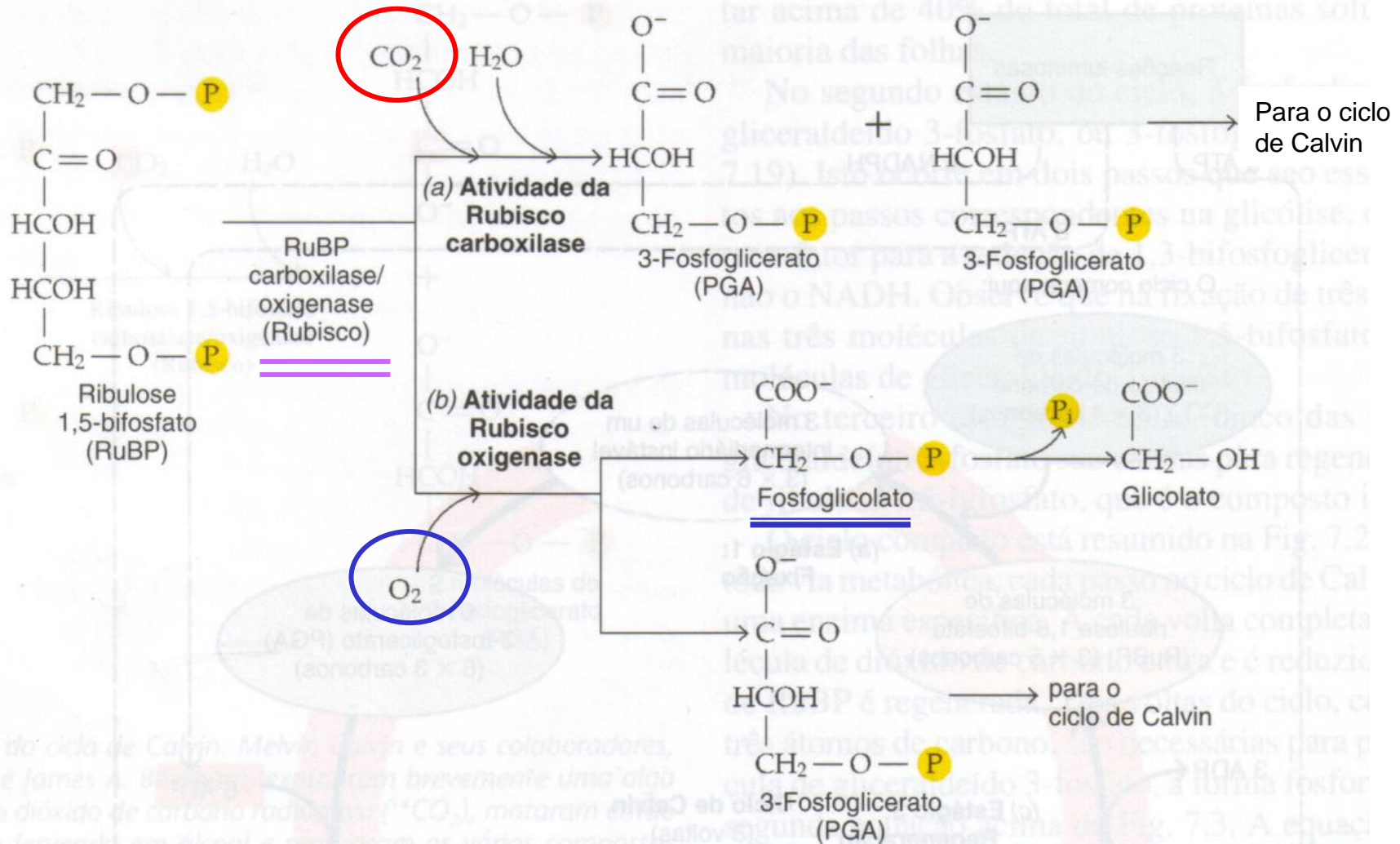
↓ afinidade da RUBISCO por CO₂

↑ t°C

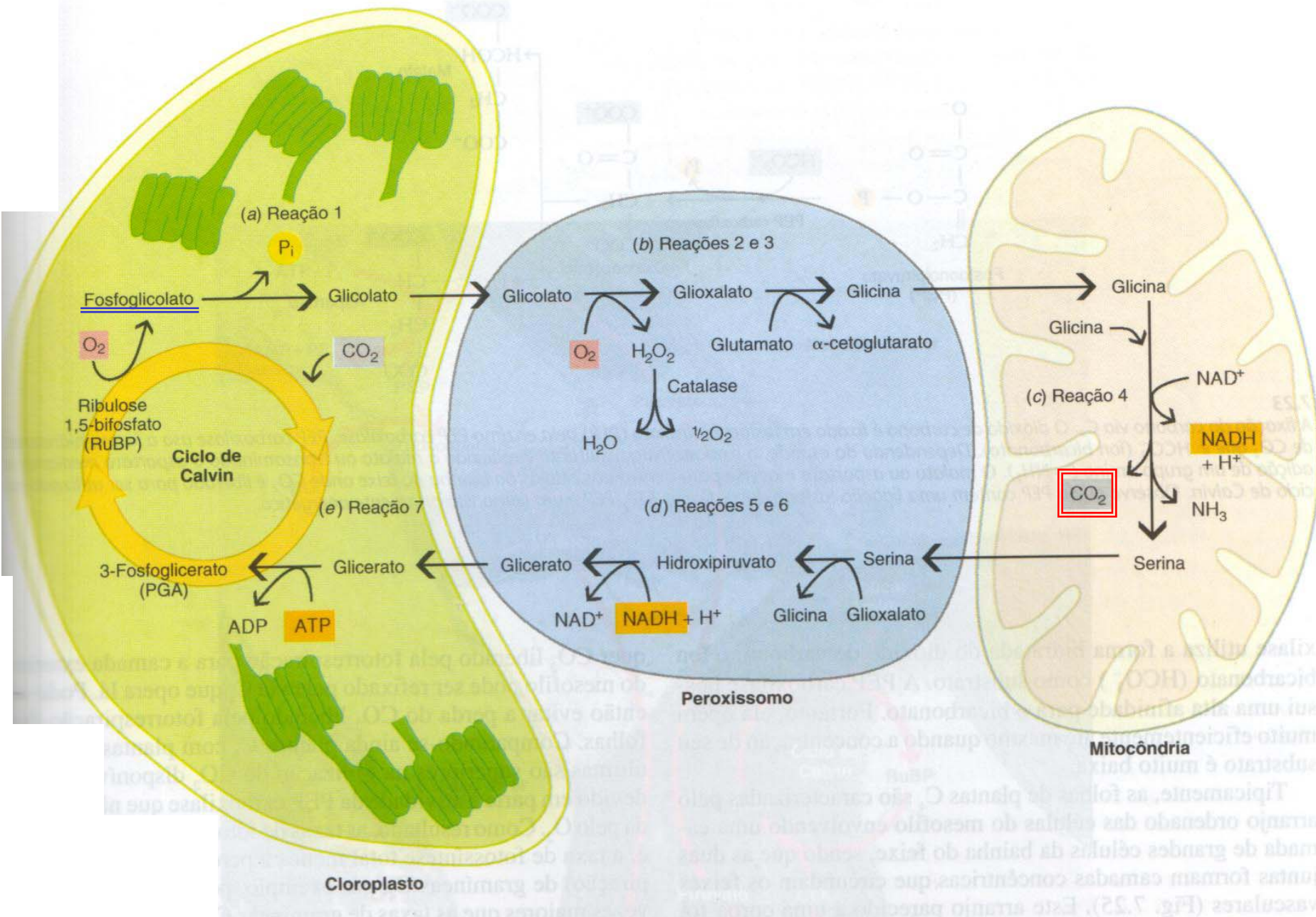
↑ afinidade da RUBISCO por O₂

↑ RESPIRAÇÃO

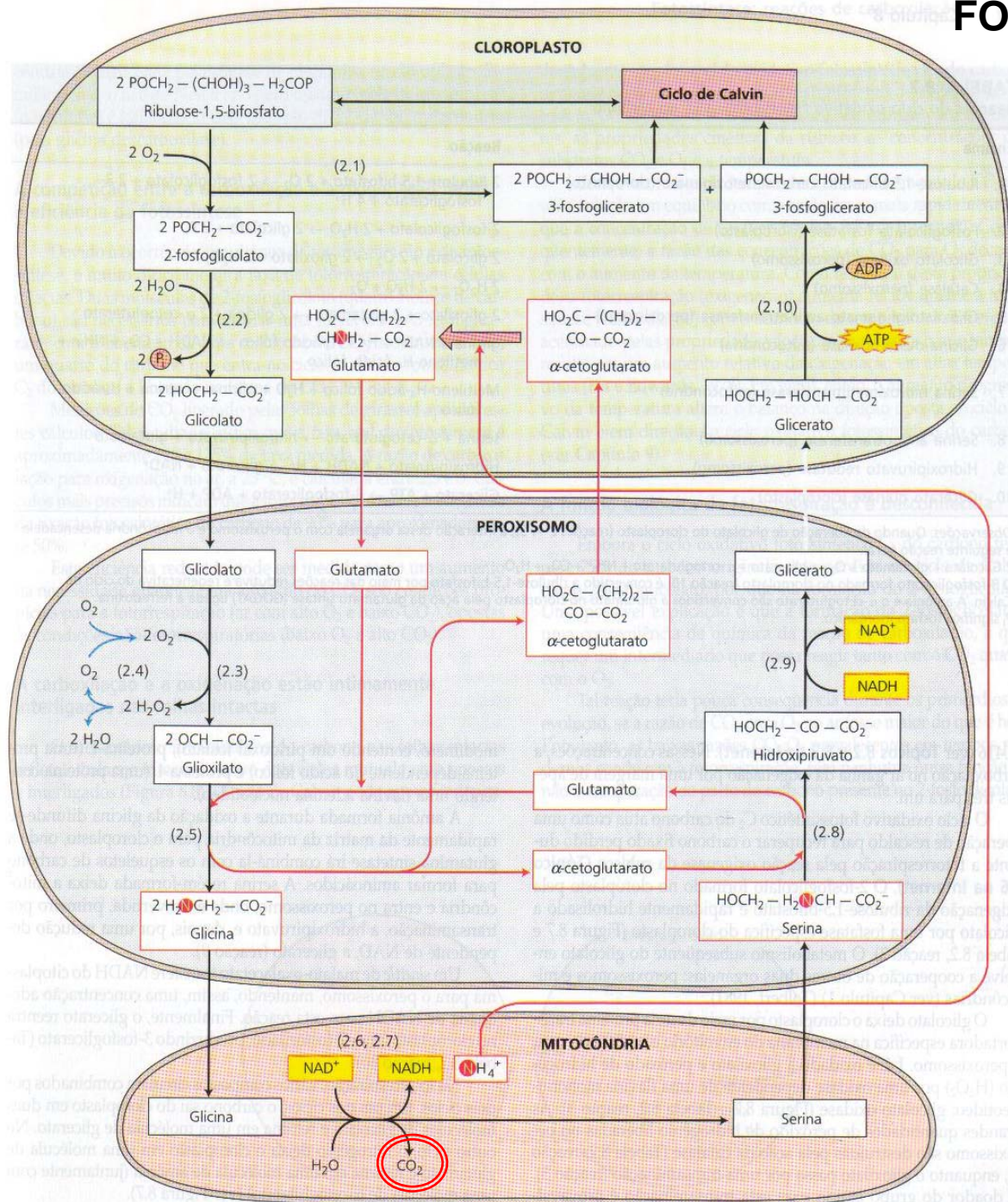
FOTORRESPIRAÇÃO



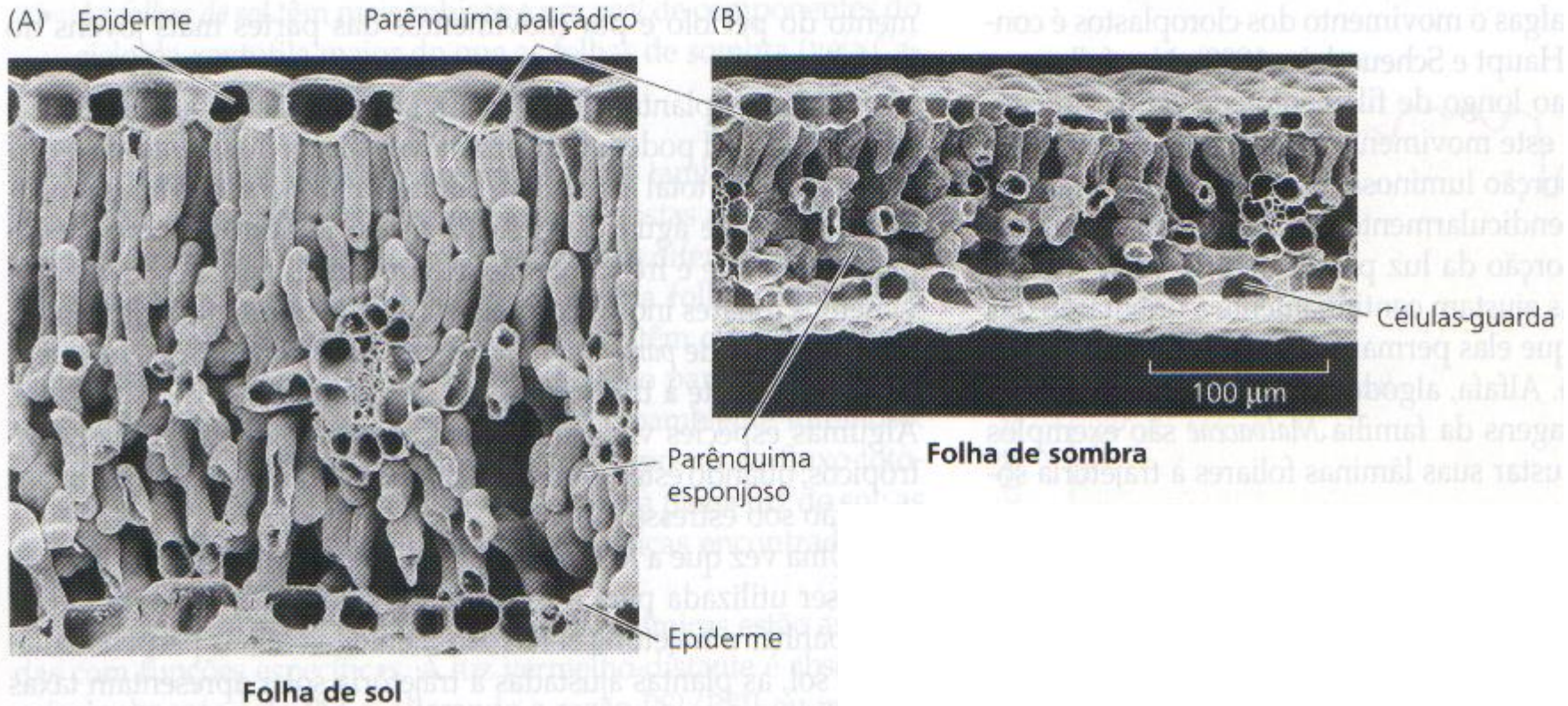
FOTORRESPIRAÇÃO



FOTORRESPIRAÇÃO



ADAPTAÇÕES ECOLÓGICAS



Electromicrografia de varredura de *Thermopsis montana* (leguminosa) no sol e na sombra.

ADAPTAÇÕES ECOLÓGICAS

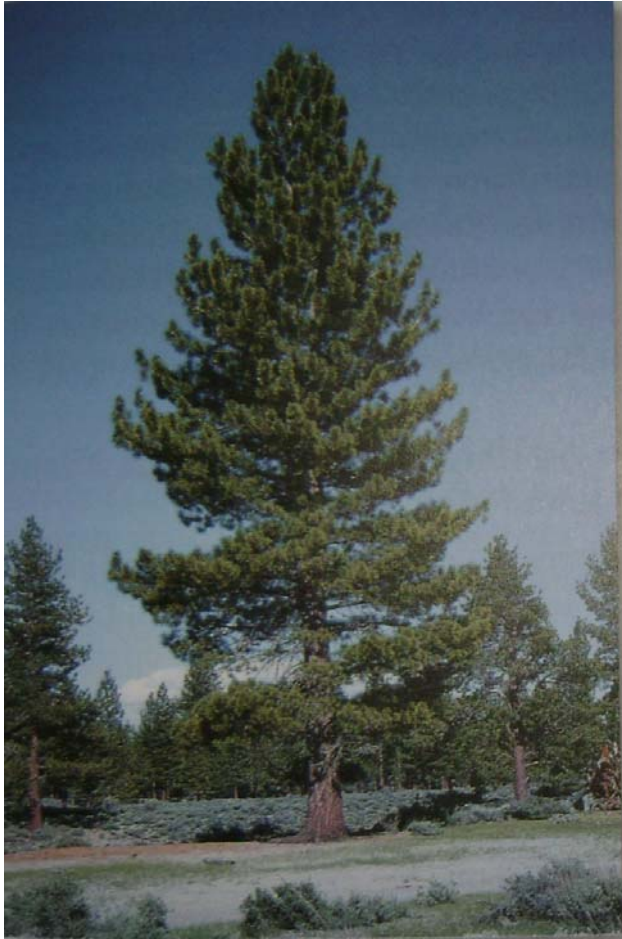
FOLHA DE SOL

nº MOLÉCULAS DE CAROTENÓIDES > nº MOLÉCULAS DE CLOROFILAS

FOLHA DE SOMBRA

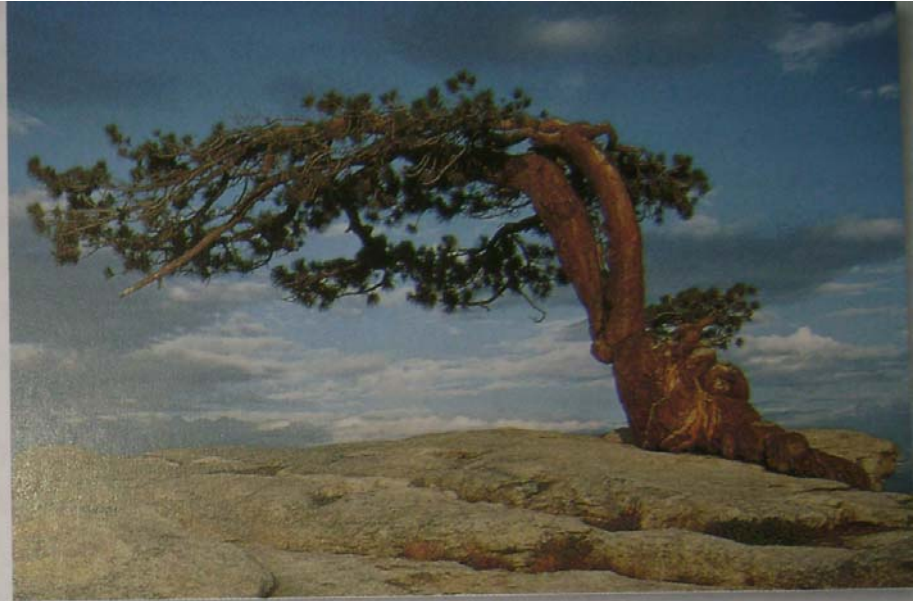
nº MOLÉCULAS DE CLOROFILAS > nº MOLÉCULAS DE CAROTENÓIDES

ADAPTAÇÕES ECOLÓGICAS



(a)

**SEM VENTO CONSTANTE
NUMA PLANÍCIE**



(b)

**COM VENTO CONSTANTE
NO ALTO DE UMA MONTANHA**

Pinus jeffreyi - Califórnia

FIM!

