

ŽIVOT

- růst
- rozmnožování
- vývoj a diferenciac
- dráždivost
- pohyb

Látková přeměna - intermediální metabolismus

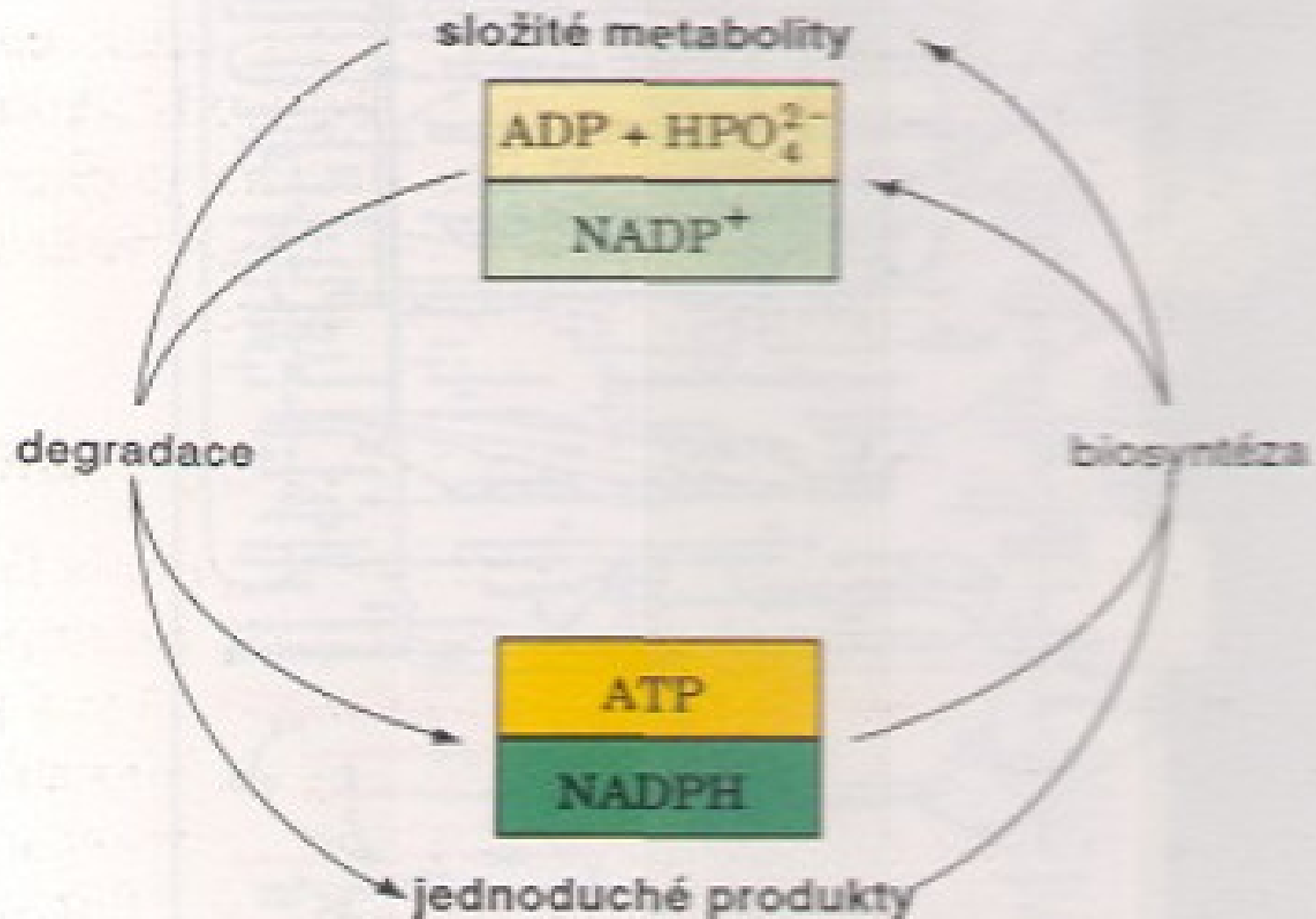
Funkce - zajišťování energie

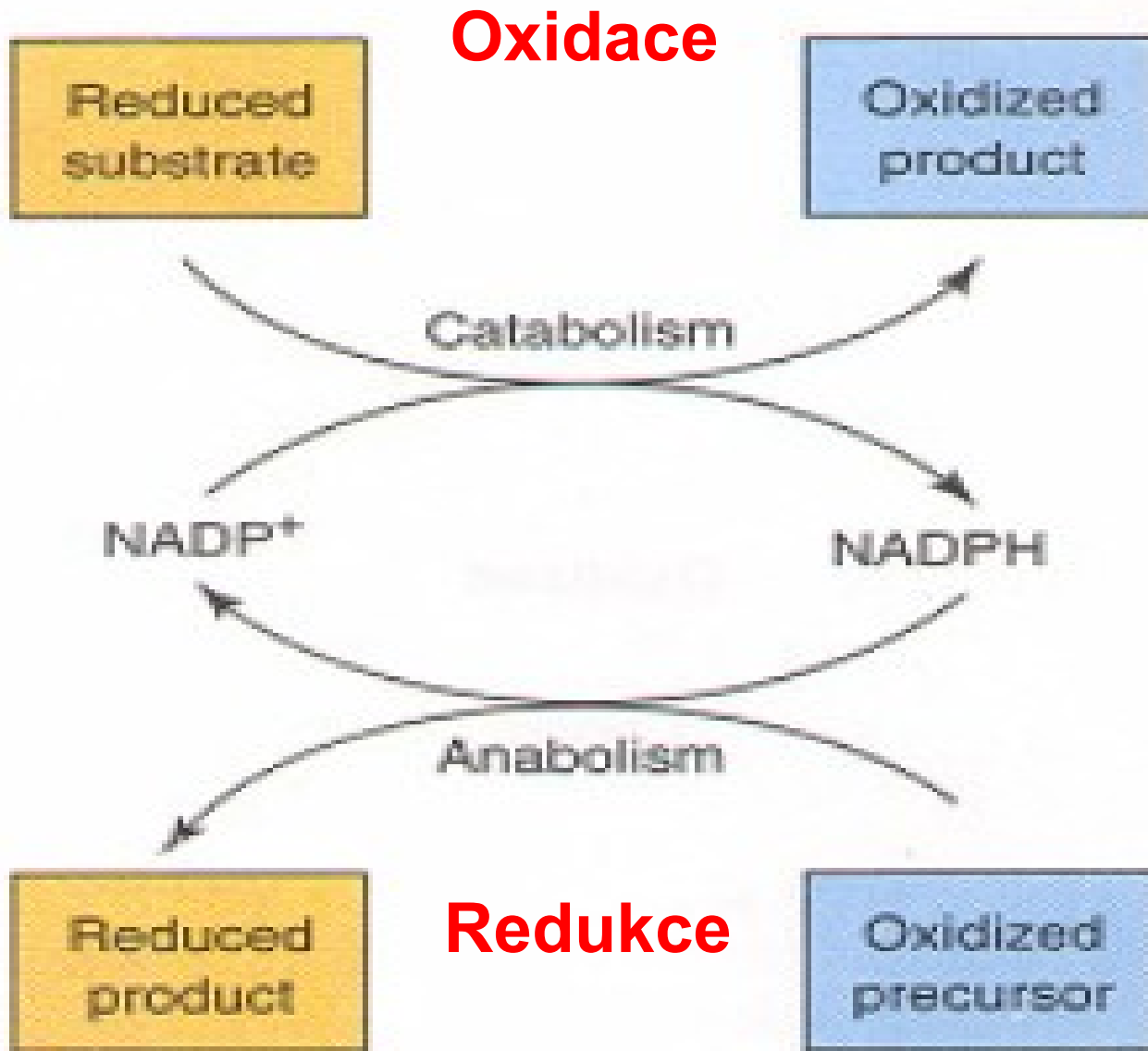
- zajišťování stavebního materiálu

Procesy - rozkladné - katabolické - disimilační

- biosyntetické - anabolické - asimilační

- amfibolické - obojí





Rozdělení organismů podle metabolismu

A. Podle zdroje přijímané energie

fototrofy - sluneční energie

chemotrofy - oxidace chemických látek

B. Podle zdroje stavebního materiálu

autotrofy - anorganické látky

heterotrofy - organické látky

C. Podle donoru elektronů

organotrofy - organické látky

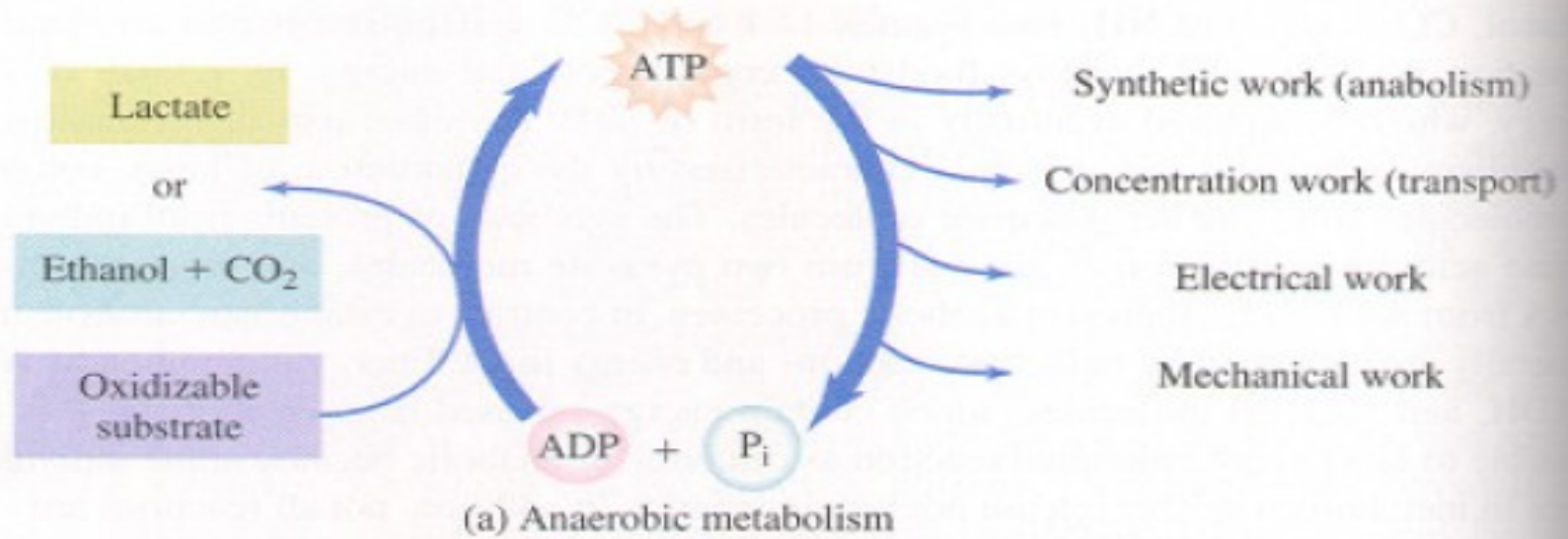
litotrofy - anorganické látky

D. Podle konečného akceptoru elektronů

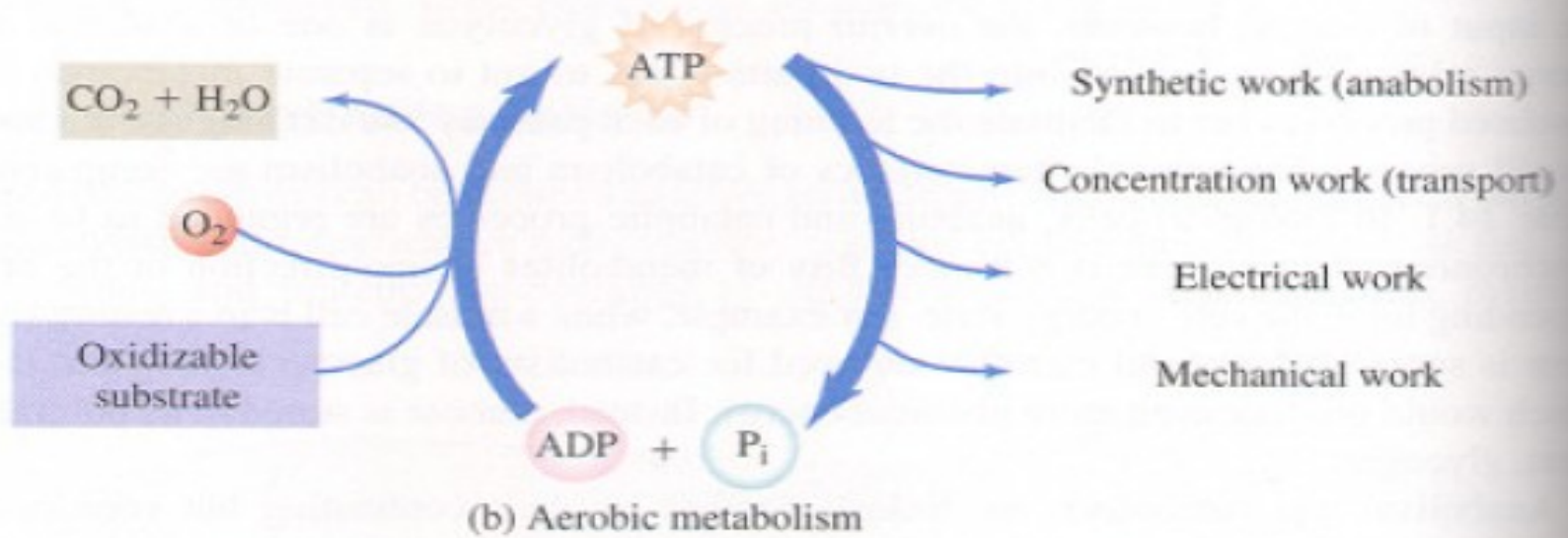
aeroby - O_2

anaeroby - NO_3^- , SO_4^{2-}

fermentace - elektrony jsou předávány na jiné organické látky



Fermentace



Respirace

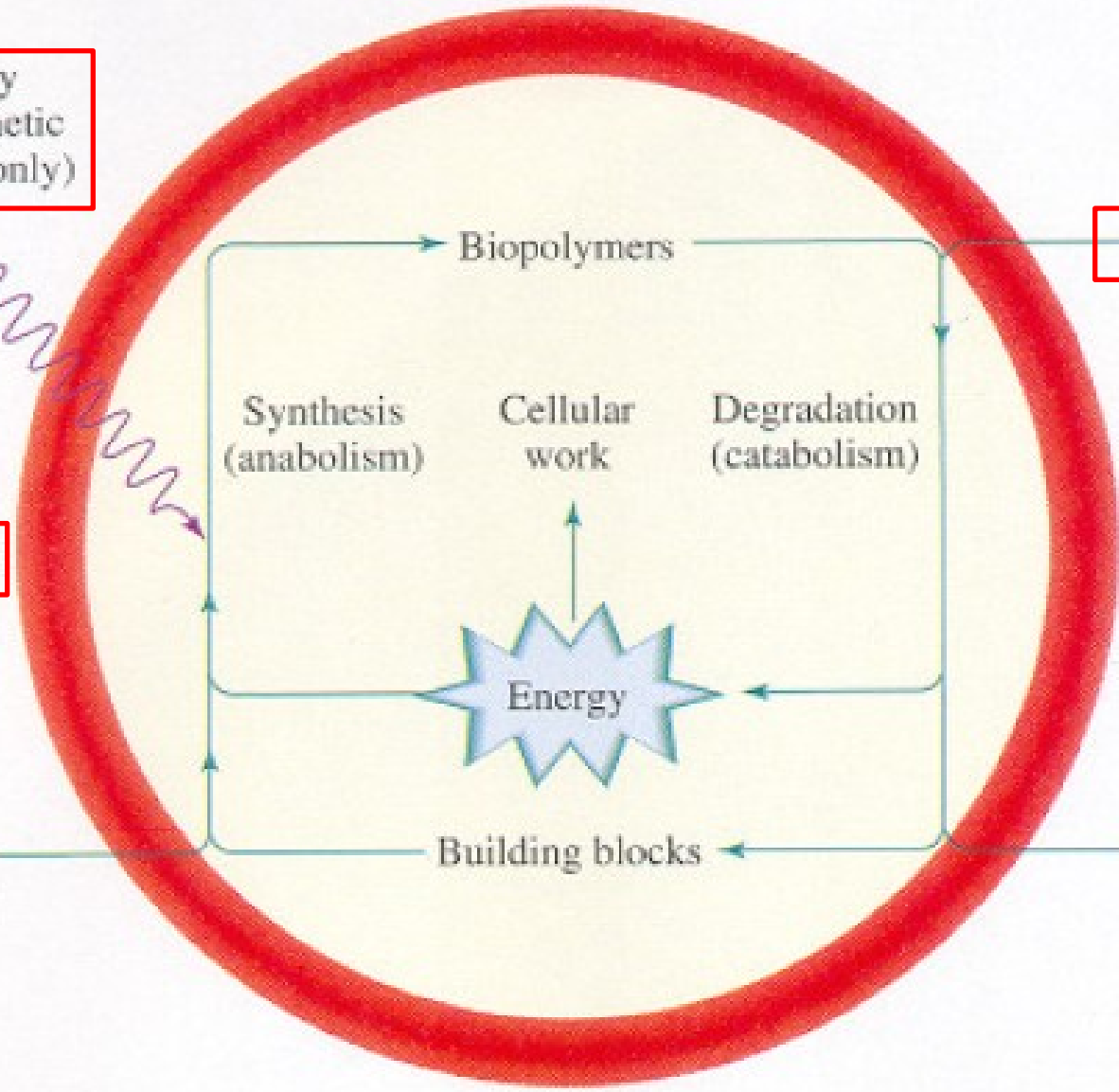
Light energy
(photosynthetic
organisms only)

Food

Autotrophs

Heterotrophs

Food
(CO₂)



Energy

Synthesis
(anabolism)

Cellular
work

Degradation
(catabolism)

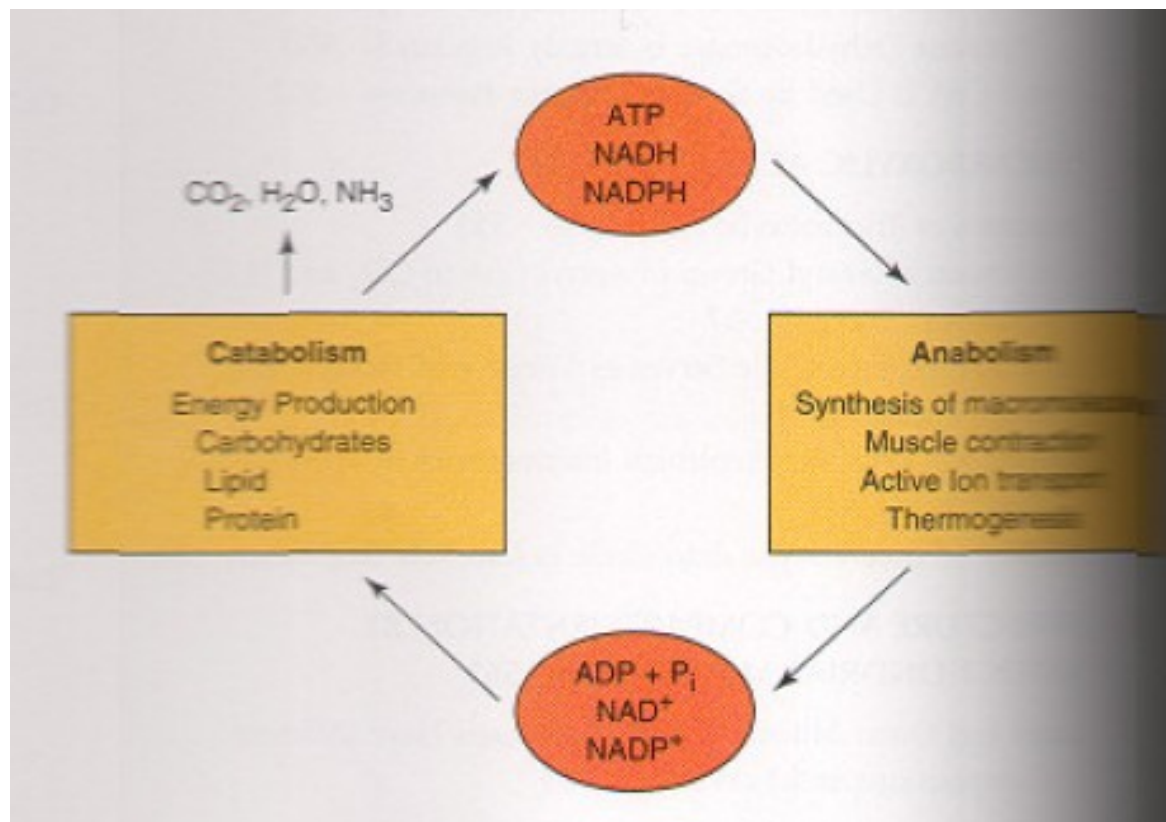
Biopolymers

Building blocks

Wastes

Metabolismus

H. KREBS - tři fáze metabolismu



Katabolismus - degradační fáze metabolismu - konvergentní

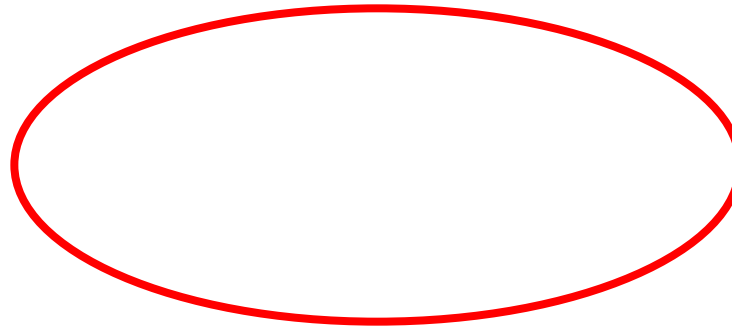
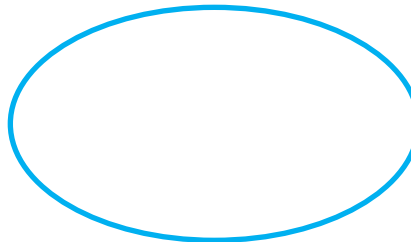
- Funkce**
- produkce energie
 - poskytuje prekurzory
 - poskytuje NADPH

1. Fáze - složité molekuly štěpeny na stavební jednotky **0 % energie**
2. Fáze - stavební jednotky převedeny na C₁ a C₂ látky **30 % energie**
3. Fáze - citrátový cyklus + dýchací řetězec **70 % energie**

Katabolismus

I.fáze

0 %



Anabolismus - biosyntetická fáze metabolismus - divergentní

Funkce - zajišťování stavebního materiálu pro funkci a růst

1. Fáze - citrátový cyklus poskytuje prekurzory
2. Fáze - z prekurzorů jsou syntetizovány stavební jednotky
3. Fáze - ze stavebních jednotek jsou syntetizovány
biopolymery

Bioenergetika

1. *Chemická energie*
2. *Mechanická - pohybová energie*
3. *Osmotická - transportní energie*
4. *Elektrická energie*
5. *Strukturní energie*
6. *Regulační energie*
7. *Tepelná energie*
8. *Světelná energie*

Chemická energie - energie vazeb a strukturního uspořádání
chemických sloučenin

Enthalpie H - reakční teplo při konstantním tlaku

$\Delta H < 0$ - reakce exogenní

$\Delta H > 0$ - reakce endogenní

Gibbsova energie G - změna energie při konstantním tlaku a teplotě

$$\Delta G = \Delta H - T\Delta S \quad \text{Entropie}$$

$$\Delta G^{\circ} = -RT \ln K$$

$$\Delta G^{\circ} = -nF \Delta E^{\circ}$$

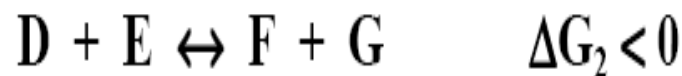
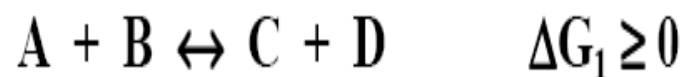
$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

$$\Delta G^{\circ} = \sum G^{\circ}_{\text{produktů}} - \sum G^{\circ}_{\text{vychoz. Látek}}$$

$\Delta G < 0$ - reakce exergonické

$\Delta G > 0$ - reakce endergonické

Spřažení reakcí



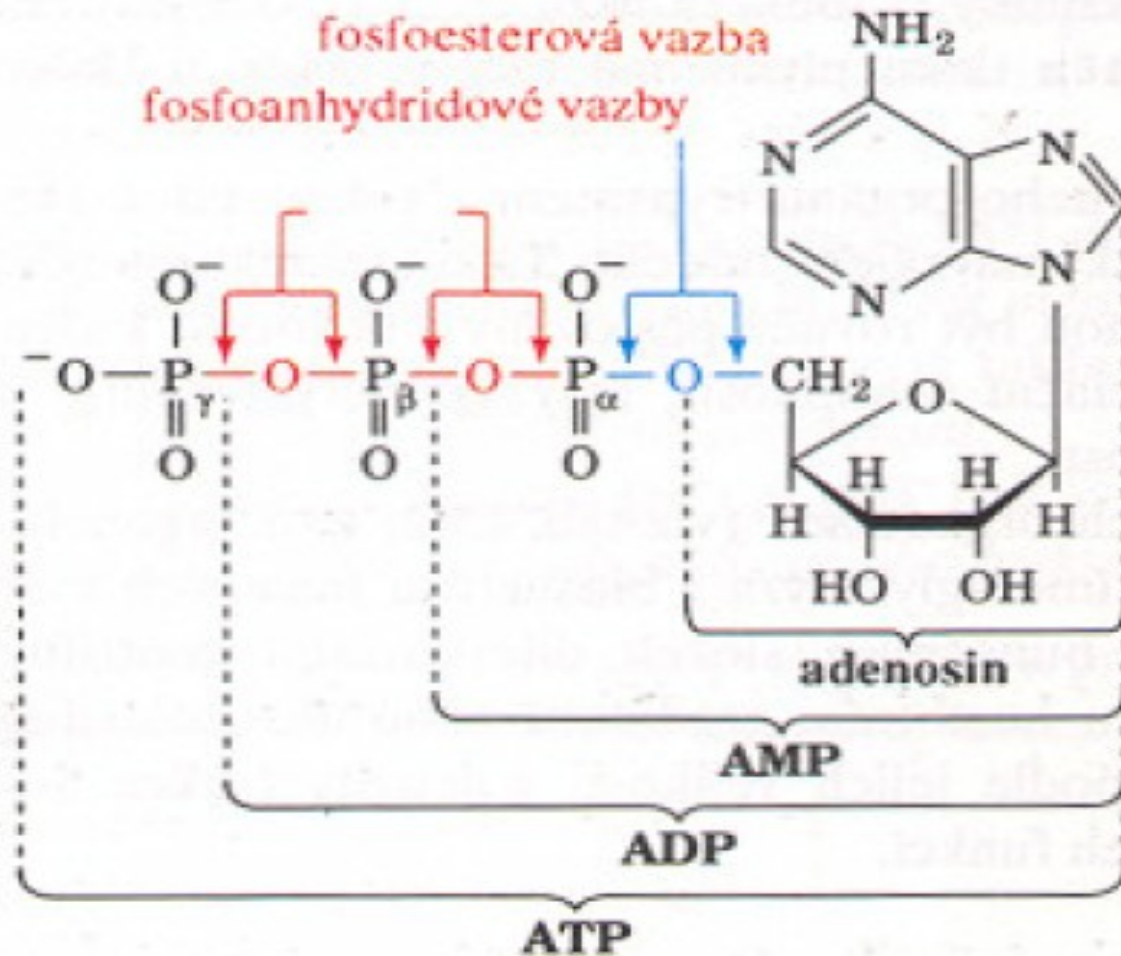
$$\Delta G = \Delta G_1 + \Delta G_2$$

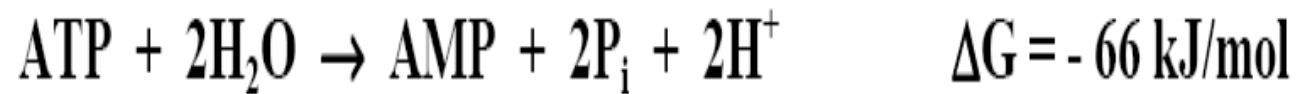
Makroergické sloučeniny - makroergická vazba

1. při procesech uvolňování energie jsou schopny část této energie zachytit a uchovat
2. při procesech vyžadujících energii mohou svým rozkladem tuto uchovanou energii uvolnit a předat

ATP - univerzální přenašeč energie

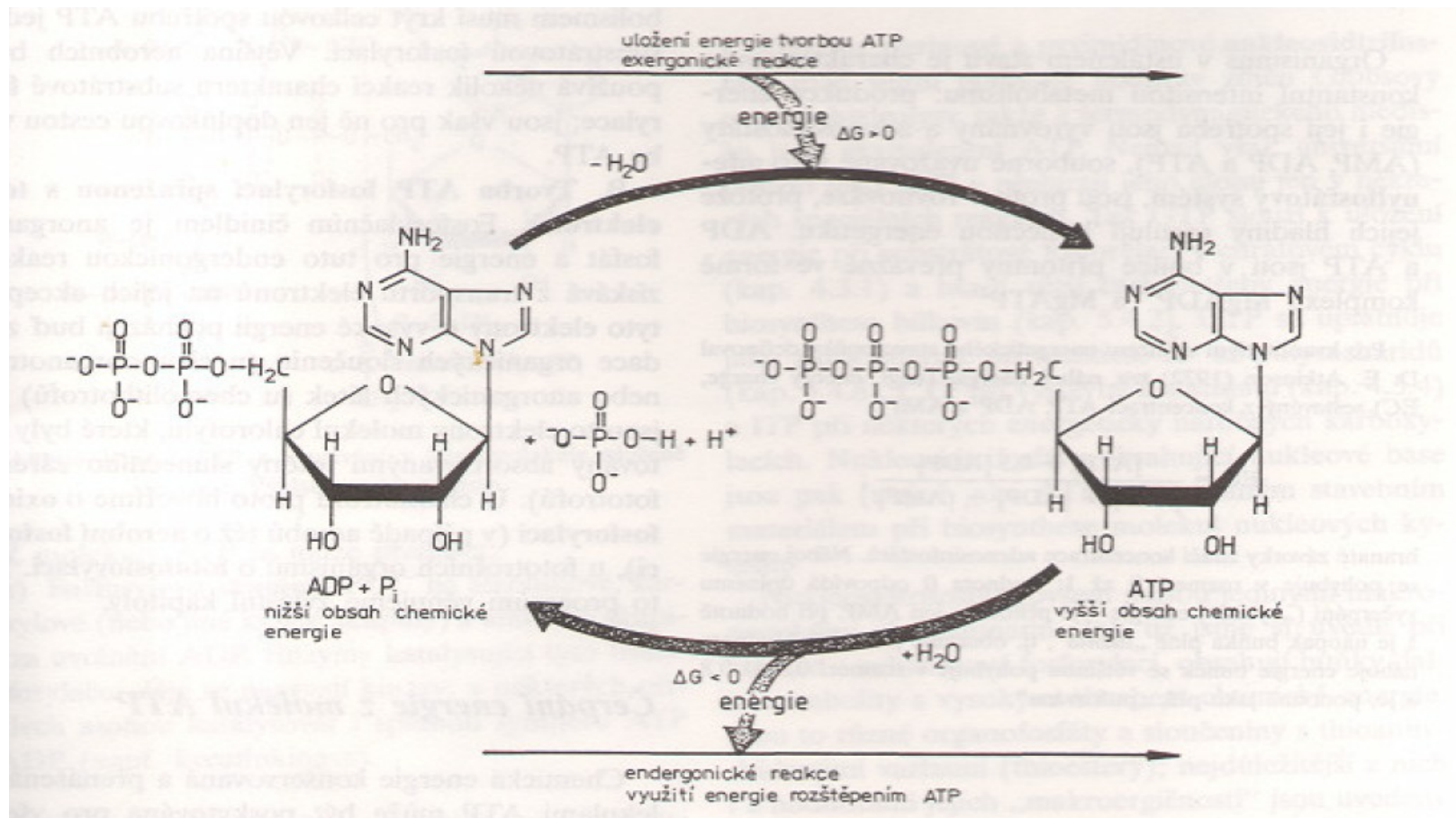
LIPMANN a KALCKAR 1941





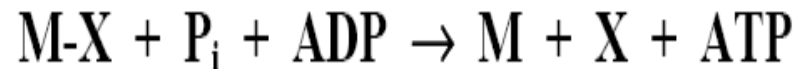
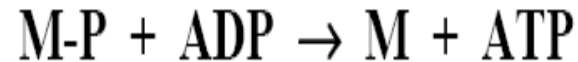
ATP - univerzální přenašeč energie

LIPMANN a KALCKAR 1941



Tvorba ATP

1. *Substrátová fosforylace*



2. *Fosforylace spřažena s tokem elektronů*

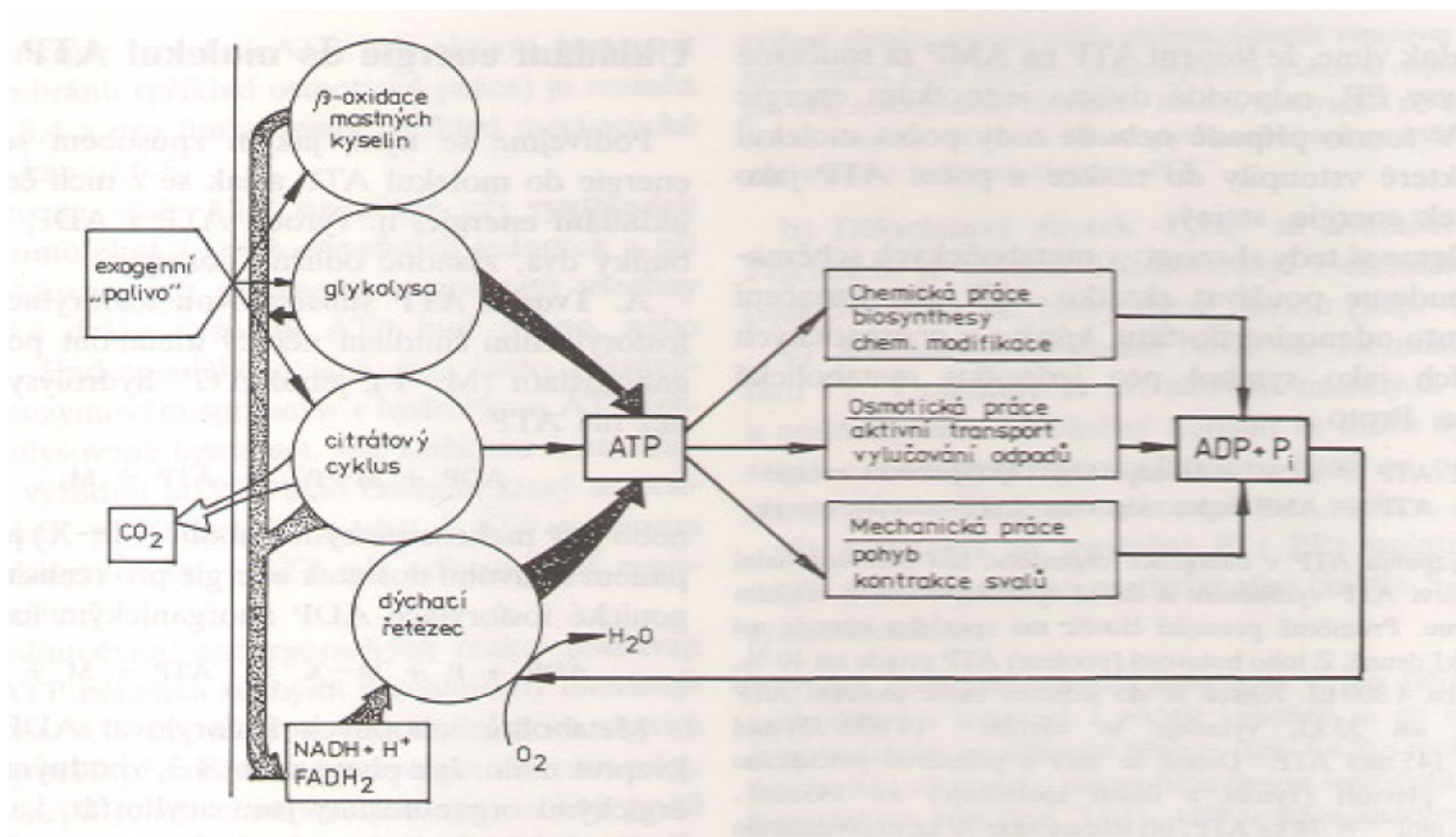
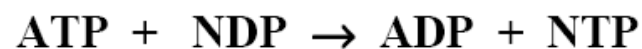
- oxidační fosforylace
- fotofosforylace

3. *Adenylátkinasovou reakcí*



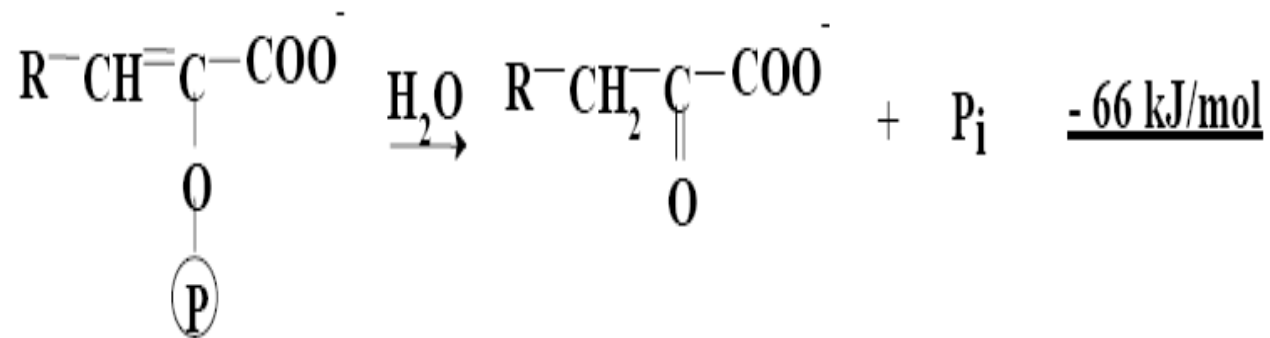
Spotřeba ATP

- Biosyntetické reakce
- Počáteční stádia odbourávání živi
- Fyziologické procesy
- Vzájemné přeměny nukleotidů

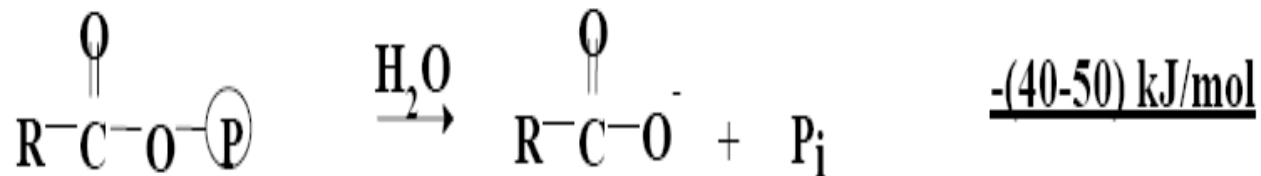


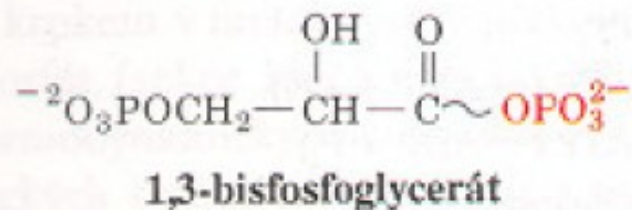
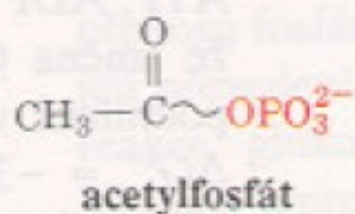
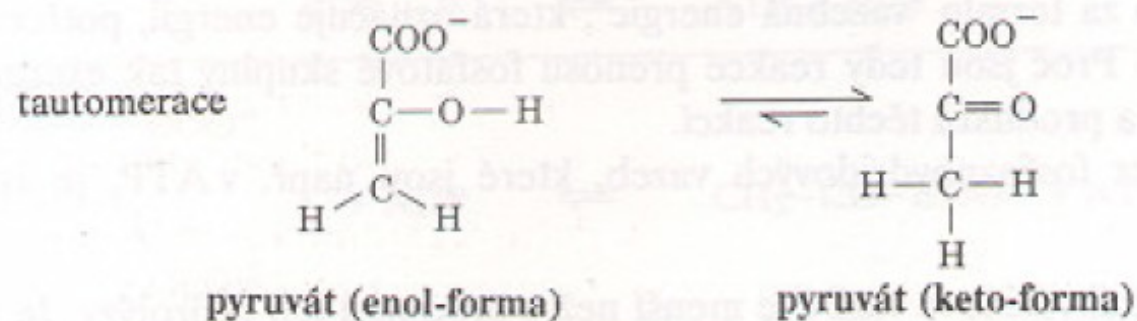
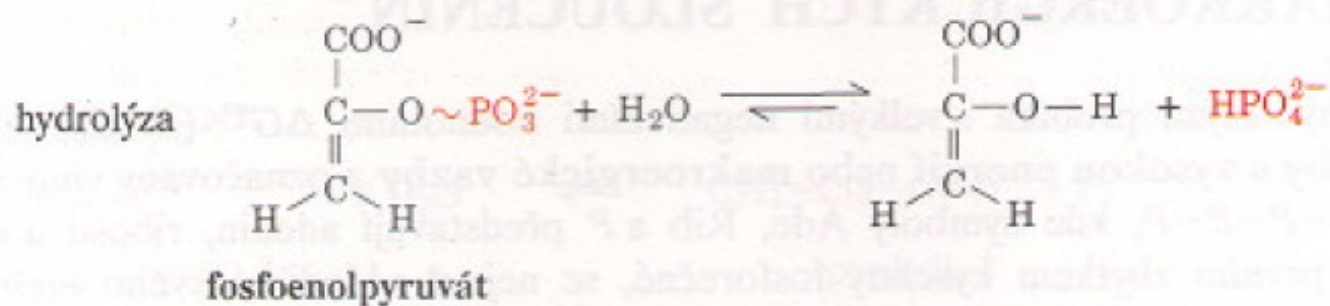
Další makroergické sloučeniny

ENOYLFOSFÁTY

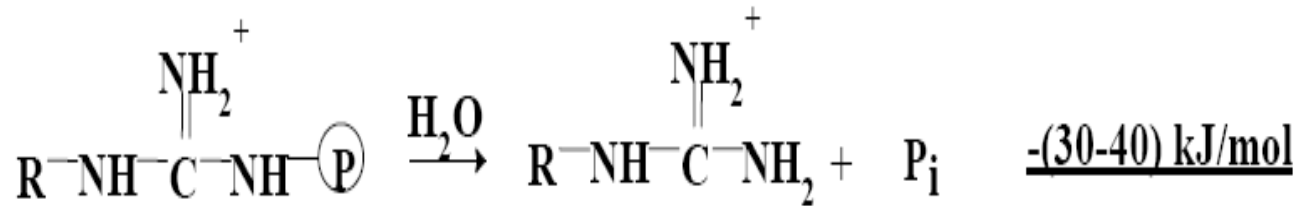


ACYLFOSFÁTY

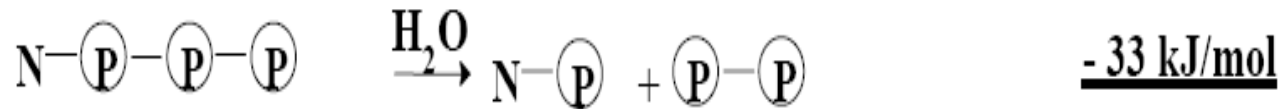
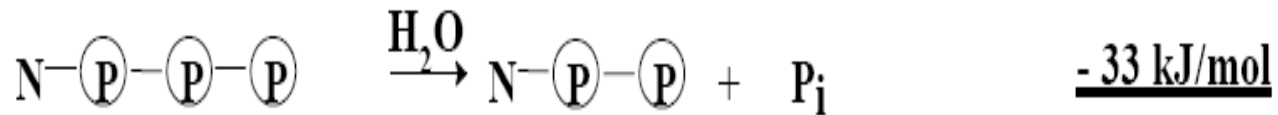


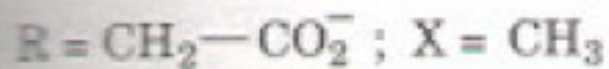
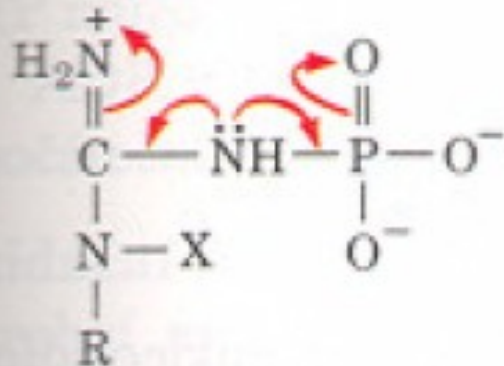


GUANIDIUMFOSFÁTŸ



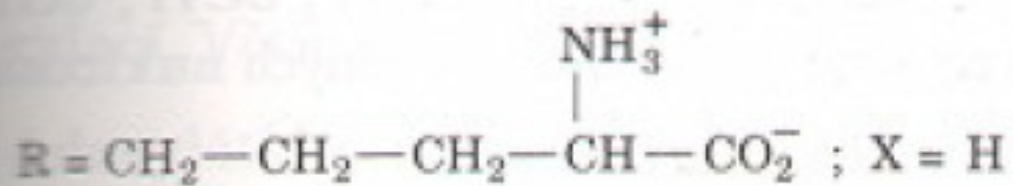
NUKLEOTIDŸ





fosfokreatin

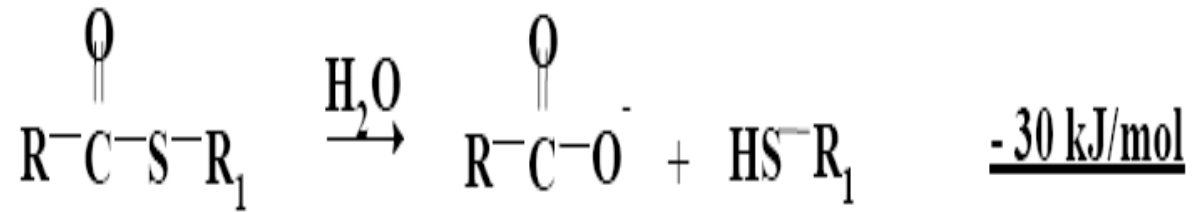
obratlovci



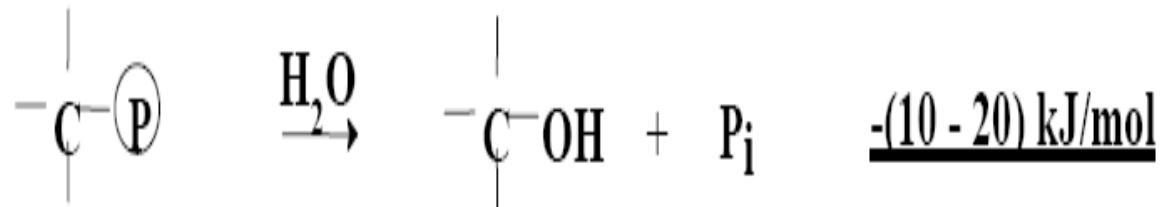
fosfoarginin

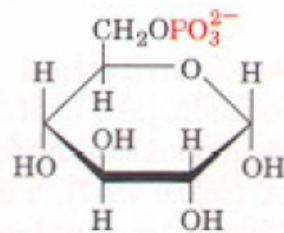
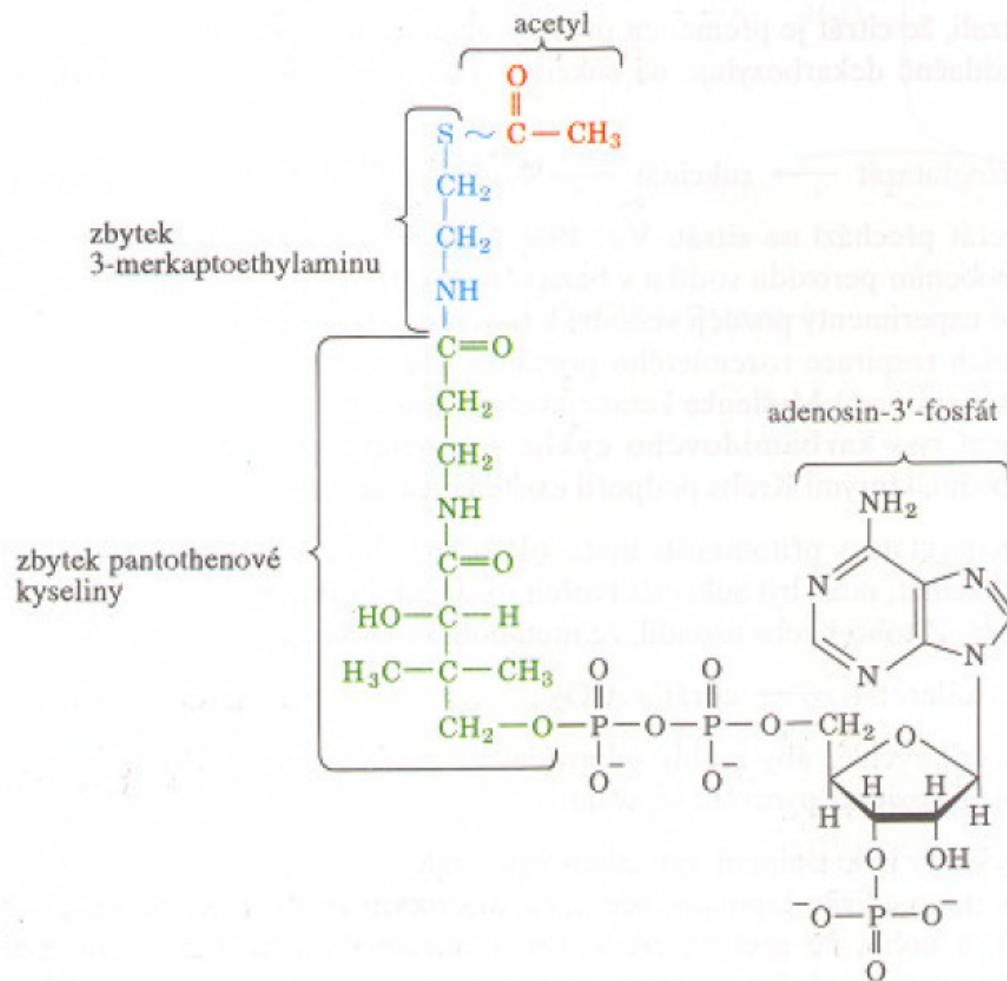
bezobratli

ACYLTHIOESTERY

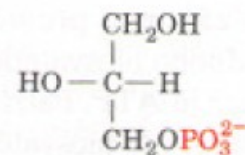


FOSFOMONOESTERY





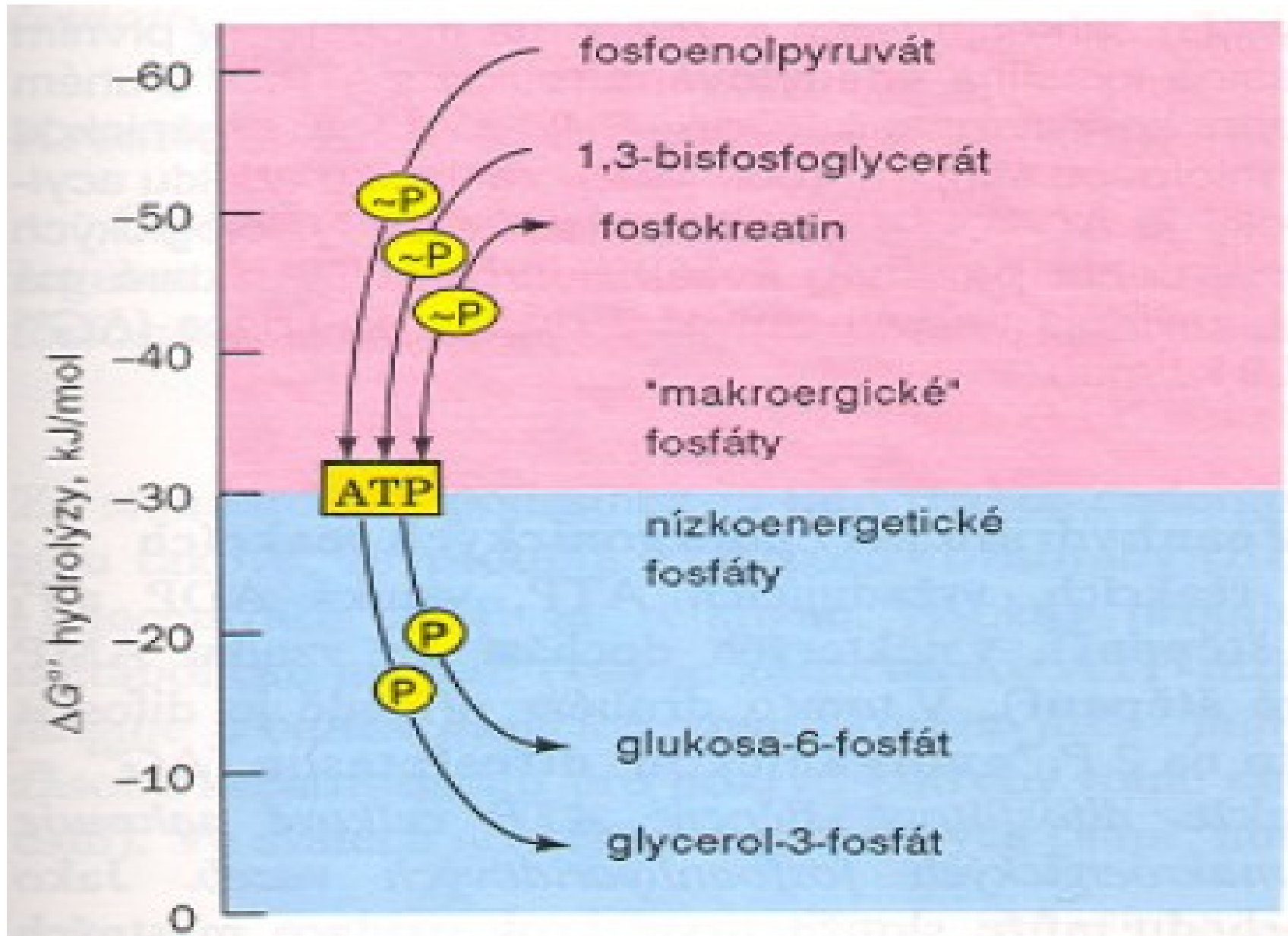
α -D-glukosa-6-fosfát



L-glycerol-3-fosfát

Phosphorylated Compounds	ΔG° (kJ/mol) ^a	Phosphoryl Group Transfer Potential
Phosphoenolpyruvate	-61.9	Highest
1,3-Biphosphoglycerate	-49.3	
Phosphocreatine	-43.0	
ATP	-30.5	
ADP	-30.5	
Glucose 1-phosphate	-20.9	
Glucose 6-phosphate	-13.8	
Glycerol 1-phosphate	-9.2	Lowest

^aThese values are for hydrolysis reactions (the transfer potential of the phosphoryl group to H₂O).



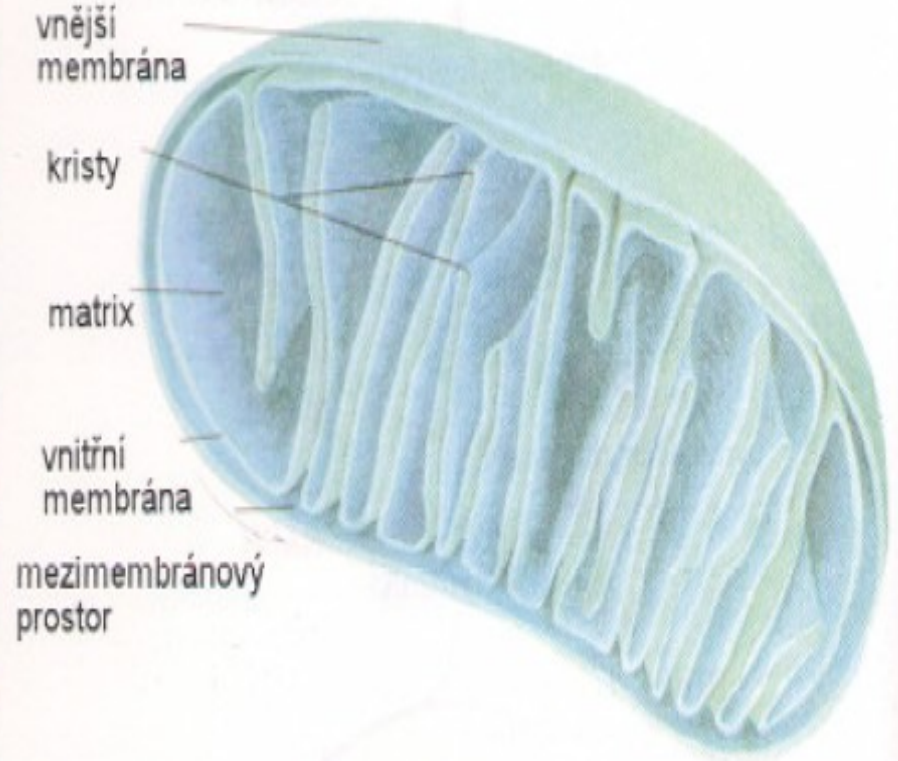
DÝCHACÍ ŘETĚZEC A OXIDAČNÍ FOSFORYLACE



Mitochondrie

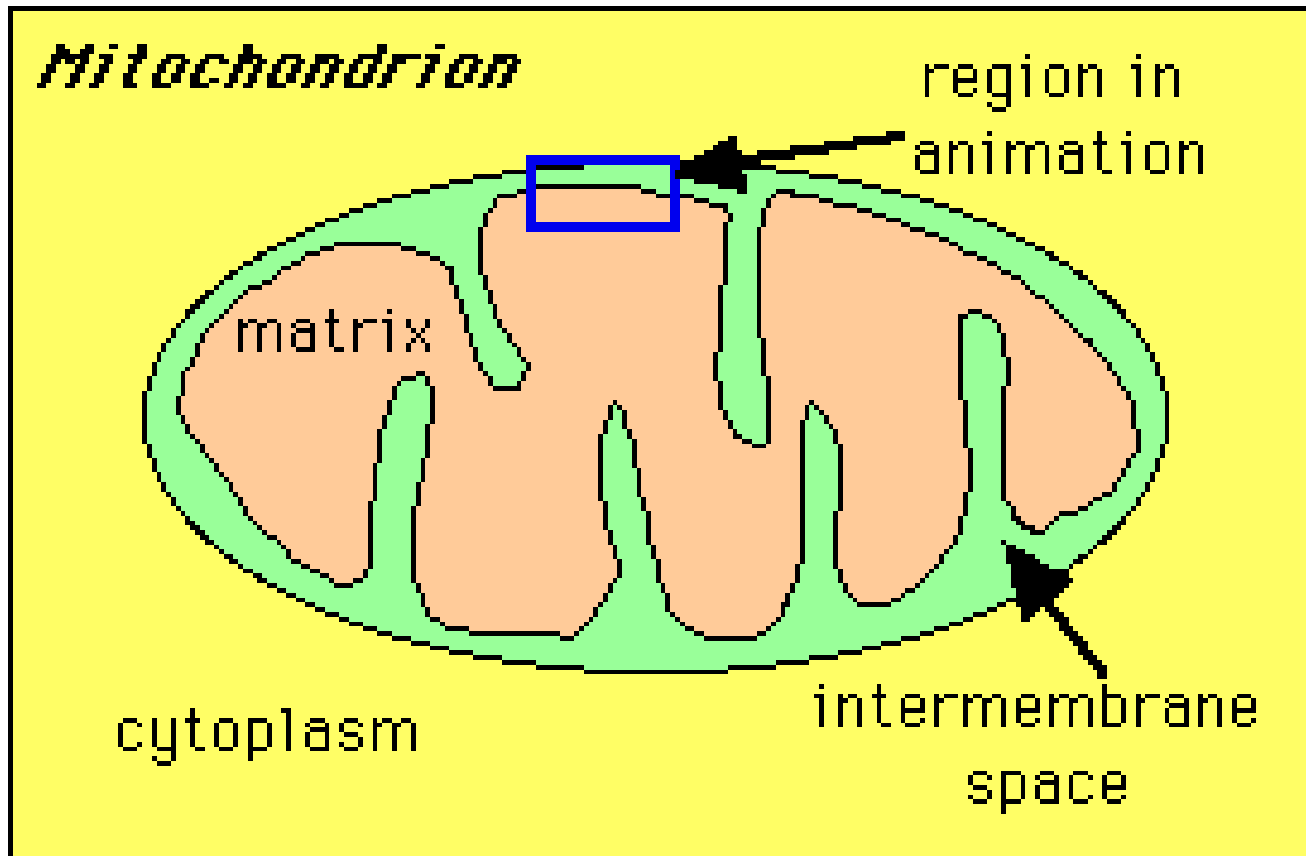


(a)

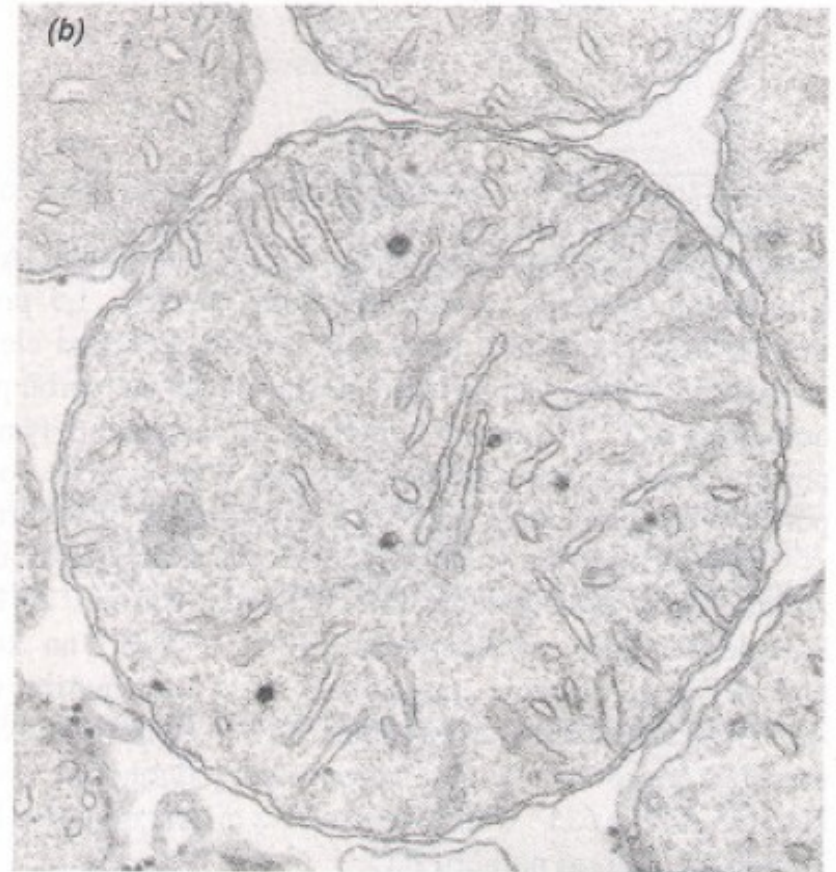
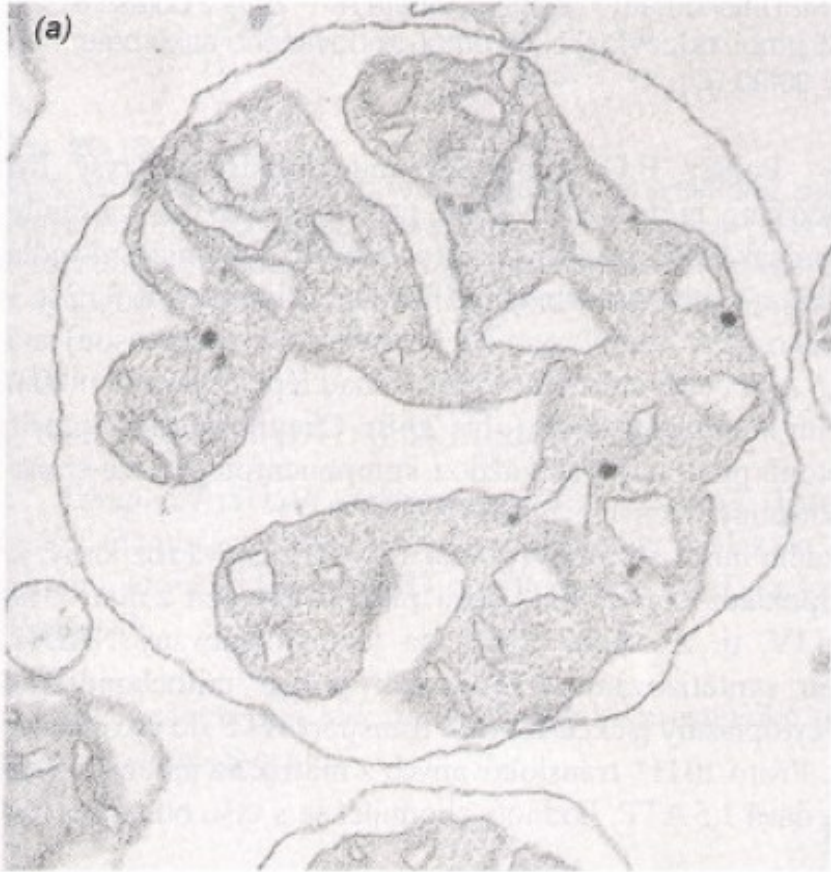


(b)

Lokalizace



Mitochondrie

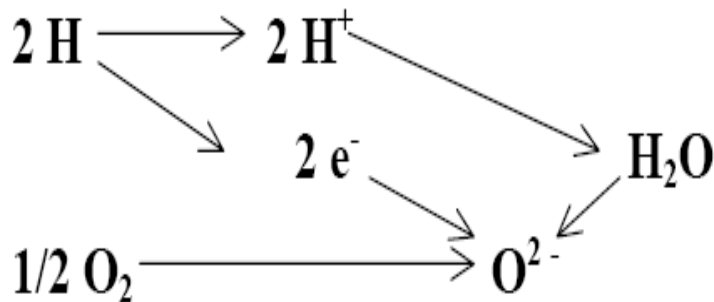


DÝCHACÍ ŘETĚZEC A OXIDAČNÍ FOSFORYLACE

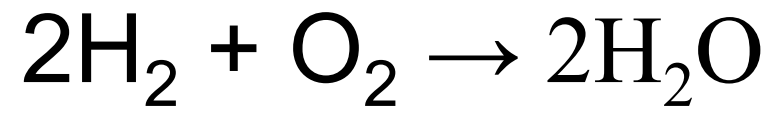


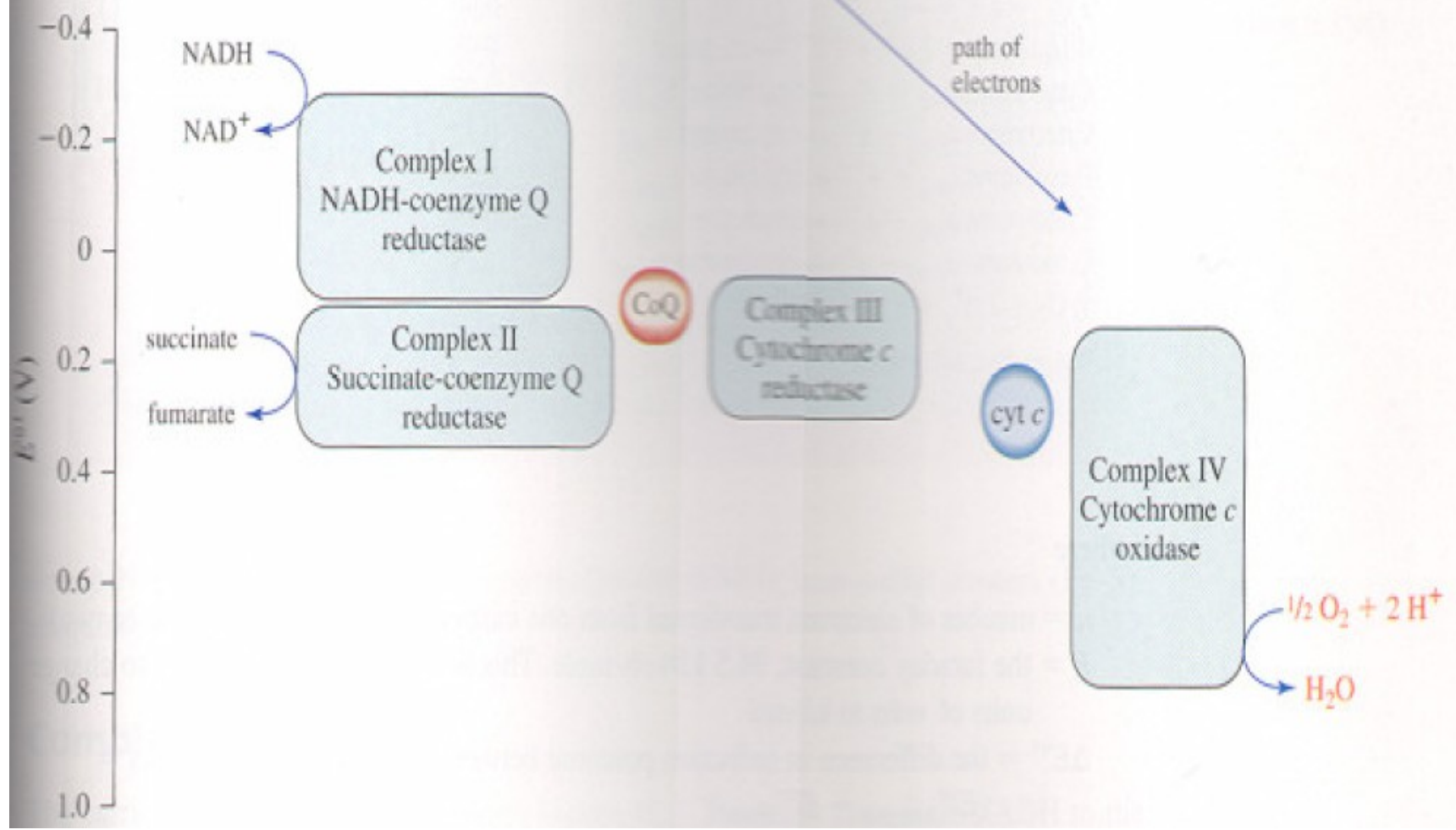
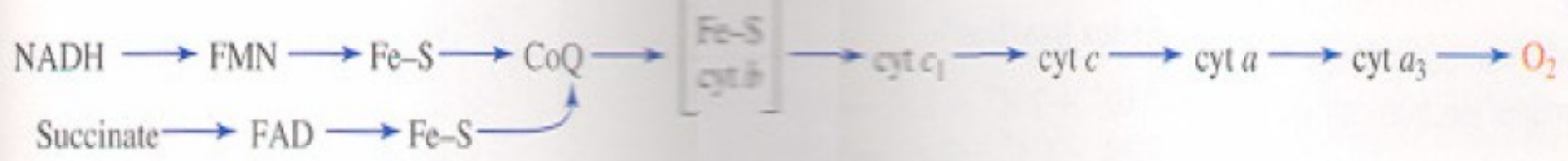
Aerobní respirace

NADH →
FADH₂ →



Živočichové
Rostliny
Některé bakterie





Complex I

NADH dehydrogenase
FMN
Fe-S centers

NADH:ubiquinone (Q)
oxidoreductase

Complex II

Succinate dehydrogenase
FAD (covalent)
Fe-S centers
b-type heme

Succinate:ubiquinone (Q)
oxidoreductase

Mobilní
přenašeč

UQ/UQH₂
pool

Complex III

Cytochrome bc₁ complex
2 b-type hemes
Rieske Fe-S center
c-type heme (cyt c₁)

Ubiquinol (QH₂):cytochrome c
oxidoreductase

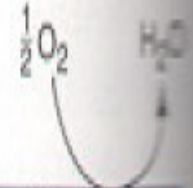
Mobilní
přenašeč

Cytochrome c

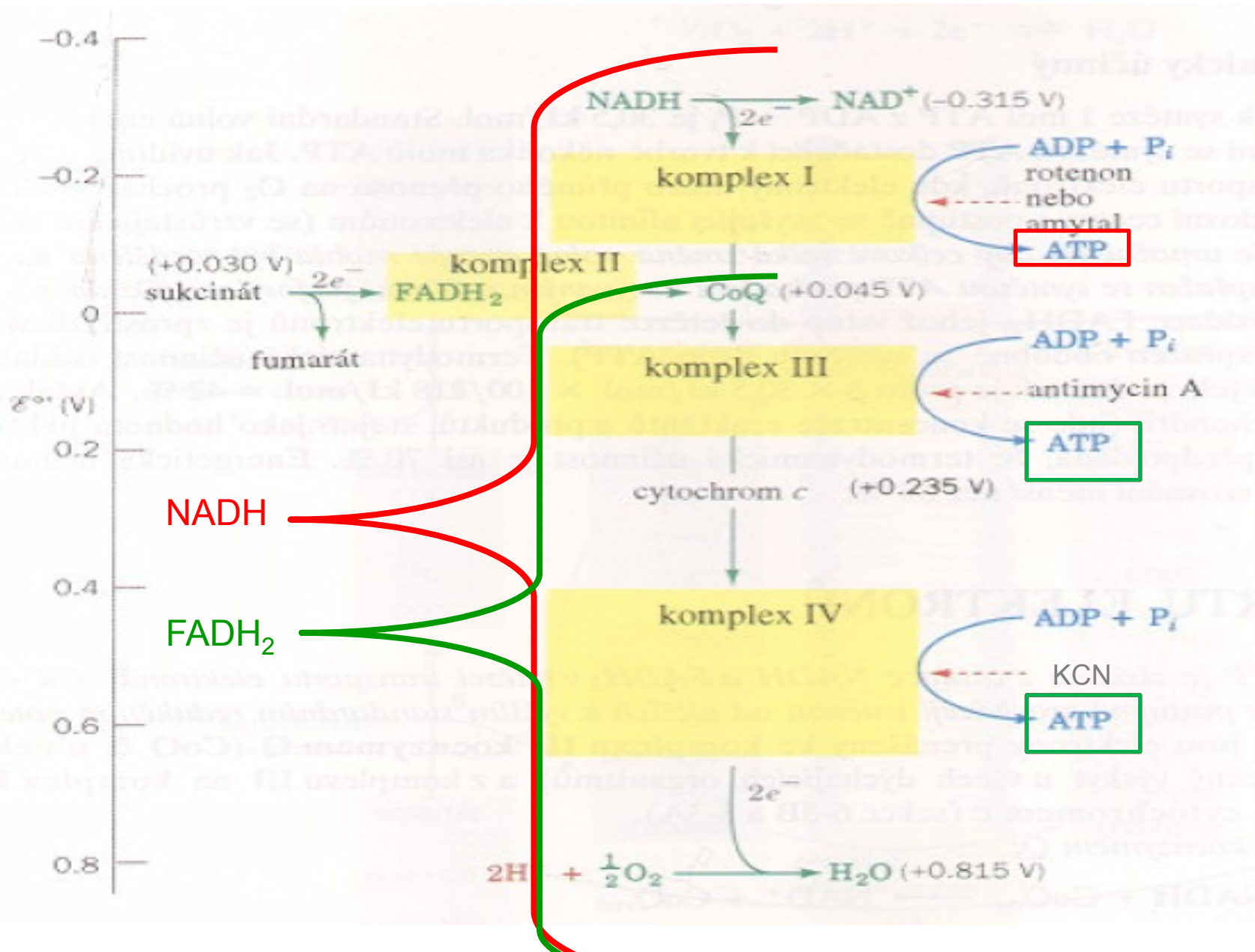
Complex IV

Cytochrome aa₃ complex
2 a-type hemes
Cu ions

Cytochrome c oxidase



Chức năng: Keton

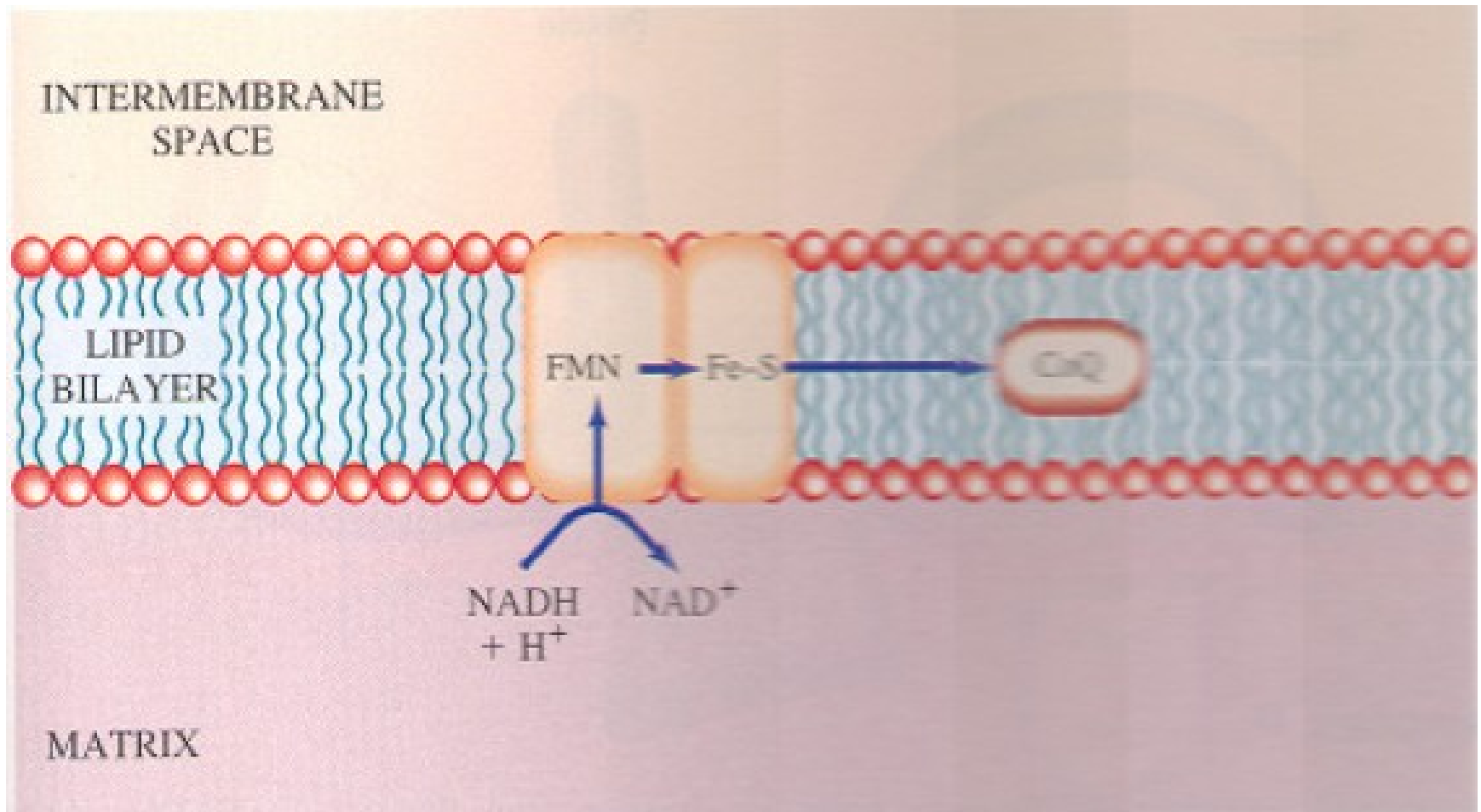


$$\Delta G = -nF\Delta E^{\circ}$$

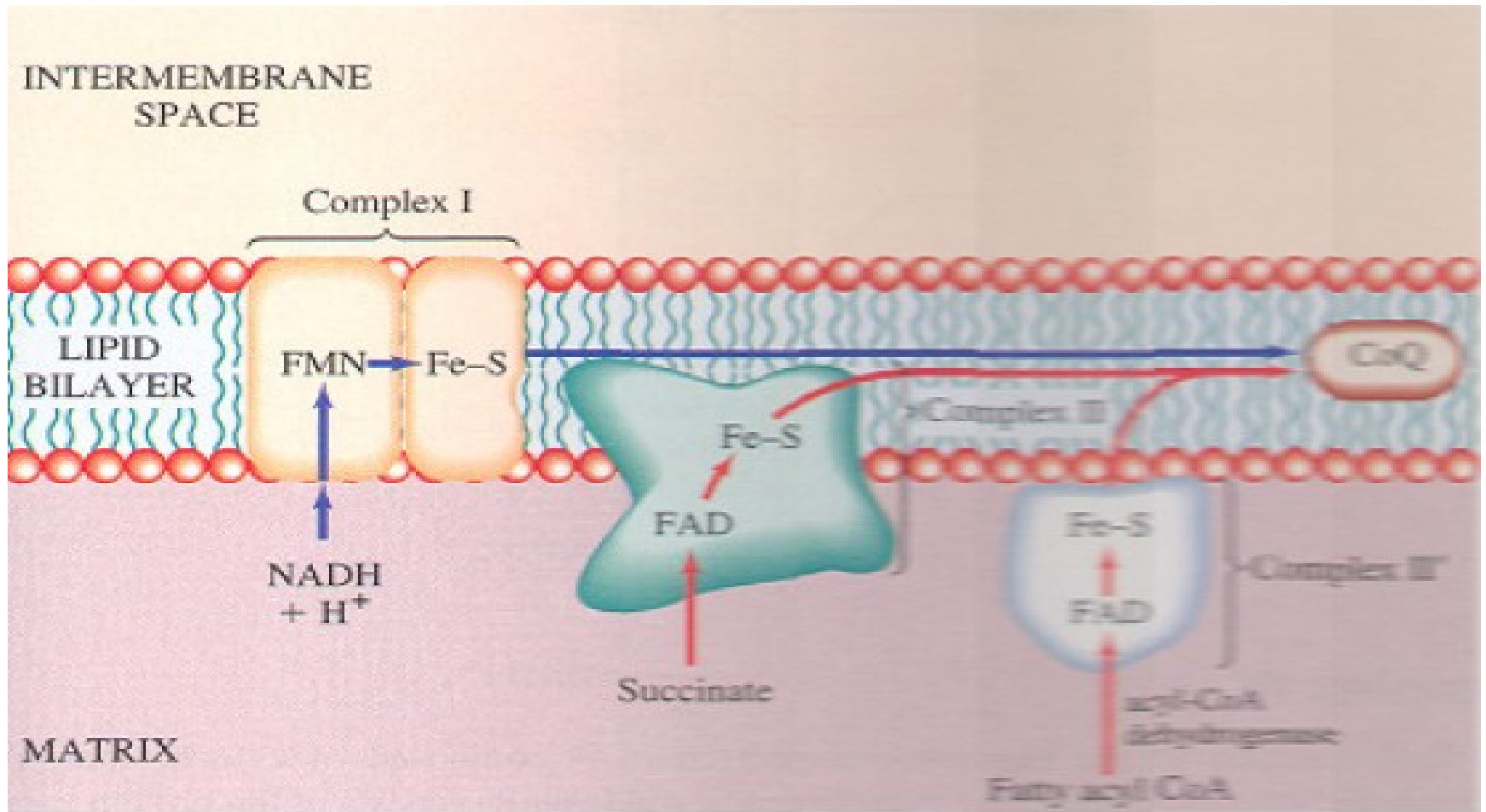
$$\Delta E^{\circ} = E_2^{\circ} - E_1^{\circ} \text{ — green line —}$$

$$0,18\text{ V} \sim +35\text{ kJ/mol}$$

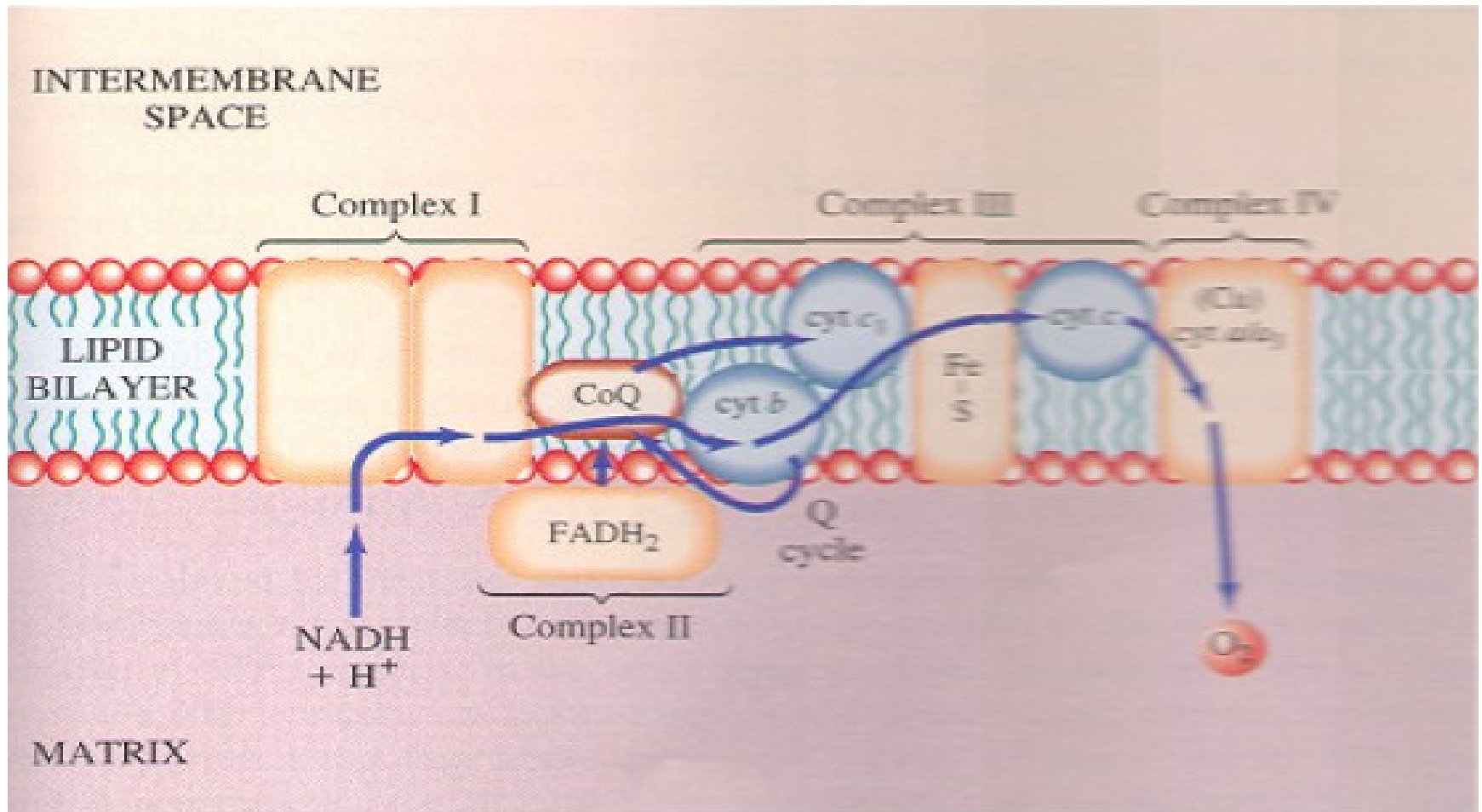
Komplex I



Komplex II

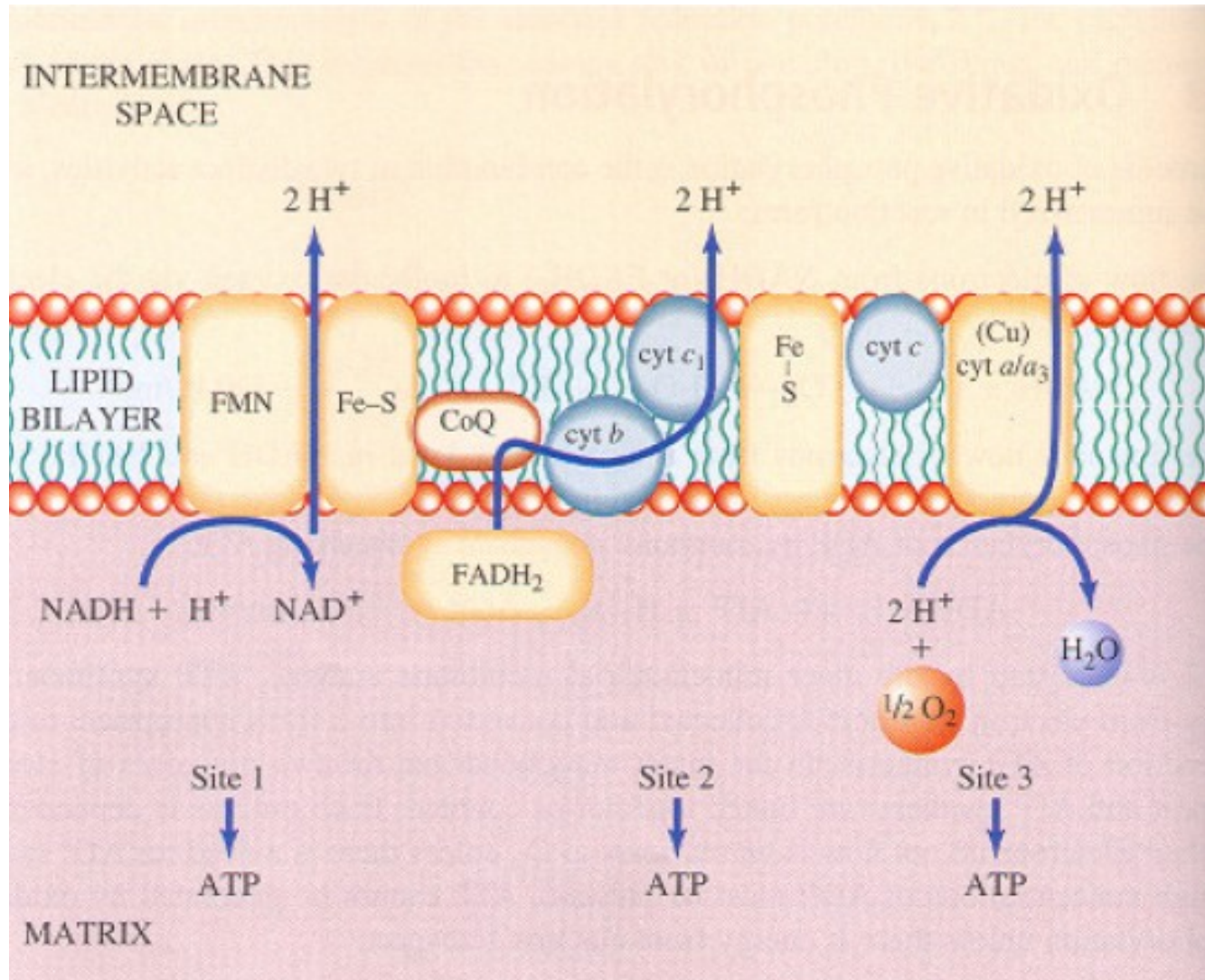


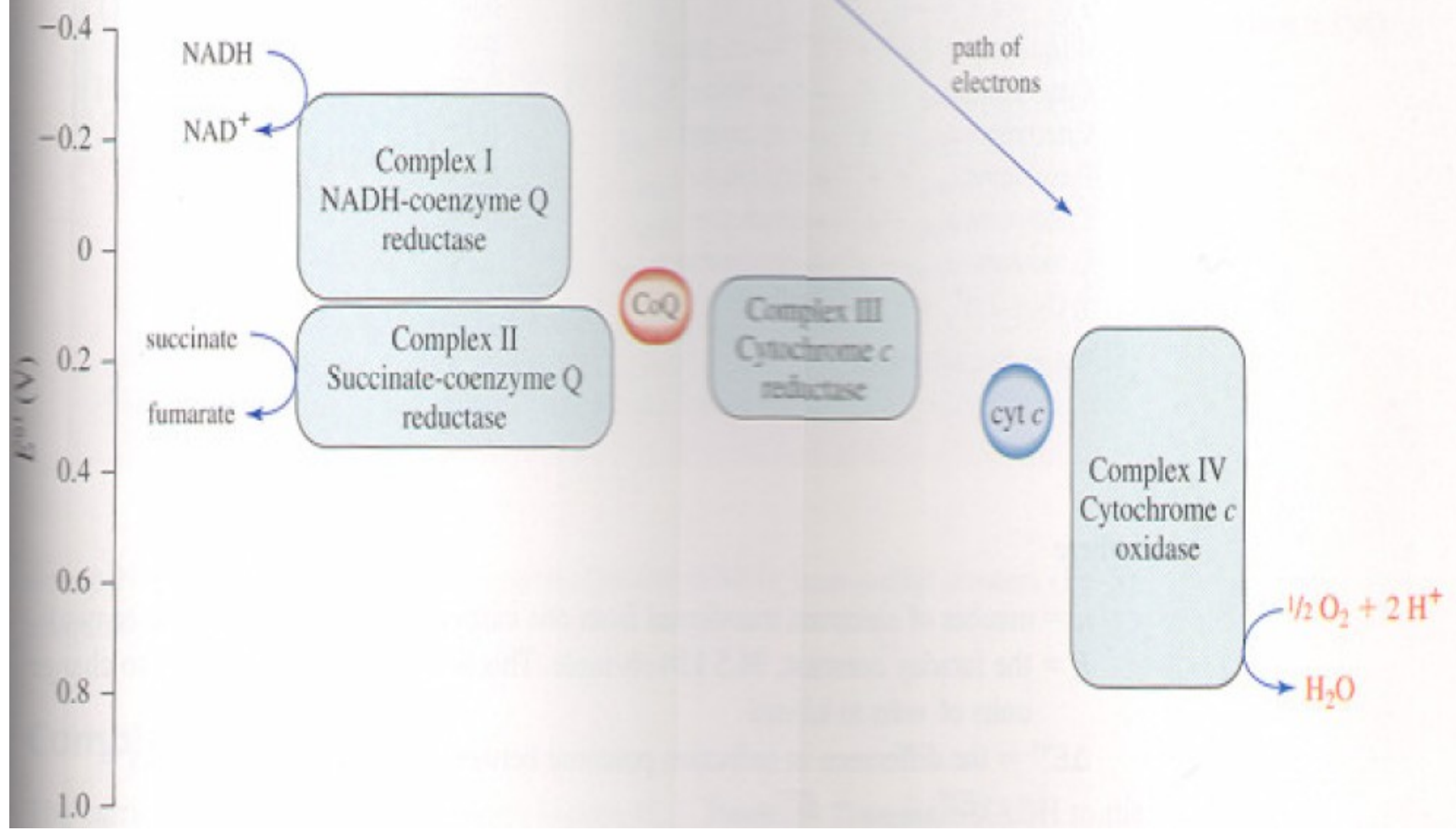
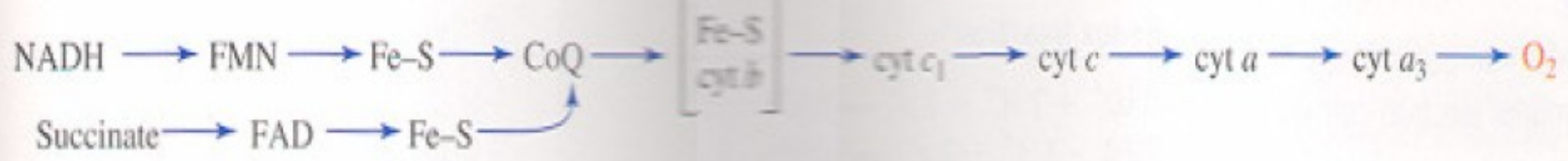
Komplex III a IV

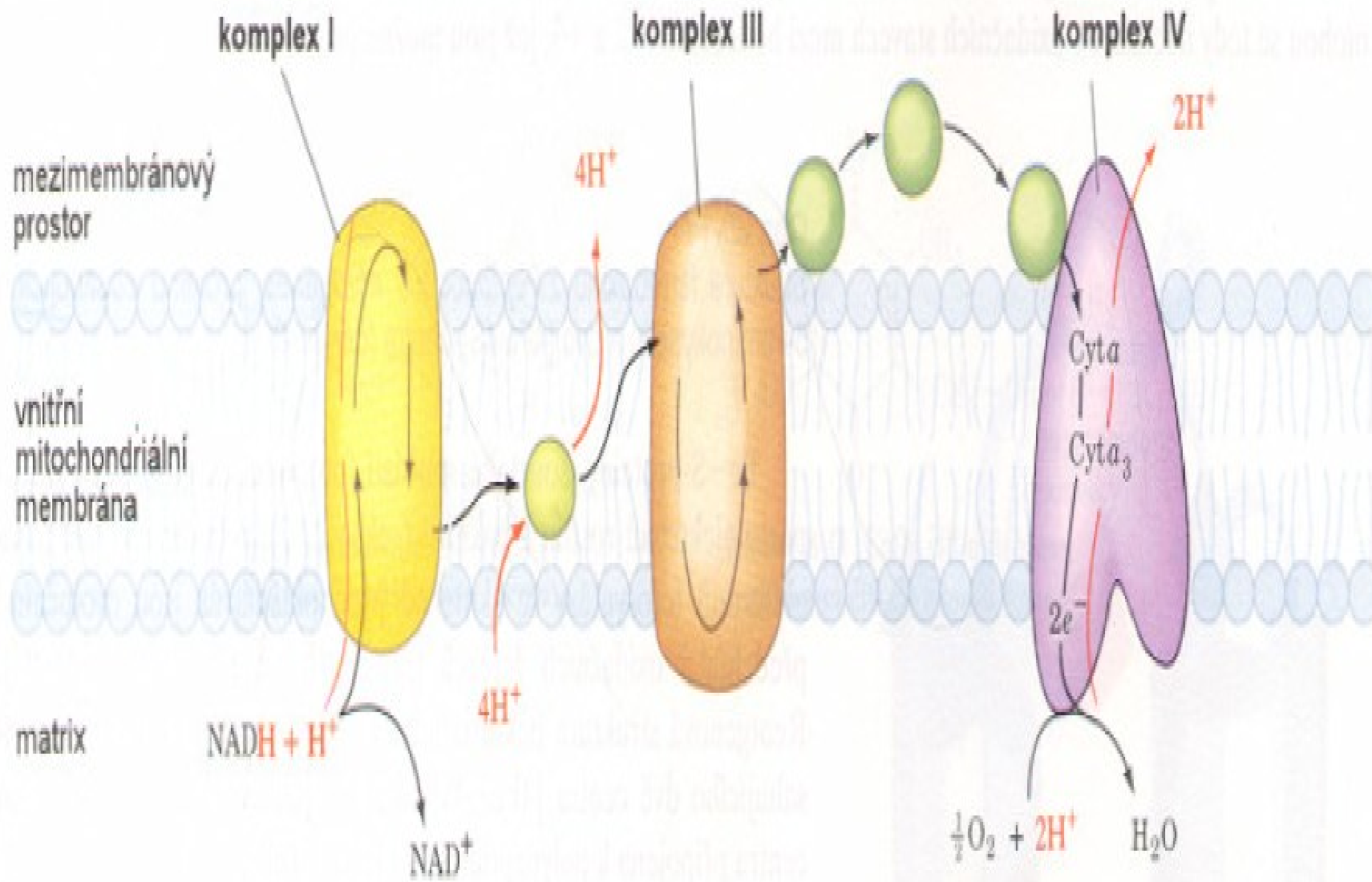


Chemiosmotická teorie

Mitchell 1961

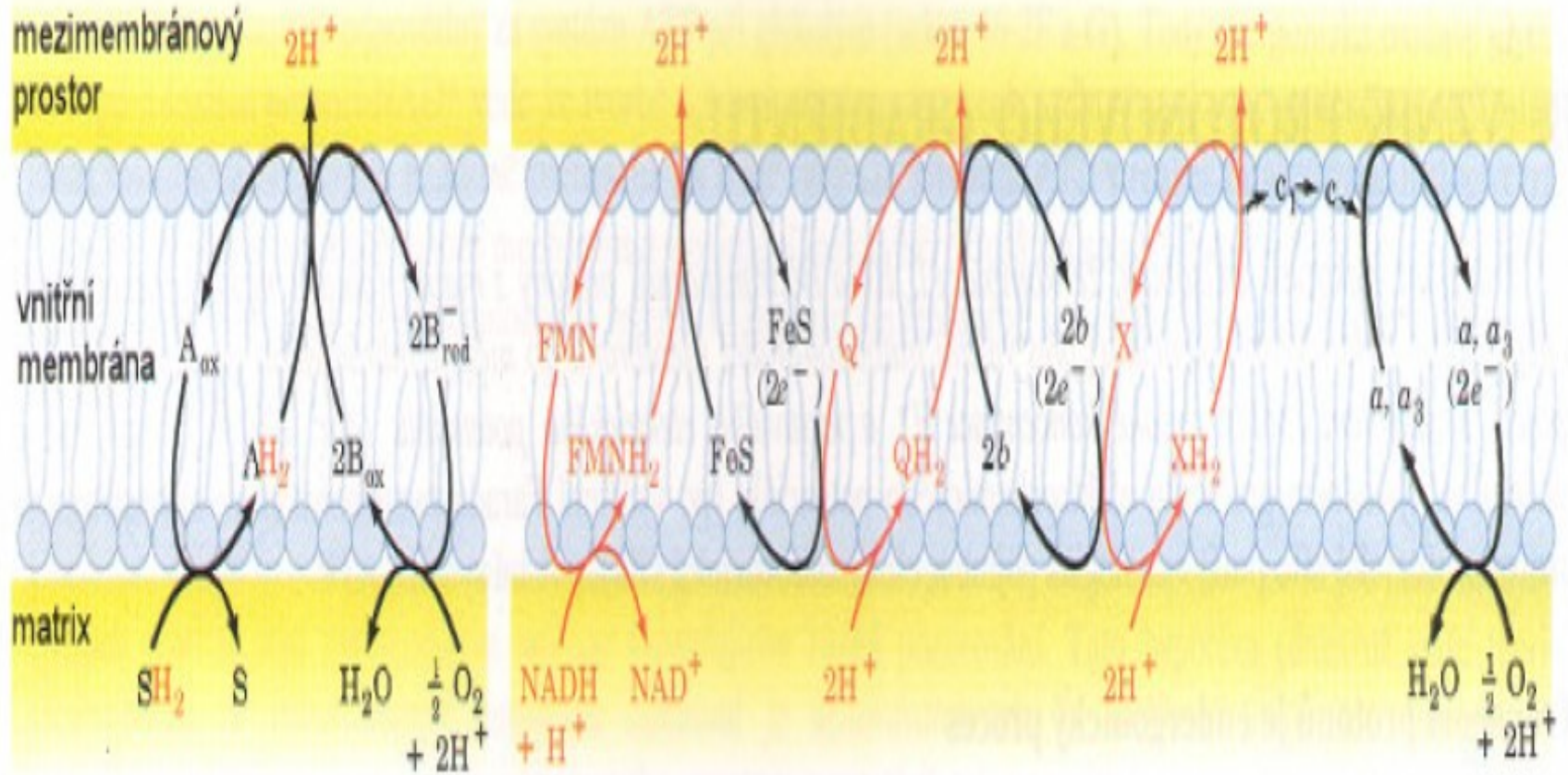




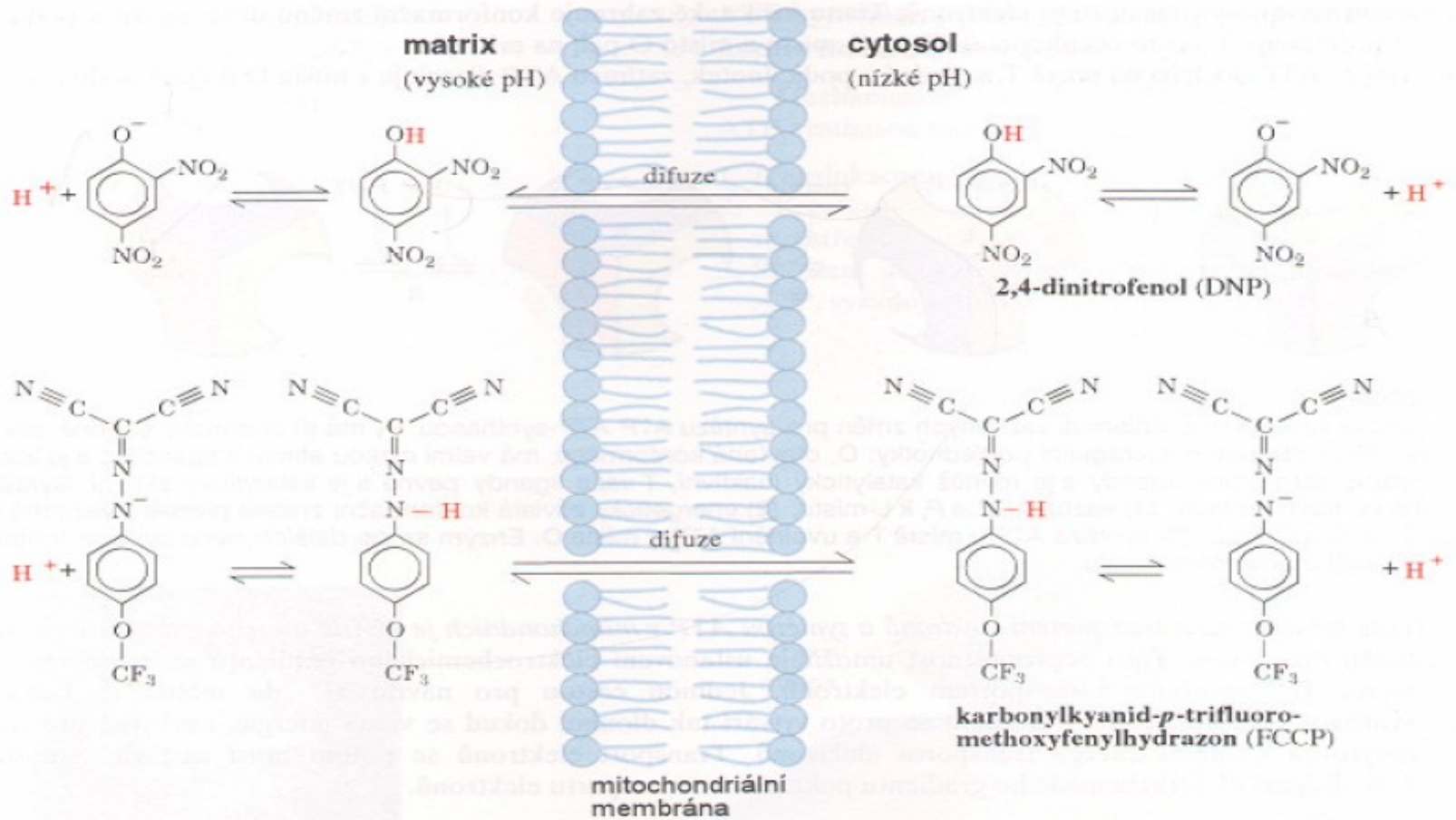


jednoduchá
(a) redoxní
smyčka

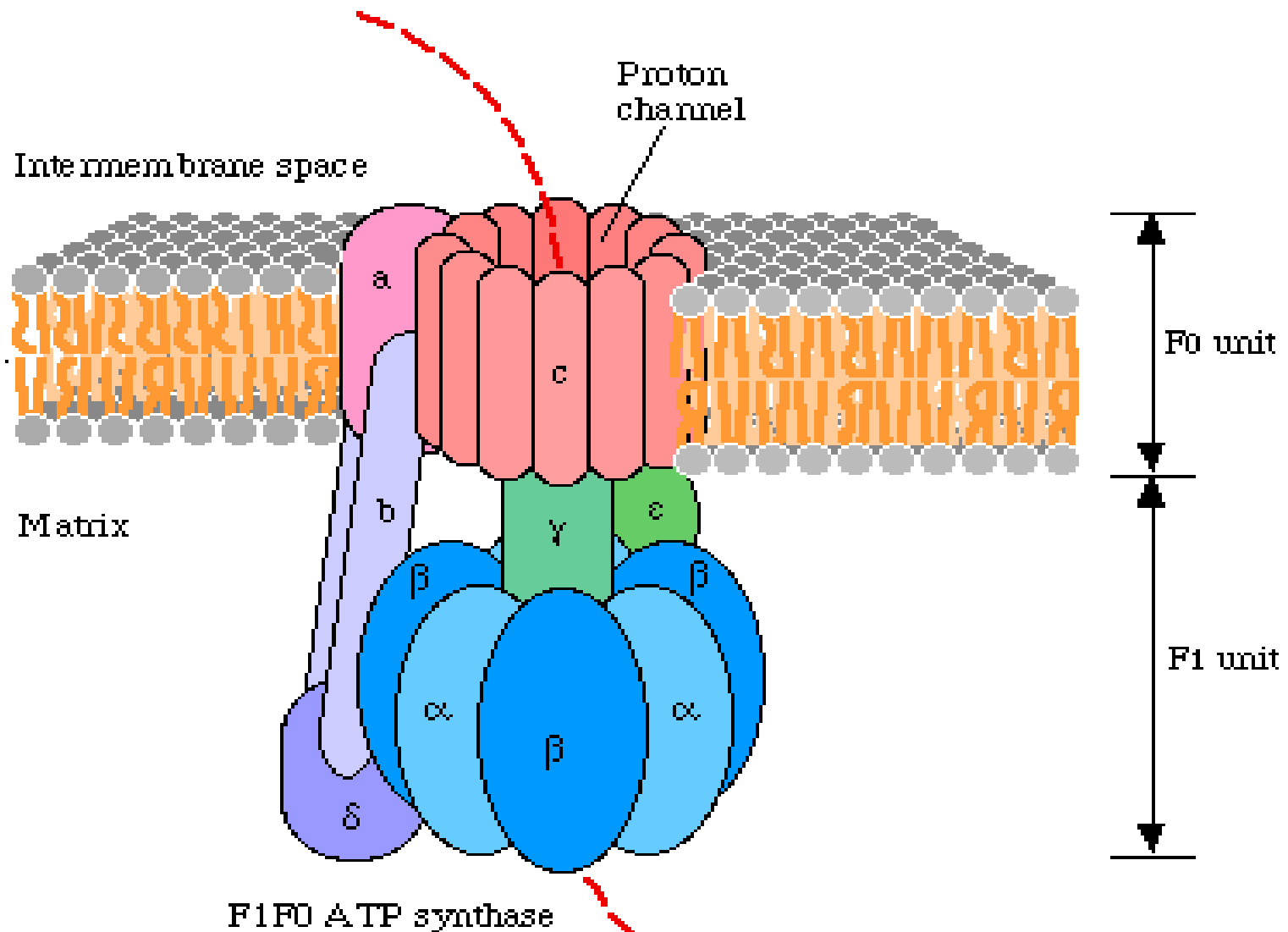
soustava
(b) redoxních
smyček

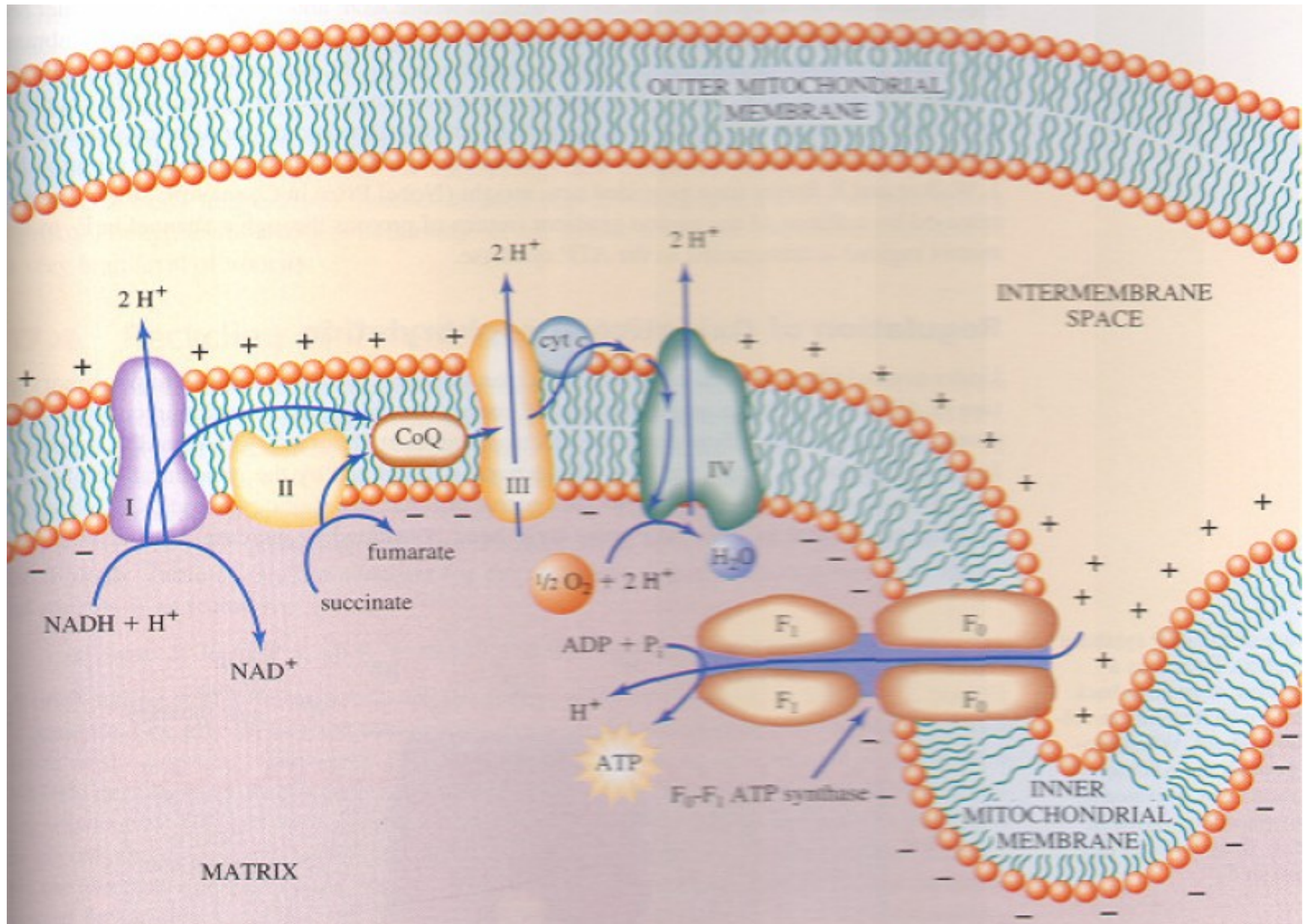


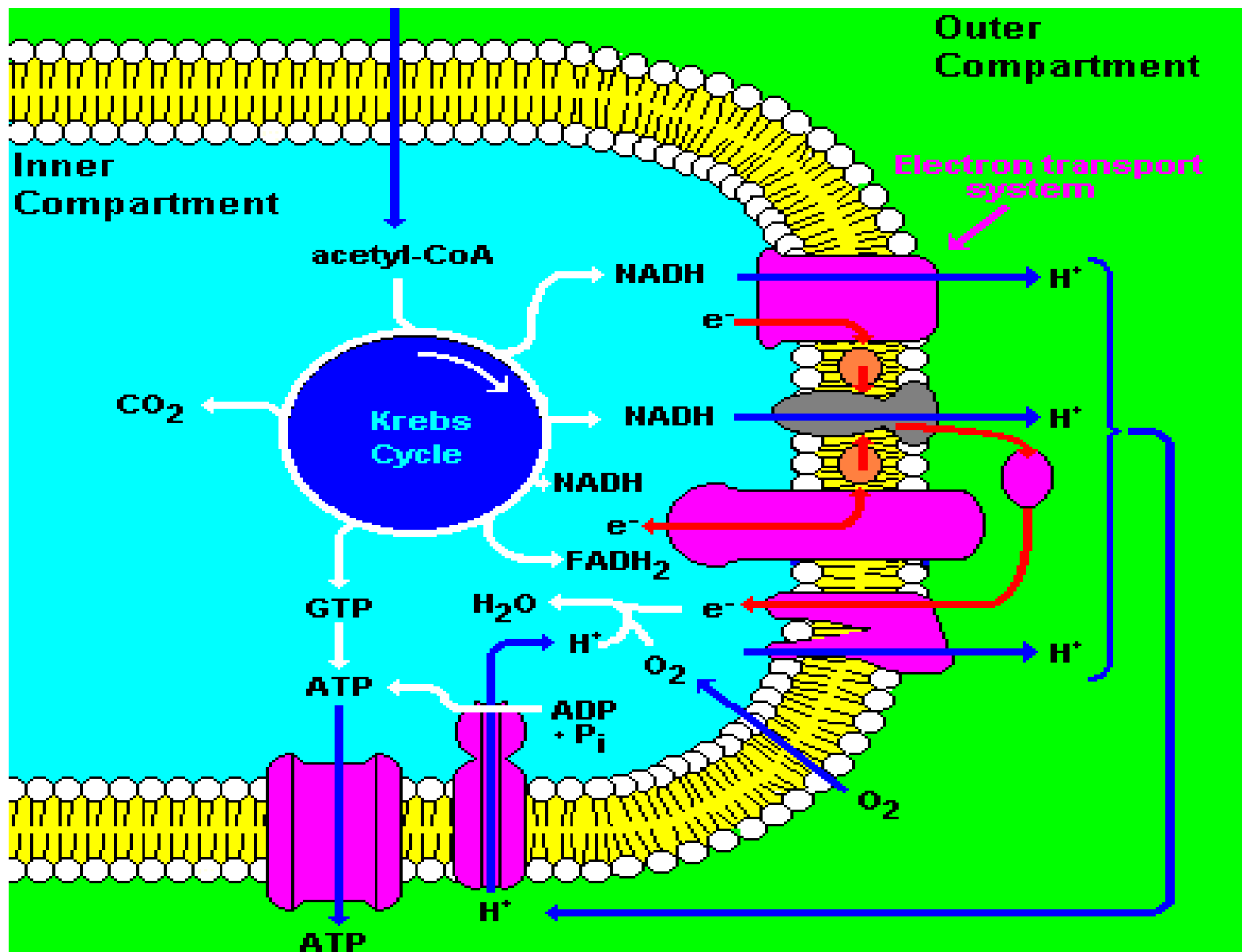
Rozpojovače



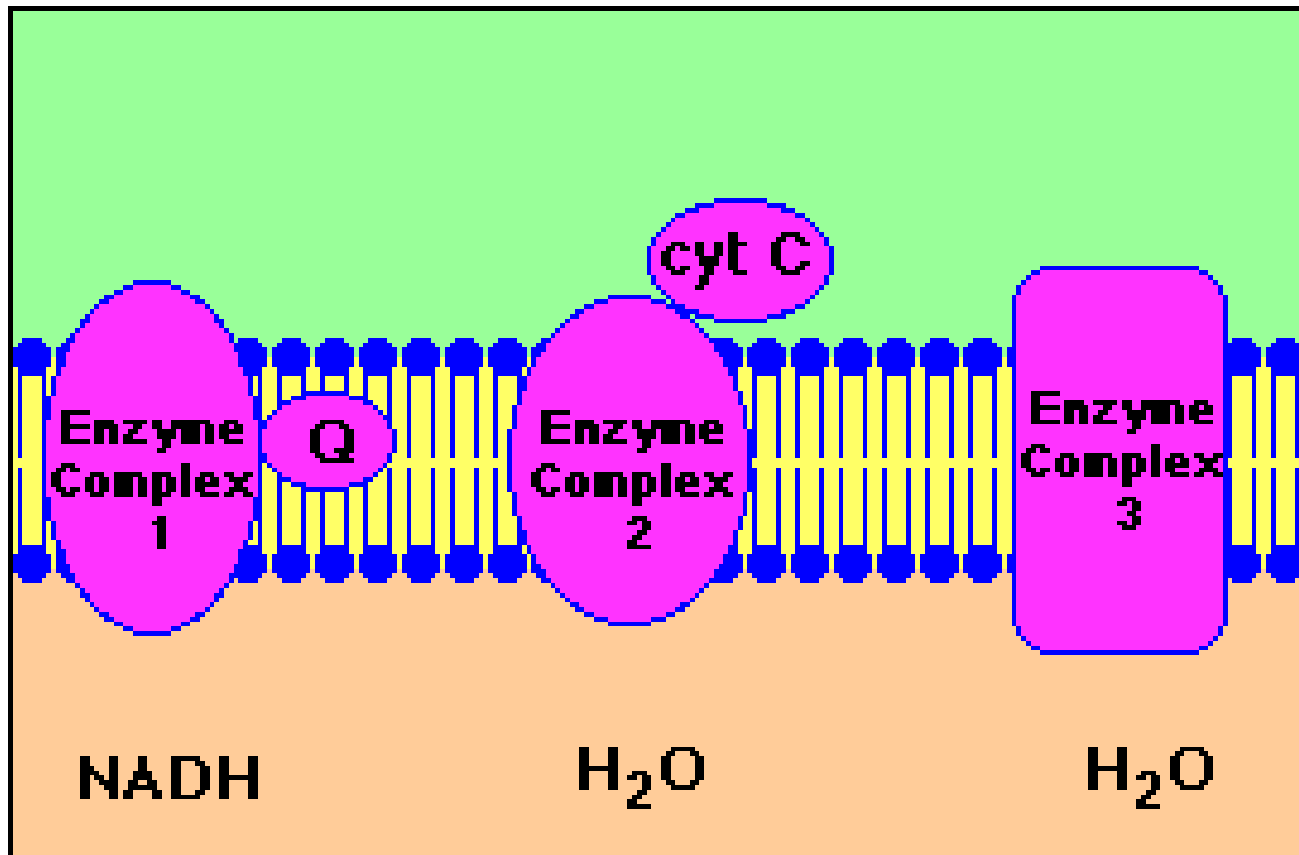
ATPase



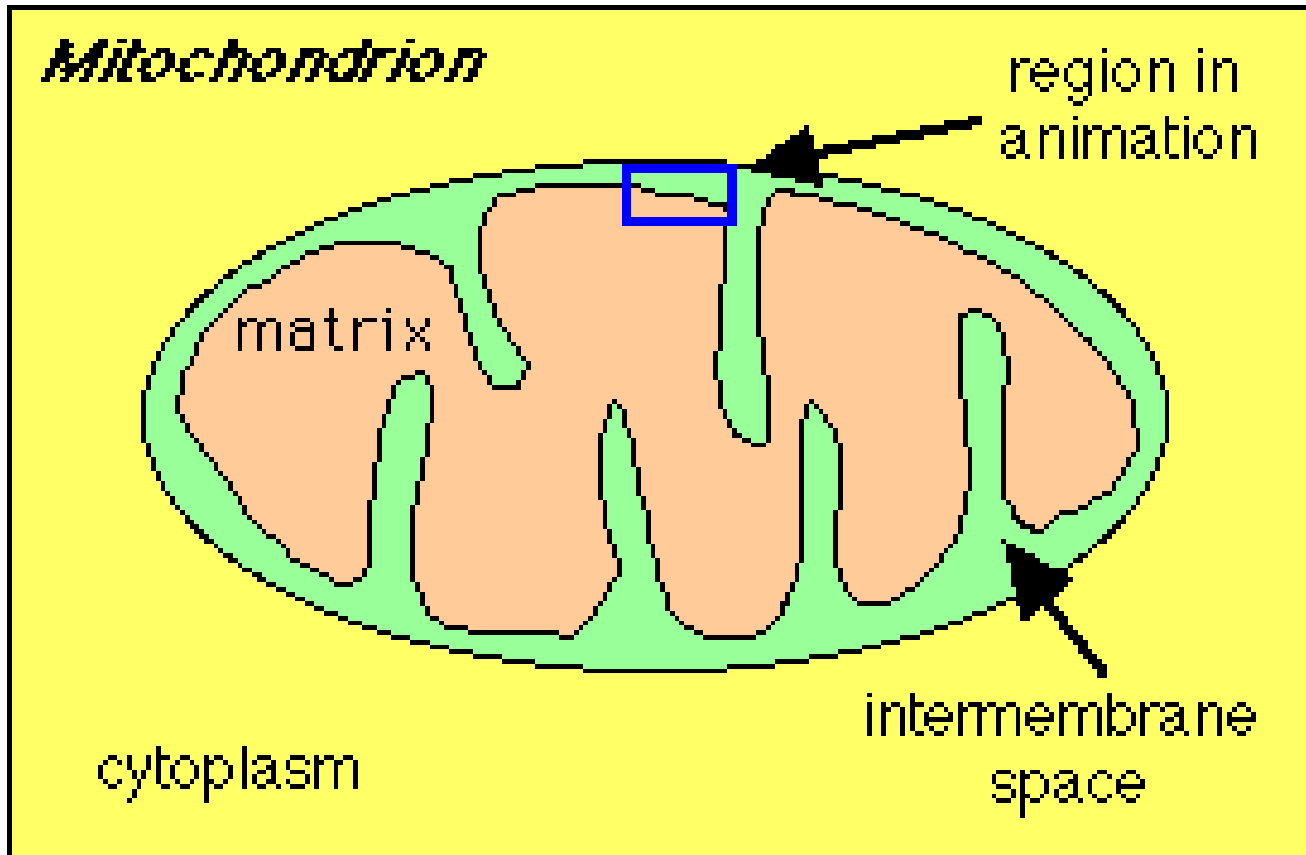




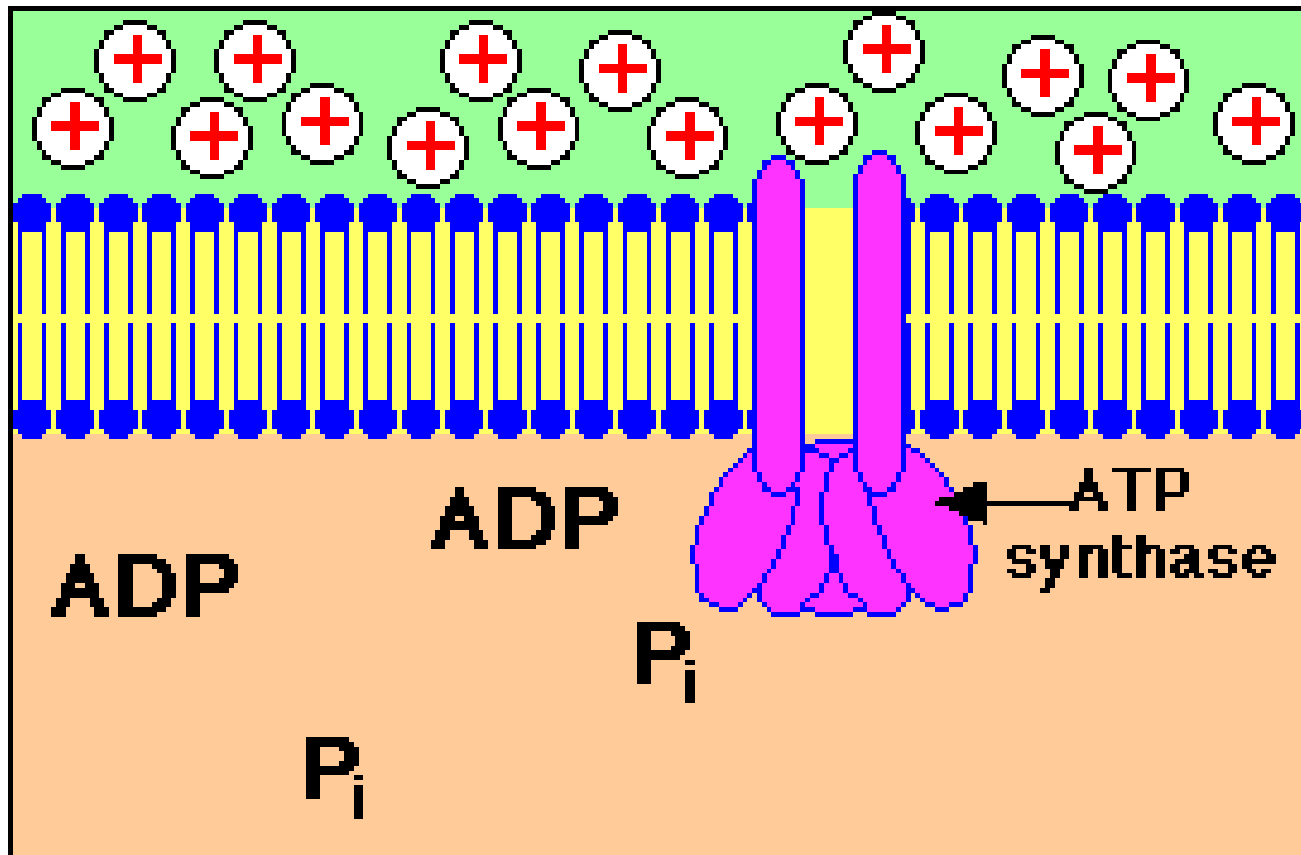
Transport elektronů



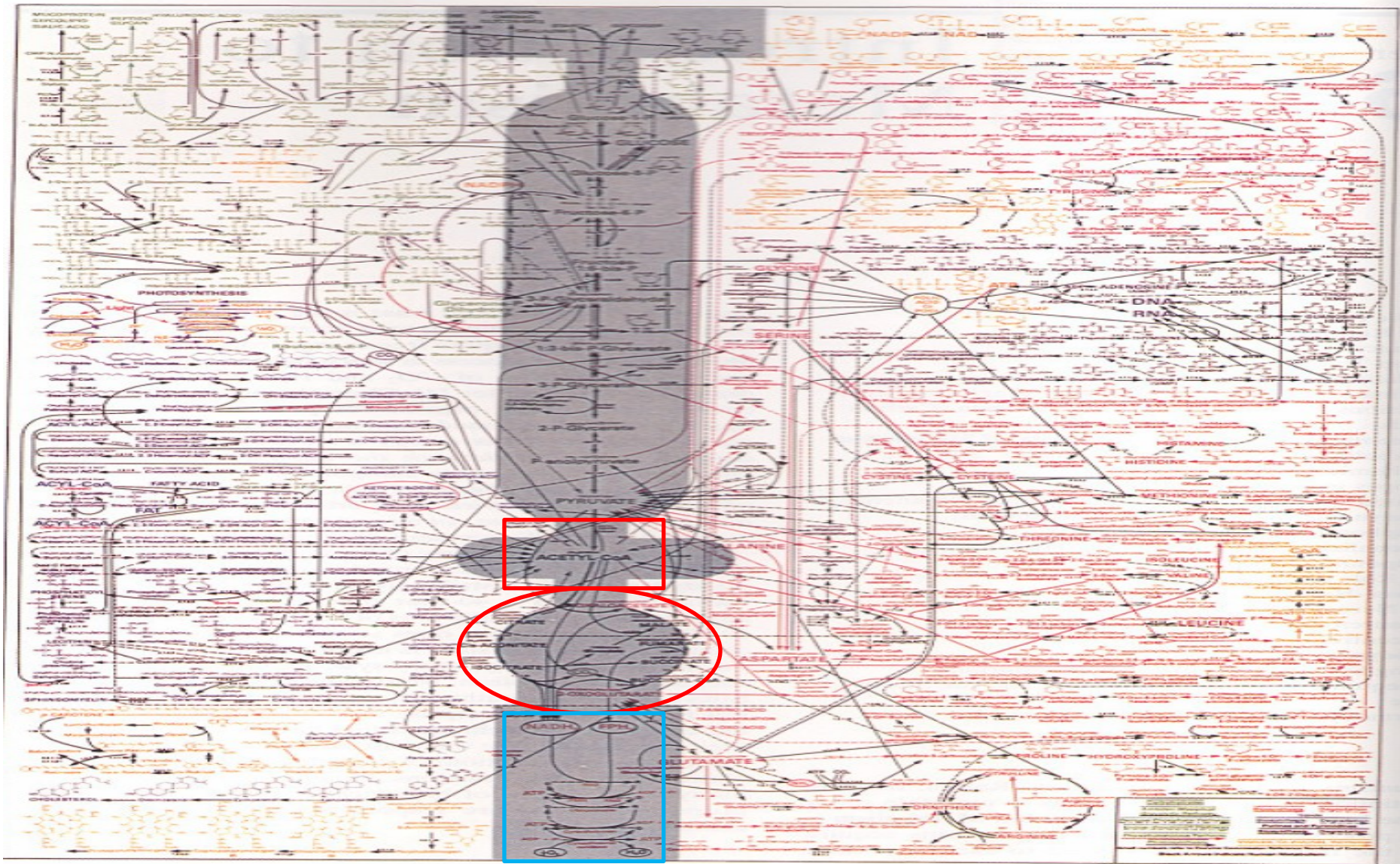
Lokalizace



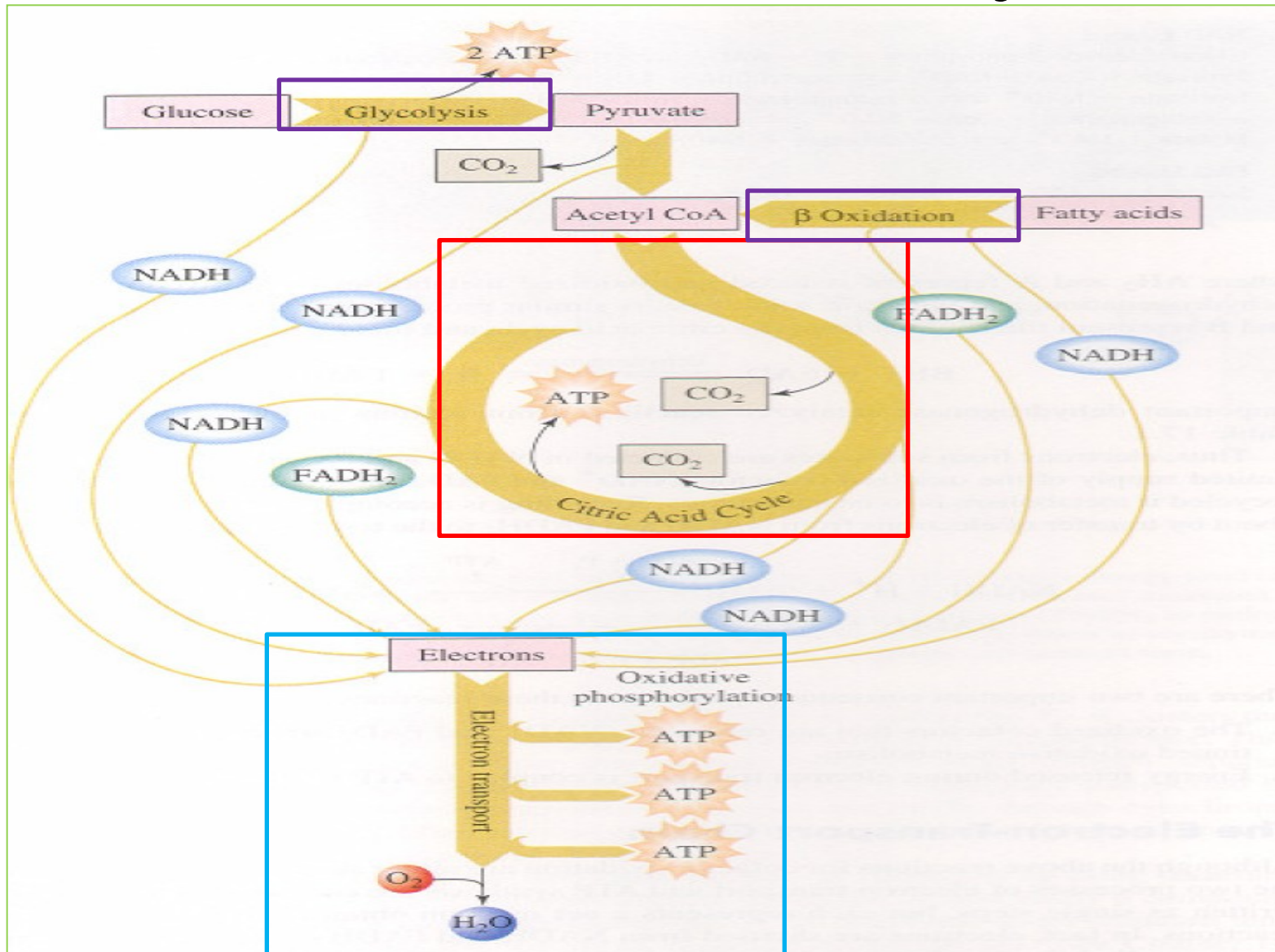
ATPase



Metabolické dráhy

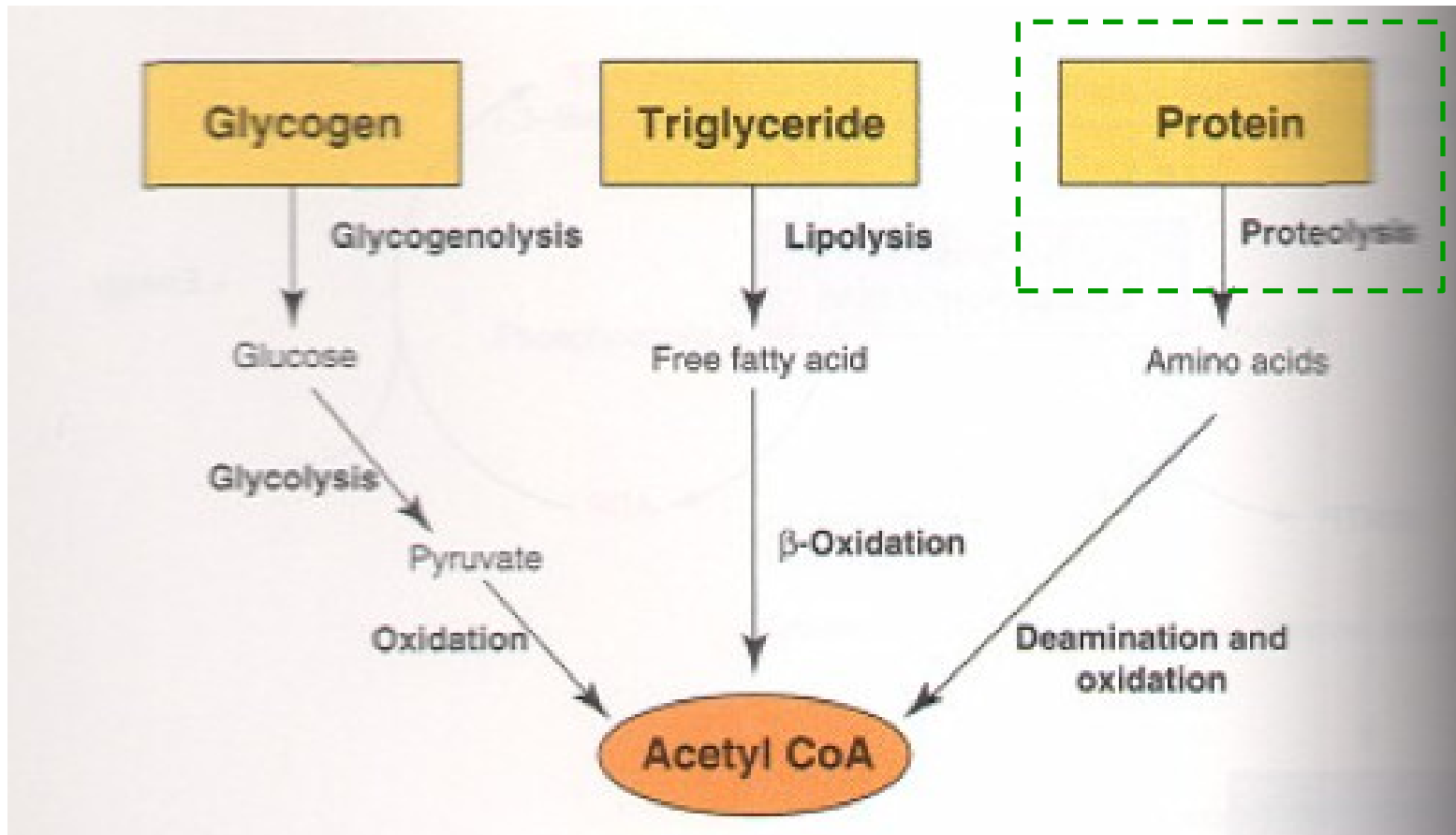


Metabolické dráhy



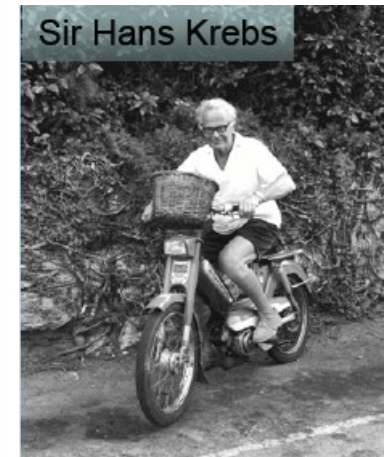
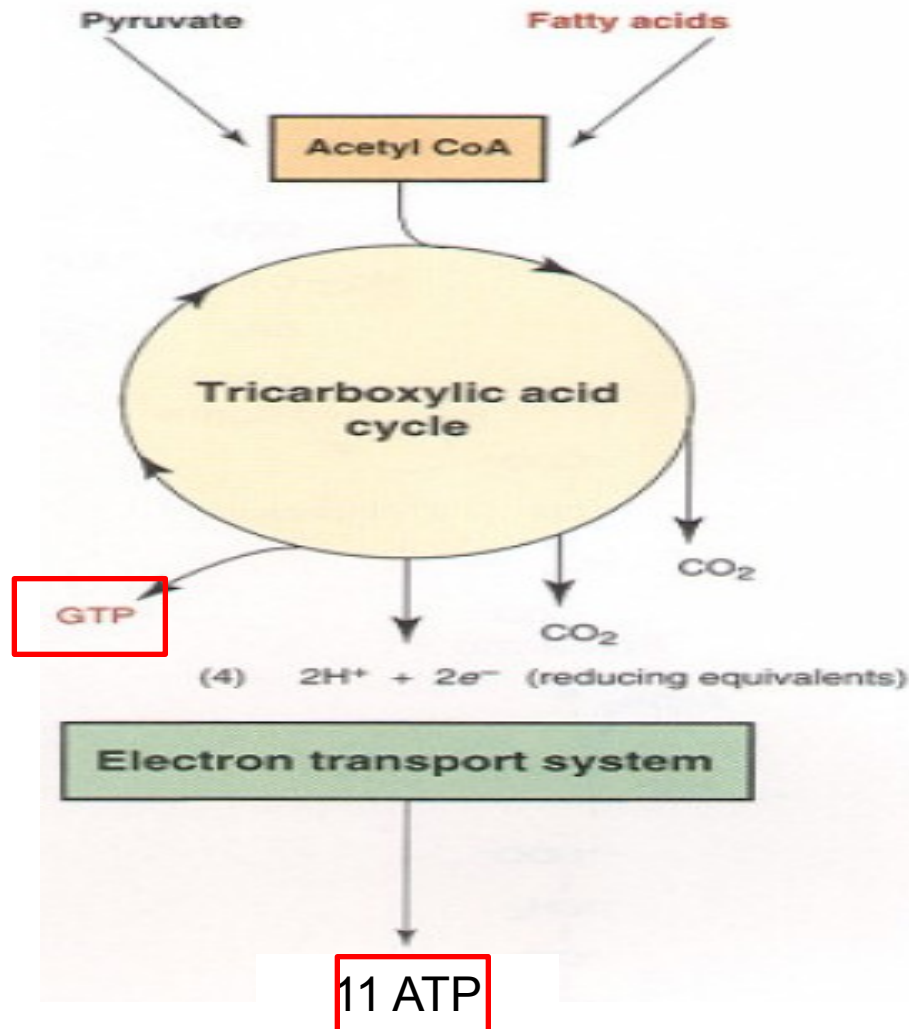
CITRÁTOVÝ CYKLUS

H.Krebs (1937) - Krebsův cyklus, cyklus trikarboxylových kyselin



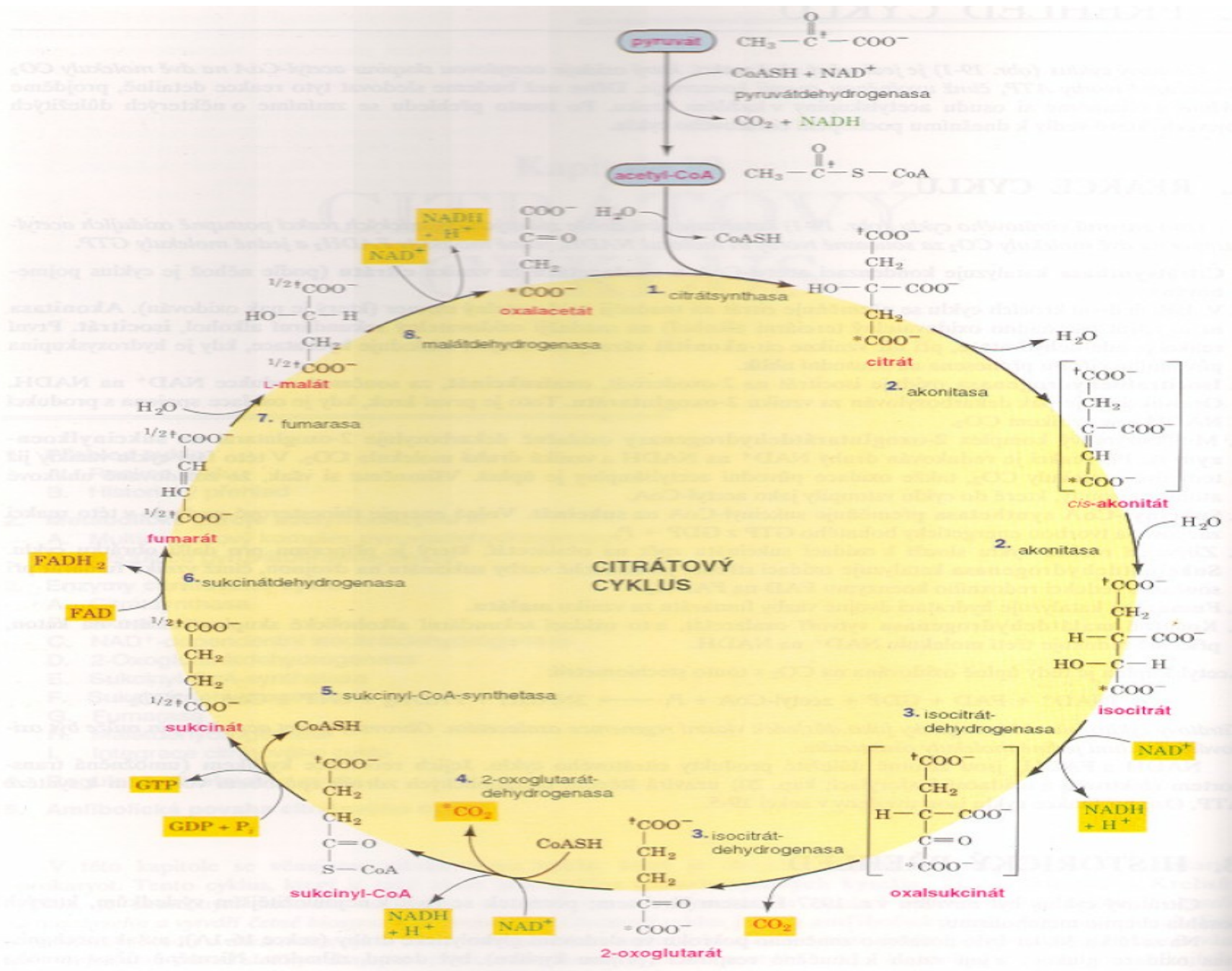
CITRÁTOVÝ CYKLUS

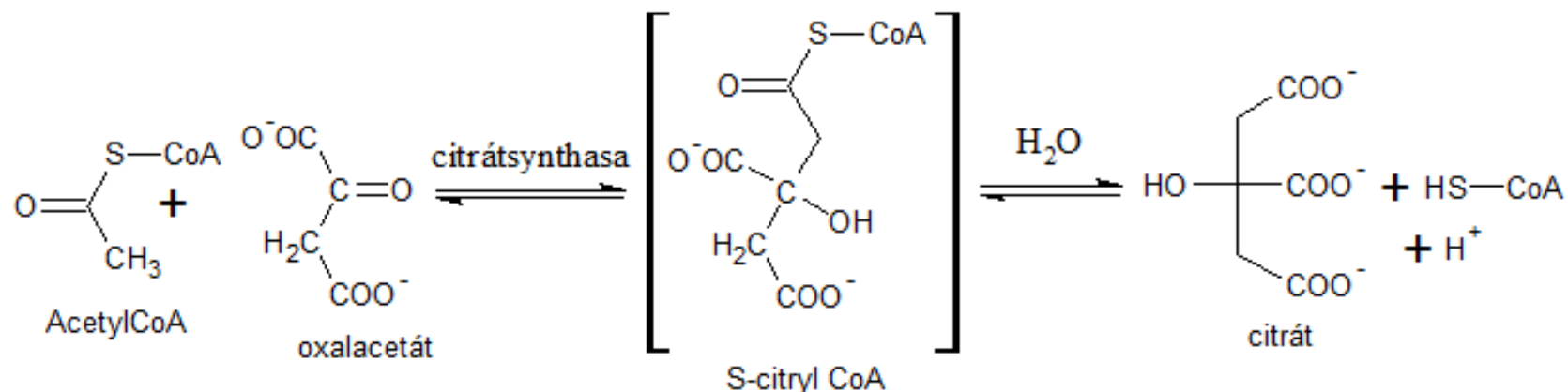
H.Krebs (1937) - Krebsův cyklus, cyklus trikarboxylových kyselin

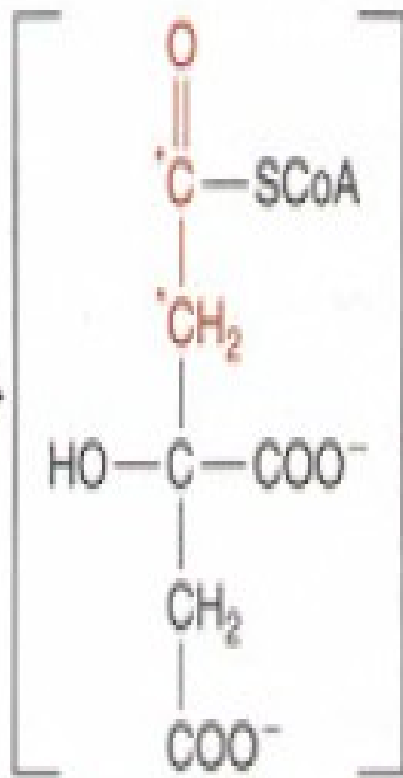


Sir Hans Krebs

1953 NC

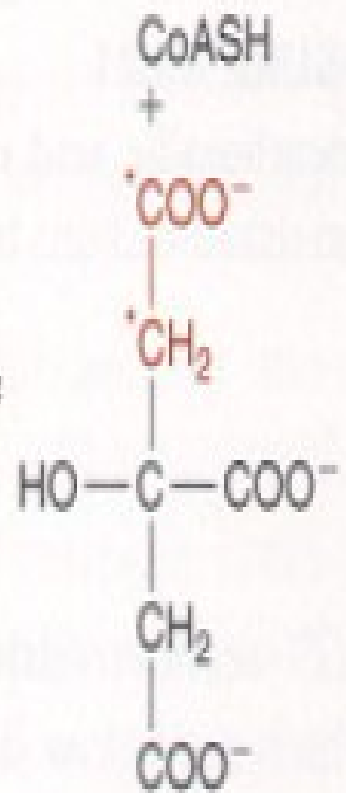






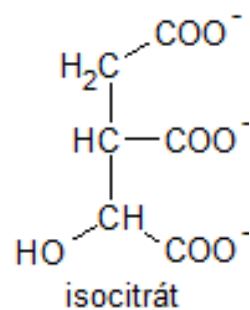
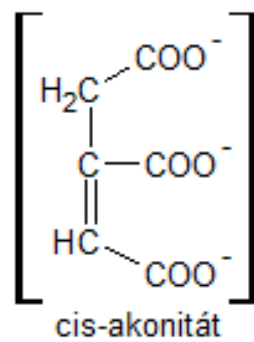
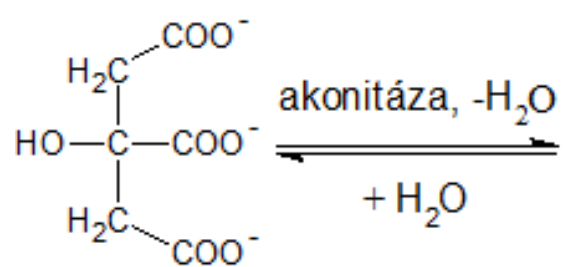
Enzyme-bound
citroyl-SCoA

H₂O



Citrate

CITRATE SYNTHASE



100

150

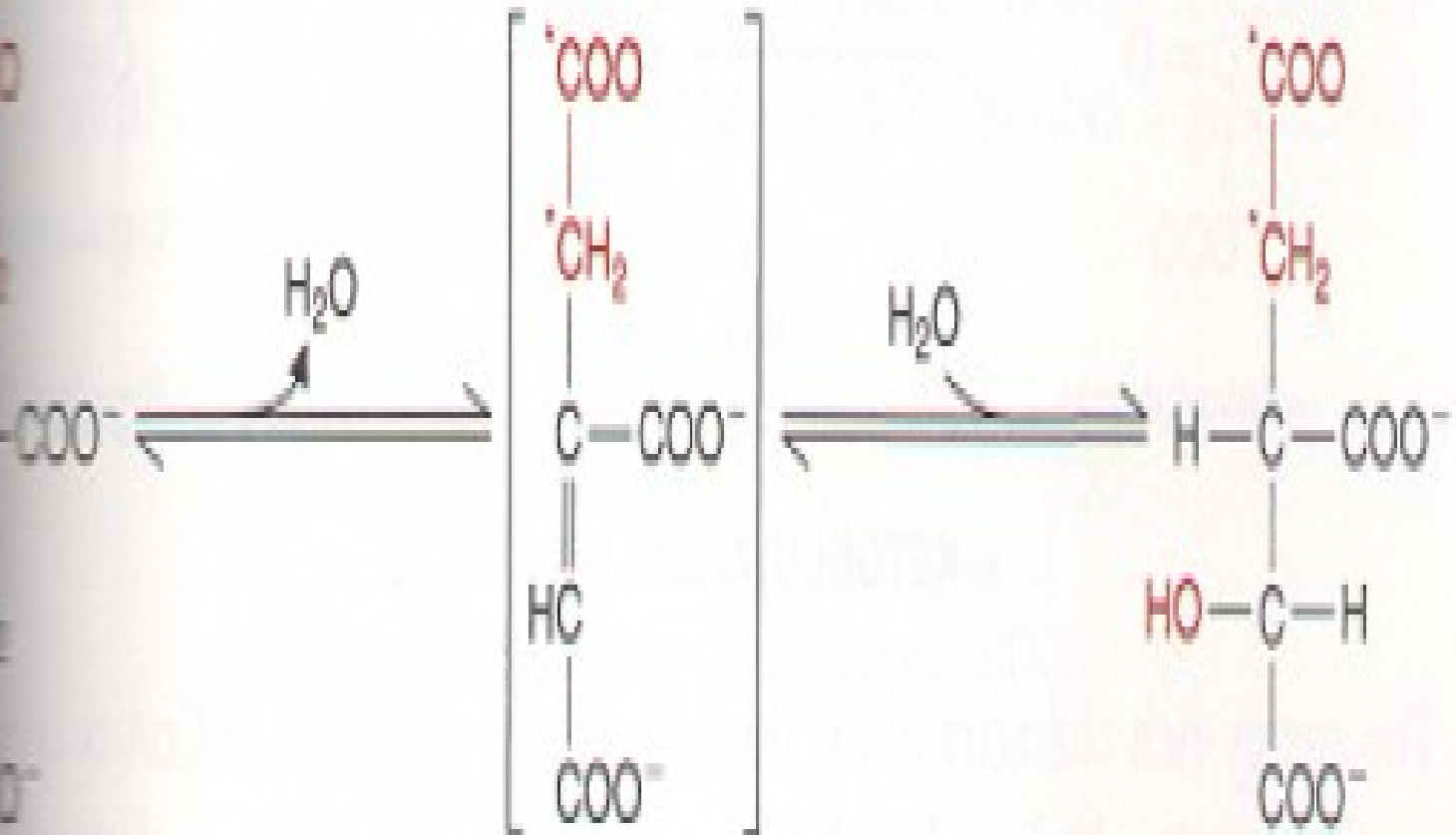
200

250

200

150

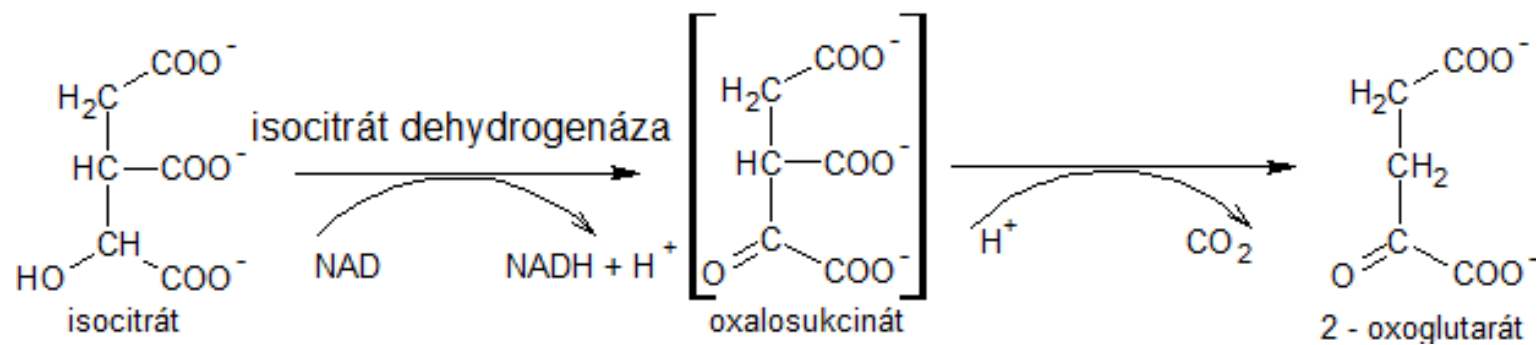
100

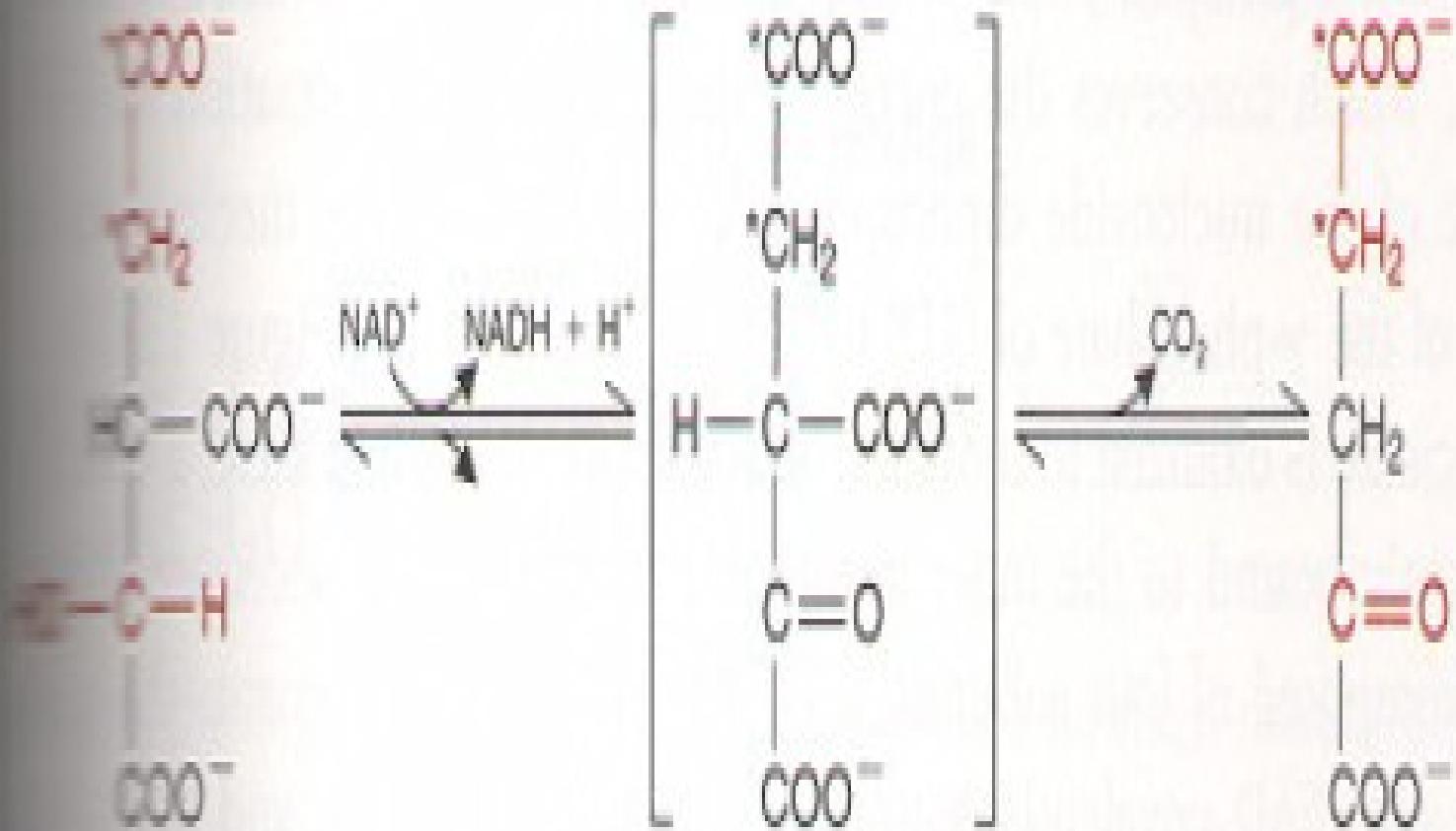


cis-Aconitate

Isocitrate

ACONITASE



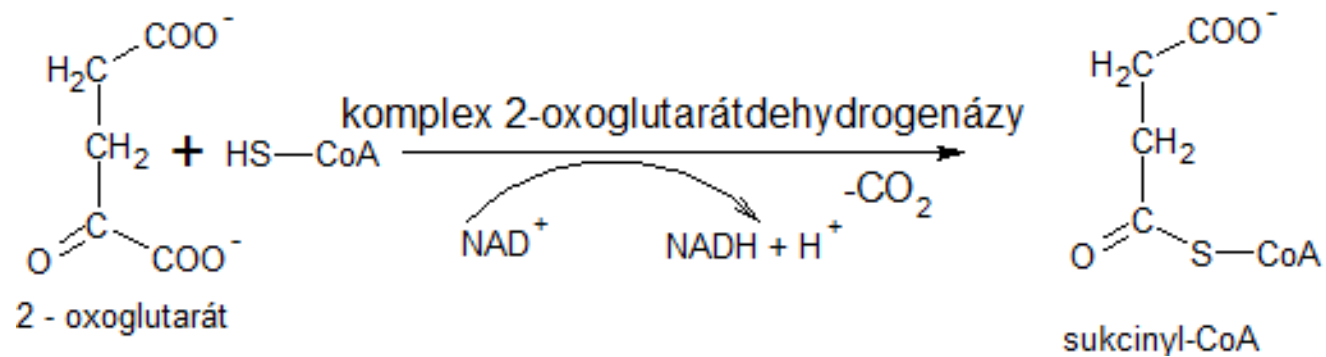


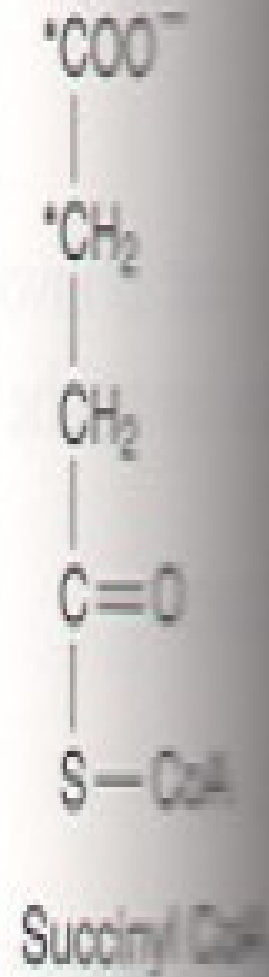
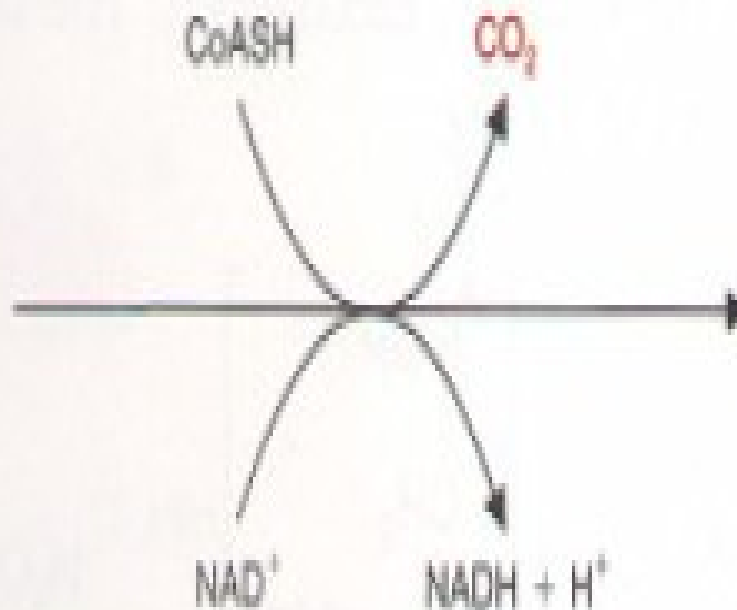
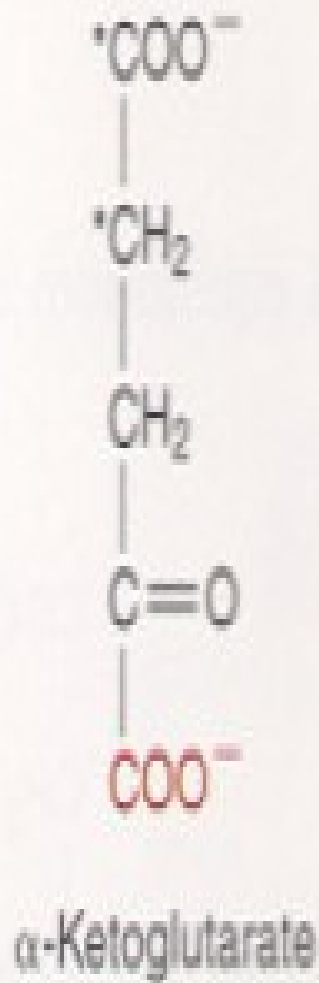
isocitrate

Oxalosuccinate

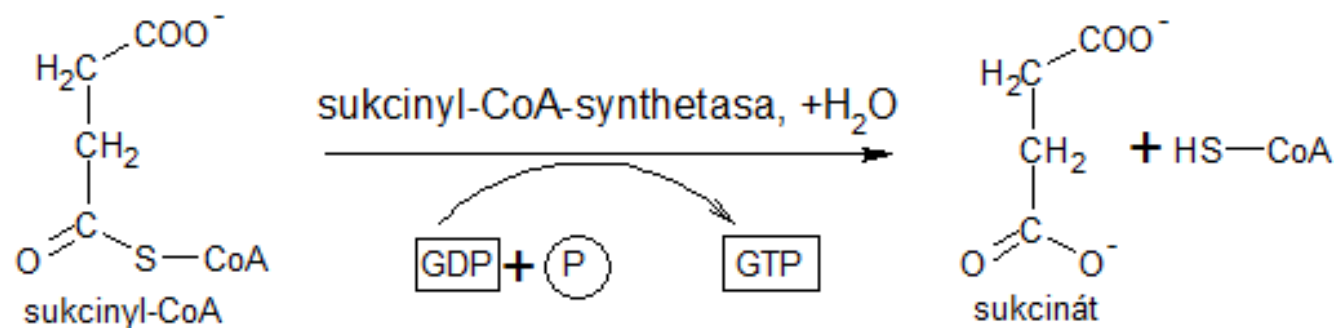
α -Ketoglutarate

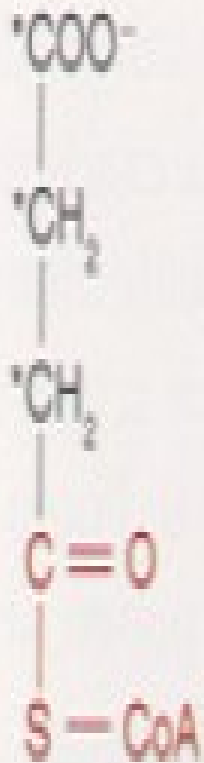






3 enzymy + 5 kofaktorů



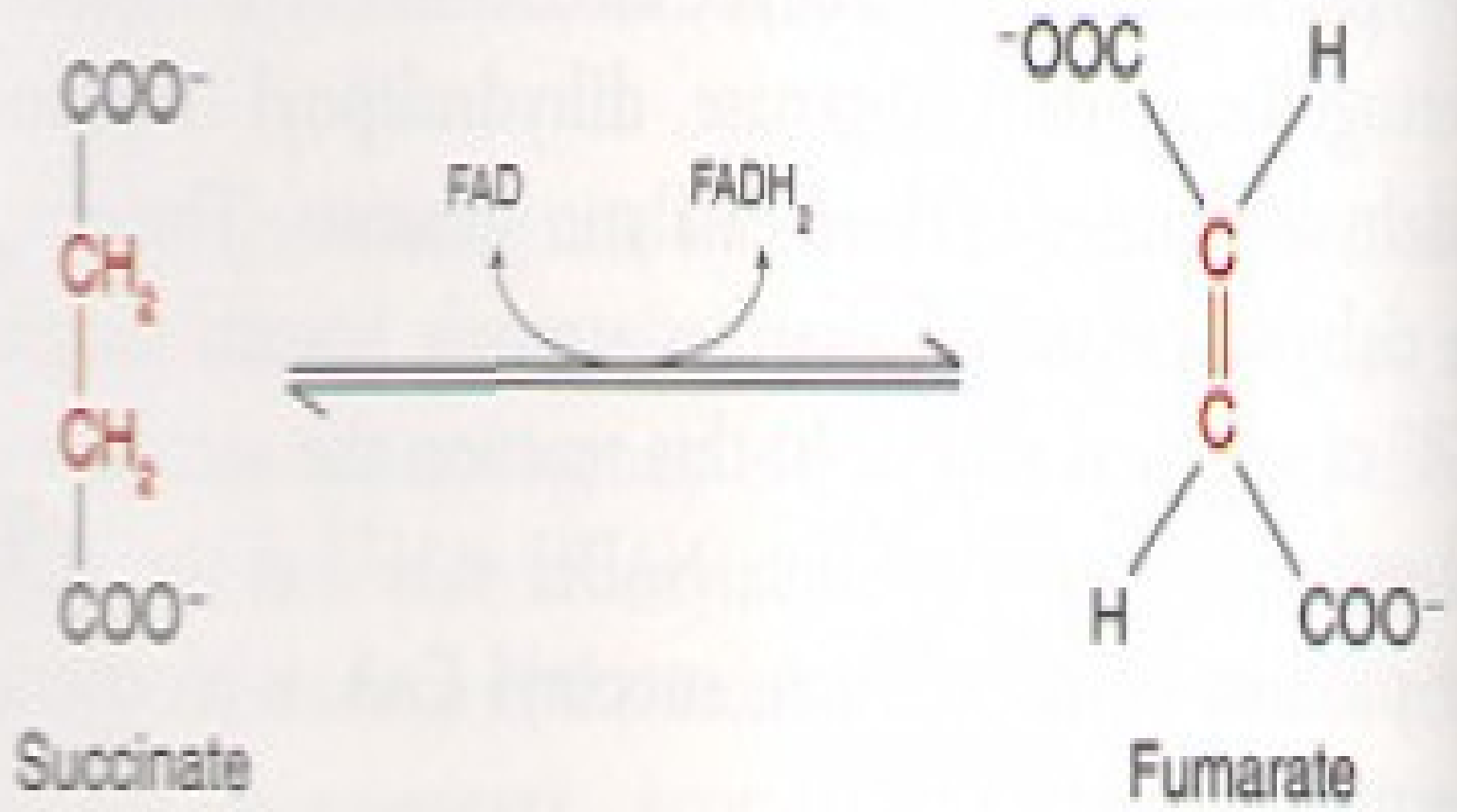


Succinyl CoA

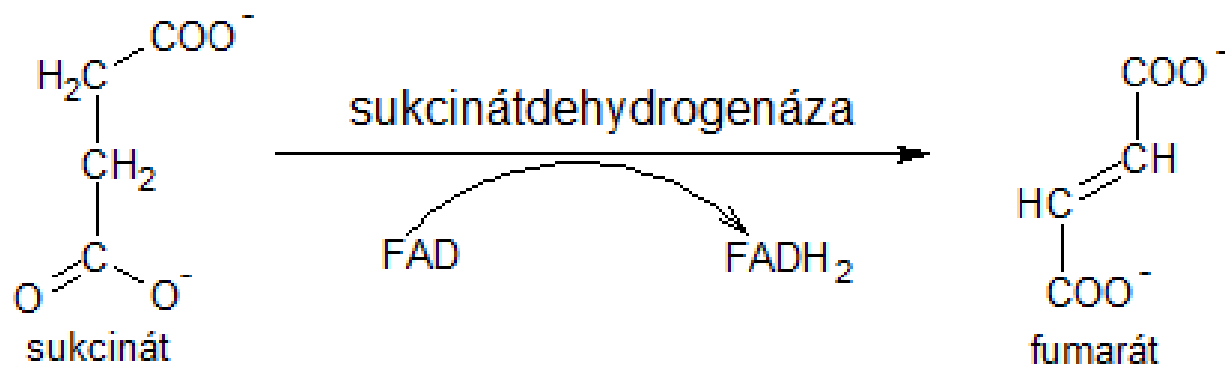


Succinate

SUCCINYL CoA SYNTHETASE

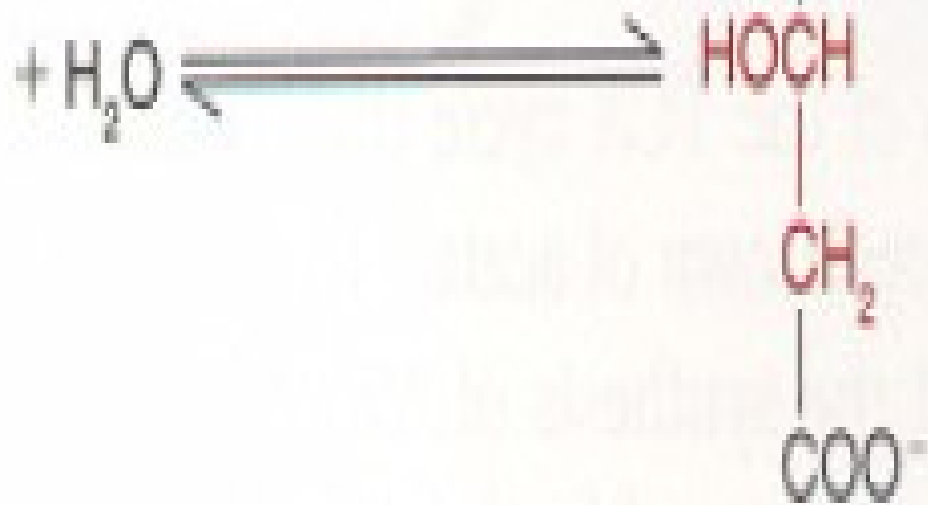


SUCCINATE DEHYDROGENASE



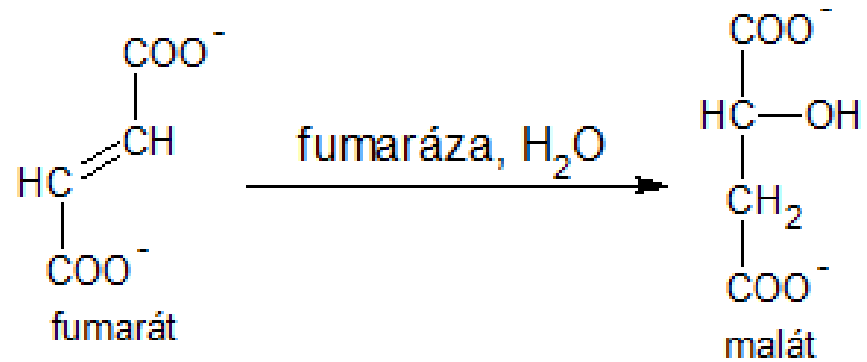


Fumarate



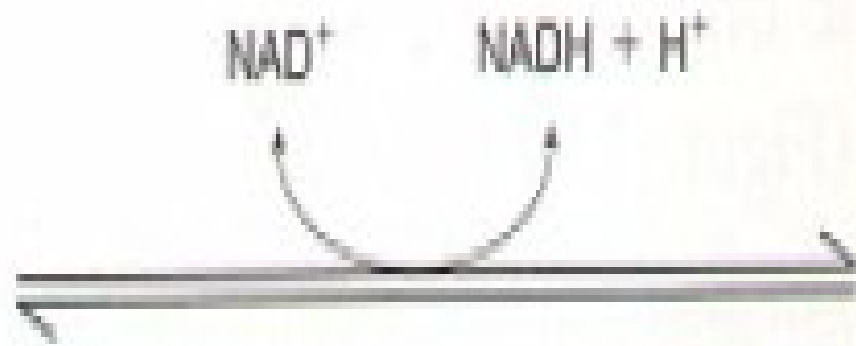
L-Malate

FUMARASE



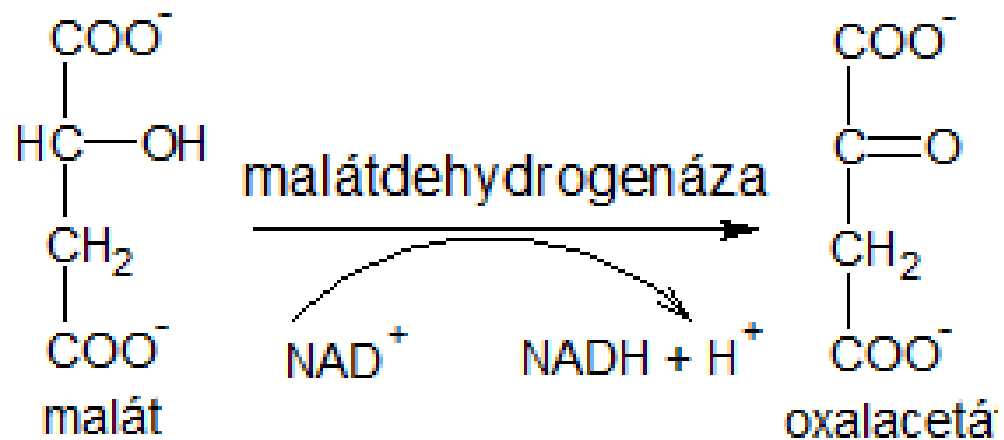


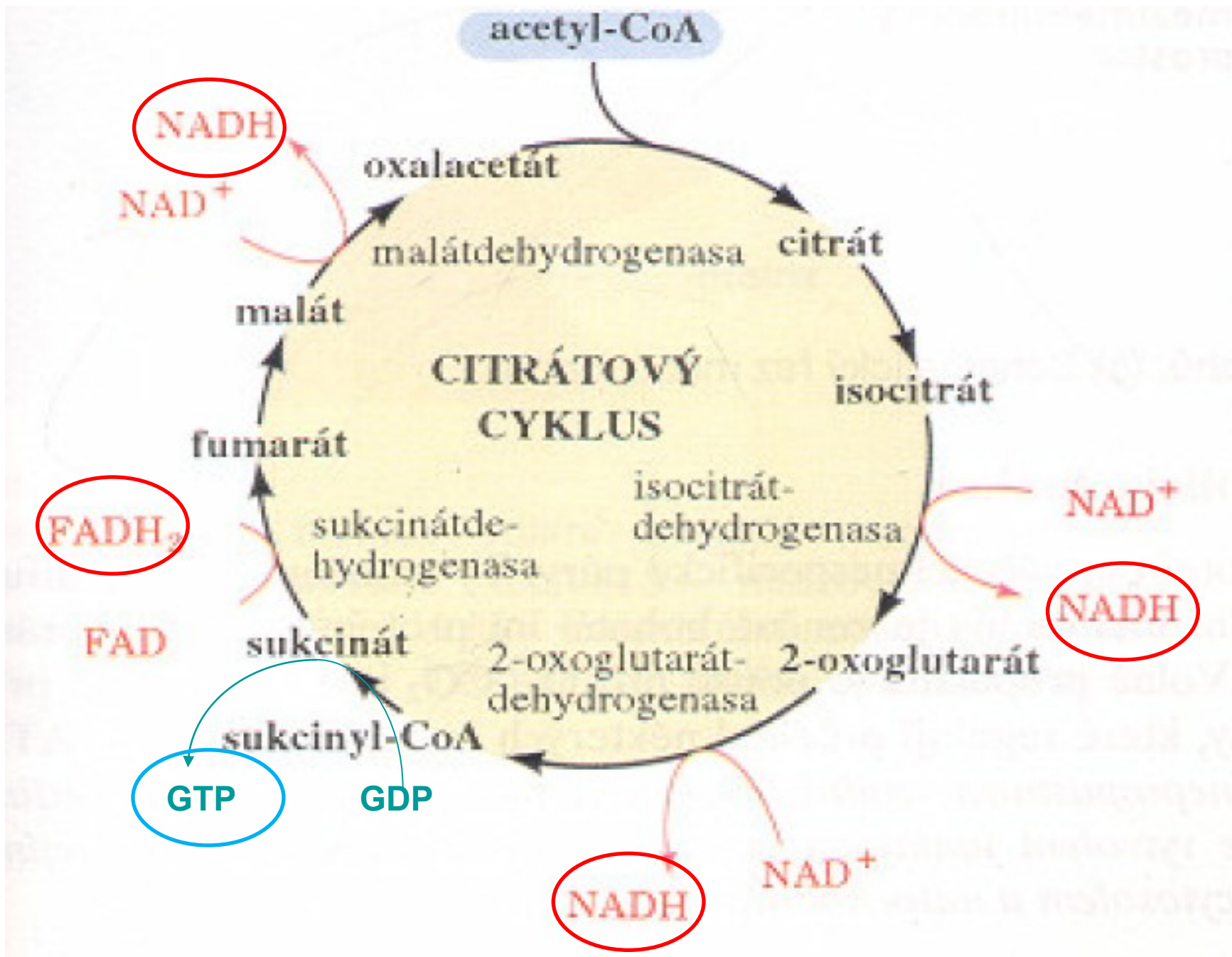
L-Malate



Oxaloacetate

MALATE DEHYDROGENASE





Bilance cyklu :



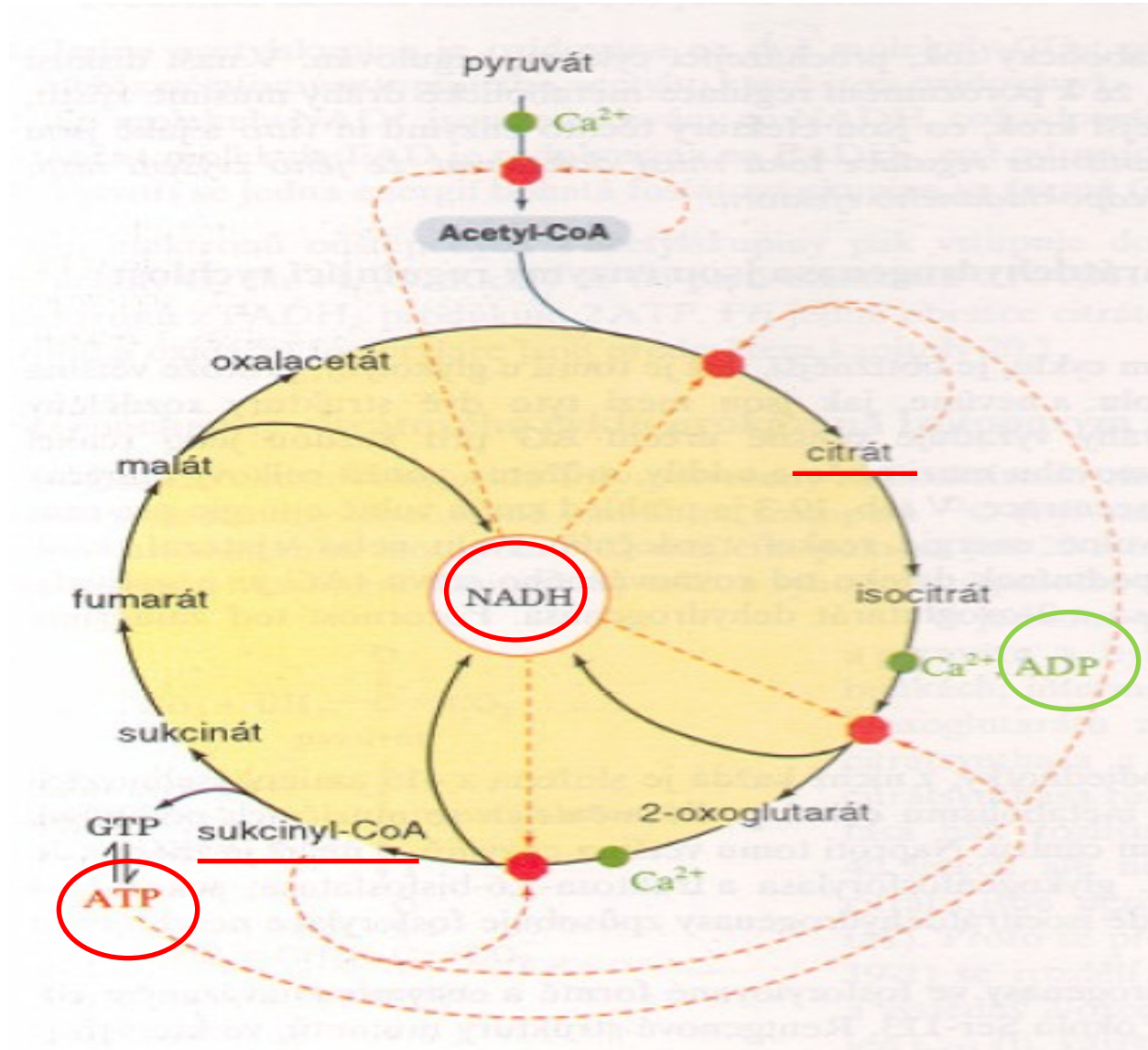
3 NADH	3 x 3 ATP	9 ATP
--------	-----------	-------

1 FADH ₂	1 x 2 ATP	2 ATP
---------------------	-----------	-------

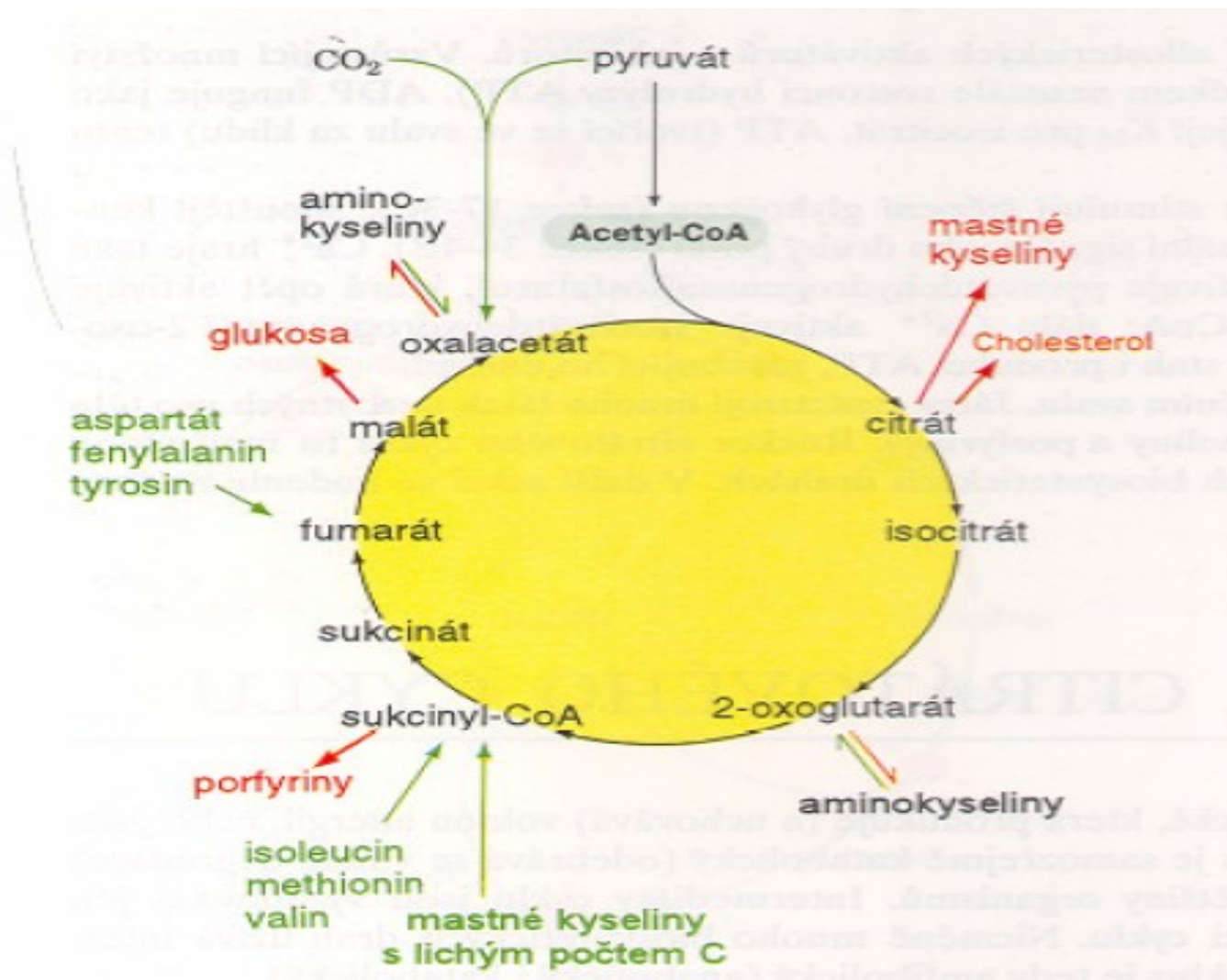
1 GTP	1 x 1 ATP	1 ATP
-------	-----------	-------

CELKEM	12 ATP/AcetylCoA
--------	------------------

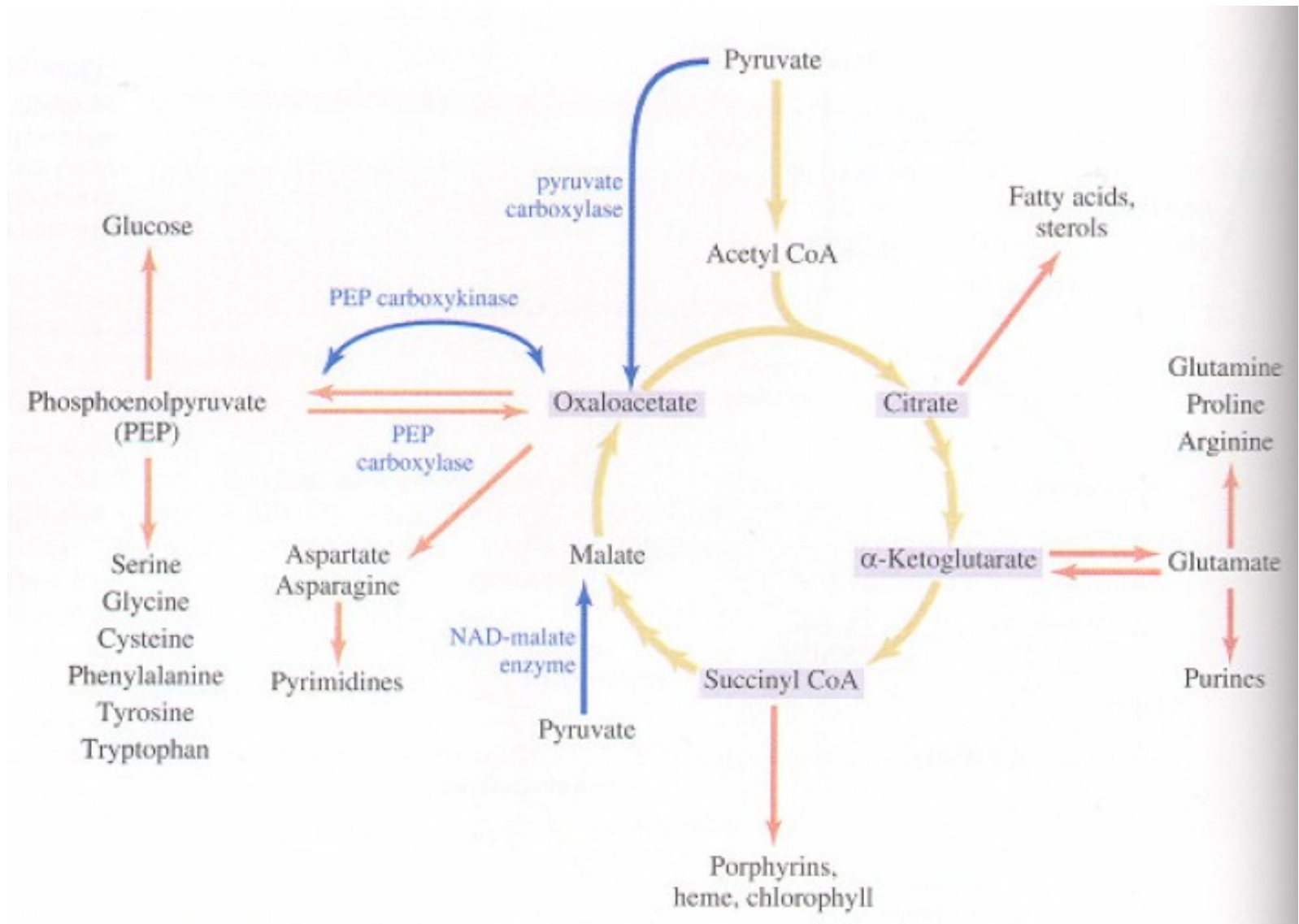
Regulace



Odbourávání jiných živin



Amfibolická povaha cyklu



Anaplerotické reakce

Table 16.5

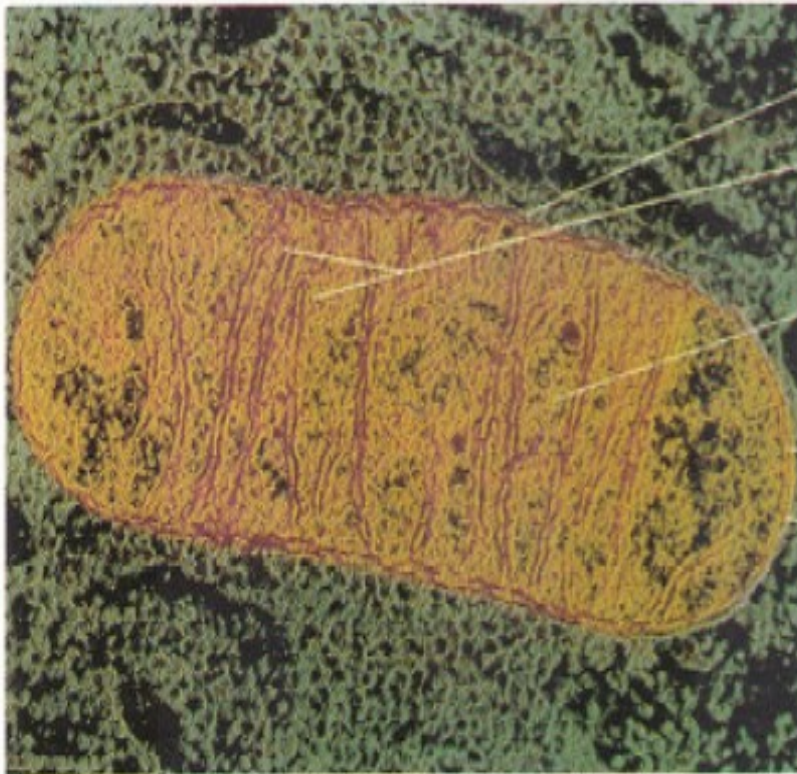
Anaplerotic reactions to replenish the citric acid cycle intermediates oxaloacetate and malate

Enzyme	Reaction	Comments
Pyruvate carboxylase	$\text{Pyruvate} + \text{CO}_2 + \text{ATP} + \text{H}_2\text{O} \rightleftharpoons \text{oxaloacetate} + \text{ADP} + \text{P}_i$	Also the starting point for gluconeogenesis
PEP carboxykinase	$\text{Phosphoenolpyruvate} + \text{CO}_2 + \text{GDP} \rightleftharpoons \text{oxaloacetate} + \text{GTP}$	The reverse reaction is important in gluconeogenesis
PEP carboxylase	$\text{Phosphoenolpyruvate} + \text{CO}_2 \rightleftharpoons \text{oxaloacetate} + \text{P}_i$	Found in higher plants and bacteria
NAD-malate enzyme	$\text{Pyruvate} + \text{CO}_2 + \text{NADH} + \text{H}^+ \rightleftharpoons \text{malate} + \text{NAD}^+$	Found in plants and microorganisms

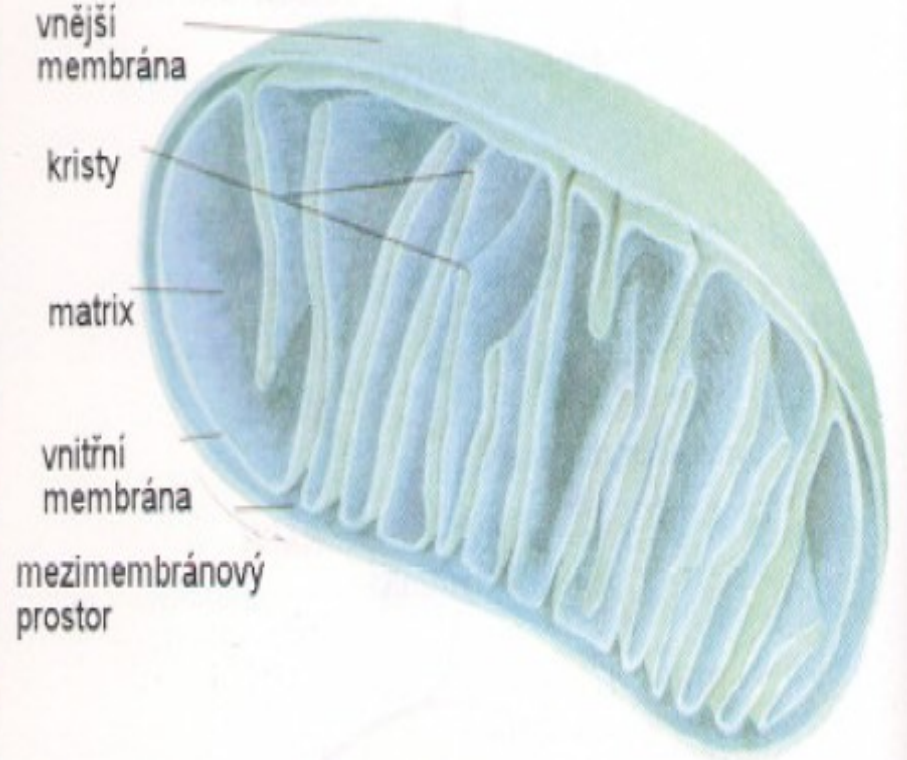
Table 16-5 Concepts in Biochemistry, 3/e

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Lokalizace citrátového cyklu



(a)



(b)

METABOLISMUS SACHARIDŮ

Štěpení oligosacharidů a polysacharidů

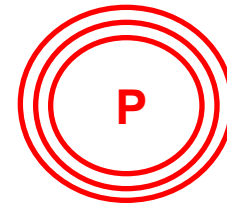
A. Štěpení sacharidů při trávení potravy

α – amylasa	sliny, pankreas	škrob	Dextriny, maltosa, glukosa
amyloglukosidasa	střeva	glykogen	maltosa
maltasa	"	maltosa	glukosa
laktasa	"	laktosa	glukosa, galaktosa
sacharasa	"	sacharosa	glukosa fruktosa
celulasy	houby, bakterie	celulosa	glukosa

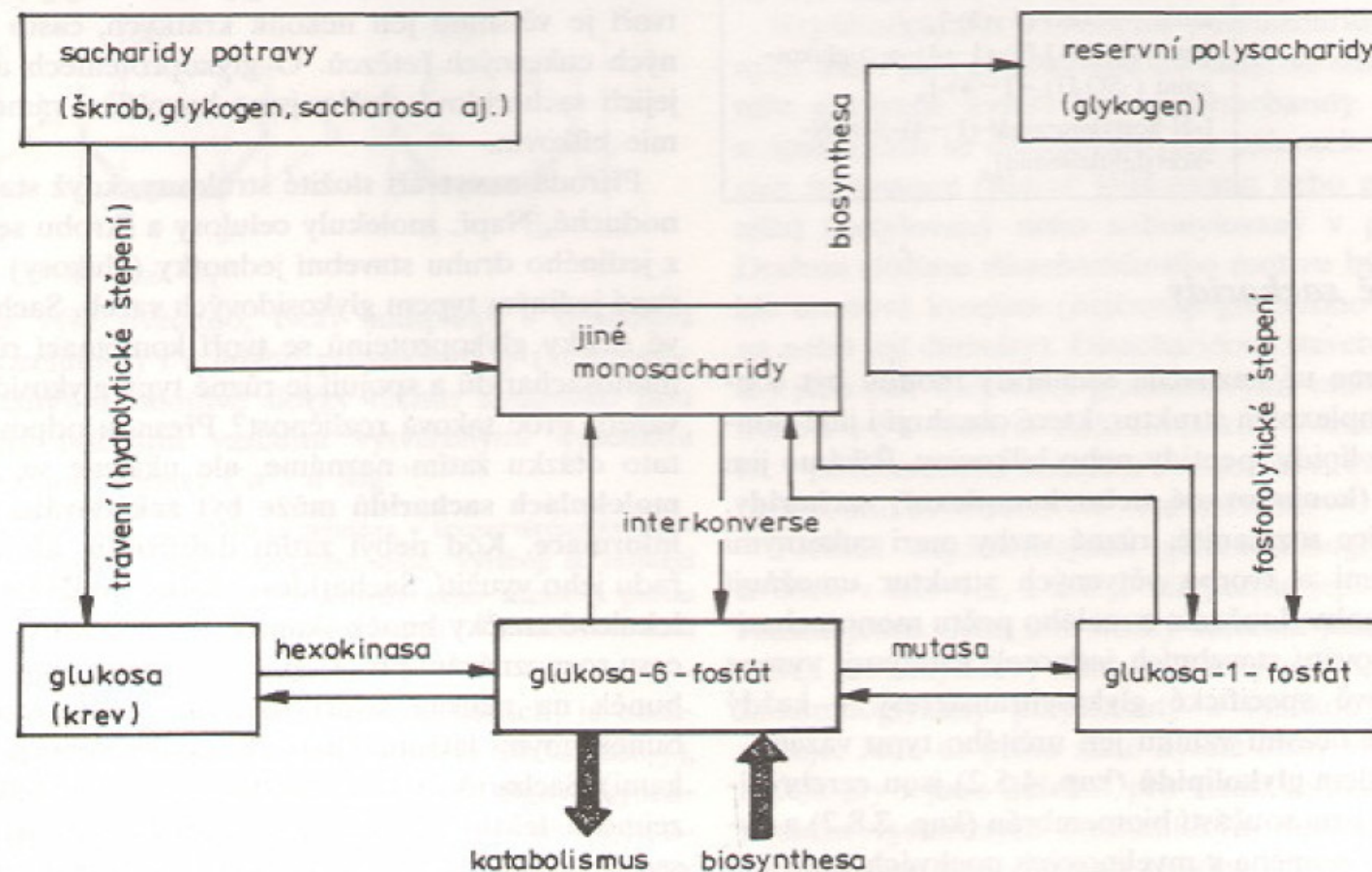
B. Štěpení rezervních polysacharidů

fosforylasa	játra	glykogen	glukosa-1-P
β – amylasa	rostliny	škrob	maltosa

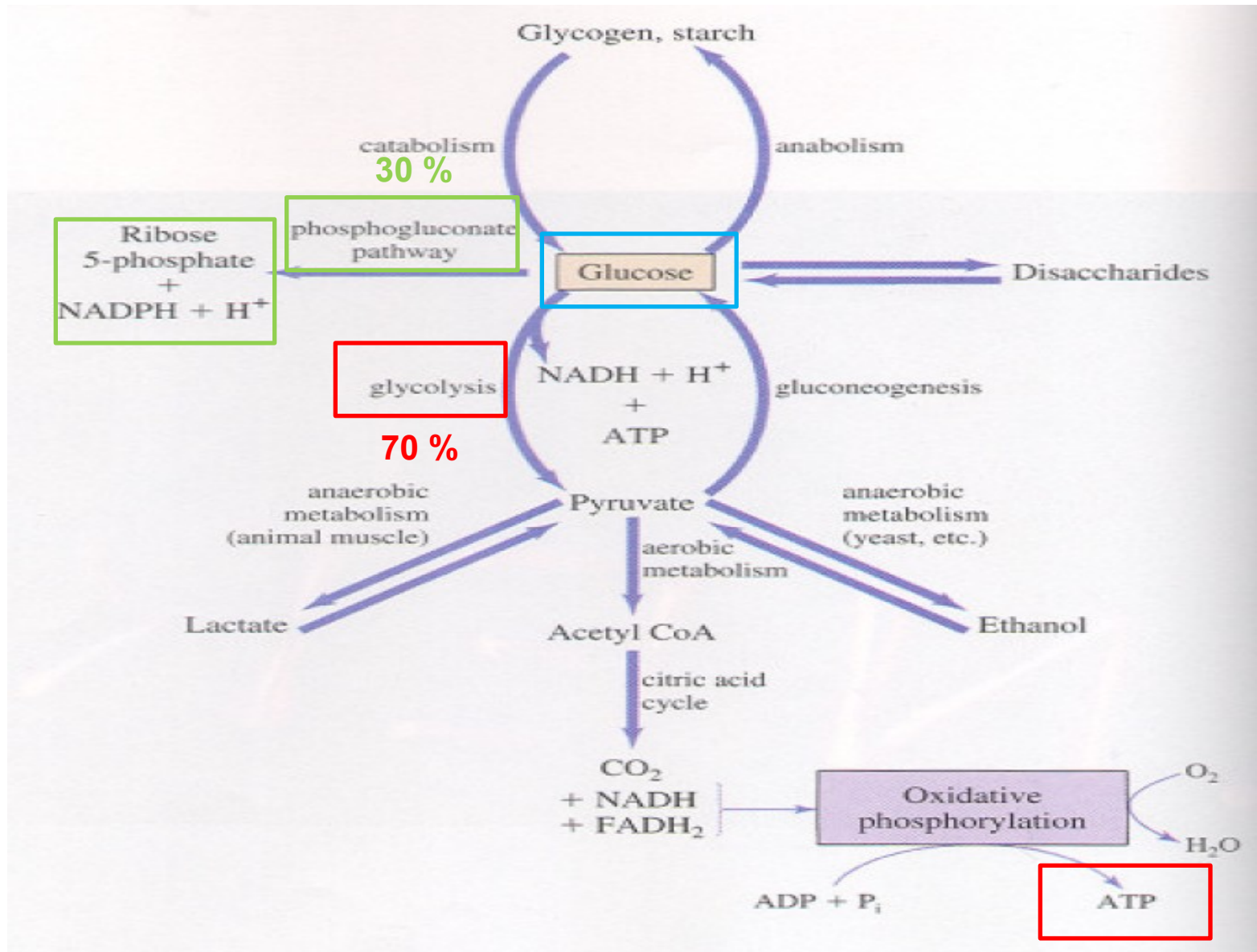
Glukosa-6-fosfát - klíčový metabolit



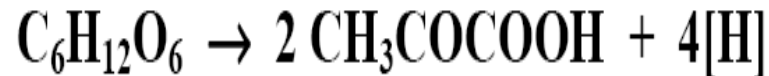
- Fosforylací glukosy z potravy
- Izomerací glukosa-1-fosfátu z tkáňového glykogenu
- Izomeracemi a epimeracemi jiných monosacharidů



METABOLISMUS SACHARIDŮ



GLYKOLÝZA



Historie :

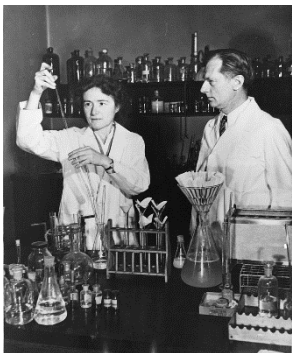
- 19. stol. Paster - kvasinky

Buchner - kvasniční extrakt

- 1905 - 1910 Harden, Young

- 1940 Embden, Meyerhof, Parnas

Manželé Corriovi



GLYKOLÝZA



glukosa

$2\text{ADP} + 2\text{P}_i$

2NAD^+

fruktosa-1,6-bisfosfát

2ATP

2NADH

2 pyruvát

anaerobní mléčné kvašení

2NADH

2NAD^+

2 laktát

aerobní oxidace

CITRÁTOVÝ CYKLUS

2NADH

6O_2

oxidační fosforylace

2NAD^+

$6\text{CO}_2 + 6\text{H}_2\text{O}$

anaerobní alkoholové kvašení

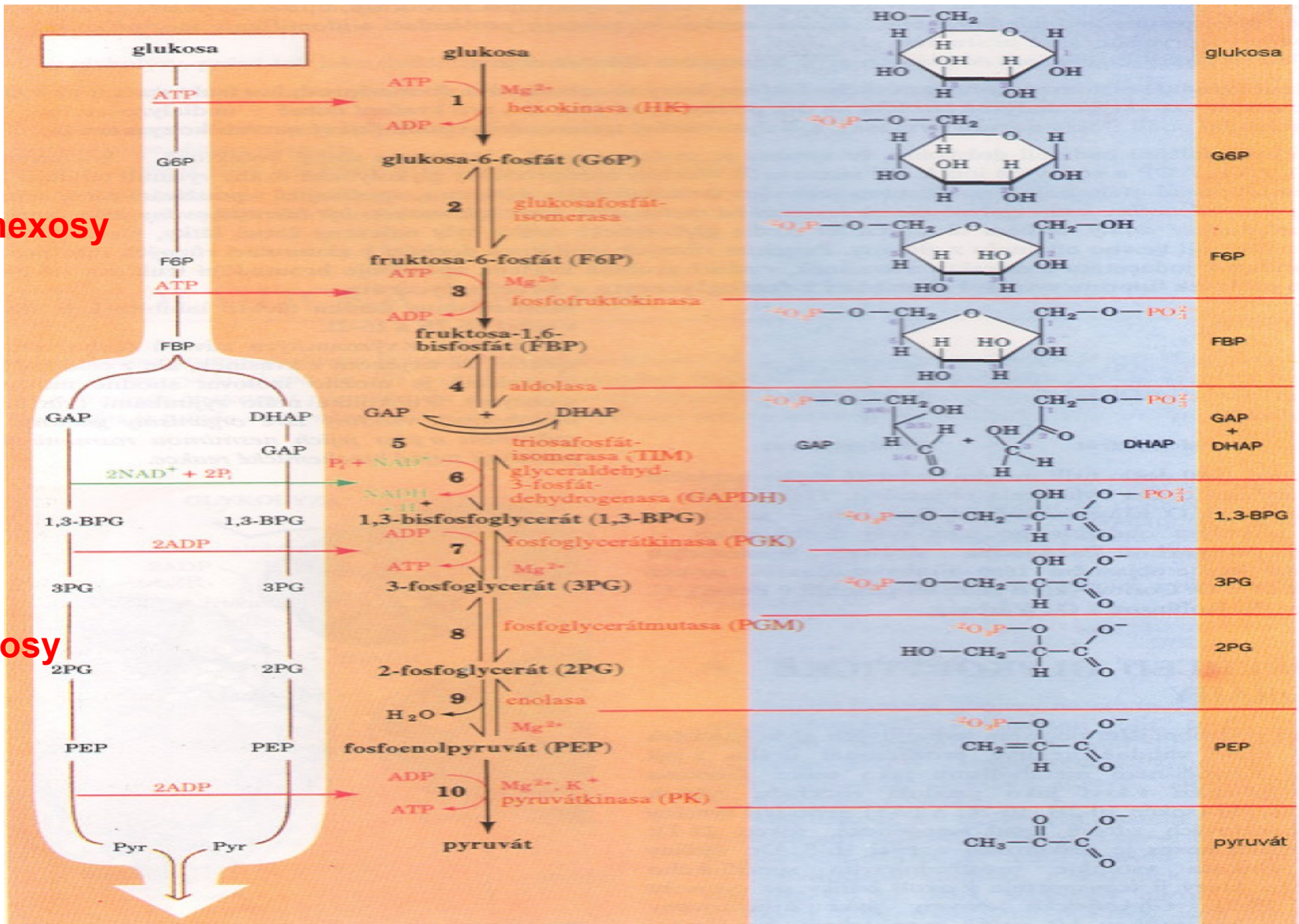
2NADH

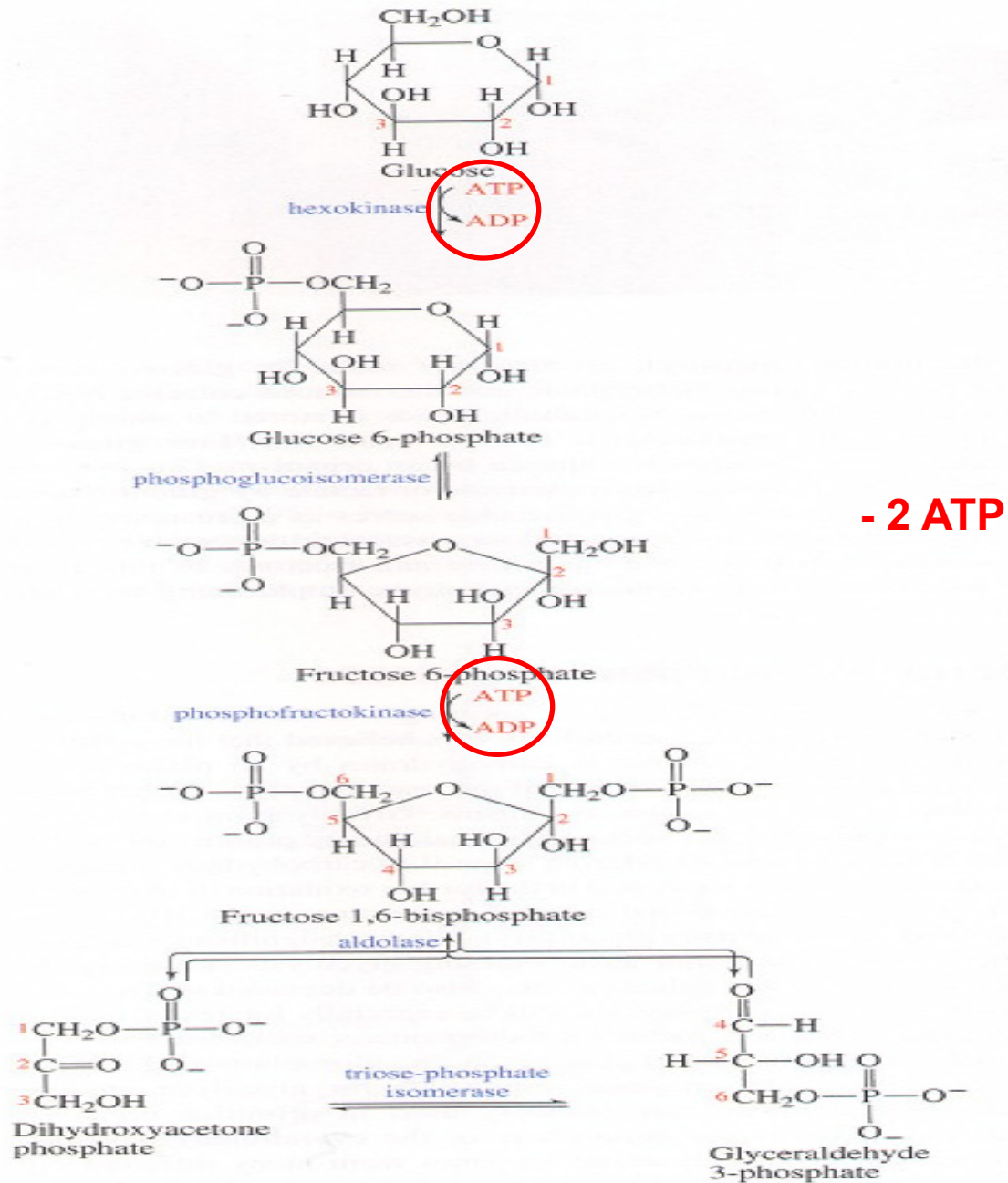
2NAD^+

$2\text{CO}_2 + 2\text{ethanol}$

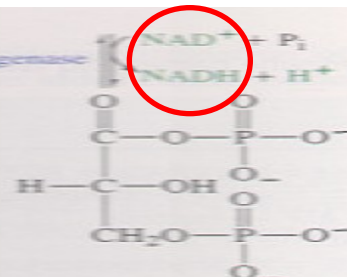
hexosy

triosy



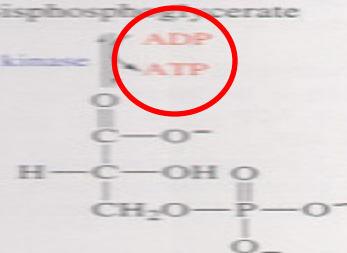


glyceraldehyde-3-phosphate dehydrogenase



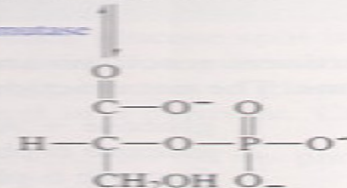
1,3-Bisphosphoglycerate

phosphoglycerate kinase



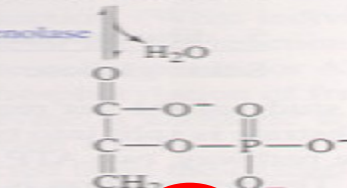
3-Phosphoglycerate

phosphoglycerate mutase



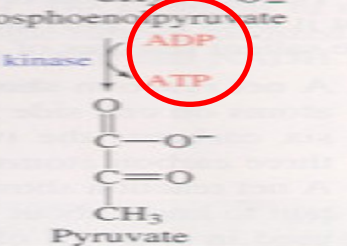
2-Phosphoglycerate

enolase



Phosphoenolpyruvate

pyruvate kinase

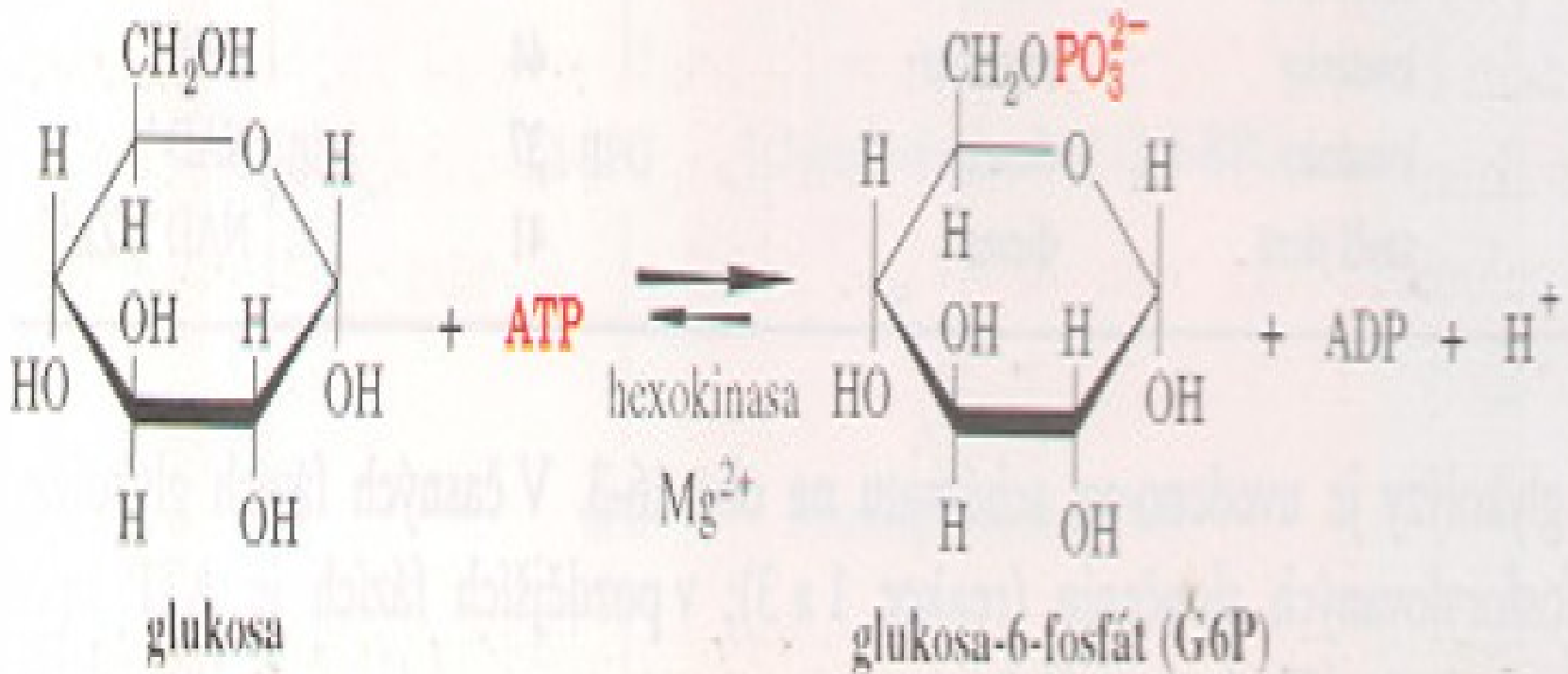


Pyruvate

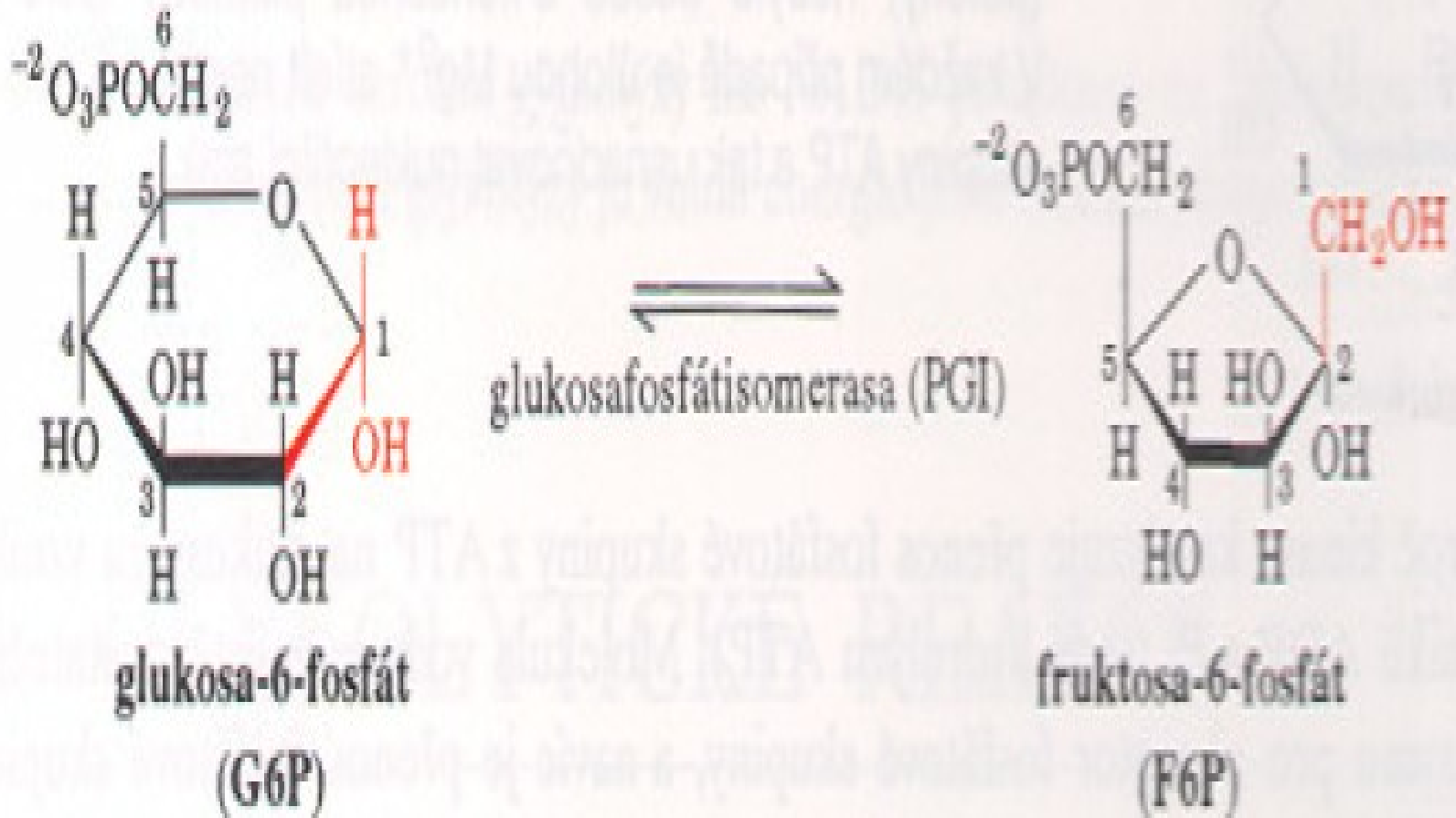
2 x

2 x (2ATP + NADH)

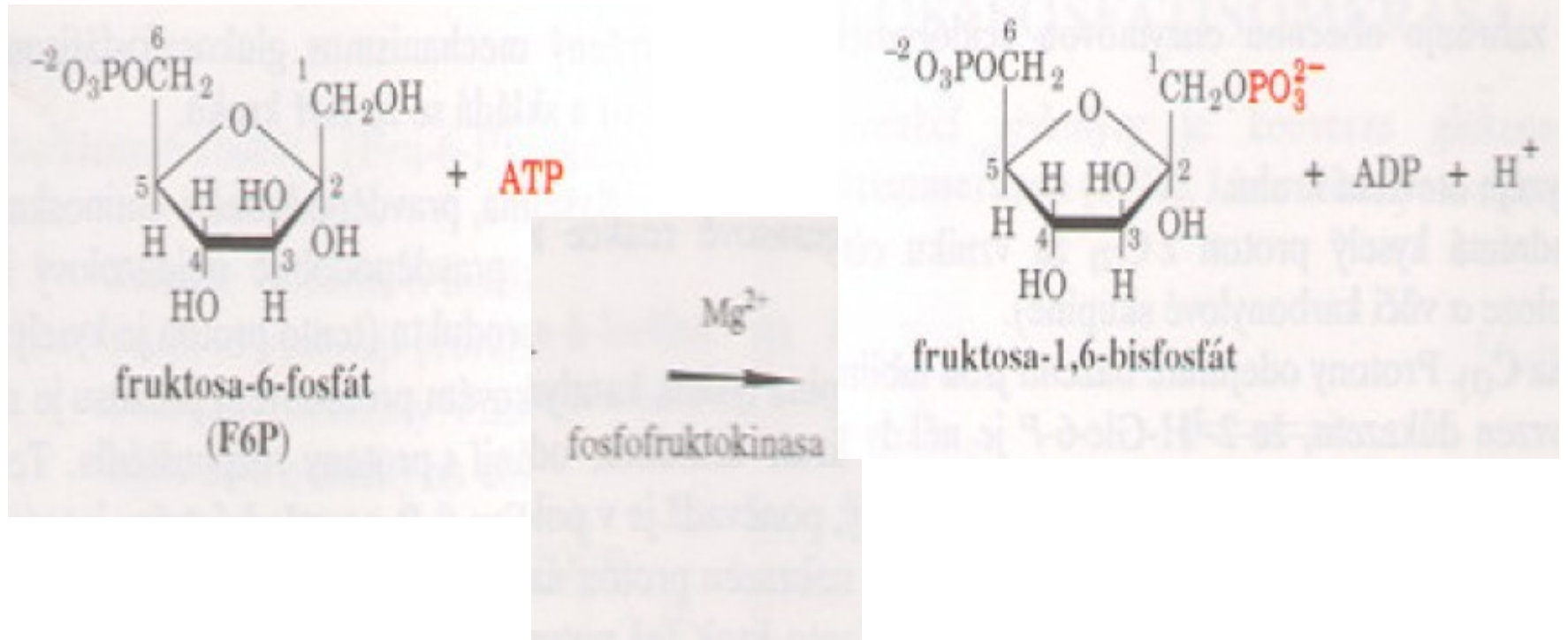
Hexokinasa - glukokinasa



Glukosafosfátisomerasa



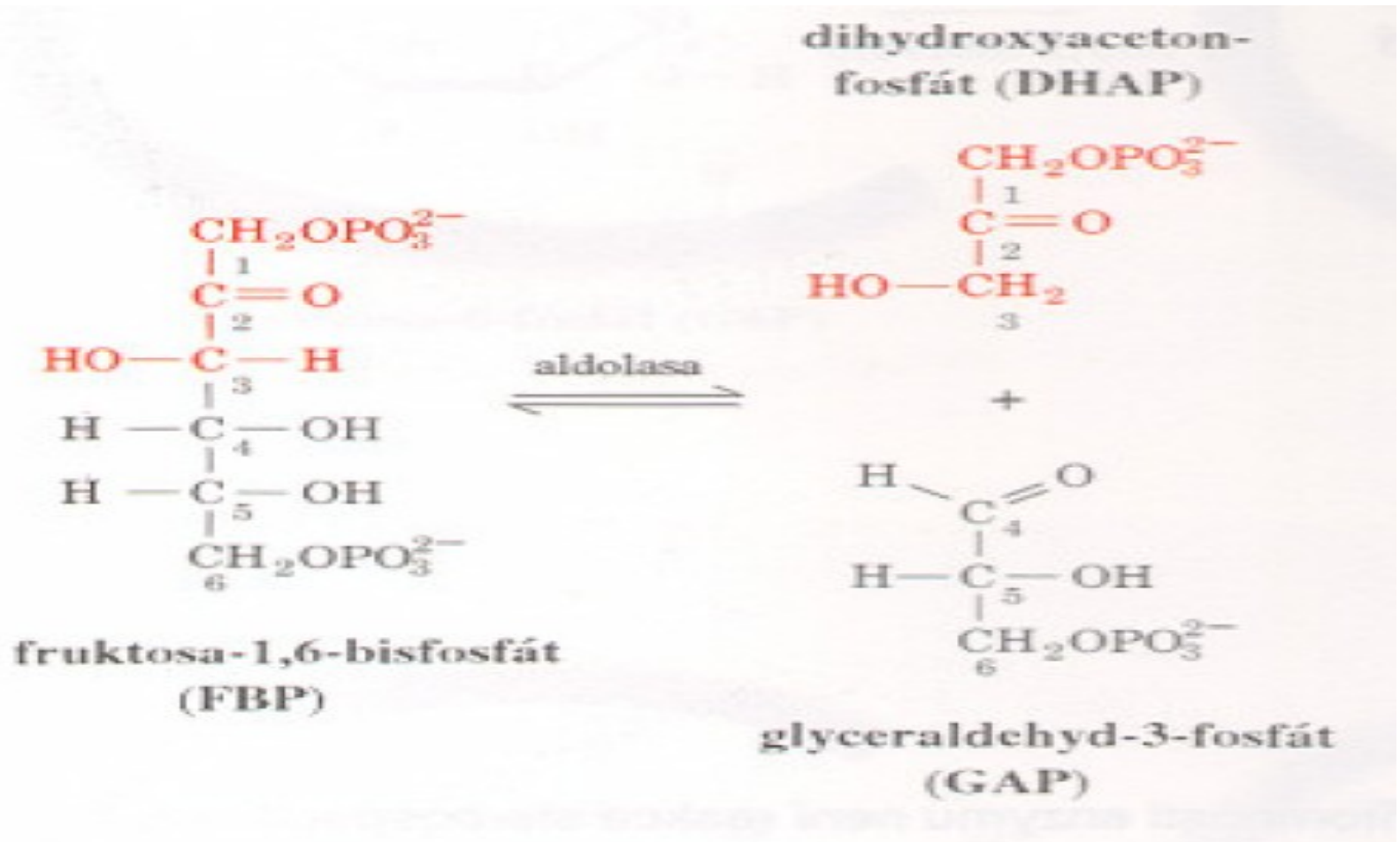
Fosfofruktokinasa



+ ADP, AMP

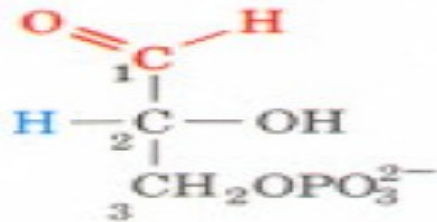
- ATP, citrát, fosfoenolpyruvát

Aldolsa



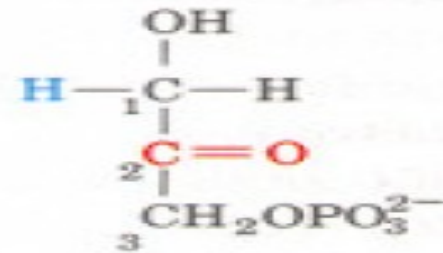
Triosafosfátisomerasa

4 %

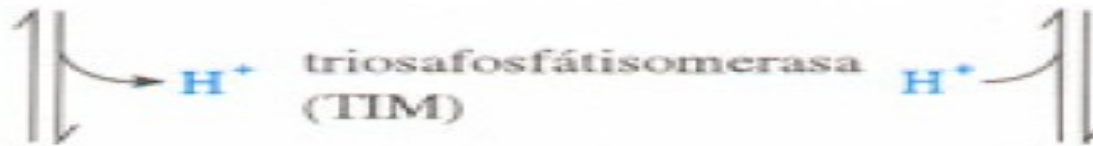


glyceraldehyd-3-fosfát
(aldosa)

96 %

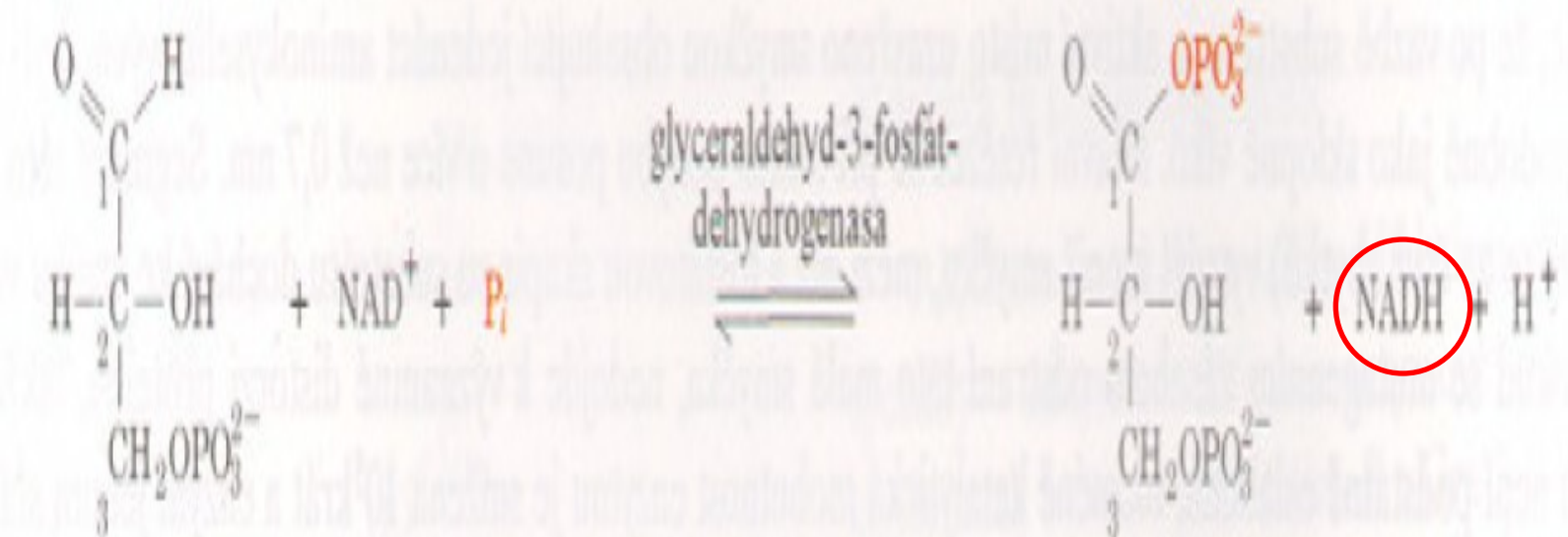


dihydroxyaceton-fosfát
(ketosa)



endiolový intermediát

Glyceraldehyd-3-fosfát-dehydrogenasa

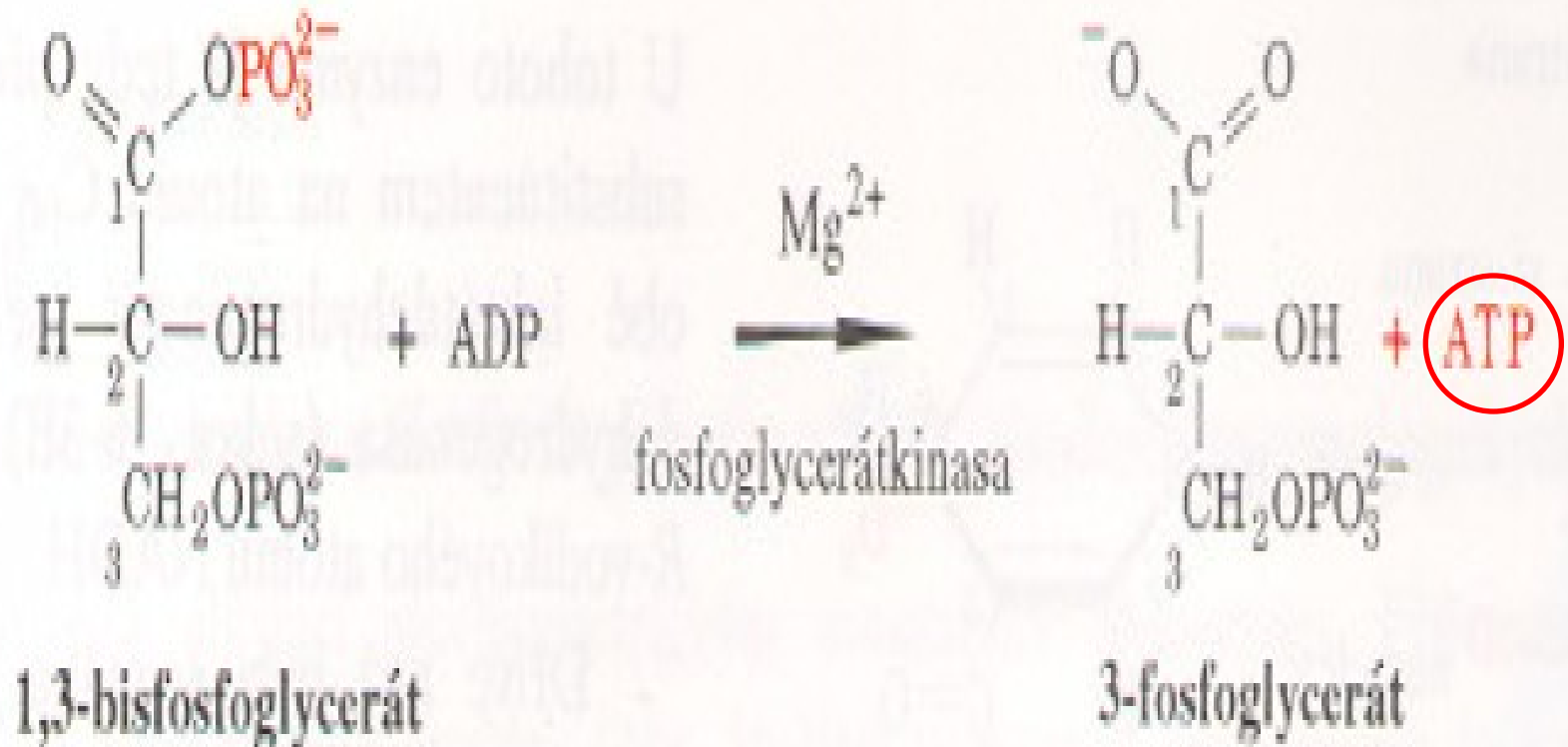


glyceraldehyd-3-fosfát

(GAP)

1,3-bisfosfoglycerát

Fosfoglycerátkinasa



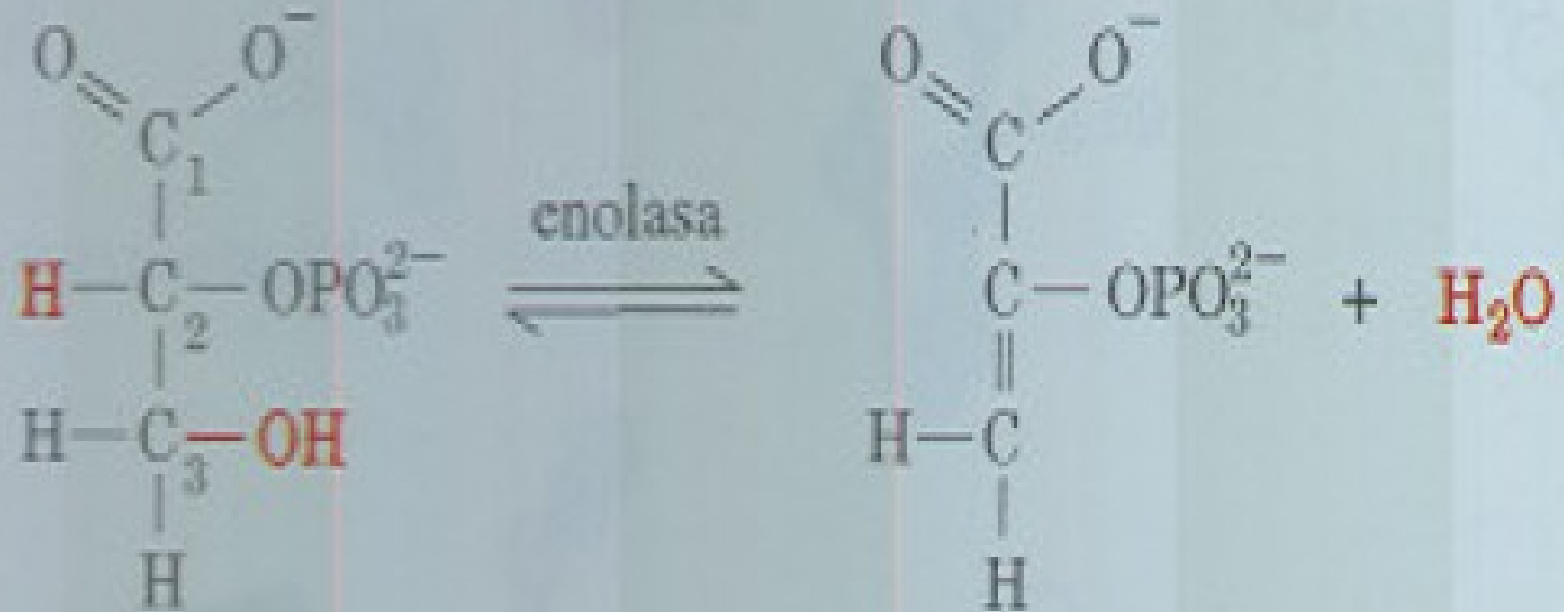
Fosfoglycerátmutasa



3-fosfoglycerát

2-fosfoglycerát

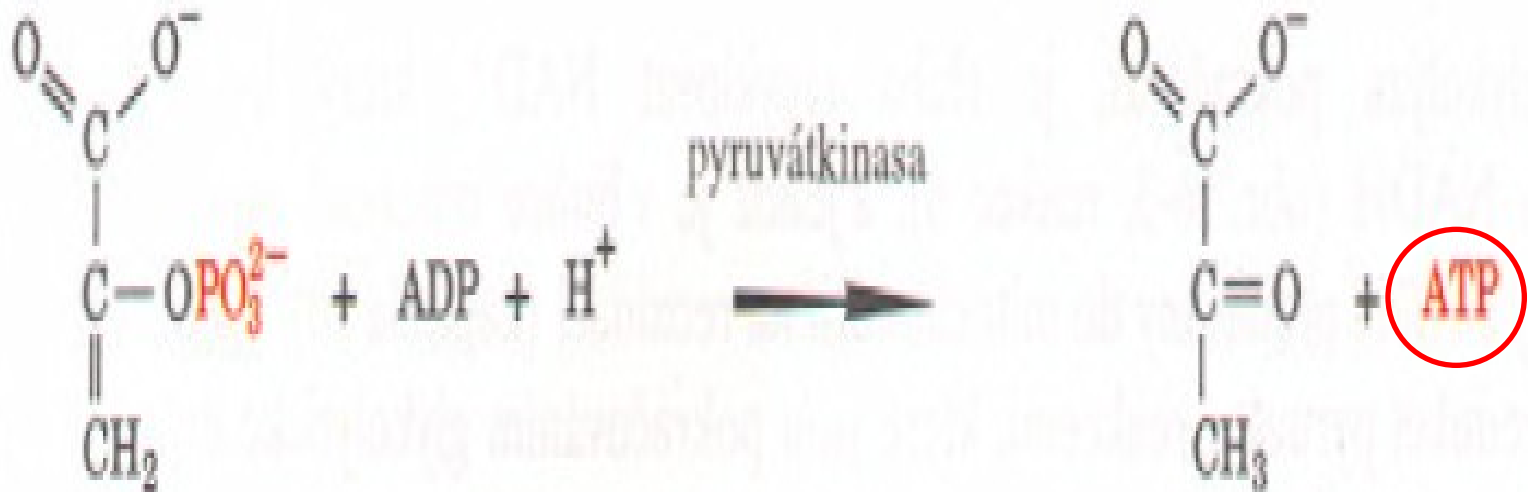
Enolasa



2-fosfoglycerát

fosfoenolpyruvát

Pyruvátkinasa



fosfoenolpyruvát

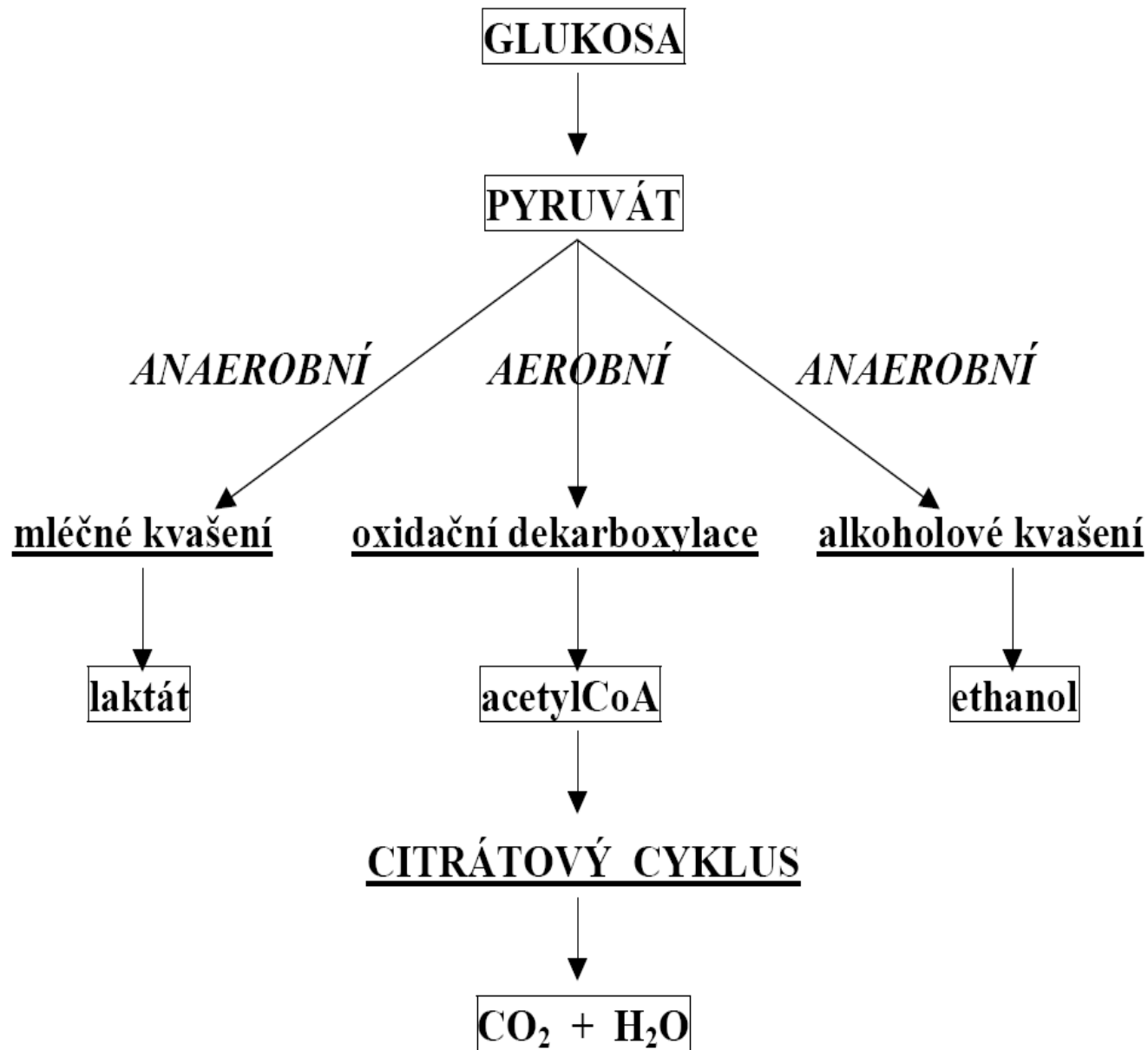
pyruvát

Bilance glykolýzy

glukosa + 2 NAD⁺ + 2 ADP + 2Pi

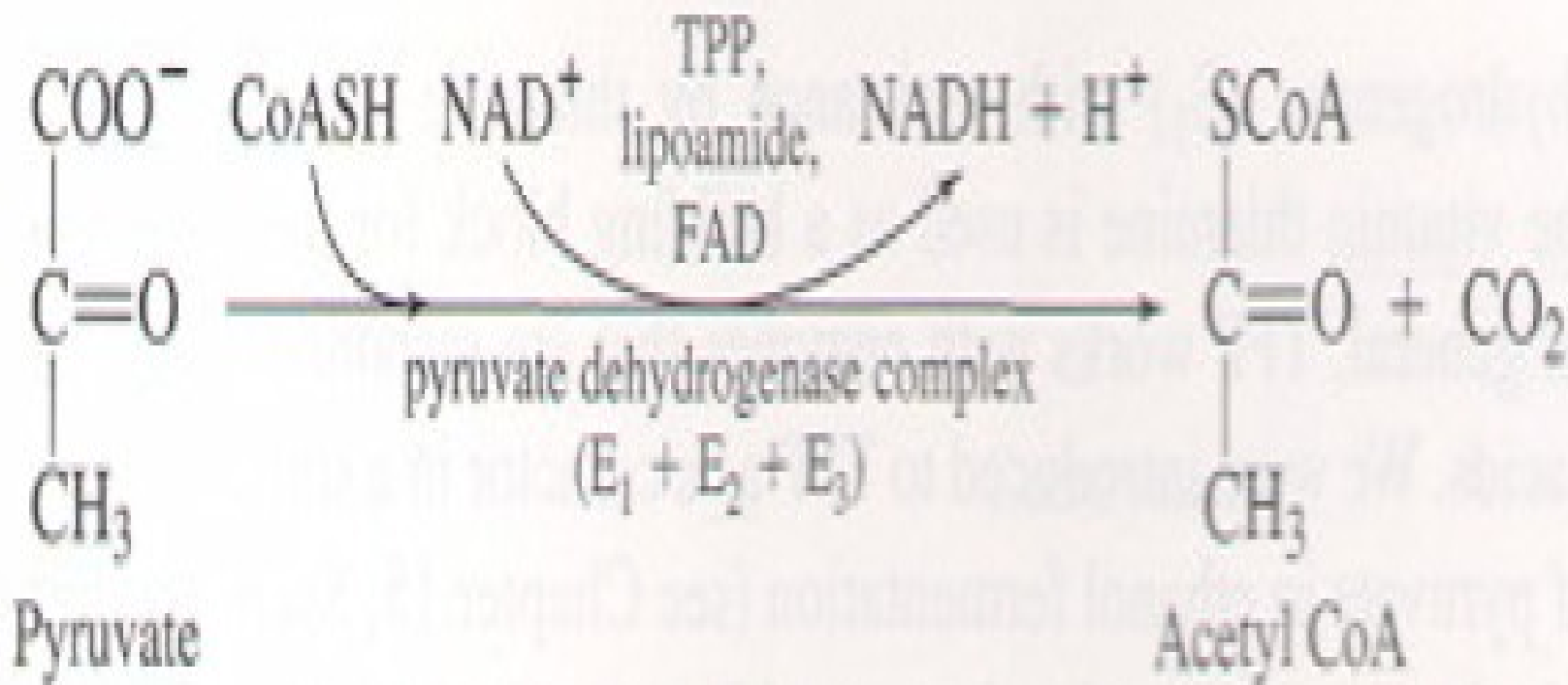
→

2 pyruvát + 2 ATP + 2 NADH + 2 H⁺ + 2 H₂O

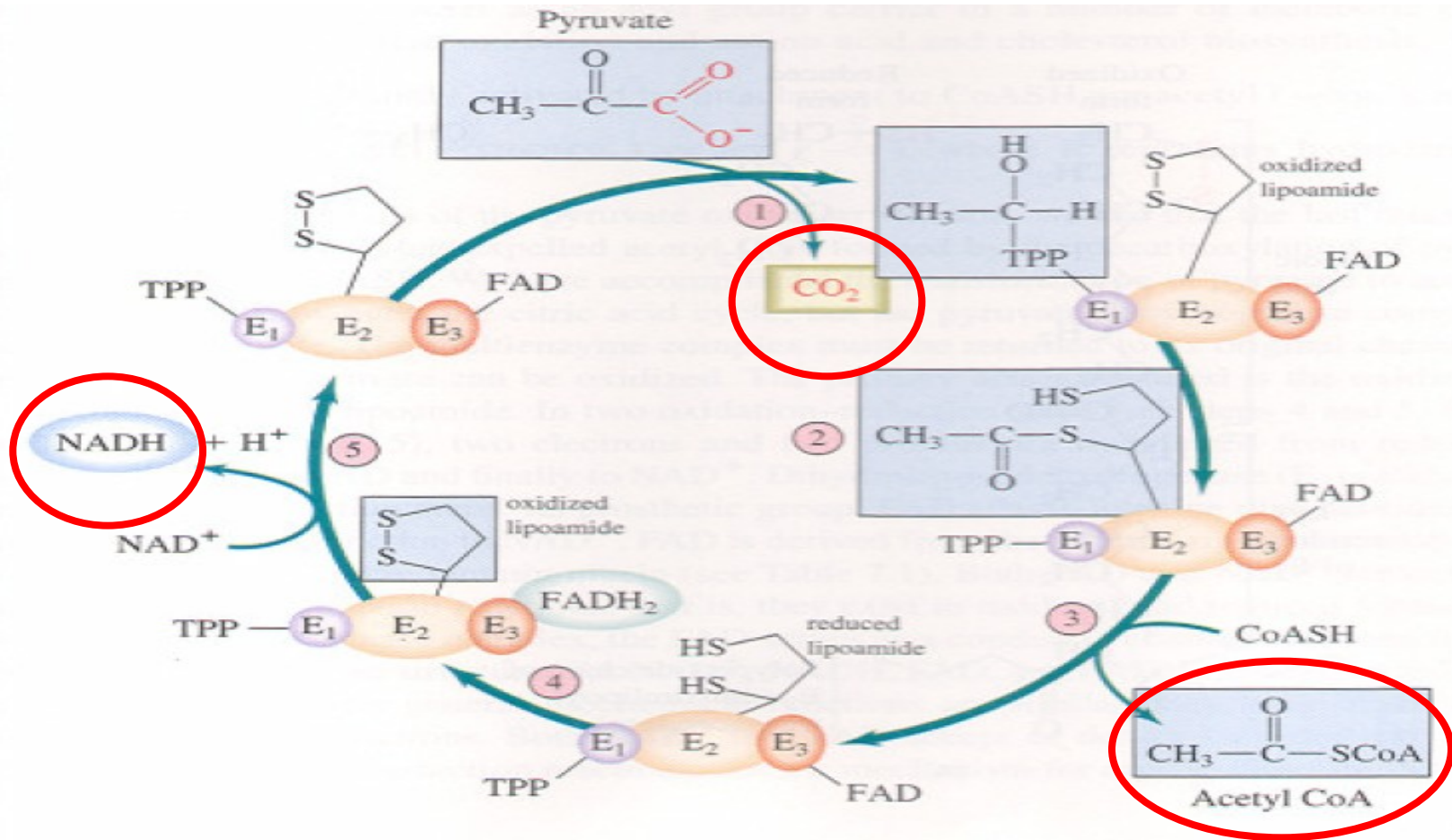


Aerobní odbourávání

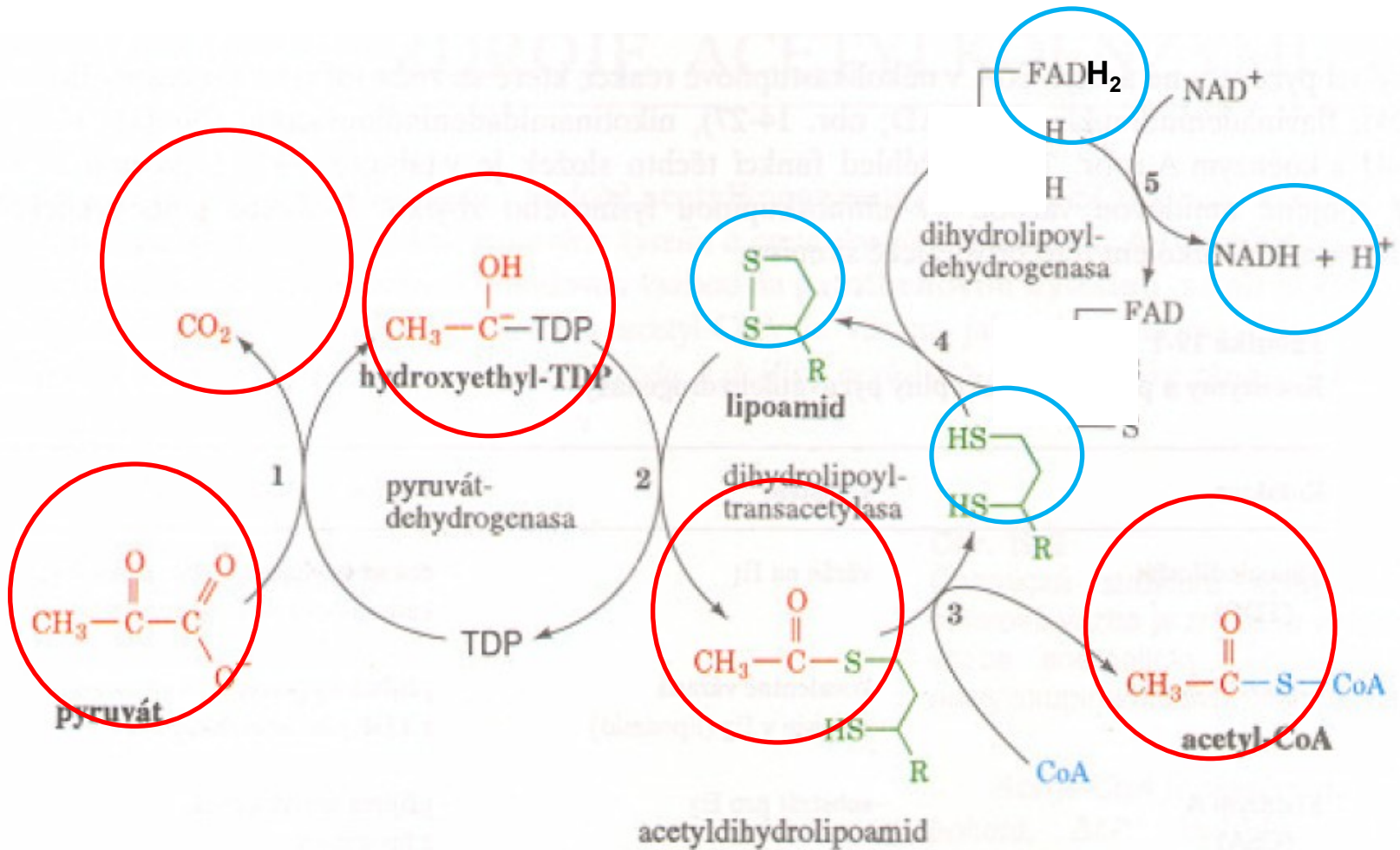
Oxidační dekarboxylace :



Pyruvátdehydrogenasa

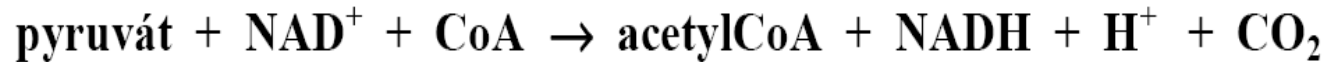


Pyruvátdehydrogenasa

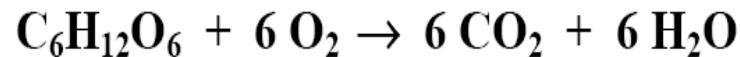


Aerobní odbourávání

Oxidační dekarboxylace :



Bilance aerobní glykolýzy :

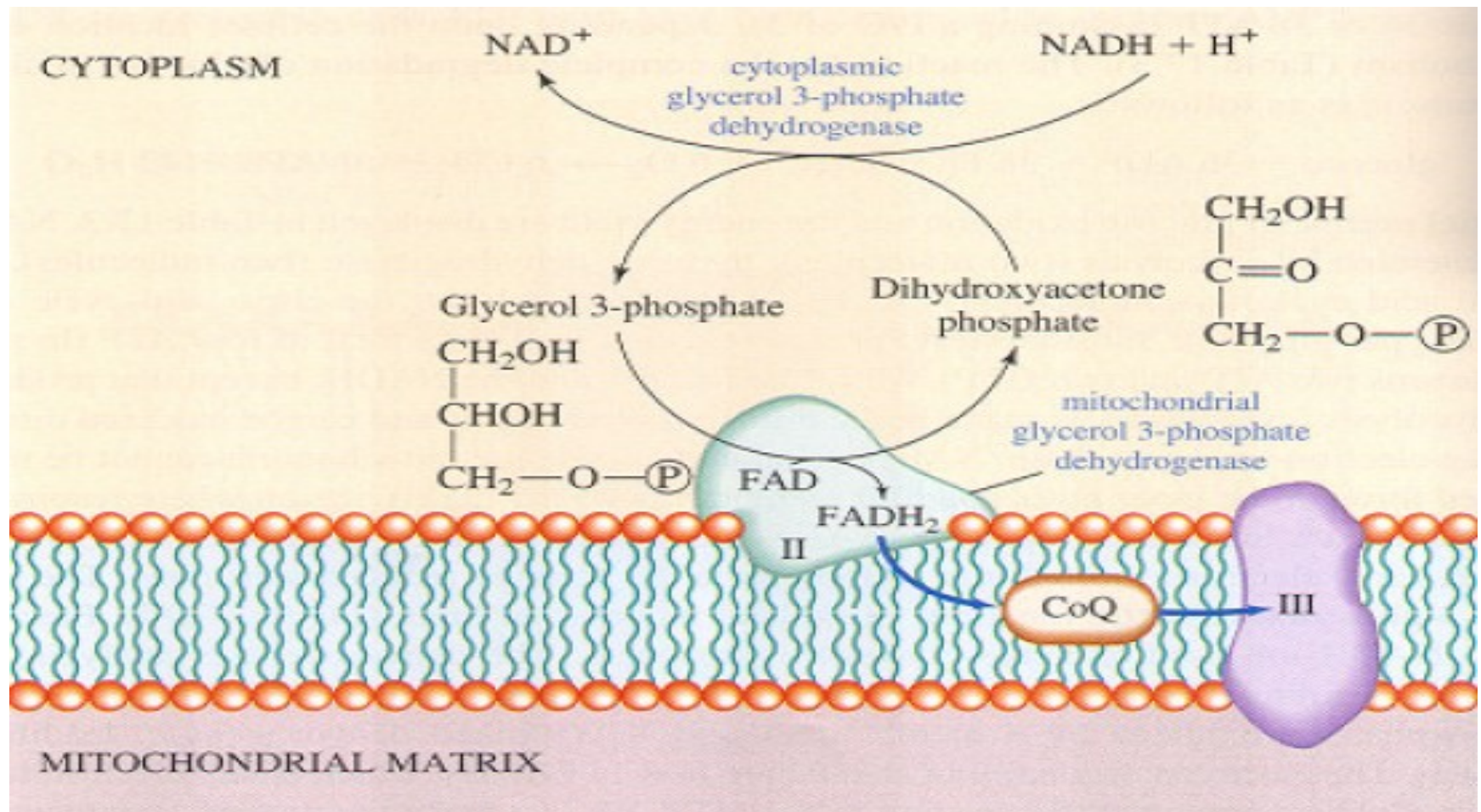


Glykolýza	1 ATP + 1 NADH	(4-1) ATP
Oxidační dekarboxylace	1 NADH	3 ATP
Citrátový cyklus	1 ATP 3 NAD + FADH ₂	12 ATP
CELKEM	18 ATP/ triosu tj.	36 ATP/ glukosu tj. 40 %

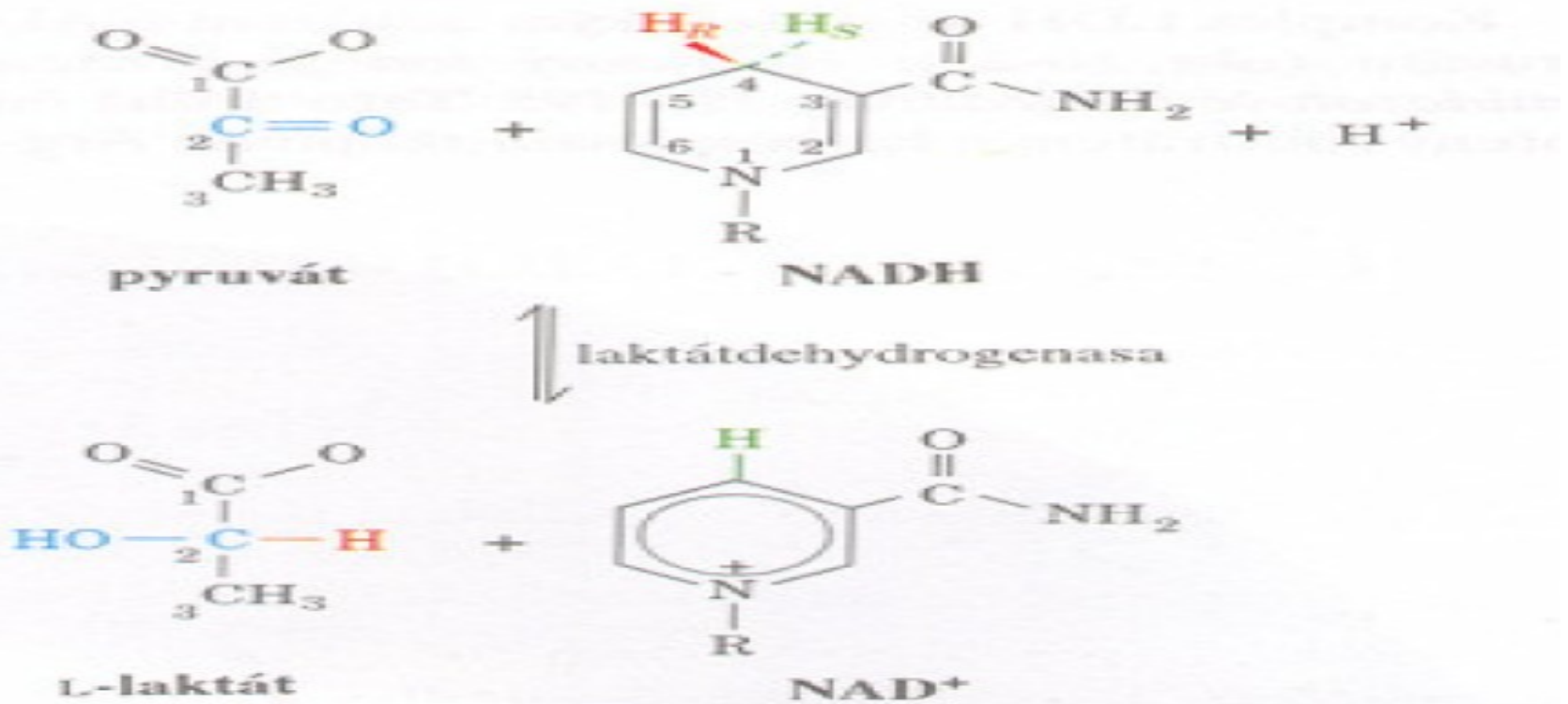
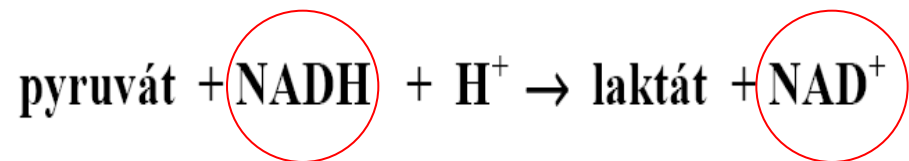
CYT

MIT

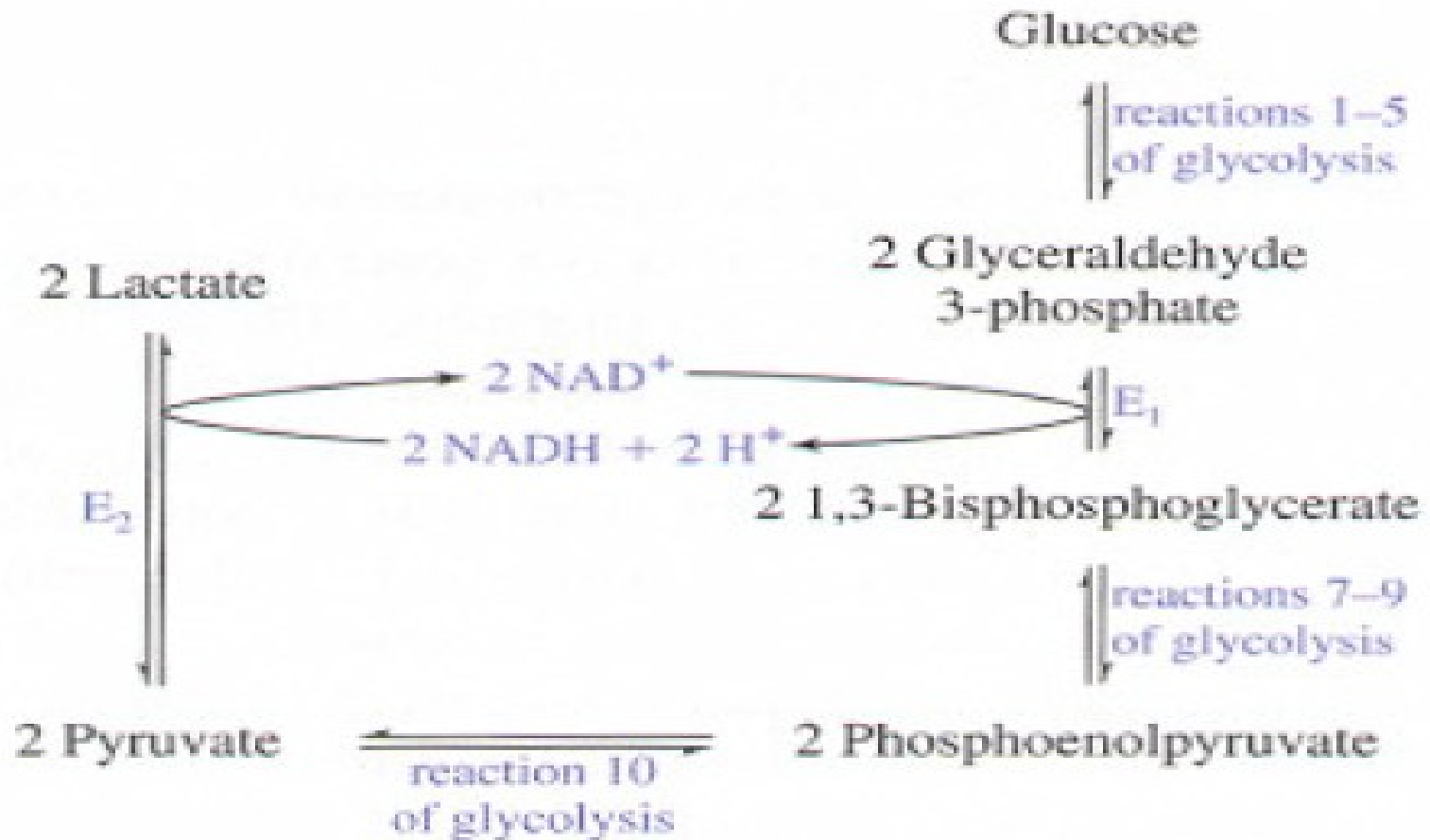
G-3-P DH člunek



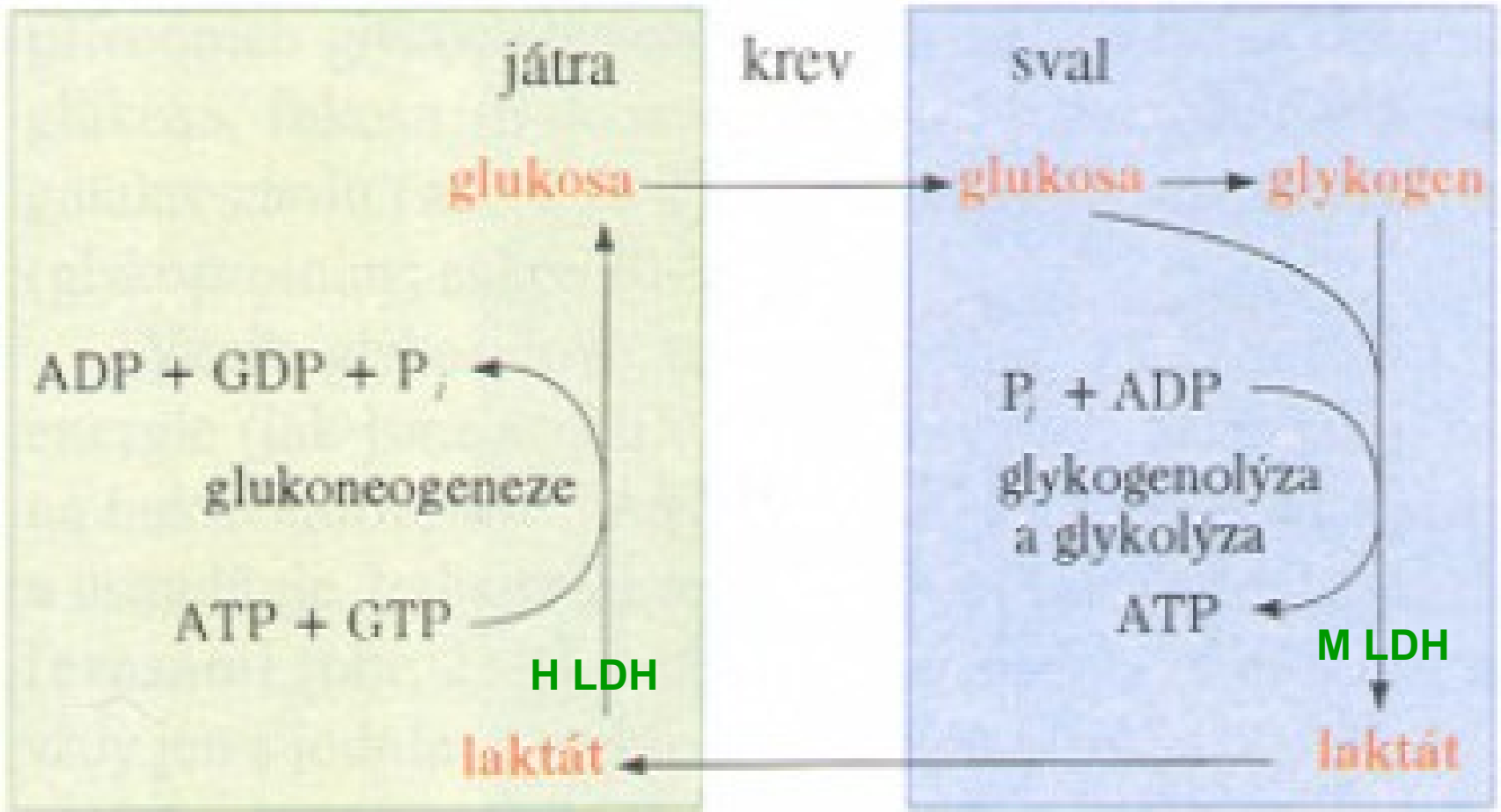
Mléčné kvašení



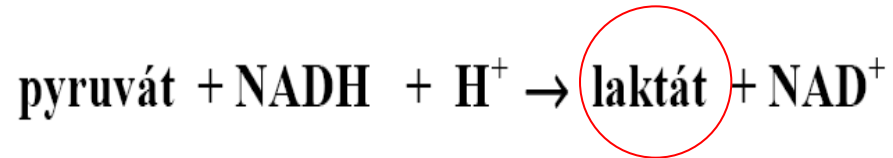
Mléčné kvašení



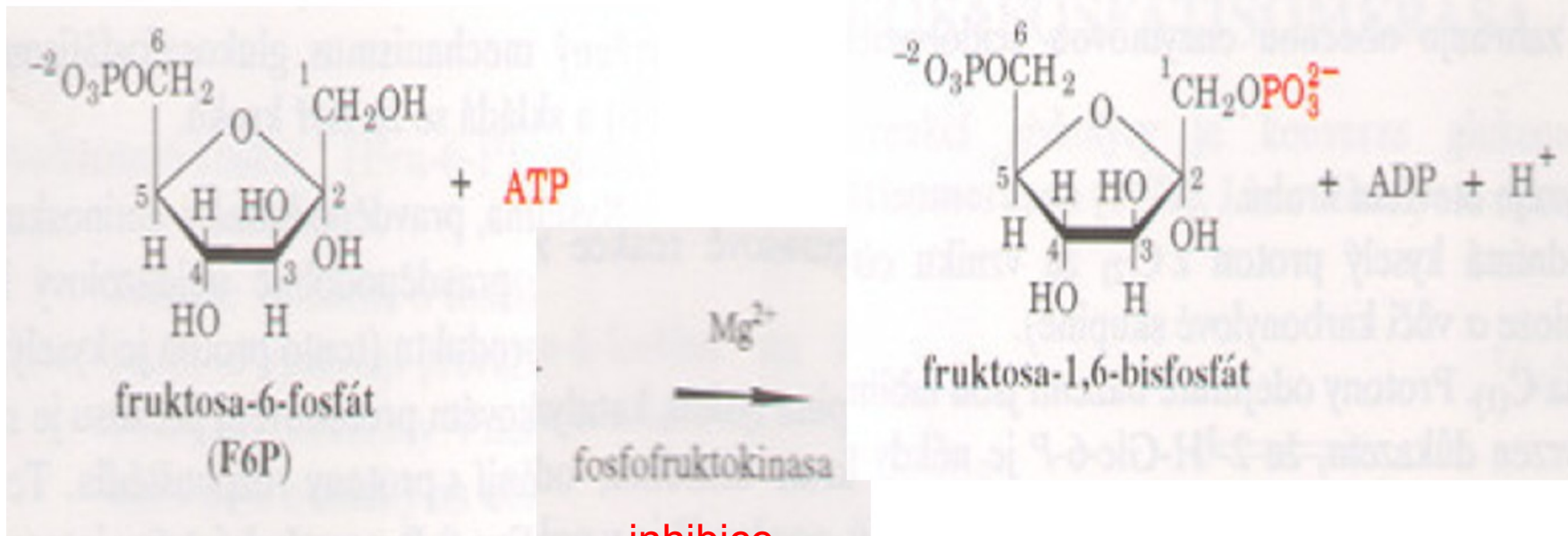
Coriho cyklus



Mléčné kvašení

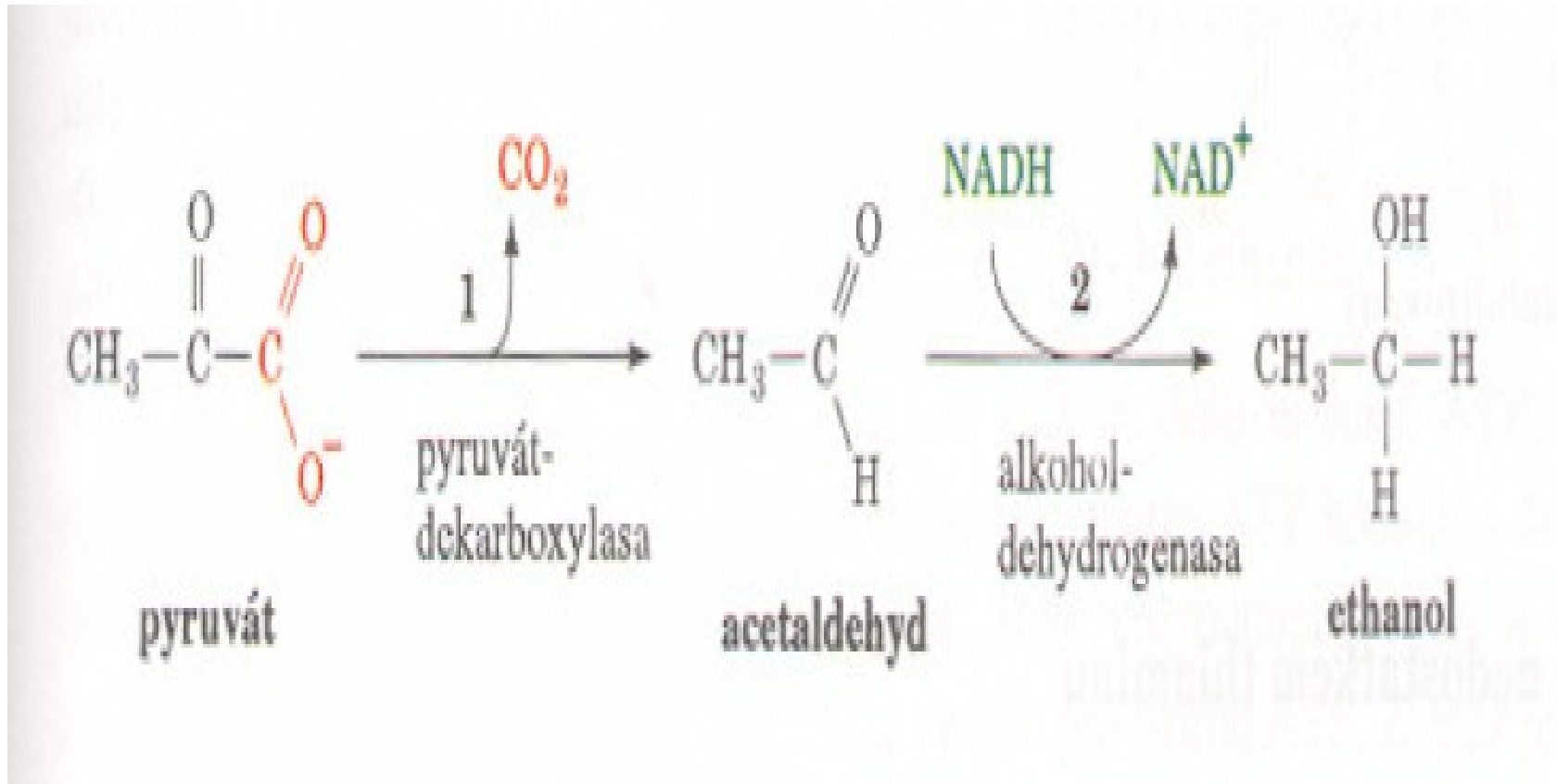
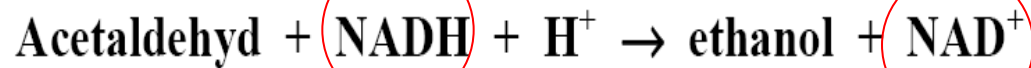


pH 7 → 6,4

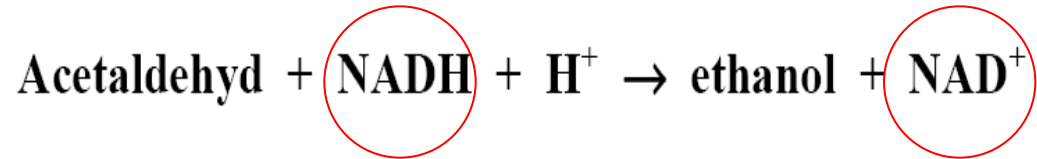


inhibice

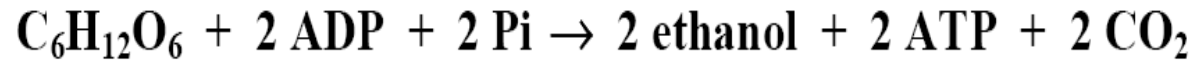
Alkoholové kvašení



Alkoholové kvašení



Bilance alkoholového kvašení :



Glykolýza 1 ATP + 1 NADH

Alkoholové kvašení - 1 NADH

CELKEM 1 ATP/ triosu tj. 2 ATP/ glukosu tj. 2 %

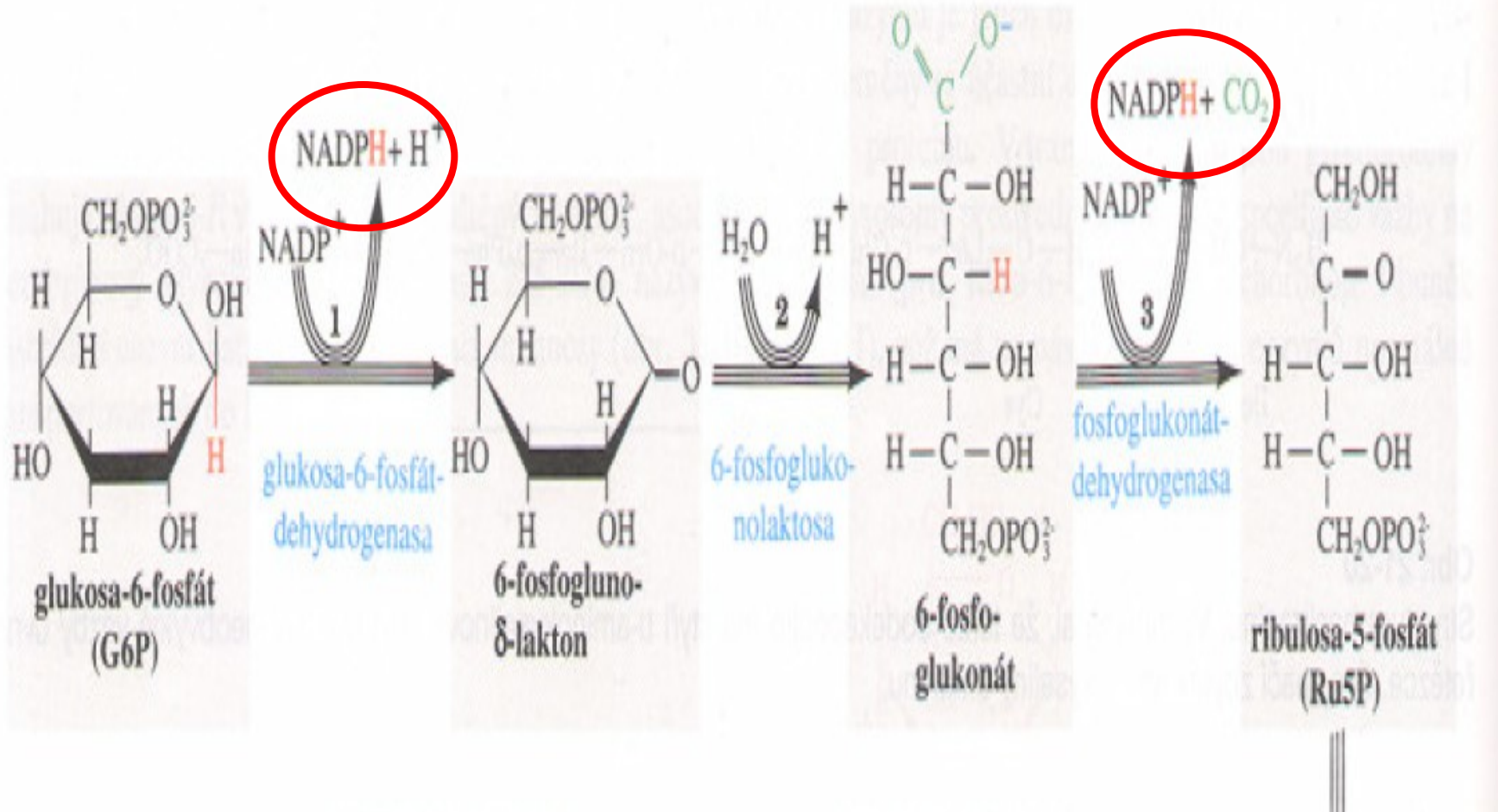
Další druhy kvašení

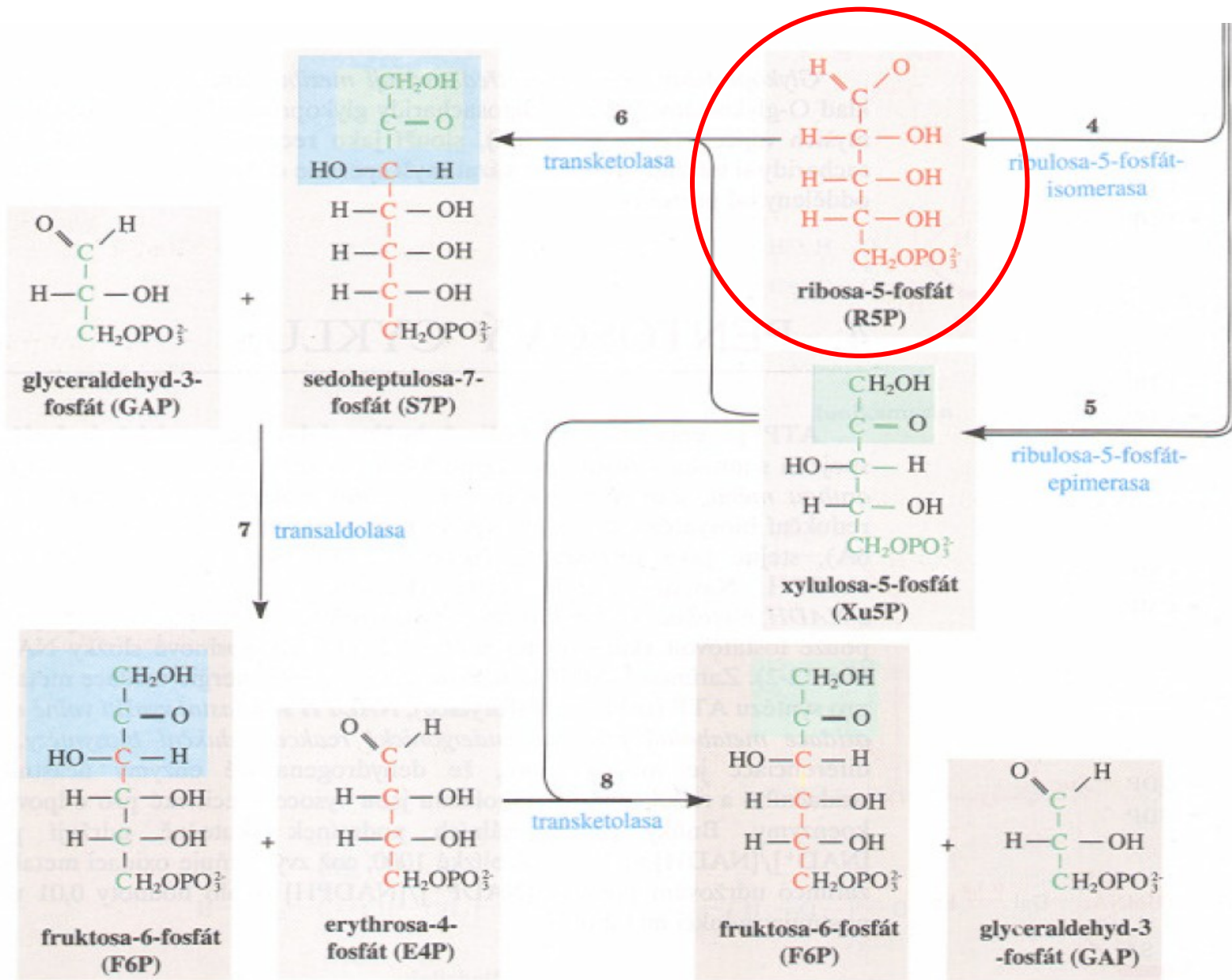
- Mléčné - *Lactobacterium*
glukosa → laktát
- Propionové - *Propionibacterium*
glukosa → k. propionová
- Máselné - *Clostridium*
glukosa → k. máselnou
- Octové - *Acetobacter* O_2
glukosa → k. octová
- Citronové - *Aspergillus* CO_2
glukosa → k. citronová

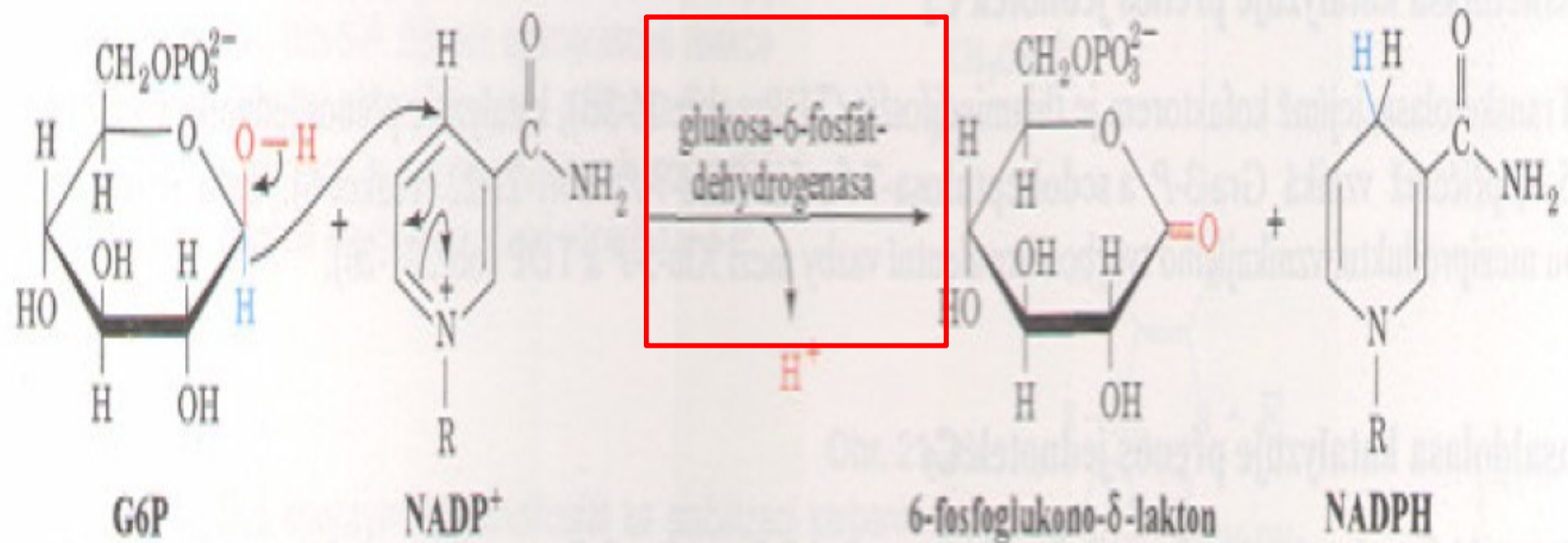
pravé

nepravé

Pentosový cyklus

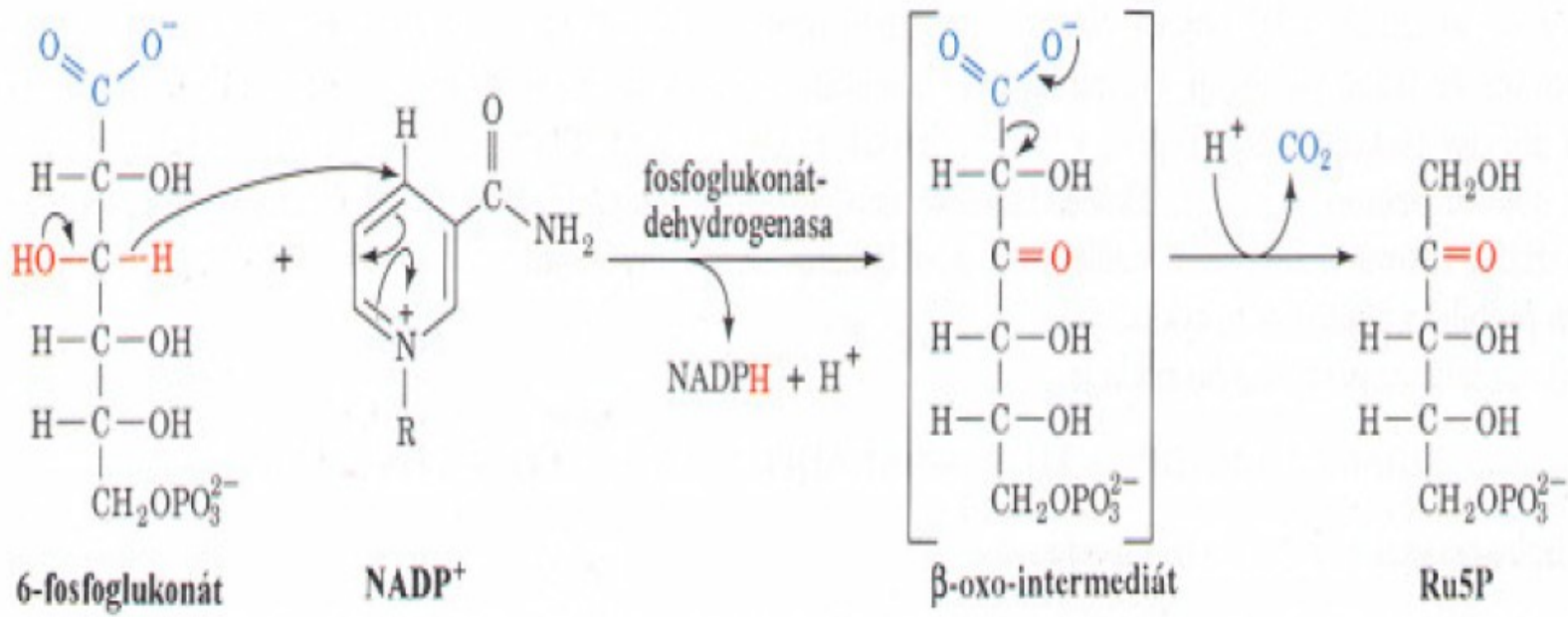




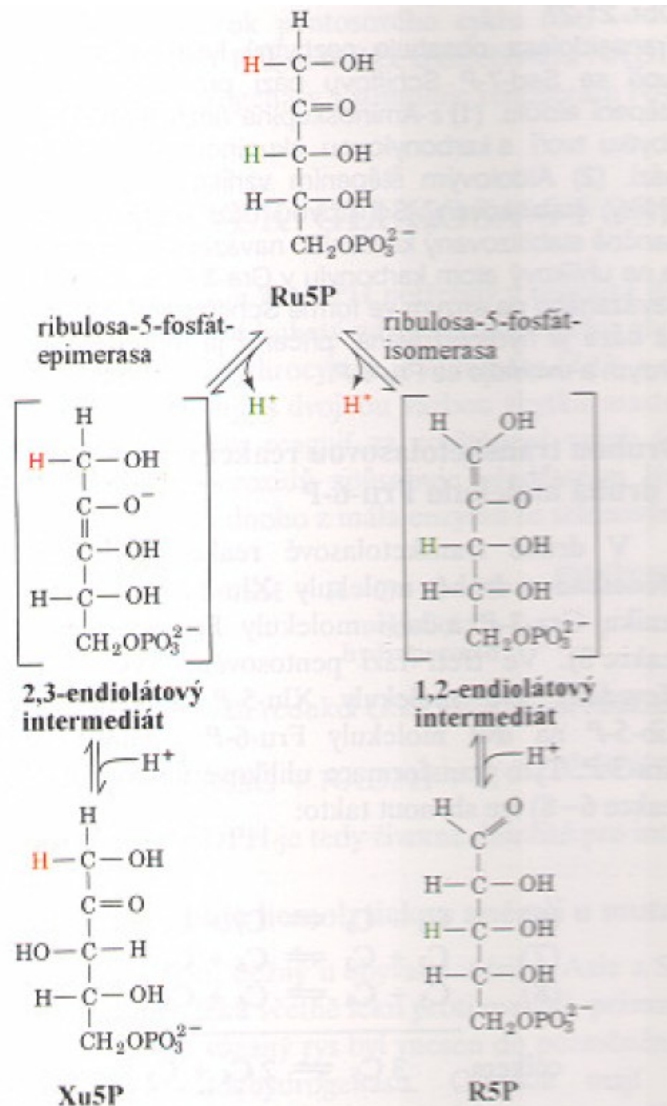


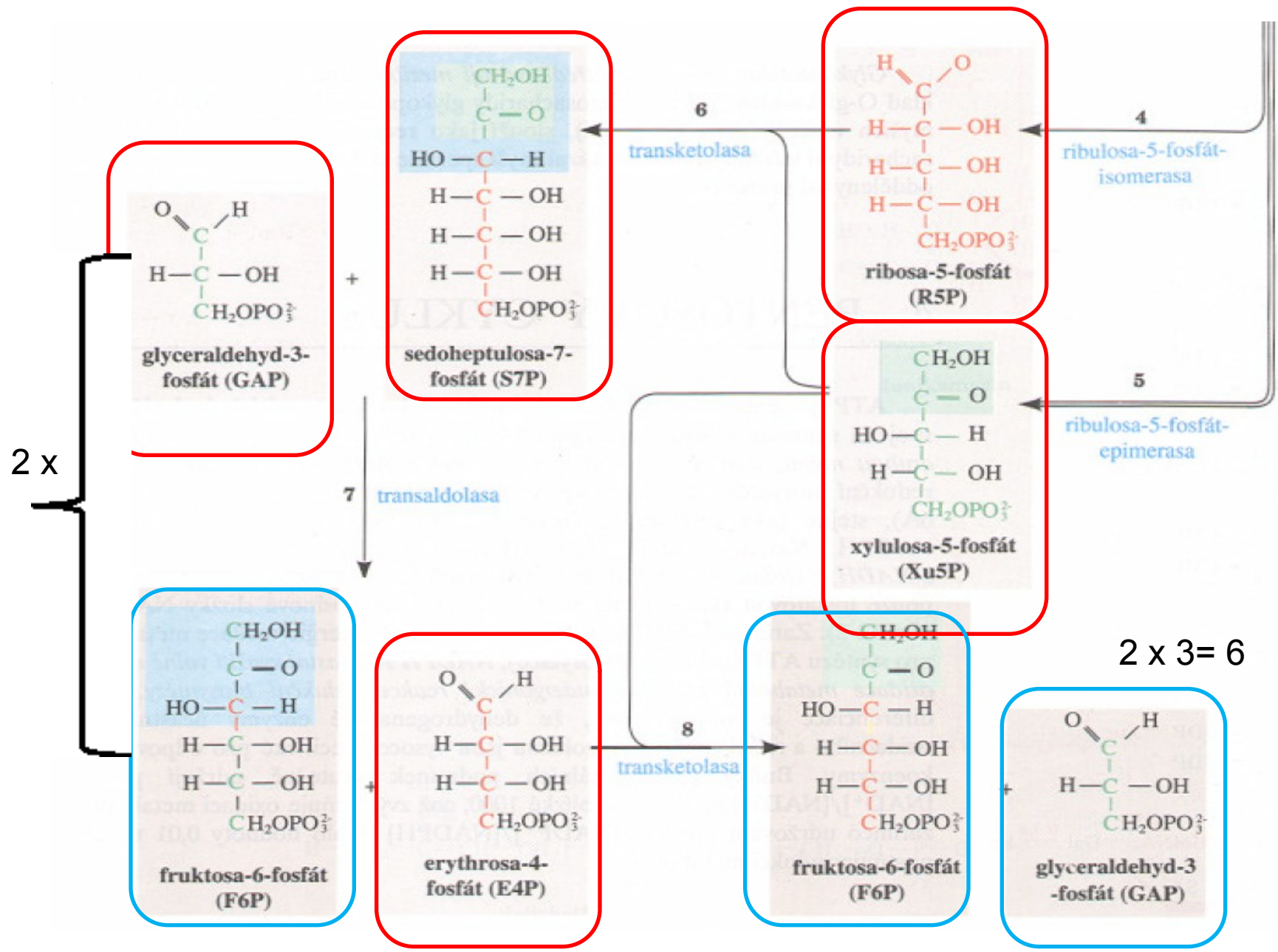
+ NADP⁺

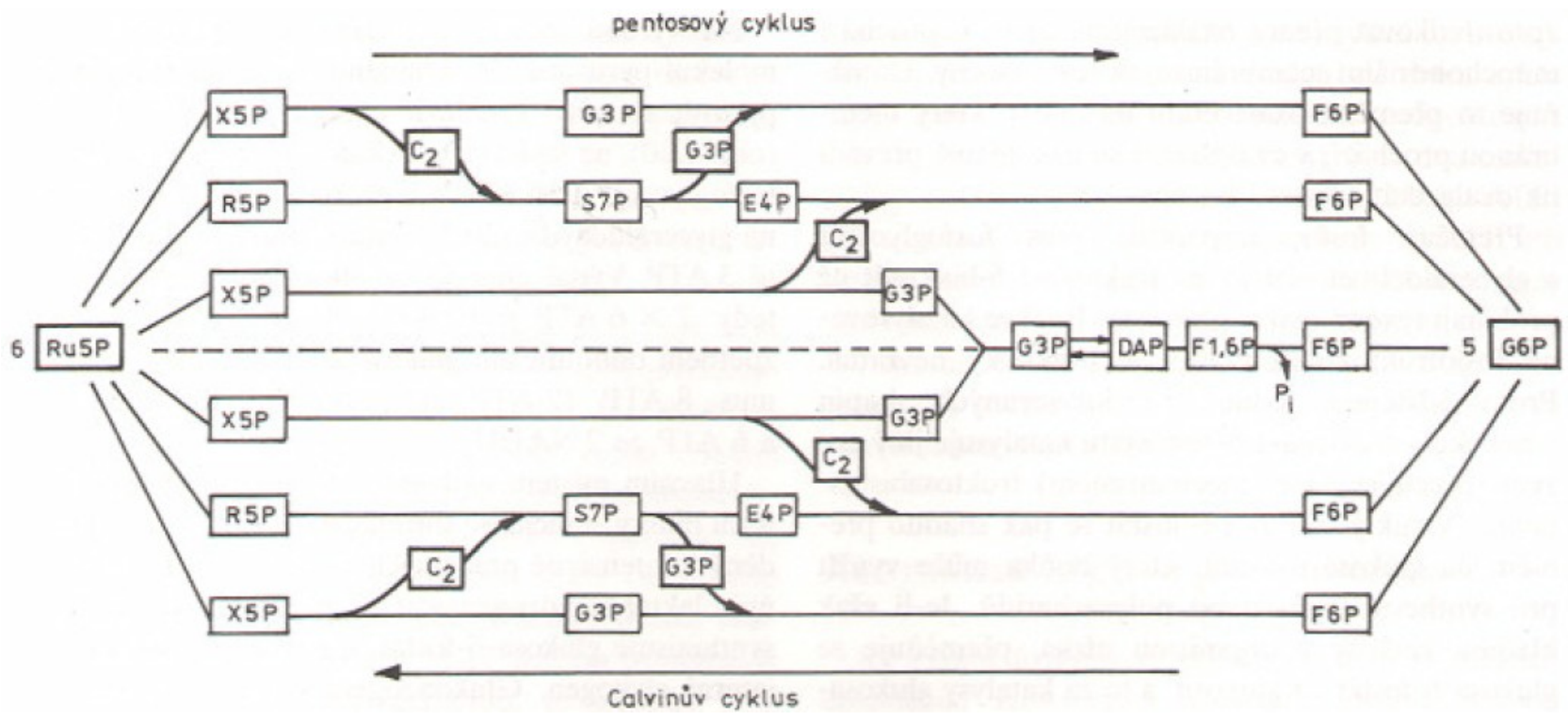
- NADPH

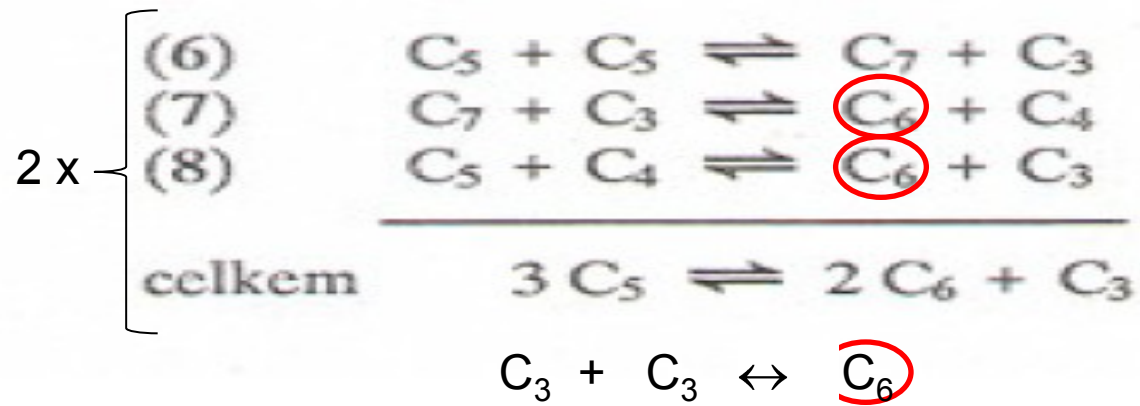


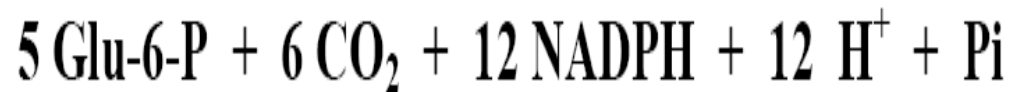
Regenerační fáze







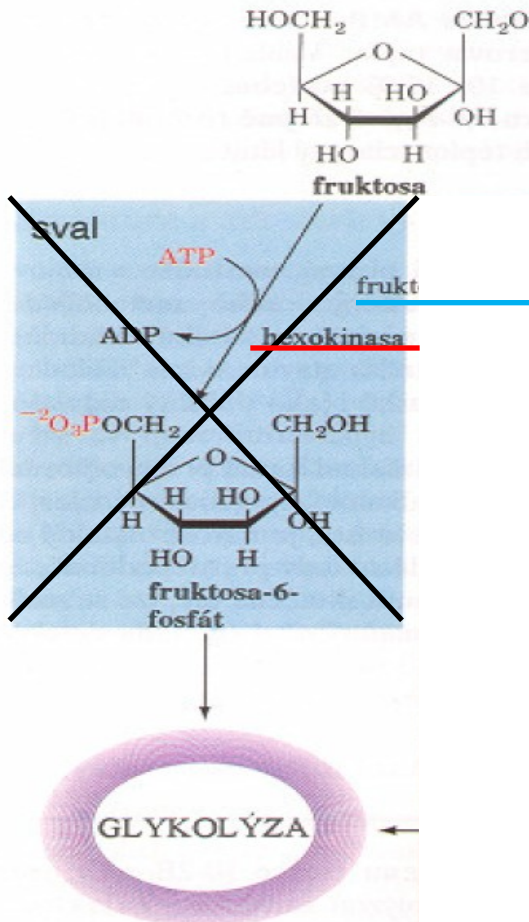




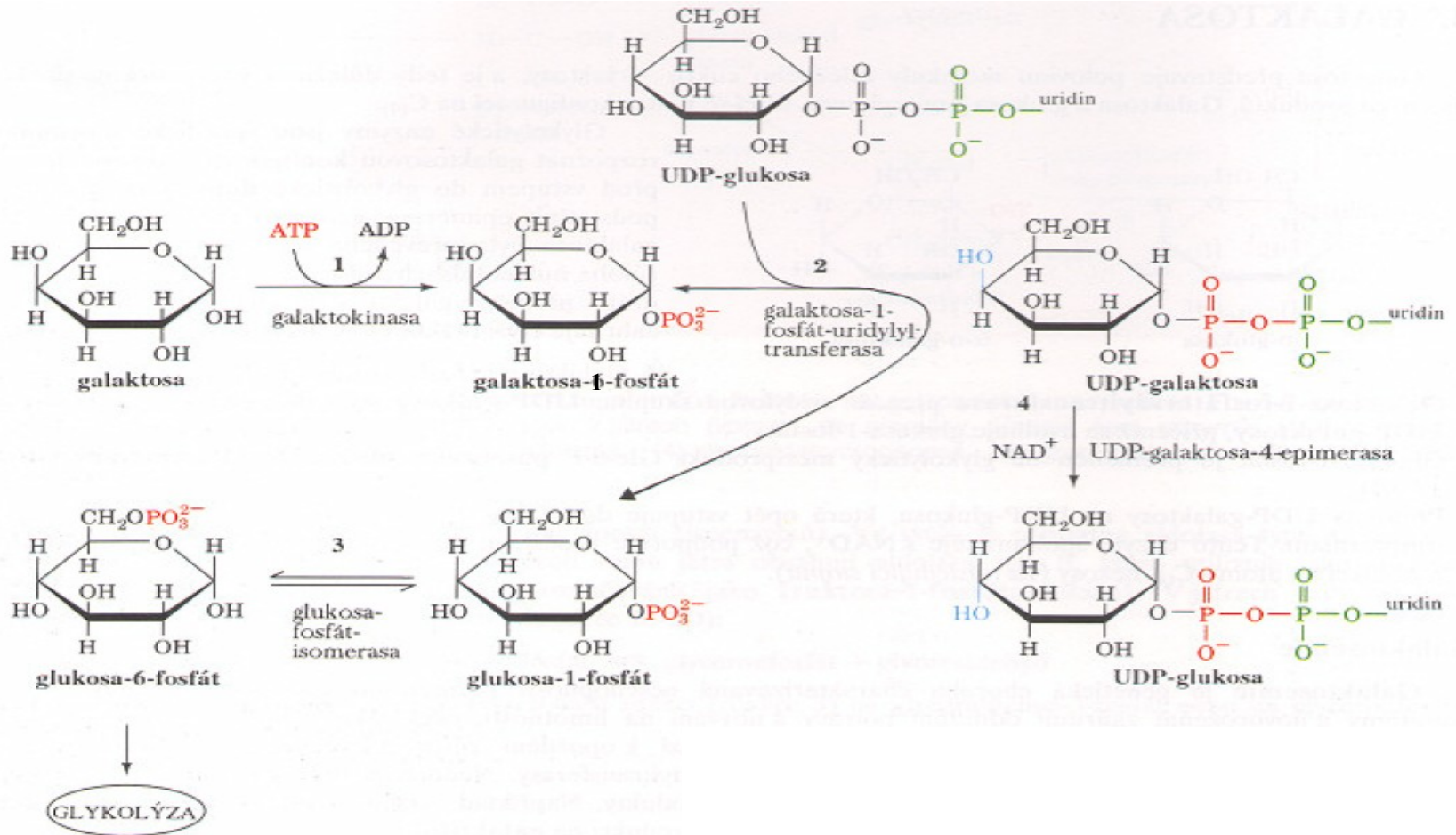
glykolýza	-	36 ATP
pentosový cyklus	-	36 ATP

CYT

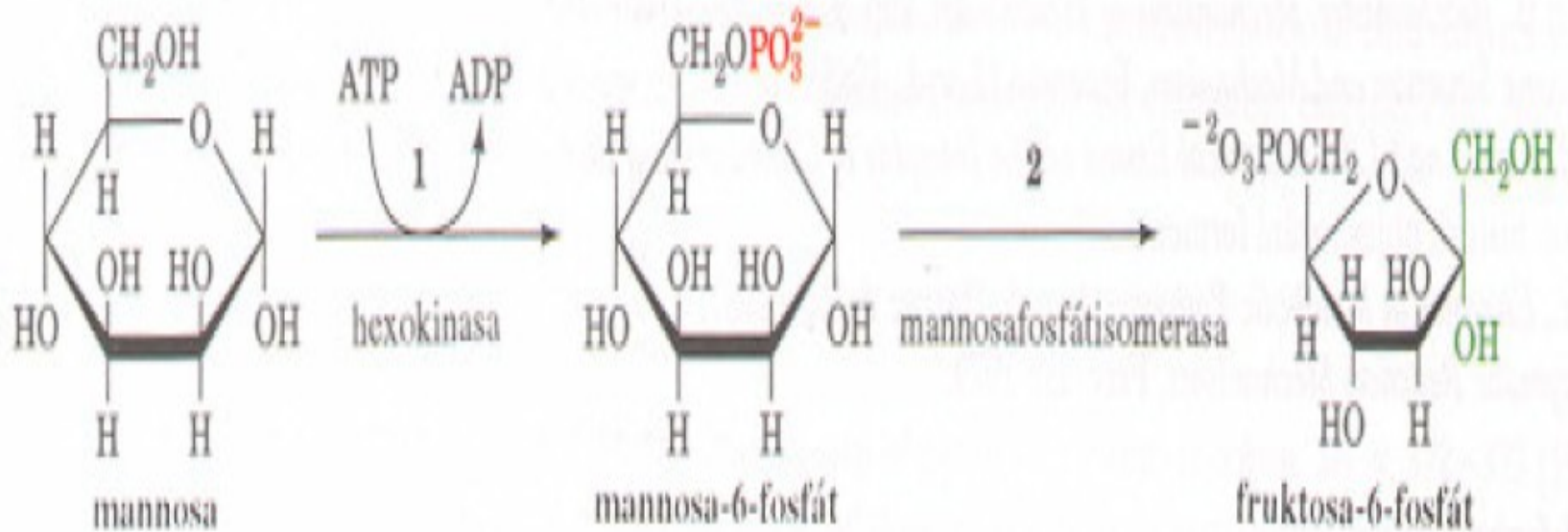
Fruktosa



Galaktosa



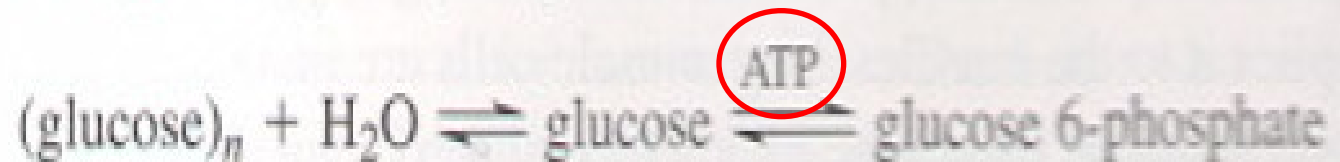
Manosa



Glykogen

Hydrolytic cleavage catalyzed by amylase:

Trávící

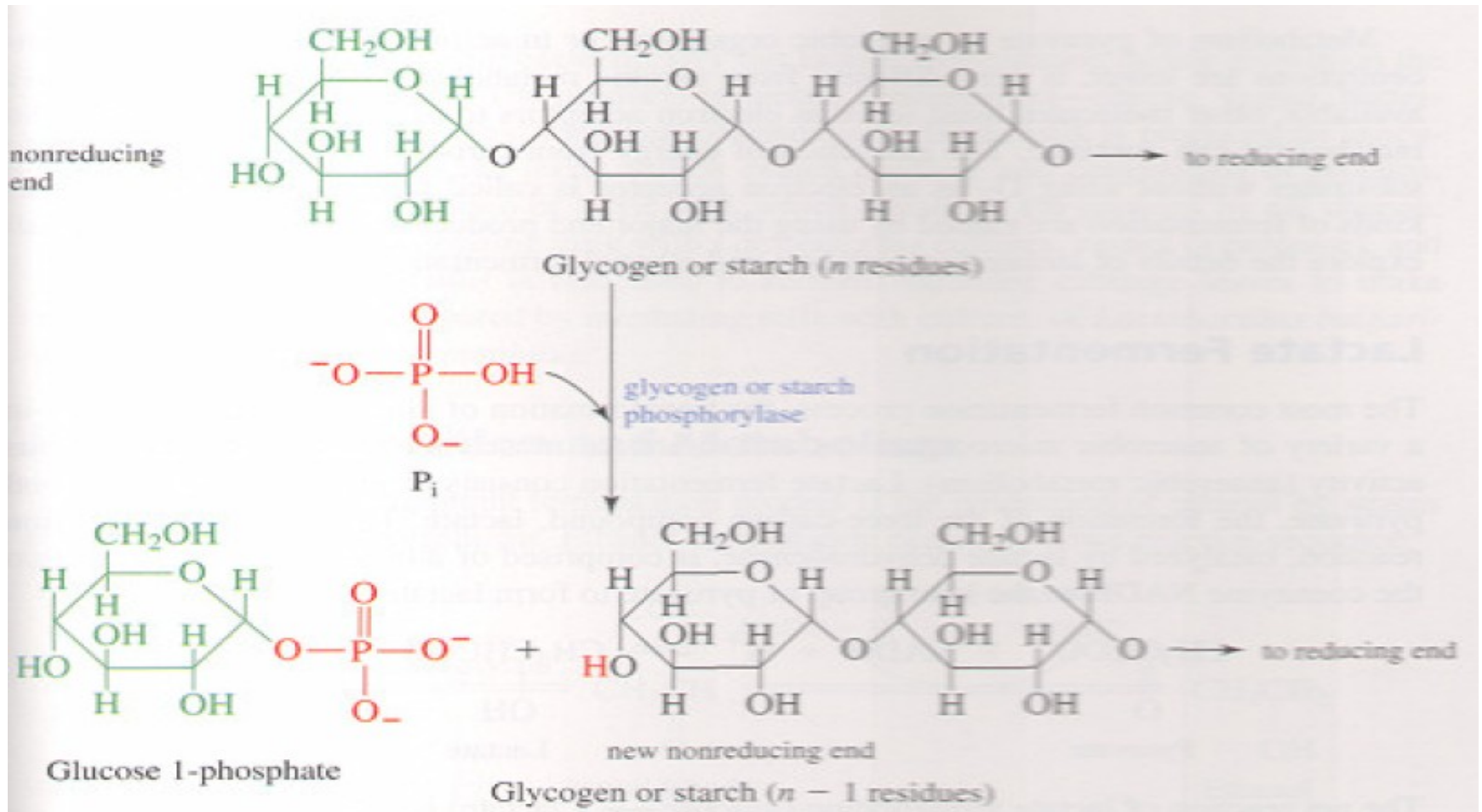


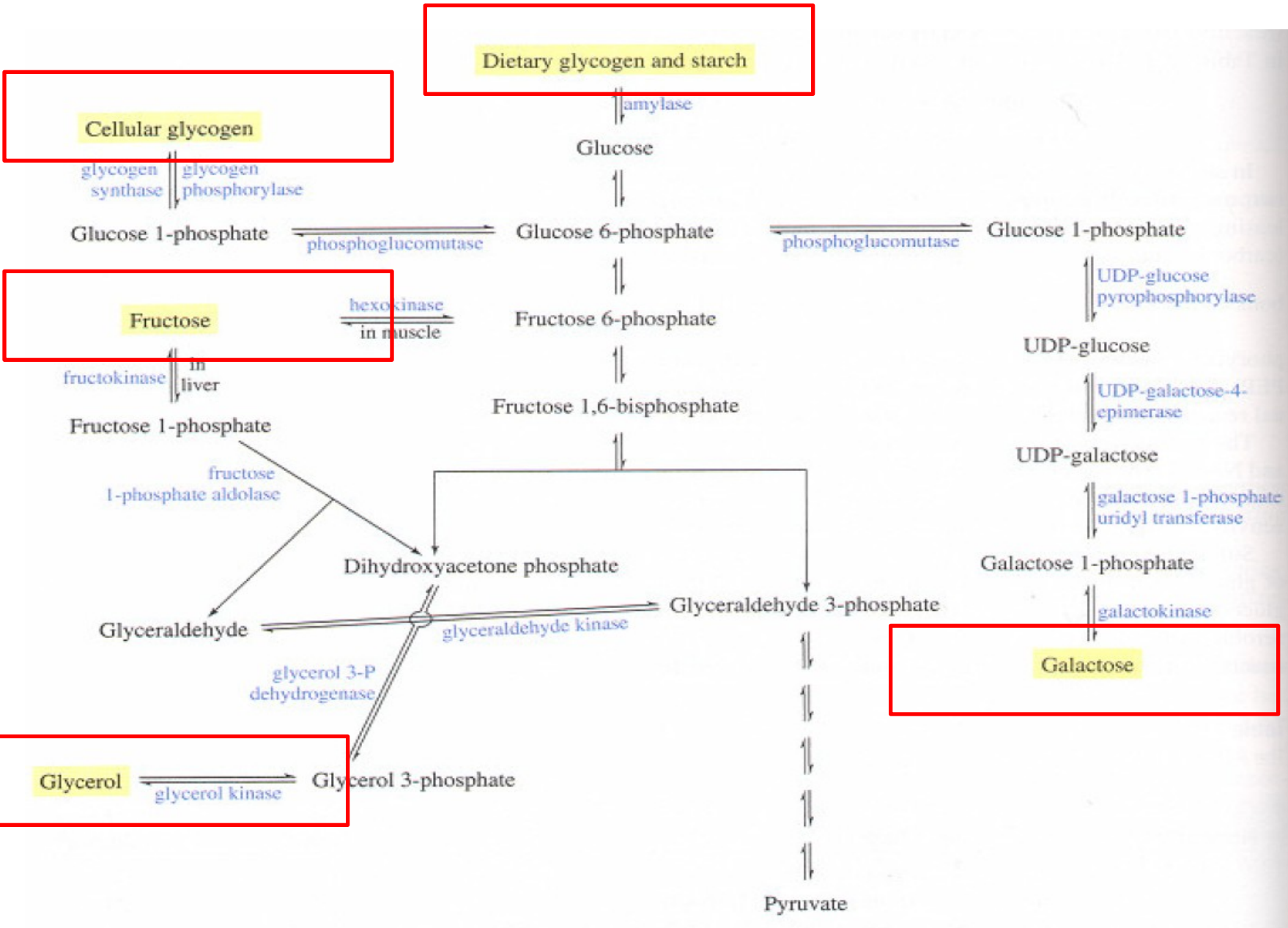
Phosphorolytic cleavage catalyzed by phosphorylase:

Tkářový

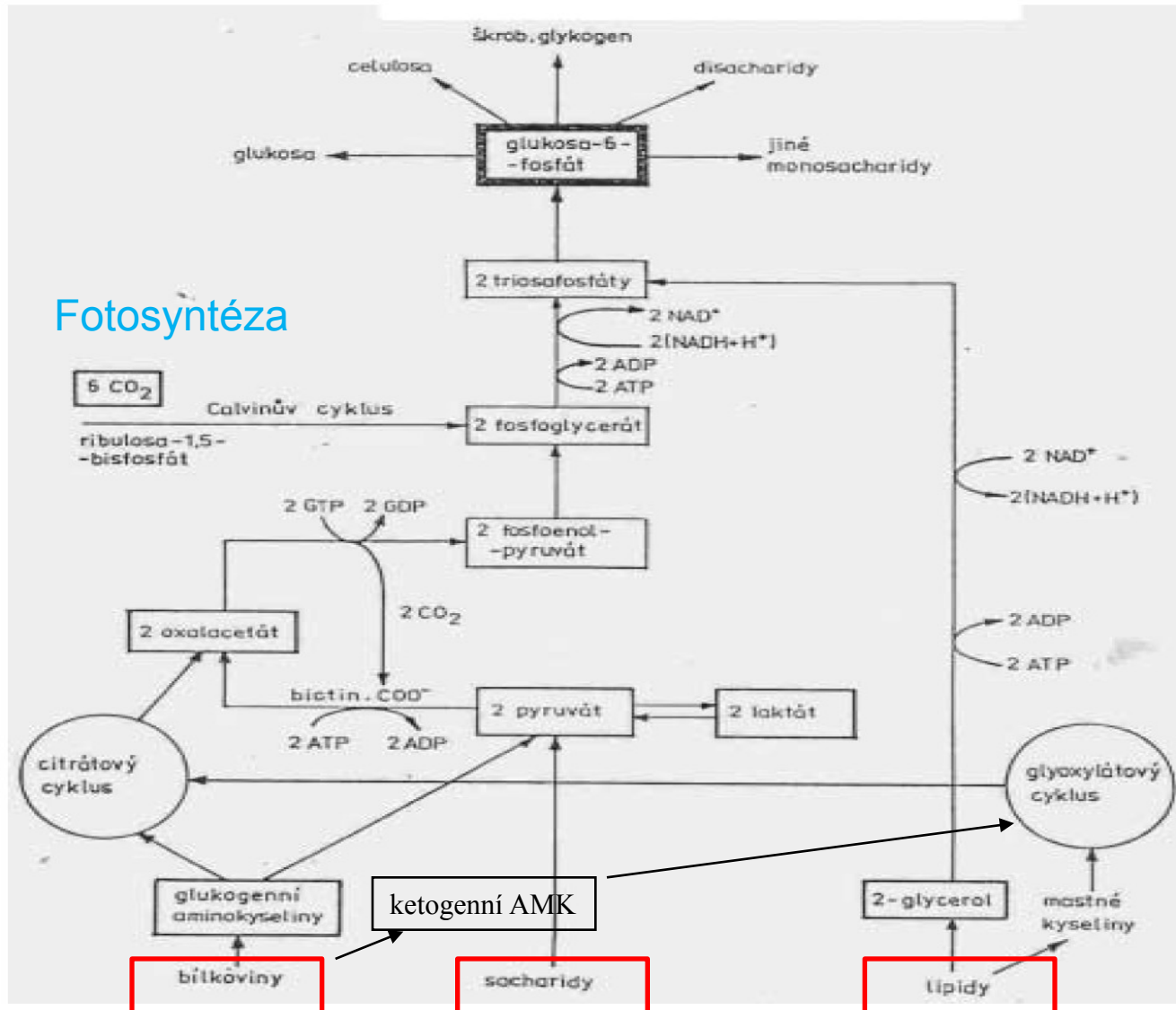


Glykogen





BIOSYNTÉZA SACHARIDŮ



Fotosyntéza

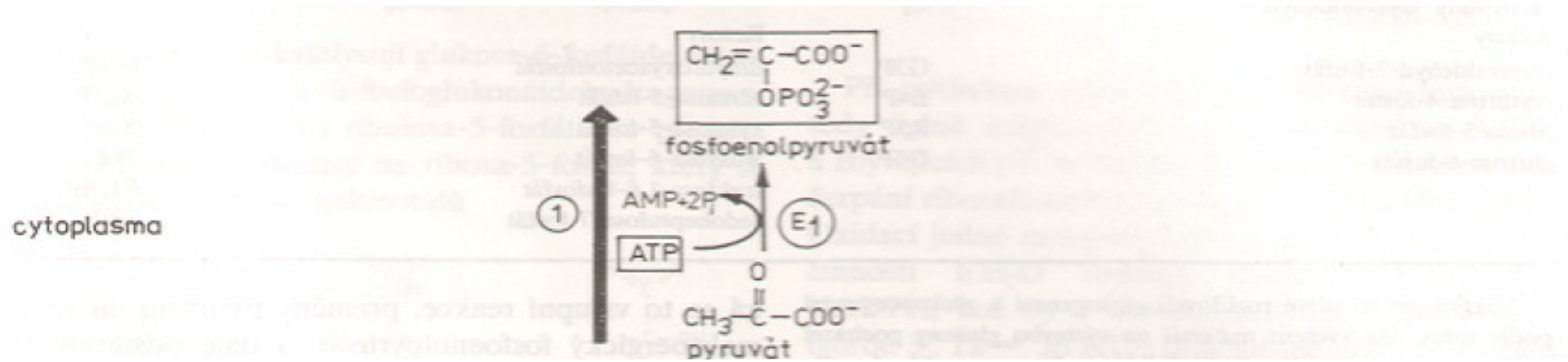
Glukoneogenese

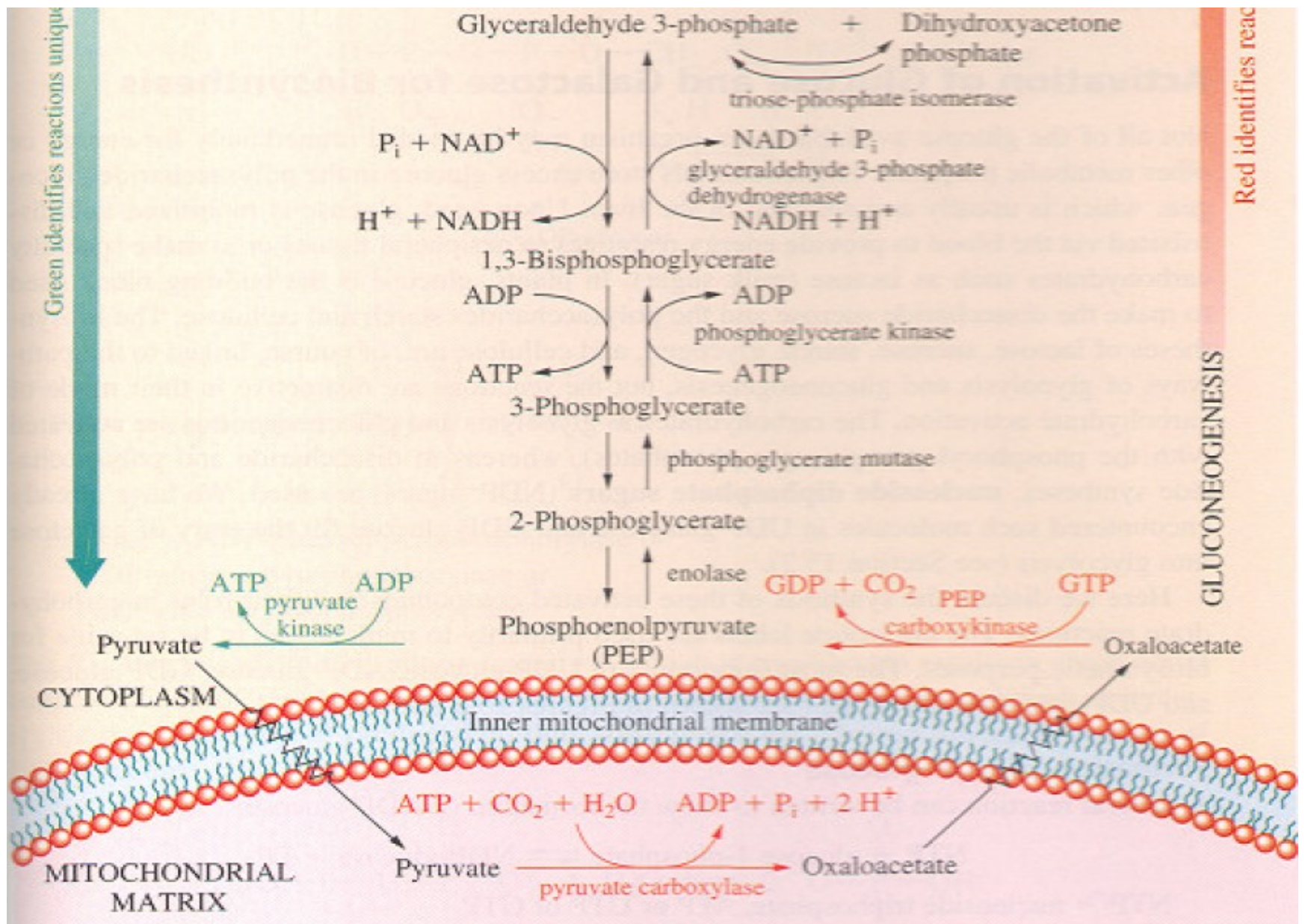
BIOSYNTÉZA SACHARIDŮ

- Glukoneogenese
- Fotosyntéza

Glukoneogenese

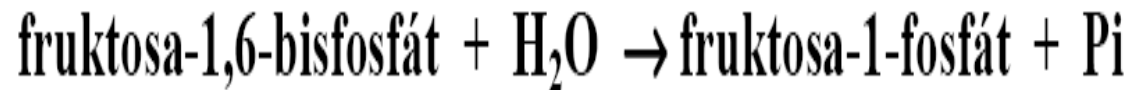
1. Vznik fosfoenolpyruvátu





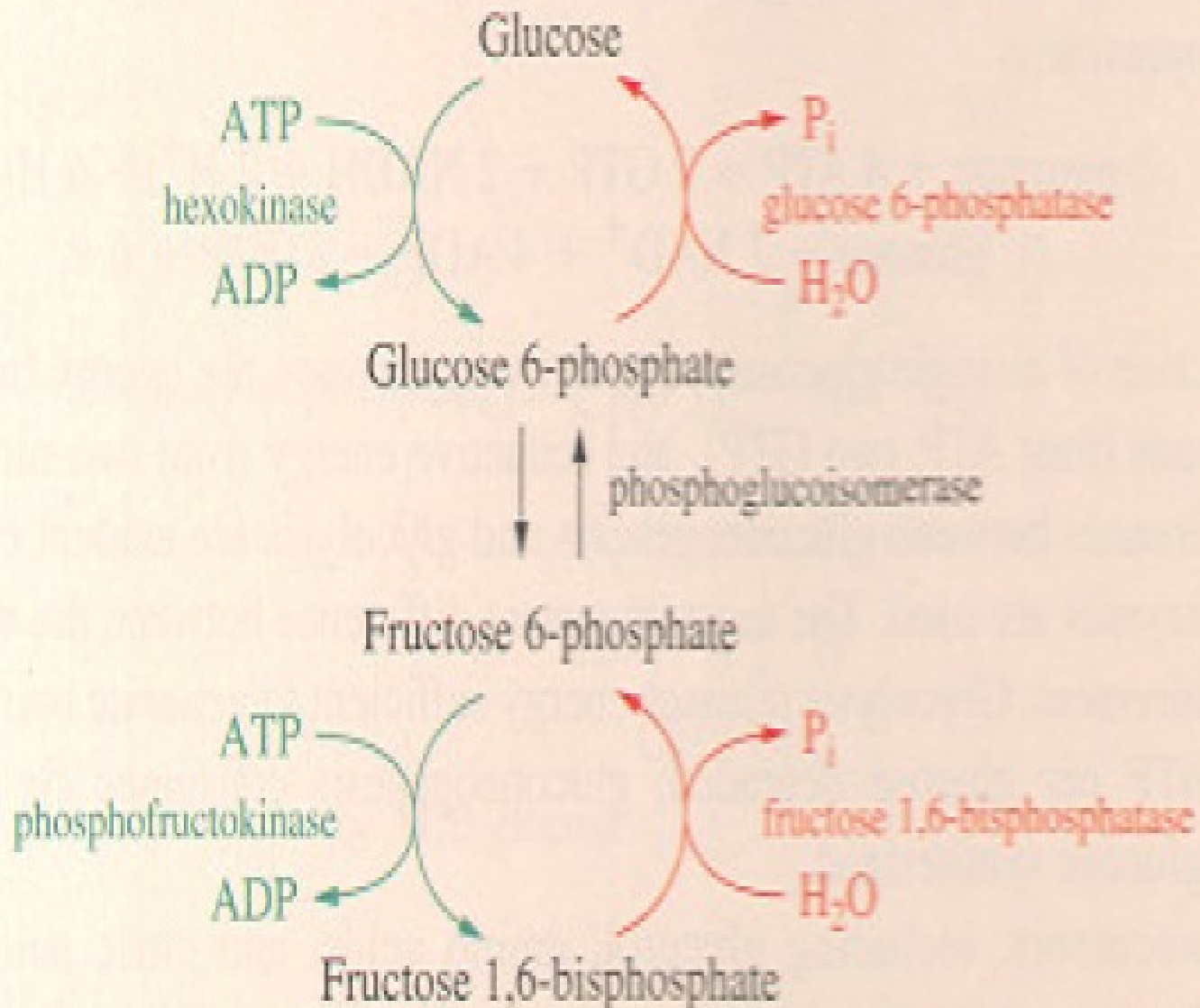
2. *Hydrolytické reakce*

A. fruktosabisfosfatasa

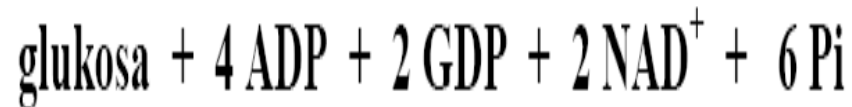


B. glukosafosfatasa



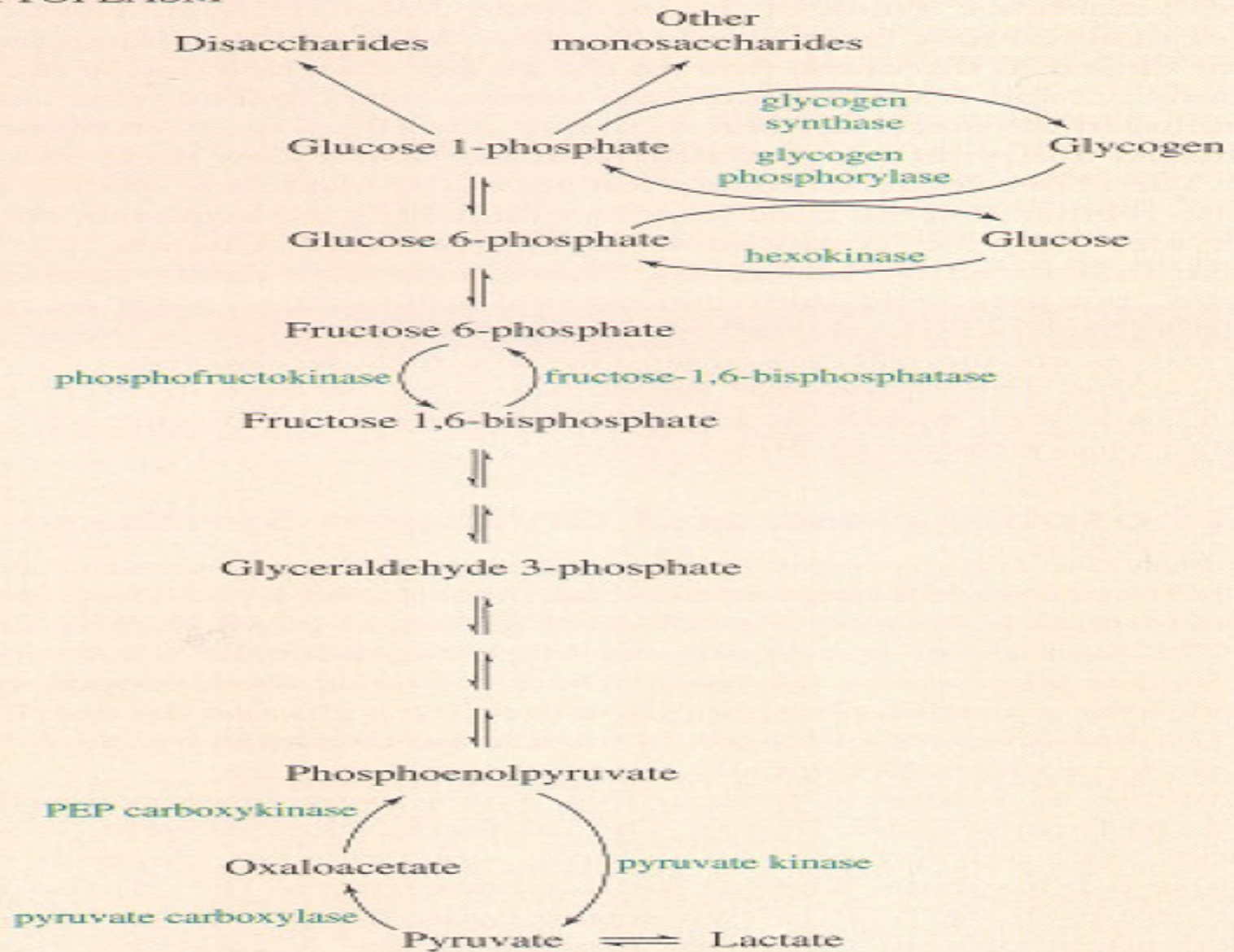


Bilance glukoneogenese



$$\text{glykolysa (8 ATP) - glukoneogenese (12 ATP) = -4 ATP}$$

CYTOPLASM



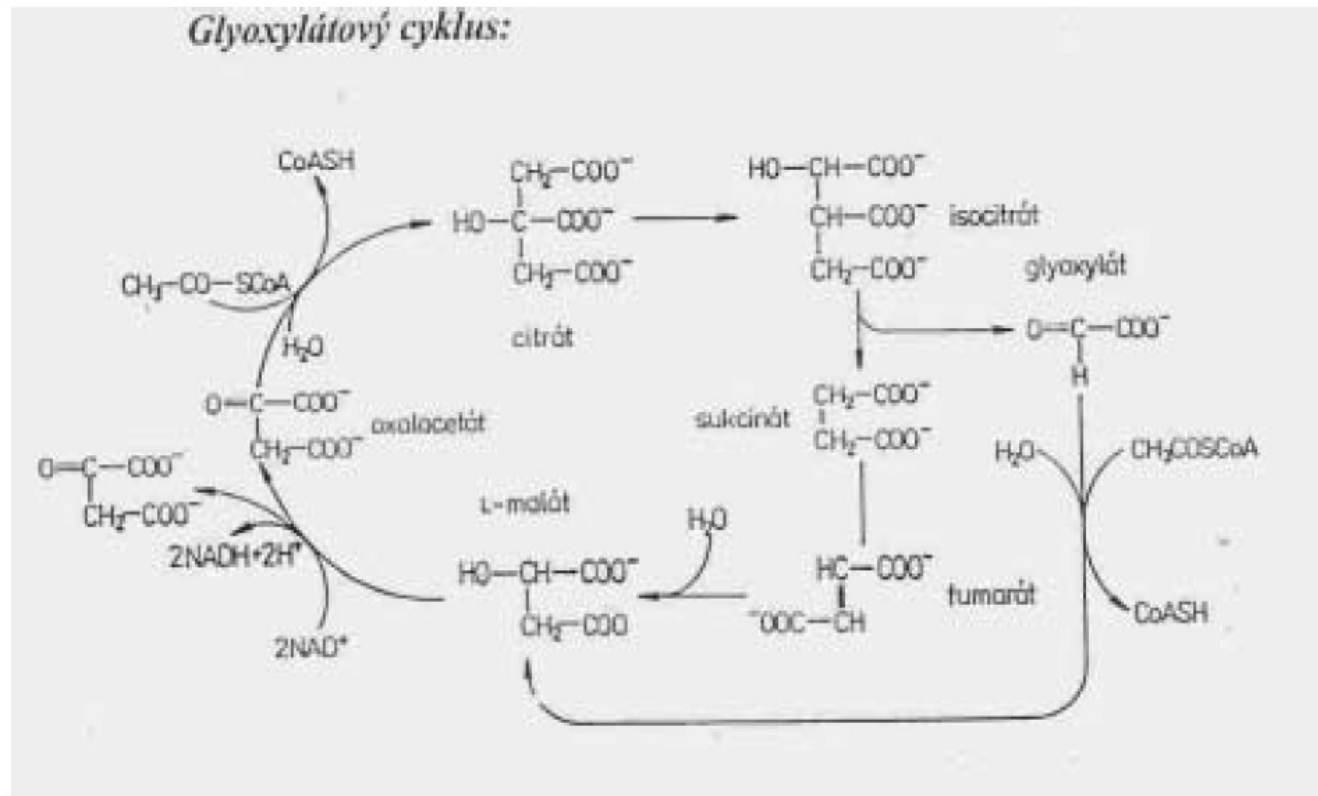
Biosyntéza glukosy z dalších prekurzorů

- **glukogenní aminokyseliny -pyruvát a meziprodukty citrátového cyklu**

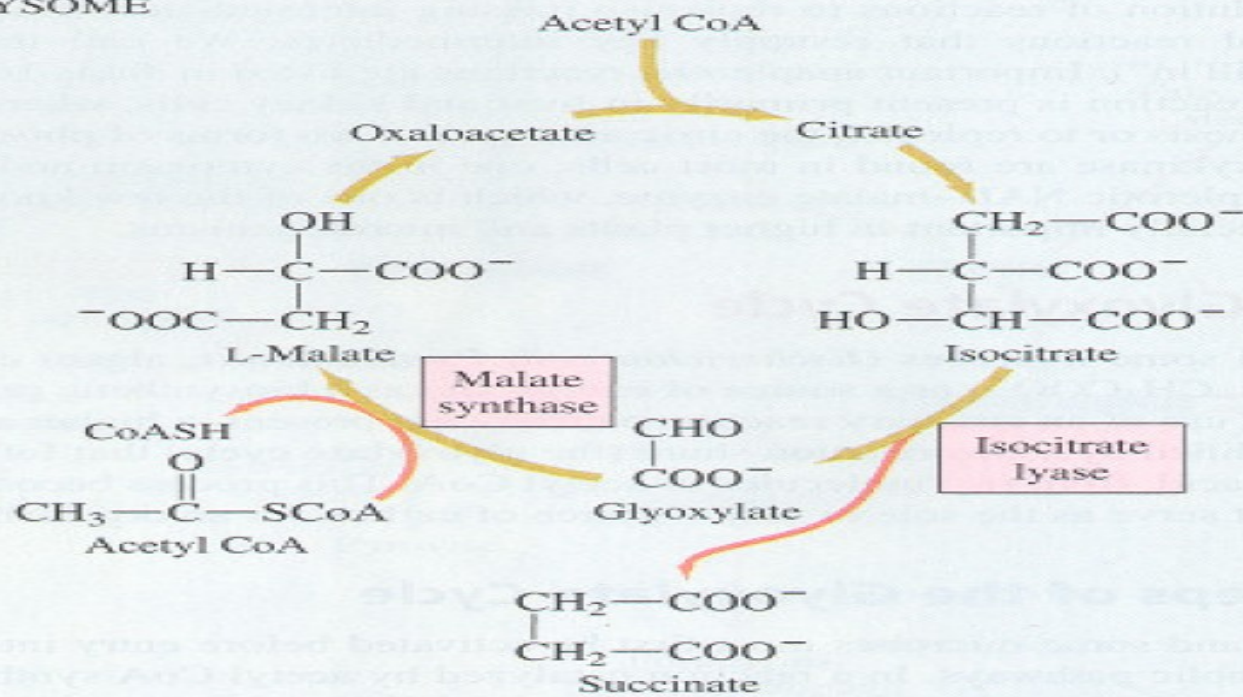
Biosyntéza glukosy z dalších prekurzorů

- lipidy - glycerol a acetylCoA + ketogenní AMK

Glyoxylátový cyklus:



GLYOXYYSOME



MITOCHONDRIA

Succinate → Fumarate → L-Malate

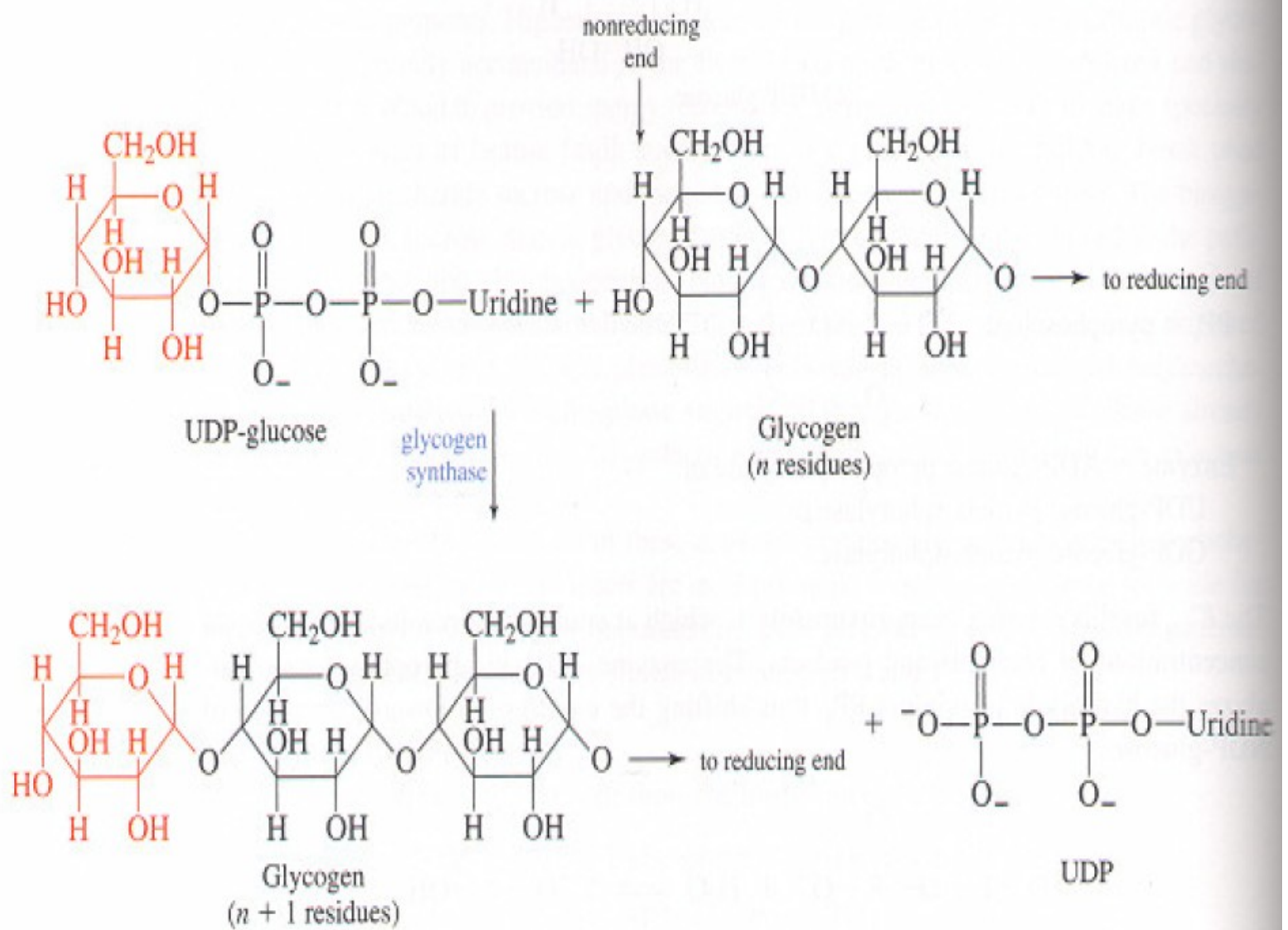
CYTOPLASM

Phosphoenolpyruvate ← Oxaloacetate ← L-Malate

(Gluconeogenesis)

Glucose

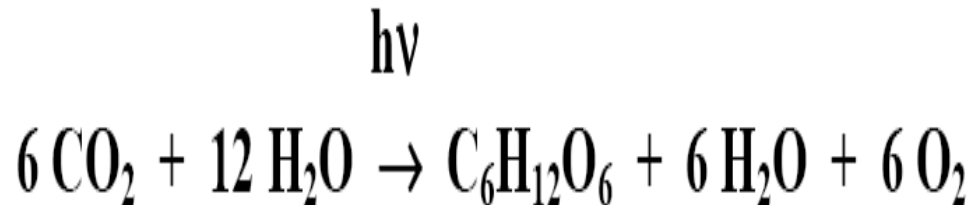
Biosyntéza oligo- a polysacharidů



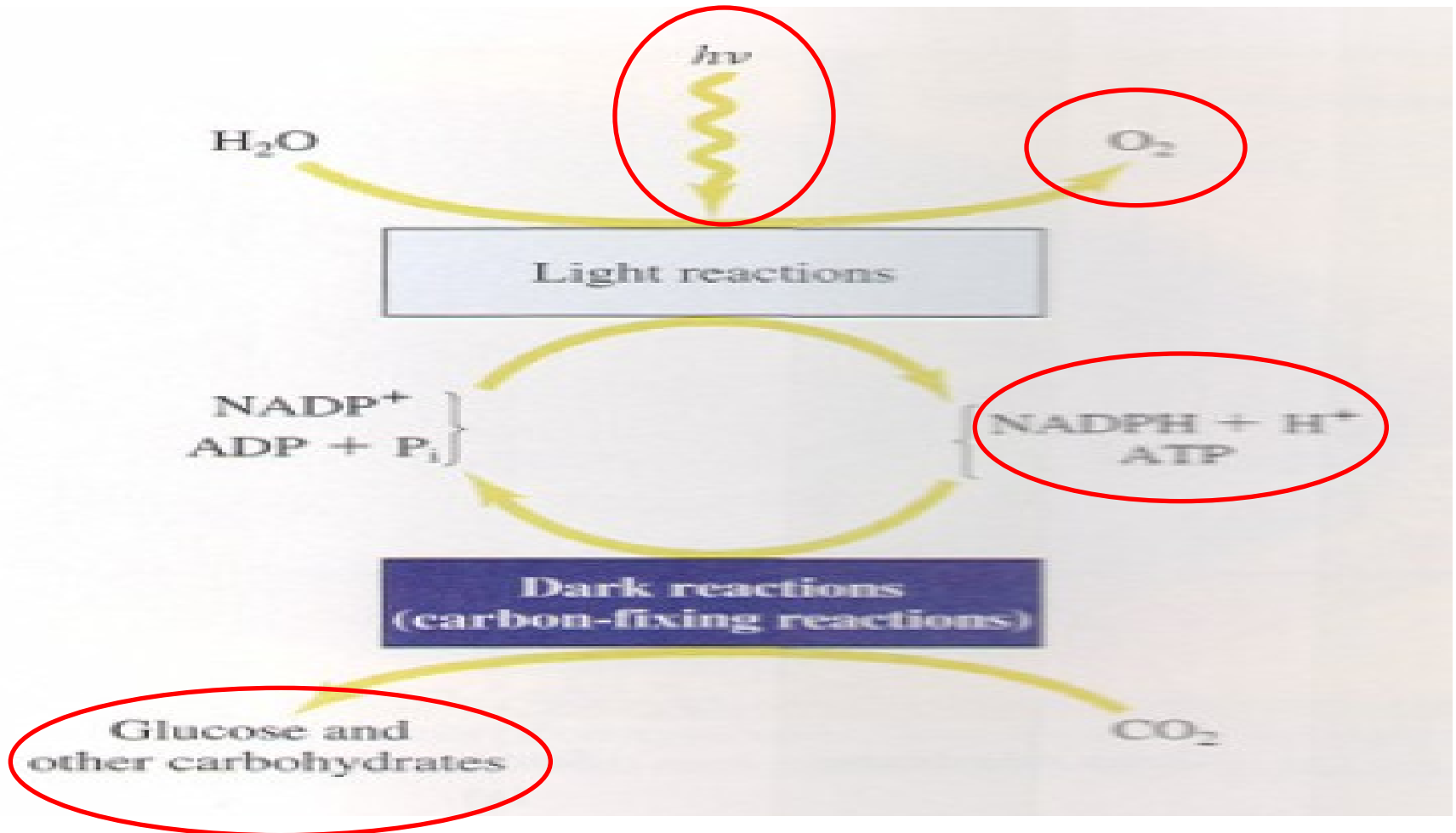
FOTOSYNTÉZA

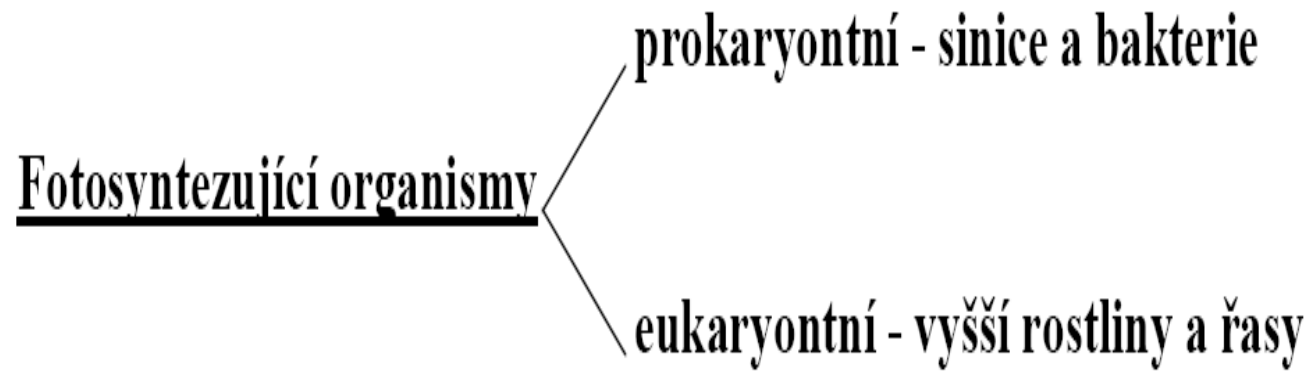
Význam :

- zachycení sluneční energie a syntéza glukosy z CO_2 a H_2O
- produkce O_2

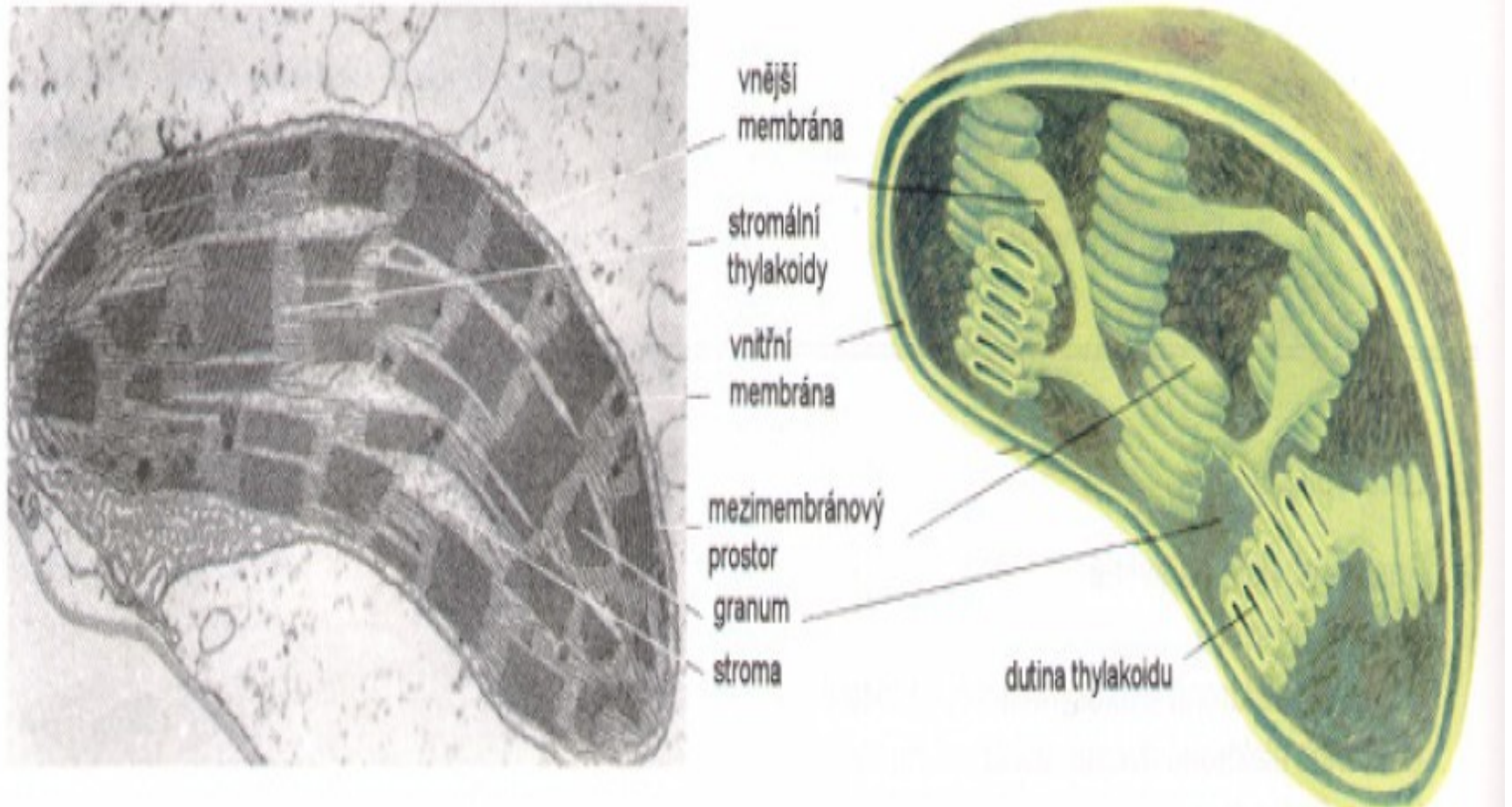


Světelná a temná fáze

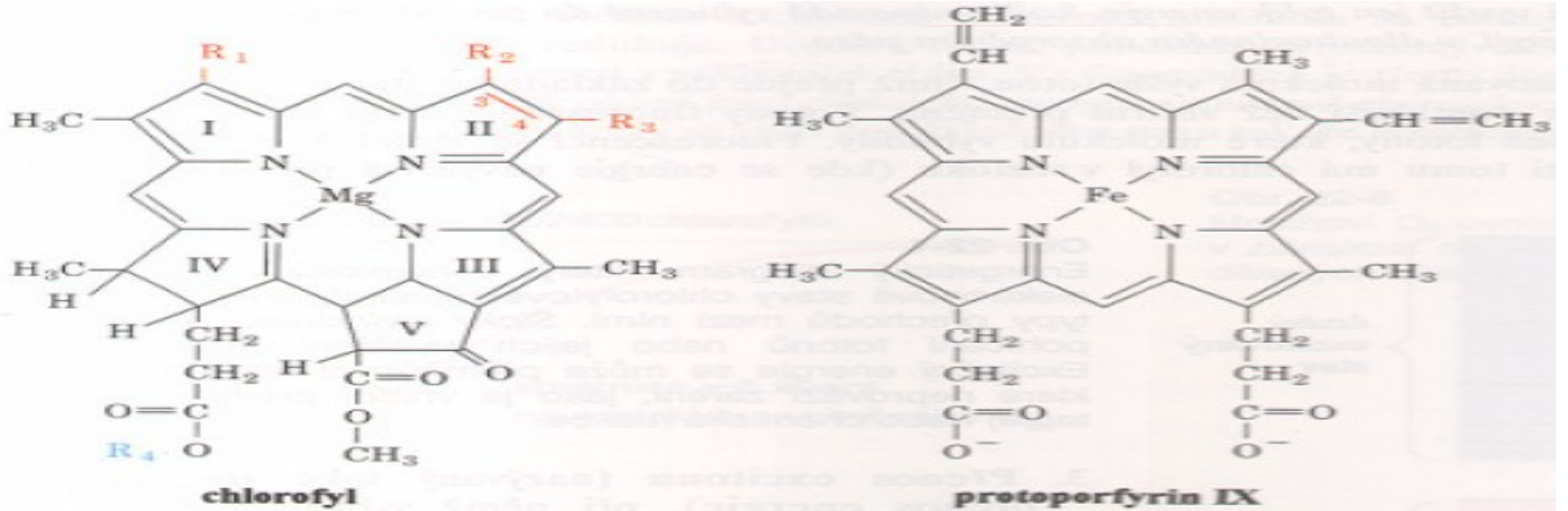




Chloroplast

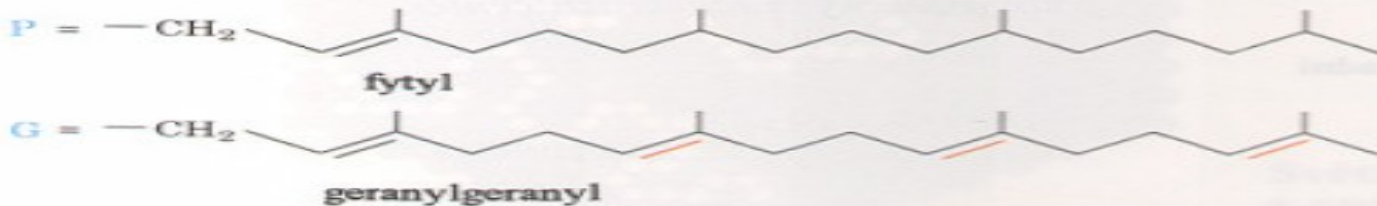


Chlorofyly



	R_1	R_2	R_3	R_4
chlorofyl a	$-\text{CH}=\text{CH}_2$	$-\text{CH}_3$	$-\text{CH}_2-\text{CH}_3$	P
chlorofyl b	$-\text{CH}=\text{CH}_2$	$-\text{C}(=\text{O})-\text{H}$	$-\text{CH}_2-\text{CH}_3$	P
bakteriochlorofyl a	$-\text{C}(=\text{O})-\text{CH}_3$	$-\text{CH}_3^a$	$-\text{CH}_2-\text{CH}_3^a$	P or G
bakteriochlorofyl b	$-\text{C}(=\text{O})-\text{CH}_3$	$-\text{CH}_3^a$	$=\text{CH}-\text{CH}_3^a$	P

^a bez dvojné vazby mezi polohami $\text{C}_{(3)}$ a $\text{C}_{(4)}$



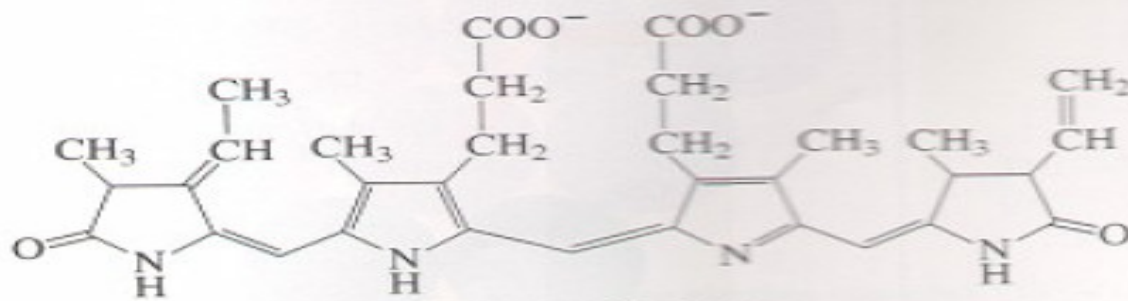
Pomocná barviva



(a) β -Carotene

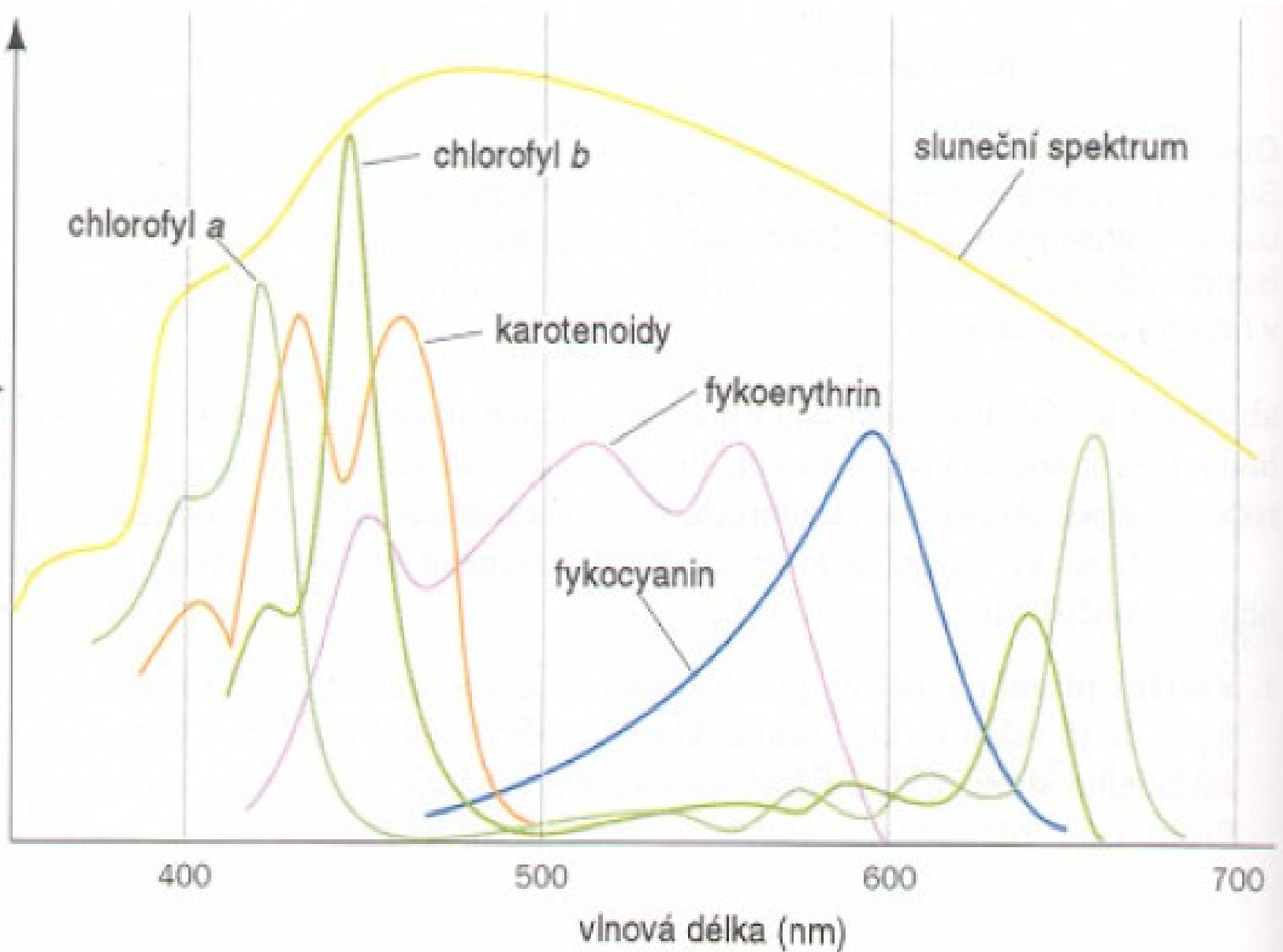


(b) Lutein



(c) Phycoerythrobilin

absorpce



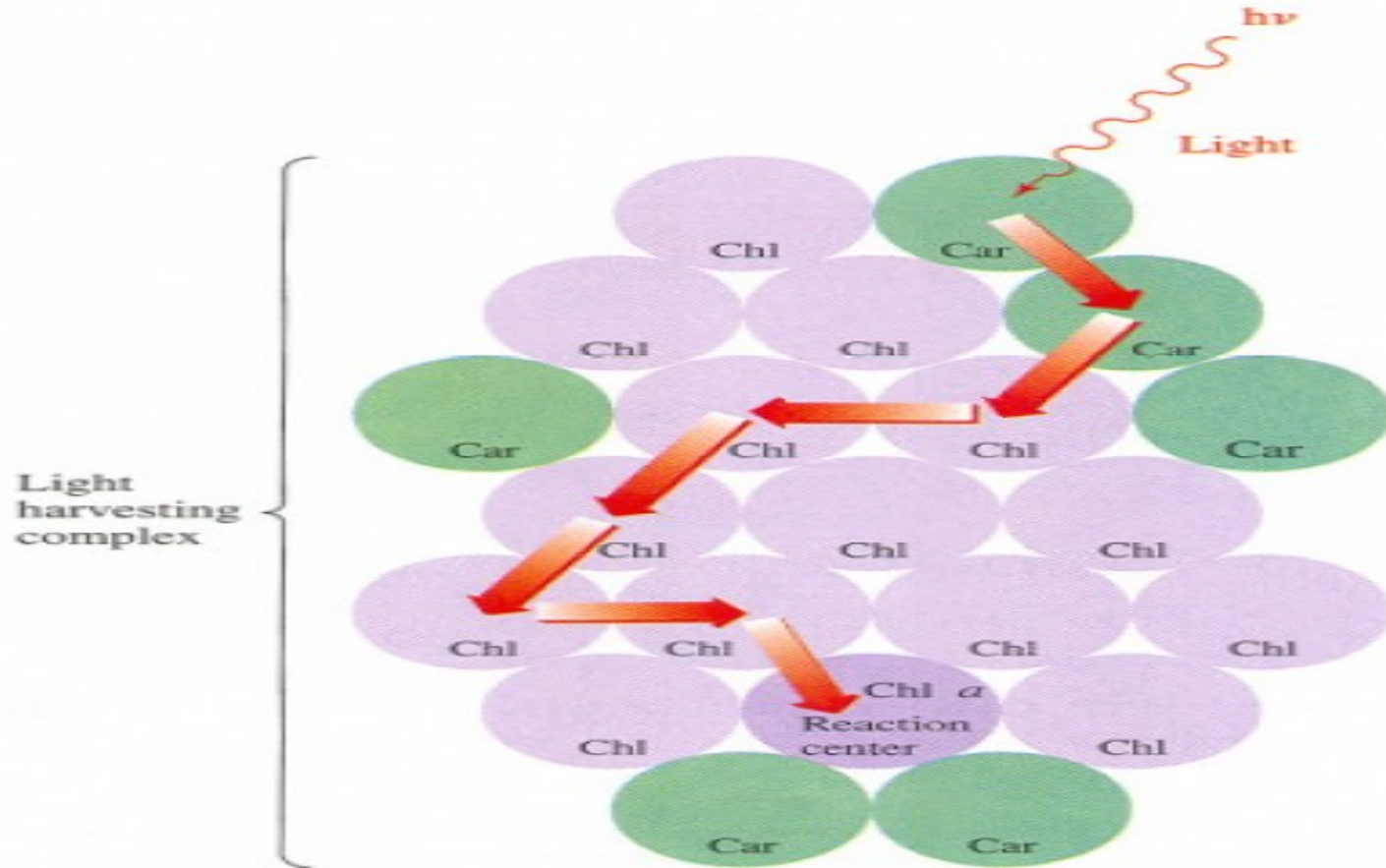
Světelná fáze

- proces zachycení záření
- cyklický tok elektronů - cyklická fotofosforylace → ATP
- necyklický tok elektronů - necyklická fotofosforylace → ATP,

NADP

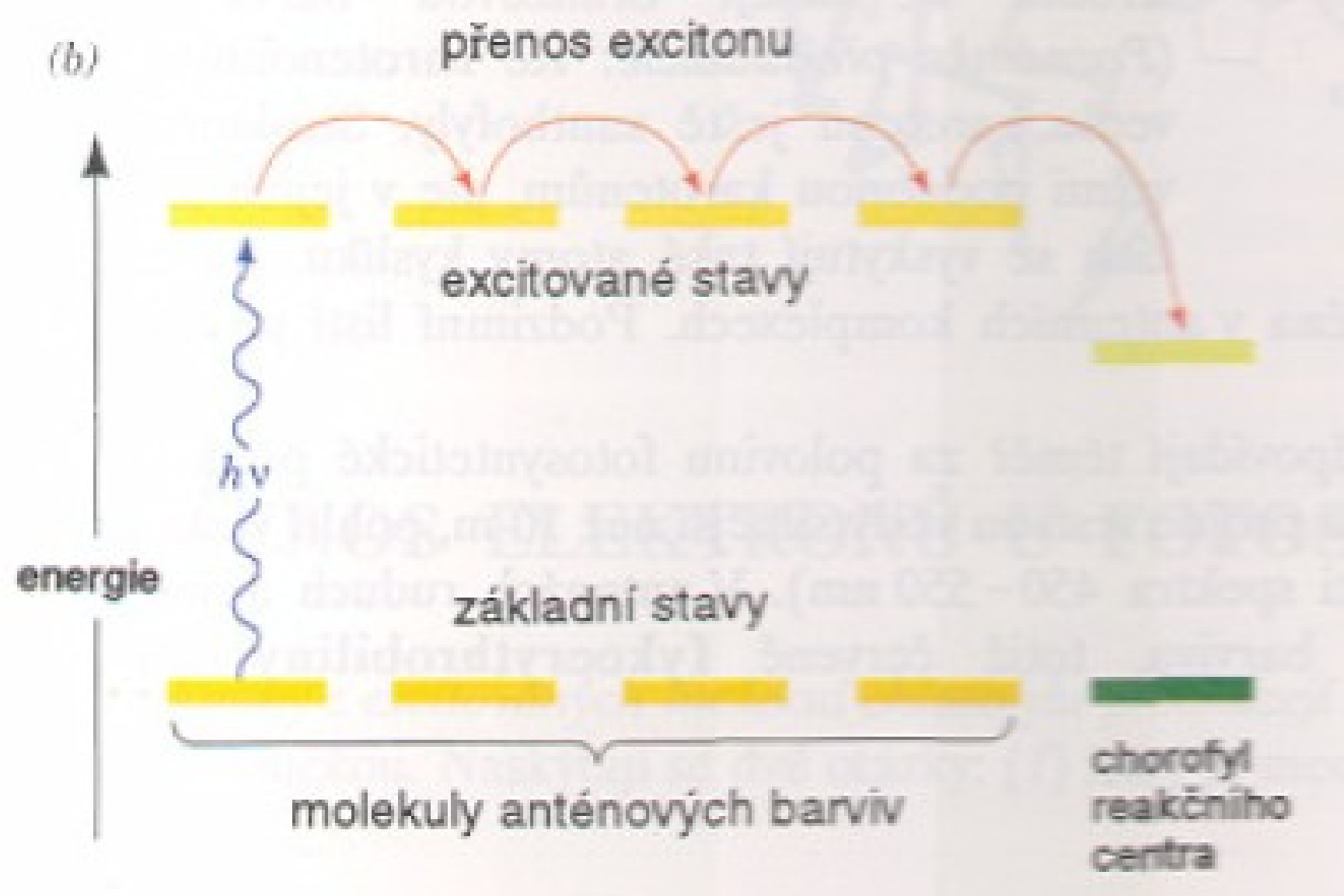
- fotolýza vody - $\text{H}_2\text{O} \rightarrow 2 \text{H}^+ + 2 \text{e}^- + \frac{1}{2} \text{O}_2$
- spřažení transportu elektronů se syntézou ATP

Proces zachycení záření kvantosomy

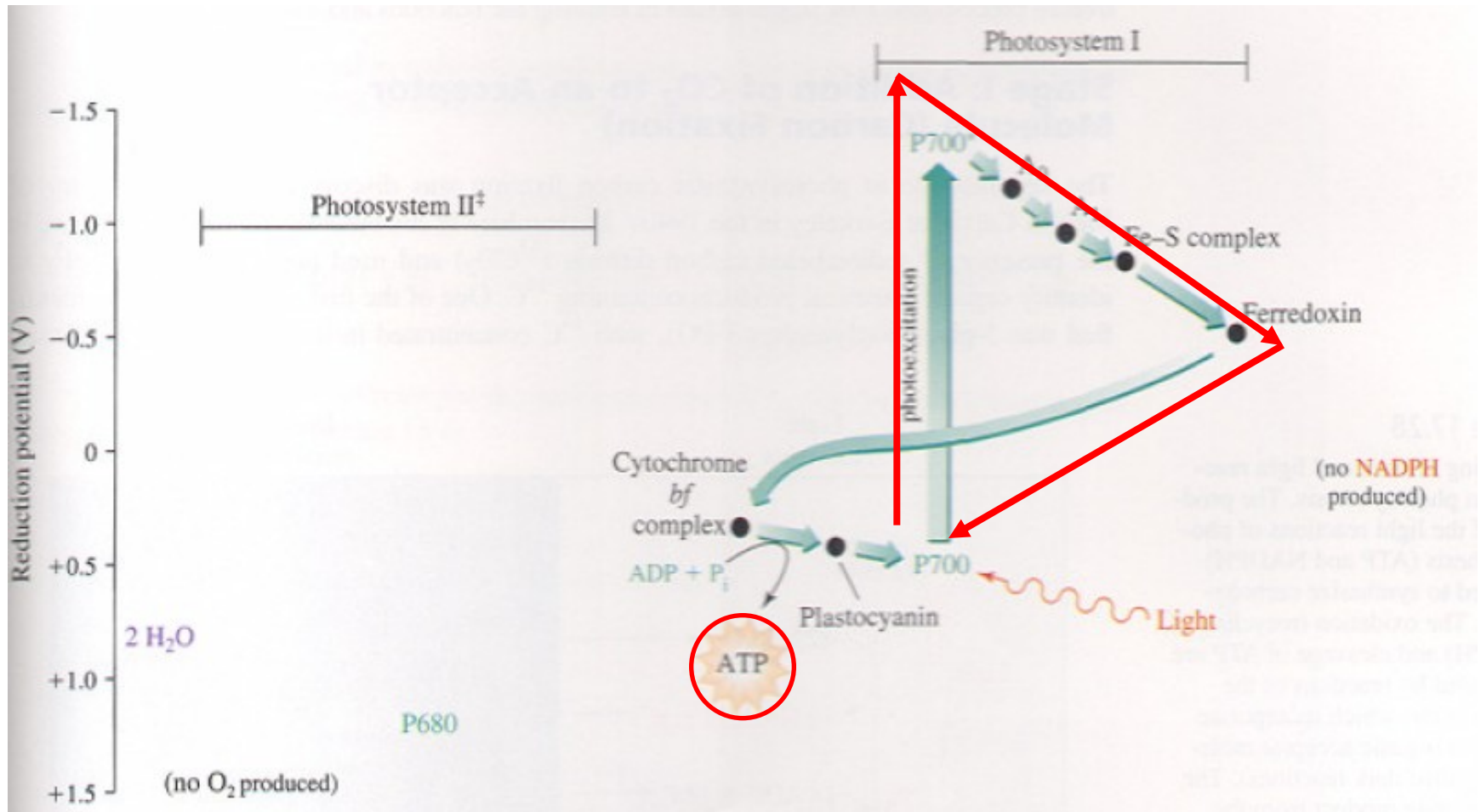


Anténní chlorofyl : chlorofyl reakčního centra (300 : 1)

(b)



Cyklický tok- produkce ATP



Necyklický tok- produkce NADPH

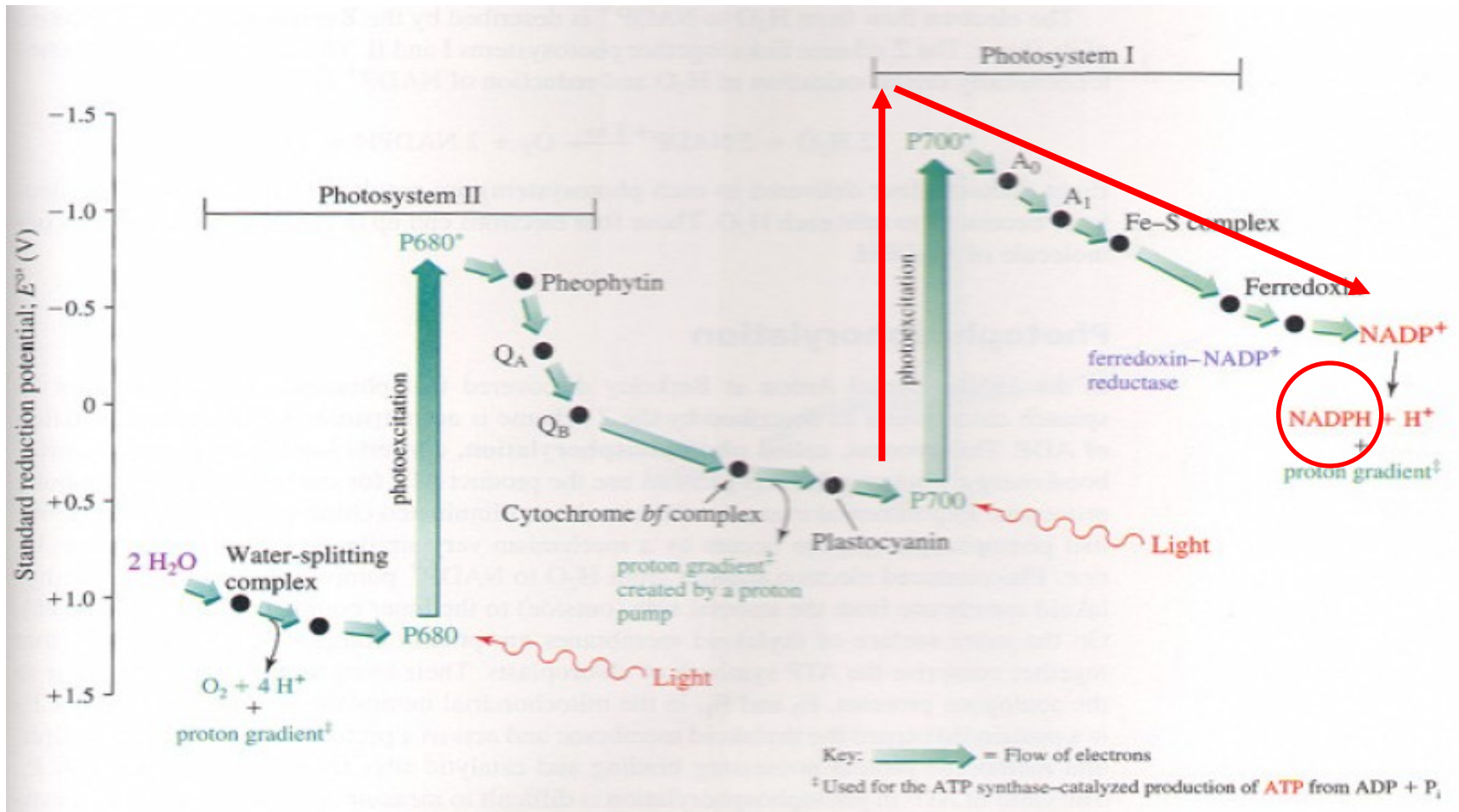
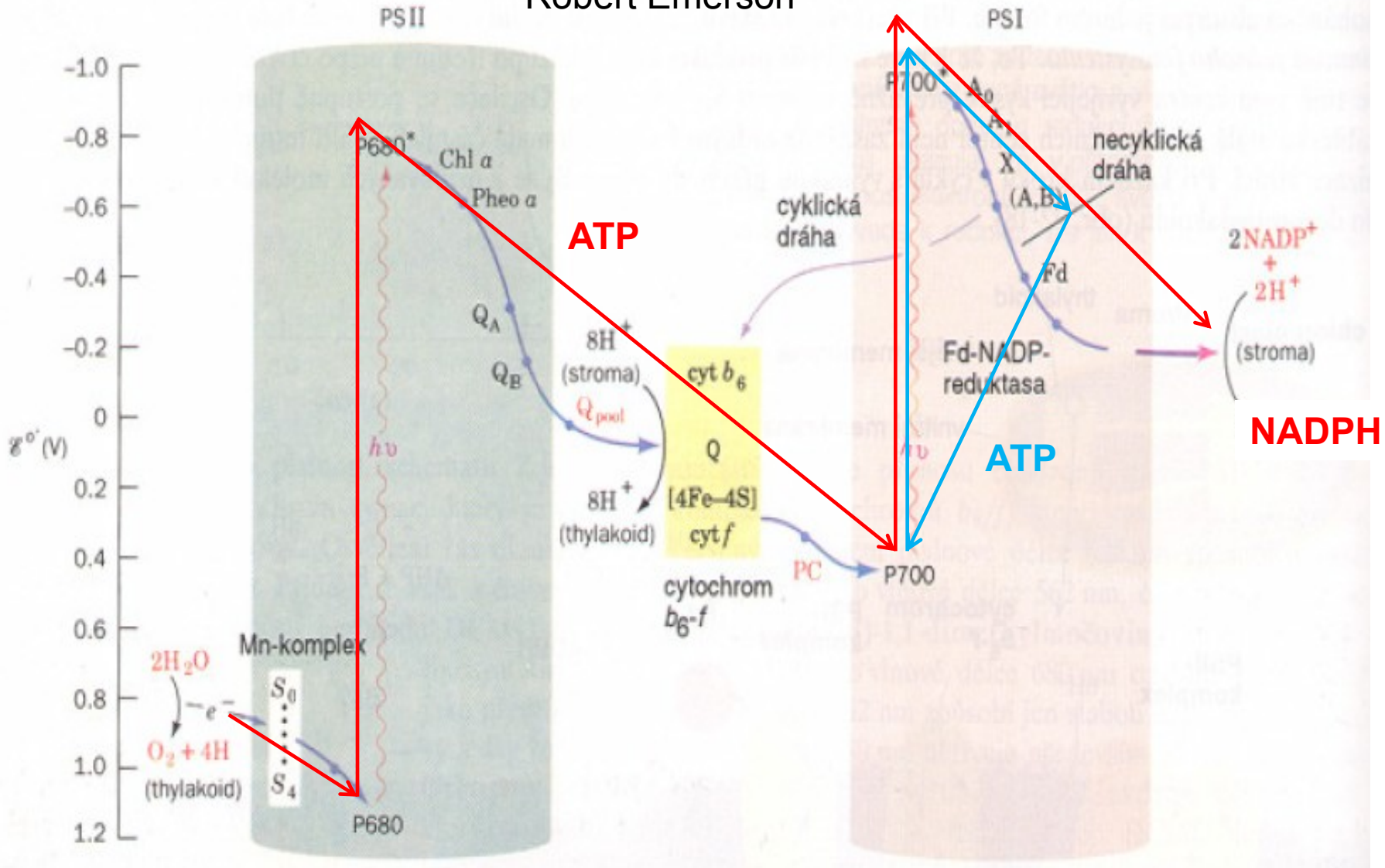
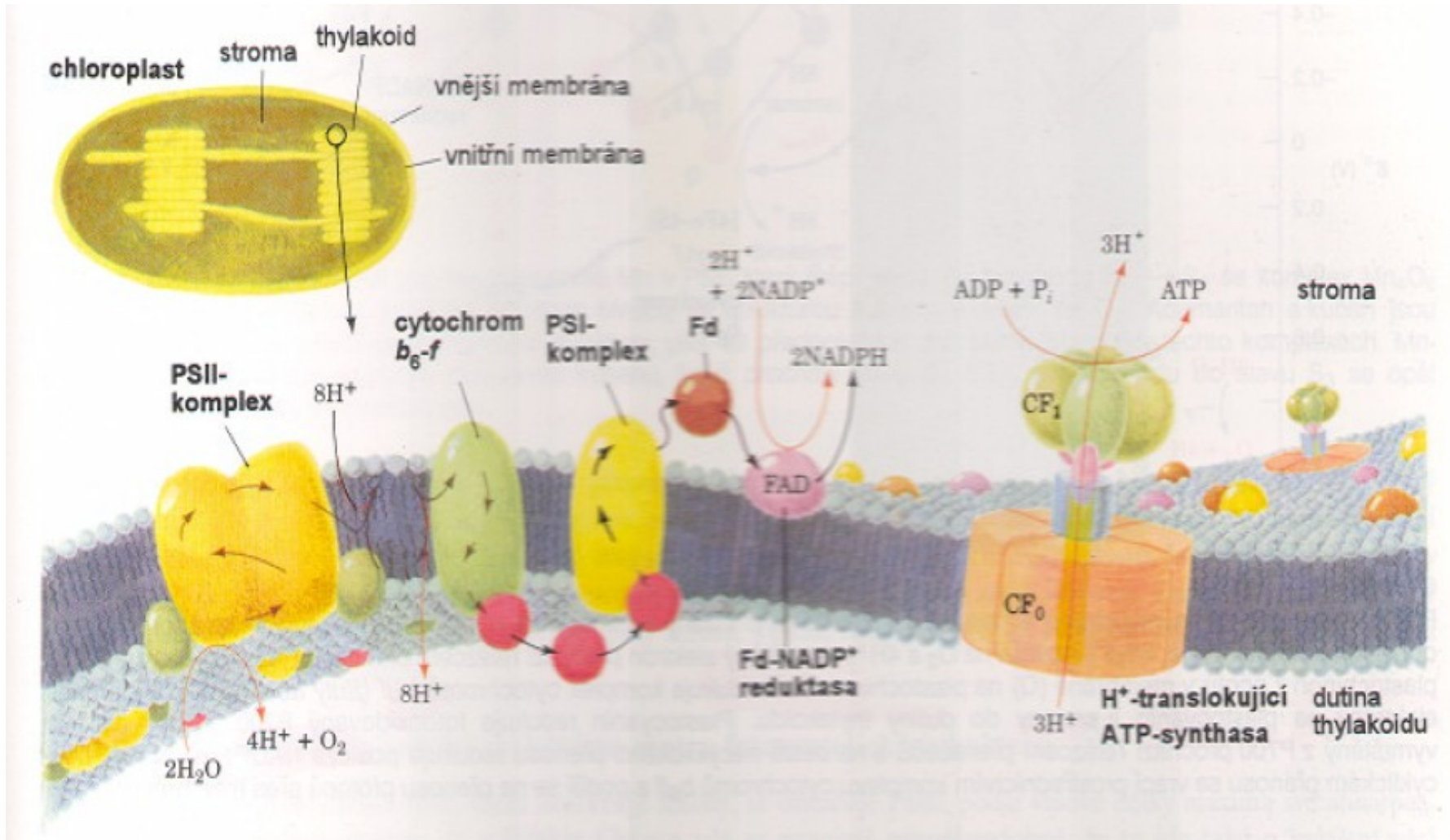


Schéma fotosystémů I a II

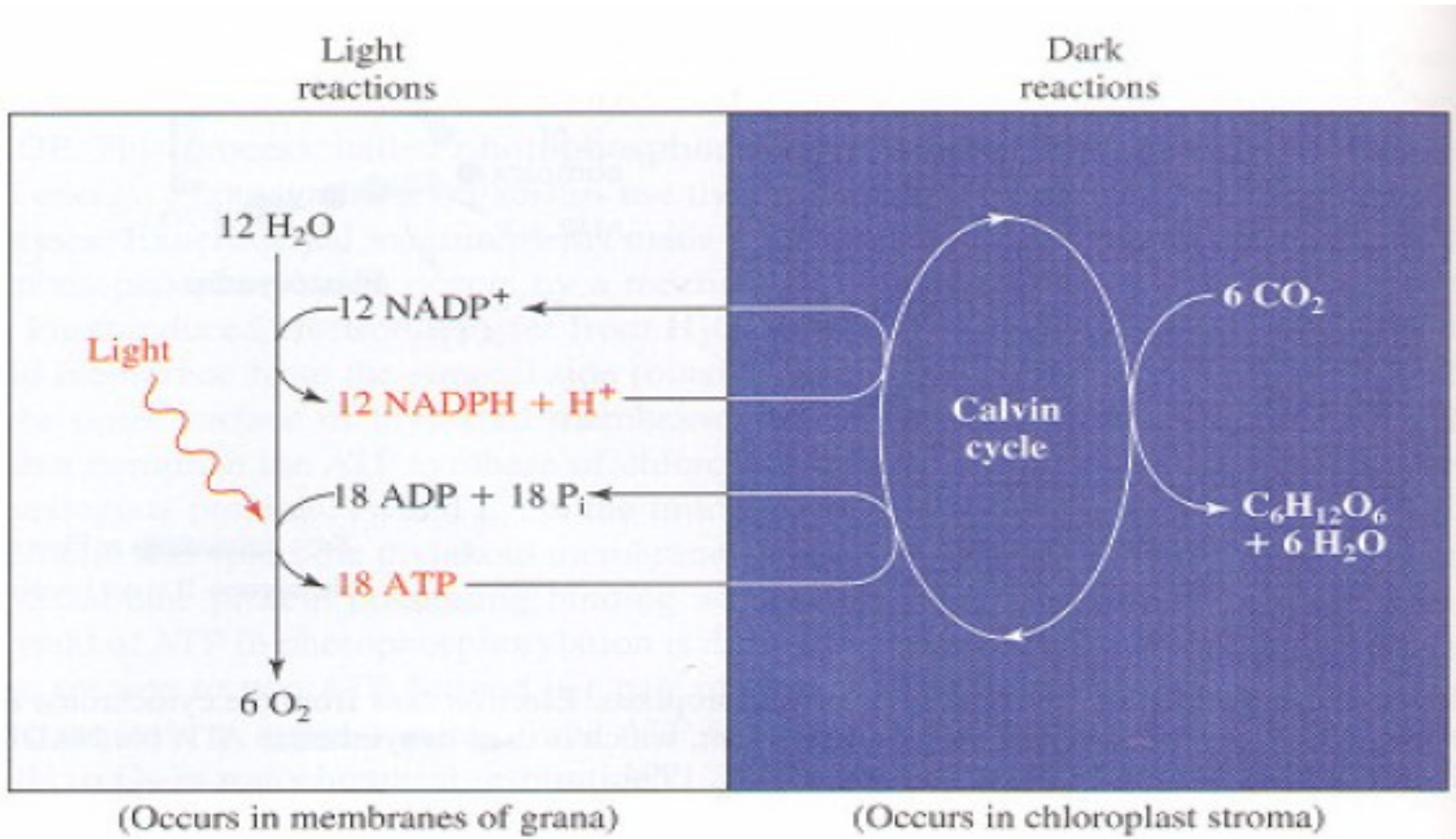
Robert Emerson



Spřažení toku elektronů a fotofosforylace

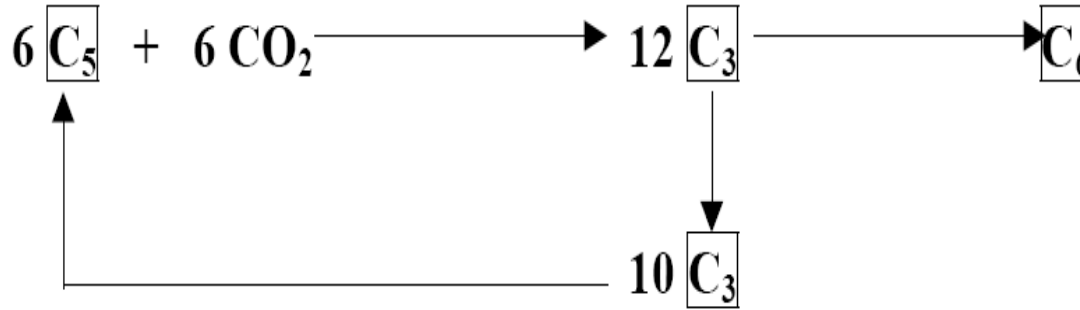


Světelná a temná fáze



Temná fáze

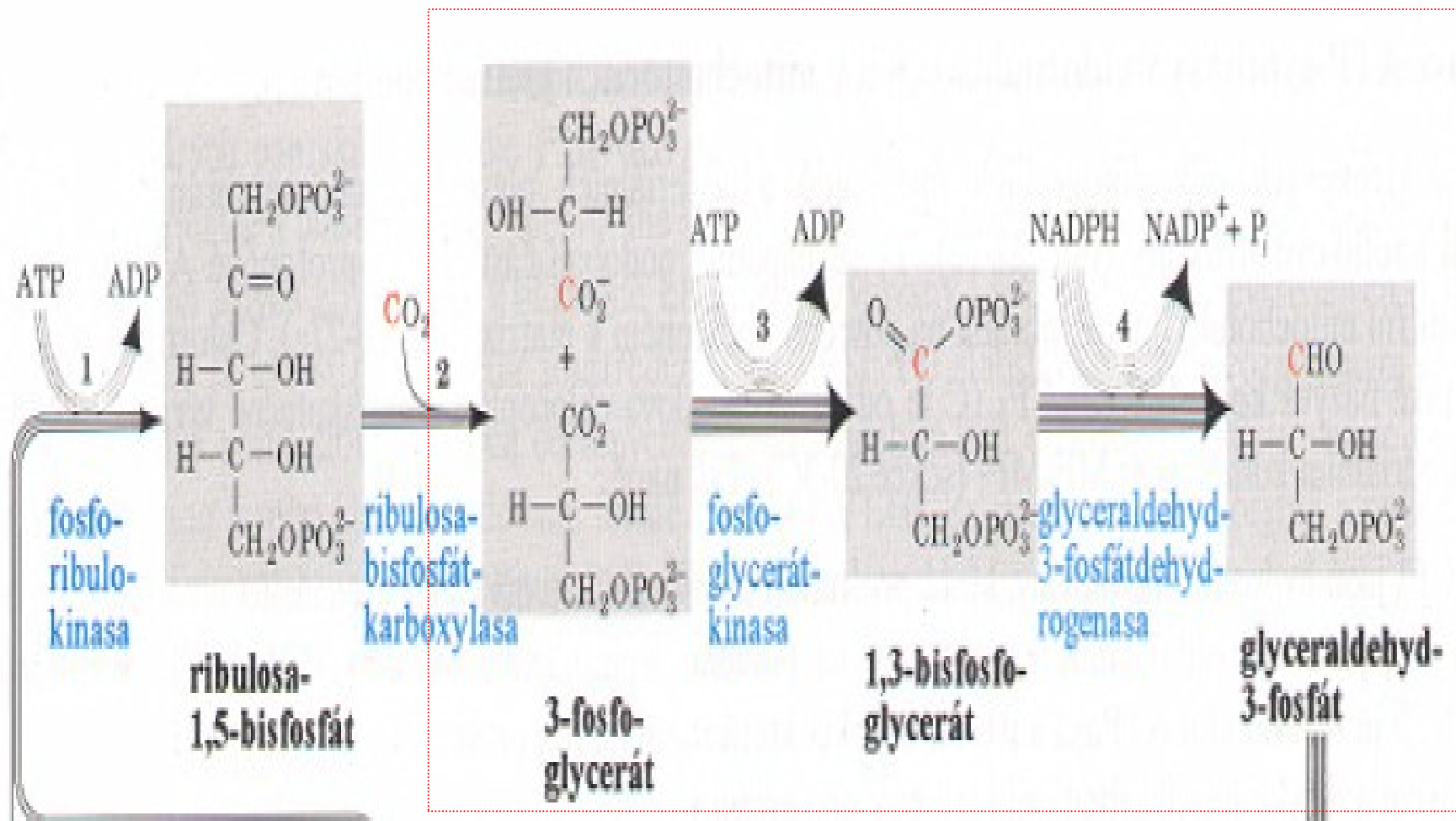
M.CALVIN



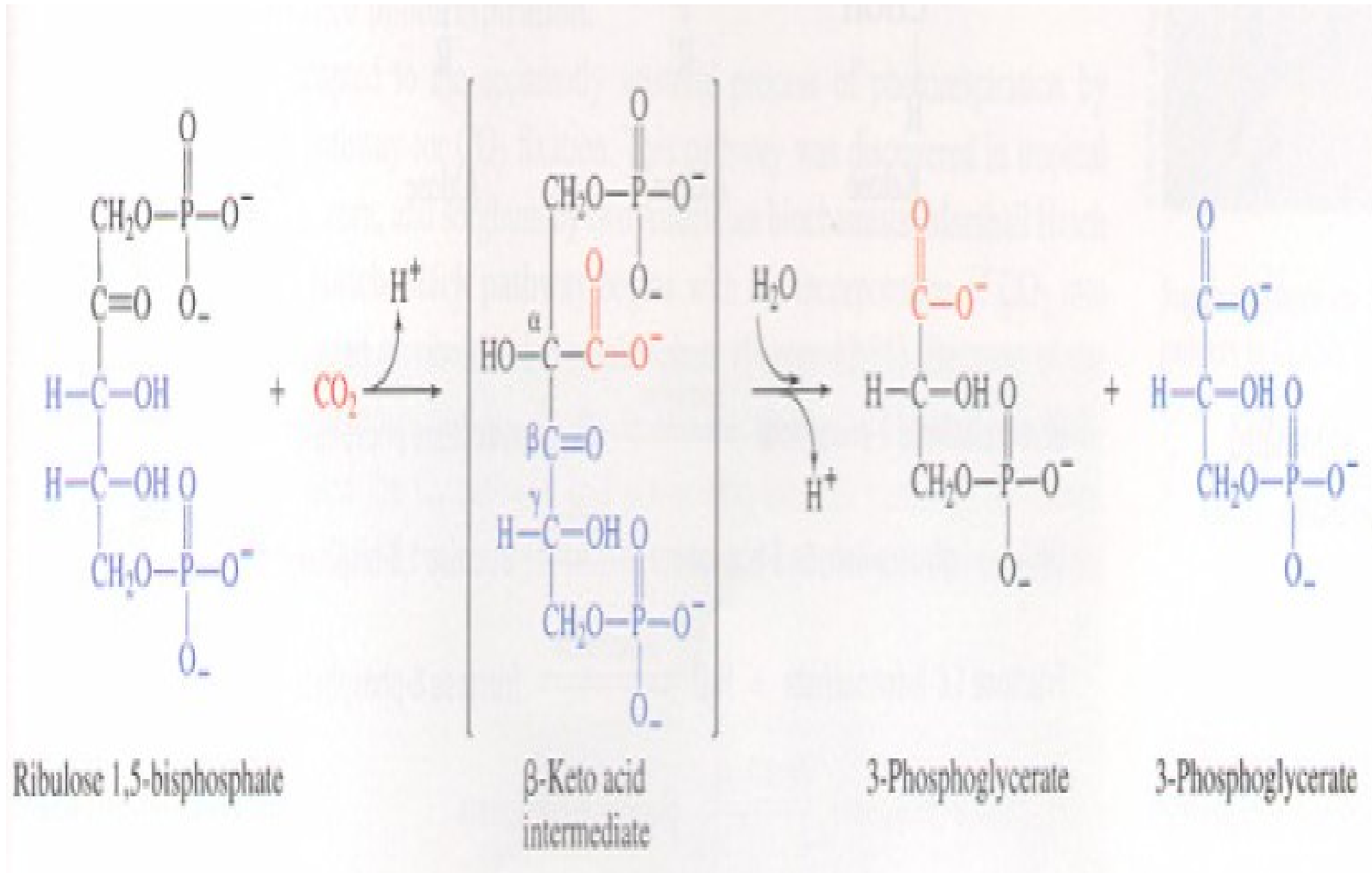
C₃ rostliny

- většina rostlin a řas
- akceptor CO₂ ribulosa-5-P
- produkt 3-P-glycerát

Calvinův cyklus

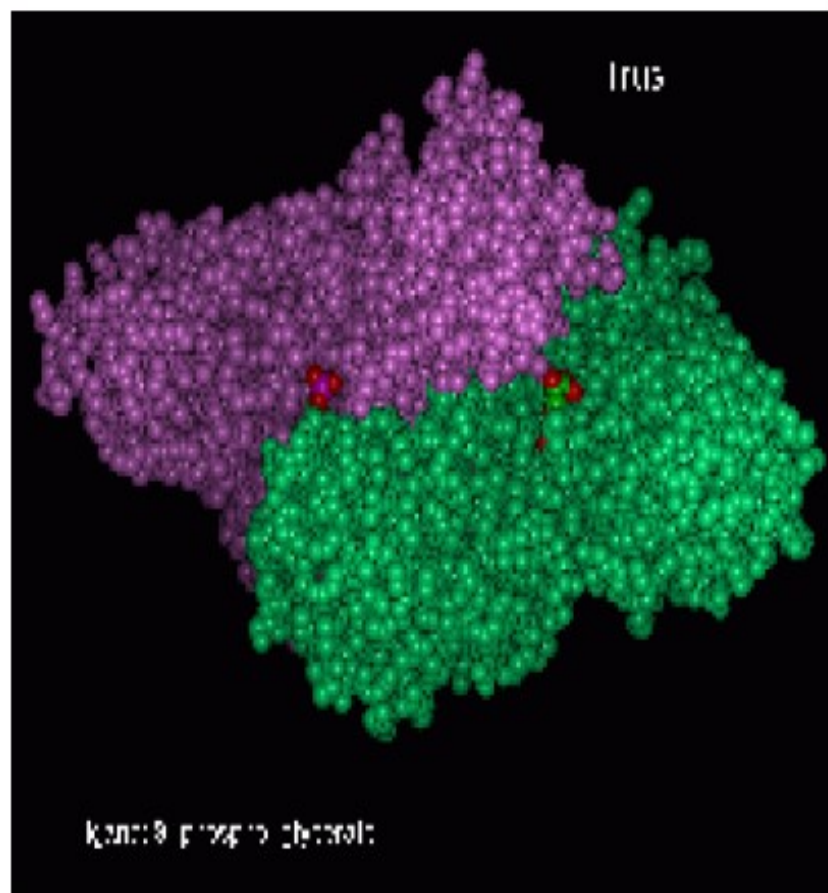


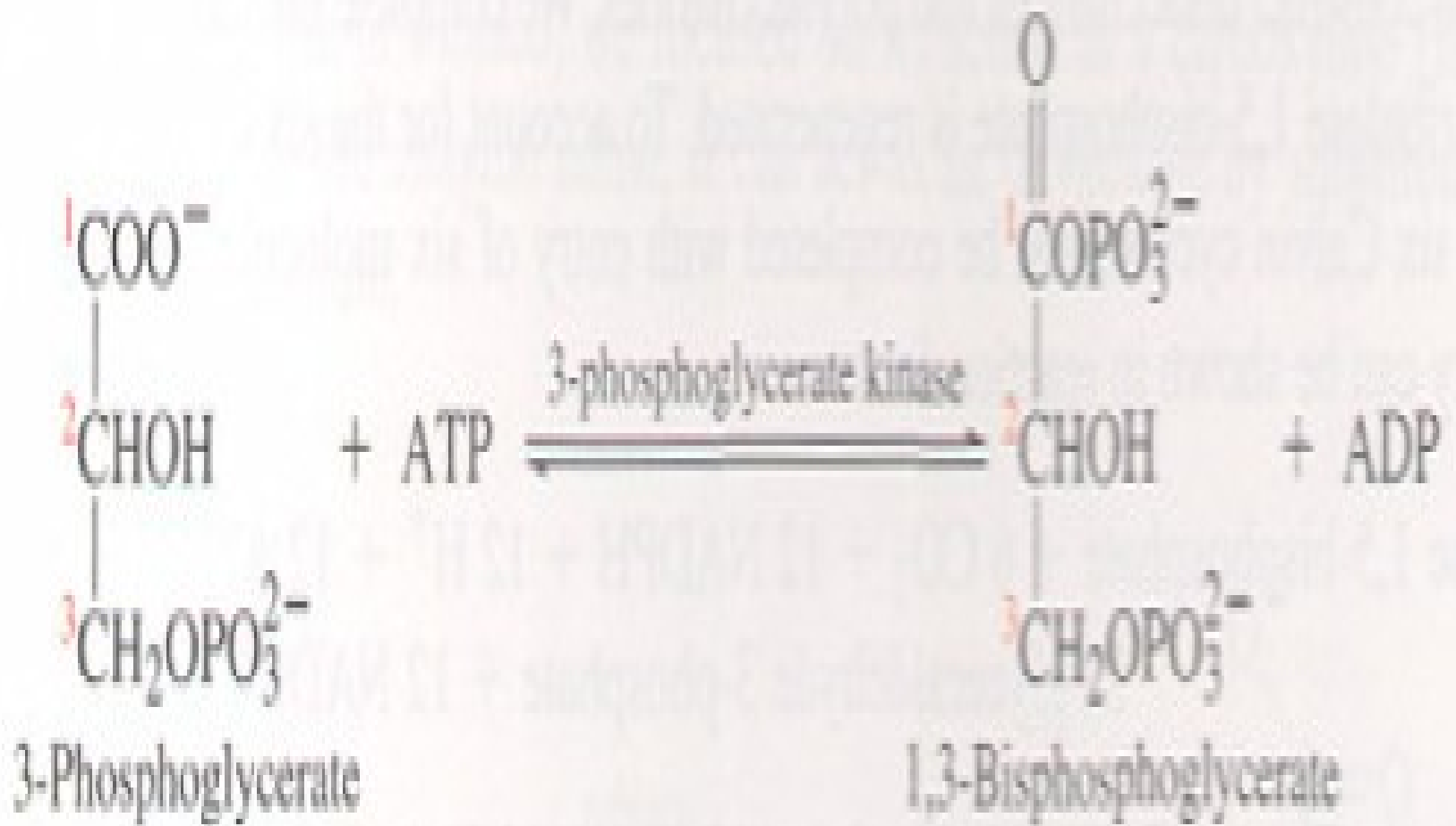
Rubisco



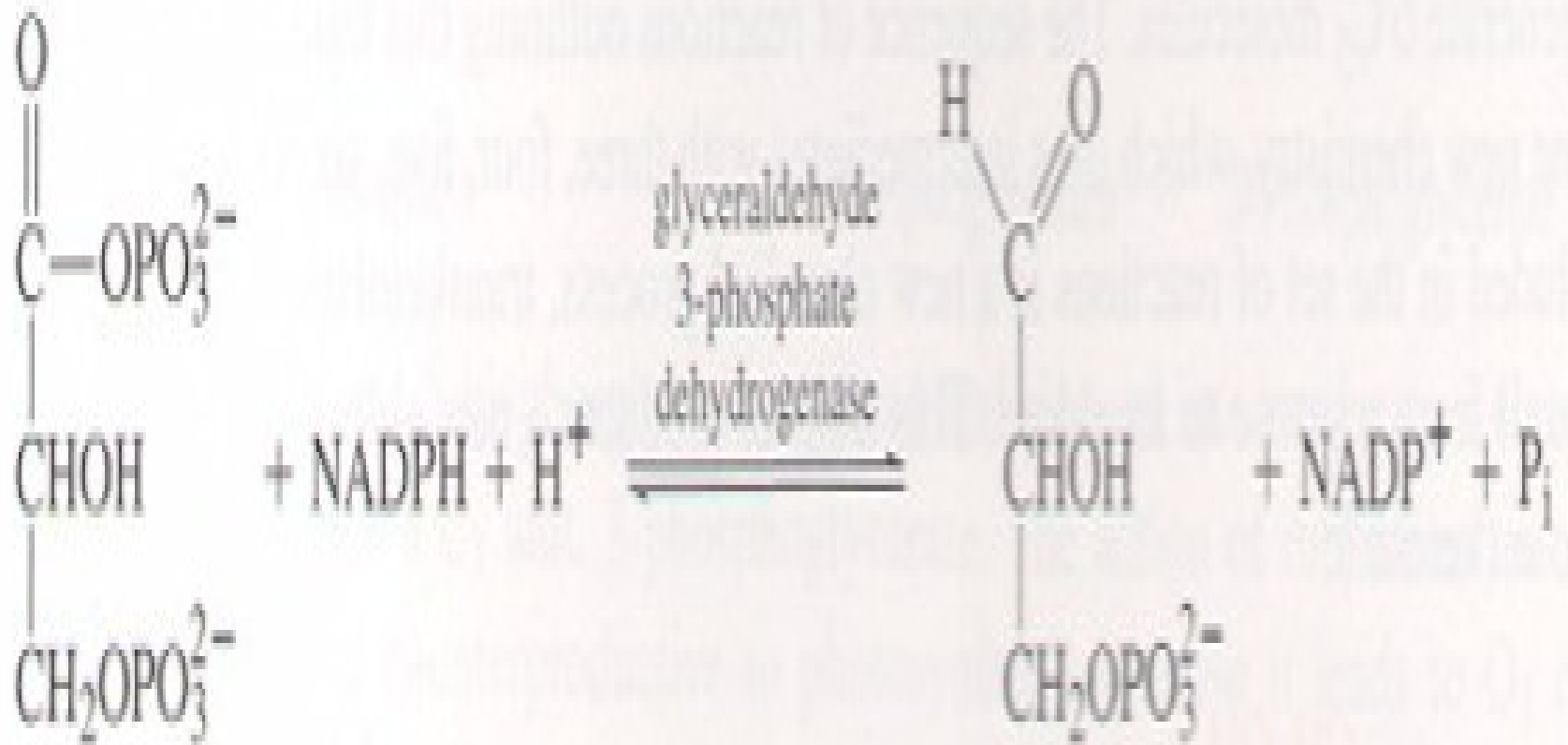
RUBISCO

2 podjednotky (1 katalytická)





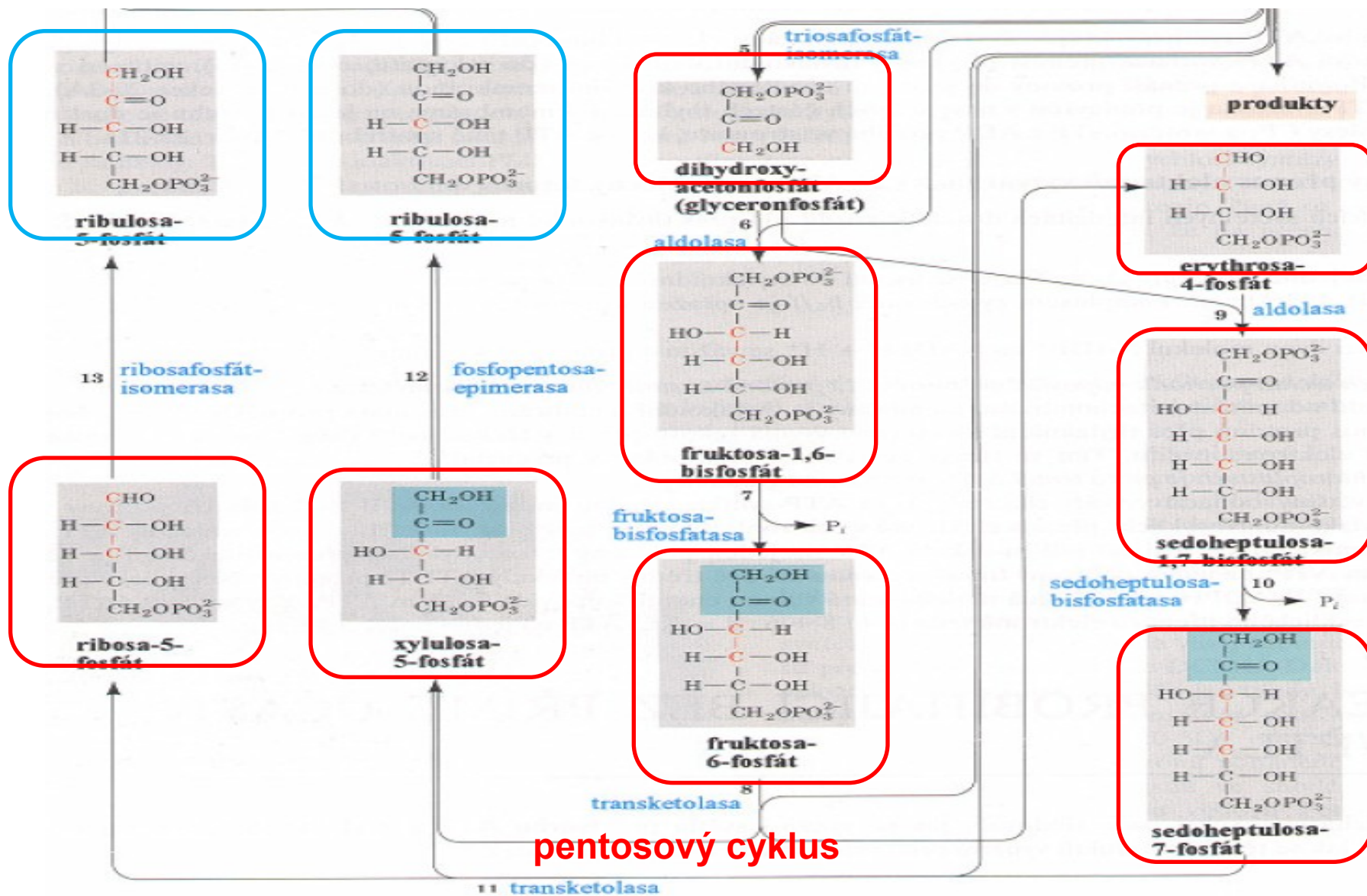
glykolysa

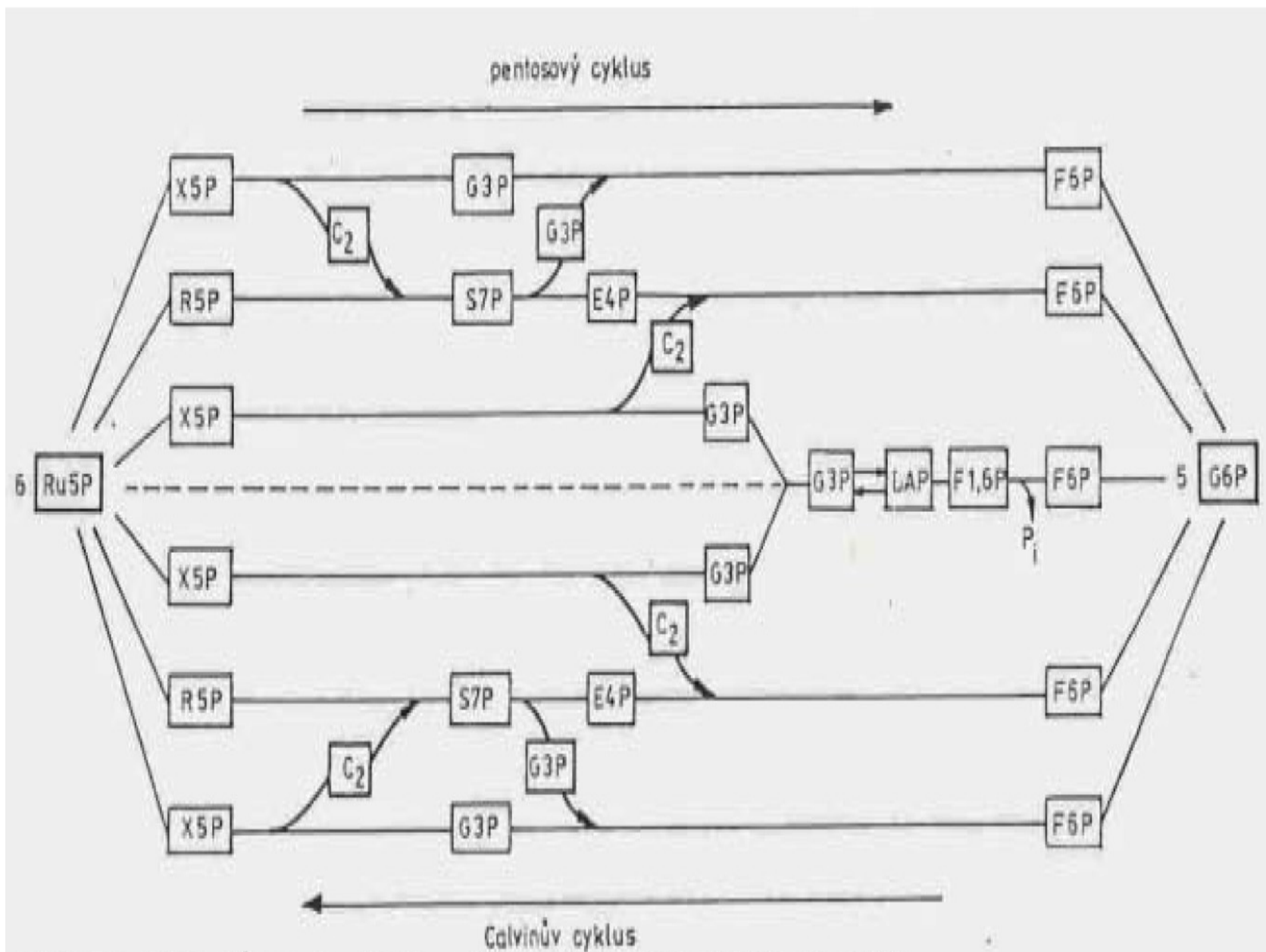


glykolysa

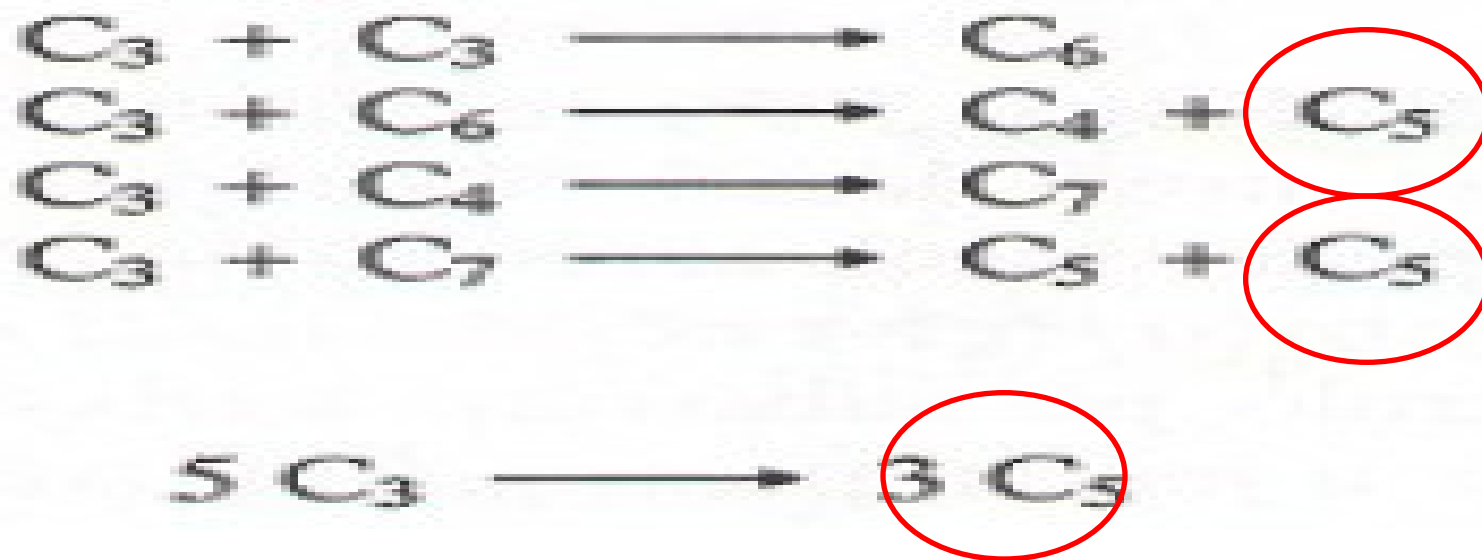
Calvinův cyklus

GA3P





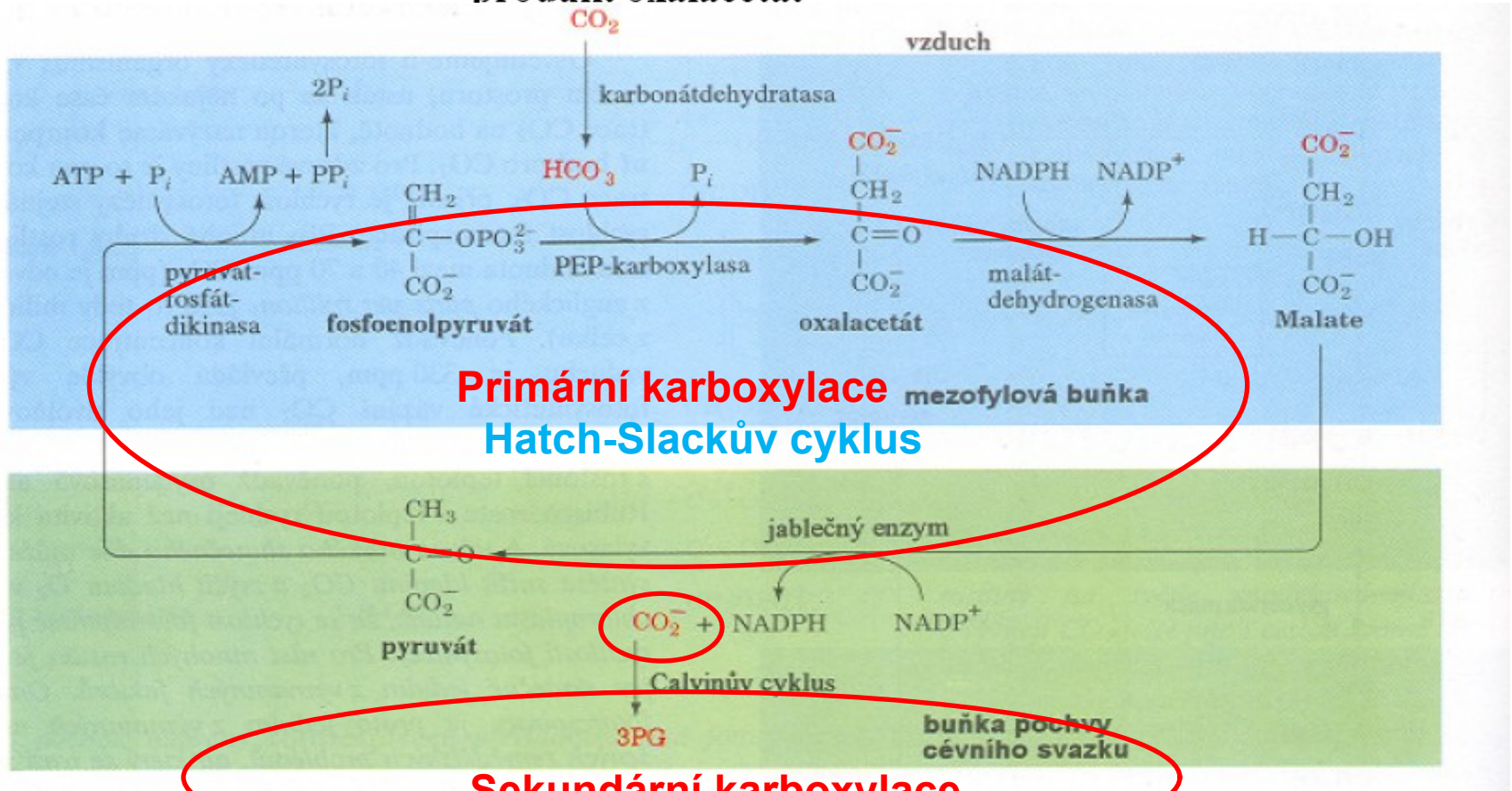
pentosový cyklus



pentosový cyklus

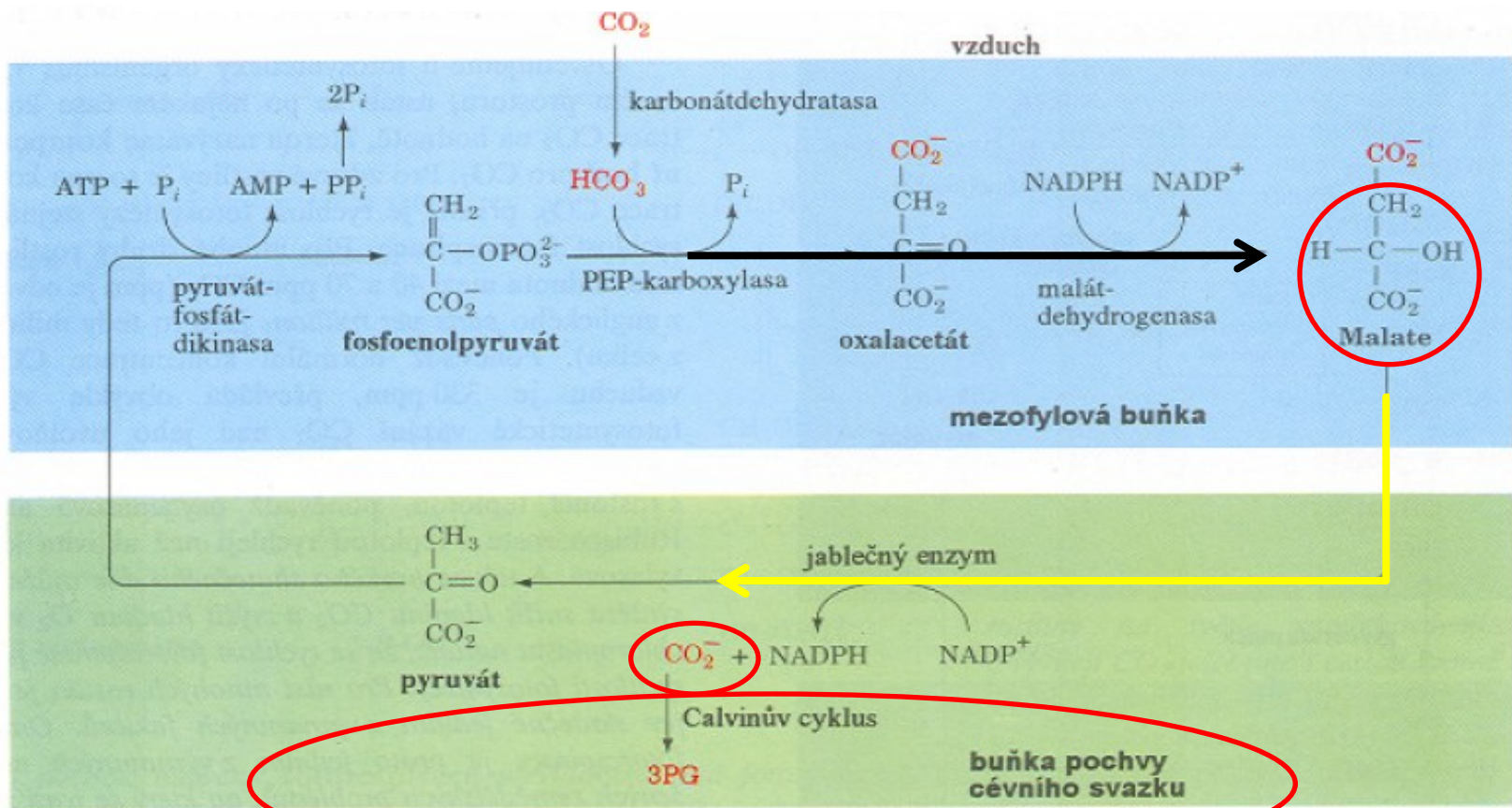
C₄ rostliny

- rychlerostoucí tropické rostliny
- akceptor CO₂ fosfoenolpyruvát
- produkt oxalacetát



Primární karboxylace
Hatch-Slackův cyklus

Sekundární karboxylace
Calvinův cyklus



- CAM rostliny** - tučnolisté
- příjem CO₂ probíhá v noci

Fotorespirace

