# GLIKOLIZA, GLUKONEOGENEZA IN FOSFOGLUKONATNA POT


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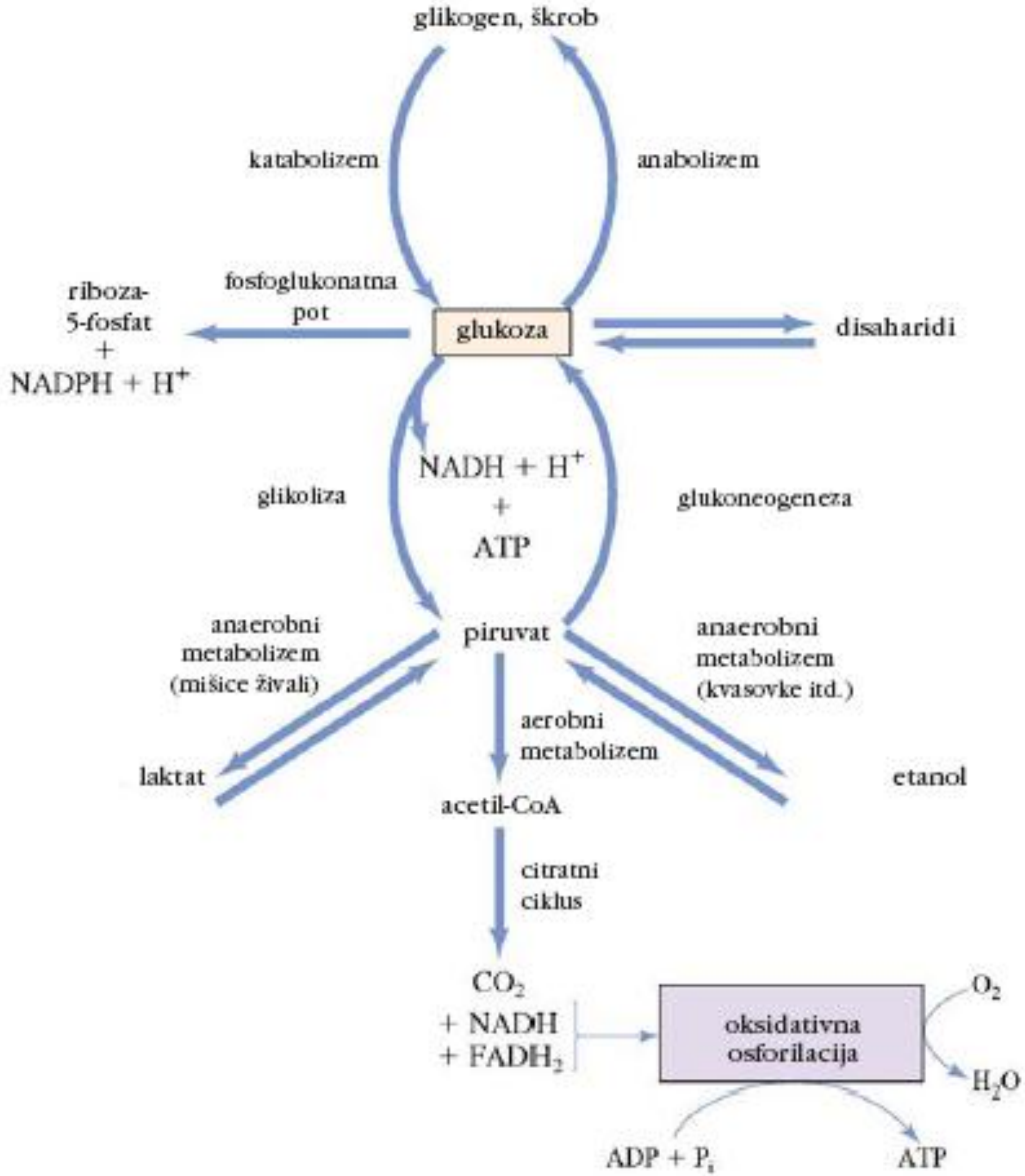

glikogen, škrob
katabolizem
anabolizem
riboza-
5-fosfat
+
NADPH + H+
fosfoglukonatna
pot
glukoza
disaharidi
NADH + H+
+
ATP
glikoliza
glukoneogeneza
anaerobni
metabolizem
(mišice živali)
piruvat
anaerobni
metabolizem
(kvasovke itd.)
aerobni
metabolizem
laktat
acetil-CoA
etanol
citratni
ciklus
CO2
+ NADH
+ FADH2
oksidativna
osforilacija
O2
H2O
ADP + Pi
ATP

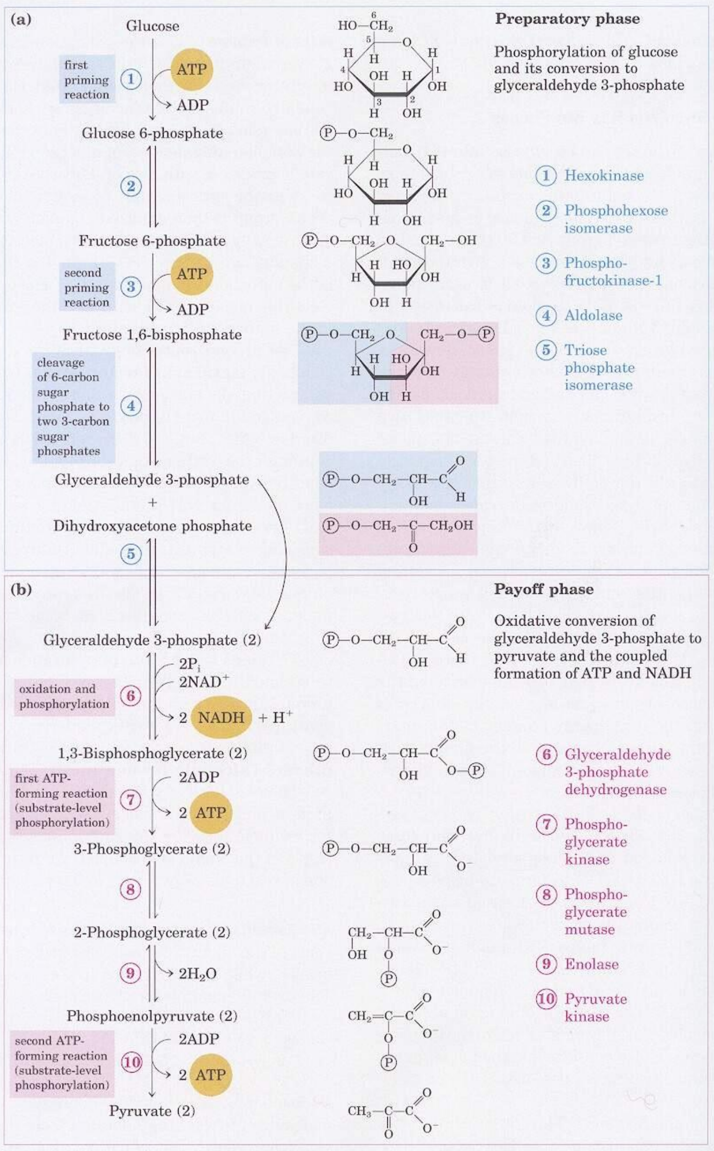
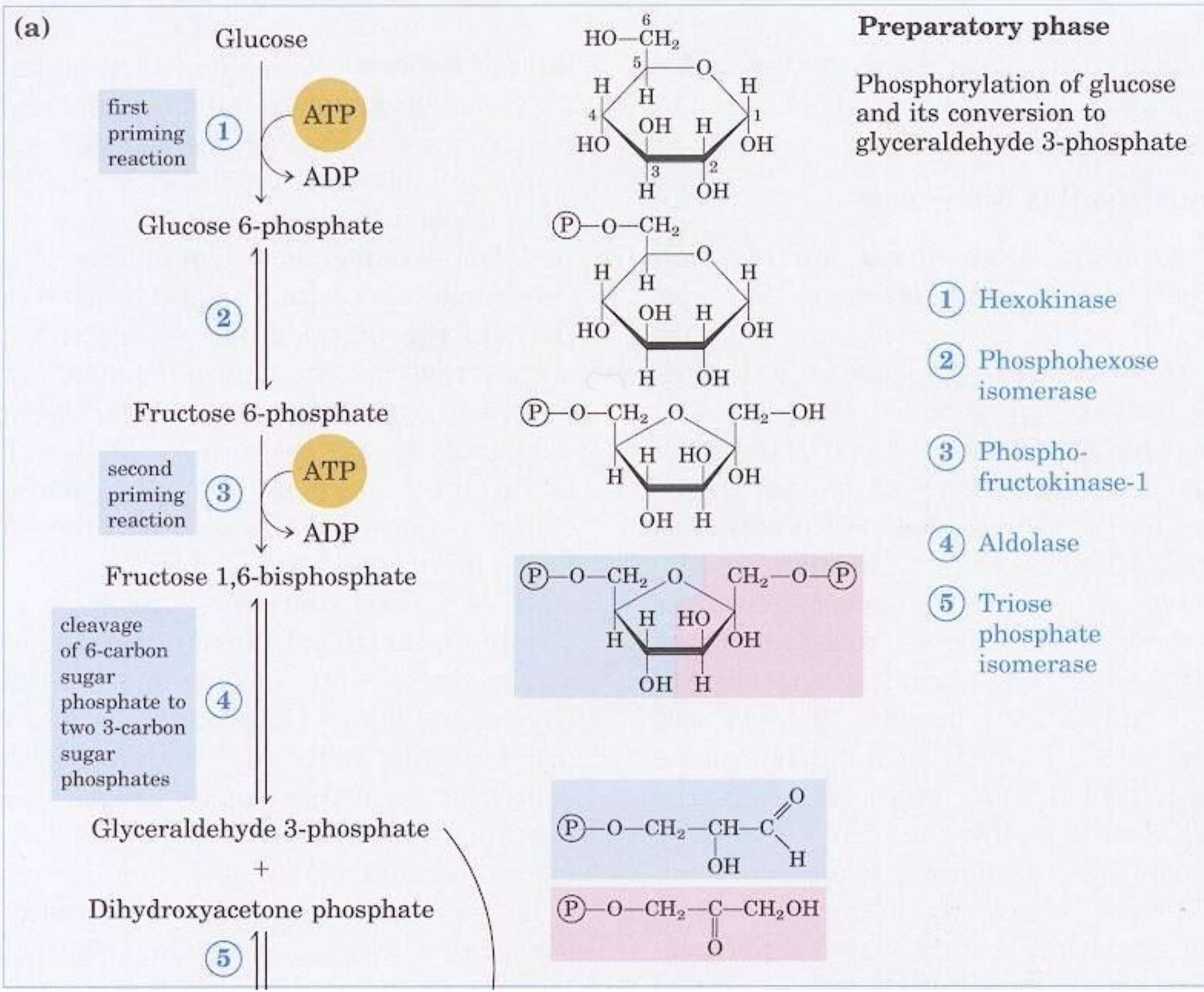
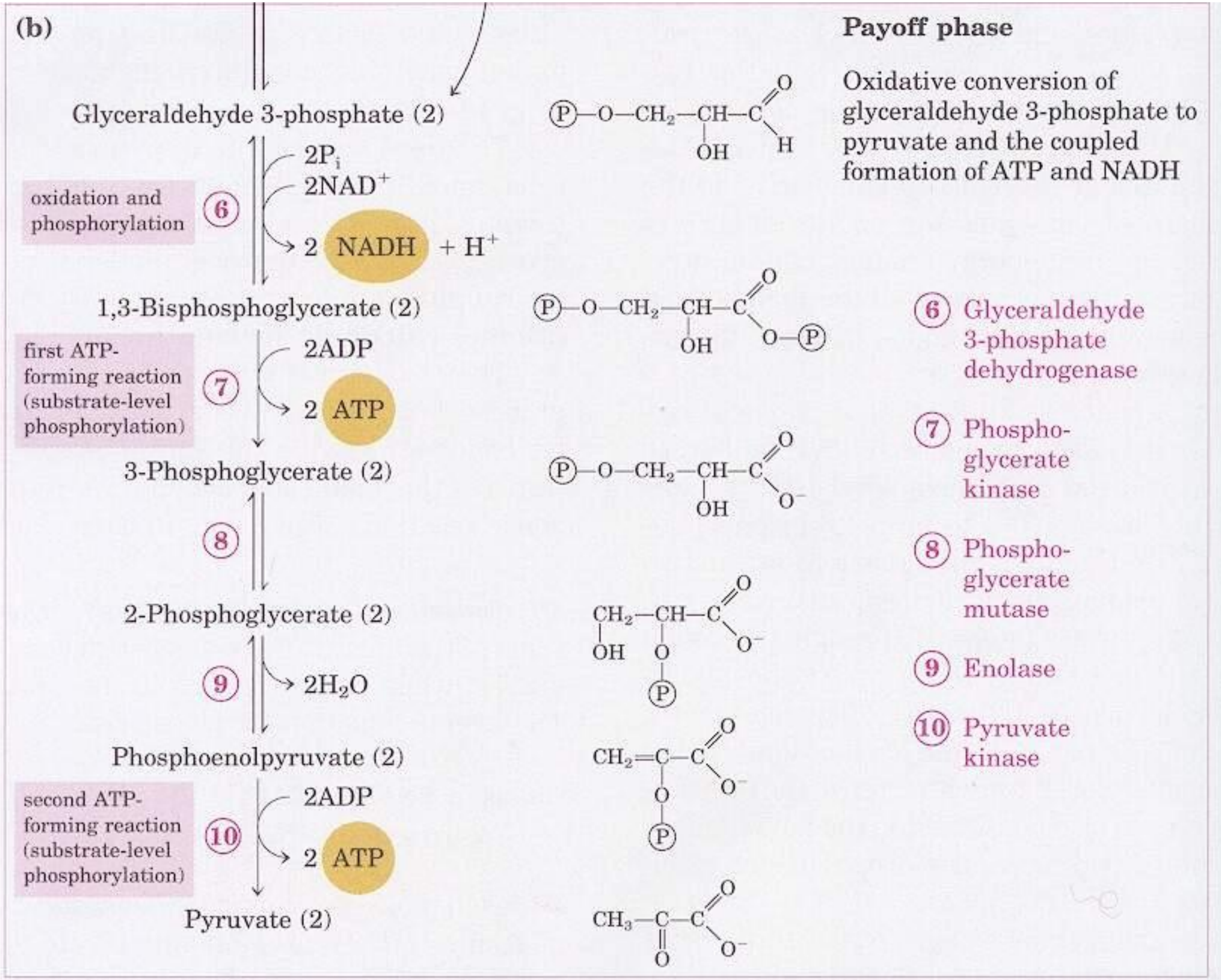



**FIGURE 14–2** **The two phases of glycolysis.** For each molecule of glucose that passes through the preparatory phase **(a),** two molecules of glyceraldehyde 3-phosphate are formed; both pass through the payoff phase **(b).** Pyruvate is the end product of the second phase of glycolysis. For each glucose molecule, two ATP are consumed in the preparatory phase and four ATP are produced in the payoff phase, giving a net yield of two ATP per molecule of glucose converted to The numbered reaction steps are catalyzed by the enzyme the right, and also correspond to the numbered headings i discussion. Keep in mind that each phosphoryl group, re here as Ⓟ, has two negative charges ($—PO_3^{2-}$).


(a)
Glucose
first priming reaction
1
ATP
ADP
Glucose 6-phosphate
2
Fructose 6-phosphate
second priming reaction
3
ATP
ADP
Fructose 1,6-bisphosphate
cleavage of 6-carbon sugar phosphate to two 3-carbon sugar phosphates
4
Glyceraldehyde 3-phosphate
+
Dihydroxyacetone phosphate
5
Preparatory phase
Phosphorylation of glucose and its conversion to glyceraldehyde 3-phosphate
1 Hexokinase
2 Phosphohexose isomerase
3 Phosphofructokinase-1
4 Aldolase
5 Triose phosphate isomerase



(b)
Payoff phase
Oxidative conversion of glyceraldehyde 3-phosphate to pyruvate and the coupled formation of ATP and NADH
Glyceraldehyde 3-phosphate (2)
2P$_i$
2NAD$^+$
oxidation and phosphorylation
6
2 NADH + H$^+$
1,3-Bisphosphoglycerate (2)
first ATP-forming reaction (substrate-level phosphorylation)
7
2ADP
2 ATP
3-Phosphoglycerate (2)
8
2-Phosphoglycerate (2)
9
2H$_2$O
Phosphoenolpyruvate (2)
second ATP-forming reaction (substrate-level phosphorylation)
10
2ADP
2 ATP
Pyruvate (2)
6 Glyceraldehyde 3-phosphate dehydrogenase
7 Phosphoglycerate kinase
8 Phosphoglycerate mutase
9 Enolase
10 Pyruvate kinase

## Reakcije glikolize z imeni običajnih encimov in vrsto reakcij

| št. reakcije | reakcija | encim[a] | vrsta reakcije[b] |
|---|---|---|---|
| 1 | glukoza+ATP ⟶ glukoza-6-fosfat + ADP | heksokinaza | 2 |
| 2 | glukoza-6-fosfat ⇌ fruktoza-6-fosfat | fosfoglukoizomeraza | 5 |
| 3 | fruktoza-6-fosfat + ATP ⟶ fruktoza-1,6-bisfosfat + ADP | fosfofruktokinaza | 2 |
| 4 | fruktoza-1,6-bisfosfat ⇌ dihidroksiacetonfosfat+gliceralaldehid-3-fosfat | aldolaza | 4 |
| 5 | dihidroksiacetonfosfat - gliceraldehid-3-fosfat | triozafosfat-izomeraza | 5 |
| 6 | gliceraldehid-3-fosfat+Pi+NAD+ ⇌ 1,3-bisfosfoglicerat+NADH+H+ | gliceraldehid-3-fosfat-izomeraza | 1,2 |
| 7 | 1,3-bisfosfoglicerat + ADP ⇌ 3-fosfoglicerat + ATP | fosfoglicerat-kinaza | 2 |
| 8 | 3-fosfoglicerat ⇌ 2-fosfoglicerat | fosfoglicerat-mutaza | 5 |
| 9 | 2-fosfoglicerat ⇌ fosfoenolpiruvat + H2O | enolaza | 4 |
| 10 | fosfoenolpiruvat + ADP ⟶ piruvat + ATP | piruvat-kinaza | 2 |

[a] Navedena so trivialna imena encimov.

[b] Vrsta reakcije:(1) oksidoredukcija, (2) prenos skupin, (3) hidroliza, (4) nehidrolitična cepitev, (5) izomerizacija in premestitev in (6) nastanek vez i z uporabo energije ATP.

Obračun števila nastalih oziroma porabljenih molekul ATP in NADH pri glikolizi

| številka[a] | reakcija (na molekulo glukoze)[a] | sprememba ATP (na molekulo glukoze)[b] | sprememba NADH (na molekulo glukoze)b |
|---|---|---|---|
| 1 | glukozapp1glukoza-6-fosfat | -1 | 0 |
| 3 | fruktoza-6-fosfatpp1fruktoza1,6-bisfosfat | -1 | 0 |
| 6 | 2 gliceraldehid-3-fosfat - 2 1,3-bisfosfoglicerat | 0 | +2 |
| 7 | 2 1,3-bisfosfoglicerat - 2 3-fosfoglicerat | +2 | 0 |
| 10 | 2 fosfoenolpiruvatpp12 piruvat | +2 | 0 |
| Skupaj | | +2 | +2 |

[a] Številka ustreza številki reakcije v tabeli 15.1.

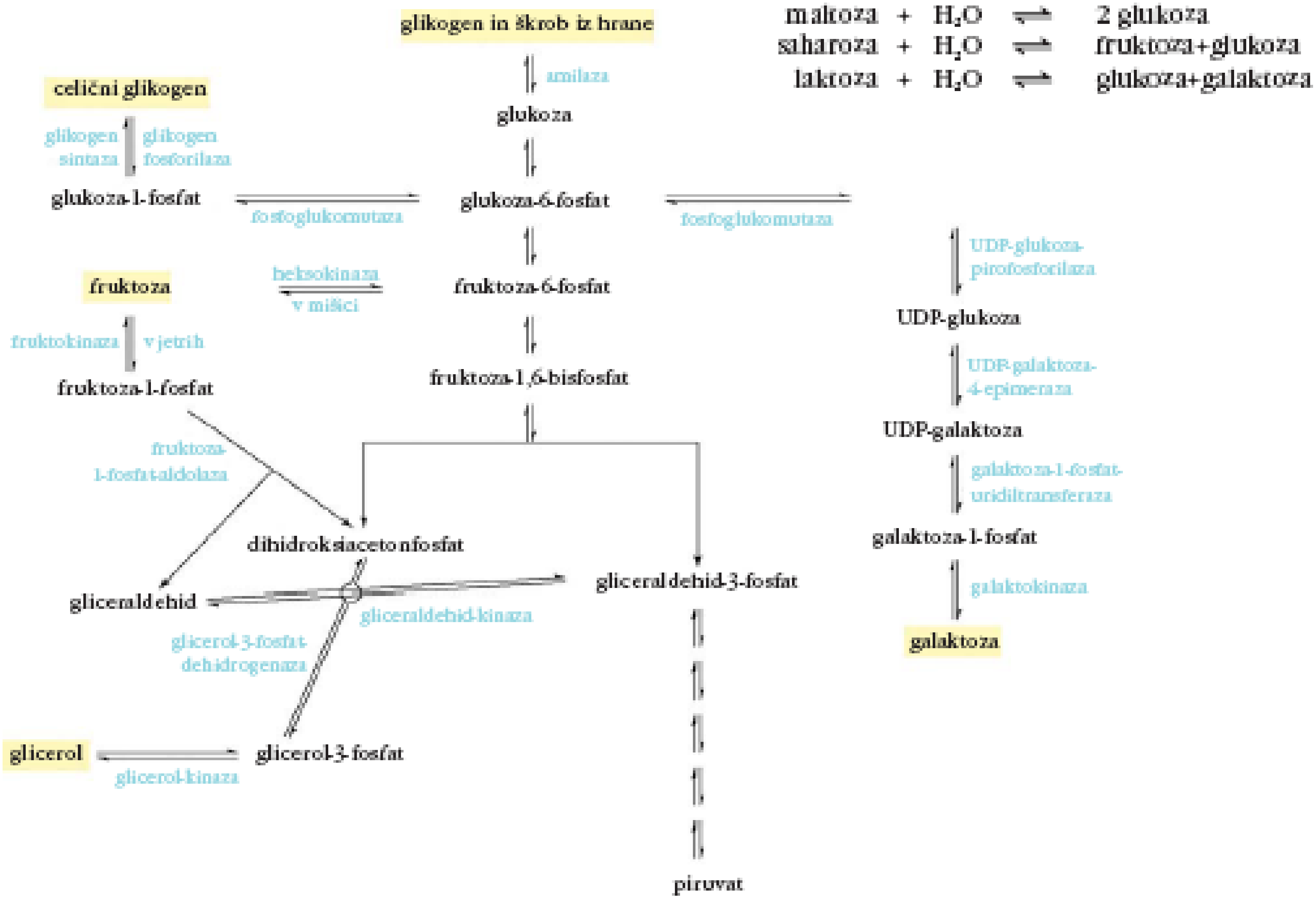
[b] Negativen predznak označuje porabo ATP s cepitvijo fosfoanhidridne vezi; pozitiven predznak označuje nastanek ATP (iz ADP) ali NADH (iz NAD+).

$$\text{glukoza} + 2\ \text{ATP} \rightarrow 2\ \text{gliceraldehid-3-fosfat} + 2\ \text{ADP}$$

$$2\ \text{gliceraldehid-3-fosfat} + 2\ P_i + 4\ \text{ADP} + 2\ \text{NAD}^+ \rightarrow 2\ \text{piruvat} + 4\ \text{ATP} + 2\ \text{NADH} + 2\ H^+ + 2\ H_2O$$

$$\text{glukoza} + 2P_i + 2\text{ADP} + 2\ \text{NAD}^+ \rightarrow 2\ \text{piruvat} + 2\ \text{ATP} + 2\ \text{NADH} + 2H^+ + 2\ H_2O$$

# Vstop drugih ogljikovih hidratov v glikolizo



# Razgradnja glikogena

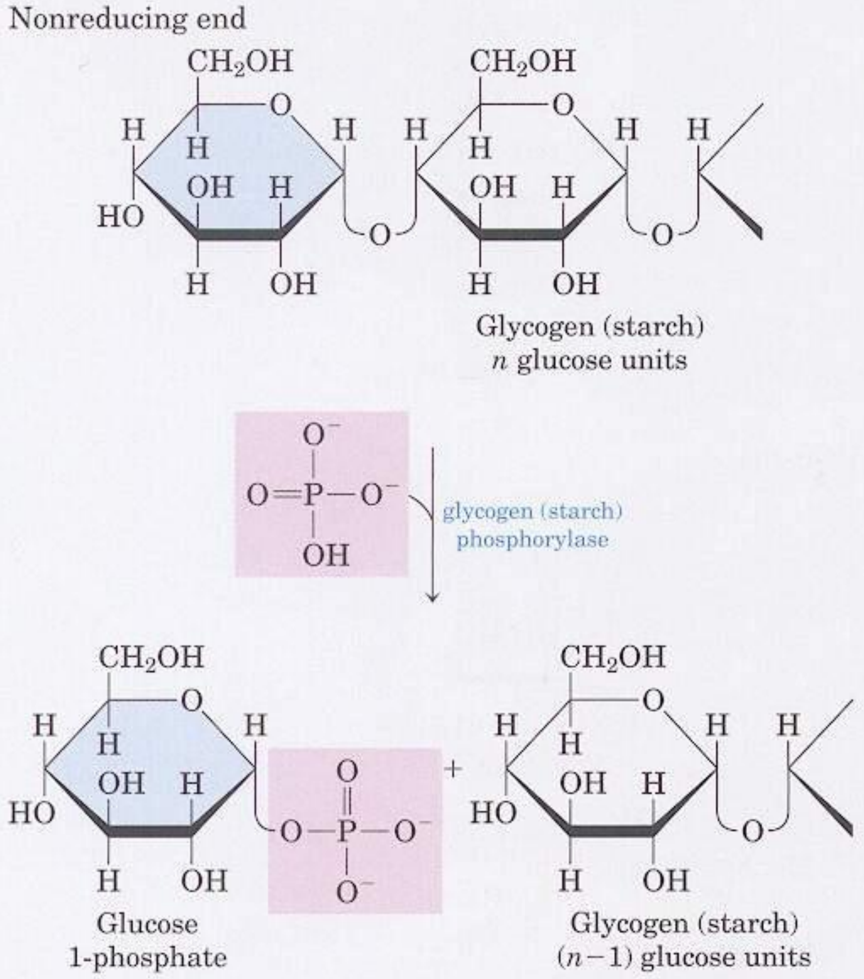
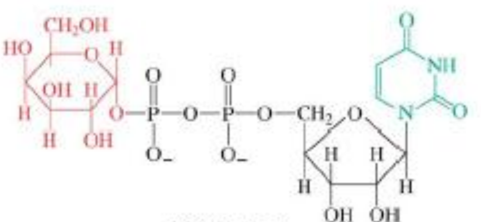



**FIGURE 14–10 Glycogen breakdown by glycogen phosphorylase.** The enzyme catalyzes attack by inorganic phosphate (pink) on the terminal glucosyl residue (blue) at the nonreducing end of a glycogen molecule, releasing glucose 1-phosphate and generating a glycogen molecule shortened by one glucose residue. The reaction is a *phosphorolysis* (not hydrolysis).

# Pretvorba galaktoze v glukozo-1-fosfat




UDP-galaktoza

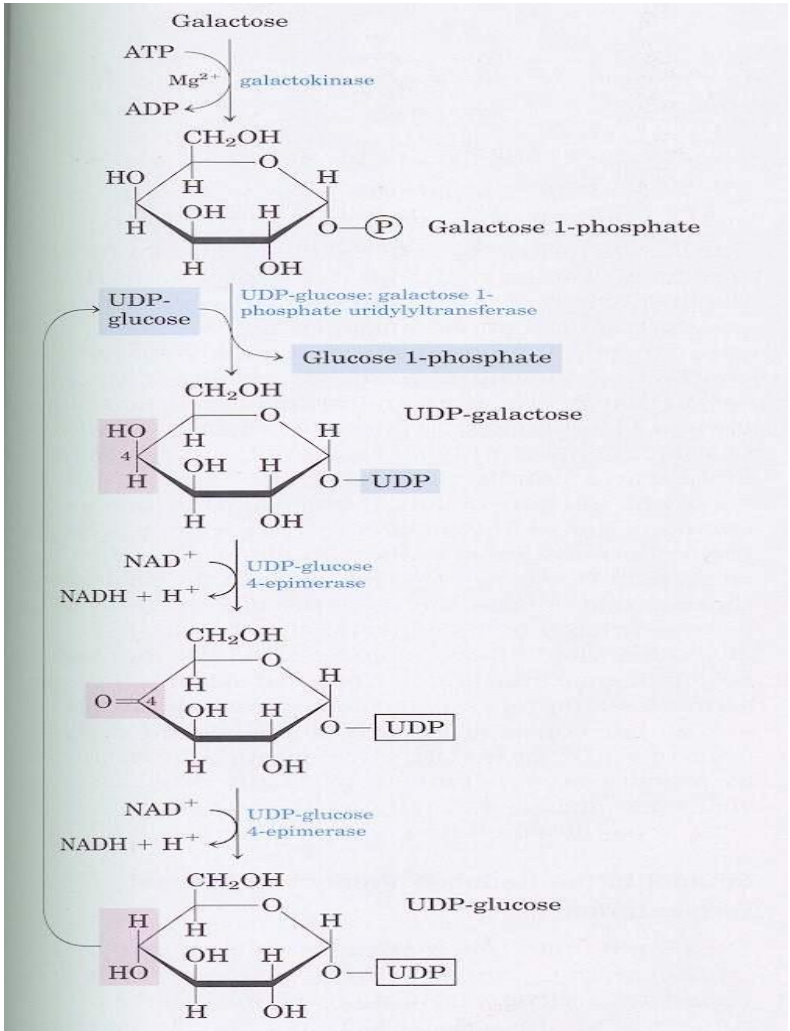



**FIGURE 14–11 Conversion of galactose to glucose 1-phosphate.** The conversion proceeds through a sugar-nucleotide derivative, UDP-galactose, which is formed when galactose 1-phosphate displaces glucose 1-phosphate from UDP-glucose. UDP-galactose is then converted by UDP-glucose 4-epimerase to UDP-glucose, in a reaction that involves oxidation of C-4 (pink) by $NAD^+$, then reduction of C-4 by NADH; the result is inversion of the configuration at C-4. The UDP-glucose is recycled through another round of the same reaction. The net effect of this cycle is the conversion of galactose 1-phosphate to glucose 1-phosphate; there is no net production or consumption of UDP-galactose or UDP-glucose.

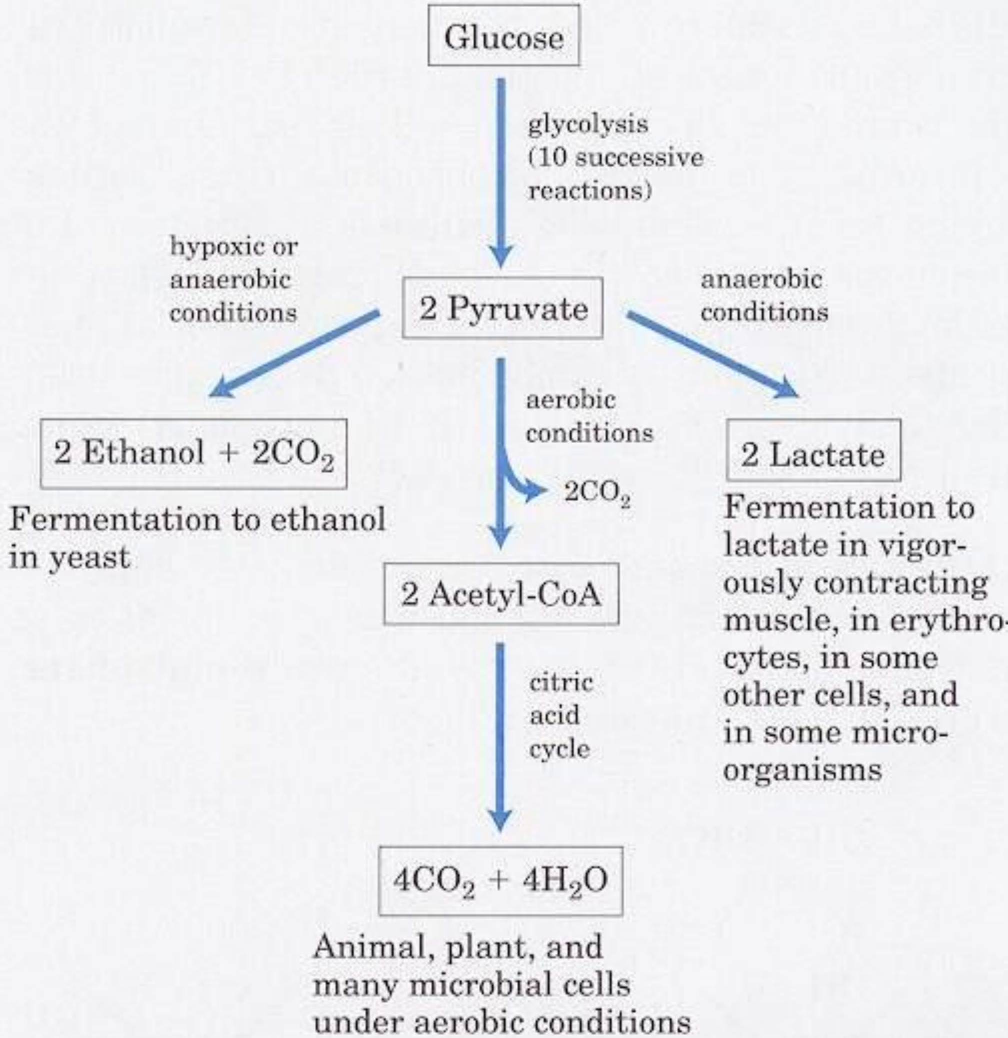
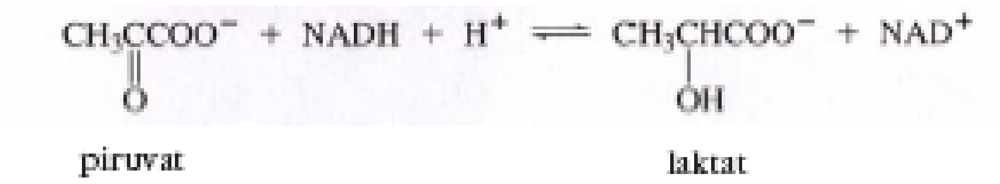



**FIGURE 14–3 Three possible catabolic fates of the pyruvate formed in glycolysis.** Pyruvate also serves as a precursor in many anabolic reactions, not shown here.

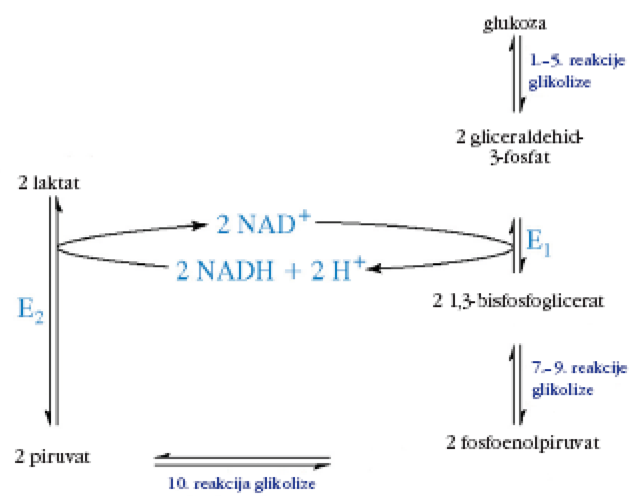
# Mlečnokislinska fermentacija




Neto reakcija pri mlečnokislinski fermentaciji (glukoza→2 laktata) je:

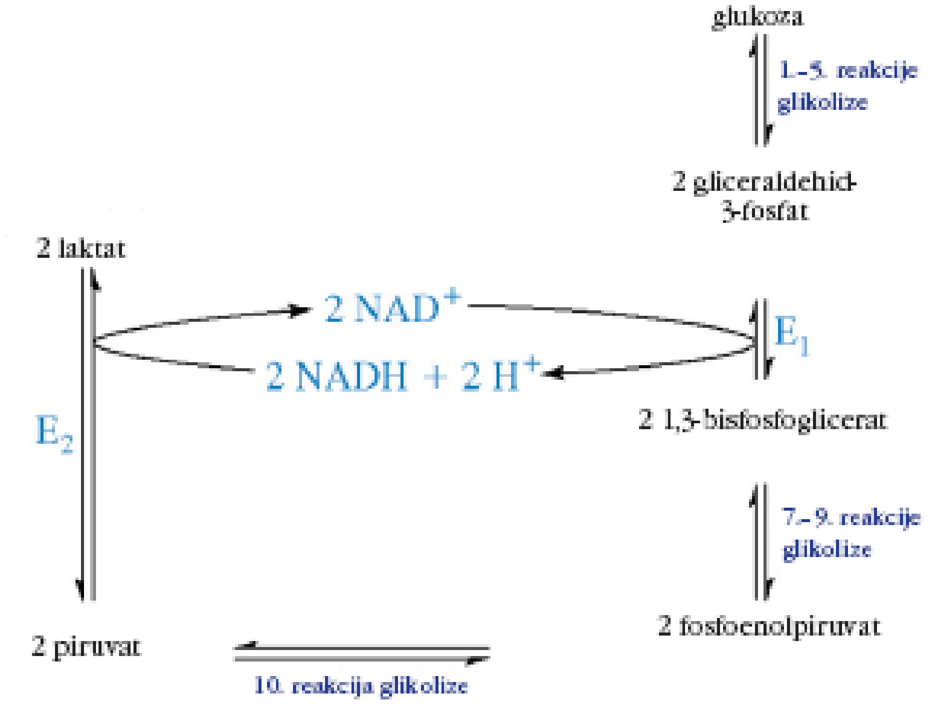
$$\text{glukoza} + 2ADP + 2P_i \rightarrow 2\ \text{laktata} + 2ATP + 2H_2O$$

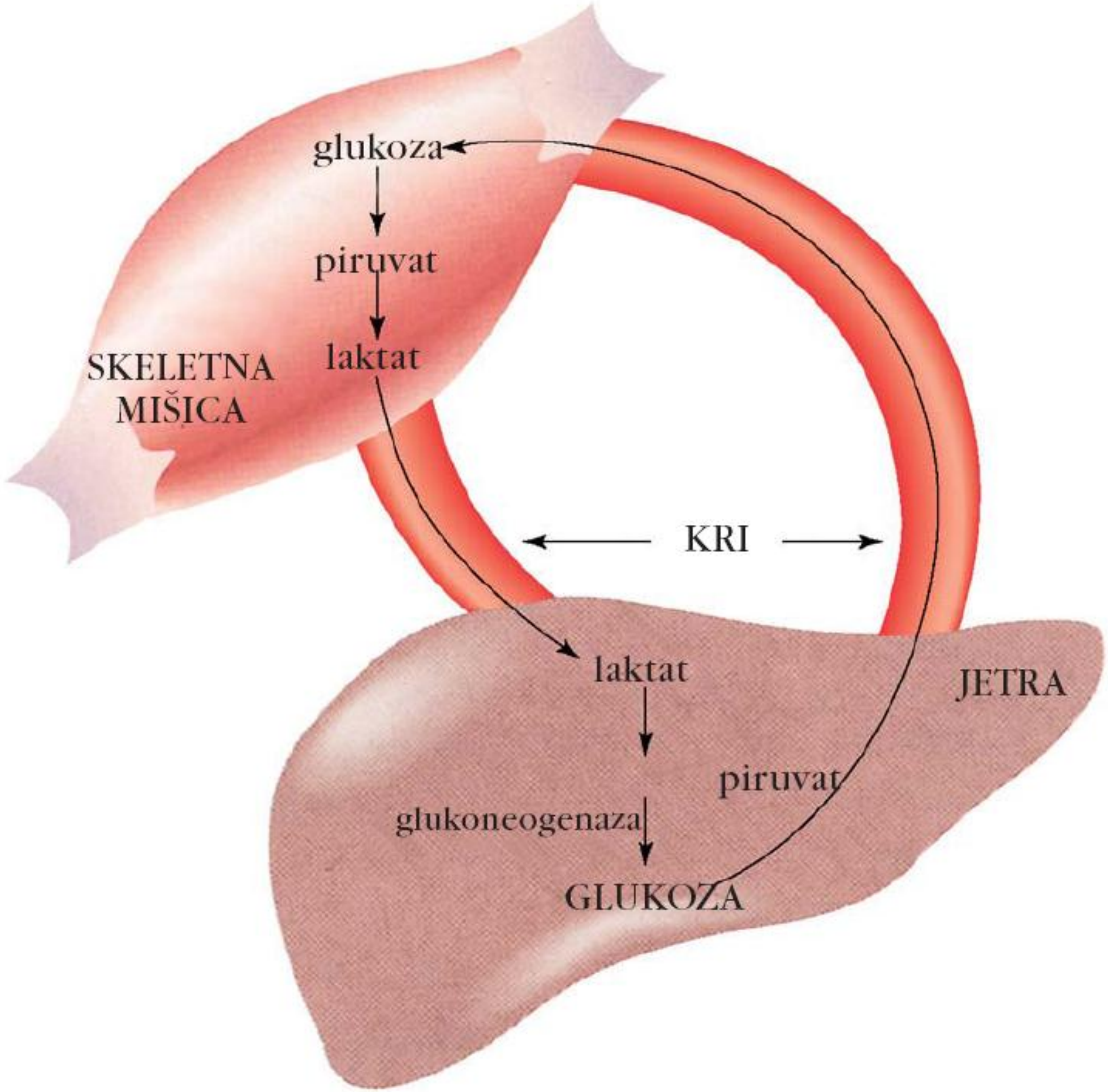
Slika 15.6
Sklopitev glikolize in mlečnokislinske fermentacije. Redukcija piruvata reciklira NADH v NAD⁺. E1 = gliceraldehid-3-fosfat-dehidrogenaza, E2 = laktat-dehidrogenaza. Neto izkoristek nastanka NADH pri pretvorbi glukoze v mlečno kislino je nič.



# Cori ciklus

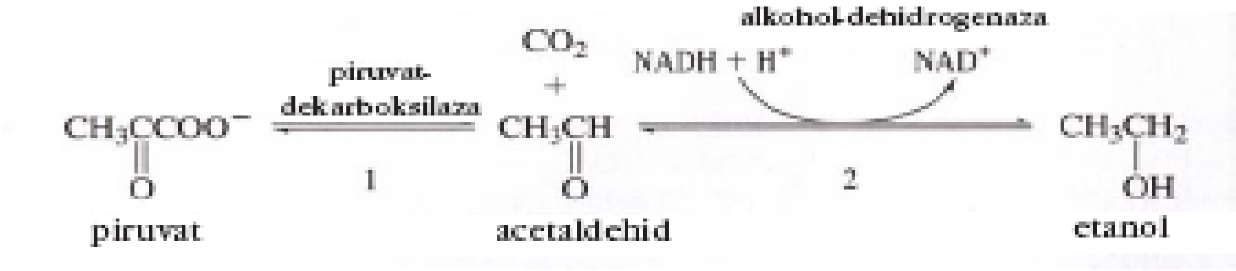
Slika 15.6
Sklopitev glikolize in mlečnokislinske fermentacije. Redukcija piruvata reciklira NADH v NAD⁺. E1 = gliceraldehid-3-fosfat-dehidrogenaza, E2 = laktat-dehidrogenaza. Neto izkoristek nastanka NADH pri pretvorbi glukoze v mlečno kislino je nič.




glukoza
piruvat
laktat
SKELETNA MIŠICA
KRI
laktat
JETRA
piruvat
glukoneogenaza
GLUKOZA

## Alkoholna fermentacija in metabolizem etanola

# Anairobni pogoji



# Aerobni metabolizem etanola

Pri ljudeh, ima pitje alkoholnih pijač pomembne biokemijske, klinične in socialne posledice. Zaužiti etanol se najprej v jetrih oksidira s citosolno alkohol-dehidrogenazo:

$$\underset{\text{etanol}}{CH_3CH_2OH} + NAD^+ \rightleftharpoons \underset{\text{acetaldehid}}{CH_3CHO} + NADH + H^+$$

Drugo oksidacijsko stopnjo katalizira aldehid-dehidrogenaza

$$\underset{\text{acetaldehid}}{CH_3CHO} + NAD^+ \rightleftharpoons \underset{\text{acetat}}{CH_3COO^-} + NADH + H^+$$

# GLUKONEOGENEZA

# Sinteza ogljikovih hidratov iz enostavnih prekurzorjev

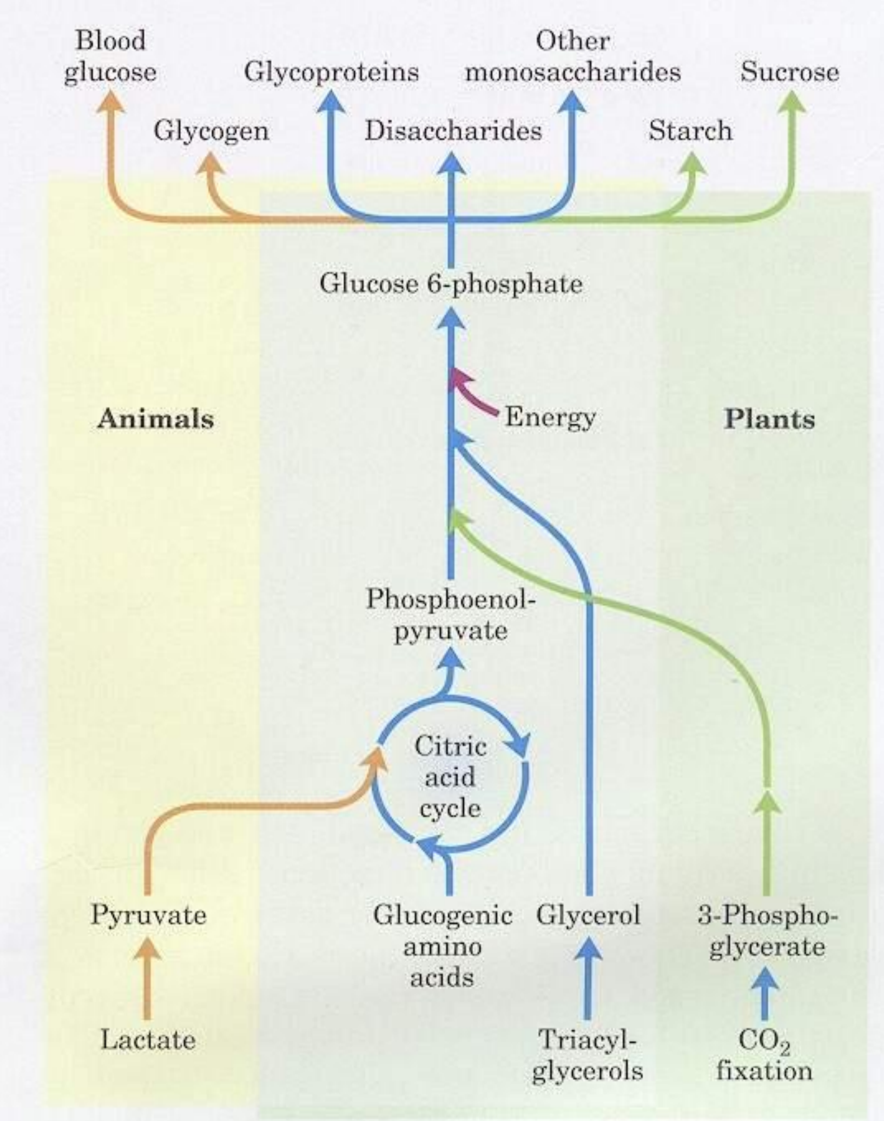
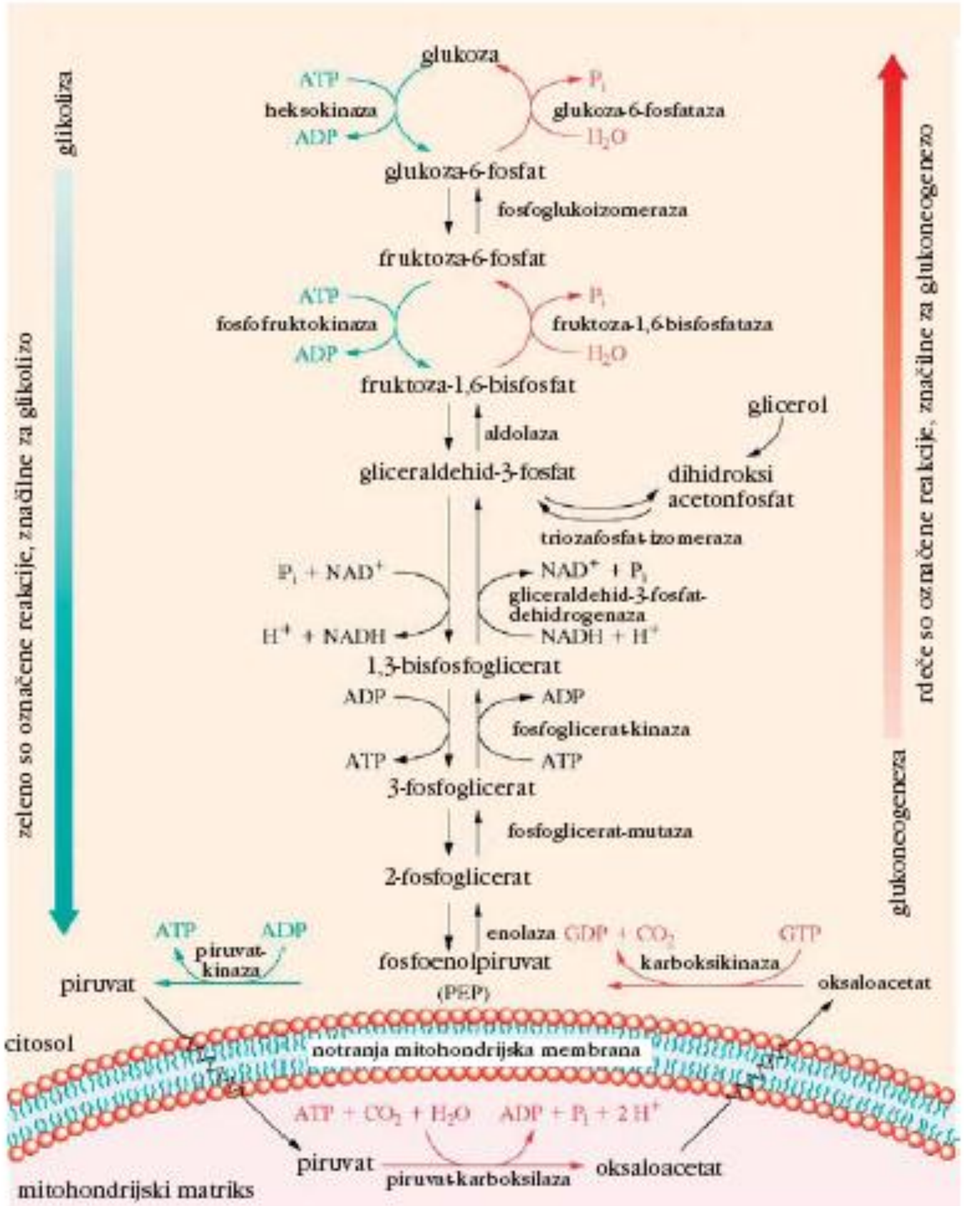



**FIGURE 14–15 Carbohydrate synthesis from simple precursors.** The pathway from phosphoenolpyruvate to glucose 6-phosphate is common to the biosynthetic conversion of many different precursors of carbohydrates in animals and plants. Plants and photosynthetic bacteria are uniquely able to convert $CO_2$ to carbohydrates.




Slika 15.9

Metabolizem glukoze; prikazane so reakcije glikolize in glukoneogeneze.

Ireverzibilne reakcije glikolize, ki jih v glukoneogenezi nadomeščajo druge reakcije

| števika[a] | reakcija | encim | $\Delta G^{0'}$ (kJ/mol) |
|---|---|---|---|
| 1 | glukoza+ATP → glukoza-6-fosfat+ADP | heksokinaza | -16,7 |
| 3 | fruktoza-6-fosfat+ATP → fruktoza-1,6-bisfosfat+ADP | fosfofruktokinaza | -14,2 |
| 10 | PEP+ADP → piruvat+ATP | piruvat-kinaza | -31,4 |

[a] Številka se nanaša na številke reakcij v tabeli 15.1.

## Reakcije glukoneogeneze z začetkom pri piruvatu

| številka | reakcija |
|---|---|
| 1 | piruvat+CO2+ATP → oksaloacetat+ADP+Pi |
| 2 | oksaloacetat+GTP ⇌ fosfoenolpiruvat+$CO_2$+GDP |
| 3 | fosfoenolpiruvat+$H_2O$ ⇌ 2-fosfoglicerat |
| 4 | 2-fosfoglicerat ⇌ 3-fosfoglicerat |
| 5 | 3-fosfoglicerat+ATP ⇌ 1,3-bisfosfoglicerat |
| 6 | 1,3-bisfosfoglicerat+NADH+H+ ⇌ gliceraldehid-3-fosfat+$NAD^+$+Pi |
| 7 | gliceraldehid-3-fosfat ⇌ dihidroksiacetonfosfat |
| 8 | gliceraldehid-3-fosfat+dihidroksiacetonfosfat ⇌ fruktoza-1,6-bisfosfat |
| 9 | fruktoza-1,6-bisfosfat+$H_2O$ → fruktoza-6-fosfat+Pi |
| 10 | fruktoza-6-fosfat ⇌ glukoza-6-fosfat |
| 11 | glukoza-6-fosfat+$H_2O$ ⇌ glukoza+Pi |

**TABLE 14–2 Free-Energy Changes of Glycolytic Reactions in Erythrocytes**

| *Glycolytic reaction step* | $\Delta G'^{\circ}$ *(kJ/mol)* | $\Delta G$ *(kJ/mol)* |
|---|---|---|
| ① Glucose + ATP $\longrightarrow$ glucose 6-phosphate + ADP | −16.7 | −33.4 |
| ② Glucose 6-phosphate $\rightleftharpoons$ fructose 6-phosphate | 1.7 | 0 to 25 |
| ③ Fructose 6-phosphate + ATP $\longrightarrow$ fructose 1,6-bisphosphate + ADP | −14.2 | −22.2 |
| ④ Fructose 1,6-bisphosphate $\rightleftharpoons$ dihydroxyacetone phosphate + glyceraldehyde 3-phosphate | 23.8 | 0 to −6 |
| ⑤ Dihydroxyacetone phosphate $\rightleftharpoons$ glyceraldehyde 3-phosphate | 7.5 | 0 to 4 |
| ⑥ Glyceraldehyde 3-phosphate + $P_i$ + $NAD^+$ $\rightleftharpoons$ 1,3-bisphosphoglycerate + NADH + $H^+$ | 6.3 | −2 to 2 |
| ⑦ 1,3-Bisphosphoglycerate + ADP $\rightleftharpoons$ 3-phosphoglycerate + ATP | −18.8 | 0 to 2 |
| ⑧ 3-Phosphoglycerate $\rightleftharpoons$ 2-phosphoglycerate | 4.4 | 0 to 0.8 |
| ⑨ 2-Phosphoglycerate $\rightleftharpoons$ phosphoenolpyruvate + $H_2O$ | 7.5 | 0 to 3.3 |
| ⑩ Phosphoenolpyruvate + ADP $\longrightarrow$ pyruvate + ATP | −31.4 | −16.7 |

Note: $\Delta G'^{\circ}$ is the standard free-energy change, as defined in Chapter 13 (p. 491). $\Delta G$ is the free-energy change calculated from the actual concentrations of glycolytic intermediates present under physiological conditions in erythrocytes, at pH 7. The glycolytic reactions bypassed in gluconeogenesis are shown in red. Biochemical equations are not necessarily balanced for H or charge (p. 506).

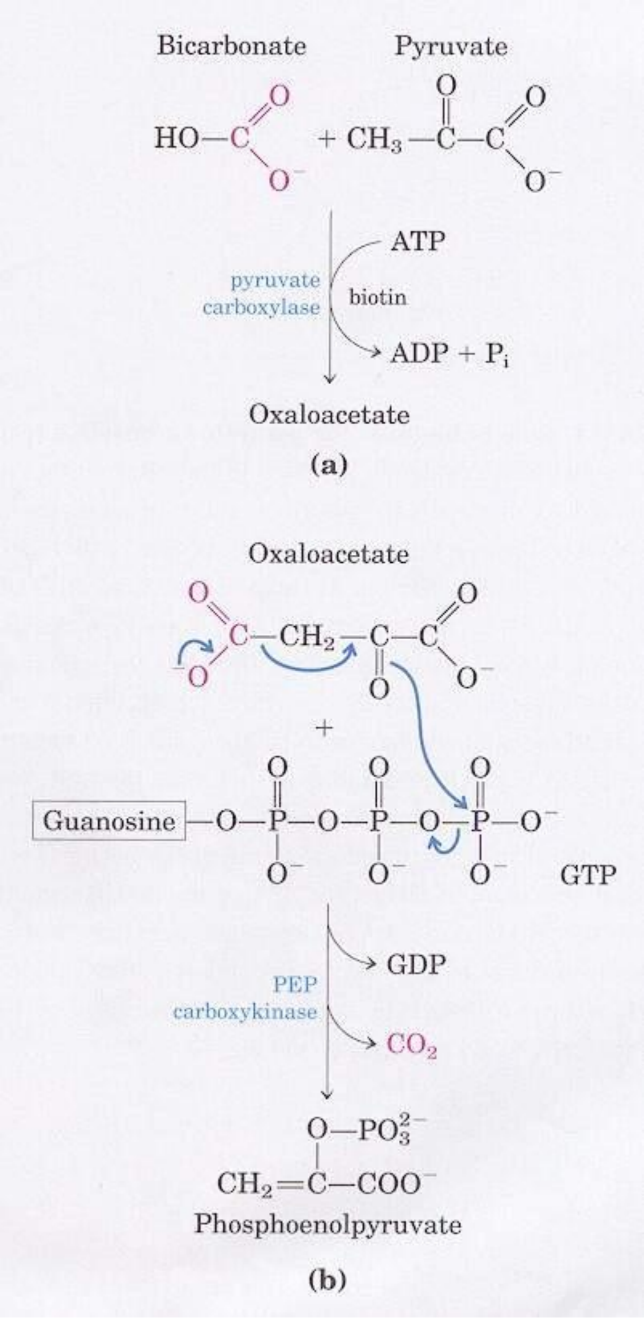



**FIGURE 14–17 Synthesis of phosphoenolpyruvate from pyruvate.** (a) In mitochondria, pyruvate is converted to oxaloacetate in a biotin-requiring reaction catalyzed by pyruvate carboxylase. **(b)** In the cytosol, oxaloacetate is converted to phosphoenolpyruvate by PEP carboxykinase. The $CO_2$ incorporated in the pyruvate carboxylase reaction is lost here as $CO_2$. The decarboxylation leads to a rearrangement of electrons that facilitates attack of the carbonyl oxygen of the pyruvate moiety on the $\gamma$ phosphate of GTP.

# I. obvoz

$$piruvat + ATP + GTP \rightarrow fosfoenolpiruvat + ADP + GDP + P_i$$

Reakcije glukoneogeneze. 1. obvoz. Citosolni piruvat ali laktat se lahko uporabita za sintezo fosfoenolpiruvata s citosolnimi in mitohondrijskimi encimi.

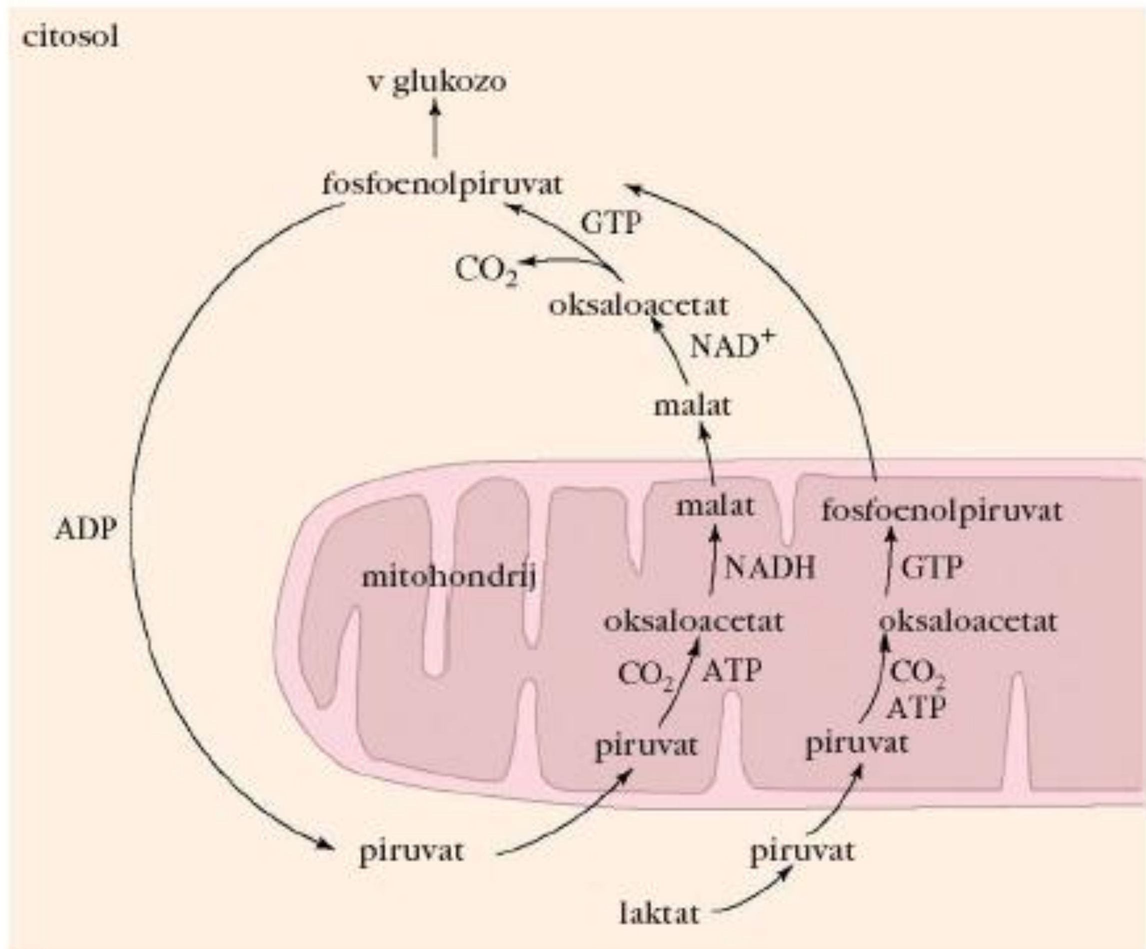


**TABLE 14–3 Sequential Reactions in Gluconeogenesis Starting from Pyruvate**

| | |
|---|---|
| Pyruvate + $HCO_3^-$ + ATP $\longrightarrow$ oxaloacetate + ADP + $P_i$ | ×2 |
| Oxaloacetate + GTP $\rightleftharpoons$ phosphoenolpyruvate + $CO_2$ + GDP | ×2 |
| Phosphoenolpyruvate + $H_2O$ $\rightleftharpoons$ 2-phosphoglycerate | ×2 |
| 2-Phosphoglycerate $\rightleftharpoons$ 3-phosphoglycerate | ×2 |
| 3-Phosphoglycerate + ATP $\rightleftharpoons$ 1,3-bisphosphoglycerate + ADP | ×2 |
| 1,3-Bisphosphoglycerate + NADH + $H^+$ $\rightleftharpoons$ glyceraldehyde 3-phosphate + $NAD^+$ + $P_i$ | ×2 |
| Glyceraldehyde 3-phosphate $\rightleftharpoons$ dihydroxyacetone phosphate | |
| Glyceraldehyde 3-phosphate + dihydroxyacetone phosphate $\rightleftharpoons$ fructose 1,6-bisphosphate | |
| Fructose 1,6-bisphosphate $\longrightarrow$ fructose 6-phosphate + $P_i$ | |
| Fructose 6-phosphate $\rightleftharpoons$ glucose 6-phosphate | |
| Glucose 6-phosphate + $H_2O$ $\longrightarrow$ glucose + $P_i$ | |
| *Sum:* 2 Pyruvate + 4ATP + 2GTP + 2NADH + $2H^+$ + $4H_2O$ $\longrightarrow$ glucose + 4ADP + 2GDP + $6P_i$ + $2NAD^+$ | |

I. obvoz

$$piruvat + ATP + GTP \rightarrow fosfoenolpiruvat + ADP + GDP + P_i$$

II. obvoz

$$fruktoza\text{-}1,6\text{-}bisfosfat + H_2O \rightleftharpoons fruktoza\text{-}6\text{-}fosfat + P_i$$

III. obvoz

$$glukoza\text{-}6\text{-}fosfat + H_2O \rightleftharpoons glukoza + P_i$$

Povzetek glukoneogeneze:

$$2\ piruvat + 4ATP + 2GTP + 2NADH + 2H^+ + 6H_2O \rightarrow glukoza + 2NAD^+ + 4ADP + 2GDP + 6P_i$$

## Aktivacija glukoze in galaktoze za biosintezo

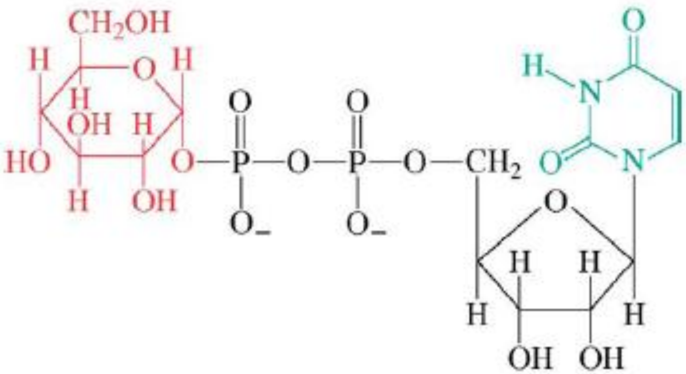
**Nastanek NDP-glukoze**

Nastanek NDP-glukoze lahko zapišemo s splošno reakcijo:

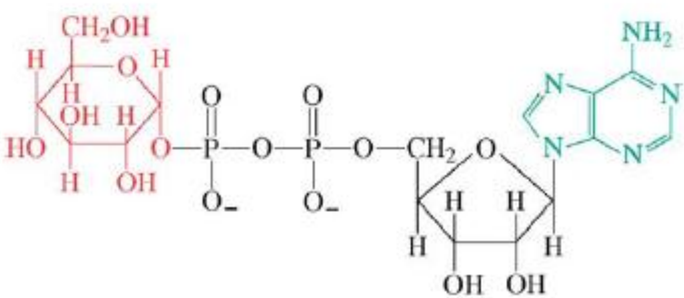
$$\text{NTP+glukoza-1-fosfat - NDP-glukoza+PP}_i$$

NTP = nukleozidtrifosfat, ATP ali UTP ali GTP

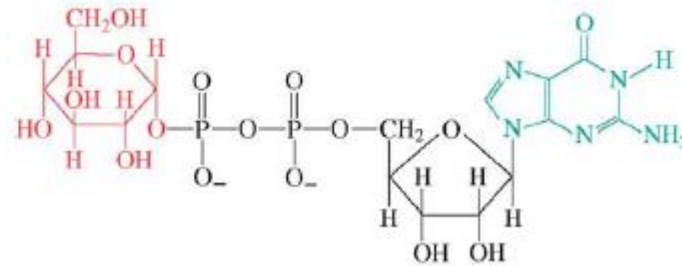
NDP-glukoza = nukleoziddifosfat-glukoza, ADP-glukoza ali UDP-glukoza ali GDP-glukoza



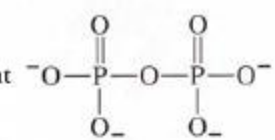
(a) UDP-glukoza



(b) ADP-glukoza



(c) GDP-glukoza

1 PPi - pirofosfat 

Encim: ADP-glukoza-pirofosforilaza ali
UDP-glukoza-pirofosforilaza ali
GDP-glukoza-pirofosforilaza

## Nastanek UDP-galaktoze

Sinteza UDP-galaktoze poteka po dveh možnih poteh:

1. Izomerizacija UDP-glukoze

$$\text{UDP-glukoza} \rightleftharpoons \text{UDP-galaktoza}$$

   Encim = UDP-glukoza-4-epimeraza

2. Izmenjava UDP

$$\text{galaktoza-1-fosfat} + \text{UDP-glukoza} \rightleftharpoons \text{UDP-galaktoza} + \text{glukoza-1-fosfat}$$

   Encim = galaktoza-1-fosfat-uridiltransferaza

# Sinteza polisaharidov

## Glikogen

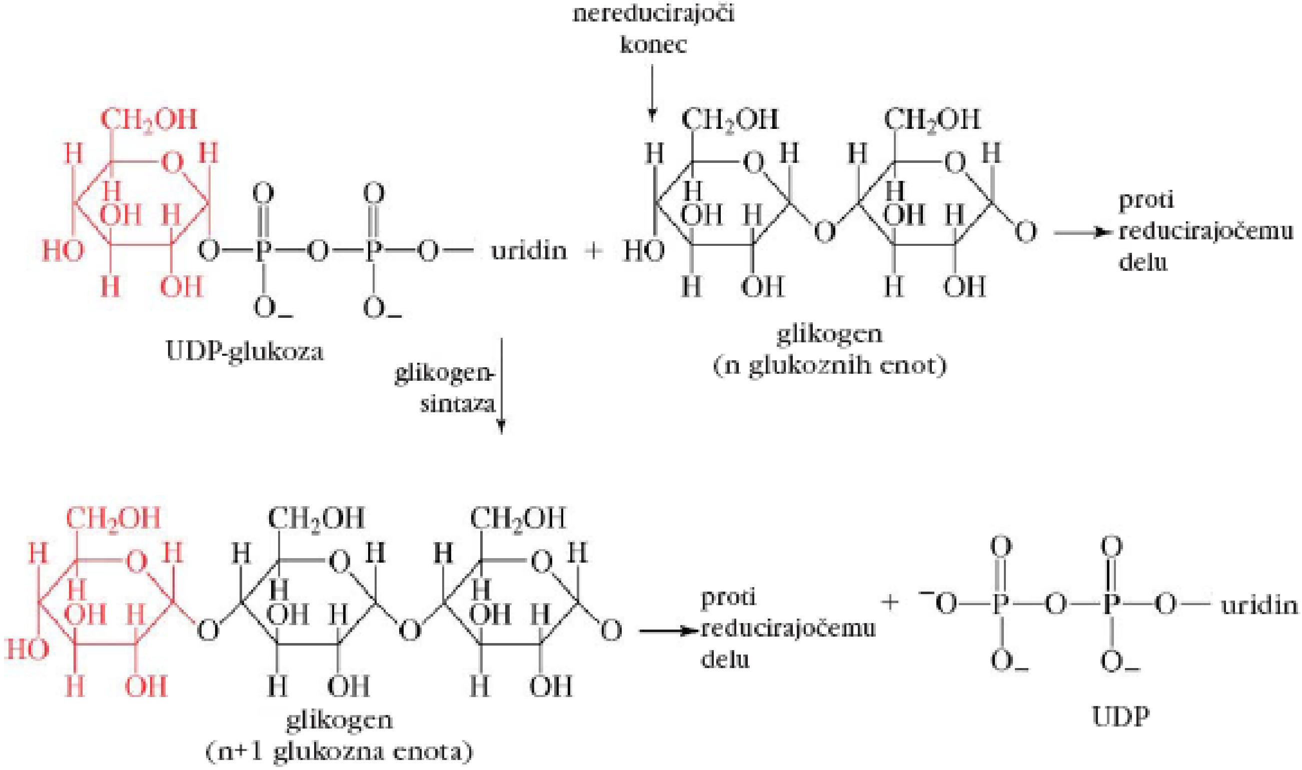
Presežek glukoze se pri živalih skladišči kot polisaharid glikogen:

$$\text{UDP-glukoza} + (\text{glukoza})_n \rightleftharpoons \text{UDP} + (\text{glukoza})_{n+1}$$

obstoječi glikogen — podaljšani glikogen

Delovanje glikogen-sintaze. Glukozna enota, aktivirana z vezavo UDP, se dodaja na nereducirajočem koncu obstoječega glikogena. Glukozne enote se lahko dodajajo na vse nereducirajoče glikogenske molekule.

$$\text{glukoza-6-fosfat} + \text{UTP} + (\text{glukoza})_n + H_2O \rightarrow (\text{glukoza})_{n+1} + \text{UDP} + 2P_i$$



## Škrob

Shranjevanje glukoze pri rastlinah poteka podobno kot pri živalih, le da se glukoza, preden se vgradi v škrob (glukoza$_n$), aktivira z ADP in ne z UDP.

$$\text{ADP-glukoza} + \underset{\substack{\text{obstoječi}\\\text{škrob}}}{(\text{glukoza})_n} \rightleftharpoons \text{ADP} + \underset{\substack{\text{podaljšani}\\\text{škrob}}}{(\text{glukoza})_{n+1}}$$

Škrob-sintaza katalizira dodatek nove glukozne enote na nereducirajoči del obstoječe škrobne molekule z nastankom $\alpha(1\rightarrow4)$ glikozidne vezi.

## Celuloza

Celuloza, glavni strukturni polisaharid v celičnih stenah rastlin in nekaterih bakterij, je sestavljena iz glukoznih enot, ki so povezane z $\beta(1\rightarrow4)$ glikozidno vezjo (glej poglavje 8.4). Sinteza poteče podobno kot pri škrobu. Aktivirana oblika glukoze je pri nekaterih organizmih UDP-glukoza, pri nekaterih pa GDP-glukoza.

$$\text{UDP-glukoza ali GDP-glukoza} + \underset{\substack{\text{obstoječa}\\\text{celuloza}}}{(\text{glukoza})_n} \rightleftharpoons \text{UDP ali GDP} + \underset{\substack{\text{podaljšana}\\\text{celuloza}}}{(\text{glukoza})_{n+1}}$$

## Sinteza disaharidov

### Laktoza

Disaharid laktoza (mlečni sladkor) se po porodu aktivno sintetizira v mlečni žlezi sesalcev. Laktoza nastane s povezavo aktivirane galaktoze z glukozo:

$$\text{UDP-galaktoza} + \text{glukoza} \rightleftharpoons \text{UDP} + \text{laktoza}$$

Encimski sistem laktoza-sintaza katalizira nastanek β(1→4) glikozidne vezi med dvema monosaharidoma (glej Okno v biokemijo 15.1).

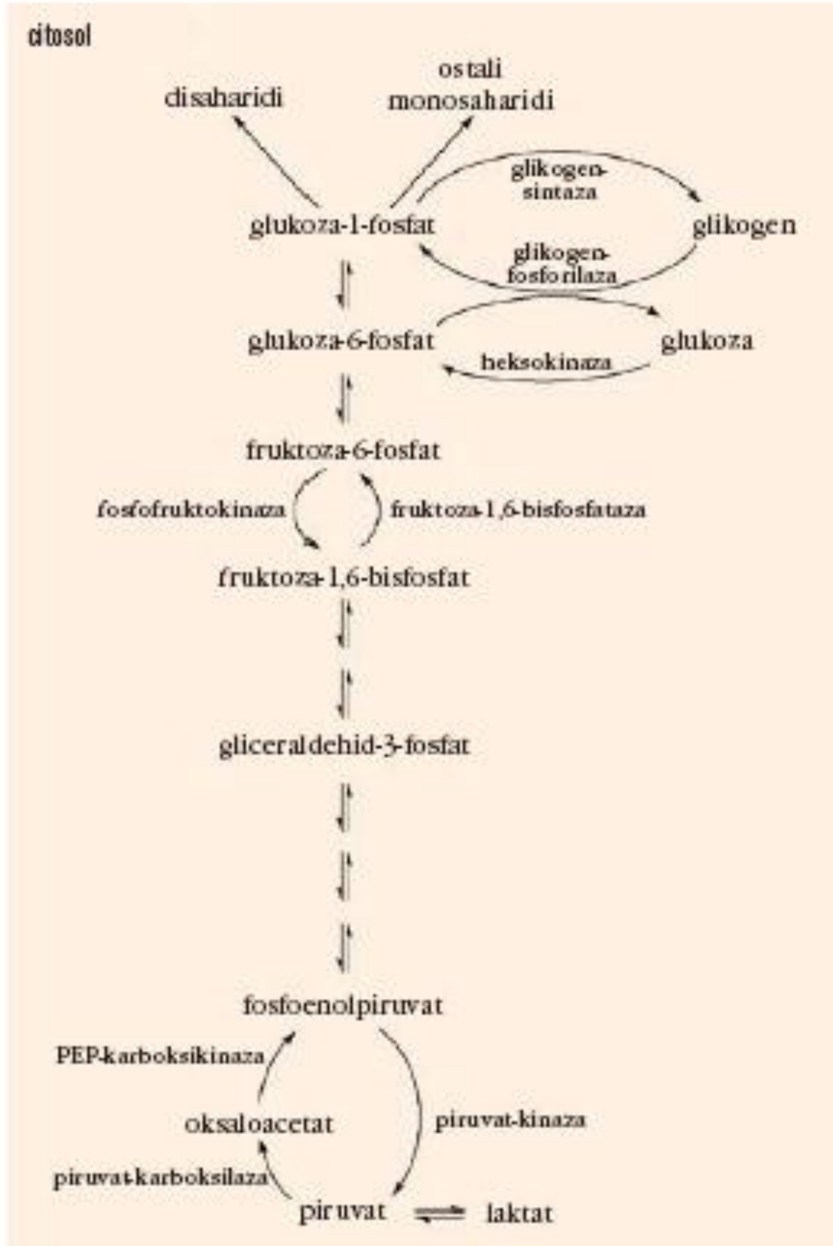
### Saharoza

Disaharid saharoza je glavni sladkor pri večini vrst sadja in zelenjave, zlasti veliko pa ga vsebujeta sladkorni trs in sladkorna repa. Saharoza, transportna oblika monosaharidov, potrebnih za pridobivanje energije in biosintetske procese, se prenaša po rastlini preko floema (sekundarnega žilnega sistema rastlin). Disaharid se sintetizira v dveh stopnjah iz glukoze, aktivirane z UDP, in iz fruktoze, aktivirane s fosfatom:

$$\text{UDP-glukoza} + \text{fruktoza-6-fosfat} \xrightleftharpoons{\text{saharoza-6-fosfat-sintaza}} \text{saharoza-6-fosfat} + \text{UDP}$$

$$\text{Saharoza-6-fosfat} \xrightleftharpoons{\text{fosfataza}} \text{saharoza} + P_i$$

# REGULACIJA METABOLIZMA OGLJIKOVIH HIDRATOV



## Regulatorni encimi v metabolizmu ogljikovih hidratov

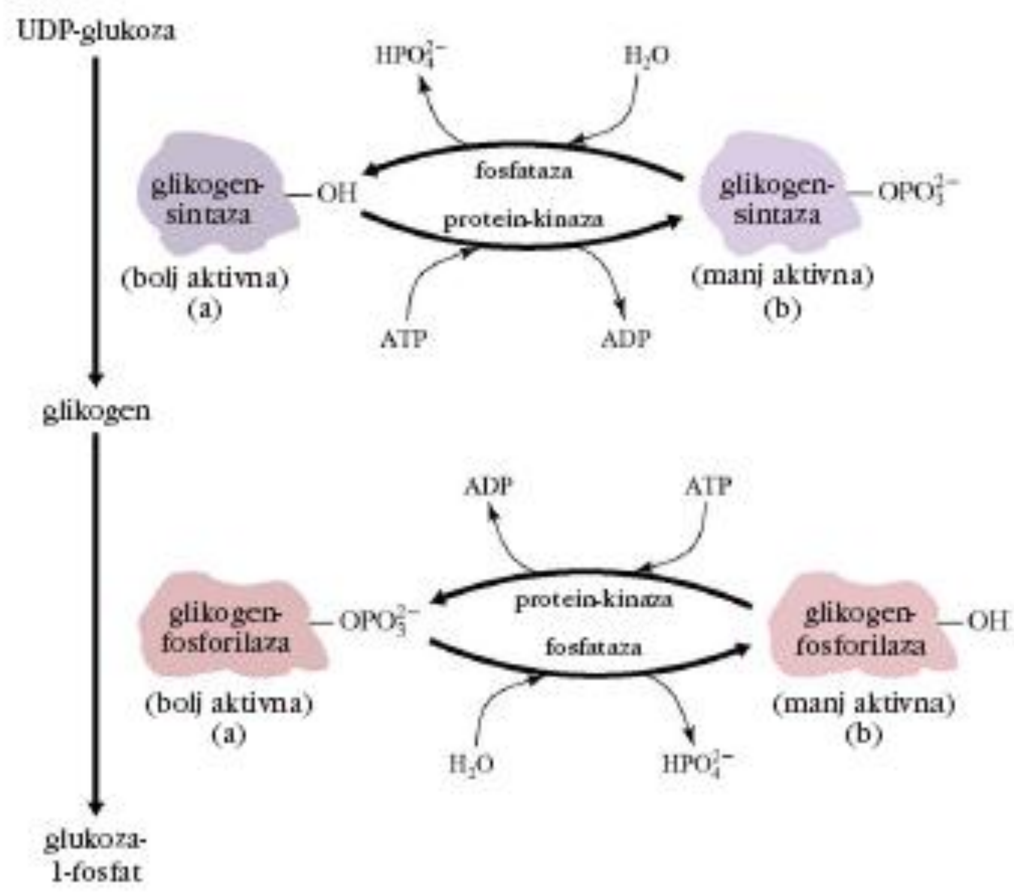
| ime encima | ⊕ modulator[a] | ⊖modulator[a] | komentar |
|---|---|---|---|
| glikogen-fosforilaza | | | |
| oblika (a) | - | - | aktivna v vseh razmerah |
| oblika (b) | AMP | G6P[b] | razmerje med oblikama (a) in (b) uravnavajo hormoni |
| glikogen-sintaza | | | |
| oblika (a) | - | - | aktivna v vseh razmerah |
| oblika (b) | G6P[b] | - | razmerje med oblikama (a) in (b) uravnavajo hormoni |
| heksokinaza | - | G6P[b] | inhibicija s povratno zvezo |
| fosfofruktokinaza | AMP, F2,6BP[c] | ATP, citrat | glavna kontrolna točka glikolize |
| fruktoza-1.6-bisfosfataza | - | AMP, F2,6BP[c] | regulacijska stopnja v sintezi glukoze |
| piruvat-kinaza | - | ATP,acetil-CoA | uravnavana tudi z izoencimskimi oblikami |
| piruvat-karboksilaza | acetil-CoA | - | pomaga vzdrževati stalno koncentracijo glukoze in oksaloacetata |

[a] + alosterični modulatorji stimulirajo encim; -alosterični modulatorji inhibirajo encim.

[b] G6P = glukoza-6-fosfat

[c] F2,6-BP = fruktoza-2,6-bisfosfat

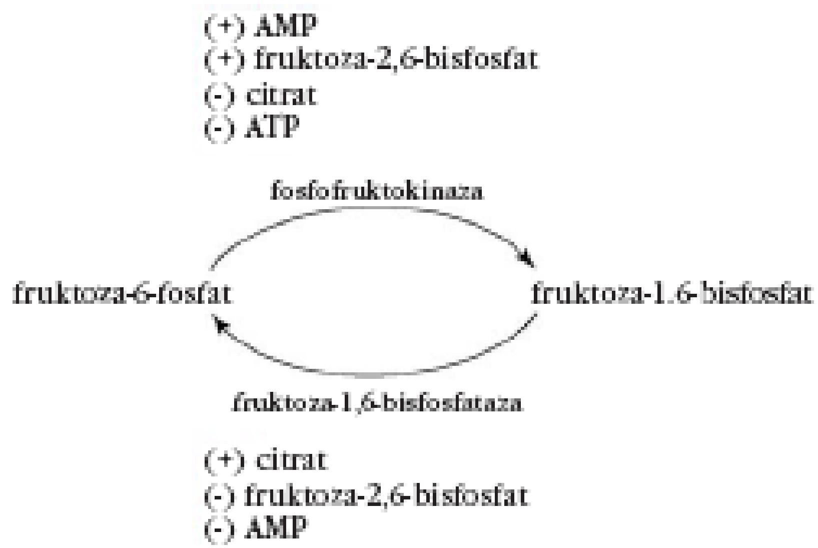
# GLIKOGEN SINTAZA IN GLIKOGEN FOSFORILAZA



# Fruktoza-1,6-bisfosfataza

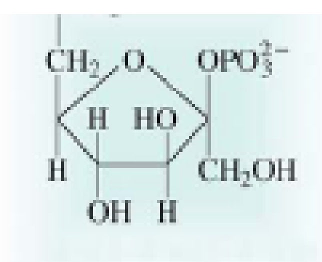
$$\text{ATP} + \text{fruktoza-6-fosfat} \xrightleftharpoons{\text{PFK}} \text{ADP} + \text{fruktoza-1,6-bisfosfat}$$

$$\text{fruktoza-1,6-bisfosfat} + H_2O \xrightleftharpoons{\text{FBP}} \text{fruktoza-6-fosfat} + P_i$$




Recipročno uravnavanje fosfofruktokinaze in fruktoza-1,6-bisfosfataze.

Struktura fruktoza-2,6-bisfosfata, alosteričnega modulatorja, ki stimulira delovanje fosfofruktokinaze.




fruktoza-2,6-bisfosfat

## Piruvat-kinaza in piruvat-karboksilaza

Piruvat-kinaza (PK) je tetrameren protein, ki za svojo aktivnost potrebuje $Na^+$ ali $K^+$ ione. ATP inhibira piruvat-kinazo in tako upočasni nastanek piruvata.

Piruvat-karboksilaza (PC) je pomemben regulatorni encim glukoneogeneze. PC katalizira nastanek oksaloacetata z vezavo $CO_2$ na piruvat. PC je aktivna samo, kadar ima na razpolago intermediat acetil-CoA. Metabolične logike te stopnje ne boš

# FOSFOGLUKOZNA POT

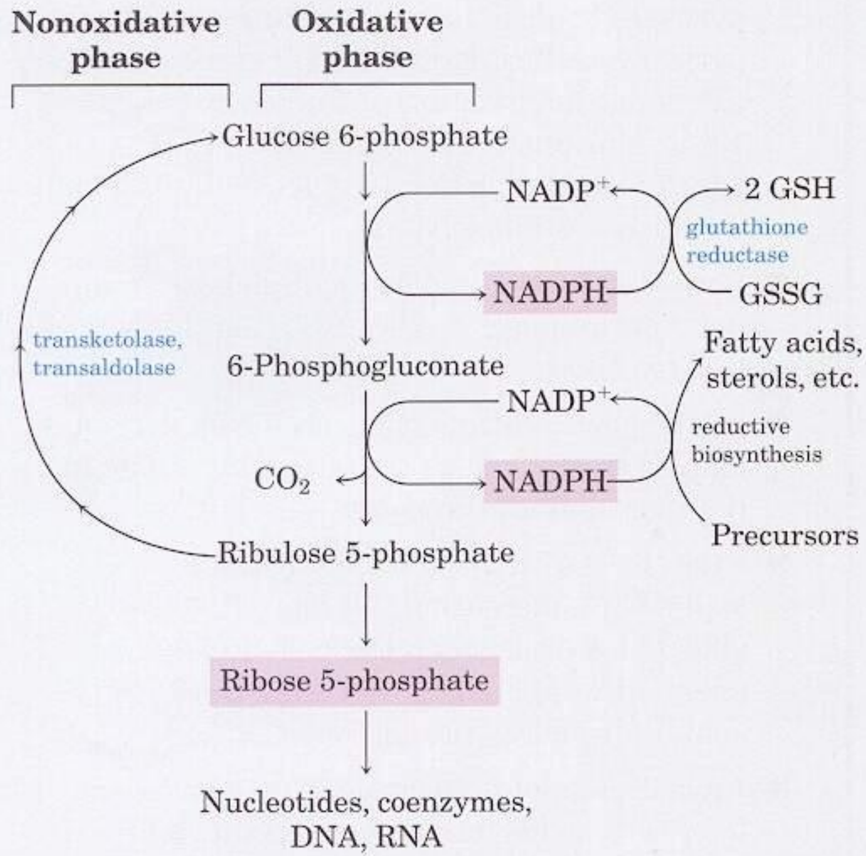



**FIGURE 14–20 General scheme of the pentose phosphate pathway.** NADPH formed in the oxidative phase is used to reduce glutathione, GSSG (see Box 14–3) and to support reductive biosynthesis. The other product of the oxidative phase is ribose 5-phosphate, which serves as precursor for nucleotides, coenzymes, and nucleic acids. In cells that are not using ribose 5-phosphate for biosynthesis, the nonoxidative phase recycles six molecules of the pentose into five molecules of the hexose glucose 6-phosphate, allowing continued production of NADPH and converting glucose 6-phosphate (in six cycles) to $CO_2$.

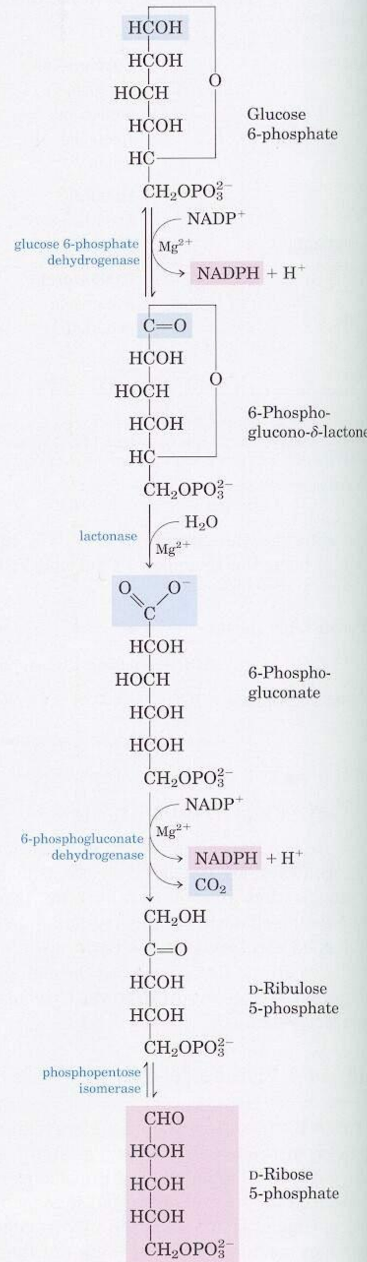



**FIGURE 14–21 Oxidative reactions of the pentose phosphate pathway.** The end products are ribose 5-phosphate, $CO_2$, and NADPH.