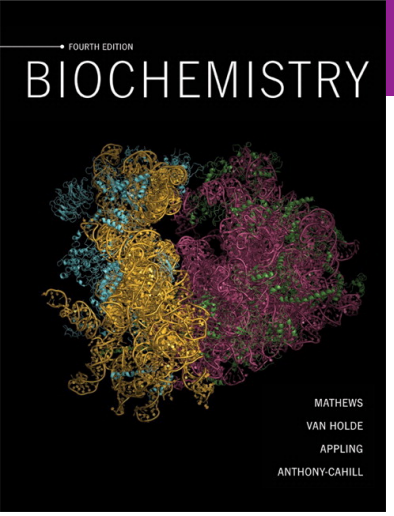

Chapter 13

Carbohydrate Metabolism: Glycolysis, Gluconeogenesis, Glycogen Metabolism, and the Pentose Phosphate Pathway

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分機:5159

Glycolysis

Catabolic and anabolic processes in anaerobic carbohydrate metabolism:

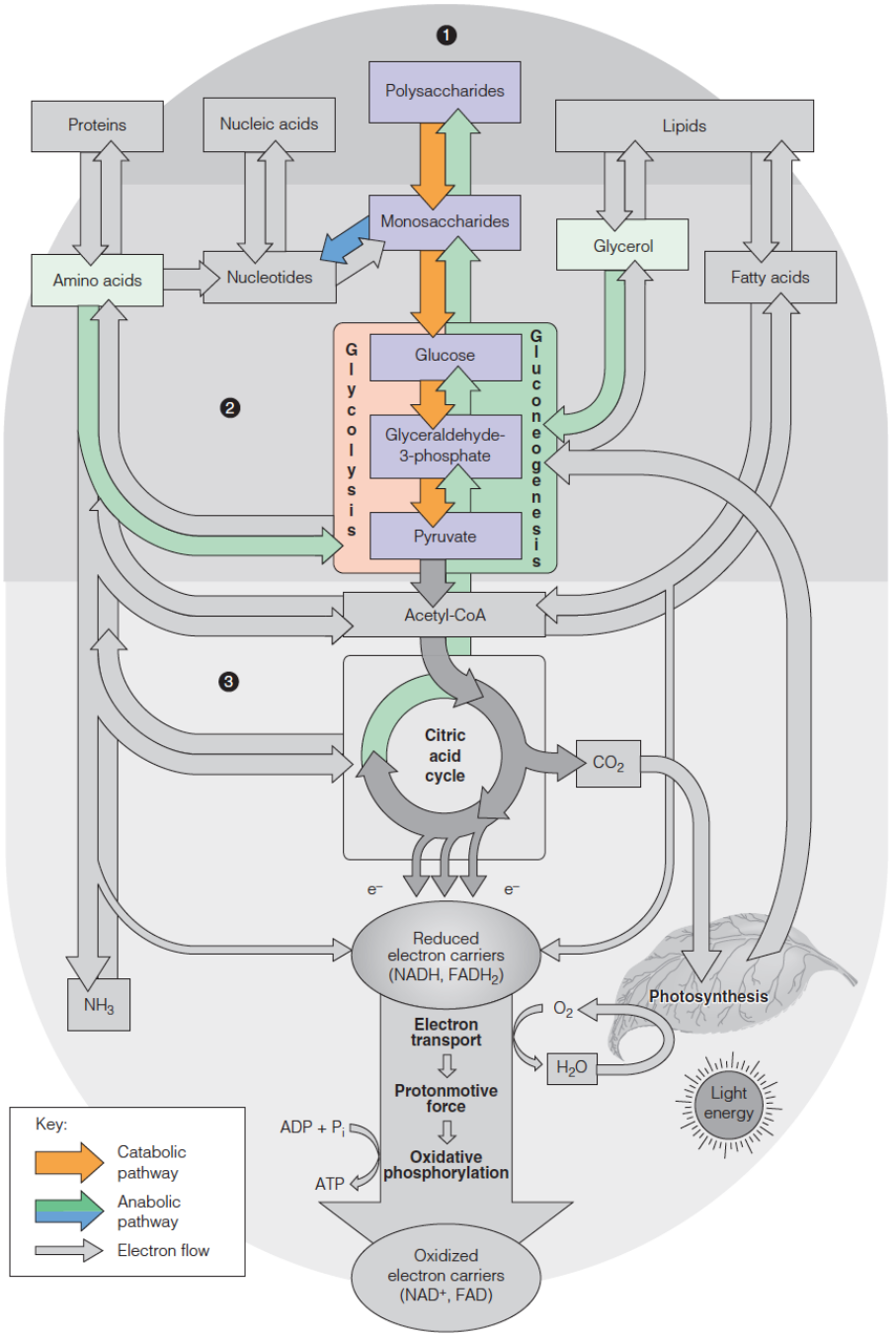
•The gold arrows show the glycolytic pathway and the breakdown of polysaccharides that supply this pathway.

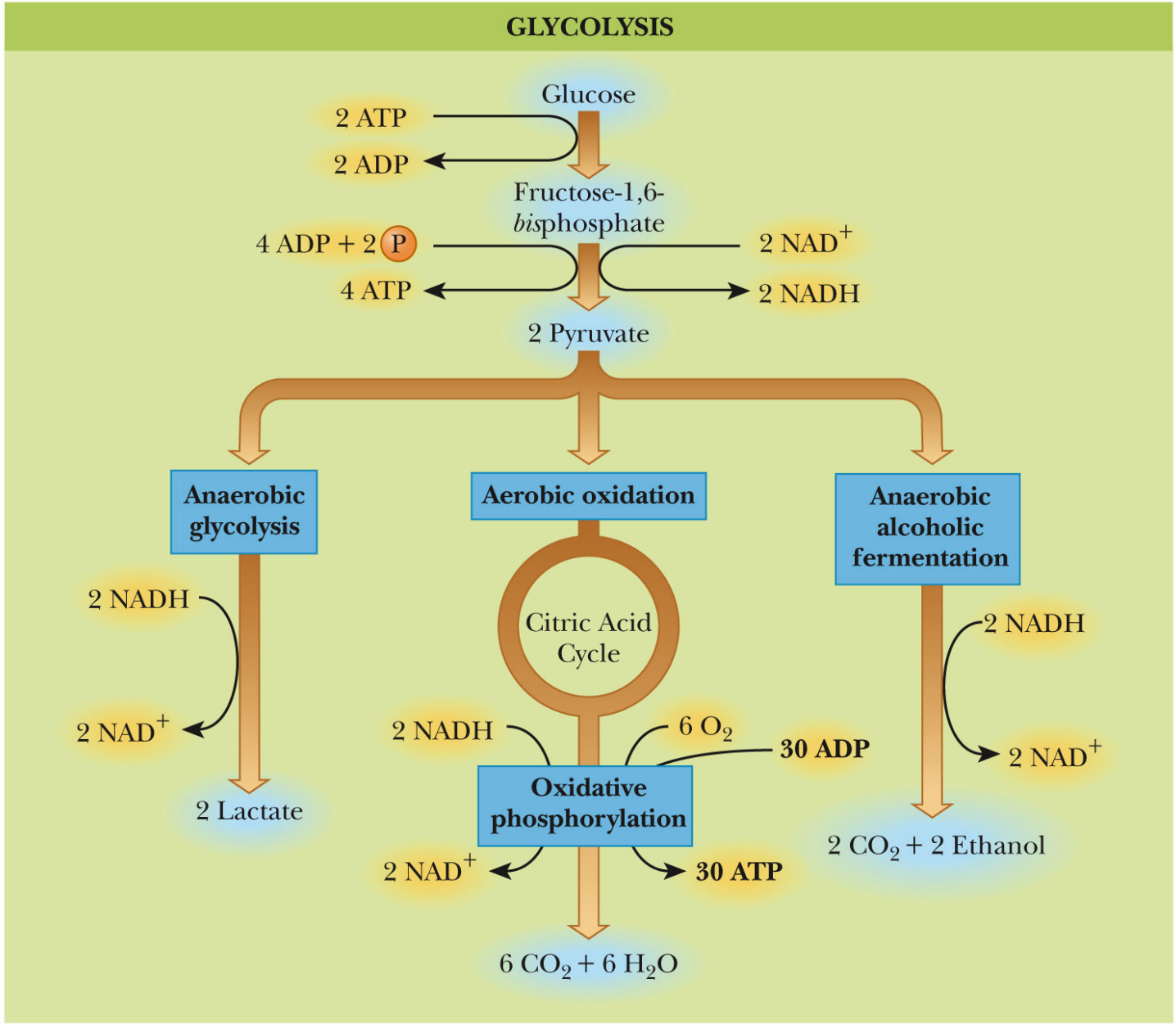
•***Glycolysis*** generates ATP ***anaerobically*** and provides fuel for the aerobic energy-generating pathways.

•The green arrows show the ***gluconeogenesis*** pathway, the synthesis of polysaccharides such as glycogen.

•The blue arrow shows the ***pentose phosphate pathway***, an alternative carbohydrate oxidation pathway needed for nucleotide synthesis.

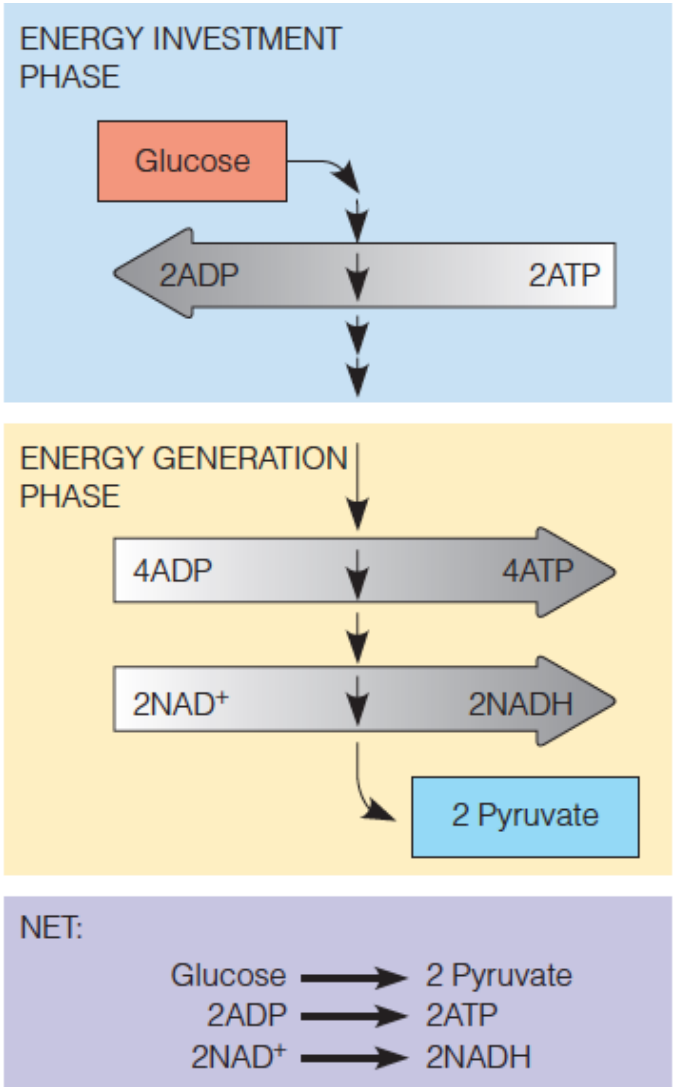
•The numbers 1, 2, and 3 identify the three stages of metabolism




GLYCOLYSIS
Glucose
2 ATP
2 ADP
Fructose-1,6-
bisphosphate
4 ADP + 2 P
4 ATP
2 NAD+
2 NADH
2 Pyruvate
Anaerobic glycolysis
Aerobic oxidation
Anaerobic alcoholic fermentation
2 NADH
2 NAD+
2 Lactate
Citric Acid Cycle
2 NADH
6 O2
30 ADP
Oxidative phosphorylation
2 NAD+
30 ATP
6 CO2 + 6 H2O
2 NADH
2 NAD+
2 CO2 + 2 Ethanol

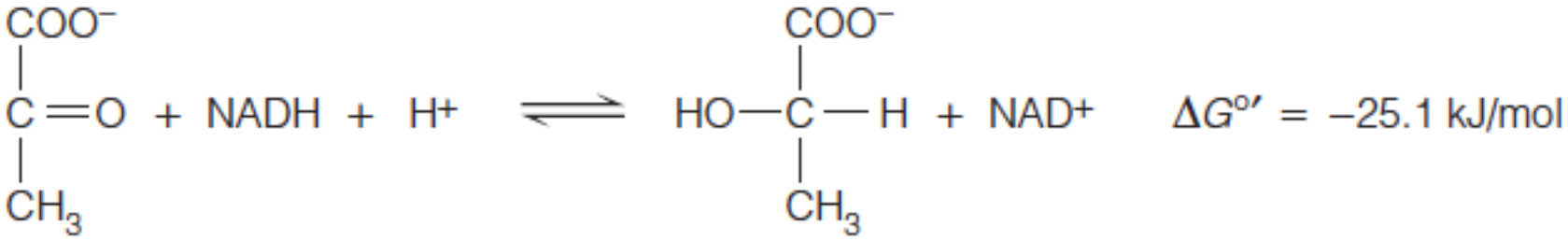
Glycolysis: An Overview

The two phases of glycolysis and the products of glycolysis:



Glycolysis: An Overview

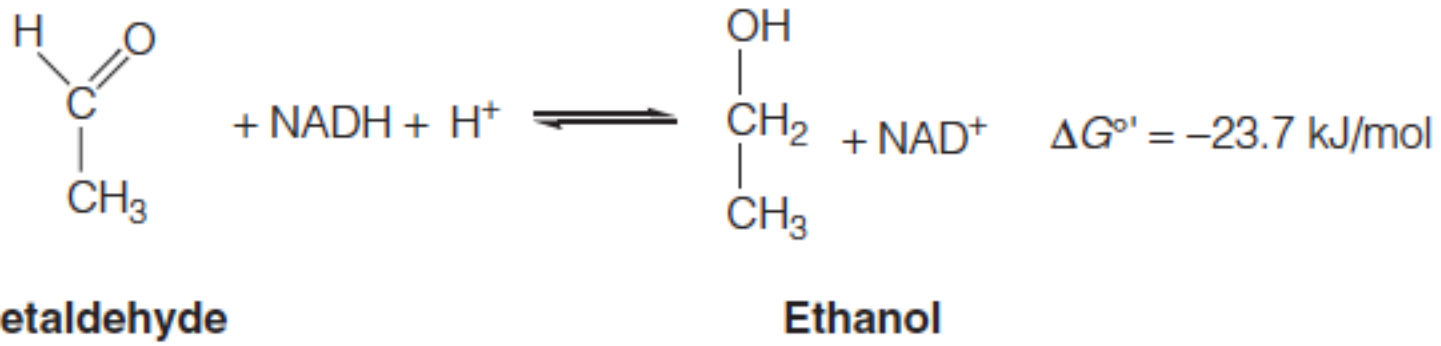
- A ***fermentation*** is an energy-yielding metabolic pathway with no net change in the oxidation state of products compared to substrates.
- Anaerobic glycolysis (like aerobic glycolysis) leads to pyruvate, but the pyruvate is then reduced, so no net oxidation of glucose occurs.



Pyruvate **L-Lactate**

Glycolysis: An Overview

- ***Alcoholic fermentation*** involves cleavage of pyruvate to acetaldehyde and CO_2 with the acetaldehyde then reduced to ethanol by alcohol dehydrogenase:

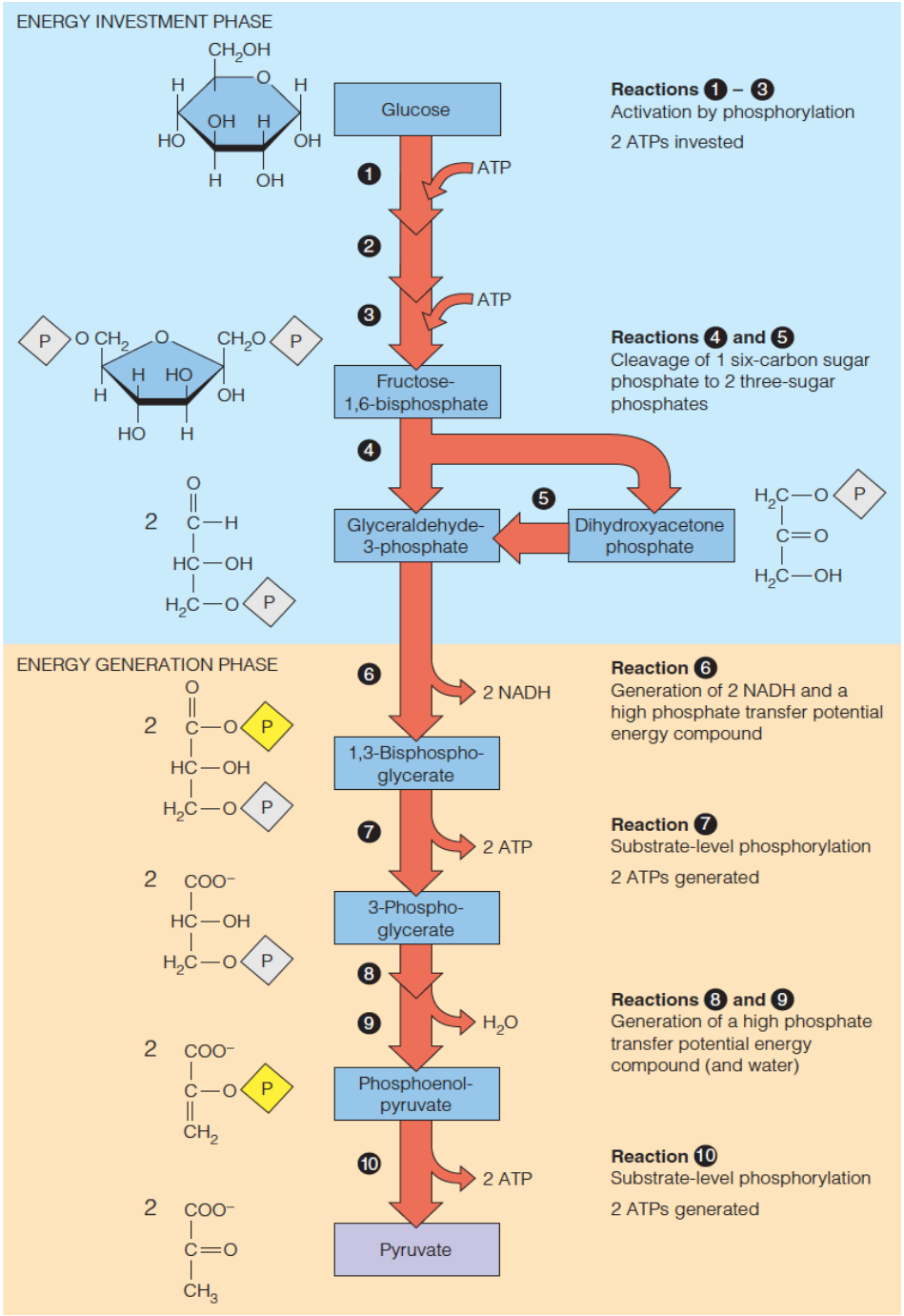


Reactions of Glycolysis

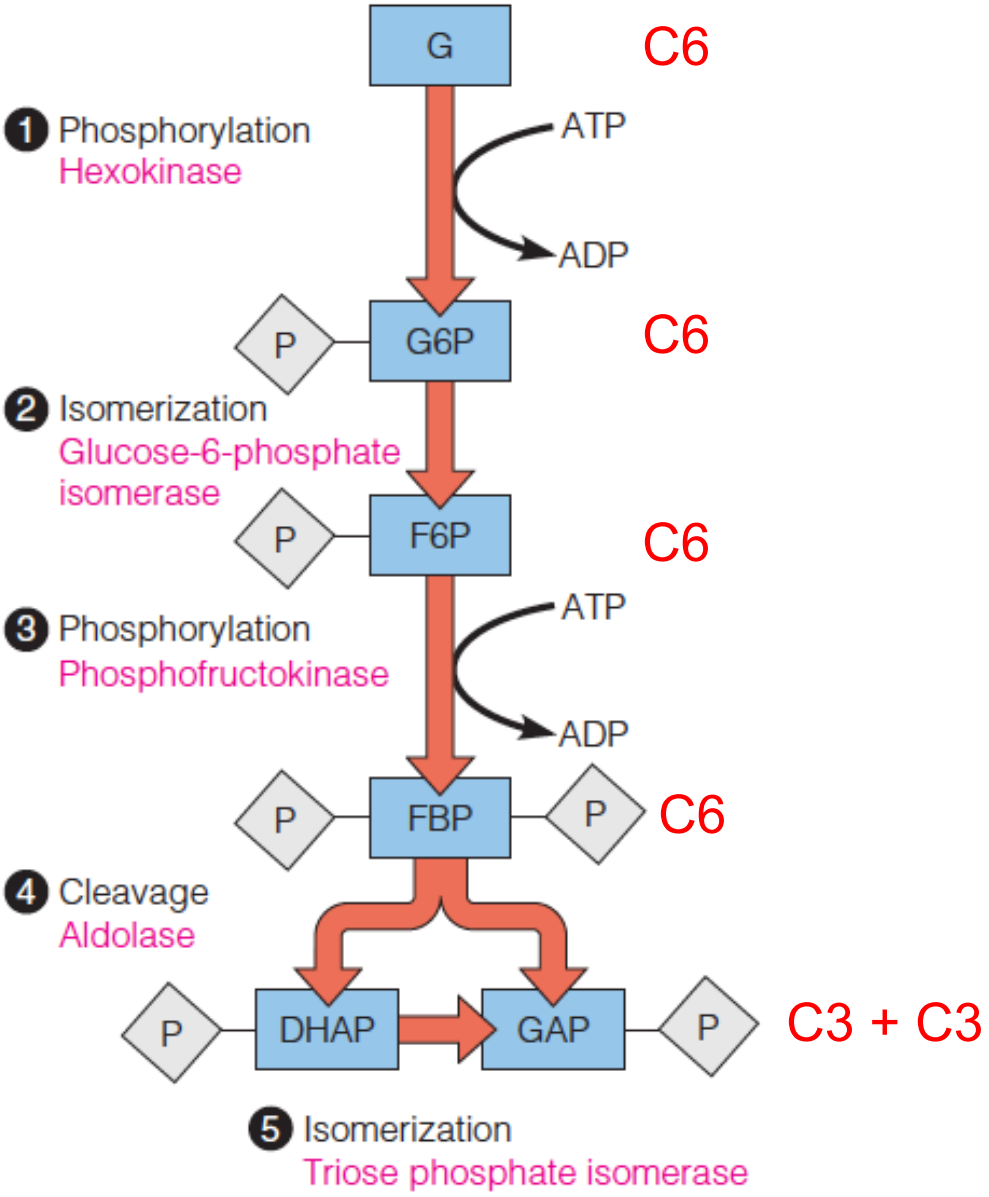
An overview of glycolysis:

- This condensed view of glycolysis shows the key intermediates and reactions in each of the two major phases.

- In the energy-generating phase, two ATPs are produced for each ATP utilized in the energy-investment phase.



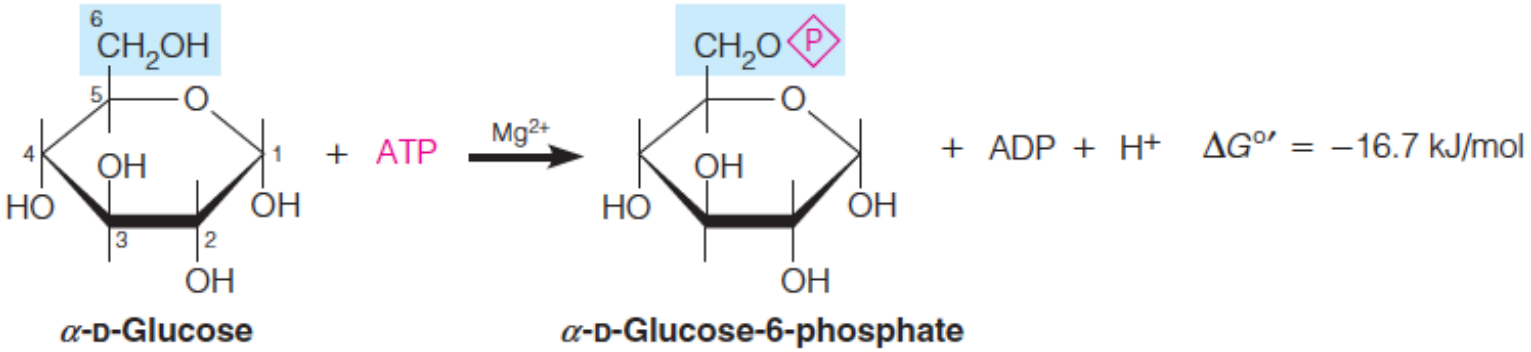
Glycolysis(*energy-investment phase*)



Glycolysis

Reaction 1: The First ATP Investment

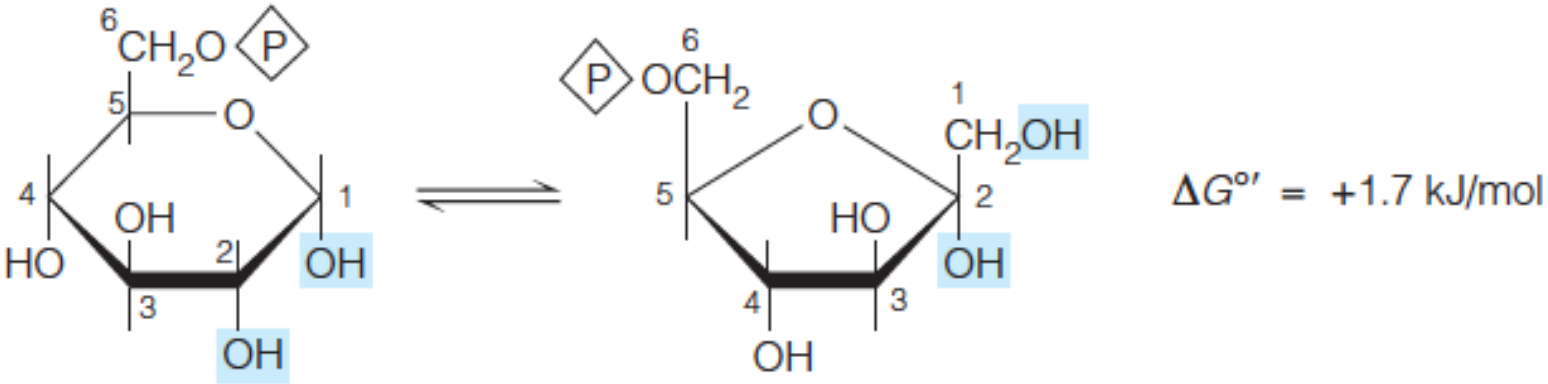
Glycolysis begins with the ATP-dependent phosphorylation of glucose, catalyzed by ***hexokinase***.



Glycolysis

Reaction 2: Isomerization of Glucose-6-phosphate.

•The next reaction, catalyzed by **glucose-6-phosphate isomerase** (also called phosphoglucoisomerase), is the readily reversible isomerization of the aldose, glucose-6-phosphate (G6P), to the corresponding ketose, fructose-6-phosphate (F6P).



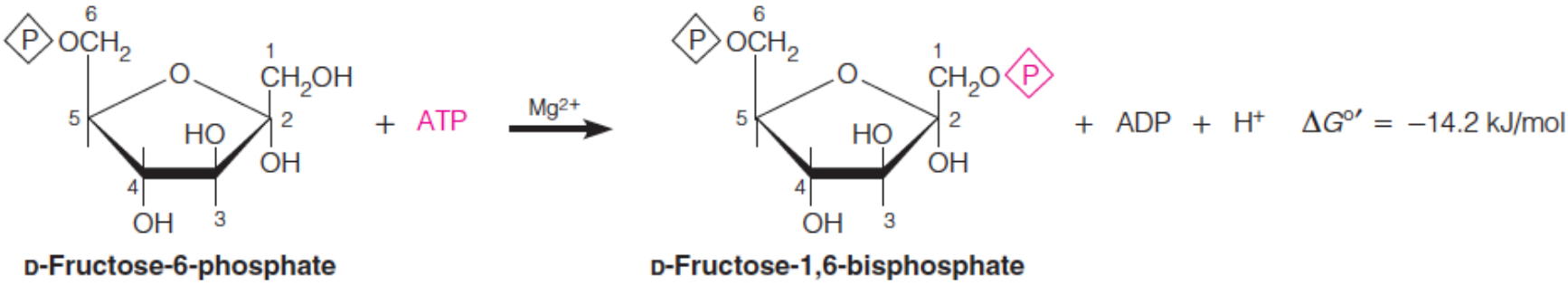
α-D-Glucose-6-phosphate

D-Fructose-6-phosphate

Glycolysis

Reaction 3: The Second Investment of ATP

•***Phosphofructokinase*** catalyzes a second ATP-dependent phosphorylation, to give a hexose derivative, fructose-1,6-bisphosphate (FBP), phosphorylated at both carbons 1 and 6.



D-Fructose-6-phosphate

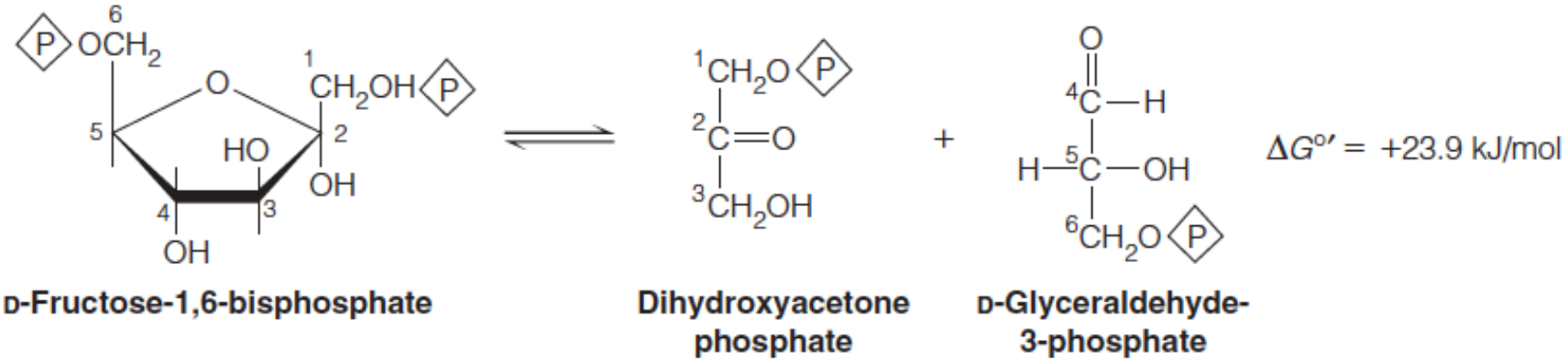
D-Fructose-1,6-bisphosphate

Glycolysis

Reaction 4: Cleavage to Two Triose Phosphates

•**Fructose-1,6-bisphosphate aldolase,** catalyzes the "splitting of sugar" that is connoted by the term glycolysis.

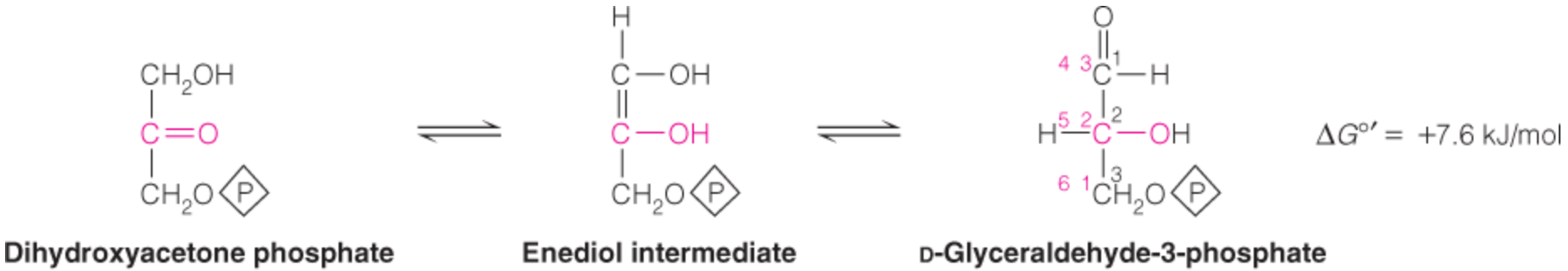
•The six-carbon sugar fructose-1,6-bisphosphate is cleaved to give 2 three-carbon intermediates, glyceraldehyde-3-phosphate and dihydroxyacetone phosphate (DHAP).



Glycolysis

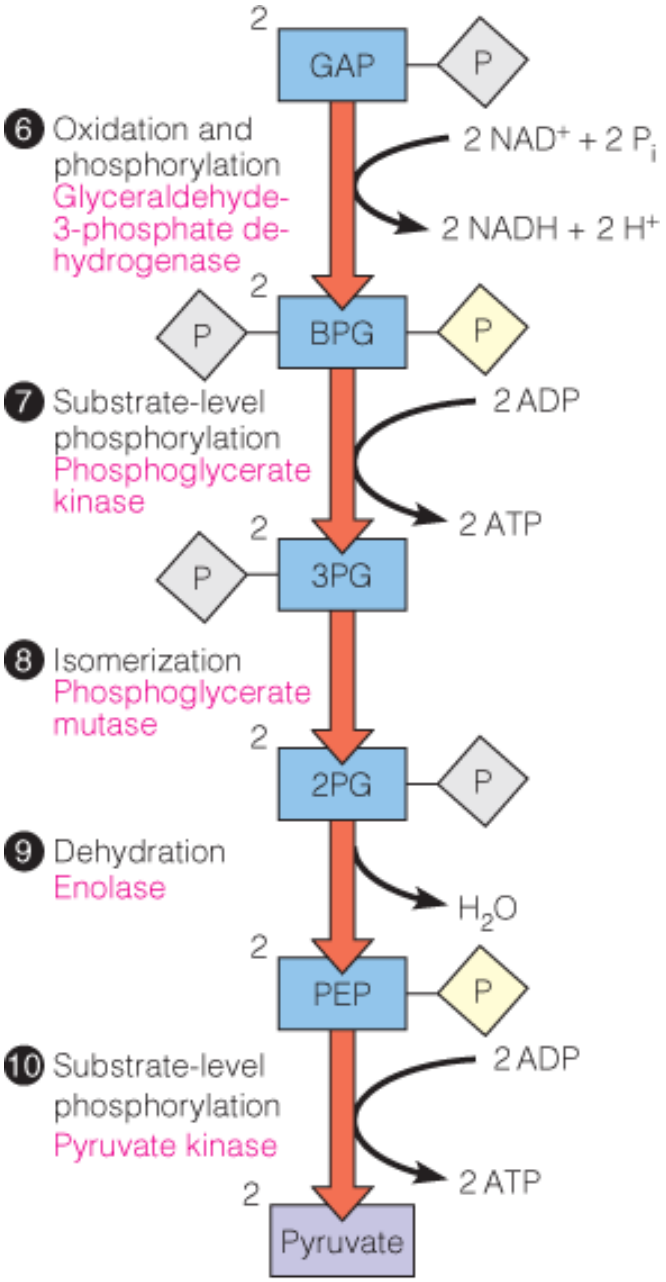
Reaction 5: Isomerization of Dihydroxyacetone Phosphate

•The function of reaction 5, catalyzed by **triose phosphate isomerase**, is conversion of one of the products from reaction 4, dihydroxyacetone phosphate (DHAP), to the other, glyceraldehyde-3-phosphate (GAP).



Dihydroxyacetone phosphate **Enediol intermediate** **D-Glyceraldehyde-3-phosphate**

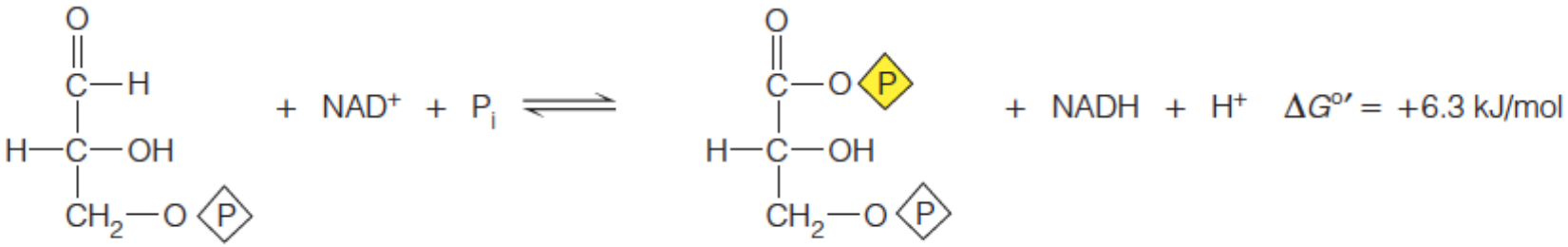
Glycolysis(energy generation phase)



Glycolysis

Reaction 6: Generation of the First Energy-Rich Compound

•This reaction, catalyzed by ***glyceraldehyde-3-phosphate dehydrogenase***, is among the most important in glycolysis, partly because it generates the first intermediate with high phosphate transfer potential and partly because it generates a pair of reducing equivalents.



D-Glyceraldehyde-3-phosphate

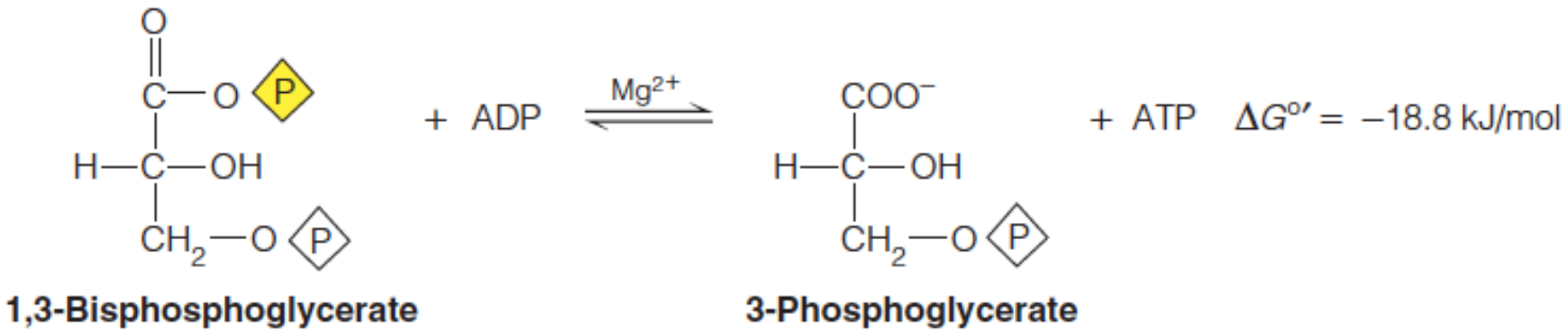
1,3-Bisphosphoglycerate

Glycolysis

Reaction 7: The First Substrate-Level Phosphorylation

•Because of its high phosphate transfer potential, 1,3-bisphosphoglycerate has a strong tendency to transfer its acyl-phosphate group to ADP, with resultant formation of ATP.

•This substrate-level phosphorylation reaction is catalyzed by ***phosphoglycerate kinase.***



Reactions of Glycolysis

- Phosphoglycerate kinase catalyzes the first glycolytic reaction that forms ATP.
- The glyceraldehyde-3-phosphate dehydrogenase and phosphoglycerate kinase are thermodynamically coupled:

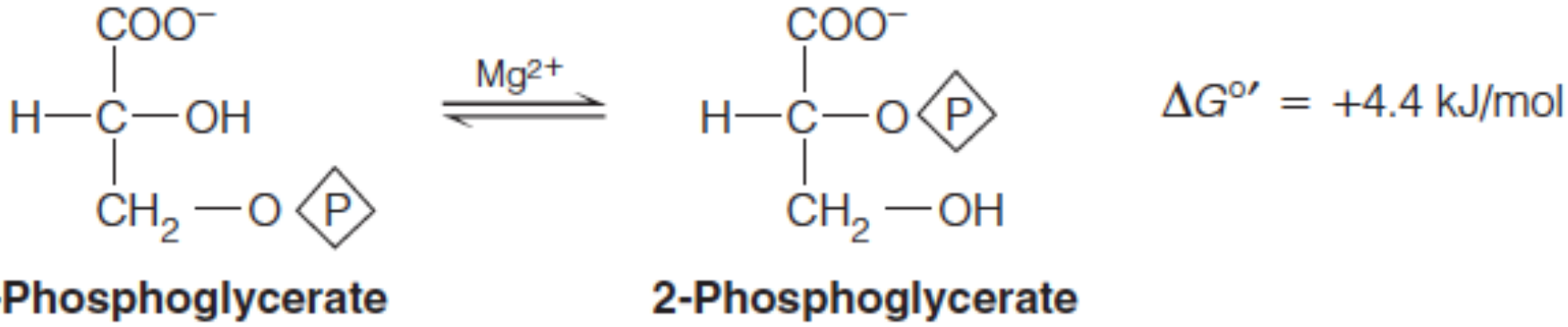
	$\Delta G^{\circ\prime}$ (kJ/mol)
glyceraldehyde-3-P + P_i + NAD^+ → 1,3-bisphosphoglycerate + NADH + H^+	+6.3
1,3-bisphosphoglycerate + ADP → 3-phosphoglycerate + ATP	−18.8
glyceraldehyde- 3-P + P_i + ADP + NAD^+ → 3-phosphoglycerate + ATP + NADH + H^+	$\Delta G^{\circ\prime}_{Sum} = -12.5$

Glycolysis

Reaction 8: Preparing for Synthesis of the Next High-Energy Compound

•Activation of 3-phosphoglycerate begins with an isomerization catalyzed by ***phosphoglycerate mutase***.

•The enzyme transfers phosphate from position 3 to position 2 of the substrate to yield 2-phosphoglycerate.



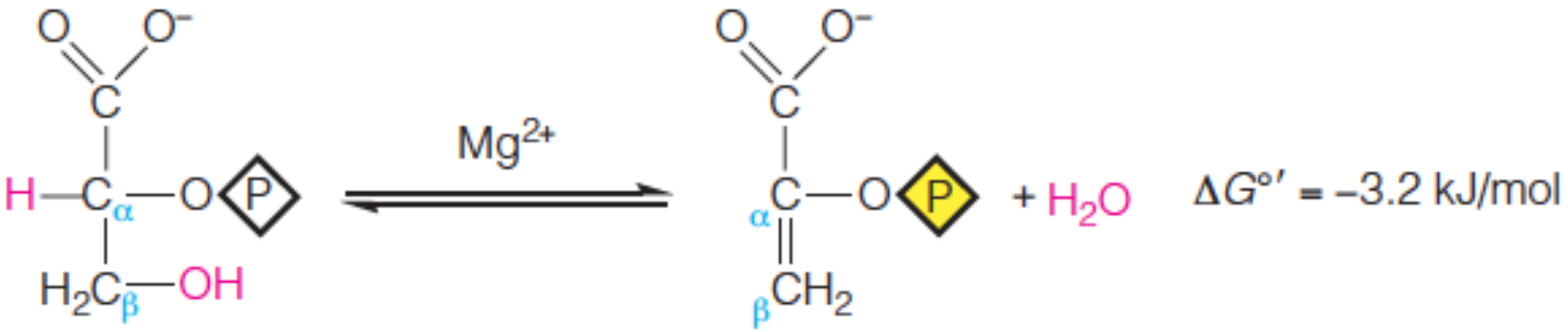
3-Phosphoglycerate **2-Phosphoglycerate**

Reactions of Glycolysis

Reaction 9: Synthesis of the Second High-Energy Compound

•Reaction 9, catalyzed by ***enolase***, generates phosphoenolpyruvate (PEP), another compound with very high phosphate transfer potential.

•PEP participates in the second substrate-level phosphorylation of glycolysis.

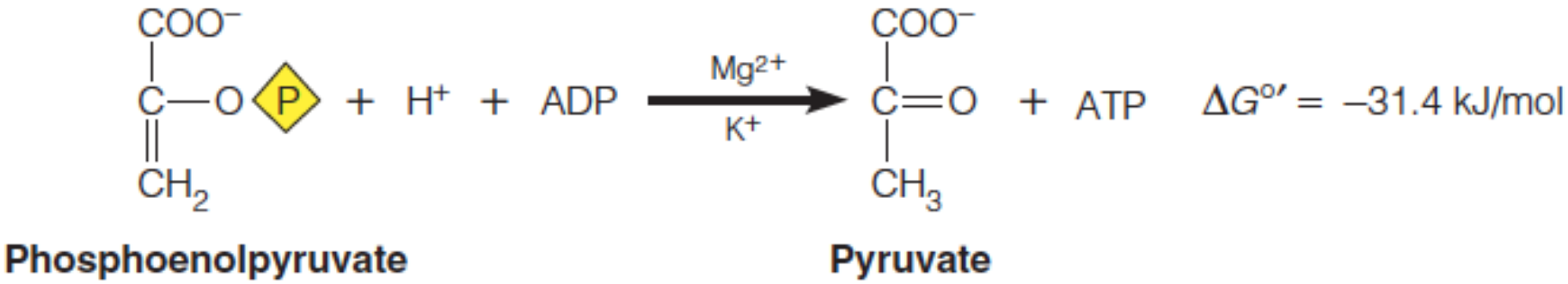


2-Phosphoglycerate **Phosphoenolpyruvate**

Reactions of Glycolysis

Reaction 10: The Second Substrate-Level Phosphorylation

•In the last reaction, catalyzed by ***pyruvate kinase***, phosphoenolpyruvate transfers its phosphoryl group to ADP in another substrate-level phosphorylation.



Pyruvate kinase deficiency

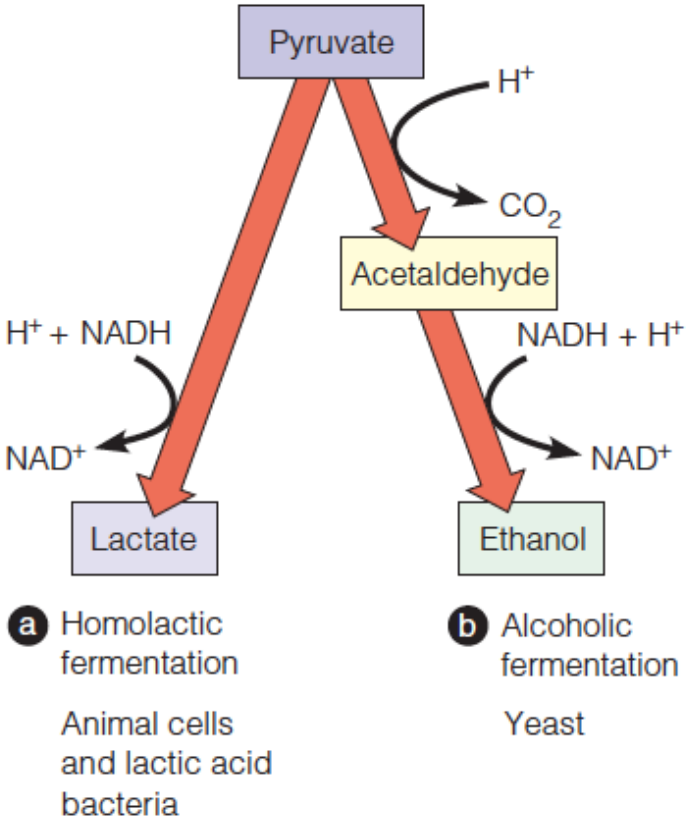
•**Pyruvate kinase deficiency**, also called **erythrocyte pyruvate kinase deficiency**.

•Pyruvate kinase deficiency is the second most common cause of enzyme-deficient **hemolytic anemia**, following G6PD deficiency.

•Human genetic deficiencies of erythrocyte pyruvate kinase causes accumulation of PEP and 2,3-BPG in blood, and 2,3-BPG inhibits the oxygen binding to hemoglobin.

Metabolic Fates of Pyruvate

- Pyruvate must be reduced to lactate when tissues are insufficiently aerobic to oxidize all of the NADH formed in glycolysis.
- Microorganisms can oxidize NADH via fermentations producing lactate or ethanol.

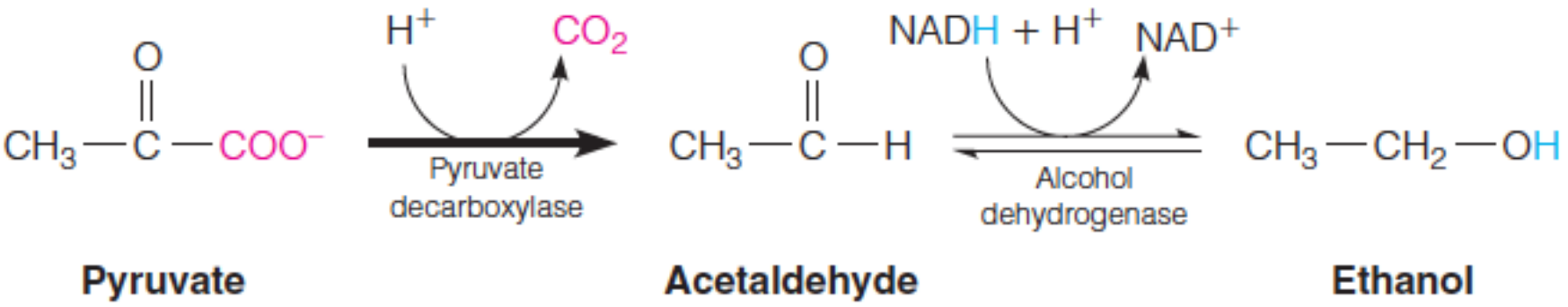


Metabolic Fates of Pyruvate

Yeast converts pyruvate to ethanol in a two-step pathway:

•This alcoholic fermentation starts with the nonoxidative decarboxylation of pyruvate to acetaldehyde, catalyzed by ***pyruvate decarboxylase***.

•NAD^+ is regenerated in the next reaction, the NADH-dependent reduction of acetaldehyde to ethanol, catalyzed by ***alcohol dehydrogenase.***

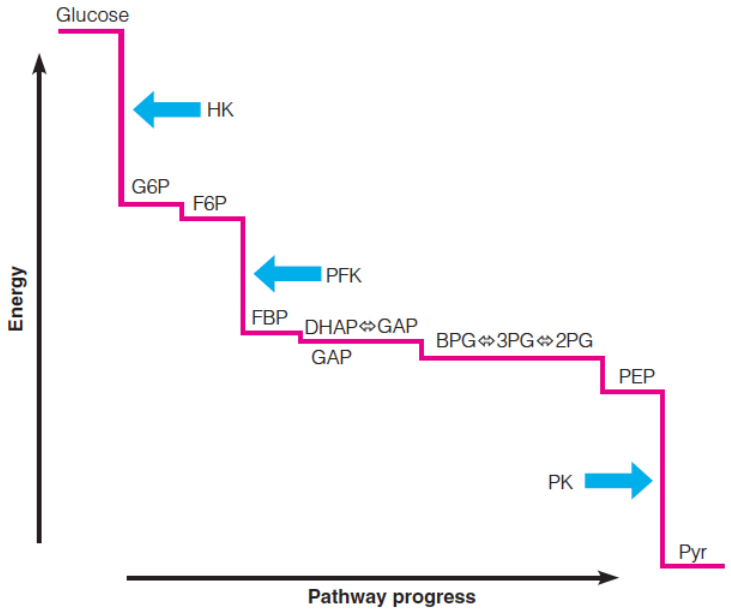


Energy and Electron Balance Sheets

Energy profile of anaerobic glycolysis:

•Most of the reactions function at or near equilibrium and are freely reversible *in vivo*.

•The three enzymes that catalyze reactions so highly exergonic as to be virtually irreversible(arrows) are subject to allosteric control.



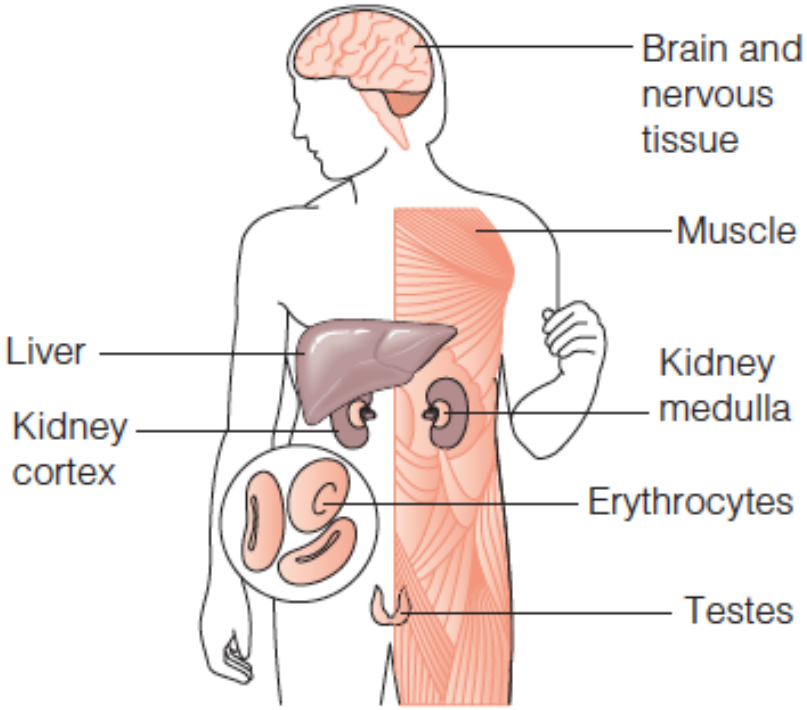
Gluconeogenesis

Synthesis and use of glucose in the human body:

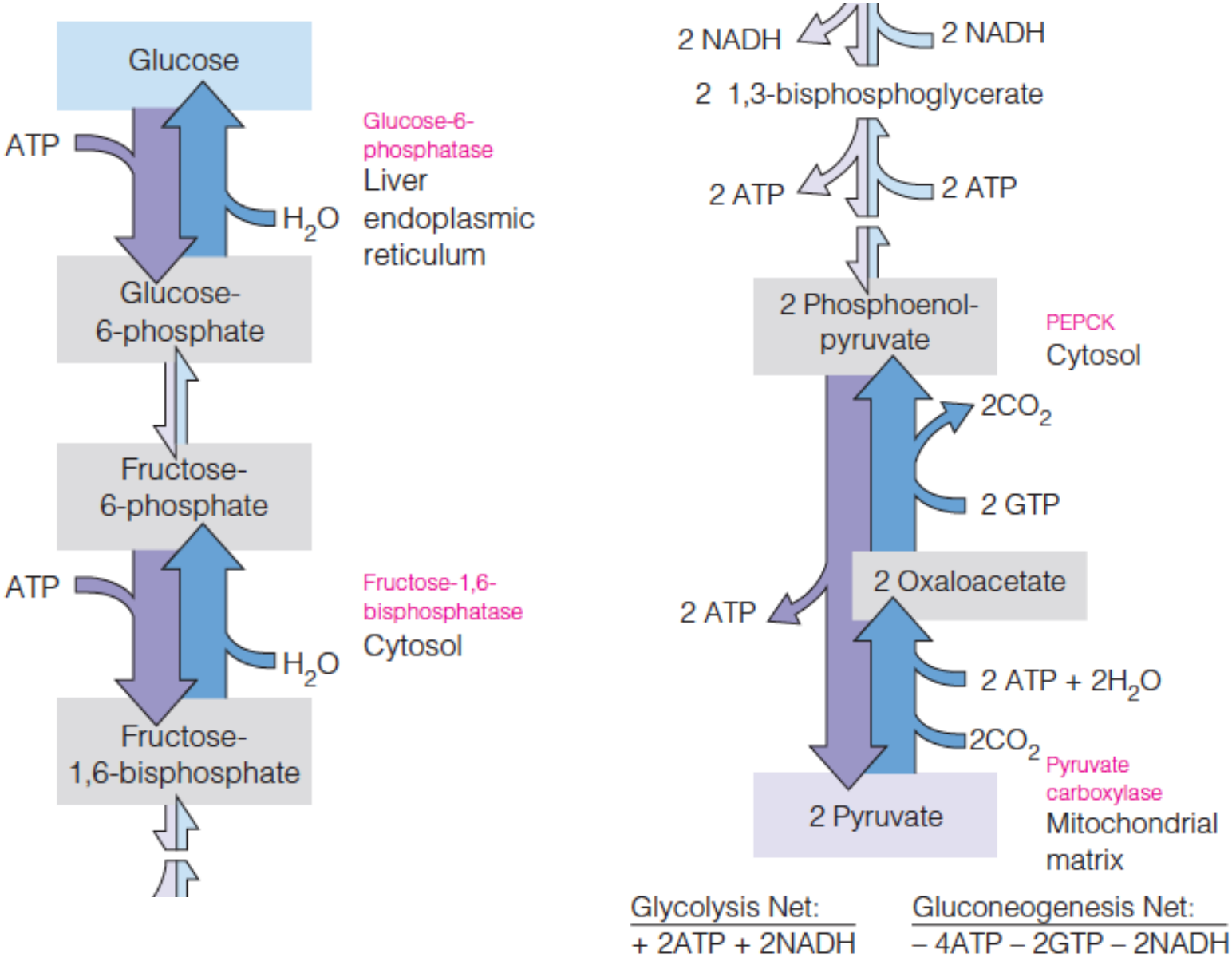
•**Liver** and **kidney cortex** are the primary gluconeogenic tissues.

•Brain, skeletal muscle, kidney medulla, erythrocytes, and testes use glucose as their sole or primary energy source, but they lack the enzymatic machinery to synthesize it.

•Synthesis of glucose from noncarbohydrate precursors is essential for maintenance of blood glucose levels within acceptable limits.



Reactions of glycolysis and gluconeogenesis:



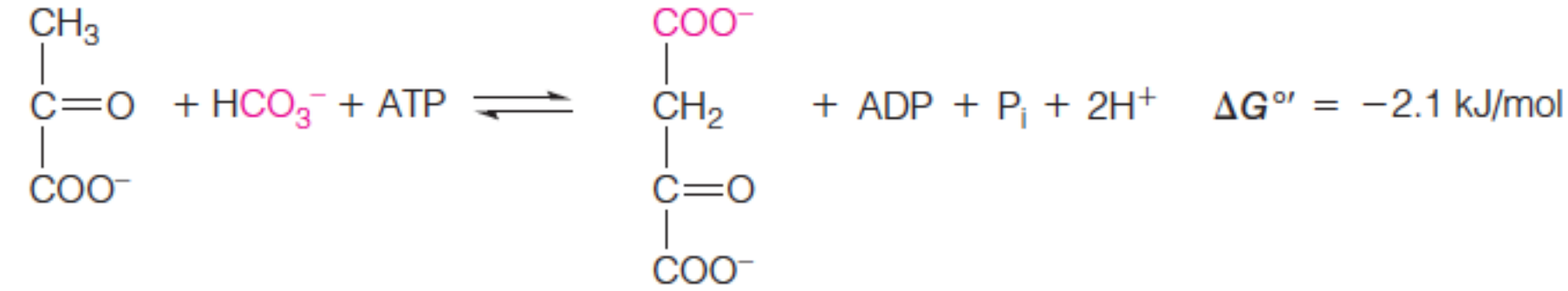
Gluconeogenesis

Bypass 1: Conversion of Pyruvate to Phosphoenolpyruvate

•The bypass of pyruvate kinase begins in the mitochondrion and involves two reactions.

•Pyruvate carboxylase catalyzes the ATP- and biotin-dependent conversion of pyruvate to oxaloacetate.

•The enzyme requires acetyl-CoA as an allosteric activator:



Pyruvate **Oxaloacetate**

Gluconeogenesis

- To be used for gluconeogenesis, **oxaloacetate must move out of the mitochondrion to the cytosol**, where the remainder of the pathway occurs.

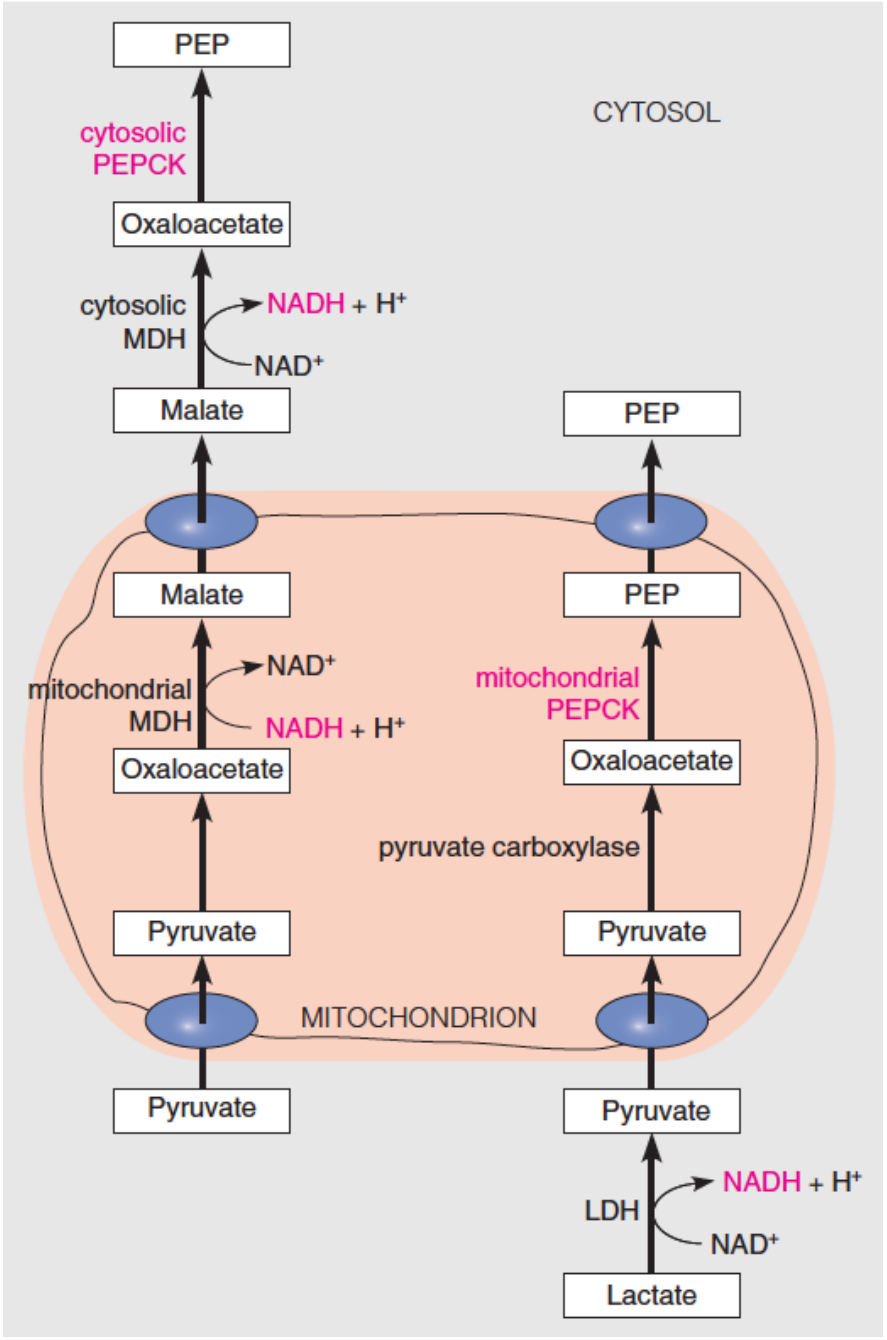
- However, the mitochondrial membrane does not have an effective transporter for oxaloacetate.

- Therefore, oxaloacetate is reduced by mitochondrial malate dehydrogenase to malate, which is transported into the cytosol by exchange for orthophosphate and then reoxidized by cytosolic malate dehydrogenase.

- Once in the cytosol, oxaloacetate is acted on by ***phosphoenolpyruvate carboxykinase*** (PEPCK) to give phosphoenolpyruvate:

Gluconeogenesis

PEPCK isozymes provide alternative routes to PEP and cytoplasmic reducing equivalents:

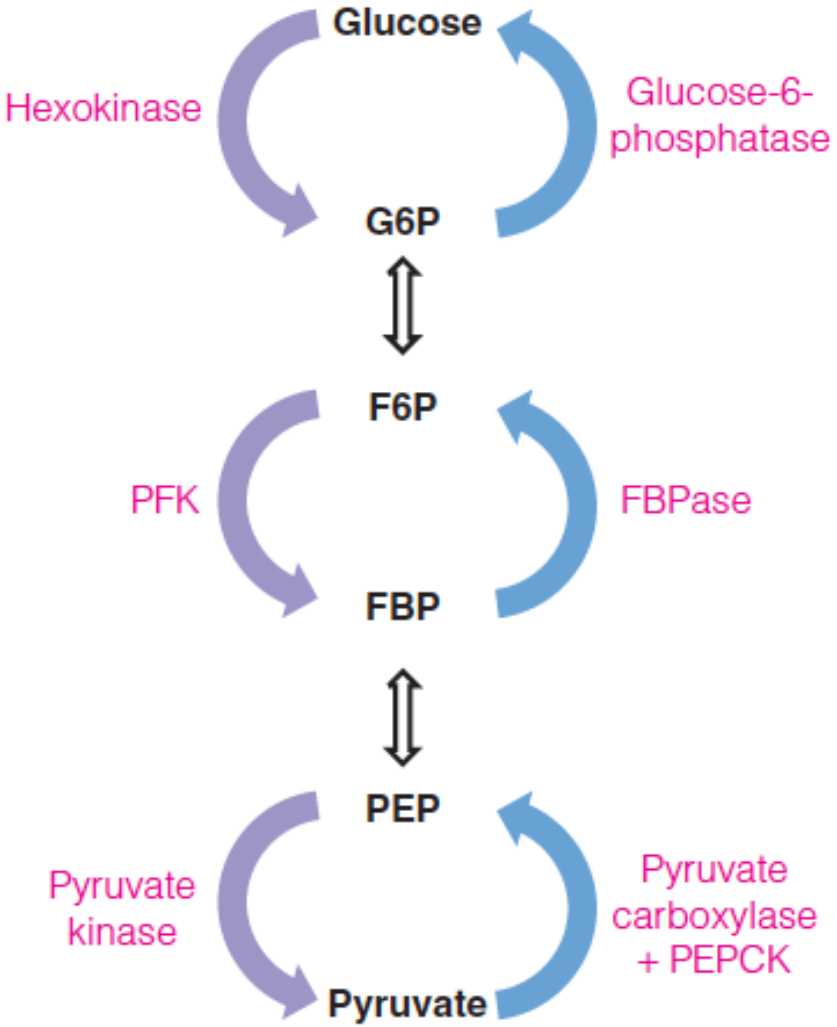


Gluconeogenesis

- **Bypass 2: Conversion of Fructose-1,6-bisphosphate to Fructose-6-phosphate**
    - The PFK reaction of glycolysis is essentially irreversible, but only because it is driven by phosphate transfer from ATP.
    - A bypass reaction in gluconeogenesis involves a simple hydrolytic reaction, catalyzed by **fructose-1,6- bisphosphatase**.
- **Bypass 3: Conversion of Glucose-6-phosphate to Glucose**
    - Glucose-6-phosphate cannot be converted to glucose by reverse action of hexokinase or glucokinase because of the high positive ΔG^o of that reaction; phosphate transfer from ATP makes that reaction virtually irreversible.
    - Another enzyme specific to gluconeogenesis, ***glucose-6-phosphatase,*** also involves a simple hydrolysis.

Coordinated Regulation of Glycolysis and Gluconeogenesis

Comparative substrate cycles in glycolysis/gluconeogenesis:

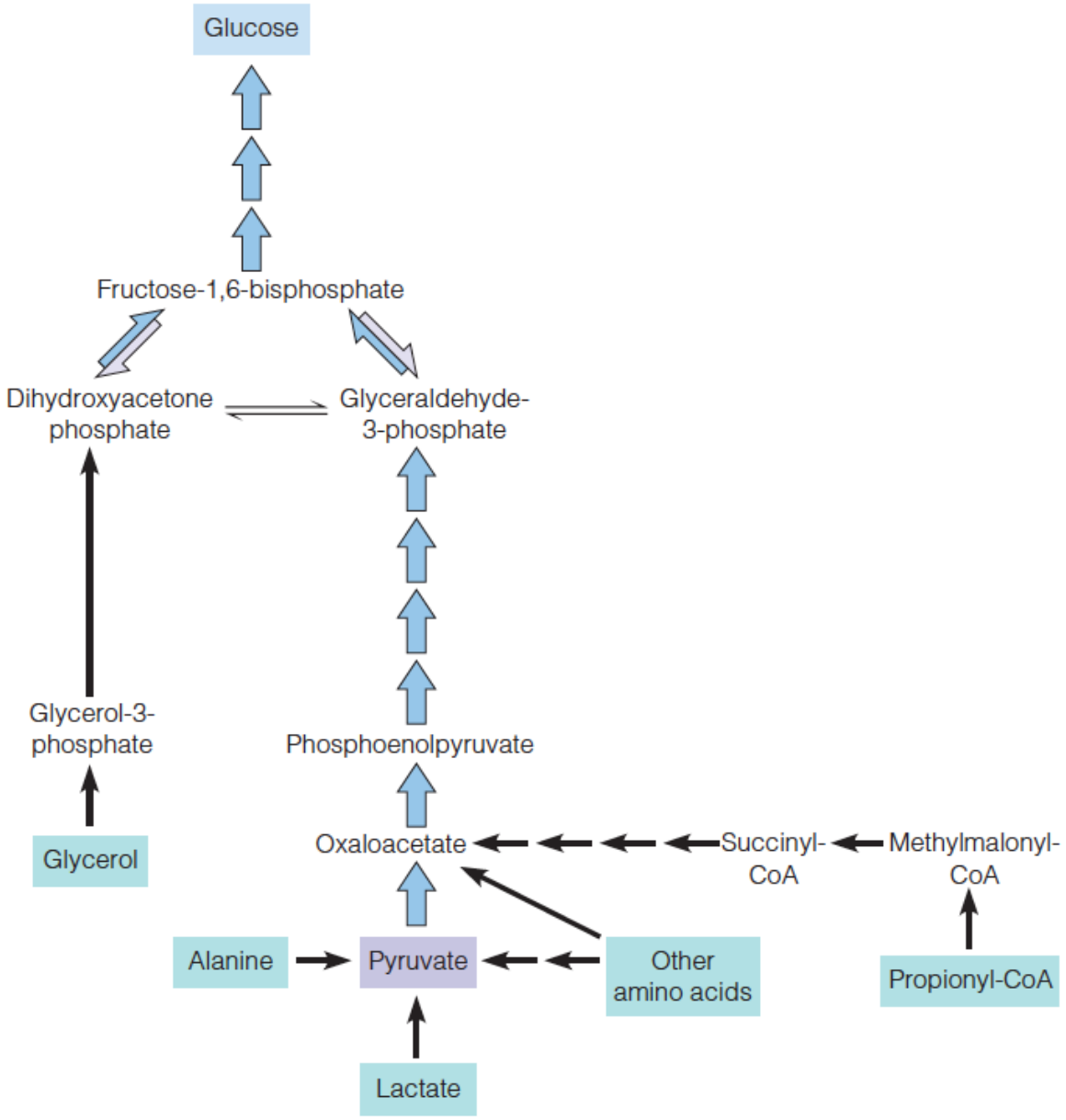


Gluconeogenesis

TABLE 13.2 Summary of gluconeogenesis, from pyruvate to glucose

Reaction	$\Delta G^{\circ\prime}$ (kJ/mol)
Pyruvate + HCO_3^- + ATP $\longrightarrow$ oxaloacetate + ADP + P_i	−2.1 (−4.2)
Oxaloacetate + GTP $\rightleftharpoons$ phosphoenolpyruvate + CO_2 + GDP	+2.9 (+5.8)
Phosphoenolpyruvate + H_2O $\rightleftharpoons$ 2-phosphoglycerate	+6.4 (+12.8)
2-Phosphoglycerate $\rightleftharpoons$ 3-phosphoglycerate	−4.4 (−8.8)
3-Phosphoglycerate + ATP $\rightleftharpoons$ 1,3-bisphosphoglycerate + ADP	+18.8 (+37.6)
1,3-Bisphosphoglycerate + NADH + H^+ $\rightleftharpoons$ glyceraldehyde-3-phosphate + NAD^+ + P_i	−6.3 (−12.6)
Glyceraldehyde-3-phosphate $\rightleftharpoons$ dihydroxyacetone phosphate	−7.6
Glyceraldehyde-3-phosphate + dihydroxyacetone phosphate $\rightleftharpoons$ fructose-1,6-bisphosphate	−23.9
Fructose-1,6-bisphosphate + H_2O $\longrightarrow$ fructose-6-phosphate + P_i	−16.3
Fructose-6-phosphate $\rightleftharpoons$ glucose-6-phosphate	−1.7
Glucose-6-phosphate + H_2O $\longrightarrow$ glucose + P_i	−13.8
Net: 2 Pyruvate + 4ATP + 2GTP + 2NADH + $2H^+$ + $4H_2O$ $\longrightarrow$ glucose + 4ADP + 2GDP + $6P_i$ + $2NAD^+$	−32.7

Gluconeogenesis (gluconeogenic precursors)

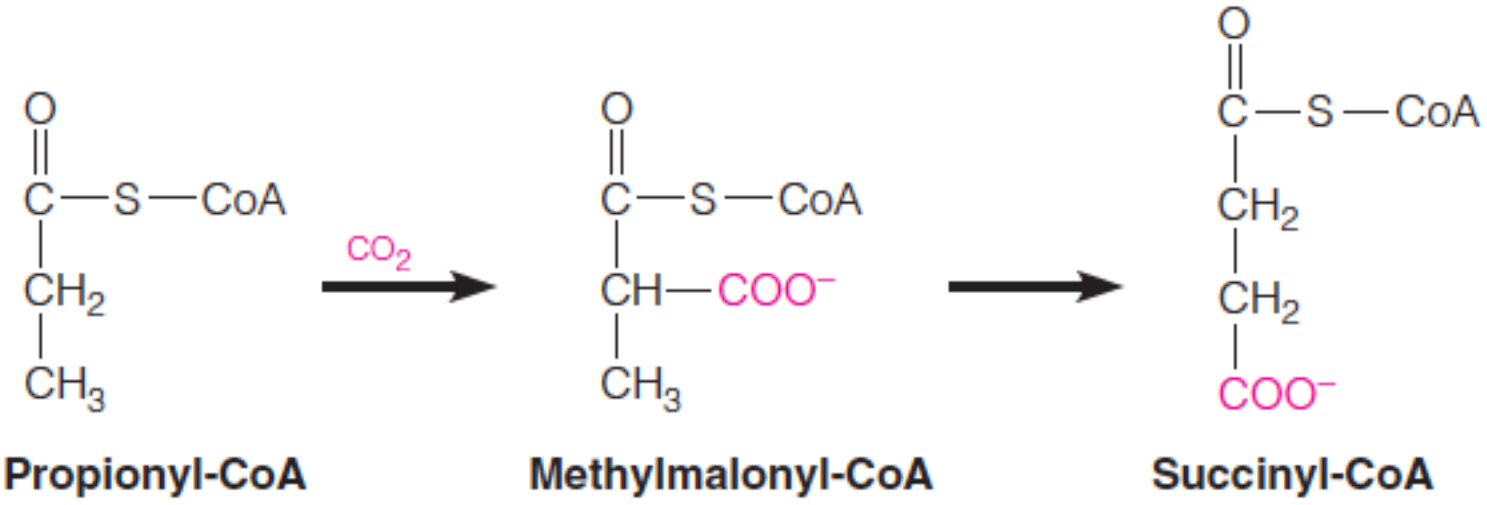


Gluconeogenesis

- In all organisms a three-carbon acyl-CoA, ***propionyl-CoA***, is generated either from the breakdown of some amino acids or from the oxidation of **fatty acids with odd numbers of carbon** atoms.

- Propionyl-CoA enters gluconeogenesis via its conversion to succinyl-CoA and then to oxaloacetate.

- The process involves a coenzyme derived from vitamin B_{12}.

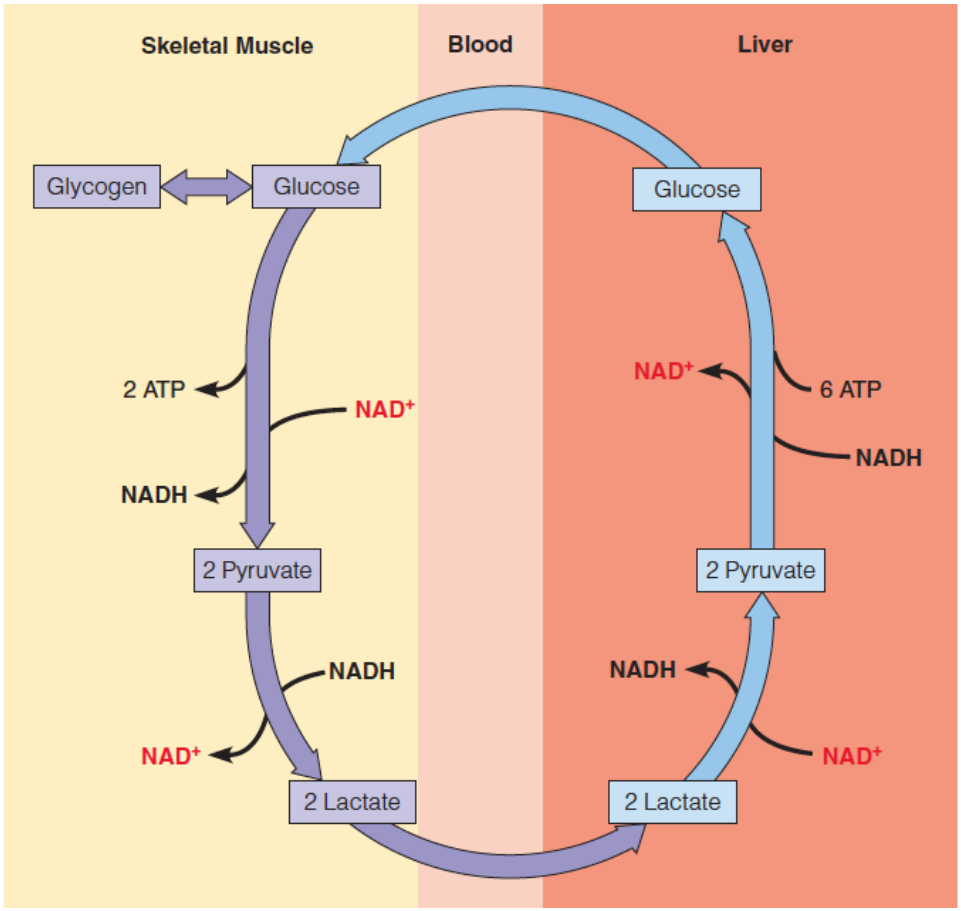


Gluconeogenesis

The Cori cycle:

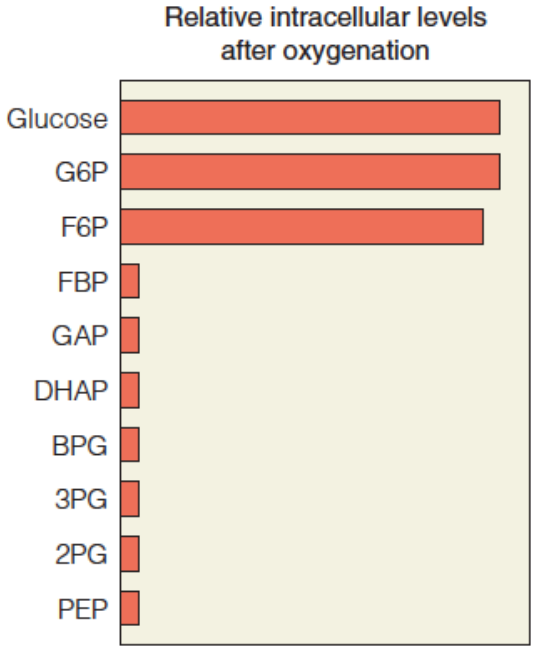
•Lactate produced in glycolysis during muscle exertion is transported to the liver, for resynthesis of glucose by gluconeogenesis.

•Transport of glucose back to muscle for synthesis of glycogen, and its reutilization in glycolysis, completes the cycle.



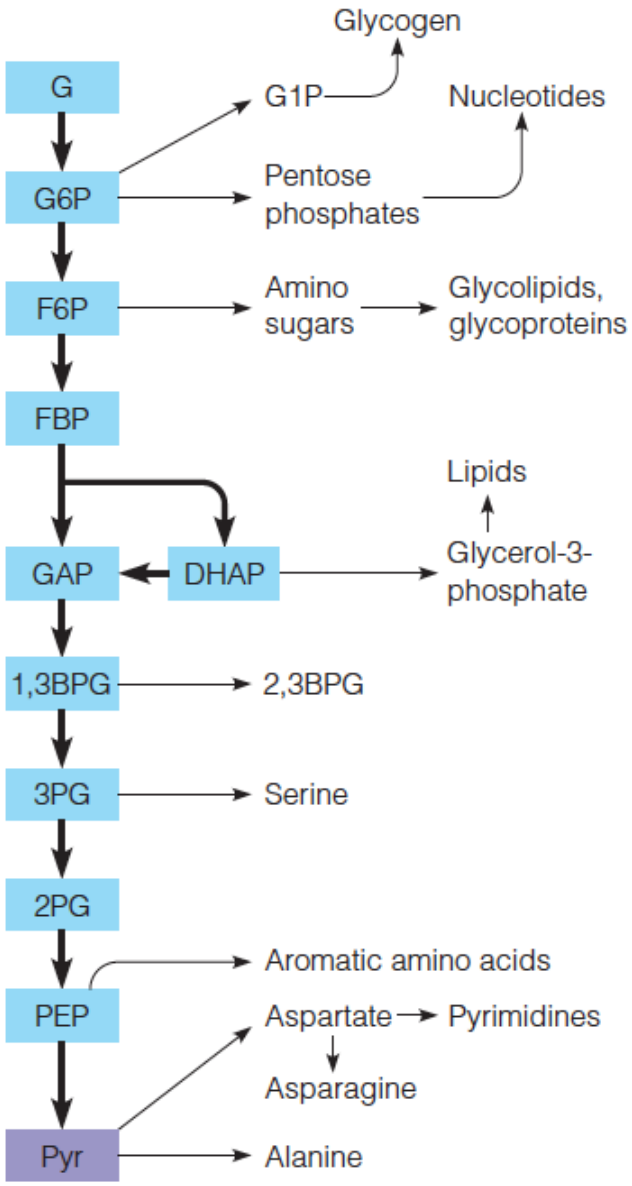
Coordinated Regulation of Glycolysis and Gluconeogenesis

- Louis Pasteur observed that when anaerobic yeast cultures metabolizing glucose were exposed to air, the rate of glucose utilization decreased dramatically.
- It became clear that this phenomenon, known as the ***Pasteur effect***, involves the **inhibition of glycolysis by oxygen.**
- This effect makes biological sense because far more energy is derived from complete oxidation of glucose than from glycolysis alone.



Coordinated Regulation of Glycolysis and Gluconeogenesis

Alternative fates of glycolytic intermediates in biosynthetic pathways:



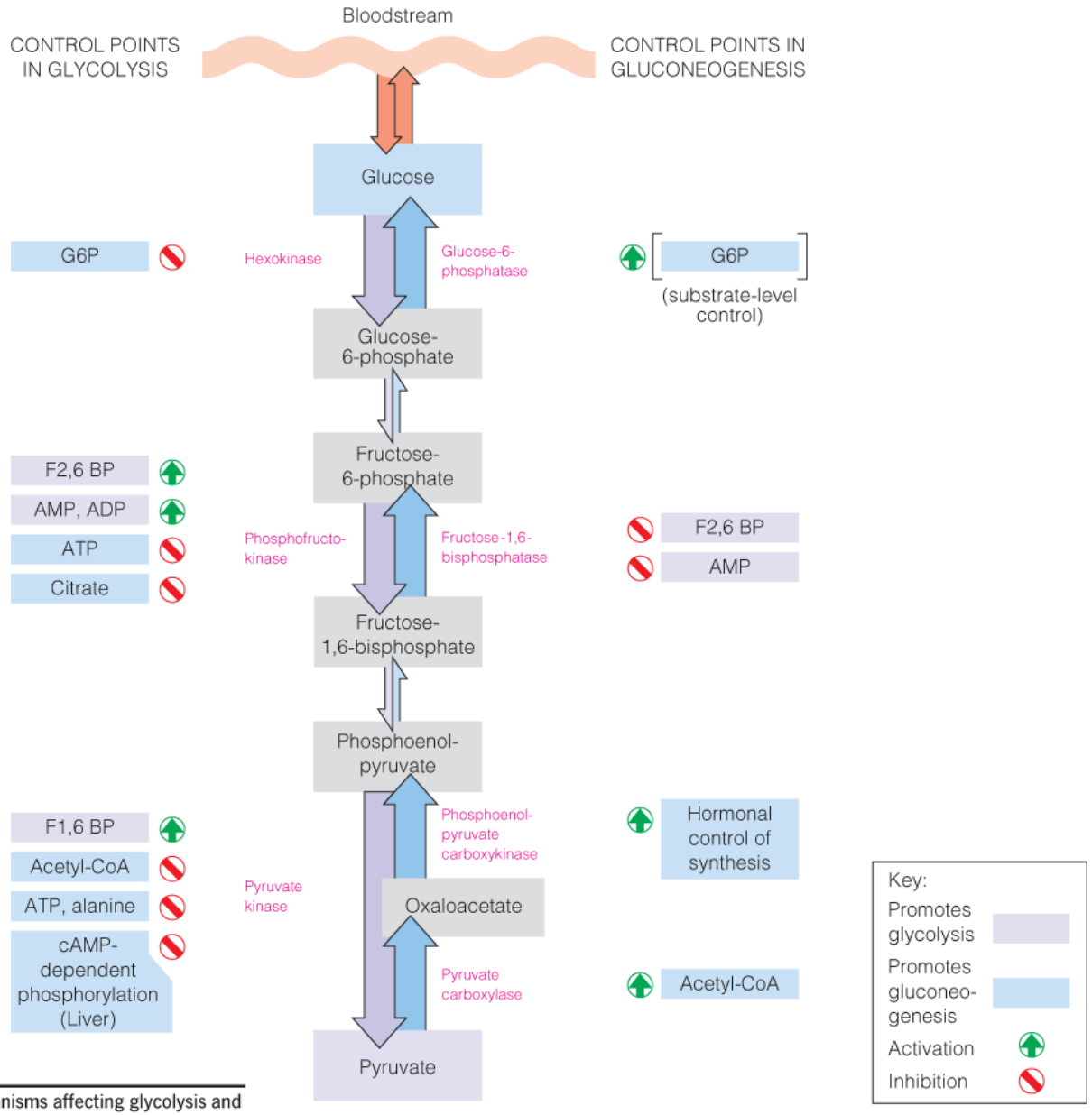


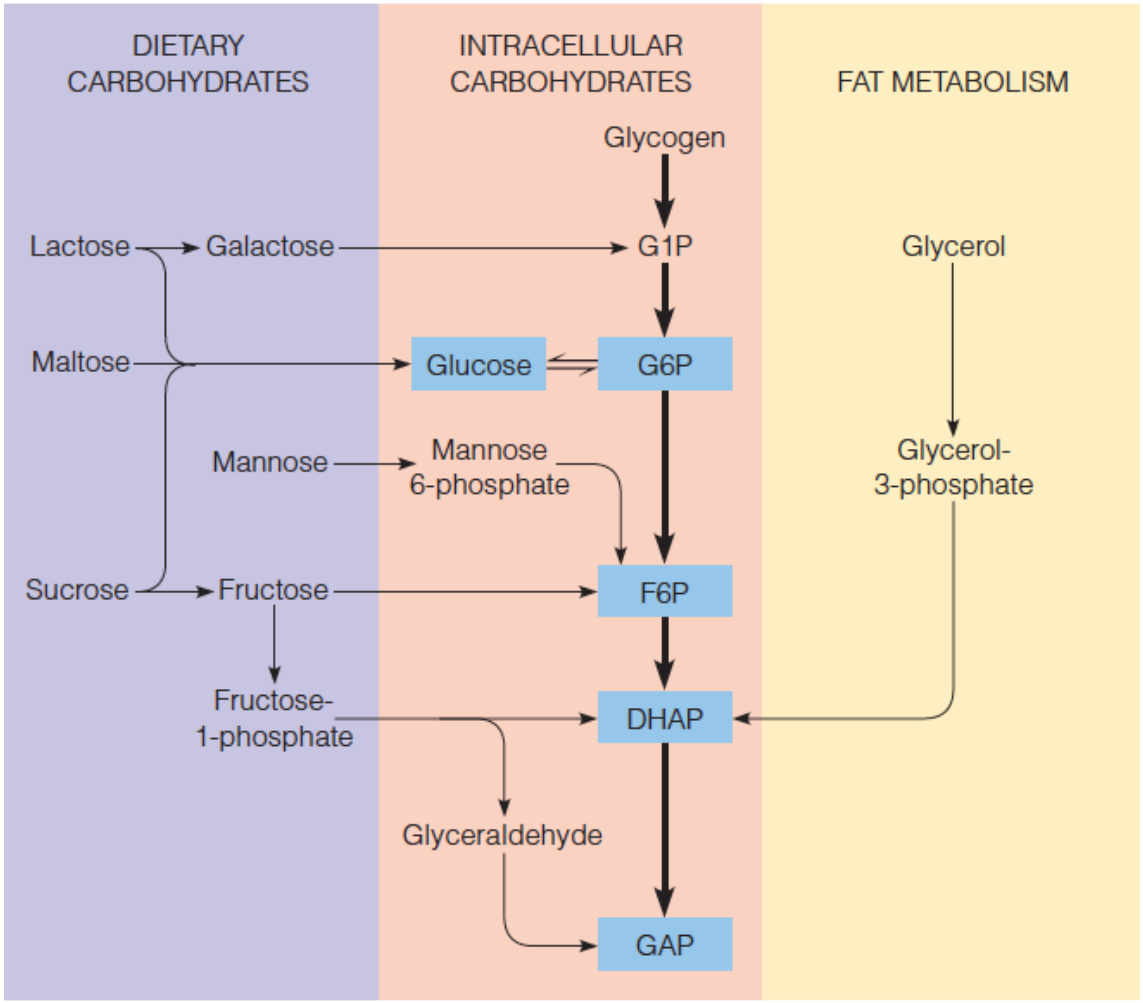
FIGURE 13.18

Major control mechanisms affecting glycolysis and gluconeogenesis. The figure shows the strongly exergonic reactions of glycolysis and gluconeogenesis and the major activators and inhibitors of these reactions.

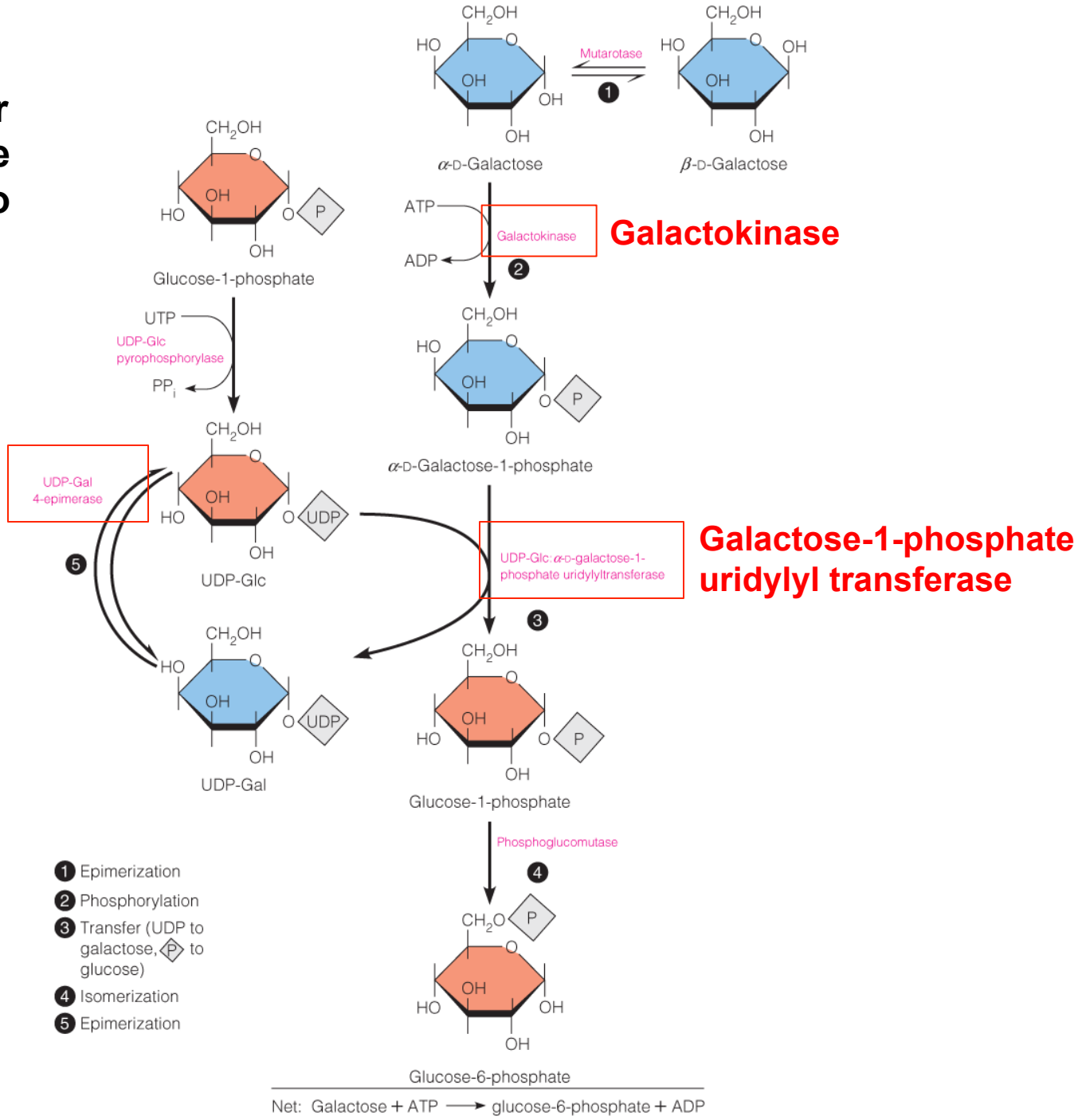
Entry of Other Sugars into the Glycolytic Pathway

Routes for utilizing substrates other than glucose in glycolysis:

•In animals, most of the carbohydrate other than glucose and glycogen comes from the diet, and most of the glycerol is derived from lipid catabolism.



Leloir pathway for utilizing galactose by converting it to glucose-6-phosphate:

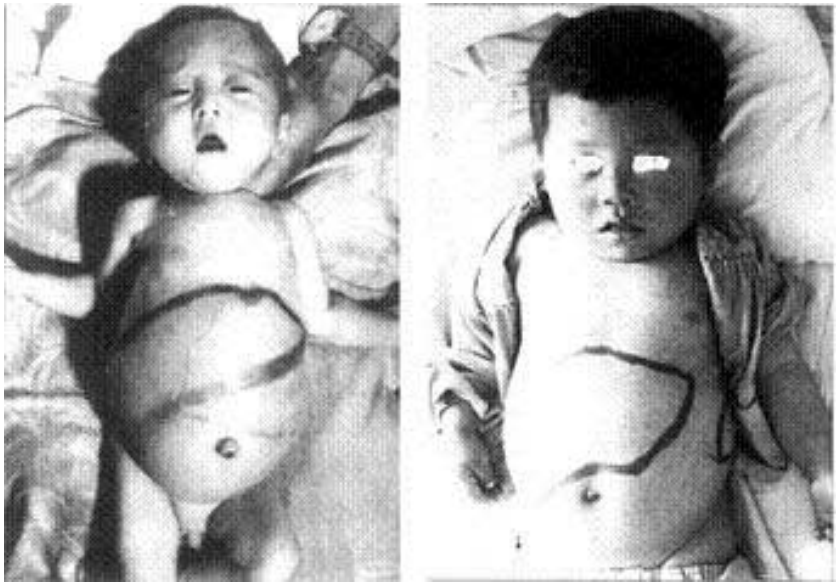


Galactosemia（半乳糖血症）

Most common form:
deficiency of UDP-glucose: **Galactose-1-phosphate uridylyl transferase**

Rarer form: deficiency of **Galactokinase** or **UDP-galactose-4-epimerase**

Clinical symptom:
Mental retardation
Visual cataracts
Enlargement of the liver and other organs

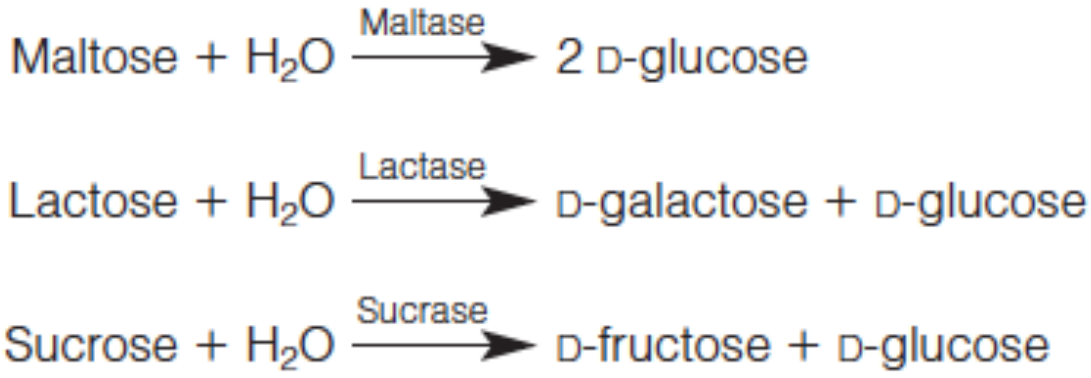


Entry of Other Sugars into the Glycolytic Pathway

The three disaccharides most abundant in foods are maltose, lactose, and sucrose:

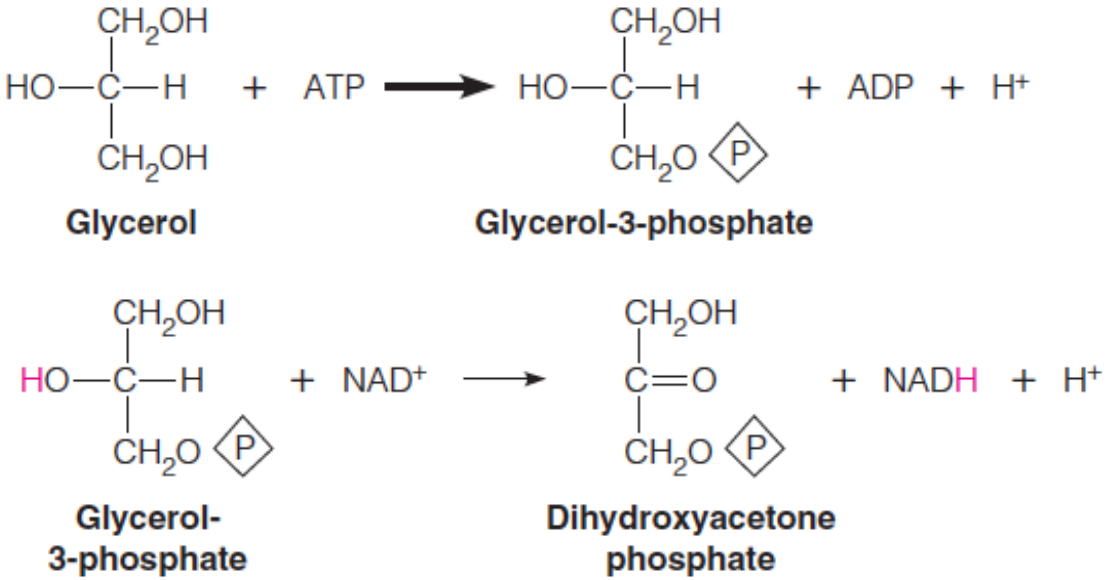
•Maltose is available primarily as an artificial sweetener, derived from starch, while lactose and sucrose are abundant natural products.

•In animal metabolism they are hydrolyzed in cells lining the small intestine, to give the constituent hexose sugars:



Entry of Other Sugars into the Glycolytic Pathway

- The digestion of neutral fat (triacylglycerols) and most phospholipids generates glycerol as one product.
- In animals, glycerol first enters the glycolytic pathway by the action in liver of ***glycerol kinase***.
- The product is then oxidized by glycerol-3-phosphate dehydrogenase to yield dihydroxyacetone phosphate, which is catabolized by glycolysis.



Polysaccharide Metabolism

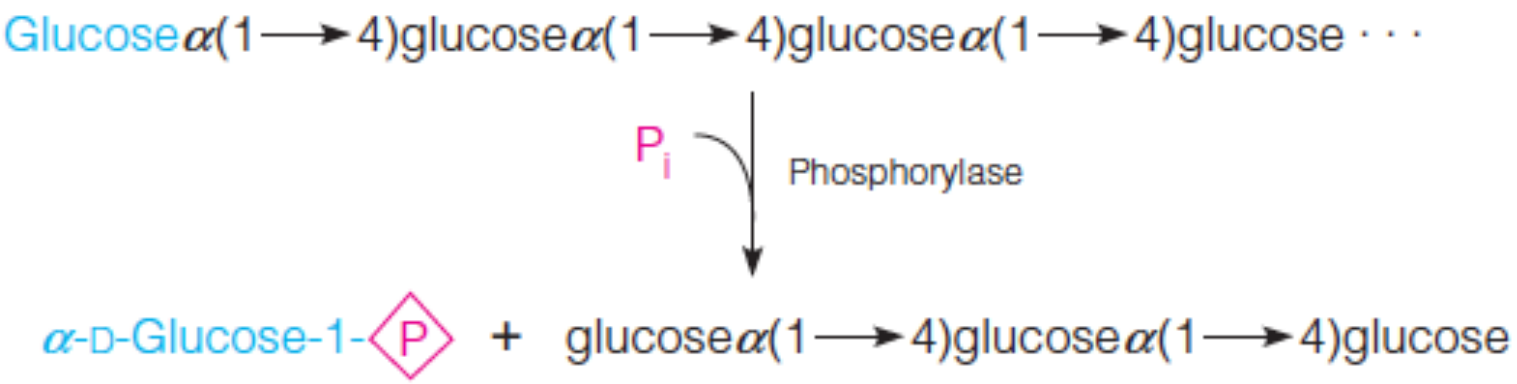
- In animal metabolism, two primary sources of glucose are derived from polysaccharides:

  1. Digestion of dietary polysaccharides, chiefly starch from plant foodstuffs and glycogen from meat.

  2. Mobilization of the animal's own glycogen reserves.

Glycogen Metabolism in Muscle and Liver

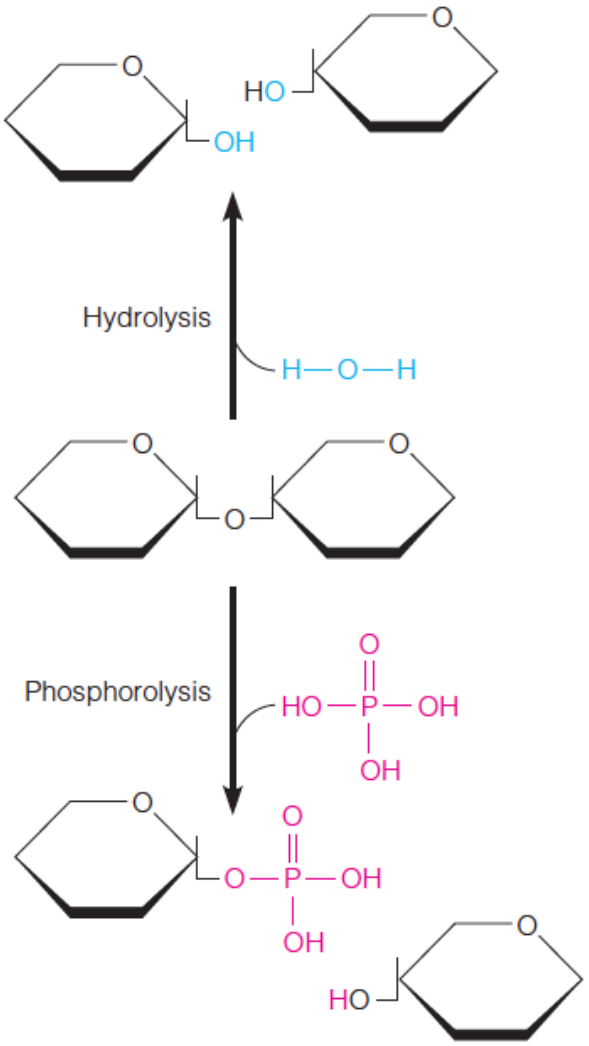
- The principal glycogen stores in vertebrates are in **skeletal muscle** and **liver**.
- Breakdown of these stores into usable energy, or mobilization of glycogen, involves sequential phosphorolytic cleavages of bonds, catalyzed by ***glycogen phosphorylase***.
- In plants, starch is similarly mobilized by the action of starch phosphorylase .
- Both reactions release **glucose-1-phosphate** from nonreducing ends of the glucose polymer:



Polysaccharide Metabolism

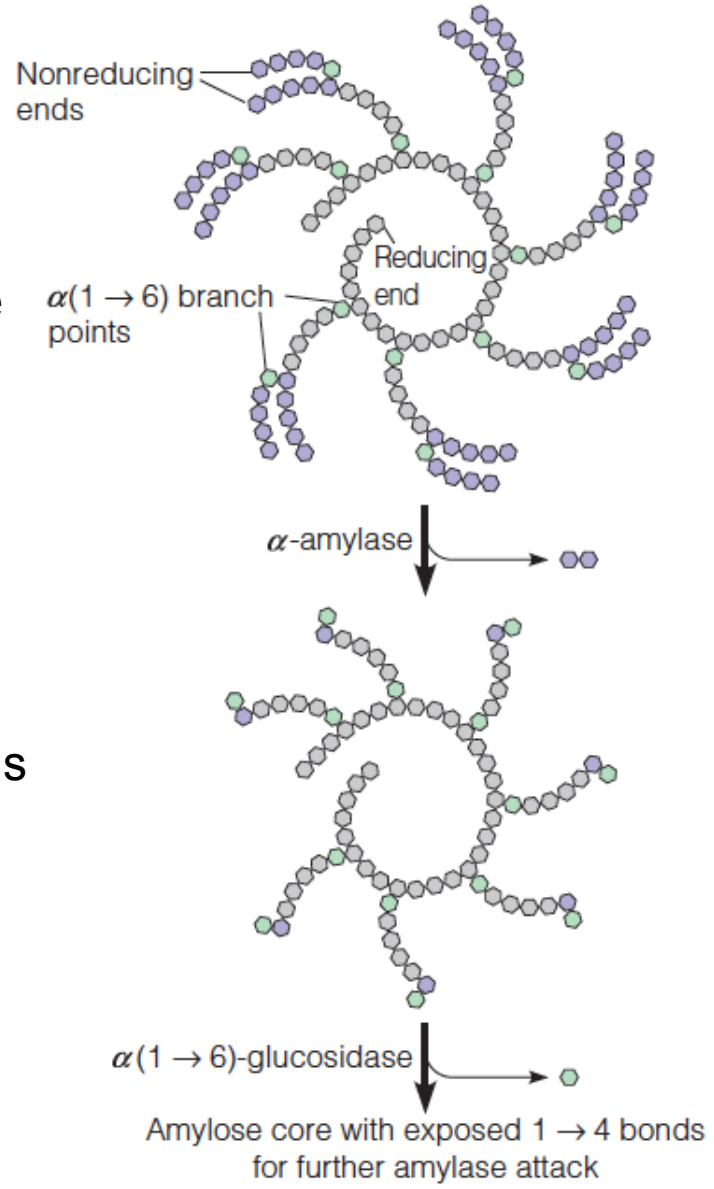
Cleavage of a glycosidic bond by hydrolysis or Phosphorolysis:

This formal diagram shows how the elements of water or phosphoric acid, respectively, are added across a glycosidic bond.



Polysaccharide Metabolism

- Dietary polysaccharides are metabolized by ***hydrolysis*** to monosaccharides.
- Intracellular carbohydrate stores, as glycogen, are mobilized as phosphorylated monosaccharides by ***phosphorolysis***.
- **α-Amylase** in saliva cleaves bonds $\alpha(1\rightarrow4)$ between the maltose units of amylopectin (or glycogen).
- However, it cannot cleave $\alpha(1\rightarrow6)$ glycosidic bonds in the branched polymer, and a limit dextrin accumulates unless ***$\alpha(1\rightarrow6)$-glucosidase*** (***debranching enzyme***) is present.
- (Type III Glycogen storage disease)



Glycogen Metabolism in Muscle and Liver

The debranching process in glycogen catabolism:

(a)A glycogen chain following activity by phosphorylase, which cleaves off glucose residues to within four residues of the branch point.

(b)The glycogen chain following transferase activity by the debranching enzyme. The three remaining glucose residues with linkage have been transferred to a nearby nonreducing end.

(c)The glycogen chain following α(1→6)-glucosidase activity by the debranching enzyme, which has removed the last remaining glucose residue of the branch.

•Phosphorylase will cleave off all but four glucose units of the newly elongated branch, beginning the debranching process again.

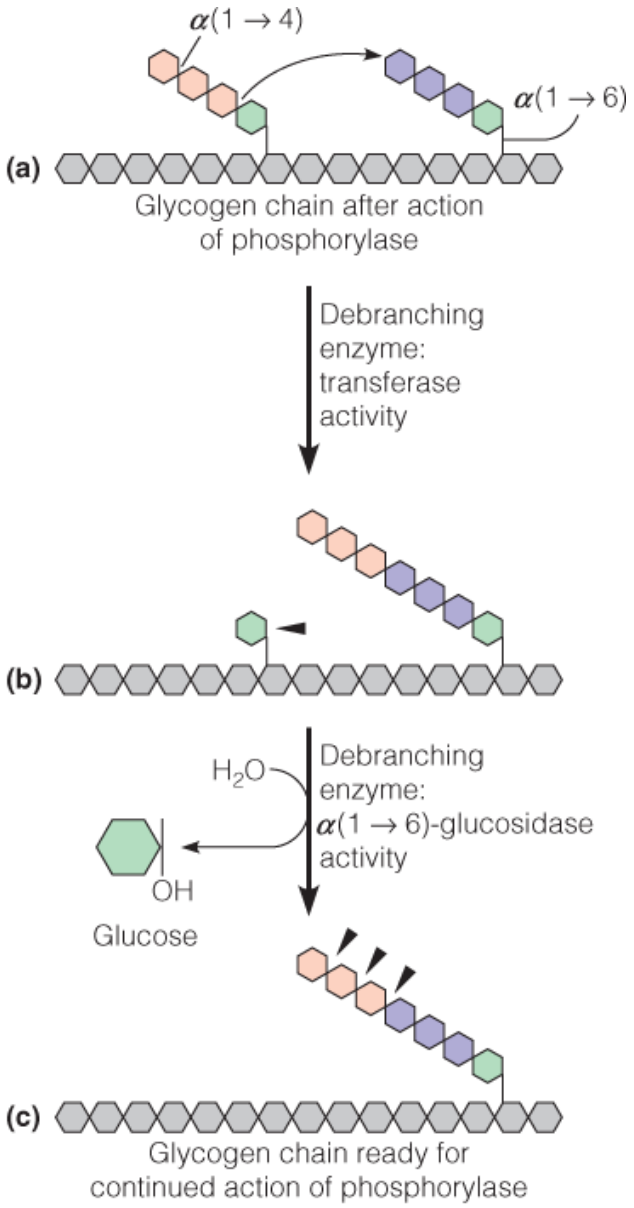


FIGURE 13.27

Glycogen Metabolism in Muscle and Liver

- ***UDP-glucose*** is the metabolically activated form of glucose for glycogen synthesis.
- Glycogen biosynthesis requires ***glycogen synthase*** for polymerization and a ***transglycosylase*** to create branches.

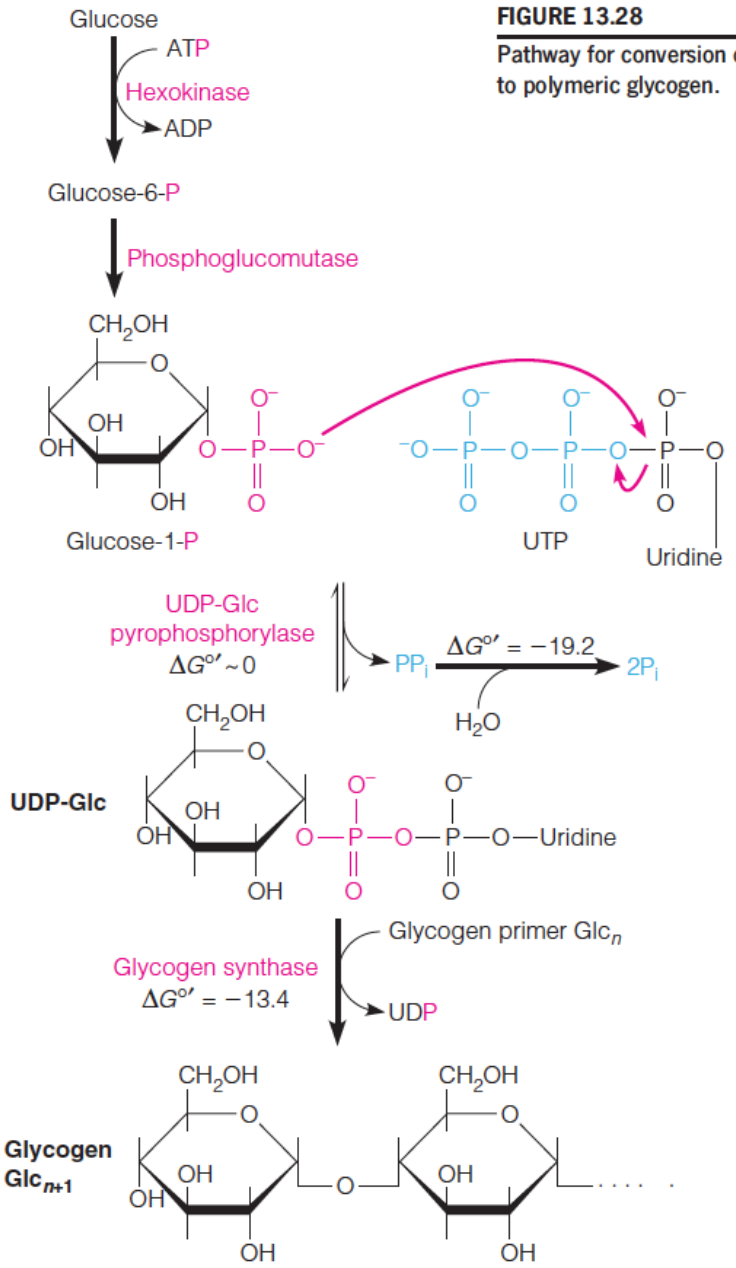
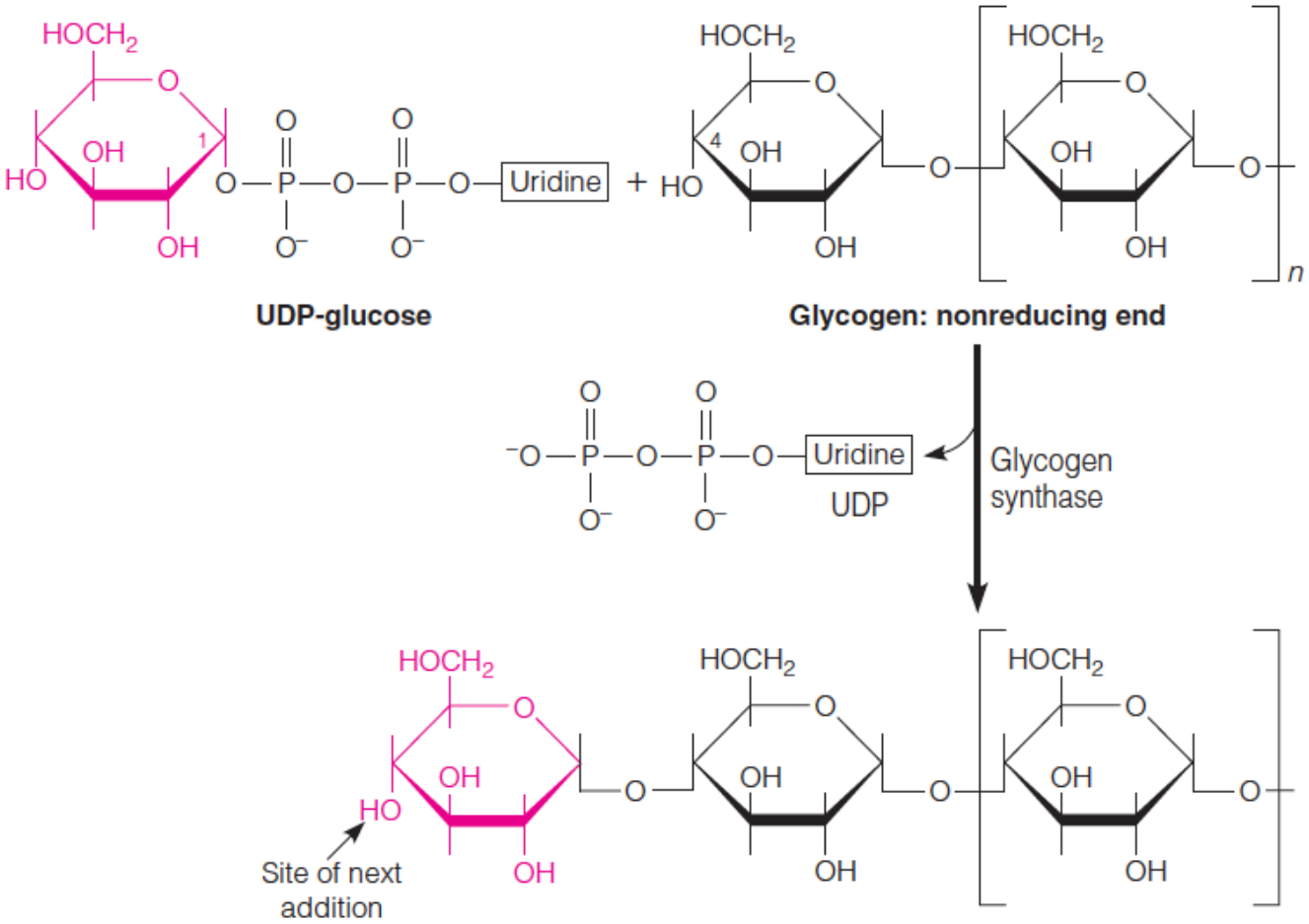


FIGURE 13.28
Pathway for conversion of glucose monomers to polymeric glycogen.

Glycogen Metabolism in Muscle and Liver

The glycogen synthase reaction:

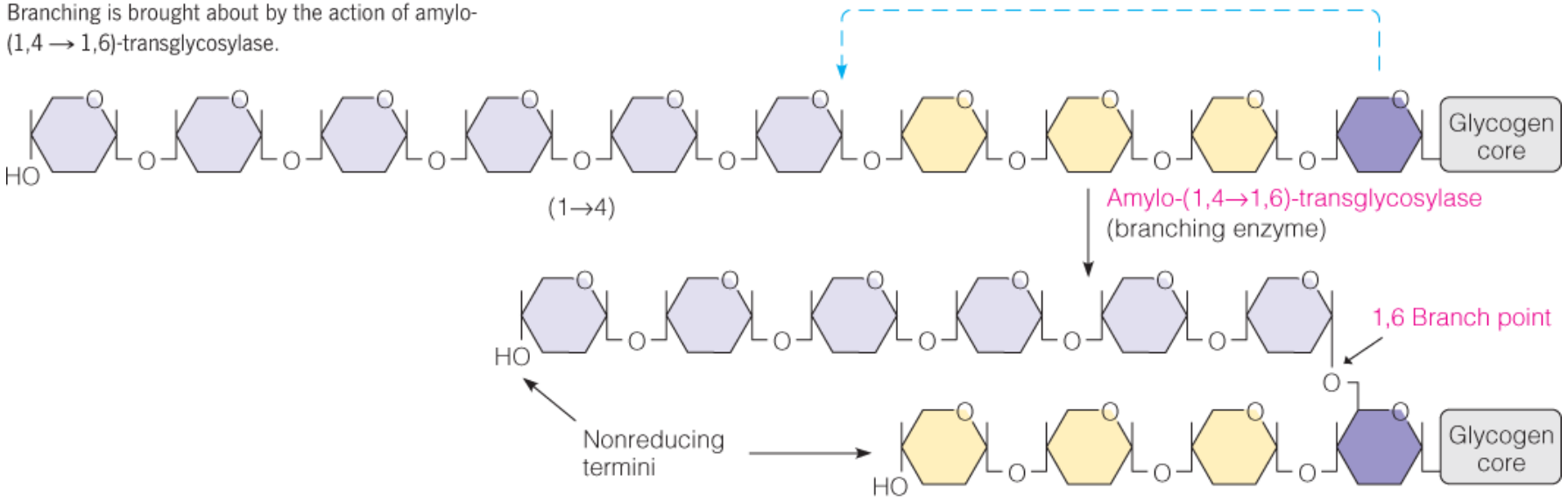


Coordinated Regulation of Glycogen Metabolism

- The branching process in glycogen synthesis.
- Branching is brought about by the action of ***amylo-(1,4→1,6)-transglycosylase***.

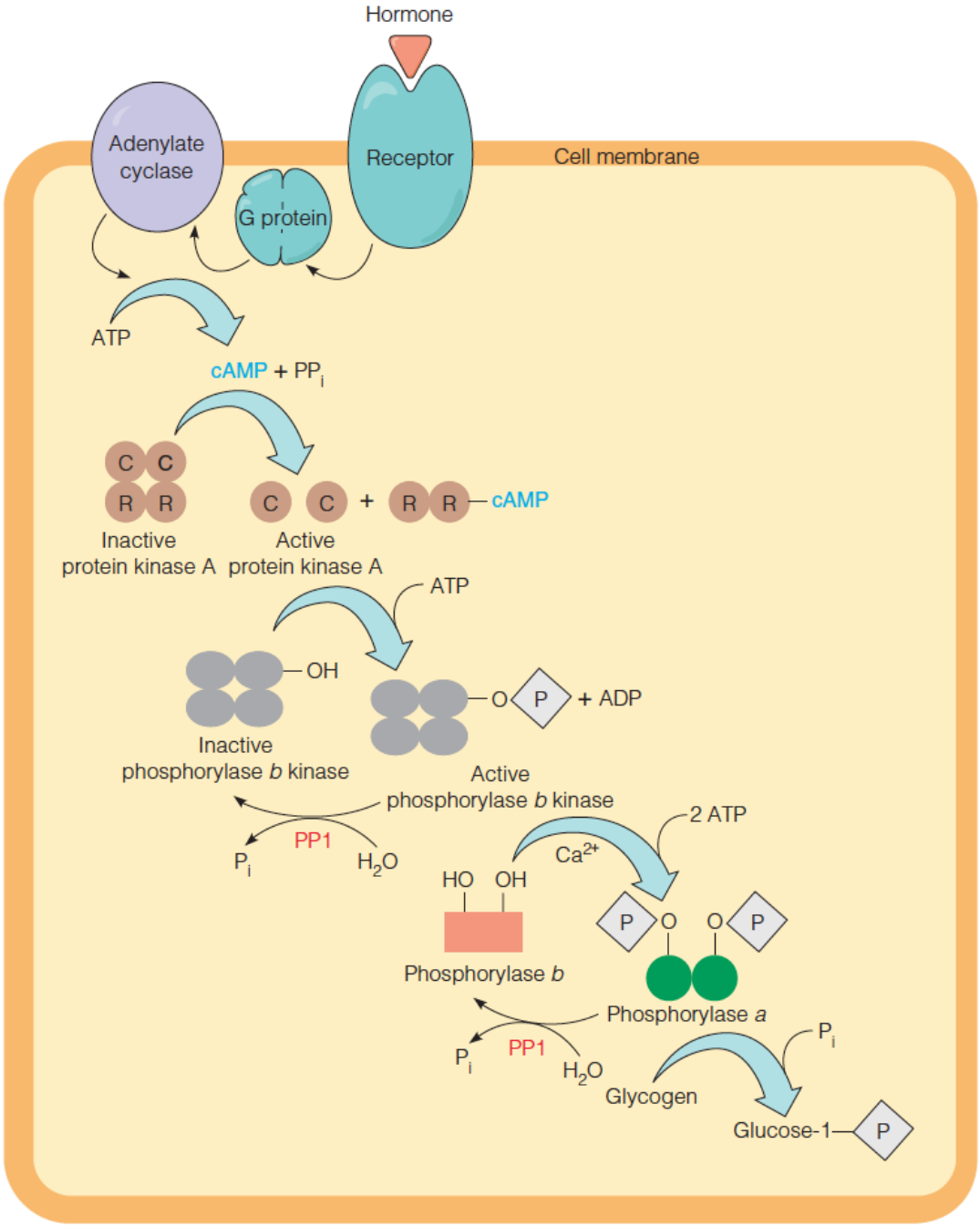
FIGURE 13.30

The branching process in glycogen synthesis.
Branching is brought about by the action of amylo-(1,4 → 1,6)-transglycosylase.



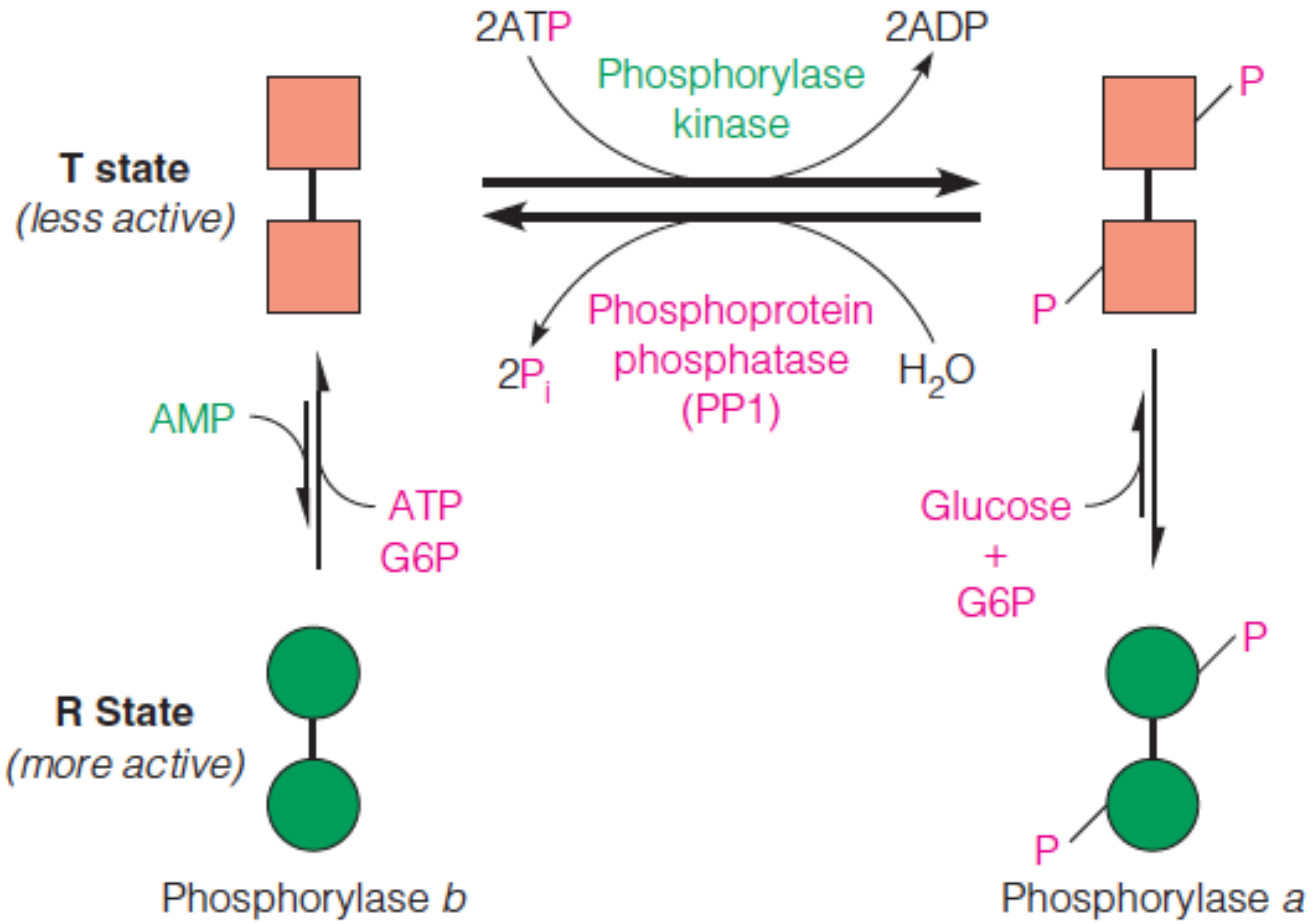
The regulatory cascade controlling glycogen breakdown:

- Glycogen mobilization is controlled hormonally by a metabolic cascade that is activated by **cAMP** formation and involves successive phosphorylations of enzyme proteins.
- The rapid mobilization of muscle glycogen triggered by **epinephrine** is one of several components of the “fight or flight” response.



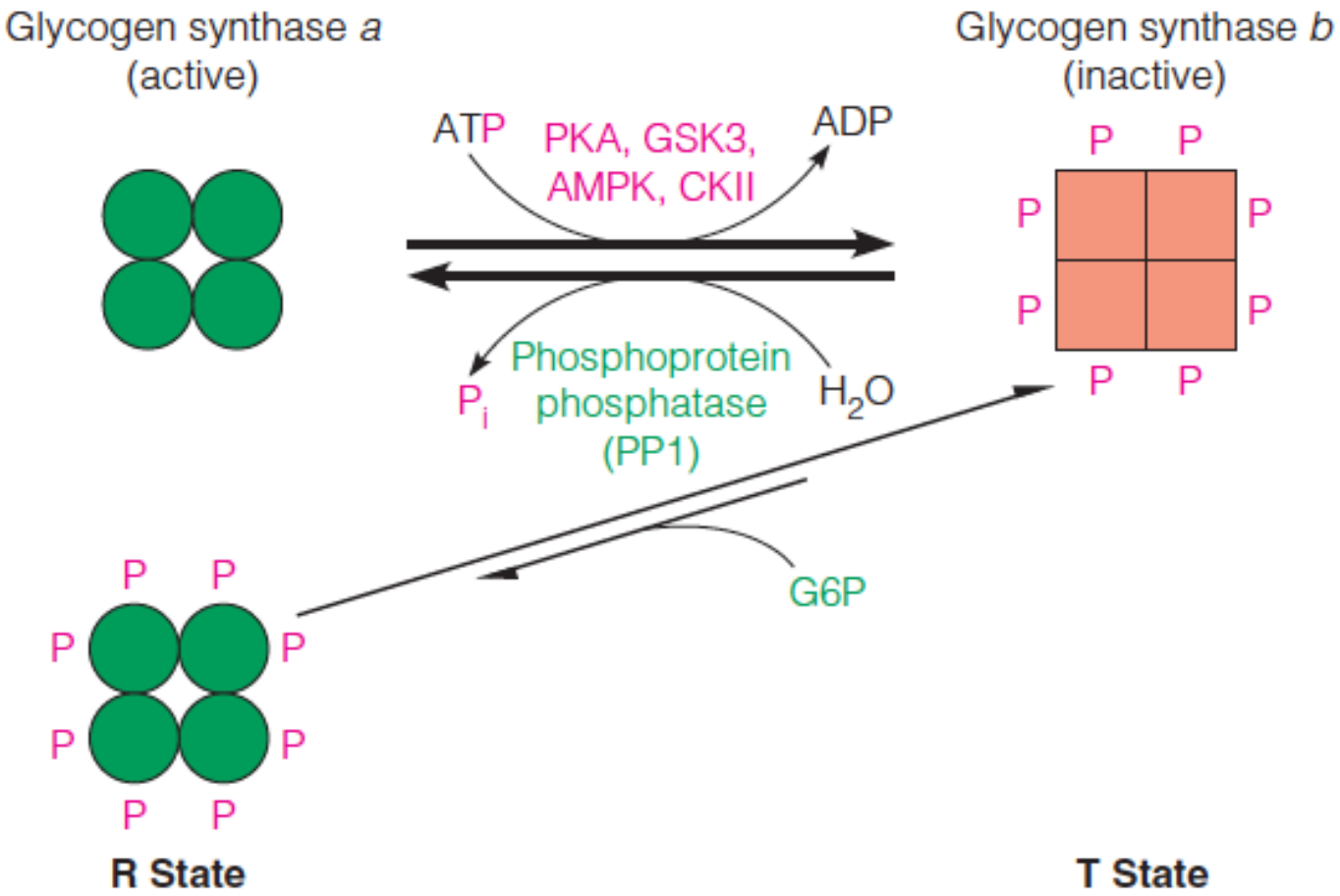
Coordinated Regulation of Glycogen Metabolism

Control of glycogen phosphorylase activity:

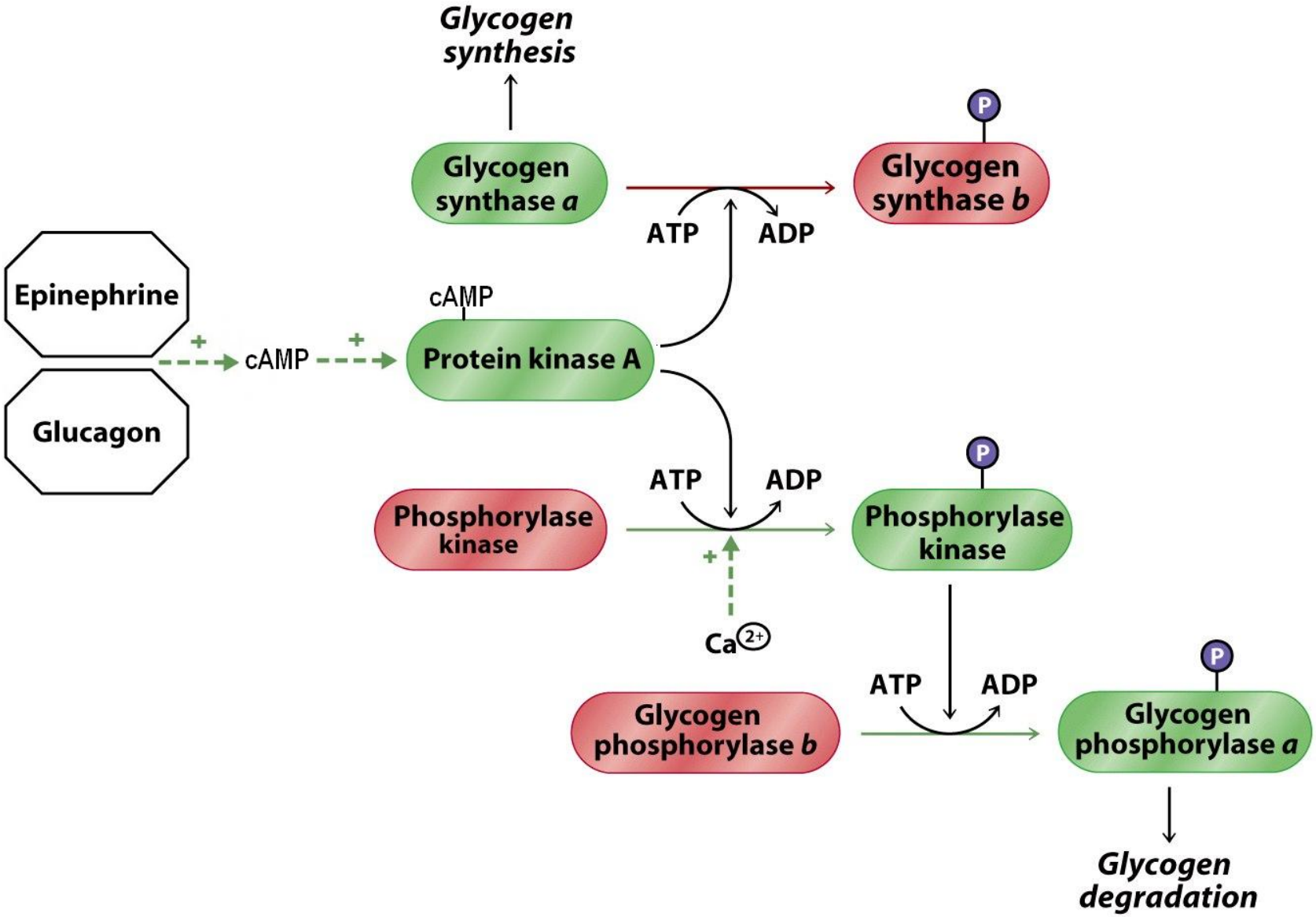


Coordinated Regulation of Glycogen Metabolism

Control of glycogen synthase activity:



PKA: cAMP-dependent protein kinase A
AMPK: AMP-activated protein kinase
GSK3: Glycogen synthase kinase 3
CKII: Casein kinase II



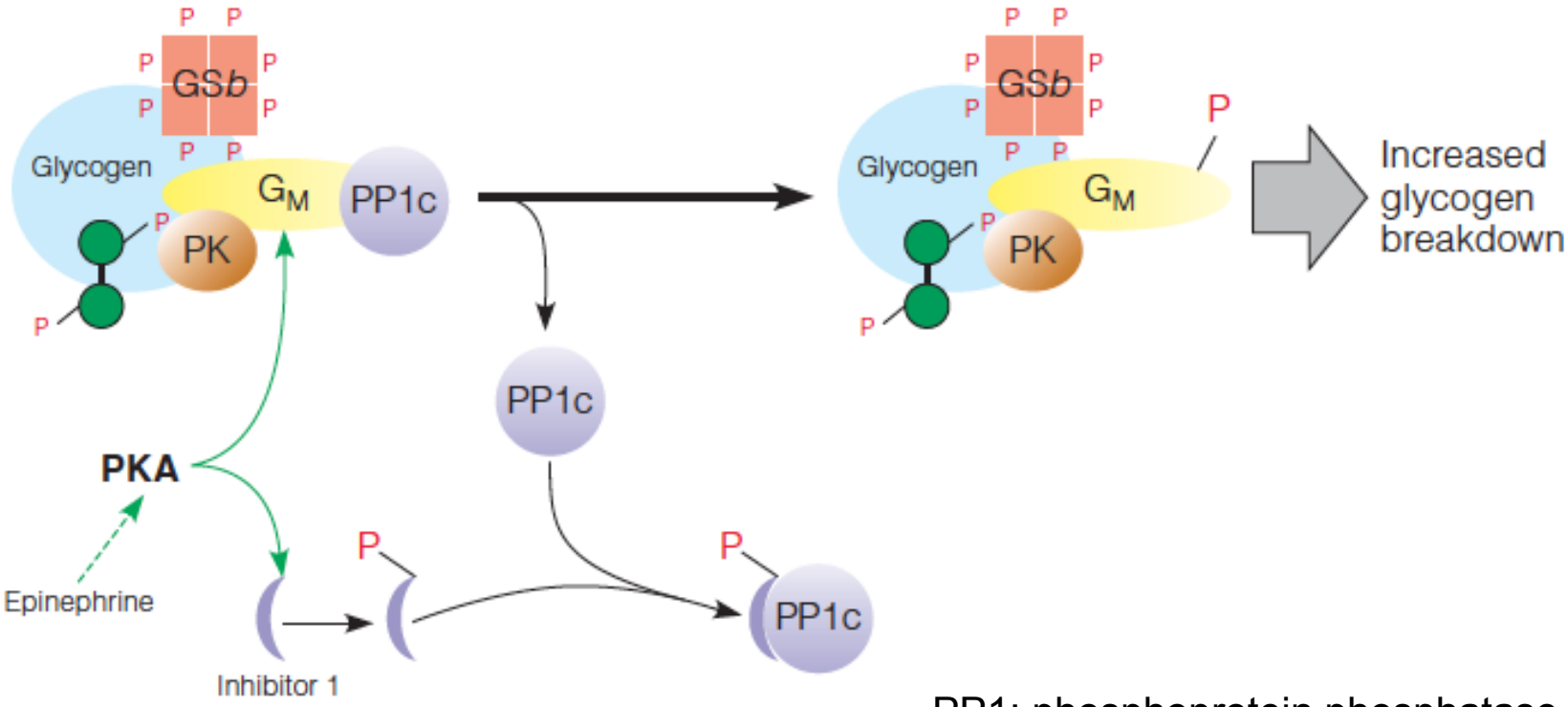
Coordinated Regulation of Glycogen Metabolism

- Conditions that activate glycogen breakdown inhibit glycogen synthesis, and *vice versa*.

- Glycogen synthase activity is controlled by phosphorylation, through mechanisms comparable to those controlling glycogen breakdown by phosphorylase but having reciprocal effects on enzyme activity.

Coordinated Regulation of Glycogen Metabolism

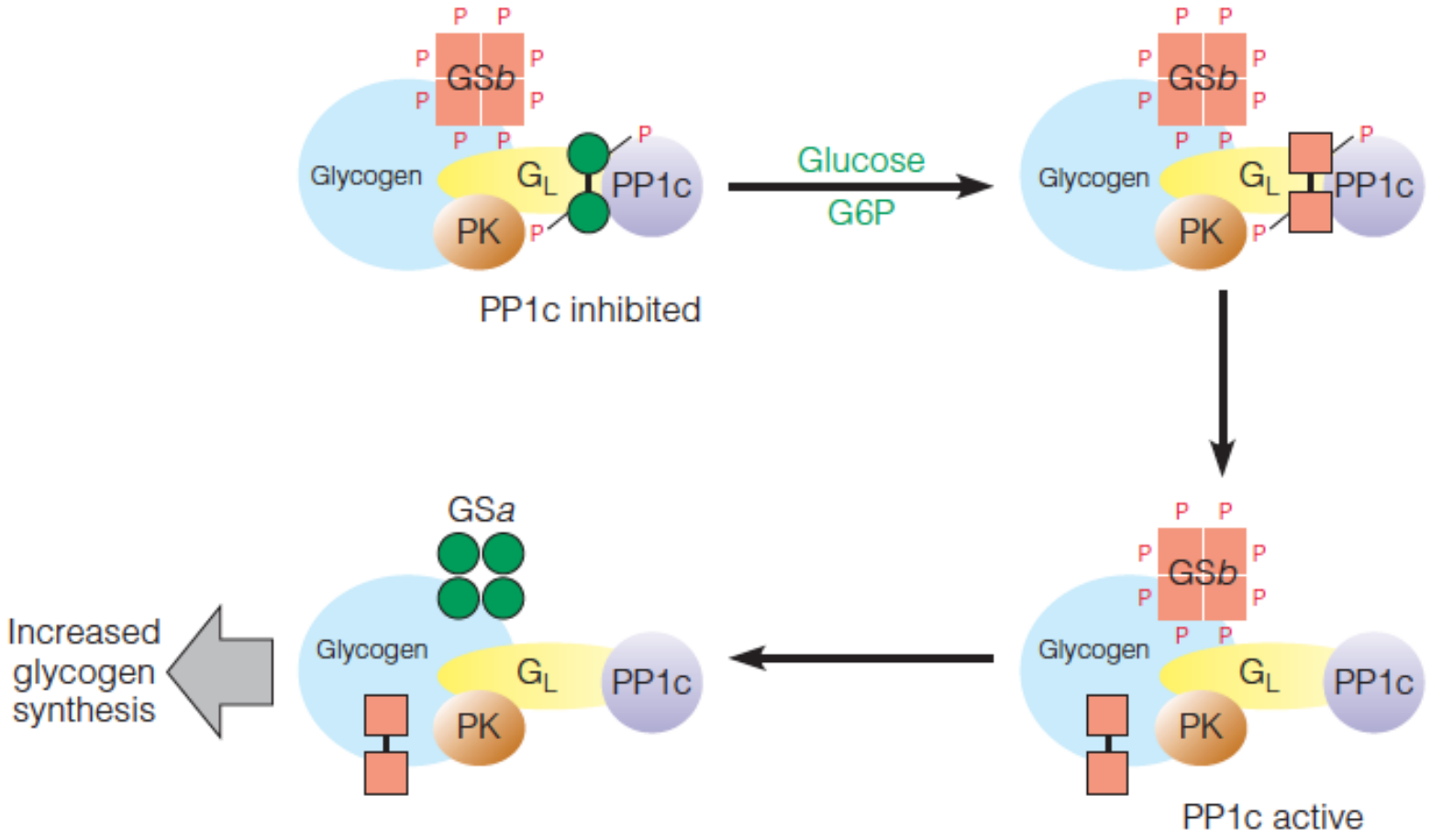
Regulation of phosphoprotein phosphatase 1 (PP1) in muscle:



PP1: phosphoprotein phosphatase 1
PK: phosphorylase b kinase
GSb: Glycogen synthase b
Glycogen phosphorylase a (green)

Coordinated Regulation of Glycogen Metabolism

Regulation of phosphoprotein phosphatase 1 (PP1) in liver:



Coordinated Regulation of Glycogen Metabolism

TABLE 13.3 Human congenital defects of glycogen metabolism

Type	Common Name	Enzyme Deficiency	Glycogen Structure	Organ Affected
Ia	von Gierke Disease	Glucose-6-phosphatase (ER)	Normal	Liver, kidney, intestine
Ib		Glucose-6-phosphate transporter (ER)	Normal	Liver
III	Cori or Forbes Disease	Debranching enzyme	Short outer chains	Liver, heart, muscle
IV	Andersen Disease	Branching enzyme	Abnormally long unbranched chains	Liver and other organs
V	McArdle Disease	Muscle glycogen phosphorylase	Normal	Skeletal muscle
VI	Hers Disease	Liver glycogen phosphorylase	Normal	Liver, leukocytes
VII	Tarui Disease	Muscle phosphofructokinase	Normal	Muscle
IX		Liver phosphorylase kinase	Normal	Liver
-		Glycogen synthase	Normal	Liver

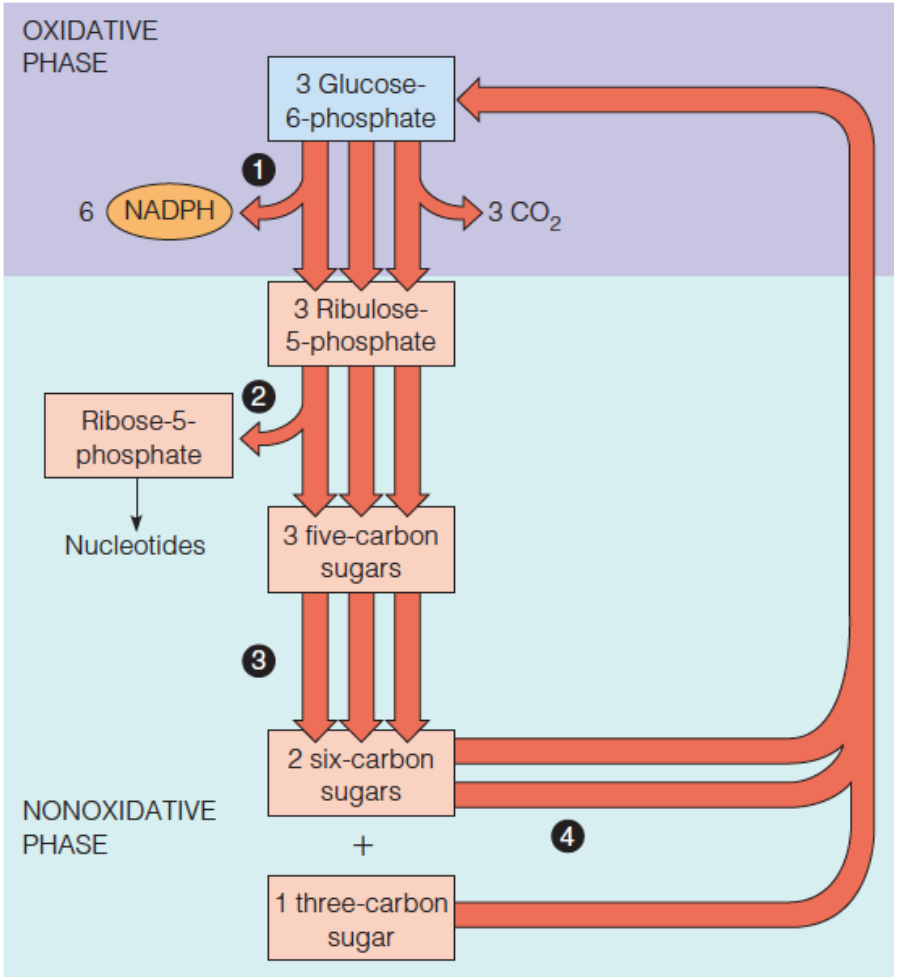
The Pentose Phosphate Pathway

The ***pentose phosphate pathway*** converts glucose to various other sugars, which can be used for energy.

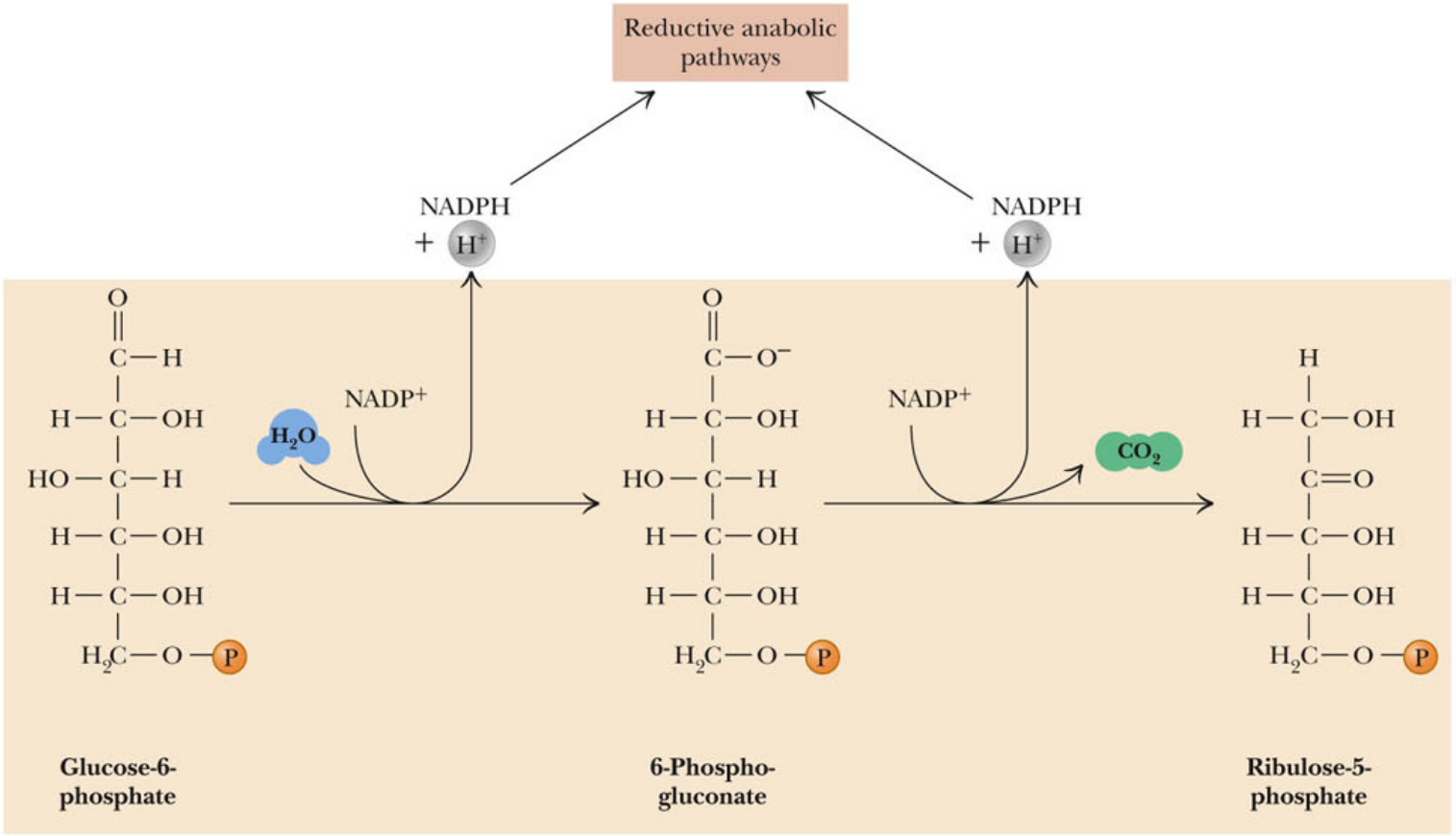
Its most important products, however, are ***NADPH*** and ***ribose-5-phosphate***.

In stage 1, the ***oxidative phase***, glucose-6-phosphate is oxidized to ribulose-5-phosphate and CO_2, with production of NADPH.

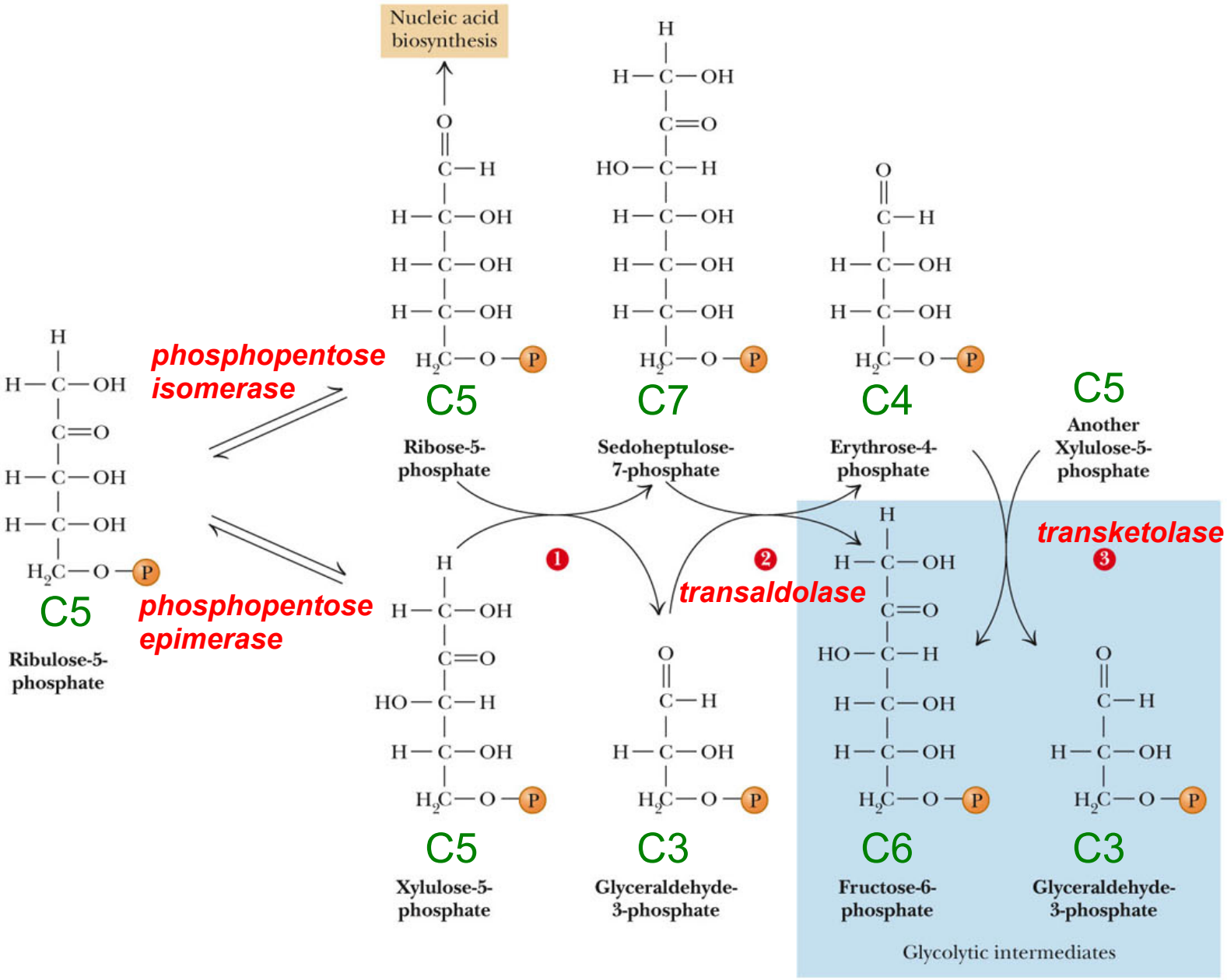
The remaining stages constitute the ***nonoxidative phase*** of the pathway.



The Pentose Phosphate Pathway



The Pentose Phosphate Pathway

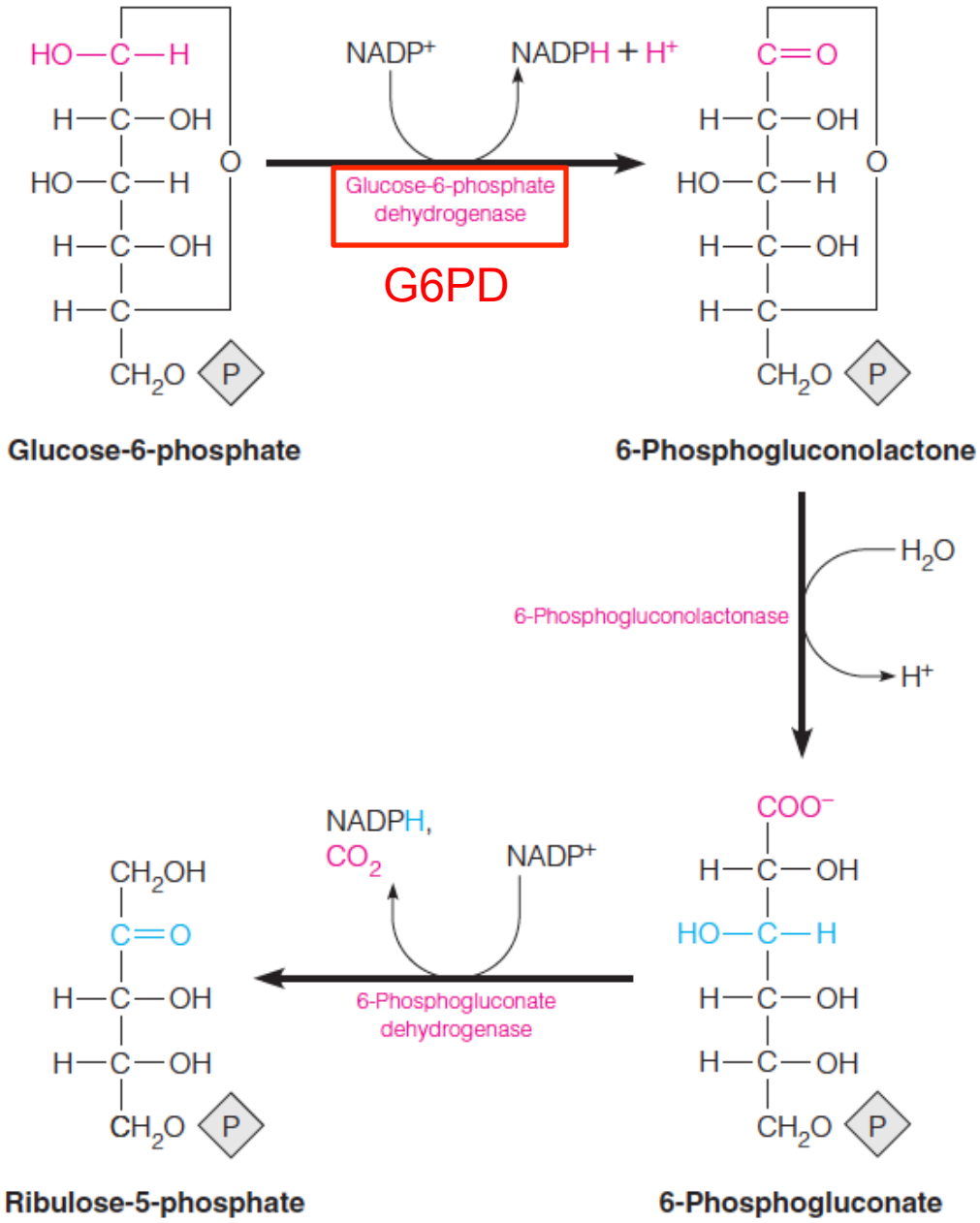


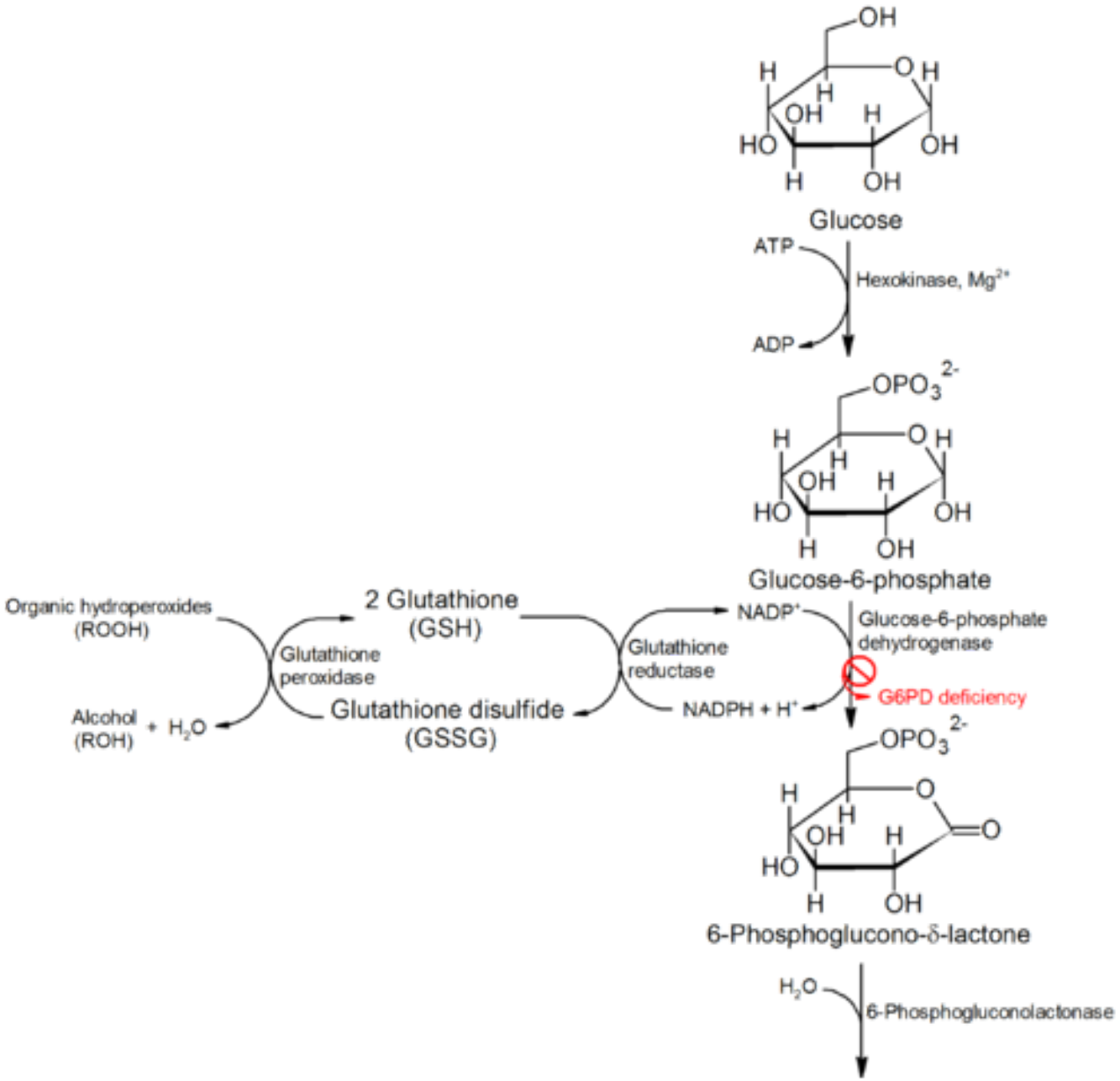
The Pentose Phosphate Pathway

Oxidative phase of the pentose phosphate pathway:

- The three reactions of the oxidative phase include two oxidations, which produce NADPH.

- The pentose phosphate pathway primarily generates NADPH for reductive biosynthesis and ribose-5-phosphate for nucleotide biosynthesis.




Glucose
ATP
ADP
Hexokinase, Mg^{2+}
Glucose-6-phosphate
Organic hydroperoxides (ROOH)
Alcohol (ROH) + H_2O
Glutathione peroxidase
2 Glutathione (GSH)
Glutathione disulfide (GSSG)
Glutathione reductase
$NADP^+$
$NADPH + H^+$
Glucose-6-phosphate dehydrogenase
G6PD deficiency
6-Phosphoglucono-δ-lactone
H_2O
6-Phosphogluconolactonase

Glucose-6-phosphate dehydrogenase deficiency (蠶豆症)

Glucose-6-phosphate dehydrogenase (G6PD) is essential for assuring a normal life span for red blood cells, and for oxidizing processes.

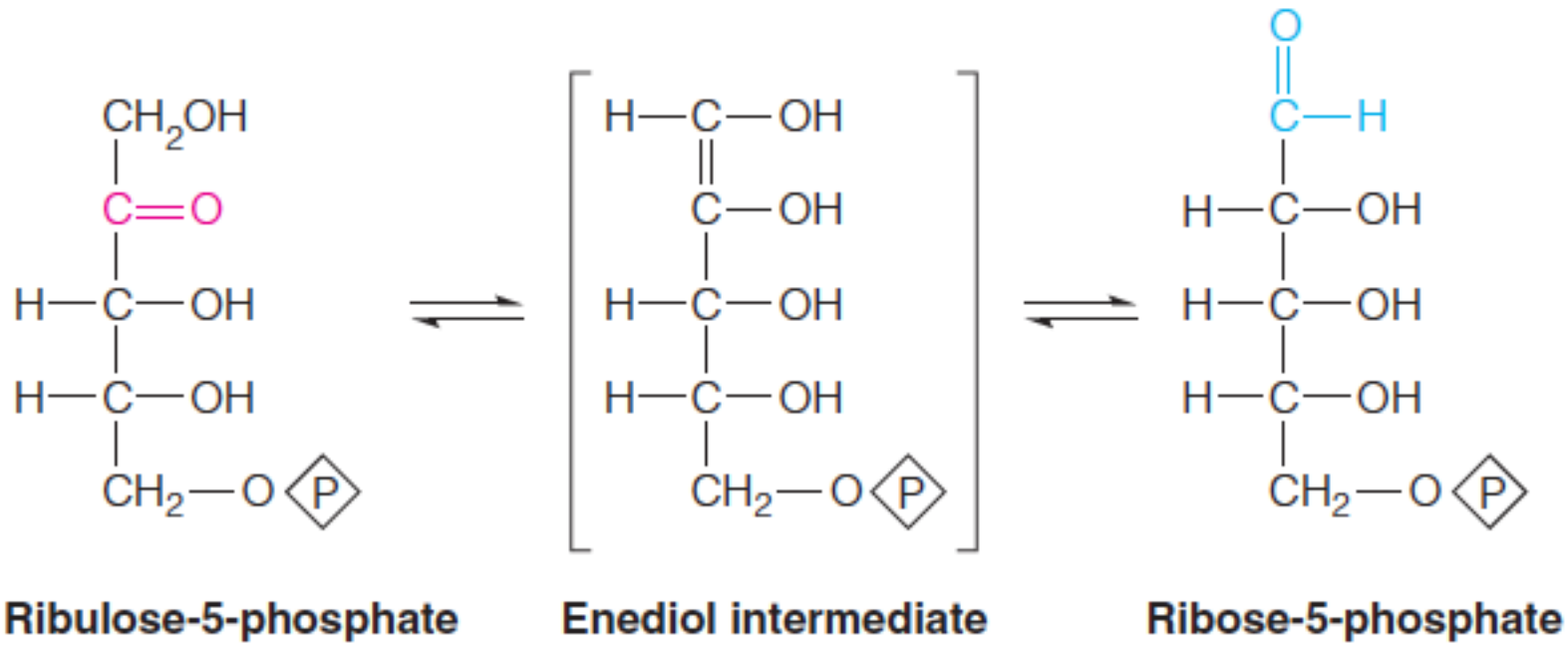
G6PD deficiency is a hereditary abnormality in the activity of an erythrocyte enzyme which causes serve hemolytic anemia.

蠶豆症之所以會以「蠶豆」得名,這是因為竹北客家庄幼童曾吃過煮熟的蠶豆後,主要症狀為發燒、臉色蒼白、血色尿,並且有輕微黃疸,幾天之內就有五 名孩童相繼死亡,經公衛學者調查發現,是急性溶血性貧血,患者的紅血球破裂血色素大量流失所致。

台灣平均一百位新生兒中約有三名罹患此症，蠶豆症小孩若平日即隨時注意避免各類易引起溶血的物質，或在發生溶血時，施以合適的治療，就不會有任何後遺症，亦不會影響身高，體重及智能等各方面的發展。所以此症雖為一種遺傳性疾病，但只要平日多加注意，則小孩亦可完全正常的長大。

The Pentose Phosphate Pathway

- In the nonoxidative phase, some of the ribulose-5-phosphate produced in the oxidative phase is converted to ribose-5 phosphate by ***phosphopentose isomerase***.



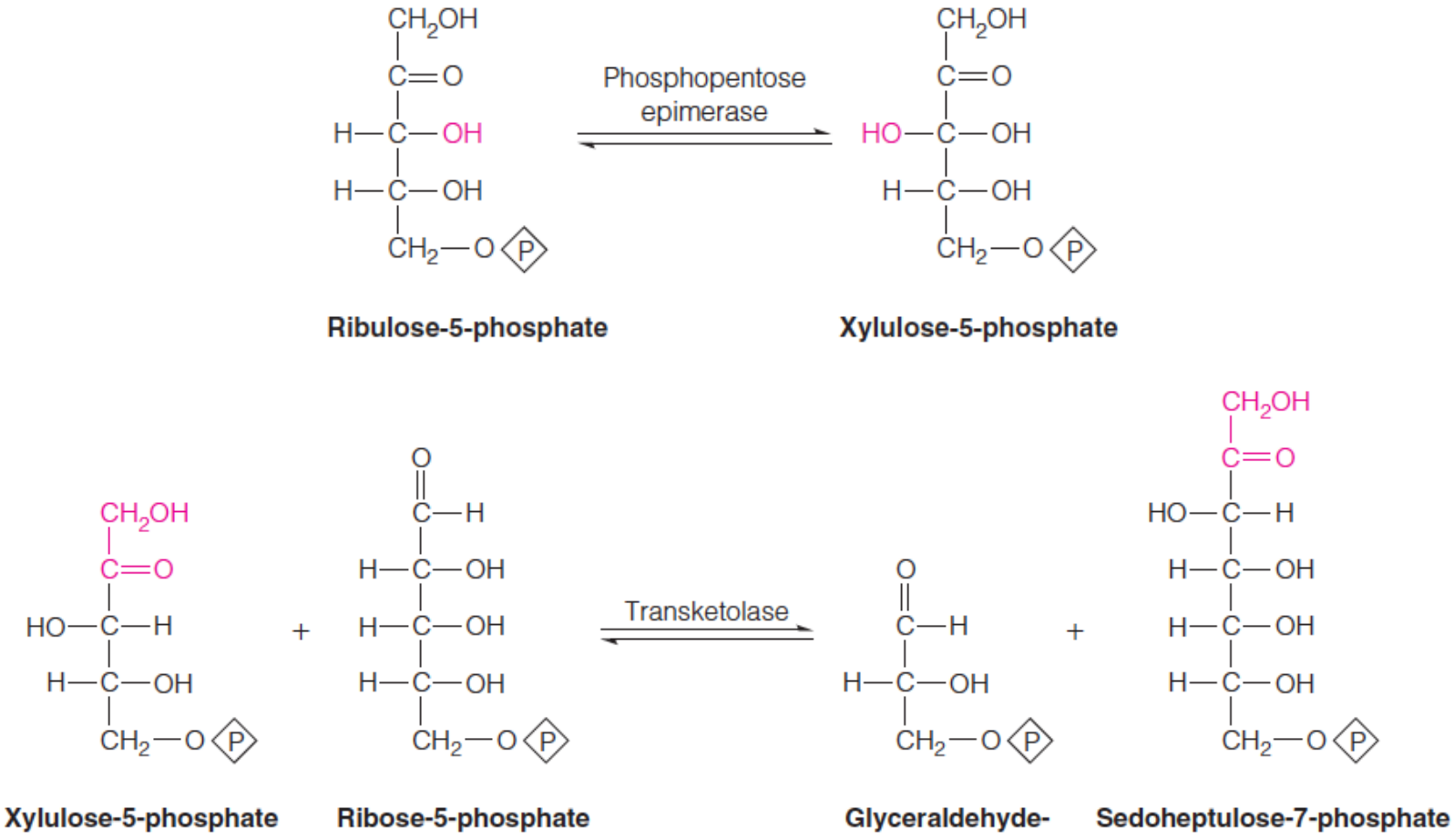
Ribulose-5-phosphate **Enediol intermediate** **Ribose-5-phosphate**

The Pentose Phosphate Pathway

- The reaction sequence of the nonoxidative branch converts 3 five-carbon sugar phosphates to 2 six-carbon sugar phosphates and 1 three-carbon sugar phosphate.
- The hexose phosphates formed can be catabolized either by recycling through the pentose phosphate pathway or by glycolysis.
- The triose phosphate is glyceraldehyde-3-phosphate, a glycolytic intermediate.
- Three enzymes involved are:
    - ***phosphopentose epimerase***
    - ***transketolase***
    - ***transaldolase***

The Pentose Phosphate Pathway

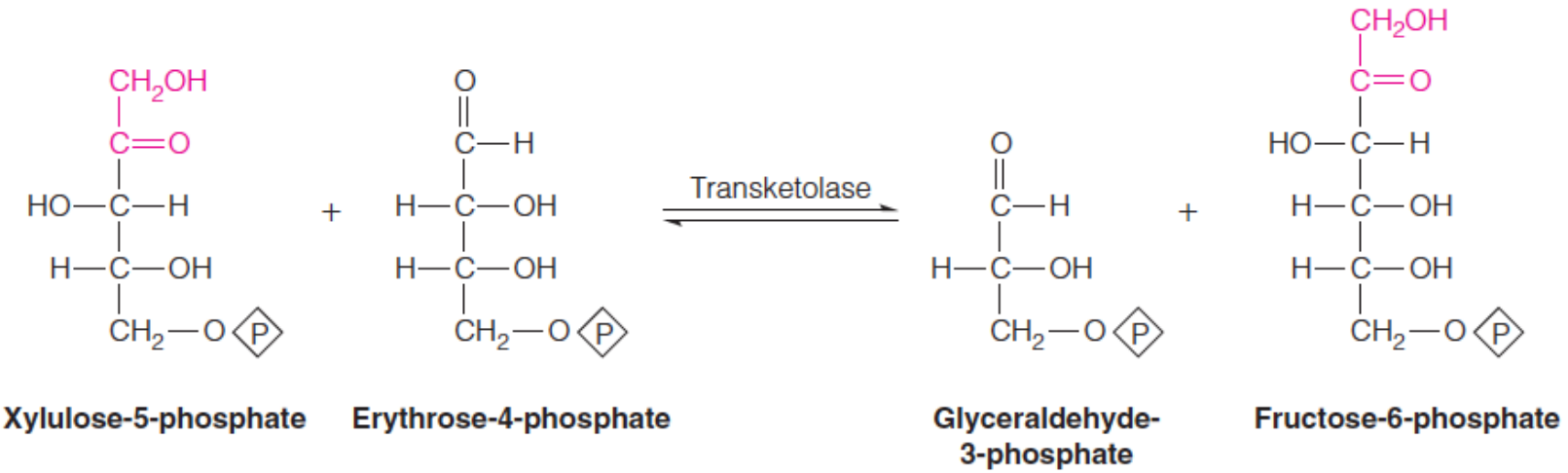
- The nonoxidative branch begins with both ribulose-5-phosphate and ribose-5-phosphate.



The Pentose Phosphate Pathway

- Transketolase catalyzes a transfer of a two-carbon fragment from xylulose-5-phosphate to ribose-5-phosphate to give a triose phosphate, glyceraldehyde-3-phosphate, and a seven-carbon sugar, sedoheptulose-7-phosphate.

- In the final reaction of pentose phosphate catabolism, transketolase acts on another molecule of xylulose-5-phosphate, transferring a glycolaldehyde fragment to erythrose-4-phosphate and generating a three-carbon product and a six-carbon product—glyceraldehyde-3-phosphate and fructose-6-phosphate, respectively.



The Pentose Phosphate Pathway

dihydroxyacetone

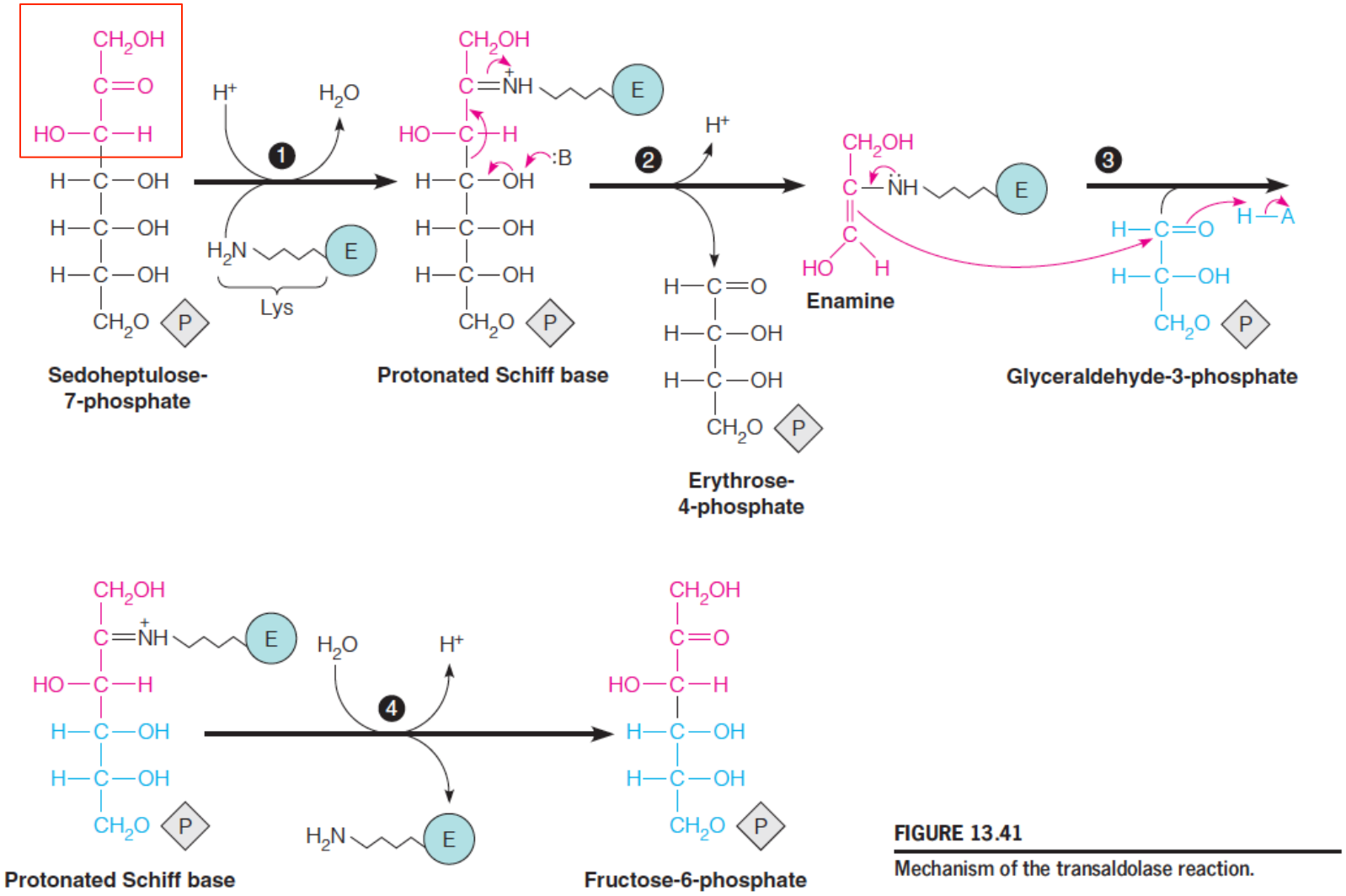


FIGURE 13.41

Mechanism of the transaldolase reaction.