Carbohydrate Metabolism

Digestion: The principal sites of dietary carbohydrate digestion are the mouth and intestinal lumen.

Absorption: Mainly the upper part of small intestine.

Route of absorption: By the portal vein to the liver, i.e., blood stream chiefly in the form of hexoses (glucose, fructose, mannose and galactose) and as pentose sugars (ribose).

Blood values of glucose:

- The normal fasting value:70-110 mg/100 ml.
- After meal: 120-150 mg/100 ml.

Glucose sources in human body:

- Dietary carbohydrates.
- Liver glycogenolysis.
- Gluconeogenesis.

The fate of absorbed glucose:

- Glucose oxidation.
- Glycogenesis.
- Lipogenesis.
- Lose in urine (in special conditions).

Glucose oxidation (glycolysis)

Definition: is the oxidation of glucose into pyruvic acid (in the presence of oxygen) or lactic acid (in absence of oxygen).

Location: It occurs in the cytoplasm of the cell.

Important: It is the main source of energy for the human body.

Calculation of energy:

In absence of oxygen

4 ATP are gained:

2 ATP ⇨ from conversion of 1,3 diphosphoglyceric acid (diphosphoglycerate) into 3 phosphoglyceric acid (phosphoglycerate).

2 ATP ⇨ from conversion of phosphoenolpyruvic acid (phosphoenolpyruvate) into pyruvic acid (pyruvate).

2 ATP are lost:

ATP ⇨ for activation of glucose to glucose-6-phosphate.

ATP ⇨ for activation fructose-6-phosphate to fructose-1,6-biphosphate.

So 4 ATP -2 ATP = 2 ATP

In the presence of oxygen

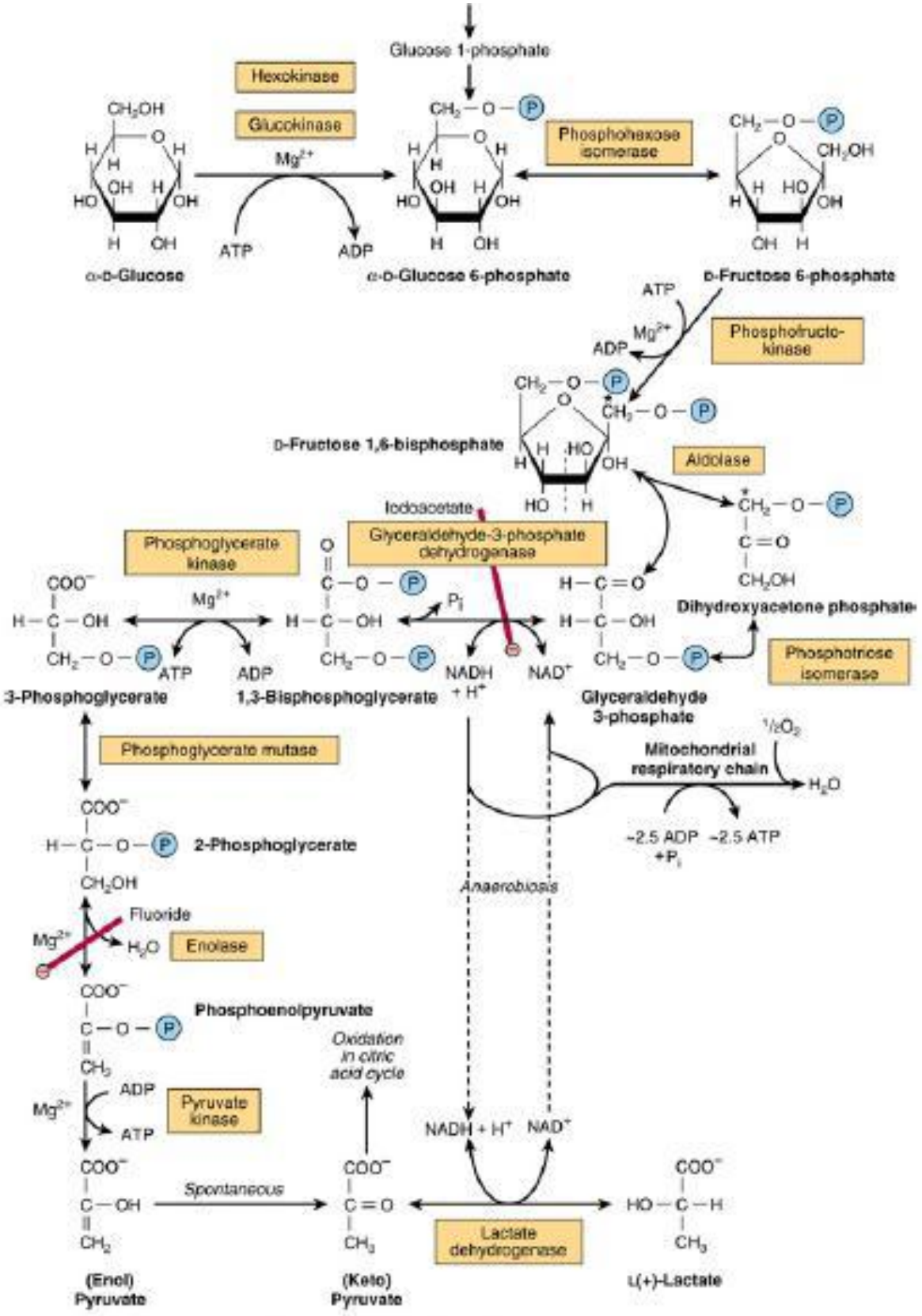
2 NADH + H+ are oxidized in the respiratory chain giving either 4 ATP or 6 ATP

So 2 ATP + 4 ATP = 6 ATP (NAD schuttle)

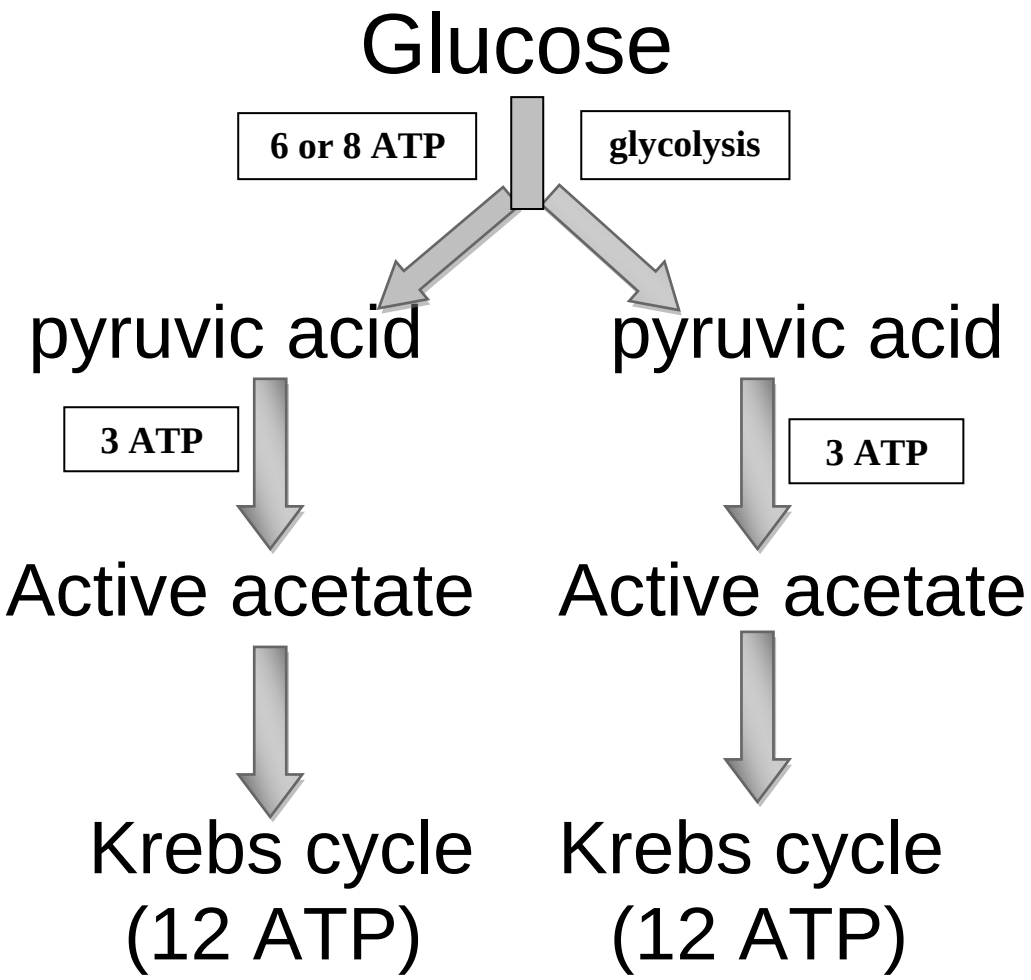
in muscle and nerve.

2 ATP + 6 ATP = 8 ATP (Maltase schuttle)

in liver and heart.


Glucose 1-phosphate
Hexokinase
Glucokinase
Mg2+
ATP
ADP
α-D-Glucose
α-D-Glucose 6-phosphate
Phosphohexose isomerase
D-Fructose 6-phosphate
ATP
Mg2+
ADP
Phosphofructo-kinase
D-Fructose 1,6-bisphosphate
Aldolase
Iodoacetate
Glyceraldehyde-3-phosphate dehydrogenase
Phosphoglycerate kinase
Dihydroxyacetone phosphate
Phosphotriose isomerase
3-Phosphoglycerate
1,3-Bisphosphoglycerate
NADH + H+
NAD+
Glyceraldehyde 3-phosphate
Phosphoglycerate mutase
1/2O2
Mitochondrial respiratory chain
H2O
~2.5 ADP ~2.5 ATP +Pi
2-Phosphoglycerate
Anaerobiosis
Fluoride
Mg2+
H2O
Enolase
Phosphoenolpyruvate
Oxidation in citric acid cycle
ADP
ATP
Pyruvate kinase
NADH + H+
NAD+
Spontaneous
Lactate dehydrogenase
(Enol) Pyruvate
(Keto) Pyruvate
L(+)-Lactate

Glycolysis



So complete oxidation of one molecule of glucose (glycolysis and krebs cycle) in the presence of oxygen gives:

8 + 30 = 38 ATP or 6 + 30 = 36 ATP

Glycogenesis

Definition: It is the synthesis of glycogen from glucose.

Location: It take place mainly in the liver and muscle**.**

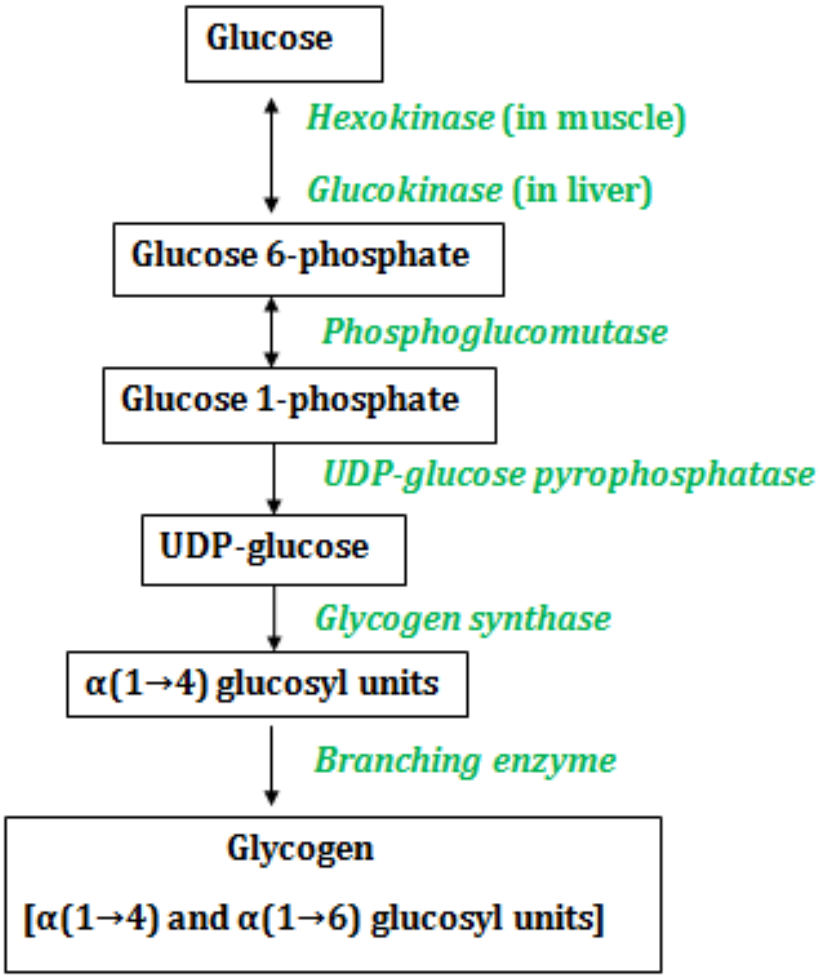


Diagram: Steps of glycogenesis

Glycogenolysis

Definition: It is the breakdown of glycogen to glucose in the liver and glucose-6-phosphate in the muscle due to absence of glucose-6-phosphatase enzyme.

Location: It take place mainly in the liver and muscle**.**

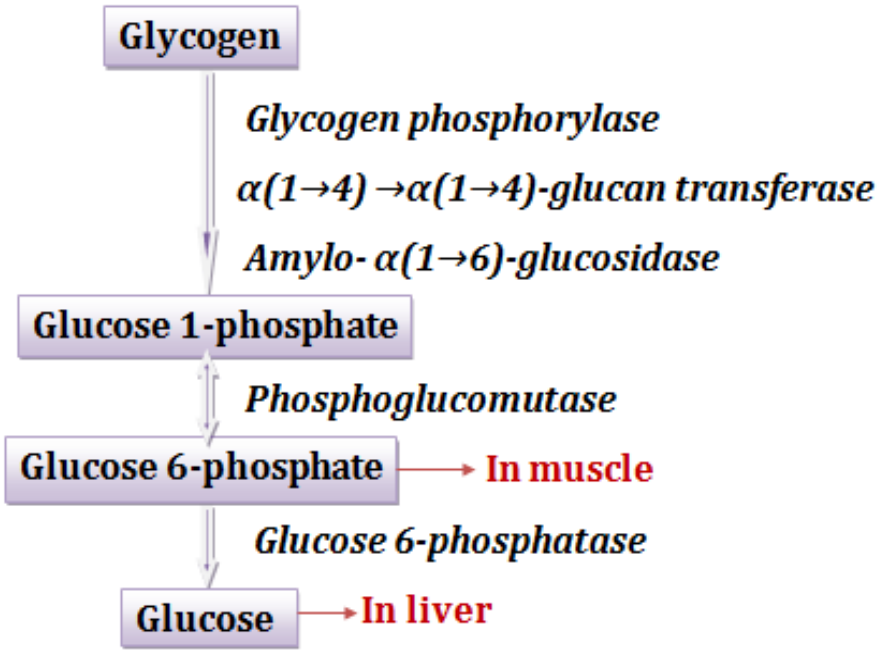


Diagram: Steps of glycogenolysis

Gluconeogenesis

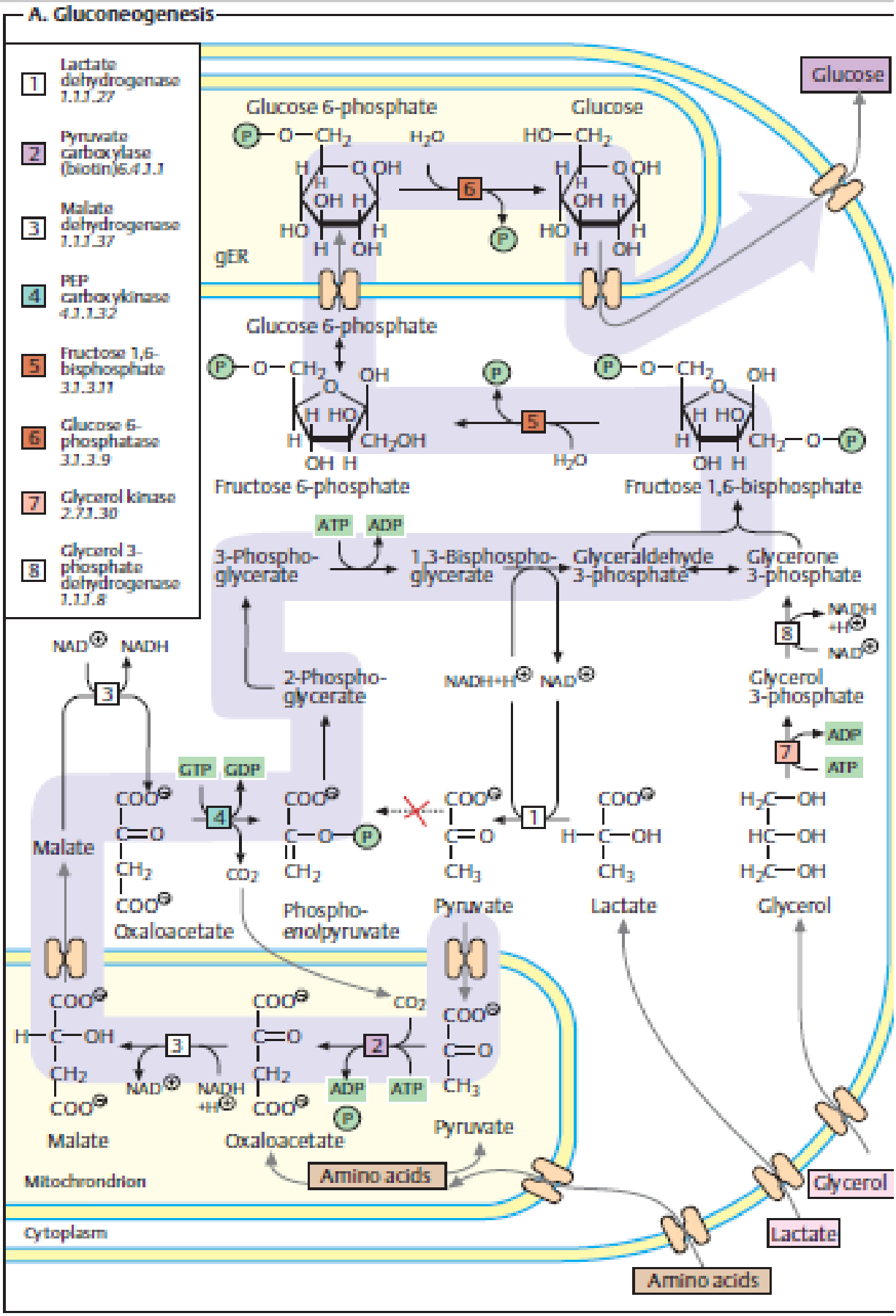
Definition: It is the formation of glucose from non- carbohydrate source.

Location: It take place mainly in the liver and kidney**.**

Important:

1. It is the main source of blood glucose if the amount of carbohydrate taken up in food is not sufficient or during long starvation.
2. It removes the lactate from the blood that produced by erythrocytes and skeletal muscles. It also removes the glycerol produced by adipose tissue.

Sourses: Lactat, glucogenic amino acids, and glycerol.


A. Gluconeogenesis
1 Lactate dehydrogenase 1.1.1.27
2 Pyruvate carboxylase (biotin) 6.4.1.1
3 Malate dehydrogenase 1.1.1.37
4 PEP carboxykinase 4.1.1.32
5 Fructose 1,6-bisphosphatase 3.1.3.11
6 Glucose 6-phosphatase 3.1.3.9
7 Glycerol kinase 2.7.1.30
8 Glycerol 3-phosphate dehydrogenase 1.1.1.8
Glucose
Glucose 6-phosphate
Glucose
gER
Glucose 6-phosphate
Fructose 6-phosphate
Fructose 1,6-bisphosphate
3-Phospho-glycerate
1,3-Bisphospho-glycerate
Glyceraldehyde 3-phosphate
Glycerone 3-phosphate
Glycerol 3-phosphate
2-Phospho-glycerate
Malate
Oxaloacetate
Phospho-enolpyruvate
Pyruvate
Lactate
Glycerol
Malate
Oxaloacetate
Pyruvate
Mitochrondrion
Cytoplasm
Amino acids
Glycerol
Lactate
Amino acids

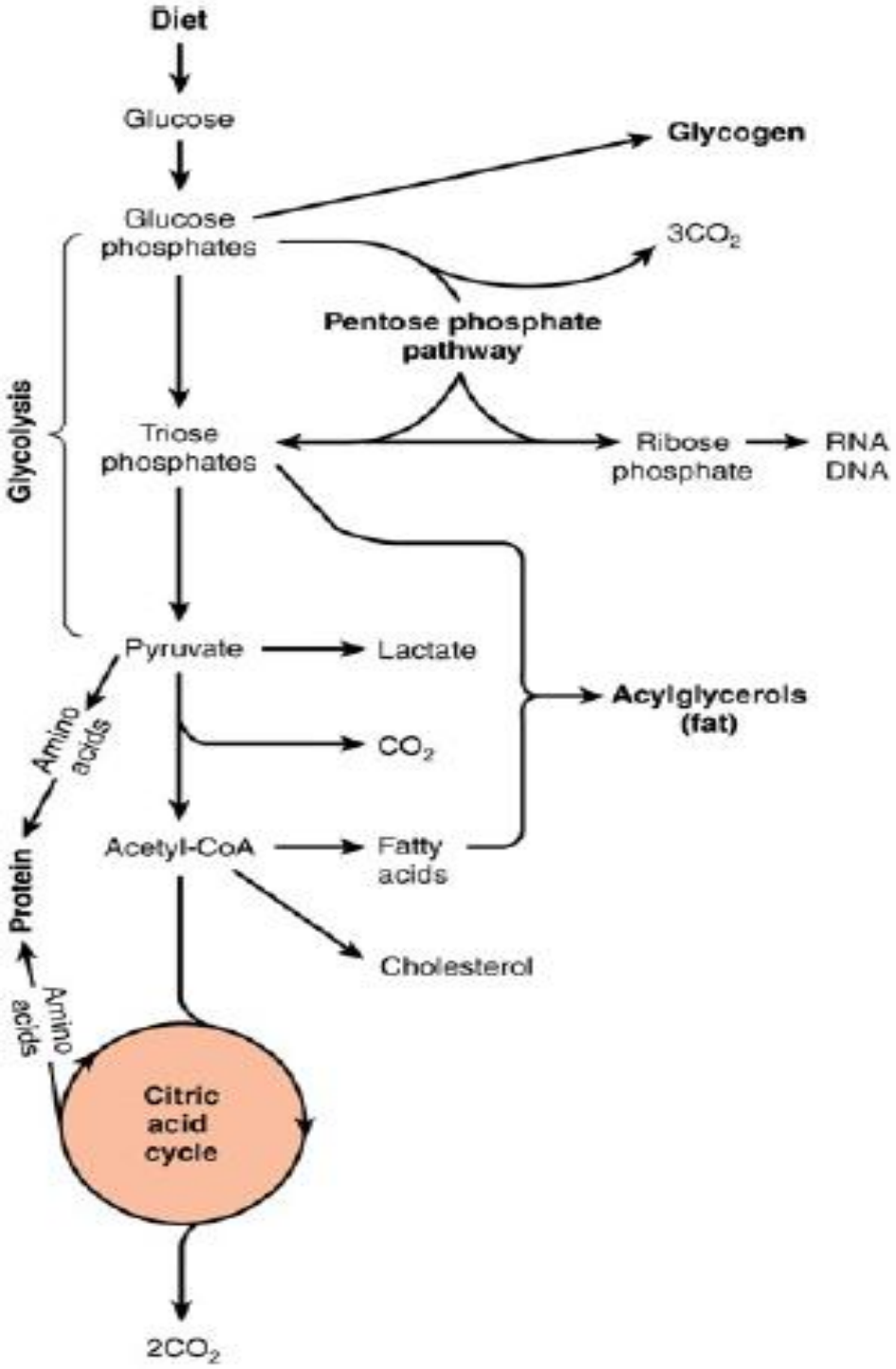


Diagram for the fate of absorbed glucose

Regulation of blood glucose

By tissues

Gastrointestinal tract:

It prevents hyperglycemia (high blood glucose level) after carbohydrate meal. When the glucose contacts with the intestinal mucosa, it secretes into the blood certain factors which stimulate insulin secretion.

The liver:

It plays the most important role in regulation of blood glucose level.

In hyperglycemia: It decreases blood glucose by:

1.Glycogenesis.

2.Oxidation of glucose.

3.Lipogenesis.

In hypoglycemia: It increases blood glucose by:

1.Glycogenolysis.

2.Gluconeogenesis.

3.Interconversion from different hexoses(fractoseor and galactose) into glucose.

Muscles:

It prevent hyperglycemia by:

1.Glycogenesis.

2.Oxidation of glucose.

Adipose tissue:

It prevent hyperglycemia by increasing lipogenesis.

The kidney:

It prevent glucose loss in urine.

It adds little glucose to the blood by gluconeogenesis.

By hormones

Insulin:

It lowers the blood glucose level by increasing:

1.Glycogenesis.

2.Oxidation of glucose.

3.Lipogenesis.

4.Glucose uptakes.

It also inhibits:

1.Glycogenolysis.

2.Gluconeogenesis

Glucagon and adrenaline:

They increase the blood glucose level by increasing glycogenolysis and gluconeogenesis and inhibiting glycogenesis.

Glucocorticoids and growth hormone:

They increase the blood glucose level by increasing gluconeogenesisand inhibiting glucose uptake, oxidation and lipogenesis.

Thyroxine:

It increases the blood glucose level by:

1.Increasing the rate of glucose absorption from intestine.

2.Stimulating glycogenolysisand gluconeogenesis.

3.Inhibiting glycogenesis.

4.Increasing the catabolism of insulin.