

# Overview of Carbohydrate Digestion and Metabolism

# FST/AN/HN 761

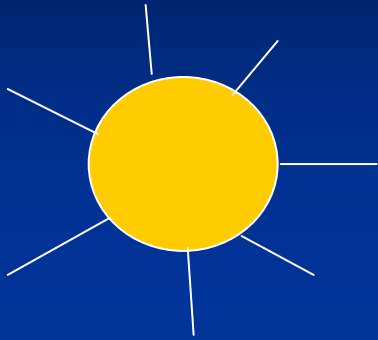
- FST 761
- Dr. Jeff Firkins – Carbohydrates
- Dr. Josh Bomser – Lipids
- TA- Amy Long, MS
- Reading / Writing Assignments
- Text - Biochemical and Physiological Aspects of Human Nutrition- Martha H. Stipanuk.
- Today – Overview of carbohydrates (Jan 7)

# Carbohydrates

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- Carbohydrates are called carbohydrates because they are essentially hydrates of carbon (i.e. they are composed of carbon and water and have a composition of  $(\text{CH}_2\text{O})_n$ ).
- The major nutritional role of carbohydrates is to provide energy and digestible carbohydrates provide **4 kilocalories per gram**. **No single carbohydrate is essential**, but carbohydrates do participate in many required functions in the body.

# Photosynthesis: Sun's energy becomes part of glucose molecule



energy

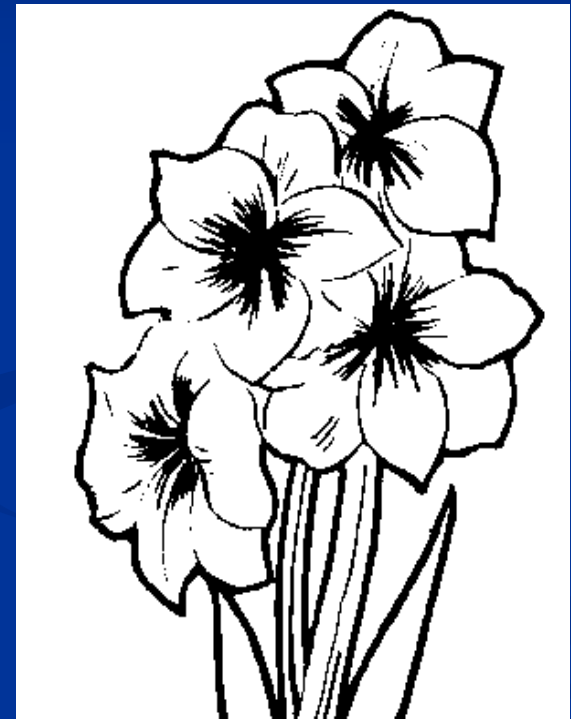
Carbon dioxide

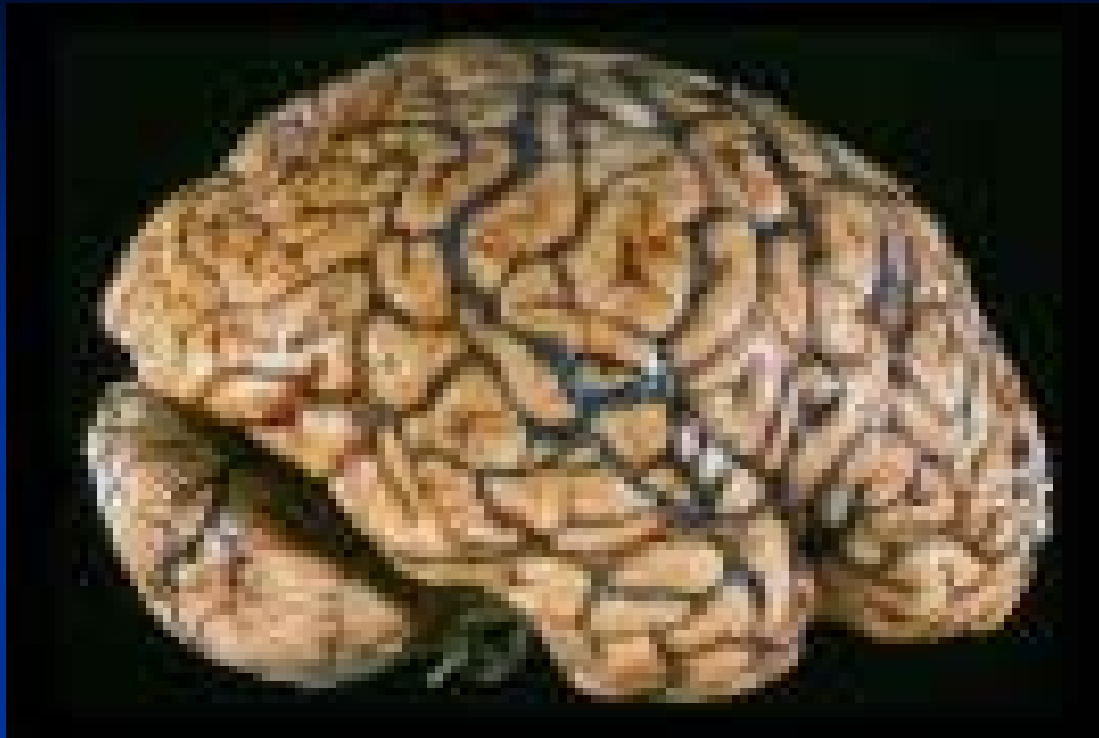
Water

Chlorophyll



GLUCOSE

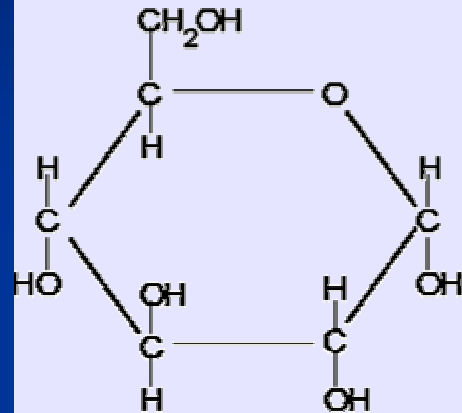




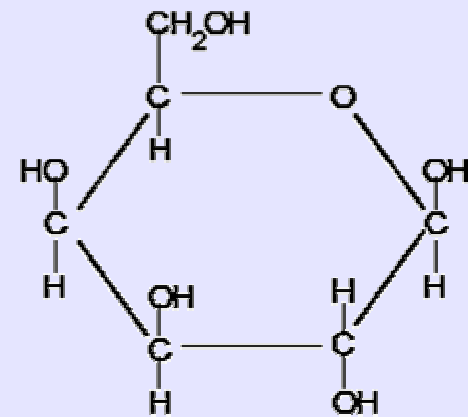
120 grams of glucose / day = 480 calories

# Simple Sugars -

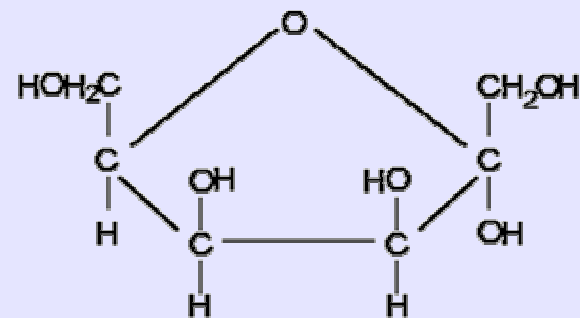
## Structures of Common Monosaccharides



Glucose

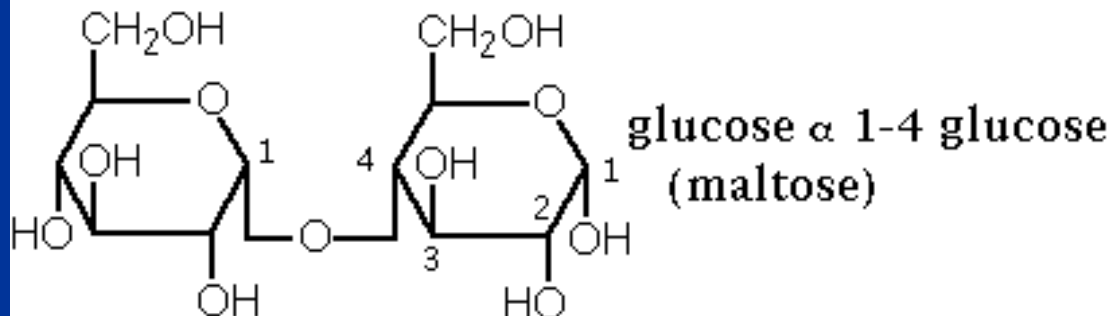
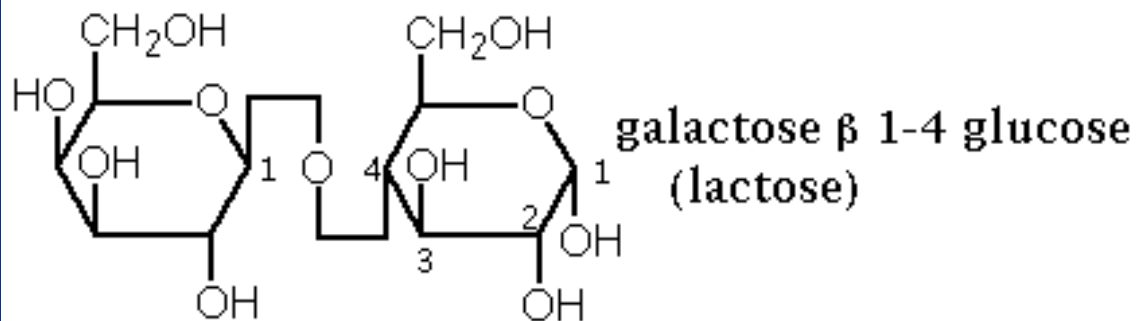
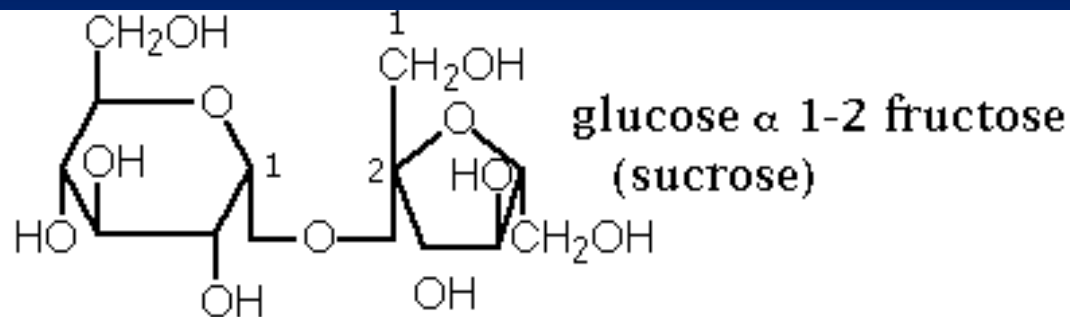


Galactose



Fructose

# Disaccharides

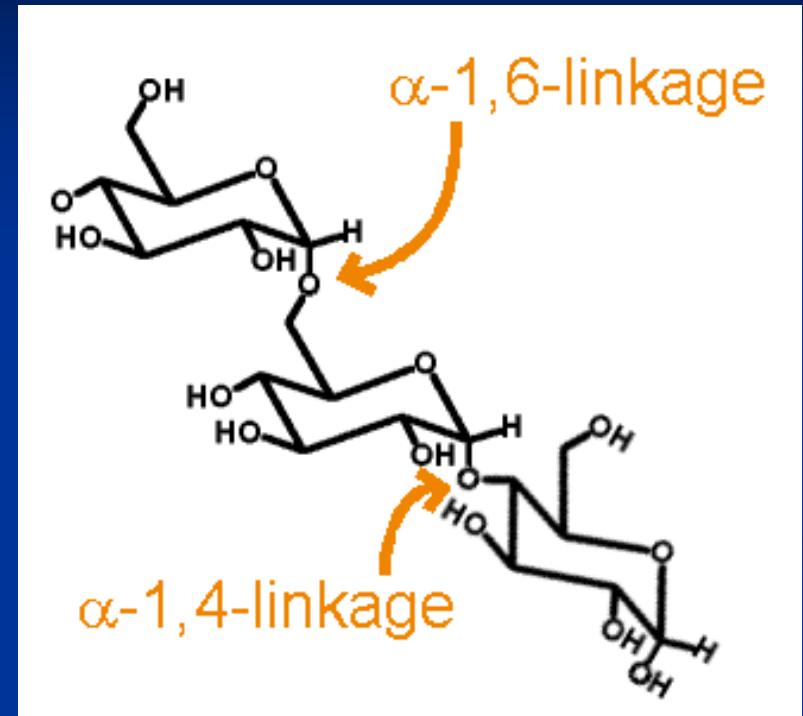


# Complex carbohydrates

- Oligosaccharides
- Polysaccharides
  - Starch
  - Glycogen
  - Dietary fiber (Dr. Firkins)

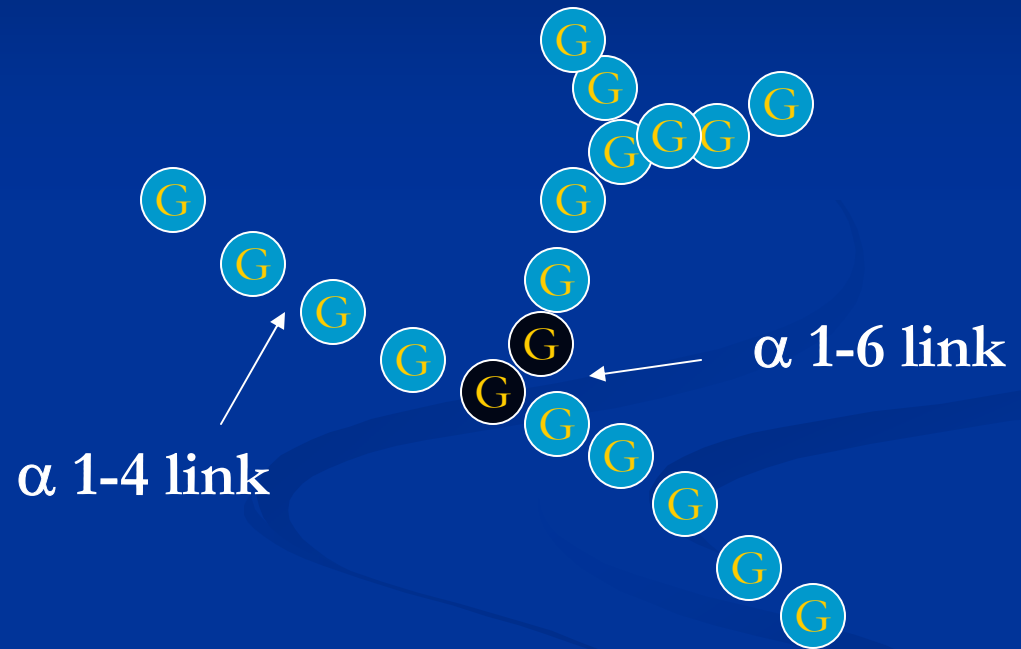
# Starch

- Major storage carbohydrate in higher plants
- Amylose – long straight glucose chains ( $\alpha$ 1-4)
- Amylopectin – branched every 24-30 glc residues ( $\alpha$  1-6)
- Provides 80% of dietary calories in humans worldwide



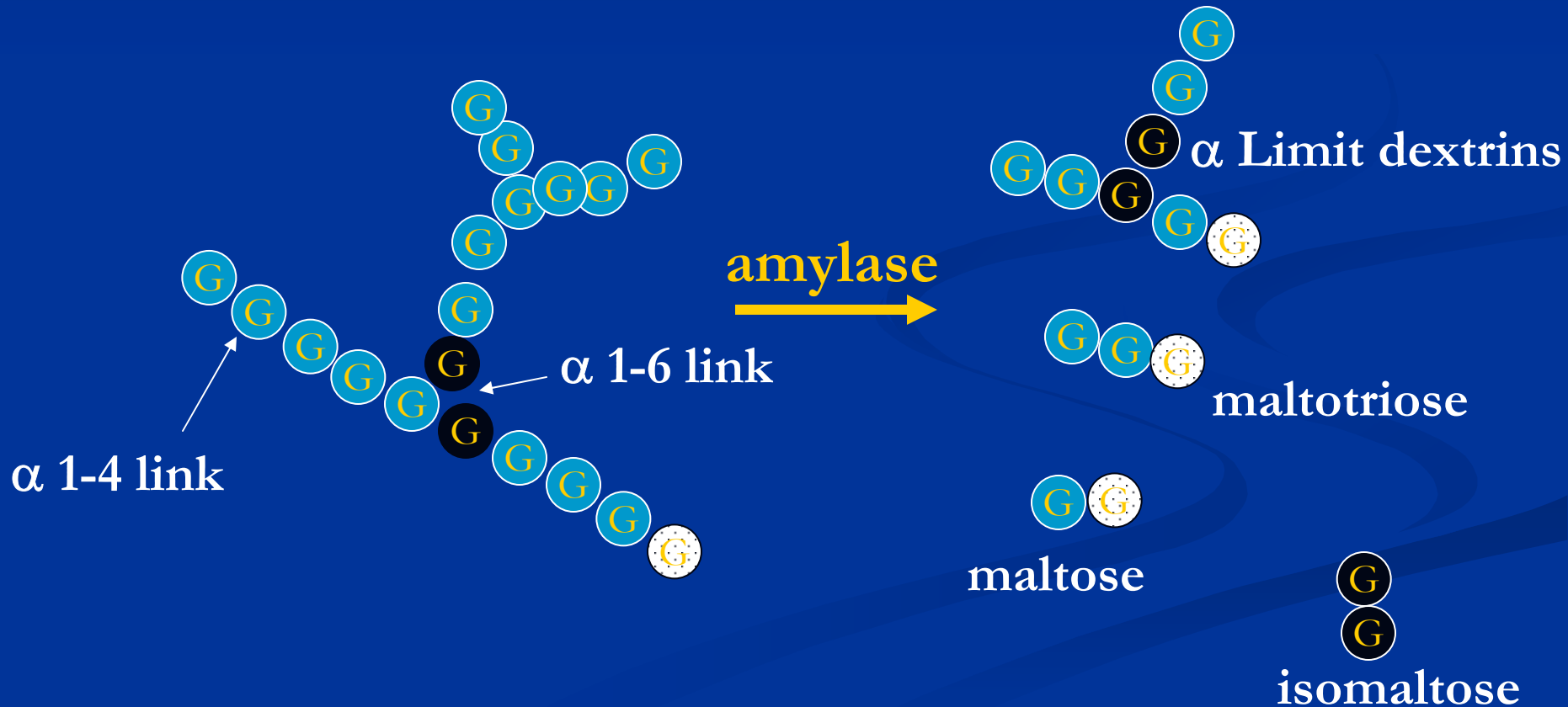
# Glycogen

- Major storage carbohydrate in animals
- Long straight glucose chains ( $\alpha$ 1-4)
- Branched every 4-8 glc residues ( $\alpha$  1-6)
- More branched than starch
- Less osmotic pressure
- Easily mobilized



# Digestion

- Pre-stomach – Salivary amylase :  $\alpha$  1-4 endoglycosidase



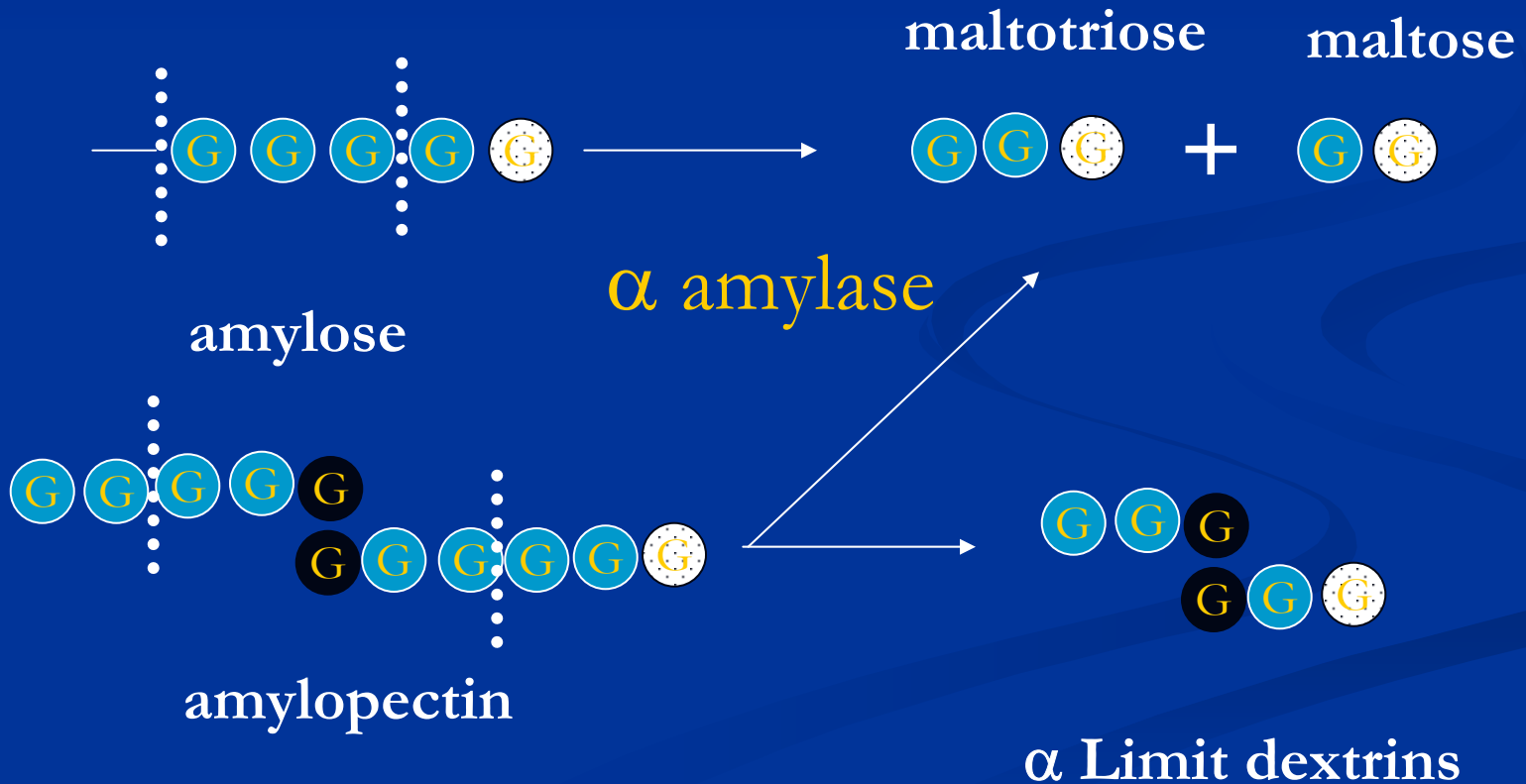
# Stomach

- Not much carbohydrate digestion
- Acid and pepsin to unfold proteins
- Ruminants have forestomachs with extensive microbial populations to breakdown and anaerobically ferment feed

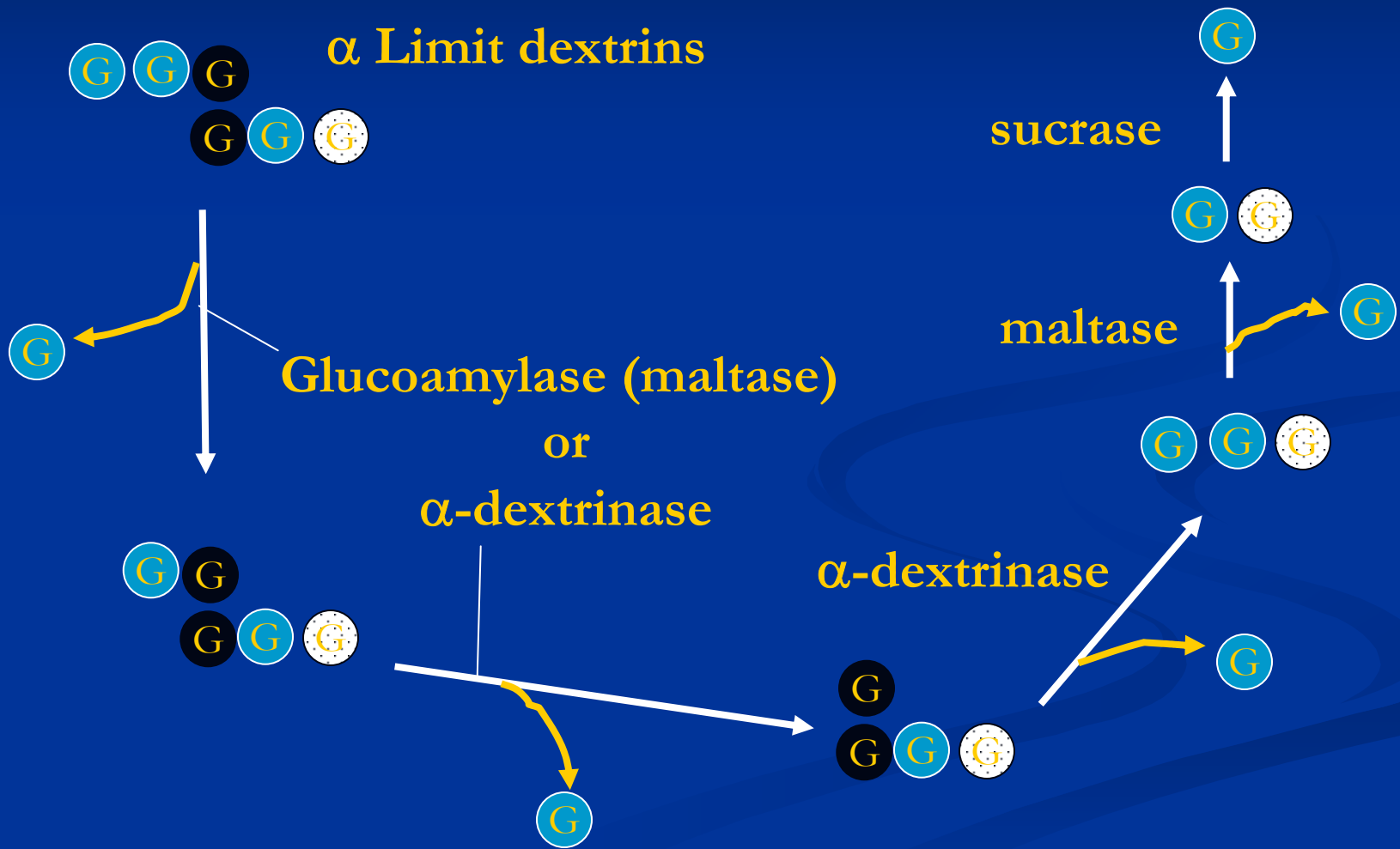
# Small Intestine

## ■ Pancreatic enzymes

### $\alpha$ -amylase



# Oligosaccharide digestion..cont



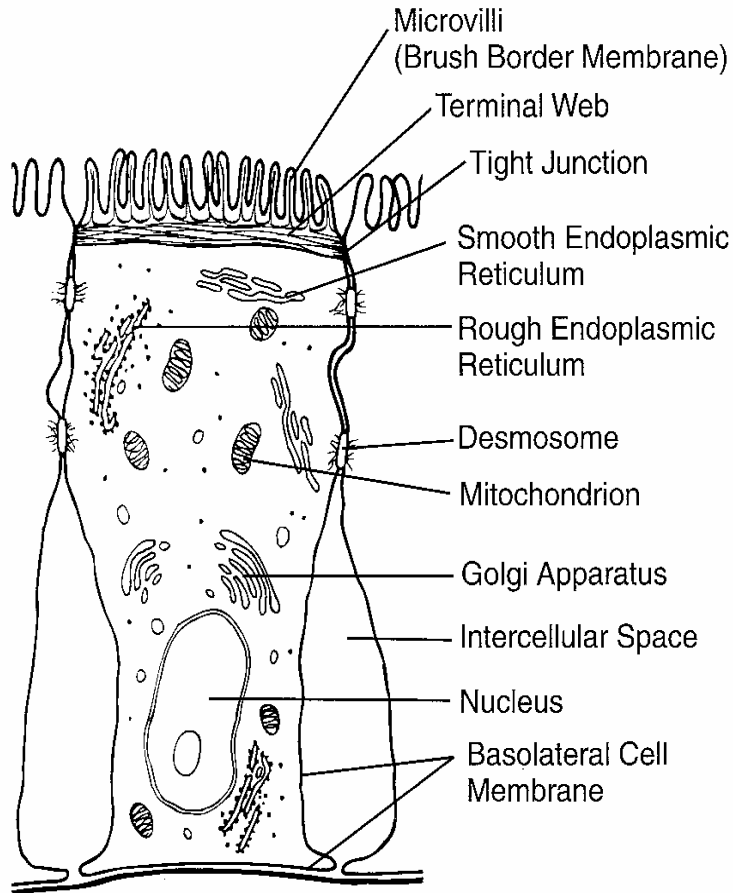
# Small intestine

Portal for transport of virtually all nutrients

Water and electrolyte balance

Enzymes associated with intestinal surface membranes

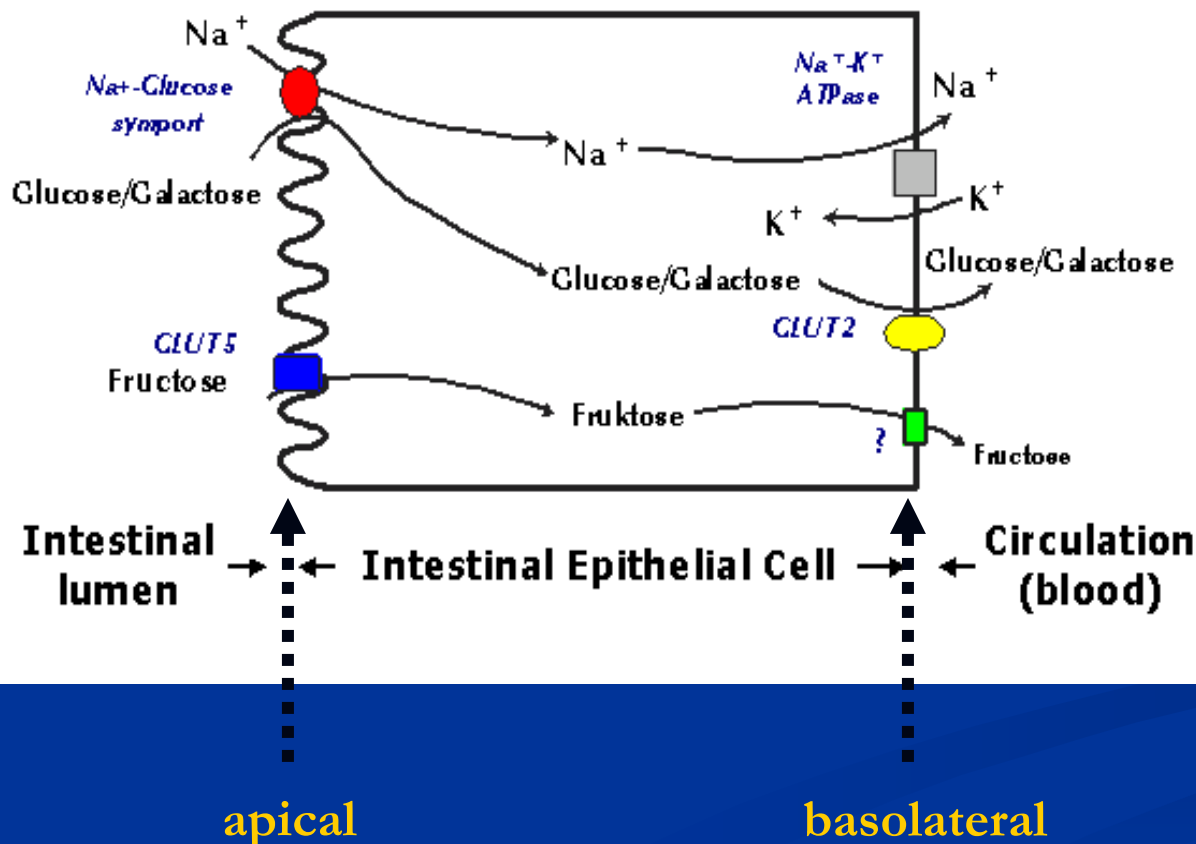
- i. Sucrase
- ii.  $\alpha$  dextrinase
- iii. Glucoamylase (maltase)
- iv. Lactase
- v. peptidases



**Figure 4-5.** Ultrastructure of a small intestinal epithelial cell (enterocyte).

# Carbohydrate absorption

## Uptake of Monosaccharides in the Small Intestine

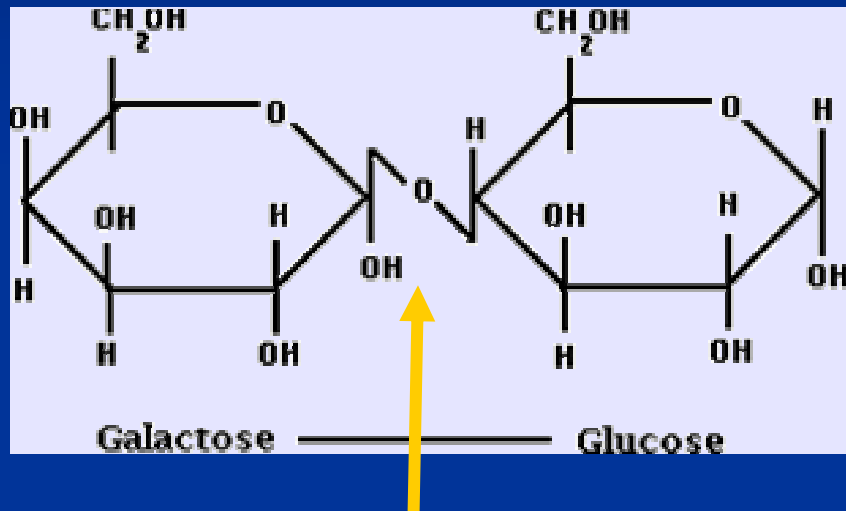


[Hexose transporter](#)

# Glucose and galactose absorption

- **Read Chapter 5 and answer the questions on page 102 of Stipanuk. Be prepared to discuss them on Friday**

# Carbohydrate malabsorption



$\beta$  1-4 linkage

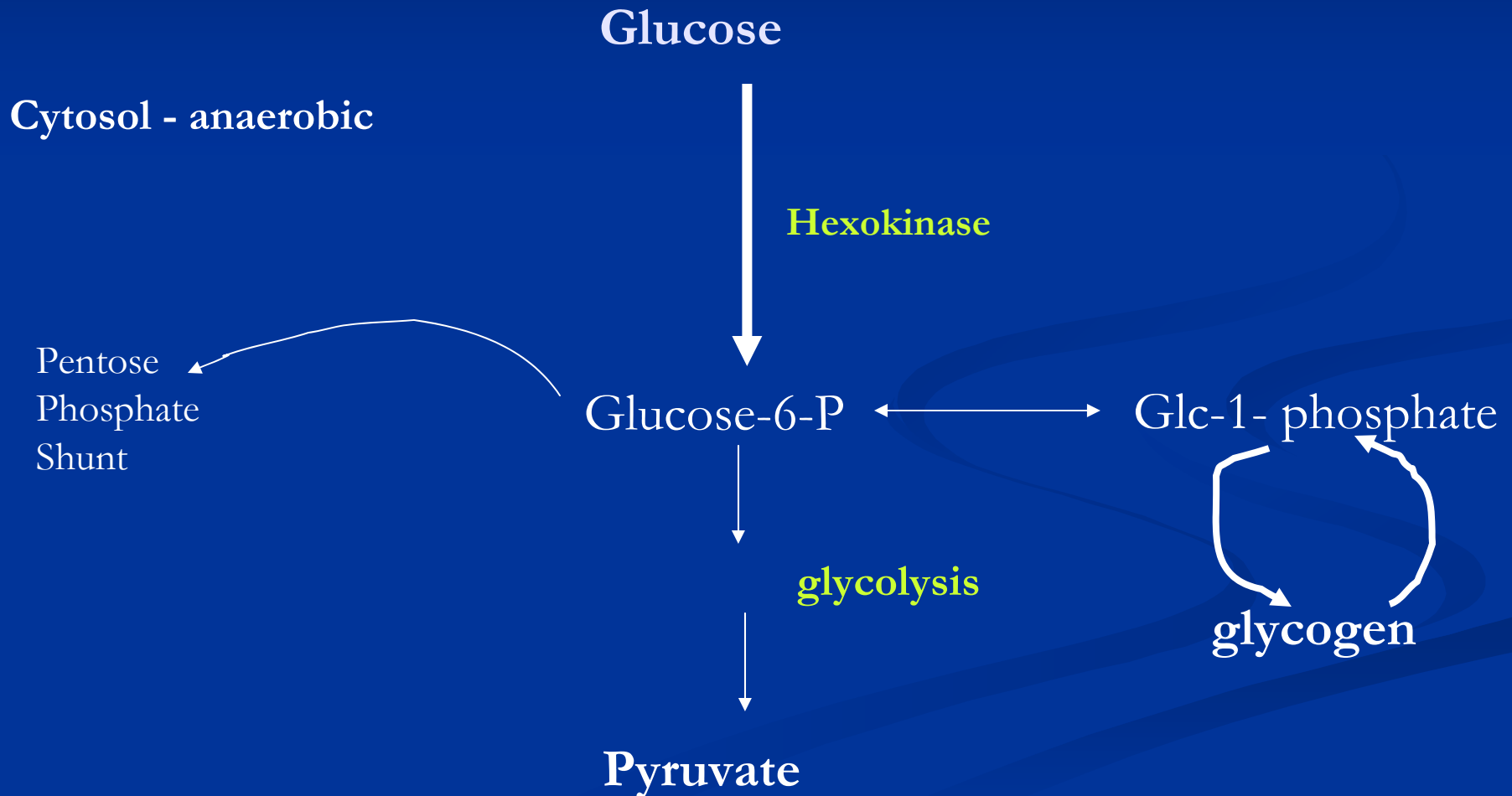
- Lactose intolerance (hypolactasia), page 100.
- Decline lactase with age
- Lactose fermented in LI –
  - Gas and volatile FA
  - Water retention – diarrhea/bloating
- Not all populations
  - Northern European – low incidence
  - Asian/African Americans – High

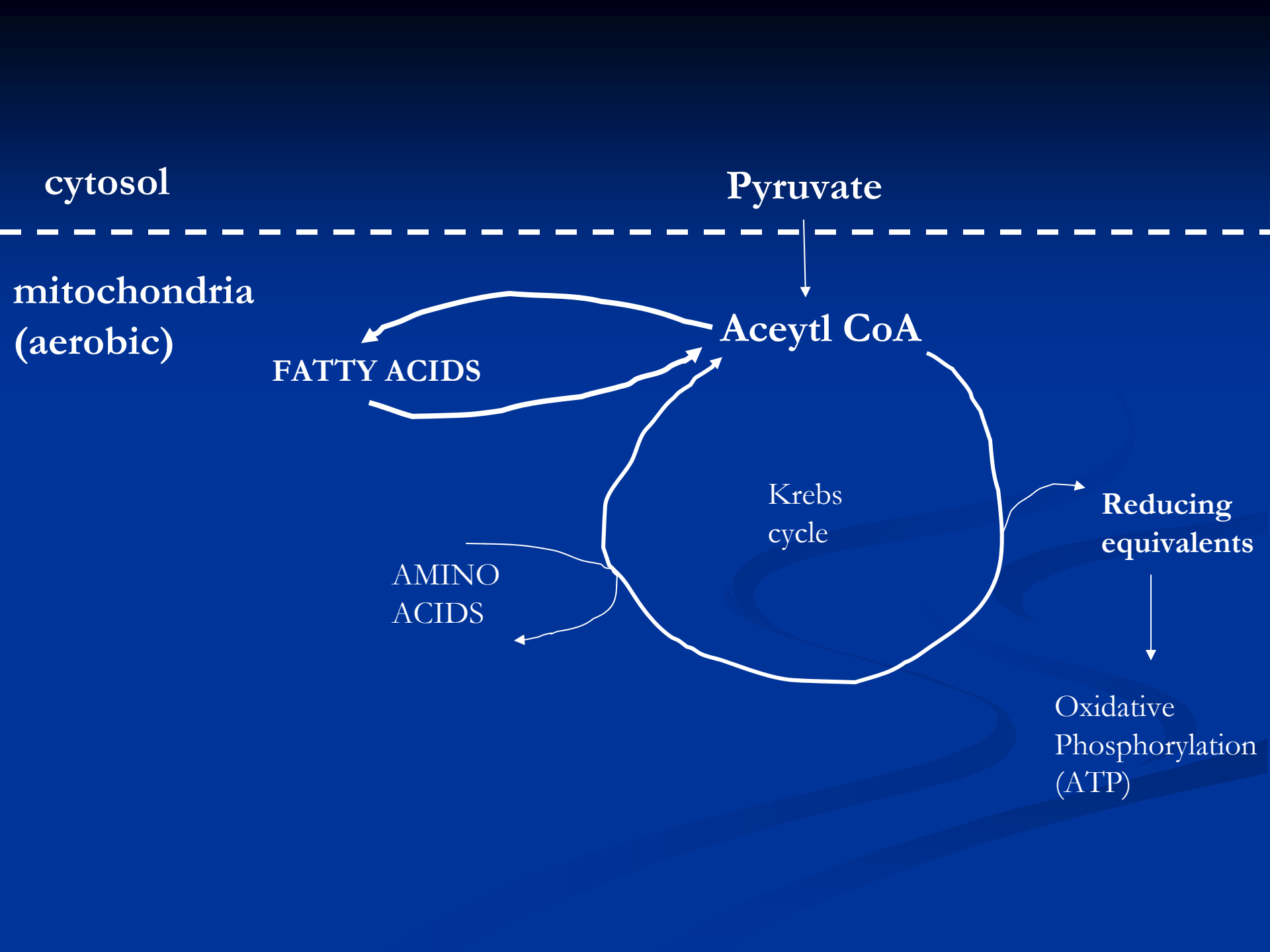
**Metabolism** – the chemical changes that take place in a cell that produce energy and basic materials needed for important life processes

- millions of cells
- Multiple organs (liver, adipose, heart, brain)
- Thousands of enzymes
- Various conditions (fed, fasted, exercise, stress)

# Carbohydrates

- Serve as primary source of energy in the cell
- Central to all metabolic processes





cytosol

Pyruvate

mitochondria  
(aerobic)

FATTY ACIDS

Acetyl CoA

AMINO ACIDS

Krebs cycle

Reducing equivalents

Oxidative Phosphorylation (ATP)

No mitochondria

Glucose  
Glycogen  
Lactate

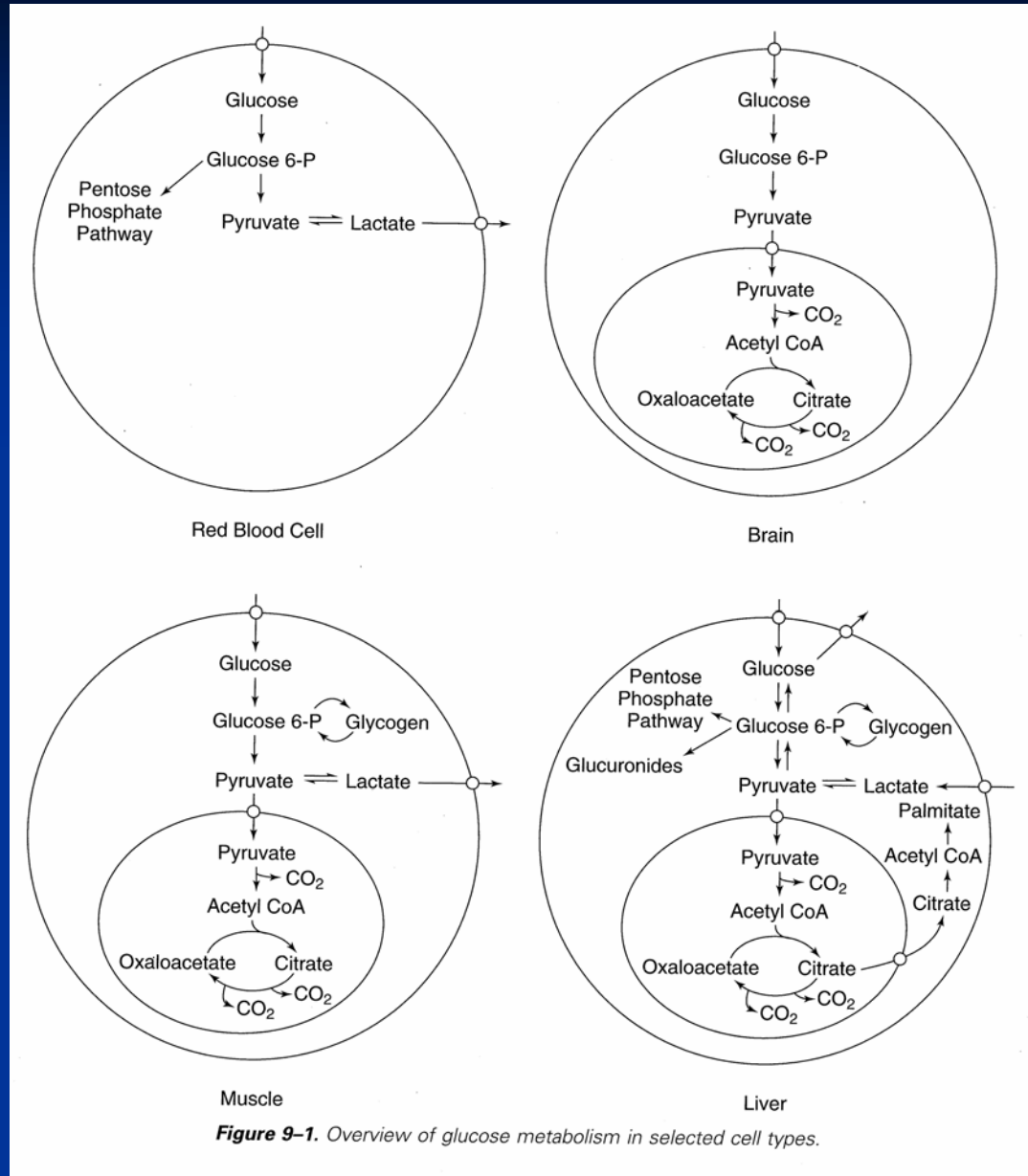
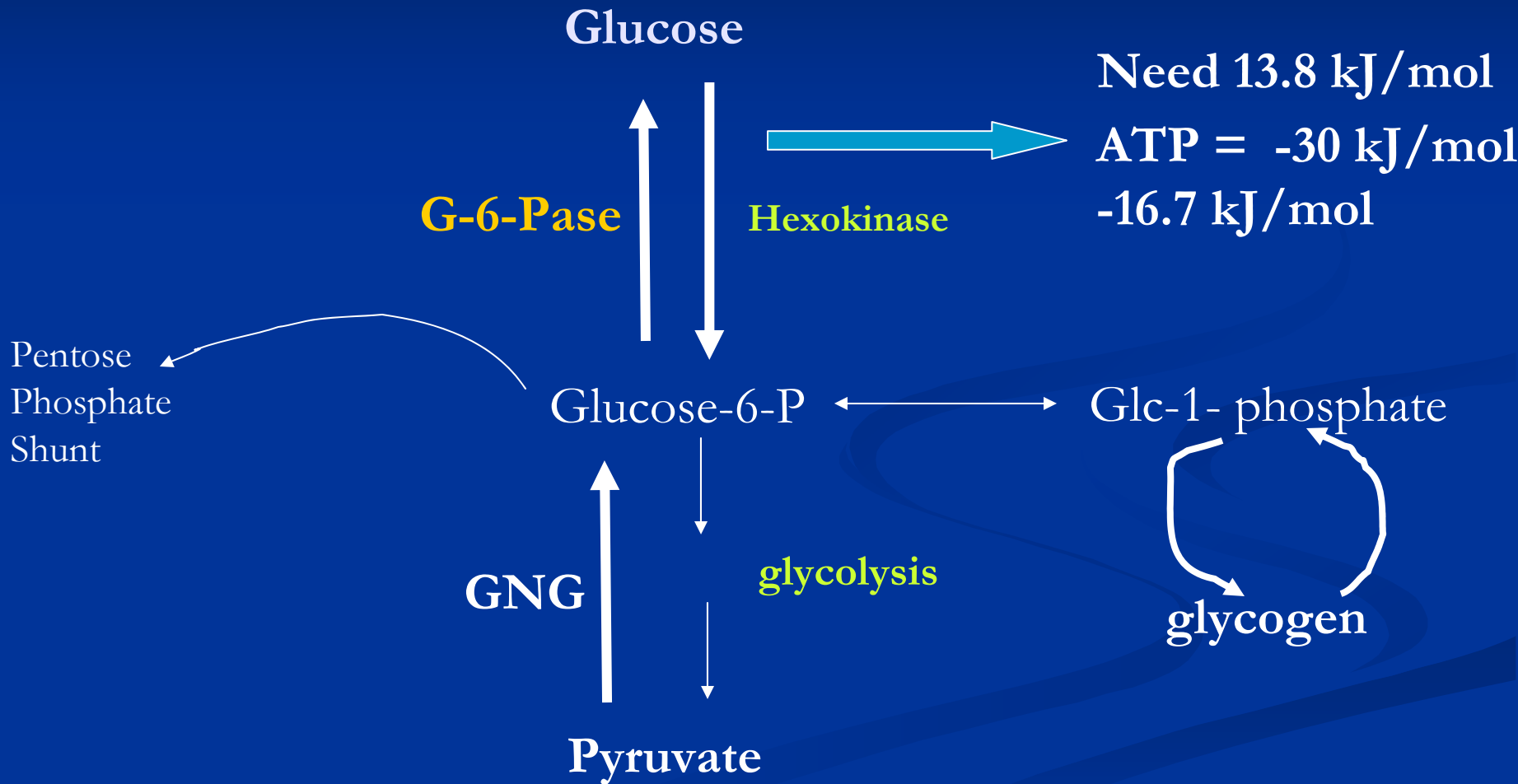


Figure 9-1. Overview of glucose metabolism in selected cell types.

Glucose  
Glucose  
Glucose

The Full  
Monty

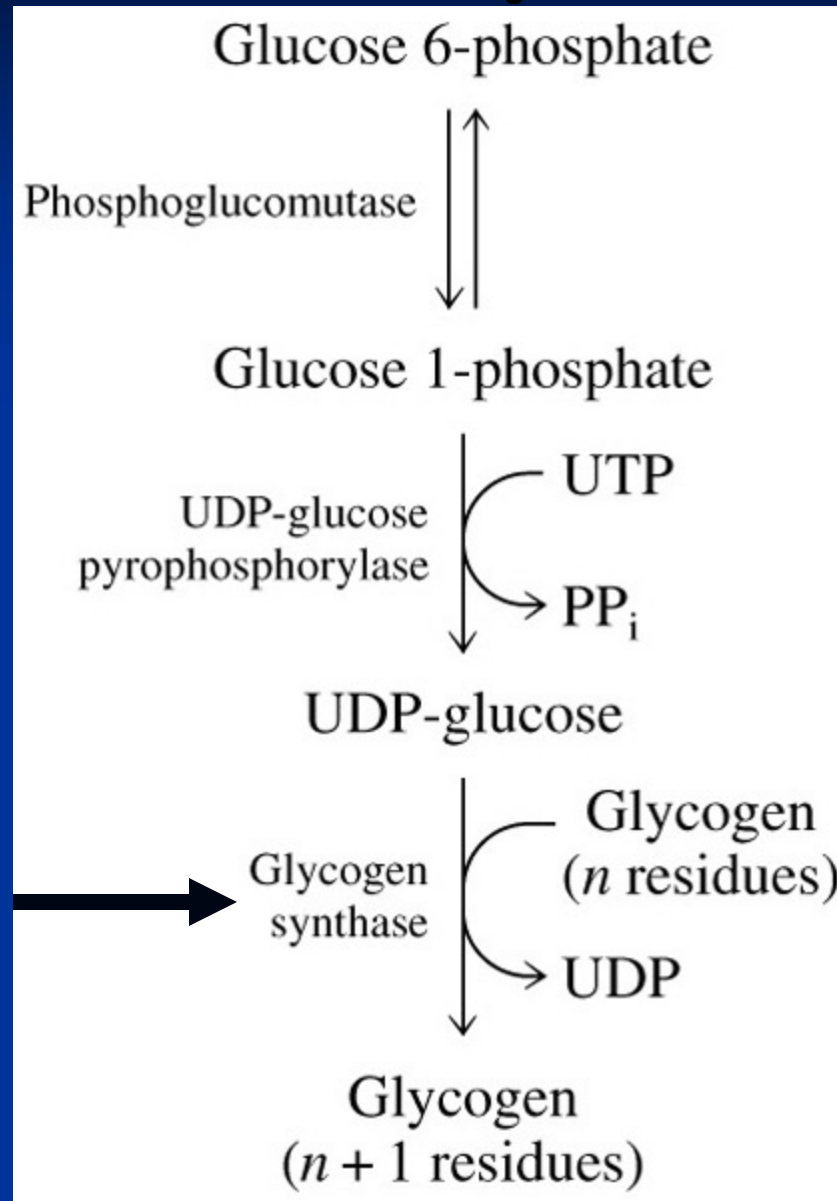
# Fasted State



# Controlling Metabolic Flux

1. Control enzyme levels
2. Control of enzyme activity (activation or inhibition)

# Control of enzyme activity



insulin



IR



P

Protein Kinase B  
(inactive)



OH



Protein Kinase B  
(active)

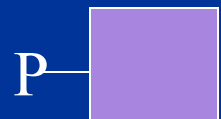
Glycogen synthase kinase  
(active)



OH



Glycogen synthase kinase  
(inactive)



Glycogen synthase  
(inactive)



OH

Glycogen synthase  
(active)



Glycogen formation

# Controlling Metabolic Flux

1. Control enzyme levels

2. Control of enzyme activity (activation or inhibition)

3. Compartmentalization

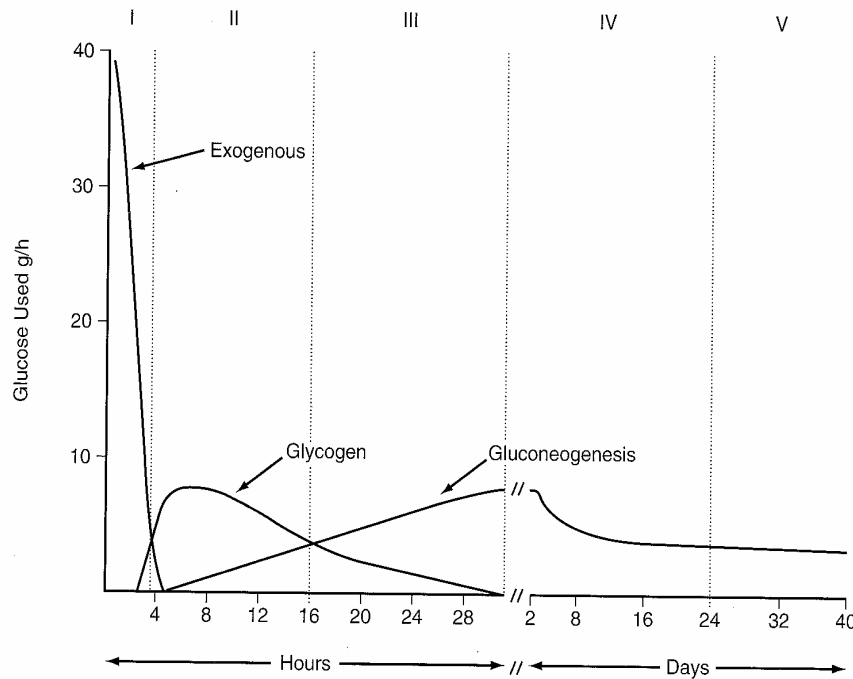
Fatty acid oxidation occurs in mitochondrial matrix

Fatty acid synthesis occurs in endoplasmic reticulum membrane exposed to the cytoplasm of the cell.

4. Hormonal control

# Glucose utilization





	I	II	III	IV	V
ORIGIN OF BLOOD GLUCOSE	Exogenous	Glycogen, Hepatic Gluconeogenesis	Hepatic Gluconeogenesis, Glycogen	Gluconeogenesis, Hepatic and Renal	Gluconeogenesis, Hepatic and Renal
TISSUES USING GLUCOSE	All	All Except Liver, Muscle and Adipose Tissue at Diminished Rates	All Except Liver, Muscle and Adipose Tissue at Rates Intermediate Between II and IV	Brain, RBCs, Renal Medulla, Small Amount by Muscle	Brain at a Diminished Rate, RBCs, Renal Medulla
MAJOR FUEL OF BRAIN	Glucose	Glucose	Glucose	Glucose, Ketone Bodies	Ketone Bodies, Glucose

**Figure 16-1.** Glucose utilization versus time in the five phases of glucose homeostasis. Stage I refers to the absorptive or postprandial period; II, to the postabsorptive period; III, to early starvation; IV, to intermediate starvation; and V, to prolonged starvation. (From Ruderman, N. B., Aoki, T. T. and Cahill, G. F., Jr. [1976] Gluconeogenesis and its disorders in man. In: Gluconeogenesis: Its Regulation in Mammalian Species [Hanson, R. W. and Mehlman, M. A., eds.]. John Wiley & Sons, New York. Copyright 1976, Wiley Interscience.)

## Stage 1 – postprandial

All tissues utilize glucose

## Stage 2 – postabsorptive

KEY – Maintain blood glucose

Glycogenolysis

Gluconeogenesis

Lactate

Pyruvate

Glycerol

AA

Propionate

Spare glucose by metabolizing fat

## Stage 3- Early starvation

Gluconeogenesis

## Stage 4 – Intermediate starvation

gluconeogenesis

Ketone bodies

## Stage 5 – Starvation

# Carbohydrate Metabolism/ Utilization- Tissue Specificity

- Muscle – cardiac and skeletal
  - Oxidize glucose/produce and store glycogen (fed)
  - Breakdown glycogen (fasted state)
  - Shift to other fuels in fasting state (fatty acids)
- Adipose and liver
  - Glucose → acetyl CoA
  - Glucose to glycerol for triglyceride synthesis
  - Liver releases glucose for other tissues
- Nervous system
  - Always use glucose except during extreme fasts
- Reproductive tract/mammary
  - Glucose required by fetus
  - Lactose → major milk carbohydrate
- Red blood cells
  - No mitochondria
  - Oxidize glucose to lactate
  - Lactate returned to liver for Gluconeogenesis