Chapter 25: Metabolism and Nutrition

Chapter Objectives

INTRODUCTION

1. Generalize the way in which nutrients are processed through the three major metabolic fates in order to perform various energetic and structural functions in the body.

CARBOHYDRATE METABOLISM

2. Review carbohydrate metabolism in the GI tract, liver and body cells.
3. Describe the controlled, facilitated entry of glucose into different cell types, and the means to capture and/or release it from specific cells.
4. Describe the processes of glycolysis (review in text), glycogenesis, glycogenolysis, and gluconeogenesis. Describe starting materials and end products and which hormones control each process.

LIPID METABOLISM

5. Explain the formation and removal of chylomicrons from blood.
6. Discuss how lipids are transported in blood.
7. Discuss the sources of cholesterol and indicate the concentrations that are considered as potential problems for coronary artery disease.
8. Describe how lipolysis breaks down the triglycerides into glycerol and fatty acids. Explain where glycerol enters carbohydrate metabolism. Describe how fatty acids undergo beta oxidation and where those products enter the carbohydrate metabolism pathway.
9. Describe ketogenesis and lipogenesis.

PROTEIN METABOLISM

10. Trace the general path of amino acid absorption and use by the liver and the body as a whole. List the hormones that have a role in controlling protein metabolism.
11. Describe the difference between essential and non-essential amino acids.

METABOLIC ADAPTATIONS

12. Distinguish between the major characters of the absorptive and postabsorptive state in term of the conditions that establish the states and hormones that control the associated activities.
13. Discuss the metabolic reactions that occur for glucose, amino acids, and lipids that predominate during the absorptive state.
14. Describe how metabolism during the absorptive state is regulated.

15. Describe the reactions of the postabsorptive state.
16. Describe how metabolism during the postabsorptive state is regulated.

NUTRITION

17. Discuss the seven guidelines for healthy eating.
18. Discuss the importance of minerals in the body.
19. Discuss the importance of vitamins in the body. Distinguish between water soluble and lipid soluble vitamins.
20. Discuss when vitamin and mineral supplements should be taken.

Chapter Lecture Notes

Introduction to Metabolism

The food we eat is our only source of energy for performing biological work (Fig 25.1)

Three major metabolic destinations for the principle nutrients from food

- used for energy for active processes
- synthesized into structural or functional molecules
- stored as fat or glycogen for later use

Don't have time to go over the central pathway of metabolism; the processes of glycolysis, Krebs (TCA) cycle, and the electron transport chain/oxidative phosphorylation

Please review on your own to recall the pathways

Will not be tested on those pathways

Most metabolism based on the central pathway which involves glucose

Digestive system brings carbohydrate nutrients into body

- polysaccharides broken down into simple sugars
- absorption of simple sugars (glucose, fructose & galactose)

Liver gets first chance at processing the incoming nutrients

- fructose & galactose transformed into glucose
- excess glucose can be stored as glycogen (also in muscle)

Body cells

- can oxidize glucose to produce energy

can store glucose as glycogen (liver & muscle)

can convert glucose into fats or amino acids

can store energy as triglycerides in adipose tissue (limited amount in muscle)

Glucose Movement into Cells

In GI tract and kidney tubules

Na^+/glucose symporters

Most other cells

GluT facilitated diffusion transporters

insulin increases the insertion of GluT transporters in the membrane of most cells

in liver & brain, always lots of GluT transporters

Glucose 6-phosphate forms immediately inside cell (requires ATP) thus, glucose is "hidden" when it is in the cell

concentration gradient remains favorable for more glucose to enter

Other Carbohydrate Pathways

Glycogenesis (Fig 25.11)

production of glycogen, a polysaccharide, for glucose storage

4 steps to glycogen formation in liver or skeletal muscle

stimulated by insulin

Glycogenolysis (Fig 25.11)

breakdown of glycogen for glucose release to the bloodstream

not a simple reversal of steps

one of the enzymes of glycogenolysis, phosphorylase, is activated by glucagon (pancreas) or epinephrine (adrenal gland)

the final enzyme of the glycogenolysis pathway, glucose-6-phosphatase, is only in hepatocytes

liver has the ability to release glucose to the bloodstream

muscle cannot release glucose but uses the glucose released from glycogen as an energy source for ATP production

Gluconeogenesis - the conversion of protein or fat molecules into glucose (Fig 25.12)

glycerol (from fats) may be converted to glyceraldehyde-3-phosphate

some amino acids may be converted to pyruvic acid

stimulated by cortisol, thyroid hormone, epinephrine, glucagon, and human growth hormone

Lipid Metabolism

Lipid transport - most lipids are transported in the blood in combination with proteins as lipoproteins

Chylomicrons (2 % protein)

form in intestinal mucosal cells

transport exogenous (dietary) fat

VLDLs (10% protein) (Fig 25.13)

transport endogenous triglycerides (from liver) to fat cells

converted to LDLs

LDLs (25% protein) - “bad cholesterol”

carry 75% of blood cholesterol to body cells

HDLs (40% protein) - “good cholesterol”

carry cholesterol from cells to liver for elimination

Cholesterol

Two sources of cholesterol

food we eat

liver synthesis

For adults, desirable levels of blood cholesterol

TC (total cholesterol) under 200 mg/dl

LDL under 130 mg/dl

HDL over 40 mg/dl

Normally, triglycerides are in the range of 10-190 mg/dl

Lipid storage

lipids are stored in the body as triglycerides in adipose tissue

Lipid catabolism – lipolysis (Fig 25.14)

triglycerides are split into fatty acids and glycerol

stimulated by epinephrine, norepinephrine, or glucocorticoids

glycerol can be converted into glucose by conversion into glyceraldehyde-3-phosphate

beta oxidation – fatty acids are broken down as carbon atom pairs

the resulting pairs are converted to acetyl-coA and enter the Krebs cycle

Lipid catabolism – ketogenesis (Fig 25.14)

two acetyl-CoA (from beta oxidation) bond to form acetoacetic acid which can then be converted to beta-hydroxybutyric acid and acetone (ketone bodies)

occurs in liver

diffuses to other tissues through bloodstream

heart muscle & kidney cortex prefer to use acetoacetic acid for ATP production

Lipid anabolism – lipogenesis (Fig 25.14)

lipogenesis - conversion of glucose or amino acids into lipids

stimulated by insulin

occurs in liver and adipose cells

Protein Metabolism

Digestion, absorption and transport

proteins are hydrolyzed into amino acids in small intestine

amino acids are absorbed by the capillaries of villi and enter the liver via the hepatic portal vein

Transport into cells

amino acids enter cells by active transport

influenced by human growth hormone and insulin

Protein anabolism

synthesized into proteins inside cells

stimulated by human growth hormone, thyroxine, and insulin

liver cells can convert amino acids into glucose and the glucose is stored as glycogen

liver cells can convert amino acids into triglycerides and the triglycerides are stored as fat

Protein catabolism (Fig 25.15)

Liver cells convert amino acids into substances that can enter the Krebs cycle

deamination removes the amino group (NH_2)

converts it to ammonia (NH_3) & then urea

urea is excreted in the urine

Amino Acids

Essential amino acid - amino acids that cannot be synthesized by the human body or are

synthesized in inadequate amounts

must be a part of the diet

10 of 20 are essential at some point in life

Nonessential amino acids can be synthesized by body cells by a process called transamination

Metabolic Adaptations

Your metabolic reactions depend on how recently you have eaten

Absorptive state – storage (Fig 25.17)

ingested nutrients enter the blood and lymph from the GI tract

most body cells produce ATP by oxidizing glucose

glucose transported to the liver is converted to glycogen or triglycerides

most dietary lipids are stored in adipose tissue

amino acids are converted to carbohydrates, fats, and proteins in liver cells

Regulation of the Absorptive State (Table 25.3)

Insulin

gastric inhibitory peptide and the rise in blood glucose concentration stimulate insulin release

Insulin's functions

increases anabolism & synthesis of storage molecules (glycogen)

decreases catabolic or breakdown reactions

promotes entry of glucose & amino acids into cells

stimulates phosphorylation of glucose

enhances synthesis of triglycerides

stimulates protein synthesis along with thyroid & growth hormone

Postabsorptive State - maintanence of normal blood glucose level (70 to 110 mg/100 ml of blood) (Fig 25.18)

~4 hours after a meal

glucose enters blood from 3 major sources

glycogen breakdown in liver produces glucose

glycerol from adipose converted by liver into glucose

gluconeogenesis using amino acids produces glucose

most body cells will use alternative fuel sources for ATP production

fatty acids from fat tissue fed into Krebs as acetyl-CoA

lactic acid produced anaerobically during exercise

oxidation of ketone bodies by heart & kidney

Regulation of the Postabsorptive State (Table 25.4)

Glucagon

stimulates gluconeogenesis & glycogenolysis within the liver

Norepinephrine and Epinephrine

hypothalamus detects low blood sugar

activates sympathetic neurons and adrenal medulla

stimulates glycogen breakdown & lipolysis

raises glucose & free fatty acid blood levels

Nutrition

Guidelines for healthy eating (Fig 25.20)

eat a variety of foods

maintain a healthy weight

chose foods low in fat, saturated fat, and cholesterol

eat plenty of vegetables, fruits, and grain products

use sugar only in moderation

use salt and sodium only in moderation

drink alcohol only in moderation or not at all

Minerals

Inorganic substances = 4% body weight (Table 25.5)

Functions

calcium & phosphorus form part of the matrix of bone

help regulate enzymatic reactions

calcium, iron, magnesium & manganese

magnesium is catalyst for conversion of ADP to ATP

form buffer systems

regulate osmosis of water

generation of nerve impulses

Vitamins

Vitamins - organic nutrients that maintain growth and normal metabolism

function in enzyme systems as coenzymes (Table 25.6)

most vitamins cannot be synthesized by the body

no single food contains all of the required vitamins – one of the best reasons for eating a varied diet

based on solubility, vitamins fall into two main groups

Fat-soluble vitamins

emulsified into micelles and absorbed along with ingested dietary fats by the small intestine

stored in cells (particularly liver cells)

vitamins A, D, E, and K

Water-soluble vitamins

absorbed along with water in the GI tract and dissolve in the body fluids

excess quantities of these vitamins are excreted in the urine

the body does not store water-soluble vitamins well

include the B vitamins and vitamin C

Vitamin and Mineral Supplements

Better to eat a balanced diet rather than taking supplements except in special circumstances

iron for women with heavy menstrual bleeding

iron & calcium for pregnant or nursing women

folic acid if trying to become pregnant

reduce risk of fetal neural tube defects

calcium for all adults

B_{12} for strict vegetarians

antioxidants C and E recommended by some