Chpt. 25: Nutrition & Metabolism

Cells break down organic molecules to obtain energy

Most energy production takes place in the?

Metabolism: refers to all chemical reactions in an organism

Cellular Metabolism: all chemical reactions within cells

catabolism

anabolism
- for structural maintenance or repairs
- to support growth
- secretions
- build nutrient reserves: glycogen, fats

nutrient pool: source of substrates for both catabolic and anabolic reactions.

Organic Compounds:

1. Glycogen: most abundant storage carbohydrate

2. Triglycerides: most abundant storage lipids

3. Proteins: most abundant organic components in body

6 categories of nutrients: CHO, lipid, protein, vitamin, minerals, water

1. CHO: 4kcal/g

• glycogen (storage form of glucose in animals), starch (storage form of glucose in plants) & cellulose (found in plants – fiber)

•most CHO from plants (except lactose & glycogen)
monosaccharides & disaccarided: sugars, fruits, honey
Polysaccharides: starch, graines, legumes, vegetables, fiber

•functions of CHO: Energy: cells use glucose for energy (fructose & galactose are converted into glucose in the liver)
Remember: neurons & RBC only use glucose for energy

Dietary Requirements: 60-70% of diet: complex better than simple
Too many carbs: obesity, increase triglycerides, GI irritation
Too few: body converts protein & fats to glucose: could cause keotacidosis

Glycemic index:

2. Lipids: 9kcal/g

•cholesterol from animal products: meat, egg yolk

• triglycerides (TG): main form of lipids

•essential fatty acids: linoleic acid: helps form prostaglandins

•saturated vs unsaturated: saturated are solid at room temperature (meat, dairy, chocolate)
Unsaturated: oils, nuts, seeds

Omega-6 vs. Omega-3 fatty acids & health: both are polyunsaturated: abundant in plant & fish oils

Omega-6: (GLA)
• used to form prostaglandins – regulate inflammation, blood pressure, heart, gastrointestinal & kidney functions

• evening primrose oil, black currant seed oil, flaxseed oil, have high GLA content and may help relieve pain associated with rheumatoid arthritis, relieve PMS, endometriosis, reduce symptoms of eczema & psoriasis, also cause healthy skin & hair. Might clear up acne.

-prevent & improve diabetic neuropathy (diabetics have problems forming GLA

Omega-3
• mainly found in cold-water fish (albacore tuna, salmon, mackerel)

• improve heart health – lower cholesterol, stabilize irregular heart beat (decrease arrhythmia), protect blood vessels from disease (decrease atherosclerosis), lower triglyceride levels, decrease clotting

• reduce hypertension, improve autoimmune diseases, act as anti- inflammatory agents, help with arthritis pain

• improve depression, help with brain functioning-improve communication within brain (*Lorenzo's Oil* was an omega-3 fatty acid) being researched for depression, manic-depression(bi-polar), schizophrenia

• aid cancer prevention (breast & colon cancers)

•functions of lipids
triglycerides: energy: main fuel for hepatocytes & skeletal muscle

cholesterol: forms cell membranes, bile salts, steroid hormones

adipose tissue: cushioning, insulates, concentrated energy

•Dietary Requirements:
Saturated fat: 10% or less
Cholesterol: 300 mg or less

Consume too many: obesity, increased risk of CVD, high cholesterol
Consume too little: decrease weight, problems with heat (loss of subcutaneous fat)

3. Proteins: 4kcal/g

•animal products contain complete protein (contain all essential amino acids)

•legumes, nuts, cereals: missing 1 or more essential amino acids

•functions of protein: tissue building (collagen, keratin, actin, myosin), antibodies, hormones, hemoglobin, DO NOT WANT TO BURN FOR ATP

•4 factors determining if protein (AA) used for energy

1. All or none law

all the amino acids necessary to build the protein must be present in sufficient quantities to make the protein.

2. Adequacy of caloric intake:

if don't take in enough fats and carbs will use protein for energy

3. Nitrogen balance of body:

(protein metabolism releases NH2)
nitrogen provides information on protein levels

if protein synthesis = protein breakdown in balance

positive nitrogen balance = more protein being synthesized then broken down

during growth, children, pregnancy

negative nitrogen balance = more protein is broken down than synthesized

during physical/emotional stress, infection, injury, poor diet, starvation

4. Hormonal Controls

anabolic hormones

growth hormone

testosterone

catabolic hormones:

glucocorticoids (cortisol)

•Dietary requirements: .8 g/kg body weight

Consume too many: obesity
Consume too little: decrease weight, tissue wasting, anemia, growth retardation

4. Vitamins

•organic compounds: needed in small amounts for growth/health

-not used for energy or structurally

•coenzymes

•water soluble: B complex & C

B vitamins: assist in metabolism
B12:
Vitamin C?

•fat soluble: A,D,E, K
Functions:

5. Minerals

•macrominerals: Ca^{++}, P, K^+, S, Na^+, Cl^-, Mg^{++}

•microminerals: Fe, Cu, Zn

• Na^+, Cl^-, K^+: RMP, action potentials, water balance

• Ca^{++}

6. Water: most abundant & important inorganic compound in living organisms

•properties

1. Absorbs & releases a lot of heat before changing states: good for temperature regulation

2. polarity/solvent properties
   "universal solvent"

3. Reactivity
   Dehydration synthesis
   Hydrolysis

4. Cushioning

Aerobic Cellular Respiration:

3 pathways: glycolysis, Krebs cycle, electron transport chain

glycolysis always occurs
if oxygen available the Krebs cycle and ETC will run

Oxidation-Reduction Reactions

•reactions within cells producing ATP

•oxidation: loss of electrons

•reduced: gain of electrons

enzymes catalyze oxidation-reduction reaction
$NAD + 2H^+ \leftrightarrow NADH + H^+$
$FAD + 2H \leftrightarrow FADH_2$

Mechanisms of ATP Synthesis:

2 mechanisms

1. substrate-level phosphorylation
   occurs during glycolysis and the krebs cycle
   ADP + P -----→ ATP

2. oxidative phosphorylation
   during electron transport chain only

CHO Metabolism

•glucose to cells: enters cell and is immediately phosphorylated to glucose-6-phosphate: enzymes: hexokinase/glucokinase

This is important for 2 reasons:

1.
2.

•oxidation of glucose:

$C_6H_{12}O_6 + 6O_2 \text{ ---> } 6H_2O + 6\ CO_2 + 38\ ATP + heat$

Glycolysis:

•occurs in cytoplasm

•Final products of Glycolysis
   2 molecules of pyruvic acid
   2 molecules $NADH_2$ (go to ETC for oxidative phosphorylation)
   4 molecules of ATP = Net gain of 2 ATP

•pyruvic acid:
   •with oxygen: pyruvic acid continues on to Krebs Cycle & ETC

   •without oxygen: $NADH_2$ cannot unload H+ at ETC so "dumps" them onto pyruvic acid to form lactic acid

Krebs Cycle:

•occurs in
•fueled by acetyl CoA

<u>transition reaction</u> pyruvic acid enters mitochondria & converted to acetyl CoA

1st step of Krebs Cycle: oxaloacetic acid + acetyl CoA = citric acid

End products: $NADH_2$, $FADH_2$, ATP, CO_2

what happens to levels of oxaloacetic acid when on low-CHO diet/diabetic/starvation?

Electron Transport Chain:

- directly uses
- catabolic reactions in

- H removed from oxidation of food split into protons (H+) and electrons
electrons passed through chain to generate energy to pump H+ across inner membrane: this creates a "battery"

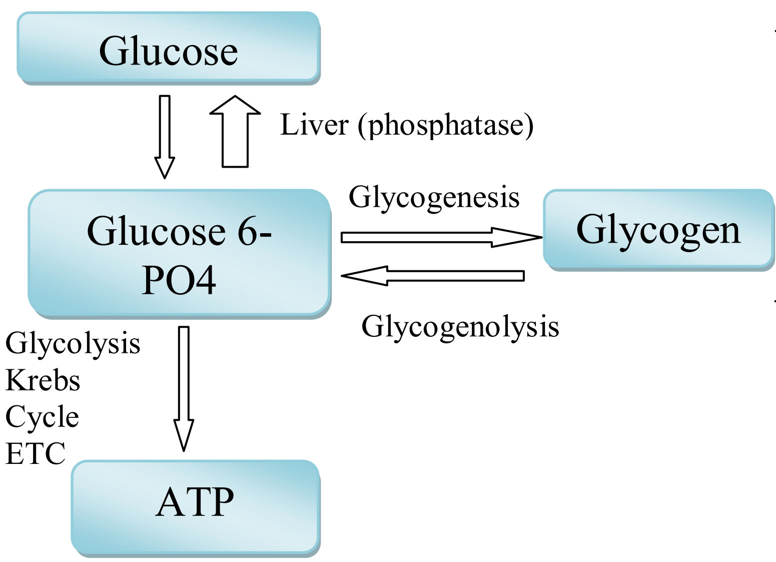
The importance of oxidative phosphorylation

- components of ETC: cytochromes and respiratory enzyme complexes

oxidation of each $NADH_2$ =
oxidation of each $FADH_2$ =

Total ATP production: 36 (38) ATP per glucose

Glycogenesis and Glycogenolysis



Glycogenesis:

-occurs in skeletal muscle and the liver

-glucose → glucose 6-PO4 → glycogen

Glycogenolysis:
-occurs directly in the liver
-requires phosphatase to convert glucose 6-PO4 → glucose

-occurs indirectly in skeletal muscle (glycogen → glucose 6-PO4 → pyruvic acid → bloodstream to liver

Gluconeogenesis: making glucose from glycerol and/or proteins

Lipid Metabolism:

TG first hydrolyzed into glycerol and FA

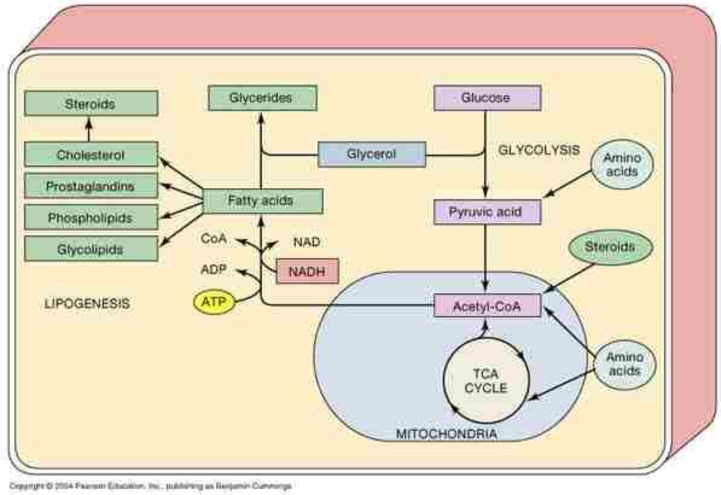
1. Glycerol converted to glyceraldehyde 3-phosphate
   which converts to pyruvic acid enters glycolysis, Krebs cycle, ETC

   each glycerol produces 18(19) ATP molecules

2. Fatty Acids

•undergo Beta oxidation: breaks fatty acid chain down into 2-Carbon acetyl CoA molecules

typical FA produces 147 ATP molecules



<u>Lipogenesis and Lipolysis:</u>

<u>Lipogenesis</u>: Making Lipids

<u>Lipolysis:</u> Breaking down lipids for energy

one Tg – 459 (460) ATP molecules

note: when occurs at high rate can cause ketoacidosis
(i.e. starvation diet, low CHO diet or diabetic)
(low glucose levels deplete oxaloacetic acid levels which causes acetyl CoA to accumulate).

Lipoproteins: CM (chylomicron), VLDL, IDL, LDL, HDL (High Density Lipoprotein)

Synthesized in liver & ingested in diet

<u>Cholesterol Transport:</u>
VLDL takes fat from liver to adipose cells: drops off fat and becomes IDL

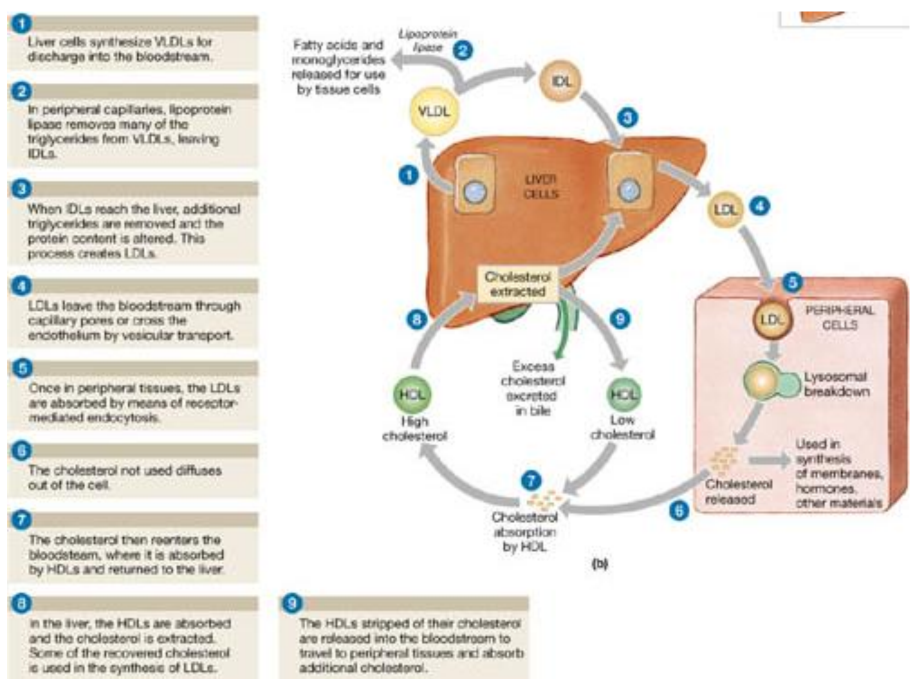
IDL returns to the liver

LDL leaves liver travels via blood to all cells –

enters cells via receptor mediated endocytosis
(receptors genetically determined)

LDL used by cell to

HDL: cleans up arteries



Clinical Cholesterol Levels

TC: high risk of CV disease & CAD if >240 mg/dl and low risk if < 200 mg/dl

HDL: high risk if < 35 mg/dl, low risk if >45 mg/dl

LDL high risk if > 160 mg/dL and low risk if < 130 mg/dL

Tg (fasting) should be less than 150 mg/dl

LDL = total cholesterol – HDL – Tg/5

Causes of High Cholesterol:

1. Family History
2. Diabetes and/or obesity
3. Diet: cholesterol, saturated fats

4. Lifestyle

Treatment of High Cholesterol:

1.) Pharmacological:

Statins:

Cholesterol Absorption Inhibitors

Combination of both

Meds to lower triglycerides

2.) Dietary Modifications:

Increase intake of monounsaturated fats

Decrease intake of saturated fats/cholesterol

Increase intake of fiber

Increase intake of whole grains, fruits, veggies

3.) Lifestyle Modifications:

Protein Metabolism:

The body synthesizes 100,000 – 140,000 different proteins

Uses 20 amino acids
Cellular proteins are recycled

Protein Synthesis

-occurs in

Proteins and ATP Production

- When glucose and lipid reserves are inadequate, liver cells
  - Break down internal proteins
  - Absorb additional amino acids from blood

Oxidation of amino acids:

1. deamination in liver: amino group (NH2) cleaved off – converted into ammonia (NH3)
   ammonia highly toxic
   hepatocytes convert ammonia to urea & release to blood to kidneys for elimination

   Remaining amino acid can be used to form ATP

Absorptive and Postabsorptive States:

•metabolic controls equalize blood concentration of nutrients

•absorptive: the period following a meal

•postabsorptive: aprx. 3-4 hours after a meal
Body relies on internal energy reserves for energy demands

A. Absorptive State:

anabolic processes:

1. CHO:

•absorb monosaccharides to liver where glucose synthesized from

•glucose enters cell and is phosphorylated into glucose 6PO4 which is:

1.
2.
3.

2. Triglycerides:

•absorbed into lymph as CM, enter blood, Tg is split off and CM remnant goes to liver for processing

Tg:

•used to produce ATP by Adipose cells, skeletal muscle and hepatocytes

•Fatty acids and glycerol can be used to synthesize

3. Amino Acids:

•absorbed amino acids go to liver & tissue cells where they are used to for protein synthesis

4. **Hormonal Control:**

•insulin: main hormone of absorptive state

•Functions of insulin:

↑ activity of hexokinase & glucokinase

Glycogenesis

Lipogenesis

Protein synthesis

•Diabetes Mellitus:

Type I: insulin dependant

Causes:

Type II: noninsulin dependant

Causes:

B. Postabsorptive State: Number one priority is to maintain blood glucose for?

#1 hormone: glucagon

Sources of Blood Glucose:

1. **CHO:**

Glycogenolysis:

1. In Liver: has phosphatase: directly converts glycogen → glucose

2. In Skeletal Muscle:

2. Lipids

Lipolysis: (Epi, glucagon, cortisol)

1.) for ATP

2.) for gluconeogenesis

3. Protein

Catabolism of Cellular Proteins

1.) for ATP

2.) for gluconeogenesis

Triggered by cortisol & glucagon

4. Glucose Sparing

Tissues switch over and burn fat for fuel – "spare the glucose" for the neurons.
GH important for this phase

5. Hormone and Neural Controls:

A. Sympathetic Nervous System:
   NE & Epi: lipolysis

B. Hormonal Controls:
   •triggered by
   1. Glucagon
   2. Cortisol

   3. Growth Hormone

   Glucagon:
      -hyperglycemic hormone
      - targets?

      Functions:
         1. glycogenolysis

         2. gluconeogenesis

         3. lipolysis

Body Energy Balance:

Energy intake = total energy output

Metabolic Rate: if daily energy intake exceeds energy demands – body stores excess energy as triglycerides in adipose tissue

If daily caloric expenditure exceeds dietary supply

Metabolic Rate:

BMR: Basal metabolic rate: minimum resting energy expenditure of awake/resting person

Measuring BMR: monitoring respiratory activity (oxygen consumption)

Dependant on body surface area
Also affected by:

TMR: Total metabolic rate
All the daily activities + BMR

Dietary Thermogenesis: increase in metabolism following eating

Current beliefs are: Food intake controlled by:

1. Nutrient signals

Increased blood glucose levels cause?

Increased blood fatty acids levels cause?

2. Chemical Signals

Neurotransmitters:

a.) Galanin

b.) Neuropeptide Y

Hormones

a.) insulin

b.) glucagon

c.) amylin

d.) ghrelin

e.) leptin

e.) CCK

f.) cortisol

g.) estrogen

Stress: increases cortisol, insulin = hungry

Insulin resistance:

Metabolic Syndrome (syndrome X): cluster of conditions which increase risk of heart disease, diabetes, & stroke.

Presence of 3 or more:

1.) increased abdominal obesity

2.) BP > 120/80 mmHg

3.) Increased Triglycerides (>150 mg/dL)

4.) Decreased HDL (<40 men, <50 women)

5.) Elevated fasting blood glucose (>100mg/dL)

6.) Insulin Resistance

3. Body temperature:

4. Psychological factors:

Regulation of Body Temperature – Thermoregulation

- enzymes function best at body temperature

    -too hot denatures enzymes

Homeostatic mechanisms to maintain temperature (thermoregulation)

- The body produces heat as a byproduct of metabolism
- Increased physical or metabolic activity generates more heat
- Heat produced is retained by water in body
- For temperature to remain constant heat must be lost to environment

- core:
- shell:

Average core body temperature: 37º C (98.6º F)
In adults temperature of 106ºF causes convulsions

- blood: heat exchanger:

    -conserve heat: arterioles in skin vasoconstrict

    -if shell warmer than external environment: heat lost from body

Mechanisms of Heat Exchange:

-heat always flows down

1. Radiation:
    - loss of heat by infrared waves
2. Conduction:
    - transfer heat between objects in direct contact with each other
3. Convection
    - results from conductive heat loss to air at body surface
    - cooler air replaces warmer air (which rises) from the body
    - cooler air absorbs heat better
    - anything that moves air rapidly
    - conduction/convection
4. Evaporation:

Regulation of Heat Gain and Heat Loss: coordinated by hypothalamus

Hypothalamus: •"thermostat"

- thermoregulatory centers:
- receives input from thermoreceptors

1. Heat Gain Center:
   when environ. temperature is cold

   1. Vasoconstriction of cutaneous blood vessels
      •sympathetic system

      •decreases
      •shell temperature

   2. Increase in metabolic rate
      •NE

   3. Shivering
      •involuntary contractions of

   4. Increased thyroxine

2. Heat Loss Center
   •core body temperature increases,

   1. Vasodilation of cutaneous blood vessels
      -increases heat loss

   2. Increased Sweating
      -evaporation:
      -but need

Thermoregulatory Problems in Infants

Temperature regulation is not completely functional
Lose heat quickly
Body temperatures are less stable

Infants have brown fat

Hyperthermia: increased body temp.

-heat exhaustion:
   Dehydration

   Skin is cool & clammy

-heat stroke:
   skin becomes

Fever:

-WBC, macrophages, secrete pyrogens which cause hypothalamus neurons to secrete prostaglandins

-vasoconstriction
-skin cools:

-temperature increases =

When infection passes, body temperature needs to return to normal, heat loss mechanisms are active to lose heat: vasodilate

Hypothermia:
    Slows metabolic rate