BIO132 Chapter 25 Metabolism and Energetics Lecture Outline

Metabolism
1. Catabolism
   A. Hydrolysis → monomers
   B. Cellular respiration → ATP
2. Anabolism

Carbohydrate metabolism
1. Catabolism
   Cellular respiration
      A. Glycolysis
         - glucose → pyruvic acid
         - ATP, NADH
      B. Decarboxylation & Citric Acid Cycle
         1. acetyl CoA + oxaloacetic acid → citric acid → CO₂
            - NADH, FADH₂, ATP
      C. Electron transport
         - NADH, FADH₂, O₂ → H₂O
         - ATP
         With oxygen 36 ATP per glucose
         Fermentation 2 ATP per glucose
2. Anabolism
   Gluconeogenesis
3. Functions
   A. glycogen
   B. ATP synthesis
   C. Complex molecules

Lipid metabolism
1. Catabolism
   Lipolysis
      - triglyceride → glycerol + fatty acids
   A. glycerol → pyruvic acid
      - Citric acid cycle
   B. fatty acids → (Beta oxidation) → acetyl
      - Citric acid cycle
2. Anabolism
   A. Lipogenesis
   B. Cholesterol
   C. Essential fatty acids
      1. Linolenic acid
      2. Linoleic acid
3. Functions
   A. ATP synthesis
   B. Cell membranes
   C. Myelin
   D. Bile salts
   E. Steroid hormones
   F. Cell signaling
   G. Storage
   H. Insulation
4. Transport
   Lipoproteins
      A. Chylomicrons
      B. VLDL
      C. IDL

D. LDL
E. HDL

Distribution

Protein metabolism
1. Catabolism
   Deamination (Vitamin B6)
      - ammonia → urea
      - Citric acid cycle
   Protein starvation
2. Anabolism
   A. Essential amino acids
   B. Synthesis
      - Amination
      - Phenylketonuria
         - phenylalanine → tyrosine
3. Functions
   A. Structure
   B. Enzymes
   C. Hormones

Nucleic acid metabolism
RNA nucleotides
         - ribose → glucose
         - Glycolysis
   C. U → acetyl
      - Citric acid cycle
   A. G → (deaminated) → uric acid
      - Gout

Metabolic interactions

Regions
1. Liver
2. Adipose
3. Skeletal muscle
4. Neural tissue
5. Peripheral tissues

Metabolic activity
1. Absorptive state
   A. Hormones
      1. Insulin
      2. Growth Hormone
      3. Androgens / Estrogens
   B. Tissues
      1. Liver
         - Glycogenesis
      2. Adipose
         - Lipogenesis
      3. Peripheral tissues
2. Postabsorptive state
   A. Hormones
      1. Glucagon
      2. Epinephrine
      3. Glucocorticoids
      4. Growth hormone
   B. Tissues

Amy Warenda Czura, Ph.D.
1
SCCC BIO132 Chapter 25 Handout
1. Liver
   Glycogenolysis
   Gluconeogenesis
   Ketone bodies
   Ketosis
   Ketoacidosis
   Diabetes mellitus
2. Adipose
   Lipolysis
3. Skeletal muscle
   Protein hydrolysis

Balance diet
1. substrates for ATP
2. essential amino acids
3. essential fatty acids
4. nitrogen
5. minerals
6. vitamins
   fat soluble: A, D, E, K
   water soluble: B, C, niacin, folacin, biotin
   Vitamin B12

Bioenergetics
   Calorie
   Metabolic rate
   BMR
   BMI
   Leptin

Thermoregulation
   Heat transfer
   1. radiation
   2. conduction
   3. convection
   4. evaporation

Hypothalamus
   Hot
   1. peripheral vasodialtion
   2. sensible perspiration
   3. increased respiration
   Pyrexia
   Heat stroke
   Cold
   1. vasoconstriction
   2. nonshivering thermogenesis
   3. shivering
   Hypothermia
   Frost bite
   Fever
   Volume vs. surface area
   Infants: Brown fat

Aging
   ↑ diabetes
   ↓ metabolic rate
   ↑ malnutrition
**Cellular Respiration Review:**

1. **Glycolysis:**
   - anaerobic, occurs in cytoplasm
   - 1 glucose oxidized into 2 pyruvic acids
   - 2 ATP produced by substrate level phosphorylation
   - 2 NADH produced by reduction of NAD via oxidation of glucose
   - If no O₂ available, pyruvic acid reduced to lactic acid (fermentation)
     - Erythrocytes (RBCs) → glycolysis only (no mitochondria!)
     - Skeletal muscle → fermentation when no O₂
     - Neurons and cardiac muscle cannot ferment, need O₂

2. **Decarboxylation + Krebs / Citric Acid Cycle:**
   - occur in matrix of mitochondria
   **Decarboxylation:**
     - 2 pyruvic acid decarboxylated and oxidized into 2 acetyl Co A + 2 CO₂ with 2 NADH
   **Citric Acid Cycle:**
     - 2 acetyl combined with 2 oxaloacetic acids creating 2 citric acids
     - citric acid decarboxylated and oxidized → 4 CO₂, 6 NADH, 2 FADH₂
     - 2 ATP generated by substrate level phosphorylation

3. **Electron Transport:**
   - aerobic, occurs on cristae of mitochondria
   - NADH and FADH₂ reduced during glycolysis and citric acid cycle are oxidized
   - electrons are passed to cytochromes, finally accepted by oxygen
   - 32 ATP generated by chemiosmosis / oxidative phosphorylation
   - 12 H₂O produced as waste from oxidation of oxygen

* With oxygen, 1 glucose will produce 36 ATP in most human tissue cells.

* Without oxygen, 1 glucose will produce 2 ATP in human tissue cells that are capable of fermentation (not neurons or cardiac muscle).
**Lipoprotein Classes:**

(Increased lipids = decreased density)

1. Chylomicrons:
   95% triglycerides, from intestinal epithelium, delivers lipids from gut to liver

2. Very Low Density Lipoproteins:
   triglycerides (high levels), phospholipids, cholesterol; delivers triglycerides from liver to tissues

3. Intermediate Density Lipoproteins:
   VLDLs with triglycerides removed, return to liver for processing

4. Low Density Lipoproteins:
   high cholesterol, low triglycerides and phospholipids, deliver cholesterol from liver to tissues

5. High Density Lipoproteins:
   equal protein and lipids (cholesterol and phospholipids), return cholesterol to liver for degradation

---

**Lipoprotein Distribution**

1. Liver synthesizes VLDLs and releases them into blood

2. Triglycerides are removed in capillaries making IDLs from the VLDLs.

3. IDLs return to liver, triglycerides removed and proteins altered, making LDLs from the IDLs which are released to blood.

4. LDLs travel to the peripheral tissues.

5. Cells endocytose LDLs and break them down.

6. Extra cholesterol diffuses out of cells and enters blood.

7. Cholesterol binds to HDLs in blood and returns to liver.

8. HDLs at liver have cholesterol extracted to form empty HDLs, new LDLs, and bile salts.

9. Empty HDLs return to the blood to pick up free cholesterol.
Metabolic Interactions: 5 important regions for metabolism

1. Liver
   - site of metabolic regulation and control
   - can break down or synthesize most molecules for use by other cells
   - stores glycogen reserves
2. Adipose
   - stores triglyceride reserves
3. Skeletal Muscle
   - stores glycogen reserves
   - has contractile proteins that can be catabolized
4. Neural Tissue
   - high energy demand but no reserves
   - requires constant supply of glucose
5. Peripheral Tissues
   - no reserves
   - catabolize a wide range of substrates

Patterns of Metabolic Activity

1. **The Absorptive State** (anabolism exceeds catabolism)
   Occurs for ~4hr post meal while nutrients are being transported to liver then tissues
   Some nutrients used immediately, some stored as reserves
   
   A. Hormones involved
      1. **Insulin**: promotes glucose uptake and utilization by cells
      2. **Growth Hormone**: promotes amino acid uptake and protein synthesis by cells
      3. **Androgens and Estrogens**: promote amino acid utilization in protein synthesis

   B. Tissues involved
      1. **Liver**
         - regulates blood glucose levels:
           - removes excess glucose from blood and performs glycogenesis (formation of glycogen from glucose)
           - excess glucose converted into triglycerides and converted to VLDLs for storage in adipocytes
           - amino acids not tightly regulated
             - some absorbed for protein and enzyme synthesis
             - some converted to more rare amino acids for use by body cells
      2. **Adipose Tissue**
         - absorb fatty acids and glycerol from the blood and triglycerides from VLDLs
         - absorb glucose for ATP synthesis to drive lipogenesis (triglyceride formation)
         - all excess nutrients converted and stored as triglycerides
      3. **Peripheral Tissues**
         - absorb glucose for ATP synthesis
         - absorb amino acids for protein synthesis
2. **The Post Absorptive State** (catabolism dominates)

Periods when there is no more absorption from GI; cells must rely on energy reserves:
- **Glycogen**: liver and skeletal muscle
- **Triglycerides**: adipose tissue
- **Proteins**: muscle tissue

Primary goal is to maintain glucose levels to the brain

A. Hormones involved
   1. **Glucagon**: promotes release of glucose from liver
   2. **Epinephrine**: promotes release of glucose from liver, promotes lipolysis in adipose and release of glycerol and fatty acids
   3. **Glucocorticoids**: inhibits use of glucose by body tissues, promotes use of fatty acids
   4. **Growth Hormone**: complements glucocorticoids

   (*As blood glucose levels ↓, glucagon and epinephrine levels ↑ and insulin levels ↓*)

B. Tissues involved

1. **Liver**
   - glycogenolysis to cleave glucose from glycogen and release it into blood
   - gluconeogenesis (via glucocorticoid stimulation) to synthesize glucose from lipids
   - triglyceride conversion:
     - glycerol → glucose
     - fatty acids → acetyl → ketone bodies
   - amino acid conversion: amino acids deaminated and converted to ketone bodies
   Ketone bodies: released into blood, absorbed by peripheral tissues, converted to acetyl and catabolized in the Citric Acid Cycle

   * During starvation:
     - high concentrations of ketone bodies will be present in all body fluids = ketosis
     - oxaloacetic acid from Citric Acid Cycle will be converted into glucose for brain
     - acetyl and ketone bodies will not be able to enter Citric Acid Cycle
     - ketone bodies (acids and acetone) build up
     - can lead to ketoacidosis (low blood pH) → death
     - long term nonfatal ketosis → bone loss, kidney damage, heart disease

   *Diabetes mellitus: no insulin, no glucose use, use of lipids and proteins → ketosis

2. **Adipose**
   - fat mobilization: lipolysis converts triglycerides → glycerol + fatty acids which are released into blood:
     - body cells use them for ATP synthesis
     - liver uses them for gluconeogenesis

3. **Skeletal Muscle**
   - catabolism of contractile proteins, release of amino acids for use by liver in gluconeogenesis and ketone body formation

*Most peripheral tissue cells in post absorptive state, lacking insulin stimulation, switch from glucose to ketone bodies for ATP synthesis
Neurons can only use glucose*