**Objectives:**

**Part 1.** Review of Body Tissues (from anatomy).
**Part 2.** Cell Metabolism and Respiration  
(review of Intro. Biology &)

We are skipping all the stuff on cell structure, organelles, DNA, mitosis & meiosis. You had enough of that in Intro. Biology, *RIGHT?*

http://people.fmarion.edu/tbarbeau/physio_cell_supplements.htm

**Part 1: Tissue Types of the Body**

- **Muscle tissue**  
  For movement of body, or organs, or blood, and regulate entry or exit of materials into / out of body.

- **Nervous tissue**  
  For conduction of nerve (electrical) signals.

- **Epithelial tissue**  
  For covering body or organ surfaces, lining cavities & glands.

- **Connective tissue**  
  For supporting tissue, providing special functions.
3 Types Muscle Tissue:
- Found in heart.
- Is under autonomic control.

Cardiac muscle cell.

- Found in muscles of body movement.
- Is under somatic control.

Skeletal muscle cell.

- Found in lungs, blood vessels, GI tract, urinary tract, & reproductive tracts.
- Is under autonomic control.

Smooth muscle cell.

• For conducting nerve (electrical) impulses.
• In CNS & PNS

2 Types of nerve cells:
- 1. Neurons – transmit electrical signals (action potentials) between neurons or between neuron & muscle or gland cells.
Epithelium = Continuous layer of epithelial cells that forms a membrane (covering) for body or organ surfaces, lining cavities & glands.

- a. simple epithelium = single cell layer thick epithelium (allows for easy diffusion of substances across, like lining of lung alveoli or intestines). Can be shaped squamous, cuboidal, or columnar.
- b. stratified epithelium = multiple cell layer thick epithelium for protection, like our skin or lining our mouth. Can be shaped squamous, cuboidal, or columnar.

See next slide for diff types of epithelium and where located in body!
Connective Tissue - for supporting tissue, providing special tissues. (Pg 53 - 55)

Composed of:
> fibers – provide strength or flexibility to tissue, or repair tissue. (collagen, elastin)
> ground substance = matrix that supports fibers, cells, and other structures in tissue.
> specialized cells = see later

Categories of connective tissue:
1. Connective tissue proper
   - loose = fat & areolar tissue
   - dense = tendons & ligaments

2. Specialized connective tissue
   - cartilage, bone, blood

Specialized cells of connective tissue: (NOT IN BOOK!)
> Macrophages = cells that migrate from blood into tissues seeking out & destroying pathogens. (macro = “big” and phage = “eater”)

> Adipocytes = fat cells. For cushioning body & organs, and for energy storage.
> **Fibroblasts** = cells that make new fibers, for repair and growth of tissue. (Where scar tissue comes from)

![Fibroblasts](image1)

> **Mast cells** = cells that secrete “histamine” in response to an allergen & mediate allergic reactions.

![Mast cells](image2)

**Mild to severe histamine reactions:**

– **erythema** = patches of reddened, inflamed, bumpy skin. Often referred to as “hives”.

– **Localized erythema** (only at site of contact w/allergen not bad.

– **Systemic erythema** (all over body in response to allergen NOT GOOD!)

![Histamine Reactions](image3)
**Anaphylactic reactions** = life-threatening systemic response to histamine.

**Presentation (symptoms):** labored breathing, closed airways, swelling of face, lips, erythema, rapid heart rate, dizziness, vomiting, fainting.

- Bee / wasp stings
- peanuts

➢ **Adult stem cells** = cells in major tissue types of body that can replace dead or damaged cells. These are different from embryonic stem cells (which are totipotent or can become ANY tissue type in body)

**We have stem cells in:**
- Skin
- Bones
- Muscles
- Lining of GI tract
- Blood cells (RBCs, WBCs)
- Teeth
- Liver
- etc....

Read Clinical App Pg 47, and [Online Clinical App: Stem Cells](#)
Review

- 4 Tissue types of body.
  > nervous, muscle, epithelial, & connective

- Connective tissue
  – > Common features
  > Categories of (connective tissue proper, specialized)

- Specialized cells of connective tissue

Part 2: Cell Respiration & Metabolism

Objectives:

1. Understand what molecules our cells metabolize for energy. Carbohydrate, lactic acid, lipid, and amino acid metabolism
2. Understand the basics of cell respiration.
3. Become familiar with anaerobic & aerobic cell respiration

See Supplements Page! >> Cell Physiology
1. Types of Cell Metabolism

Metabolism of molecules (Table 5.1 – NOT IN BOOK)

i) Carbohydrate metabolism – body’s preferred source of energy.

ii) Lipid metabolism – body will metabolize when carbs used up.

iii) Protein metabolism (amino acids) – body will metabolize when lipids used up.

iv) Lactic acid metabolism – body routinely metabolizes all the time.

Table 5.1 | Common Terms for Some Metabolic Processes in the Body

<table>
<thead>
<tr>
<th>Term</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycolysis</td>
<td>Conversion of glucose into two molecules of pyruvic acid</td>
</tr>
<tr>
<td>Glycogenesis</td>
<td>The production of glycogen, mostly in skeletal muscles and the liver</td>
</tr>
<tr>
<td>Glycogenolysis</td>
<td>Hydrolysis (breakdown) of glycogen; yields glucose 6-phosphate for glycolysis, or (in the liver only) free glucose that can be secreted into the blood</td>
</tr>
<tr>
<td>Gluconeogenesis</td>
<td>The production of glucose from noncarbohydrate molecules, including lactic acid and amino acids, primarily in the liver</td>
</tr>
<tr>
<td>Lipogenesis</td>
<td>The formation of triglycerides (fat), primarily in adipose tissue</td>
</tr>
<tr>
<td>Lipolysis</td>
<td>Hydrolysis (breakdown) of triglycerides, primarily in adipose tissue</td>
</tr>
<tr>
<td>Ketogenesis</td>
<td>The formation of ketone bodies, which are four-carbon-long organic acids, from fatty acids; occurs in the liver</td>
</tr>
</tbody>
</table>
Body cells want to metabolize carbohydrates first!

A) Glucose metabolism = “glycolysis”
- Used by cells to make energy (ATP) through Cell respiration pathway.

B) Glycogen metabolism = buildup or breakdown of glycogen

Ex. Glycogenesis = creation of glycogen from glucose molecules.

Ex. Glycogenolysis = breakdown of glycogen into glucose.

Glycogenesis = creation of glycogen from glucose molecules

\[
\text{glycogen synthase} \\
\text{Glucose + glucose} \rightarrow \text{Glycogen}
\]

Glycogenolysis = breakdown of glycogen into glucose

\[
\text{glycogen phosphorylase} \hspace{1cm} \text{glucose 6 phosphatase} \\
\text{glycogen} \rightarrow \text{glucose 6-phosphate} \rightarrow \text{free glucose}
\]
2. Basics of Cell Respiration – use of glucose in cell respiration:

**Glycolysis**

- use of glucose for **cell respiration**

- Occurs in cell cytoplasm

- **Conversion of 1 glucose molecule into:**
  - > 2 ATP (net)
  - > 2 NADH$_2$
  - > 2 Pyruvate molecules

Pyruvate then can go one of 2 ways
- depends on if O$_2$ is present or not

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Pyruvate then can go one of 2 ways
- depends on if O$_2$ is present or not

- **Anaerobic respiration**
- No oxygen

**Emergency!** (in heart/brain)

**Glycolysis**

- **Aerobic respiration**
- Oxygen present

- **Pyruvate Processing**
- **The Krebs cycle**
- **ETC**

**Products =**
- 34 - 36 ATP

**Fermentation**

- Oxygen present

**Products =**
- 2 ATP
- Lactic acid (lactate)
**Ischemia, Serum Lactate, and Heart Attack**

Ischemia & Angina Pectoris - [Clinical App](#)

“Ischemia” = loss of blood flow to organ or tissue.

**Loss of blood flow to heart:**
- without arterial blood & O2 heart resorts to anaerobic respiration.
- Produces lactate, causes “angina pectoris” or pain radiating down L arm and in chest.
- Prelude to “myocardial infarction” (heart attack)

- Normal serum lactate = 1- 0.5 mmol/L
- **Hyperlactatemia** (high serum lactate) = > 4mmol/L

Serum Lactate as a Marker of Acute Myocardial Infarction

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**Aerobic respiration**

3 Steps of aerobic respiration (AFTER GLYCOLYSIS):

1. **Pyruvate processing (pyruvate conversion)**
   - 2 pyruvate → 2 Acetyl CoA, 2 NADH₂, 2 CO₂

2. **Kreb’s cycle (citric acid cycle)**
   - 2 Acetyl CoA → 2 ATP, 6 NADH₂, 2 FADH₂, 4 CO₂

3. **Electron transport chain (ETC)**
   - 6 NADH₂, 2 FADH₂ → 30 – 32 ATP, 10 NAD+, 2 FAD+, 12 H₂O
1. **Glucose**

   - Glycolysis
     - 2 NADH + H
     - 2 ATP
     - 2 Pyruvate

2. **Pyrurate processing**
   - 2 Acetyl CoA
   - 6 NADH + H
   - 2 FADH2
   - 4 CO2
   - 2 ATP

3. **Kreb's cycle**
   - 10 NAD+ 2 FAD 12 H2O
   - ATP
   - ~30-32 ATP

4. **Electron Transport Chain**

   **Aerobic Respiration Total = 34-36 ATP**

   *image by T. Barbeau* 23

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**Electron Transport System and Formation of ATP**

- **Hydrogen**
- **ATP synthase**
- **ATP**

This enzyme allows protons to pass back into the cell and couples the energy released in this process to the phosphorylation of ADP to form ATP.

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When aerobic respiration goes wrong!

Read online Clinical App: cyanide
**Question:** Why do we need oxygen???

= As final electron acceptor in ETC in production of ATP!

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**Metabolism of carbohydrates, lactic acid, lipids, & amino acids.**

“Gluconeogenesis” = production of glucose from non-carbohydrate sources (i.e. lactic acid, lipids, and amino acids) when needed.

- **Lactic acid metabolism** – regularly occurs in liver to prevent acidosis from skeletal muscle activity.

- **Lipid metabolism** – occurs when need energy (ATP) when carbohydrates not available (fasting or heavy exercise).

- **Amino acid metabolism** – occurs when need energy and lipids have been used up, or due to muscle damage/atrophy.
**Lactic acid (lactate) metabolism = “The Cori cycle”**

= lactic acid (from skeletal muscle activity & anaerobic respiration) can cause “metabolic acidosis” and drive blood pH ↓.

Liver “recycles” lactic acid in blood into:
- **Free glucose** (to be returned to blood stream)
  (due to enzyme only in liver – *glucose 6 phosphatase*)
- Stored **glycogen** (for future need)
- Reverses metabolic acidosis

### Lipid Metabolism:

**“Lipogenesis”** = conversion of excess glucose into white fat (triglycerides) stored in adipose & liver. Stimulus = “insulin”

Vs

**“Lipolysis”** = conversion of white fat (triglycerides) or ketones into molecules that can be used to make ATP, glucose, and glycogen. Stimulus = “cortisol”
**Lipid Metabolism:**

“**Lipogenesis**” = conversion of excess glucose into white fat (triglycerides) in adipose & liver. **Stimulus** = “insulin”

1. Extra blood **Glucose** enters glycolysis to make **pyruvate**.

2. Pyruvate converted into **Acetyl CoA** (now can go into many paths!)

3. Acetyl CoA used by liver to make: a) **cholesterol**, b) **ketones**, c) **fatty acids**

   a) **cholesterol** converted into 1) bile for digestion or 2) used for steroids
   b) **ketones** – metabolized for energy (ATP) in **ketosis** if no carbs in **lipolysis**.
      
      3 types ketones:
      
      i) **acetone** – waste product excreted in urine (sweet breathe!)
      ii) **acetoacetic acid**
      iii) **beta-hydroxybutyric acid**

   c) **fatty acids** – converted into white fat (triglycerides) for energy storage.

**Lipid Metabolism:**

“**Lipolysis**” = conversion of white fat (triglycerides) into molecules that can be used for energy (ATP).

A) **Ketones metabolized for ATP**

B) **fatty acids**

   - converted back into Acetyl CoA – can be enter directly in Kreb’s cycle for ATP
   - Acetyl CoA – can be converted back into pyruvate and then changed into:
      - glucose (gluconeogenesis)
      - glucose can be stored as glycogen (glycogenesis)
**Lipid Metabolism, conti...**

**Ketosis** = use of ketones for energy  
Read online Clinical App: cyanide

**Ketoacidosis** = when ketosis causes blood pH to decrease (become acidic).

**Metabolic acidosis** = any metabolic process (such as ketosis) that can cause a decrease in blood pH.

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**Amino acid metabolism**

- **Amino acids** = building blocks of protein
- **Essential a.a.** = that which we need to consume in diet because body doesn’t make
- **Nonessential a.a.** = ones our body can make.
- **Excess a.a. converted by liver into pyruvate or other acids. These can be used:**
  - 1) in Kreb’s cycle for ATP
  - 2) converted to fat (lipolysis) or glucose (gluconeogenesis)
- **Un-used a.a. (excess or what body absolutely cannot use)**
  > liver converts a.a. into Urea and is excreted by kidneys as ammonia.
- blood panels include **BUN** (blood urea nitrogen) to determine kidney function.
- Normal BUN = 10 – 20 mg/dl. Higher BUN called “**azotemia**” and can indicate excess a.a. metabolism and /or kidney failure.
Ques: Metabolism of what molecules can lead to metabolic acidosis?

Disorder in amino acid metabolism:

**Phenylketonuria (PKU)** – **Read online Clinical App:**
Genetic condition of mutation in gene for enzyme *Phenylalanine hydrolase* (PAH).

[Need PAH to metabolize amino acid “phenylalanine”. Without PAH phenylalanine builds up in body and is converted to “phenylketone”, which is excreted in urine.]

Phenylketone is toxic, causes seizures.

**Treatment:**
Restrict phenylalanine in diet.
(nutrition labels have a warning)