Objectives:

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

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

Muscle tissue

For conduction of nerve (electrical) signals.

Nervous tissue

For covering body or organ surfaces, lining cavities & glands.

Epithelial tissue

For supporting tissue, providing special functions.

Connective tissue
Review!

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)

![Image of fibroblasts](image)

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

![Image of mast cells](image)

**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!

![Image of mild to severe histamine reactions](image)
**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.

➢ **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.
   - Carbohydrates (first!)
   - Lipid (next)
   - Amino acid metabolism (routine & emergency)
   - Lactic acid metabolism (routine & emergency)

2. Understand the basics of cell respiration.

3. Become familiar with anaerobic & aerobic cell respiration

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.

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**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!

Carbohydrate metabolism is the fastest (shortest) route to making ATP!

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

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

Glycogenolysis = breakdown of glycogen into glucose

\[
\text{glycogen phosphorylase} \quad \text{glucose 6 phosphatase} \\
\text{glycogen} \rightarrow \text{glucose 6-phosphate} \rightarrow \text{free glucose}
\]
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 Pyruvate molecules

Pyruvate then can go one of 2 ways
- depends on if O\(^2\) is present or not
Pyruvate then can go one of 2 ways - depends on if $O^2$ is present or not

- **Anaerobic respiration** (in heart/brain)
  - Products = 2 ATP
  - Lactic acid (lactate)

- **Glycolysis**
  - Aerobic respiration (Oxygen present)
  - Products = 34 - 36 ATP

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**Ischemia, Serum Lactate, and Heart Attack**


“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
Aerobic respiration

3 Steps of aerobic respiration (AFTER GLYCOLYSIS):

1. Pyruvate processing (pyruvate conversion)
   \[2 \text{ pyruvate} \rightarrow 2 \text{ Acetyl CoA, 2 NADH, 2 CO}_2\]

2. Kreb’s cycle (citric acid cycle)
   \[2 \text{ Acetyl CoA} \rightarrow 2 \text{ ATP, 6 NADH, 2 FADH}_2, 4 \text{ CO}_2\]

3. Electron transport chain (ETC)
   \[6 \text{ NADH, 2 FADH}_2 \rightarrow 30 – 32 \text{ ATP, 10 NAD}, 2 \text{ FAD}, 12 \text{ H}_2\text{O}\]
When aerobic respiration goes wrong!

Read online Clinical App: cyanide
Where Cell Respiration Occurs

**Question:**
Why do we need oxygen???

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

Fig 5.11
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 used to make Acetyl CoA for ATP

   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)

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**Lipid Metabolism, contin…**

**Ketosis** = use of ketones for energy

**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.
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 (lipogenesis) 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)