CONCEPT 3 – ENERGY AND METABOLISM

1. Energy
    a. Organisms use free energy for organization, growth and reproduction. Loss of order or free energy flow results in death.
    b. More free energy (ex. Food) than needed will be stored for growth (roots, glycogen, fat, etc.).
    c. Matter and energy are not created but change form (1st law of thermo; ex. Sun energy to bond energy in glucose) and entropy is increasing in disorganization of energy (i.e. heat released by cell respiration). More organized or built up compounds have more free energy and less entropy (i.e. glucose) and less organized have less free energy and more entropy (i.e. carbon dioxide).
    d. Reactions can be coupled to maintain a system, ex. Photosynthesis and cell respiration

2. Cellular respiration $C_6H_{12}O_6 + 6O2 \rightarrow 6CO_2 + 6H_2O$
    a. Makes ATP for cell use; uses glucose and oxygen makes waste products of carbon dioxide and water; occurs in mitochondria; NADH is electron carrier used
    b. Glycolysis
        (1) occurs in cytoplasm; anaerobic
        (2) rearranges the bonds in glucose molecules, releasing free energy to form ATP from ADP through substrate-level phosphorylation resulting in the production of pyruvate.
    c. Kreb's cycle
        (1) occurs in mitochondrial matrix
        (2) also called the citric acid cycle
        (3) occurs twice per molecule of glucose
        (4) Pyruvate is oxidized further and carbon dioxide is released ; ATP is synthesized from ADP and inorganic phosphate via substrate level phosphorylation and electrons are captured by coenzymes (NAD+ and FAD).
        (5) NADH and FADH2 carry electrons to the electron transport chain.
    d. Electron Transport Chain and Chemiosmosis
        (1) The electron transport chain captures electrons, pumping H^+ ions into the inter-membrane space of the mitochondria.
        (2) Electrons are accepted by O_2 molecule forming H_2O
        (3) Concentration of H^+ builds up within inter-membrane space lowering the pH and ions rush through ATP synthase into the mitochondria matrix. Rush of ions "spins" ATP synthase protein, causing ADP and P_i to join forming ATP by oxidative phosphorylation

Cellular Respiration Thinking Questions

1. Using your knowledge of the process of cellular respiration:
    a. Describe the journey of a single carbon atom from glucose in cellular respiration

C in glucose → C in pyruvate → CO_2 or → C in acetyl CoA → CO_2 or → C in oxaloacetate

    b. Describe the journey of a single hydrogen atom from glucose in cellular respiration

H in glucose → H in NADH or → H in pyruvate → H in NADH or H in acetyl CoA → H in NADH or H in Citric Acid Cycle → H^+ outside cristae → H^+ through synthase → H in H_2O or H in another molecule

    c. Describe the function of the oxygen molecules in cellular respiration

The inhaled oxygen is used as the final electron acceptor of the electron transport chain. The oxygen, electrons and 2 hydrogens form together as metabolic water.

2. It is estimated that more than 2×10^{26} molecules of ATP are hydrolyzed in the human body daily. If each molecule was used only once you would need approximately 160 kg (350 lbs) of ATP daily. The repeated use of ATP molecules through the ATP cycle saves the body a huge amount of resources and energy. ATP is synthesized in two ways:

- **Substrate-level phosphorylation**—Energy released during a reaction, such as the breakdown of sugar molecules, is used directly to synthesize ATP. A small amount of energy is generated through this process.
- **Electron transfer (oxidative phosphorylation)**—Energy from the movement of electrons from one molecule to another, via electron carriers, is used to synthesize ATP. Most cellular ATP is synthesized by electron transfer in the mitochondria.

Dinitrophenol (DNP) is an "uncoupler," which means it interferes with the flow of electrons during electron transfer. Fifty years ago, DNP was given as a drug to help patients lose weight.

a. Why would taking DNP make someone lose weight?

Since DNP interferes with production of ATP, a deficit of ATP would occur. As a result, cells are stimulated to break down even more molecules in a fruitless attempt to increase ATP levels.

b. Why would taking DNP be dangerous?

Too much DNP will block all but substrate-level ATP production. This will eventually lead to cellular and organism death.

3. Under laboratory conditions, muscle cells were broken up and separated into fractions of mitochondria and cytoplasm in an attempt to learn more about cellular respiration. Each fraction was incubated with glucose or pyruvate. Tests were carried out during incubation for the presence of either carbon dioxide or lactic acid. The results are shown below:

Cell Fraction	CO_2	Lactic Acid
Mitochondria incubated with glucose	Absent	Absent
Mitochondria incubated with pyruvate	Present	Absent
Cytoplasm incubated with glucose	Absent	Present
Cytoplasm incubated with pyruvate	Absent	Present

Must have pyruvate as starting material
Resp.
Fermentation

a. What does the presence of lactic acid in a sample indicate about what process is occurring in each cell fraction?

Indicates fermentation

b. Explain why lactic acid was produced by the cytoplasm fraction incubated with glucose, but not the mitochondrial fraction.

Glycolysis in the Cytoplasm leads to fermentation
Glycolysis cannot occur in mitochondria.

c. Why was no carbon dioxide produced by either fraction incubated with glucose?

CO_2 is not made in glycolysis (cytoplasm) and mitochondria can't break down glucose.

d. Why did the cytoplasm fraction produce lactic acid in the presence of both glucose and pyruvate?

without mitochondria, glycolysis leads to lactic acid

e. Why did the mitochondria produce carbon dioxide in the presence of pyruvate but not in the presence of glucose?

Mitochondria can't break down glucose, but do break down pyruvate

4. An experiment to measure the rate of respiration in crickets and mice at 10°C and 25° C was performed using a respirometer, an apparatus that measures changes in gas volume. Respiration was measured in mL of O_2 consumed per gram of organism over several five-minute trials and the following data were obtained.

Organism	Temperature (°C)	Average respiration (mL O_2/g/min)
Mouse	10	0.0518
Mouse	25	0.0321
Cricket	10	0.0013
Cricket	25	0.0038

a. Which organism at which temperature had the fastest metabolic rate (produced the most ATP) during its trials? Explain how you know.

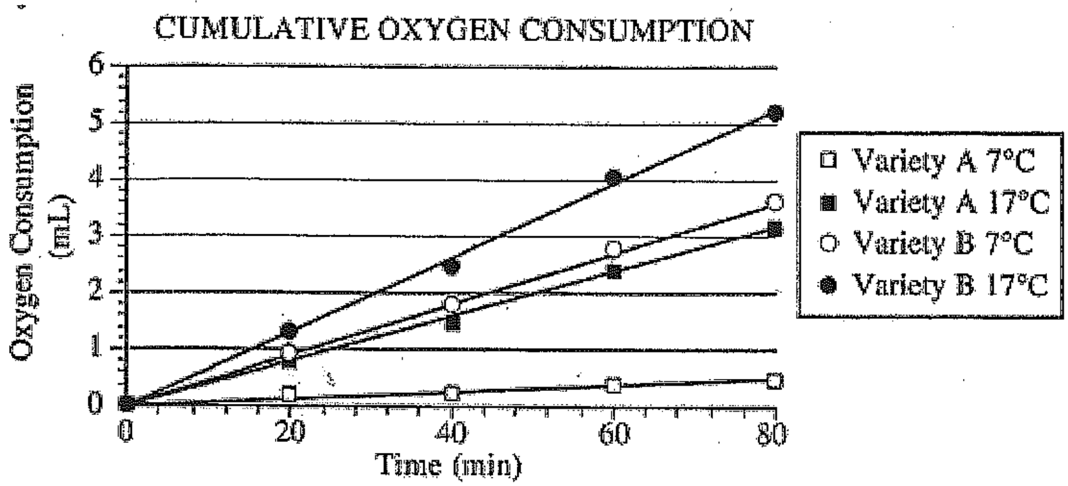
The mouse at 10°C had the fastest metabolic rate. An increase in oxygen use directly correlates to ATP production.

b. According to the data, the mice at 10°C demonstrated greater oxygen consumption per gram of tissue than did the mice at 25°C. Propose an explanation for why this is.

Since mice maintain a constant internal temperature they must work harder (metabolize more) to generate more heat in colder temps.

5. Energy and Metabolism Short Free Response (4 points)

An agricultural biologist was evaluating two newly developed varieties of wheat as potential crops. In an experiment, seedlings were germinated on moist paper towels at 20°C for 48 hours. Oxygen consumption of the two-day-old seedlings was measured at different temperatures. The data are shown in the graph below.



In a second experiment, Variety A seedlings at 17°C were treated with a chemical that prevents NADH from being oxidized to NAD+. **Predict** the most likely effect of the chemical on metabolism and oxygen consumption of the treated seedlings. **Explain** your prediction.

Energy and Metabolism Short Free Response

Prediction (1 point each; 2 points maximum)

- Metabolism/respiration stops/declines/decreases/slows down.
- Oxygen consumption stops/declines/decreases/slows down.

Explanation (1 point each; 3 points maximum)

- Glycolysis/Krebs cycle/ETC will stop.
- ATP levels will drop/decline/decrease.
- Oxygen cannot accept electrons from ETC.