Concept 1 - Thinking Practice
1. If the following molecules were to undergo a dehydration synthesis reaction, what molecules would result? Circle the parts of each amino acid that will interact and draw the resulting molecule.

Amino acid 1

Amino acid 2

2. Construct a bar graph that displays the relative amounts of hydrogen, carbon, oxygen, and nitrogen in each of the four types of macromolecules (carbohydrates, lipids, proteins, nucleic acids).

3. Describe the relationship between substrate concentration and reaction rate shown in the graph below and propose an explanation for it.

As the substrate concentration increases, the rate of the reaction increases, then stabilizes. This is likely because initially, adding more substrate increases enzyme activity as there are more reactants to bind with. At a certain point, the enzymes become saturated with substrate, however, and cannot work any faster with the addition of substrate.
4. DNA polymerase from *T. aquaticus* (*Taq*) is used in PCR (polymerase chain reaction). PCR is a technique where millions of copies of DNA can be made from one original copy. In this method, the target DNA molecule is subjected to temperatures over 95 °C to make the double-stranded DNA separate. The temperature is then lowered slightly to allow primers to anneal before the *Taq* polymerase catalyzes the reactions to incorporate new nucleotides into the complementary strands. The cycle is then repeated over and over until there are millions of copies of the target DNA.

   a. Predict why this bacterial polymerase is used instead of a human polymerase.

   *Bacterial polymerase is likely used because human polymerase would denature during PCR because of the high temperature at which the technique is performed.*

   b. What would happen if you used a human polymerase in a series of PCR reactions?

   *The human polymerase would denature and would not be able to build a complementary strand for the DNA.*

5. Imagine a protein chain that includes the following amino acids among several others.

   ![Amino acid structures](image)

   a. Which of the amino acids could form a hydrogen bond with another amino acid in the chain to stabilize the secondary structure of a β-pleated sheet?

   Serine and asparagine, because they both contain polar R-groups

   b. Which of the amino acids could form disulfide bonds with another amino acid in the chain to stabilize the tertiary structure of the protein?

   Cysteine, because it contains sulfur in its R-group

   c. Which of the amino acids could participate in hydrophobic interactions with another amino acid in the chain to stabilize the tertiary structure of the protein?

   Phenylalanine, because it has a nonpolar R-group
**Concept 2 - Thinking Practice**

1. For each molecule shown to the right, answer the following, providing justifications for each:
   a. Is it polar or nonpolar?
   b. Is it hydrophobic or hydrophilic?
   c. In order to be transferred into a cell, would the molecule require a protein channel?

2. Biological systems rely heavily on the properties of water movement. Excretion, digestion, and blood pressure are just a few examples of situations where water balance is important. Suppose you have a semi-permeable membrane that ONLY water can pass. On one side of the membrane you have 0.1 M CaCl₂. On the other side of the membrane, you have 0.1 M Glucose. CaCl₂ ionizes in water to produce 3 ions. Glucose does not ionize in water. ASSUME THE TEMPERATURE IS 25°C.

   **0.1 M CaCl₂** | **0.1 M Glucose**

   a. Calculate the water potential for each side of the membrane.

   *Left side: -7.4 bars*
   *Right side: -2.5 bars*

   b. Describe which way water will move and explain your answer.

   *Water will move to the left side of the apparatus. Water always diffuses towards areas with low water potential.*
3. **Embedded proteins** are often found spanning the membrane of a cell or organelle. These proteins serve as channels for specific molecules to travel through the membrane, either into or out of the cell.

![Diagram of a neuron action potential](image)

- What sections of the embedded protein chain are most likely to contain amino acids with hydrophobic R-groups? Explain your reasoning.

  The portion of the embedded protein that is within the membrane is most likely to contain amino acids with hydrophobic R-groups because the fatty acid tails of the phospholipids are in the internal part of the membrane and are hydrophobic.

- What sections of the embedded protein chain are most likely to contain amino acids with hydrophilic R-groups? Explain your reasoning.

  The portion of the embedded protein that is on the outside and the inside of the membrane is most likely to contain amino acids with hydrophilic R-groups because the phosphate of the phospholipids are on the part of the membrane that faces the inside and outside of the cell. The internal and external cell environments are composed of mostly water and are therefore hydrophilic.

4. The following diagram shows an action potential of a neuron. For each question, you can answer with one letter or multiple letters.

  a. At which letters would you find Na+ voltage gated channel OPEN? C

  b. At which letter(s) would you find the Na+/K+ pump WORKING? E

  c. At which letter(s) would you find K+ voltage gated channels OPEN? D

  d. At point F, would there be a more positive charge on the INSIDE or OUTSIDE of the neuron? **outside**

  e. At point B, would you find more Na+ on the INSIDE or OUTSIDE of the neuron? **Outside**

  f. Tetrodotoxin is a neurotoxin that blocks Na+ voltage gated channels. How would the function of the neuron be altered by the presence of this toxin?

    *Tetrodotoxin would not allow Na⁺ to diffuse into a neuron after receiving a stimulus. The potential of the neuron would therefore not be able to increase as shown in part C of the graph.*

5. Tay-Sachs disease is a human genetic abnormality that results in cells accumulating and becoming clogged with very large and complex lipids. Which cellular organelle must be involved in this condition? **Lysosomes**
Concept 3 - Thinking Questions

1. The figure below outlines the process of cellular respiration. Glucose and oxygen are both reactants in this process.
   a. Describe the journey of a single carbon atom from glucose in cellular respiration
   b. Describe the journey of a single hydrogen atom from glucose in cellular respiration

(a and b answered together)
Glucose moves into the cell via a protein channel (because glucose is hydrophilic). Two molecules of ATP are hydrolyzed, attaching two phosphates to glucose. The glucose molecule then undergoes a series of decomposition reactions. Hydrogen is removed from glucose and the energy is stored in molecules of NADH. These reactions in two, 3-carbon pyruvate molecules and 4 molecules of ATP. Each pyruvate then enters the Kreb’s cycle where the remaining hydrogens are removed and stored in molecules of NADH and FADH\(_2\). Two additional molecules of ATP are created. The original carbon and oxygen from glucose are released as 3 molecules of CO\(_2\) per pyruvate (6 CO\(_2\) molecules in total).

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

Oxygen functions as an electron acceptor during oxidative phosphorylation in the inner mitochondrial membrane. When NADH and FADH\(_2\) release hydrogen and electrons into the electron transport chain, O\(_2\) is needed to bind with them. H\(_2\)O is formed as a result.
2. The figure below outlines the process of photosynthesis. Carbon dioxide and water are both reactants in this process.
   a. Describe the journey of a single hydrogen atom from water in photosynthesis.

   *When light strikes chlorophyll in photosystem II, electrons from chlorophyll are energized and “escape.” Water is hydrolyzed (split) for a replacement electron. H⁺ ions and electrons are joined with NADP⁺ to form NADPH. This NADPH is then utilized in the light independent reactions to form glucose.*

   b. Describe the journey of a single oxygen atom from water in photosynthesis.

   *In the process described above, hydrogen is joined with NADP⁺, but the oxygen from the split water molecule is not needed, so it is joined with another oxygen from a second split water molecule to form O₂. The oxygen can then be released by the plant through its stroma, or sent to the mitochondria for use in cellular respiration.*

   c. Describe the journey of a carbon dioxide molecule in photosynthesis.

   *CO₂ enters into the light independent reactions of photosynthesis in the stroma of the chloroplast. There, it goes through a series of reactions that utilize the hydrogens stored in NADPH from the light dependent reactions to form glucose.*
3. It is estimated that more than $2 \times 10^{26}$ 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?

_DNP would make someone lose weight because individuals can only undergo substrate-level phosphorylation. This requires them to break down large amounts of glucose, which allows them to lose weight._

b. Why would taking DNP be dangerous?

_Taking DNP would be dangerous because most ATP is synthesized during oxidative phosphorylation, a process that the cells of someone taking DNP are unable to do. An individual taking DNP may not be able to synthesize enough ATP to perform needed cellular functions._

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.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Temperature (°C)</th>
<th>Average respiration (mL O$_2$/g/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouse</td>
<td>10</td>
<td>0.0518</td>
</tr>
<tr>
<td>Mouse</td>
<td>25</td>
<td>0.0321</td>
</tr>
<tr>
<td>Cricket</td>
<td>10</td>
<td>0.0013</td>
</tr>
<tr>
<td>Cricket</td>
<td>25</td>
<td>0.0038</td>
</tr>
</tbody>
</table>

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 because it’s average respiration was the highest. This means it was taking in the greatest amount of O$_2$ and therefore production the greatest amount of ATP via oxidative phosphorylation._
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.

*Mice at 10°C demonstrated greater oxygen consumption because they were colder. Mice are endotherms, meaning they regulate their body temperature, keeping it at a constant value. When their environmental temperature decreases, mice need to produce greater amounts of ATP to maintain their internal temperature. They therefore have to take in greater amounts of oxygen to perform cellular respiration.*

5. 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:

<table>
<thead>
<tr>
<th>Cell Fraction</th>
<th>CO₂</th>
<th>Lactic Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitochondria incubated with glucose</td>
<td>Absent</td>
<td>Absent</td>
</tr>
<tr>
<td>Mitochondria incubated with pyruvate</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Cytoplasm incubated with glucose</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Cytoplasm incubated with pyruvate</td>
<td>Absent</td>
<td>Present</td>
</tr>
</tbody>
</table>

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

*Fermentation is occurring in both cytoplasm samples, but not in the mitochondria samples.*

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

*Fermentation, the process that produces lactic acid, requires enzymes located in the cytoplasm, but not found in the mitochondria.*

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

*CO₂ production occurs in the Kreb’s cycle, which takes place in the inner mitochondrial matrix; therefore, it would be impossible to produce CO₂ in the cytoplasm fraction with glucose. The Kreb’s cycle requires pyruvate, not glucose, as a reactant, which explains why CO₂ could not be produced in the mitochondria fraction with glucose.*

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

*Lactic acid is produced during fermentation in the cytoplasm, using pyruvate as a reactant; this explains why lactic acid could be produced in the cytoplasm fraction with pyruvate. Glycolysis is a process that breaks down glucose into pyruvate and also occurs in the cytoplasm, so the cytoplasm fraction with glucose just need to first undergo glycolysis, then fermentation could occur.*
e. Why did the mitochondria produce carbon dioxide in the presence of pyruvate but not in the presence of glucose?

*CO₂ production occurs in the Kreb’s cycle, which takes place in the inner mitochondrial matrix. The Kreb’s cycle requires pyruvate, not glucose, as a reactant, which explains why CO₂ could not be produced in the mitochondria fraction with glucose.*

6. The figures to the right display the absorption range for several different pigments found in plants (top) and the rate of photosynthesis at varying conditions of wavelength in one plant species (bottom):

   a. What color and wavelength of light is reflected by the plant species tested? How do you know?

   *Carotenoid reflects red, orange, yellow and green light. Chlorophyll a reflects blue, green, and red light. Chlorophyll b reflects red light. To find the type of light reflected by each pigment, you must find the colors of light for which the relative absorption in Figure A is 0.*

   b. What wavelength(s) increase the rate of photosynthesis in the plant species tested? What pigment does this correspond to? How do you know?

   *Violet-blue and orange-red light increase the rate of photosynthesis, according to figure b. Figure b must correspond to either chlorophyll a or chlorophyll b, as both of these pigments absorb these light colors and therefore use them to drive photosynthesis.*
1. Refer to the figure to the right.
   a. What process is being shown in this picture?
      
      *Mitosis*

   b. What type of organism are these cells from? How do you know?
      
      *Plant cells because they have a rigid cell wall*

   c. Identify a numbered cell for each of the four major stages of mitosis.
      
      1 – Metaphase
      2 – Metaphase
      3 – Prophase
      4 – Telophase, cytokinesis
      5 – Telophase, cytokinesis
      6 – Metaphase
      7 – Prophase
      8 – Anaphase
      9 – Telophase, cytokinesis

   d. In what stage are most of the cells in this image? What does this indicate about the amount of time spent in each phase of the cell cycle?
      
      *Most cells are in interphase. This indicates that interphase is the longest portion of the cell cycle.*

2. Paclitaxel is a chemotherapy drug used to treat a variety of cancers. Paclitaxel inhibits both assembly and disassembly of microtubules.
   a. Which phase in the cell cycle is affected by Paclitaxel? How does this drug inhibit the growth of cancer?
      
      *Paclitaxel affects prophase-telophase of the cell cycle. If microtubules are unable to form, spindle fibers will not be able to attach to chromosomes and separate them during mitosis. This inhibits cell division, therefore not allowing cancer cells to reproduce.*
b. Paclitaxel affects not only cancer cells, but normal cells as well. Would the effects of Paclitaxel be seen first in organs that have quickly dividing cells (like the intestine and hair follicles) or in organs that have slow or nondividing cells (like muscles and the nervous system). Justify your reasoning.

The effects of Paclitaxel would first be seen in organs that have quickly dividing cells. Because these cells need to divide, but would not be able to do so, effects would be obvious in these cells first.

3. Two students debate about proteins that regulate the cell cycle. One argues that MPF triggers the production of cyclin, while the other argues that cyclin triggers the production of MPF.

a. Based on the figure to the right, which statement is correct and why?

Cyclin triggers the production of MPF. Cyclin gradually builds up throughout the cell cycle, which ultimately leads to the rapid production of MPF during the M phase. When cyclin levels fall during the M phase, MPF activity drops shortly thereafter.

b. Propose a possible function of MPF, based on when it is produced in the cell cycle.

MPF likely causes cell division because it is only present during mitosis. The purpose of mitosis is cell division.