BIO 1201 Thermal Metabolism Lab

Supplemental Worksheet

Answer the following questions as you go through the Thermal Metabolism Lab Introductory and Post-Activity PowerPoint materials. Please consult your instructor

**Introductory PowerPoint Questions:**

1. Which of the following do you expect to INCREASE during intense exercise, based on your personal experiences and what we’ve learned so far in this lecture? Circle the best answer(s). There may be more than one correct answer.
2. Energy use
3. Body temperature
4. Heart rate
5. Breath rate
6. One of the processes in the last question does NOT increase. Can you explain WHY?

**Hypothesis Development Questions:**

1. Is the following a well-stated hypothesis?

“Arctic hares grow a thicker fur coat in the winter”

1. Yes
2. No
3. Based on the ERUPT rubric, propose a hypothesis statement to answer one of the following questions. As part of your response, make sure to indicate which of the three questions you are trying to answer. For example, you might start by writing, "A frog's breathing rate will increase/decrease with temperature because ...."

**Select one question to answer:**

* How will a frog’s breathing rate change at warmer or colder body temperatures, and why?
* How will a human’s body temperature and heart rate change with cold exposure, and why?
* How will temperature affect the speed of a chemical reaction (such as H2O2 decomposition or the bicarbonate reaction), and why?

**Post-Experiment Questions:**

1. Did the frogs breathe faster or slower at warmer temperatures?
2. Faster
3. Slower
4. Did the chemical reaction go faster or slower at warmer temperatures?
5. Faster
6. Slower
7. Based on the Cold Pressor test experimental results, how does a human’s heart rate change during and immediately following cold exposure?
8. No change in heart rate
9. Heart rate decreased, relative to just before starting the test
10. Heart rate increased, relative to just before starting the test
11. Which of the following is the best-stated prediction and hypothesis regarding a human’s metabolic response to cold exposure?
12. Human metabolic rates stay relatively the same in response to temperature shifts because humans are homeothermic
13. Human metabolic rates increase when the environmental temperature shifts up or down, to maintain thermal homeostasis.
14. Human metabolic rates change when the environmental temperature shifts up or down, to maintain thermal homeostasis.
15. Human metabolic rates increase when the environmental temperature gets colder, to maintain thermal homeostasis.
16. Human metabolic rates decrease when the environmental temperature gets colder, to maintain thermal homeostasis.
17. Which of the following is the best-stated prediction and hypothesis regarding a human’s body temperature response to cold exposure?
18. Human body temperatures change when temperature shifts up or down, because their body temperature depends on the environmental temperature.
19. Human body temperatures stay relatively the same because human metabolisms adjust to maintain thermal homeostasis.
20. Human body temperatures stay relatively the same because humans are homeothermic.
21. Human body temperatures increase when the environmental temperature gets colder, to maintain thermal homeostasis.
22. Human body temperatures decrease when the environmental temperature gets colder, to maintain thermal homeostasis.
23. As with any experiment, there are important sources of variation that can influence the test results, potentially resulting in data that may be difficult to interpret. For example, it is important to have the subject relax for a few minutes prior to the start of the test to ensure their heart rate has stabilized to their resting baseline. It is also important for the subject to remain calm and relaxed throughout the full time course of the experiment.

Select which of the following would be likely to happen if a subject experiences anxiety about the cold pressor test.

1. If a subject was anxious before putting their hand in ice water, their heart rate might be elevated before the test, but then go down during the test as they calm down.
2. If a subject experienced pain from the cold exposure that induced an anxiety response during the test, their heart rate might elevate during the cold exposure, and remain elevated for a long time following the test.
3. If a subject was anxious before putting their hand in ice water, their heart rate might remain elevated before, during, and after the test.
4. All of these seem like reasonable possibilities.

**Post-Chemistry Follow-up Lecture Questions:**

1. Based on the lecture, which of the following is NOT a true statement about enzyme catalysts? Circle the best answer.
2. Enzyme catalysts are necessary for metabolic reactions like H2O2 decomposition, which have high activation energies that prevent them from occurring spontaneously at normal body temperatures.
3. Enzymes bind to chemical reactant(s) and stabilize the transition state for the reaction, making it easier for a reaction to occur.
4. Your body needs to constantly make new enzymes to replace old enzymes that were used up by chemical reactions.
5. Enzymes reduce the activation energy of a chemical reaction, i.e., the amount of kinetic energy needed for a reaction to occur.
6. Enzymes are protein molecules that may be thousands of times larger than the chemical reactants they bind to.
7. Which of the following is NOT true about the influence of temperature on chemical reaction rates? Circle the best answer.
8. Molecules move faster when temperature is higher.
9. Molecules need enough kinetic energy when they collide for a reaction to occur.
10. Higher temperatures mean there is more kinetic energy available to drive chemical reactions.
11. Higher temperatures lower the activation energy necessary for a reaction to occur.
12. Think back to the Frog Respirometry experiment and apply what you’ve now learned about temperature’s effect on chemical reactions. Circle the most correct statement from the following:
13. Frogs breathe faster as their body temperatures increase, because the chemical reactions driving metabolism go faster at higher temperatures, thus requiring more oxygen.
14. Frogs breathe slower as their body temperatures increase, because their metabolisms do not have to work as hard to maintain a constant body temperature.
15. Frogs breathe faster as their body temperatures increase, because their metabolisms need to work harder to maintain a constant body temperature.
16. Frogs breathe slower as their body temperatures increase, because the chemical reactions driving metabolism go slower at higher temperatures, thus requiring less oxygen.

**Data Analysis: Frog Respirometry and Thermal Chemistry Questions:**

Your instructor will compile your class data in a .csv file with the CASE SENSITIVE headers: ‘temperature’, ‘response’, and ‘mass’. Temperature should be recorded in degrees Celsius. The ‘mass’ header should be provided for all datasets but is only relevant for the Frog Respirometry dataset.

Using the link provided on Moodle, access the Thermal Performance Curve web application (Shiny-R app). Follow the instructions on the web page to run each analysis and record your results below. The Alka-Seltzer dataset is available on Moodle, with the response recorded in units of grams reacted per second.

Upload the hydrogen peroxide decomposition .csv file.

This dataset should contain reaction-rate results (mL oxygen per second) for the hydrogen peroxide decomposition experiment, compiled by your instructor. These are direct measurements of a chemical reaction rate, so there is no need to check the box to "correct for organism body mass". Leave the "Normal error distribution" box unchecked to run the model using the (recommended) log-normal error distribution. Click the "Start Analysis" button to fit the Arrhenius model to your dataset.

The first output graph shows the relationship between temperature (in degrees C) and the chemical reaction rate ("Response"). The model fit curves upward, reflecting the exponential nature of temperature effects on chemical reactions. Note that in statistical terminology, the x-axis for a regression analysis is referred to as the independent or "predictor" variable, and the y-axis is referred to as the dependent or "response" variable.

Recall from the Chemistry mini-lecture that the Arrhenius equation predicts a straight-line relationship between ln(Rate) and the inverse of temperature (in degrees Kelvin). The second graph shows this relationship, displaying 1/(kT) on the x-axis and ln(Response) on the y-axis. We can use the best-fit line on this graph to estimate two key parameters for the Arrhenius model: the scaling constant (A) and the activation energy (Ea).

1. **In the space below, provide an estimate for the activation energy for the catalase-assisted hydrogen peroxide decomposition reaction, based on this analysis.**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_ electron volt units (eV)**

Next, upload the "**AlkaSeltzer.csv**" dataset. Once uploaded, click "Start Analysis" again to fit the Arrhenius model to this new dataset. The response variable now is the reaction rate for the sodium bicarbonate contained in each Alka-Seltzer tablet, in units of grams reacted per second (g/s).

1. **In the space below, provide an estimate for the activation energy for the bicarbonate reaction, based on this analysis.**

**\_\_\_\_\_\_\_\_\_\_\_\_\_ electron volt units (eV)**

A graph or image presented in a scientific report is called a "Figure". It is important to always provide an explanatory description of every figure, typically in the space below the figure. In science writing, this description is called the "figure legend", not to be confused with the within-panel symbol keys that are referred to as "legends" in programs like Microsoft Excel. The first sentence of a scientific figure legend serves as the figure's title. Any additional sentences provide extra details that a reader might need to correctly interpret the figure, as in the example below. More examples of how to format scientific figures and tables can be found in the Bates College Guide to Scientific Tables and Figures, by Greg Anderson, available in the Additional Resources folder.

Diagram

Description automatically generated

1. **In the space below, compose a scientific figure legend describe the second graph of sodium bicarbonate reaction rates that you created in response to the previous question (see the second graph output from your analysis). Your figure legend should be concise but provide enough information for an uninformed reader to understand what the graph shows.**

Next, upload the Frog Respirometry dataset, with ‘response’ recorded as breaths per second and ‘mass’ recorded as frog mass in grams. Once uploaded, make sure to check the box to "Correct for organism mass". This is important, because we predicted that smaller frogs would have faster breath rates and we'd like to account for that variation to make our analysis of temperature effects more precise. The Thermal Performance Curve web app corrects for organism mass by dividing rate processes by mass to the negative 1/4 power (M^-0.25).

Click "Start Analysis" again to fit the Arrhenius model to this new dataset. The response variable now is the frog breath rate, in units of breaths per second.

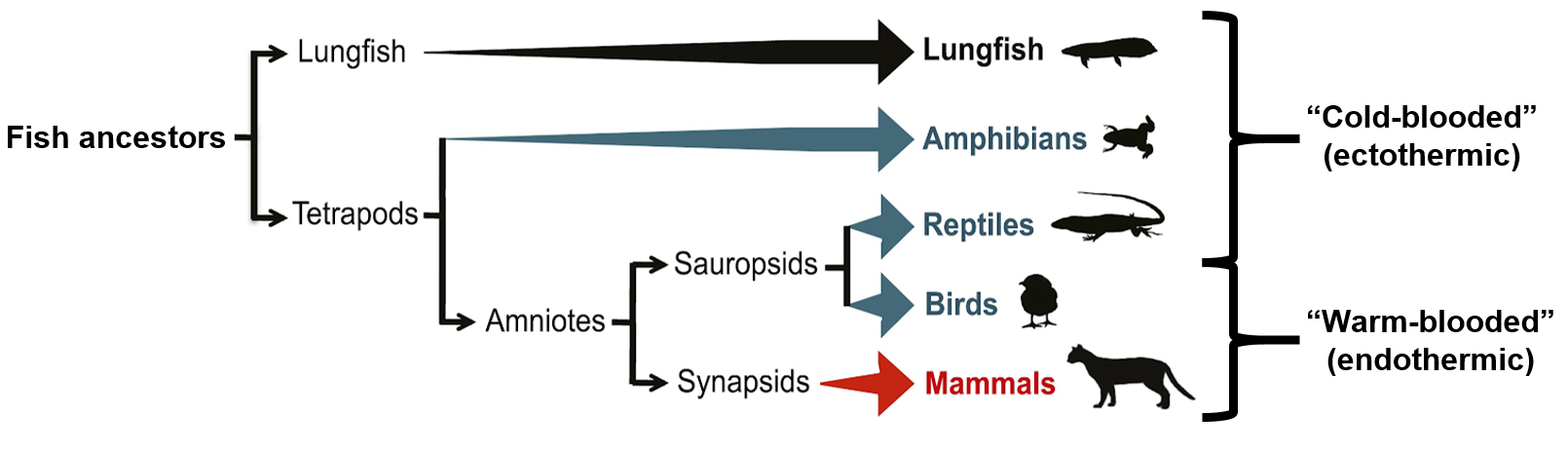
1. **In the space below, provide an estimate for the activation energy for frog respiration, based on this analysis.**

**\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ electron volt units (eV)**

1. **In the space below, compose a scientific figure legend describe the second graph of frog breath rates that you created in response to the previous question (see the second graph output from your analysis). Your figure legend should be concise but provide enough information for an uninformed reader to understand what the graph shows.**
2. Which of the following statements accurately describes the results from all three experiments? Circle all that apply (there may be more than one correct answer).
3. The chemistry experiments generated much higher activation energy estimates than the frog respiration experiment.
4. None of the activation energy estimates were similar to each other.
5. Catalase-assisted decomposition of hydrogen peroxide had a lower activation energy estimate than that of unassisted H2O2 decomposition.
6. All three experiments yielded similar activation energy estimates.
7. The frog respiration experiment generated a much higher activation energy estimate than the chemistry experiments.

**Post-Biology Follow-up Lecture Questions:**

1. Based on the experiments and your own experiences, what are some key similarities and differences between endotherm (“warm-blooded”) and ectotherm (“cold-blooded”) metabolic responses to temperature?
2. Is homeothermy (warm-blooded) a BETTER thermal strategy than poikilothermy (cold-blooded)?
3. Better strategy
4. Worse strategy
5. None of the above
6. What are some BENEFITS of maintaining a constant warm body temperature that might have selected for endothermy in mammal ancestors?
7. What are some DRAWBACKS of maintaining a constant warm body temperature, that might have selected for ectothermy in amphibian ancestors?

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1. Humans and frogs diverged ~320 million years ago. Was our last common ancestor probably warm-blooded (homeothermic) or cold-blooded (poikilothermic)?
2. Warm-blooded (homeothermic)
3. Cold-blooded (poikilothermic)
4. Based on this phylogeny, was the last common ancestor of birds and mammals more likely to have been warm-blooded (homeothermic) or cold-blooded (poikilothermic)?
5. We haven’t been given enough information to distinguish between these two hypotheses (i.e., they are equally parsimonious explanations of this phylogeny)
6. Cold-blooded (poikilothermic)
7. Warm-blooded (homeothermic)