6. HOMEOSTASIS

Background

The human body is very sensitive to temperature changes. Humans are constantly exposed to temperature changes in their surroundings. Despite these constant temperature changes, the core body temperature remains at approximately 98.6 °F. The condition of maintaining a stable internal temperature is known as **homeostasis** (*homeo-*, “similar” and *-stasis, “standing still”). Warm-blooded animals use diverse strategies to keep body temperature at a specific set point. These mechanisms are collectively referred to as **thermoregulation**.

The brain and nervous system play an important role in the body’s response to external stimuli and other events that change internal conditions in some way. The hypothalamus is the integrating center for thermoregulation, as it receives information about the external environment, interprets that information, and responds to changes by sending signals to multiple organ systems. For example, the hypothalamus may send signals that adjust blood flow to compensate for changes in the body’s core temperature. **Vasodilation** (widening of the vessels) increases the surface area available for heat to be released while **vasoconstriction** reduces the surface area for heat loss. In addition, sweating cools the body, while shivering generates warmth.

In this lab you will analyze the body’s response to a cold stimulus using a temperature probe to measure the surface temperature of the skin, then relate the results to thermoregulation.

Driving Question

What happens to the temperature of the hands when exposed to a significant drop in external temperature? Is the process of thermoregulation observable and reproducible?

Materials and Equipment

Use the following materials to complete the initial investigation. For conducting an experiment of your own design, check with your teacher to see what materials and equipment are available.

- Data collection system
- Fast response temperature probes (2)
- Wireless temperature links or PASCO sensors with a 3.5-mm connection (2)
- Standard alcohol thermometer
- Small adhesive bandages (2) or medical tape
- Large shallow bowl or pan
- Ice
- Water
- Paper towels

Safety

Follow these important safety precautions in addition to your regular classroom procedures:

- Wear safety goggles at all times.
- If you experience severe discomfort, you should remove your hand from the ice bath. While there will be some discomfort, most individuals can tolerate the cold water for 40 seconds without issue.
- Do not submerge your hand in ice water for more than 60 seconds. The risk of frostbite is minimal, but prolonged numbness in the hand could occur if left in the ice bath for too long.
- If you design an experiment requiring the use of gloves, use non-latex gloves to eliminate any risk posed from allergies to latex gloves.
Initial Investigation

Complete the following investigation before designing and conducting your own experiment. Record all observations, data, explanations, and answers in your lab notebook.

1. Put on your safety goggles.

2. Open the 6 ABI Homeostasis lab file. Plug both fast response temperature probes into the appropriate sensors. Select one probe to be distinguished as “Sensor 1” and connect it to your device first. Connect “Sensor 2” next and keep track of sensor numbers.

   NOTE: If the lab file is not available, create a two-graph display that shows (Sensor 1) Temperature versus Time in the first graph and (Sensor 2) Temperature versus Time in the second graph.

3. Prepare an ice bath by filling a shallow bowl or pan with water to a depth of approximately 3 cm, then add ice. Test the water height to make sure your right hand can be covered by ice water just past the first set of knuckles as shown in Figure 2. The palm should be completely submerged in the ice bath.

4. Set the standard thermometer in the ice bath and let it stand for 5 minutes; complete the next step while you wait. After 5 minutes, check the thermometer to make sure the ice bath temperature is between 4 °C and 8 °C. Add or remove ice as needed.

5. Determine which student in the group will be the test subject. Prepare the test subject for data collection:
   a. Use a small bandage or 2-cm piece of medical tape to secure the temperature probe from Sensor 1 to the pointer finger on the left hand as shown in Figure 1.
   b. Secure the probe from Sensor 2 to the pointer finger on the right hand.
   c. Have the test subject sit comfortably in a chair and relax, resting both hands on the table or lab bench surface.

6. Start collecting data while the test subject is relaxed. Allow the test subject’s skin temperature to be measured for at least 30 seconds. Record the final temperatures for each hand in your notebook. This is the test subject’s baseline hand temperature.

7. Is the baseline hand temperature the same as the body’s core temperature? Explain your answer.

8. Follow the steps below to test how the body responds to the stimulus of a hand being placed in ice water.
a. The test subject should sit relaxed with both hands resting on the table surface. Begin recording data.

b. After 10–20 seconds, instruct the test subject to place their right hand in the ice bath as shown in Figure 2. The hand should be submerged up to the first knuckle of each digit, and the palm should be flat on the surface of the water. Leave the left hand relaxed on the table.

   *NOTE: The temperature probe should NOT be submerged in the ice bath.*

c. Keep the right hand in the ice bath for 60 seconds.

   *NOTE: It is expected that the test subject will experience discomfort. However, if the cold becomes too painful, the subject may withdraw their hand and continue with the next step.*

d. After 60 seconds, remove the right hand from the ice water. Gently and quickly blot the hand dry, taking care not to disturb the temperature probe, and then place the hand on the surface of the table.

e. Continue data collection for five or more minutes—the recovery period—after removing the hand from the ice water. Stop collecting data after the recovery period.

9. What factors determine the accuracy of the temperature reading?

10. Draw or print a record of the temperature data. Analyze the data for temperature changes that occurred during the time of ice water immersion (from approximately 20 seconds to 80 seconds) and during the five or more minutes following immersion (the recovery period).

11. Did the temperature of the left hand (the control) change when the opposite hand was in ice water? If yes, describe the change that occurred. What purpose does the left hand serve in this experiment?

12. Did the temperature of the right (experimental) hand change when it was submerged in ice water? If yes, describe the change that occurred.

13. Describe trends in the temperature data collected during the recovery period and discuss whether either hand recovered the baseline hand temperature.

14. In response to a hot or cold stimulus that threatens homeostasis, the body can alter blood flow by dilating or constricting certain blood vessels (vasodilation and vasoconstriction), notably blood vessels that supply blood to the skin. Is there any evidence from this investigation that the ice water immersion caused vasodilation or vasoconstriction in the right hand? Use evidence to support your claim.

15. What was the maximum rate of change in temperature of the experimental (right) hand over the course of the 3-minute recovery period? How did the rate of change compare to that of the opposite (left) hand?
Design and Conduct an Experiment

In addition to temperature, other parameters are carefully regulated within the body, such as blood pressure and heart rate. The hypothalamus plays an important role in maintaining homeostasis for all of these parameters. Consider additional variables to test related to thermoregulation, or plan and carry out an experiment to investigate homeostasis with regards to other physiological parameters.

Design and carry out your experiment using either the Design and Conduct an Experiment Worksheet or the Experiment Design Plan. Then complete the Data Analysis and Synthesis Questions.

Design and Conduct an Experiment: Data Analysis

1. From your observations and your data:
   a. Describe how the independent variable you manipulated affected the dependent variable of your experiment. Does the data support your hypothesis? Justify your claim with evidence from your experiment.
   b. Based on the evidence you collected, explain why the results occurred.

2. Is there any evidence in your data or from your observations that experimental error or other uncontrolled variables affected your results? If yes, is the data reliable enough to determine if your hypothesis was supported?

3. Identify any new questions that have arisen as a result of your research.

Synthesis Questions

1. If someone is exposed to cold weather for extended periods of time, where are they most likely to get frostbite? Use the results of the Initial Investigation to support your answer.

2. Below is a diagram of thermoregulation in the human body. The body detects a change from normal body temperature and responds to maintain homeostasis. Copy and complete the diagram by identifying A, B, C, and D. In other words, what responses can help bring body temperature back to normal?
3. The nervous system plays a critical role in maintaining homeostasis for an organism. The system detects external stimuli, transmits and integrates information about the stimuli, and produces one or more responses.

   a. Describe the basic structure of the neurons that compose the nervous system and explain how neurons detect stimuli and transmit information to various parts of the body.

   b. Draw a diagram to illustrate the connection between the following structures during the body's response to a cold stimulus: hypothalamus, efferent and afferent nerves, smooth muscles that surround arteries, and thermoreceptors.

   c. Vasoconstriction occurs when the smooth muscles surrounding arteries contract. How do nerves cause muscle contraction?

4. Vertebrates have evolved a variety of strategies to deal with thermoregulation: the ability to maintain homeostasis with regard to body temperature.

   a. Ectothermy and endothermy are two different approaches to thermoregulation. Define each approach and describe the benefits and costs associated with each one.

   b. Mammals are endotherms and have evolved a wide variety of adaptations to deal with the different challenges to thermoregulation in the world's biomes. Identify three biomes with distinctly different climates. For each biome, name a mammal that lives there and list at least two adaptations each mammal has that relate to thermoregulation.

   c. Smaller mammals have higher basal metabolic rates (BMR) than larger mammals. Explain the relationship between body size, BMR, and thermoregulation.
Design and Conduct an Experiment Worksheet

In addition to temperature, other parameters are carefully regulated within the body, such as blood pressure and heart rate. The hypothalamus plays an important role in maintaining homeostasis for all of these parameters. Consider additional variables to test related to thermoregulation, or plan and carry out an experiment to investigate homeostasis with regards to other physiological parameters.

Develop and conduct your experiment using the following guide.

1. Based on your knowledge of homeostasis, what environmental factors (abiotic or biotic) could affect homeostasis in the human body?

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2. Create a driving question: choose one of the factors you've identified that can be controlled in the lab and develop a testable question for your experiment.

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3. What is the justification for your question? That is, why is it biologically significant, relevant, or interesting?

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4. What will be the independent variable of the experiment? Describe how this variable will be manipulated in your experiment.

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5. What is the dependent variable of the experiment? Describe how the data will be collected and processed in the experiment.

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6. Write a testable hypothesis (If...then...).

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7. What conditions will need to be held constant in the experiment? Quantify these values where possible.

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8. How many trials will be run for each experimental group? Justify your choice.

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9. What will you compare or calculate? What analysis will you perform to evaluate your results and hypothesis?

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10. Describe at least 3 potential sources of error that could affect the accuracy or reliability of data.

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11. Use the space below to create an outline of the experiment. In your lab notebook, write the steps for the procedure of the lab. (Another student or group should be able to repeat the procedure and obtain similar results.)

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12. Have your teacher approve your answers to these questions and your plan before beginning the experiment.