Homeostasis and Negative Feedback — Concepts and Breathing Experiments

I. Homeostasis and Negative Feedback

Your body maintains a relatively constant body temperature, even when the external environment gets colder or hotter. Your body also maintains relatively constant levels of O₂, CO₂, H⁺ and other internal conditions. This maintenance of relatively constant internal conditions is called homeostasis.

1. Why is homeostasis important? For example, what could go wrong if your body temperature got too low or too high?

2. Complete this table to describe how your body’s responses prevent body temperature from getting too low or too high.

<table>
<thead>
<tr>
<th>When you get chilled, how does your body respond?</th>
<th>When you get too hot, how does your body respond?</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does this response help to warm your body?</td>
<td>How does this response help to cool your body?</td>
</tr>
</tbody>
</table>

Part of your brain functions as a thermostat or temperature control center. If your body temperature gets too low or too high, the temperature control center triggers a response that brings your body temperature back to a set point. Usually, the set point for body temperature is approximately 37°C (~98.6°F).

3. Complete this flowchart to show how a person’s temperature control center keeps body temperature close to 37°C.

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1 By Drs. Ingrid Waldron, Lori Spindler and Jennifer Doherty, Dept Biology, Univ Pennsylvania, © 2019. Teachers are encouraged to copy this Student Handout for classroom use. This Student Handout and Teacher Preparation Notes with background information, instructional suggestions, and information to guide the student investigations are available at http://serendipstudio.org/sci_edu/waldron/#breath.
4. The top row of this flowchart gives a definition of **negative feedback**. Complete the second and third rows to show how body temperature regulation is an example of negative feedback.

   In negative feedback, if the regulated variable deviates from the set point, this stimulates a response that reverses the initial change which brings the regulated variable back to the setpoint.

   e.g., if body temperature falls below $\sim 37^\circ C$, this stimulates which

   e.g., if body temperature rises above $\sim 37^\circ C$

5a. Does the flowchart in question 3 show negative feedback? yes ___  no ___

5b. Explain your reasoning.

6. Explain how negative feedback contributes to homeostasis.

Homeostasis and negative feedback do not mean that body temperature is always constant. For example, when you have an infection, your body temperature may increase and you may develop a fever. The fever helps your immune system fight the infection.

7. This flowchart shows how a person who has an infection develops a fever. Notice that the person is shivering, even though his body temperature is at the normal set point $= 37^\circ C$. Explain why he is shivering.

   - Body temperature is $37^\circ C$.
   - Cells that are fighting an infection release a chemical signal that is carried by the blood to the temperature control center. This chemical signal **increases the set point** for temperature regulation to $\sim 39^\circ C (102^\circ F)$.
   - Temperature control center detects that body temperature is below the new set point.
   - More heat generated, so body warms.
   - Body temperature increases to the higher set point.
   - Shivering
II. Positive Feedback

In many ways, positive feedback is the opposite of negative feedback. In positive feedback, an initial change stimulates more change in the same direction. So, positive feedback produces rapid change.

This figure shows how positive feedback contributes to the rapid formation of a platelet plug in an injured blood vessel.

- The injured tissue attracts platelets.
- These platelets secrete chemical signals that attract more platelets to the site of the injury.
- Many platelets accumulate quickly and plug the hole in the injured blood vessel.

8. Explain how positive feedback helps to prevent excessive blood loss after a blood vessel has been injured.

9. To show two important differences between positive feedback and negative feedback, fill in each blank with one of the following: close to a set point / rapid change / reverses / same.

<table>
<thead>
<tr>
<th>Positive Feedback</th>
<th>Negative Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>An initial change stimulates more change in the _____ direction.</td>
<td>An initial change away from the set point stimulates a response that ________ the initial change.</td>
</tr>
<tr>
<td>Positive feedback produces _________.</td>
<td>Negative feedback keeps a regulated variable (e.g. body temperature) _________.</td>
</tr>
</tbody>
</table>

10. Explain why positive feedback and negative feedback are appropriate names for these two different types of feedback.

11a. If you are in a cold environment, shivering can increase your body temperature. Is shivering part of positive feedback ___ or negative feedback ___?

11b. Explain your reasoning.
III. Negative Feedback and Changes in Breathing
In this section you will investigate how negative feedback can cause changes in breathing. For this investigation, you will breathe the air in an 8-gallon plastic garbage bag for four minutes.

12a. Think about what will happen as you repeatedly re-breathe the air in the bag. How will the gases in the bag change?

12b. How should your breathing change in order to maintain homeostasis from the beginning to the end of your time of re-breathing the air in the bag?

Procedure
A. If you have asthma or some other breathing difficulty, check with your teacher about whether or not you should breathe into a bag. Each person whose health permits should complete steps B and C while other group members observe.

B. To prepare to breathe into your bag, open the bag completely and swish it through the air until the bag is nearly full of air. Then, gather the top of the bag in both hands and use your finger to open a small hole in the center just big enough to surround your nose and mouth. Hold this opening tightly over your nose and mouth.

C. Stand up and breathe into your bag for 4 minutes (or as long as you can). Try to breathe as normally as possible.

D. Notice any changes in breathing rate (the number of breaths per minute) and depth of breathing (the amount of air taken in with each breath). If you are observing another group member, watch how a crease in the bag changes as the person breathes in and out. This will help you to notice any changes in rate or depth of his/her breathing. Record your observations in question 13.

13a. Describe how your breathing changed as you continued to breathe into the bag.

13b. Describe how breathing changed for each of the other subjects in your group.

<table>
<thead>
<tr>
<th>Subject Name</th>
<th>Changes in Breathing Rate and Depth</th>
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</table>

14a. Summarize the overall pattern of changes in breathing rate and depth.

14b. What do you think caused these changes in breathing?
The following questions will help you to understand the negative feedback that caused the changes in breathing as each subject continued to re-breathe the air in the bag.

15. Why do you need to breathe all day and all night? Your answer should include the information in this chart.

![Cellular respiration of glucose produces ATP.](chart)

When you inhale (breathe in), air with $O_2$ is sucked into your lungs. This figure shows how $O_2$ gets from the air in your lungs to all the cells in your body.

In your lungs there are millions of tiny air sacs, each surrounded by many tiny blood vessels. $O_2$ diffuses from the air in the air sacs to the blood in these tiny blood vessels.

This blood carries $O_2$ from your lungs to your heart, and your heart pumps the blood to tiny blood vessels near every cell in your body. There, the $O_2$ diffuses from your blood into your cells.

16. Draw a long arrow that shows how $O_2$ moves from the air in your lungs to the cells throughout your body.

17a. Draw another long arrow that shows how the $CO_2$ produced by your body’s cells gets to the air sacs in your lungs.

17b. How is the $CO_2$ in the air sacs in your lungs removed from your body?

18a. Compared to the air you inhale, the air you exhale (breathe out) has ________ $CO_2$.  
(less / more)

18b. Compared to the air you inhale, the air you exhale has ________ $O_2$.  
(less / more)

18c. Explain your reasoning.
19. As a person re-breathes the air in the bag over and over again:
   • What happens to the level of CO₂ in the air in the bag? decreases ____ increases ____
   • What happens to the level of O₂ in the air in the bag? decreases ____ increases ____

20. Suppose that, as the person re-breathed the air in the bag over and over again, there was no change in his rate or depth of breathing.
   • What would happen to the levels of CO₂ in his blood? decrease ____ increase ____
   • What would happen to the levels of O₂ in his blood? decrease ____ increase ____

20b. Explain your reasoning.

21a. Explain how negative feedback could have caused the changes in breathing you observed as each subject re-breathed the air in the bag over and over again. (Hint: The regulated variables for this negative feedback are blood levels of O₂ and CO₂.)

21b. Draw a flowchart diagram that shows this negative feedback regulation of blood levels of O₂ and CO₂.

22a. Gloria drove from sea level to the top of a tall mountain. As she strolled around the top of the mountain, she noticed that she was breathing faster and deeper than usual. Explain how this change in Gloria’s breathing contributed to homeostasis. (Hint: Air pressure is significantly lower at high altitudes than at sea level, so there is less O₂ in a given volume of air.)

22b. Use your negative feedback model in question 21 to describe how negative feedback caused Gloria’s faster and deeper breathing at high altitudes.
IV. Investigating a Hypothesis or Question concerning Homeostasis and Changes in Breathing

Answer the questions in this section on a separate page or pages.

In this section you will design and carry out an experiment to test a hypothesis or answer a question about changes in breathing that contribute to homeostasis.

23a. Write a hypothesis or question that you will be able to investigate in your classroom.

23b. Develop a plan for an experiment to test your hypothesis or answer your question. Your teacher can recommend a method for measuring the rate and/or depth of breathing in your experiment. Describe the procedure for your experiment. Be specific about the sequence of steps in your procedure, including:
   - what you want your subjects to do
   - when and how you will measure breathing.

23c. Your teacher will review your group’s hypothesis or question and your plan for your experiment. Make any improvements recommended by your teacher.

24a. Make a data sheet for collecting your data.

24b. Plan how you will analyze your group’s data. Your plan should include some way to summarize your results in a table and/or graph that will help you to test your hypothesis or answer your question. If you will be making graphs, decide what type of graph you will prepare and what variables will be included.

24c. Your teacher will review your data sheet and your plan for analyzing your data. Make any improvements recommended by your teacher.

25a. Before you begin your experiment, practice your method for measuring the rate and/or depth of breathing until your method is reliable and valid. (Reliable methods produce the same, consistent results on different repetitions of the same experiment. Valid methods produce results that accurately reflect the variable you are trying to measure.)

25b. Carry out the experiment for each subject in your group, and record your data in your data sheet.

25c. Analyze your data

26. Prepare a brief report that includes:
   a. your hypothesis or question
   b. a summary of your methods
   c. your graph, table or other summary of your data
   d. your interpretations of your data and conclusions concerning your hypothesis or question
   e. an interpretation of your results using the concept of homeostasis
   f. an evaluation of the strengths and weaknesses of your experimental methods and design.