1 Introduction to Physiology

Synopsis

This chapter is an introduction to the study of human physiology with an emphasis on homeostasis. The chapter begins with a discussion of the hierarchical organization of the body, moving from cells to tissues to organs to organ systems. Characteristics of each of the four basic tissue types are discussed as well. This topic is followed by a discussion of the body's external and internal environments and the exchange of materials between these environments. Next, the body's fluid compartments and total body water are explained. This explanation is followed by a discussion of homeostasis. Included in this discussion are the basic principles behind negative feedback control and positive feedback control systems. An example of homeostatic regulation of blood glucose concentration is described. Specifically, the concept of negative feedback is explored within a discussion of regulating elevated blood glucose concentrations.

The chapter ends with a discussion of the current diabetes epidemic. The prevalence of the disease and the correlations between obesity and diabetes are explored. The types of diabetes are identified—namely, type 1 diabetes mellitus, type 2 diabetes mellitus, gestational diabetes, prediabetes, and diabetes insipidus. The criteria for diagnosing the disease, its symptoms, and the treatment for diabetes mellitus are addressed. The discussion of diabetes mellitus is meant to emphasize organ system integration via the study of the disease. In each of the following chapters, the topic of diabetes mellitus will be revisited and students will be reminded of the correlations between the various organ systems of the body.

Media for Students and Instructors

See the Quick Reference Guide for a list of chapter-specific MasteringA&P resources.

Solve It – these tutorials engage students in a multi-step case study in which they must analyze real data. Students begin by reading a clinical scenario and answering a question in the book, with the opportunity to delve deeper in an assignable activity in MasteringA&P.
*Solve It activities are available for select chapters in the text. Chapter 1 does not have a specific Solve It activity.

Interpreting Data – these tutorials coach students on interpretation and analysis of graphs and charts. Ensuring that students understand and make the most of in-text graphs and figures, these tutorials are assignable in MasteringA&P.

- Obesity and Diabetes Type II

IP2.0 – these coaching activities help student dive deeper into complex physiological processes. Fun, interactive tutorials, games and quizzes give students additional explanations to help them grasp complex physiological concepts and processes. IP2.0 is updated for today's technology and emphasis on active learning.

Learning Catalytics – is a bring your own device student engagement, assessment and classroom intelligent system. Instructors can assess students in real time using open-ended tasks to probe student understanding and facilitate peer-to-peer learning.

Chapter Basics

Key Terms

cell
connective tissue
cell
effector
endocrine gland
epithelia exocrine gland
extracellular fluid (ECF)
plasma
positive feedback
glands
homeostasis
hormone
integrating center
internal environment
interstitial fluid (ISF)
intracellular fluid (ICF)
regulated variable
set point
lumen muscle
fiber negative
feedback neuron
organ
organ
system
physiology
tissues
total body water (TBW)

Chapter Outline

I. Organization of the Body

A. Cells, Tissues, Organs, and Organ Systems

1. Cells and Tissues

2. Organs and Organ Systems

B. The Overall Body Plan: A Simplified View

1. The Body's External Environment

2. The Body's Internal Environment

a. The Exchange of Materials Between the External and Internal Environments

b. Body Fluid Compartments

II. Homeostasis: A Central Organizing Principle of Physiology

A. Negative Feedback Control in Homeostasis

III. The Diabetes Epidemic

A. Prevalence of Diabetes

B. Obesity and Diabetes

C. Classifications of Diabetes

Interpreting Data: Obesity and Diabetes Type II
A graph with two scatterplots are depicted. Students compare and contrast the relationship between body mass index (BMI) and the age-adjusted risk for developing Type II Diabetes Mellitus for men and women. Following the completion of this activity, students' understanding could be challenged by asking them to develop a scatterplot comparing male and female student total years of school completed versus the number of courses students have completed.

1. Diabetes Mellitus
2. Gestational Diabetes
3. Prediabetes
4. Diabetes Insipidus

D. Diagnosing Diabetes Mellitus

E. Symptoms of Diabetes Mellitus

F. Treatment of Diabetes Mellitus

FOCUS ON DIABETES

Due to the prevalence of diabetes mellitus in the world population, it is a major health concern. Diabetes mellitus is such a detrimental disease due to its pervasive nature; the disease affects all organ systems.

Cross References

Chapter 3: Cell Metabolism—While addressing the body's internal environment, it would be timely to discuss a cell's need for oxygen in cellular respiration and the production of carbon dioxide that results from this process.

Chapter 6: The Endocrine System: Endocrine Glands and Hormone Actions—A nice example of negative feedback is the relationship between thyroid releasing hormone, thyroid stimulating hormone, and thyroid hormones.

Chapter 9: The Nervous System: Central Nervous System—During the discussion of feedback mechanisms, it would be appropriate to point out that the brain serves as an integrating center for many feedback processes.

Chapter 14: The Cardiovascular System: Blood Vessels, Blood Flow, and Blood Pressure—One homeostatic mechanism crucial to the regulation of blood pressure is the baroreceptors, which influence blood vessel diameter, heart rate, contractility, and, ultimately, blood pressure.

Chapter 19: The Urinary System: Fluid and Electrolyte Balance—Given the urinary system's role in regulating fluid balance, it would be appropriate to discuss this function of the kidney while lecturing on total body water and extracellular fluid.

Chapter 21: The Endocrine System: Regulation of Energy Metabolism and Growth—Insulin lowers blood glucose, amino acid, and lipid concentrations by promoting the uptake and storage of carbohydrates, amino acids, and lipids.

Chapter 22: The Reproductive System—Good examples of positive feedback mechanisms are oxytocin, which plays a key role during childbirth, and luteinizing hormone, which triggers ovulation.

Chapter 24: Diabetes: Mellitus—Diabetes mellitus results when feedback mechanisms do not function properly; the disease affects all organ systems. The effects of diabetes mellitus on the various organ systems are discussed in every chapter, culminating with a full discussion of diabetes in Chapter 24.

In the Classroom

In-Class Discussion Questions

1. Of all the organ systems, one has a function that is different than all the others. Which one is it, and how is it different?
   Answer: The reproductive system. It is for survival of the species, whereas the others function in survival of the individual.

2. Think of all the devices you use on a regular basis. Part 1: See if you can come up with one that runs on a negative feedback system. Part 2: outline that system.
   Answer: Varies

3. Most variables in the body are regulated to maintain homeostasis. Can you come up with one that is not regulated to a set point?
   Answer: Hormones associated with ovulation are regulated, but they fluctuate and do not have a constant set point. There are both positive and negative feedback loops in reproductive hormones. Positive feedback occurs just before ovulation. This is an example in which the response of the system goes in the same direction as the change that sets it in motion.

4. Based on Figure 1.9 and Table 1.4, what might be a method to combat type II diabetes mellitus in the United States.
   Answer: Make weight control a public health issue.

Critical Thinking and Application

1. Using the heart as an example organ, review your knowledge of anatomy by describing how this organ is composed of the four basic tissue types. In your description, name at least one part of the heart that is composed of each of the four basic cell types.

   Answer: The thickest layer of the heart wall, the myocardium, is made up of **cardiac muscle**. The inside of the heart is lined with **epithelium** called endothelium (and referred to as the endocardium). The heart itself is innervated by branches of the vagus nerve and several sympathetic nerves, so it contains **neurons**. Lastly, the fibrous pericardium and the skeleton of the heart are made up of dense **connective tissue**.

2. Maintenance of nearly constant blood glucose levels at approximately 100 mg/dL of blood is a physiological priority. Suppose you are a scientist who wants to better understand blood glucose homeostasis. You perform an experiment where you take samples of an individual's blood once each hour for a 24-hour period while your subject goes about his or her regular daily routine. You then measure the glucose level in the samples of blood and plot the data as a line graph. What do you predict this line will look like?

   Answer: You should expect your graph to **fluctuate up and down over the course of the day**. If the person is not a diabetic, the blood glucose level should fluctuate around approximately 100 mg/dL. After meals, you would expect the glucose level to rise. After long periods of fasting (i.e., overnight), you would expect the blood glucose level to drop. You would not expect your data to be graphed as a straight line at 100 mg/dL.

3. When you run a cycle in your washing machine, you set the size of the load on the washer and turn it on, and the washer begins to fill the tub with water. Eventually, the water reaches the appropriate level, the water turns off, and the wash cycle begins. Which kind of feedback system is at work in controlling the water level? Identify as many components of the feedback system as you can.

Answer: This is an example of a **negative feedback system**. The regulated variable is the water level. The set point is the level you set on the machine when you tell it what size load you want to wash. The sensors are water level sensors present in the machine. The effectors are the valves that control the flow of water into the machine.

4. Returning to the problem in Question 3, identify all the components of the feedback system that are at work to control the water temperature if you set it to 100°F. Which kind of feedback system is used to control water temperature?

Answer: Once again, this is an example of **negative feedback**. The regulated variable is the water temperature. The set point is 100°F. The sensors are temperature sensors in the washing machine. The effectors are the valves controlling the flow of hot and cold water into the machine.

5. Which process is being described in each of the following situations?

a) Movement of amino acids from the lumen of the small intestine into the bloodstream.

b) Movement of bile from the liver or gallbladder into the lumen of the small intestine.

c) Elimination of urea from the body via the urine.

Answer: a) absorption b) secretion c) excretion

6. An individual is stung on her shoulder by a bee. A variety of chemical mediators are released, making capillaries in her shoulder more "leaky" (i.e., permeable) to plasma proteins and other components. As fluid and proteins leak into the interstitial spaces, the individual's shoulder becomes red and swollen. Describe the changes (increase, decrease, or no change) in her total body water, intracellular fluid, extracellular fluid, plasma, and interstitial fluid levels that take place immediately following the bee sting.

Answer:

Total body water = no change
Intracellular fluid = no change (possible increase over a longer period of time)
Extracellular fluid = no change
Plasma = decrease
Interstitial fluid = increase

7. Heat stroke is a condition that can result from (among other things) prolonged exercise in the heat. If body temperature raises to a high enough level, it damages the temperaturecontrol centers in the hypothalamus. Once damaged, these control centers will not initiate the appropriate responses for heat loss by the body, and body temperature will increase even further. Body temperature will continue to increase until death ensues or emergency treatment is provided. Which type of feedback mechanism is at work in the development of heat stroke?

Answer: Heat stroke is an example of **positive feedback**.

8. Refer to Question 7. Explain how heat stroke represents a failure of homeostasis. Which part of the normal feedback system is damaged in this example?

Answer: Heat stroke represents a failure of homeostasis because the negative feedback is no longer functioning properly and has become a positive feedback system. In addition, this example demonstrates that all parts of the normal feedback mechanism must be working properly for homeostasis to be maintained. In this example, the **integrating center is damaged**. Even if the effectors are working properly, without the necessary

feedback occurring in the hypothalamus, the entire system fails.

In-Class Exercise: Concept Map

Assign this activity to check students' understanding of feedback mechanism. Once students complete the activity, they should check their answers with a neighbor and be prepared to share their maps with the class.

Instructions

1. Read the information below and then identify the following factors: regulated variable, set point, integrating center, sensors, and effectors.

   Normal blood pressure is 110/70 mm Hg. The baroreceptors in the carotid arteries and aortic arch are responsible for sensing blood pressure. When an increase in the blood pressure occurs, the information is relayed to a part of the brain known as the medulla oblongata. As a result, the medulla oblongata sends signals via nerves to the precapillary sphincters indicating that they should dilate. It also sends signals to the heart indicating that it should slow down. Increased arteriolar diameter and decreased heart rate will cause blood pressure to return to normal.

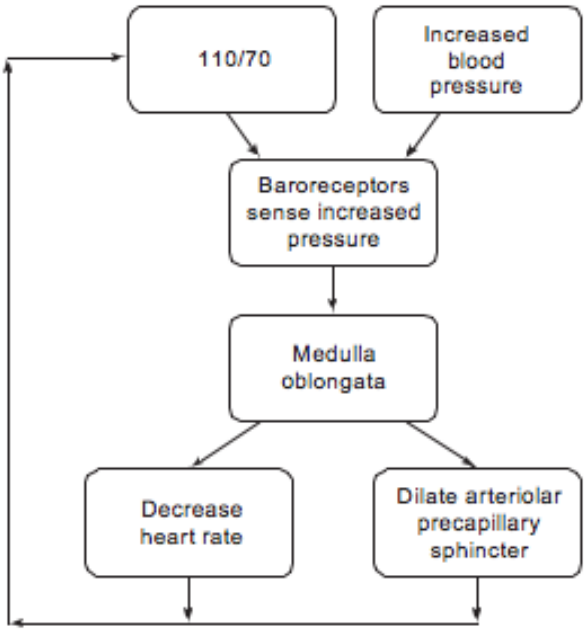
2. Draw a concept map depicting the feedback relationship between the following terms: increased blood pressure, 110/70, baroreceptors, medulla oblongata, dilate, precapillary sphincters, decrease heart rate

Answers

1. Regulated variable = increased blood pressure

Set point = 110/70 mm Hg
Integrating center = medulla oblongata
Sensors = baroreceptors
Effectors = precapillary sphincters and heart

2.



Classroom Demonstrations/Activities

1. Using a glass or cup as an example, demonstrate a structure/function relationship. Then give students an object they are likely to be unfamiliar with and ask them to come up with possible functions of that object simply based on its structure.

2. As you are discussing negative feedback, use the function of a thermostat as an example of negative feedback. If your classroom has a thermostat in an obvious location, use it as a prop for your discussion.
3. After introducing control systems, give students a few minutes to brainstorm about what they think are regulated variables in the body.
4. Use the effect of oxytocin on the uterus during childbirth as an example of a positive feedback system. This is a nice, clear example because the point when the initial stimulus is removed is quite obvious (the baby is born).
5. If your classroom has a thermostat, set it higher or lower than normal before the class begins. Ideally, your students should be removing coats or putting them on and shivering, depending on the temperature. By the time you get to negative feedback and the thermostat example, you can add in a discussion of thermoregulation and introduce the body's "thermostat": the hypothalamus.

Helpful Hints

1. In your first lectures, you set the tone for the rest of the semester. Be sure to make your expectations clear from the beginning. Students should be working on a problem the first day of class. Many students tend to put off studying until the last minute. If you encourage them to begin actively learning from the first day of class, they will be more likely to develop good habits.
2. If you present your lectures electronically (using PowerPoint presentations, for instance), make copies of your lecture notes available for students via handouts, the course website, or other means. If they don't have to take notes, students are more likely to listen carefully and need to make only small additions to their notes as they follow along. This helps students to be more interactive and prevents you from moving too fast for them.
3. Set up a class e-mail list or a web-based discussion site for your students. This is a wonderful format that allows students to "talk" to one another about setting up workgroups or to post questions and answers (they are very good at helping each other). Additionally, when you have a class announcement on an "off" day, you can be sure that all of your students will receive it before going to class.

Outside Resources

Discoveries in Physiology: Current and Classic Research

1. Baptiste, R. K., Barone, B. B., et al. Risk factors for type 2 diabetes among women with gestational diabetes: A systemic review. *American Journal of Medicine,* 122 (2009): 207–214.
2. Bernard, C. *An Introduction to the Study of Experimental Medicine.* New York: Dover Publications, 1957.
3. Concannon, P., Rich, S. S., and Nepom, G. T. Genetics of type 1A diabetes. *New England Journal of Medicine,* 360 (2009): 1646–1654.
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5. Jouanna, J., and Devevoise, M. B. *Hippocrates (Medicine and Culture).* Baltimore: Johns Hopkins

University Press, 1999.

6. Marieb, E., and K. Hoehn. *Human Anatomy and Physiology,* 9th ed. San Francisco: Pearson Education, 2013.

7. Mourad, J. J., and LeJeune, S. Blood pressure control, risk factors and cardiovascular prognosis in patients with diabetes: 30 years of progress. *Journal of Hypertension 26,* suppl (2008): S7–13.

8. Northrop, R. B. *Endogenous and Exogenous Regulation and Control of Physiological Systems.* Boca Raton: CRC Press, 1999.

9. Weiss, D. *Physician Extraordinary: William Harvey.* New York: Delacorte Press, 1975.

10. Wolfe, E. L., Barger, A. C., and Benison, S. *Walter B. Cannon: Science and Society.*Cambridge: Harvard University Press, 2000.

Multimedia

Videotapes, DVDs, and Streaming

1. *NOVA: Doctors' Diaries.* (PBS: 112 min., 2008, DVD). Description: Follows seven aspiring doctors as they undergo the exhilarating and grueling years of medical training.
2. *NOVA: The Universe Within.* (PBS: 60 min., 1992, DVD). Description: Travel along for an incredible visual tour inside the human body with micro-photography and computer animation. By the creators of *The Miracle of Life*.
3. *Homeostasis*. (FHS: 20 min., 1995, DVD, 3-year streaming webcast). Includes regulation of temperature and blood sugar, feedback mechanisms, water balance.
4. *Hot and Cold.* (FHS: 26 min., 1984, DVD, 3-year streaming webcast). How the body regulates and maintains a relatively constant internal temperature during a day of skiing.

