

Obesity

Activity Summary

Students make hormone-receptor models to understand how hormones bind to specific receptors before initiating a cellular response.

Materials for Class Demonstration

- string
- signs labeled with the parts involved in the leptin feedback cycle (see Step 3)

Materials for Each Team

- copy of the “Hormones and Receptors” student handout
- copy of the “Model Diagrams” student handout
- 4 twist-ties
- clear, pint-size plastic container (e.g., soda bottle)
- funnel that fits the container
- 20 ml vegetable oil
- water
- 2 pipe cleaners
- sealable plastic bag
- 8 cotton swabs
- Styrofoam ball (or apple or orange)
- piece of clay (about 3 cubic centimeters)
- 10-15 toothpicks

Background

Hormones are produced by endocrine glands (e.g., pituitary, pineal, thyroid, thymus, adrenal, pancreas, ovary, and testes) and some non-endocrine organs (e.g., brain, lungs, kidneys, liver, thymus, skin, adipose tissue, and placenta). The endocrine system is a precisely controlled chemical communication system that regulates many physiologic processes in the body. Important parts of the endocrine system include:

- glands or tissues that produce and secrete hormones,
- tissue (referred to as target tissue: see Key Terms) and receptors responsive to specific hormones,
- chemical products produced by target tissue in response to hormones, and
- the resulting action of these products on the body.

Some hormones can act on many cell types, while others act on just one type. And, hormones regulate cells in different ways: some affect the very cells that make the hormone; other hormones regulate neighboring cells; still others regulate cells at a distance from where they are made. Hormones that regulate cells at a distance travel through the bloodstream.

LEARNING OBJECTIVES

Students will be able to:

- make a hormone-receptor model that shows how hormones only enter specific tissues.
- describe properties common to tissues that respond to hormones: the presence of a hormone-specific receptor, and the triggering of a cellular response once the hormone binds to the receptor.
- discuss how the hormone leptin plays a role in appetite.

The Biology of Fat

Learn how the body regulates weight by carefully controlling the storage and burning of fat and how a better understanding of these complex metabolic systems could lead researchers to treatments that curb obesity and improve public health. Available free from the Howard Hughes Medical Institute as four downloadable videos at biointeractive.org/obesity

CLASSROOM ACTIVITY (CONT.)

Consequently, these hormones come in contact with many different organs, tissues, and cell types. Yet, they only trigger a response where there is a functional receptor with a strong affinity for that hormone. Once the hormone binds to its receptor, cellular processes, such as changing which genes in a cell are active or triggering the production of a protein, are initiated.

A target tissue's response to hormones is regulated by hormone concentration (there must be enough hormone to initiate a response), the number of receptors on the cell membrane, and the affinity the receptor and hormone have for each other. Hormone receptors are often large proteins with a specific structure, including a place for a hormone to attach (i.e., the binding site) and a part that produces chemicals that stimulate a cellular response. In addition to producing chemicals that stimulate a cell's response, target cells also often make substances that provide a feedback signal, which directs the cells producing a hormone to either increase or decrease the hormone level. Disease can result when hormone production is too high or low or when hormone receptors are blocked or nonfunctional.

Leptin is a hormone produced by the body's fat tissue (adipocytes), and, typically, the amount made is proportional to the amount of fat tissue. Leptin helps regulate food intake and control how fats are distributed and stored in the body. Under normal circumstances, when a person's fat level drops, less leptin is produced. The part of the brain called the hypothalamus detects this decreased signal, and this decrease stimulates a person's desire to eat. Similarly, when the fat level returns to or exceeds a person's usual level, the leptin level rises. This increased signal reduces a person's desire to eat.

One form of obesity in humans is due to a mutation in the gene responsible for leptin production. More common, however, is a mutation in the genes that encode for leptin receptors. In both cases, the amount of leptin available to body tissues is very different for people with a mutation than for those without it. So even after eating a full meal, people with these mutations can still feel hungry, making it easy to overeat and to gain weight. Mice that are unable to produce leptin become tremendously obese. Leptin injections cure this condition. This technique also works on those few people born with an inability to produce leptin. But since it is much more common to have a problem with the leptin receptor, most obese people do not lose significant amounts of weight when given leptin injections.

In this activity, students make models that illustrate hormone-receptor systems. These models underscore the need for the hormone and receptor to be matched in order for them to be able to bind strongly to one another. The models also show how mutations can interfere with the functioning of a hormone-receptor system.

KEY TERMS

endocrine system: A chemical communication system in the body that controls physiologic processes, such as growth, development, and appetite.

hormones: Chemical messengers made by one type of cell that regulate the function of other types of cells (and sometimes the cell that made the hormone). Hormones have a specific structure that can bind to specific receptors, allowing for precise control of the cells they regulate.

leptin: A hormone produced by fatty tissue (adipocytes) that acts on the brain, ultimately influencing appetite, body fat storage, and other physiologic processes.

mutation: A change in a gene that alters the message carried by the gene. The gene product (often a protein) may be altered so that it functions differently or not at all.

plasma membrane: The outer membrane of animal cells, made of a lipid bi-layer. It controls the movement of substances in and out of the cell.

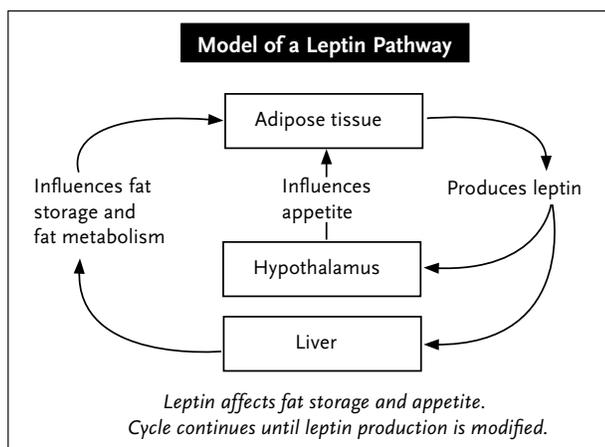
receptor: A molecule on the plasma membrane or inside a cell that binds to a specific substance, such as a hormone, and triggers a cellular response. For peptide hormones, receptors are in the plasma membrane. For steroid and thyroid hormones, the receptors are in the cytoplasm and nucleus.

target tissue: A tissue with a receptor for a specific hormone that responds chemically to the hormone.

CLASSROOM ACTIVITY (CONT.)

Procedure

- 1 After viewing the segment, have students direct you in making a diagram on the board that shows how hormones such as leptin function. As you make the diagram, review key vocabulary terms. Include information such as:
 - glands and tissues produce and secrete hormones (*Leptin is produced in fatty tissue.*)
 - target tissues and target cells (*because of their receptors*) respond to specific hormones (*Cells in the hypothalamus and liver have specific receptors for leptin.*)
 - hormones stimulate target tissues and cells to produce chemical products (*Once stimulated by a hormone, target tissues and cells produce proteins and other kinds of molecules.*)
 - the chemical products produced by target tissues and cells affect the body in particular ways. (*Leptin affects appetite, fat storage, and fat metabolism.*)
- 2 Remind students that models play an important role in helping people understand systems, abstract concepts, and processes that are difficult to experience directly. Develop a list of subjects that have been made familiar through the use of models, such as DNA, the atom, the solar system, plate tectonics, the cell, and the human body. Have students explain ways each model helps people better understand a concept, system, or process. In addition, discuss the limitations of each model. Tell students that, in the activity, they will be making models of hormones and receptors to help them understand how hormones work and why they act only on specific tissues.



- 3 Have students create a simplified model of the leptin pathway. Distribute string (representing the circulatory system) and signs (labeled adipose tissue, hypothalamus, and liver). Discuss how the model represents the components listed in Step 1.

STANDARDS CONNECTION

The “Hormones and Receptors” activity aligns with the following National Science Education Standards (see books.nap.edu/html/nsees).

GRADES 5–8

Science Standard C Life Science

- Structure and function in living systems
- Regulation and behavior

GRADES 9–12

Science Standard C Life Science

- The cell
- The molecular basis of heredity

Classroom Activity Author

Developed by WGBH Educational Outreach staff.

CLASSROOM ACTIVITY (CONT.)

- 4 Discuss the model by asking questions, such as:
 - Why it is important that a hormone enter the correct tissue? (*The body needs the hormone response to occur in a particular place.*)
 - How can a hormone enter some tissues but not others? (*A hormone can only enter tissues and cells with receptors that correspond to that hormone. Hormones and receptors are specific for each other the way a key opens a specific lock.*)
 - What might happen if hormones and receptors were not precisely matched? (*If a hormone were to attach strongly to just any receptor, a wide variety of tissues and cells would respond to the hormone, and body functions would not be precisely regulated.*)
 - What might happen if a target tissue were to receive too much or too little hormone? (*The tissue's response would be excessive or inadequate, which could lead to problems or disease.*)
- 5 Divide the class into teams. Distribute the materials and student handouts. Tell students to do Steps 1–5, making the different hormone-receptor models.
- 6 After students complete their models, ask each team to present one to the class. Discuss how mutations affecting hormone concentration in the bloodstream or the ability of a receptor to respond to a hormone might affect a person with the mutation. After discussing the models, have students answer the four questions on the handout.
- 7 As an extension or for homework, have students research Type 1 and Type 2 diabetes. While both involve irregularities in hormone production or hormone receptors, the way each type manifests itself and how they are treated are very different.

LINKS AND BOOKS

Links

NOVA scienceNOW

pbs.org/nova/sciencenow/3313/03.html

Offers an array of obesity-related resources, including additional activities, streamed video, and reports by experts.

Chipping Away at Leptin's Effects

hhmi.org/news/friedman.html

Describes how researchers have identified genes that are specifically regulated by the hormone leptin.

Hormones, Receptors, and Control Systems

arbl.cvmbs.colostate.edu/hbooks/pathophys/endocrine/basics/index.html

Includes an overview of endocrinology and information on hormones, receptors, and target cells.

Leptin's Legacy

practicingsafescience.org/bulletin/mar2003/leptin/leptin2.html

Reviews research on leptin's role in the body.

Molecular Studies of Food Intake and Body Weight

hhmi.org:80/research/investigators/friedman.html

Discusses studies that focus on leptin's action and how leptin is regulated.

Books

Biology Coloring Book

by Robert D. Griffin. Collins, 1986.

Provides detailed diagrams of human body structures and systems.

The Concise Encyclopedia of the Human Body

David Burnie. Dorling Kindersley, 1995.

Presents detailed illustrations and informative text and captions.

ACTIVITY ANSWER

Write a possible outcome or consequence of the following mutations or conditions.

- A mutation alters the amount of hormone produced: *(When little or no hormone is available to bind to the receptor, there will be little or no hormone-activated product made in the target cell. When too much hormone is produced, the target cell may produce an excess of hormone-activated product. Both situations may cause problems or disease.)*
- A mutation prevents a hormone from binding to the receptor: *(With the receptor unable to bind to a hormone, no hormone-activated product will be made at the target cell. This may cause problems or disease.)*
- There is no cell or tissue to produce a hormone: *(Without any hormone, no hormone-activated product will be made at the target cell. This may cause problems or disease.)*

Write at least two strengths and two limitations of each model system.

	Model 1	Model 2	Model 3
Strengths	<ul style="list-style-type: none"> • easy to manipulate hormone • hormone can enter cell • has lipid membrane 	<ul style="list-style-type: none"> • lock and key specificity clear • pipe cleaners show two membrane features 	<ul style="list-style-type: none"> • lock and key specificity clear • receptor (clay) is obvious
Limitations	<ul style="list-style-type: none"> • lock and key specificity not as clear • lipid membrane only covers part of cytoplasm 	<ul style="list-style-type: none"> • can't show hormone entering cell • no cytoplasm in target cell 	<ul style="list-style-type: none"> • can't show hormone entering cell • membrane bi-layer not obvious

Student Handout Questions

- 1 Which model best represents a hormone-receptor system? Why?
Answers will vary.
- 2 Which mutation or condition might be “corrected” by hormone injection? *The two mutations or conditions that might be aided by hormone injections are: a mutation that blocks hormone production and a condition where there is no tissue to produce a hormone.*
- 3 Which mutation or condition might respond to a transplant of the tissue able to produce the needed hormone? *The two mutations or conditions that might be aided by a transplant are: a mutation that blocks hormone production and a condition where there is no tissue to produce a hormone.*
- 4 Which mutation or condition would most likely respond to gene therapy (i.e., injecting genes that can help the body produce functional products)? *The first two situations would benefit if functioning, healthy genes could be incorporated into a patient's DNA. The third would not, because the necessary tissue to utilize the gene does not exist in the first place.*

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Major funding for NOVA is provided by Google.

Major funding for NOVA scienceNOW is provided by the National Science Foundation and the Howard Hughes Medical Institute. Additional funding is provided by the Alfred P. Sloan Foundation.

Additional funding provided by the Corporation for Public Broadcasting and public television viewers.

This material is based upon work supported by the National Science Foundation under Grant No. 0229297. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.



Hormones and Receptors

Hormones are the body’s chemical messengers. They typically travel through the bloodstream and initiate a response in cells (called target cells) far from where the hormones were made. To enter a

target cell, a hormone binds to specific receptors on the cell. In this activity, you will make hormone-receptor models, use them to understand specific mutations, and then assess each model’s strengths and limitations.

	Model 1	Model 2	Model 3	Model 4
Strengths				
Limitations				

Procedure

- 1 Assemble the three hormone-receptor models illustrated on your Model Diagrams handout.
- 2 For each model, label the following parts: hormone, plasma membrane, cytoplasm, and hormone receptor.
- 3 Write a possible outcome or consequence of the following mutations or conditions.

- A mutation alters the amount of hormone produced: _____

- A mutation prevents a hormone from binding to the receptor: _____

- There is no cell or tissue to produce a hormone: _____

- 4 Design your own hormone-receptor cell model. List your materials and draw and label your model in box 4 on the Model Diagrams handout.
- 5 In the above table, write at least two strengths and two limitations of each model system.

Questions

Write your answers on a separate sheet of paper.

- 1 Which model best represents a hormone-receptor system? Why?
- For Questions 2–4, refer to the gene mutations and conditions addressed in Step 3 above.*
- 2 Which mutation or condition might be “corrected” by hormone injection?
 - 3 Which mutation or condition might respond to a transplant of the tissue that could produce the needed hormone?
 - 4 Which mutation or condition would most likely respond to gene therapy (i.e., injecting genes that can help the body produce functional products)?

Model Diagrams

Procedure

- 1 Assemble the three hormone-receptor models, using the listed materials.
- 2 Label the following parts: hormone, plasma membrane, cytoplasm, hormone receptor.
- 3 Design and label your own hormone-receptor model.

Materials	Model Diagram
<p>1 The Oil Membrane and the Funnel Receptor</p> <ul style="list-style-type: none"> • twist-tie • funnel • jar • vegetable oil • water 	
<p>2 The Cotton Swab Membrane and the Pipe Cleaner Receptor</p> <ul style="list-style-type: none"> • pipe cleaner • cotton swabs • freezer bag 	
<p>3 The Toothpick Membrane and the Clay Receptor</p> <ul style="list-style-type: none"> • Styrofoam ball • toothpicks • clay 	
<p>4 Materials for your model:</p>	<p>Draw a model of your own and label it:</p>