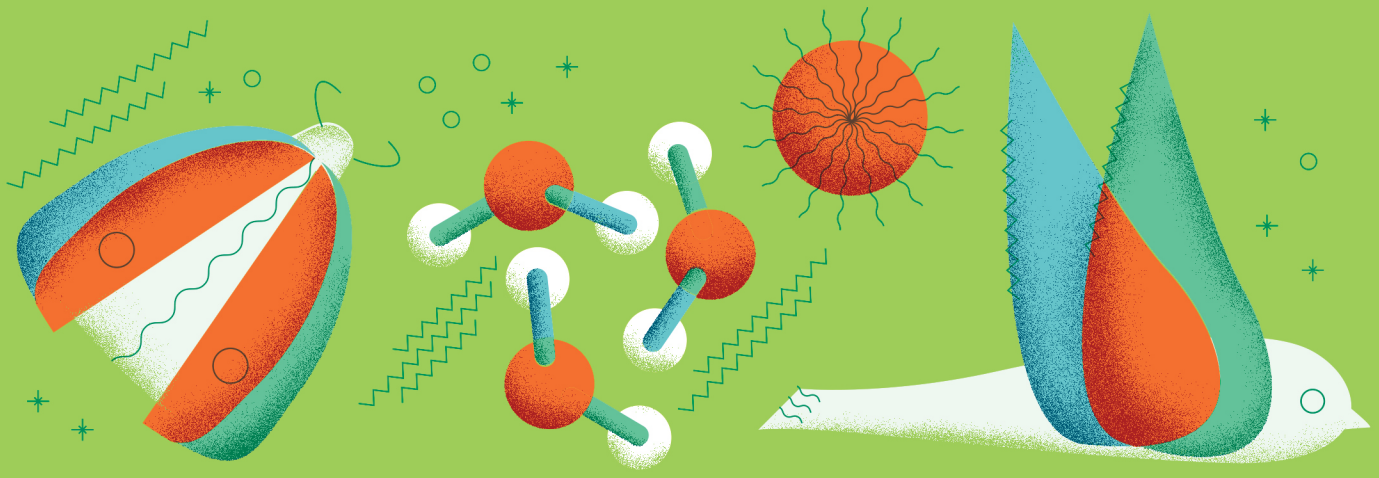
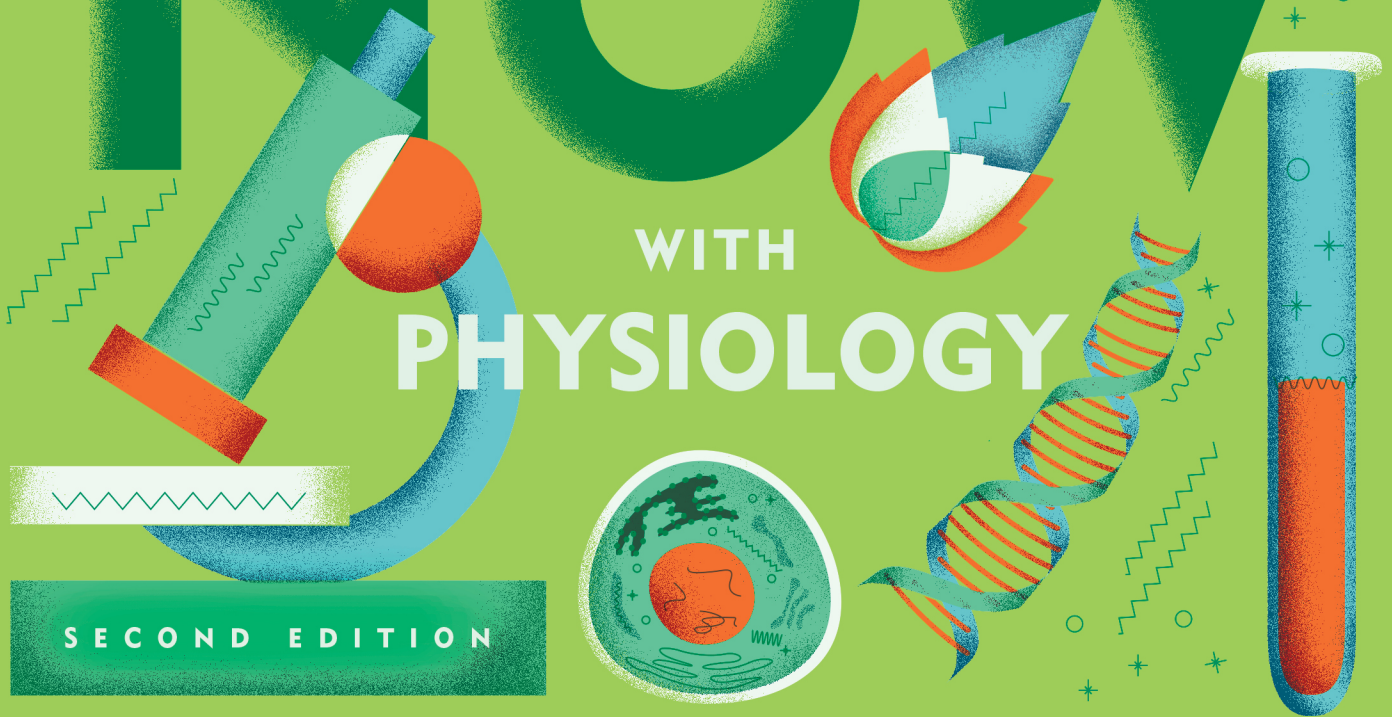
Anne Houtman ◦ Megan Scudellari ◦ Cindy Malone



BIOLOGY NOW

WITH PHYSIOLOGY



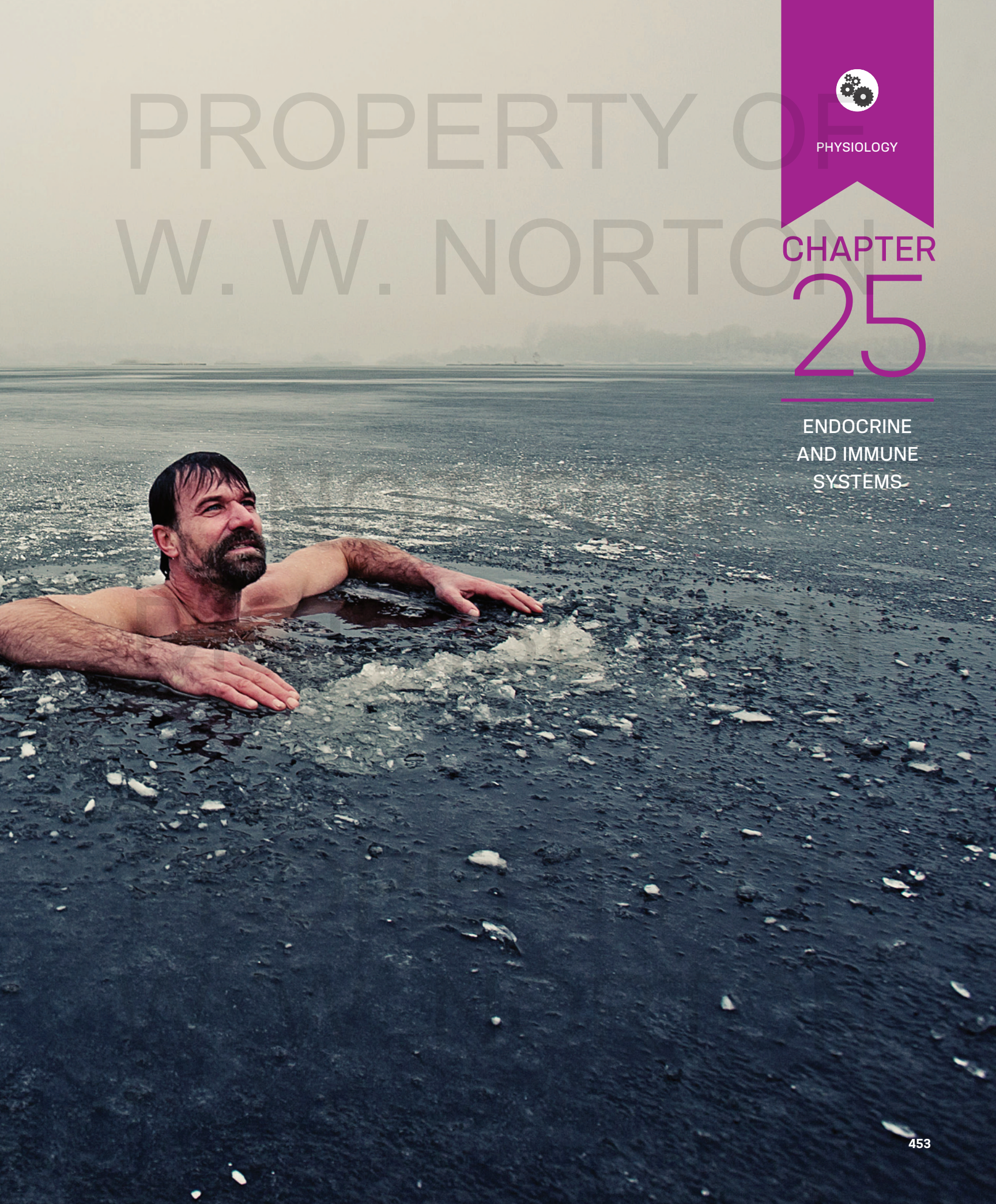
SECOND EDITION

Testing the Iceman

A Dutch daredevil claims he can fend off disease with his mind. Two skeptical scientists take the case.

After reading this chapter you should be able to:

- Explain how cells communicate with each other via the endocrine system.
- Describe different ways a hormone can act on a target cell.
- Identify the immune system's first, second, and third lines of defense.
- Compare and contrast the role of white blood cells in the innate and adaptive immune systems.
- Diagram the processes of inflammation and blood clotting.
- Distinguish between a primary and a secondary adaptive immune response.
- Create a flowchart depicting the sequence of events as a vertebrate immune system responds to a pathogen.



PHYSIOLOGY

CHAPTER 25

ENDOCRINE AND IMMUNE SYSTEMS

The scantily clad young men lie on the ground, looking up toward the sky. With sunglasses on and hands propped behind their heads, they look as if they're tanning at the beach—but there are no piña coladas or warm sand here. Instead, these 18 men, wearing only swim trunks, are lying on cold, white snow in the mountains of Poland. And lying with them is the Iceman.

Wim Hof, a Dutch daredevil known as the "Iceman," who holds numerous world records for cold exposure, breathes deeply, leading the youths in an exercise. Over 4 days, he will train them to tolerate extreme cold. During his rigorous program, they will swim in near-freezing water every day and climb a snow-covered mountain in just shorts (**Figure 25.1**). Hof claims that exposure to the cold, combined with meditation and breathing exercises, will enable the men to fend off illness and disease.

Matthijs Kox stands to the side of the Iceman's trainees, taking notes. Kox, a researcher in intensive-care medicine at Radboud University Medical Center in the Netherlands, first met Hof in 2010, when the Iceman was visiting another laboratory at the university. A team in the physiology department was measuring Hof's ability to regulate his core temperature while standing in an ice bath (**Figure 25.2**). The scientists were surprised to find that rather than decreasing as expected, Hof's core temperature actually increased, and his metabolism climbed. While standing in the ice bath talking to his examiners, Hof mentioned that he could also consciously modulate his autonomic nervous system and immune system.

It was an unbelievable claim. The autonomic nervous system operates body functions that humans cannot voluntarily control, such as heartbeat and blood pressure. The **immune system**—a remarkable defense system that protects us against most infectious agents—has also long been known to be involuntary.

Figure 25.1

"Iceman" Wim Hof trains volunteers under extreme conditions

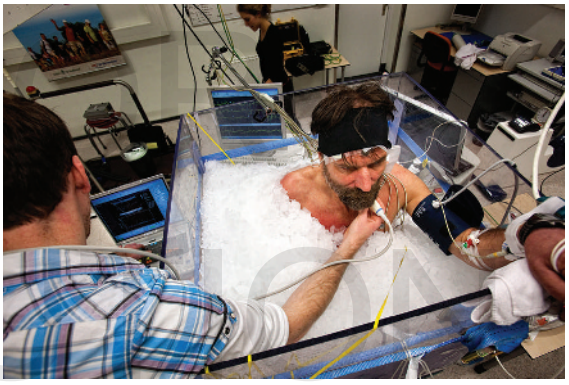


Figure 25.2

Hof's vital signs are monitored while he is immersed in ice

But Hof had a history of doing the unbelievable. He claimed the Guinness World Record for longest ice bath by staying immersed in ice for 1 hour, 52 minutes, and 42 seconds. He climbed part of Mount Everest wearing nothing but shorts. He ran a marathon through the snow at 4°F (20°C), again wearing only shorts.

Hof's testers in the physiology unit told him that a Radboud University professor named Peter Pickkers had a way to measure a person's immune response. So, Hof hoofed it to Pickkers's office, shook his hand, and said, "I can modulate my immune system. I heard you can measure it. Will you measure mine?"

WIM HOF

Wim Hof, better known as the "Iceman," is a Dutch celebrity who holds numerous world records for withstanding extreme cold.

Hormonal Changes

Pickkers was skeptical of Hof's claim, which had a whiff of pseudoscience. But Hof was an interesting character, so Pickkers went online and watched videos of his feats. "There were remarkable things I did not know of—things that, if you had asked me beforehand, I would have said, 'That's not possible. It's not possible to run half a marathon barefoot in the snow,'" says Pickkers. "But he did that."

Pickkers raised the idea of testing Hof to Kox, who was one of Pickkers's PhD students at the time, studying how the brain and immune system interact. Pickkers and Kox discussed the possibility at length, and they decided to give Hof a chance to document his claim. But they would do it while adhering strictly to the principles of the scientific process. "You can imagine some people wondered what we were doing with this guy," says Kox. "So we really focused on doing this in a very sound, precise manner, with no doubt about the scientific integrity of the project."

Hof claimed that the regimen for consciously controlling his immune system required three components: cold exposure, meditation, and breathing exercises. So, the team tested Hof's blood before and after an 80-minute full-body ice bath while Hof performed breathing and meditation exercises. Each time the scientists took blood, they went back to the lab and exposed the blood cells to molecules of endotoxin, a substance found in the cell walls of bacteria that activates an immune response in the human body. They wanted to see how Hof's immune cells in the blood would react to the endotoxin. After the regimen of ice, breathing, and meditation, Hof's cells had a far more subdued immune system response, showing very low levels of proteins associated with activation of the immune system, compared to similar cells before the regimen. The cause of that subdued immune response was unclear, but the researchers suspected that stress hormones played a role.

Hormones are signaling molecules produced by certain cells that tell other cells what to do under specific situations or at certain times in the life cycle of the individual. Hormones are produced by specialized secretory cells of the **endocrine system** (**Figure 25.3**).

Secretory cells are often organized into discrete organs called **endocrine glands**. Major endocrine glands are located throughout the human body. Unlike exocrine glands, such as tear ducts, endocrine glands do not have ducts or tubes that deliver secretions from the gland to the site of action. Instead, endocrine glands release hormones into body fluids such as blood, which

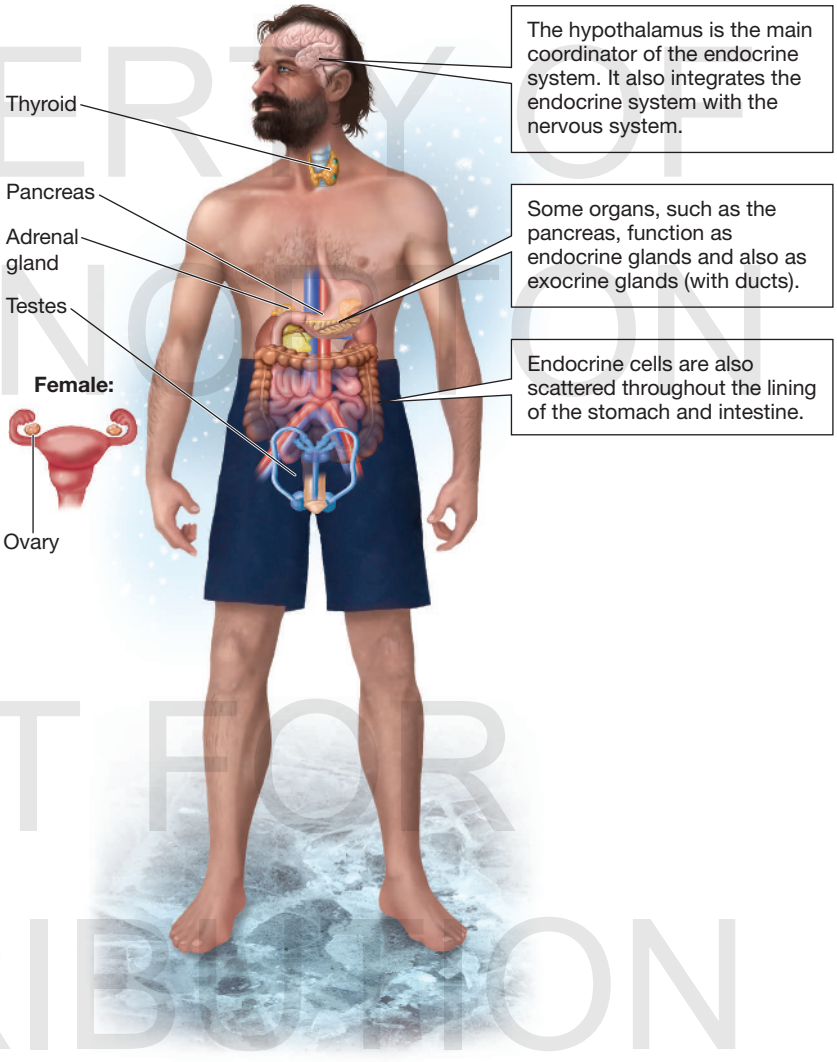


Figure 25.3

The endocrine system is composed of hormone-secreting cells

The endocrine system consists of cells organized into ductless glands, plus scattered endocrine cells embedded in other tissues or organs. These cells all release hormones directly into the circulatory system.

Q1: What organ coordinates the endocrine system?

Q2: How does an endocrine gland differ from an exocrine gland?

Q3: How do male and female endocrine systems differ?

enabled him to control his autonomic nervous and immune systems.

But Hof claimed that he was not an outlier, that he could teach his technique to anyone. "I'm sure everybody is able to do this," Hof told Pickkers. Pickkers challenged him to demonstrate that he could do this. For scientific validation, Hof needed to teach his method to a group of healthy volunteers so that Pickkers could then compare that group's immune responses to those of an untrained control group of volunteers. In this controlled way, Hof might produce stronger scientific evidence for his claim.

Innate Defenders

If Hof was right—if it really was possible to voluntarily control the immune system—the discovery would do more than change our understanding of the immune system; it would offer hope to people with autoimmune diseases, individuals in whom the immune system is overactive.

When healthy, the immune system protects animals from most infectious agents, called **pathogens**. Human pathogens include viruses, bacteria, and protists, as well as some fungi and multicellular animals such as parasitic worms. A well-known example is human immunodeficiency virus or HIV, the virus responsible for AIDS (see "What Makes HIV so Deadly?" on page 460).

Pathogens infect animals only if they can find a way into the body. An animal's first line of defense against pathogens is its **external defenses**, which reduce the likelihood that a harmful organism or virus will gain access to internal tissues. Linings that separate the "outside" from the "inside" of the body—the skin and the linings of the lungs, for example—act as a physical barrier to keep out most pathogens. Other external defenses include chemical agents (such as enzymes) and chemical environments (such as acidic conditions) that keep invaders from attaching to or growing on body surfaces (**Figure 25.7**).

Although external defenses do a good job of keeping out most pathogens, the body is still vulnerable. Mucous membranes, in the nasal cavity and other parts of the body, are a common point of entry for pathogens. Wounds, in the form of cuts, abrasions, and punctures, are common, and many pathogens will take advantage of breaks in the skin to gain entry to their hosts.

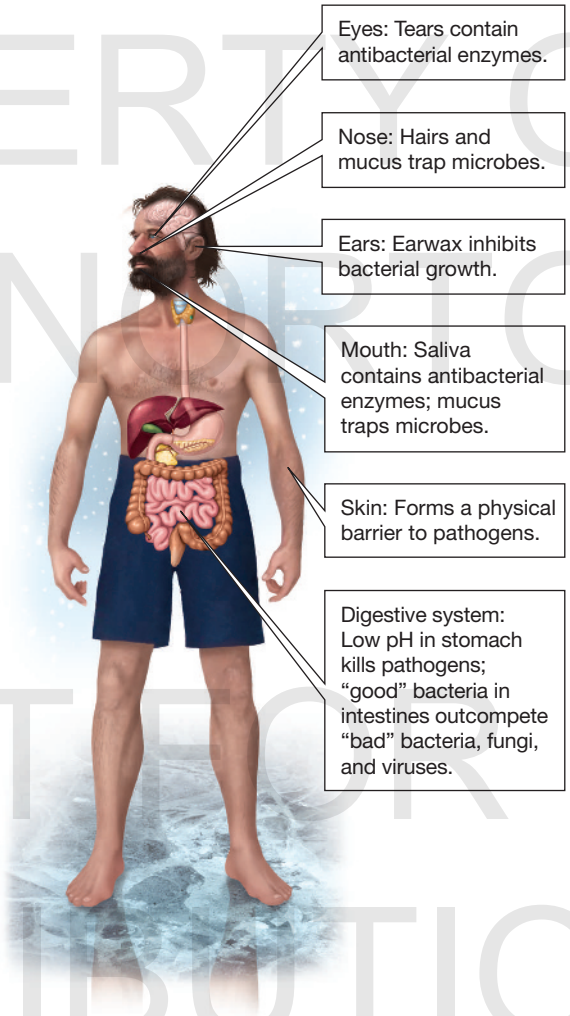


Figure 25.7

The immune system's first line of defense is to prevent the entry of pathogens

Our skin and the linings of our respiratory and digestive systems form physical and chemical barriers against pathogens.

Q1: **What is the main physical barrier that animals use to keep out pathogens?**

Q2: **Give an example of a chemical defense within the digestive system.**

Q3: **Explain why rubbing your eyes and nose during flu and cold season is not recommended.**

Once inside, pathogens confront a second line of defense: the cells and defensive proteins of the **innate immune system**. To mount an internal defense that kills, disables, or isolates invading

6 Link each term with the correct definition.

ADAPTIVE IMMUNE RESPONSE	1. The glands and specialized cells that produce hormones.
ENDOCRINE SYSTEM	2. The blood cells and molecules that provide a nonspecific response to pathogens.
INNATE IMMUNE RESPONSE	3. The region of the brain that coordinates the endocrine system and integrates it with the nervous system.
HYPOTHALAMUS	4. Long-term defense against pathogens centered in the lymphatic system.

Challenge Yourself

7 Identify whether each of the following is characteristic of either antibody-mediated (A) or cell-mediated (C) immunity.

___ a. The immune response relies on Y-shaped proteins to identify pathogens.

___ b. B cells produce proteins specific to a pathogen.

___ c. Lymphocytes that matured in the thymus identify infected cells.

___ d. Antigens on the pathogen allow it to be identified as nonself.

___ e. Infected cells are destroyed so that an infection cannot spread to other cells.

8 Select the correct terms:

The first time you are exposed to a pathogen, the (**primary / secondary**) immune response is activated. The (**primary / secondary**) immune response to a pathogen is stronger and more rapid. You acquire (**active / passive**) immunity to a pathogen when your own body creates the antibodies against that pathogen. (**Active / Passive**) immunity comes from the antibodies produced by another person, such as your mother when you were in utero or nursing. The immunity conferred by vaccines is an example of (**active / passive**) immunity.

9 Beginning with a perceived threat (for example, a spider), identify the correct order of events in the stress response by numbering them from 1 to 5.

___ a. Target cells amplify the hormonal signal to produce a response.

___ b. The liver breaks down glycogen to glucose, and the heart increases its rate and the force of its contractions.

___ c. Adrenaline reaches target cells in the liver and heart.

___ d. The hypothalamus signals the adrenal glands that a threat is present.

___ e. The adrenal glands release adrenaline into the bloodstream.

Try Something New

10 Wim Hof and his trainees had increased levels of the stress hormone adrenaline and decreased immune function during the experiments described in this chapter. How might these changes negatively affect the endocrine and immune systems over the long term?

11 Which of the following is *not* true of a B cell?

(a) It is a kind of lymphocyte.

(b) It is produced in the bone marrow.

(c) It matures in the thymus.

(d) It is part of the adaptive immune response.

(e) All of the above are true of B cells.

12 Increased body temperature (fever) is part of the body's innate immune response. Fever is uncomfortable and can be dangerous if very high. It is often treated with over-the-counter medicines like acetaminophen, ibuprofen, naproxen, or aspirin. What are possible negative effects of this treatment?

Leveling Up

13 **Life choices** While clotting is an important component of the innate immune response, it can also be dangerous. For example, a blood clot could block an artery to the heart or brain, leading to a heart attack or stroke. Aspirin reduces blood clotting by interfering with the body's production of a lipid called thromboxane A2. This lipid normally helps platelets clump together (see Figure 25.10), so aspirin, by inhibiting its production, reduces clotting and "thins the blood." Some doctors may prescribe a daily dose of aspirin for patients who are at risk of heart attack or stroke. Review the U.S. Preventive Services Task Force 2016 recommendations on daily aspirin therapy (https://www.uspreventiveservicestaskforce.org/Page/Document/RecommendationStatementFinal/aspirin-to-prevent-cardiovascular-disease-and-cancer), and then answer the following questions.

a. Do you fall into one of the categories for which daily aspirin therapy is recommended? If yes, which one? If no, is there an aspirin therapy category that you think you'll be in eventually?

b. How strong is the evidence supporting aspirin therapy in the category you identified in the previous question, if any? (See the "Grade" column in the task force recommendations.)

c. With this information in hand, do you plan to take aspirin daily at some point in your life?

d. Will you speak with your doctor before taking aspirin daily? Why or why not?

e. Do you know anyone who has had a heart attack or stroke? Do they take aspirin daily?