35 Control by the Endocrine and Nervous Systems

Chapter Outline

If you have a relative or a friend who has diabetes mellitus, you know someone with an endocrine disease. Insulin is one of many important hormones, the main chemical messengers found in the blood. Produced and released by endocrine glands, hormones travel through the blood and influence the activity of target cells—those cells that have the receptor proteins to bind hormones. The binding of the hormone and its receptor produces a biochemical change in the target cell, thus accomplishing the target cell's role as an effector in a homeostatic system. In this chapter, we will also review the nervous system as a signaling system from Chapter 34.

Big Idea 2 and **Big Idea 3** are central to understanding hormones and neural integration. The specific parts of the AP Biology curriculum covering **Big Idea 2:** Biological systems utilize free energy and molecular building blocks to grow, to reproduce, and to maintain dynamic homeostasis, include:

- **2.C.1**: Organisms use feedback mechanisms to maintain their internal environments and respond to external environmental changes.

The specific parts covering **Big Idea 3:** Living systems store, retrieve, transmit, and respond to information essential to life processes, include:

- **3.A.4**: The inheritance pattern of many traits cannot be explained by simple Mendelian genetics.
- **3.B.2**: A variety of intercellular and intracellular signal transmissions mediate gene expression.
- **3.D.2**: Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.
- **3.E.1**: Individuals can act on information and communicate it to others.

Chapter Review

Concept 35.1 *explains that neurons and endocrine cells communicate with other cells to carry out their functions of control and coordination. Most intercellular communication takes place by means of chemical signals that are released from a nerve cell (neuron) or an endocrine cell and travel to another cell, called the target cell. The signal molecules bind to receptors on the target cell, triggering it to respond. The responses can affect an animal's function, anatomy, and behavior. Muscle tissue, for example, is subject to both neuronal and endocrine system control. The two systems are specialized to carry out different types of control and coordination. The nervous system and neurons are involved when a fast response is needed, such as pulling a hand away from a hot stove. On the other hand, when a longer, slower response is needed, such as muscle-building and growth, the endocrine system takes on additional importance.*

1. Communication in the endocrine system is sometimes described as slow and broadcast signaling. Describe "slow" and "broadcast" features in the endocrine system.

2. Hormones can reach all of the cells in the body, but only some of the cells change activity in response. Describe the features of a given cell that determine its ability to respond to a particular hormone.

Concept 35.2 *states that hormones are chemicals released by endocrine glands into the blood. Hormones serve as messengers when they reach their receptor proteins on or in target cells. Only cells with the appropriate receptor proteins will be directly altered by the arrival of the hormone—all other (receptor-less) cells are non-target cells. Chemically, most hormones are amines, proteins, or steroids. Descriptions of two insect hormones are presented, reiterating the ancient origin of chemical signaling pathways in animals and plants.*

Receptor proteins are just as important as hormones. Cells that lack receptor proteins for hormone Q cannot show a direct response to hormone Q; it is as if Q were not even there. Receptor proteins are located either on the plasma membranes of target cells (especially true for the receptors of hormones that are proteins, e.g., insulin) or in the cytosol and nucleus of the target cells (especially true for lipid-soluble hormones, e.g., steroids). In both cases, the binding of the hormone to its receptor protein is the event that alters the biochemistry of the target cell, eliciting its "effector" responses for homeostasis.

3. Hormones can act on the cell that produces them (autocrine effect), neighboring cells (paracrine effect), and distant cells after passage in the blood (endocrine, or hormonal, effect). Discuss whether it is possible for a single molecule to work via all three effector routes.

4. Discuss the water solubility and lipid solubility of protein hormones and steroid hormones.

5. In humans, prolactin is a hormone that stimulates milk synthesis in the mammary glands, but in salmon, prolactin is a signal that mediates physiological changes needed for moving from saltwater to freshwater. Discuss how this particular hormone can have very different effects in different organisms.

6. The insect pictured here is the adult reproductive form of the genus *Rhodnius*. The juvenile form of these blood-sucking insects can live up to a week after being decapitated. Molting from the advanced juvenile stage to the adult form takes place seven days after a blood meal. However, when the juvenile is decapitated immediately after a blood meal, the headless juvenile does not show any apparent molting changes, even a full week later, but it is still alive. Explain what this result tells us about the source of a "molting hormone" in these animals.

7. Estrogens are a group of steroid hormones that stimulate growth in many of their target cells. Propose the reasons for testing whether or not a breast cancer tumor in a human mammary gland expresses the gene for the estrogen receptor.

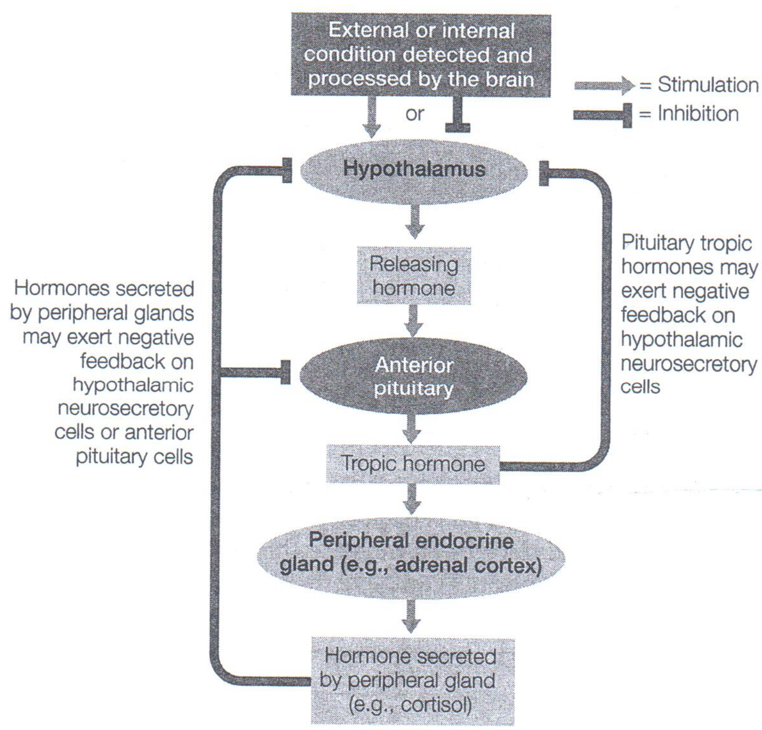
8. Epinephrine is a hormone secreted by adrenal glands when a person is exercising or is profoundly startled. This chemical has opposite effects in different parts of the circulation: it reduces blood flow in the gastro-intestinal tract, but it increases blood flow in large skeletal muscles. Discuss the means by which one signal (epinephrine) can have these two opposite effects (vasoconstriction and vasodilation).

9. Discuss the downregulation of insulin receptors, seen in patients with type II diabetes mellitus.

Concept 35.3 *describes the hypothalamus and the pituitary gland. Along with the hypothalamus in the brain, the pituitary gland plays a central role in orchestrating hormone secretion and allowing hormonal control mechanisms to function in homeostasis. In humans, the pituitary gland has two main parts: the anterior pituitary gland (APG), located near the front of the head; and the posterior pituitary gland (PPG), located closer to the back of the head. Despite their proximity to each other, the APG is made up of specialized epithelial cells arising first in the roof of the embryonic mouth, whereas the PPG is a down-growth from the embryonic brain. The APG and PPG both secrete protein hormones; those from the PPG are released by the nerve endings of neurons from the hypothalamus, and those from the APG are released after the APG cells are stimulated by releasing hormones secreted from the hypothalamus. You will not need to memorize most of the hormonal details in this chapter, but you should work to understand how classes of hormones function.*

10. Explain why the hormones secreted by the anterior pituitary gland are called *tropic* hormones.

11. The stress hormone axis is organized in the pattern shown in the diagram at the right. This axis includes a hypothalamic hormone (CRH) that stimulates secretion by the APG, an APG hormone (ACTH) that stimulates steroid synthesis (cortisol) in the adrenal glands, and adaptive responses, like glucose release from the liver and reduced immune system activity. Explain why the stress hormone axis includes a part that is in the brain. (*Hint*: Think about the many forms of stress in life.)



12. Cortisol has receptors in cells of the immune system and the liver. Cortisol receptors are also found in the hypothalamic and pituitary components of the stress hormone axis. Explain the roles of the hypothalamic and pituitary receptor proteins, referencing the concept of feedback.

Concept 35.4 *provides some examples of mammalian hormones. To analyze a hormone system, review the following:*

- *Source of the hormone*
- *Stimuli that elicit the secretion of the hormone*
- *Cellular location of the hormone's receptor proteins*
- *Link between the target cell response and homeostasis*

Remember that negative feedback requires receptor proteins, too.

13. Thyroid hormones boost metabolism when environmental conditions become more difficult, for example, during cold weather. Explain how boosted metabolism can aid an animal's survival as temperatures decline.

14. The condition called *goiter* often appears as a large swelling of the neck in the region of the thyroid gland. In hypothyroid goiter, the gland is greatly enlarged as it unsuccessfully attempts to make thyroid hormones. Thyroid hormones are normally secreted when the hypothalamus releases thyrotropin-releasing hormone, leading to increased secretion of thyroid-stimulating hormone from the pituitary gland. Address each of the following by circling TRUE or FALSE and then explaining your logic.

a. Persons with hypothyroid goiter have very high levels of thyroid hormones in their blood.
TRUE FALSE [*choose one, then explain*]

b. Persons with hypothyroid goiter have very high levels of thyroid-stimulating hormone.
TRUE FALSE [*choose one, then explain*]

c. Persons with hypothyroid goiter have very high levels of thyrotropin-releasing hormone.
TRUE FALSE [*choose one, then explain*]

15. Compare the role of androgens in the development of male reproductive systems with that in female reproductive systems.

16. Compare the operation of the hypothalamic–pituitary–gonadal hormone axis before and after puberty, limiting your discussion to male reproduction.

Concept 35.5 *provides an overview of the endocrine systems of insects and other arthropods, such as crayfish and crabs. For example, many insects have antidiuretic and diuretic hormones that control excretion of water by the insect organs that serve kidney functions. Diuretic hormones promote excretion of a high volume of water. Some of the blood-sucking insects secrete diuretic hormones immediately after a blood meal. These hormones promote rapid excretion of much of the water in the blood, thereby concentrating the nutritious part of the meal (the blood proteins) in the gut. The best-understood endocrine systems in insects control growth and development through the action of several hormones: prothoracicotropic hormone (PTTH), ecdysone, and juvenile hormone.*

17. Explain how juvenile hormone affects the maturation of insects.

18. Arthropods (insects and crustaceans) have exoskeletons that must be shed (ecdysis) to allow the animals to grow larger. Explain how an arthropod can shed its shell.

Science Practices & Inquiry

In the AP Biology Curriculum Framework, there are seven **Science Practices**. In this chapter we focus on **Science Practice 5**: The student can perform data analysis and evaluation of evidence. More specifically, we focus on **Practice 5.1**: The student can analyze data to identify patterns or relationships.

Question 19 asks you to analyze data that indicate how organisms exchange information in response to internal changes and external cues, and which can change behavior (**Learning Objective 3.40**).

19. The time courses of action for different hormones vary widely. Some hormones are released rapidly, establish their effects almost immediately, and are cleared from the bloodstream within minutes. Others are released slowly and remain in the blood for many hours or even days. One way of characterizing the time course of a hormone is to measure its half-life in the blood: the length of time it takes for the blood level of a given hormone to fall to half of the baseline (maximum) following its release (or injection).

The table at the right gives blood concentrations of thyroxine (T_4) following a 600-µg injection of T_4.

Time (hrs)	T_4 (mg /dL)
0	7.5
6	13.7
12	12.3
24	11.1
36	10.7
48	10.3
60	9.9
72	9.5
84	9.3
96	9.1

a. Plot these data on the grid provided.

b. Consider what you know about the functioning of T_4. Would you expect this hormone to have a short half-life or a long half-life? Explain your answer.

c. Use your graph to estimate the half-life of T_4 in the bloodstream. Give your answer to the nearest 0.1 hour.