Chapter 45: Hormones and the Endocrine System

1. What is a hormone?

In animals, hormones are secreted into the extracellular fluid, circulate in the hemolymph or blood, and communicate regulatory messages throughout the body.

2. Why does a hormone elicit a response only with target cells?

Each hormone has specific receptors in the body. Although a given hormone can reach all cells of the body, only some cells have receptors for that hormone. A hormone elicits a response only from specific target cells that have the matching receptor. Cells lacking a receptor for that particular hormone are unaffected.

3. Which of the body's two long-distance regulating systems involves chemical signals by hormones?

Chemical signaling by hormones is the function of the endocrine system, one of the two basic systems of communication and regulation throughout the body. Hormones secreted by endocrine cells regulate reproduction, development, energy metabolism, growth, and behavior.

4. What is the other major communication and control system?

The nervous system is a network of neurons, specialized cells that transmit signals along dedicated pathways. These signals in turn regulate neurons, muscle cells, and endocrine cells. Signaling by neurons can regulate the release of hormones.

5. Explain the difference between an endocrine gland and an exocrine gland and give an example of each.

Endocrine glands are endocrine cells grouped in ductless organs, such as the thyroid glands of the neck. While endocrine glands secrete hormones directly into the surrounding fluid, exocrine glands, such as salivary glands, have ducts that carry secreted substances onto body surfaces or into body cavities.

6. Compare the action of hormones, local regulators, neurotransmitters, and pheromones and give an example of each.

Local regulators such as cytokines act over short distances and reach their target cells solely by diffusion. Depending on the target cell, signaling by local regulators can be either paracrine (target cell is near the secreting cell) or autocrine (secreting cell targets itself). At synapses, neurons secrete molecules called neurotransmitters (such as acetylcholine) that diffuse a very short distance to bind to receptors on the target cells. In neuroendocrine signaling, specialized neurons called neurosecretory cells secrete molecules that diffuse from nerve cell endings into the bloodstream. These molecules (such as vasopressin), which travel through the bloodstream to target cells, are a class of hormone called neurohormones. Pheromones, chemicals that are released into the external environment, allow members of the same animal species to communicate with each other. For example, when a foraging ant discovers a new food source, it marks its path back to the nest with a pheromone.

7. Explain five different types of signals. ✐

In endocrine signaling, secreted molecules diffuse into the bloodstream and trigger responses in target cells anywhere in the body. In paracrine signaling, secreted molecules diffuse locally and trigger a response in neighboring cells. In autocrine signaling, secreted molecules diffuse locally and trigger a response in the cells that secrete them. In synaptic signaling, neurotransmitters diffuse across synapses and trigger responses in cells of target tissues (neurons, muscles, or glands). In neuroendocrine signaling, neurohormones diffuse into the bloodstream and trigger responses in target cells anywhere in the body.

8-9. Explain this difference between water-soluble and lipid-soluble hormones.

Water-soluble hormones are secreted by exocytosis, travel freely in the bloodstream, and bind to cell-surface signal receptors. Binding of such hormones to receptors induces changes in cytoplasmic molecules and sometimes alters gene transcription (synthesis of messenger RNA molecules). In contrast, lipid-soluble hormones diffuse out across the membranes of endocrine cells. Outside the cell, they bind to transport proteins that keep them soluble in the aqueous environment of the bloodstream. Upon leaving the bloodstream, they diffuse into target cells, bind to intracellular signal receptors, and trigger changes in gene transcription.

10. Discuss the two major cellular response pathways.

hormone type	*method of secretion*	*mode of travel in bloodstream*	*location of receptors*	*examples*
water-soluble	exocytosis	freely	cell surface	insulin
lipid-soluble	diffusion	in transport proteins	intracellular	steroids (e.g. cortisol)

11. What endocrine gland secretes epinephrine?

Adrenal glands secret epinephrine.

12. What are the two intracellular responses in the liver to epinephrine? How do they help the body deal with short-term stress?

When epinephrine reaches the liver, it binds to a G protein-coupled receptor in the plasma membrane of target cells. The binding of hormone to receptor triggers a cascade of events involving synthesis of cyclic AMP (cAMP) as a short-lived second messenger. Activation of protein kinase A by cAMP leads to activation of an enzyme required for glycogen breakdown and inactivation of an enzyme necessary for glycogen synthesis. The net result is that the liver releases glucose into the bloodstream.

13. Explain the signal transduction pathway for epinephrine.

Target cell recognition of epinephrine involves G protein-coupled receptors. Liver cells have a β-type epinephrine reactor that activates the enzyme protein kinase A, which in turn regulates enzymes in glycogen metabolism. In blood vessels supplying skeletal muscle, the same kinase activated by the same epinephrine receptor inactivates a muscle-specific enzyme. The result is smooth muscle relaxation and hence increased blood flow. In contrast, intestinal blood vessels have an α-type epinephrine receptor. Rather than activate protein kinase A, the α receptor triggers a distinct signaling pathway involving a different G protein and different enzymes. The result is smooth muscle contraction and restricted blood flow to the intestines.

14. Explain how the lipid-soluble hormone estradiol binds to intracellular receptors.

In female birds and frogs, estradiol, a form of estrogen, has a specific receptor in liver cells. Binding of estradiol to this receptor activates transcription of the gene for the protein vitellogenin. Following translation of the mRNA, vitellogenin is secreted and transported in the blood to the reproductive system.

15. Explain how one hormone can have several different effects.

Tissues vary in their response to epinephrine, for instance, because they vary in their receptors or signal transduction pathways.

16. Explain how the local regulator nitric oxide (NO) is affected by Viagra, a drug used to treat male erectile dysfunction.

The gas nitric oxide (NO) functions in the body as both a neurotransmitter and a local regulator. NO activates an enzyme that relaxes the smooth muscle cells surrounding endothelial cells in blood vessel walls, resulting in vasodilation, which improves blood flow to tissues. In human males, NO's ability to promote vasodilation enables sexual function by increasing blood flow to the penis, producing an erection. The drug Viagra (sildenafil citrate), a treatment for male erectile dysfunction, sustains an erection by prolonging activity of the NO response pathway.

17. Why do prostaglandins contribute to muscle contractions in females?

A group of local regulators called prostaglandins are modified fatty acids. In semen that reaches the reproductive tract of a female, prostaglandins stimulate the smooth muscles of the female's uterine wall to contract, helping sperm reach an egg. At the onset of childbirth, prostaglandin-secreting cells of the placenta cause the nearby muscles of the uterus to become more excitable, helping to induce labor.

18. What occurs in a negative feedback loop?

In a negative feedback loop, the response reduces the initial stimulus. By decreasing or abolishing hormone signaling, negative-feedback regulation prevents excessive pathway activity.

19. Compare a pair of antagonistic hormones.

hormone	*secreted by*	*action*
insulin	beta cells in pancreas	triggers uptake of glucose from the blood into body cells, decreasing blood glucose concentration
glucagon	alpha cells in pancreas	triggers release of glucose into the blood from body cells, increasing blood glucose concentration

20. Explain the control of blood glucose by insulin and glucagon.

Insulin lowers blood glucose levels by stimulating nearly all body cells outside the brain to take up glucose from the blood. Insulin also decreases blood glucose by slowing glycogen breakdown in the liver and inhibiting the conversion of glycerol (from fats) and amino acids to glucose. Glucagon influences blood glucose levels mainly through its effects on target cells in the liver. When the blood glucose level decreases to a level at or below the normal range, a primary effect of glucagon is to signal liver cells to increase glycogen hydrolysis, convert amino acids and glycerol to glucose, and release glucose into the bloodstream. The net result is a return of the blood glucose level to the normal range. Within the liver, glucagon and insulin regulate nutrient processing in ways that support glucose homeostasis.

21. What occurs in diabetes mellitus?

The disease diabetes mellitus is caused by a deficiency of insulin or a decreased response to insulin in target tissues. Blood glucose levels rise, but cells are unable to take up enough glucose to meet metabolic needs. Instead, fat becomes the main substrate for cellular respiration. In severe cases, acidic metabolites formed during fat breakdown accumulate in the blood, threatening life by lowering blood pH and depleting sodium and potassium ions from the body.

22. Distinguish between type 1 diabetes and type 2 diabetes.

Type 1 diabetes (insulin-dependent) is an autoimmune disorder in which the immune system destroys the beta cells of the pancreas. Type 1 diabetes, which usually appears during childhood, destroys the person's ability to produce insulin. Treatment consists of insulin, typically injected several times daily. Stem cell research may someday provide a cure for type 1 diabetes by generating replacement beta cells that restore insulin production by the pancreas. Type 2 diabetes (non-insulin-dependent) is characterized by a failure of target cells to respond normally to insulin. Insulin is produced, but target cells fail to take up glucose from the blood, and blood glucose levels remain elevated. Although heredity can play a role in type 2 diabetes, excess body weight and lack of exercise significantly increase the risk. This form of diabetes generally appears after age 40 and afflicts more than 90% of people with diabetes. Many can control their blood glucose levels with regular exercise and a healthy diet; some require medications.

23. Which type of diabetes is correlated with obesity?

The resistance to insulin signaling in type 2 diabetes is sometimes due to a genetic defect in the insulin receptor or the insulin response pathway. In many cases, however, events in target cells suppress activity of an otherwise functional response pathway. One source of this suppression appears to be inflammatory signals generated by the innate immune system. How obesity and inactivity relate to this suppression is being studied currently.