Hypothalamus and Pituitary Gland

The hypothalamus and the pituitary gland regulate the endocrine system.

James Hugh Murphy, "The Irish Giant".
Due to a hormonal imbalance, James Hugh Murphy (1842-1875) grew to 7 feet 3 inches tall.
Science Source.

Topics Covered in this Module
- Signaling Between the Hypothalamus and the Pituitary
- Regulation of Endocrine Signaling

Major Objectives of this Module
- Explain how the hypothalamus signals to the pituitary.
- Distinguish between tropic and non-tropic effects of hormones.
- Describe an example of an endocrine axis.
Signaling Between the Hypothalamus and the Pituitary

The endocrine system, which is responsible for maintaining homeostasis, includes endocrine glands and hormone-producing cells in non-endocrine organs such as the heart, liver, stomach, kidneys, and intestines (Figure 1). The hypothalamus is a gland of the endocrine system that provides a critical link between sensory input from the nervous system and physiological and behavioral output from the endocrine system. The pituitary allows the hypothalamus to communicate with other endocrine cells.

The hypothalamus is a master coordinator of hormone release.

The hypothalamus is a region of the brain located between the thalamus and the brainstem. Along with the thalamus, pineal gland, and posterior pituitary, the hypothalamus is derived from an embryonic structure known as the diencephalon (Figure 2). The hypothalamus is present in the brains of all vertebrates; the human hypothalamus is about the size of an almond. The hypothalamus coordinates a wide range of functions in the body, controlling hormone release, body temperature, thirst, hunger, circadian rhythms, emotional responses, and sexual behavior and reproduction.
The hypothalamus produces releasing hormones when stimulated by its own sensory receptors or by neural signals from elsewhere in the brain. Releasing hormones are so named because they induce the release of specific hormones from the anterior pituitary. An example of a releasing hormone is growth-hormone-releasing hormone (GHRH), which is produced by neuroendocrine cells in the hypothalamus. GHRH travels to the anterior pituitary, where it induces the release of growth hormone (GH), a polypeptide hormone that stimulates growth, cell reproduction, and regeneration of cells and tissues. The hypothalamus also releases inhibiting hormones — hormones that inhibit the anterior pituitary from releasing other hormones. Two inhibiting hormones produced by the hypothalamus are somatostatin, which inhibits the secretion of growth hormone by the anterior pituitary, and dopamine, which inhibits prolactin secretion.

### Table 1: Hormones produced in the hypothalamus

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyrotropin-releasing hormone (TRH)</td>
<td>Stimulates release of thyroid-stimulating hormone (TSH) and prolactin from anterior pituitary</td>
</tr>
<tr>
<td>Growth-hormone-releasing hormone (GHRH)</td>
<td>Stimulates release of growth hormone (GH) from anterior pituitary</td>
</tr>
<tr>
<td>Gonadotropin-releasing hormone (GnRH)</td>
<td>Stimulates release of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) from anterior pituitary</td>
</tr>
<tr>
<td>Corticotropin-releasing hormone (CRH)</td>
<td>Stimulates release of adrenocorticotropic hormone (ACTH) from anterior pituitary</td>
</tr>
<tr>
<td>Somatostatin</td>
<td>Inhibits release of GH from anterior pituitary</td>
</tr>
<tr>
<td>Dopamine</td>
<td>Inhibits release of prolactin from anterior pituitary; functions as a neurotransmitter in other situations</td>
</tr>
</tbody>
</table>

Table 1 summarizes the hormones produced by the hypothalamus and their effects.

### Test Yourself

What physical characteristics would be expected in a person with an abnormally low production of GHRH?

Submit

The pituitary gland is divided into two structurally and functionally distinct regions. The median eminence is the lower portion of the hypothalamus. The pituitary gland is a pea-sized structure that extends from the median eminence. The pituitary is divided into two lobes — the posterior pituitary and the anterior pituitary. The two lobes of the pituitary differ in the hormones they produce and the types of cells they contain. The posterior pituitary is an extension of the hypothalamus that contains axons of neurosecretory cells originating in the hypothalamus. These neurosecretory cells produce the hormones oxytocin and vasopressin (also known as antidiuretic hormone, or ADH). Both hormones are released from the posterior pituitary into the bloodstream (Figure 3). The effects of these hormones will be detailed later in this module.
The posterior pituitary is an extension of the hypothalamus. Neurosecretory cells in the hypothalamus synthesize posterior pituitary hormones; these neurosecretory cells have axons extending into the posterior pituitary, and the hormones made by the cells are secreted from the posterior pituitary.

The anterior pituitary, which is a separate organ from the hypothalamus and anterior pituitary, secretes six major hormones that are transported throughout the body via the bloodstream. Hormone production is regulated by the hypothalamus, which secretes releasing and inhibiting hormones into a capillary bed near the median eminence. The hypothalamic hormones flow through portal blood vessels to another capillary bed at the anterior pituitary (Figure 4).
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Figure 4: The anterior pituitary.
The hypothalamus secretes hormones into a capillary bed that is linked to capillary beds of the anterior pituitary by portal blood vessels.

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Table 2 summarizes the hormones produced by the anterior pituitary, their effects in the body, and the hypothalamic hormones that regulate their secretion. The effects of the anterior pituitary hormones are described in greater detail in a separate module.

<table>
<thead>
<tr>
<th>Anterior pituitary hormone</th>
<th>Effect</th>
<th>Regulatory hypothalamic hormone(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thyroid-stimulating hormone (TSH)</td>
<td>Stimulates the thyroid gland to produce thyroxine (T₄) and triiodothyronine (T₃), which enhance metabolism</td>
<td>Thyrotropin-releasing hormone (TRH) (stimulates)</td>
</tr>
<tr>
<td>Adrenocorticotrophic hormone (ACTH)</td>
<td>Stimulates production and release of corticosteroids (and mineralocorticoids and androgens, weakly) from the adrenal cortex</td>
<td>Corticotropin-releasing hormone (CRH) (stimulates)</td>
</tr>
<tr>
<td>Follicle-stimulating hormone (FSH)</td>
<td>In women, stimulates the growth and development of the egg cell and ovarian follicle, which produces estrogen; in men, stimulates activity of Sertoli cells, which support sperm development</td>
<td>Gonadotropin-releasing hormone (GnRH) (stimulates)</td>
</tr>
<tr>
<td>Luteinizing hormone (LH)</td>
<td>In women, triggers ovulation and formation of the corpus luteum, which produces progesterone; in men, stimulates testosterone production by Leydig cells in the testes</td>
<td>Gonadotropin-releasing hormone (GnRH) (stimulates)</td>
</tr>
<tr>
<td>Growth hormone (GH)</td>
<td>Stimulates cell growth and division in a wide range of tissues</td>
<td>Growth-hormone-releasing hormone (GHRH) (stimulates); somatostatin (inhibits)</td>
</tr>
<tr>
<td>Prolactin (PRL)</td>
<td>In lactating women, stimulates the production of milk in mammary glands</td>
<td>TRH</td>
</tr>
</tbody>
</table>

Table 2: Summary of anterior pituitary hormones and their effects.

http://www.nature.com/principles/ebooks/principles-of-biology-104015/29145746/1
Prolactin (PRL) the mammary glands; in both sexes, and in some non-mammalian animals, may contribute to parenting behaviors (stimulates); dopamine (inhibits)

Table 2: Major hormones produced in the anterior pituitary.

IN THIS MODULE

- Signaling Between the Hypothalamus and the Pituitary
- Regulation of Endocrine Signaling
- Summary
- Test Your Knowledge

WHY DOES THIS TOPIC MATTER?

Cancer: What's Old Is New Again
Is cancer ancient, or is it largely a product of modern times? Can cutting-edge research lead to prevention and treatment strategies that could make cancer obsolete?

PRIMARY LITERATURE

How can nematodes help reduce obesity in humans?
A whole-organism screen identifies new regulators of fat storage.
Regulation of Endocrine Signaling

A common theme of the endocrine system is the regulation of hormone secretion by other hormones. A hormone can be classified into two general categories based on the tissues on which it acts. Tropic hormones are hormones that act on endocrine cells to stimulate the production of other hormones. By contrast, non-tropic hormones have a direct effect on their target cells. For example, thyroid-stimulating hormone (TSH) is a tropic hormone because it stimulates the release of the thyroid hormones triiodothyronine (T<sub>3</sub>) and thyroxine (T<sub>4</sub>) from the thyroid gland. Some hormones, such as growth hormone (GH), exhibit both tropic and non-tropic effects. As a non-tropic hormone, GH directly stimulates cell growth and division in a wide range of cells. In addition, as a tropic hormone, GH stimulates the liver to produce insulin-like growth factors (IGFs), which are secreted into the blood and promote bone and cartilage growth.

Finally, two types of feedback loops are essential to endocrine function. In negative feedback loops, a physiological change initiates responses that tend to mitigate or oppose that change. In positive feedback loops, the stimulus initiates responses that amplify, prolong, or intensify the initial stimulus. Feedback loops between the hypothalamus, pituitary, and endocrine glands appear in many forms of endocrine regulation.

For example, a negative feedback loop between the hypothalamus, pituitary and endocrine glands regulates body temperature. A drop in body temperature stimulates release thyroid-releasing hormone (TRH) from the hypothalamus. TRH stimulates the release of TSH from the anterior pituitary, which in turn stimulates the release of T<sub>3</sub> and T<sub>4</sub> hormones from the thyroid gland. T<sub>3</sub> and T<sub>4</sub> increase metabolism, which raises body temperature. When body temperature is sufficiently high, TSH production stops, and secretion of the other hormones in this feedback loop decreases as a result. The rate of metabolism decreases, which lowers body temperature.

Labor is controlled by a positive feedback loop involving the hypothalamus: the baby's head pushes against the stretch receptors in the cervix. The stretch receptors send a neural signal to the hypothalamus that stimulates oxytocin secretion from the posterior pituitary. Oxytocin stimulates contractions, which increase the stimulation of stretch receptors. The cycle continues until the baby is born.

Test Yourself

Are the releasing hormones produced by the hypothalamus tropic or non-tropic hormones?

Neural signals directly stimulate the release of some hormones.
Hormones are released in response to stimuli from inside or outside the body. In both cases, sensory cells of the nervous system receive the stimulus and send neural signals to the brain. The brain then relays these signals to the hypothalamus, which in turn regulates hormone secretion through the pituitary gland.

Two hormones are produced in the hypothalamus and released from the posterior pituitary in response to signaling from the hypothalamus or elsewhere in the brain (Figure 4). Oxytocin, which is released in response to pressure on the cervix during labor, stimulates uterine contraction during childbirth. In addition, oxytocin promotes the release of milk from the mammary glands in response to infant suckling. Finally, the release of oxytocin may be involved in certain social behaviors such as maternal care, pair bonding, and monogamy. In response to increased blood osmolality sensed by cells in the hypothalamus, or low blood volume sensed by pressure receptors in the heart and major blood vessels, the posterior pituitary releases vasopressin. Vasopressin increases the reabsorption of water by the kidney, thus reducing the amount of water excreted in the urine. A diuretic is something that increases urine production, and vasopressin opposes this effect. An important consequence of increased water reabsorption is an increase in blood volume, which results in increased blood pressure. Vasopressin also plays an important role in social behavior, and evidence suggests that it is involved in maternal bonding.

Figure 5: Hormones secreted from the posterior pituitary originate in the hypothalamus.
In response to signals from the nervous system, neurosecretory cells in the hypothalamus produce vasopressin (also known as antidiuretic hormone or ADH) and oxytocin. The axons of these cells extend into the posterior pituitary, where these hormones are released into the bloodstream.
Another example of neural regulation of hormonal signaling involves the response to acute stress, also known as the "fight-or-flight" response. During a stressful event, such as the moment when a driver must swerve to avoid a traffic accident, visual, auditory, and tactile stimuli are integrated in the fear center of the brain, which sends a neural signal to the hypothalamus. In response, the hypothalamus sends a neural signal through the spinal cord to the inner part of the adrenal gland, called the adrenal medulla, which synthesizes the hormones epinephrine and norepinephrine. These hormones produce the familiar "adrenaline rush" by rapidly increasing the availability of glucose in the blood, providing a source of energy for the muscles and nervous system to respond to the stressful situation.

An axis of signaling between the hypothalamus, pituitary, and an endocrine gland regulates the secretion of some hormones.

An endocrine axis is a group of endocrine glands that signal to one another in sequential order. In an endocrine axis, the hypothalamus secretes releasing hormones that induce the release of tropic hormones from the anterior pituitary. The tropic hormones, in turn, stimulate hormone release from a target endocrine gland, which secretes a third hormone to carry out the physiological effect. Endocrine axes are regulated by feedback systems.

An example of an endocrine axis regulated by negative feedback is the hypothalamic-pituitary-thyroid axis (HPT axis), which regulates thyroid hormone production. A drop in metabolic rate causes an increase in thyroid hormone production, which increases the metabolic rate. (An increase in metabolic rate has the opposite effect — that is, it results in a decrease in thyroid hormone production.) Another example of an axis is the one that regulates cortisol levels in the body; this axis is known as the hypothalamic-pituitary-adrenal (HPA) axis.

The hypothalamic-pituitary-gonadal axis (HPG axis) controls sperm production in males and the ovarian cycle in females. In both males and females, gonadotropin-releasing hormone (GnRH) from the hypothalamus stimulates the anterior pituitary to release gonadotropins, hormones that stimulate the gonads — the ovaries in females and the testes in males. Two gonadotropins are produced in humans, FSH and LH. In males, FSH promotes growth of Sertoli cells, which nourish sperm cells, and LH stimulates testosterone production. In a negative feedback loop, testosterone inhibits LH production by the anterior pituitary and GnRH production by the hypothalamus. Sertoli cells also produce a hormone that inhibits FSH production.

The ovarian cycle in females is alternately regulated by negative and positive feedback loops. In the ovaries, FSH and LH stimulate secretion of the sex steroid hormones estrogen and progesterone. Low levels of estrogen and progesterone that occur early in the menstrual cycle inhibit GnRH secretion from the hypothalamus and FSH and LH secretion from the anterior pituitary, resulting in a negative feedback loop. Although low estrogen levels inhibit GnRH production, high estrogen levels have the opposite effect; they stimulate GnRH production. As the menstrual cycle progresses, estrogen production gradually increases. High levels of estrogen have a stimulatory effect on GnRH production, which results in a positive feedback loop. LH and FSH levels surge, resulting in ovulation. Once ovulation occurs, estrogen levels drop, and stimulation of LH and FSH production ceases.

Do the same hormones always produce the same effects on target glands?

Test Yourself
drugs are administered to block the production of testosterone. The female contraceptive Depo-Provera, which contains a progesterone derivative called depot-medroxyprogesterone acetate (DMPA), can be used for chemical castration. Depo-Provera is typically administered as an injection every 3 months, which facilitates compliance. Androcur (cyproterone acetate) is another progesterone-like drug used for chemical castration. Lupron (Lupron), which blocks GnRH receptors, thereby decreasing LH and FSH production, can also be used in chemical castration. Androcur and Lupron are used to treat prostate cancer because testosterone drives the growth of some prostate cancer cells.

Reducing testosterone levels in men lowers the frequency and intensity of sexual thoughts and suppresses erections and ejaculations, and, unlike surgical castration, chemical castration is reversible. Thus, proponents argue that chemical castration is an effective and relatively humane way of managing individuals considered a threat to children and women without resorting to surgical castration or life imprisonment. However, testosterone-reducing drugs have a number of side effects in men, including weight gain, fatigue, loss of body hair, gynecomastia (abnormal breast enlargement in men), and increased risk for osteoporosis. Many opponents of chemical castration believe that coerced administration of any drug, especially one with so many side effects, is inhumane. Other detractors believe that most sex offenders are motivated by violent urges rather than overactive sex drives. As a result, reducing testosterone levels by chemical castration may not address the underlying motivation for committing sex crimes.

Some hormones are secreted from endocrine tissues within non-endocrine organs.

In addition to the major endocrine glands directly controlled by the hypothalamus and anterior pituitary, there are also a number of tissues within non-endocrine organs that secrete hormones and thus qualify as endocrine tissues. The pancreas is one such example of a non-endocrine organ with endocrine tissues. Most pancreatic tissue is composed of exocrine cells, which secrete digestive enzymes and bicarbonate ion into the digestive tract. However, interspersed among the exocrine cells are clusters of cells known as the islets of Langerhans, which secrete the hormones insulin and glucagon (and small quantities of somatostatin and several minor hormones). Insulin, which reduces blood glucose, and glucagon, which increases blood glucose, are essential to the homeostasis of glucose levels in the body. Loss of the islets of Langerhans results in type 1 diabetes.

The kidney also contains endocrine tissues. In response to reduced blood pressure, specialized cells in the kidney activate the hormone angiotensin II, which increases blood pressure and stimulates aldosterone release from the adrenal cortex. Aldosterone acts on the kidney to increase water and sodium ion reabsorption, which also tends to increase blood pressure. If blood pressure or volume increases too much, however, endocrine cells in the atria of the heart respond to the increased stretch of the atria by secreting atrial natriuretic peptide (ANP), which inhibits aldosterone production and promotes the excretion of excess sodium ions and water in the urine. Finally, endocrine cells in the digestive system and adipose tissue secrete a number of hormones that regulate hunger, satiety (fullness), and digestion rate in response to stretching of the stomach muscle and the presence of specific nutrient molecules in ingested food.
Summary

OBJECTIVE Explain how the hypothalamus signals to the pituitary.

The hypothalamus communicates to the anterior pituitary using a series of releasing and inhibiting hormones. The hormones are released into a capillary bed near the median eminence of the hypothalamus and pass through the portal blood vessels to a capillary bed at the anterior pituitary. There, the hypothalamic hormones influence the secretion of hormones by the anterior pituitary. The hypothalamus also produces hormones that are transported through the axons of neurosecretory cells to the posterior pituitary, where they are released.

OBJECTIVE Distinguish between tropic and non-tropic effects of hormones.

Tropic hormones are hormones that induce other endocrine glands to release hormones. Examples of tropic hormones include the hypothalamic releasing hormones (which act on the anterior pituitary), TSH (which acts on the thyroid), and FSH/LH (which act on the gonads). Non-tropic hormones are hormones that act directly on target cells to produce physiological effects. Examples include the thyroid hormones (which stimulate metabolism in a wide range of cells) and ADH (which acts directly in the kidney). Some hormones, such as growth hormone, exert both tropic and non-tropic effects depending on the target tissue.

OBJECTIVE Describe an example of an endocrine axis.

In an endocrine axis, release of hormones from a series of endocrine glands is regulated by feedback loops. Hormones secreted by the thyroid, adrenal cortex, and gonads are regulated by the HPT, HPA, and HPG axes, respectively. All three of these axes exhibit negative feedback in their regulation; in addition, the HPG axis exhibits positive feedback during the ovulation phase of the menstrual cycle in females.

Key Terms

- **adrenal cortex**: The outer layer of the adrenal gland; produces cortisol, aldosterone, and a small quantity of sex hormones; biologically distinct from the adrenal medulla and produces different hormones.

- **adrenal medulla**: The inner layer of the adrenal gland; produces epinephrine and norepinephrine; biologically distinct from the adrenal cortex and produces different hormones.

- **anterior pituitary**: The anterior portion of the pituitary gland, which secretes growth hormone, TSH, LH, FSH, ACTH, and prolactin.

- **antidiuretic hormone (ADH)**: Also known as vasopressin; a peptide hormone produced in the hypothalamus and released from the posterior pituitary that increases the water permeability of the transport epithelial cells of the distal convoluted tubules and collecting ducts in the kidney; also involved in maternal bonding.

- **endocrine axis**: A sequence of endocrine glands and the hormones they secrete; consists of a hypothalamic releasing hormone that controls the secretion of a tropic hormone produced by the anterior pituitary, which in turn regulates the hormone(s) secreted by a target endocrine gland.

- **gonad**: An organ that produces gametes and sex steroid hormones; the male gonads are the testes, and the female gonads are the ovaries.

- **gonadotropin**: Any of several peptide hormones that target the gonads; examples include follicle-stimulating hormone (FSH), luteinizing hormone (LH), and human chorionic gonadotropin (hCG).

- **hypothalamus**: A region of the brain below the thalamus in humans important for maintaining homeostasis in many organ systems and serving as a link between the nervous system and endocrine system.

- **inhibiting hormone**: A hormone produced by the hypothalamus that inhibits release of hormones from the anterior pituitary.

- **median eminence**: The portion of the hypothalamus immediately adjacent to the pituitary gland; location at which the hypothalamic releasing hormones are secreted before entering the portal blood vessels.

- **negative feedback loop**: A process in which a physiological change initiates responses that tend to mitigate or oppose that change.

- **non-tropic hormone**: A hormone that directly produces a response from cells of the body.

- **parathyroid gland**: Any of four endocrine glands on the posterior surface of the thyroid gland that secrete parathyroid hormone (PTH) in response to low blood calcium levels.
pineal gland
An endocrine gland located deep in the brain between the cerebral hemispheres; secretes melatonin, which regulates sleep patterns and circadian rhythm.

portal blood vessels
Blood vessels that connect one capillary bed to another without first going through the heart; two major networks of portal vessels join capillaries of the intestines and liver and capillaries of the hypothalamus and anterior pituitary.

positive feedback loop
A stimulus initiates responses that amplify, prolong, or intensify the initial stimulus.

posterior pituitary
The posterior portion of the pituitary gland, which releases oxytocin and vasopressin (ADH) upon hypothalamic stimulation.

prolactin
A peptide hormone produced in the anterior pituitary that stimulates the production of milk in the mammary glands of lactating mammals; may also be involved in parental behaviors in males and non-mammalian species.

releasing hormone
Any of several hormones produced by the hypothalamus that stimulate the release of specific hormones from the anterior pituitary; examples include corticotropin-releasing hormone (CRH, which induces ACTH secretion) and gonadotropin-releasing hormone (GnRH, which induces FSH and LH secretion).

tropic hormone
Any hormone that stimulates the production of hormones in another endocrine gland; examples include the hypothalamic releasing hormones (which stimulate the anterior pituitary) and thyroid-stimulating hormone (which stimulates the thyroid).

vasopressin
Also known as antidiuretic hormone (ADH); a peptide hormone produced in the hypothalamus and released from the posterior pituitary that increases the water permeability of the transport epithelial cells in the distal convoluted tubules and collecting ducts of the kidney; also involved in maternal bonding.

IN THIS MODULE
► Signaling Between the Hypothalamus and the Pituitary
► Regulation of Endocrine Signaling
► Summary
► Test Your Knowledge

WHY DOES THIS TOPIC MATTER?
Cancer: What's Old Is New Again
Is cancer ancient, or is it largely a product of modern times? Can cutting-edge research lead to prevention and treatment strategies that could make cancer obsolete?

PRIMARY LITERATURE
How can nematodes help reduce obesity in humans?
A whole-organism screen identifies new regulators of fat storage.
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Test Your Knowledge

1. Which of the following is true of the hormone FSH?
   - FSH secretion is stimulated by CRH from the hypothalamus.
   - FSH stimulates production of testosterone in males and estrogen in females.
   - FSH stimulates the development of the egg and sperm cells.
   - FSH is stimulated by the hypothalamic releasing hormone GHRH.
   - In females, FSH and LH production are regulated by a negative feedback loop.

2. Which of the following hormones is a non-tropic hormone?
   - GnRH
   - FSH
   - TSH
   - thyroid hormone
   - ACTH

3. After vigorous exercise, a person becomes dehydrated. Which hormone would the body begin to produce as a result of this condition?
   - growth-hormone-releasing hormone
   - prolactin
   - gonadotropin-releasing hormone
   - ADH
   - oxytocin

4. Hormones travel directly through neurosecretory cells between which pair of endocrine glands?
   - hypothalamus and thyroid
   - thyroid and posterior pituitary
   - anterior pituitary and posterior pituitary
   - hypothalamus and posterior pituitary
   - hypothalamus and anterior pituitary

5. Which of the following statements about releasing hormones is true?
   - Releasing hormones can be produced by any endocrine tissue.
   - Releasing hormones are primarily produced by the hypothalamus.
   - Releasing hormones are produced by the hypothalamus and anterior pituitary.
   - Releasing hormones are produced by the hypothalamus and posterior pituitary.
   - Releasing hormones are produced by the anterior and posterior pituitary.

6. Which of the following correctly describes the function and target tissue of luteinizing hormone (LH)?
   - stimulates GnRH secretion in the hypothalamus
   - stimulates FSH secretion in the anterior pituitary
   - stimulates sex steroid secretion in the gonads
   - stimulates ADH release from the posterior pituitary
   - stimulates GnRH secretion in the hypothalamus

7. Abnormal hormone secretion by which of the following glands was most likely responsible for the exaggerated height exhibited by Charles Byrne, the so-called “Irish Giant”?
   - testes
   - anterior pituitary
   - adrenal medulla
   - posterior pituitary
   - adrenal cortex

8. Which of the following statements about chemical castration is true?
   - Chemical castration can be accomplished by administration of a progesterone-like drug that causes a decrease in testosterone production.
   - Chemical castration can be accomplished by administration of a progesterone-like drug to interrupt the action of growth hormone.
   - Chemical castration is irreversible.
   - Administration of a progesterone-like drug causes an exaggeration of male secondary sex characteristics.
Chemical castration has no side effects.