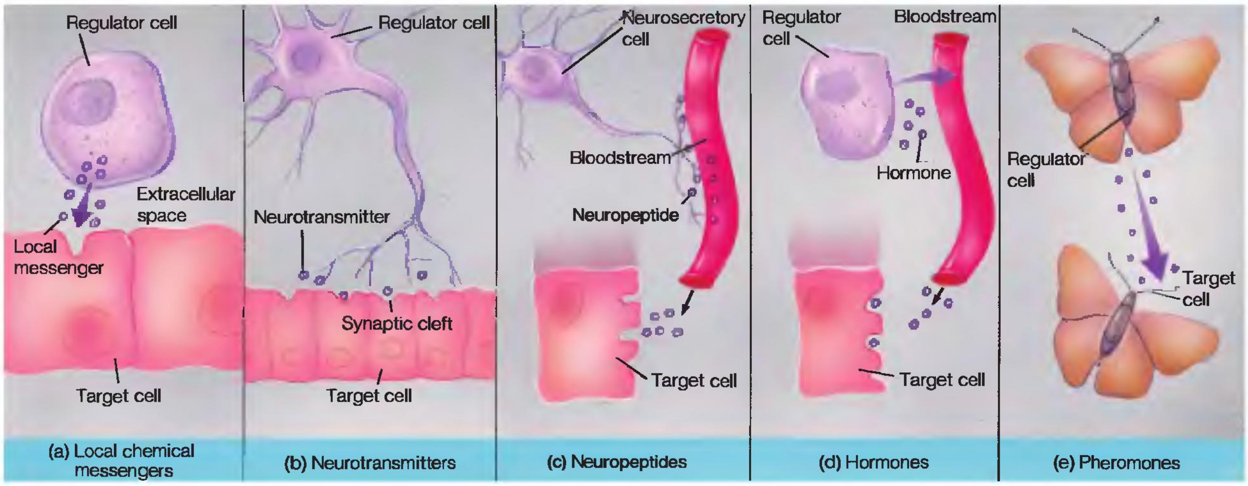

FIGURE 25.1

Chemical Messengers: Targets and Transport. *(a)* Short-distance local messengers act on an adjacent cell. *(b)* Individual nerve cells secrete neurotransmitters that cross the synaptic cleft to act on target cells. *(c)* Individual nerve cells can also secrete neuropeptides (neurohormones) that travel some distance in the bloodstream to reach a target cell. *(d)* Regulatory cells, usually in an endocrine gland, secrete hormones, which enter the bloodstream and travel to target cells. *(e)* Regulatory cells in exocrine glands secrete pheromones. They leave the body and stimulate target cells in another animal.

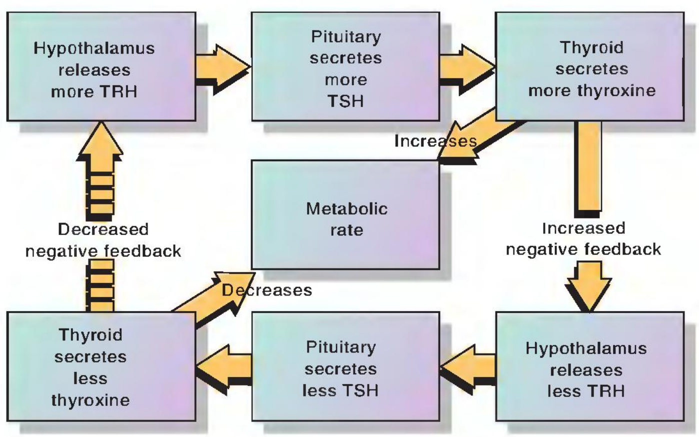

FIGURE 25.2

Hormonal Feedback. Negative feedback system that helps control metabolic rate in a vertebrate such as a dog. (TRH = thyrotropin-releasing hormone; TSH = thyroid-stimulating hormone.)

maintain homeostasis. For example, suppose that the rate of chemical activity (metabolic rate) in the body cells of a dog slows (figure 25.2). The hypothalamus responds to this slow rate by releasing more thyrotropin-releasing hormone (TRH), which causes the pituitary gland to secrete more thyrotropin, or thyroid-stimulating hormone (TSH). This hormone, in turn, causes the thyroid gland to secrete a hormone called thyroxine. Thyroxine increases the metabolic rate, restoring homeostasis. Conversely, if the metabolic rate speeds up, the hypothalamus releases less TRH, the pituitary secretes less TSH, the thyroid secretes less thyroxine, and the metabolic rate decreases once again, restoring homeostasis.

MECHANISMS OF HORMONE ACTION

Hormones modify the biochemical activity of a target cell or tissue. Two basic mechanisms are involved. The first, the fixed-membrane-receptor mechanism, applies to hormones that are proteins or amines. Because they are water-soluble and cannot diffuse across the plasma membrane, these hormones initiate their response by means of specialized receptors on the plasma membrane of the target cell. The second, the mobile-receptor mechanism, applies to steroid hormones. These hormones are lipid-soluble

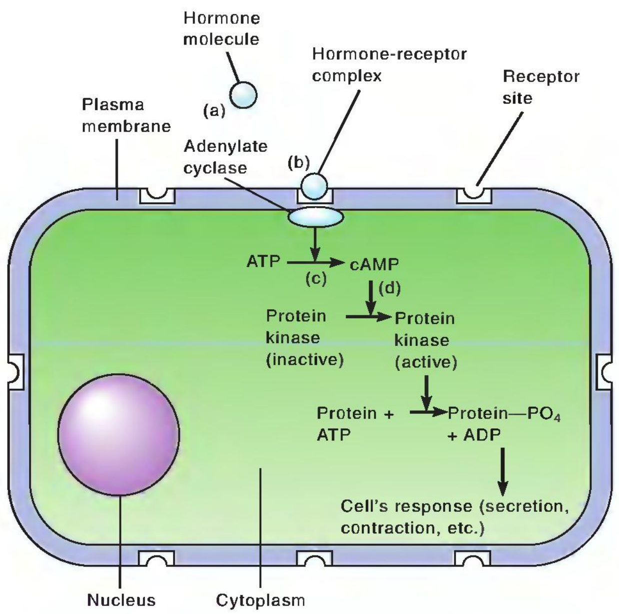

FIGURE 25.3

Steps of the Fixed-Membrane-Receptor Mechanism of Hormonal Action. *(a)* A protein hormone molecule (such as epinephrine) diffuses from the blood to a target cell. *(b)* The binding of the hormone to a specific plasma membrane receptor activates adenylate cyclase (a membrane-bound enzyme system). *(c)* This enzyme system catalyzes cyclic AMP formation (the second messenger) inside the cell. *(d)* Cyclic AMP (cAMP) diffuses throughout the cytoplasm and activates an enzyme called protein kinase, which then phosphorylates specific proteins in the cell, thereby triggering the biochemical reaction, leading ultimately to the cell's response.

and diffuse easily into the cytoplasm, where they initiate their response by binding to cytoplasmic receptors.

FIXED-MEMBRANE-RECEPTOR MECHANISM

With the fixed-membrane-receptor mechanism, an endocrine cell secretes a water-soluble hormone that circulates through the blood stream (figure 25.3*a*). At the cells of the target organ, the hormone acts as a "first or extracellular messenger," binding to a specific receptor site for that hormone on the plasma membrane (figure 25.3*b*). The hormone-receptor complex activates the enzyme adenylate cyclase in the membrane (figure 25.3*c*). The activated enzyme converts ATP into a nucleotide called cyclic AMP, which becomes the "second (or intracellular) messenger." Cyclic AMP diffuses throughout the cytoplasm and activates an enzyme called protein kinase, which causes the cell to respond with its distinctive physiological activity (figure 25.3*d*). After inducing the target cell to perform its specific function, the enzyme phosphodiesterase inactivates cyclic AMP. In the meantime, the receptor on the plasma membrane loses the first messenger and now becomes available for a new reaction.

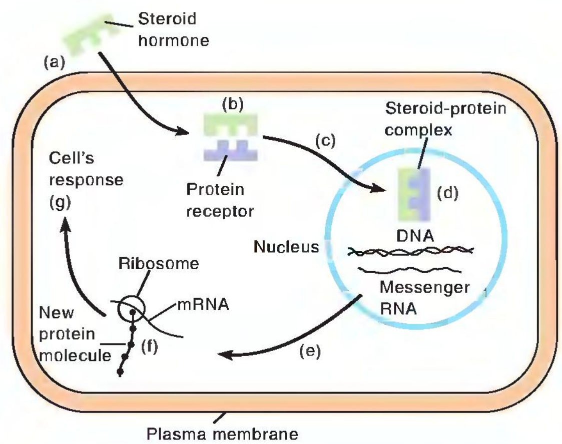

FIGURE 25.4

Steps of the Mobile-Receptor Mechanism. *(a)* A steroid hormone molecule (e.g., testosterone) diffuses from the blood to a target cell and then across the plasma membrane of the target cell. *(b)* Once in the cytoplasm, the hormone binds to a receptor that *(c)* carries it into the nucleus. *(d)* This steroid-protein complex triggers transcription of specific gene regions of DNA. *(e)* The messenger RNA transcript is then translated into a gene product via *(f)* protein synthesis in the cytoplasm. *(g)* The new protein then mediates the cell's response.

MOBILE-RECEPTOR MECHANISM

Because steroid hormones pass easily through the plasma membrane, their receptors are inside the target cells. The mobile-receptor mechanism involves the stimulation of protein synthesis. After being released from a carrier protein in the bloodstream, the steroid hormone enters the target cell by diffusion and binds to a specific protein receptor in the cytoplasm (figure 25.4*a,b*). This newly formed steroid-protein complex acquires an affinity for DNA that causes it to enter the nucleus of the cell, where it binds to DNA and regulates the transcription of specific genes to form messenger RNA (figure 25.4*c,d*). The newly transcribed mRNA leaves the nucleus and moves to the rough endoplasmic reticulum, where it initiates protein synthesis (figure 25.4*e,f*). Some of the newly synthesized proteins may be enzymes whose effects on cellular metabolism constitute the cellular response attributable to the specific steroid hormone (figure 25.4*g*).

SOME HORMONES OF INVERTEBRATES

The survival of any group of animals depends on growth, maturation, and reproduction coinciding with the most favorable seasons of the year so that climate and food supply are optimal. Thus, chemicals regulating growth, maturation, and reproduction probably were among the first hormones to appear during the course of animal evolution.

The first hormones were probably neurosecretions. As discussed next, most of the chemicals functioning as hormones in invertebrate animals are neurosecretions called neuropeptides.