Animal hormones are chemical signals that are secreted into the circulatory system and communicate regulatory messages within the body.

Hormones reach all parts of the body, but only target cells have receptors for that hormone.

Insect metamorphosis is regulated by hormones.

Two systems coordinate communication throughout the body: the endocrine system and the nervous system.

The endocrine system secretes hormones that coordinate slower but longer-acting responses including reproduction, development, energy metabolism, growth, and behavior.

The nervous system conveys high-speed electrical signals along specialized cells called neurons; these signals regulate other cells.

Intercellular Communication

The ways that signals are transmitted between animal cells are classified by two criteria:

- The type of secreting cell
- The route taken by the signal in reaching its target

Endocrine Signaling

Hormones secreted into extracellular fluids by endocrine cells reach their targets via the bloodstream.

Endocrine signaling maintains homeostasis, mediates responses to stimuli, regulates growth and development.

Local regulators are molecules that act over short distances, reaching target cells solely by diffusion.

In paracrine signaling, the target cells lie near the secreting cells.

In autocrine signaling, the target cell is also the secreting cell.
• In synaptic signaling, neurons form specialized junctions with target cells, called synapses

• At synapses, neurons secrete molecules called neurotransmitters that diffuse short distances and bind to receptors on target cells

• In neuroendocrine signaling, specialized neurosecretory cells secrete molecules called neurohormones that travel to target cells via the bloodstream

• Pheromones

• Members of the same animal species sometimes communicate with pheromones, chemicals that are released into the environment

• Pheromones serve many functions, including marking trails leading to food, a wide range of functions that include defining territories, warning of predators, and attracting potential mates

• Three major classes of molecules function as hormones in vertebrates
  – Polypeptides (proteins and peptides)
  – Amines derived from amino acids
  – Steroid hormones

• Water Soluble Hormones

• Binding of a hormone to its receptor initiates a signal transduction pathway leading to responses in the cytoplasm, enzyme activation, or a change in gene expression

• The hormone epinephrine has multiple effects in mediating the body’s response to short-term stress

• Epinephrine binds to receptors on the plasma membrane of liver cells

• This triggers the release of messenger molecules that activate enzymes and result in the release of glucose into the bloodstream

• Lipid-Soluble Hormones

• The response to a lipid-soluble hormone is usually a change in gene expression

• Steroids, thyroid hormones, and the hormonal form of vitamin D enter target cells and bind to protein receptors in the cytoplasm or nucleus
• Protein-receptor complexes then act as transcription factors in the nucleus, regulating transcription of specific genes

• Local Regulators
• Local regulators are secreted molecules that link neighbouring cells or directly regulate the secreting cell

• Types of local regulators
  – **Cytokines** and **growth factors**
  – **Nitric oxide (NO)**
  – **Prostaglandins**

• Simple Hormone Pathways
• Hormones are released from an endocrine cell, travel through the bloodstream, and interact with specific receptors within a target cell to cause a physiological response

• For example, the release of acidic contents of the stomach into the duodenum stimulates endocrine cells there to secrete secretin

• This causes target cells in the **pancreas**, a gland behind the stomach, to raise the pH in the duodenum

• Control of Blood Glucose
• **Insulin** (decreases blood glucose) and **glucagon** (increases blood glucose) are antagonistic hormones that help maintain glucose homeostasis

• The pancreas has clusters of endocrine cells called pancreatic islets with alpha cells that produce glucagon and beta cells that produce insulin

• Insulin reduces blood glucose levels by
  – Promoting the cellular uptake of glucose
  – Slowing glycogen breakdown in the liver
  – Promoting fat storage, not breakdown

• Glucagon increases blood glucose levels by
  – Stimulating conversion of glycogen to glucose in the liver
– Stimulating breakdown of fat and protein into glucose

• **Diabetes mellitus** is perhaps the best-known endocrine disorder

• It is caused by a deficiency of insulin or a decreased response to insulin in target tissues

• It is marked by elevated blood glucose levels

• **Type I diabetes mellitus** (insulin-dependent) is an autoimmune disorder in which the immune system destroys pancreatic beta cells

• **Type II diabetes mellitus** (non-insulin-dependent) involves insulin deficiency or reduced response of target cells due to change in insulin receptors

• Coordination of Systems

• The hypothalamus receives information from the nervous system and initiates responses through the endocrine system

• Attached to the hypothalamus is the **pituitary gland** composed of the posterior pituitary and anterior pituitary

• The **posterior pituitary** stores and secretes hormones that are made in the hypothalamus

• The **anterior pituitary** makes and releases hormones under regulation of the hypothalamus

**Posterior Pituitary Gland**

• The two hormones released from the posterior pituitary act directly on nonendocrine tissues
  – Oxytocin regulates milk secretion by the mammary glands
  – **Antidiuretic hormone (ADH)** regulates physiology and behavior

**Anterior Pituitary Gland**

• Hormone production in the anterior pituitary is controlled by releasing and inhibiting hormones from the hypothalamus

• For example, prolactin-releasing hormone from the hypothalamus stimulates the anterior pituitary to secrete **prolactin (PRL)**, which has a role in milk production

• Thyroid Regulation
• A hormone can stimulate the release of a series of other hormones, the last of which activates a nonendocrine target cell; this is called a hormone cascade pathway

• The release of thyroid hormone results from a hormone cascade pathway involving the hypothalamus, anterior pituitary, and thyroid gland

• Hormone cascade pathways typically involve negative feedback

• Hypothyroidism, too little thyroid function, can produce symptoms such as
  – Weight gain, lethargy, cold intolerance

• Hyperthyroidism, excessive production of thyroid hormone, can lead to
  – High temperature, sweating, weight loss, irritability and high blood pressure

• Malnutrition can alter thyroid function

• Graves disease, a form of hyperthyroidism caused by autoimmunity, is typified by protruding eyes

• *Thyroid hormone* refers to a pair of hormones
  – *Triiodothyronin* (T₃), with three iodine atoms
  – *Thyroxine* (T₄) with four iodine atoms

• Insufficient dietary iodine leads to an enlarged thyroid gland, called a goiter

• A tropic hormone regulates the function of endocrine cells or glands

• Three primarily tropic hormones are
  – *Follicle-stimulating hormone* (FSH)
  – *Luteinizing hormone* (LH)
  – *Adrenocorticotropic hormone* (ACTH)

• *Growth hormone* (GH) is secreted by the anterior pituitary gland and has tropic and nontropic actions

  • It promotes growth directly and has diverse metabolic effects

  • It stimulates production of growth factors
• An excess of GH can cause gigantism, while a lack of GH can cause dwarfism

• Parathyroid & Vitamin D

• Two antagonistic hormones regulate the homeostasis of calcium (Ca\(^{2+}\)) in the blood of mammals
  
  – **Parathyroid hormone (PTH)** is released by the parathyroid glands
  
  – **Calcitonin** is released by the thyroid gland

• PTH increases the level of blood Ca\(^{2+}\)
  
  – It releases Ca\(^{2+}\) from bone and stimulates reabsorption of Ca\(^{2+}\) in the kidneys
  
  – It also has an indirect effect, stimulating the kidneys to activate vitamin D, which promotes intestinal uptake of Ca\(^{2+}\) from food

• Calcitonin decreases the level of blood Ca\(^{2+}\)
  
  – It stimulates Ca\(^{2+}\) deposition in bones and secretion by kidneys

• Adrenal Responses to Stress

• The adrenal glands are adjacent to the kidneys

• Each **adrenal gland** actually consists of two glands: the *adrenal medulla* (inner portion) and *adrenal cortex* (outer portion)

• The adrenal medulla secretes epinephrine (adrenaline) and **norepinephrine** (noradrenaline)

• These hormones are members of a class of compounds called **catecholamines**

• They are secreted in response to stress-activated impulses from the nervous system

• They mediate various fight-or-flight responses

• Epinephrine and norepinephrine
  
  – Trigger the release of glucose and fatty acids into the blood
  
  – Increase oxygen delivery to body cells
  
  – Direct blood toward heart, brain, and skeletal muscles, and away from skin, digestive system, and kidneys
• The release of epinephrine and norepinephrine occurs in response to involuntary nerve signals
• The adrenal cortex releases a family of steroids called **corticosteroids** in response to stress
• These hormones are triggered by a hormone cascade pathway via the hypothalamus and anterior pituitary (ACTH)
• Humans produce two types of corticosteroids: glucocorticoids and mineralocorticoids
  • **Glucocorticoids**, such as cortisol, influence glucose metabolism and the immune system
  • **Mineralocorticoids**, such as aldosterone, affect salt and water balance
• The adrenal cortex also produces small amounts of steroid hormones that function as sex hormones
  • Gonadal Sex Hormones
  • The gonads, testes and ovaries, produce most of the sex hormones: androgens, estrogens, and progestins
  • All three sex hormones are found in both males and females, but in significantly different proportions
  • The testes primarily synthesize **androgens**, mainly **testosterone**, which stimulate development and maintenance of the male reproductive system
  • Testosterone causes an increase in muscle and bone mass and is often taken as a supplement to cause muscle growth, which carries health risks
  • **Estrogens**, most importantly **estradiol**, are responsible for maintenance of the female reproductive system and the development of female secondary sex characteristics
  • In mammals, progestins, which include **progesterone**, are primarily involved in preparing and maintaining the uterus
  • Synthesis of the sex hormones is controlled by FSH and LH from the anterior pituitary
  • Melatonin & Biorhythms
• The **pineal gland**, located in the brain, secretes **melatonin**

• Light/dark cycles control release of melatonin

• Primary functions of melatonin appear to relate to biological rhythms associated with reproduction