The Endocrine System

The endocrine system is a control system which affects bodily activities by releasing chemical messengers called hormones into the bloodstream.

The endocrine glands include the pituitary, thyroid, parathyroid, adrenal, pineal, and thymus glands. Organs such as the ovaries, testes, kidneys, pancreas, stomach, and small intestines contain areas of endocrine tissue which secretes hormones. The placenta, formed during pregnancy, also produces hormones.

Functions of Hormones

1. regulate metabolic processes and energy balance
2. control the rates of chemical reactions
3. aid in the transport of substances through membranes
4. regulate water and electrolyte balances
5. play a role in reproduction such as gamete production, fertilization, and nourishment of the embryo and fetus
6. play a role in growth and development
7. regulate the nutrient balance of the blood
8. responds to changes in environmental conditions such as infection, trauma, stress, dehydration, starvation, and temperature

Hormones

A hormone is an organic substance secreted by a cell into the interstitial spaces surrounding the cells. Hormones pass into the blood or lymph and are transported to various parts of the body where they affect target cells and tissues.

The majority of hormones are composed of amino acids and they include hormones of the pituitary, parathyroid, pancreas, and adrenal medulla. Other hormones are lipid-soluble and are the thyroid hormones and steroid hormones. The steroid hormones are synthesized from cholesterol and produced by the ovaries, testes, and adrenal cortex.

Prostaglandins are synthesized from fatty acids found in the plasma membranes. They produce effects in the immediate area in which they are formed. Prostaglandins regulate blood pressure, cause contractions of the smooth muscle in the small intestines and uterus, reduce or increase the production of hydrochloric acid in the stomach, regulate blood clotting and induce fever.
Hormone Action

One mechanism of hormone action occurs between the hormone and the receptor site on the outer surface of the plasma membrane. When a hormone reaches the target cell it is called the first messenger. The first messenger attaches to the specific receptor site, which is an integral protein on the outer surface of the plasma membrane. Cell function may be altered. When the hormone attaches to the receptor site, a membrane-bound enzyme called adenylate cyclase is activated and causes the conversion of ATP into cyclic AMP or cAMP. Cyclic AMP diffuses throughout the cell and binds to an intracellular receptor and acts as a second messenger. Cell function is altered according to the message indicated by the hormone. Cyclic AMP activates enzymes called protein kinases which results in the transfer of phosphate groups from ATP to protein substrate molecules altering their shape. Some are converted from inactive to active forms which alters cell activities and processes such as membrane permeability, activation of enzymes, promoting the synthesis of proteins, and stimulating or inhibiting metabolic pathways. Calcium ions may be involved with cyclic AMP as third messengers. The calcium ions bind to an intracellular protein called calmodulin. The calmodulin becomes activated and, in turn, activates certain enzymes.

Steroid hormones and thyroid hormones can diffuse through the plasma membrane of target cells. They combine with specific protein receptors on the nucleus. The hormone-receptor complex moves into the nucleus and binds to a protein receptor on the DNA molecule in the nucleus. Specific genes on the DNA molecule are activated and produce enzymes which regulate cell functions and activities.

In most cases the amount of hormone released by an endocrine gland or tissue is determined by the body’s need for the hormone and is regulated by a negative feedback system.
<table>
<thead>
<tr>
<th>Endocrine Gland and Hormone</th>
<th>Target</th>
<th>Principal Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. hypothalamus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Releasing and inhibiting hormones</td>
<td>anterior pituitary</td>
<td>stimulates or inhibits secretion of specific hormones; regulates anterior pituitary hormones</td>
</tr>
</tbody>
</table>

2. posterior pituitary (storage and release of hypothalamic hormones)

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<tr>
<th>Hormone</th>
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<tbody>
<tr>
<td>a. oxytocin</td>
<td>uterus, mammary glands</td>
<td>stimulates contraction of the uterus; stimulates ejection of milk into ducts</td>
</tr>
<tr>
<td>b. antidiuretic hormone (ADH)</td>
<td>kidneys</td>
<td>stimulates reabsorption of water by kidneys; raises blood pressure</td>
</tr>
</tbody>
</table>

3. anterior pituitary

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Target</th>
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</thead>
<tbody>
<tr>
<td>a. growth hormone (GH)</td>
<td>tissues, bone</td>
<td>stimulates cell division, protein synthesis, fat mobilization, bone growth; slows carbohydrate metabolism</td>
</tr>
<tr>
<td>b. prolactin</td>
<td>mammary glands</td>
<td>stimulates milk production and secretion</td>
</tr>
<tr>
<td>c. thyroid-stimulating hormone (TSH)</td>
<td>thyroid gland</td>
<td>stimulates secretion of thyroid hormones</td>
</tr>
</tbody>
</table>
d. adrenocorticotropin hormone (ACTH)  
   stimulates secretion of adrenal cortex hormones

e. gonadotropic hormones (FSH) and (LH)  
   (follicle stimulating hormone; luteinizing hormone)  
   stimulates gamete and sex hormone production

4. thyroid gland

  a. thyroxine (T₄), triiodothyronine (T₃)  
     (follicle cells)  
     increases metabolic rate; helps regulate normal growth and development

  b. calcitonin (para-follicular cells)  
     bone, kidney, intestine  
     lowers blood calcium level by inhibiting removal of calcium from bone

5. parathyroid glands

  parathyroid hormone (PTH)  
  bone, kidney, intestine  
  increases blood calcium level by stimulating bone breakdown; stimulates calcium reabsorption in kidneys; activates vitamin D
6. **pancreas**

- **a. insulin** (beta cells)  
  - liver, muscles, adipose tissue  
  - lowers blood glucose level by facilitating glucose uptake and utilization by cells; stimulates glycogenesis; stimulates fat storage and protein synthesis

- **b. glucagon** (alpha cells)  
  - liver, muscles, adipose tissue  
  - raises blood glucose level by stimulating glycogenolysis and gluconeogenesis

7. **adrenal medulla**

- **epinephrine** and **norepinephrine**  
  - skeletal muscle, cardiac muscle, blood vessels, liver, adipose tissue  
  - helps body cope with stress; increases heart rate, blood pressure, metabolic rate (fight-or-flight); raises blood sugar level; stimulates smooth muscle contractions

8. **adrenal cortex**

- **a. mineralcorticoids** (aldosterone) (from zona glomerulosa)  
  - kidney  
  - maintains sodium and phosphate balance; excretes potassium (mineral and electrolyte balance)

- **b. glucocorticoids** all tissues (cortisol) (from zona fasiculata)  
  - helps body adapt to long-term stress; raises blood glucose level; mobilizes fat
<table>
<thead>
<tr>
<th>9. ovary</th>
<th></th>
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<tbody>
<tr>
<td><strong>a. estrogens</strong></td>
<td>skin, muscle, bone, reproductive structures</td>
</tr>
<tr>
<td><strong>b. progesterone</strong></td>
<td>uterus, breasts</td>
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<table>
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<th>10. testes</th>
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<tbody>
<tr>
<td>testosterone</td>
<td>skeletal muscles, reproductive structures</td>
</tr>
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</table>
11. **pineal gland**

- **melatonin**
- **gonads, various tissues**

  Influences reproductive processes; may control daily biorhythms; may help control onset of puberty and maturation of sex organs; decreases in light and increases in darkness

12. **thymus gland**

- **thymoses**
- **thymus gland**

  Stimulates maturation of T lymphocytes; stimulates development of some B lymphocytes into antibody-producing plasma cells

**Glycogenesis** - formation of glycogen from glucose

**Glycogenolysis** - conversion of glycogen in the liver to glucose

**Gluconeogenesis** - conversion of amino acids and fatty acids in the liver to glucose