Hormonal Effects

- regulation of ECF composition and volume
  - ADH, aldosterone, ANF
- regulation of metabolism
  - thyroid hormones, epinephrine, growth hormone, insulin and glucagon
- regulation of muscle contraction and glandular secretion
  - Epinephrine/norepinephrine

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Hormonal Effects

- regulation of stress response
  - epinephrine, glucocorticoids
- regulate growth and development
  - growth hormone, testosterone
- regulate reproductive functions
  - testosterone, estrogen and progesterone
Target Cells

- Hormones have target cells that are specific for a particular hormone due to regulation of the number and kind of receptors available for that hormone.
Hormones are made up of and categorized by their different component chemicals.
Hormone Classification

- steroids: derived from cholesterol
  - testosterone, estrogen
  - although not steroids, prostaglandins are also lipid derived (arachadonic acid)

Hormone Classification

- peptides and proteins: chains of amino acids
  - insulin
  - prolactin
  - ADH
  - ACTH
  - glucagon
  - growth hormone
Hormone Classification

- amino acid derivatives
  - epinephrine
  - norepinephrine
  - thyroid hormones
  - melatonin

Mechanisms of Action

- lipid-soluble hormones
  - steroids and thyroid hormones
  - pass through cell membrane, bind to receptor on nucleus, which carries hormone into nucleus
  - directly affects DNA to synthesize proteins
Lipid Soluble Hormones

1. Aldosterone is a lipid-soluble hormone and can easily diffuse through the plasma membrane.

2. Once inside the cell, aldosterone binds with an aldosterone receptor in the cytoplasm.

3. The aldosterone-receptor complex moves into the nucleus and binds to DNA.

4. The binding of the aldosterone-receptor complex to DNA stimulates the synthesis of messenger RNA (mRNA), which codes for specific proteins.

5. The mRNA leaves the nucleus, passes into the cytoplasm of the cell, and binds to ribosomes, where it directs the synthesis of the specific proteins.

6. The proteins synthesized on the ribosomes produce the cell's response to aldosterone. For example, aldosterone increases the synthesis of proteins that transport Na⁺ and K⁺ across epithelial plasma membranes in the kidney (see chapter 26).

Mechanisms of Action

- water-soluble hormones
  - catecholamines, peptides, and proteins
  - bind to membrane receptor, activates G protein, uses cAMP as second messenger to start chain of events to activate or deactivate already synthesized proteins (enzymes)
Water Soluble Hormones

1. After glucagon binds to a glucagon receptor, the G protein is activated (see figure 17.14).
2. The activated G protein, with GTP bound to it, binds to and activates an adenyl cyclase enzyme so that it converts ATP to cAMP.
3. The cAMP activates protein kinase enzymes, which phosphorylate specific enzymes that break down glycogen to glucose molecules and the glucose is released from liver cells.
4. Phosphodiesterase enzymes inactivate cAMP by converting cAMP to AMP.

Response
Phosphorylates specific enzymes and activates them to break down glycogen and release glucose.
Control of Hormone Secretions

- Hypothalamic-Pituitary-Effector Axis:
  - the hypothalamus senses bodily conditions or gets input from higher brain centers
  - hypothalamus secretes hormones (either releasing or inhibitory) that are carried by blood vessels to the anterior pituitary gland (hypothalamic-hypophyseal portal system)
  - releasing hormones cause the pituitary gland to secrete specific hormones; inhibitory hormones stop the gland from secreting a hormone
Control of Hormone Secretions

- Hypothalamic-Pituitary-Effector Axis:
  - the pituitary hormones (or lack of hormones) affect another organ into a desired result
  - feedback occurs on a variety of levels
    - short loop from pituitary to hypothalamus
    - long loop from target organ to hypothalamus
    - autoregulation from target organ to itself

1. Stimuli within the nervous system increase or decrease the secretion of releasing hormones and inhibiting hormones (blue balls) from neurons of the hypothalamus.

2. Releasing hormones and inhibiting hormones pass through the hypothalamo-hypophyseal portal system to the anterior pituitary.

3. Releasing hormones and inhibiting hormones leave capillaries, bind to membrane-bound receptors, and stimulate or inhibit the release of hormones (yellow squares) from anterior pituitary cells.

4. Anterior pituitary hormones (yellow squares) are carried in the blood to their target tissues (green arrows), which, in some cases, are other endocrine glands.
Anterior Pituitary Hormones

- thyroid-stimulating hormone (TSH)
  - hypothalamus senses decrease in plasma thyroid hormone level (T3), releases thyrotrophic releasing hormone (TRH)
  - pituitary releases TSH in response to TRH
  - thyroid gland releases T4 and a little T3 (T4 is converted to the active T3 in blood)
  - T3 raises metabolism level throughout body (body growth)
  - hypothyroidism, hyperthyroidism
Anterior Pituitary Hormones

- human growth hormone (hGH)
  - hypothalamus secretes growth hormone releasing hormone (GHRH) or growth hormone inhibiting hormone (GHIH)
  - multiple stimuli for release
  - under GHRH influence, the pituitary secretes hGH
  - Effectors: somatomedins (insulin-like growth factors)

Anterior Pituitary Hormones

- human growth hormone (hGH)
  - hGH and somatomedins cause fat utilization for fuel and protein build-up, stores glycogen
  - make muscle, lose fat, store sugar
  - dwarfism or gigantism from too little or too much hGH, respectively
Acromegaly

- Overproduction of hGH in adulthood

1. Stress and decreased blood glucose levels increase the release of growth hormone-releasing hormone (GHRH) and decrease the release of growth hormone-inhibiting hormone (GHIH).
2. GHRH and GHIH travel through the hypothalamo-hypophyseal portal system to the anterior pituitary.
3. Increased GHRH and reduced GHIH act on the anterior pituitary and result in increased GH secretion.
4. GH acts on target tissues.
5. Increasing GH has a negative-feedback effect on the hypothalamus, resulting in decreased GHRH and decreased GH release.

Stress
Low blood glucose

Increased growth hormone-releasing hormone (GHRH)
Decreased growth hormone-inhibiting hormone (GHIH)

Stimulatory
Inhibitory

Target tissue:
- Increases protein synthesis and decreases protein breakdown
- Increases tissue growth
- Increases fat breakdown
- Increases glucose synthesis and reduces glucose usage
- Increases somatomedin secretion
Anterior Pituitary Hormones

- follicle-stimulating hormone (FSH)
  - hypothalamus secretes gonadotropin releasing hormone (GnRH)
  - pituitary secretes FSH
  - in males, FSH causes testes to produce sperm
  - in females, FSH causes ovaries to develop a follicle
  - then causes follicles to secrete estrogens (female sex hormones)

- leutinizing hormone (LH)
  - hypothalamus secretes GnRH
  - pituitary secretes LH
  - in females, LH stimulates ovulation (release of secondary oocyte) and development of corpus luteum (details in reproduction section)
  - in males, LH causes interstitial cells of testes to secrete testosterone
Anterior Pituitary Hormones

- prolactin (PRL)
  - hypothalamus secretes prolactin releasing hormone (PRH) or prolactin inhibiting hormone (PIH, dopamine)
  - pituitary releases PRL in response to PRH
  - when breast tissue is properly prepared by pregnancy, PRL initiates and maintains milk production (lactation) by mammary glands

Anterior Pituitary Hormones

- Melanocyte stimulating hormone (MSH)
  - responsible for color changes in some animals (chameleons, etc.), but humans don't have the active form of MSH
Anterior Pituitary Hormones

- Adrenocorticotropic hormone (ACTH)
  - hypothalamus secretes corticotropin releasing hormone (CRH) in response to stress
  - pituitary secretes ACTH in response to CRH
  - ACTH causes the adrenal cortex to secrete glucocorticoids (feel no pain, etc.)

Posterior Pituitary Hormones

- unlike the anterior pituitary gland, the posterior pituitary gland does not produce hormones
- it stores hormones that are produced in the hypothalamus
Posterior Pituitary Hormones

- hypothalamic-hypophyseal tract
  - cell bodies of neurons within hypothalamus make hormones (OT and ADH)
  - hormones are transported in vesicles down the axons to the axon terminals, which are in the posterior pituitary gland
  - hormones are stored within and released from the posterior pituitary

Posterior Pituitary Hormones

- oxytocin (OT)
  - responds to stretch of the cervix (vaginal edge of uterus) during childbirth to cause uterine contractions
    - positive feedback
  - another positive feedback cycle involving OT causes milk secretion (“let-down”) from the mammary glands when suckling occurs at breast
Posterior Pituitary Hormones

- Anti-diuretic hormone (ADH)
  - Purpose is to preserve water for body
  - Stimulus for ADH release is an increase in the osmotic pressure (dehydration) of plasma
  - Sensed in the hypothalamus
  - In addition to stimulation of thirst center, increased osmotic pressure causes ADH release from posterior pituitary
Posterior Pituitary Hormones

- ADH causes
  - water reabsorption by kidneys
  - vasoconstriction
  - decreased sweating
- Low ADH is called diabetes insipidus
  - symptoms: polyurea, polydipsia, but not polyphagia

1. Osmoreceptors in the hypothalamus detect changes in blood osmolality, and sensory neurons that send action potentials through the vagus nerves to the hypothalamus detect changes in blood pressure.
2. An increase in osmolality and a decrease in blood pressure increase action potentials in ADH-secreting neurons.
3. Action potentials are carried by axons of ADH-secreting neurons through the hypothalamic-hypophysial tract to the posterior pituitary.
4. In the posterior pituitary, action potentials cause the release of ADH from the axon terminals into the circulatory system.
5. Increasing ADH acts on the kidney tubules to increase water reabsorption, resulting in a reduced urine volume, increased urine osmolality, and decreased blood osmolality. This helps maintain blood osmolality and volume.
Adrenal Gland

- divided into two major regions that have very different functions:
  - cortex and medulla

Adrenal Cortex

- Secretes three types of hormones:
  - Mineralocortioids
  - Glucocorticoids
  - Gonatocorticoids
    - not usually important except for postmenopausal women
Aldosterone
- causes kidneys to reabsorb Na+ (and water), and excrete K+
  - primary stimulus for aldosterone secretion is a rise in ECF K+ concentration
  - sensed directly by adrenal gland
  - imminent death without aldosterone due to rise in ECF K+
  - other stimuli for aldosterone secretion is a drop in blood pressure, volume, or Na+ concentration
  - sensed by kidneys, involves angiotensin II

Glucocorticoids
- cortisol, corticosterone, cortisone
- anti-inflammatory and analgesic properties
- helps prepare body for fighting stress
Adrenal Medulla

- Secretes epinephrine

1. Corticotropin-releasing hormone (CRH) is released from hypothalamic neurons in response to stress or low blood glucose levels, by way to the hypothalamic-pituitary portal system, to the anterior pituitary.

2. In the anterior pituitary, CRH binds to and stimulates cells that secrete adrenocorticotropic hormone (ACTH).

3. ACTH binds to membrane-bound receptors on cells of the adrenal cortex and stimulates the secretion of glucocorticoids, primarily cortisol.

4. Cortisol acts on target tissues, resulting in increased fat and protein breakdown, increased glucose levels, and anti-inflammatory effects.

5. Cortisol has a negative-feedback effect because it inhibits CRH release from the hypothalamus and ACTH secretion from the anterior pituitary.

Stimulatory
Inhibitory

1. Stress, physical activity, and low blood glucose levels act as stimuli to the hypothalamus, resulting in increased sympathetic nervous system activity.

2. An increased frequency of action potentials conducted through the sympathetic division of the autonomic nervous system stimulates the adrenal medulla to secrete epinephrine and some norepinephrine into the circulatory system.

3. Epinephrine and norepinephrine act on their target tissues to produce responses.

- Increases the release of glucose from the liver into the blood
- Increases the release of fatty acids from adipose tissue into the blood
- Increases heart rate
- Decreases blood flow through blood vessels of internal organs
- Increases blood flow through blood vessels of skeletal muscle and the heart
- Increases blood pressure
- Increases the function of visceral organs
- Increases the metabolic rate of skeletal muscles