Endocrinology

The endocrine system is one of two communication systems (the other being the nervous system) used by the body for communication between cells.

I. Hormones

A. Classical Definition (3 major parts)

1. Chemical produced by specific gland
2. Secreted into the blood or other fluid spaces (humors)
3. Acts on distant tissue or cells called target cells

- Target cells for a particular hormone have receptors for that hormone.

B. Modes of Transmission

1. Epicrine- direct cell to cell contact through gap junctions
2. Paracrine- cell to cell via interstitial fluid (cells do not have to be in direct contact)
3. Endocrine (classical system)–via bloodstream
4. Neurocrine- secreted by neurons, may affect other neurons, cells in contact with neuron or enter bloodstream and be transported
5. Exocrine- hormone secreted to exterior of body

- lumen of digestive system
- pheromones?

C. Biochemistry (Types of Hormones)

1. Amines: derived from the amino acid tyrosine

2. Peptides: made from amino acids

   a. types

      1. peptides (small group of aa)
      2. polypeptides
      3. true proteins

   b. receptors are in the plasma membrane.

2. Steroids: made from cholesterol
a. types

1. Adrenal Cortex: glucocorticoids and mineralocorticoids
2. Gonadal or placental or adrenal: progestins, estrogens androgens
3. Prostaglandins or Prostanoids: made from Arachidonic acid (a fatty acid)

D. Actions of Hormones

1. Change morphology
2. Cause cell division and differentiation
3. Increase protein synthesis
4. Regulate enzymes
5. Stimulate muscle contraction
6. Control exocrine secretion
7. Control endocrine secretions
8. Regulate ion movement across membranes
9. Control permeability to water
10. Control or change behavior

E. Hormone-receptor interactions

1. Receptor: protein that binds hormone and causes a biological response

   a. Hormone receptors are proteins, either found in the plasma membrane of the cell or are located in the nucleus of the cell. (Figure 1)

      1. Plasma membrane receptors require second messengers to cause response of target cells; ex. cyclic Adenosine Monophosphate (cAMP) and Phosphoinositol and Calcium. These second messengers activate or deactivate enzymes.
      2. Nuclear receptors bind to the DNA and turn on or off gene transcription (coding for new proteins; Figure 2)

II. Hypothalamic Hormones (Figure 3; Reece page 429)

A. The Hypothalamus is a part of the brain that secretes mostly peptide hormones and regulates the Pituitary, which also produces hormones.

B. Hypothalamic protein hormones: RF or RH stands for releasing factor or hormone, I stands for inhibitory

C. tropin or tropic- stimulating
D. These hormones regulate the Anterior Pituitary

1. TRF or TRH: Thyrotropin
2. CRF or CRH: Corticotropin
3. GnRH: Gonadotropin
4. PIF: Prolactin; exception to protein rule PIF is dopamine.
5. GHRH: stimulates release of Growth Hormone
6. GHIH: inhibits release of Growth Hormone; also called Somatostatin

III. Pituitary Gland

A. Double lobed gland located just below hypothalamus (figure 3)
B. Posterior Pituitary and hypothalamus are connected by nerves.
C. Anterior Pituitary and hypothalamus are connected by blood vessels called Portal Vessels.

D. Function of Pituitary Hormones

1. Anterior Pituitary Hormones

a). Growth Hormone- GH, also called Somatotropic hormone – STH
   1. stimulates growth
   2. stimulates the liver to produce somatomedins
   3. metabolic effects
      a. protein synthesis
      b. fatty acid mobilization
      c. decreased glucose uptake

b). Adrenocorticotropic Hormone - ACTH
   1. stimulates adrenal cortex
   2. metabolic effects similar to GH

c). Thyroid Stimulating Hormone – TSH
   1. stimulates release of thyroid hormone

d). Gonadotropic Hormones

1. Follicle-stimulating hormone - FSH
a. female – oogenesis
b. male – spermatogenesis

2. Luteinizing hormone – LH
   a. female - ovulation and formation of functional corpus luteum
   b. male - testosterone production

3. Prolactin-
   starts milk production, released by suckling

4. Beta-Lipoprotein Hormone
   1. secreted by same cells that secret ACTH
   2. unknown function

2. Posterior Pituitary Hormones
   a. Antidiuretic Hormone (Vasopressin)
      1. ADH
      2. increased water retention
   b. Oxytocin
      stimulates smooth muscle

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IV. Thyroid Gland Hormones of Thyroid Gland:

Thyroxine (T4) and Triodothyronine (T3)

A. The thyroid is a paired gland generally located on the trachea (Figure 4; Reece page 431)

B. Thyroid Hormones
   1. Biochemistry of T3 and T4 Formation
      a. Made from 2 Tyrosine and either 3 or 4 Iodine molecules
   2. Release and Transport of T3 and T4
a. Most production of thyroid is T4 and T3 is produced in target tissues by deiodinase enzyme.

3. Functions

a. Function of thyroid hormones is to increase metabolic activity.

b. T3 and T4 regulate basal metabolic rate (BMR).

c. Increased BMR generates heat through the sodium-potassium pump.

d. Heart rate is increased because thyroid hormones increase the heart’s receptors for Norepinephrine and Epinephrine.

4. Regulations of Secretion

a. TRH increases TSH which stimulates T4 and T3.

b. T4 and T3 have negative feedback on TRH and TSH.

c. Cold increases thyroid hormone production and heat decreases.

C. Thyroid Deficiency and Antithyroid Compounds

1. Thyroid hormone secretion is decreased by low energy diets.

2. Iodine deficient diets or chemicals found in some plants (Goitrogens) can interfere with thyroid hormone synthesis.

3. Increased energy expenditure is needed to keep pumps working.

D. Calcitonin C cells of thyroid, high Ca stimulates

1. lowers plasma Ca

2. increases Ca loss through kidneys

3. antagonistic to PTH to maintain Ca homeostasis

E. Regulation of metabolic rate by thyroid

1. Signal for more heat

2. Hypothalamic release of TRF

3. Anterior pituitary release TSH

4. Thyroid releases T3 and T4

5. Metabolism increases and more heat is released

6. Increase in heat decreases TRF
V. Parathyroid Gland – PTH

A. Located in or near the Thyroid.

B. Parathyroid Hormone and Calcium Ion Regulation

1. low Ca stimulates

2. high Ca inhibits

3. PTH increases extracellular fluid concentrations of Ca and P from bone (osteolysis)

4. PTH recruits osteoclasts
   a. specialized cells that dissolve bone

C. Action on PTH on the Kidneys

1. causes selective reabsorption of Ca

2. limits reabsorption of P

3. helps maintain 2:1 of Ca:P in blood

D. PTH and 1,25 Dihydroxycholecalciferol Formation (active form of vitamin D)

1. PTH increases formation of the active form of Vitamin D
   a. Vitamin D in the diet is inactive. It requires sunlight to produce the active form.

   b. dietary Vitamin D is converted to its active form by the liver and the kidneys under the influence of PTH

   c. Vitamin D (in its active form) stimulates Ca absorption from the diet.

   d. Vitamin D has a structure similar to steroid hormones and a receptor like steroid hormones.

E. Homeostatic Control of Ca in the Bloodstream

1. PTH Effects:
   a. Stimulates production of active form Vitamin D

   b. Increases Ca resorption at the kidney.

   c. Increase Ca removal from the bone

2. Calcitonin Effects:
   a. Decreases removal of Ca from bone
b. increases Ca loss through kidneys

V. Adrenal Glands

A. Anatomy

1. located immediately cranial to the kidneys (figure; Reece page 437)
2. divided into 2 parts Cortex and Medulla

B. Hormones of the Adrenal Cortex

1. steroid hormones made from cholesterol
2. Aldosterone
   a. regulates Na levels in body by increasing Na retention in kidney

3. Functions of the Glucocorticoids
   a. Cortisol is most important
   b. Involved in stress response
   c. Increase blood glucose levels

4. Functions of the Mineralocorticoids
   a. regulates Na levels in body by increasing Na retention in kidney
   b. promoting membrane transport of ions

5. Regulation of Glucocorticoid Secretion
   a. CRH increases ACTH which stimulates Cortisol secretion.

6. Regulation of Mineralocorticoid Secretion
   a. Stimulated by Angiotensin II

C. Hormones of the Adrenal Medulla

1. Medulla is an extension of the Sympathetic Nervous System
2. Medulla produces catecholamines
   a. Epinephrine
   b. Norepinephrine
3. These hormones are also involved in the stress response (fight or flight) and metabolic control of liver and muscles

D. Kidney Hormones:

Erythropoietin: increases red blood cell number

Renin: enzyme which activates Angiotensinogen to Angiotensin

Angiotensin stimulates secretion of Aldosterone from Adrenal cortex.

VI. Pancreatic Gland

A. Produced by Islets of Langerhans

B. Hormones of the Pancreas

1. Insulin (produced by Beta cells)
   a. lowers blood glucose levels
   b. Necessary for most cells to use glucose
   1. Exceptions: brain, liver and working skeletal muscle
   c. Causes glucose to be stored as glycogen.
   1. stimulates amino acid uptake and protein synthesis.

2. Glucagon (produced by Alpha cells)
   a. raises blood glucose levels
   b. Breaks down glycogen

3. Somatostatin
   a. inhibits secretion of insulin and glucagon
   b. moderates metabolic effects of insulin, glucagon, and GH

4. Pancreatic Polypeptide
   a. no known function

B. Control of Insulin and Glucagon Secretion

1. homeostatic controlled by blood glucose levels.

VIII. Prostaglandins and their Functions
A. Found in most tissues

B. Synthesized from Arachidonic Acid

C. Actions

1. Local Actions
   a. involved in inflammation
      1. Anti-inflammatory agents (aspirin) inhibit PG synthesis
   b. PGF2-alpha is produced local by Endometrium of Uterus and is used for Estrus Synchronization

2. Endocrine like actions
   a. in farm animals, involved as a signal for parturition
      1. stimulates uterine contractions
      2. high levels of PGF2 alpha can abort early pregnancy

IX. Gastrointestinal Hormones

A. Gastrin
   1. Increases pancreatic enzyme and bicarbonate secretion
   2. promotes movement of food through intestines

B. Secretin
   1. Increases pancreatic enzyme and bicarbonate secretion
   2. inhibits movement of food through intestines

C. CCK-cholecystokinin
   1. Increases pancreatic enzyme and bicarbonate secretion
   2. promotes movement of food through intestines

D. VIP-Vasoactive Intestinal Peptide,
   1. inhibits gastric acid secretion, stimulates bile flow

X. Nonglandular Hormones

A. Biogenic amines
1. dopamine
2. norepinephrine
3. epinephrine
   a. secreted on by the adrenal medulla
4. serotonin

B. Synthesis of biogenic amines
1. Catecholamines
   TYROSINE
   L-DOPA
   DOPAMINE
   NOREPINEPHRINE
   EPINEPHRINE

2. Indole amines
   TRYPTOPHAN
   SEROTONIN
   MELATONIN

XI. Gonadal and Placental Hormones
A. Androgens
1. main class of steroid hormones produced by male
2. has anabolic effects
3. Testosterone
   a. involved in spermatozoa production
   b. male libido
B. Estrogens
1. involved in standing heat (estrus)
2. causes growth of uterine lining

C. Progestins
1. Progesterone
   a. maintain uterine lining

XII. Steroid Synthesis (Figure 1)

XIII. Hormonal control of growth

A. Hypothalamic factors
1. GHRF increases GH
2. Somatostatin decreases GH

B. Anterior pituitary factors
1. anterior pituitary secretes GH
2. GH acts on liver, muscles, and kidneys
3. Kidneys & liver release somatomedins (IGF)
4. IGF drives nutrients into tissue, especially muscle
5. IGF decreases GHRF

XIV. Stress response

A. Hypothalamic - pituitary - adrenal axis
1. hypothalamus releases CRH
2. CRH causes anterior pituitary to release ACTH
3. ACTH causes adrenal cortex to release glucocorticoids (cortisol)
4. cortisol causes increased metabolism for fight or flight and
5. decreases CRH through negative feedback

B. Adrenal medulla
1. stress activates sympathetic nervous system
2. sympathetic nervous system causes adrenal
3. cortex to release epinephrine and norepinephrine
4. epinephrine and norepinephrine cause increased metabolism for fight or flight

XV. Neuroendocrine mechanism: Milk let down (arc-reflex response figure 2)

A. Inputs into the neocortex (sights and sounds and touch)
B. Neuron connections to the hypothalamus
C. Neuroendocrine release of oxytocin from the posterior pituitary
D. Oxytocin travels in blood to mammary gland to cause milk let down
E. This neuroendocrine loop is inhibited by stress.

XVI. Positive and Negative Feedback of Hormones on Each other
A. The reproductive system as an example: (Figure 3)