Chapter 18

Review of Endocrine Organs and Tissues ("Lecture Objectives")

The Pituitary Gland
The Pituitary Gland (Hypophysis) / Master Gland

- suspended from hypothalamus by a stalk – **infundibulum**

- location and size
  - housed in **sella turcica of sphenoid bone**
  - size and shape of kidney bean

- composed of two histologically different tissue structures with independent origins and separate functions
  - **adenohypophysis** (anterior pituitary) // arises from hypophyseal pouch (outgrowth of pharynx)
  - **neurohypophysis** (posterior pituitary) // downgrowth from brain
Anatomy of Hypothalamus

• shaped like a flattened funnel // area between optic chiasma and mammillary bodies

• forms floor and walls of third ventricle of the brain

• regulates primitive functions of the body
  – water balance
  – thermoregulation
  – sex drives
  – childbirth

• many of these functions are carried out by the hormones of the pituitary gland
• **adenohypophysis** constitutes anterior three-quarters of pituitary

  – has two segments:

    • anterior lobe (pars distalis)
    • pars tuberalis small mass of cells adhering to stalk

  – linked to hypothalamus by hypophyseal portal system

    • primary capillaries in hypothalamus connected to secondary capillaries in adenohypophysis by portal venules

    • hypothalamic hormones regulate adenohypophysis cells
• neurohypophysis constitutes the posterior one-quarter of the pituitary

  – has 3 parts:

  • median eminence, infundibulum, and the posterior lobe (pars nervosa)

  – nerve tissue /// not a typical glandular like tissue

  • nerve cell bodies in hypothalamus pass down the stalk as hypothalamo-hypophyseal tract and end in posterior lobe

  • hypothalamic neurons secrete hormones that are stored in neurohypophysis until released into blood
Hypothalamo-Hypophyseal Tract

- Third ventricle of brain
- Median eminence
- Hypothalamo-hypophyseal tract
- Stalk (infundibulum)
- Neurohypophysis
  - Posterior lobe
  - Pars tuberalis
  - Anterior lobe
- Adenohypophysis
  - Optic chiasm
  - Nuclei of hypothalamus:
    - Paraventricular nucleus
    - Supraoptic nucleus
- Pineal gland
- Cerebral aqueduct
- Mammillary body
- Anterior lobe
- Posterior lobe
- Oxytocin
- Antidiuretic hormone

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• hypothalamic releasing and inhibiting hormones travel in hypophyseal portal system from hypothalamus to anterior pituitary
• hormones secreted by anterior pituitary
Hypothalamic Hormones (1 of 5)

- eight hormones produced in hypothalamus
  - six regulate the anterior pituitary
    - two are released into capillaries in the posterior pituitary when hypothalamic neurons are stimulated (oxytocin and antidiuretic hormone)
  - six releasing and inhibiting hormones stimulate or inhibit the anterior pituitary
    - TRH, CRH, GnRH, and GHRH are releasing hormones that affect anterior pituitary secretion of TSH, PRL, ACTH, FSH, LH, and GH
    - PIH inhibits secretion of prolactin, and somatostatin inhibits secretion growth hormone & thyroid stimulating hormone by the anterior pituitary (see Table 17.3)
Hypothalamic Hormones (2 of 5)

- Synthesized in hypothalamus, stored in posterior pituitary, and released by nerve signal from hypothalamus
  - oxytocin (OT) & antidiuretic hormone (ADH)
    - both stored and released by posterior pituitary
    - right and left paraventricular nuclei produce oxytocin (OT)
    - supraoptic nuclei produce antidiuretic hormone (ADH)
    - posterior pituitary does not synthesize them
Hypothalamic Hormones (3 of 5)

- produced in hypothalamus
  - transported by hypothalamo-hypophyseal tract to posterior lobe
  - releases hormones when hypothalamic neurons are stimulated
- ADH (antidiuretic hormone)
  - increases water retention thus reducing urine volume and prevents dehydration
  - also called vasopressin because it can cause vasoconstriction
Hypothalamic Hormones (4 of 5)

- **OT (oxytocin)**
  - surge of hormone released during sexual arousal and orgasm // stimulate uterine contractions and propulsion of semen
  - promotes feelings of sexual satisfaction and emotional bonding between partners
  - stimulates labor contractions during childbirth
  - stimulates flow of milk during lactation
  - promotes emotional bonding between lactating mother and infant (love hormone!)
  - **Guess what happens to both you and your pet when you “pet your pet”!**
Histology of Pituitary Gland

(a) Anterior pituitary
- Chromophobe
- Basophil
- Acidophil

(b) Posterior pituitary
- Unmyelinated nerve fibers
- Glial cells (pituicytes)
Anterior Pituitary Hormones

- Synthesizes and secretes six principal hormones
- Two gonadotropin hormones that target male and female gonadal tissues
  - FSH (follicle stimulating hormone)
    - Female stimulates secretion of ovarian sex hormones plus development of ovarian follicles // in males regulate sperm production
  - LH (luteinizing hormone)
    - Females stimulates ovulation, stimulates corpus luteum to secrete progesterone /// males stimulates testes to secrete testosterone
Anterior Pituitary Hormones

- **TSH (thyroid stimulating hormone)** // stimulates secretion of thyroid hormone // gas pedal of body // all cells in body have receptors for TSH

- **ACTH (adrenocorticotropic hormone)** // stimulates adrenal cortex to secrete glucocorticoids

- **PRL (prolactin)** // normally inhibited // after birth secreted and stimulates mammary glands to synthesize milk // believed to enhances secretion of testosterone by testes

- **GH (growth hormone)** // stimulates mitosis and cellular differentiation // all cells in body have receptors for GH
Growth Hormone

- GH has widespread effects on the body tissues especially cartilage, bone, muscle, and fat

- induces liver to produce growth stimulants insulin-like growth factors (IGF-I) or somatomedins (IGF-II)

  • stimulate target cells in diverse tissues

  • IGF-I prolongs the action of GH

  • hormone half-life – the time required for 50% of the hormone to be cleared from the blood

    - GH half-life 6 – 20 minutes
    - IGF-I half-life about 20 hours
Growth Hormone

- GH Regulates:

  • protein synthesis increases -- boosts transcription of DNA, production of mRNA /// amino acid uptake into cells /// suppresses protein catabolism

  • lipid metabolism increased /// shifts metabolism towards fat catabolism by adipocytes /// (protein-sparing effect – save glucose for brain fuel) // this then provides energy for growing tissues

  • How would GH “reshape” appearance of body if taken as a supplement?
Growth Hormone

• carbohydrate metabolism – by mobilizing fatty acids for energy, GH functions as a glucose-sparing hormone // makes glucose available for glycogen synthesis and storage

• electrolyte balance – promotes Na\(^{+}\), K\(^{+}\), & Cl\(^{-}\) retention by kidneys, enhances Ca\(^{2+}\) absorption in intestine

• bone growth - thickening and remodeling influenced, especially during childhood and adolescence
Growth Hormone

- secretion high during first two hours of sleep
- can peak in response to vigorous exercise
- GH levels decline gradually with age
- average 6 ng/ml during adolescence, 1.5 ng/mg in old age

  • lack of protein synthesis contributes to aging of tissues and wrinkling of the skin
  
  • age 30, average adult body is 10% bone, 30% muscle, 20% fat
  
  • age 75, average adult body is 8% bone, 15% muscle, 40% fat
Pituitary Disorders
Growth Hormone

- Hypersecretion of growth hormone (GH)
  - Late onset / adult = acromegaly - thickening of bones and soft tissues in adults // especially hands, feet and face
  - Early onset / childhood or adolescence = gigantism

- pituitary dwarfism if hyposecretion – rare since growth hormone is now made by genetically engineered bacteria

Age 9  
Age 16  
Age 33  
Age 52
Hypothalamo-Pituitary-Target Organ Relationships

principle hormones and target organs / know these
Control of Pituitary Secretion

- rates of hormone secretions are not constant
  - regulated by hypothalamus /// other brain centers /// feedback from target organs

- Hypothalamic and Cerebral Control
  - anterior lobe control - releasing hormones and inhibiting hormones from hypothalamus
    - E.g. // in cold weather, pituitary stimulated by hypothalamus to release TSH // leads to generation of body heat /// homeostatic mechanism
Control of Pituitary Secretion

- posterior lobe control - neuroendocrine reflexes // oxytocin

  • neuroendocrine reflex - hormone release in response to nervous system signals

  • suckling infant $\rightarrow$ stimulates nerve endings $\rightarrow$ hypothalamus $\rightarrow$ posterior lobe $\rightarrow$ oxytocin $\rightarrow$ milk ejection

  • Also - hormone release in response to higher brain centers // milk ejection reflex can be triggered by a baby's cry

  • emotional stress can affect secretion of gonadotropins, disrupting ovulation, menstruation, and fertility
Control of Pituitary: Feedback from Target Organs

- **negative feedback // thyroid regulation**
  - increased target organ hormone levels inhibits release of hormones

- **positive feedback // childbirth**
  - stretching of uterus
  - increases OT release
  - causes contractions
  - causing more stretching of uterus
  - until delivery
Review of the Other Organs and Tissues of the Endocrine System
Pineal Gland

• attached to roof of third ventricle beneath the posterior end of corpus callosum

• after age 7, it undergoes involution (shrinkage)
  – down 75% by end of puberty
  – tiny mass of shrunken tissue in adults

• may synchronize physiological function with 24-hour circadian rhythms of daylight and darkness
Pineal Gland

- Pineal gland produces melatonin
  - The sad hormone
  - Synthesized from serotonin during the night. Longer nights mean more melatonin
  - Fluctuates seasonally with changes in day length. Longer nights mean more melatonin
  - May regulate timing of puberty in humans. Melatonin is also thought to be associated with female mood swings associated with menstruation
Pineal Gland

- Seasonal affective disorder (SAD)
  - occurs in winter or northern climates (too much melatonin)
  - symptoms - depression, sleepiness, irritability and carbohydrate craving
  - 2 to 3 hours of exposure to bright light each day reduces the melatonin levels and the symptoms (phototherapy)
Thymus

- thymus plays a role in three systems: endocrine, lymphatic, and immune
- bilobed gland in the mediastinum superior to the heart, goes through involution after puberty
- site of maturation of T cells important in immune defense
- secretes hormones (thymopoietin, thymosin, and thymulin) that stimulate development of other lymphatic organs and activity of T-lymphocytes
Thyroid Gland Anatomy

- largest endocrine gland
  - composed of two lobes and an isthmus below the larynx
  - dark reddish brown color due to rich blood supply
- thyroid follicles – sacs that compose most of thyroid
  - contain protein rich colloid
  - follicular cells – simple cuboidal epithelium that lines follicles
Thyroid Gland Anatomy

- **Thyroid Hormone**
  - secretes **thyroxine** ($T_4$ because of 4 iodine atoms) and **triiodothyronine** ($T_3$) – $T_4$ which is converted to $T_3$
  - increases metabolic rate, $O_2$ consumption, heat production (calorigenic effect), appetite, growth hormone secretion, alertness and quicker reflexes

- **Calcitonin Hormone**
  - **parafollicular** (C or clear) **cells** secrete calcitonin with rising blood calcium
  - stimulates osteoblast activity and bone formation
Note:
Negative Feedback Mechanism

1. TRH
2. Stimulatory effect
3. Inhibitory effect
4. Target organs
5. Negative feedback inhibition
6. Thyroid hormone
Histology of the Thyroid Gland

thyroid follicles are filled with colloid and lined with simple cuboidal epithelial cells (follicular cells).
Parathyroid Glands

- usually four glands partially embedded in posterior surface of thyroid gland
  - can be found from as high as hyoid bone to as low as aortic arch
Thyroid Gland Disorders

- **congenital hypothyroidism** (decreased TH)
  - hyposecretion present a birth (formerly cretinism)
  - If not treated results in cognitive disorders
  - treat with oral thyroid hormone

- **myxedema** (decreased TH)
  - adult hypothyroidism
  - treat with oral thyroid hormone

Myxedema: describes a specific form of cutaneous and dermal edema secondary to increased deposition of connective tissue components (like glycosaminoglycans, hyaluronic acid, and other mucopolysaccharides) in subcutaneous tissue as seen in various forms of hypothyroidism. It is more common in women than in men.
Thyroid Gland Disorders

- **Goiter**: any pathological enlargement of the thyroid gland

  - **endemic goiter**
    - dietary iodine deficiency
    - Unable to produce TH
    - Without TH / no negative feedback to stop TSH secretion
    - Continued increase in TSH stimulates hypertrophy of thyroid gland

  - **toxic goiter** (Graves disease)
    - autoantibodies mimic the effect of TSH on the thyroid causing hypersecretion
    - overgrown thyroid produces functional TH
Endemic Goiter
Graves' ophthalmopathy (a protrusion of one or both eyes), caused by inflammation of the eye muscles by attacking autoantibodies
Parathyroid Glands

- Secrete parathyroid hormone (PTH)
  - Increases blood Ca\(^{2+}\) levels
  - Promotes synthesis of calcitriol
  - Increases absorption of Ca\(^{2+}\)
  - Decreases urinary excretion
  - Increases bone resorption
Adrenal Gland

- small gland that sits on top of each kidney
- they are retroperitoneal like the kidney
- adrenal cortex and medulla formed by merger of two fetal glands with different origins and functions
Adrenal Medulla

- **adrenal medulla** – inner core, 10% to 20% of gland

- has **dual nature** / acting as an **endocrine gland** plus acting as a **sympathetic ganglion** of sympathetic nervous system
  - innervated by **sympathetic preganglionic fibers**
  - consists of modified sympathetic postganglionic neurons called **chromaffin cells**
  - when stimulated release **catecholamines** (epinephrine and norepinephrine) and a trace of **dopamine** directly into the bloodstream
Adrenal Medulla

- effect is longer lasting than effects of similar neurotransmitters release
  - increases alertness and prepares body for physical activity
    - mobilize high energy fuels ///  lactate, fatty acids, and glucose
    - glycogenolysis and gluconeogenesis both boost glucose levels
    - glucose-sparing effect ///  because inhibits insulin secretion ///  muscles use fatty acids saving glucose for brain
  - increases blood pressure, heart rate, blood flow to muscles, pulmonary air flow to alveoli and overall metabolic rate
  - decreases digestion and urine production /// maintenance type functions in favor of systems of “action”
Adrenal Cortex

- surrounds adrenal medulla and produces more than 25 steroid hormones called corticosteroids or corticoids
- secretes 5 major steroid hormones from three layers of glandular tissue
  - zona glomerulosa (thin, outer layer)
    - cells are arranged in rounded clusters
    - secretes mineralocorticoid – regulate the body’s electrolyte balance
  - zona fasciculata (thick, middle layer)
    - cells arranged in fascicles separated by capillaries
    - secretes glucocorticoids
  - zona reticularis (narrow, inner layer)
    - cells in branching network
    - secretes sex steroids
Categories of Corticosteroids

• mineralocorticoids – zona glomerulosa
  – regulate electrolyte balance /// aldosterone stimulates Na⁺ retention and K⁺ excretion, water is retained with sodium by osmosis, so blood volume and blood pressure are maintained

• glucocorticoids – zona fasciculata
  – regulate metabolism of glucose and other fuels
  – Especially important is cortisol /// stimulates fat and protein catabolism to drive gluconeogenesis (glucose from amino acids and fatty acids) and release of fatty acids and glucose into blood
  – helps body adapt to stress and repair tissues
  – anti-inflammatory effect by inhibiting antibody formation /// result in immune suppression with long-term use
Categories of Corticosteroids

- sex steroids – zona reticularis
  - androgens – sets libido throughout life; large role in prenatal male development (includes DHEA which other tissues convert to testosterone)
  - estradiol – small quantity, but important after menopause for sustaining adult bone mass; fat converts androgens into estrogen
Adrenal Gland Interactions

• medulla and cortex of adrenal gland are not functionally independent

• medulla atrophies without the stimulation of cortisol (made in cortex)

• some chromaffin cells of medullary origin extend into the cortex
  – they stimulate the cortex to secrete corticosteroids when stress activates the sympathetic nervous system
Adrenal Disorders

• Cushing syndrome - excess cortisol secretion
  – hyperglycemia, hypertension, weakness, edema
  – rapid muscle and bone loss due to protein catabolism
  – abnormal fat deposition // moon face and buffalo hump
- exocrine digestive gland and endocrine cell clusters (pancreatic islets) found retroperitoneal, inferior and posterior to stomach.
Pancreatic Hormones

- 1-2 million pancreatic islets (Islets of Langerhans) produce hormones
  - other 98% of pancreas cells produces digestive enzymes
- insulin secreted by B or beta (β) cells
  - secreted during and after meal when glucose and amino acid blood levels are rising
Pancreatic Hormones

- stimulates cells to absorb these nutrients and store or metabolize them *lowering blood glucose levels*

  - promotes synthesis glycogen, fat, and protein
  - suppresses use of already stored fuels
  - brain, liver, kidneys and RBCs absorb glucose without insulin, but other tissues require insulin

- insufficiency or inaction is cause of *diabetes mellitus*
Pancreatic Hormones

• **glucagon** – secreted by A or *alpha (α) cells*
  
  – released between meals when blood glucose concentration is falling
  
  – in liver, stimulates *gluconeogenesis* and *glycogenolysis*
  
  – the release of glucose into the circulation raising blood glucose level
  
  – in adipose tissue, stimulates fat catabolism and release of free fatty acids
  
  – glucagon also released in response to rising amino acid levels in blood /// promotes amino acid absorption, and provides cells with raw material for gluconeogenesis
Pancreatic Hormones // Other Hormones
(not on exam)

• **somatostatin** secreted by D or **delta (δ) cells**
  – partially suppresses secretion of glucagon and insulin
  – inhibits nutrient digestion and absorption which prolongs absorption of nutrients

• **pancreatic polypeptide** secreted by **PP cells or F cells**
  – inhibits gallbladder contraction and secretion pancreatic digestive enzymes

• **gastrin** secreted by **G cells**
  – stimulates stomach acid secretion, motility and emptying
Carbohydrate Regulation

• hyperglycemic hormones
  – raise blood glucose concentration
    • glucagon
    • growth hormone
    • epinephrine & norepinephrine
    • cortisol & corticosterone

• hypoglycemic hormones
  – lower blood glucose
    • insulin
Diabetes Mellitus

• most prevalent metabolic disease in the world
  – disruption of metabolism due to hypossecretion or inaction of insulin
  – revealed by elevated blood glucose, glucose in urine and ketones in the urine
  – symptoms:
    • polyuria (excess urine output)
    • polydipsia (intense thirst)
    • polyphagia (hunger)
Diabetes Mellitus

• DM causes elevated glucose blood levels

• Kidneys filter plasma which moves glucose into kidney tubules

• Under normal glucose concentrations // all filtered glucose reabsorbed back into body and no glucose is excreted in urine

• High glucose concentrations // exceed kidney’s proximal convoluted tubule transport maximum
  
  – limit to how fast the glucose transporters can work to reabsorb glucose from filtrate (urine)

  – excess glucose enters urine and water follows it // causes polyuria, dehydration, and thirst
Two Types of Diabetes Mellitus

- **Type 1** (IDDM) – 5 to 10% of cases in US
  - **Insulin** is required to treat Type 1
    - insulin injections, insulin pump, or dry insulin inhaler
    - Must monitoring blood glucose levels and diet
  - hereditary susceptibility if infected with certain viruses (rubella, cytomegalovirus)
  - Auto-antibodies attack and destroy pancreatic beta cells
Two Types of Diabetes Mellitus

- **Type 2** (NIDDM) – 90 to 95% of diabetics
  - Insulin is produced by pancreas
  - Cells throughout body become resistant to insulin // failure of target cells to respond to insulin
  - Risk factors are heredity, age (40+), obesity, and ethnicity – Native American, Hispanic, and Asian
  - Treated first with weight loss program and exercise since:
    - Loss of muscle mass causes difficulty with regulation of glycemia
    - Adipose signals interfere with glucose uptake into most cells
  - Oral medications improve insulin secretion or target cell sensitivity
Pathology of Diabetes

• pathogenesis:
  – cells cannot absorb glucose
  – must rely on fat and proteins for energy needs
  – results in weight loss and weakness

• fat catabolism increases free fatty acids and ketones in blood
  – ketonuria
    • promotes osmotic diuresis, loss of Na\(^+\) and K\(^+\); irregular heartbeat, and neurological issues
  – ketoacidosis
    • occurs as ketones decrease blood pH
    • deep, gasping breathing and diabetic coma are terminal result
Pathology of Diabetes

• chronic pathology (chronic hyperglycemia)

• leads to neuropathy and cardiovascular damage from atherosclerosis and microvascular disease
  – arterial damage in retina and kidneys (common in type I)
  – atherosclerosis leads to heart failure (common in type II)
  – diabetic neuropathy – nerve damage from impoverished blood flow can lead to erectile dysfunction, incontinence, poor wound healing, and loss of sensation from area
The Gonads

- Ovaries and testes are both endocrine and exocrine glands
  - Exocrine product – whole cells - eggs and sperm (cytogenic glands)
  - Endocrine product - gonadal hormones – mostly steroids

- Ovarian hormones (female ovaries)
  - Estradiol, progesterone, and inhibin

- Testicular hormones (male testes)
  - Testosterone, weaker androgens, estrogen and inhibin
Histology of Ovary

(a) Follicle - egg surrounded by granulosa cells and a capsule (theca)

(b) Testis

- Blood vessels
- Seminiferous tubule
- Germ cells
- Connective tissue wall of tubule
- Sustentacular cells
- Interstitial cells (source of testosterone)
Ovary

- theca cells synthesize androstenedione
  - converted to mainly estradiol by theca and granulosa cells
  - functions of estradiol and progesterone
    - development of female reproductive system and physique including adolescent bone growth
    - regulate menstrual cycle, sustain pregnancy
    - prepare mammary glands for lactation
Ovary

- anterior pituitary after ovulation // the remains of the follicle becomes the corpus luteum
  - secretes progesterone for 12 days following ovulation
  - Follicular cells and corpus luteum also secrete inhibin
    - inhibin suppresses FSH secretion from
After ovulation, the corpus luteum produces progesterone and inhibin. Inhibin’s negative feedback on the anterior pituitary stops FSH secretion so another follicle does not mature.

LH secretion continues.

LH stimulates the corpus luteum (CL) to produce progesterone which maintains the endometrium.
Testes

- microscopic **seminiferous tubules** produce sperm
  - tubule walls contain sustentacular (Sertoli) cells
  - Leydig cells (interstitial cells) lie in clusters between tubules
Testes

- **testicular hormones**
  - **testosterone** and other steroids from interstitial cells (cells of Leydig) nestled between the tubules
    - stimulates development of male reproductive system in fetus and adolescent, and sex drive
    - sustains sperm production
  - **inhibin** from sustentacular (Sertoli) cells
    - limits FSH secretion in order to regulate sperm production
1. GnRH from hypothalamus stimulates the anterior pituitary to secrete FSH and LH.

2. FSH stimulates sustentacular cells to secrete androgen-binding protein (ABP).

3. LH stimulates interstitial cells to secrete testosterone (androgen).

4. In the presence of ABP, testosterone stimulates spermatogenesis.

5. Testosterone also stimulates the libido and the development of secondary sex organs and characteristics.

6. Testosterone has negative feedback effects that reduce GnRH secretion and pituitary sensitivity to GnRH.

7. Sustentacular cells also secrete inhibin, which selectively inhibits FSH secretion and thus reduces sperm production without reducing testosterone secretion.

Key:
- Green arrows: Stimulation
- Red arrows: Inhibition
Endocrine Functions of Other Organs

• Skin

  - keratinocytes convert a cholesterol-like steroid into cholecalciferol using UV from sun

  - This molecule is eventually converted to Vitamin D / the sunshine hormone!
Endocrine Functions of Other Organs

- Liver
  - involved in the production of at least five hormones
  - converts cholecalciferol into calcidiol (pro Vitamin D)
  - secretes angiotensinogen (a prohormone)
    - precursor of angiotensin II (a regulator of blood pressure)
  - secretes 15% of erythropoietin (stimulates bone marrow)
  - hepcidin – promotes intestinal absorption of iron
  - source of IGF-I that controls action of growth hormone
Endocrine Functions of Other Organs

- Kidneys

  - plays role in production of three hormones

    - converts calcidiol to calcitriol, the active form of vitamin D /// increases Ca\(^{2+}\) absorption by intestine and inhibits loss in the urine

    - secrete renin that converts angiotensinogen to angiotensin I

      - enzyme in lungs (angiotensin converting enzyme) converts angiotensin I into angiotensin II / the active form

      - Angiotensin II constricts blood vessels and raises blood pressure
Endocrine Functions of Other Organs

• Kidneys (cont)
  – erythropoietin
    • produces 85% of this hormone (liver produces other 15%)
    • stimulates bone marrow to produce RBCs
Endocrine Functions of Other Organs

• Heart
  – cardiac muscle secretes atrial and brain natriuretic peptides (ANP and BNP) in response to an increase in blood pressure
  – decreases blood volume and blood pressure by increasing Na\(^+\) and H\(_2\)O output by kidneys – opposes action of angiotensin II
  – lowers blood pressure

• Stomach and small intestine secrete at least ten enteric hormones secreted by enteroendocrine cells
  – coordinate digestive motility and glandular secretion
  – cholecystokinin, gastrin, Ghrelin, and peptide YY
Endocrine Functions of Other Organs

- **Adipose tissue** secretes leptin /// slows appetite

- **Osseous tissue** – osteocalcin secreted by osteoblasts
  - increases number of pancreatic beta cells, pancreatic output of insulin, and insulin sensitivity of other body tissues
  - inhibits weight gain and onset of type II diabetes mellitus

- **Placenta**
  - secretes estrogen, progesterone and others
  - regulate pregnancy, stimulate development of fetus and mammary glands