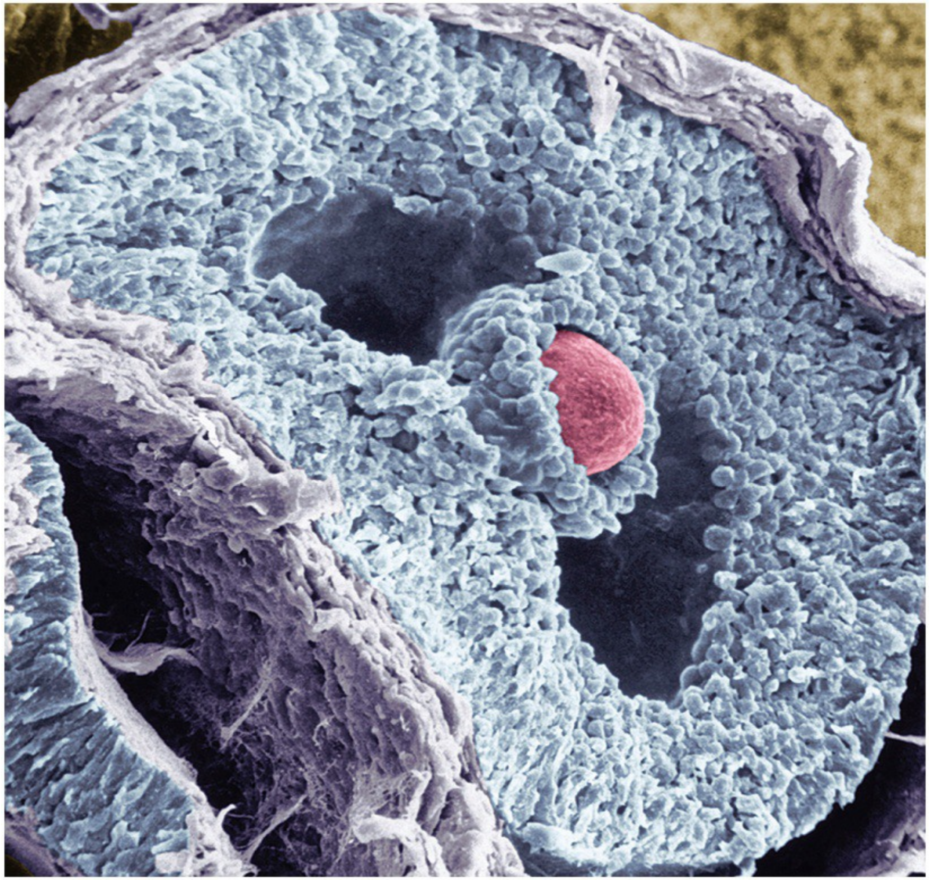
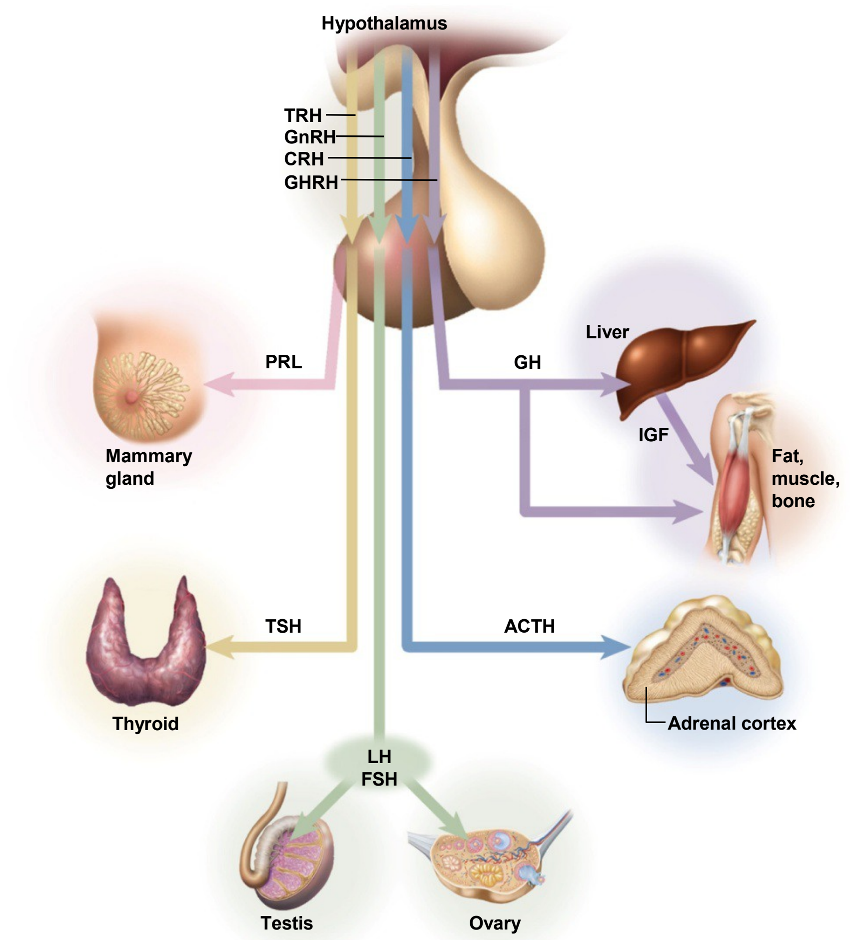
Chapter 17

Review of Endocrine Hormones

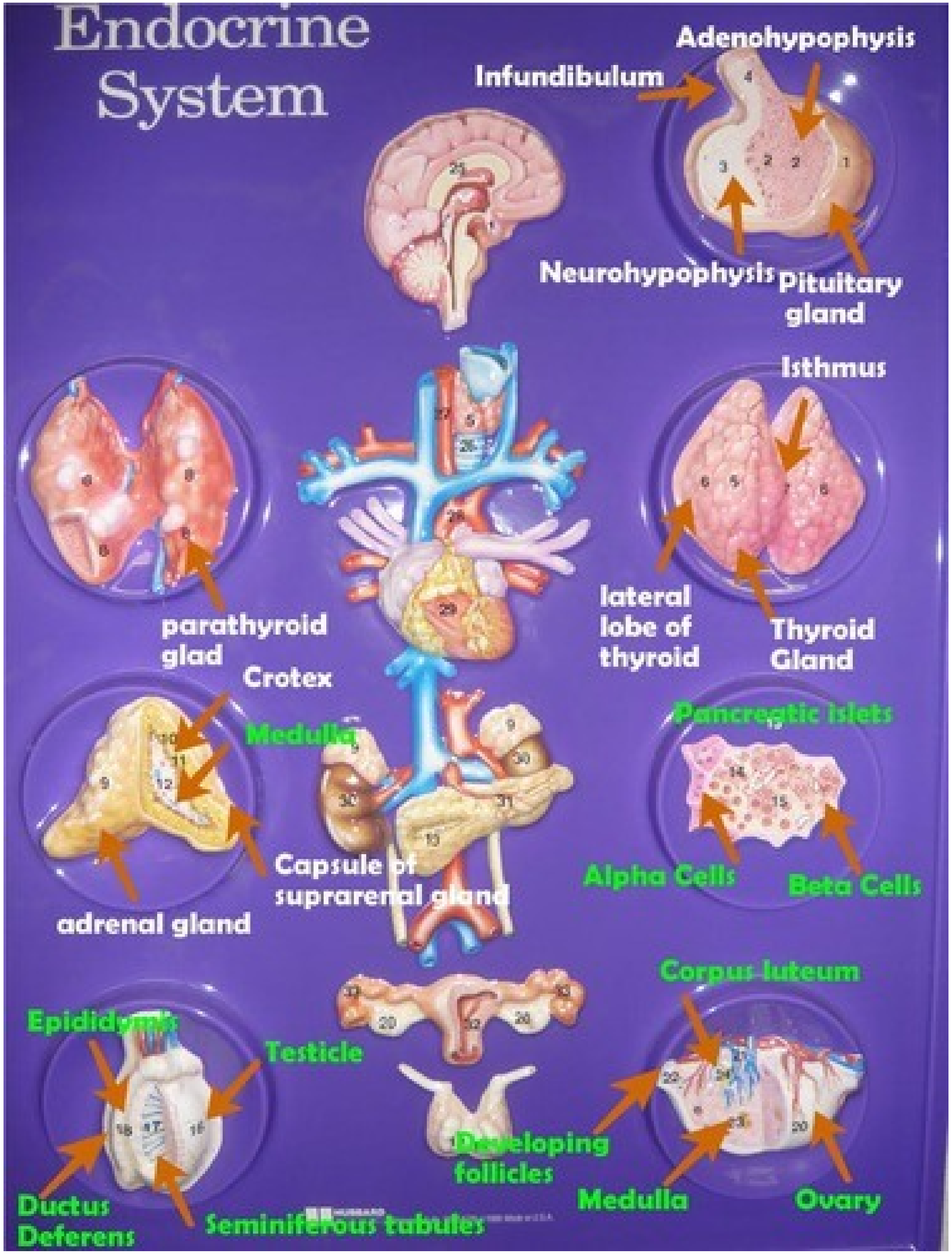
(Origin / Target Tissues / Effect)



Hypothalamo-Pituitary Hormones and Their Target Organ



Know these hormones, target tissue, and how hormone changes metabolism of target cells.


Endocrine System
Adenohypophysis
Infundibulum
Neurohypophysis
Pituitary gland
Isthmus
parathyroid glad
lateral lobe of thyroid
Thyroid Gland
Crotex
Medulla
Pancreatic islets
Capsule of suprarenal gland
adrenal gland
Alpha Cells
Beta Cells
Corpus luteum
Epididymis
Testicle
Developing follicles
Ductus Deferens
Seminiferous tubules
Medulla
Ovary

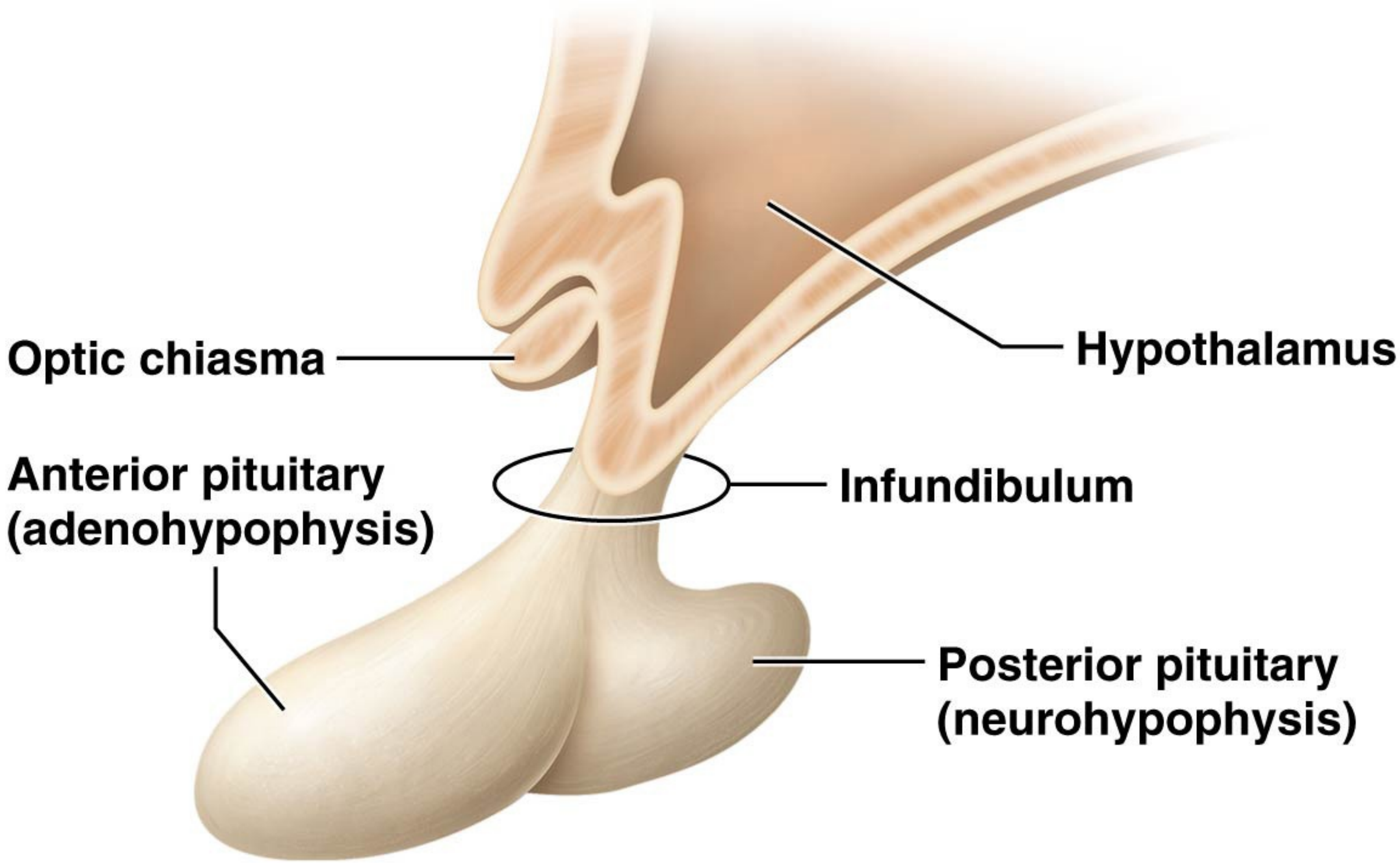
Hypothalamic Hormones

- Eight hormones are released from the hypothalamus
  - six hypothalamus “releasing or inhibiting” hormones regulate the synthesis of anterior pituitary hormones /// these hypothalamus hormones are called inhibiting or releasing hormones
  - two hypothalamus hormones are synthesized in the hypothalamus and released from the posterior pituitary
- Hypothalamic hormones stimulate or inhibit the release of anterior pituitary hormones
  - Thyroid Releasing Hormone (TRH), Corticotropin Releasing Hormone (CRH), Gonadaltropin Releasing Hormone (GnRH), and Growth Hormone Releasing Hormone (GHRH) // these hormones target the anterior pituitary to cause the release of TSH, PRL, ACTH, FSH, LH, and GH
  - PIH inhibits secretion of prolactin
  - Somatostatin inhibits secretion growth hormone & thyroid stimulating hormone by the anterior pituitary (see Table 17.3)

Why is the Pituitary Gland Called the *Master Endocrine Gland?*

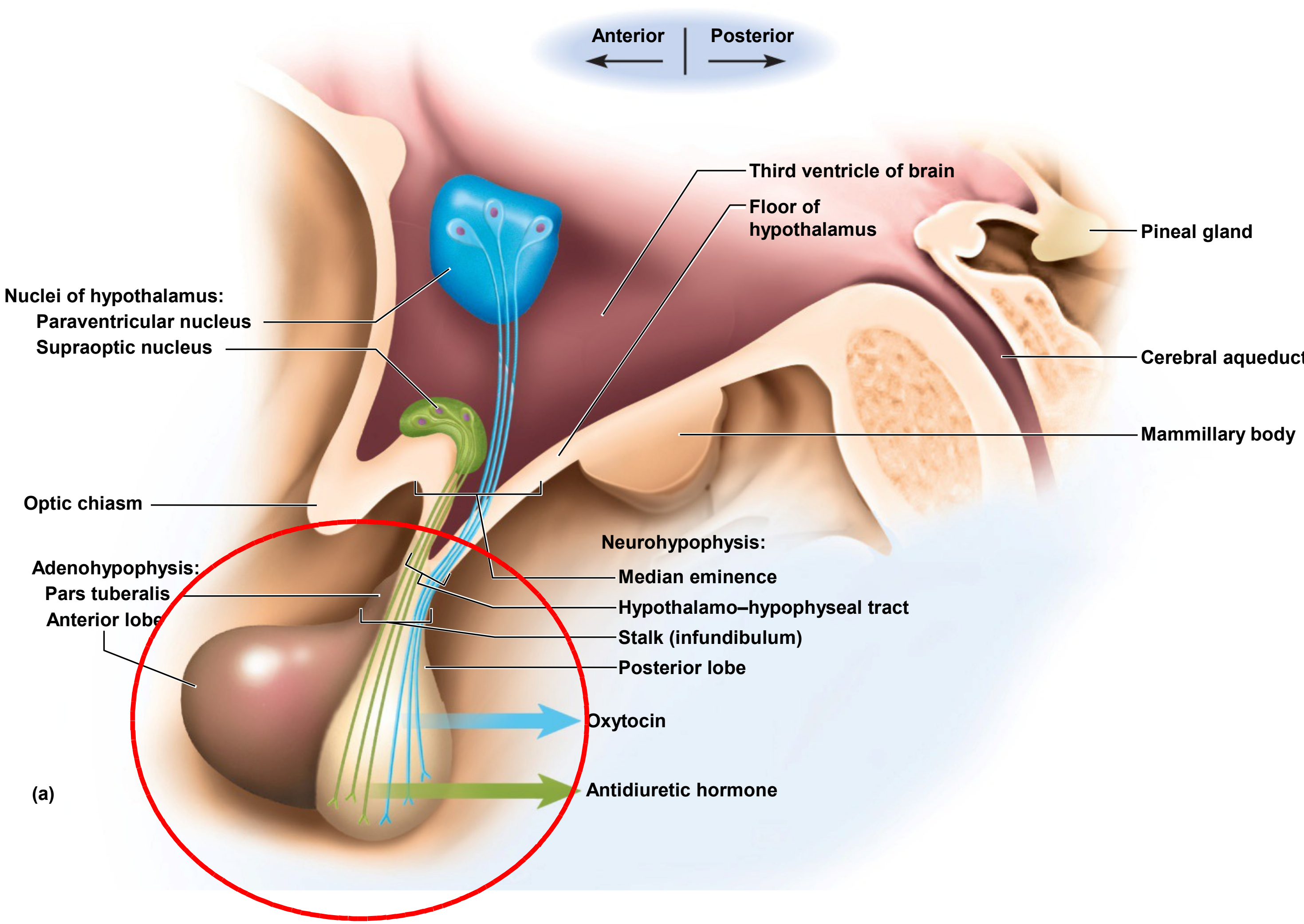
- Because the pituitary produces many different hormones with target tissue located throughout the body.
- Many of the pituitary hormones regulate the secretion of other endocrine glands located throughout the body which then secrete even more hormones.
- Pituitary gland (also called the hypophysis) is suspended from the hypothalamus by a stalk of tissue called the infundibulum
- Pituitary is located in sella turcica of sphenoid bone // size and shape of kidney bean
- Pituitary composed of two histologically different tissue structures with independent origins and separate functions
  - adenohypophysis (anterior pituitary) // arises from hypophyseal pouch (outgrowth of pharynx / epithelial tissue)
  - neurohypophysis (posterior pituitary) // downward growth from brain (nervous tissue)

Structure of the hypothalamus and pituitary gland.



(b) Structure of hypothalamus, and anterior and posterior pituitary glands

Pituitary Gland

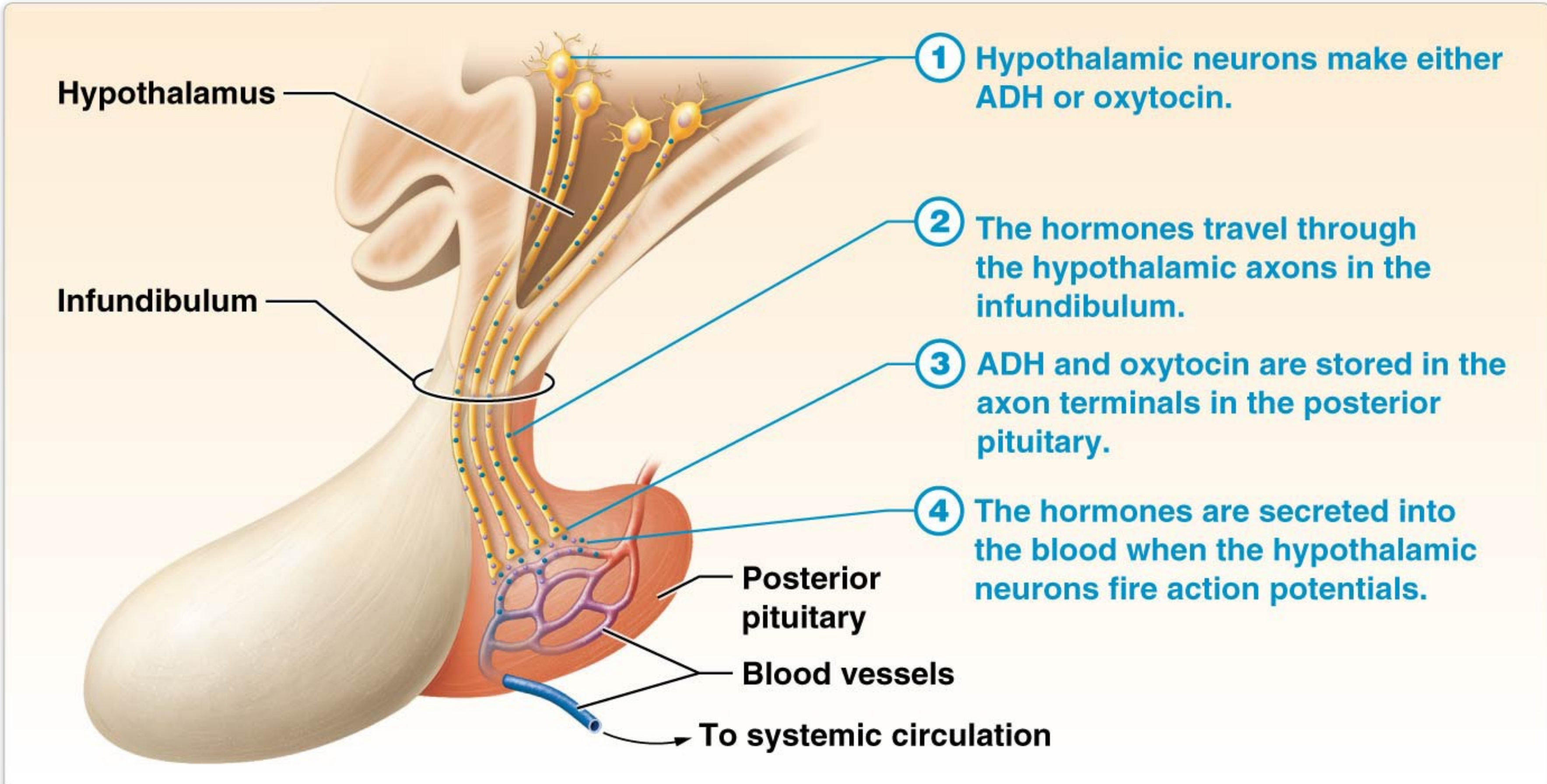


(a)

Anatomy and Function of Hypothalamus

- Shaped like a flattened funnel // area between opitic chiasma and mammillary bodies
- Forms floor and walls for the third ventricle of the brain
- Regulates functions of the body that are more "advanced" than the "medulla oblongata" funcitons
- Functions like water balance, thermoregulation, sexual cycles, childbirth
- Functions are regulated by hormones secreted by the hypothalamus
- Hormones released by the hypothalamus regulate the release of other hormones from the anterior pituitary gland into the blood
- The hypothalamus hormones may inhibit or cause the release of the anterior pituitary hormones

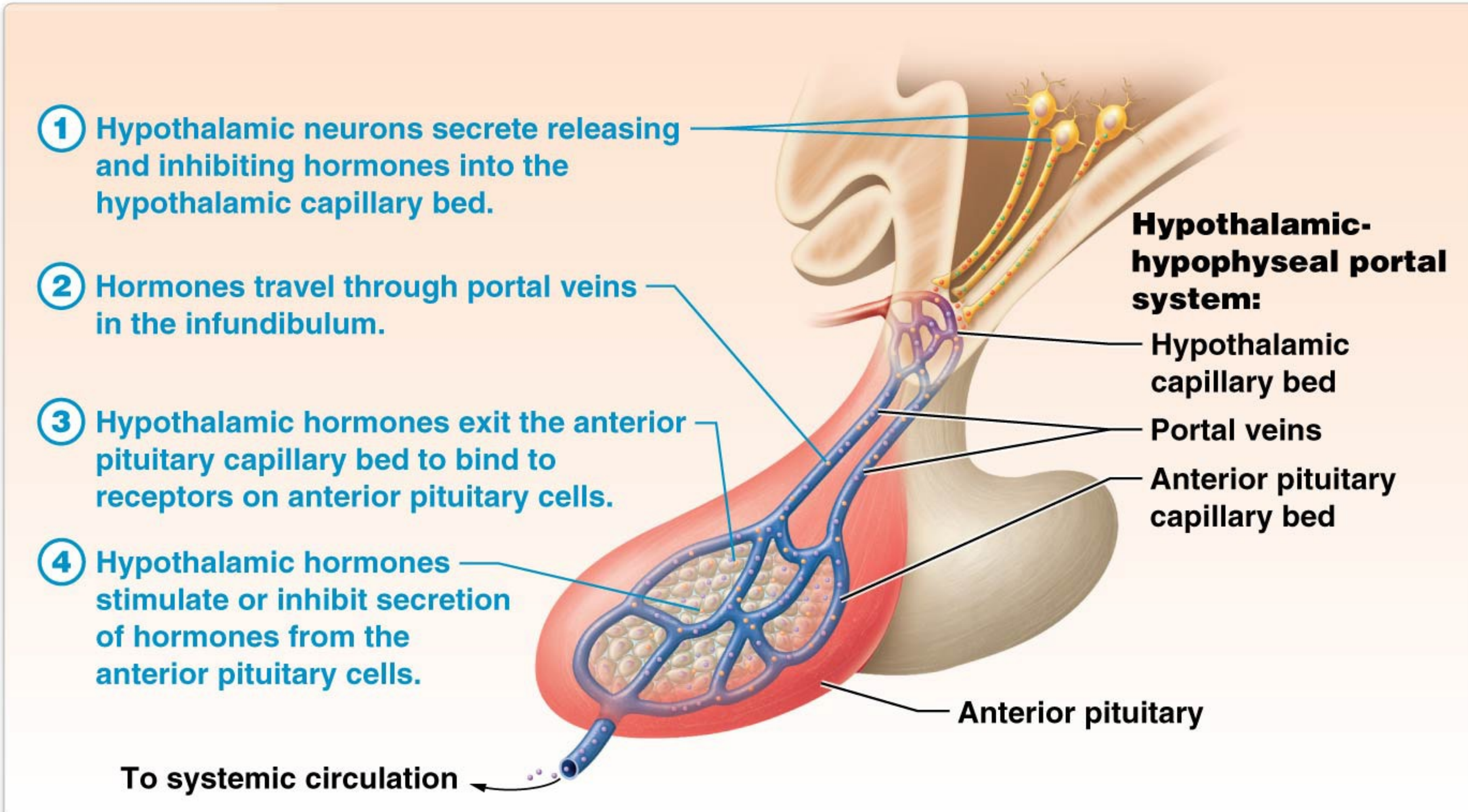
Functional relationships between the hypothalamus and posterior pituitary gland.



(a) Relationship between the hypothalamus and posterior pituitary

Hypothalamo–hypophyseal tract

Functional relationships between the hypothalamus and anterior pituitary gland.



(b) Relationship between the hypothalamus and anterior pituitary

Hypophyseal portal system

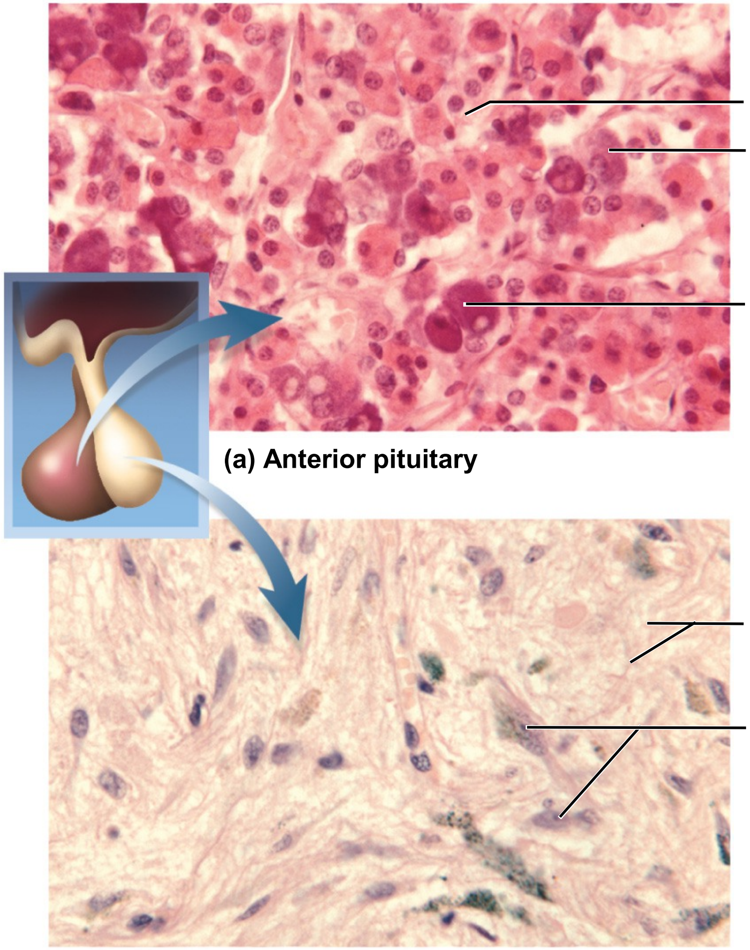
Adenohypophysis & Neurohypophysis

- 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

Adenohypophysis & Neurohypophysis

- 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 tissue
    - nerve cell's soma is in hypothalamus and passes down the stalk its axon as hypothalamo-hypophyseal tract which terminates in posterior lobe
    - hypothalamic neurons secrete hormones that are stored in neurohypophysis until the hormones are released into blood

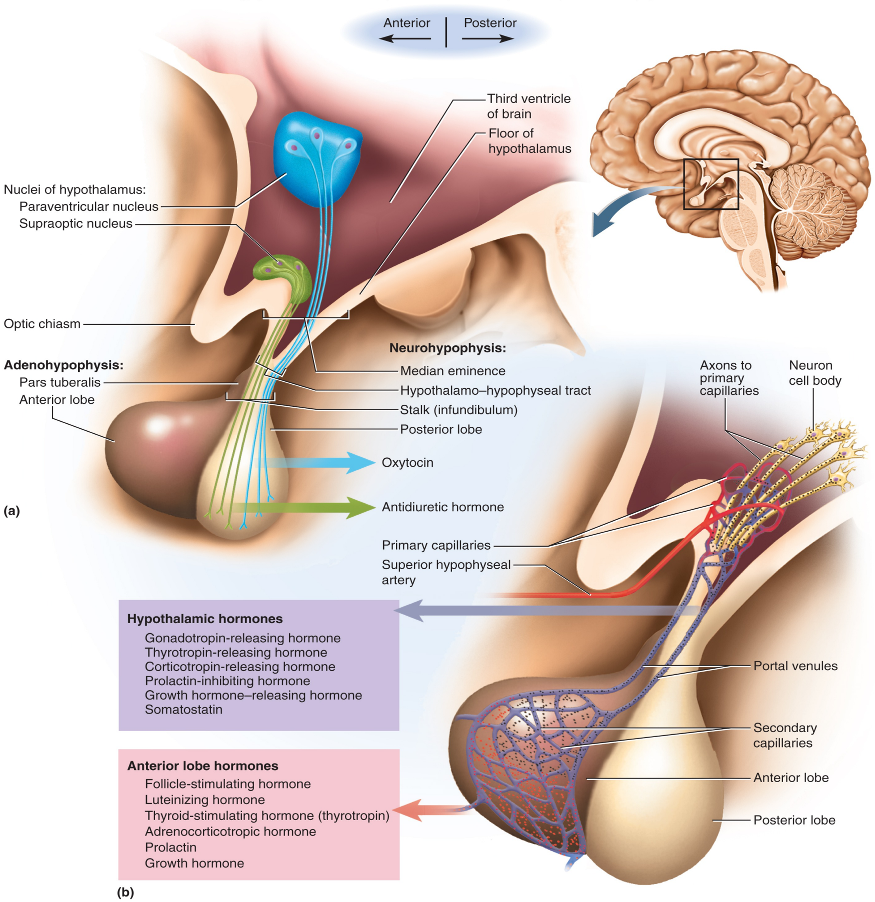
Histology of Pituitary Gland



(a) Anterior pituitary

(b) Posterior pituitary

Posterior Pituitary Hormones



- Oxytocin
- Antidiuretic Hormone

Hypothalamic Hormones Released From the Posterior Pituitary Gland

- These hormones are synthesized in hypothalamus, stored in posterior pituitary, and released upon nerve signal from the 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 these hormones but only stores them for future use

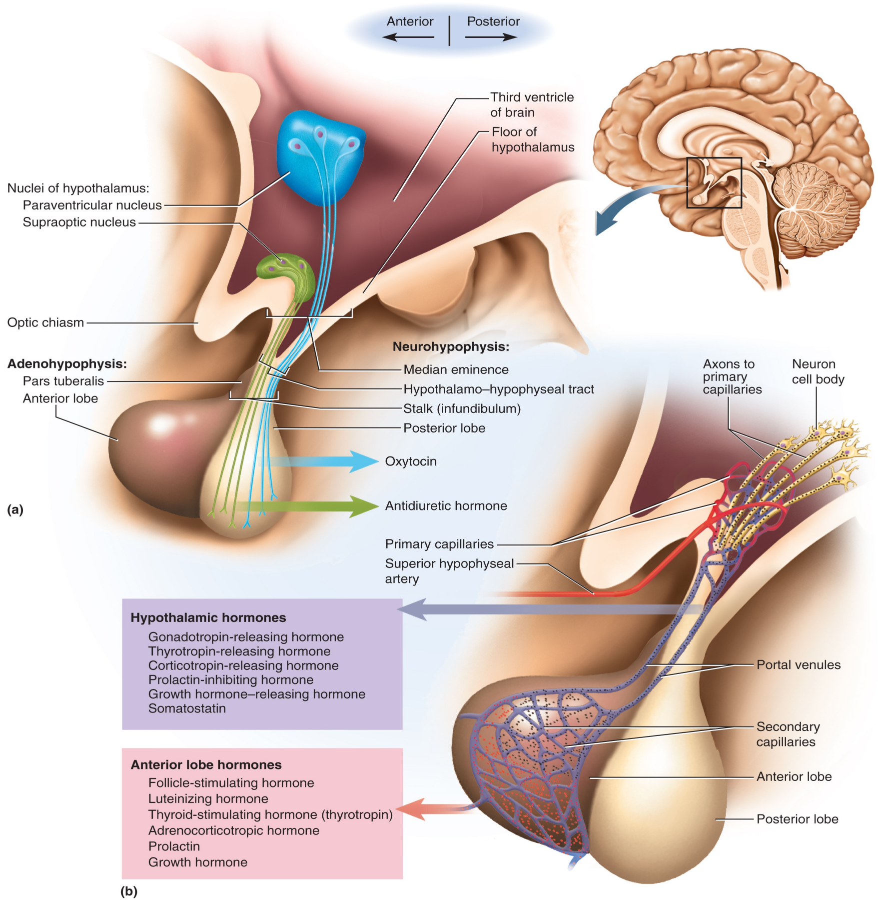
Hypothalamic Hormones

- ADH (antidiuretic hormone)
  - increases water retention thus reducing urine volume and prevents dehydration
  - also called vasopressin because it can cause vasoconstriction

Hypothalamic Hormones

- 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 you and your pet as you "pet your pet"*

Anterior Pituitary Hormones



- Follicle stimulating hormone
- Lutenizing hormone
- Thyroid stimulating hormone
- Adrenocoricotropic hormone
- Prolactin
- Growth hormone

Anterior Pituitary 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
    - 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

About Growth Hormone

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

- 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

Growth Hormone

- GH Regulates:
  - GH has different short term and long term effect.
  - Protein synthesis increases -- boosts transcription of DNA, production of mRNA
  - Amino acid uptake into cells /// suppresses protein catabolism
  - Lipid catabolism increased /// shifts metabolism towards fat catabolism by adipocytes – provides energy for growth
  - Initial increase than a decrease in blood glucose concentration
  - Protein-sparing effect

Growth Hormone

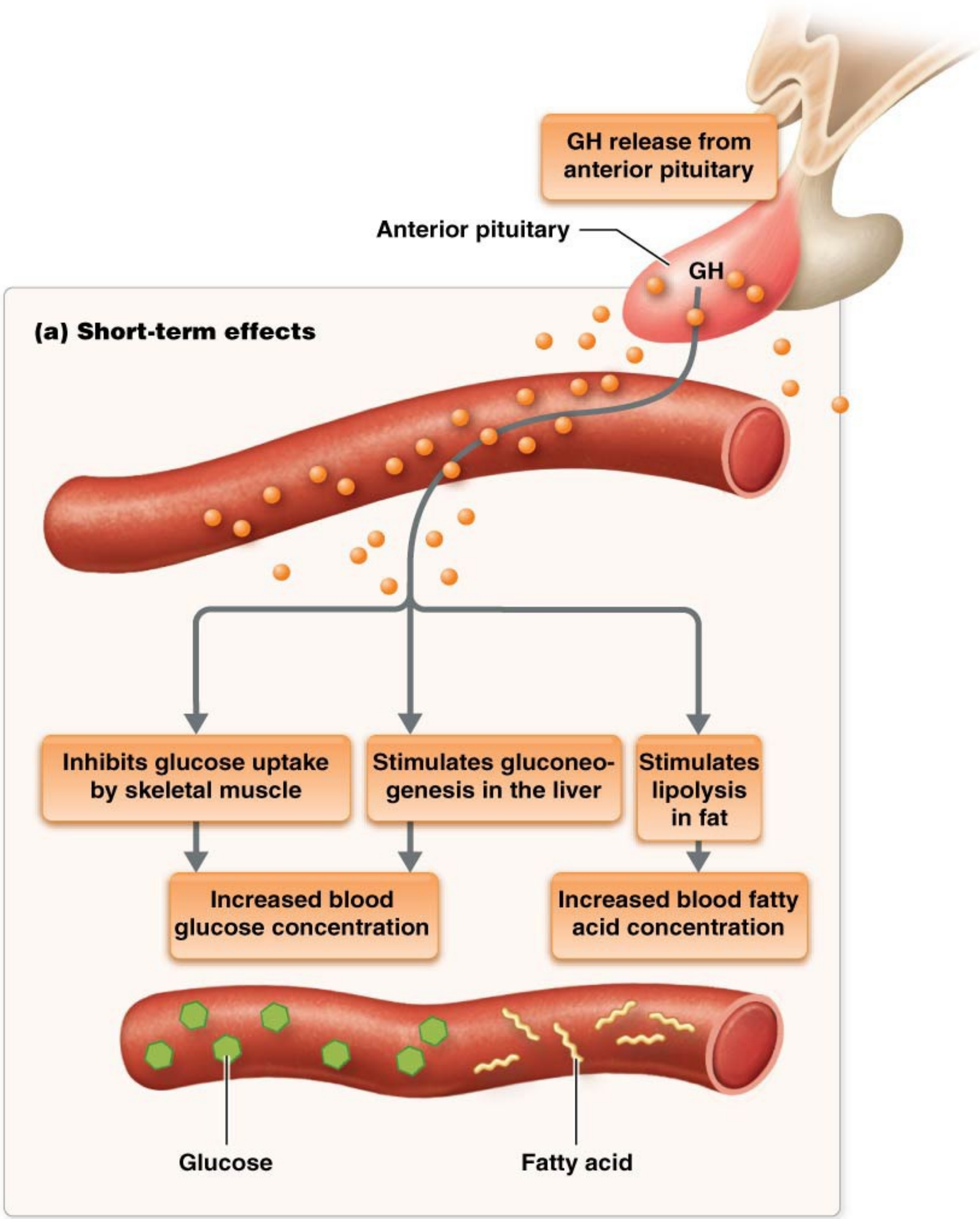
- Carbohydrate metabolism – by mobilizing fatty acids for energy, GH functions as a glucose-sparing hormone // makes glucose available for glycogen synthesis and storage

- Electrolyte balance – promotes Na^+, K^+, & Cl^- retention by kidneys, enhances Ca^{+2} absorption in intestine

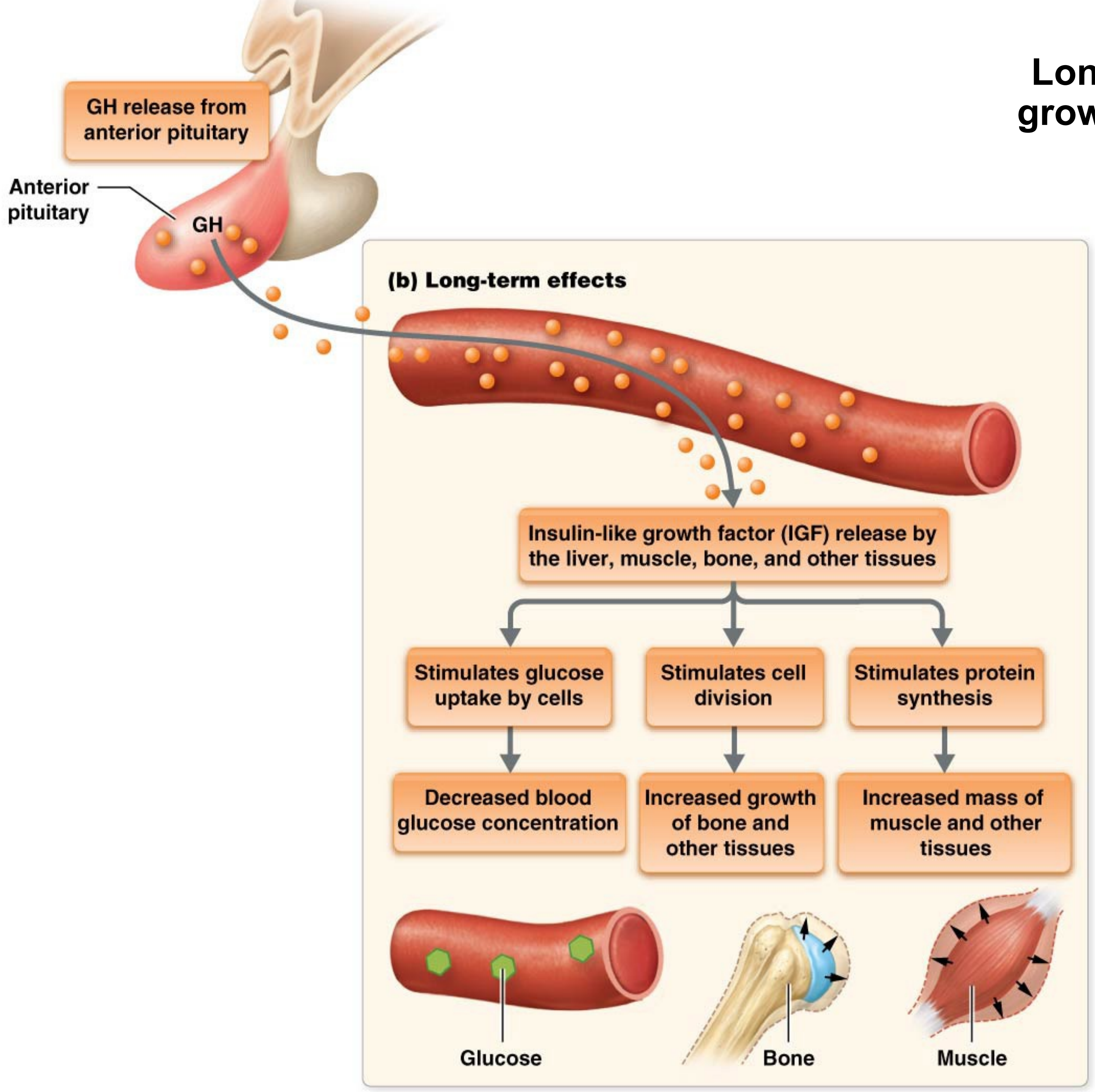
- Bone growth - thickening and remodeling influenced, especially during childhood and adolescence

- How will GH “reshape” appearance of body when GH taken as a supplement?

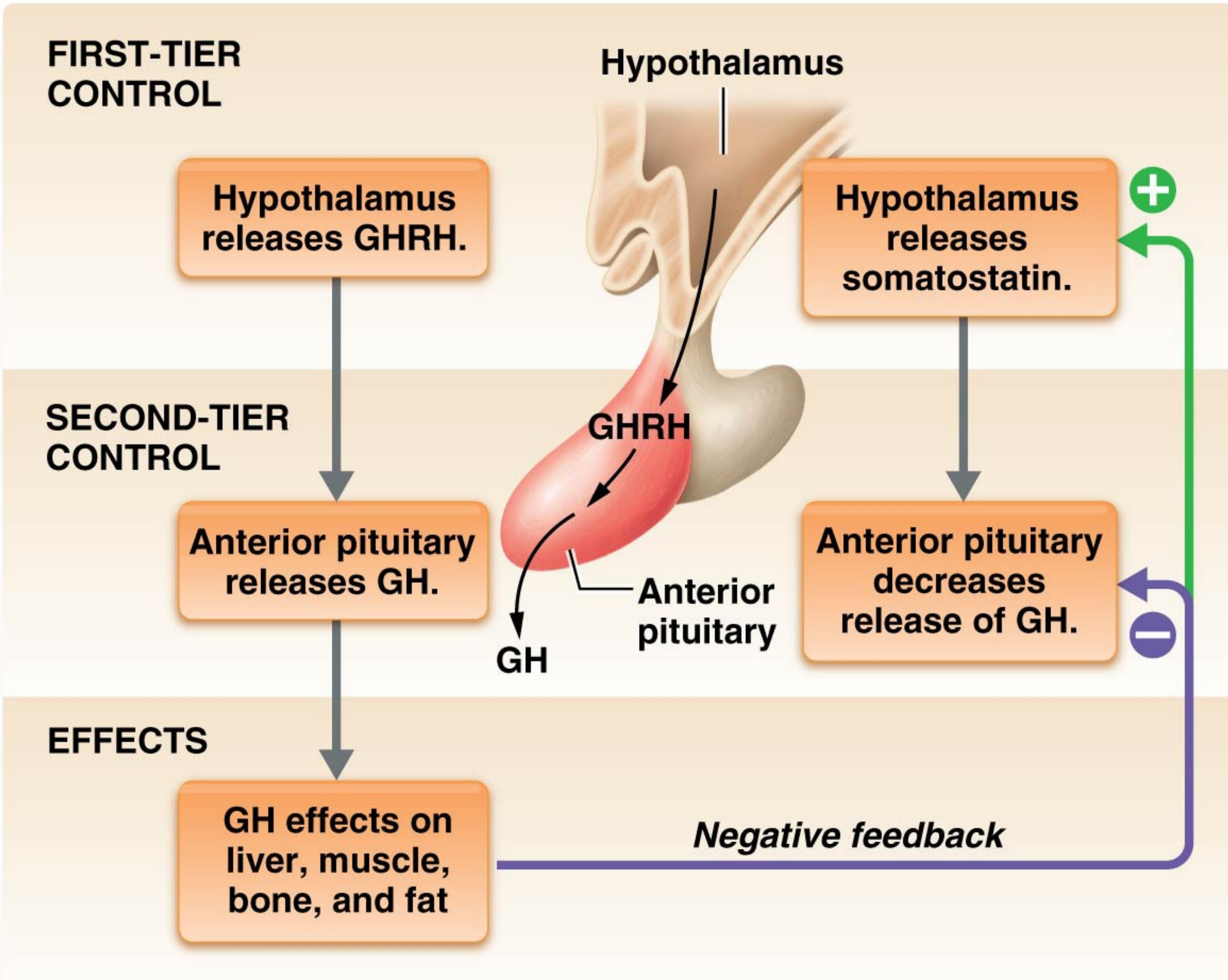
Short term effects of growth hormone (GH)



Long term effects of growth hormone (GH)



The regulation of growth hormone (GH) release.



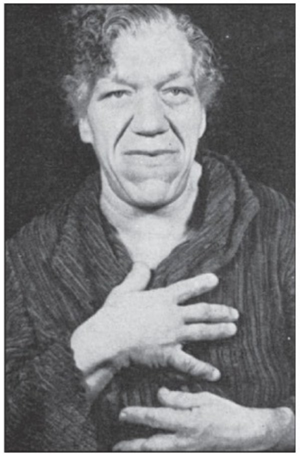
Pituitary Growth Hormone Disorders

- Hyper secretion of growth hormone (GH)
  - Late onset in adult = acromegaly - thickening of bones and soft tissues // especially in hands, feet and face
  - Early onset / childhood or adolescence = gigantism
- Hyposecretion of GH // Pituitary dwarfism - rare today since growth hormone is now made by genetically engineered bacteria

Age 9

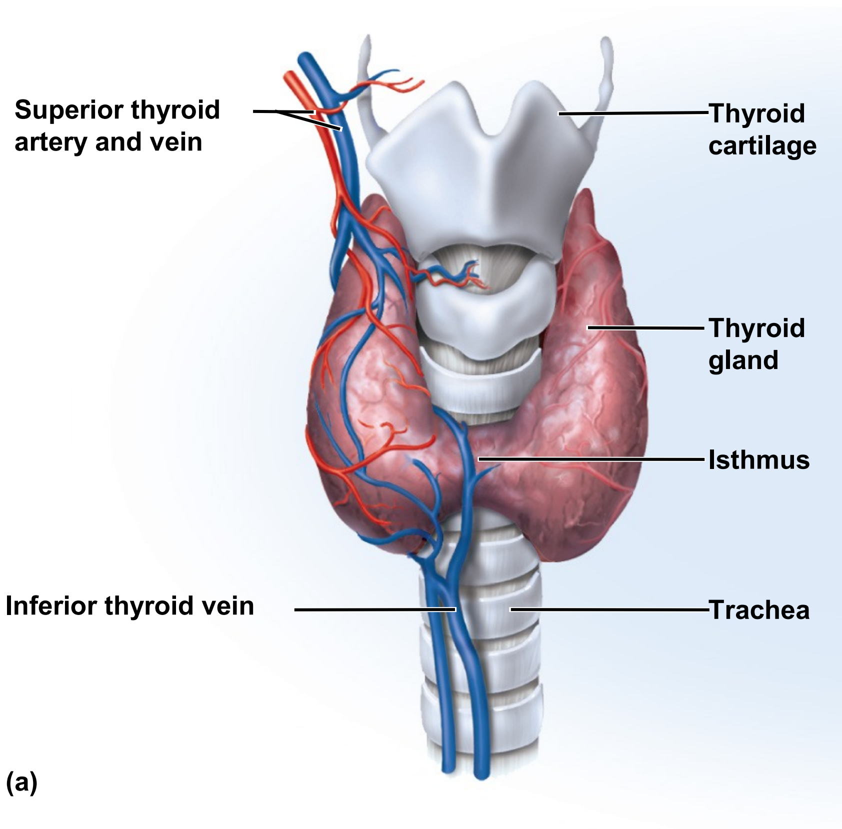
Age 16

Age 33



Age 52

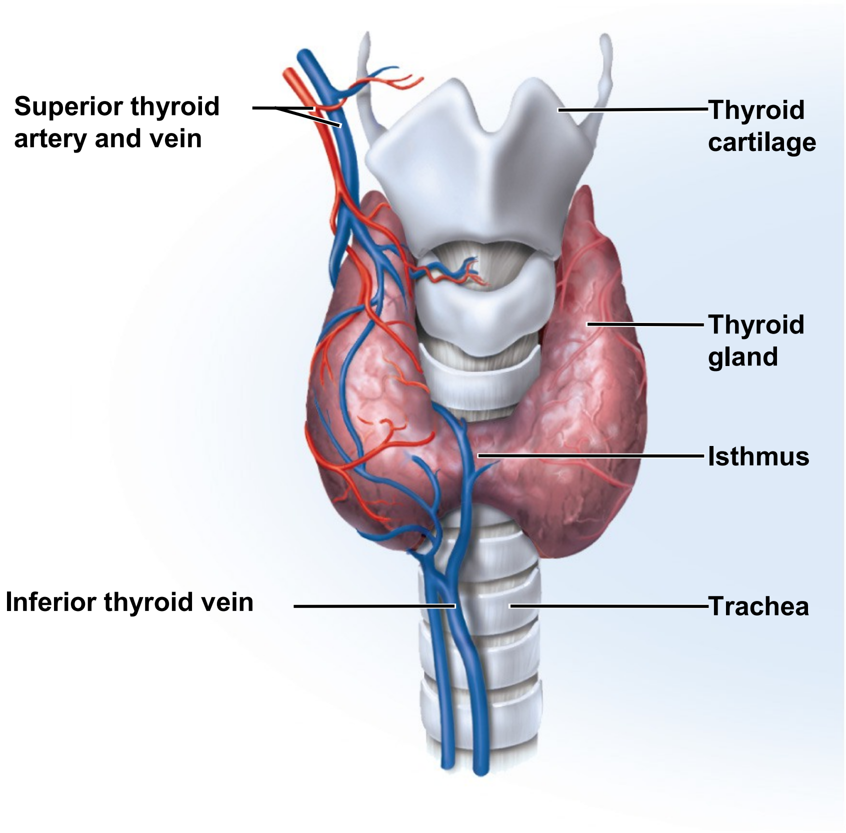
Thyroid Gland Anatomy



- 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 store most of thyroid
  - contain protein rich colloid
  - follicular cells – simple cuboidal epithelium that lines follicles

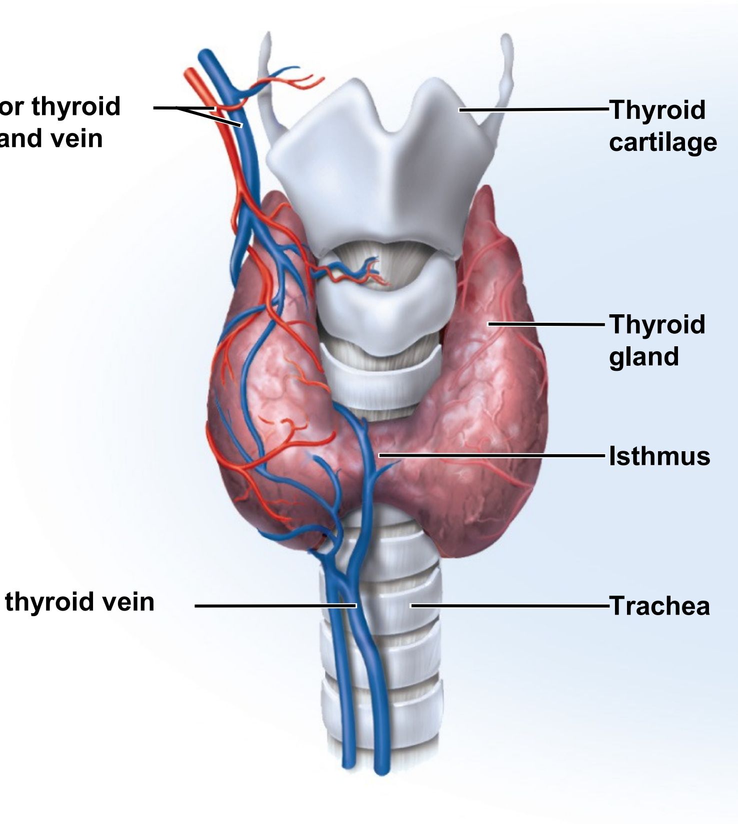
Three hormones secreted from the gland // thyroid hormone, parathyroid hormone, and calcitonin.

Thyroid Gland Anatomy



- Thyroid Hormone
  - secretes **thyroxine** (T_4 because of 4 iodine atoms) and **triiodothyronine** (T_3) – (T_4 is converted to T_3)
  - <u>increases metabolic rate, O_2 consumption, heat production (**calorigenic effect**), appetite, growth hormone secretion, alertness and quicker reflexes</u>
- Calcitonin Hormone
  - **parafollicular cells** (C cells) secrete calcitonin if blood calcium increases // stimulates bone growth moving calcium from blood to make more bone matrix
  - stimulates osteoblast activity and new bone formation

Thyroid Gland Anatomy



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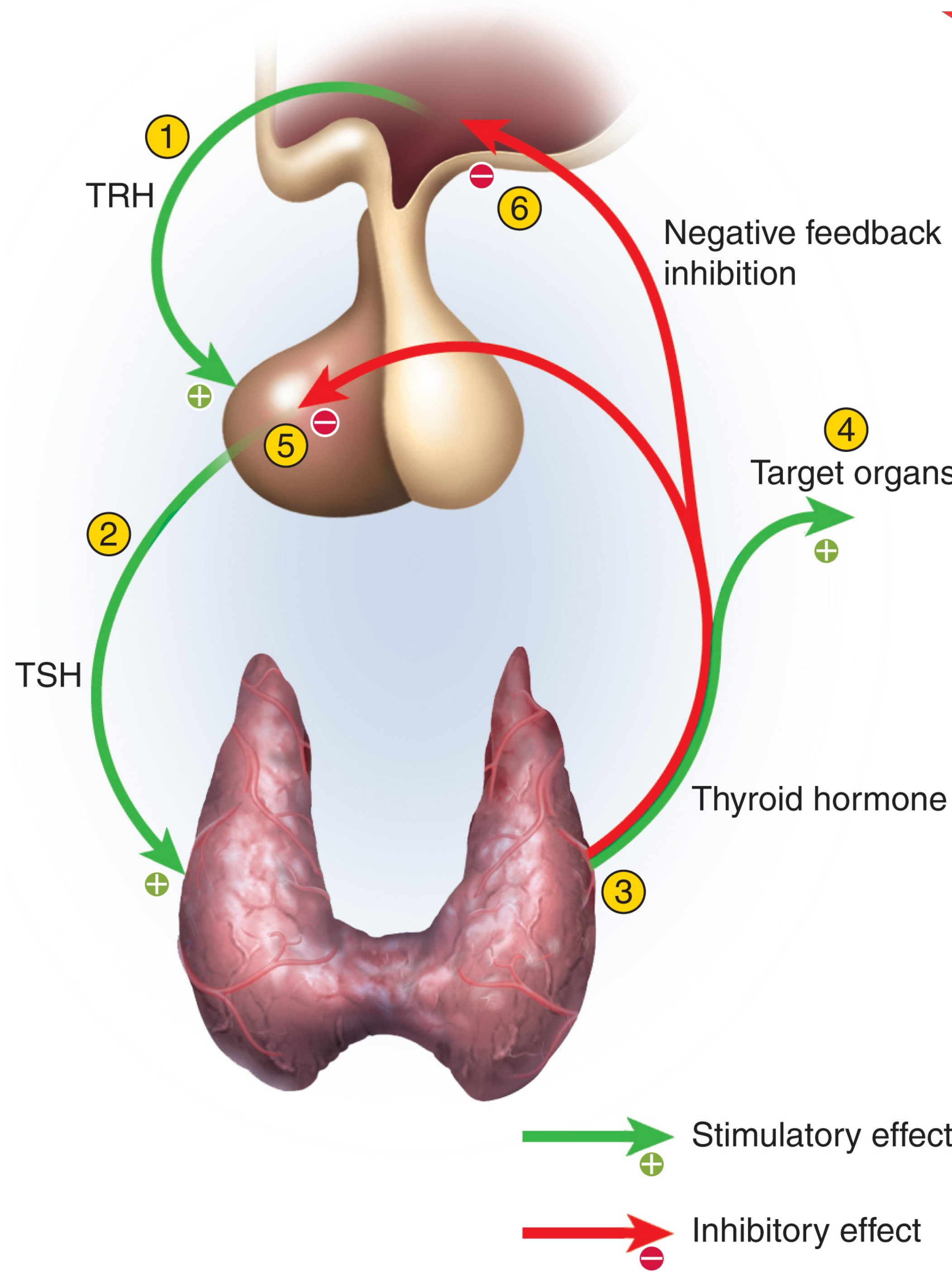
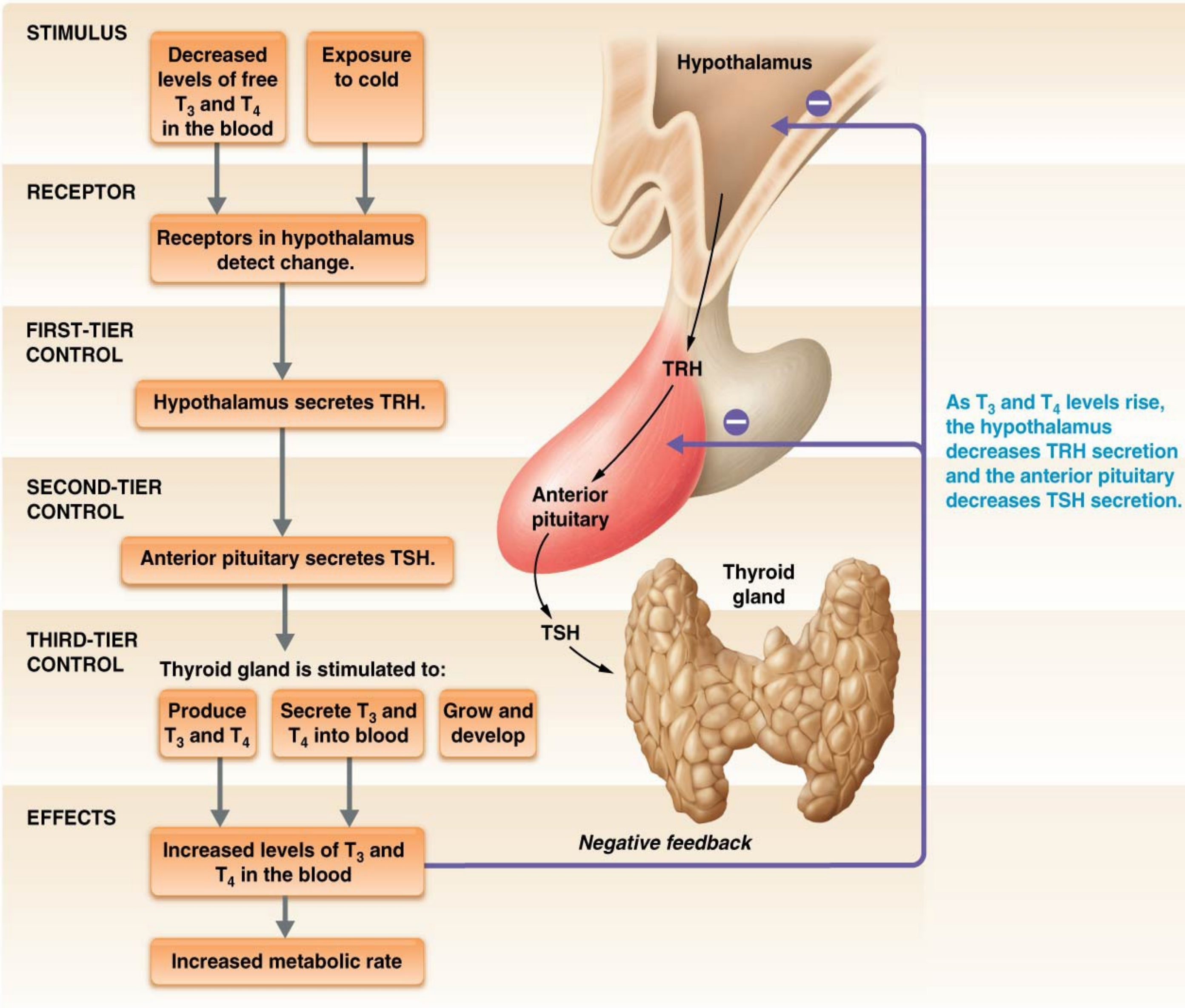
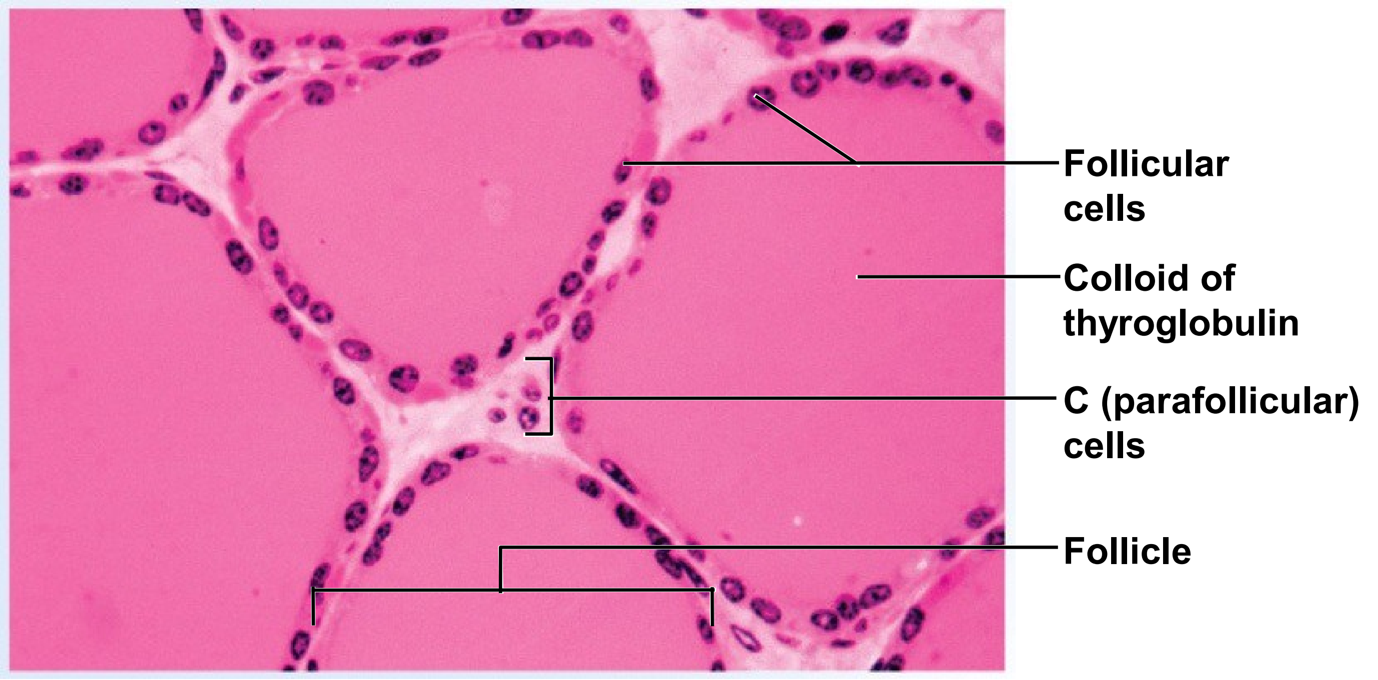
Negative Feedback Mechanism



Maintaining homeostasis: regulation of thyroid hormone production by a negative feedback loop.

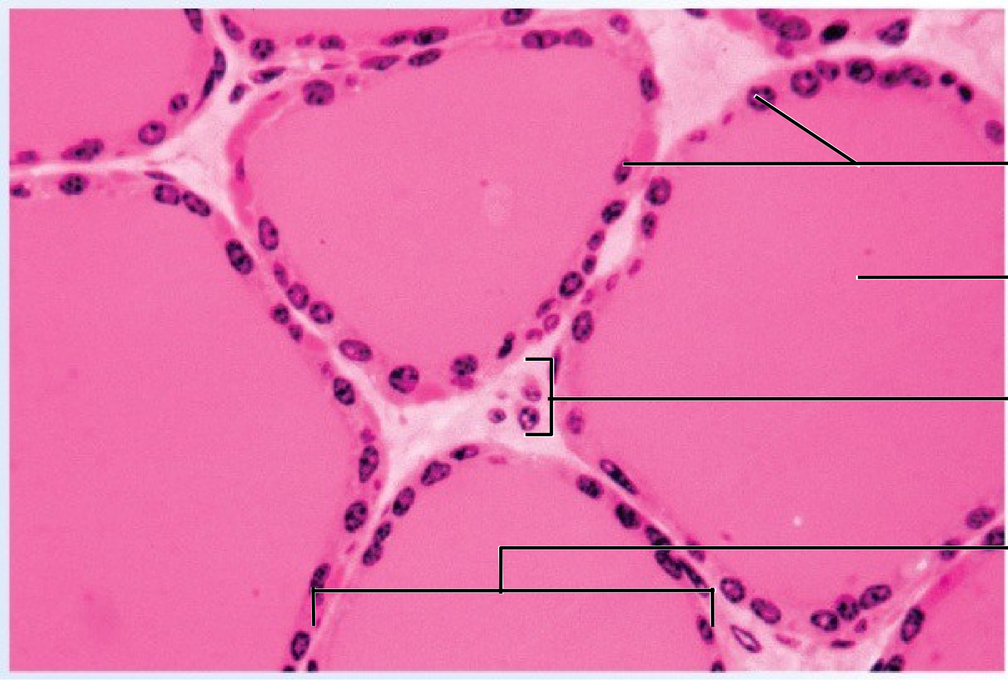


Histology of the Thyroid Gland



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

Calcitonin

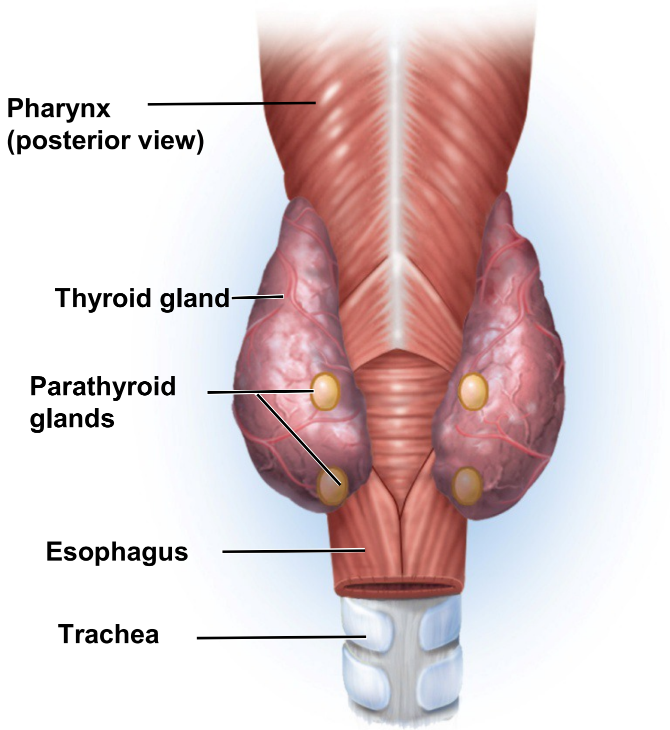


C cells produce calcitonin when blood calcium levels are high.

Calcitonin reduces blood calcium levels by stimulating osteoblasts // use blood calcium to make new bone.

Parathyroid Glands

- 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
- Secretes parathyroid hormone when blood calcium is low
- Stimulate osteoclast activity
- PG secretes parathyroid hormone // target osteoclasts // increase Ca ions in blood



(a)

Parathyroid Glands

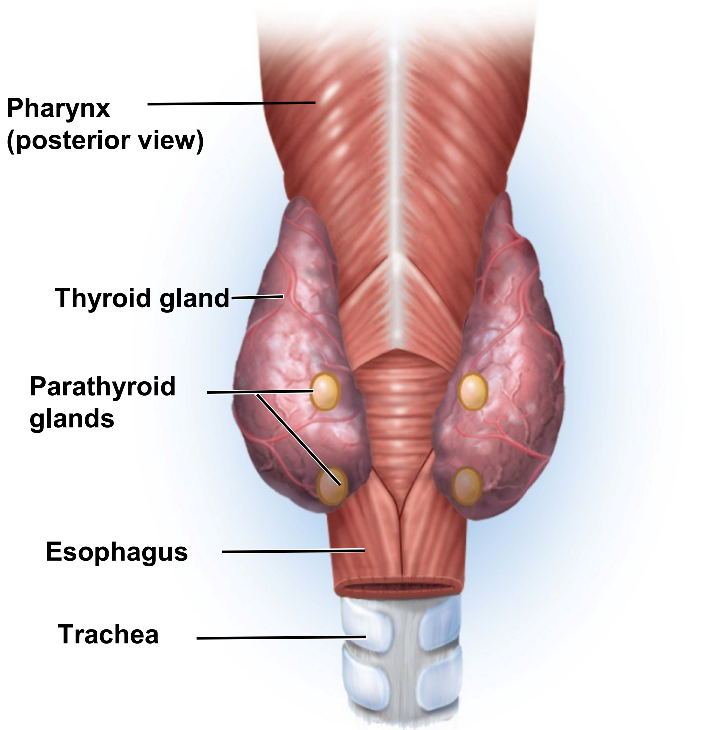
Secrete parathyroid hormone (PTH)

Increases blood Ca^{2+} levels

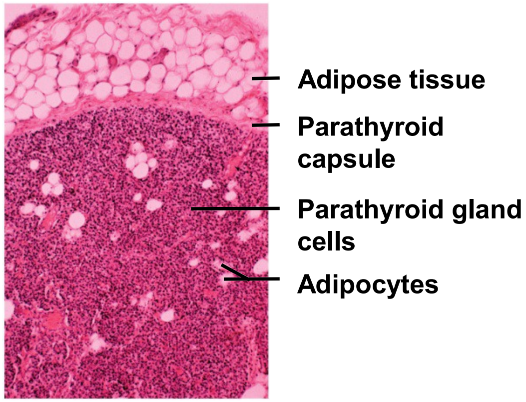
Promotes synthesis of calcitriol (vitamin D) /// increases absorption of Ca^{2+}

Decreases urinary excretion

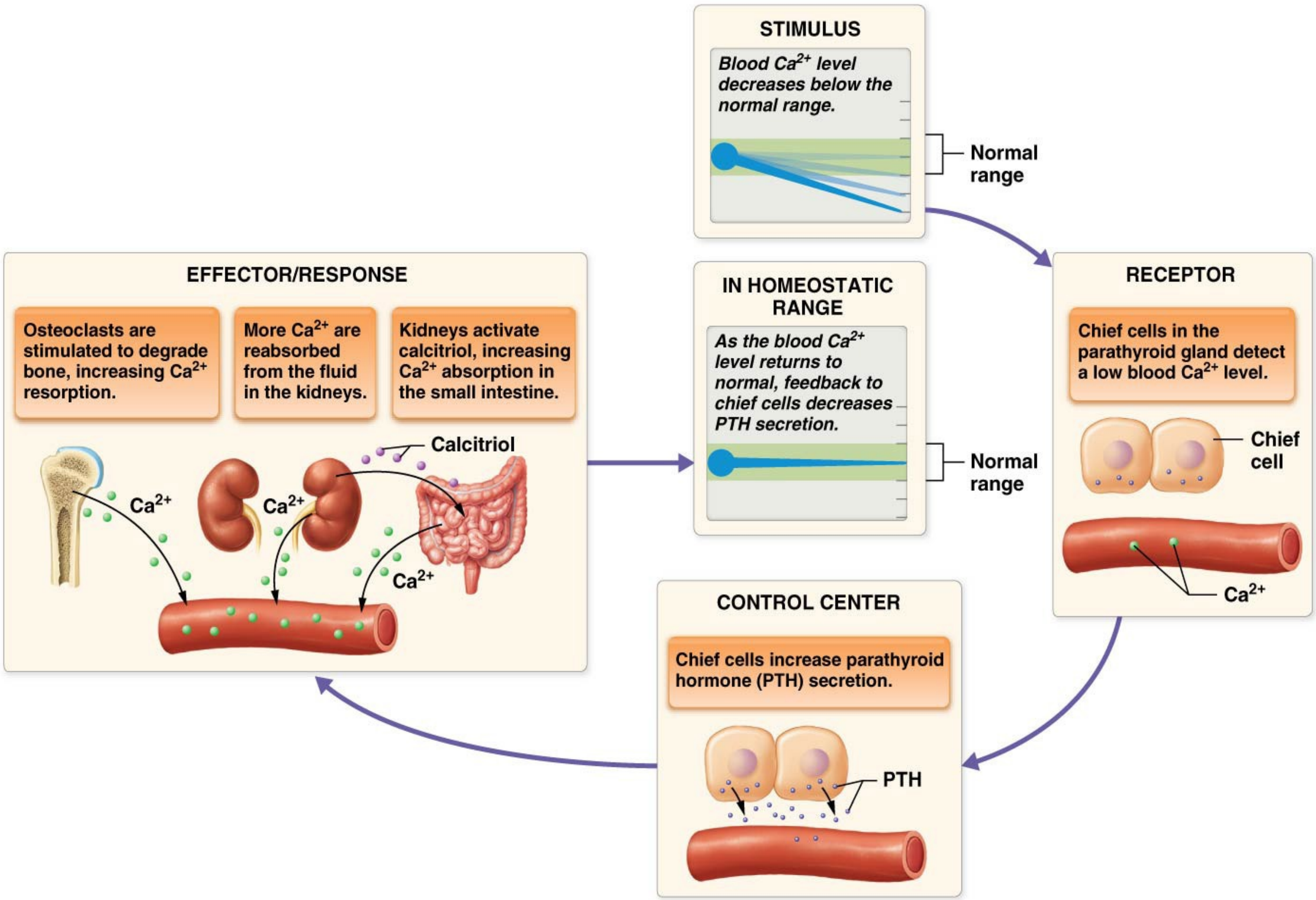
Increases bone resorption



(a)

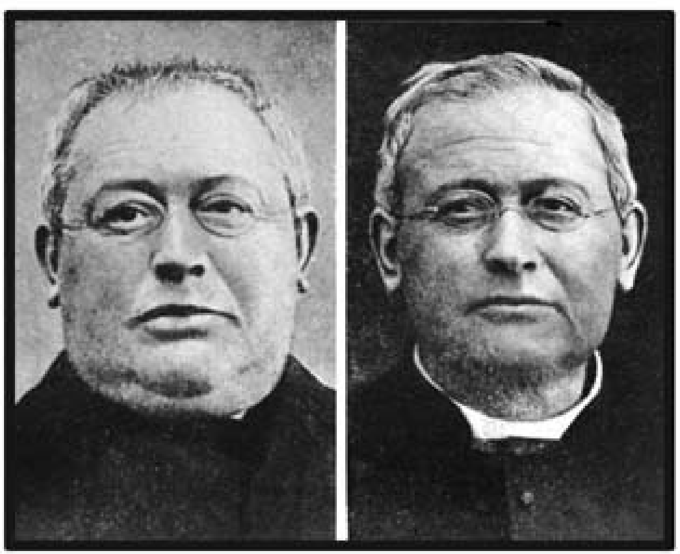


Maintaining homeostasis: regulation of blood calcium ion concentration by a negative feedback loop.



Hypothyroidism Disorders

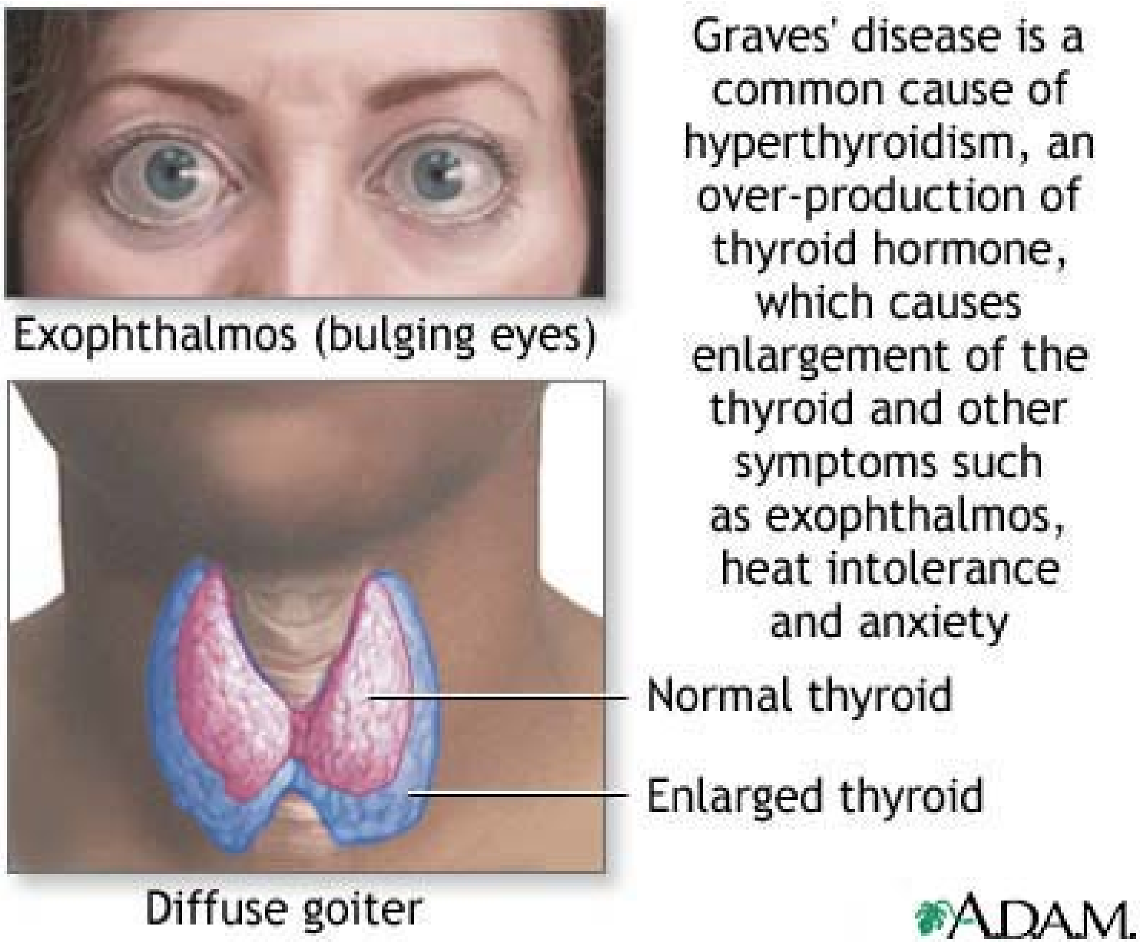
- **Congenital hypothyroidism** (decreased TH)
  - hypo-secretion present a birth
  - formerly called cretinism
  - If not treated results in cognitive disorders
  - treat with oral thyroid hormone
- **Myxedema** (decreased TH)
  - adult hypothyroidism
  - treat with oral thyroid hormone



Before / After Treatment

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 hypothyrodism. It is more common in women than in men.

Hyperthyroidism = Graves' Disease



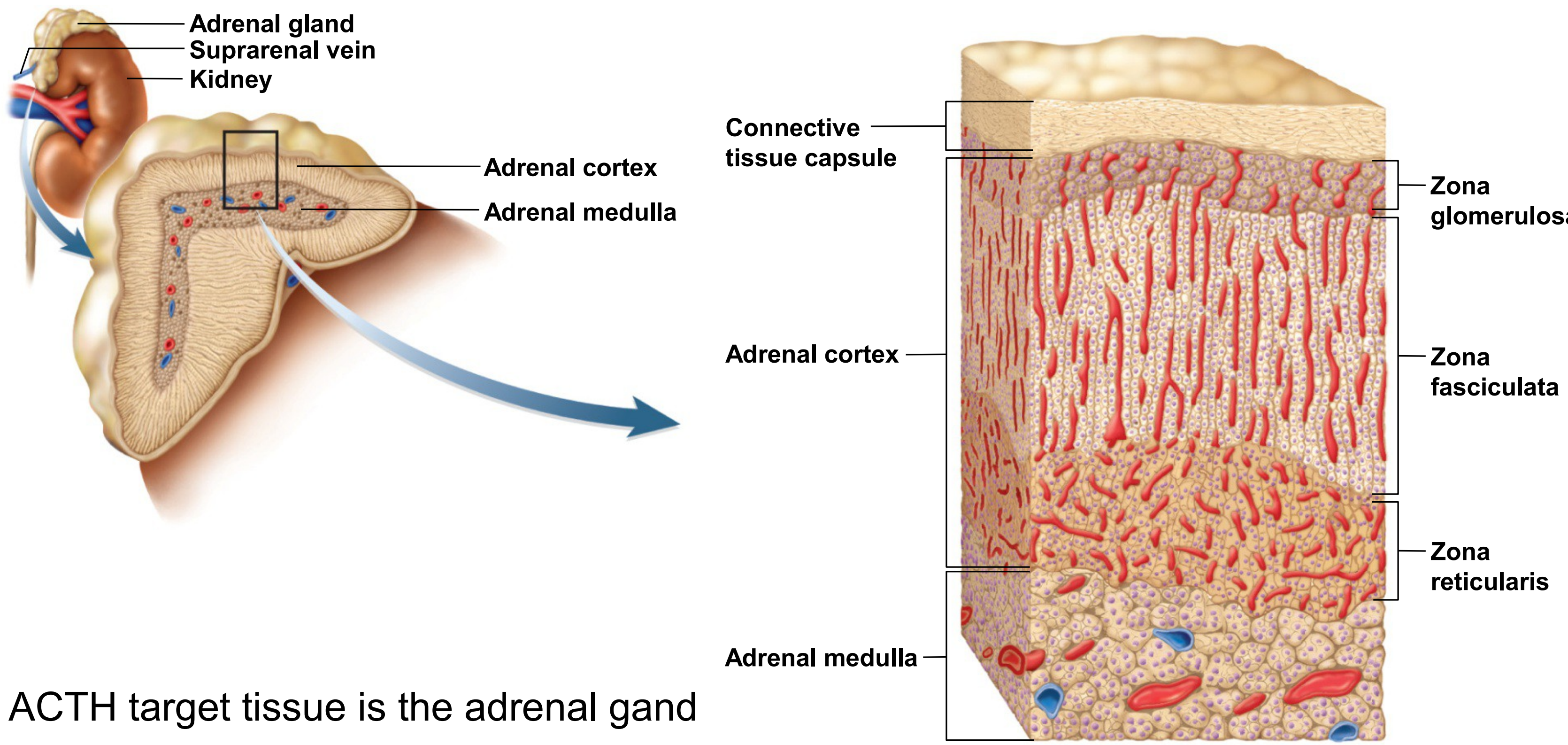
Graves' ophthalmopathy (a protrusion of one or both eyes), caused by inflammation of the eye muscles by attacking auto-antibodies)

Goiter = Thyroid Gland Disorder

- Any pathological enlargement of the thyroid gland
  - **Endemic goiter**
    - Continued secretion of thyroid stimulating hormone, hypertrophy of thyroid gland
    - Caused by dietary iodine deficiency
    - Unable to produce TH
    - Without TH / no negative feedback to stop TSH secretion
  - **Toxic goiter** (Graves disease)
    - auto-antibodies mimic the effect of TSH on the thyroid causing hyper-secretion
    - overgrown thyroid produces functional TH

Endemic Goiter

Adrenocorticotropic hormone (ACTH) Released by the Adrenal Gland's Cortex



- ACTH target tissue is the adrenal gand
- Adrenal gland is small gland that sits on top of each kidney
- Adrenal cortex and adrenal medulla formed by merger of two fetal glands with different origins and functions
- Adrenal cortex secretes mineralcorticoid and glucocorticoid hormones
- Adrenal medulla classified as a SNS ganglia (releases epinephrine and norepinephrine)
- Part of the fear, flight, or fight axis // CRF part of addiction syndrome

Secretions by the Adrenal Gland 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

Catecholamines Released by 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 /// catecholamines *inhibits insulin secretion* /// therefore muscles use fatty acids for energey and save glucose for brain (brain, kidney, RBC do not need insulin to uptake glucose)
  - 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

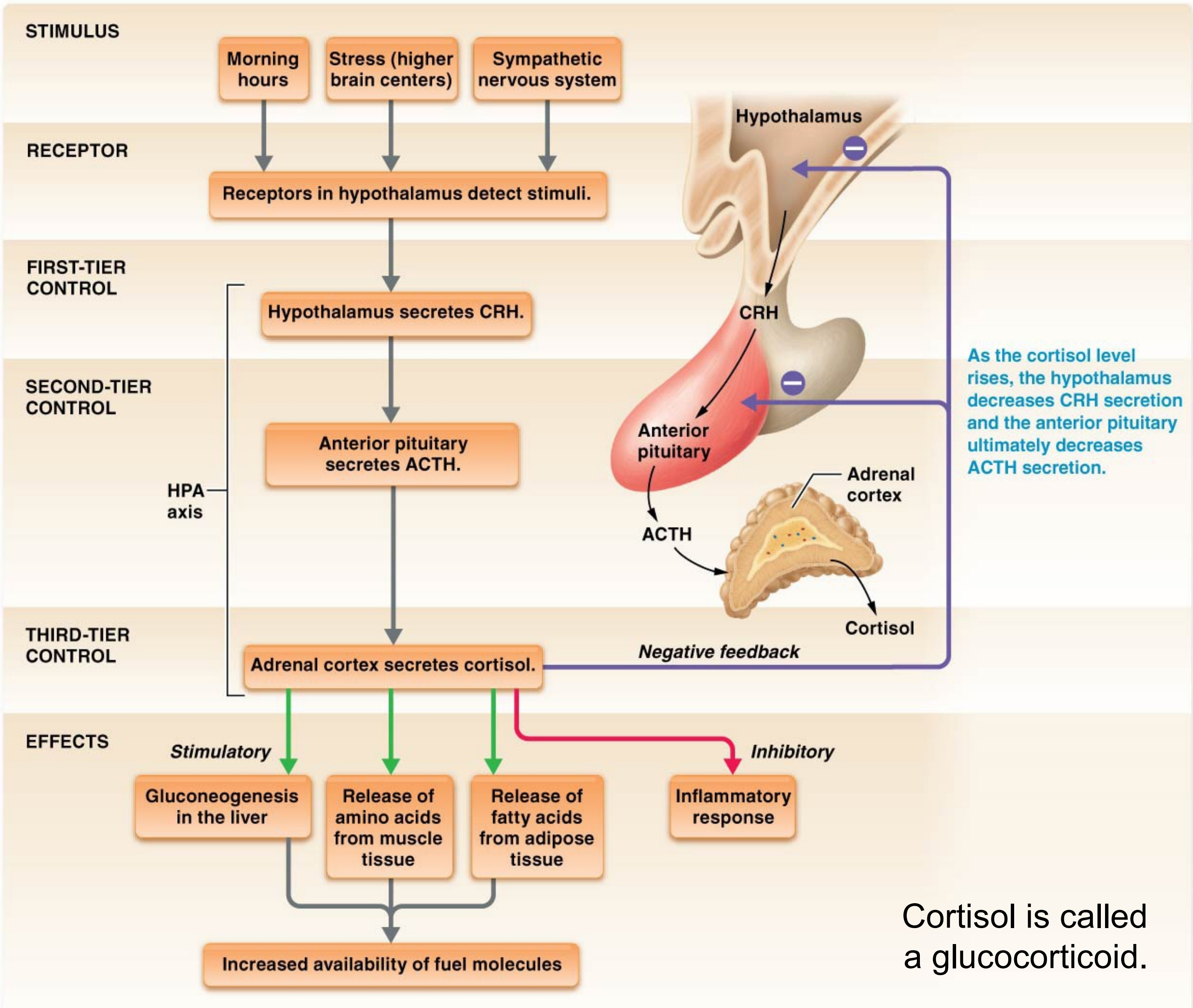
  – zona reticularis (narrow, inner layer)
    - cells in branching network
    - secretes sex steroids

Corticosteroids

- **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)
  - cause release of fatty acids and glucose into blood
  - helps body adapt to stress and repair tissues
  - anti-inflammatory effect by suppressing protein synthesis = **inhibit antibody formation** /// result in immune suppression with long-term use of cortisol

ACTH and Cortisol Regulation Using Negative Feedback Loop

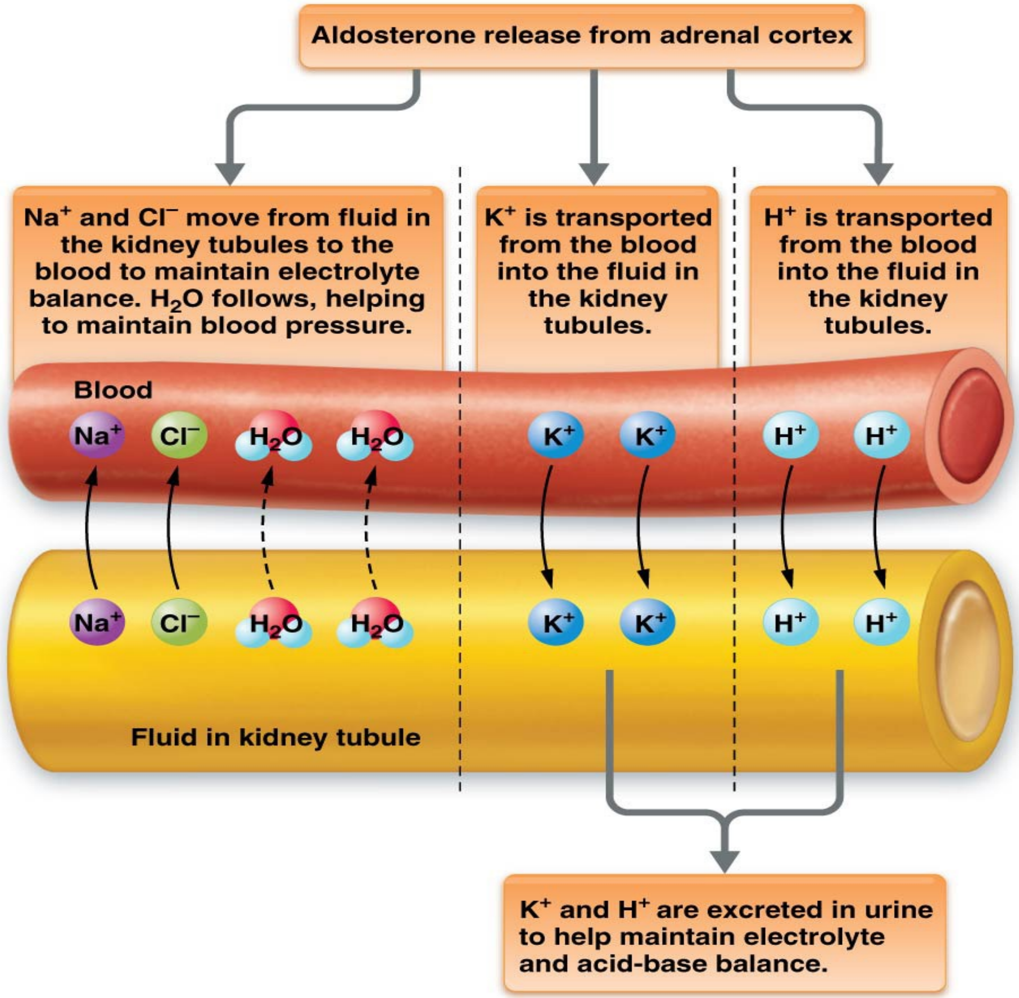
What are the end results of cortisol secretions?



Cortisol is called a glucocorticoid.

Aldosterone

- **Aldosterone is called a mineralocorticoids**
- Regulate electrolyte balance /// stimulates retention of Na^+ while increasing excretion of K^+ plus H+
- water is retained with sodium by osmosis, helps to maintain blood volume and blood pressure

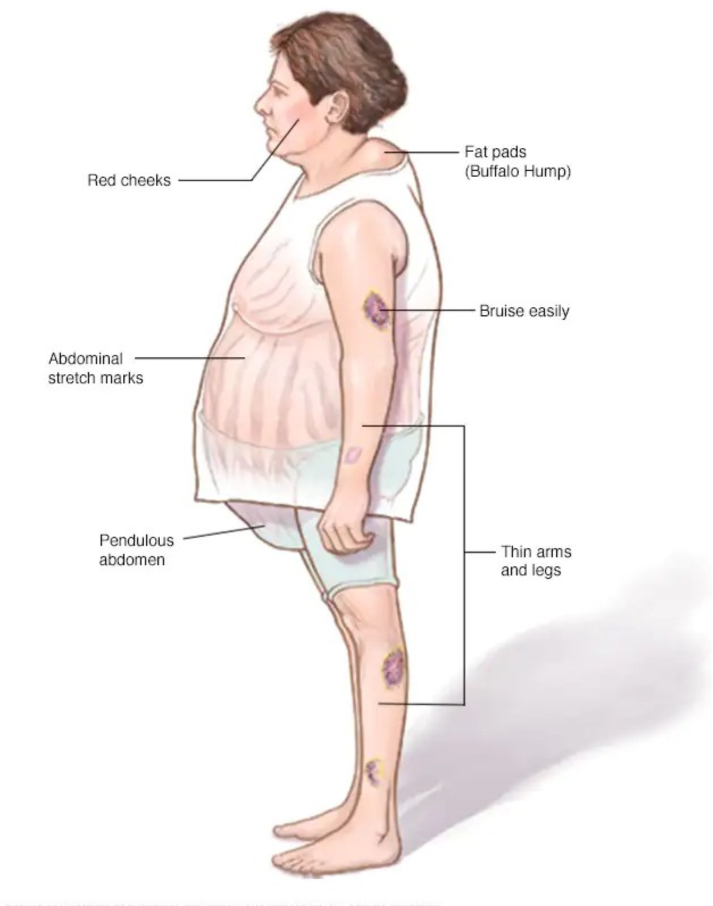


Other Adrenal Cortex Hormones

- 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

Cushing Syndrome

(Not a lecture objective)



Cushing's syndrome is a disorder that occurs when your body makes too much of the hormone cortisol over a long period of time.

Cortisol is sometimes called the “stress hormone” because it helps your body respond to stress. Cortisol also helps. maintain blood pressure. regulate blood glucose, also called blood sugar.

Enlargement of external sexual organs in children and early onset of puberty

Newborn girls exhibit masculinized genitalia

Women masculinizing effects – body hair, deeper voice, beard growth

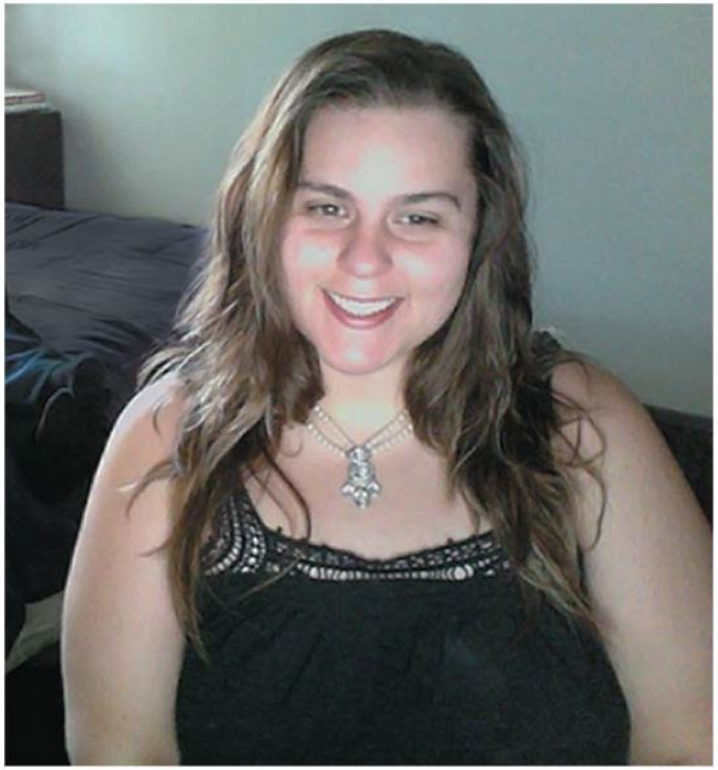
Adrenal Gland Disorder

- **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
  - Inhibits protein synthesis // increase infections // atrophy of lymph nodes

(a) (b)

a-b: From: Atlas of Pediatric Physical Diagnosis, 3/e by Zitelli & Davis, fig 9-17 1997, with permission from Elsevier

Cushing's syndrome.



(a) Patient before development of Cushing's syndrome

(b) Patient 3 years after the onset of Cushing's syndrome

Cushing Syndrome - excess cortisol secretion

Adrenogenital Syndrome (AGS)

Congenital adrenal hyperplasia is a term used to represent a group of inherited adrenal gland disorder. Patients with this condition produce an excess of the androgen hormone and insufficient amounts of cortisol and aldosterone hormones.

It is a condition that results in a lack of a specific enzyme necessary for the adrenal glands to make the necessary cortisol and aldosterone hormones within the body.

In lacking these two hormones, the body instead produces an excess amount of androgen, a kind of male sex hormone.

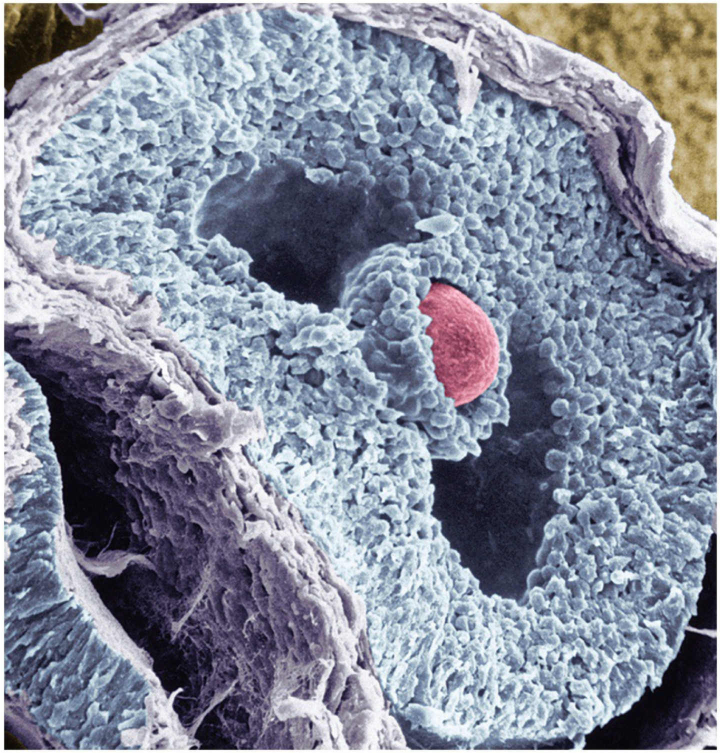
With this excess of androgen, early or inappropriate appearance of male characteristics are present. 1 in 50,000 +/- are affected

Masculinizing effects on women // increased body hair, deeper voice and beard growth

Adrenal Gland Interactions

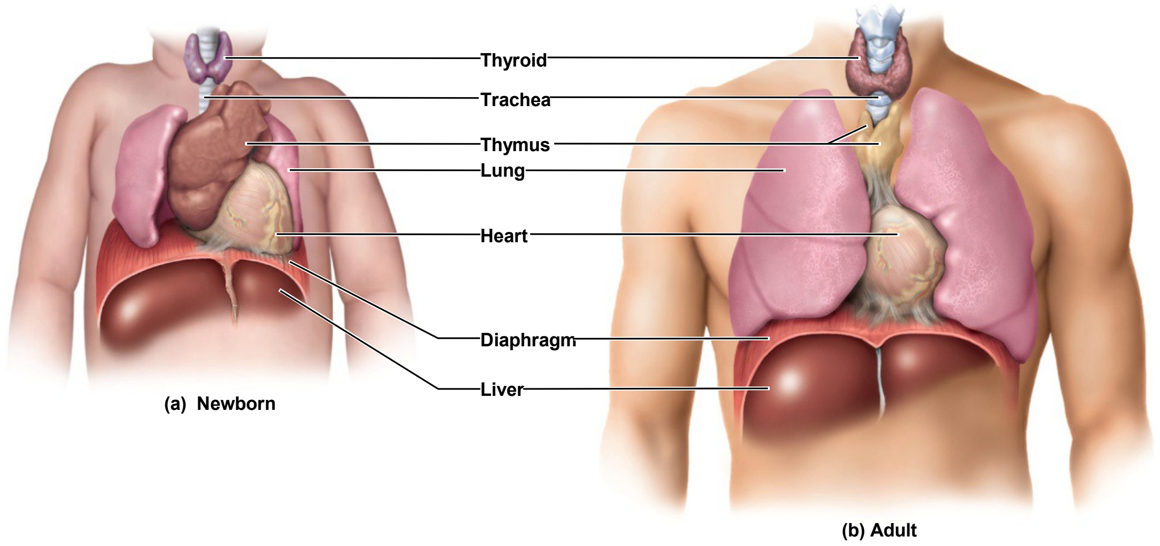
- medulla and cortex of adrenal gland are not functionally independent
- medulla atrophies without the stimulation of cortisol (made in cortex)
- some chromaffin cells of medullary origin extend into the cortex
  - chromaffin cells stimulate the cortex to secrete corticosteroids when stress activates the sympathetic nervous system

Review of Other Organs of the Endocrine System



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



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

- synchronize physiological function with 24-hour **circadian rhythms** of daylight and darkness

Pineal Gland

Pineal gland produces melatonin

Nicknamed the SAD (seasonal adjusted disease) hormone

Synthesized from serotonin during the night /// longer nights more melatonin – more "mood change" or sadness

fluctuates seasonally with changes in day length /// longer nights more melatonin

may regulate timing of puberty in humans // melatonin also thought to be associated with female mood swings associated with mensis

Pineal Gland

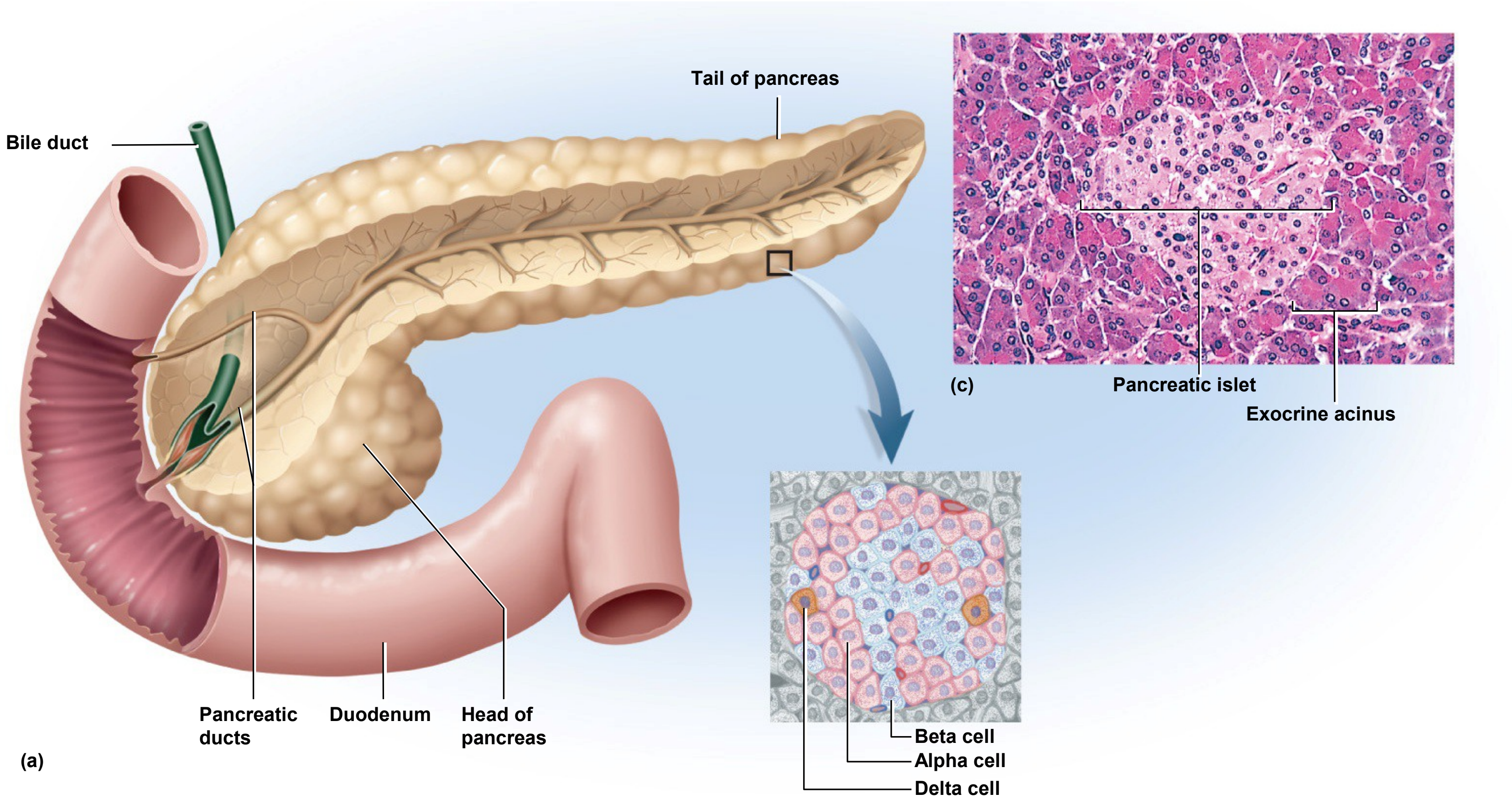
Seasonal affective disorder (SAD)

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)

Pancreas



(b) Pancreatic islet

- 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 // 2% of pancreas
- other 98% of pancreas cells produces digestive enzymes
- **insulin** secreted by **beta (β) cells** // secreted during and after meal when glucose and amino acid blood levels are rising
- **glucagon** is produced by alpha cells // released when hypoglycemic // target tissue is liver // breaks down stored glycogen into glucose which is released into blood

Insulin

- Insulin stimulates cells to absorb glucose and amino acids from GI tract and to either store or metabolize them /// this will **lower *blood glucose levels***

  - promotes synthesis glycogen, fat, and protein

  - suppresses use of already stored fuels

  - Note; brain, liver, kidneys and RBCs absorb glucose without insulin, but all other tissues require insulin

- Diabetes mellitus occurs because there is an insufficiency (not enough produced) or inaction (resistance between insulin and receptors) insulin's function

Glucagon

- **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

Hyperglycemic VS Hypoglycemic Hormones

- hyperglycemic hormones // raise blood glucose concentration
    - glucagon
    - growth hormone
    - epinephrine & norepinephrine
    - cortisol & corticosterone
- hypoglycemic hormone // lower blood glucose /// <u>only insulin</u>

Two Types of Diabetes Mellitus

- **Type 1** (Insulin Dependent Diabetes Mellitus / 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 (Non insulin dependent diabetes mellitus - 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

Diabetes Mellitus

- Most prevalent metabolic disease in the world
  - disruption of metabolism due to hyposecretion 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 and filtration moves glucose into kidney tubules

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

High glucose concentrations // exceed kidney's proximal convoluted tubule transport maximum // glucose now becomes an osmotic diuretic

DM limit to how fast the glucose transporters can work to reabsorb glucose from filtrate (urine)

Excess glucose enters urine and water follows // polyuria (excess urine output), polydipsia (intense thirst), polyphagia (hunger)

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 (make more acidic)
    - deep, gasping breathing and diabetic coma are terminal result

Result of Chronic Hyperglycemia From Diabetes

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

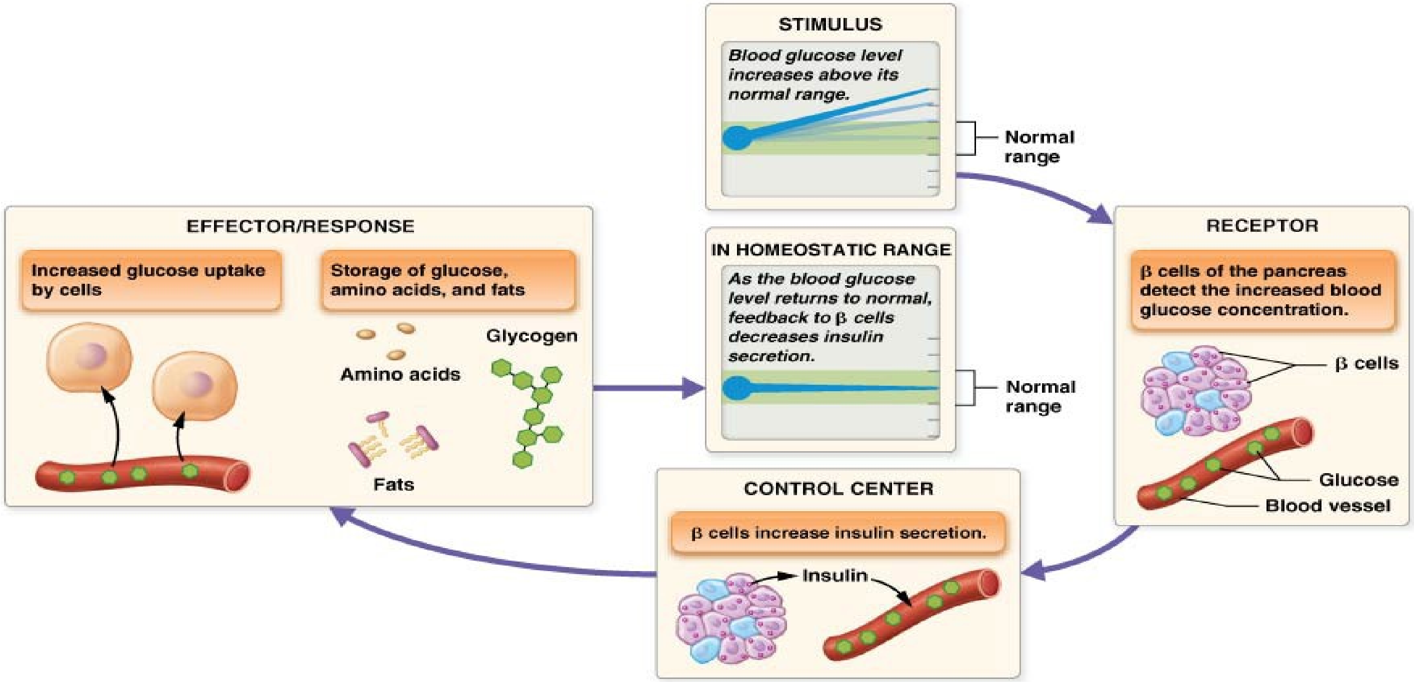
vascular problems related to “thickening” of the basement membrane in the capillaries

Other Types of Diabetes

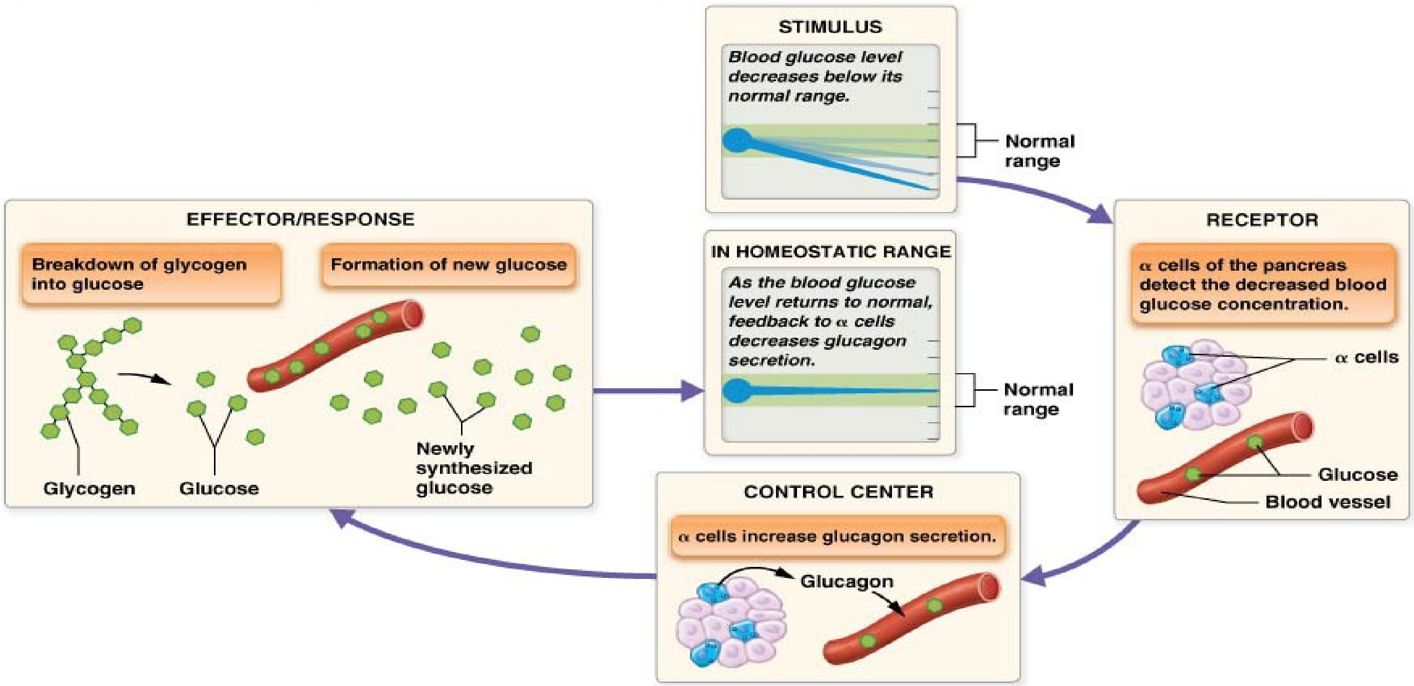
Gestational Diabetes – somatic cells of pregnant woman become “insensitive” to insulin // her blood glucose level increases

Diabetes Insipidus – normal insulin – glucagon - blood glucose levels /// ADH levels too low – results in large urine volume

Regulation of blood glucose concentration by negative feedback loops.



(a) Response by insulin to high blood glucose concentration



(b) Response by glucagon to low blood glucose concentration

Other Hormones

(The following hormones are not included on this exam. We will cover the function of these hormones as we cover other sysems.)

- **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

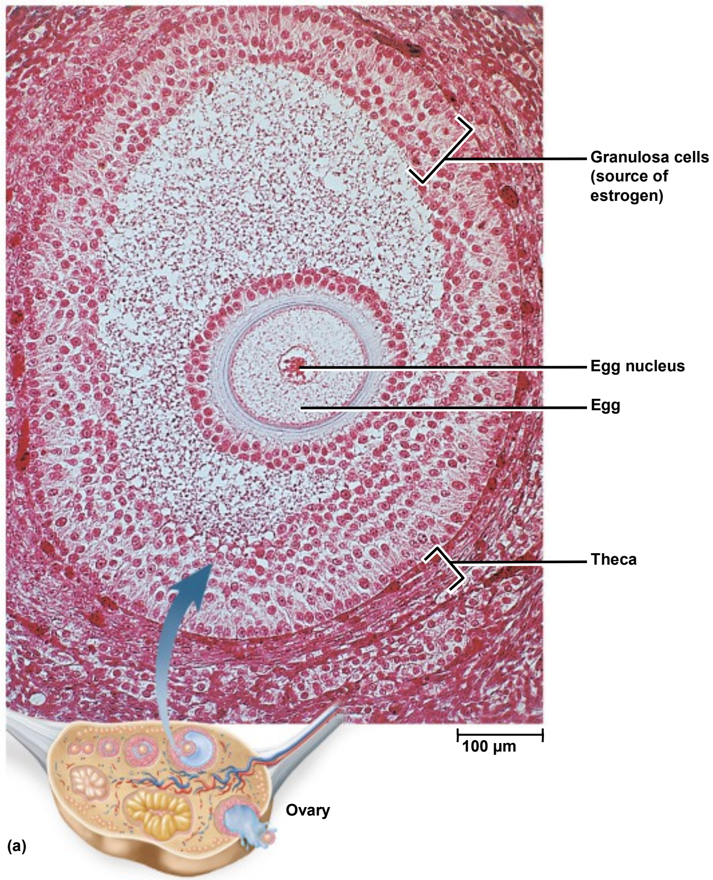
The Gonads as Endocrine Glands

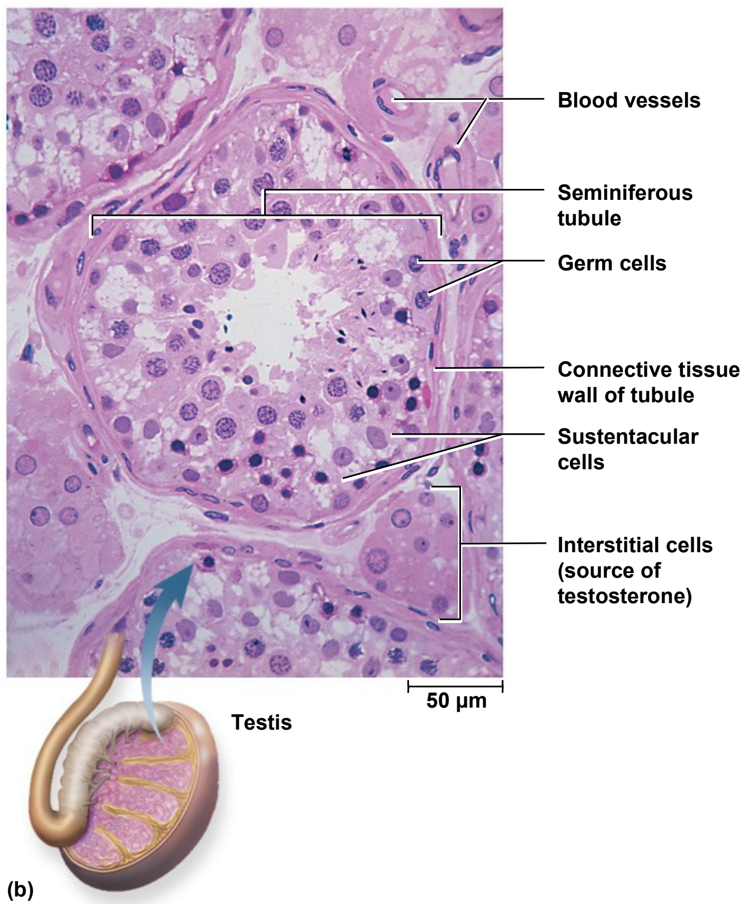
- ovaries and testes are both endocrine and exocrine glands
  - exocrine product – whole cells - eggs and sperm (cytogenic glands)
  - endocrine product - gonadal hormones – mostly steroids

- ovarian hormones (female ovaries)
  - estradiol, progesterone, and inhibin

- testicular hormones (male testes)
  - testosterone, weaker androgens, estrogen and inhibin

Histology of Ovary





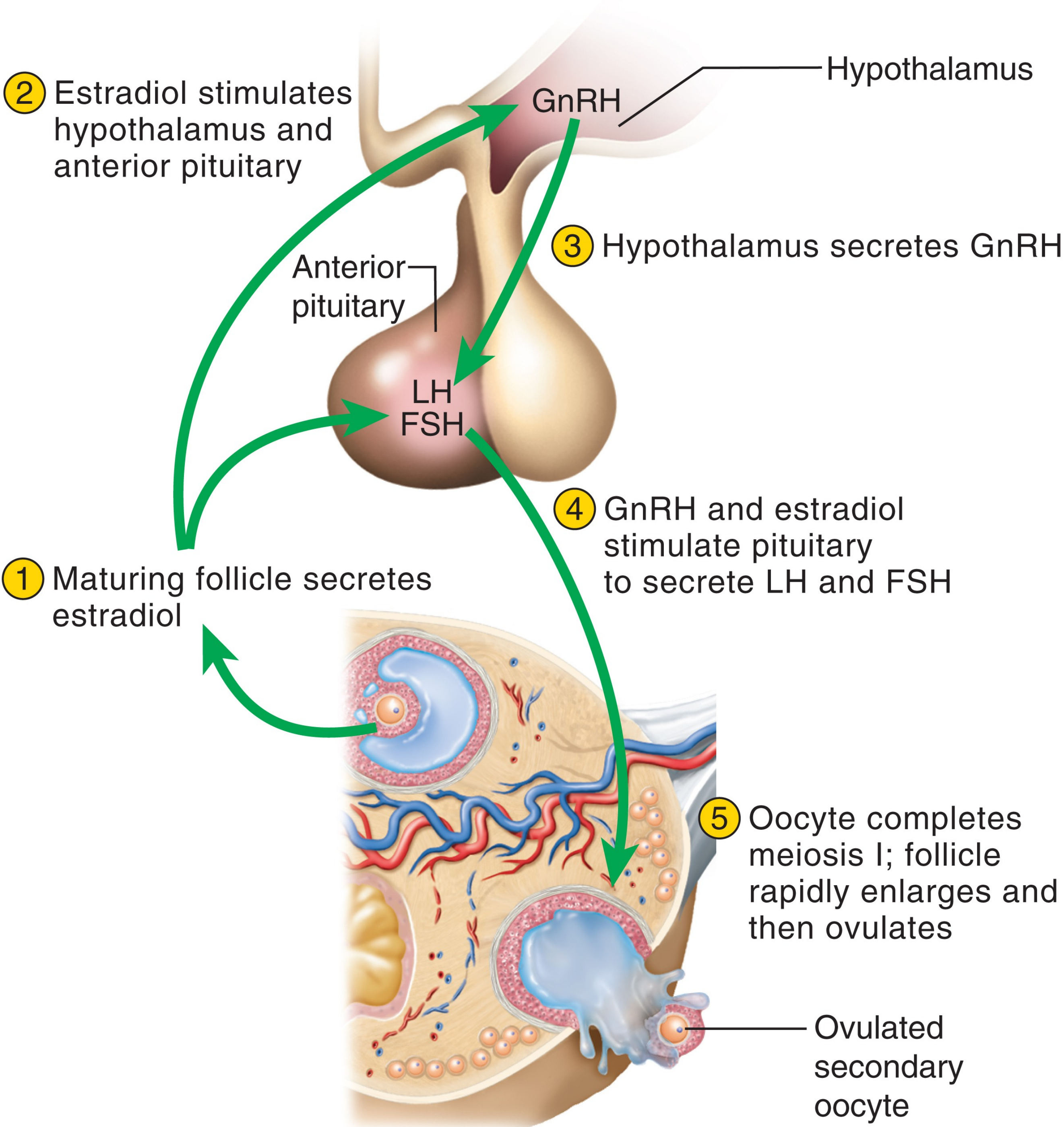
follicle - egg surrounded by granulosa cells and a capsule (theca)

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 corpus luteum produces progesterone and inhibin

Inhibin's negative feedback on anterior pituitary stops FSH secretion so another follicle does not mature

LH secretion continues

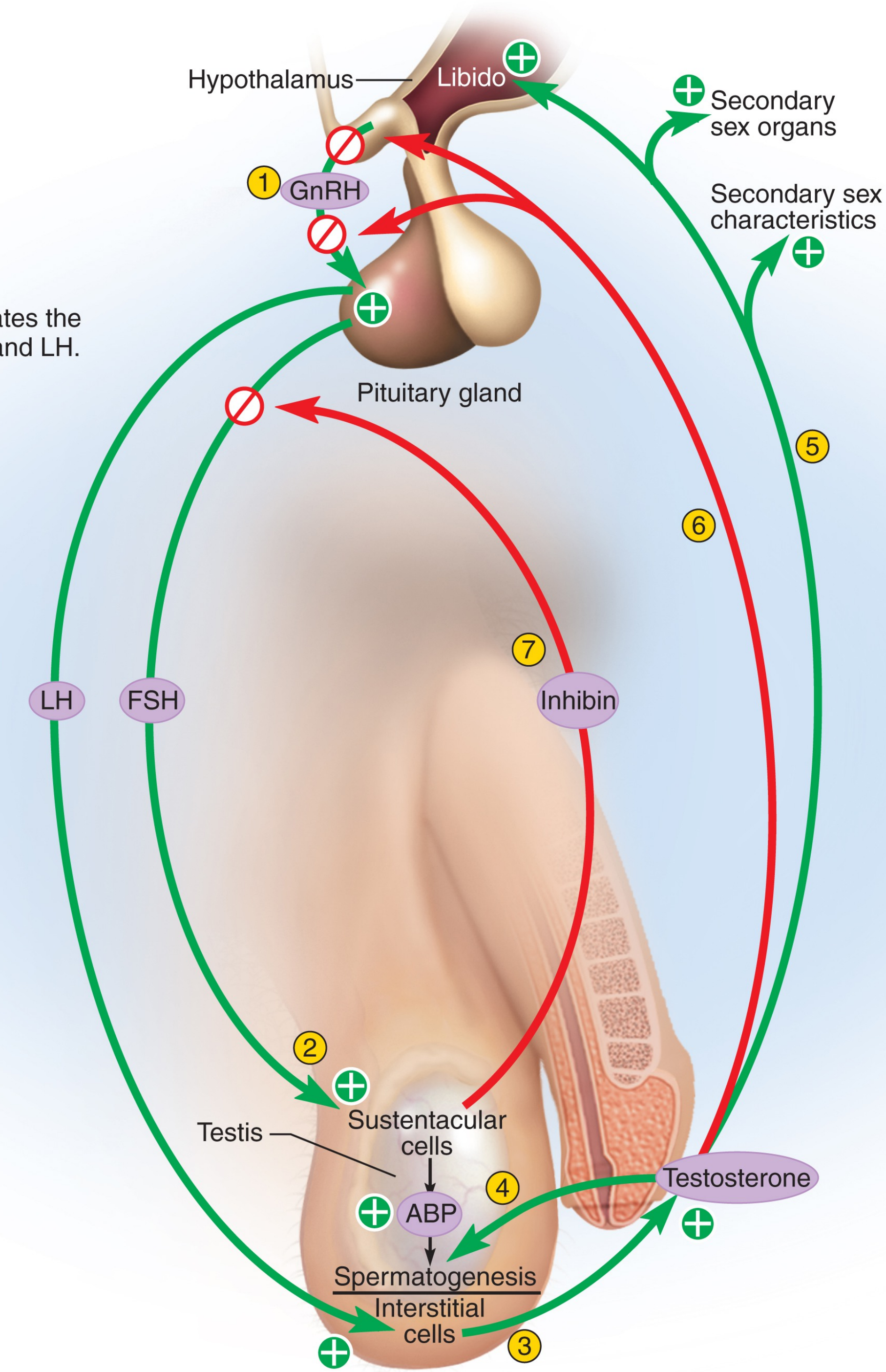
LH stimulates CL to produce progesterone which maintains endometrium

Testes

- microscopic **<u>seminiferous tubules</u>** <u>produce sperm</u>
  - 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).

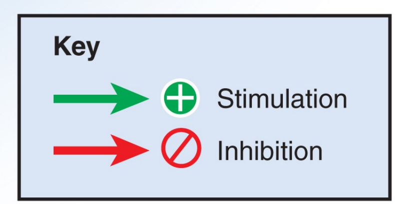
3 LH stimulates interstitial cells to secrete testosterone (androgen).

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.



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) – primary source are kidneys
  - **hepcidin** – promotes intestinal absorption of iron
  - source of insulin like growth factor (**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_2O 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, secretin, gastrin, Ghrelin, and peptide YY

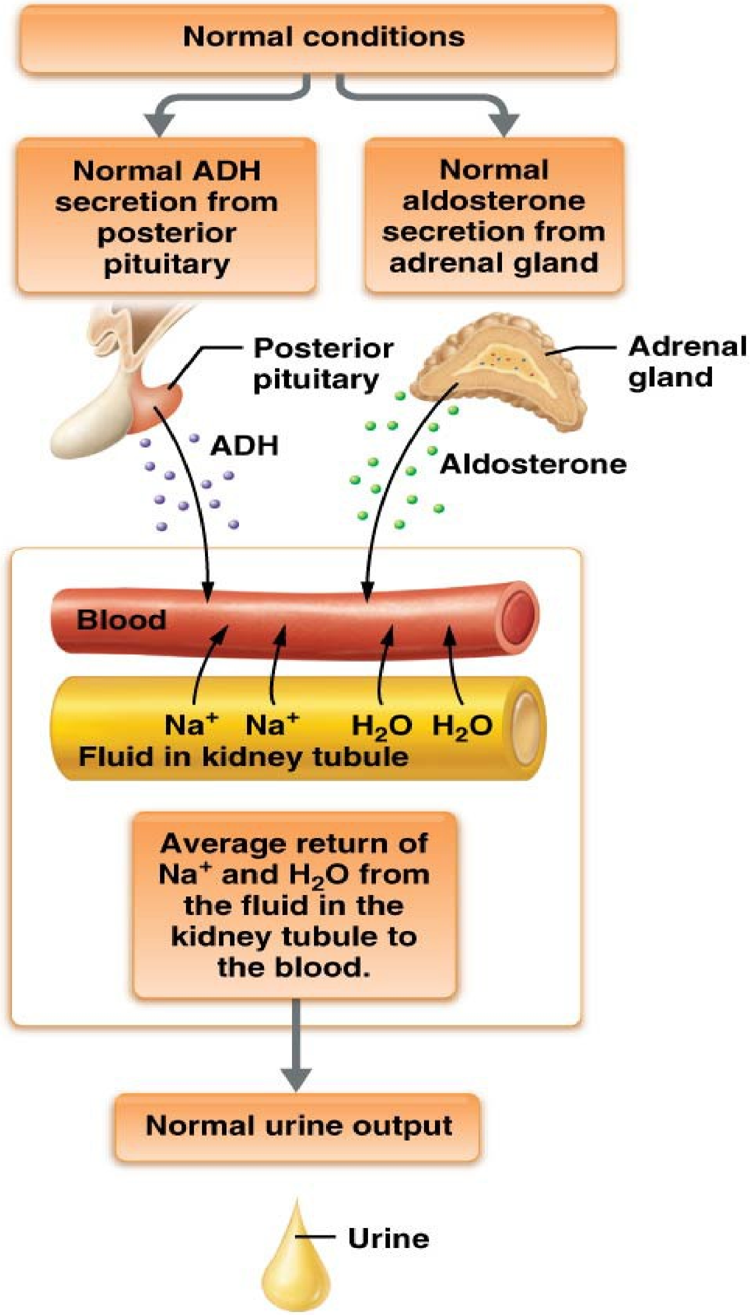
Endocrine Functions of Other Organs

- 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

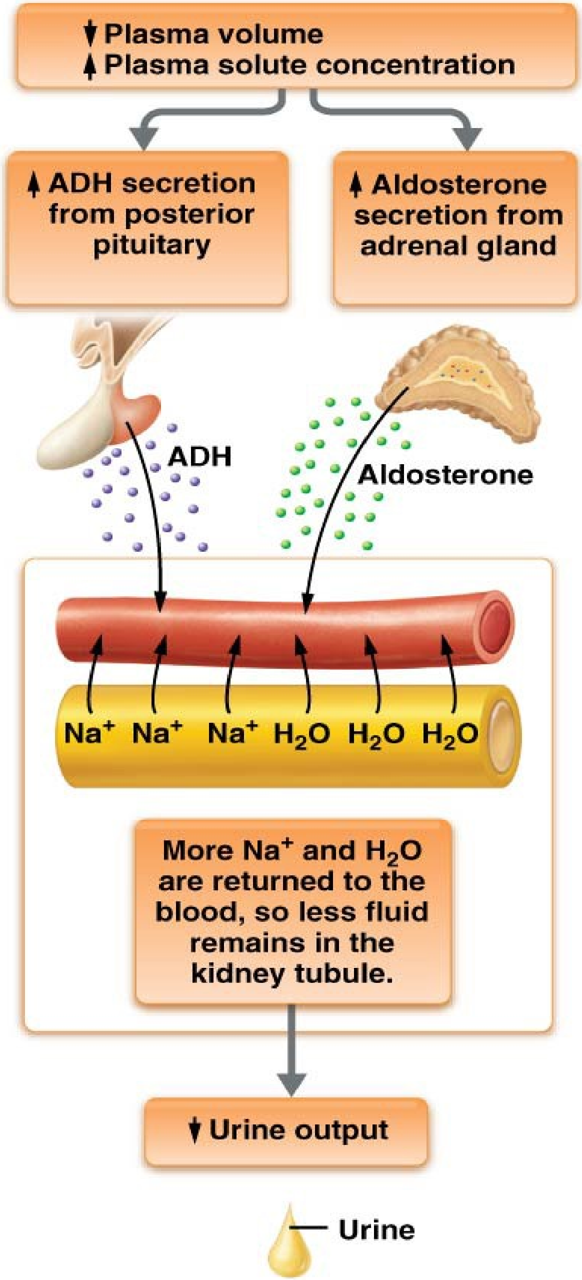
- Placenta
  - secretes estrogen, progesterone and others /// regulate pregnancy, stimulate development of fetus and mammary glands

Summary of endocrine control of fluid homeostasis.



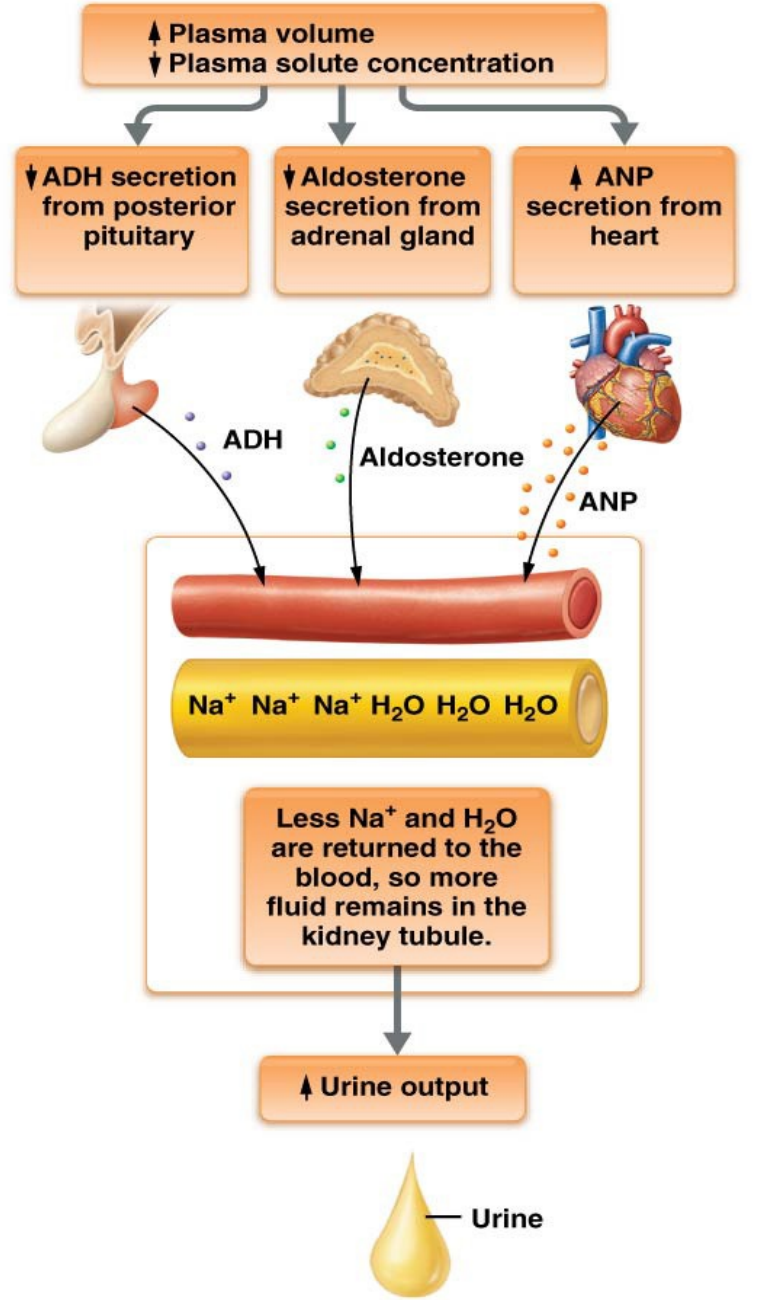
(a) Normal conditions: low ADH and aldosterone

Summary of endocrine control of fluid homeostasis.



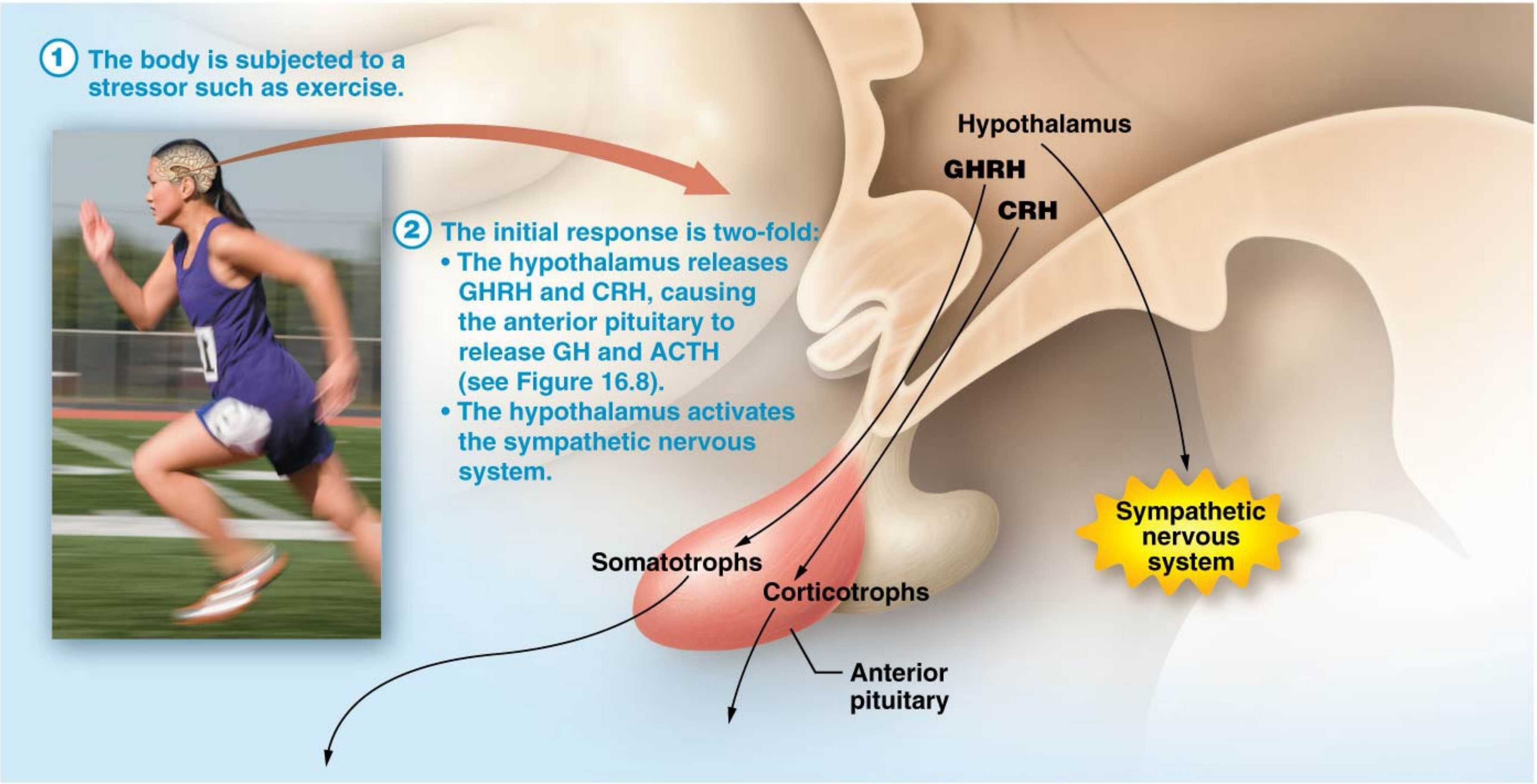
(b) Decreased plasma volume and increased plasma solute concentration: high ADH and aldosterone

Summary of endocrine control of fluid homeostasis.



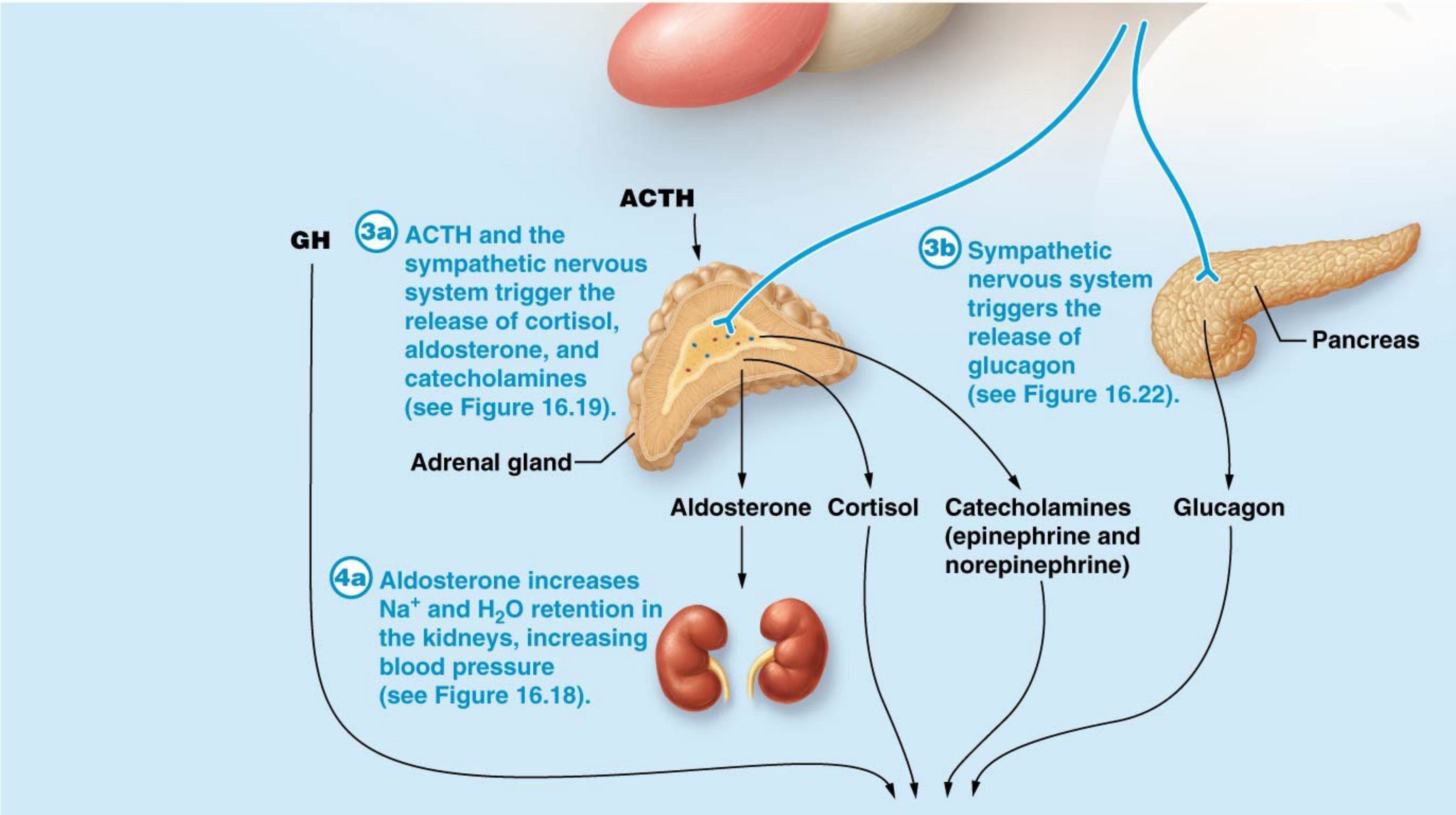
(c) Increased plasma volume and decreased plasma solute concentration: very low ADH and aldosterone, high ANP

The Big Picture of the Hormonal Response to Stress



See Next Two Slides

The Big Picture of the Hormonal Response to Stress



The Big Picture of the Hormonal Response to Stress