# ENDOCRINOLOGY ANATOMY PHYSIOLOGY

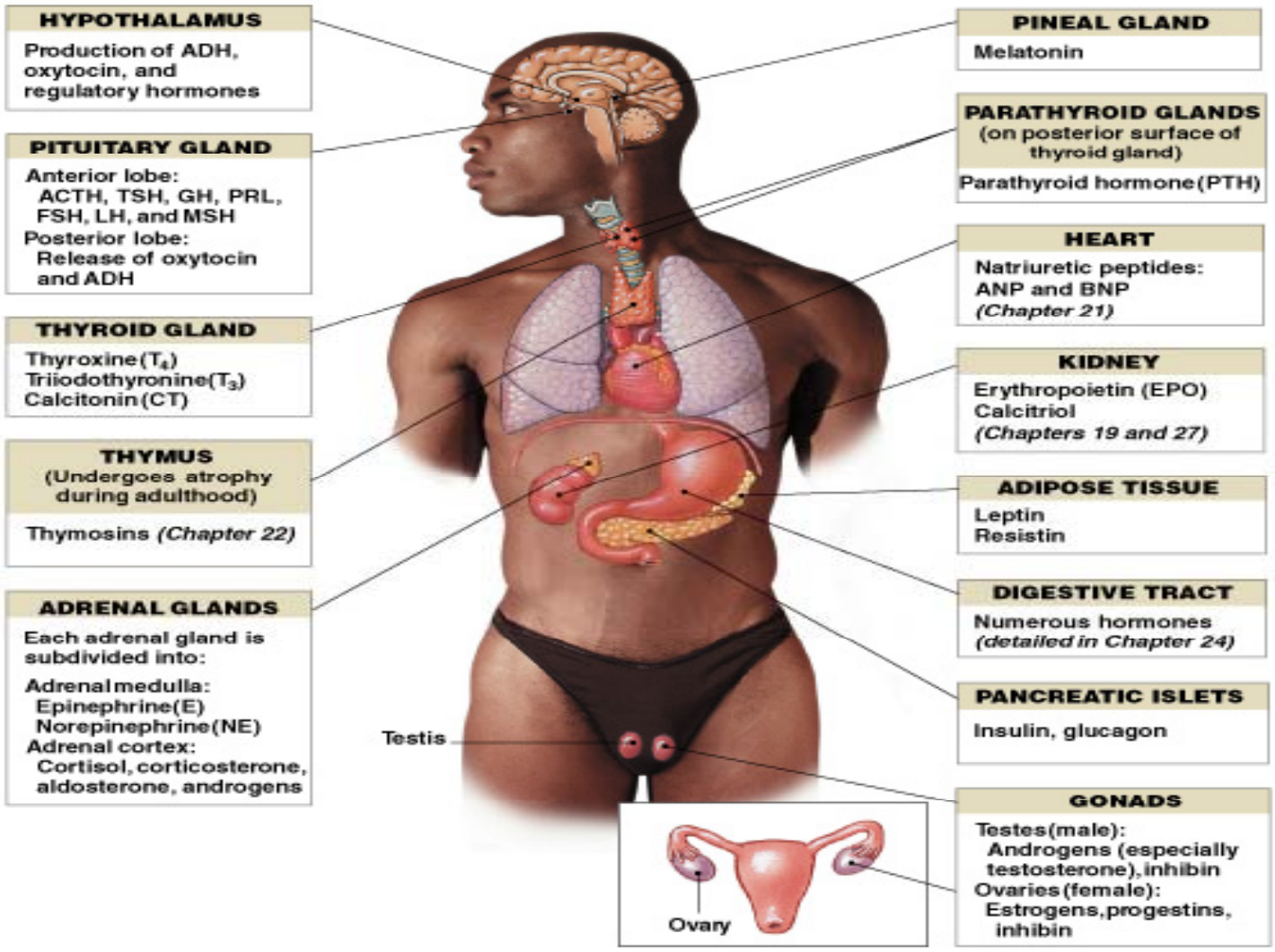
Danil Hammoudi.MD

# Endocrine System: Overview

- Acts with the nervous system to coordinate and integrate the activity of body cells
- Influences metabolic activities by means of hormones transported in the blood
- Responses occur more slowly but tend to last longer than those of the nervous system

# Endocrine System: Overview

- Some organs produce both hormones and exocrine products (e.g., pancreas and gonads)
- The hypothalamus has both neural and endocrine functions
- Other tissues and organs that produce hormones include
  - **adipose cells,**
  - **thymus,**
  - **cells in the walls of the small intestine,**
  - **stomach,**
  - **kidneys,**
  - **heart**


HYPOTHALAMUS
Production of ADH, oxytocin, and regulatory hormones
PITUITARY GLAND
Anterior lobe:
ACTH, TSH, GH, PRL, FSH, LH, and MSH
Posterior lobe:
Release of oxytocin and ADH
THYROID GLAND
Thyroxine ($T_4$)
Triiodothyronine ($T_3$)
Calcitonin (CT)
THYMUS
(Undergoes atrophy during adulthood)
Thymosins (Chapter 22)
ADRENAL GLANDS
Each adrenal gland is subdivided into:
Adrenal medulla:
Epinephrine (E)
Norepinephrine (NE)
Adrenal cortex:
Cortisol, corticosterone, aldosterone, androgens
PINEAL GLAND
Melatonin
PARATHYROID GLANDS
(on posterior surface of thyroid gland)
Parathyroid hormone (PTH)
HEART
Natriuretic peptides:
ANP and BNP
(Chapter 21)
KIDNEY
Erythropoietin (EPO)
Calcitriol
(Chapters 19 and 27)
ADIPOSE TISSUE
Leptin
Resistin
DIGESTIVE TRACT
Numerous hormones
(detailed in Chapter 24)
PANCREATIC ISLETS
Insulin, glucagon
GONADS
Testes (male):
Androgens (especially testosterone), inhibin
Ovaries (female):
Estrogens, progestins, inhibin
Testis
Ovary

# Anatomy and Physiology

- Homeostasis
  - state of equilibrium
- Hormones (chemical messengers)
- Target Tissues or Target Organs
- Hypersecretion
- Hyposecretion

# Hormones

- chemical substances produced by specialized cells (glands)
- released slowly, minute amounts, circulate in blood
- some hormones effect the entire body, some effect target organs
- most hormones are inactivated or excreted by the liver and kidneys

| | |
|---|---|
| one | pituitary gland |
| one | thyroid gland |
| four | parathyroid glands |
| two | adrenal glands |
| one | pancreas |
| one | pineal gland |

# Hormones per function

# Hormone Functions



- ACTH (adrenocorticotropic hormone)
  - Regulates the activity of the cortex of the adrenal gland
- TSH (thyroid stimulating hormone)
  - Stimulates production and release of thyroid hormone
- GH (growth hormone)
  - Stimulates growth of bones, cartilage, muscle
  - Timing and amount released determines body size

# Hormone Functions



- PRL (prolactin)
  - Stimulates breast development
  - Promotes and maintains lactation after childbirth
- FSH (follicle stimulating hormone)
  - Causes formation of ovarian follicles and stimulates them to produce estrogen
  - Stimulates sperm development in men
- LH (luteinizing hormone)
  - Initiates ovulation, maintains corpus luteum
  - Regulates testosterone production in males

# Hormone Functions



- ADH (antidiuretic hormone)
  - Reduces urine output by increasing water reabsorption in the kidney
  - Plays small role in blood pressure regulation
- Oxytocin
  - Causes uterine contractions in labor
  - Causes milk let down in lactating mothers
- Thyroid Hormone
  - Regulates metabolic rate of the entire body
  - Important in development of the nervous system

# Hormone Functions



- Calcitonin
  - Decreases bone reabsorption, lowering serum calcium levels
- PTH (parathyroid hormone)
  - Increases serum calcium
  - Decreases serum phosphorus
- Insulin
  - Released in response to high blood sugar
  - Increases cellular absorption of glucose
  - Increases rate of lipogenesis and formation of glycogen in the liver

# Hormone Functions



- Glucagon
  - Released in response to low blood sugar
  - Increases rate of gluconeogenesis (formation of sugar from fat and protein)
  - Increases lipolysis and glycogenolysis
- Epinephrine & Norepinephrine
  - Fight or flight response
  - Increase heart rate, increase skeletal muscle blood flow, decrease skin blood flow

# Hormone Functions



- Glucocorticoids (Cortisone)
  - Released in response to stress
  - Increases formation of glucose from protein and fat breakdown
  - Decreases inflammation
- Aldosterone
  - Increases blood volume by causing kidneys to retain sodium (where sodium goes water goes too) in exchange for potassium
  - Increased blood volume will increase blood pressure

# Hormone Functions



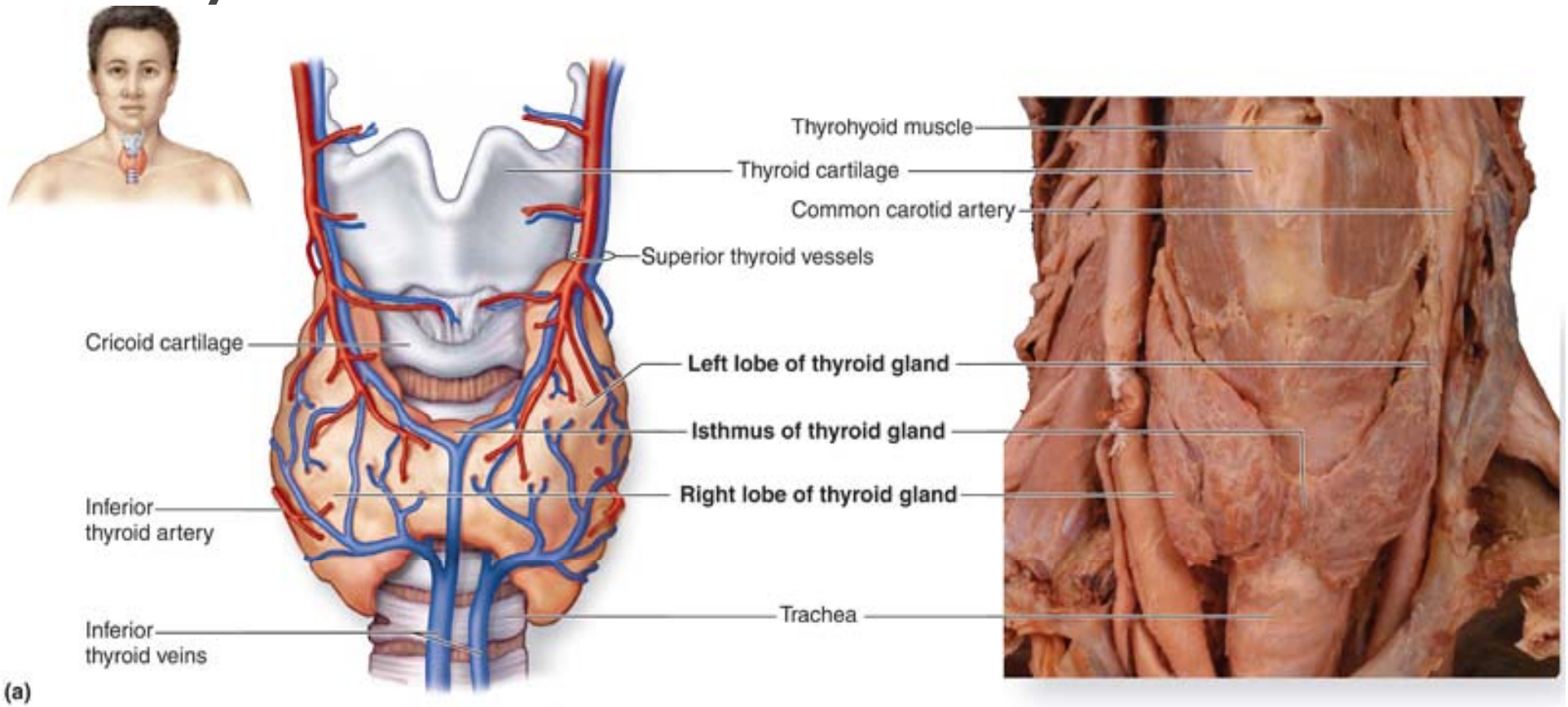
- Androgens
  - Initiates pubertal changes
  - Precursors to estrogen in postmenopausal women
- Melatonin
  - Involved in circadian rhythms
  - Day ↓ melatonin, Night ↑ melatonin
  - Produces sleepiness
- Erythropoietin
  - Stimulates RBC production

# Hormone Functions



- Calcitriol
  - Stimulates calcium and phosphate absorption
  - Stimulates calcium release from bone
  - Inhibits PTH secretion

# Thyroid


Thyrohyoid muscle
Thyroid cartilage
Common carotid artery
Superior thyroid vessels
Cricoid cartilage
Left lobe of thyroid gland
Isthmus of thyroid gland
Right lobe of thyroid gland
Inferior thyroid artery
Trachea
Inferior thyroid veins
(a)

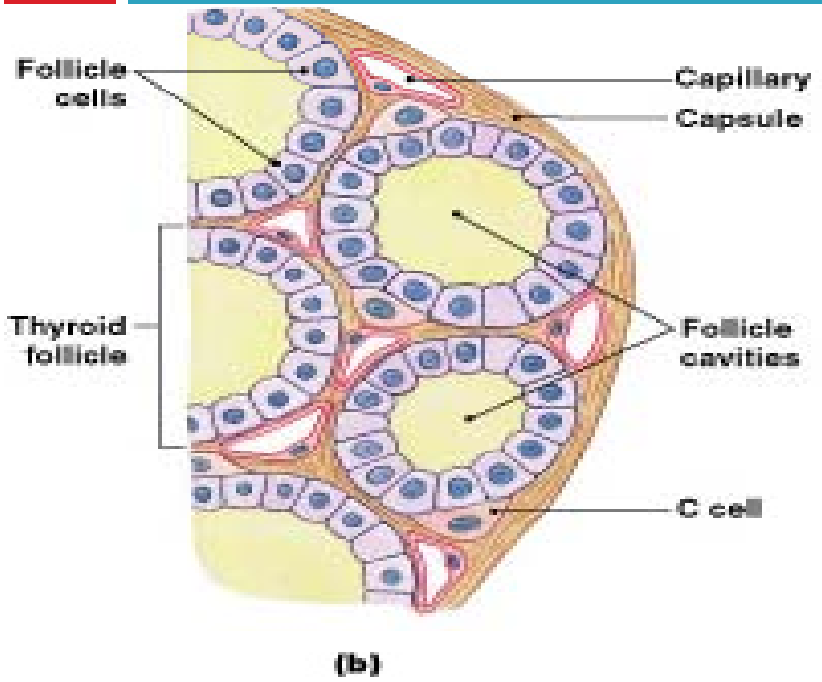
# Thyroid Secretions

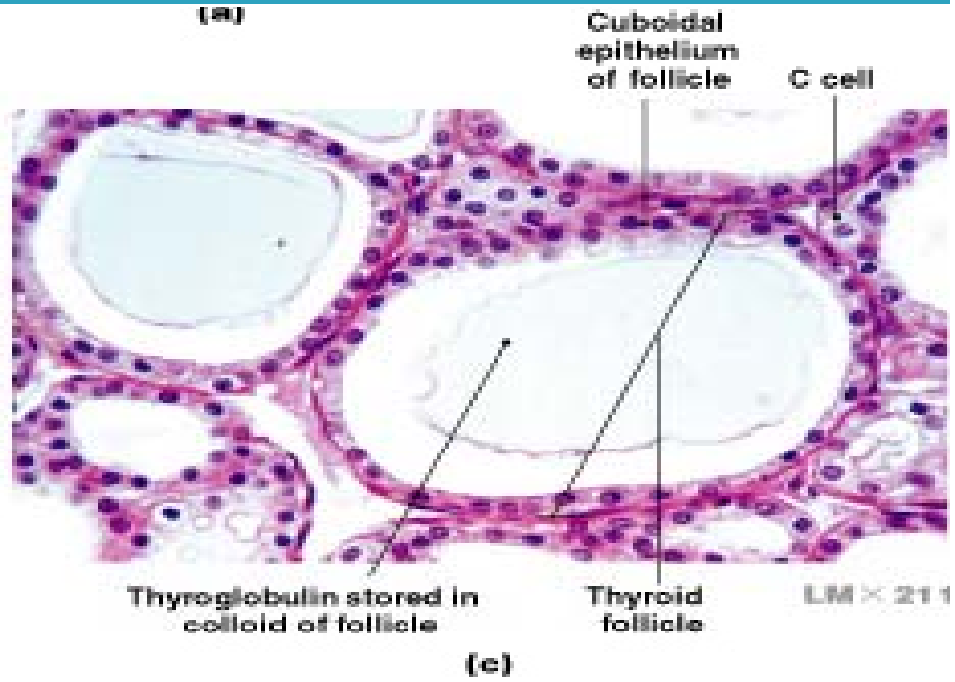
- thyroxine, T4
- triiodothytonine, T3
- regulates rate of cellular metabolism
- influences physical and mental development
- euthyroidism

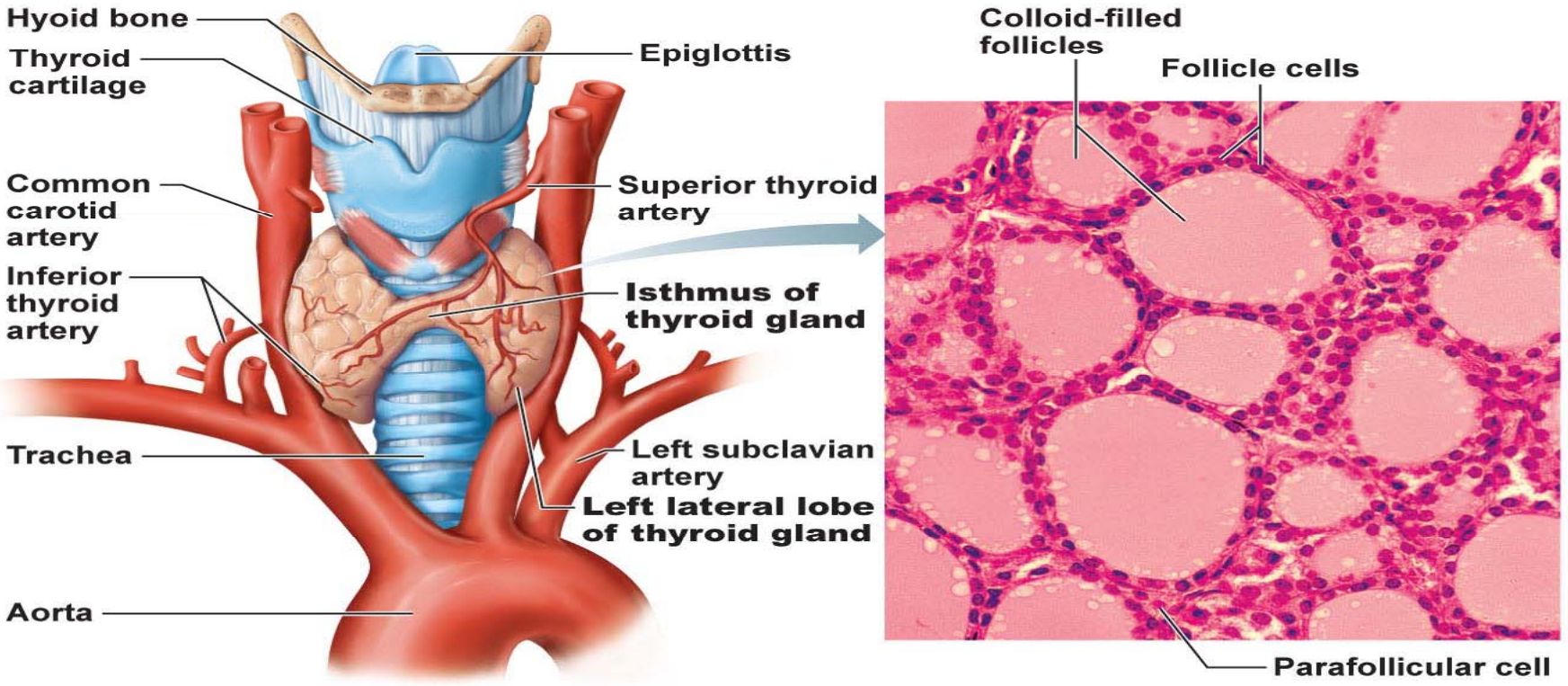
- stimulates **cellular metabolism** by increasing the rate of oxygen use with subsequent energy and heat production
- Faster **cellular metabolism** increases the cell's demand for oxygen, so more O2 must be circulated.
- Increase O2 demand leads to increase CO2
- Increase demand on circulatory system leads to increase pulse rate and heart activity.

# Thyroid Histology







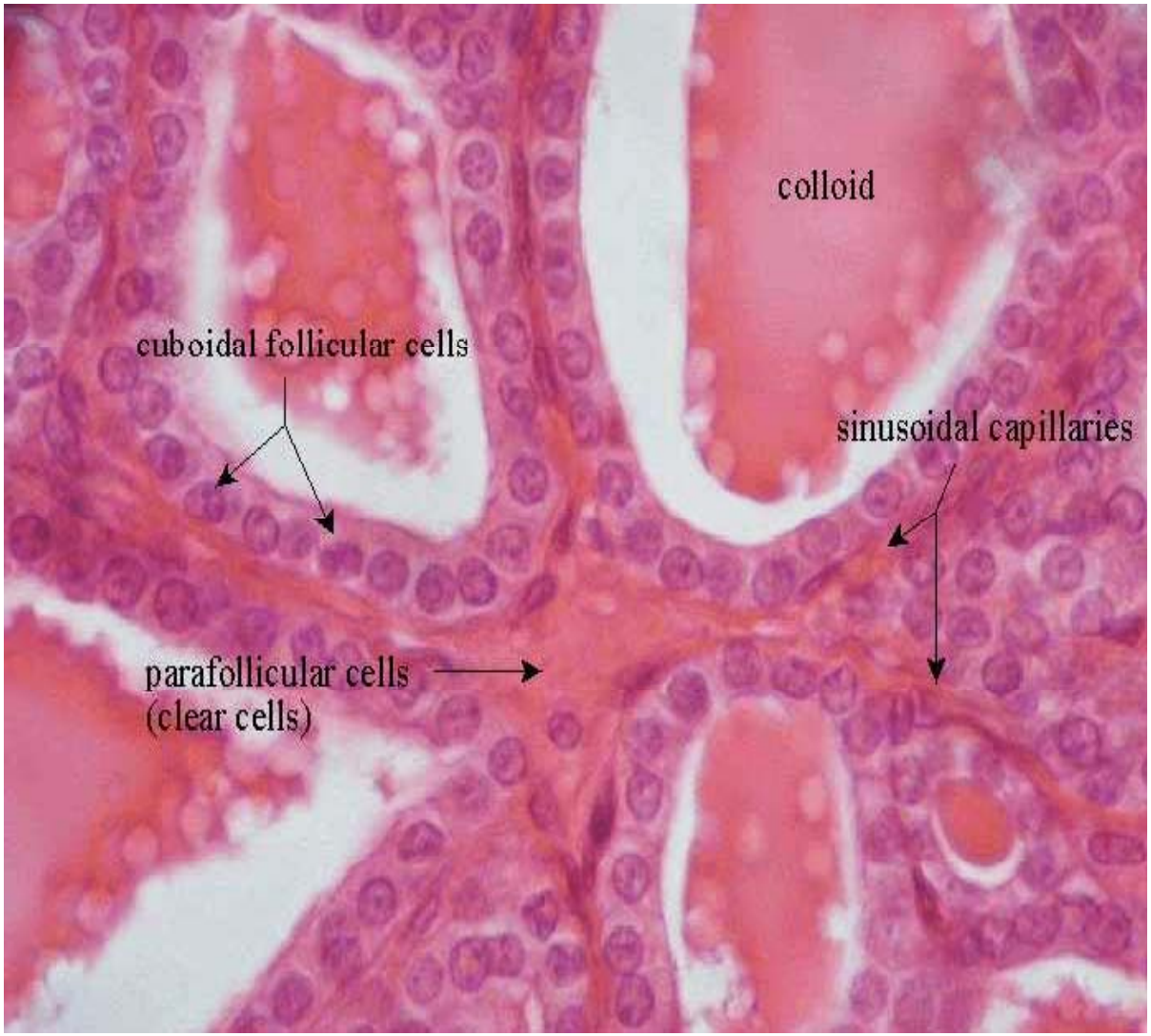

(a) Gross anatomy of the thyroid gland, anterior view

(b) Photomicrograph of thyroid gland follicles (125x)

Figure 16.8

# Thyroid Histology

- Follicular cells produce the colloid (contains precursors to thyroid hormone)
- Parafollicular cells secrete calcitonin



# Thyroid Hormone (TH)

- Actually two related compounds
  - $T_4$ (thyroxine); has 2 tyrosine molecules + 4 bound iodine atoms
  - $T_3$ (triiodothyronine); has 2 tyrosines + 3 bound iodine atoms

# Thyroid Hormone

- Major metabolic hormone
- Increases metabolic rate and heat production (calorigenic effect)
- Plays a role in
  - Maintenance of blood pressure
  - Regulation of tissue growth
  - Development of skeletal and nervous systems
  - Reproductive capabilities

# Synthesis of Thyroid Hormone

- Thyroglobulin is synthesized and discharged into the follicle lumen
- Iodides ($I^-$) are actively taken into the cell, oxidized to iodine ($I_2$), and released into the lumen
- Iodine attaches to tyrosine, mediated by peroxidase enzymes

# Synthesis of Thyroid Hormone

- Iodinated tyrosines link together to form $T_3$ and $T_4$
- Colloid is endocytosed and combined with a lysosome
- $T_3$ and $T_4$ are cleaved and diffuse into the bloodstream

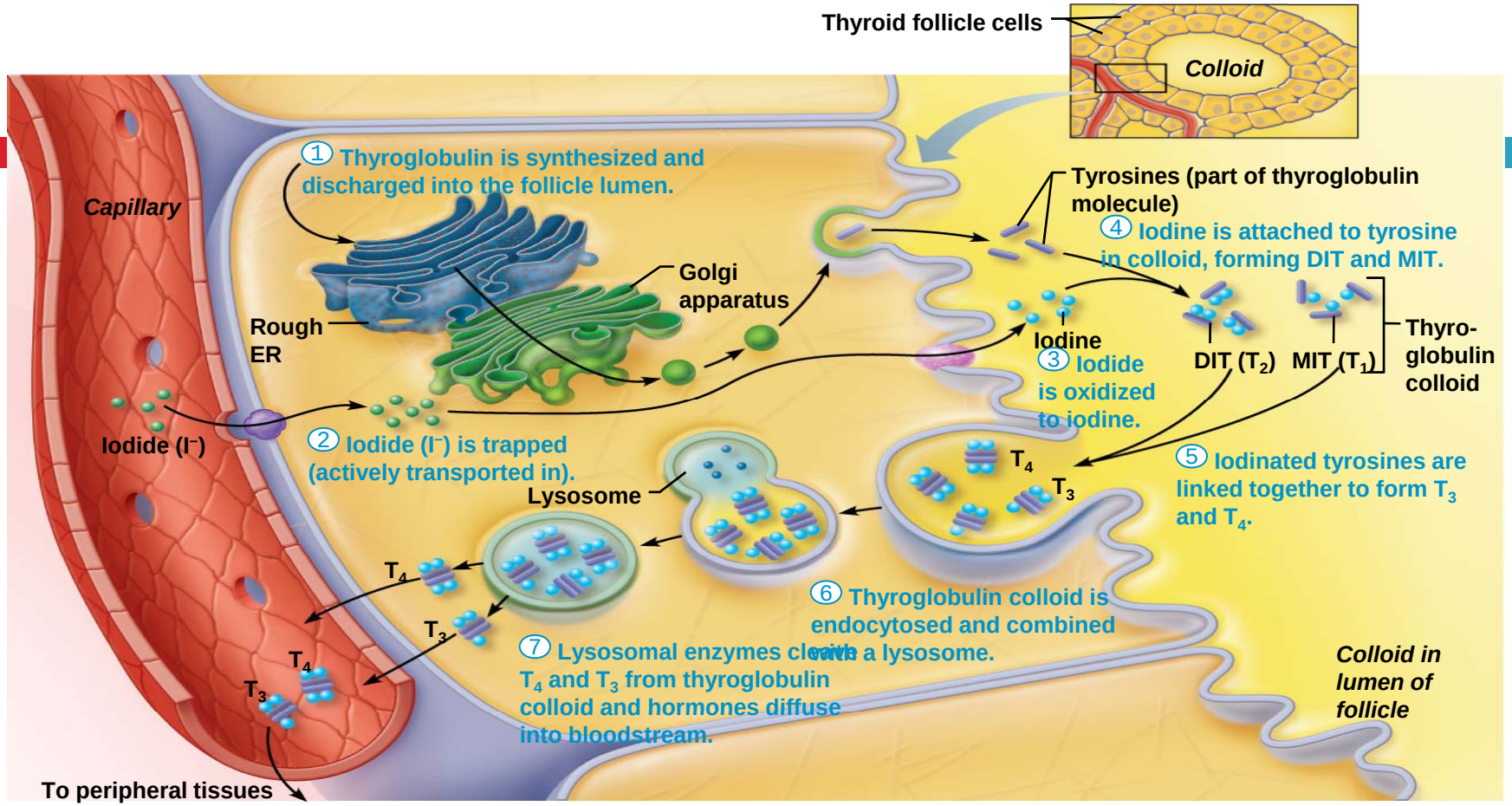

Thyroid follicle cells
Colloid
Capillary
1 Thyroglobulin is synthesized and discharged into the follicle lumen.
Golgi apparatus
Rough ER
Tyrosines (part of thyroglobulin molecule)
4 Iodine is attached to tyrosine in colloid, forming DIT and MIT.
Iodine
3 Iodide is oxidized to iodine.
DIT ($T_2$)
MIT ($T_1$)
Thyro-globulin colloid
Iodide ($I^-$)
2 Iodide ($I^-$) is trapped (actively transported in).
Lysosome
$T_4$
$T_3$
5 Iodinated tyrosines are linked together to form $T_3$ and $T_4$.
6 Thyroglobulin colloid is endocytosed and combined with a lysosome.
7 Lysosomal enzymes cleave $T_4$ and $T_3$ from thyroglobulin colloid and hormones diffuse into bloodstream.
Colloid in lumen of follicle
To peripheral tissues

**Figure 16.9**

# Transport and Regulation of TH

- $T_4$ and $T_3$ are transported by thyroxine-binding globulins (TBGs)
- Both bind to target receptors, but $T_3$ is ten times more active than $T_4$
- Peripheral tissues convert $T_4$ to $T_3$

# Transport and Regulation of TH

- Negative feedback regulation of TH release
  - Rising TH levels provide negative feedback inhibition on release of TSH
  - Hypothalamic thyrotropin-releasing hormone (TRH) can overcome the negative feedback during pregnancy or exposure to cold

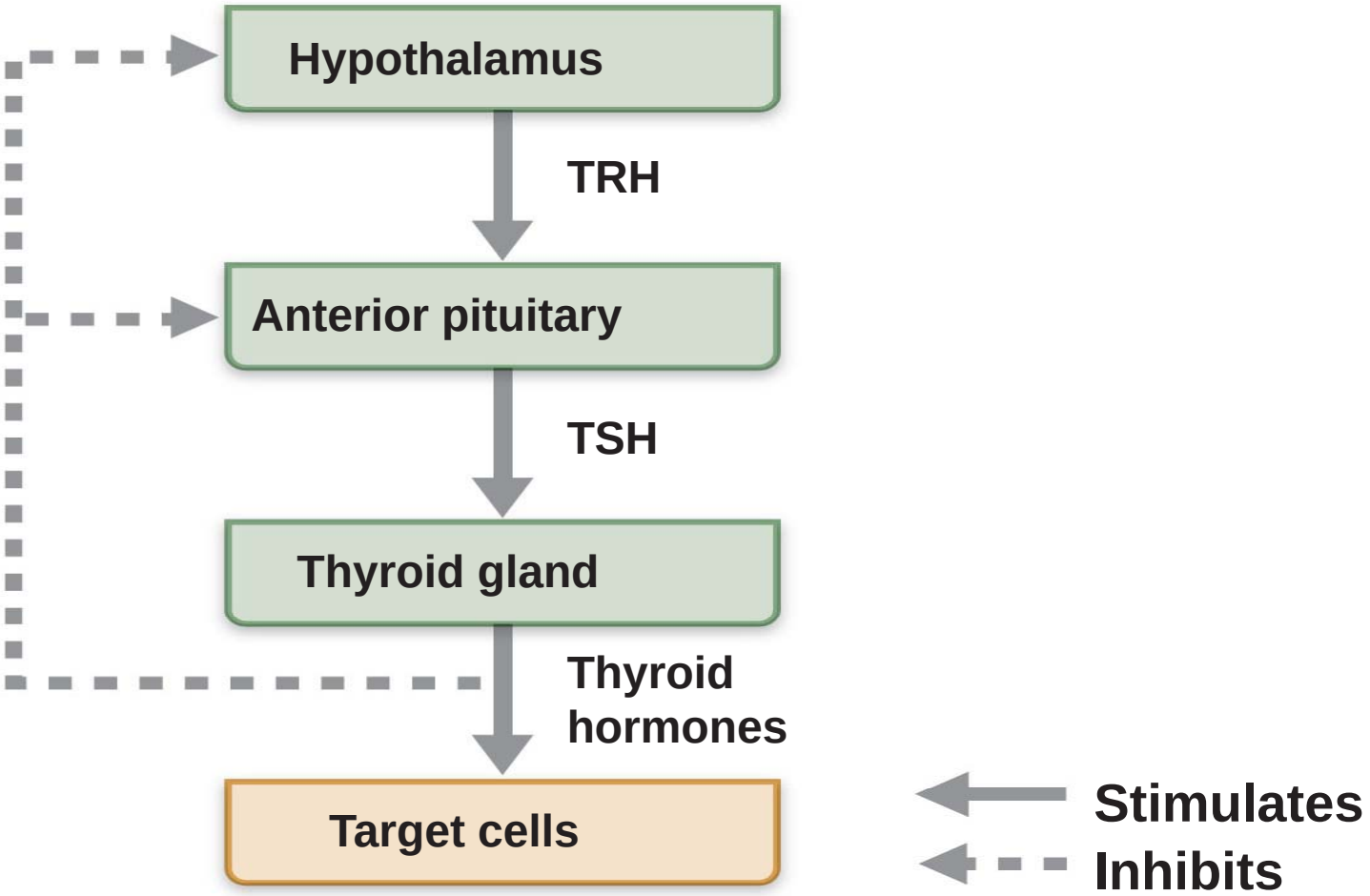

Hypothalamus
TRH
Anterior pituitary
TSH
Thyroid gland
Thyroid hormones
Target cells
Stimulates
Inhibits

Figure 16.7

# Homeostatic Imbalances of TH

- Hyposecretion in adults—myxedema; endemic goiter if due to lack of iodine
- Hyposecretion in infants—cretinism
- Hypersecretion—Graves' disease

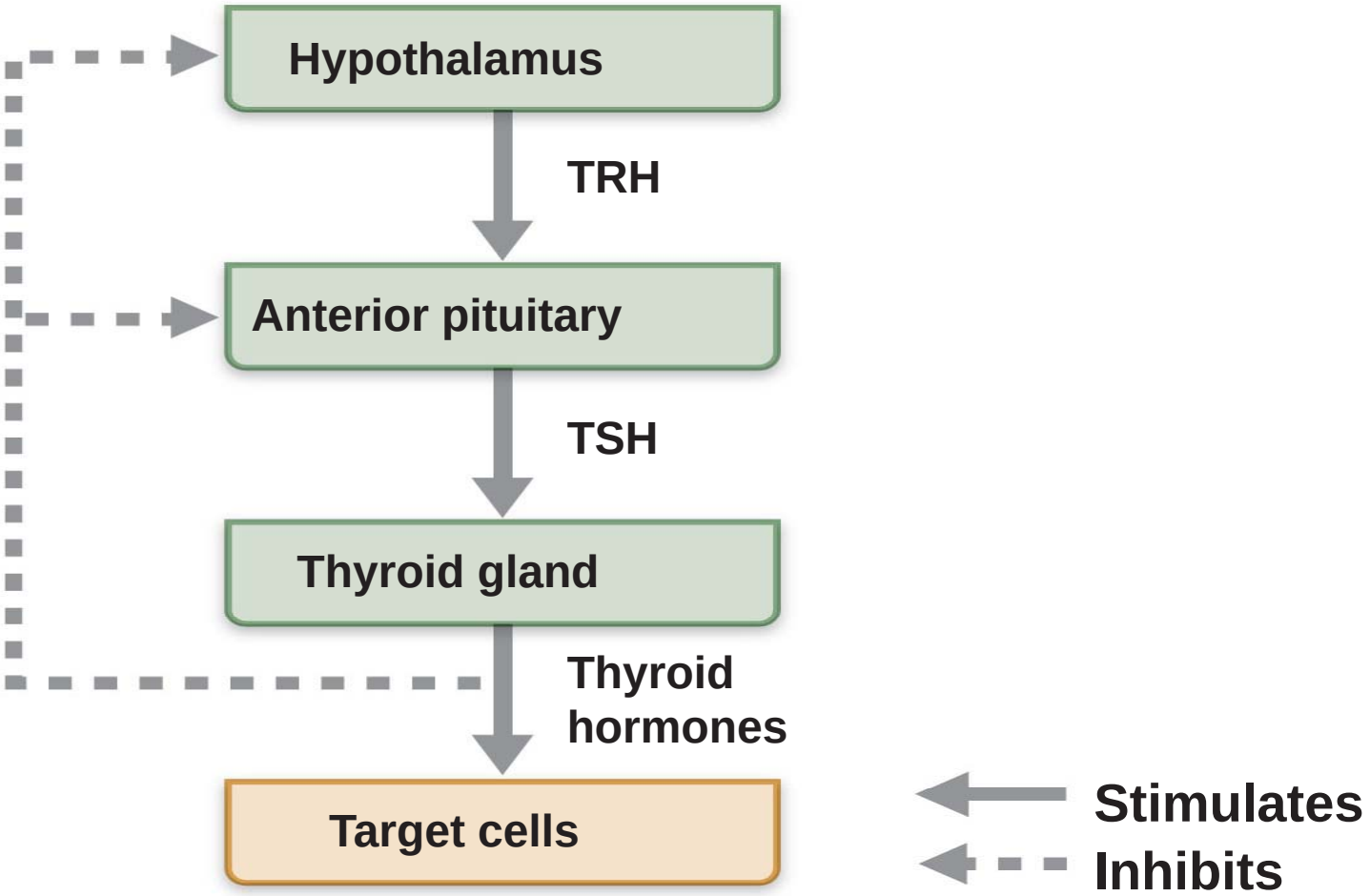

Hypothalamus
TRH
Anterior pituitary
TSH
Thyroid gland
Thyroid hormones
Target cells
Stimulates
Inhibits

Figure 16.7

# Homeostatic Imbalances of TH

- Hyposecretion in adults—myxedema; endemic goiter if due to lack of iodine
- Hyposecretion in infants—cretinism
- Hypersecretion—Graves' disease

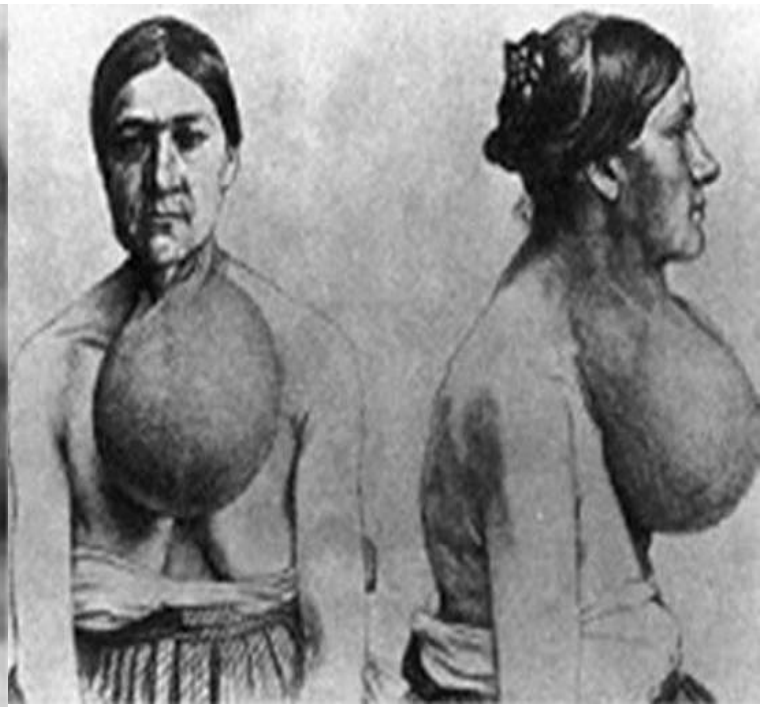


**Figure 16.10**

**Identical male twins with Hashimoto's thyroiditis were photographed at age 12. At age 8, they had the same height and appearance. During the intervening 4 years, small goiters developed and the growth of the twin on the right almost stopped. Biopsy indicated Hashimoto's thyroiditis in each twin's thyroid.**

http://www.thyroidmanager.org/Chapter8/chapter8.html

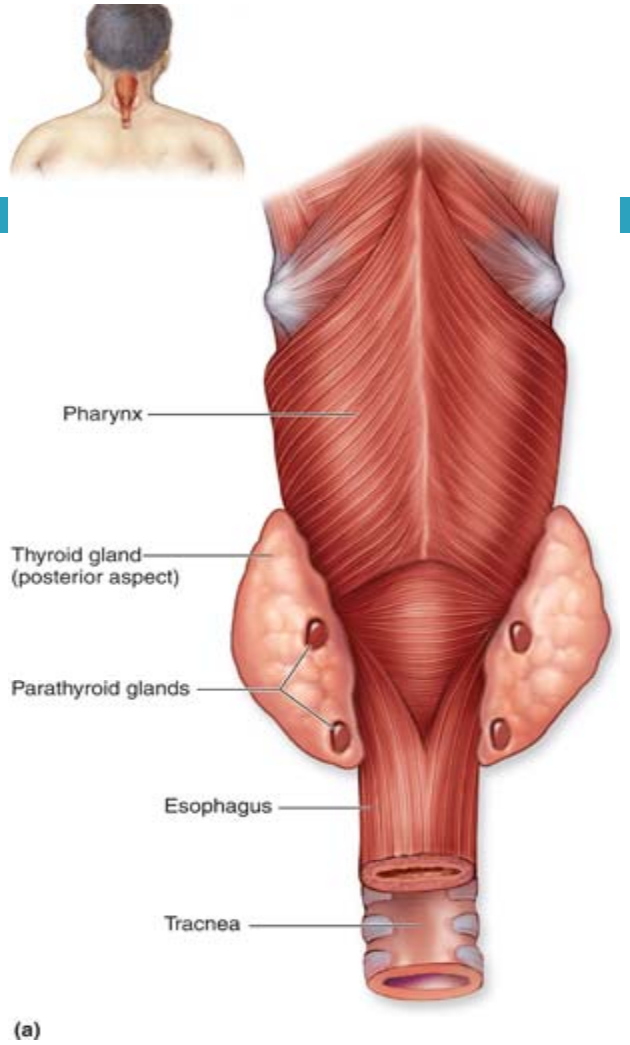
# Calcitonin

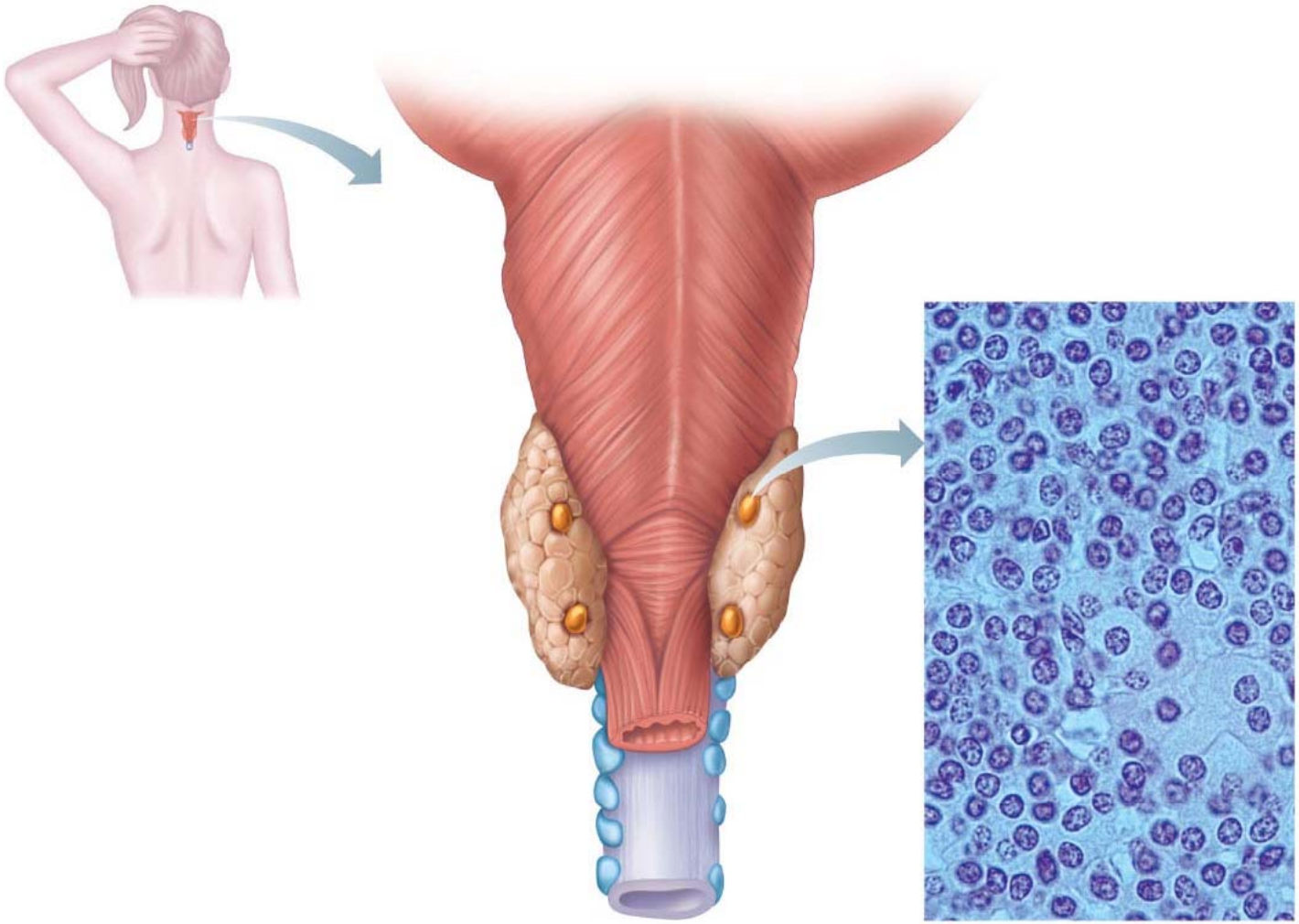
- Produced by parafollicular (C) cells
- Antagonist to parathyroid hormone (PTH)
- Inhibits osteoclast activity and release of $Ca^{2+}$ from bone matrix

# Calcitonin

- Stimulates $Ca^{2+}$ uptake and incorporation into bone matrix
- Regulated by a humoral ($Ca^{2+}$ concentration in the blood) negative feedback mechanism
- No important role in humans; removal of thyroid (and its C cells) does not affect $Ca^{2+}$ homeostasis

# Parathyroid



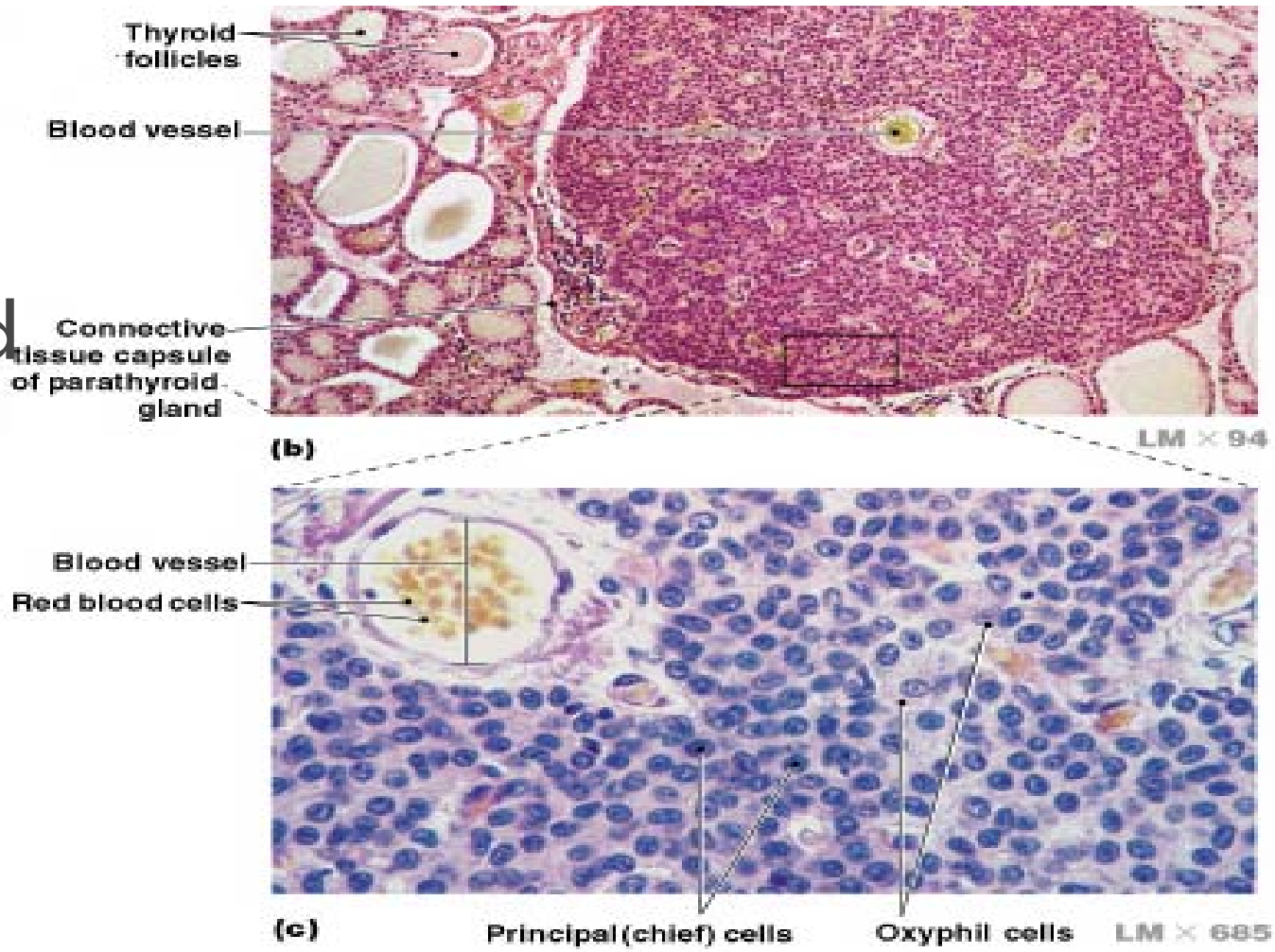


# Parathyroid Glands

- four glands
- parathyroid hormone  PTH
- regulates the level of circulating calcium and phosphate
- target organs: bones, intestines, kidneys

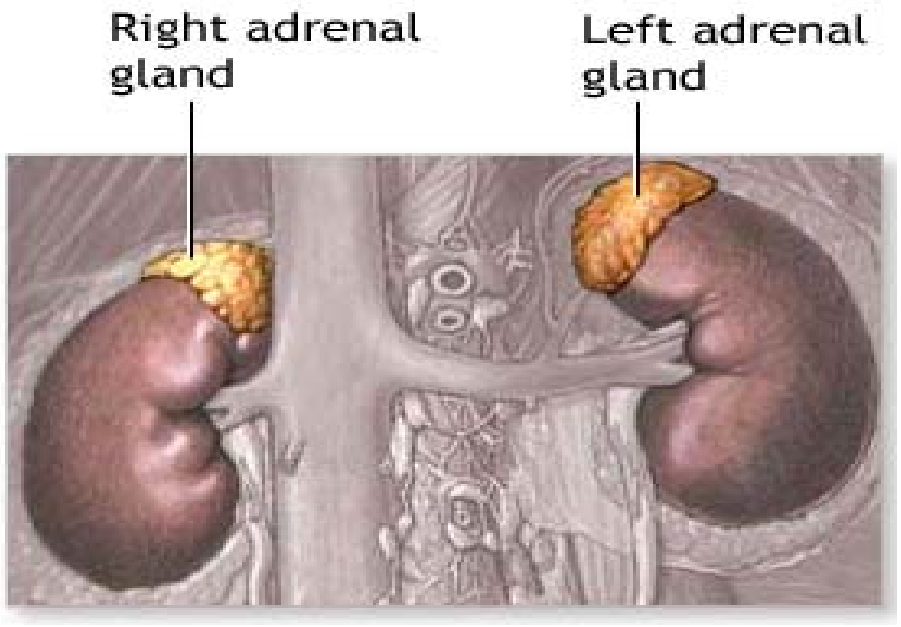
- Calcium is essential to blood-clotting mechanism
- Calcium increases the tone of heart muscle
- Calcium plays a significant role in muscle contraction
- When blood calcium levels drop, PTH is secreted to increase calcium levels

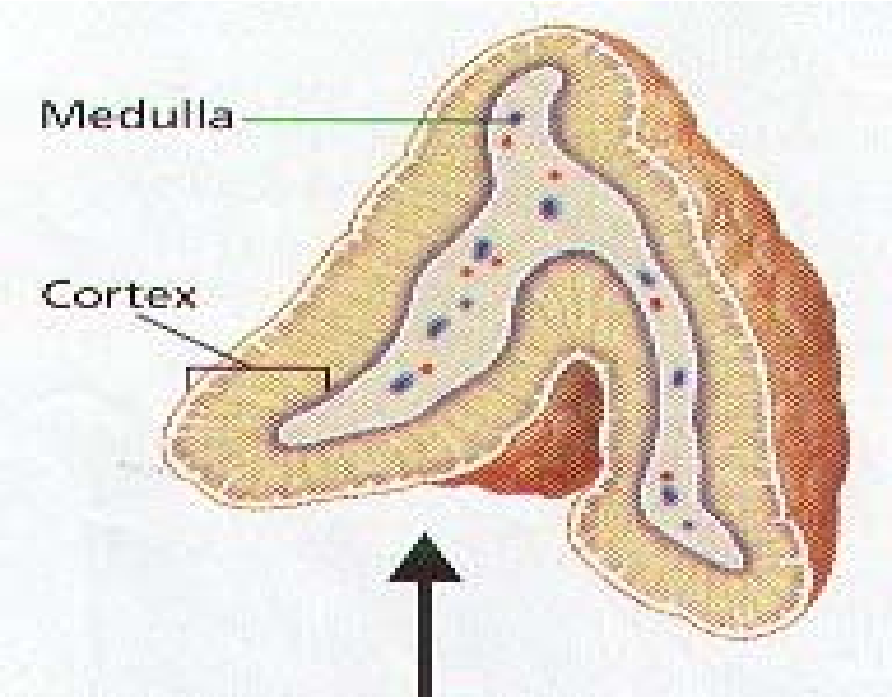
# Parathyroid Histology



# Adrenal Glands

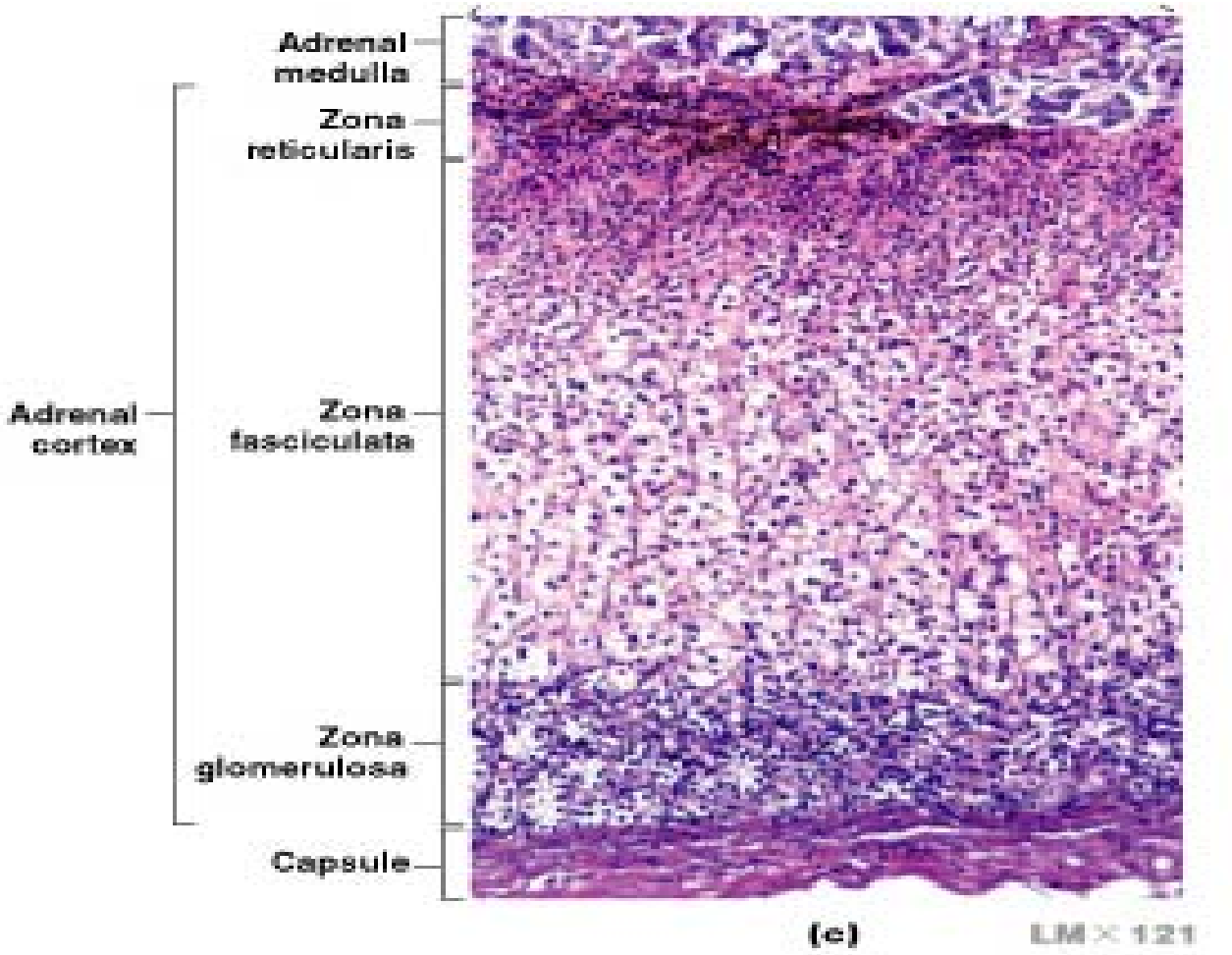




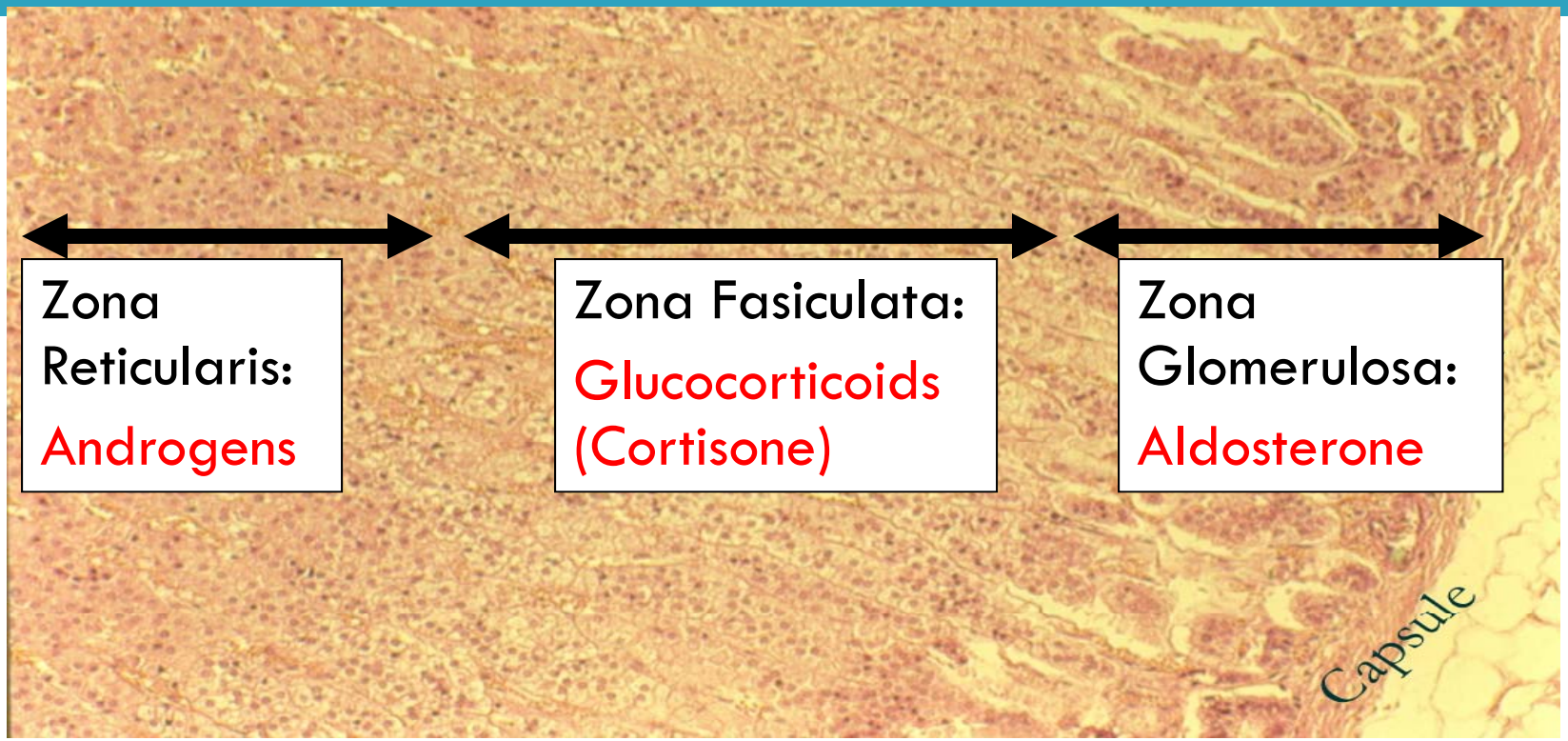
# Adrenal Histology





# Adrenal Cortex

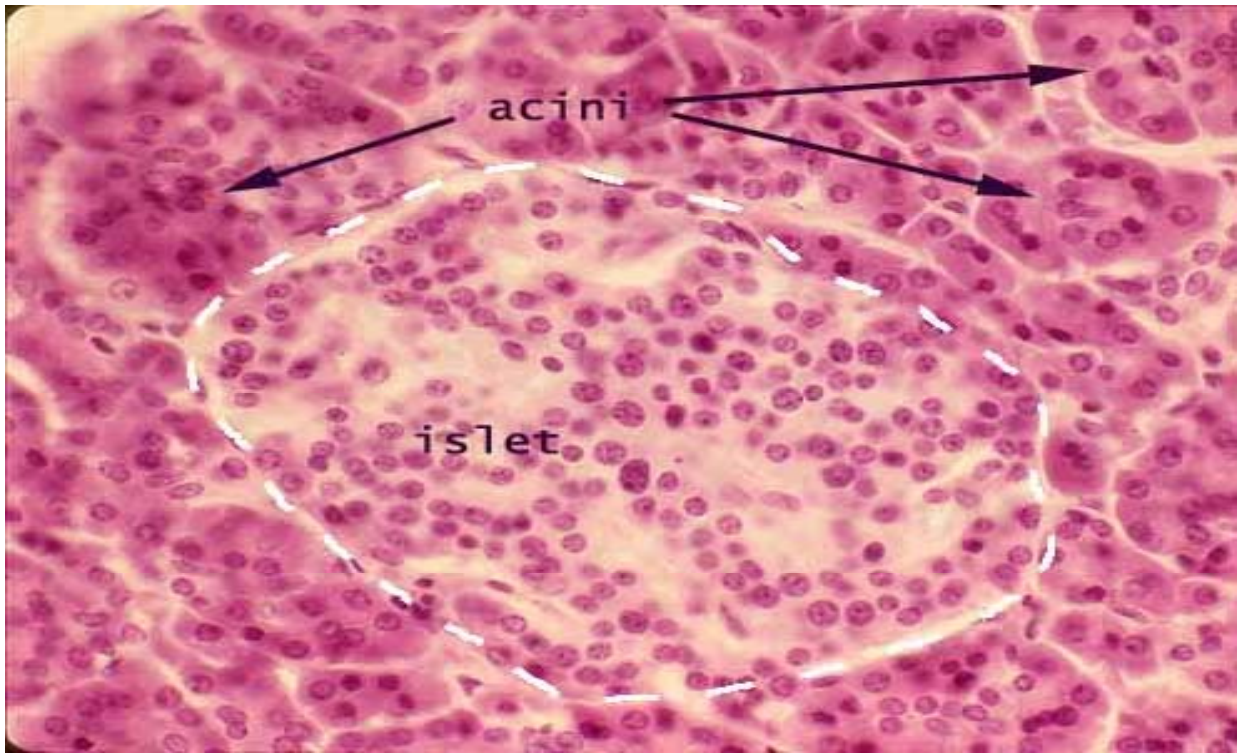


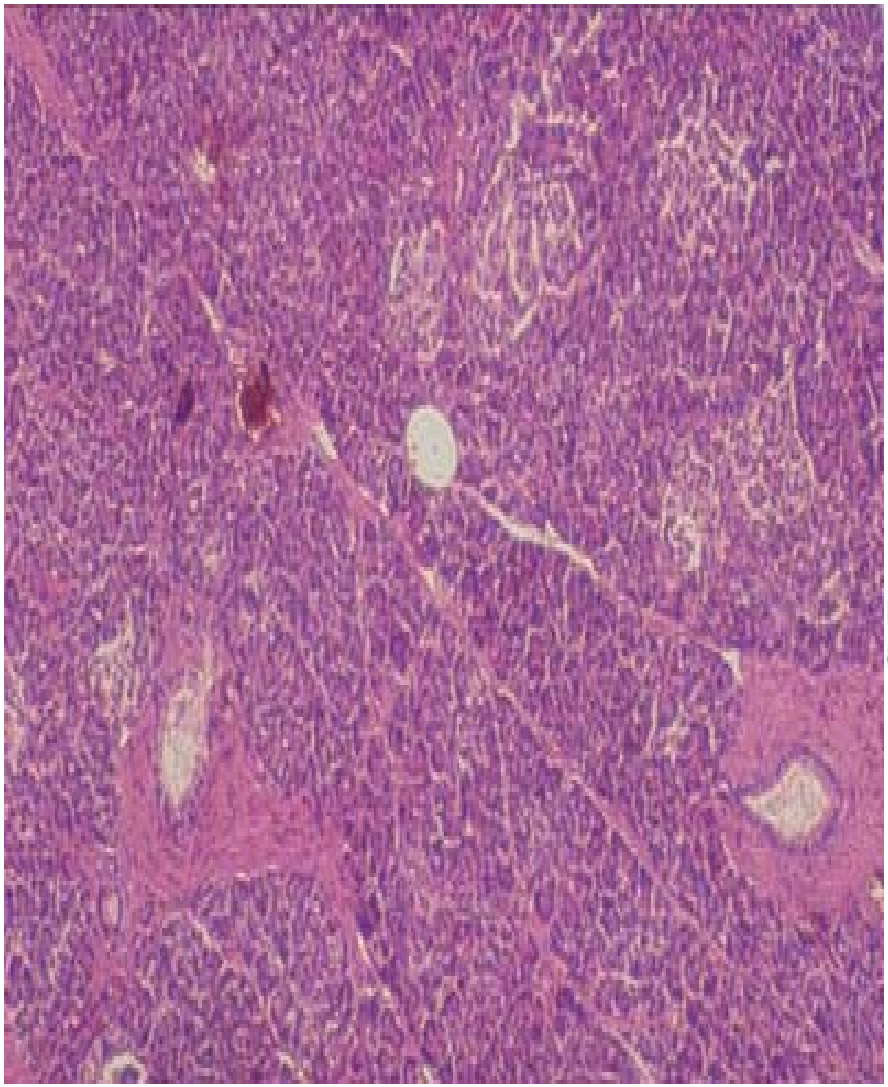


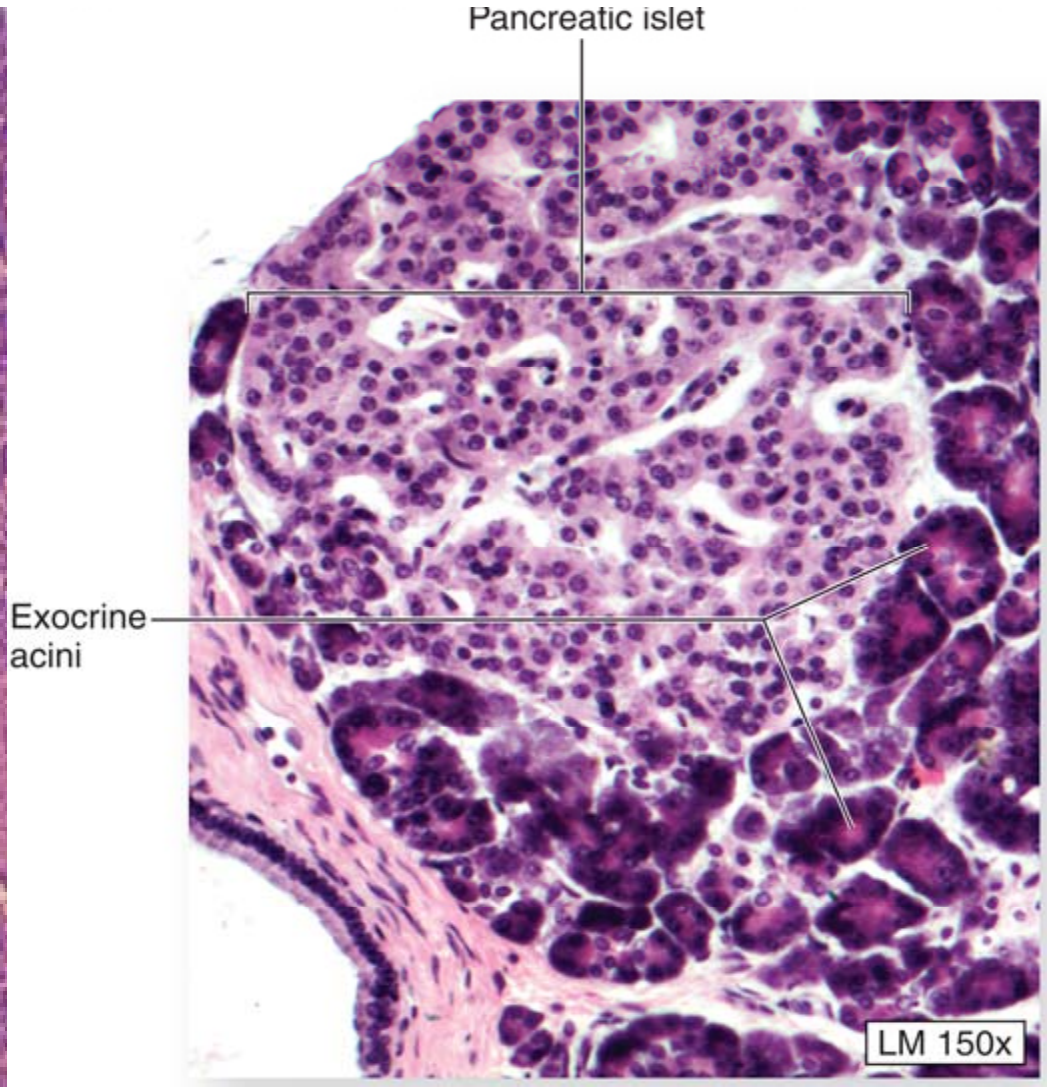
# Pancreas

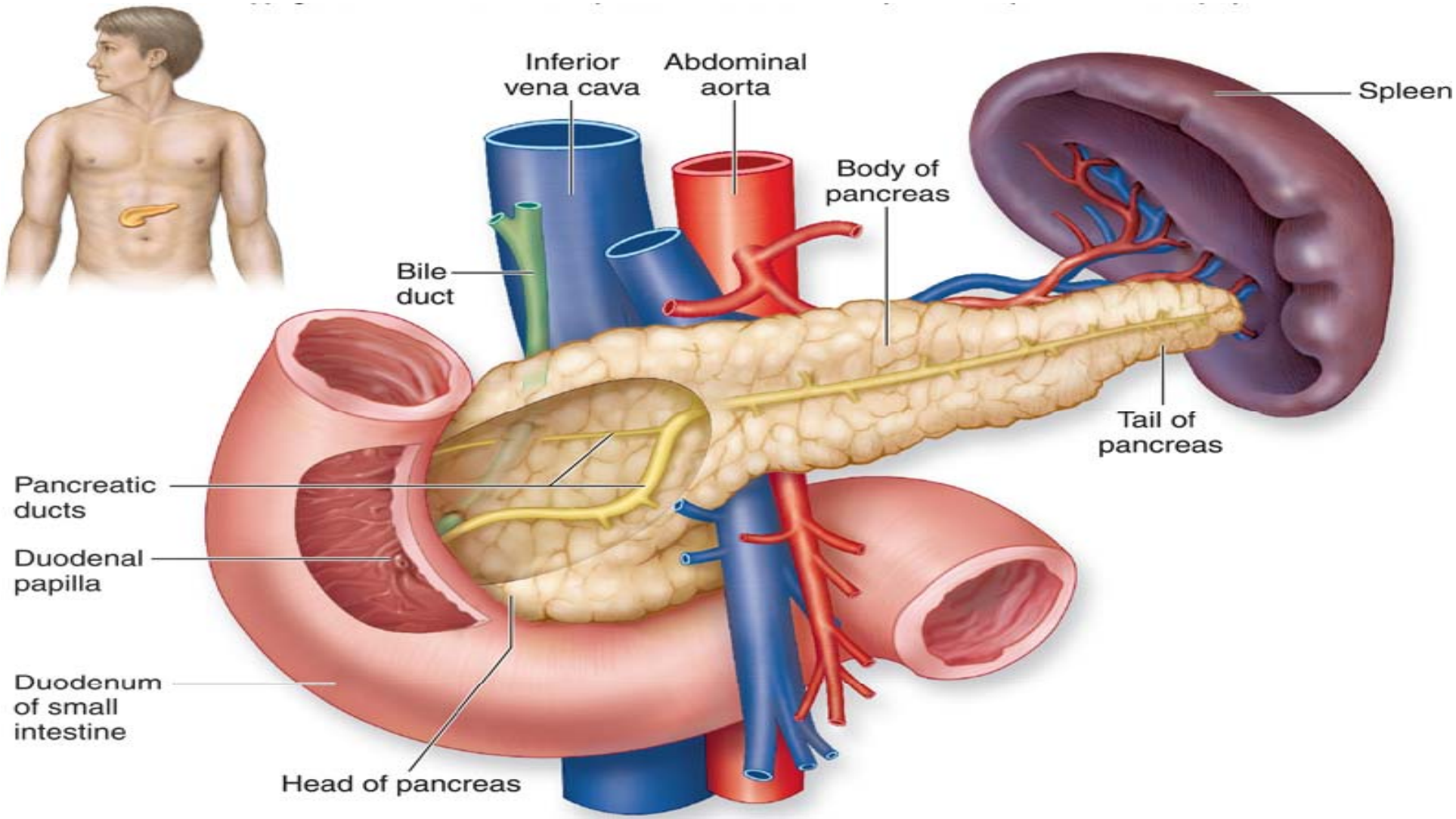


- Acinar cells secrete digestive enzymes (exocrine)
- Islet cells secrete insulin (beta cells) and glucagon (alpha cells)






Pancreatic islet
Exocrine acini
LM 150x


Inferior vena cava
Abdominal aorta
Spleen
Body of pancreas
Bile duct
Tail of pancreas
Pancreatic ducts
Duodenal papilla
Duodenum of small intestine
Head of pancreas

# Diabetes

# Diabetes Mellitus

- inadequate amount of insulin secreted
- in absence of insulin; glucose cannot enter the cells for normal metabolism
- results in hyperglycemia
- blood sugar may increase from 300 to 1200 mg/dl of blood and even higher
- cells deprived of principal nutrient, glucose
- glycosuria, diuresis, polydipsia, polyphagia

# Diabetes



- Type 1: Insulin Dependent Diabetes
- AKA: juvenile diabetes
- Caused by a lack of insulin
- Autoimmune disorder
  - Immune system destroys beta cells in the pancreas

# Diabetes



- Type 2: Non-Insulin Dependent
- Caused by an insensitivity of cells to insulin.
- Diabetes mellitus marked by hyperglycemia
  - ↑ urine production (polyuria)
  - ↑ thirst (polydipsia)
  - ↑ eating (polyphagia)

# Diagnosing Diabetes Mellitus



- Normal blood glucose levels: 70-100 mg/dl
- Diabetes mellitus:
  - A fasting glucose level above 140 mg/dl on two separate occasions, or
  - A blood sugar over 200 mg/dl 2 hours after oral glucose tolerance test with 75gm of glucose
- Impaired Glucose Tolerance (Pre-Diabetes)
  - A fasting glucose level between 100-126 mg/dl on two separate occasions, or
  - A blood sugar between 140-200 mg/dl 2 hours after oral glucose tolerance test with 75gm of glucose

# Pathology

- pheochromocytoma
  - adrenal medulla tumor
  - increase BP due to release of catacholamines
- Addison's disease - decrease cortisol
  - hyponatremia, dehydration
  - hyperkalemia
- Cushing's disease - increase cortisol
  - moon face, hirsutism

- Insulin-dependent diabetes mellitus  IDDM
  - Type I
  - Juvenile diabetes
  - destruction of Beta cells
  - more serious form
  - requires daily insulin injections

- Non-insulin-dependent diabetes mellitus
  - NIDDM
  - type II
  - maturity onset diabetes
  - less severe, often diet controlled
  - oral hypoglycemic agents
- A prolonged, excessively high carbohydrate diet over time stimulates the beta cells to secrete insulin. Result: beta cells "burn out".

- diabetic ketoacidosis (acidosis)
  - due to insulin deficiency, stress
  - metabolic shift results in excessive accumulation of ketones
- gestational diabetes mellitus
  - deficiency of insulin during pregnancy

- Diabetes Insipidus
  - Insufficient ADH
  - Inability of kidneys to respond to ADH
- extreme polydipsia and polyuria

# Oncology

- Pancreatic Cancer
- Pituitary Tumors
- Thyroid Cancer