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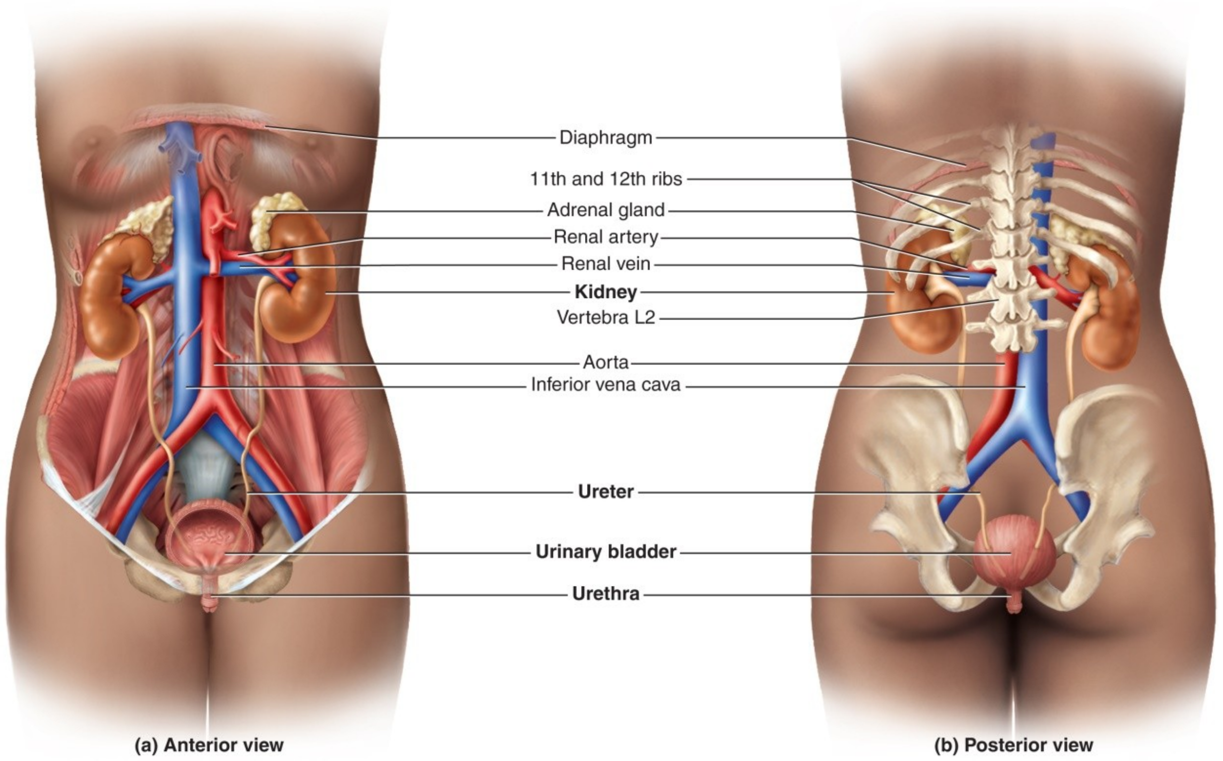
Urinary

BI 455 CHAPTER 19

Urinary system rids the body of waste products

- The urinary system is closely associated with the reproductive system
- Shared embryonic development and adult anatomical relationship
- Collectively called the urogenital (UG) system
- **Urinary system** consists of six organs: two kidneys, two ureters, urinary bladder, and urethra



Chapter 19 Key Points

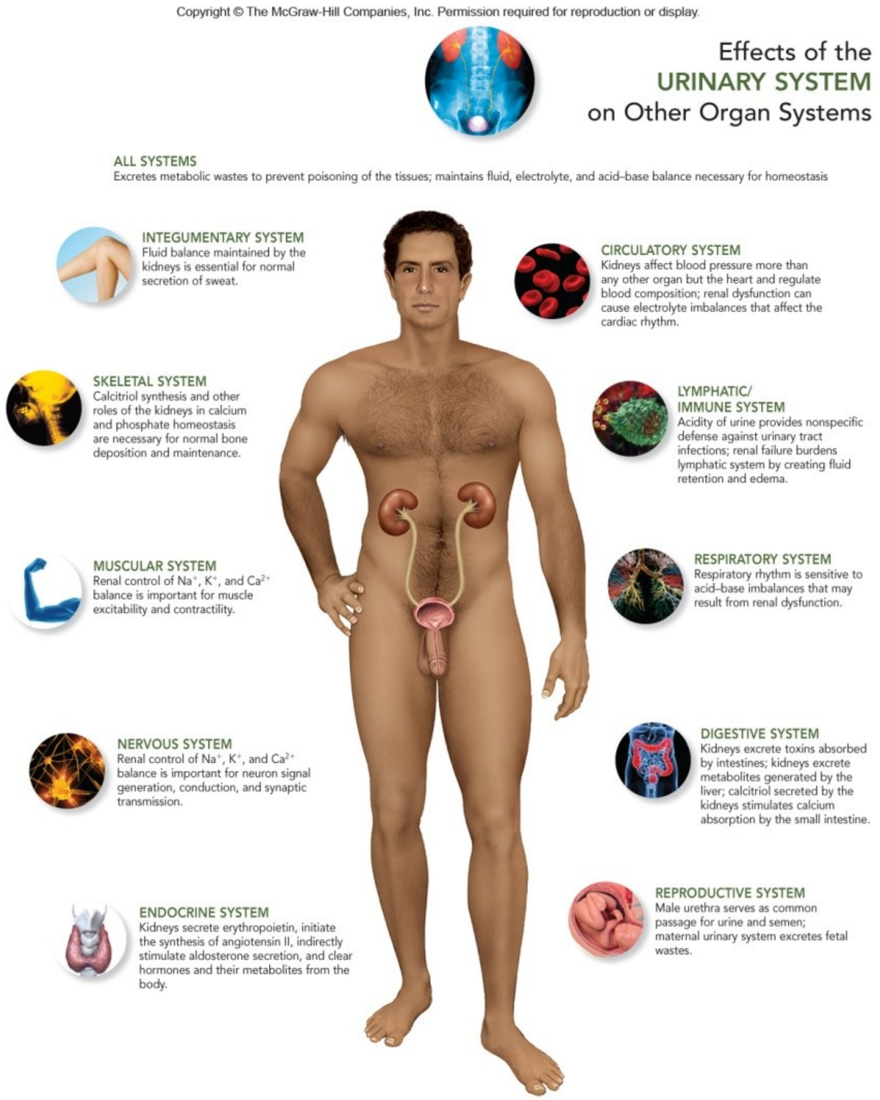
1. Urinary system function
2. Urinary anatomy
3. Urine formation
    1. Glomerular filtration
    2. Tubular reabsorption
    3. Water conservation
4. Urine function and renal tests
5. Urine storage and elimination

Bozeman Science: http://www.bozemanscience.com/osmoregulation

Crash Course: https://www.khanacademy.org/partner-content/crash-course1/crash-course-biology/v/crash-course-biology-128

Excretion: separation of wastes from body fluids and the elimination of them

Respiratory system: CO_2, small amounts of other gases, and water
Integumentary system: Water, inorganic salts, lactic acid, urea in sweat
Digestive system: Water, salts, CO_2, lipids, bile pigments, cholesterol, other metabolic waste, and food residue
Urinary system: Many metabolic wastes, toxins, drugs, hormones, salts, H^+, and water



Nitrogenous Wastes

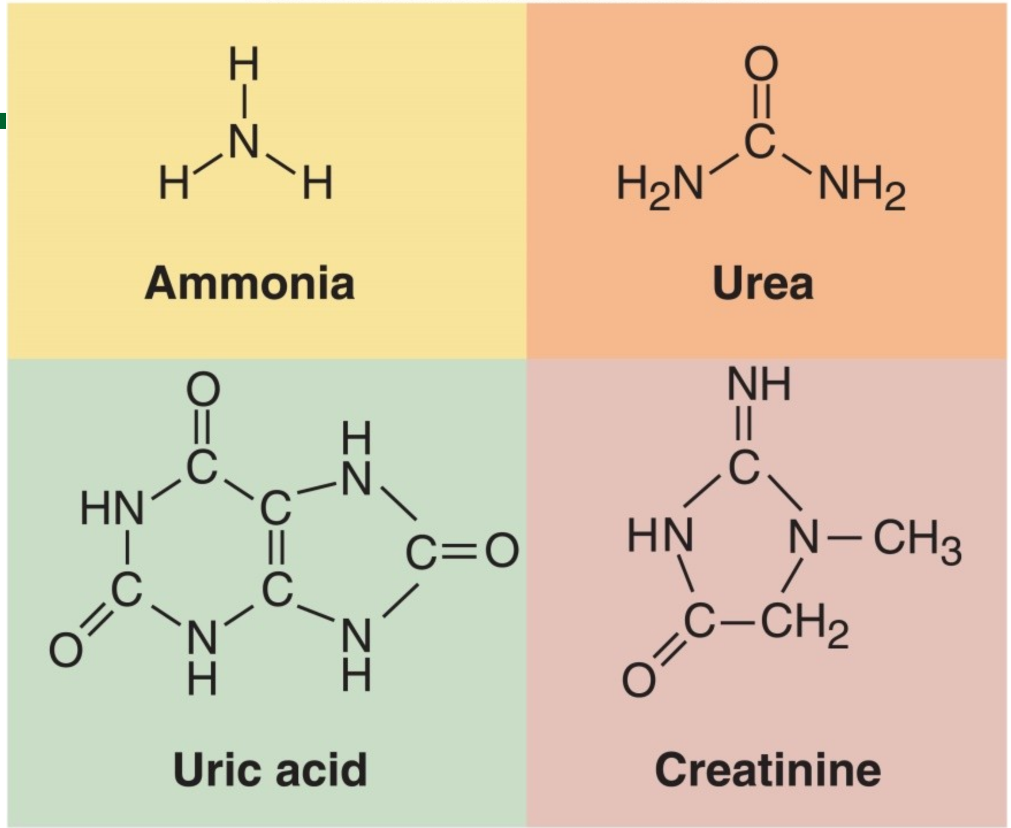
Urea: Proteins→ amino acids → NH_2 removed → forms ammonia, liver converts to urea

Uric acid: Product of nucleic acid catabolism

Creatinine: Product of creatine phosphate catabolism

Blood urea nitrogen (BUN): level of nitrogenous waste in the blood

- Normal BUN: 10 to 20 mg/dL
- **Azotemia**: elevated BUN, indicates renal insufficiency
- **Uremia**: syndrome of diarrhea, vomiting, dyspnea, and cardiac arrhythmia stemming from the toxicity of nitrogenous waste
- Treatment: hemodialysis or organ transplant

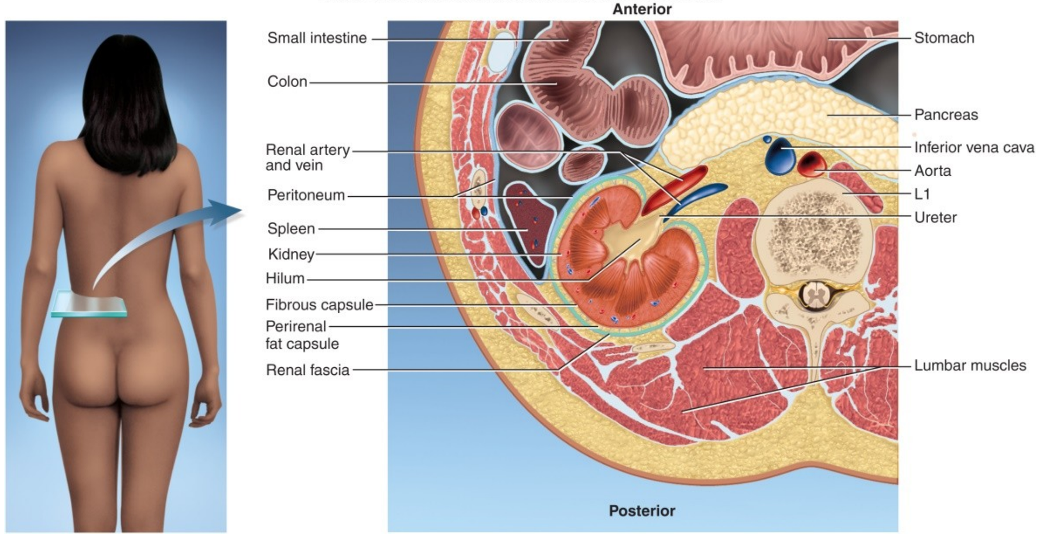


Waste: useless or present in excess of the body's needs

Metabolic waste: produced by the body

Functions of the Kidneys

1. **Filters blood plasma**
2. Regulates **blood volume** and **body fluid osmolarity** via elimination of water and solutes
3. Secretes **renin**, controlling blood pressure and electrolyte balance
4. Secretes **erythropoietin**, stimulating RBC production
5. Contributes to $\mathbf{PCO_2}$ and **acid–base balance** of body fluids
6. Final step in synthesizing hormone, **calcitriol** (Vitamin D)
7. **Gluconeogenesis** in extreme starvation

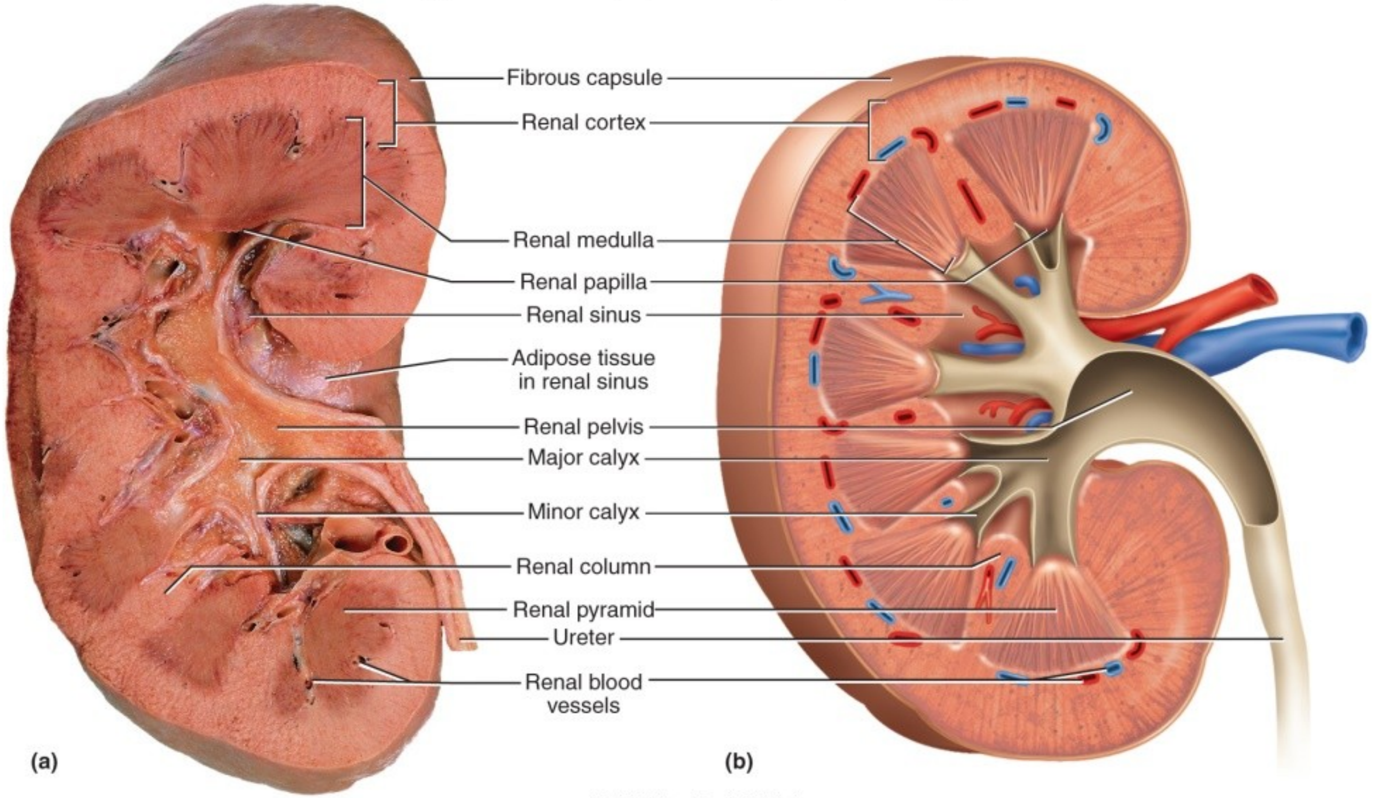


Gross Anatomy of the kidney

Renal sinus: blood lymphatic vessels, nerves, and urine-collecting structures

Renal parenchyma: glandular tissue that forms urine, Encircles the renal sinus
Two zones of renal parenchyma
- **Outer renal cortex**
- **Inner renal medulla**: **Renal columns** & Renal pyramids:

Lobe of the kidney: one pyramid and its overlying cortex



a: Ralph Hutchings/Visuals Unlimited

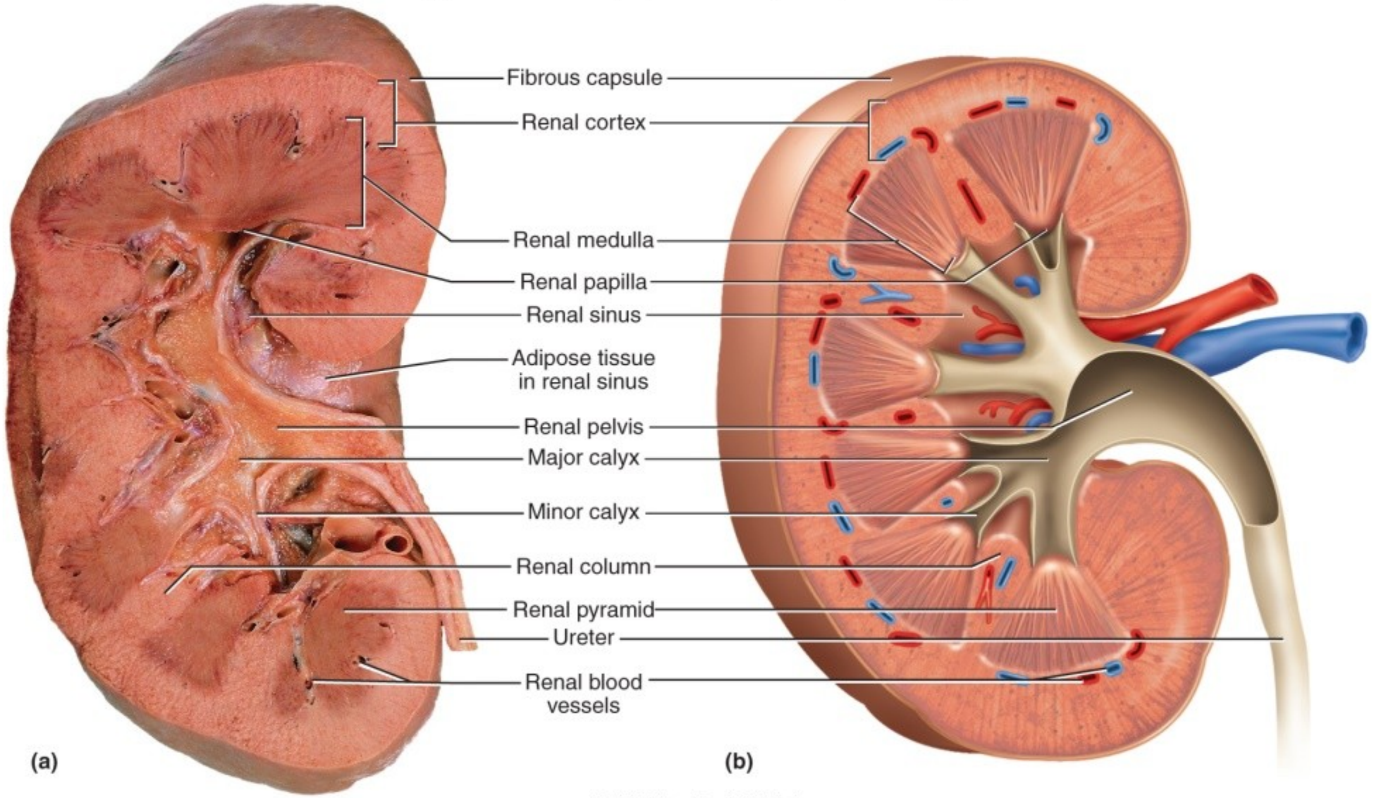
Gross Anatomy of the kidney

Minor calyx: cup nestled in papilla of each pyramid; collects it urine

Major calyces: convergence of two or three minor calyces

Renal pelvis: convergence of two or three major calyces

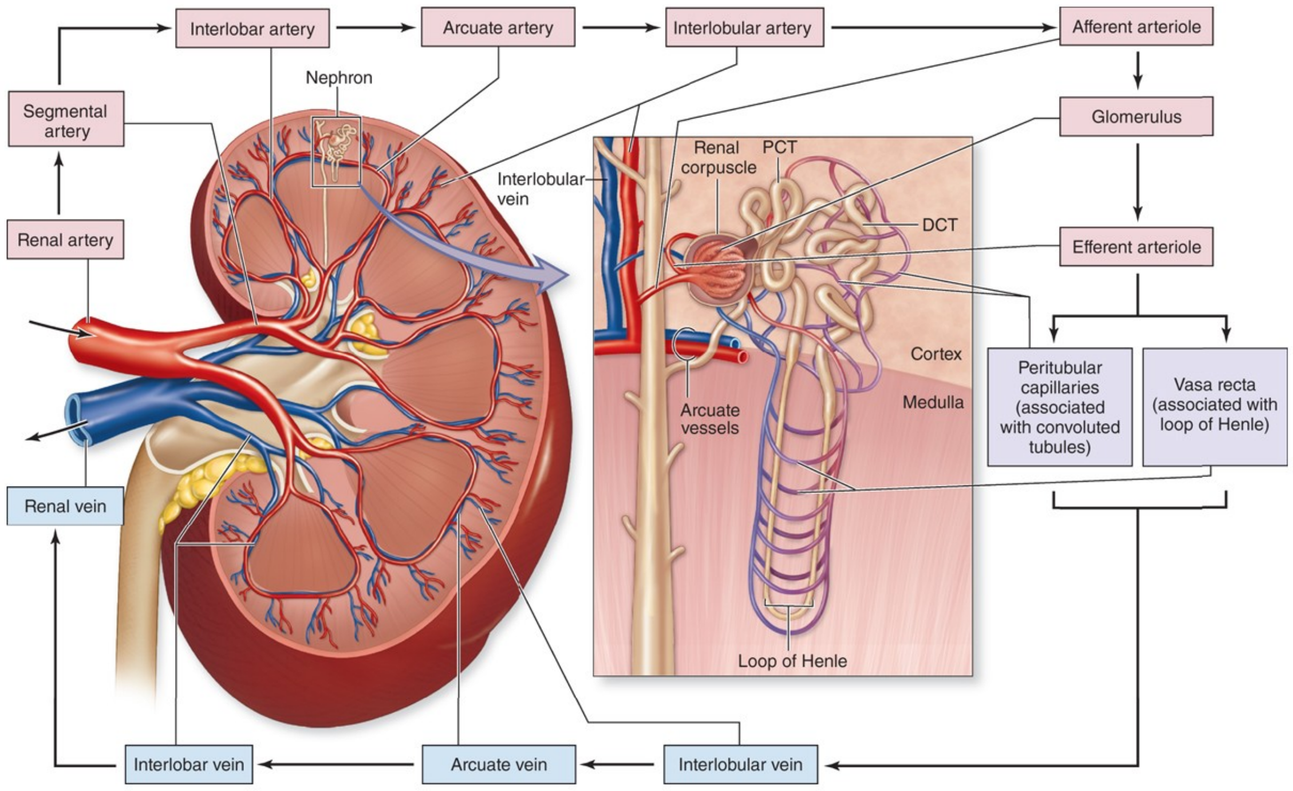
Ureter: tubular continuation of the pelvis that drains the urine down to the urinary bladder



a: Ralph Hutchings/Visuals Unlimited

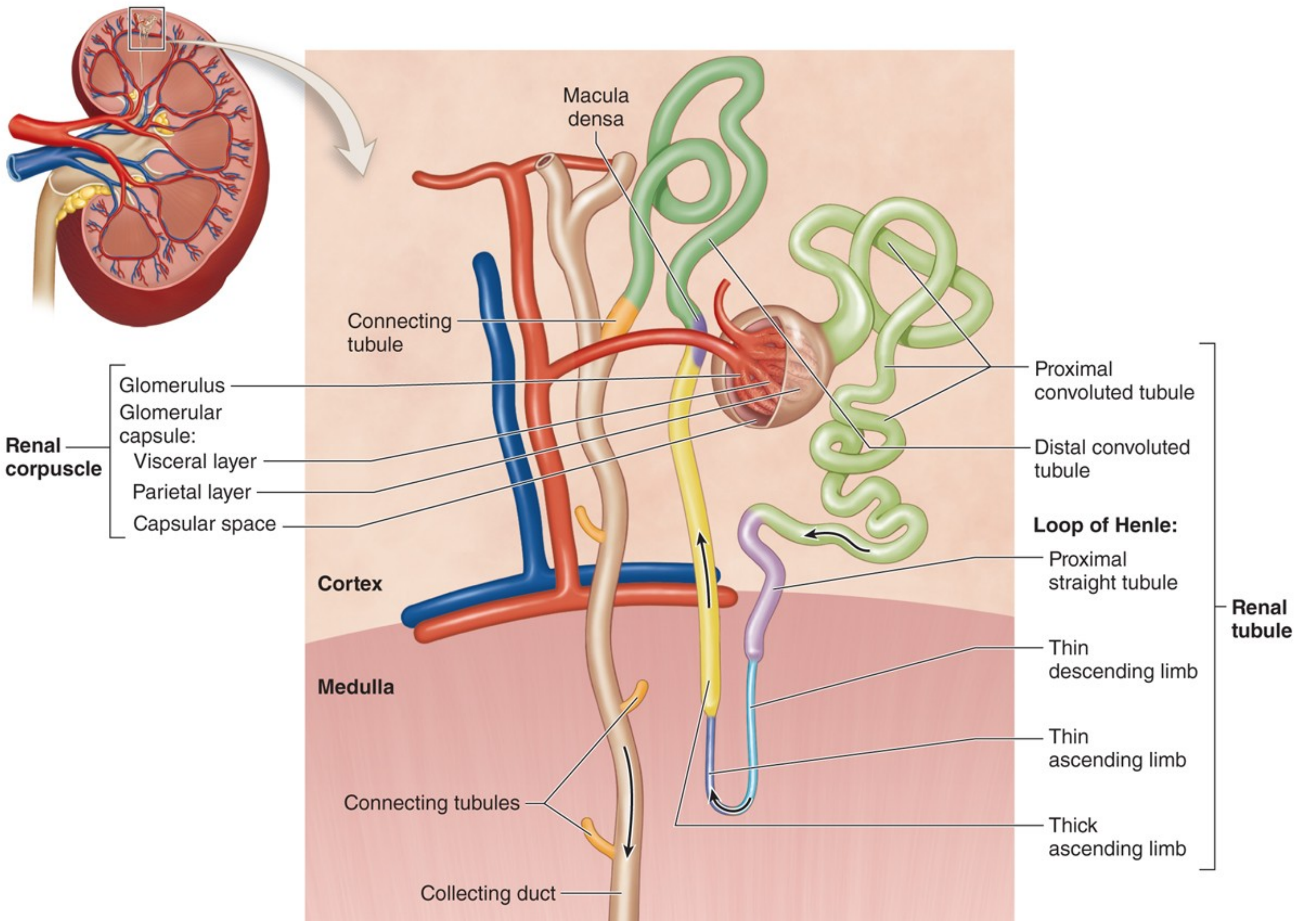
Renal Circulation: 0.4% of body weight, 21% of cardiac output

Renal artery → Interlobar arteries → Arcuate arteries: over pyramids → Interlobular (cortical radiate) arteries → afferent arterioles → 1 nephron → efferent arterioles → peritubular capillaries or vasa recta → Interlobular veins (cortical radiate) → arcuate veins → interlobar veins → Renal vein → inferior vena cava



Medical Application: Distance runners and swimmers often experience temporary proteinuria or hematuria (protein or blood in urine). Prolonged, strenuous exercise greatly reduces perfusion of kidney Glomerulus deteriorates under prolonged hypoxia

Each kidney contains approximately 1 million functional units called nephrons, which carry waste from blood to calyx



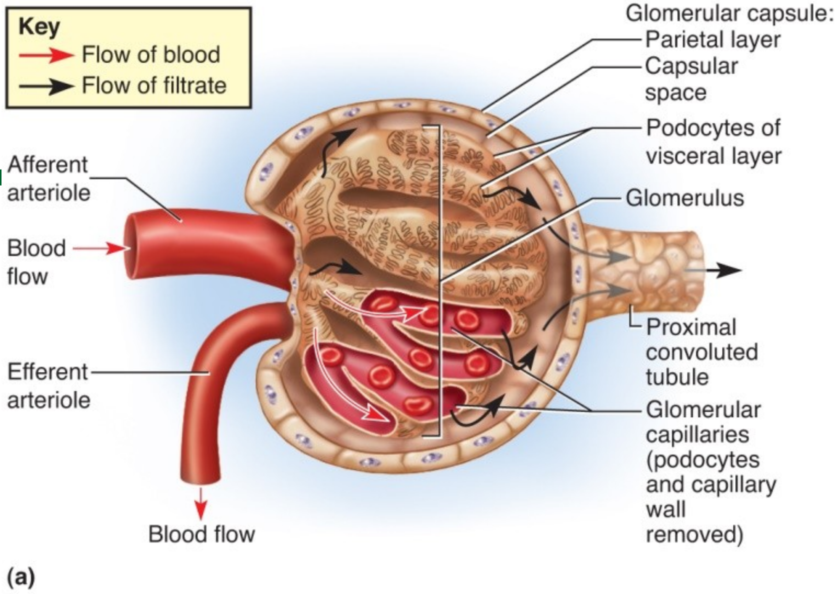
renal corpuscle →proximal convoluted tubule → loop of Henle (proximal straight tubule → thin descending limb → thin ascending limb → thick ascending limb → macula densa → distal convoluted tubule → connecting tubule → collecting duct → calyx

The Nephron

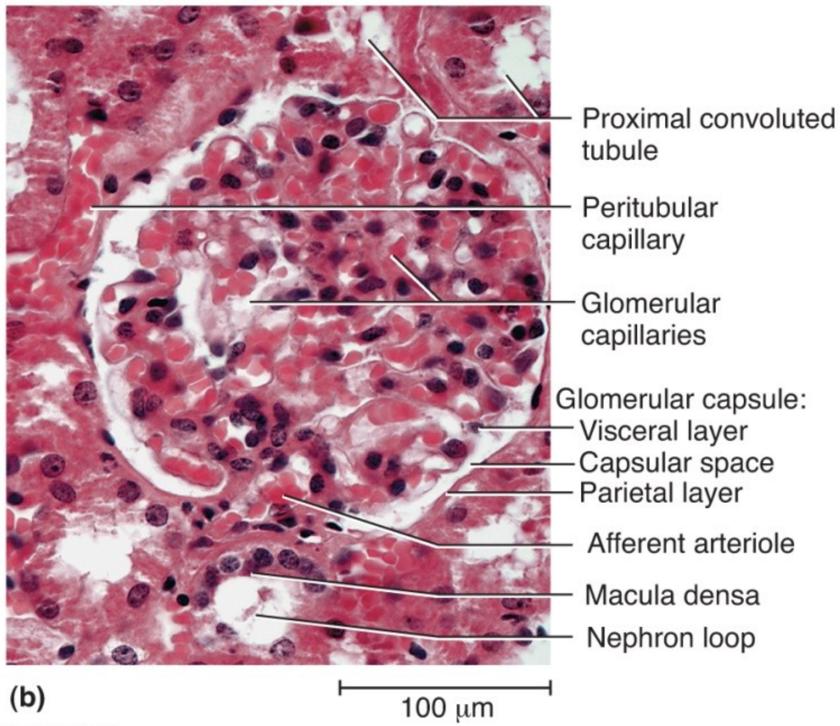
Glomerular filtrate: fluid exits glomulerular capillary → capsular space → convoluted tubule.
Note the afferent arteriole is larger than the efferent arteriole.

- **Vascular pole**: the side of the corpuscle where the afferent arterial enters the corpuscle and the efferent arteriole leaves
- **Urinary (Tubular) pole**: the opposite side of the corpuscle where the renal tubule begins

MEDICAL APPLICATION: In diseases such as diabetes mellitus and glomerulonephritis, the glomerular filter is altered and becomes much more permeable to proteins, with the subsequent release of protein into the urine (**proteinuria**). Proteinuria is an indicator of many potential kidney disorders.



(a)



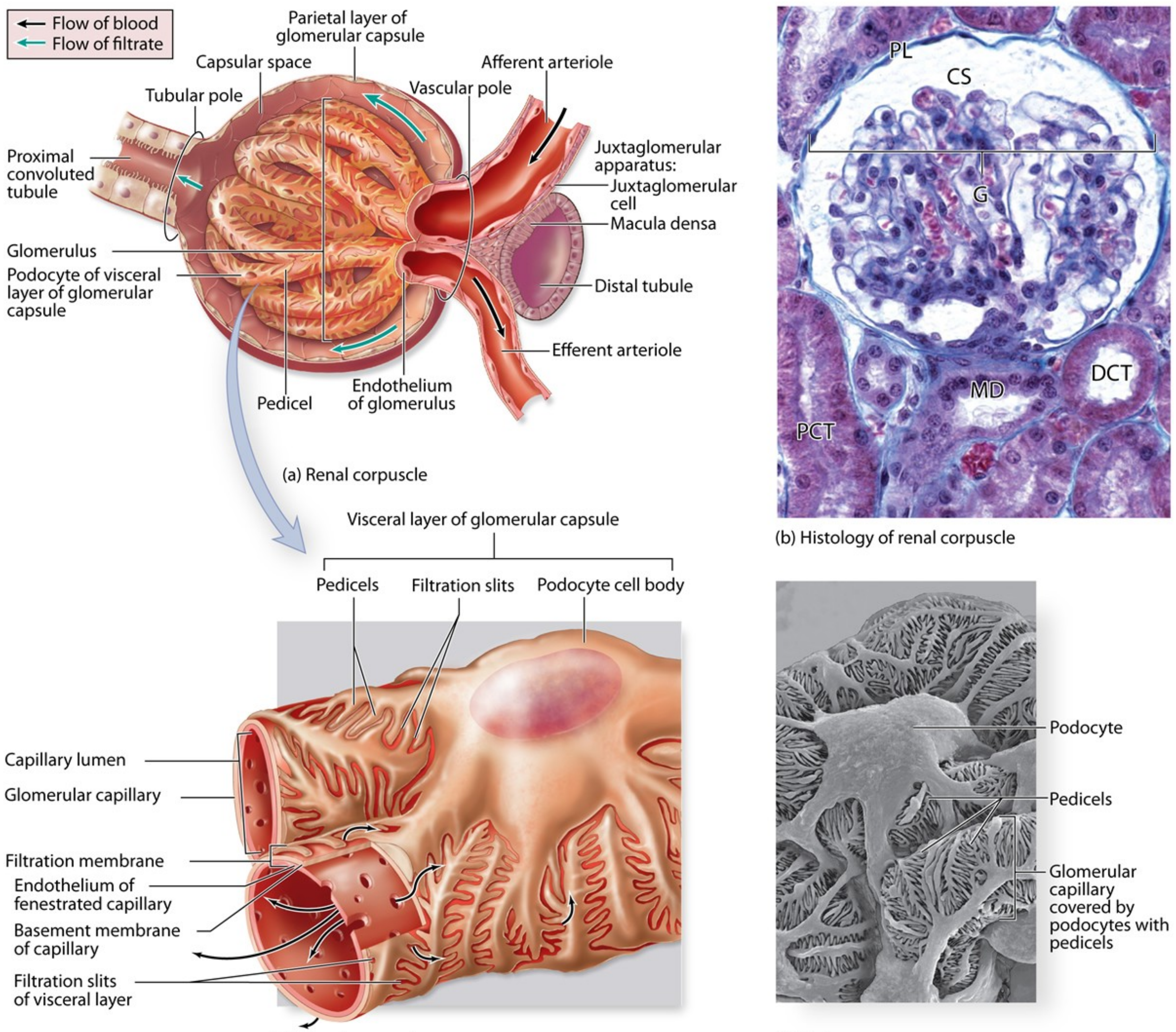
(b)

Renal corpuscle is small mass of capillaries called the glomerulus housed within a bulbous glomerular capsule: filters the blood plasma

Parietal (outer) layer of capsule: simple squamous epithelium
Visceral (inner) layer of capsule
- **podocytes** surround capillaries and create barrier against escape of large molecules
- **pedicels:** foot processes of podocytes

Capsular space separates the two layers of Bowman capsule

Blood enters and leaves the glomerulus through the afferent and efferent arterioles, respectively.
G glomerulus
CS capsular space
PL: simple squamous parietal layer of Bowman capsule. **MD** macula densa
PCT proximal convoluted tubules
DCT distal convoluted tubules



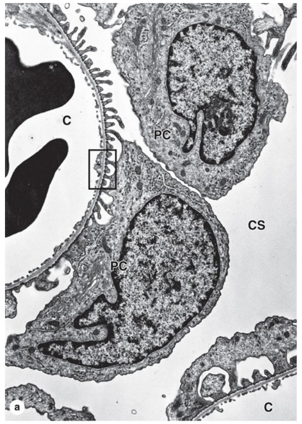
(a) Renal corpuscle
(b) Histology of renal corpuscle
(c) Filtration membrane
(d) Podocytes

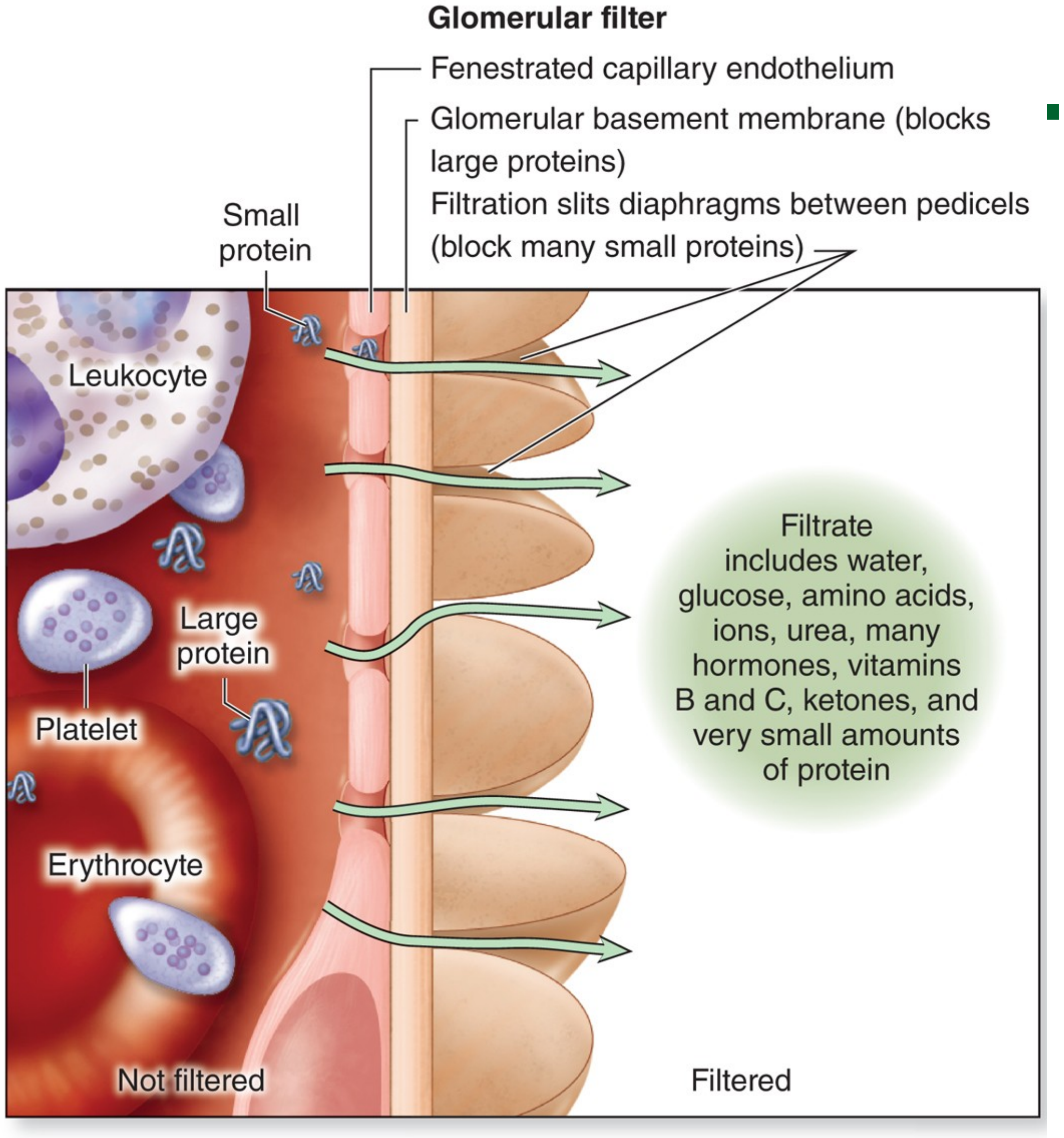
Glomerular Filter

Filtrate is produced in the corpuscle when blood plasma is forced under pressure through the **capillary fenestrations**, across the filtration **membrane** or surrounding the capillary, and through the **filtration slit** diaphragms located between the podocyte pedicels

The glomerular filtration barrier = fenestrated **capillary endothelium**, the **glomerular basement membrane (GBM)**, and **filtration slit**

MEDICAL APPLICATION Diabetic glomerulosclerosis, the thickening and loss of function in the GBM produced as part of the systemic microvascular sclerosis in diabetes mellitus, is the leading cause of (irreversible) end-stage kidney disease in the United States. Treatment requires either a kidney transplant or regular artificial hemodialysis.





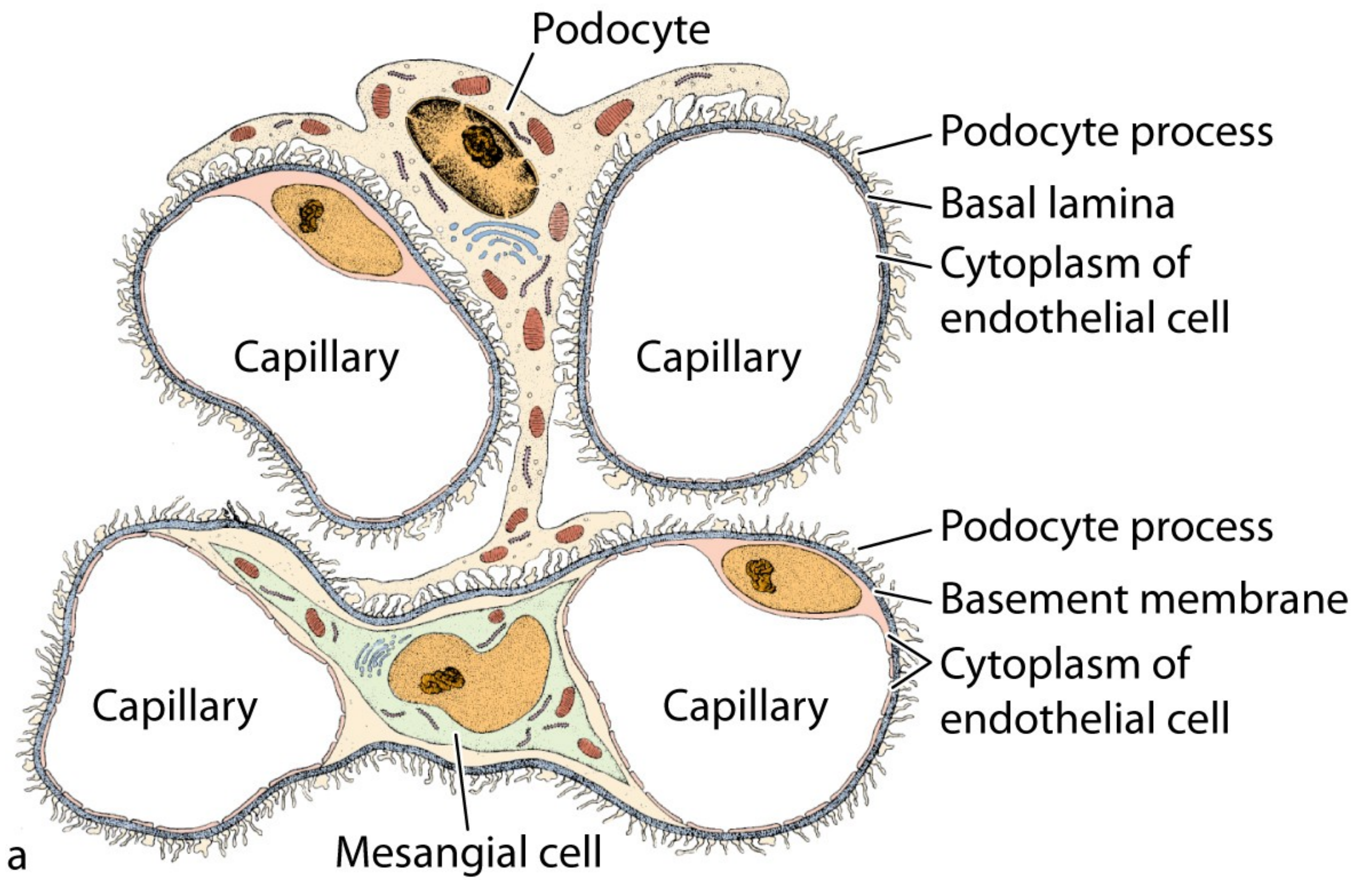
(c) Substances filtered by filtration membrane

Mesangial cells extend contractile processes (arrows) along capillaries that help regulate blood flow in the glomerulus

Mesangial cells in renal corpuscles are located between capillaries and cover those capillary surface not covered by podocyte processes.

Some mesangial processes appear to pass between endothelial cells into the capillary lumen where they may help remove or endocytose adherent protein aggregates.

Podocytes and their pedicels open to the urinary space and associate with the capillary surfaces not covered by mesangial cells



The Renal (Uriniferous) Tubule: glomerular capsule → tip of medullary pyramid

4 regions of renal tubule:

1. Proximal convoluted tubule (PCT): most coiled , Simple cuboidal epithelium with prominent microvilli for majority of absorption

2. Nephron loop (loop of Henle): long U-shaped portion of renal tubule

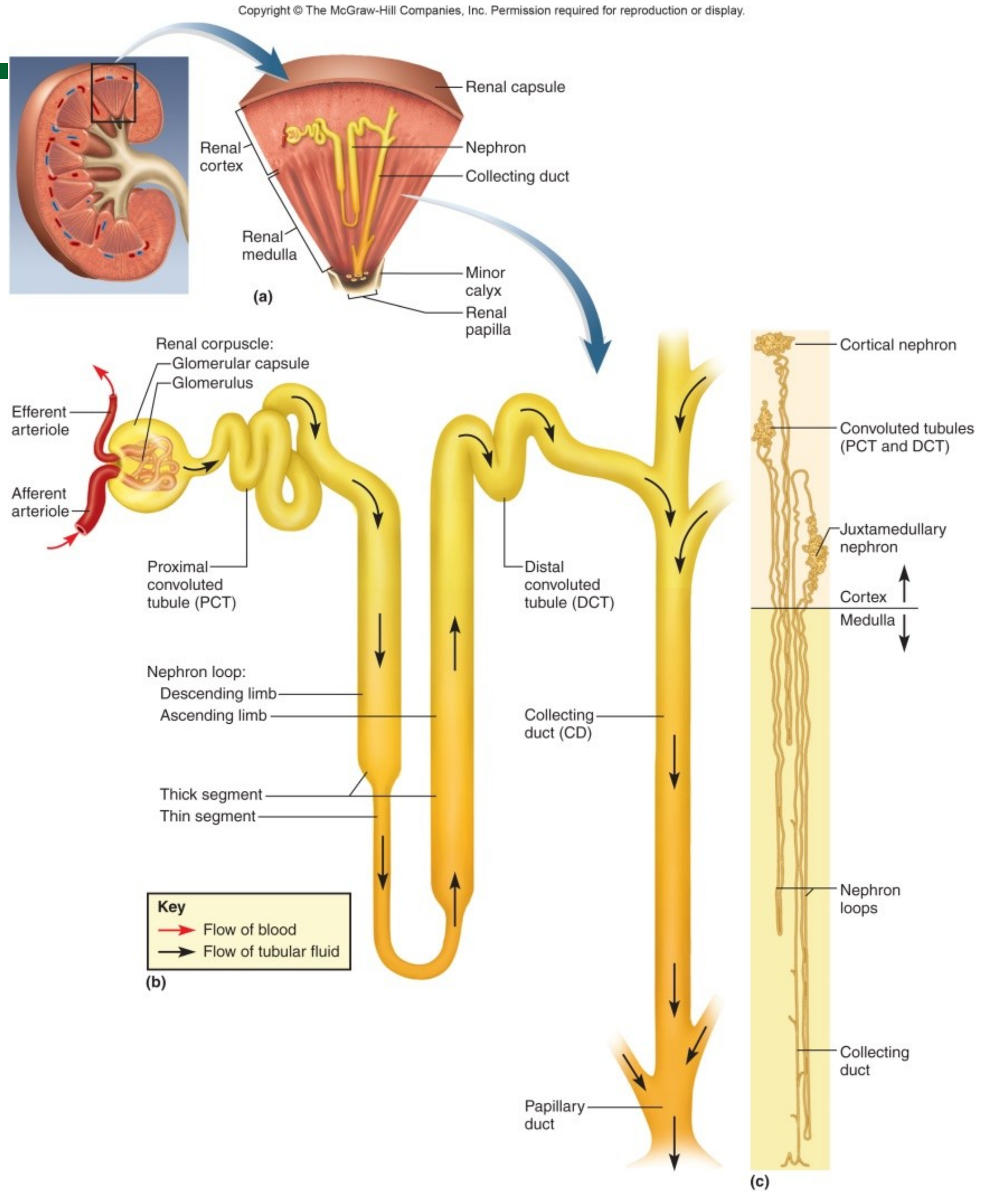
Thick segments: simple cuboidal epithelium, active transport of salts, many mitochondria

Thin segment: simple squamous epithelium, very permeable to water

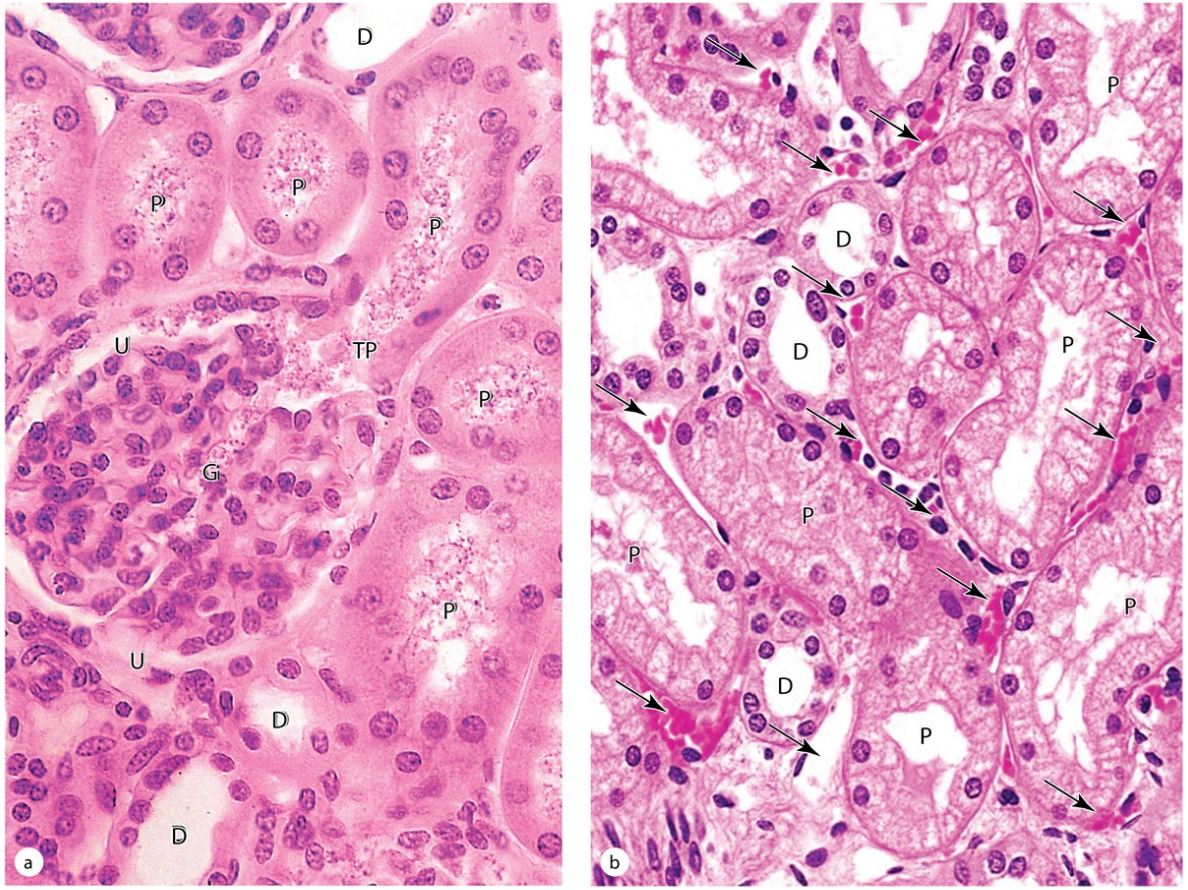
3. **Distal convoluted tubule (DCT, end of nephron)**: Cuboidal epithelium without microvilli

4. **Collecting duct**: receives from several DCTs, simple cuboidal ep.

collecting duct → papillary duct → minor calyx → major calyx → renal pelvis → ureter → urinary bladder → urethra



Renal cortex: proximal and distal convoluted tubules

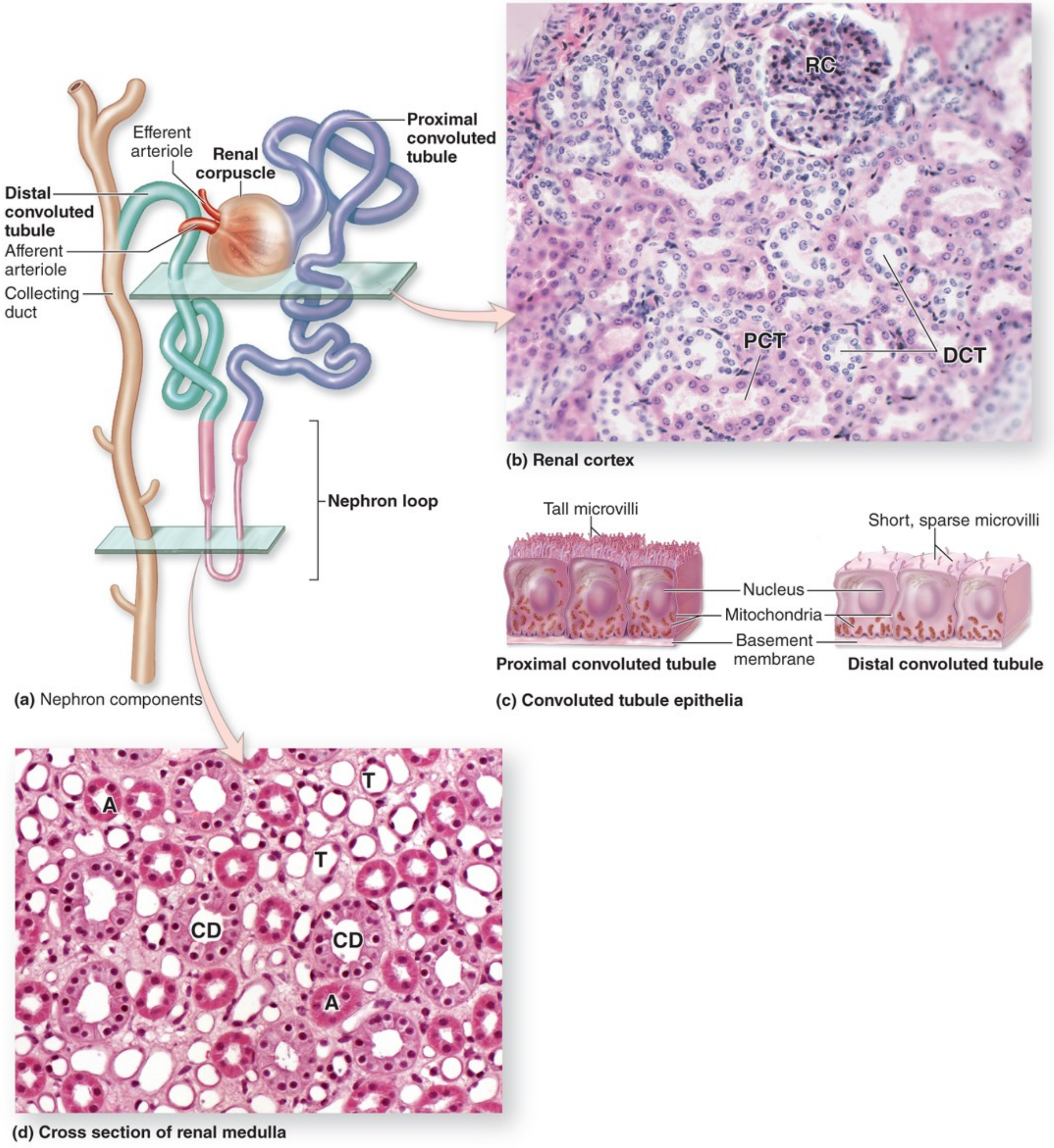


Note the **continuity at a renal corpuscle's tubular pole** (**TP**) between the simple cuboidal epithelium of a **proximal convoluted tubule** (**P**) and the simple squamous epithelium of the **capsule's parietal layer**.

The urinary space (**U**) between the parietal layer and the glomerulus (**G**) drains into the lumen of the proximal tubule. The lumens of the proximal tubules appear filled, because of the long microvilli of the brush border and aggregates of small plasma proteins bound to this structure. By contrast, the lumens of distal convoluted tubules (**D**) appear empty, lacking a brush border and protein.

Abundant **peritubular capillaries** and **draining venules** (arrows) that surround the proximal (**P**) and distal (**D**) convoluted tubules are clearly seen.

Convoluted tubules, nephron loops, and collecting ducts



RC: renal corpuscle
PCT: eosinophilic proximal convoluted tubules smaller
DCT: Less well-stained distal convoluted tubules.

Cuboidal cells of proximal and distal tubules have structural differences.

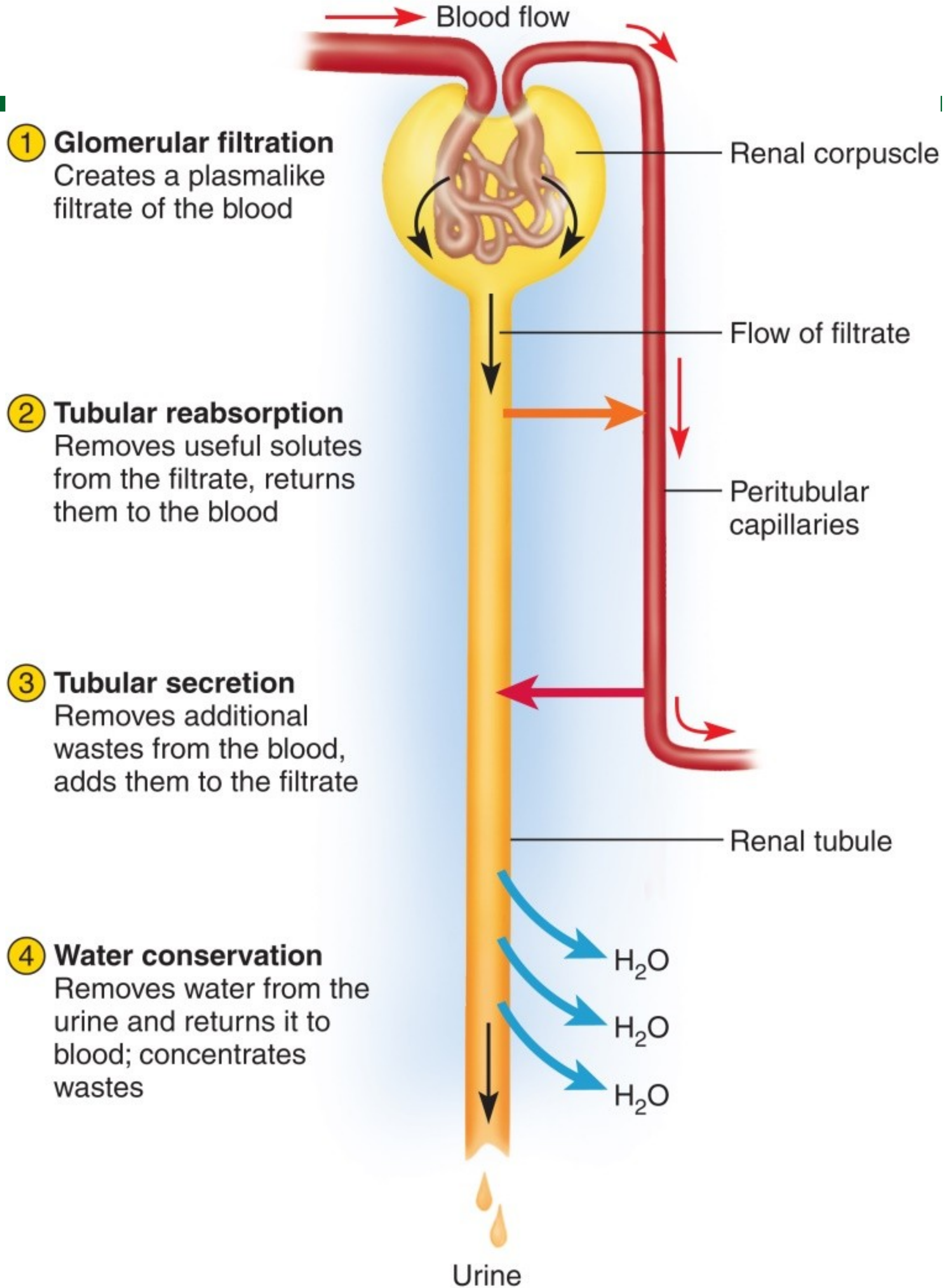
T: loops of Henle in cross section through a medullary pyramid. Simple squamous epithelium of the thin descending and ascending limbs of and its thick ascending limbs (**A**), as well as the pale columnar cells of collecting ducts (**CD**).

Urine Formation I: Glomerular Filtration

Kidneys convert blood plasma to urine in three stages

1. Glomerular filtration
   Glomerular filtrate: fluid in the capsular space, like blood plasma but almost no protein.
2. Tubular reabsorption and secretion
3. Water conservation

Urine: fluid that enters the collecting duct, little alteration beyond this point except for changes in water content



Juxtaglomerular apparatus

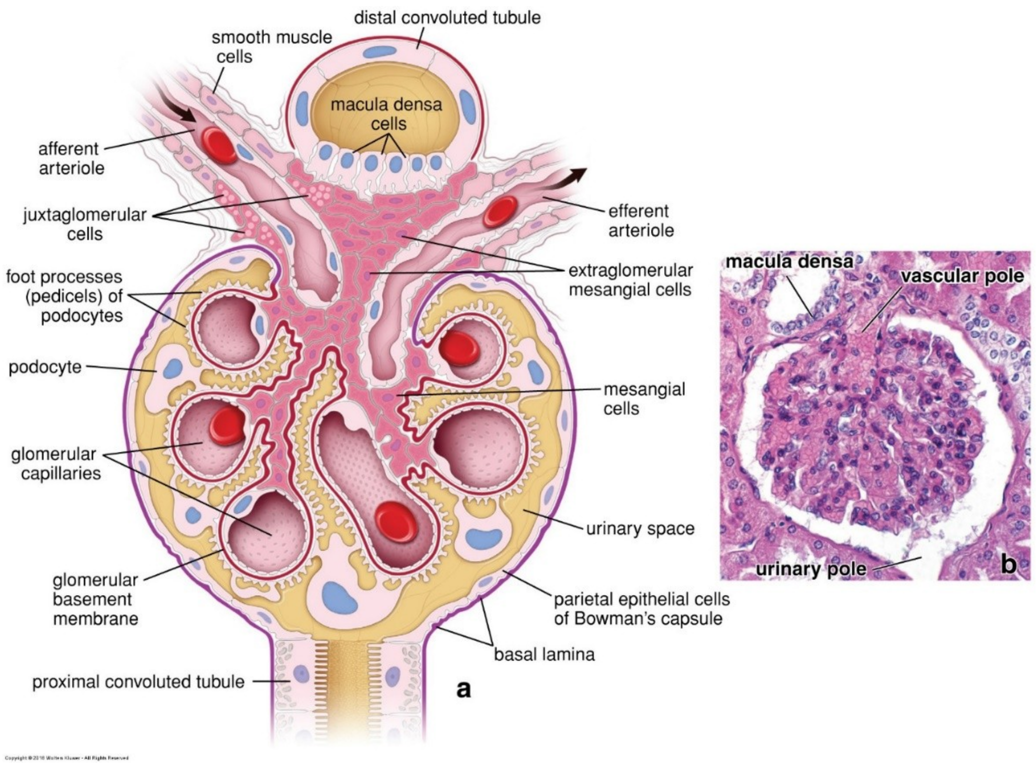
Macula densa: epithelial cells at end of the nephron facing the arterioles

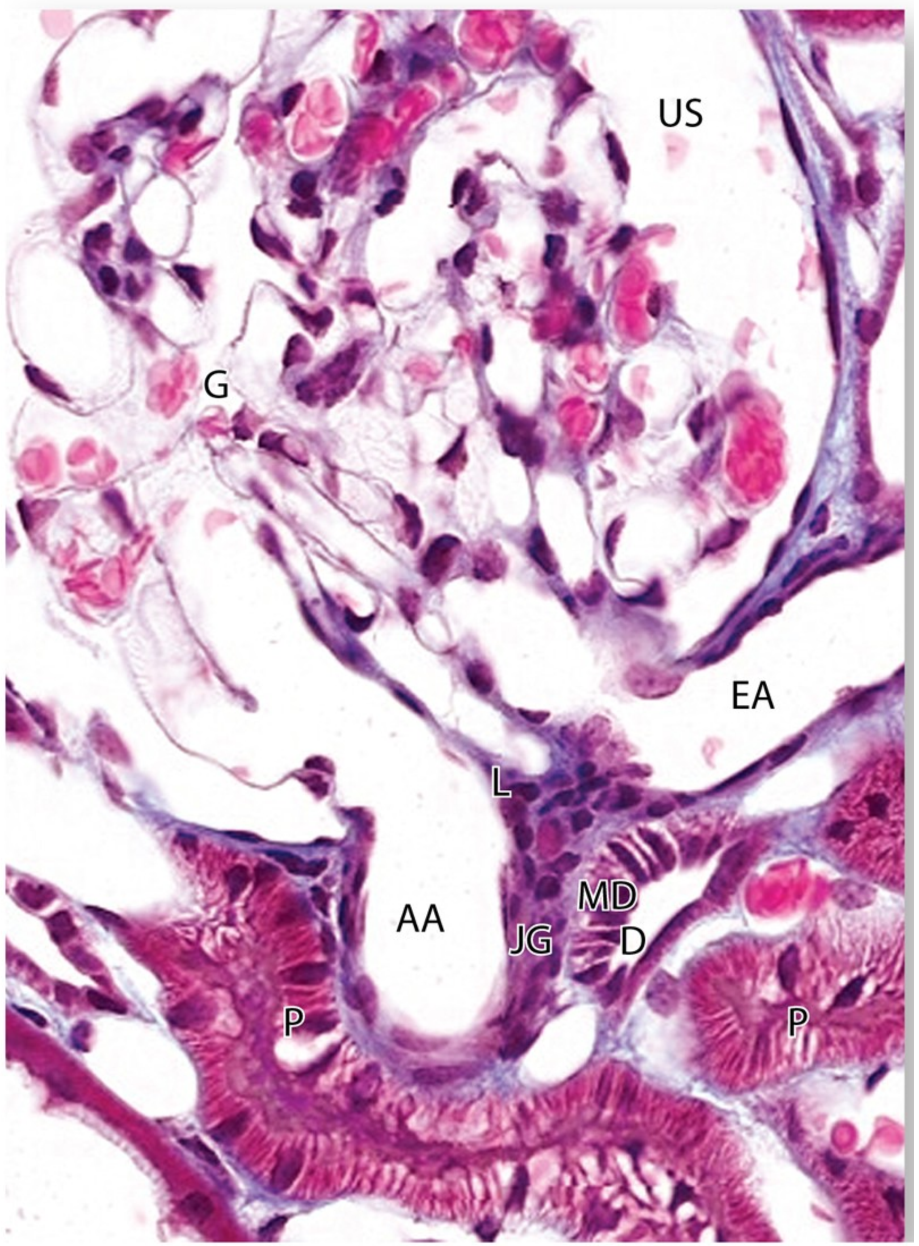
- Senses flow or fluid composition, secretes a paracrine signal that stimulates JG cells

Juxtaglomerular (JG) cells: smooth muscle cells of afferent arteriole across from macula dens, control arteriole diameter.

- Secrete in renin in response to drop in blood pressure
- Renin activates the renin-angiotensin system

angiotensinogen→ angiotensin I → angiotensin II → constricts blood vessels, increases the secretion of ADH and aldosterone (to decrease urine volume), and stimulates the hypothalamus to activate the thirst reflex → increase in blood pressure





JGA forms at the point of contact between a nephron's distal tubule (D) and the vascular pole of its glomerulus (G).

Cells of the distal tubule become columnar as a thickened region called the macula densa (**MD**).

Smooth muscle cells of the afferent arteriole's (**AA**) tunica media are converted from a contractile to a secretory morphology as juxtaglomerular granule cells (**JG**).

Also present are lacis cells (**L**), which are extraglomerular mesangial cells adjacent to the macula densa, the afferent arteriole, and the efferent arteriole (**EA**).

TABLE 19–1 Histologic features and major functions of regions within renal tubules.

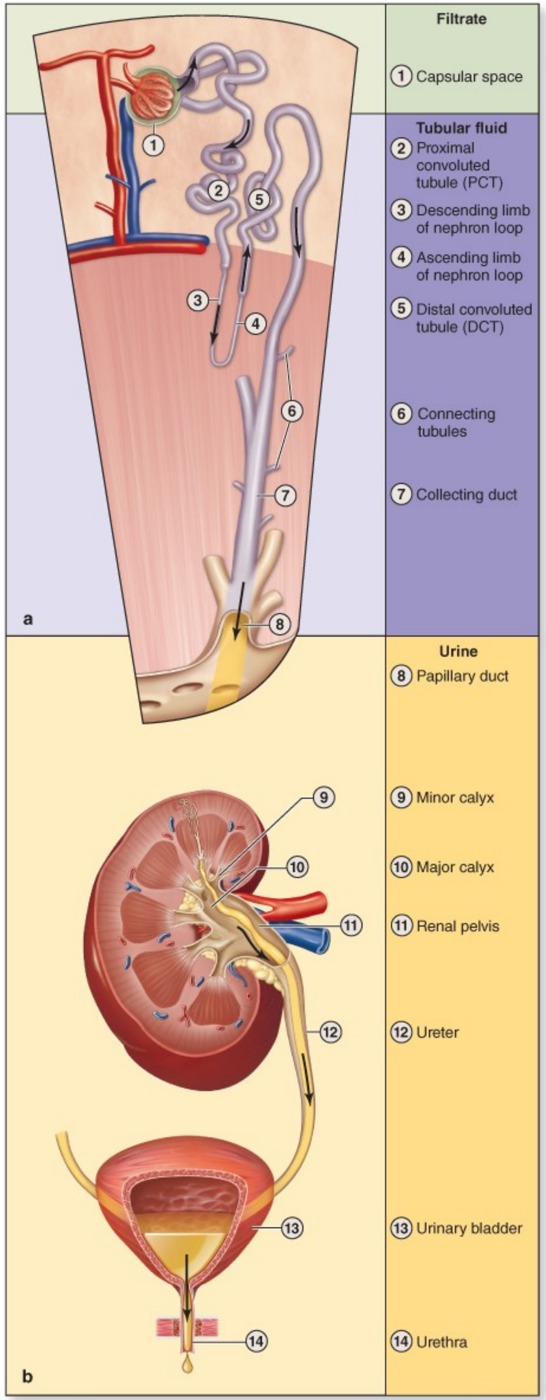
Region of Tubule	Histological Features	Locations	Major Functions
PCT	Simple cuboidal epithelium; cells well-stained, with numerous mitochondria, prominent basal folds and lateral interdigitations; long microvilli, lumens often occluded	Cortex	Reabsorption of all organic nutrients, all proteins, most water and electrolytes; secretion of organic anions and cations, H^+, and NH_4^+
Loop of Henle			
Thin limbs	Simple squamous epithelium; few mitochondria	Medulla	Passive reabsorption of Na^+ and Cl^-
TAL	Simple cuboidal epithelium; no microvilli	Medulla and medullary rays	Active reabsorption of various electrolytes
DCT	Simple cuboidal epithelium; cells smaller than in PCT, short microvilli and basolateral folds, more empty lumens	Cortex	Reabsorption of electrolytes
Collecting system			
Principal cells	Most abundant, cuboidal to columnar; pale-staining, distinct cell membranes	Medullary rays and medulla	Regulated reabsorption of water & electrolytes; regulated secretion of K^+
Intercalated cells	Few and scattered; slightly darker staining	Medullary rays	Reabsorption of K^+ (low-K^+ diet); help maintain acid-base balance

DCT, distal convoluted tubule; PCT, proximal convoluted tubule; TAL, thick ascending limb.

Fluid transport in the urinary system

Upon delivery at a minor calyx, filtrate is no longer modified by reabsorption or secretion and is called **urine**. It flows passively into the renal pelvis but moves by peristalsis along the ureters for temporary storage in the urinary bladder, which is emptied through the urethra.

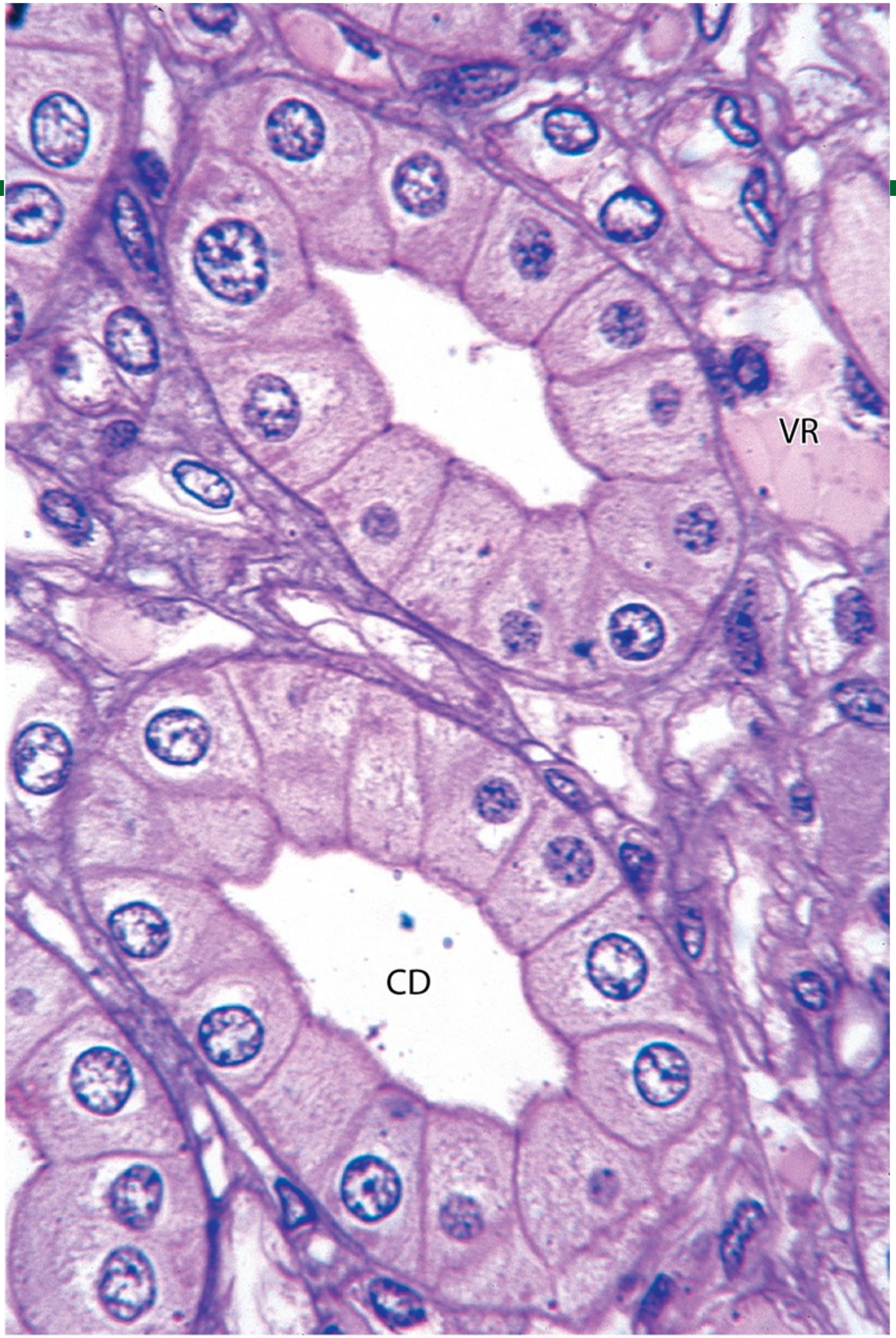
MEDICAL APPLICATION: A common problem involving the ureters is their obstruction by renal calculi (**kidney stones**) formed in the renal pelvis or calyces, usually from calcium salts (oxalate or phosphate) or uric acid. While urate stones are usually smooth and small, calcium stones can become large and irritate the mucosa. Problems caused by such stones can be corrected by either surgical removal of the stone or its disintegration using focused ultrasonic shock waves in a procedure called **lithotripsy** (https://www.youtube.com/watch?v=fR_CjlVXhzw)



Collecting Ducts

Pale-staining columnar **principal cells**, in which ADH-regulated aquaporins of the cell membrane allow more water reabsorption, are clearly seen in these transversely sectioned collecting ducts (**CD**), surrounded by interstitium with vasa recta (**VR**)

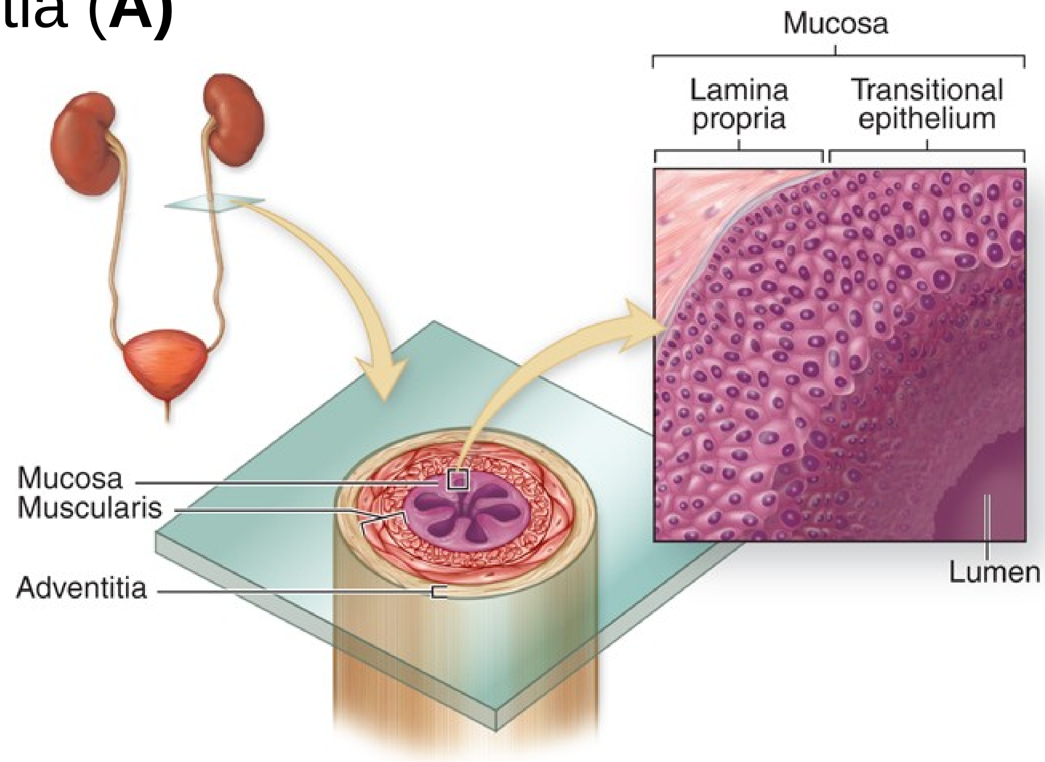
MEDICAL APPLICATION:
Bacterial infections of the urinary tract can lead to inflammation of the renal pelvis and calyces, or pyelonephritis In acute pyelonephritis bacteria often move from one or more minor calyx into the associated renal papilla, causing accumulation of neutrophils in the collecting ducts.



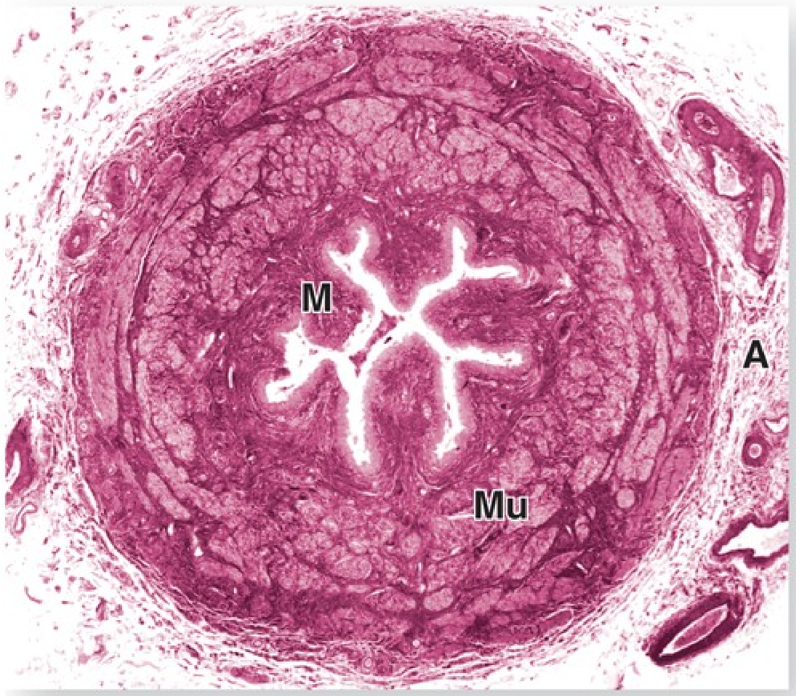
Ureter in cross section shows a characteristic pattern of longitudinally folded mucosa, surrounded by a thick muscularis that moves urine by regular waves of peristalsis.

The lamina propria is lined by a unique stratified epithelium called **transitional epithelium** or **urothelium** that is resistant to the potentially deleterious effects of contact with hypertonic urine.

Histologically the muscularis (**Mu**) is much thicker than the mucosa (**M**) and adventitia (**A)**



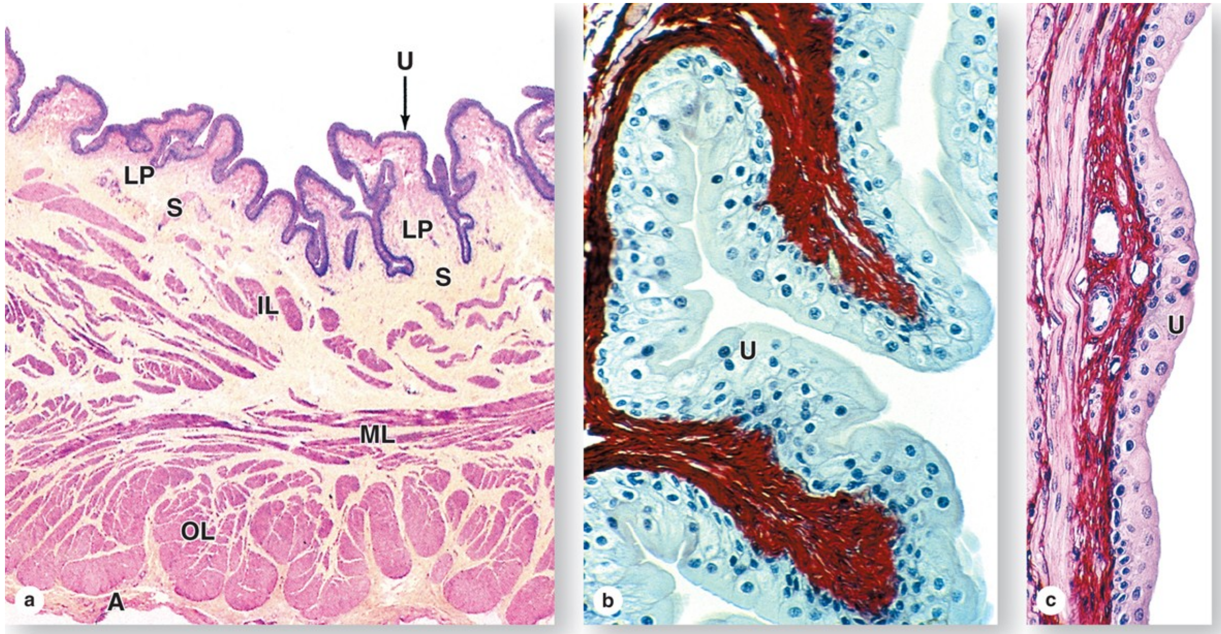
(a) Ureter cross section



(b)

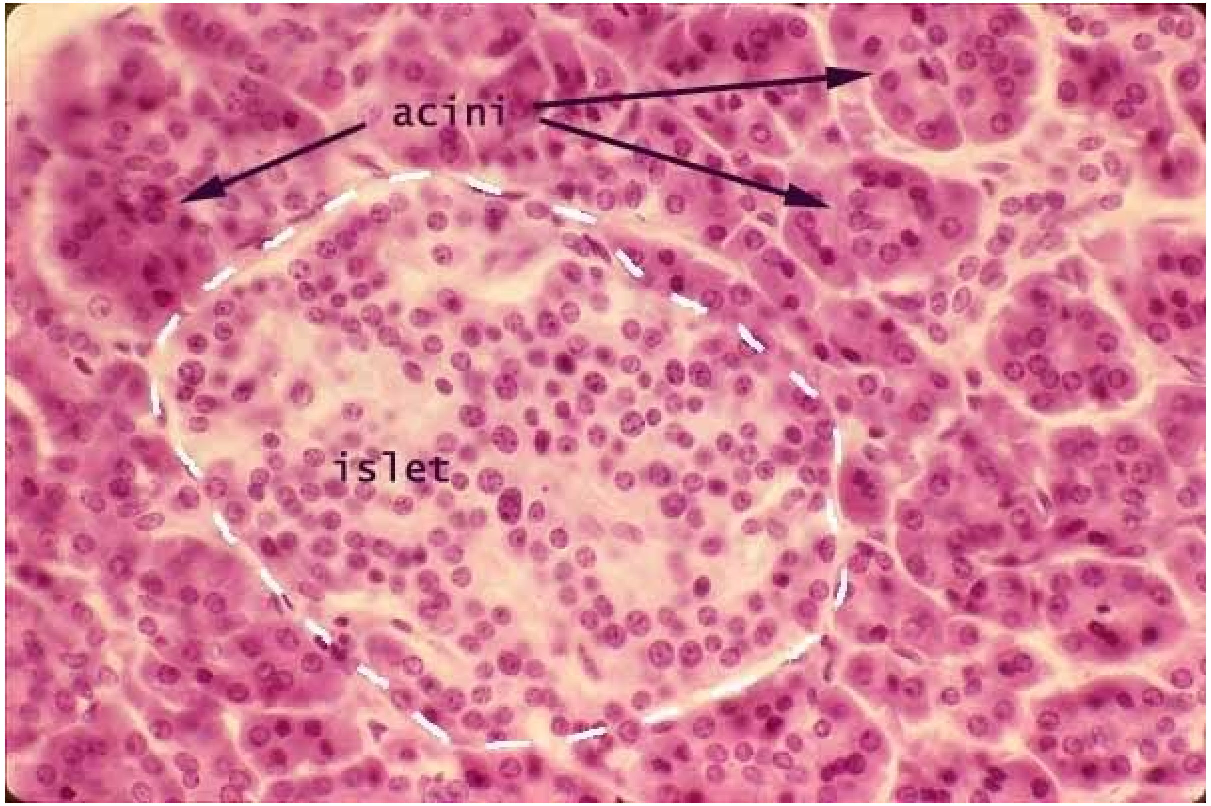
Bladder

(a) In the neck of the bladder, near the urethra, the wall shows four layers: the mucosa with urothelium (**U**) and lamina propria (**LP**); the thin submucosa (**S**); inner, middle, and outer layers of smooth muscle (**IL**, **ML**, and **OL**); and the adventitia (**A**). **(b)** When the bladder is empty, the mucosa is highly folded and the urothelium (**U**) has bulbous umbrella cells. **(c)** When the bladder is full, the mucosa is pulled smooth, the urothelium (**U**) is thinner, and the umbrella cells are flatter.



MEDICAL APPLICATION Cystitis, or inflammation of the bladder mucosa, is the most frequent problem involving this organ. Such inflammation is common during urinary tract infections, but it can also be caused by immunodeficiency, urinary catheterization, radiation, or chemotherapy.

Bladder cancer is usually some form of transitional cell carcinoma arising from unstable urothelium.



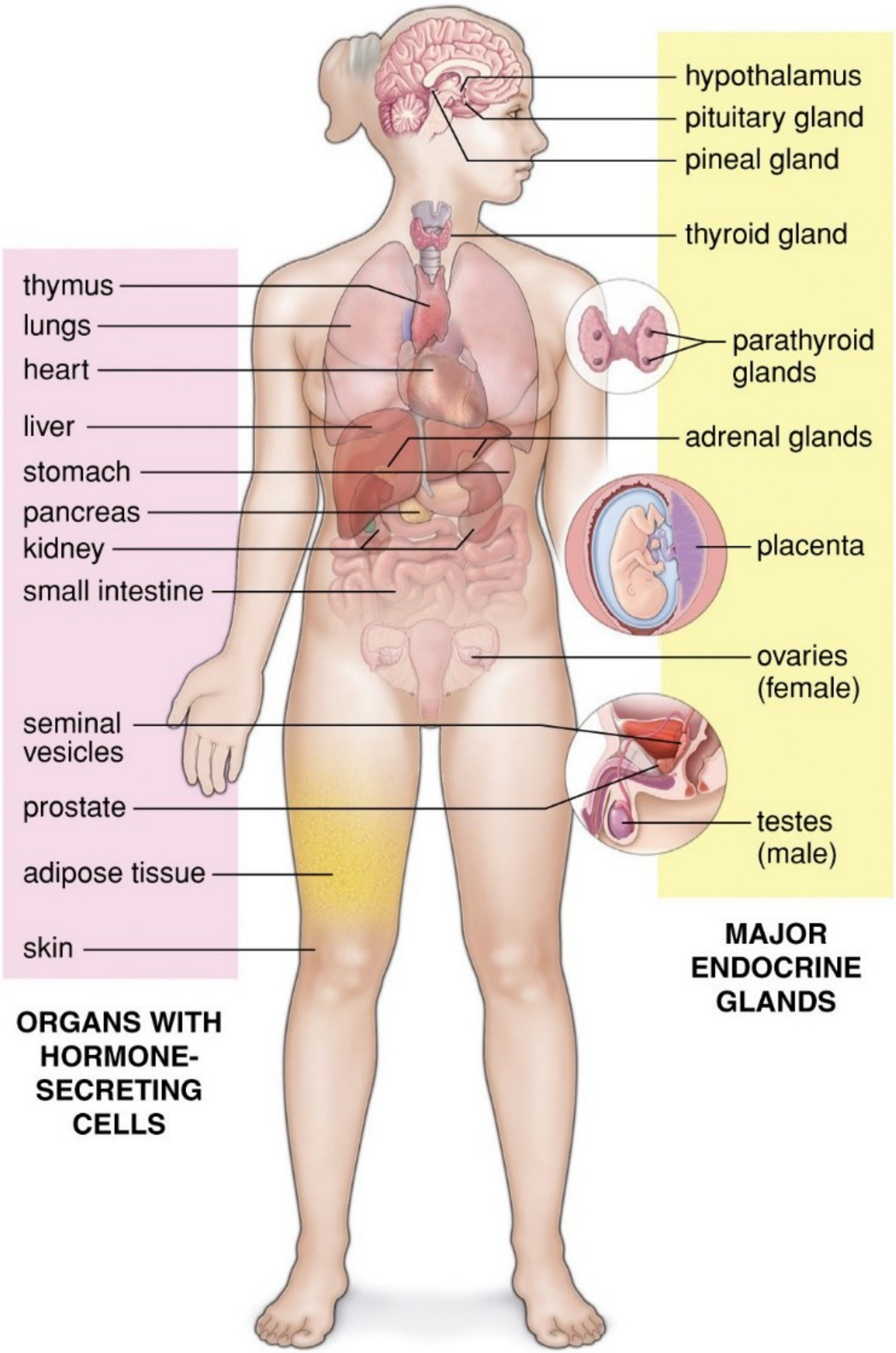
Endocrine

BI 455 CHAPTER 20

Crash Course Endocrine
https://www.khanacademy.org/partner-content/crash-course1/partner-topic-crash-course-bio-ecology/crash-course-biology/v/crash-course-biology-132

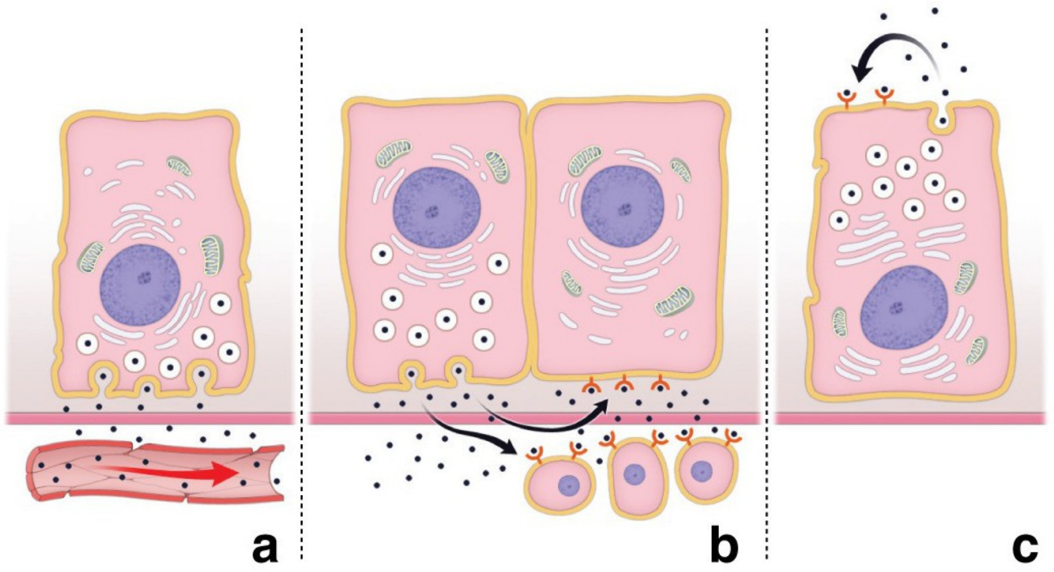
Overview of the Endocrine System

- **Endocrine system:** glands, tissues, and cells that secrete hormones
- **Endocrinology**: the study of this system and the diagnosis and treatment of its disorders
- **Endocrine glands**: organs that are traditional sources of hormones
- **Hormones**: chemical messengers that are transported by the bloodstream and stimulate physiological responses in cells of another tissue or organ, often a considerable distance away



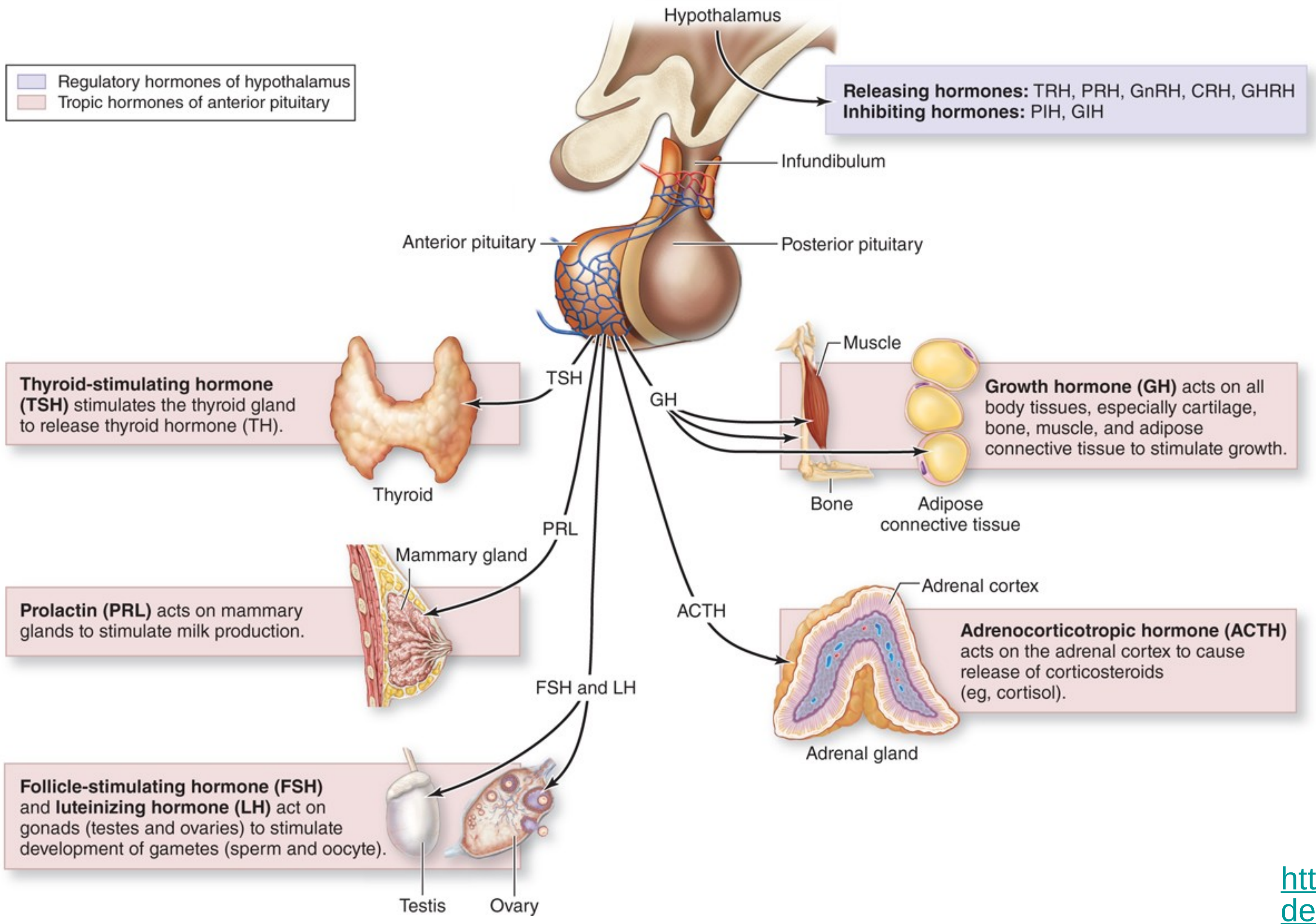
Comparison of Endocrine and Exocrine Glands

- **Exocrine glands**: Have ducts carry secretion to an epithelial surface or the mucosa of the digestive tract: “external secretions”
- **Endocrine glands**: No ducts, Contain dense, fenestrated capillary networks which allow easy uptake of hormones into bloodstream
  - “Internal secretions”, Intracellular effects such as altering target cell metabolism



Endocrine: hormone is discharged from a cell into the bloodstream and is transported to the effector cells.
Paracrine: hormone is secreted from one cell and acts on adjacent cells that express specific receptors.
Autocrine: hormone responds to the receptors located on the cell that produces it

Hormones of the Hypothalamus and Pituitary Gland are the Master Regulators of the Endocrine System



http://highered.mheducation.com/sites/0072495855/student_view0/chapter20/animation__hormonal_communication.html

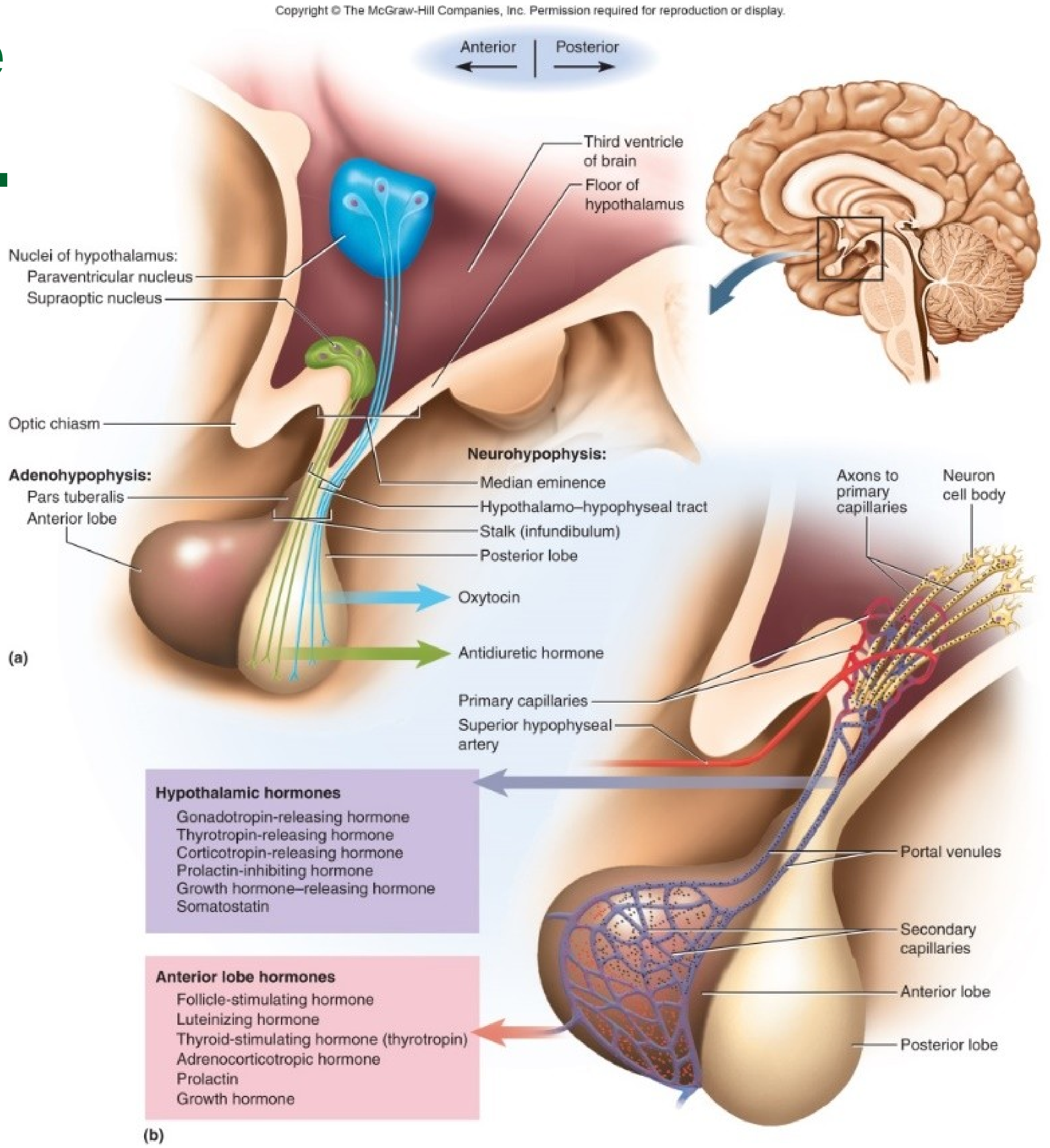
Hypothalamus is attached to poste pituitary by infundibulum stalk

Hypothalamo-hypophyseal tract: Hypothalamic nuclei (NOT posterior pituitary) synthesize oxytocin and antidiuretic hormone

- transport down fibers for storage in posterior pituitary

Hypophyseal portal system: hypothalamus → anterior pituitary gland

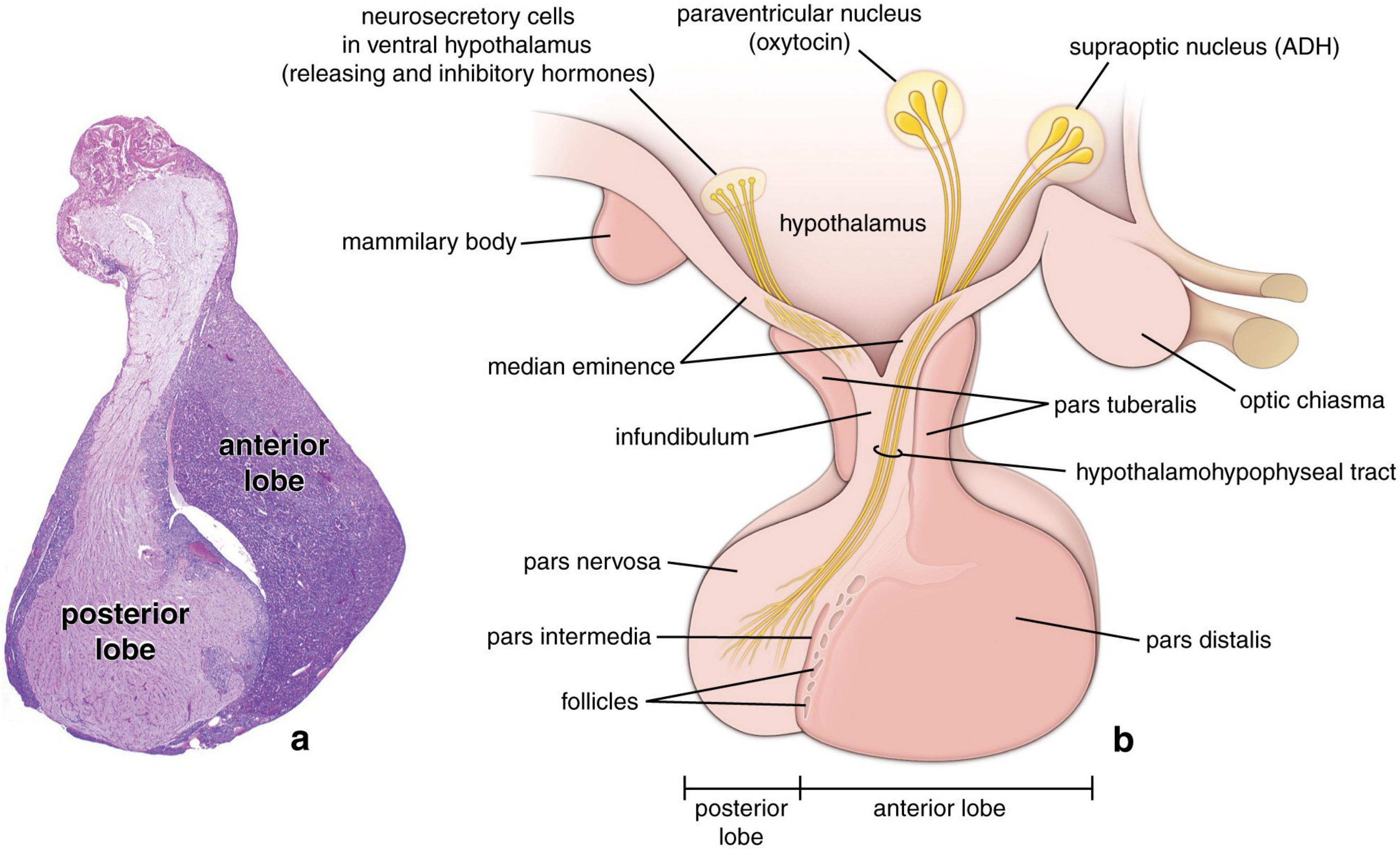
- **Portal system**: blood flows from one capillary bed to another
- **Hypothalamic Hormones** stimulate anterior pituitary via portal system

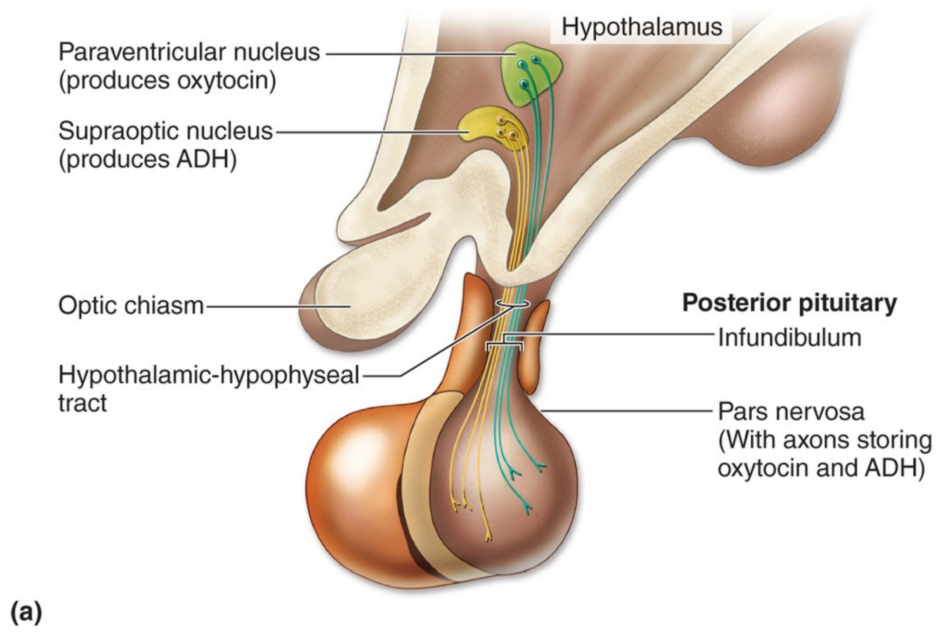


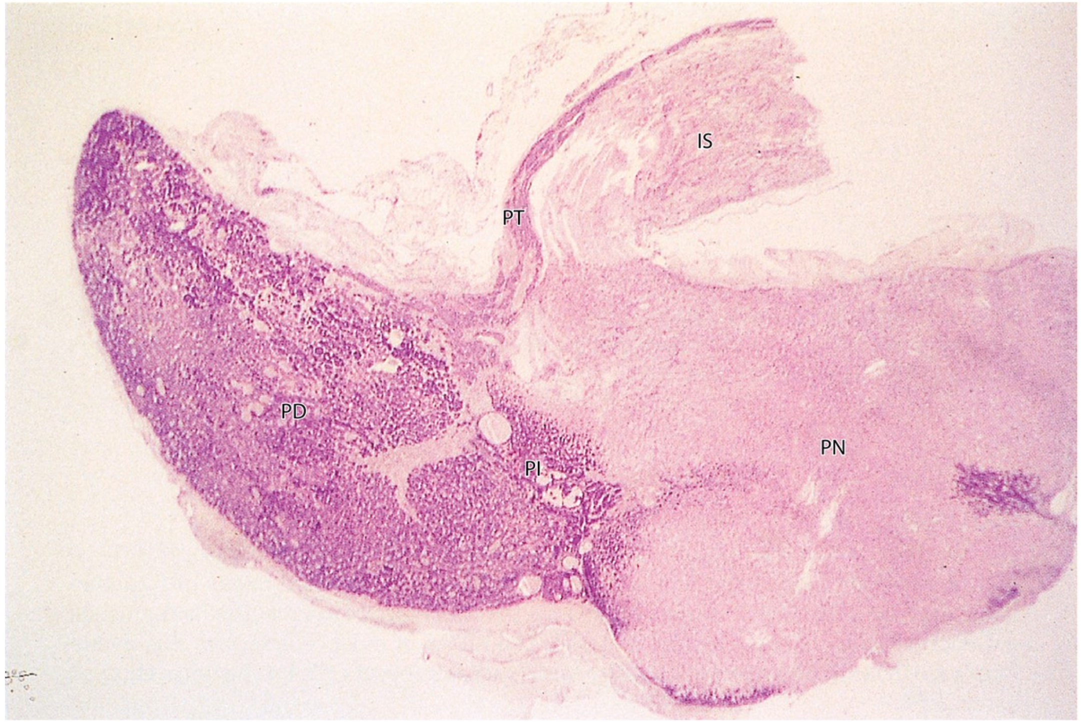
Pituitary gland (hypophysis) is sheltered in sella turcica, of sphenoid bone

Anterior pituitary (adenohypophysis): develops from pouch in roof of embryonic pharynx. Tissue looks glandular.

Posterior pituitary (neurohypophysis): Down growth from hypothalamus, retains connection to brain. Tissue looks nervous.





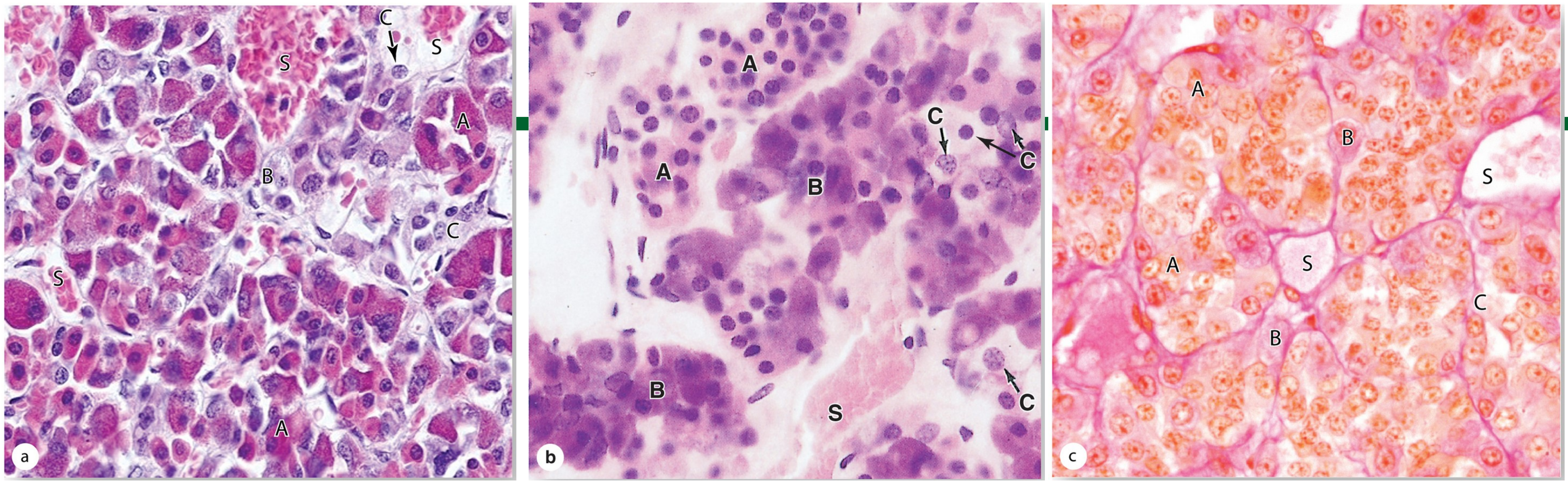


Adenohypophysis

Pars distalis: 75% of the adenohypophysis. Chromophils: basophils and acidophils, based on affinities for basic and acidic. Store hormones in granules. Chromophobes: lightly staining cells

Pars intermedia: thin zone of basophilic cells between the pars distalis and the pars nervosa of the neurohypophysis

Pars tuberalis: smaller funnel-shaped region surrounding the infundibulum of the neurohypophysis Most of the cells of the pars tuberalis are **gonadotrophs**.



Pars Distalis

acidophil cells (**A**)
basophils (**B**)
chromophobes (**C**)
capillaries and sinusoids (**S**)

TABLE 21.2 **Staining Characteristics of Cells Found in the Anterior Lobe of the Pituitary Gland**

Cell Type	Percentage of Total Cells	General Staining	Specific Staining	Product
Somatotrope (GH cell)	50	Acidophil	Orange G (PAS −)	Growth hormone (GH)
Lactotrope (PRL cell)	15–20	Acidophil	Orange G (PAS −) Herlant's erythrosine Brooke's carmosine	Prolactin (PRL)
Corticotrope (ACTH cell)	15–20	Basophil	Lead hematoxylin (PAS +)	Proopiomelanocortin (POMC), which is cleaved in human into adrenocorticotropic hormone (ACTH) and β-lipotrophic hormone (β-LPH)
Gonadotrope (FSH and LH cells)	10	Basophil	Aldehyde-fuchsin Aldehyde-thionine (PAS +)	Follicle-stimulating hormone (FSH) and luteinizing hormone (LH)
Thyrotrope (TSH cell)	~5	Basophil	Aldehyde-fuchsin Aldehyde-thionine (PAS +)	Thyroid-stimulating hormone (TSH)

MEDICAL APPLICATION: Benign pituitary adenomas often produce excessive numbers of functional acidophils or basophils. Adenomas involving somatotropic cells can cause gigantism if occurring in children before closure of the long bones' epiphyseal plates or acromegaly in adults, with musculoskeletal, neurologic, and other medical consequences.

https://vimeo.com/62985496 (0-4:30)

Neurohyphophysis: Pars nervosa and the infundibular stalk

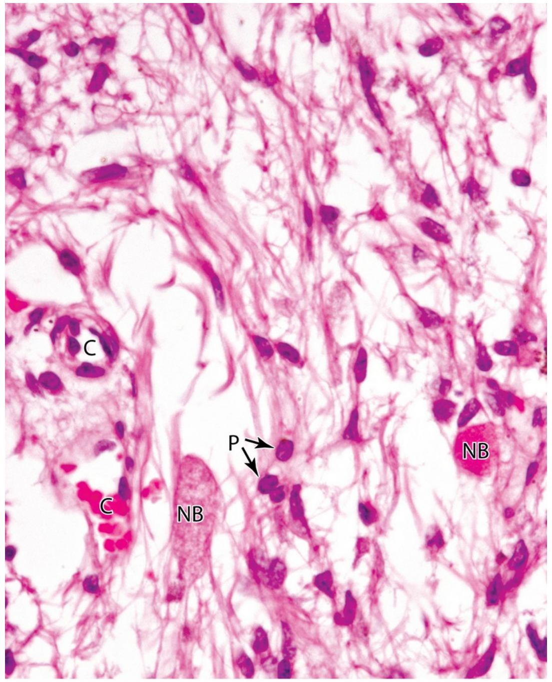


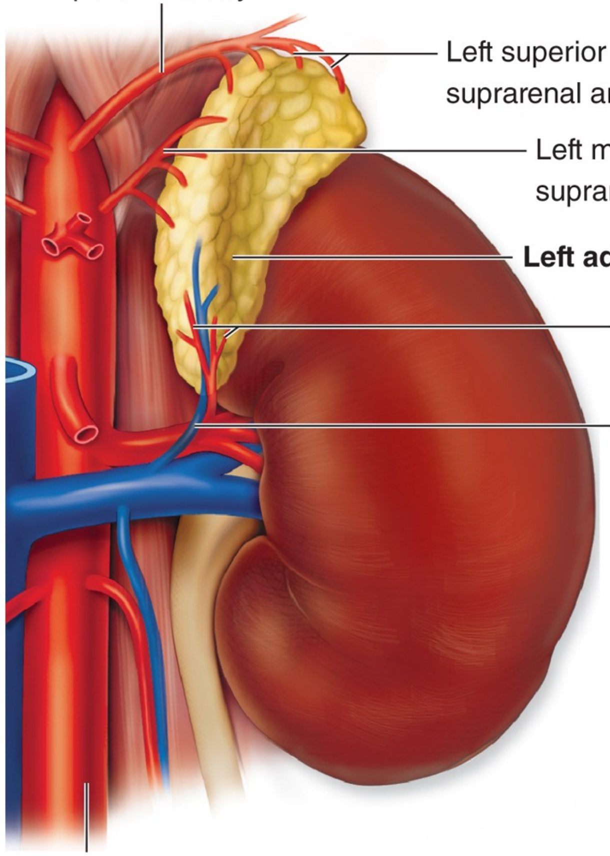
TABLE 20–3	Hormones of the posterior pituitary.
Hormone	**Function**
Vasopressin/antidiuretic hormone (ADH)	Increases water permeability of renal collecting ducts
Oxytocin	Stimulates contraction of mammary gland myoepithelial cells and uterine smooth muscle

The neurohypophysis does NOT synthesize its two hormones
Neurosecretory (**Herring**) **bodies** (**NB**): swellings at the end unmyelinated axons of hypothalamic neurons of which release oxytocin or vasopressin **(ADH)**. Released hormones are picked up by capillaries (**C**) for distribution
Pituicytes (**P**): Glial cells that resemble astrocytes

MEDICAL APPLICATION: Posterior pituitary function can be adversely affected by heritable mutations in the gene for vasopressin (ADH)-neurophysin, by compression from a tumor in adjacent tissues, and by head trauma. By lowering levels of vasopressin, such conditions can produce diabetes insipidus, a disorder characterized by inability to concentrate urine, which leads to frequent urination (polyuria) and increased thirst (polydipsia).

http://highered.mheducation.com/sites/0072495855/student_view0/chapter20/animation__hormonal_communication.html

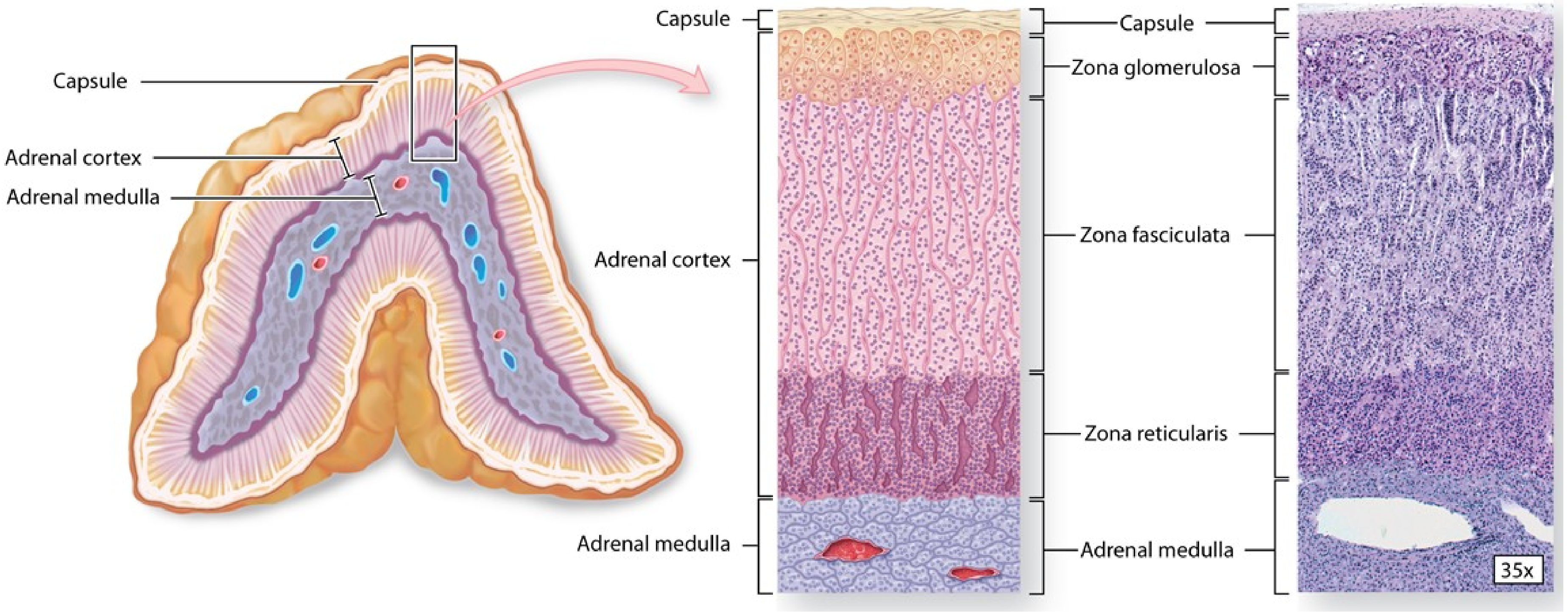
Location and blood supply of the adrenal glands



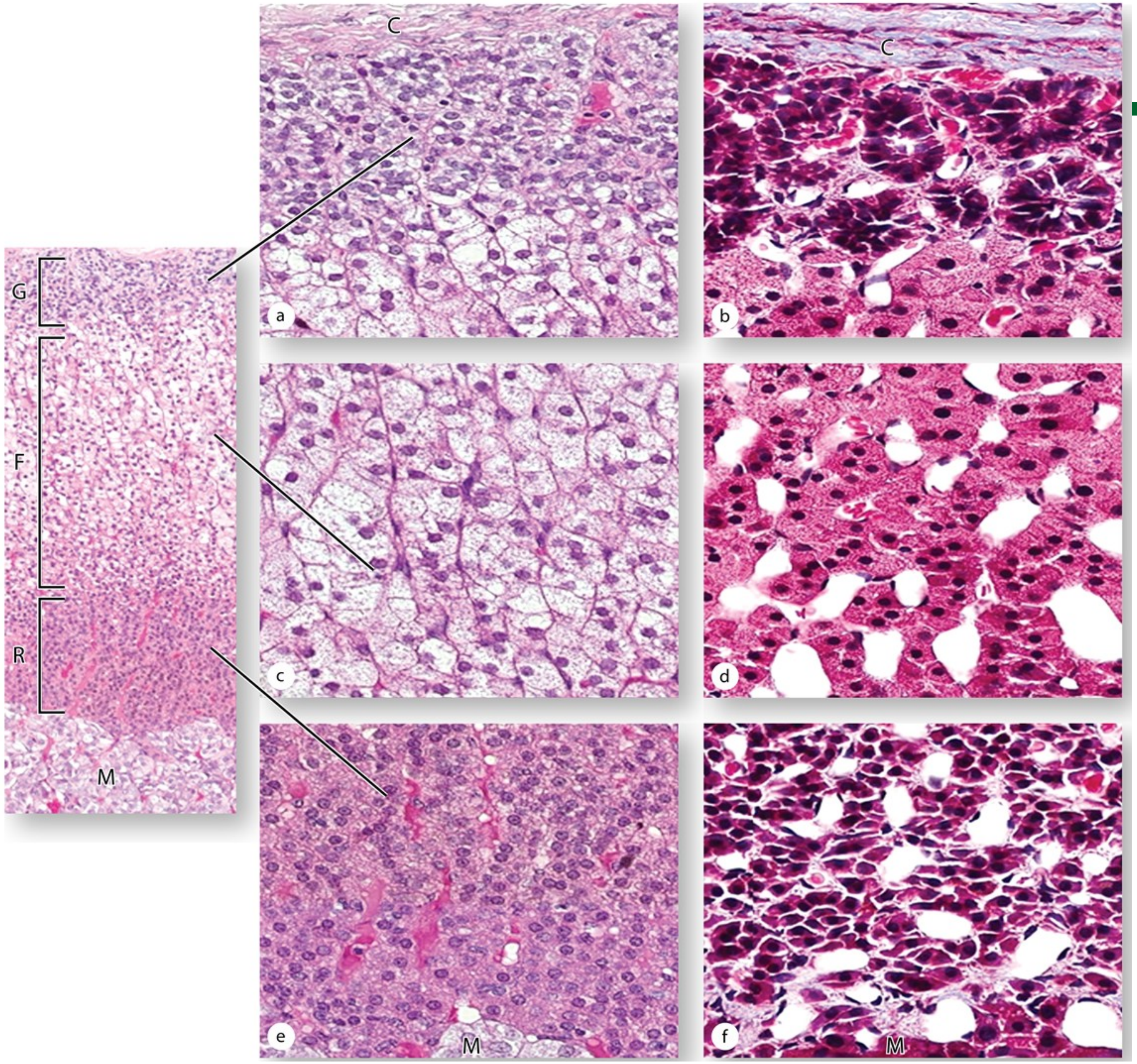
The paired adrenal glands are located at the superior pole of each kidney and each consists of an outer cortex that produces a variety of steroid hormones and an inner medulla that produces epinephrine and norepinephrine.

This anterior view of the left adrenal gland and kidney shows the blood vessels supplying these glands.

Inside the capsule of each adrenal gland is an adrenal cortex



MEDICAL APPLICATION: Addison disease or adrenal cortical insufficiency is a disorder, usually autoimmune in origin, which causes degeneration in any layer of adrenal cortex, with concomitant loss of glucocorticoids, mineralocorticoids, or androgen production.



Adrenal cortex

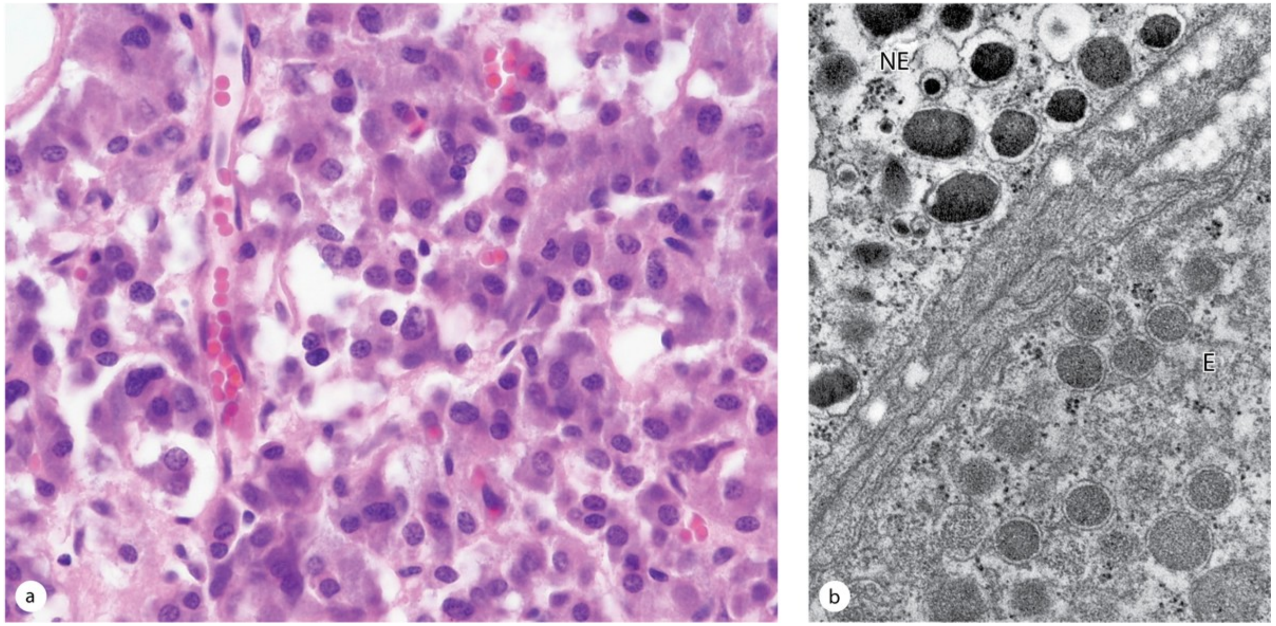
capsule (**C**), zonae glomerulosa (**G**), fasciculata (**F**), and reticularis (**R**), surrounding the medulla (**M**). Shown here are sections from two adrenal glands, stained with H&E (left) and Mallory trichrome, in which the sparse collagen appears blue (right).

(a, b) zona glomerulosa: rounded clusters of columnar cells principally secreting the mineral corticoid **aldosterone**.
(c, d) zona fasciculate: long cords of large, spongy-looking cells mainly secreting glucocorticoids such as **cortisol**.
(e, f) zona reticularis: better stained, arranged in a close network and secrete mainly **sex steroids**.

Cells of all the layers are closely associated with sinusoidal capillaries.

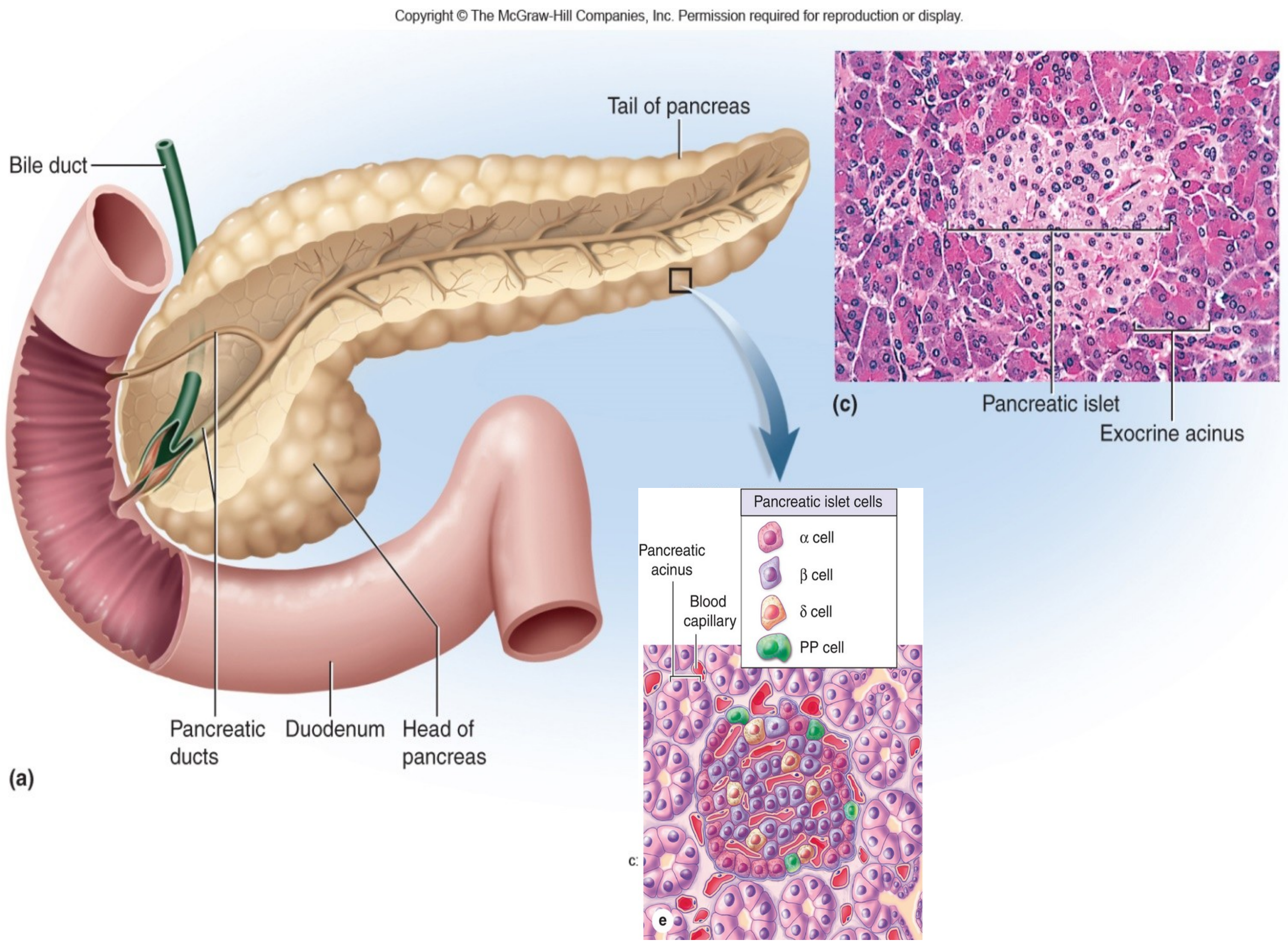
The hormone-secreting cells of the adrenal medulla are chromaffin cells, which resemble sympathetic neurons.

Chromaffin Cells: large pale-staining cells, arranged in cords interspersed with wide capillaries.
Granules of norepinephrine-secreting cells (**NE**) are more electron-dense than those of cells secreting epinephrine (**E**). Most of the hormone produced is epinephrine, which is only made in the adrenal medulla



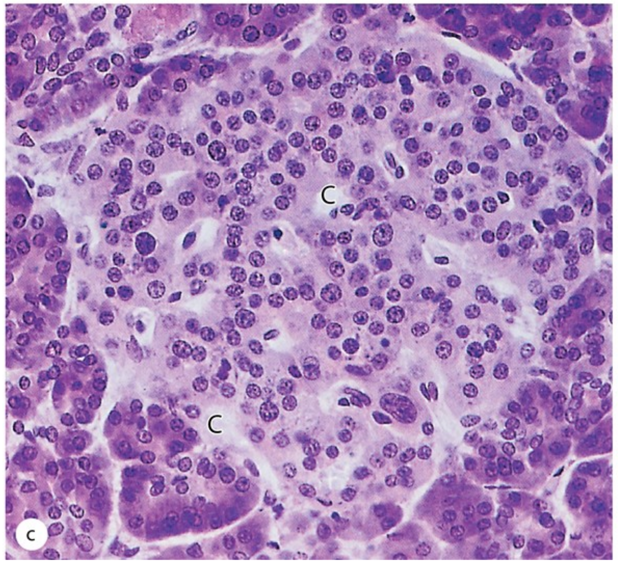
❯❯ **MEDICAL APPLICATION** In the adrenal medulla, **benign pheochromocytomas** periodically secrete high levels of atecholamines that cause swings in blood pressure between hypertension and hypotension.

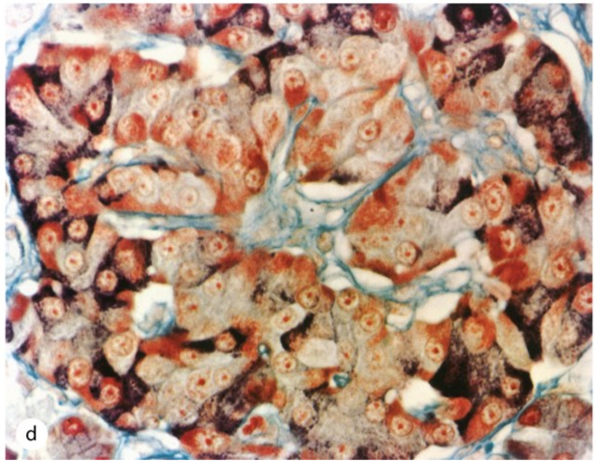
The Pancreatic Islets: endocrine cell clusters



α: glucagon breaks down **glycogen** and **fat** to increases blood glucose
β: insulin causes cell uptake of glucose, decrease of blood glucose
δ: Somatostatin inhibits release of GH and TSH in anterior pituitary and HCl secretion by gastric parietal cells
PP: Pancreatic polypeptide Polypeptide (rare) stimulates activity of gastric chief cells; inhibits bile secretion, pancreatic enzyme and bicarbonate secretion, and intestinal motility

Pancreatic islets are clumped masses of pale-staining endocrine cells embedded in the exocrine acinar tissue of the pancreas.





C: Fenestrated capillaries. This local vascular system allows specific islet hormones to help control secretion of other islet cells and the neighboring acini.

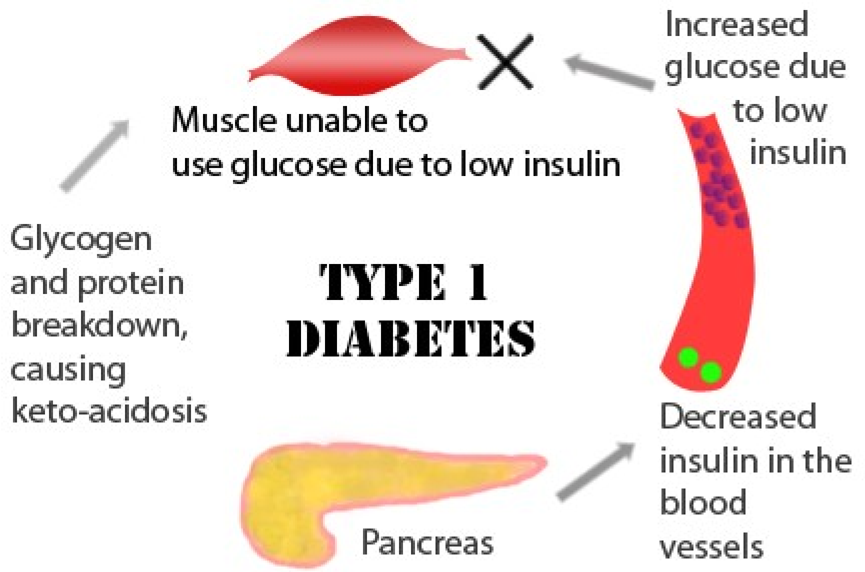
(d) An islet prepared with a modified aldehyde fuchsin stain shows that granules in the **peripheral α cells** are a deep brownish purple and the **central β cells** granules are brownish orange

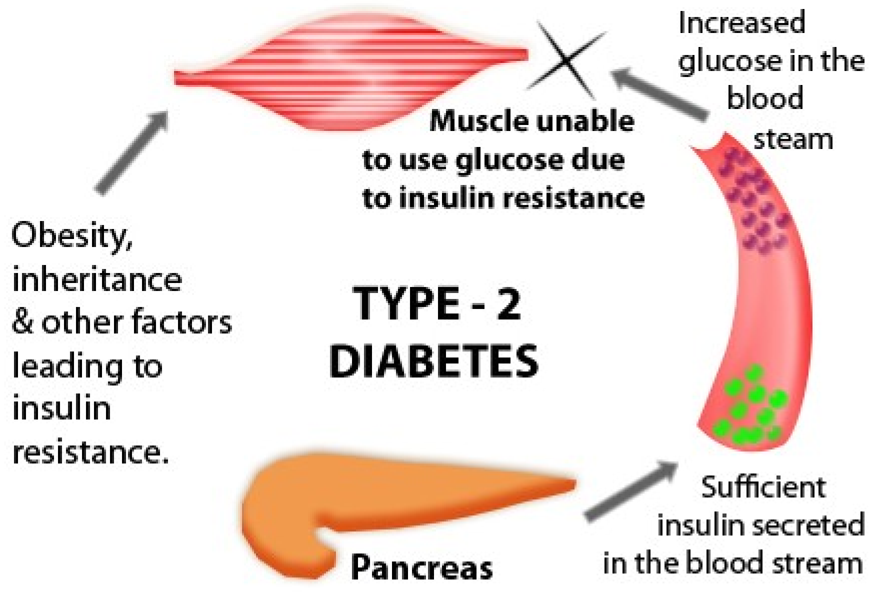
Immunohistochemistry with antibodies against the various islet polypeptide hormones allows definitive identification of each islet cell type.

MEDICAL APPLICATION: Diabetes mellitus is characterized by loss of the insulin effect and a subsequent failure of cells to take up glucose, leading to elevated blood sugar or hyperglycemia.

Type 1 diabetes or insulin-dependent diabetes mellitus (IDDM) is caused by <u>loss of the β cells</u> from autoimmune destruction and is treated by regular injections of insulin.

Type 2 diabetes or non–insulin-dependent diabetes mellitus (NIDDM), <u>β cells are present but fail to produce adequate levels of insulin</u> in response to hyperglycemia and the peripheral target cells "resist" or no longer respond to the hormone. Type 2 diabetes commonly occurs with obesity, and poorly understood, multifactorial genetic components are also important in this disease's onset.





http://highered.mheducation.com/sites/0072507470/student_view0/chapter18/animation__blood_sugar_regulation_in_diabetics.html

The Thyroid Gland

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

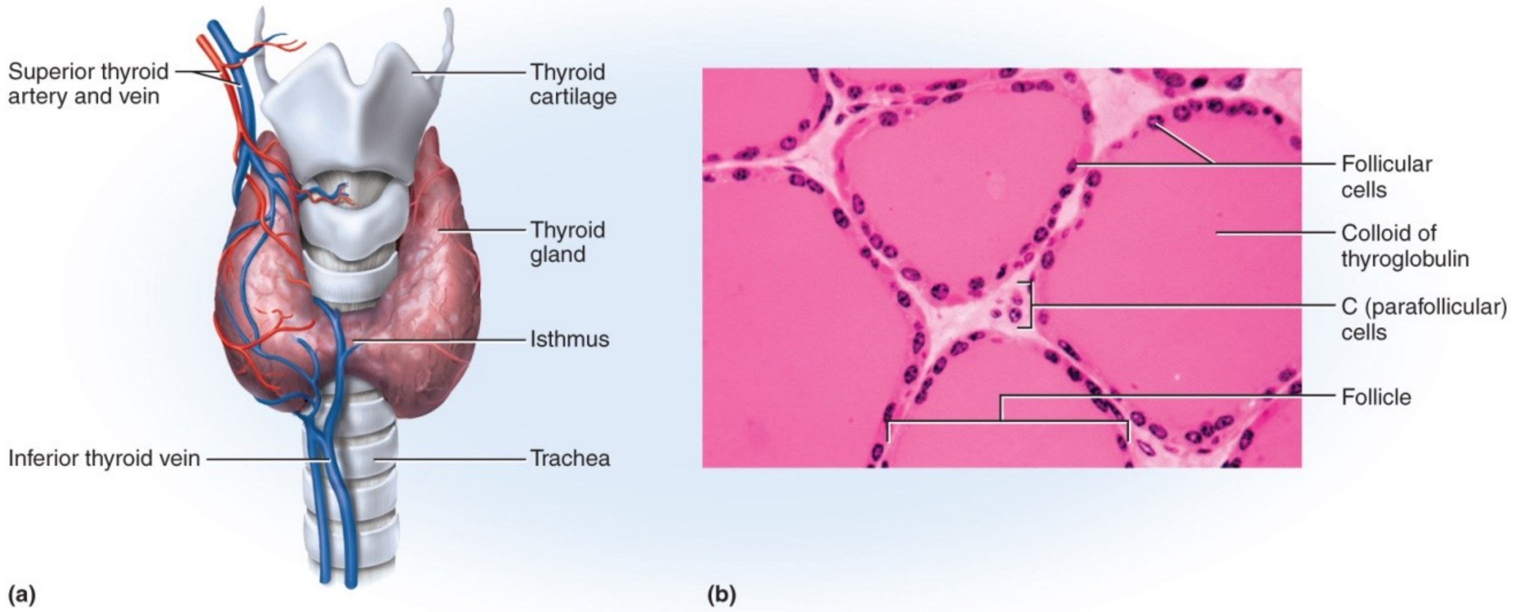
The Thyroid Gland

Thyrocytes (Follicular cells) secretes thyroxine (T_4 because of four 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, quicker reflexes

Parafollicular (C or clear) cells secrete calcitonin with rising blood calcium

- Stimulates osteoblast activity and bone formation

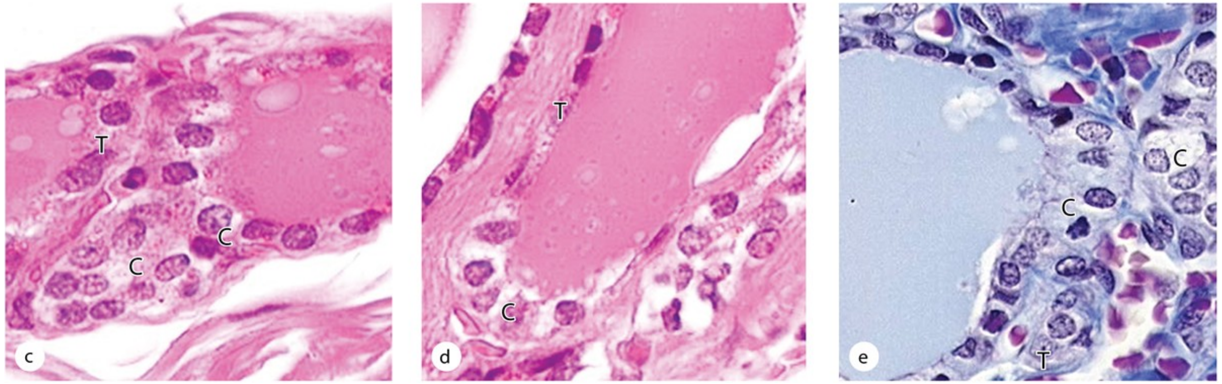


MEDICAL APPLICATION: Chronic dietary iodine deficiencies inhibit thyroid hormone production, causing thyrotropic cells of the anterior pituitary gland to produce excess TSH. This leads to excessive growth of thyroid follicles and enlargement of the thyroid gland, a condition known as goiter

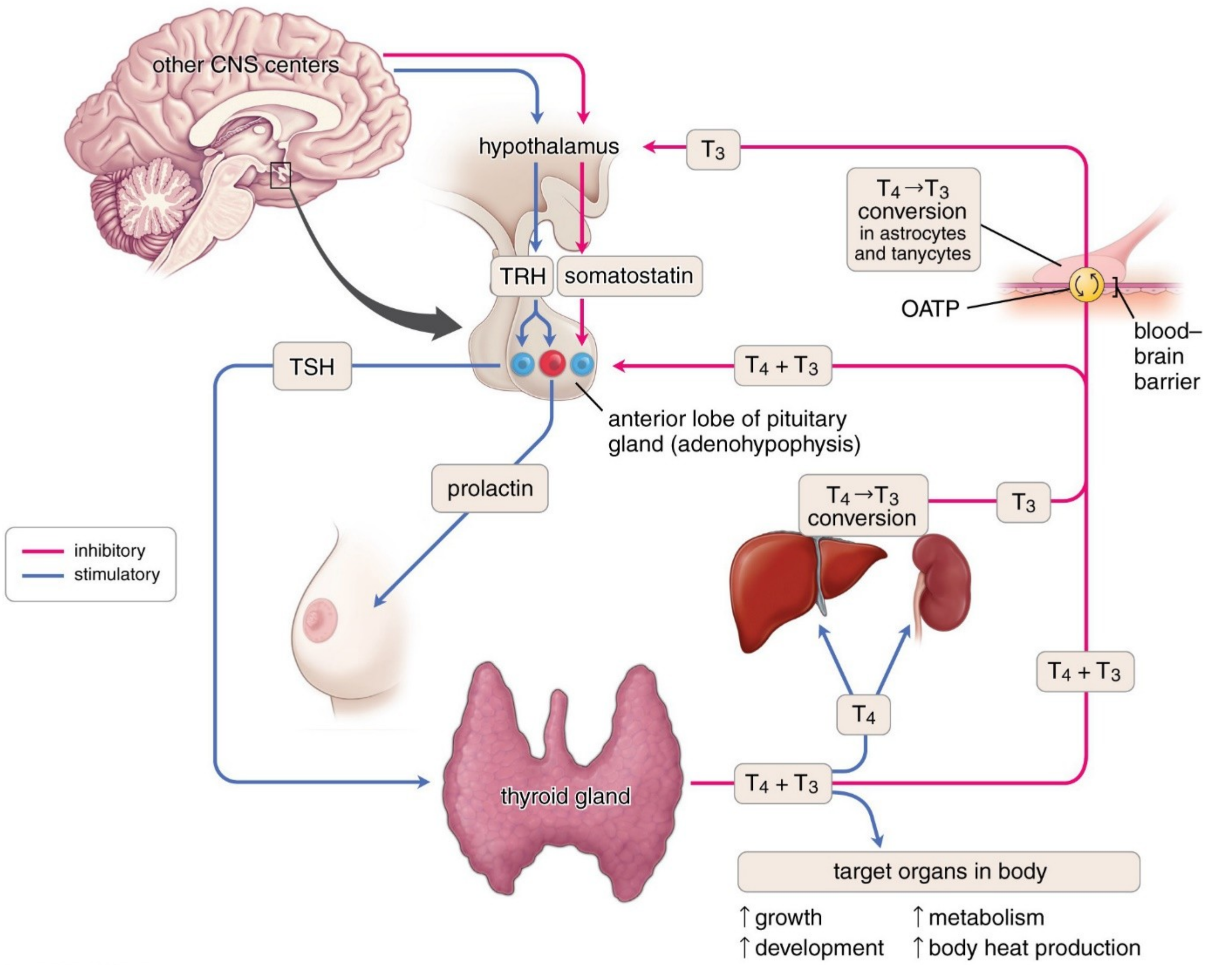
MEDICAL APPLICATIONS

Graves disease is an autoimmune disorder in which antibodies produce chronic stimulation of the follicular cells and release of thyroid hormones (hyperthyroidism), which causes a hypermetabolic state marked by weight loss, nervousness, sweating, heat intolerance, and other features.

Hypothyroidism, with reduced thyroid hormone levels, can be caused by local inflammation (thyroiditis) or inadequate secretion of TSH by the anterior pituitary gland and is often manifested by tiredness, weight gain, intolerance of cold, and decreased ability to concentrate.



Production, transport, and regulation of thyroid hormones is regulated through a negative feedback system



Follicular cells: produce 20X more T4 than T3. T4 → T3 (more active) in peripheral organs (e.g., liver, kidney)

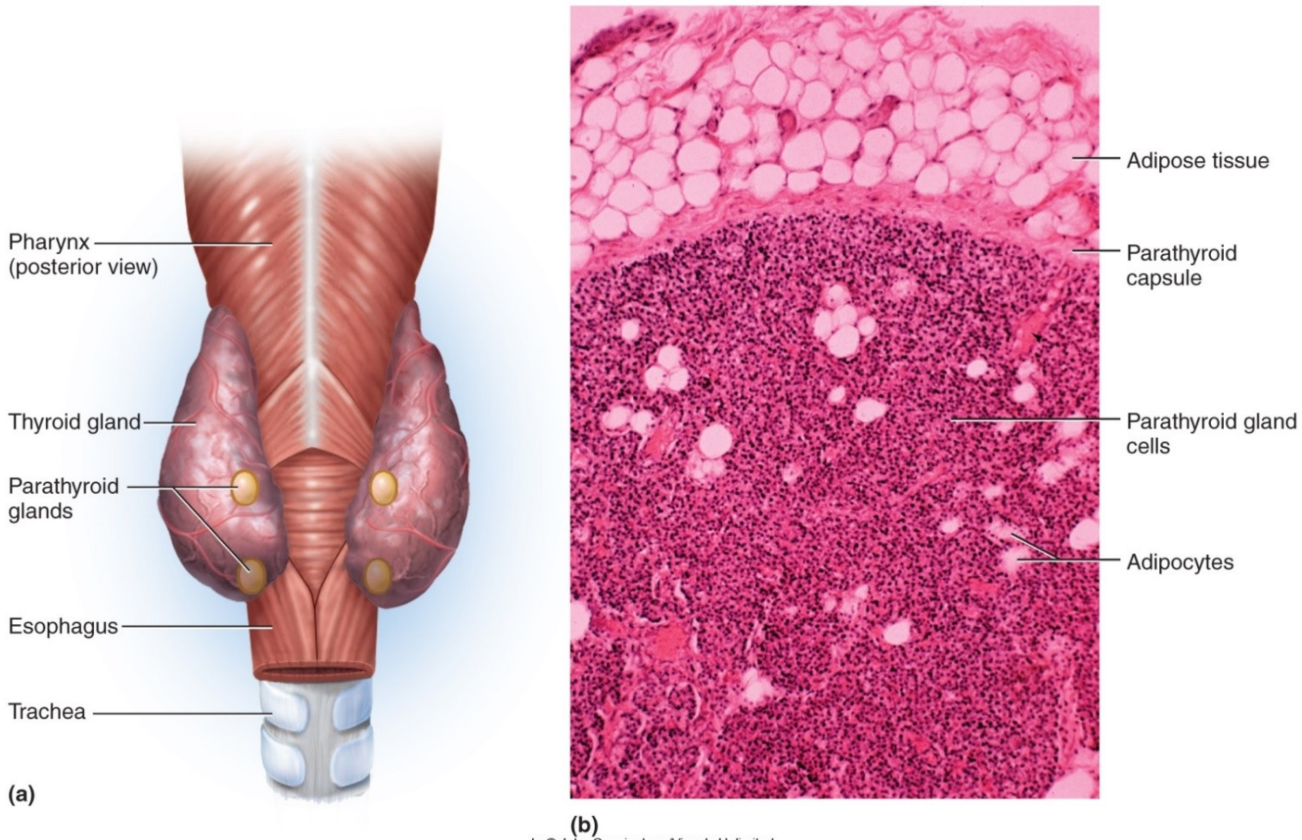
99% of T4 and T3: bound to thyroglobulin for solubility

Remaining free (unbound) T4 and T3: <u>Crosses BBB for negative feedback</u> on the system and inhibit further release In the hypothalamus, T3 inhibits TRH and stimulates somatostatin.

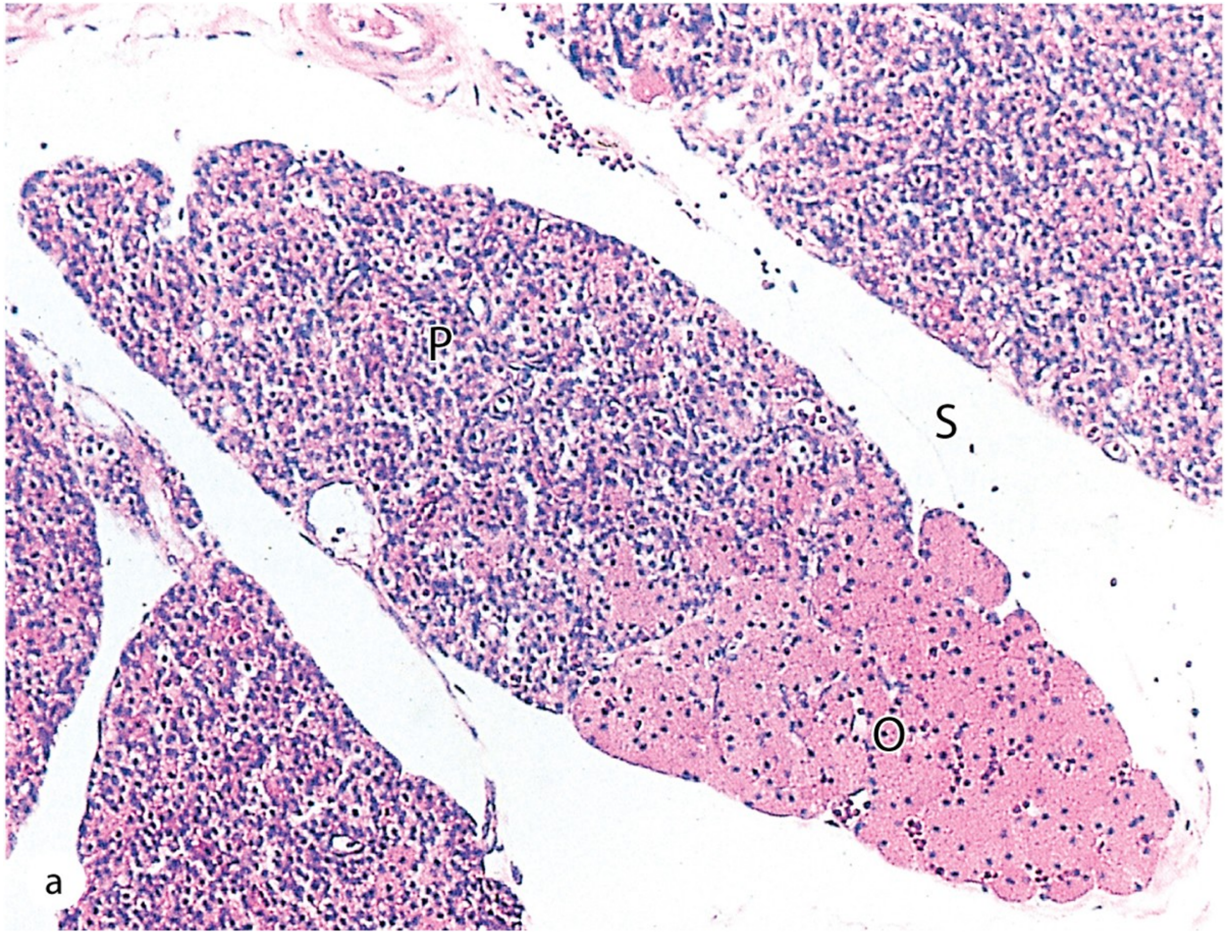
http://highered.mheducation.com/sites/9834092339/student_view0/chapter46/mechanism_of_thyroxine_action.html

The 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
- **Secrete parathyroid hormone (PTH):**
  - Increases blood Ca^{2+} levels: decreased urinary excretion, promotes synthesis of calcitriol → increased digestive absorption of Ca^{2+}
  - Increased bone resorption via increase osteoclast activity



Parathyroid histology



A small lobe of parathyroid gland, surrounded by connective tissue septa (**S**), shows mainly densely packed cords of small principal cells (**P**). Older parathyroid glands show increasing numbers of much larger and acidophilic nonfunctional oxyphil cells (**O**) that may occur singly or in clumps of varying sizes

MEDICAL APPLICATION In **hypoparathyroidism**, diminished secretion of PTH can cause bones to become more mineralized and denser and striated muscle to exhibit abnormal contractions due to inadequate calcium ion concentrations.

Excessive PTH produced in **hyperparathyroidism** stimulates osteoclast number and activity, leading to increased levels of blood calcium that can be deposited pathologically in cartilage, arteries, or the kidneys.

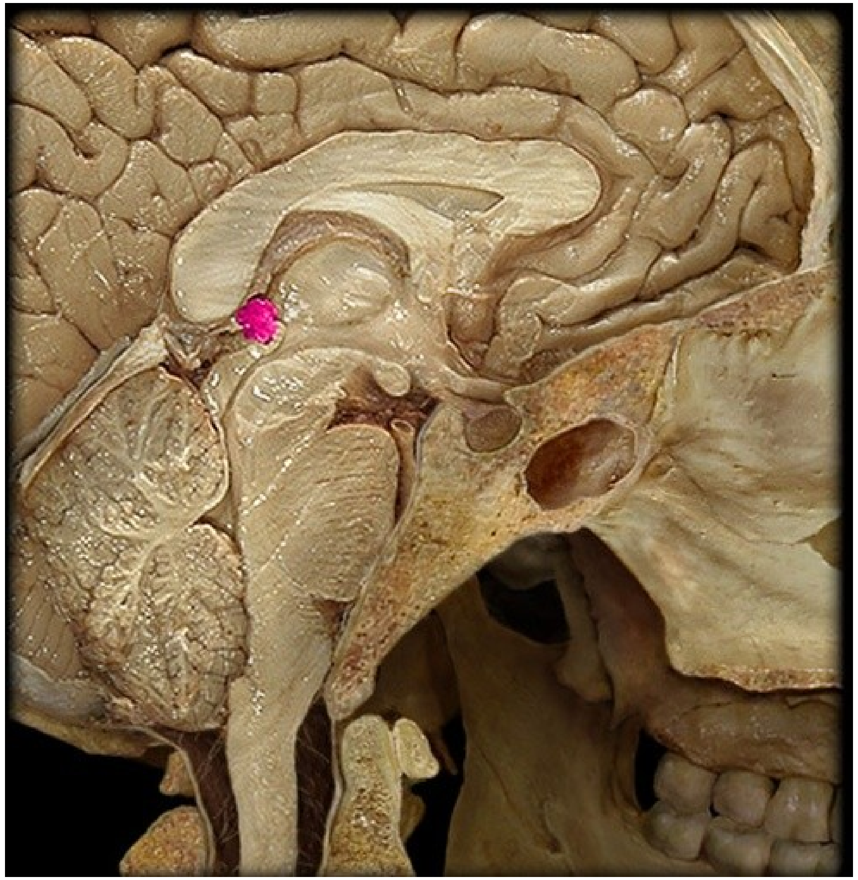
The Pineal Gland

After age 7, it undergoes **involution** (shrinkage), 75% by end of puberty

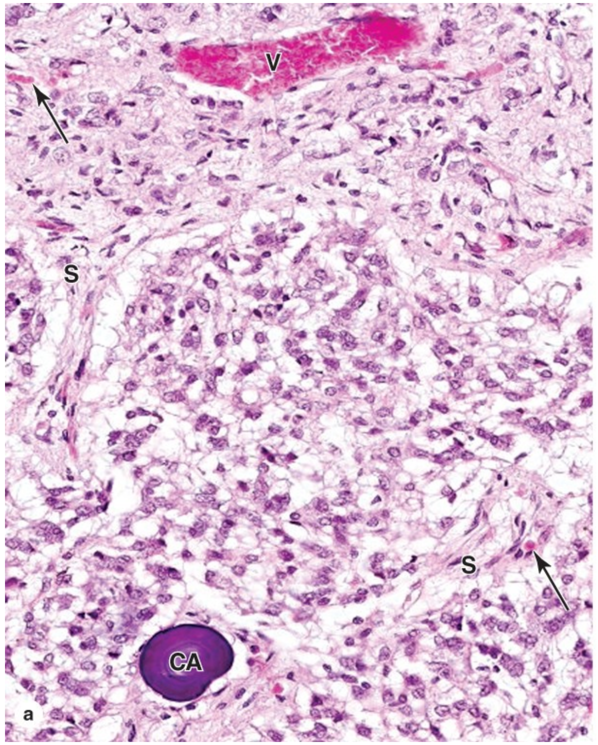
- Tiny mass of shrunken tissue in adults
- May regulate timing of puberty in humans

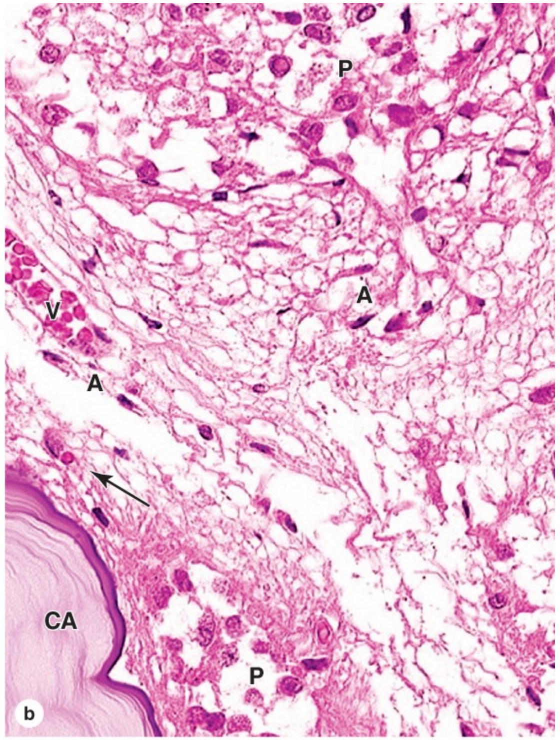
May synchronize physiological function with 24-hour **circadian rhythms** of daylight and darkness

- Synthesizes **melatonin** from serotonin during the night
- Fluctuates seasonally with changes in day length → **Seasonal affective disorder (SAD)** occurs in winter or northern climates
- Symptoms: depression, sleepiness, irritability, and carbohydrate craving
- Two to 3 hours of exposure to bright light each day reduces the melatonin levels and the symptoms (phototherapy)



Pineal Histology





Pinealocytes (**P**) surrounded by septa (**S**) containing venules (**V**) and capillaries (arrows
Corpus arenaceum (**CA**): extracellular mineral deposit called a of unknown physiologic significance but an excellent marker for the pineal

astrocytes (**A**): darker, more elongated nuclei
small blood vessels (**V**)
Capillaries (arrow) are not nearly as numerous as in other endocrine glands.

Along the septa run unmyelinated tracts of sympathetic fibers, associated indirectly with photoreceptive neurons in the retinas and running to the pinealocytes to stimulate melatonin release in periods of darkness.

MEDICAL APPLICATION

Densely calcified corpora arenacea can be used as landmarks for the midline location of the pineal gland in a various radiological examinations of the brain. Tumors originating from pinealocytes are very rare, but they can be either benign or highly malignant.

TABLE 20–5 **Cells, important hormones, and functions of other major endocrine organs.**

Gland	Endocrine Cells	Major Hormones	Major Functions
Adrenal glands: Cortex	Cells of zona glomerulosa	Mineralocorticoids	Stimulate renal reabsorption of water and Na^+ and secretion of K^+ to maintain salt and water balance
	Cells of zona fasciculata	Glucocorticoids	Influence carbohydrate metabolism; suppress immune cell activities
	Cells of zona reticularis	Weak androgens	Precursors for testosterone or estrogen
Adrenal glands: Medulla	Chromaffin cells	Epinephrine	Increases heart rate and constricts vessels
		Norepinephrine	Dilates vessels and increases glucose release
Pancreatic islets	α Cells	Glucagon	Raises blood glucose levels
	β Cells	Insulin	Lowers blood glucose levels
	δ Cells	Somatostatin	Inhibits secretion of insulin, glucagon, and somatotropin
	PP cells	Pancreatic polypeptide	Inhibits secretion of pancreatic enzymes and HCO_3^-
Thyroid glands	Follicular cells	Thyroid hormones (T_3 and T_4)	Increase metabolic rate
	Parafollicular or C cells	Calcitonin	Lowers blood Ca^{2+} levels by inhibiting osteoclast activity
Parathyroid glands	Chief cells	Parathyroid hormone (PTH)	Raises blood Ca^{2+} levels by stimulating osteoclast activity
Pineal gland	Pinealocytes	Melatonin	Regulates circadian rhythms