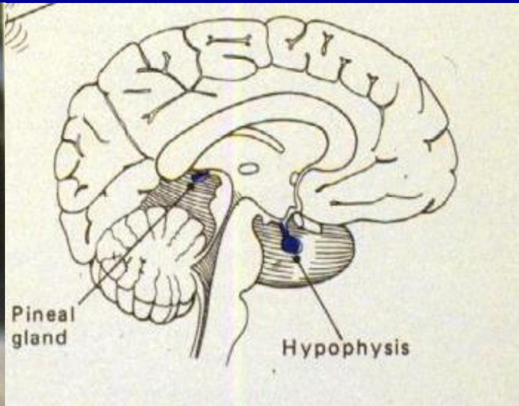
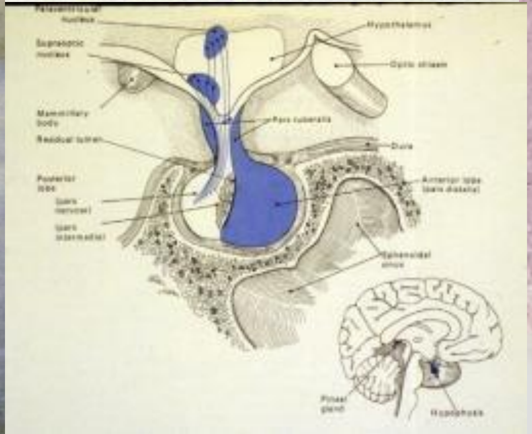
18. Endocrine System
part 1

Undergraduate – Graduate
Histology Lecture Series

Larry Johnson, Professor
Veterinary Integrative Biosciences
Texas A&M University
College Station, TX 77843

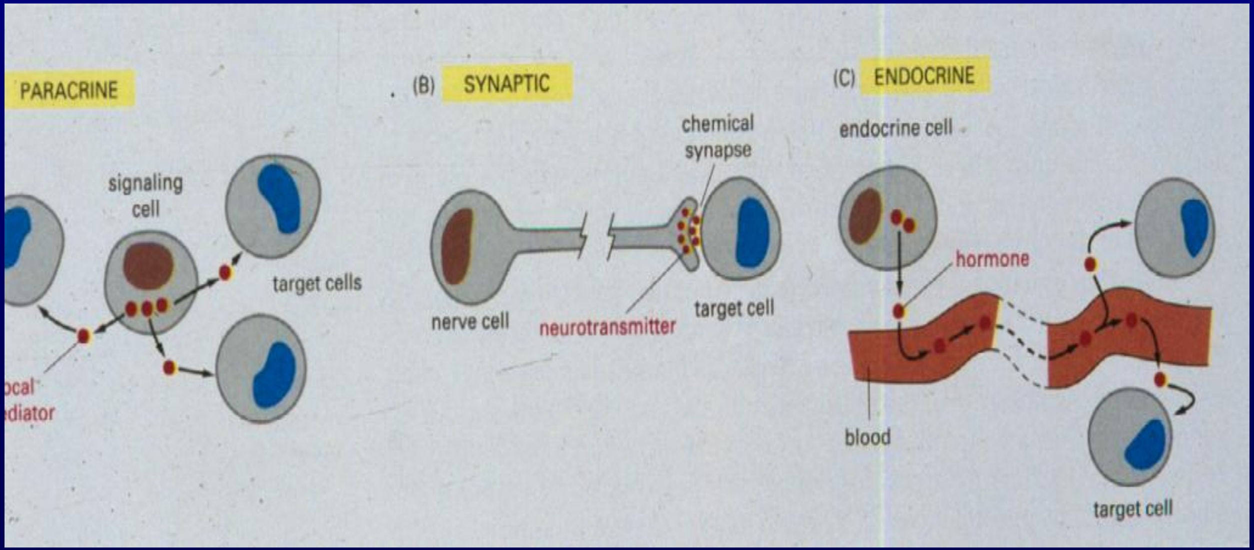


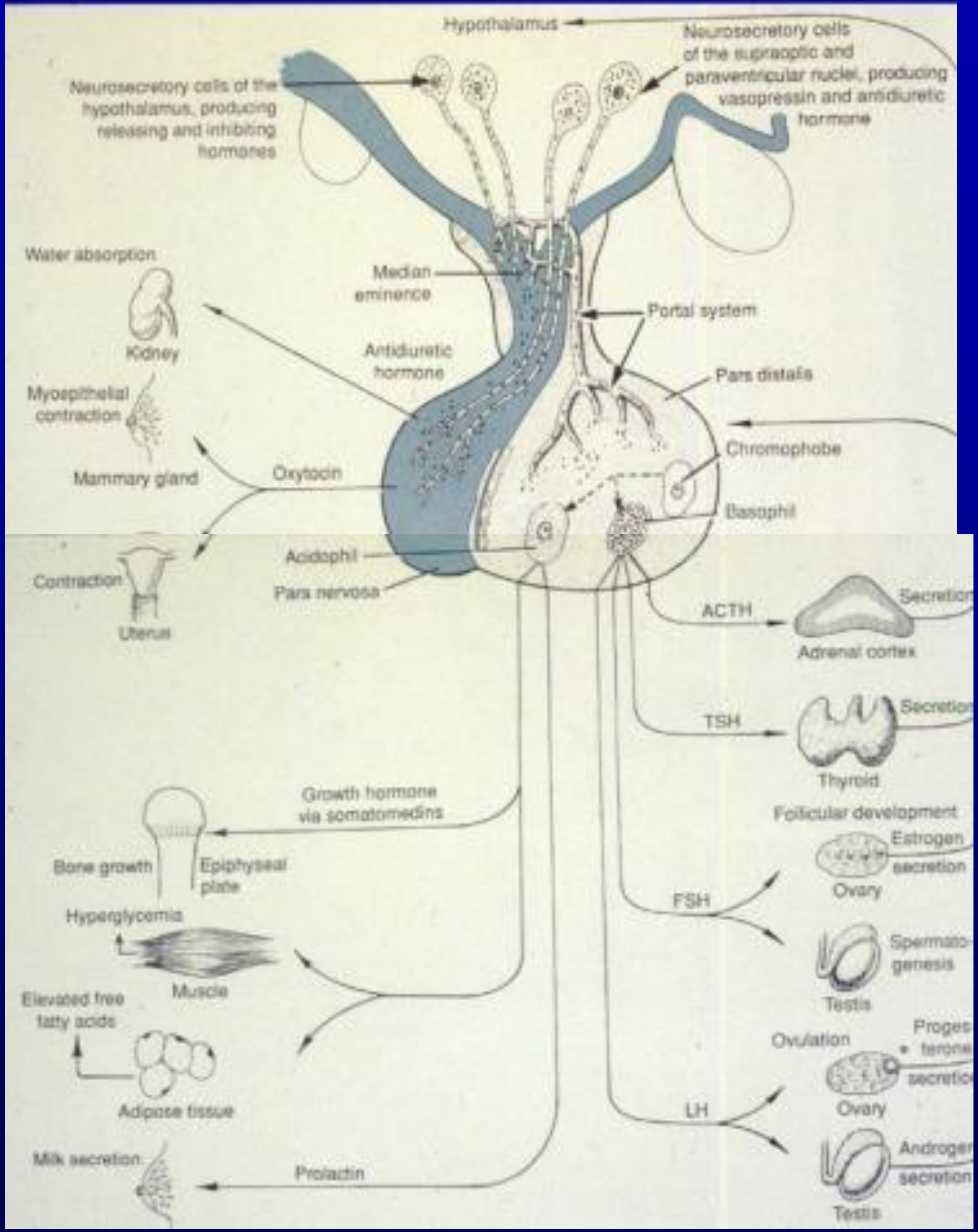


Objective

Gain a greater appreciation of the diversity of functions of the endocrine system

Recognize different organs, unique features of organs, and cells that make the endocrine system

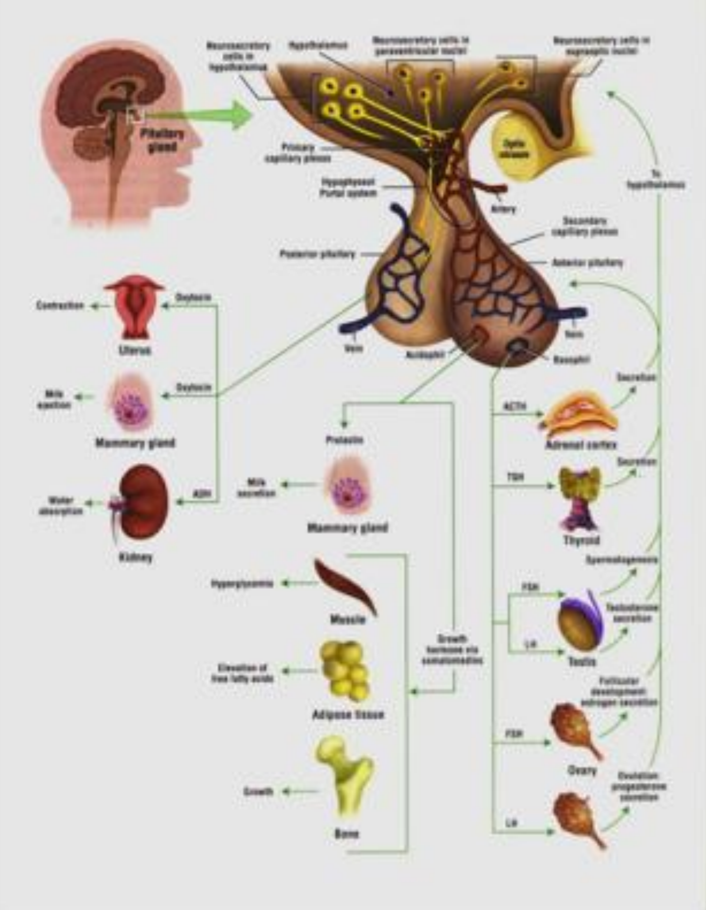




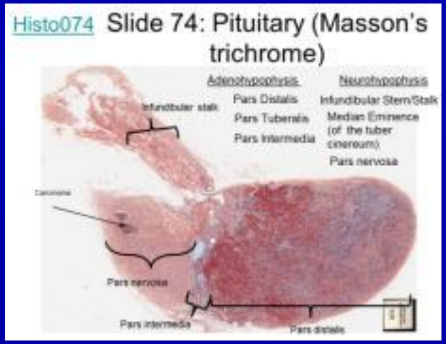
Introduction

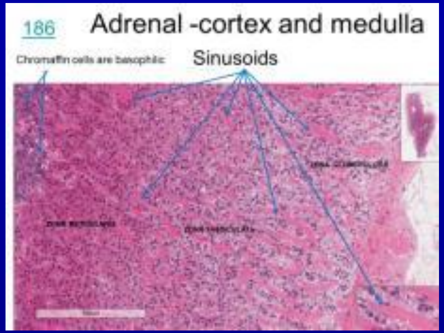
Function of endocrine system

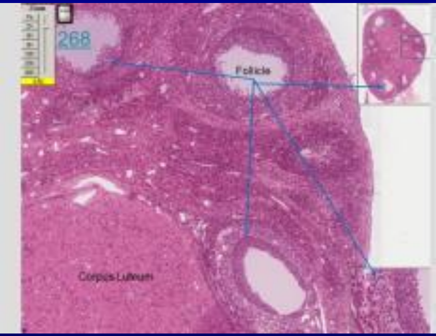
"The endocrine system is the collection of glands that produce hormones that regulate metabolism, growth and development, tissue function, sexual function, reproduction, sleep, and mood, among other things."

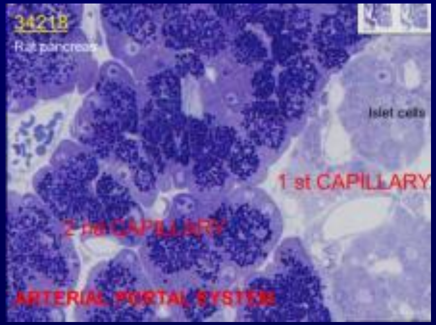


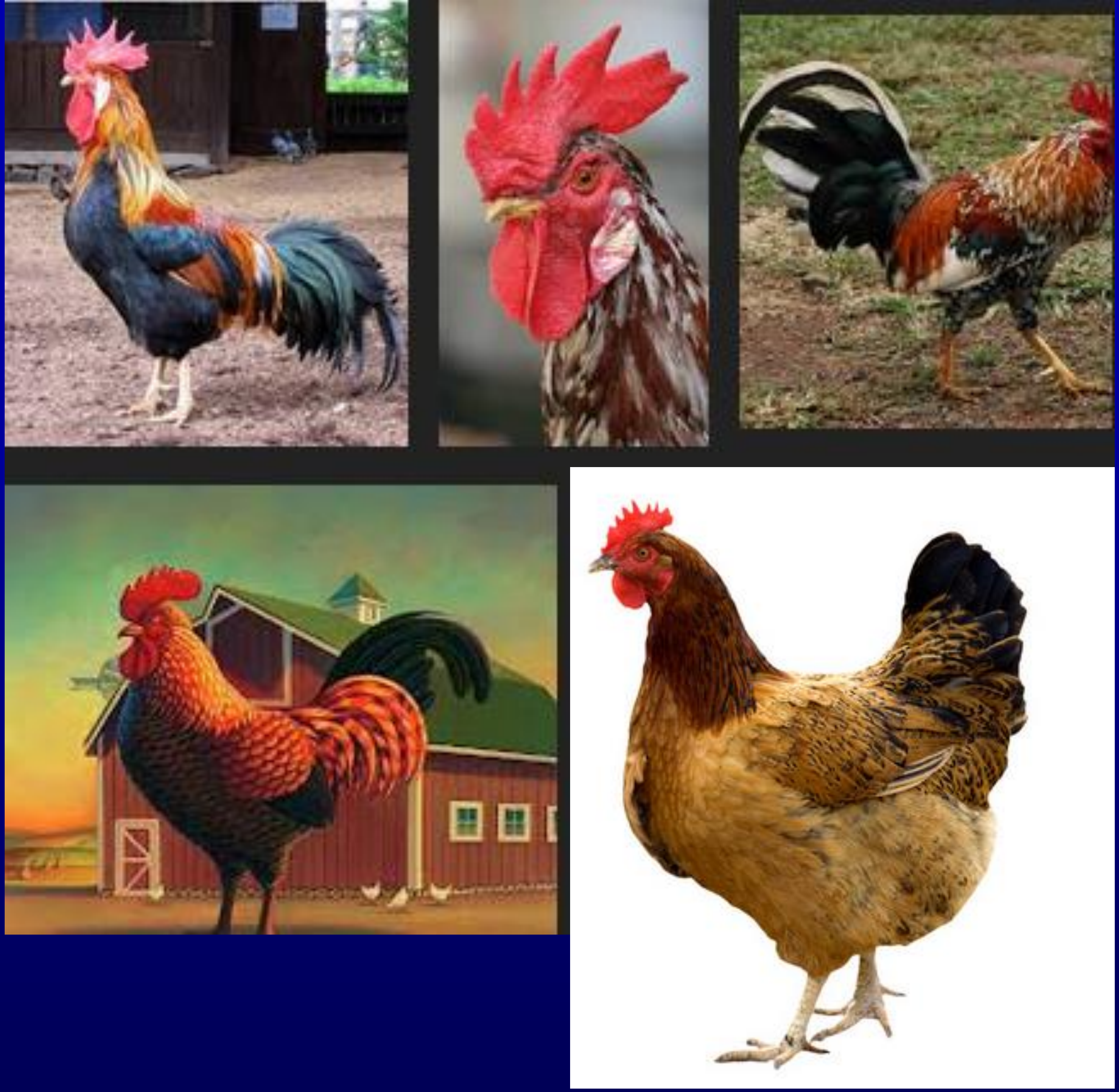
http://www.livescience.com/26496-endocrine-system.html







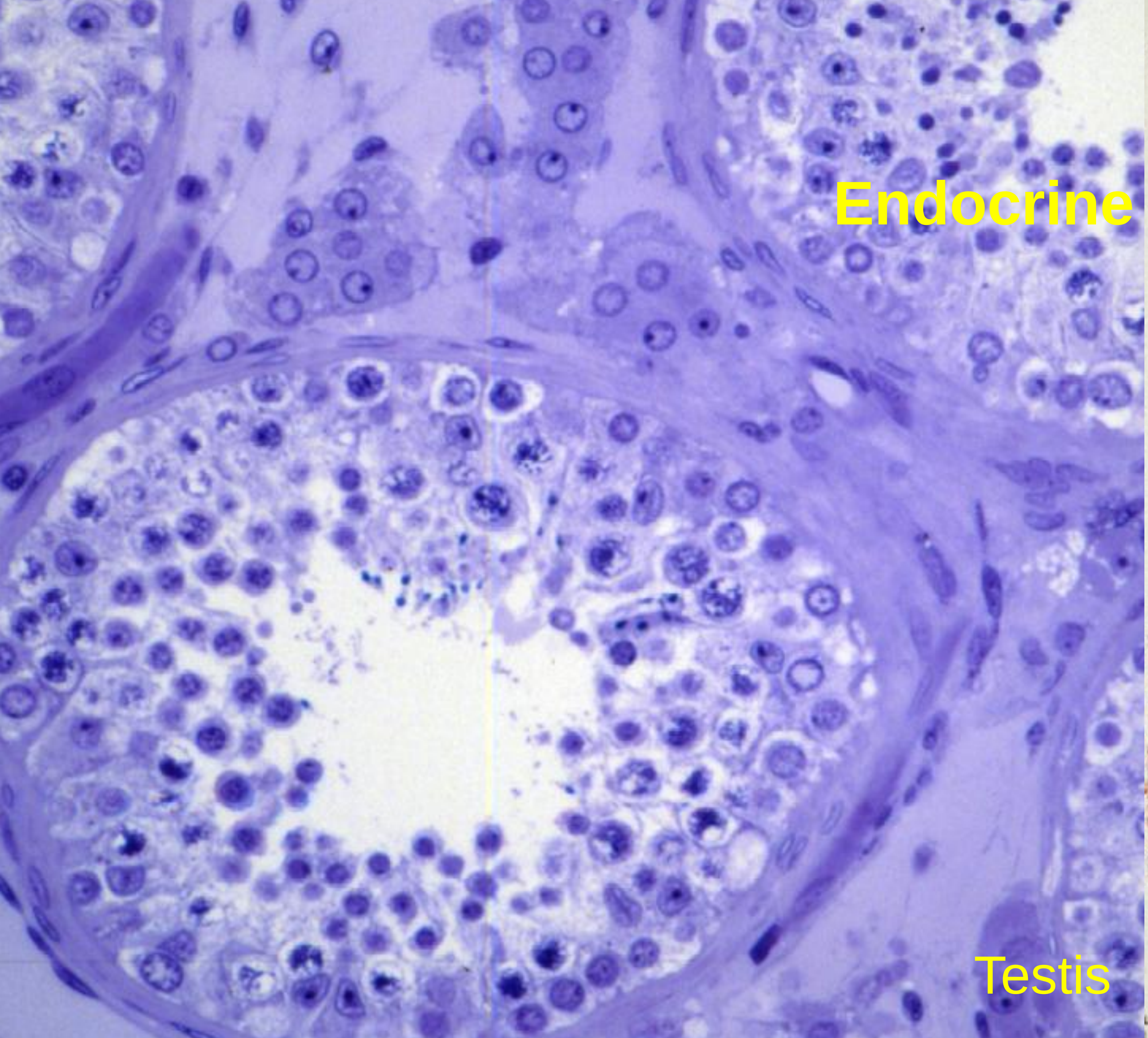




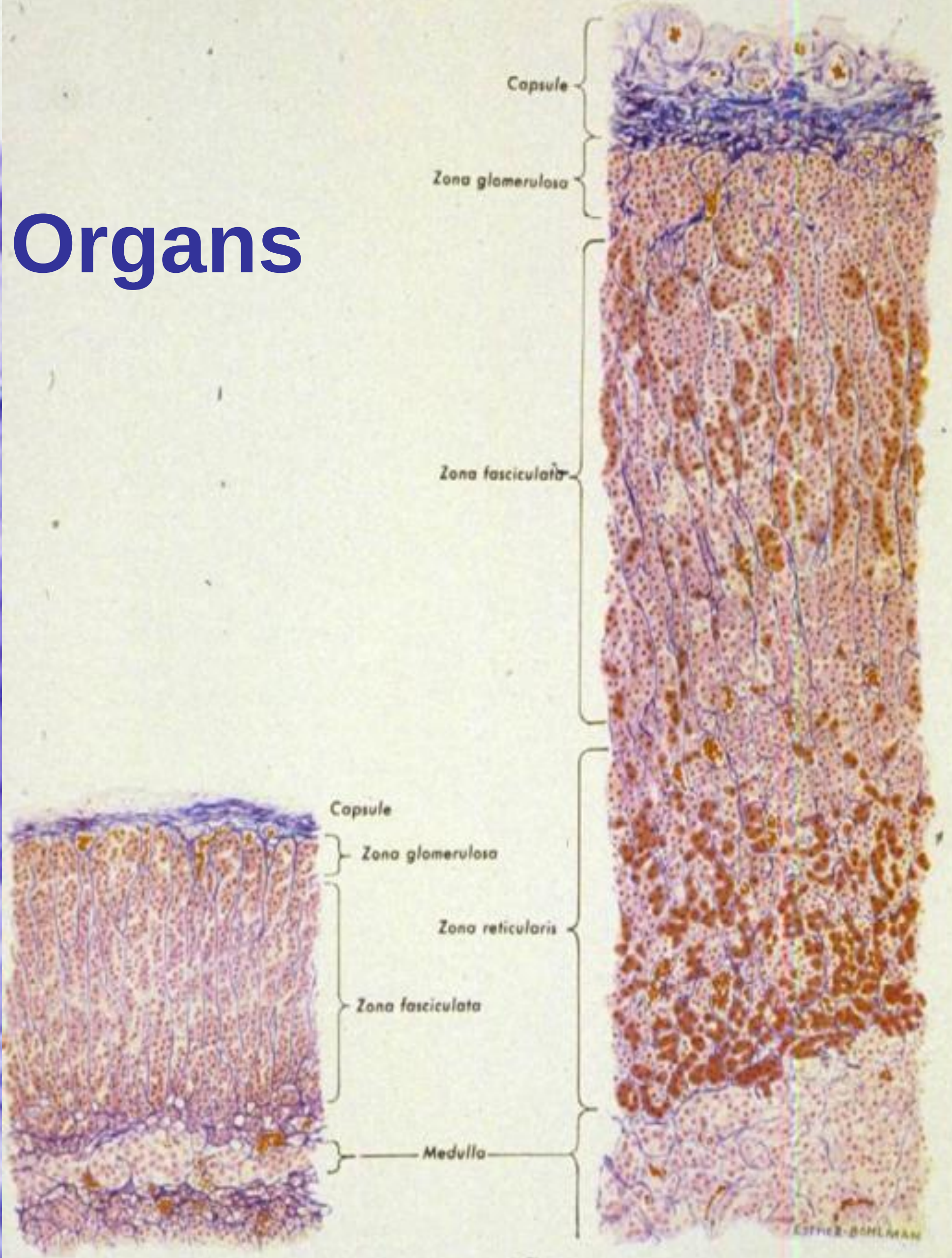
First scientific endocrine study was in the testis of roosters studying the observable effects of testosterone on the secondary sex structures (wattle and comb size).

Transplanting the testes back into the abdominal cavity prevented the reduction in size of wattle and comb in castrated roosters.

Endocrine Organs



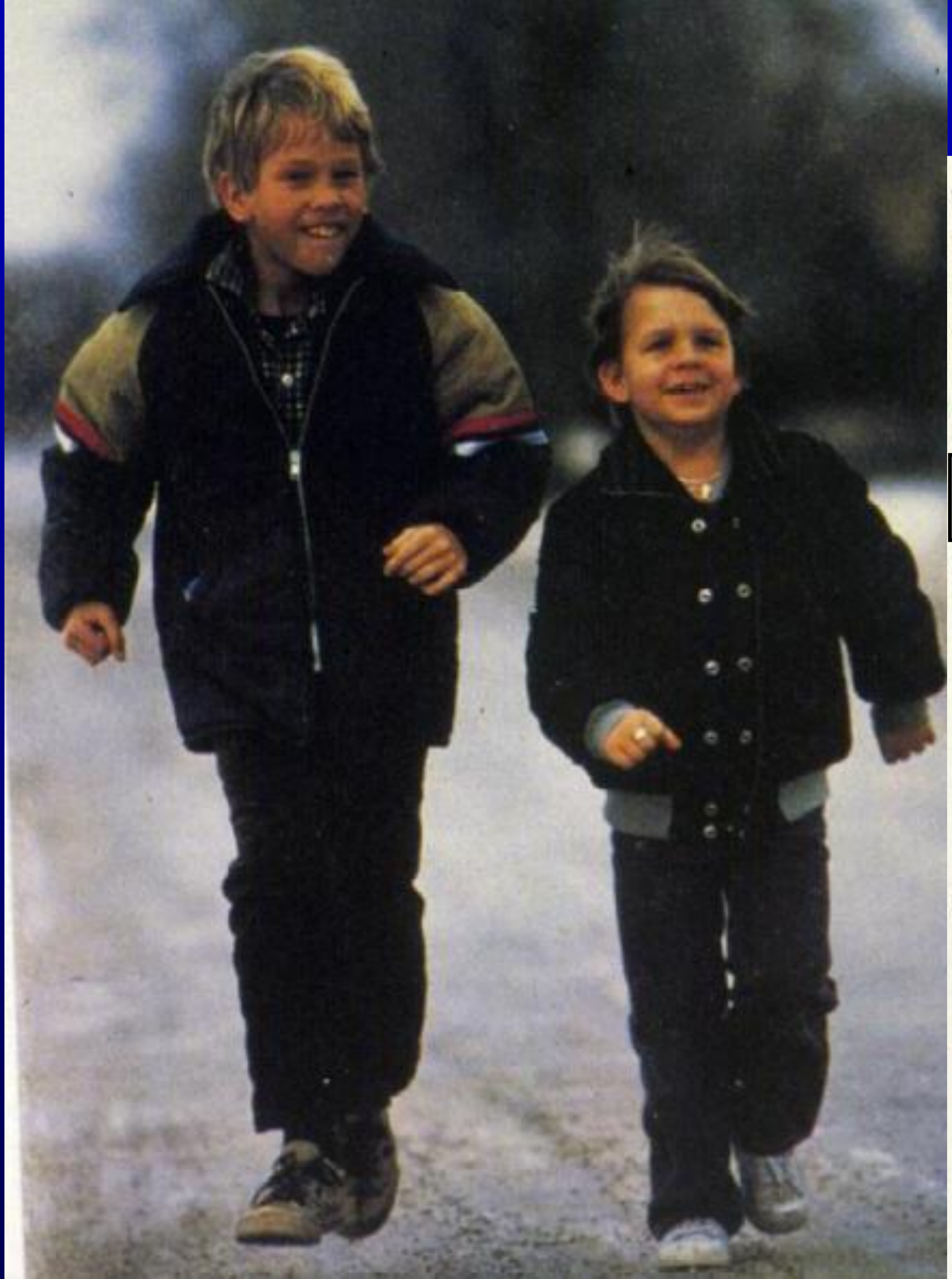
Testis



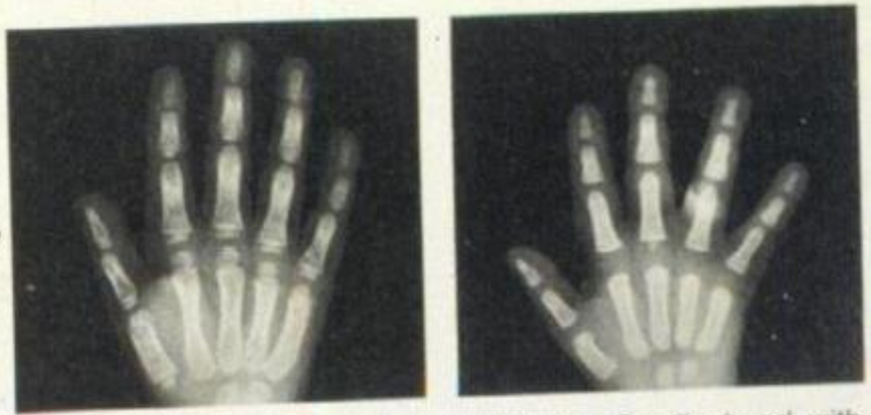
adrenal gland

ure 20–1. Sections through the adrenal glands of a 6-month-old infant *(left)* and of a man *(right)*. Mallory-azan stain
10

Growth Hormone



When a child is short for his age, it may be because he has inherited genes for short stature, but it can also be a sign that something is wrong. Possibilities include blood or liver disease, malnutrition, emotional deprivation, or insufficient production of growth hormone by the pituitary gland. One way doctors can determine whether short stature is normal, or a cause for concern, is to chart a child's growth rate. Between the ages of 3 and 9, the average youngster grows about 2 inches (5.1 centimeters) every year. Much slower growth is "a red flag," one specialist says, and signals the need for careful medical study. Injected growth hormone produces growth in some cases.



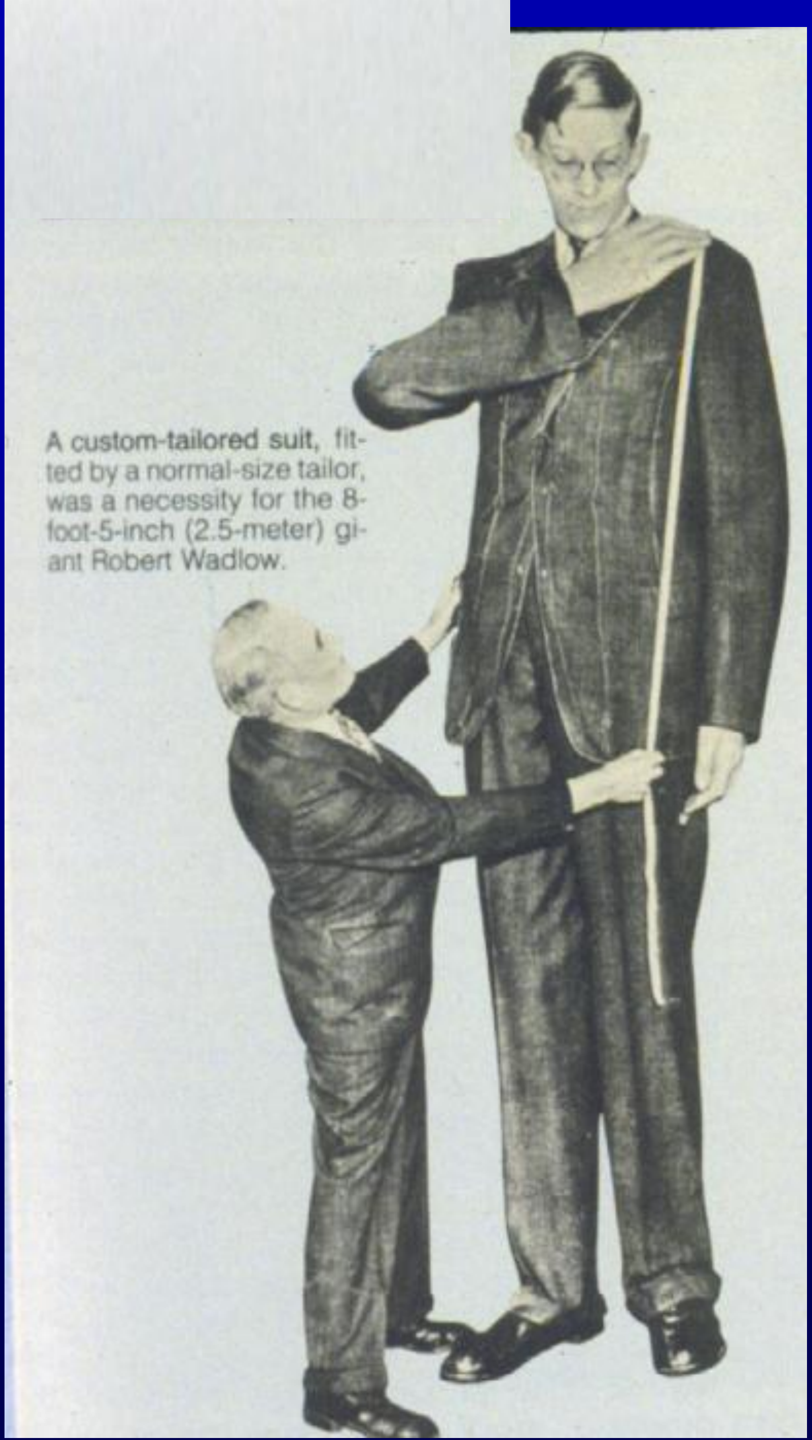
Each X ray shows the hand of a child of five. Smaller hand, with shorter bones, reveals insufficient growth hormone.

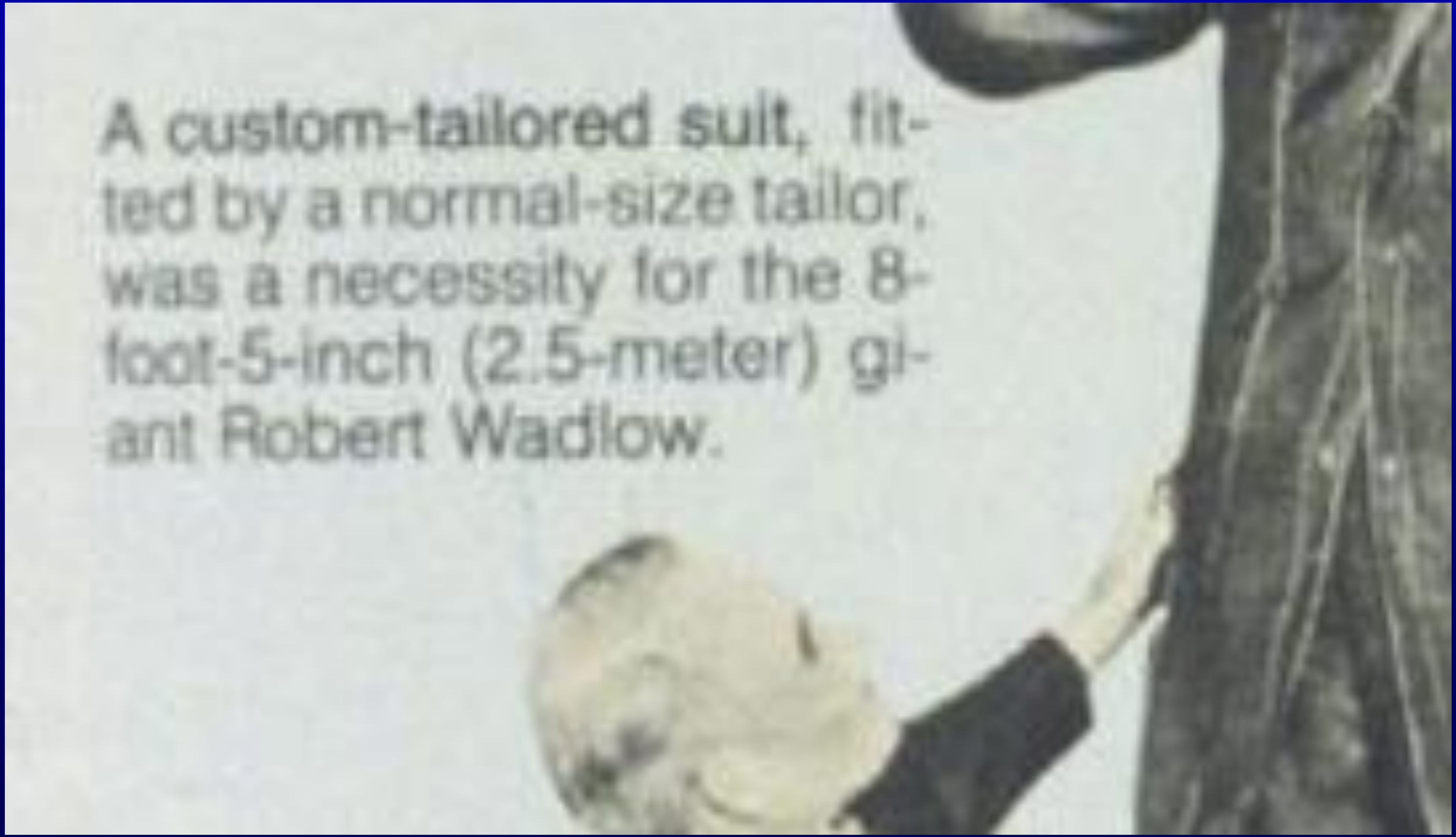
At the age of ten, a hormone-deficient boy (right) is shorter than a nine-year-old (left). Treatment with growth hormone has produced some increase in height.

Dwarf

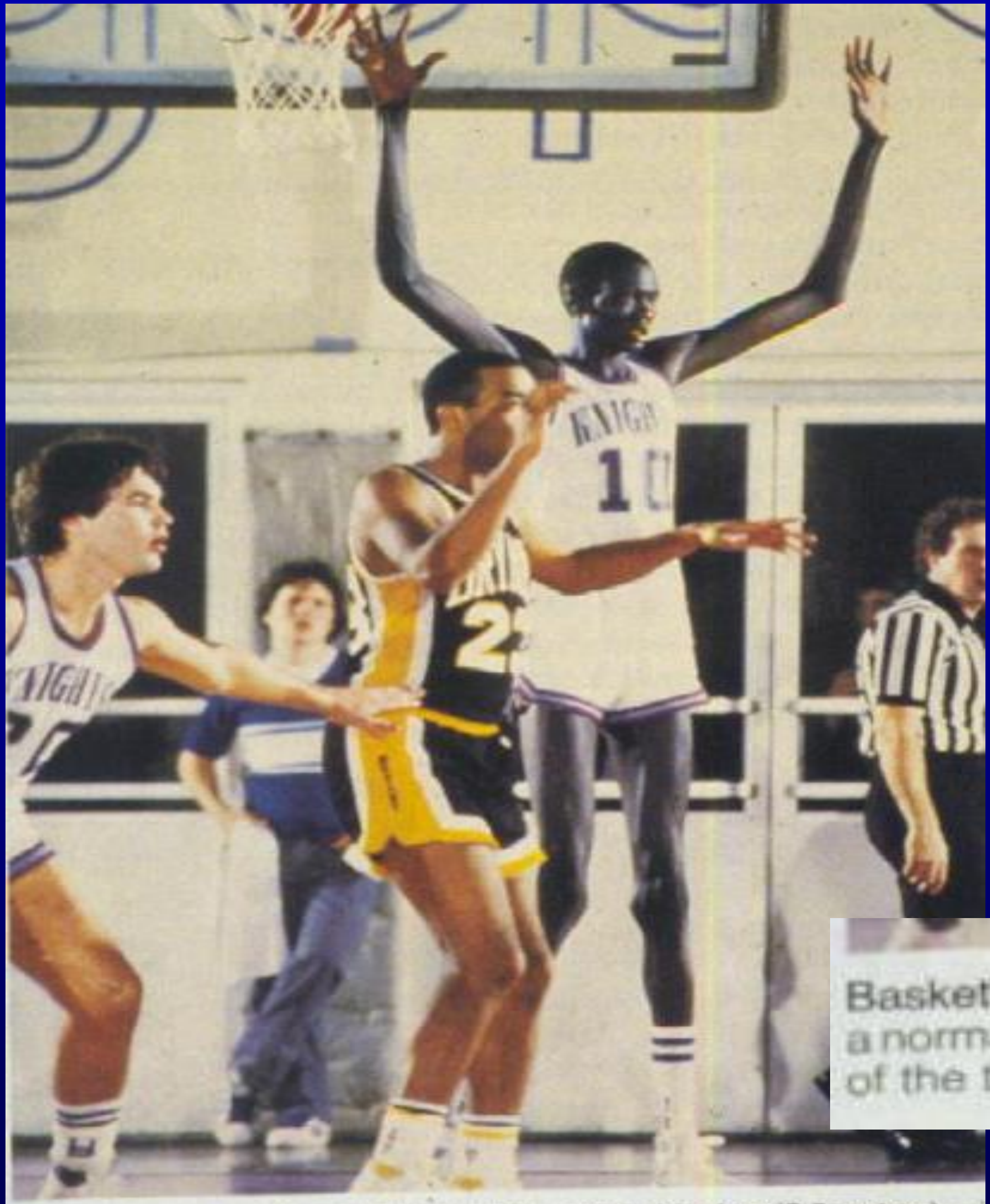
The outer-space being, E.T. the Extra-Terrestrial, in the motion picture of that name, was "played" chiefly by an elaborate piece of machinery, but in some scenes, a dwarf played the role.

Giant


A custom-tailored suit, fitted by a normal-size tailor, was a necessity for the 8-foot-5-inch (2.5-meter) giant Robert Wadlow.


A custom-tailored suit, fitted by a normal-size tailor, was a necessity for the 8-foot-5-inch (2.5-meter) giant Robert Wadlow.

Giant



Basketball player Manute Bol's height — 7 feet 6 inches (2.3 meters) — i
a normal, inherited trait. He is a member of the Sudanese Dinka tribe, on
of the tallest peoples in the world.

Basketball player Manute Bol's height — 7 feet 6 inches (2.3 meters) — i
a normal, inherited trait. He is a member of the Sudanese Dinka tribe, on
of the tallest peoples in the world.

Introduction

Overview of endocrine system

Definition of endocrine gland secretions (hormones)

Physiological blood levels of hormones

- Glucose 10^{-2} molar
- Steroid 10^{-9} molar
- Peptide 10^{-12} molar

Growth hormone (blood levels)

- 10^{-13} molar = Dwarf
- 10^{-11} molar = Giant

Control of endocrine glands

Endocrine System Overview

Endocrine glands	• No ducts, highly vascularized, rich blood supply
	  • Secretions (hormones) can be released directly into blood stream by way of the connective tissue around the secretory cells
	  • Secretions can be stored in secretory granules
	  • Secretions can be stored <u>extracellularly</u> (e.g., thyroid)
	
	Or not stored as are all steroid hormones

Pituitary gland	• Anterior pituitary = *pars distalis* or *adenohypophysis*
	  • Ectoderm
	• Posterior pituitary = *pars nervosa* or *neurohypophysis*
	  • Midbrain

Thyroid gland	• Lobules and • Colloid filled follicles (extracellular storage)
Parathyroid gland	• Capsule with septa • Cords of epithelial cells supported by reticular fibers

Adrenal gland	• Cortex
	  • Zona glomerulosa = mineralocorticoids
	  • Zona fasciculata = glucocorticoids
	  • Zona reticularis = androgens
	• Medulla
	  • Highly vascular, derived from neural crest

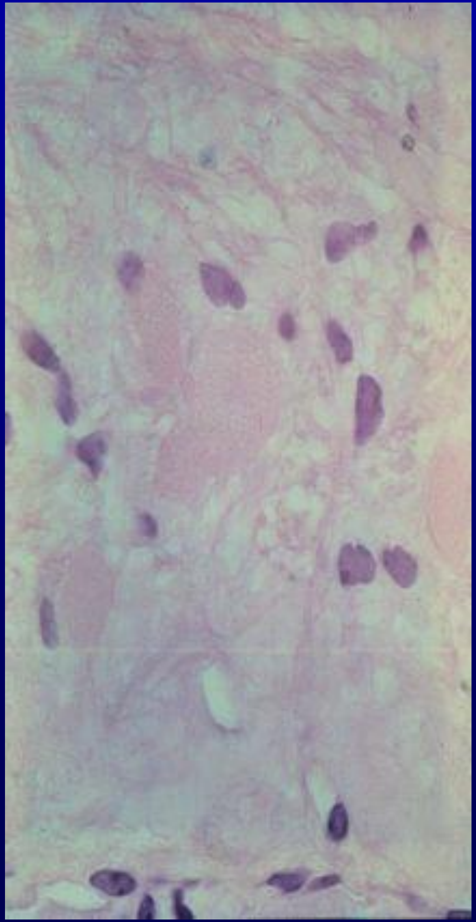
Pineal body	• *Epiphysis cerebri* • Capsule of pia mater • Lobules divided by capsule • Corpora arenacea = brain sand, pineal concretions that accumulate with age

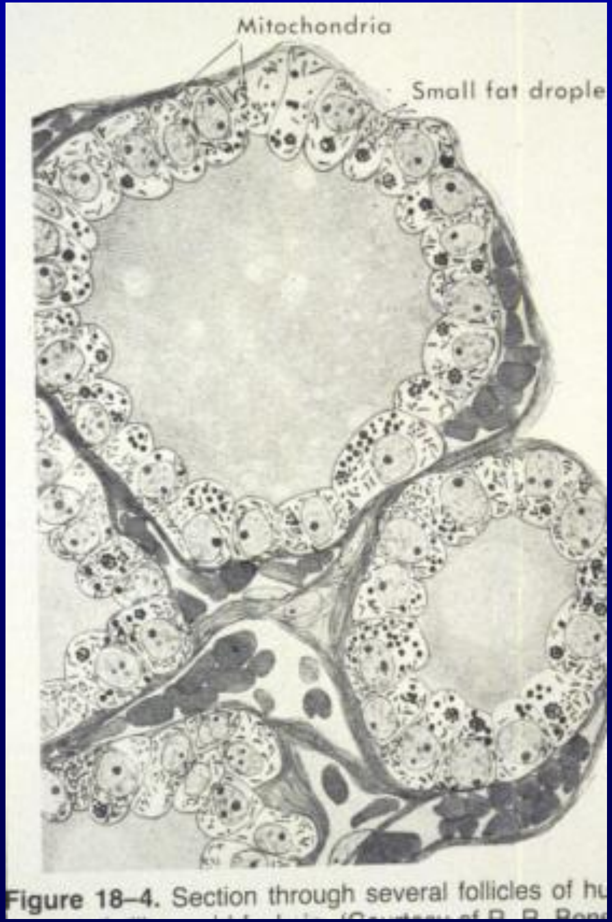
Pancreas	• Both exocrine and endocrine
	  • Endocrine portion = **Islets of Langerhans**
	    • Alpha cells = glucagon
	    • Beta = insulin
	    • Delta = somatostatin

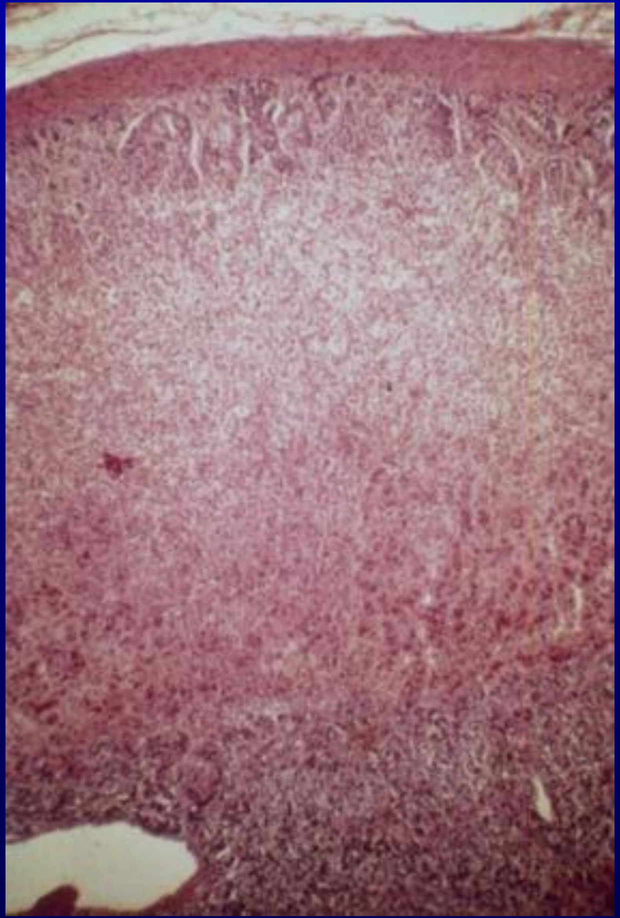
Endocrine = internal secretion

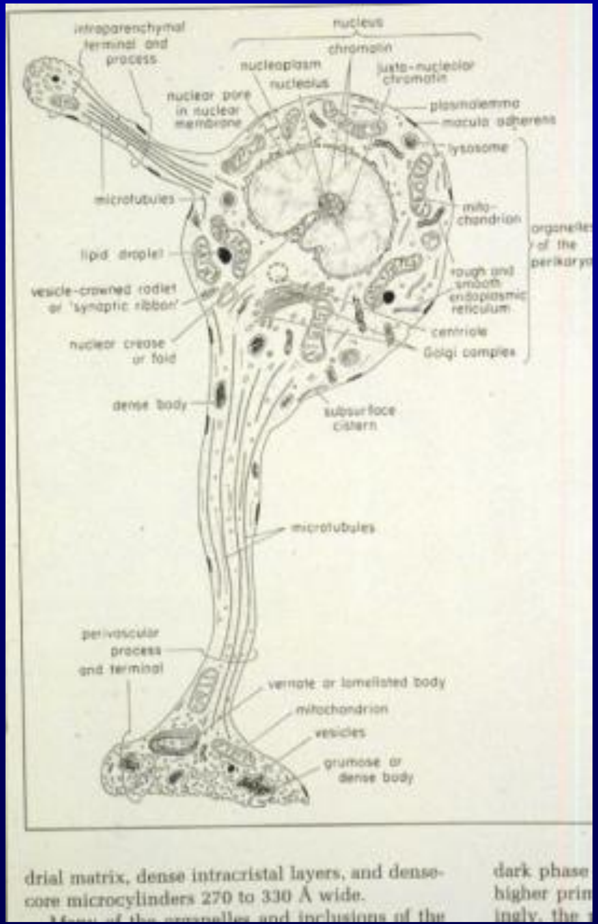
(without ducts and mostly from endoderm)

Hormone = to arouse or to set in motion







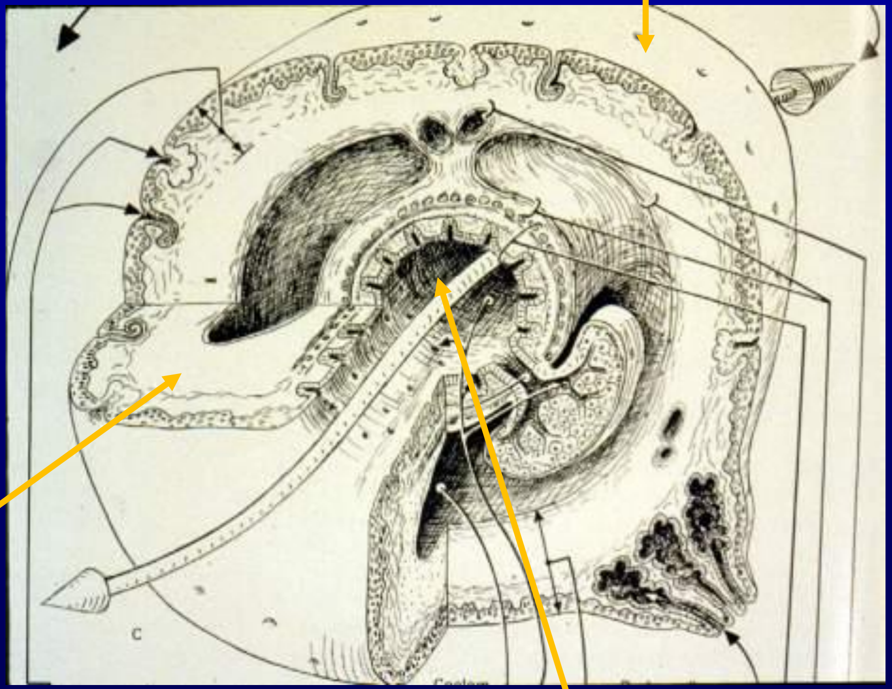


ORIGIN AND DISTRIBUTION OF EPITHELIUM

ECTODERM - EPIDERMIS OF SKIN AND EPITHELIUM OF CORNEA TOGETHER COVERS THE ENTIRE SURFACE OF THE BODY; SEBACEOUS AND MAMMARY GLANDS

ENDODERM - ALIMENTARY TRACT, LIVER, PANCREAS, GASTRIC GLANDS, INTESTINAL GLANDS

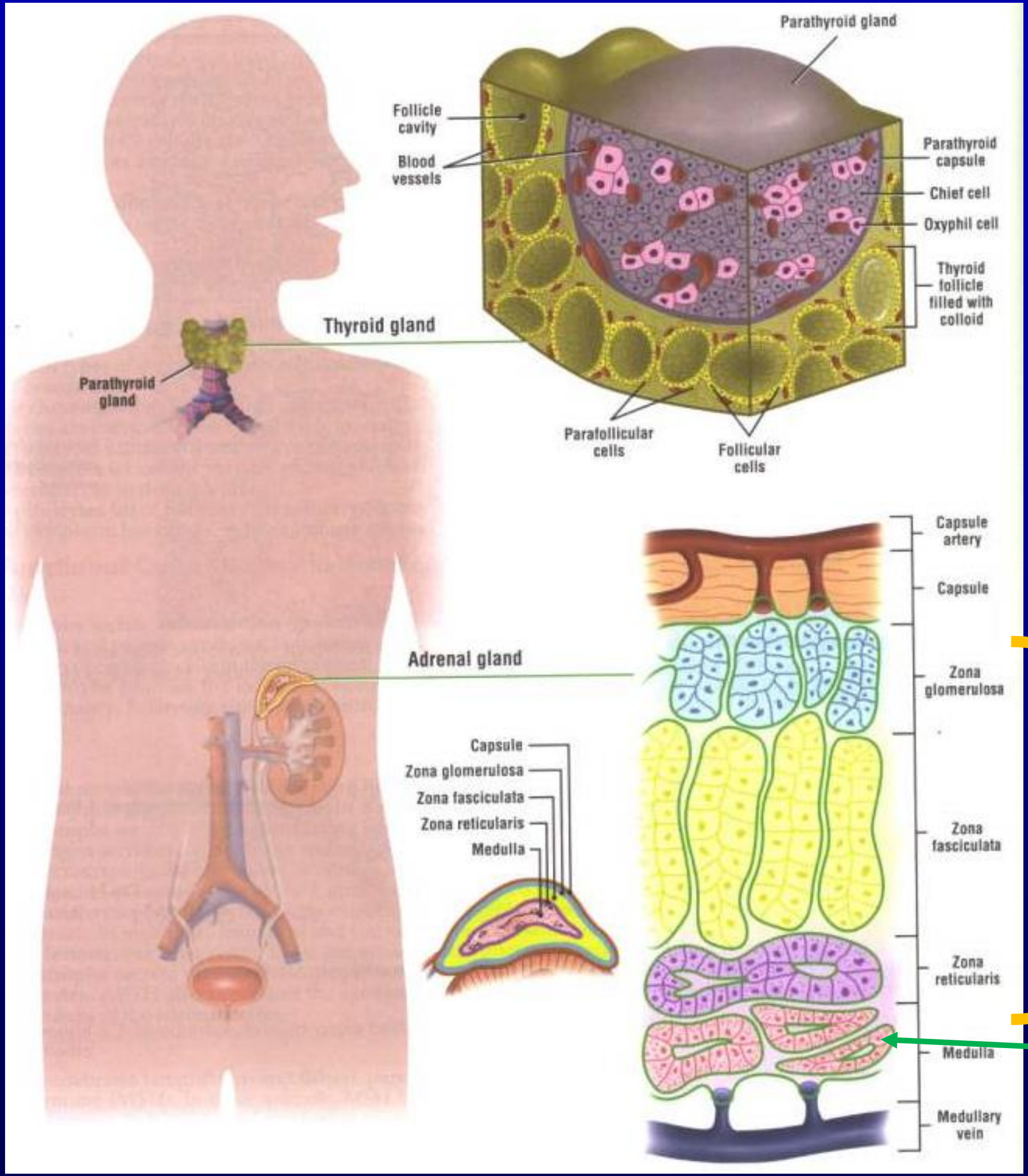
Most ENDOCRINE GLANDS



MESODERM

– ENDOTHELIUM - LINING OF BLOOD VESSELS
– MESOTHELIUM - LINING SEROUS CAVITIES

ORIGIN



ECTODERM

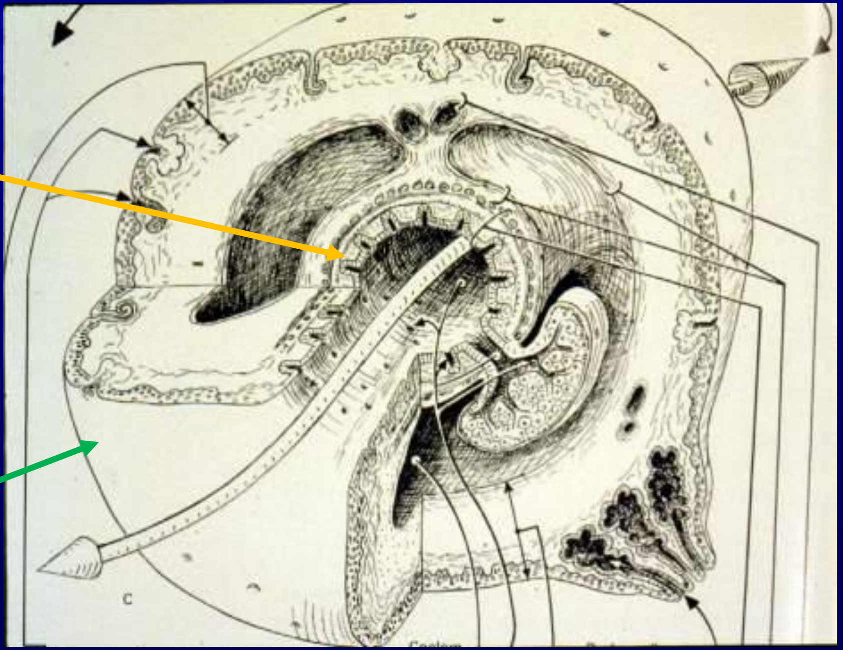
Adenohypophysis of oral ectoderm
Neurohypophysis of neural ectoderm
Adrenal medulla of neural ectoderm

ENDODERM –

Most ENDOCRINE GLANDS (including adrenal cortex)-

All LOSE CONNECTION WITH SURFACE and secrete into CT/blood

ENDODERM



ECTODERM

Releases of Neurons

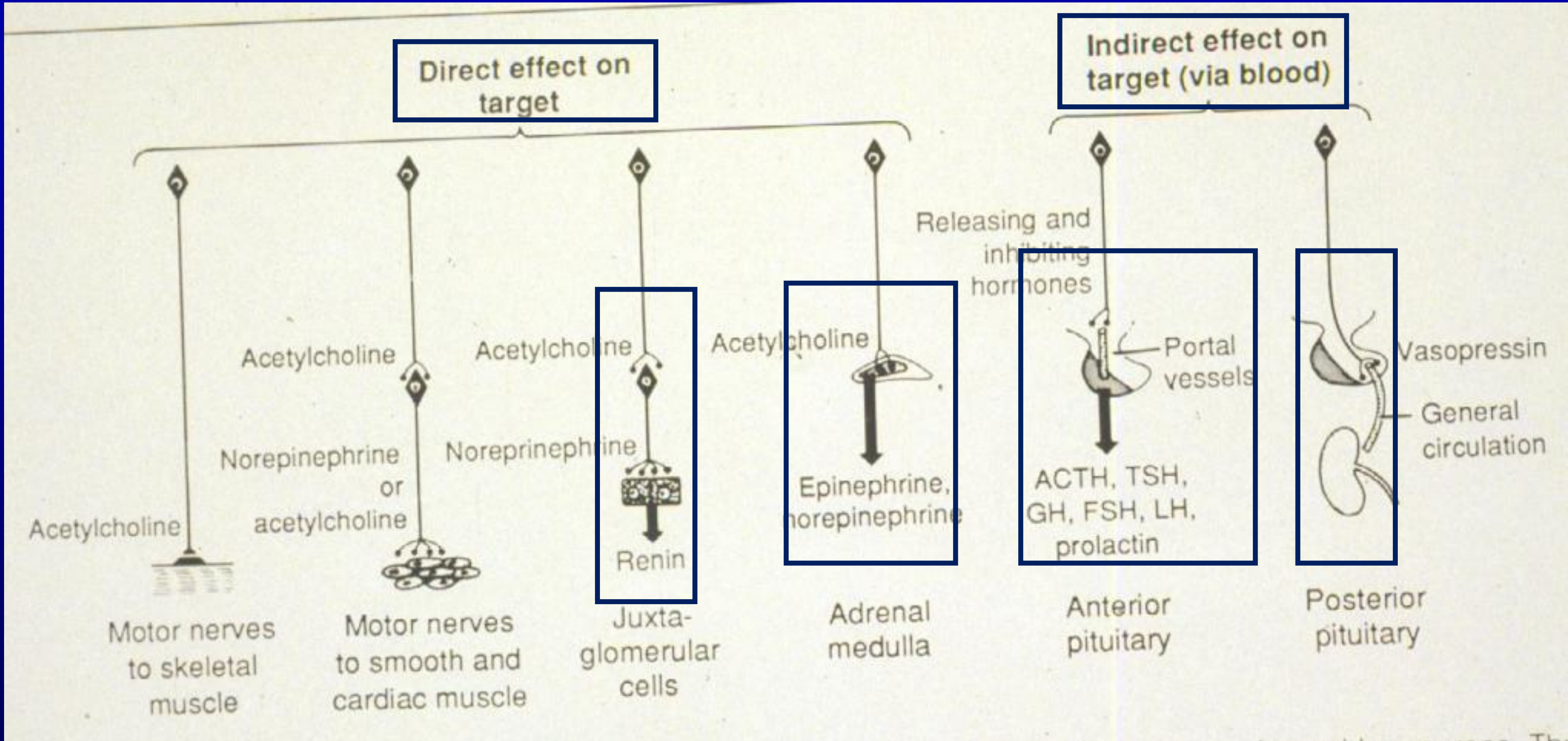
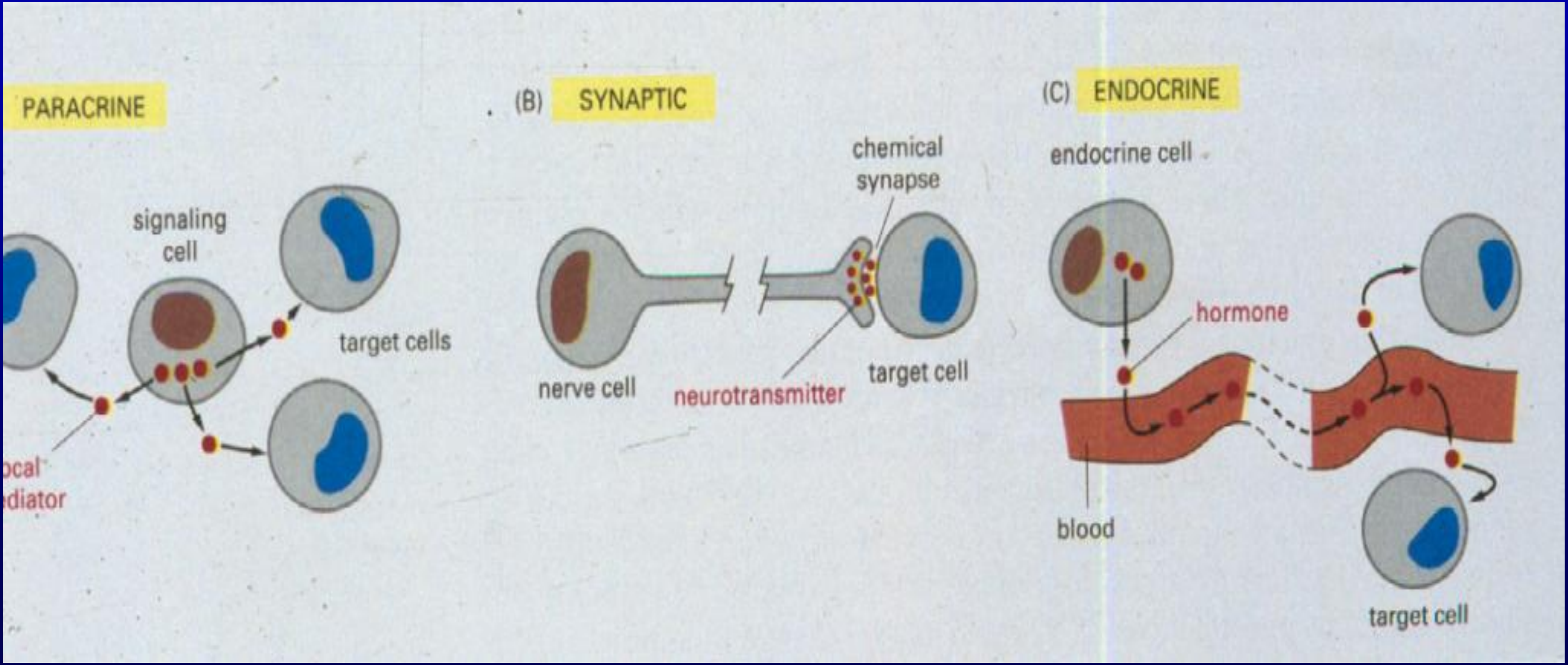
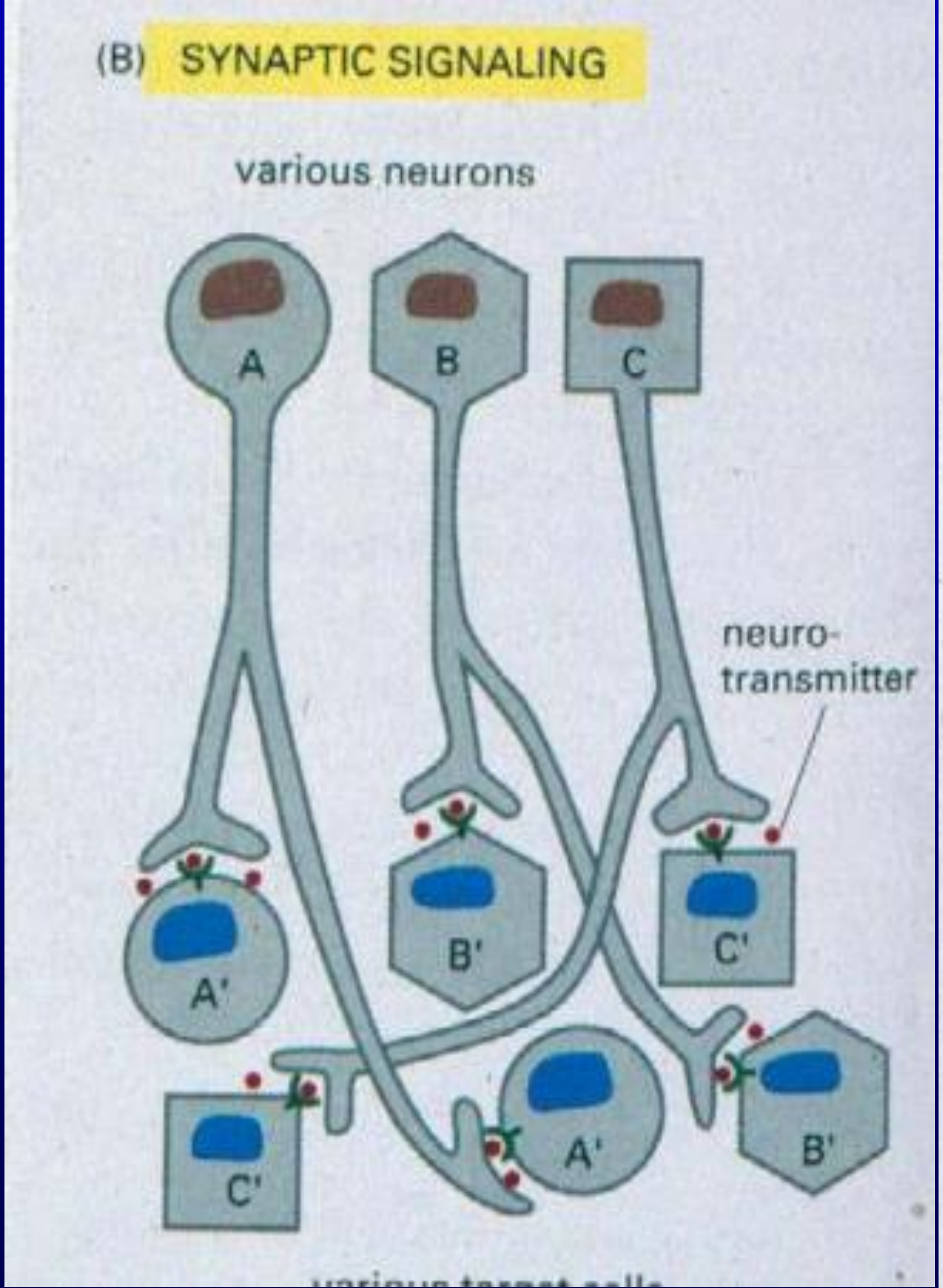


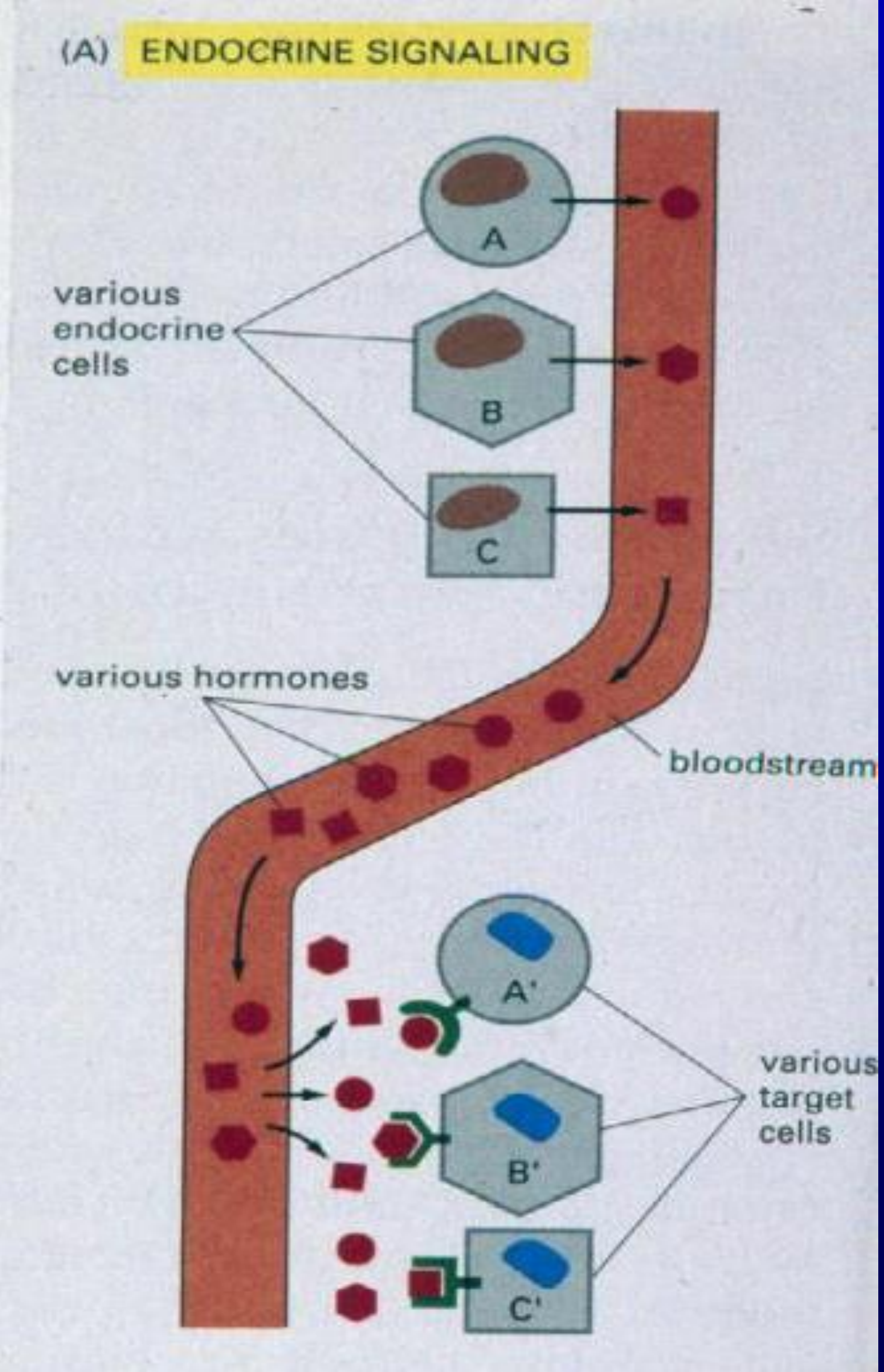
Figure 20–1. Diagrammatic representation of 6 situations in which humoral substances are released by neurons. The last 2 are examples of neurosecretion. (Reproduced, with permission, from Ganong WF. *Review of Medical Physiology*, 14th ed. Appleton & Lange, 1989.)

Endocrine



PARACRINE
signaling cell
target cells
ocal
diator
(B) SYNAPTIC
chemical synapse
nerve cell
neurotransmitter
target cell
(C) ENDOCRINE
endocrine cell
hormone
blood
target cell


(B) SYNAPTIC SIGNALING
various neurons
A
B
C
neuro-
transmitter
A'
B'
C'
A'
B'
C'


(A) ENDOCRINE SIGNALING
various
endocrine
cells
A
B
C
various hormones
bloodstream
A'
B'
C'
various
target
cells

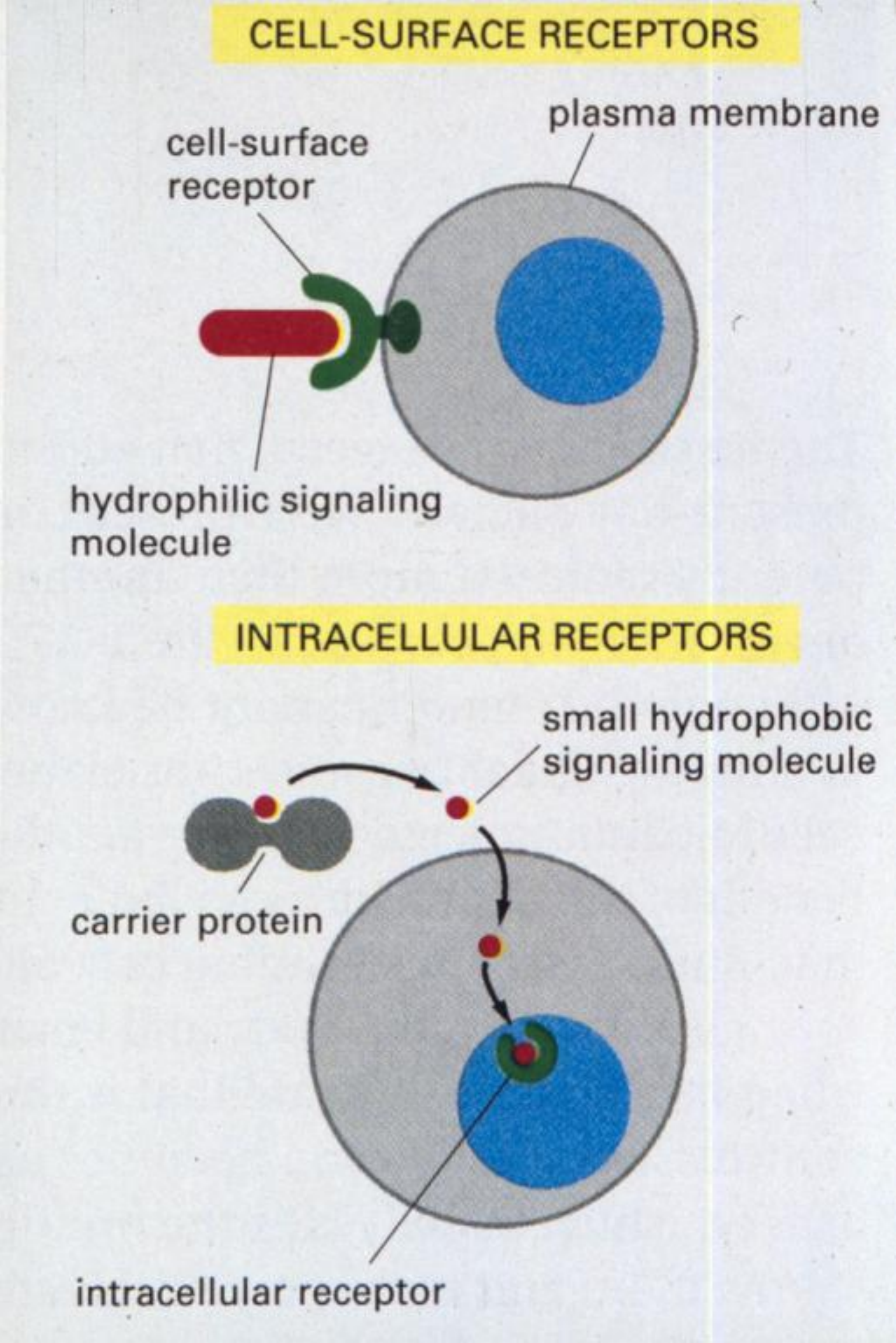
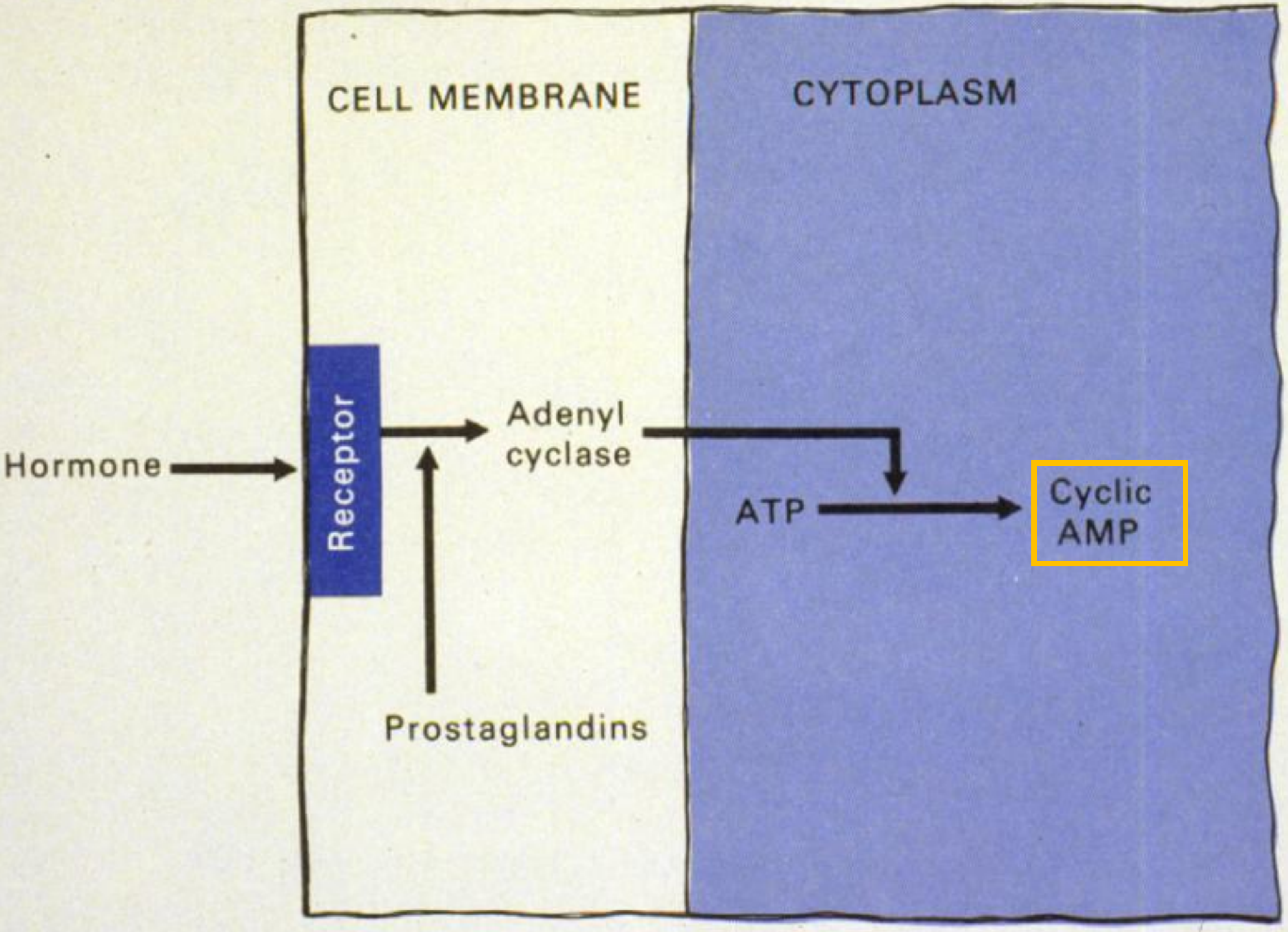

CELL-SURFACE RECEPTORS
plasma membrane
cell-surface receptor
hydrophilic signaling molecule
INTRACELLULAR RECEPTORS
small hydrophobic signaling molecule
carrier protein
intracellular receptor

Figure 31-2. The cell membrane contains the enzyme adenyl cyclase essential for the conversion of ATP to cyclic AMP. The hormone initiating the sequence is the first messenger; cyclic AMP the second.



Some hormone-induced cellular responses mediated by cyclic AMP

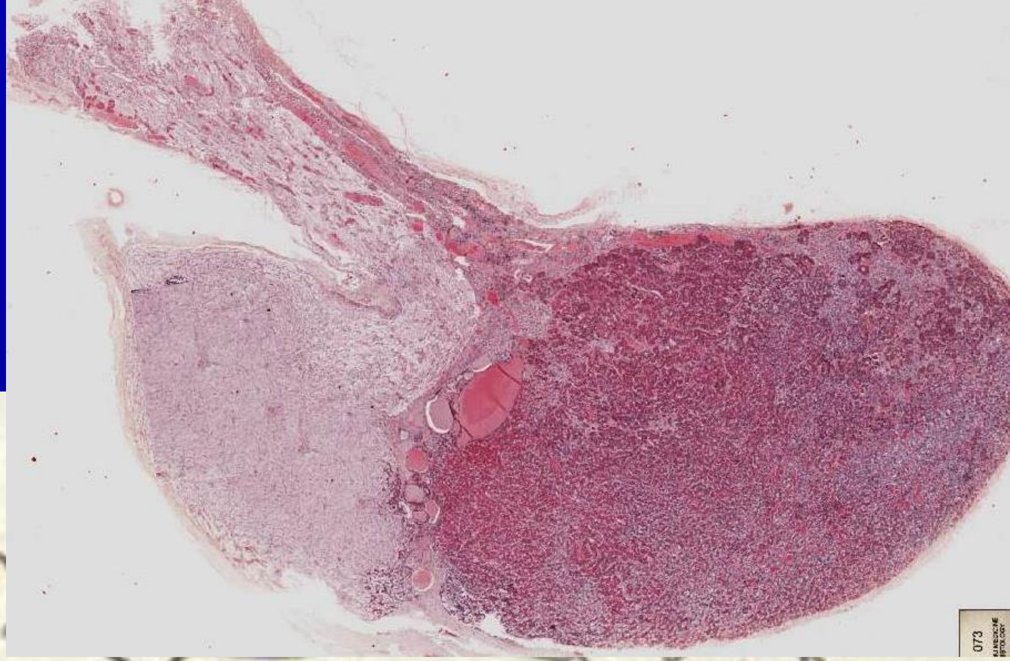
Target tissue	Hormone	Major response
Thyroid	Thyroid-stimulating hormone (TSH)	Thyroid hormone synthesis and secretion
Adrenal cortex	Adrenocorticotropic hormone (ACTH)	Cortisol secretion
Ovary	Luteinizing hormone (LH)	Progesterone secretion
Muscle, liver	Epinephrine	Glycogen breakdown
Bone	Parathyroid hormone	Bone resorption
Heart	Epinephrine	Increase in heart rate and force of contraction
Kidney	Vasopressin	Water resorption
Fat	Epinephrine, ACTH, glucagon, TSH	Triglyceride breakdown

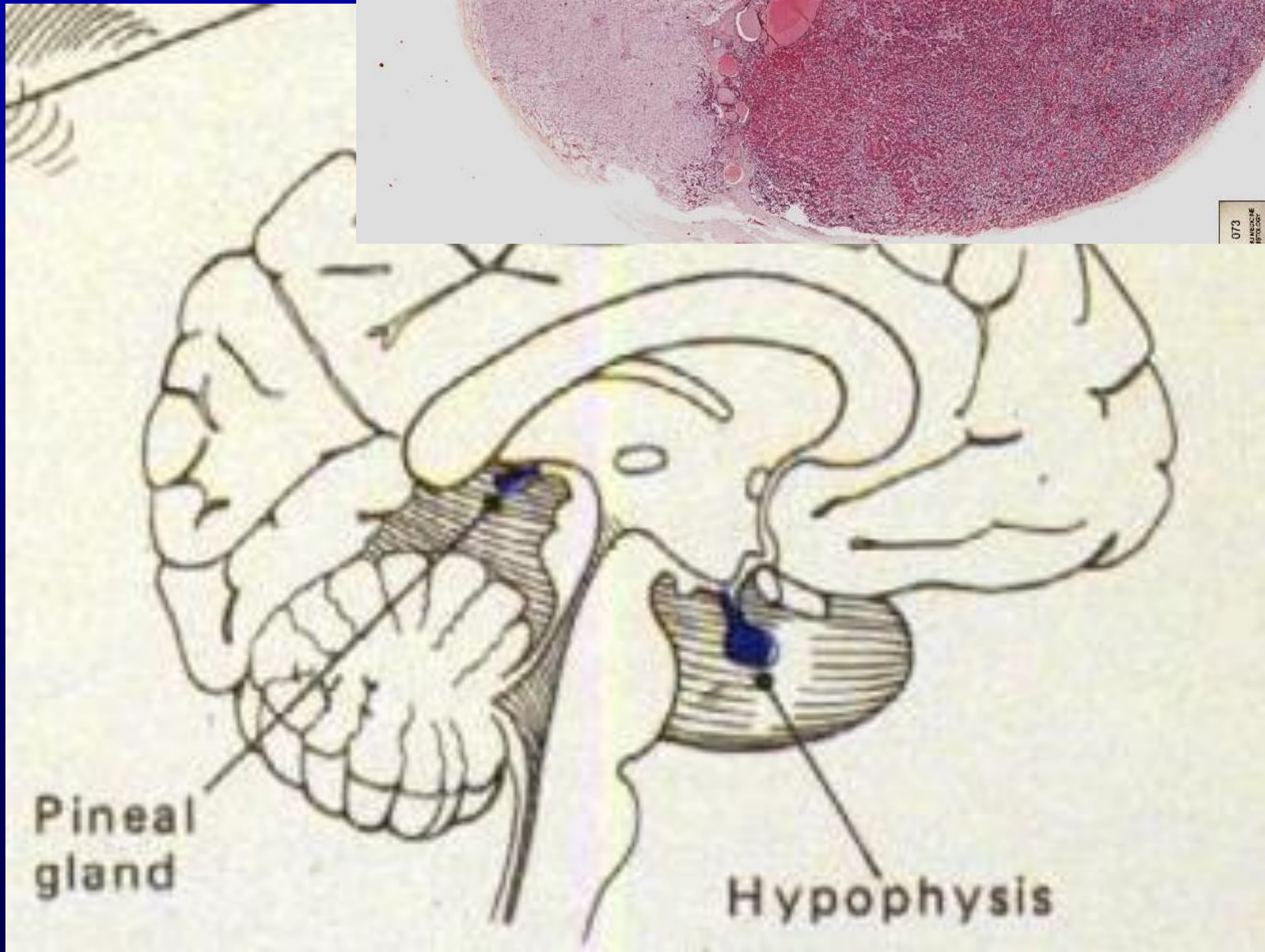
TABLE 31-2. ACTIONS OF CYCLIC AMP

TISSUE	ACTION
Liver	Increased glycogenolysis Increased phosphorylase Decreased glycogen synthetase Increased protein kinase Induction of tyrosine transaminase Induction of PEP carboxykinase Induction of serine dehydratase Increased amino acid uptake Increased ketogenesis
Adipose	Increased lipolysis Increased amino acid uptake Increased clearing-factor lipase
Anterior hypophysis	Increased release of ACTH, TSH, GH, and LH
Epithelial	Increased permeability to water
Pancreas	Increased release of insulin
Thyroid	Increased release of thyroid hormone
Cardiac muscle	Increased contractility
Smooth muscle	Increased tension Hyperpolarizes membrane potential
Adrenal	Increased steroidogenesis
Bone	Increased calcium resorption
Kidney	Increased phosphaturia Increased renin
Nerve	Increased acetylcholine release
Gastric mucosa	Increased HCl secretion
Leukocytes	Increased histamine release
Platelets	Decreased aggregation
Uterus	Increased amino acid uptake
Parotid	Increased amylase release

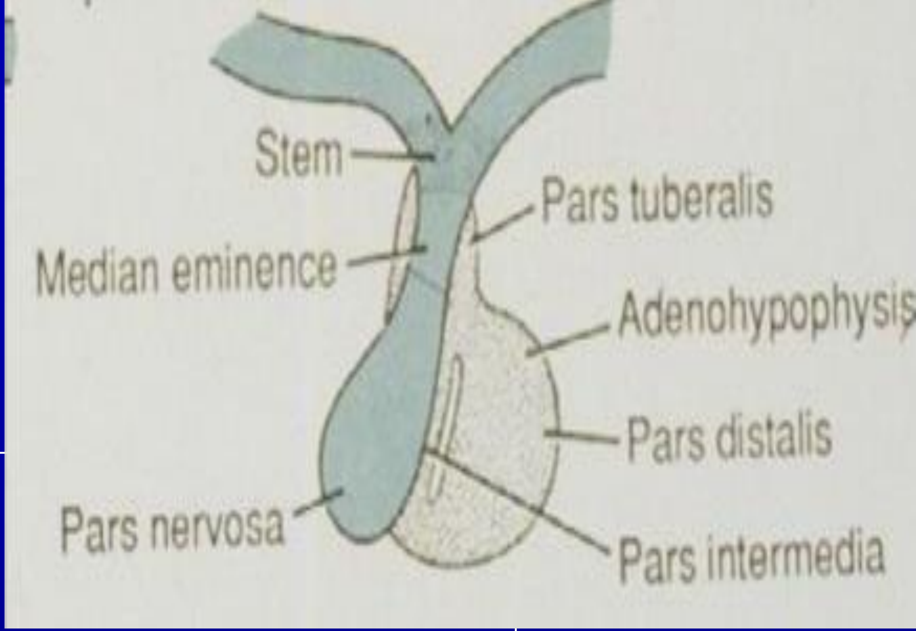
Pituitary Gland (Hypophysis)

- Produces 9 hormones
- Reciprocal relations to other endocrine organs
- Neural and vascular connection to brain
- Location is key position for interplay between nervous and endocrine systems and establishment of neuroendocrine system





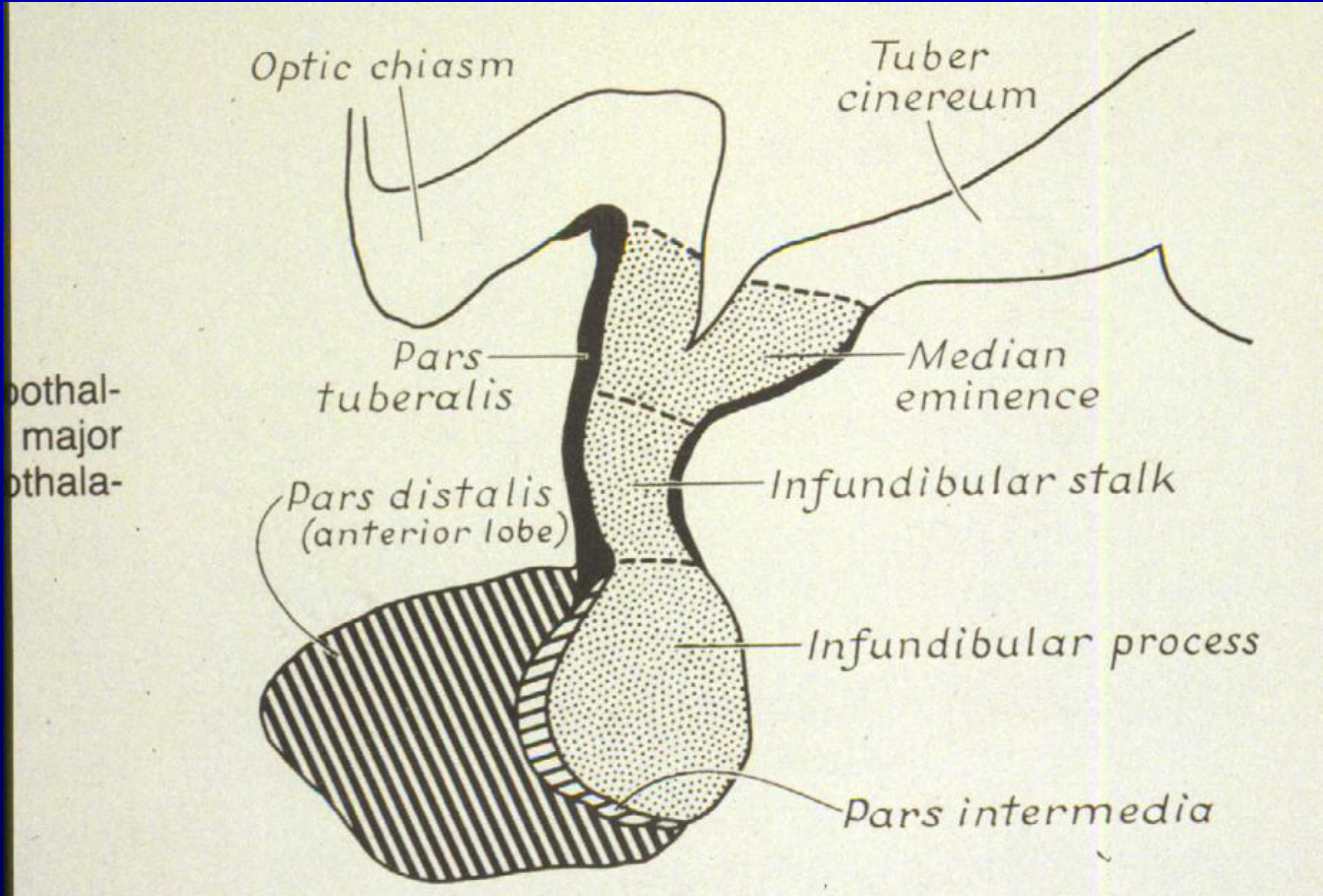
Pituitary Gland

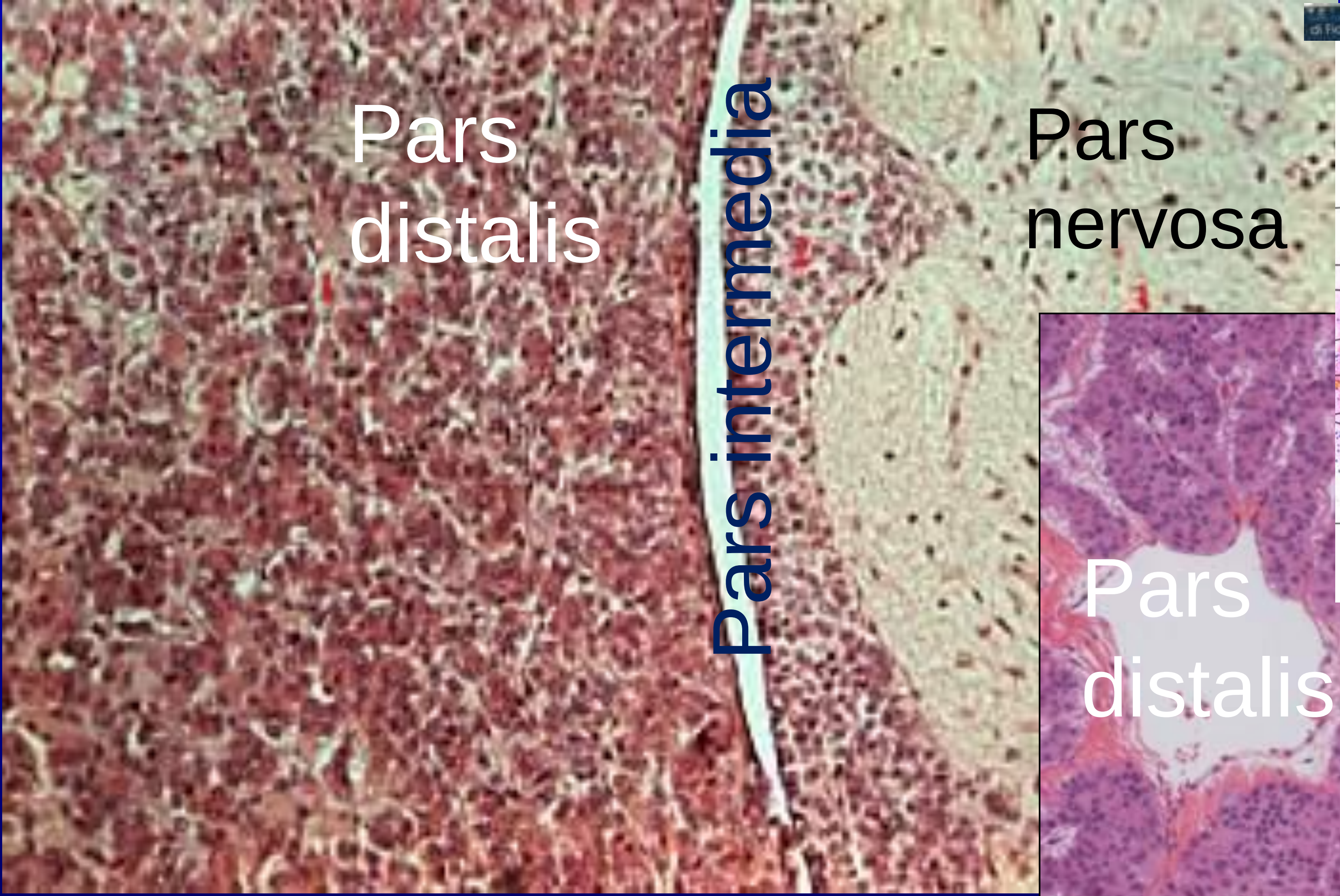


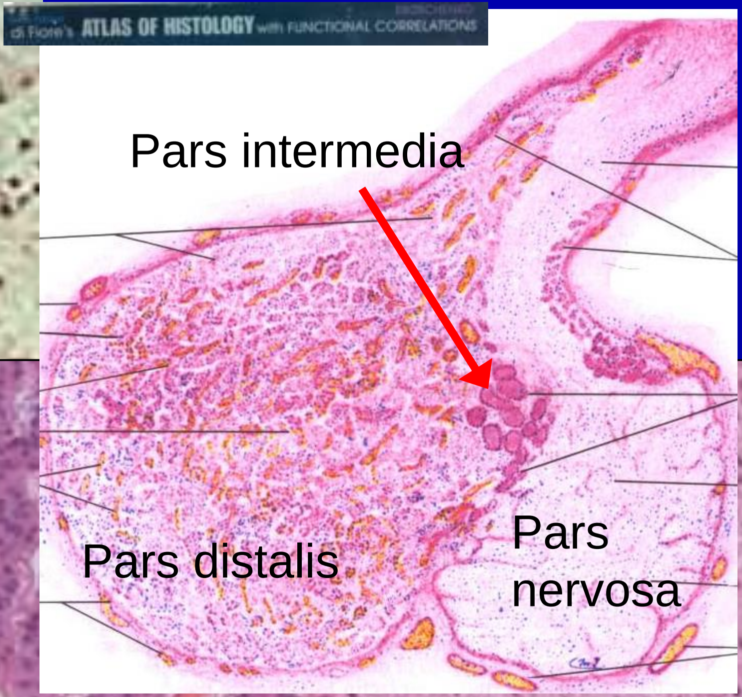
- **Adenohypophysis**
  - **Pars Distalis**
  - **Pars Tuberalis**
  - **Pars Intermedia**
- **Neurohypophysis**
  - **Pars Nervosa (Processus Infundibuli)**
  - **Infundibulum**
    - **Infundibular Stem/Stalk**
    - **Median Eminence (of the tuber cinereum)**

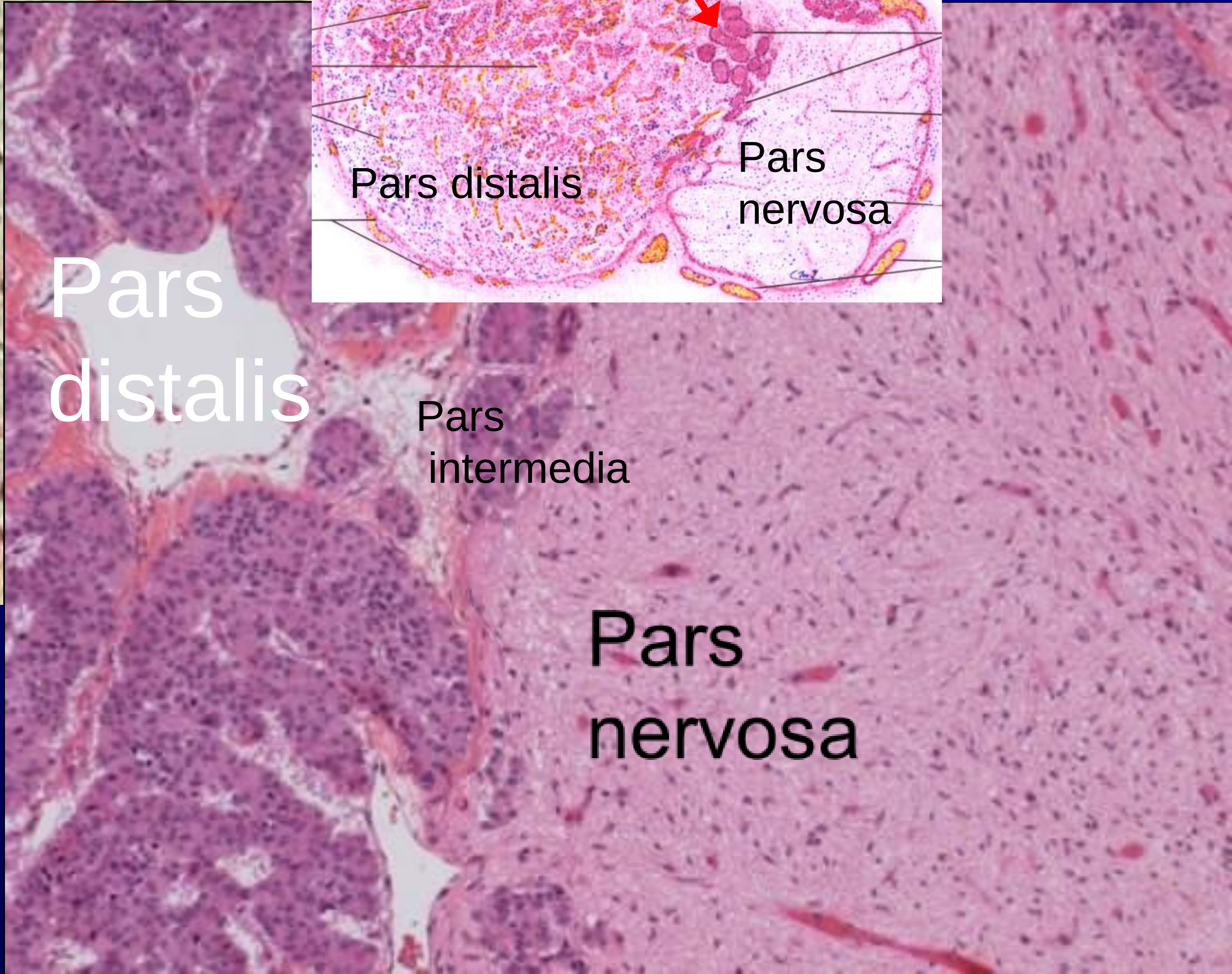
Pituitary Gland

Adenohypophysis **Neurohypophysis**





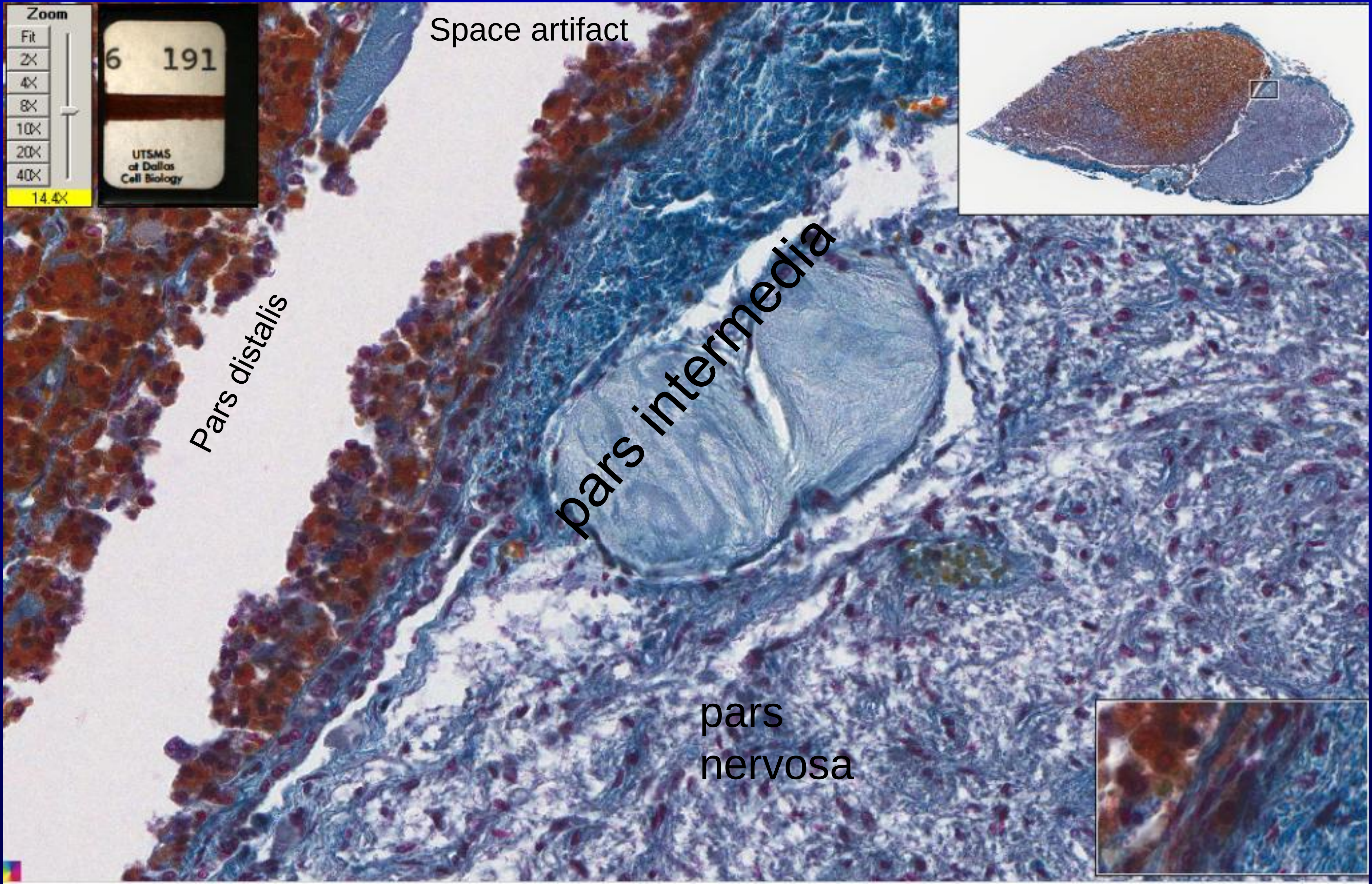




3 divisions of the pituitary gland:

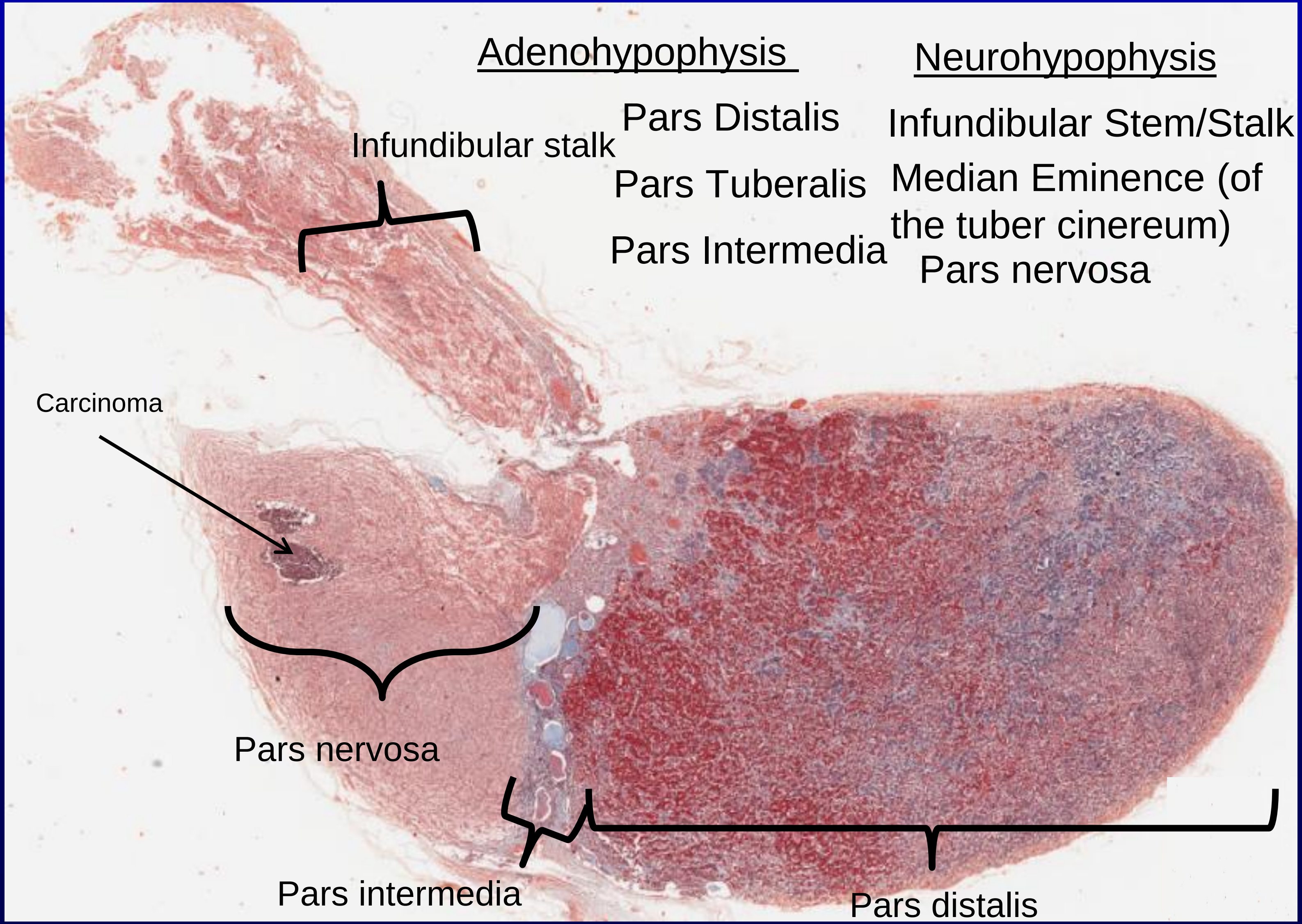
1. Pars distalis
2. Pars intermedia
3. Pars nervosa

Pituitary (Herlant's stain) pars intermedia



191

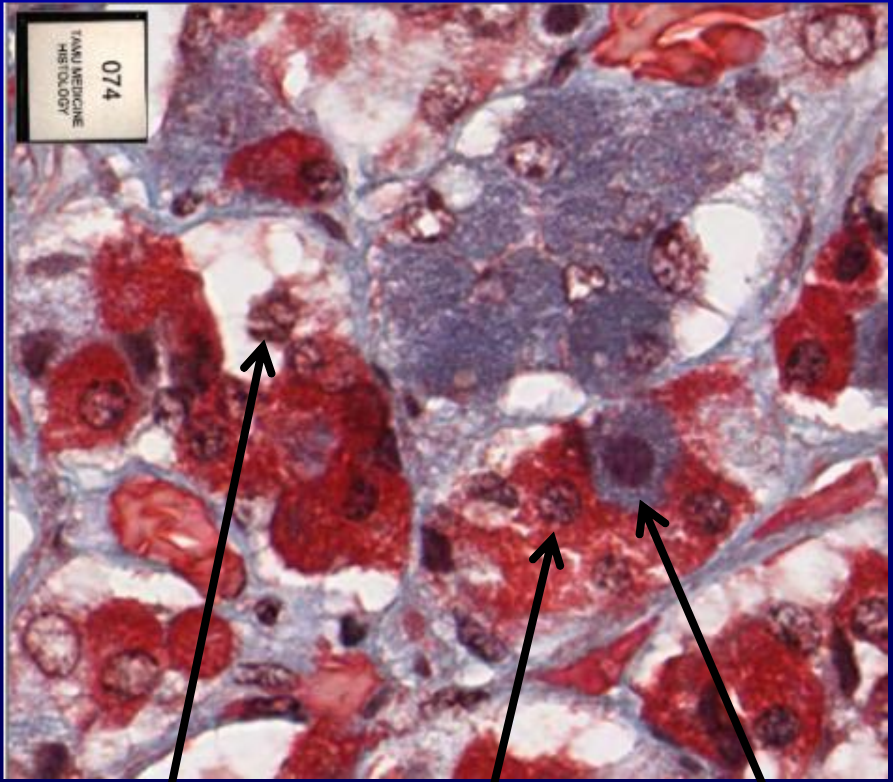
Histo074 Slide 74: Pituitary (Masson's trichrome)



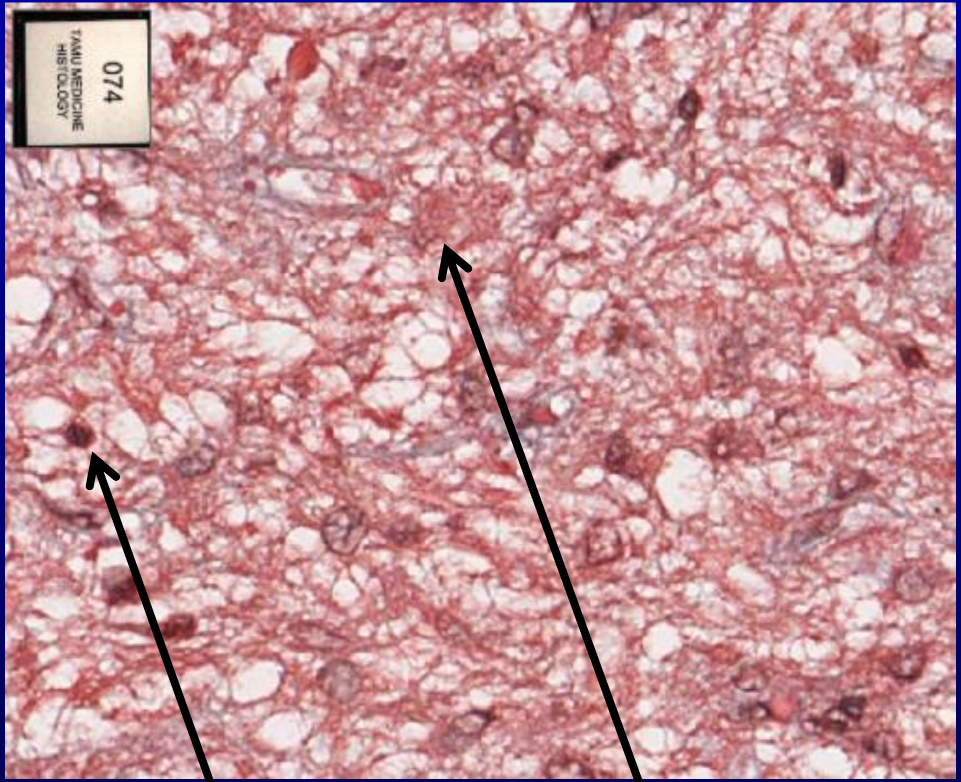
Slide 74: Pituitary (early carcinoma in posterior lobe)

Histo074

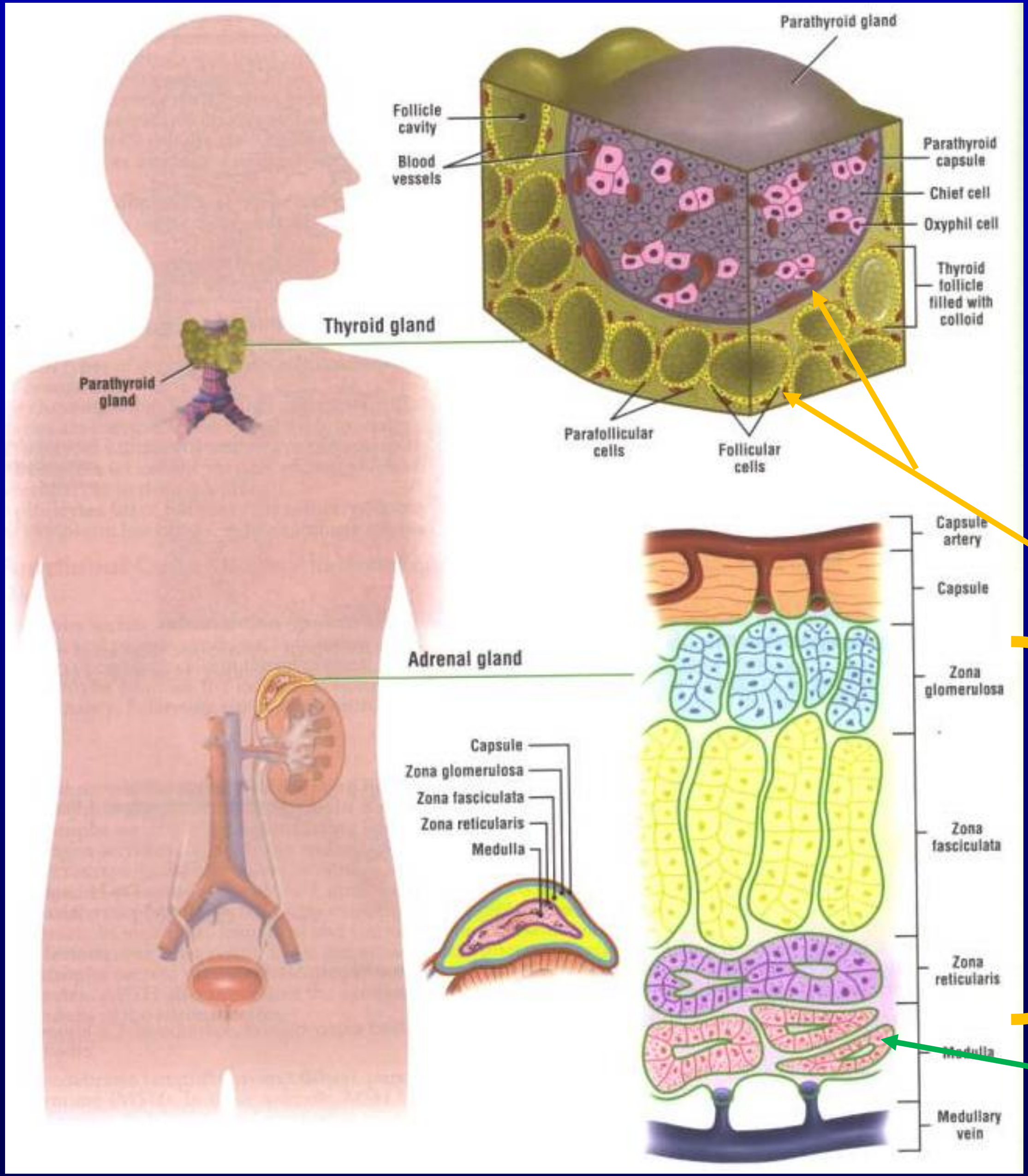
Pars distalis



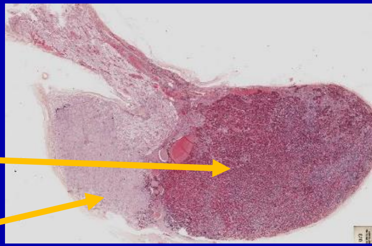
Pars nervosa



ORIGIN



ECTODERM



Adenohypophysis of oral ectoderm

Neurohypophysis of neural ectoderm

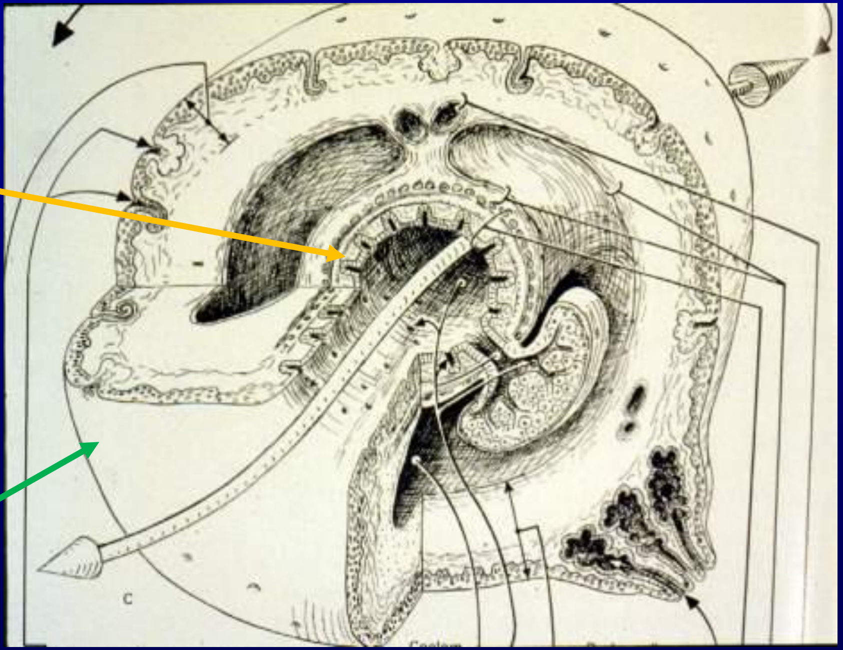
Adrenal medulla of neural ectoderm

ENDODERM –

Most ENDOCRINE GLANDS (including adrenal cortex)-

All endocrine LOSE CONNECTION WITH SURFACE and secrete into CT/blood

ENDODERM



ECTODERM

Adenohypophysis

Origin

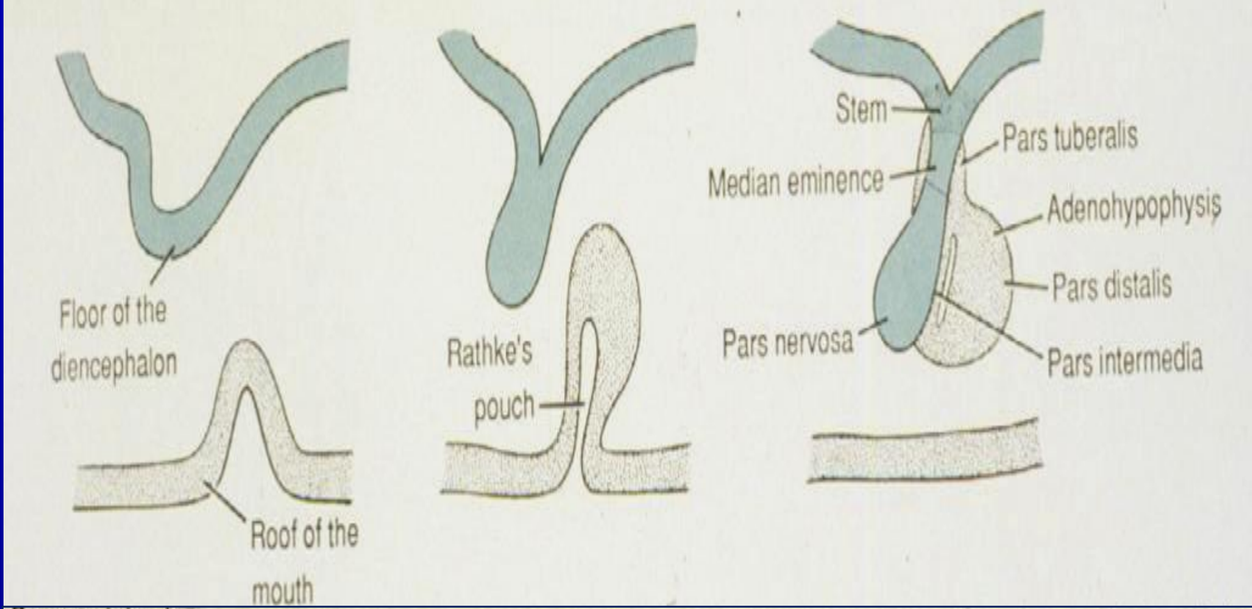
Divisions

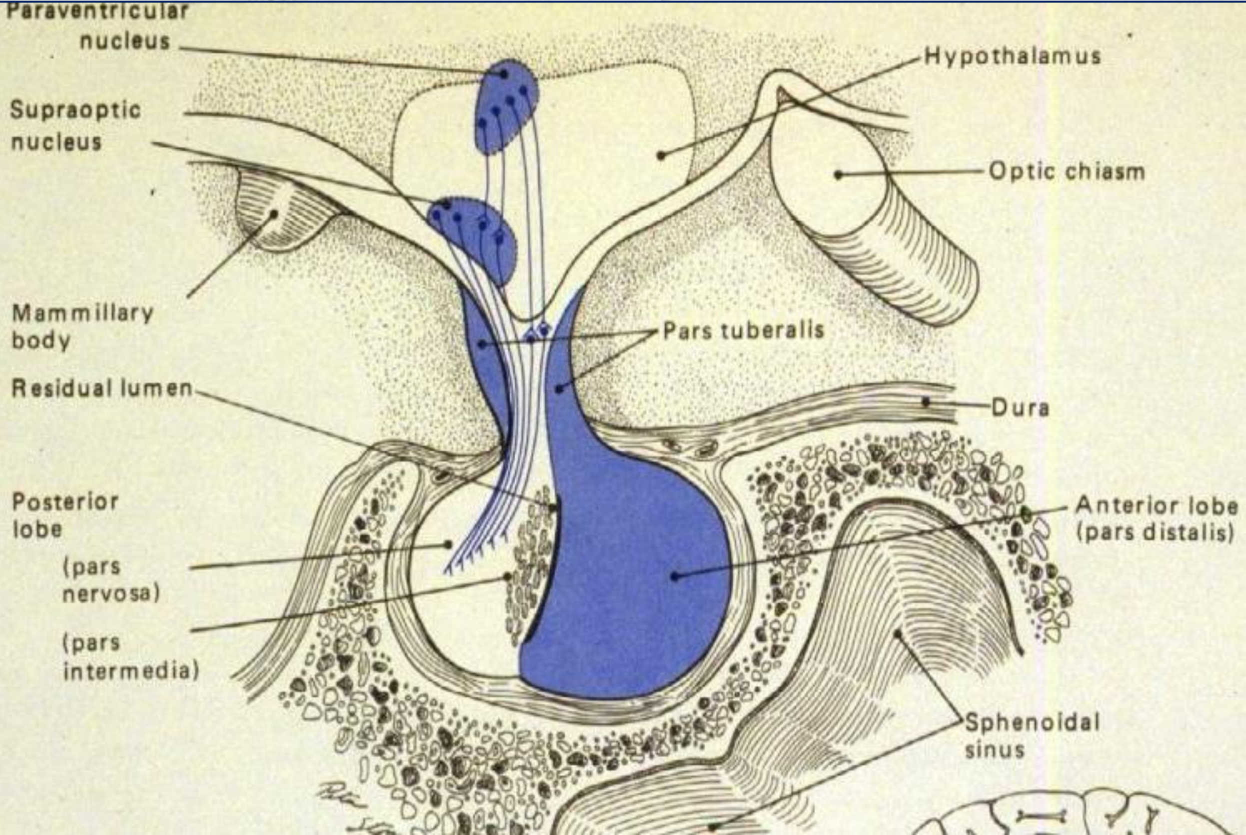
I. Pars distalis
Ii. Pars tuberalis
Iii. Pars intermedia

Relation to hypothalamus

Microscopic organization

I. Chromophobe cells
Ii. Chromophil cells
    1. Acidophils
    2. Basophils





Origin

Development of the **Adenohypophysis**

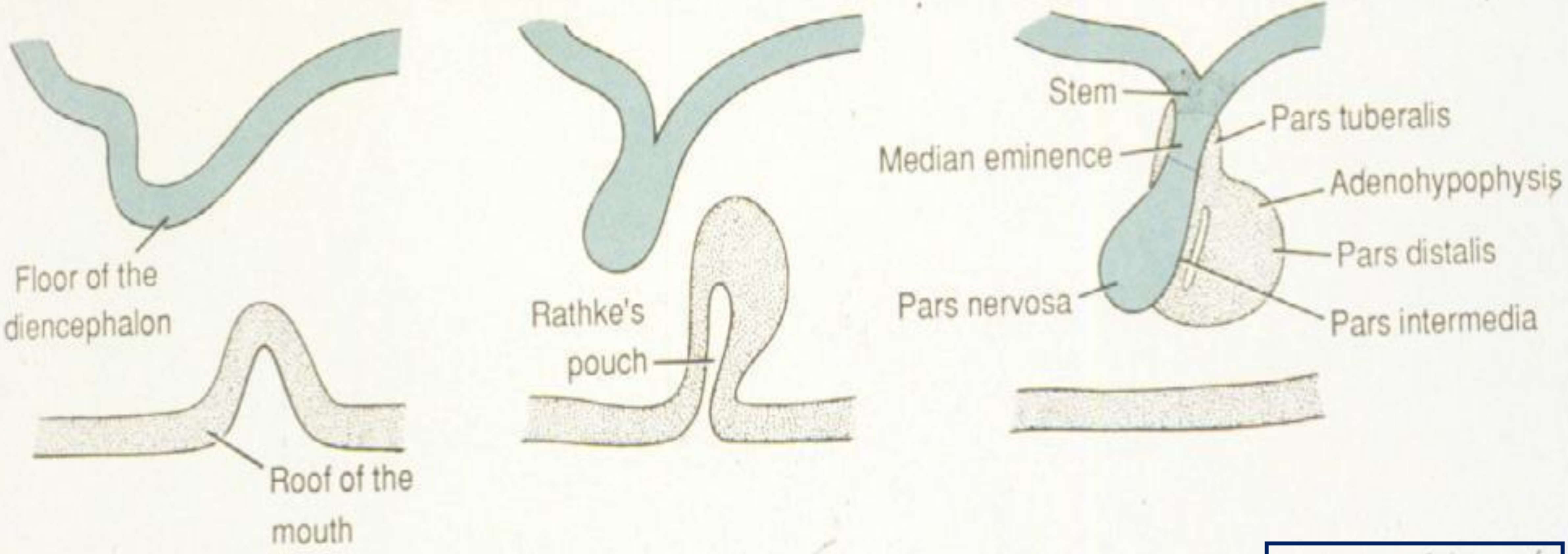
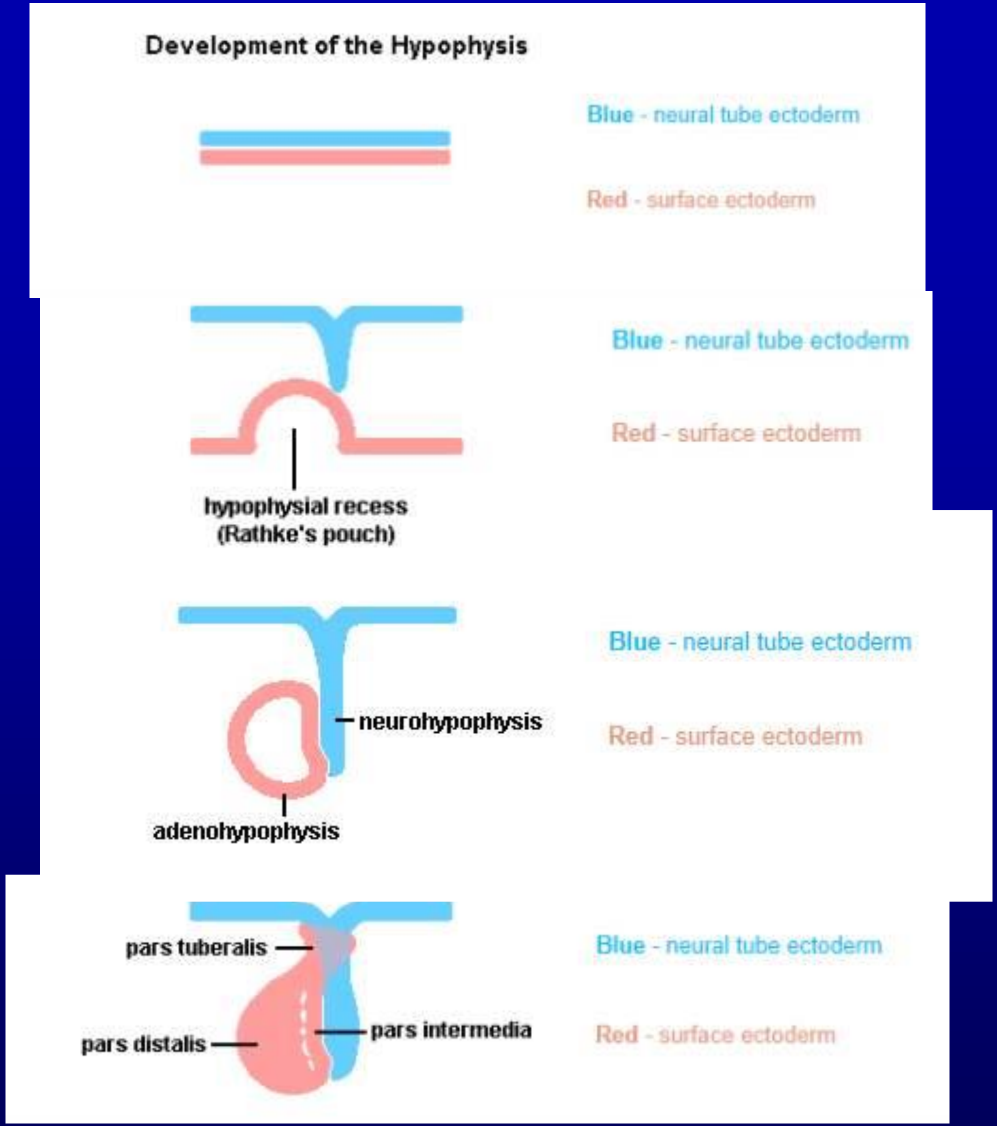
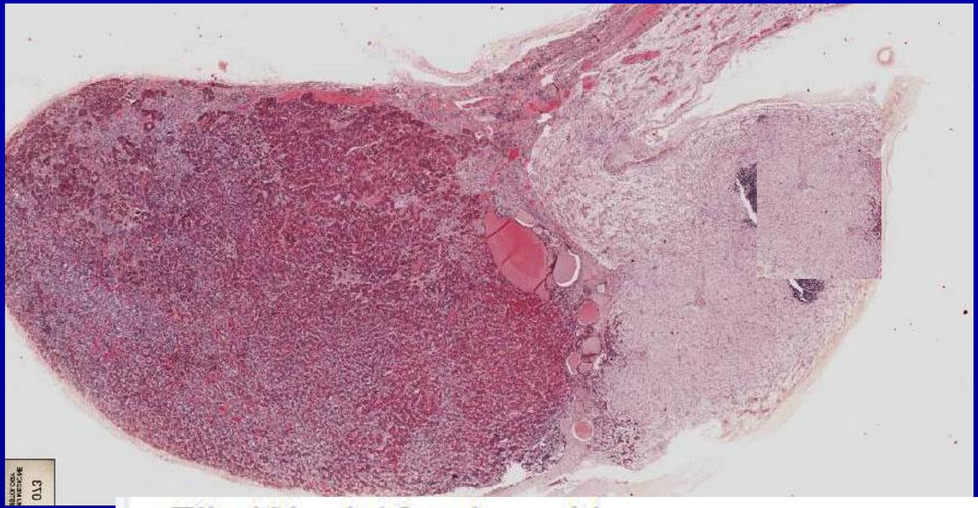
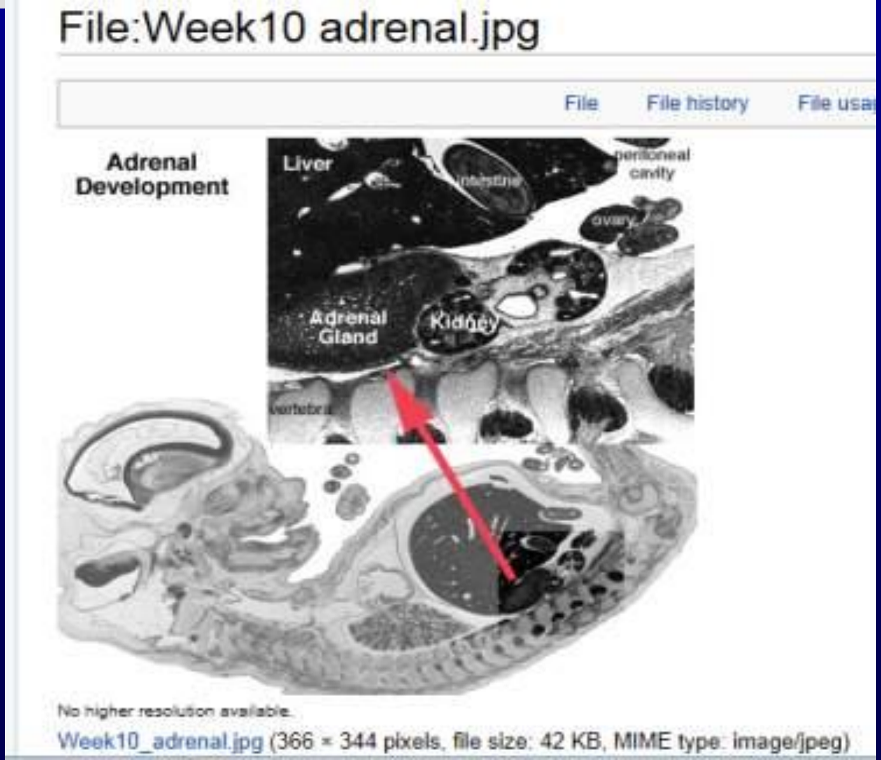


Figure 20–2. Diagram of the development of the adenohypophysis and neurohypophysis. The ectoderm of the roof of the mouth and its derivatives are shown stippled (lower portion). The upper portion shows the neural ectoderm from the floor of the diencephalon (shown in color).

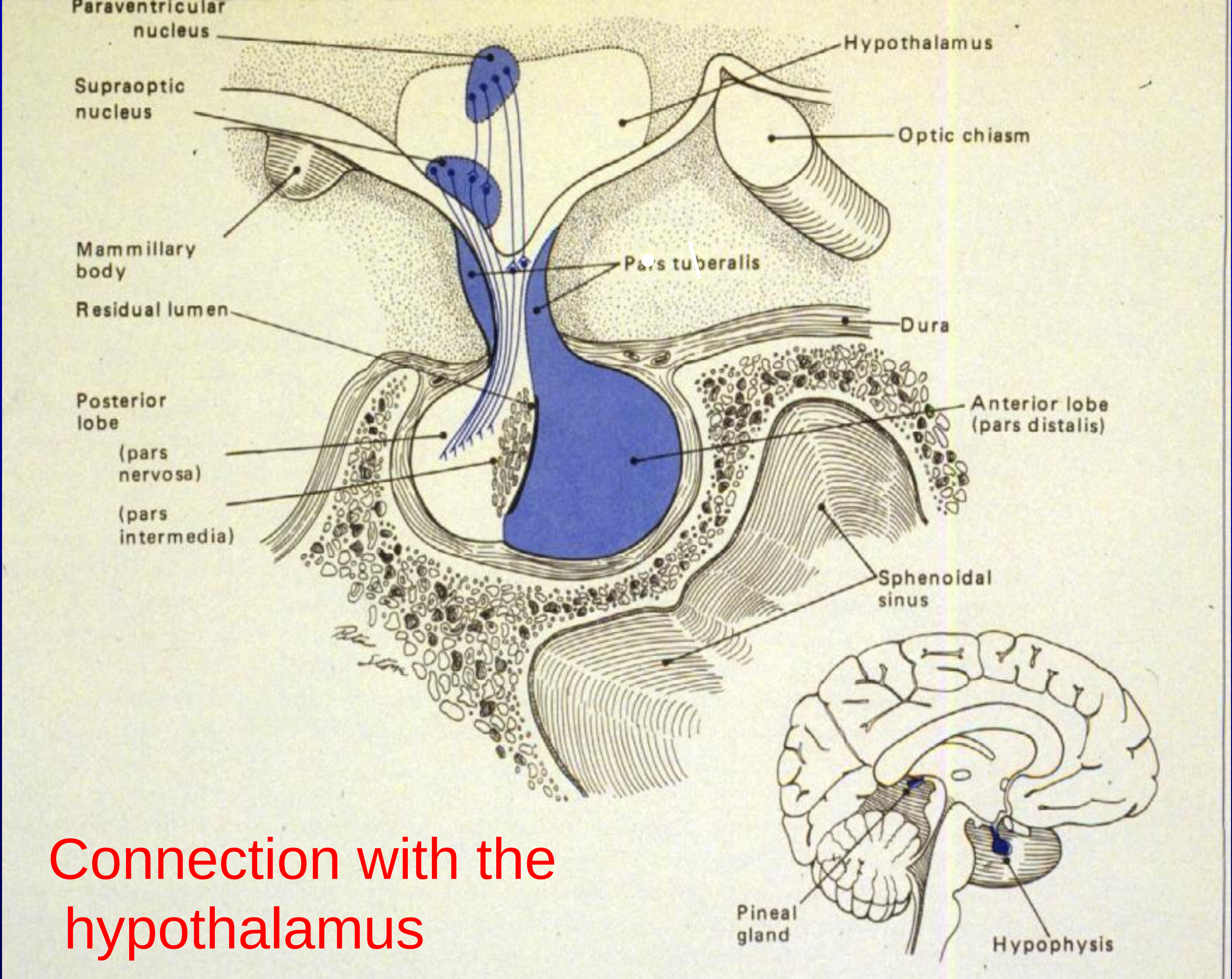
Pituitary development





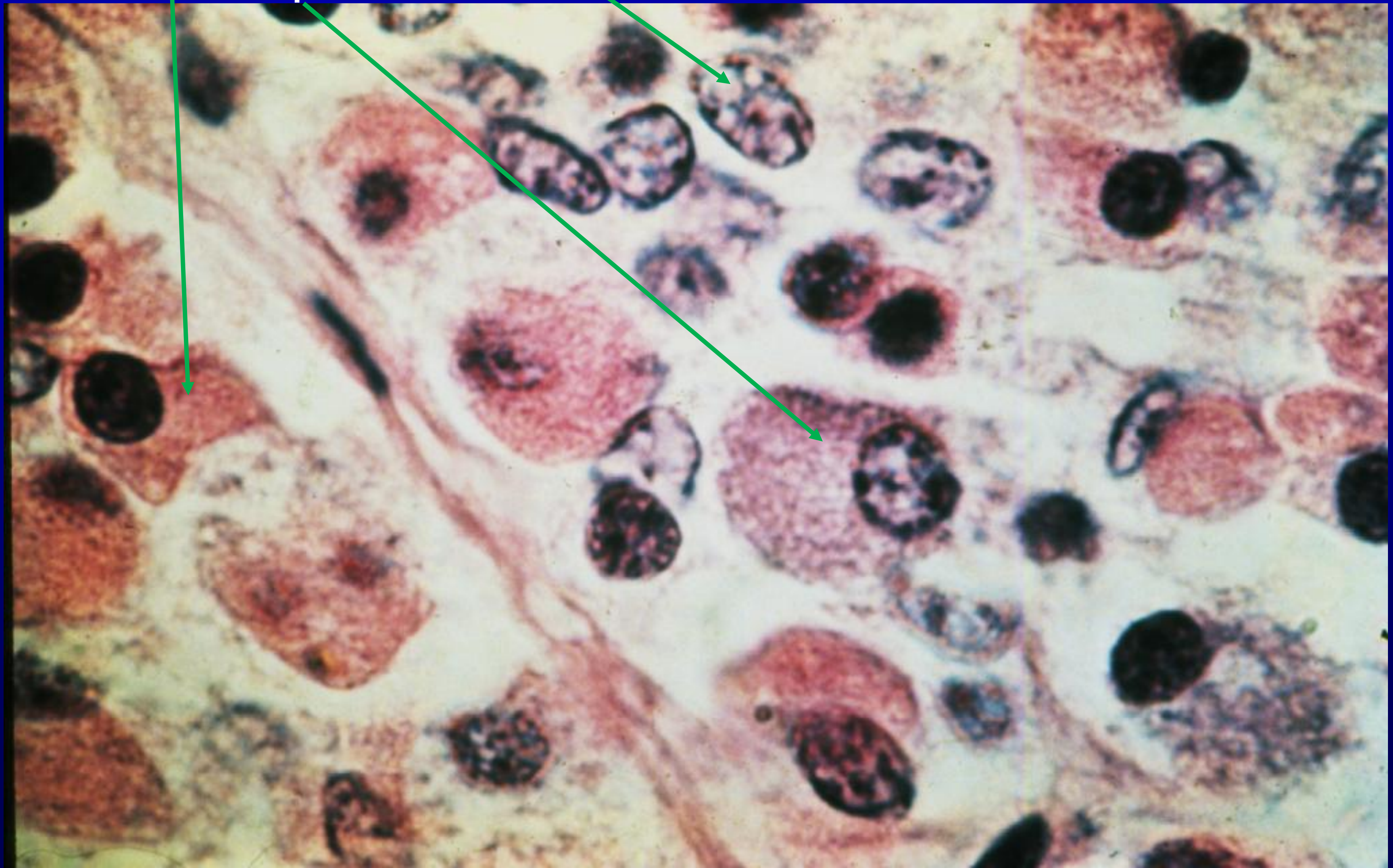


http://php.med.unsw.edu.au/embryology/index.php?title=Endocrine_System_Development



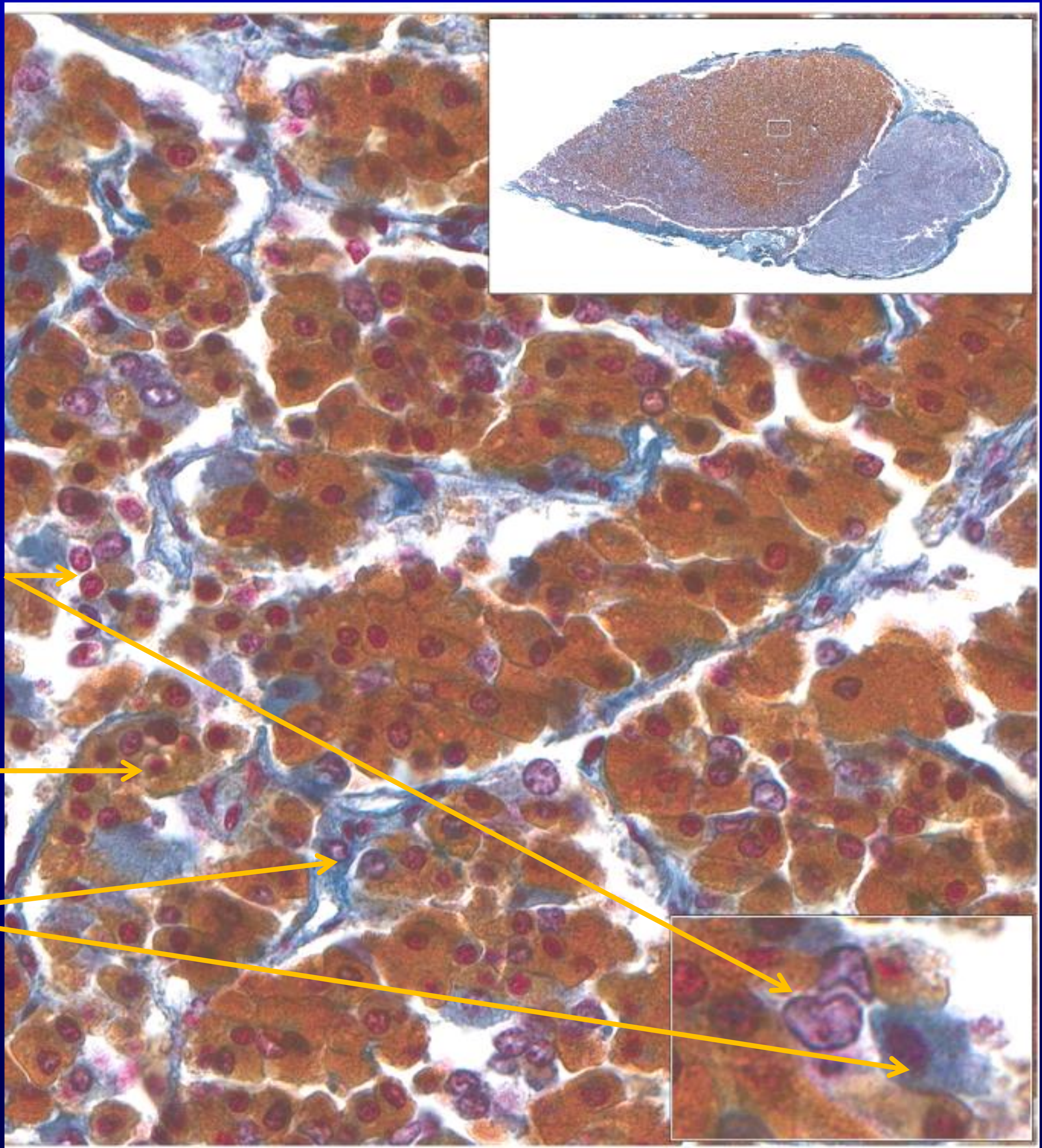
Connection with the hypothalamus

Pars Distalis



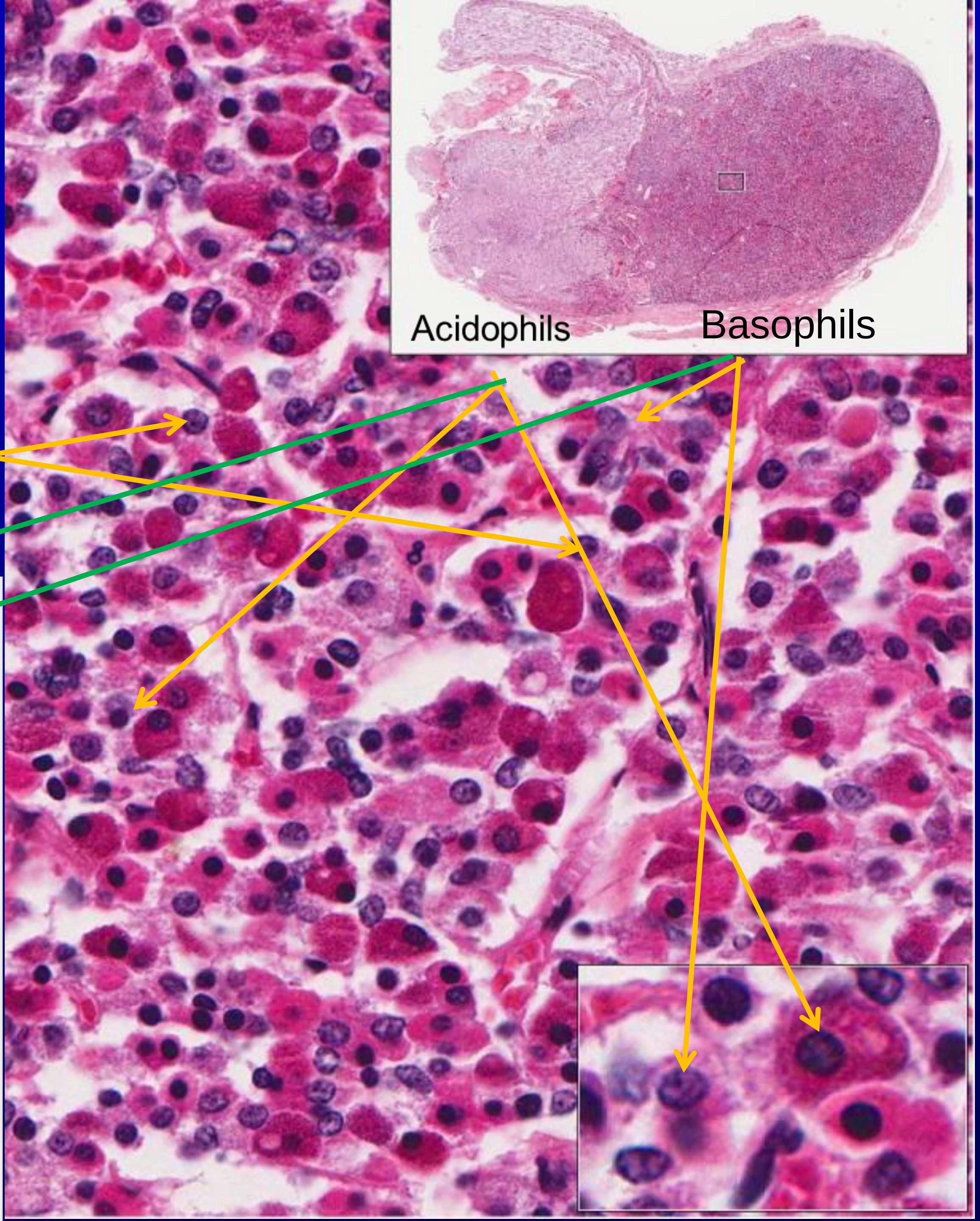
191

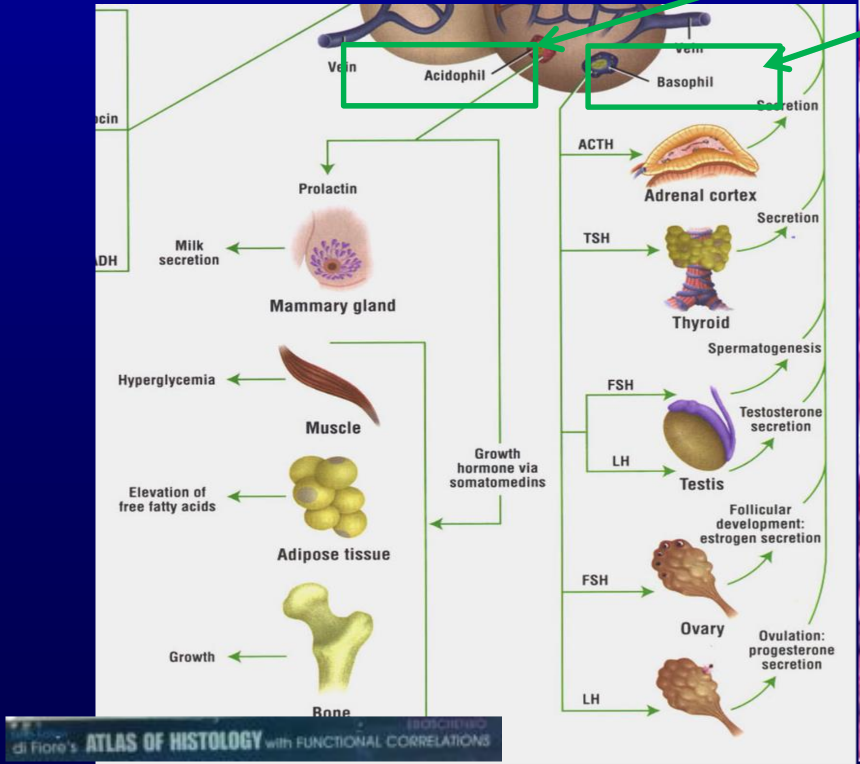
Pars distalis of Pituitary (Herlant's stain) with chromophobe cells , acidophils, and basophils



Pars distalis of Hypophysis

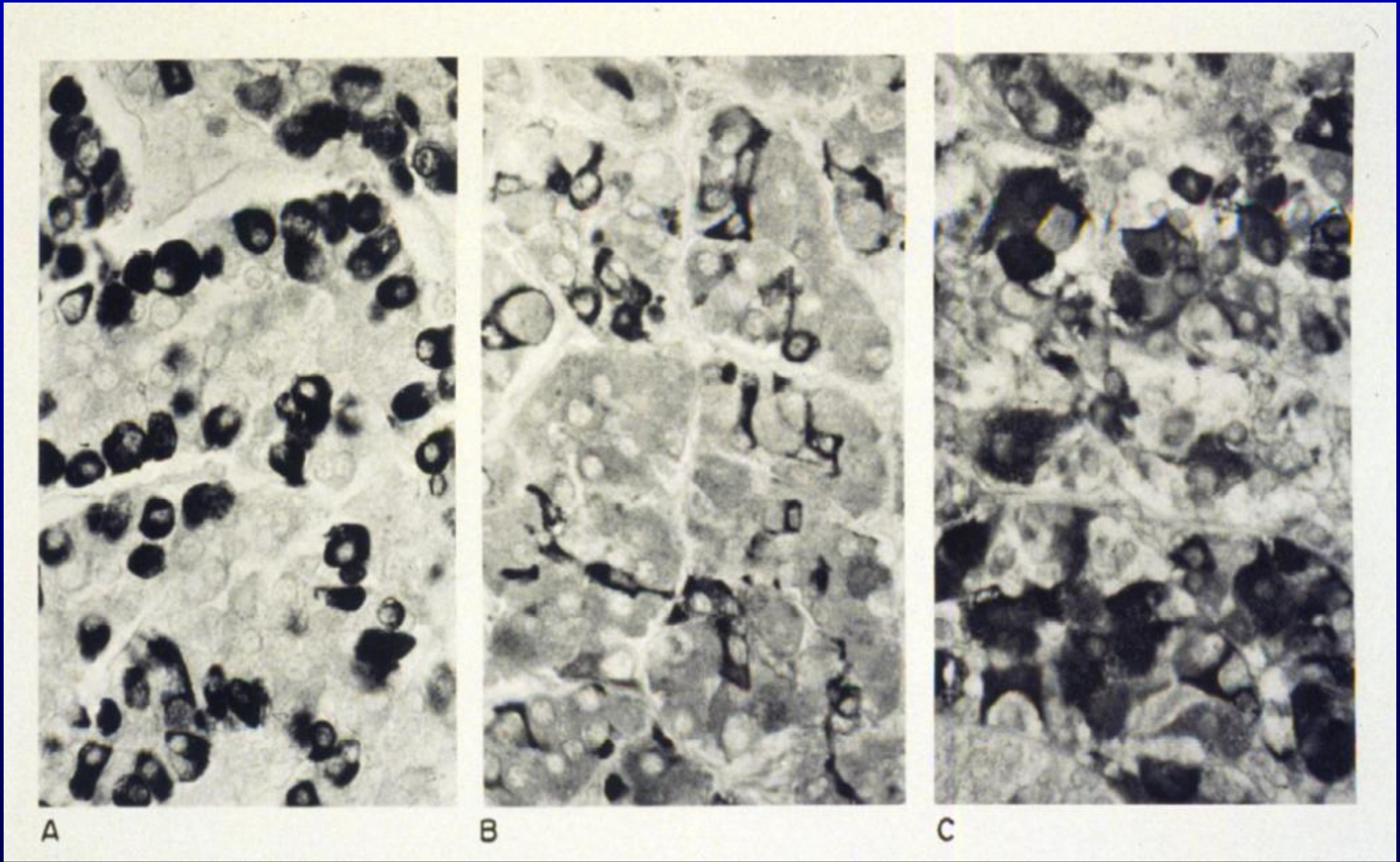
Chromophobes



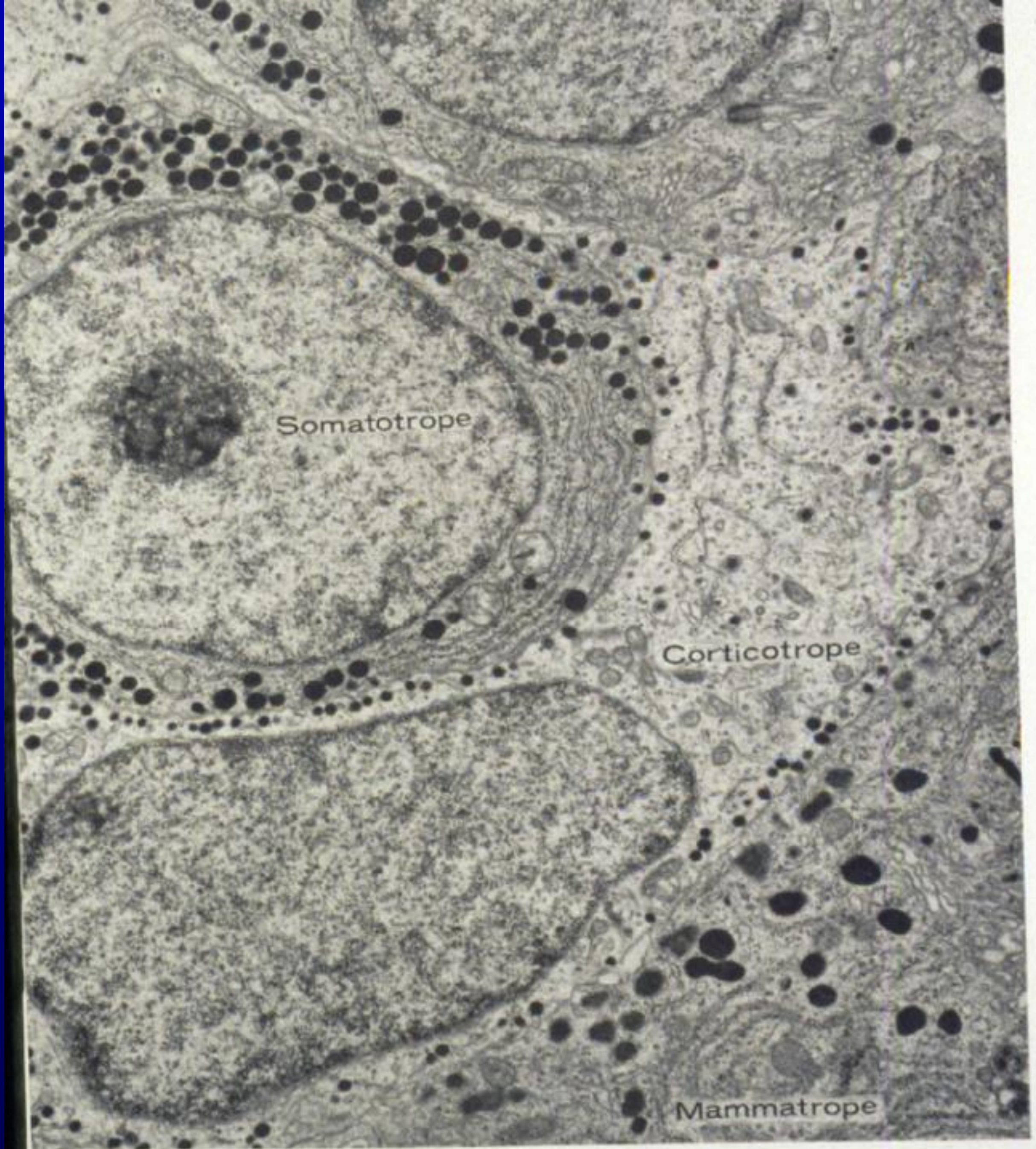


Pars Distalis

Staining for different types of cells



Pars Distalis



re 17–5. Electron micrograph of an area of the pars distalis of rat hypophysis illustrating the fine structure an ve size of the specific granules of a somatotrope, mammatrope, and corticotrope. (Micrograph from Nakayama, Nickerson, and F. R. Shelton. Lab. Invest. *21*:169, 1969.)

Pars Distalis

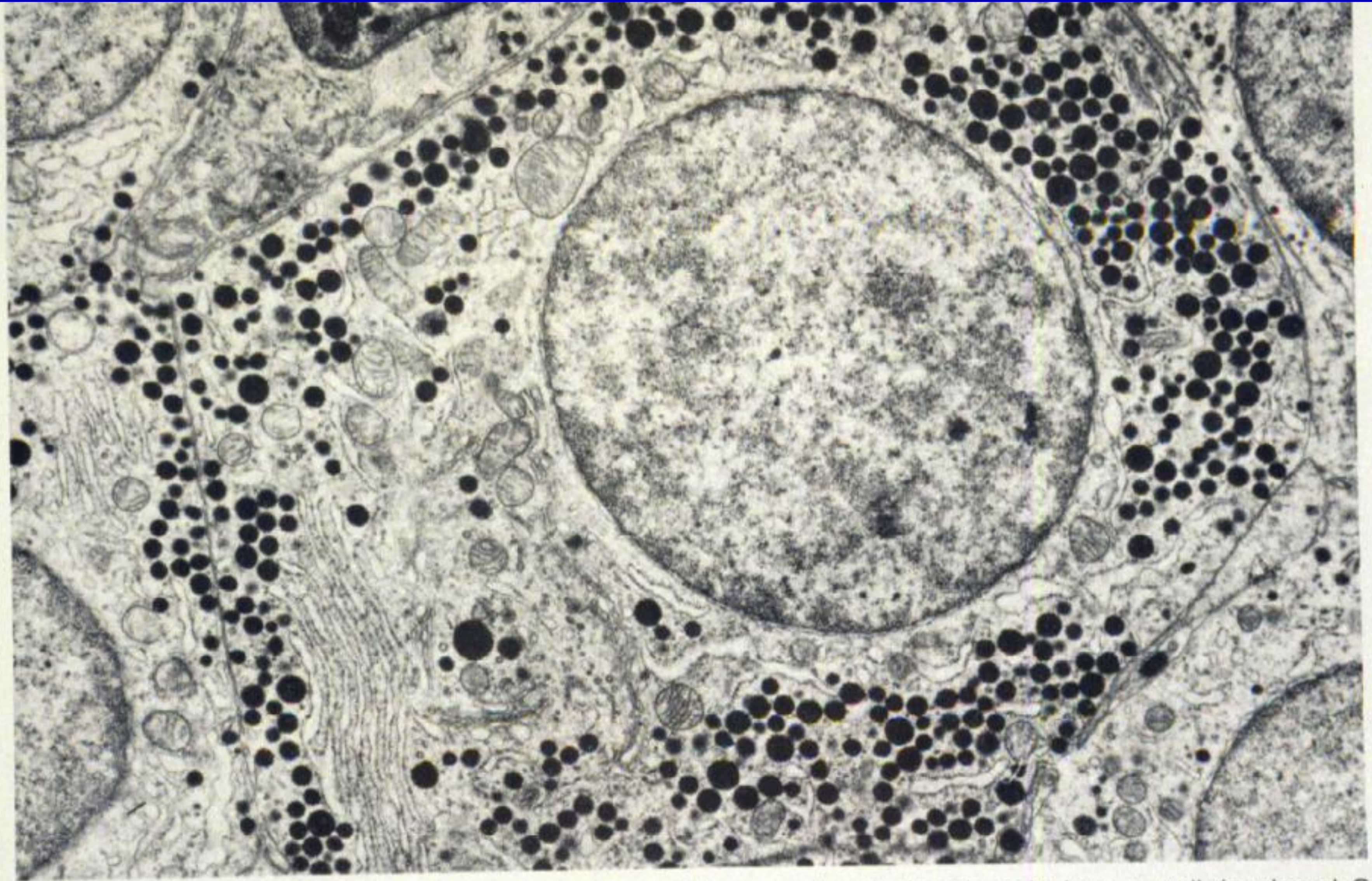


Figure 17–6. A typical somatotrope, showing numerous cisternae of endoplasmic reticulum, a well-developed Golgi complex, and many specific granules about 350 nm in diameter. (Micrograph courtesy of M. Farquhar.)

Pars Distalis

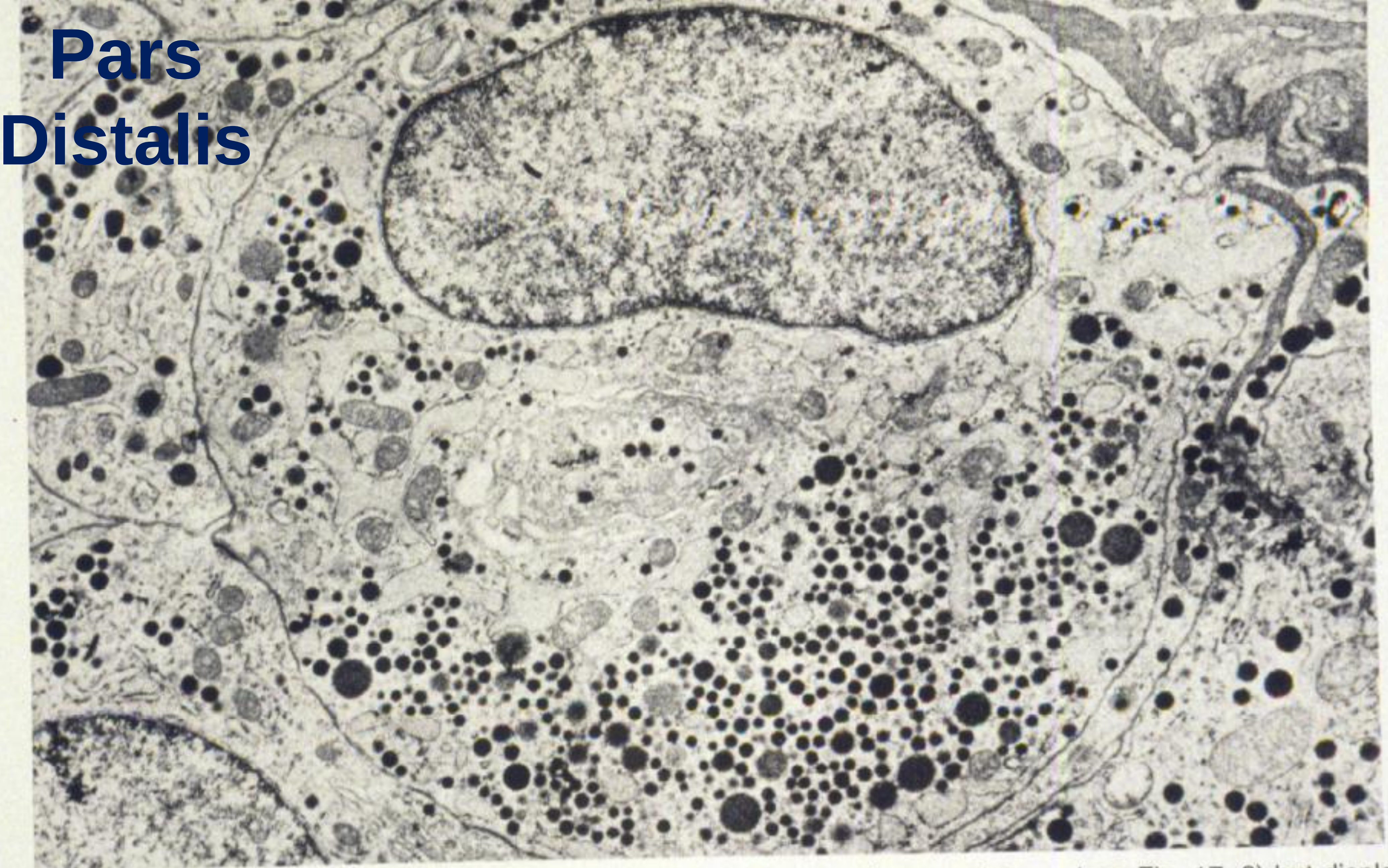


Figure 17–9. Gonadotrope with granules of relatively smaller size than the somatotrope (see Fig. 17–6) but displaying considerable variability. The endoplasmic reticulum is typically distended with an amorphous material of low density. (Micrograph courtesy of M. Farquhar.)

Pars Distalis

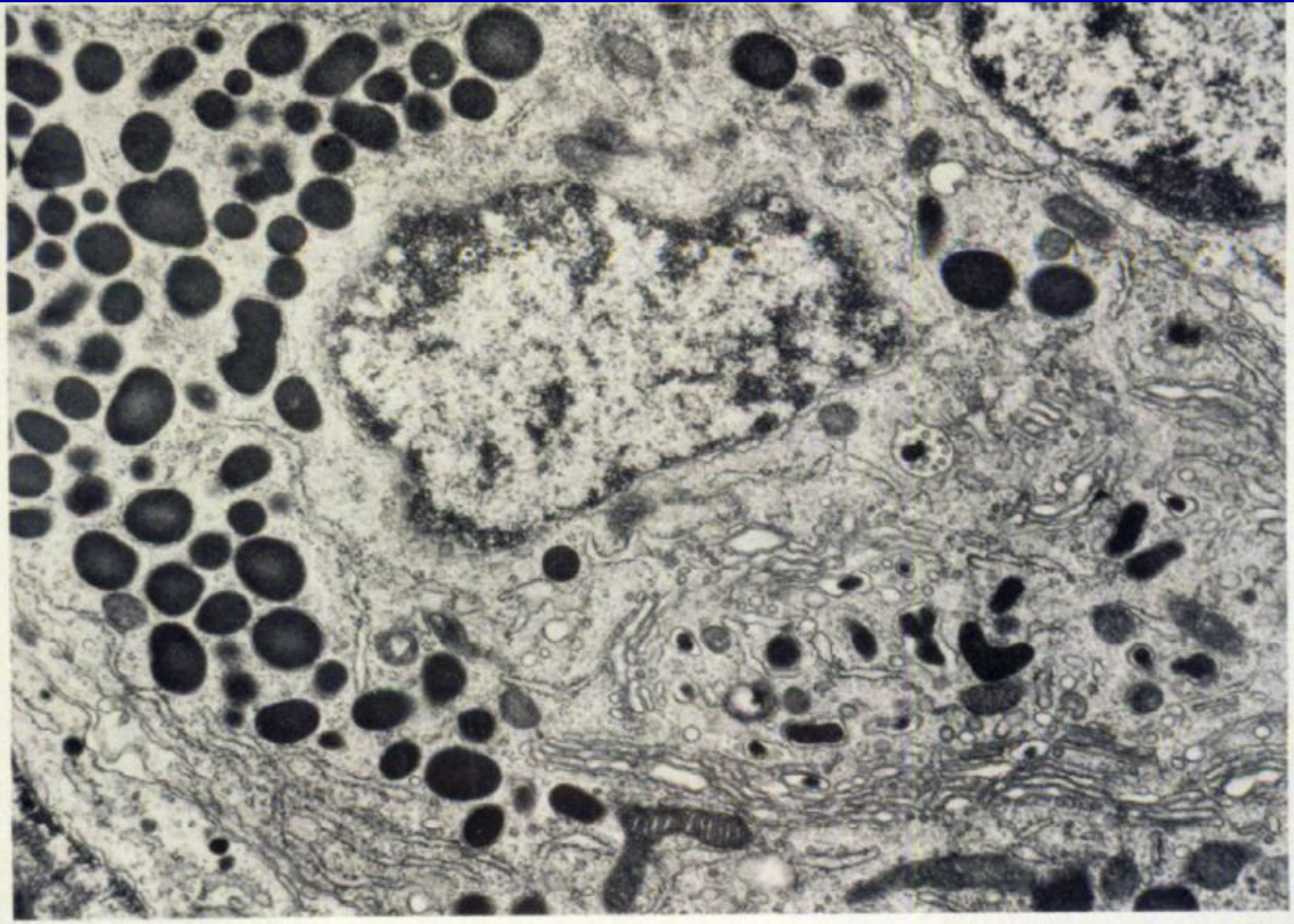
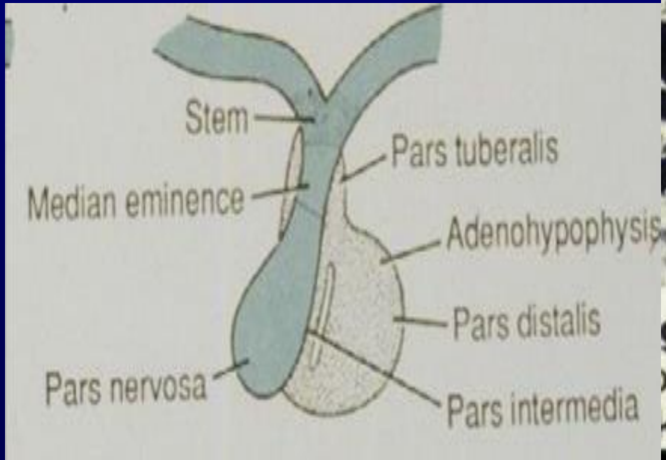


Figure 17–7. Electron micrograph of a rat mammatrope. Notice the relatively large size and irregular shape of the granules. A number of developing granules are associated with a large Golgi complex at lower right of figure. (Micrograph courtesy of M. Farquhar and T. Kanaseki.)

Pars Distalis



gure 17–12. Photomicrograph of anterior lobe of hy
ophysis of monkey injected intravenously with India
k to show the irregular, richly anastomotic sinusoids

Variations in the Microvasculature

Common:

Arteriole ⍰ **Capillary** ⍰ Venule

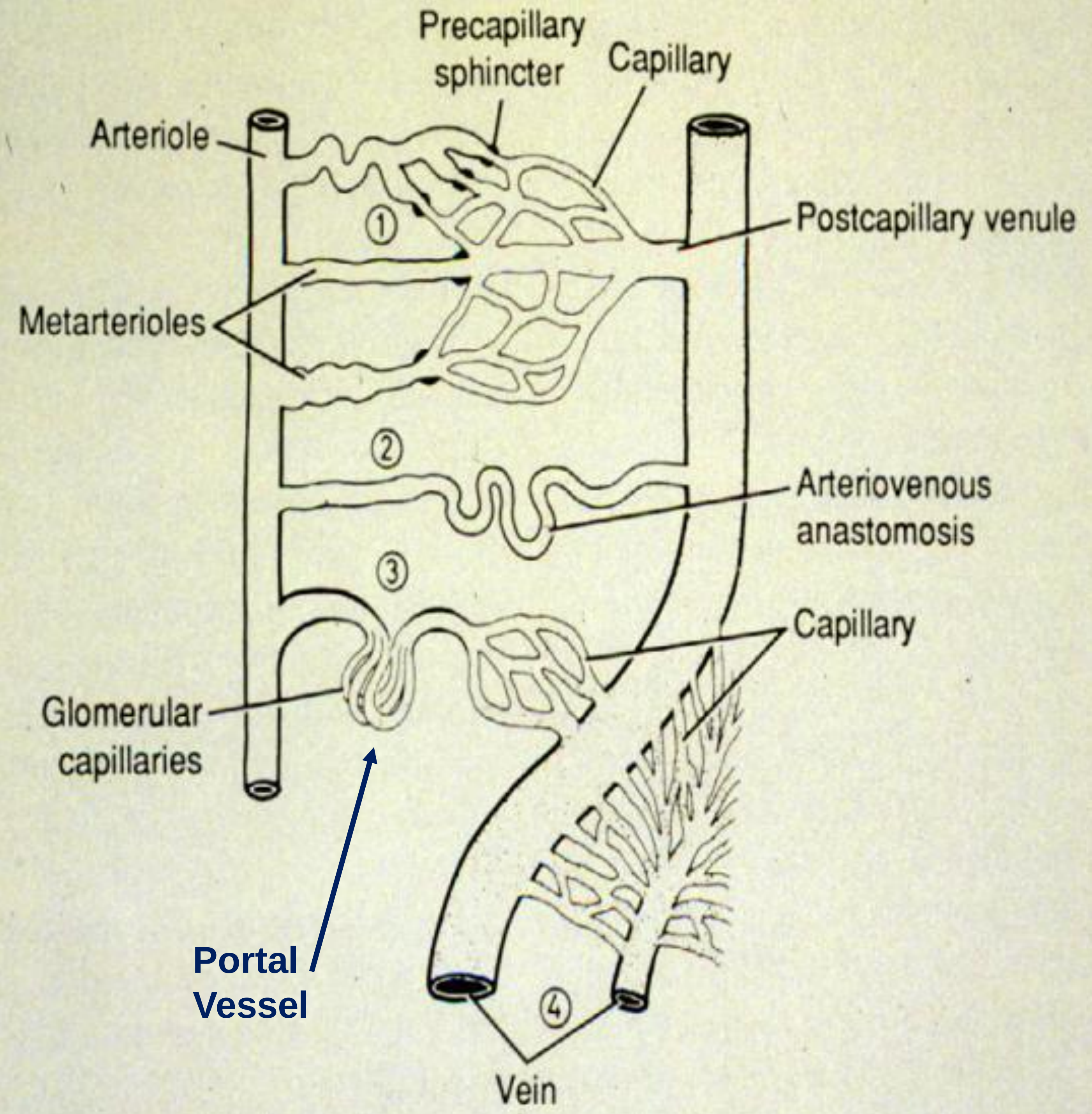
Venous portal system:

Capillary ⍰ **Portal vein** ⍰ Capillary

Arterial portal system:

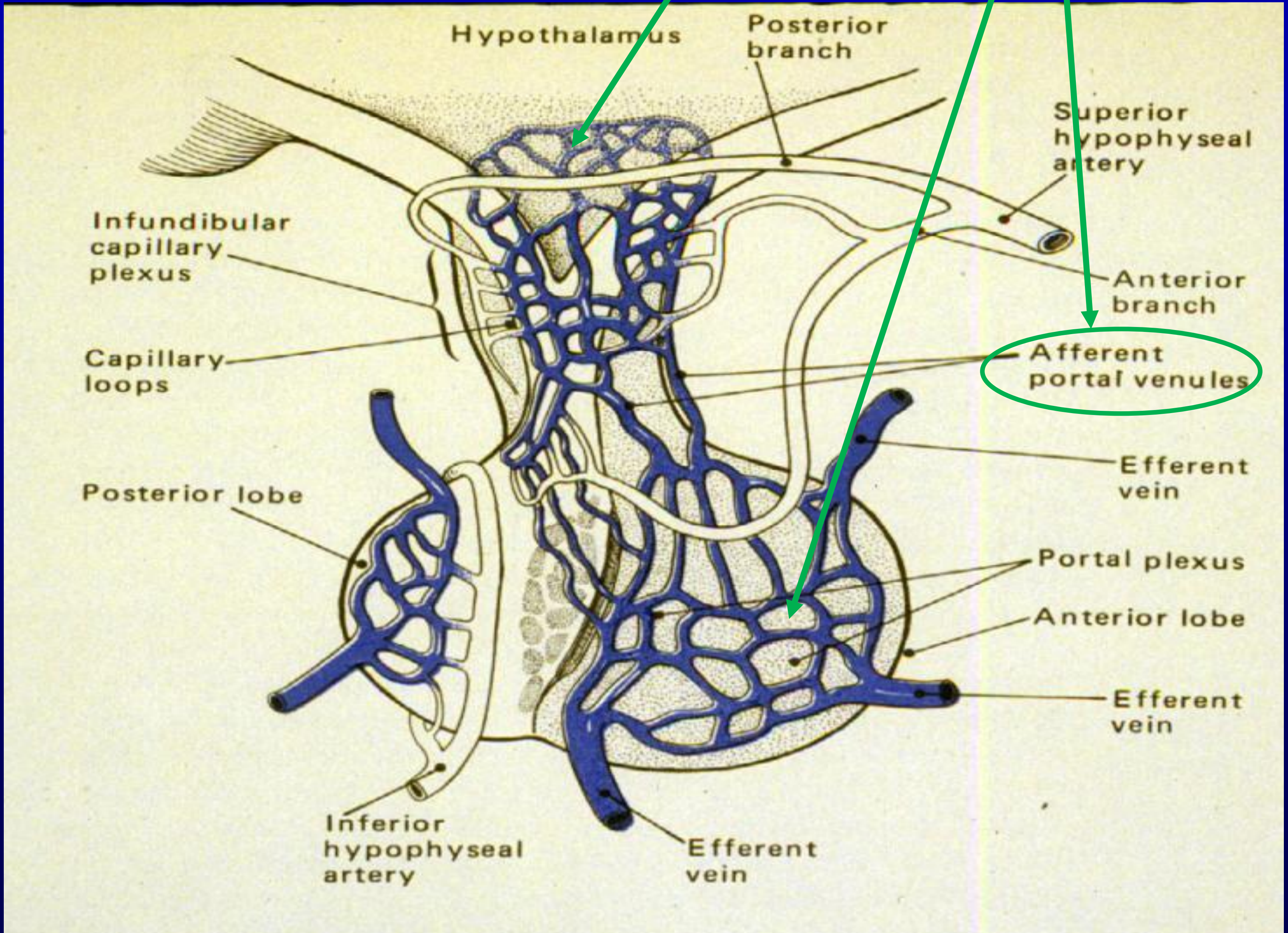
Capillary ⍰ **Portal arteriole** ⍰ Capillary

Portal system functions to **create a local change in blood composition.**



Blood supply

Venous portal system:
Capillary → portal vein → capillary



Releasing hormones are collected in first capillary bed of venous portal system.

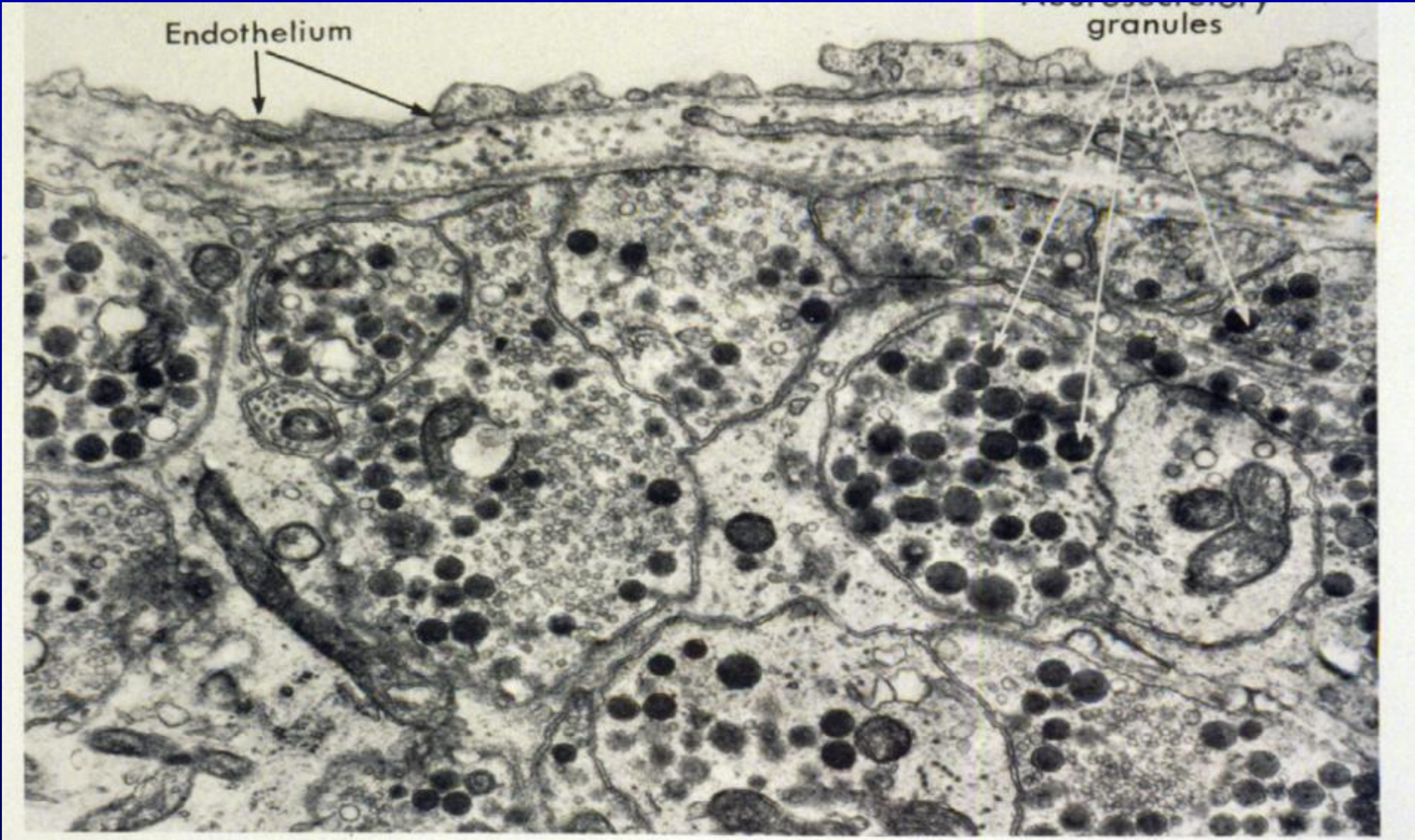
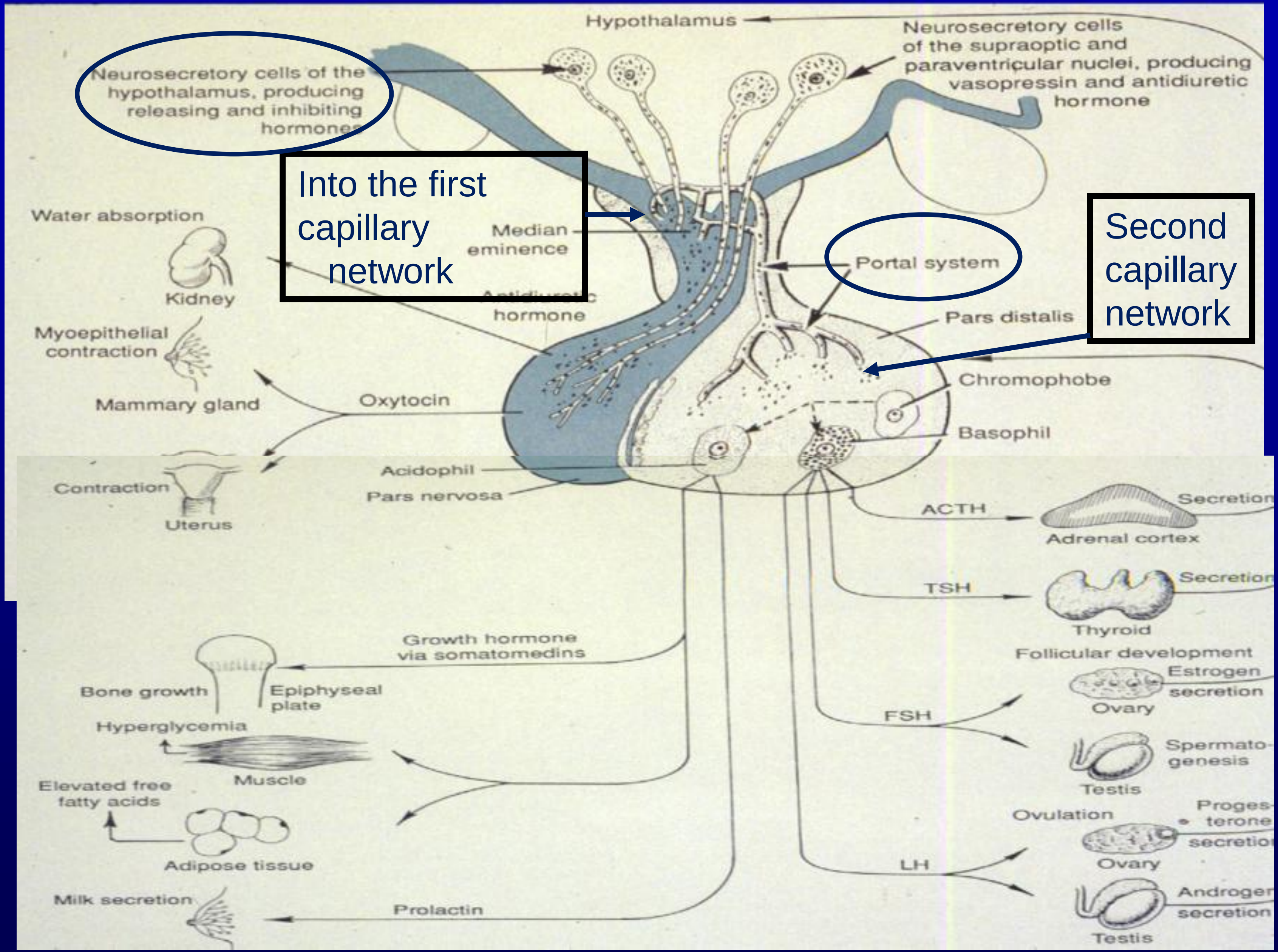
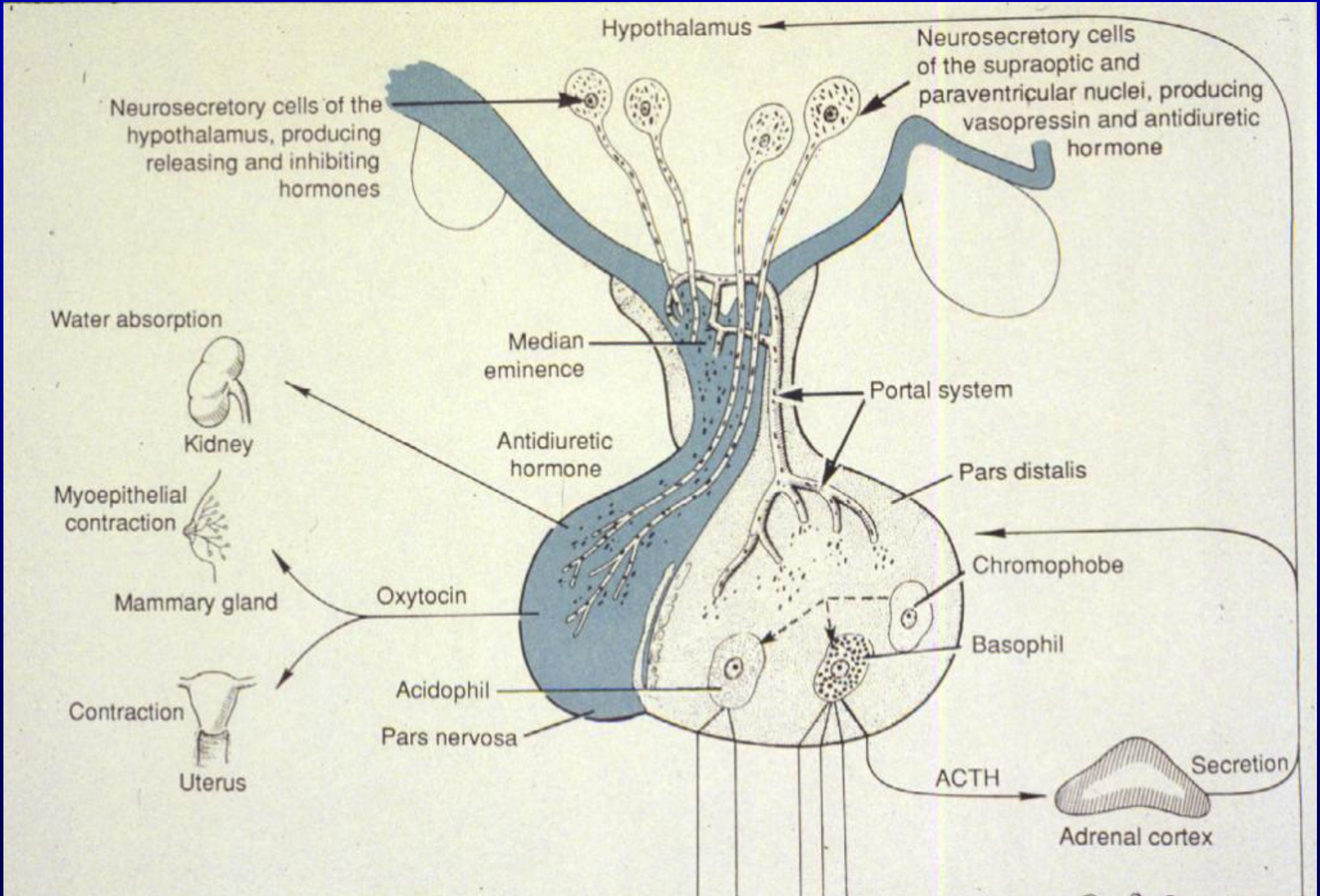


Figure 17–14. Electron micrograph of rat neurohypophysis, showing neurosecretory granules and small vesicles in the axoplasm of fibers of the hypothalamo-hypophyseal tract ending in close relation to a capillary. × 22,000. (Courtesy of

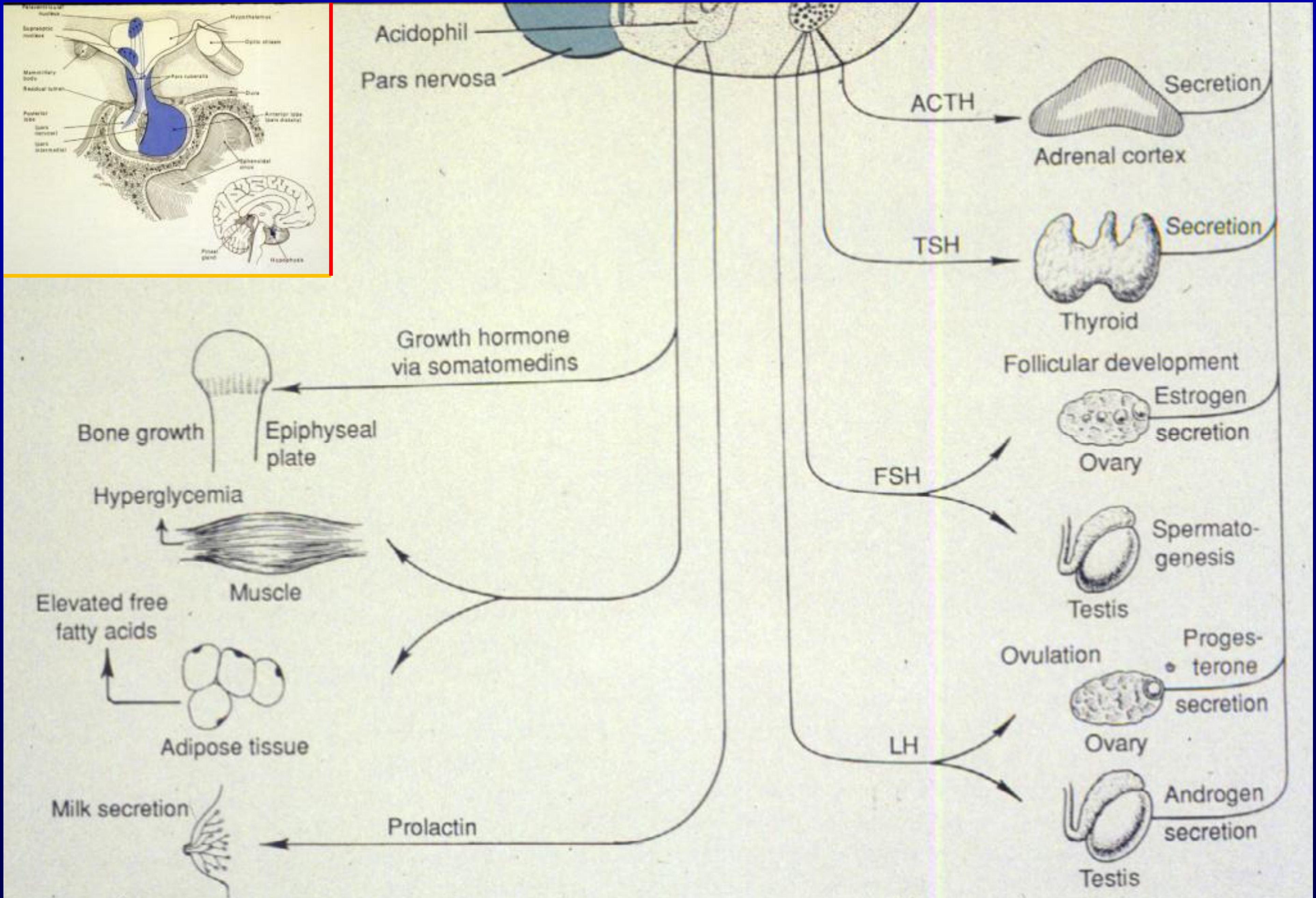
Releasing hormones are distributed in second capillary bed of venous portal system.

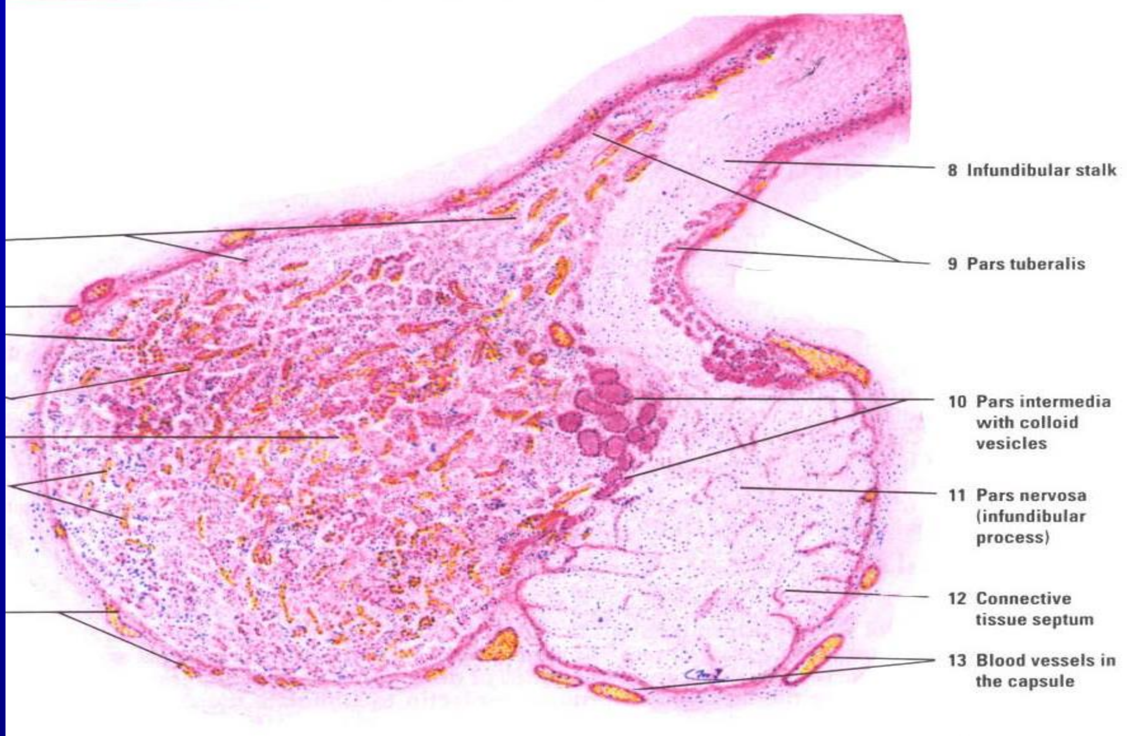


Pituitary – organ interaction

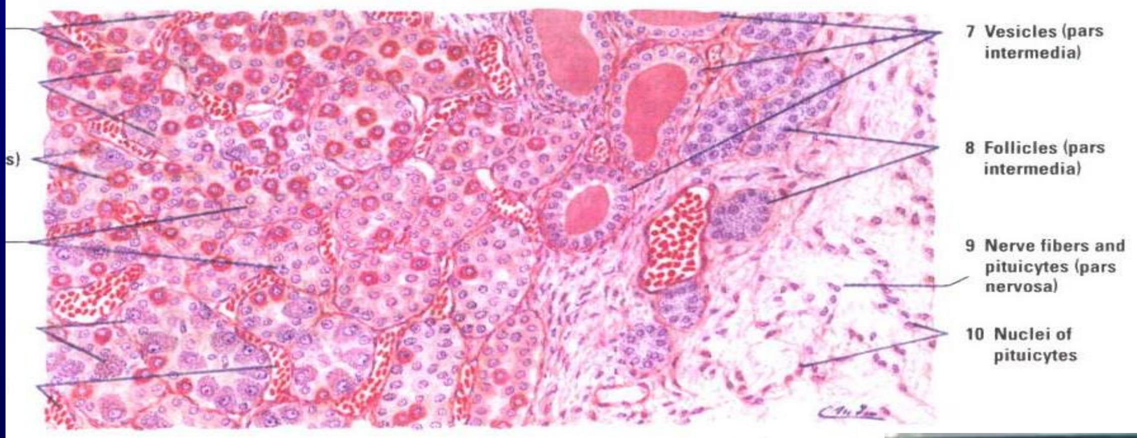


Pituitary – organ interaction

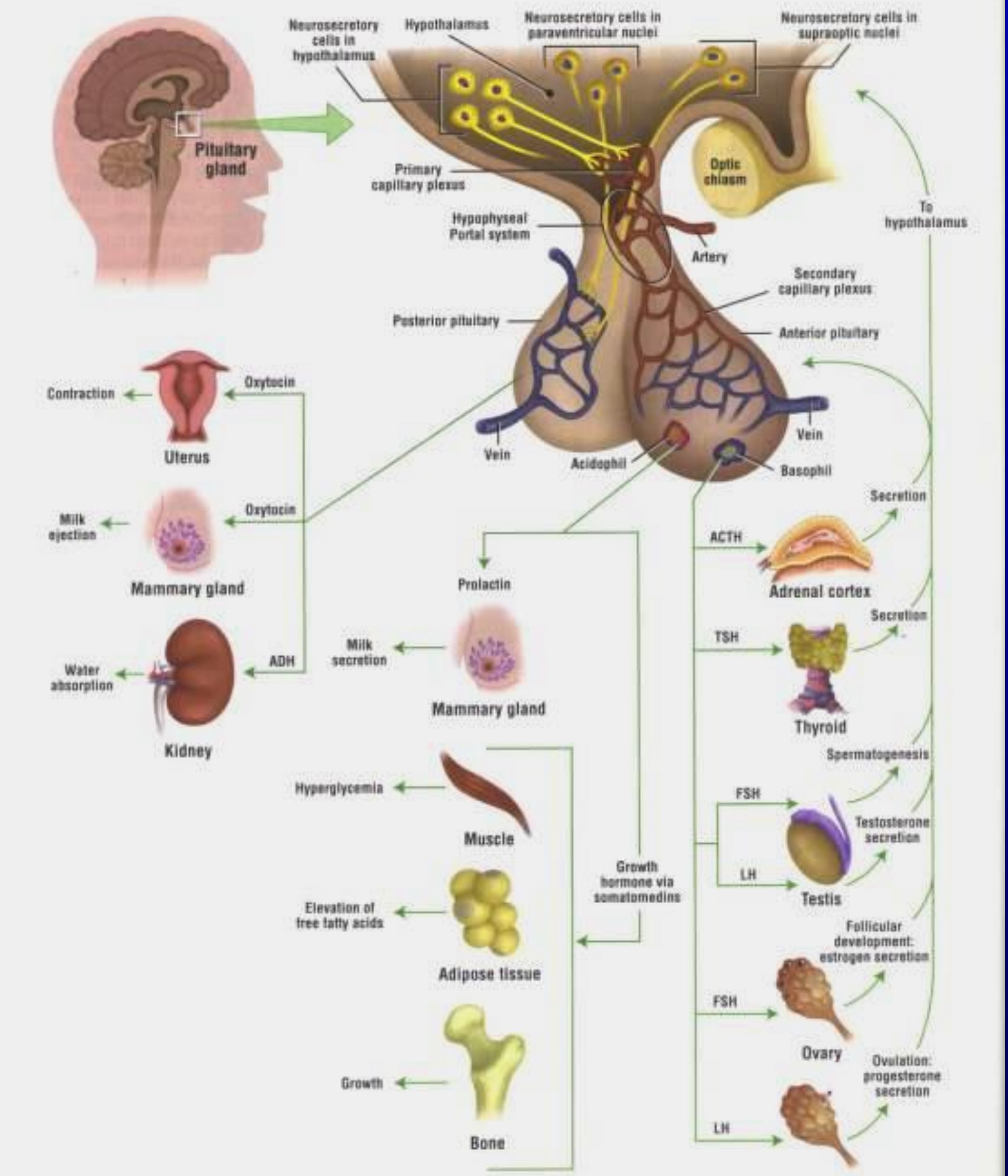




Hypophysis (panoramic view, sagittal section). Stain: hematoxylin-eosin. Low magnification.



16-2 Hypophysis (sectional view). Stain: hematoxylin-eosin. Medium magni

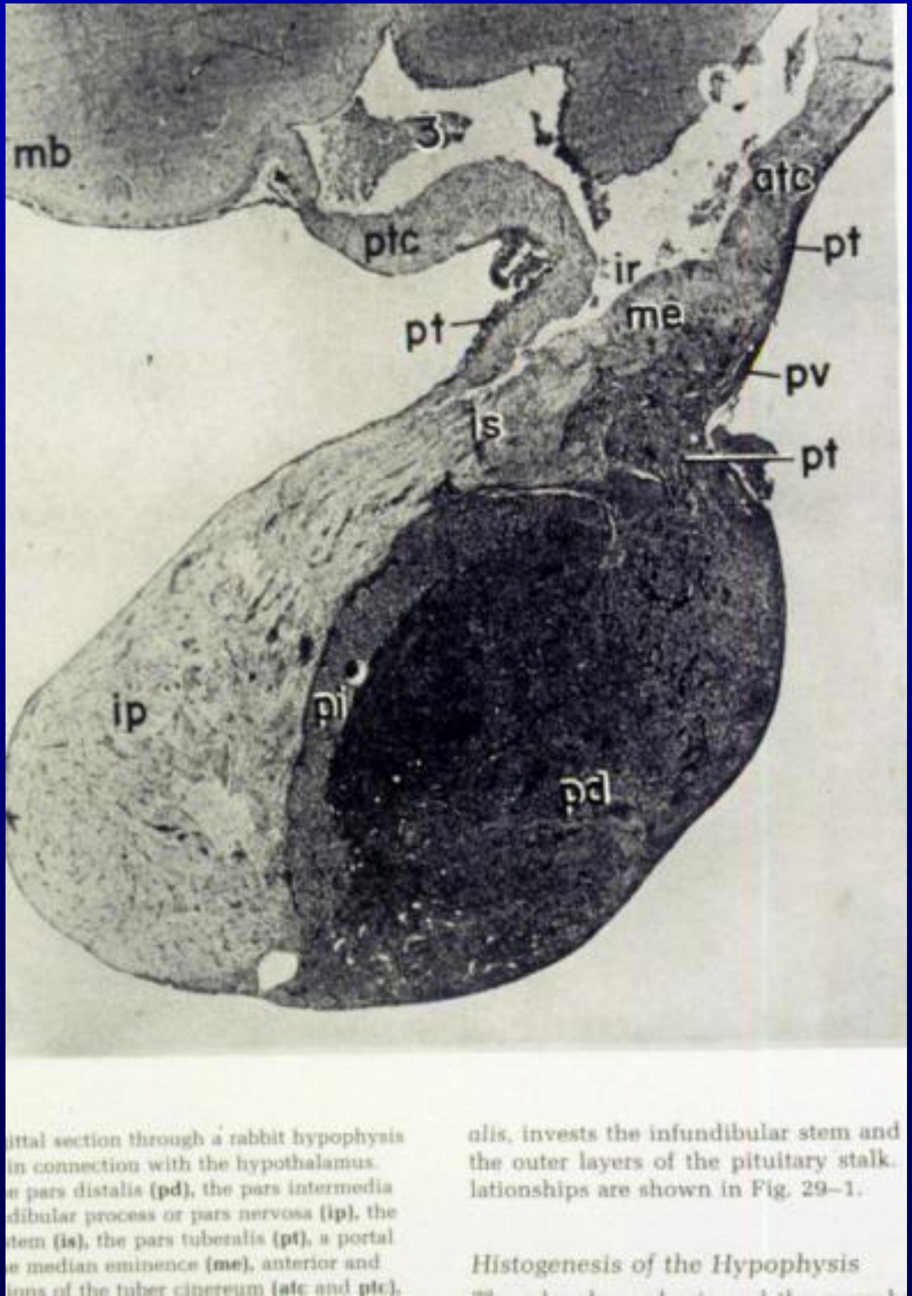


EROSCHENKO

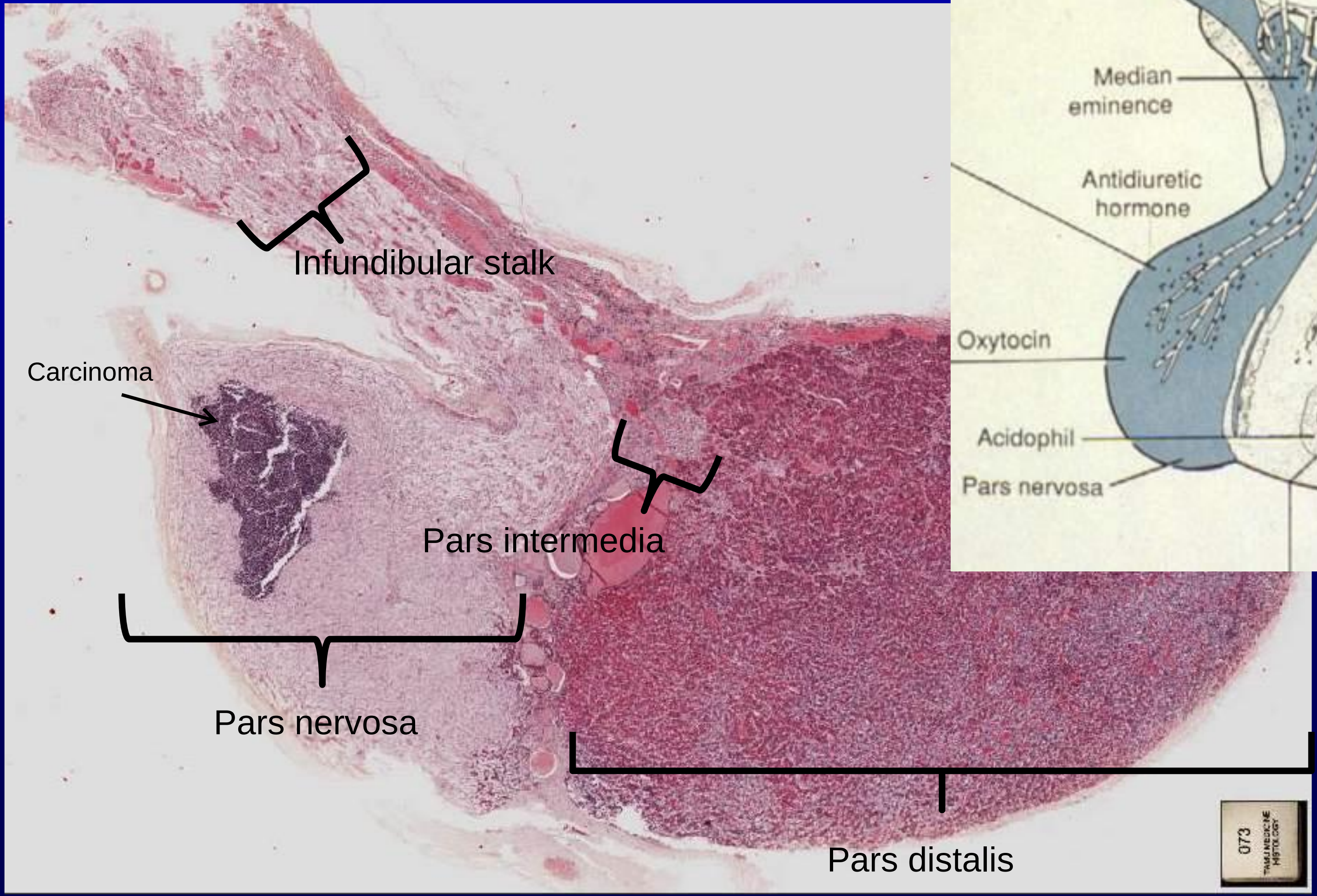
di Fiore's ATLAS OF HISTOLOGY with FUNCTIONAL CORRELATIONS

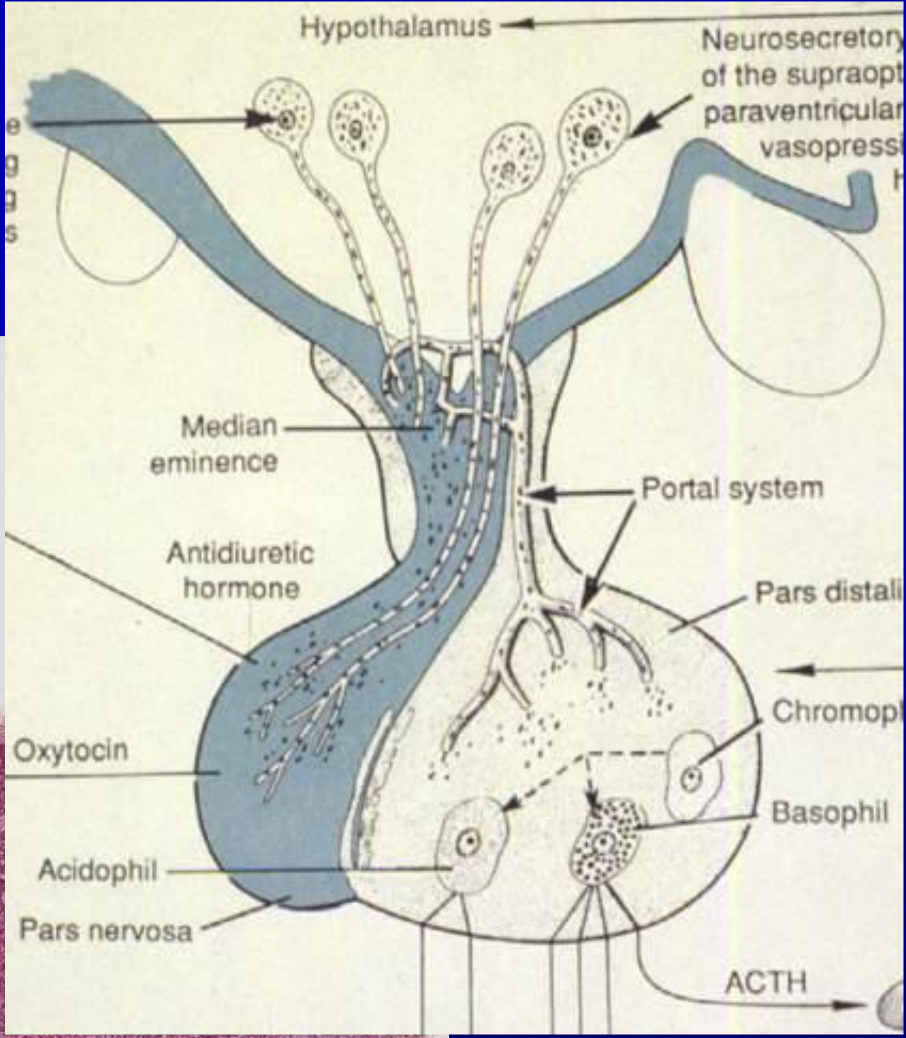
Neurohypophysis

- Origin
- Divisions
  - I. Pars nervosa
  - Ii. Infundibulum
    - 1) Stem/stalk
    - 2) Median eminence
- Relation to hypothalamus
  - Microscopic organization
  - I. Secreting nerve cells
  - Ii. Neurosecretory granules
  - Iii. Herring bodies
  - Iv. Pituicytes



Slide 73: Pituitary (early carcinoma in posterior lobe)

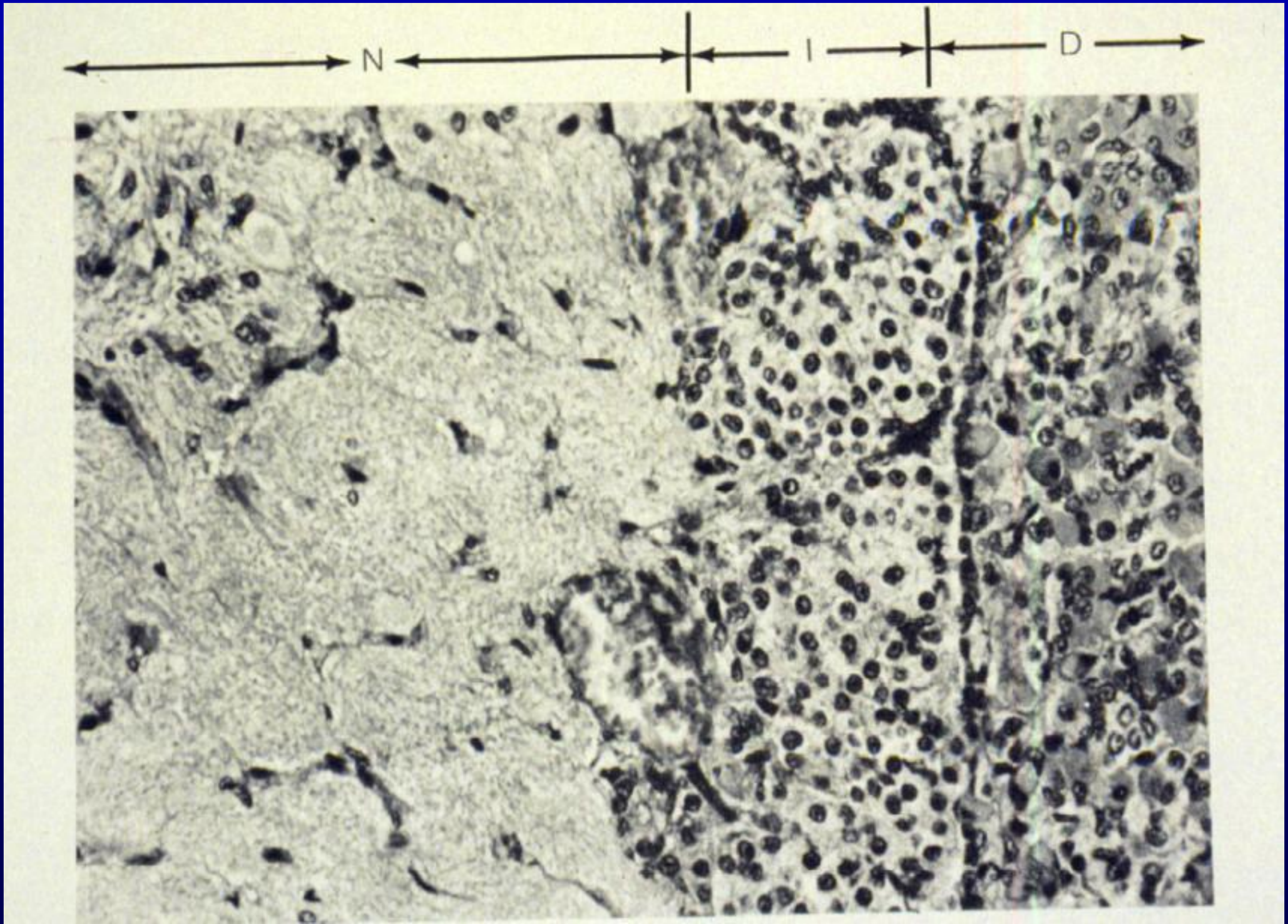




Pars Nervosa

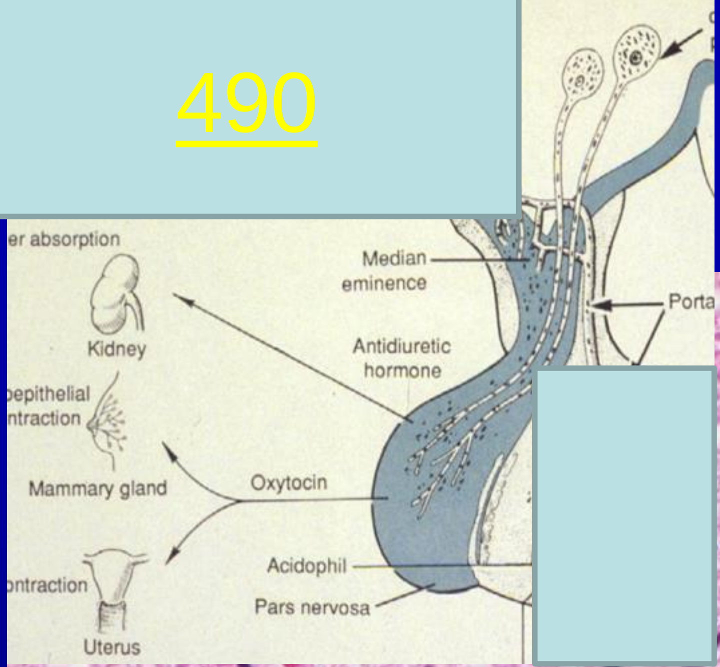
Pars Intermedia

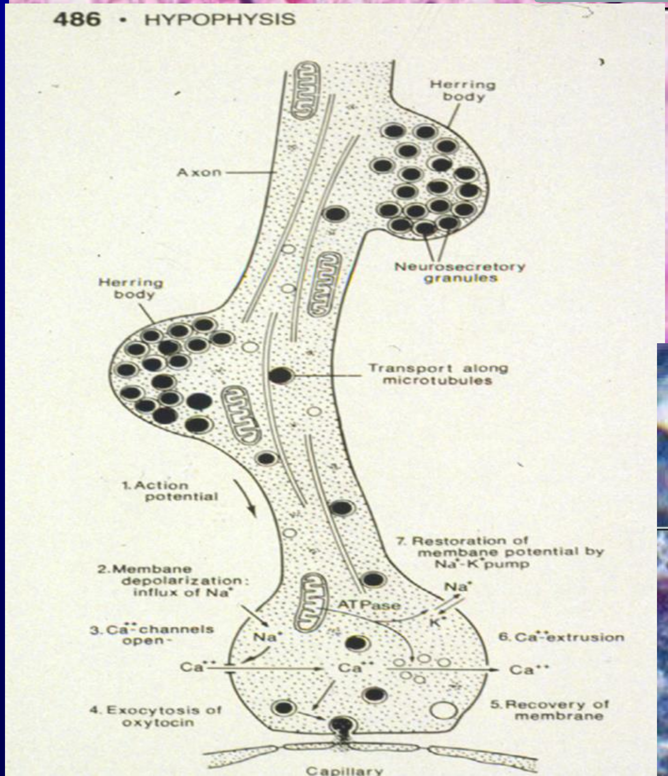
Pars Distalis

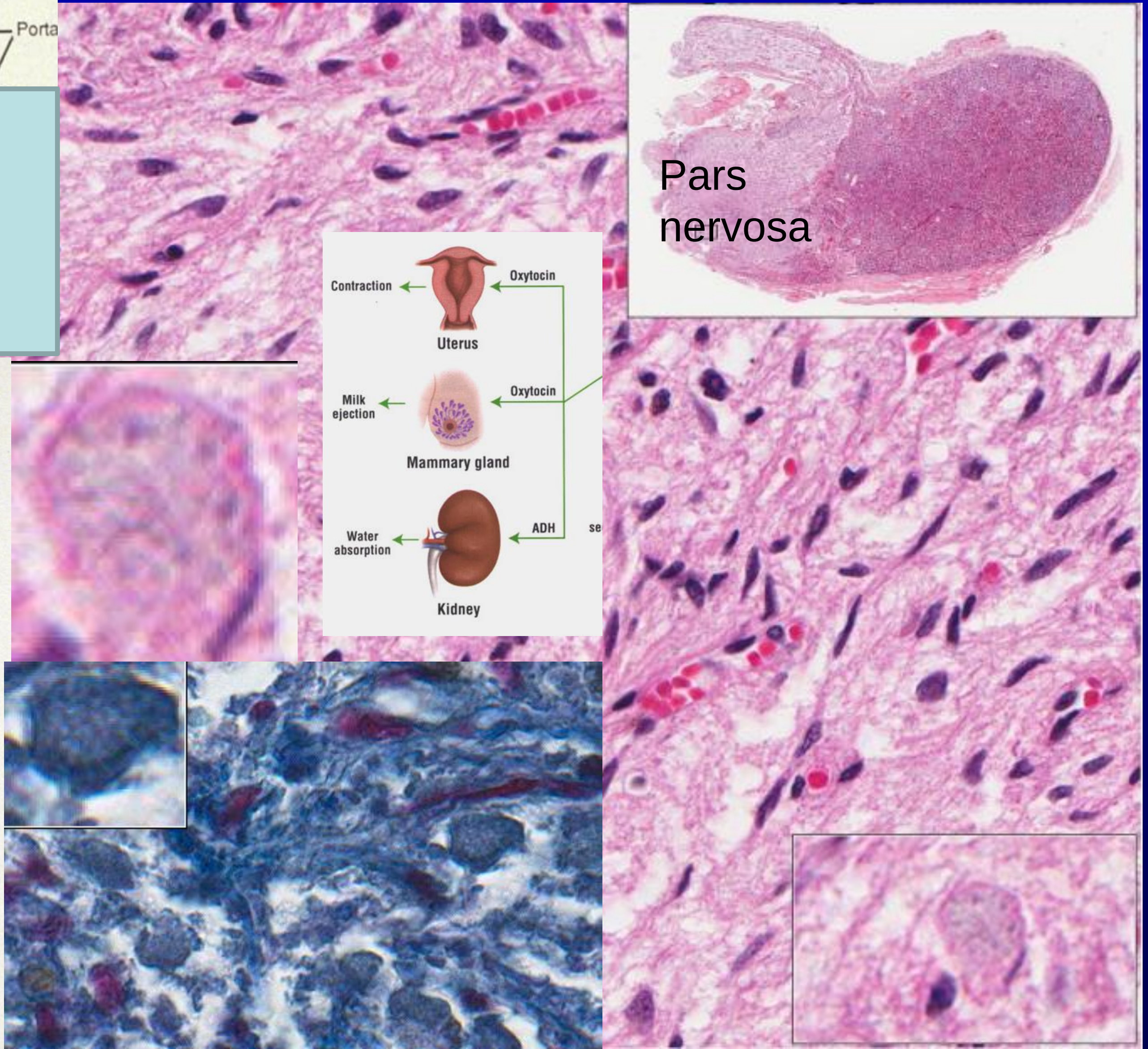


Herring bodies in pars nervosa of Hypophysis

490

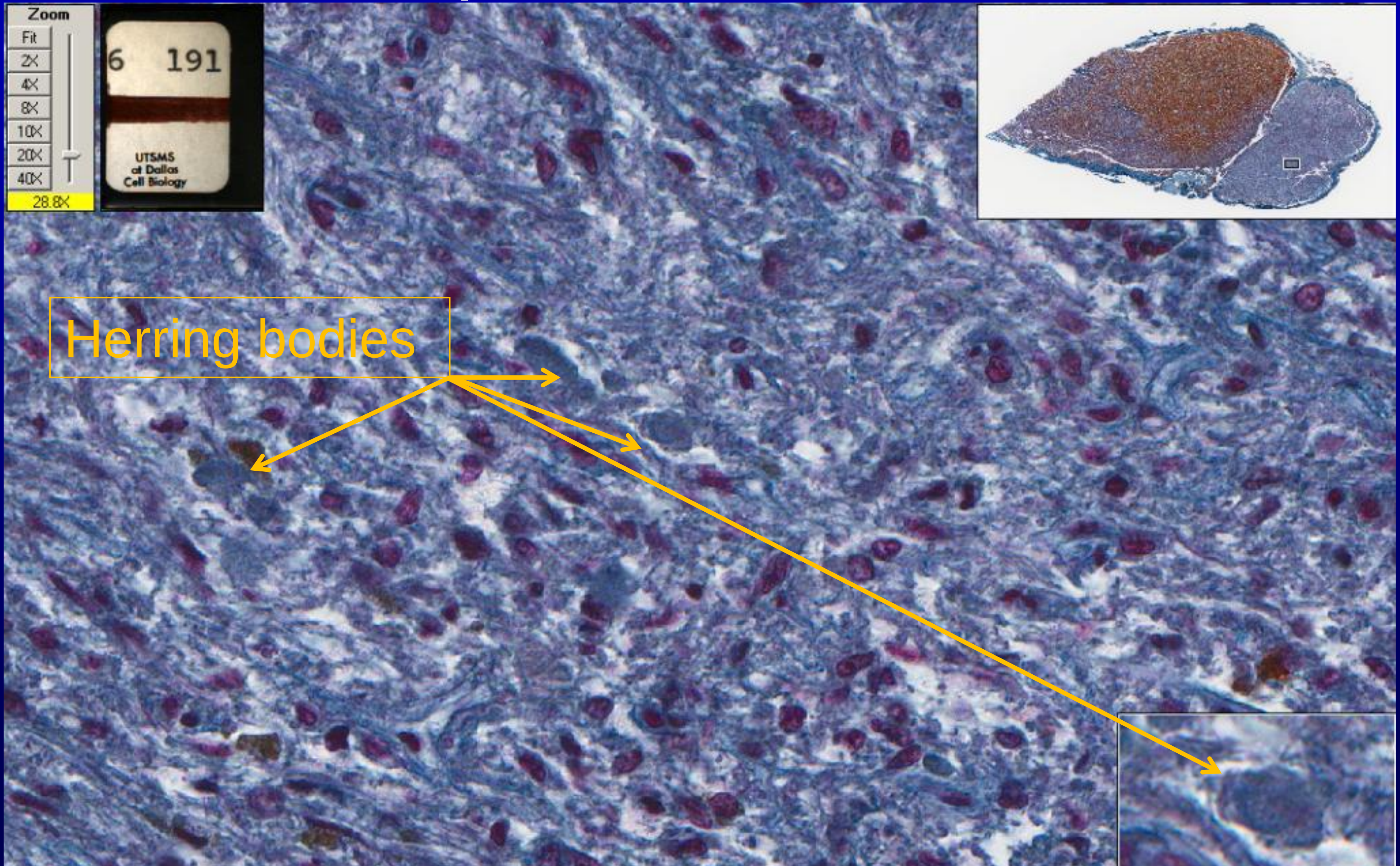






191

Pituitary (Herlant's stain) pars nervosa



Herring Bodies

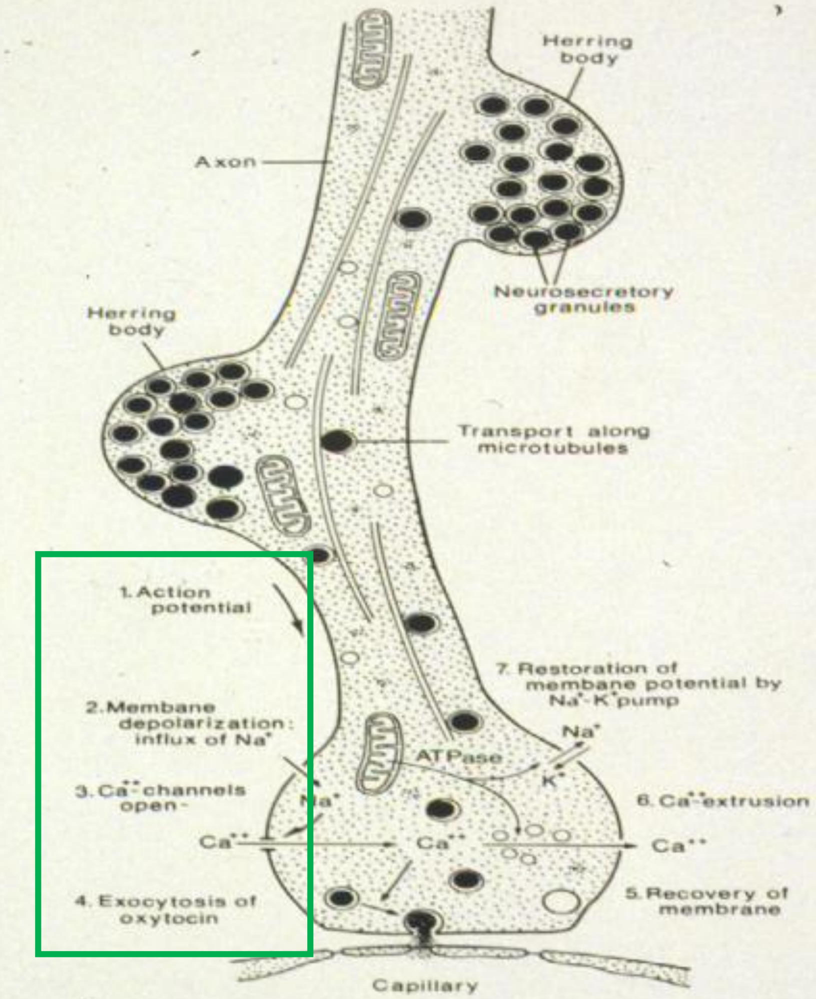


Figure 17–12. Schematic depiction of the terminal portion of an axon of the hypothalamohypophyseal tract in the neurohypophysis. The principal events in stimulus-secretion coupling are indicated. (Modified after Lincoln, D.W. 1984. *In* Hormonal Control of Reproduction. Cambridge, England, Cambridge University Press.)

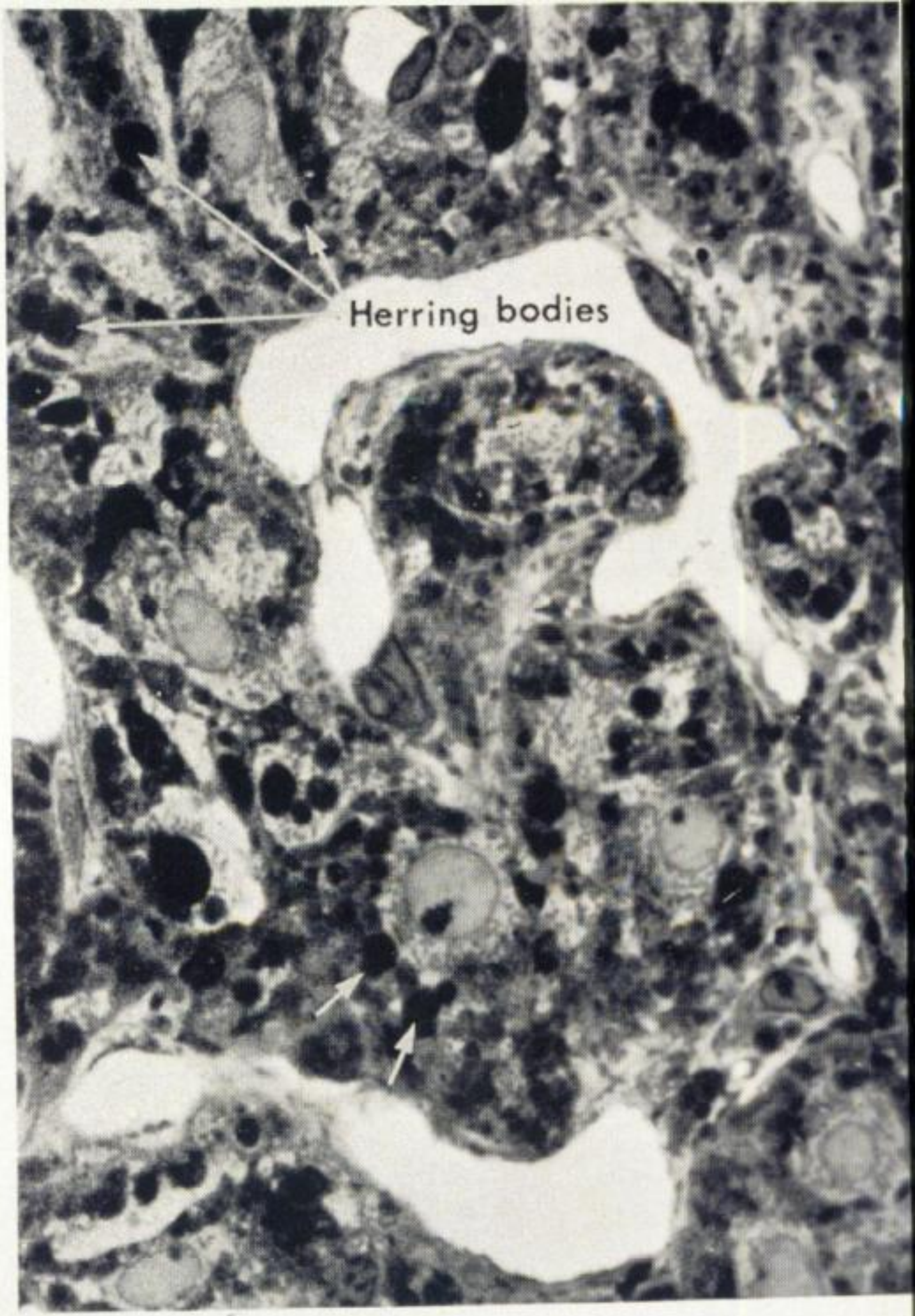


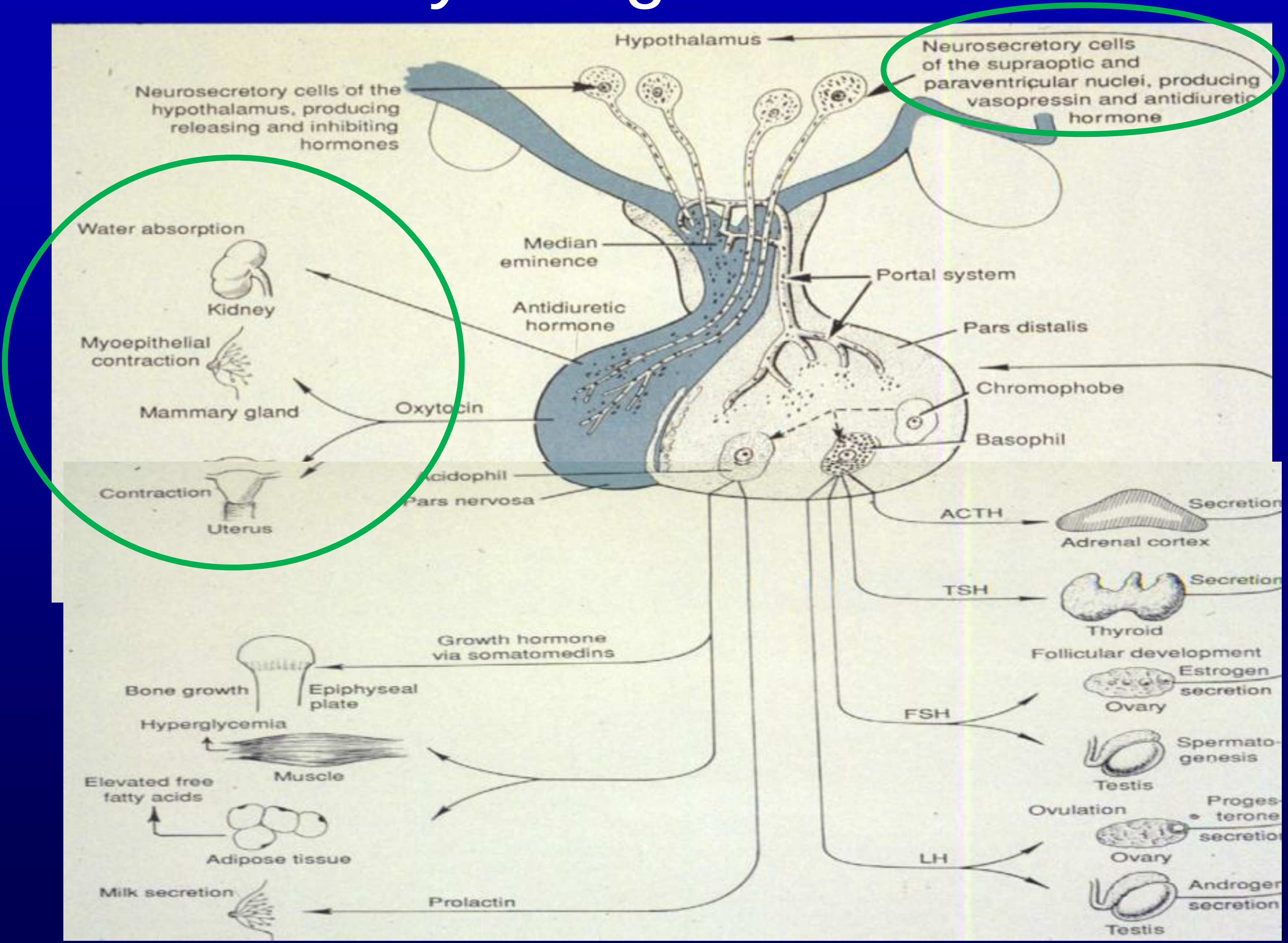
Figure 17–13. Photomicrograph of rat neurohypophys

Herring Bodies

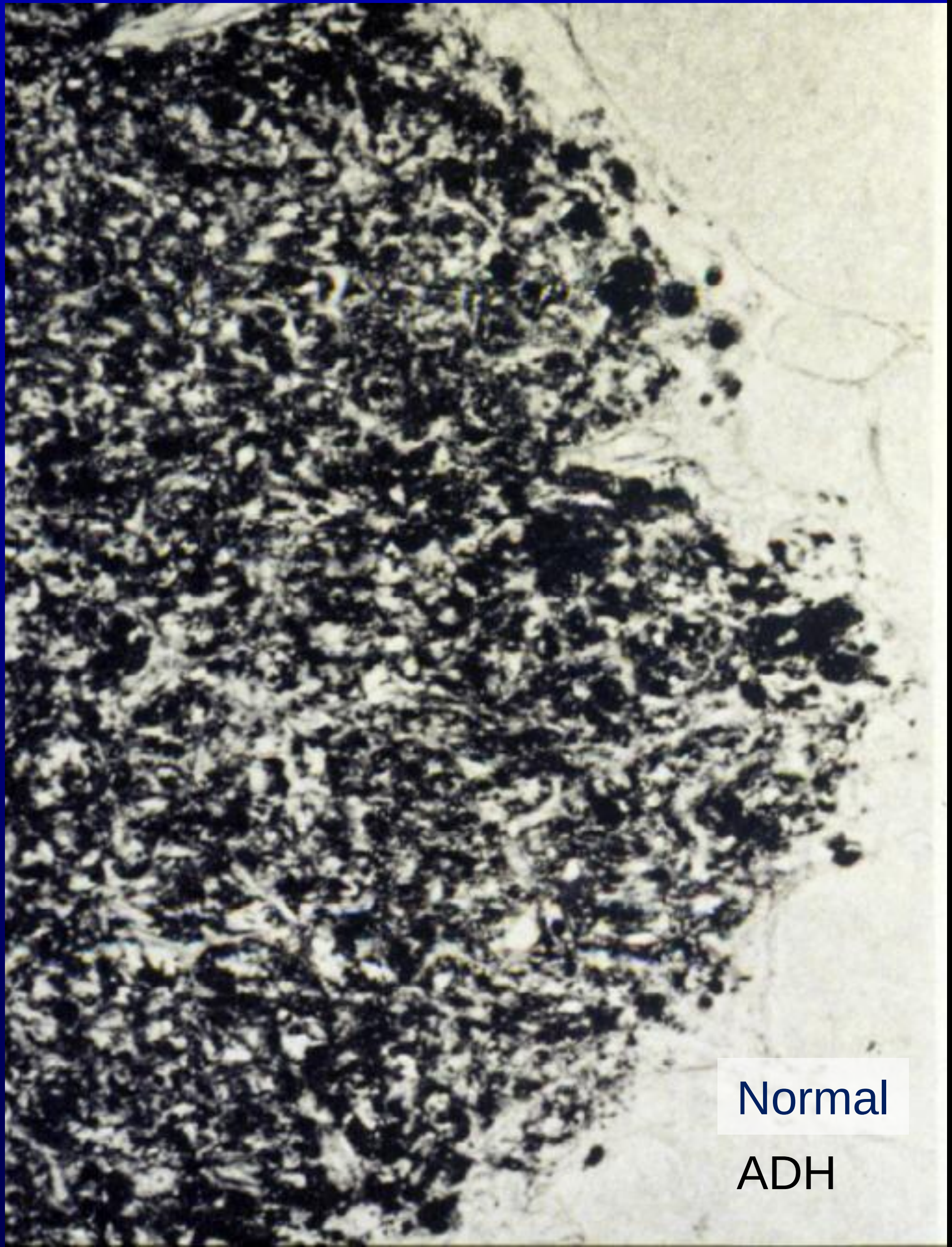
in the

Pars Nervosa

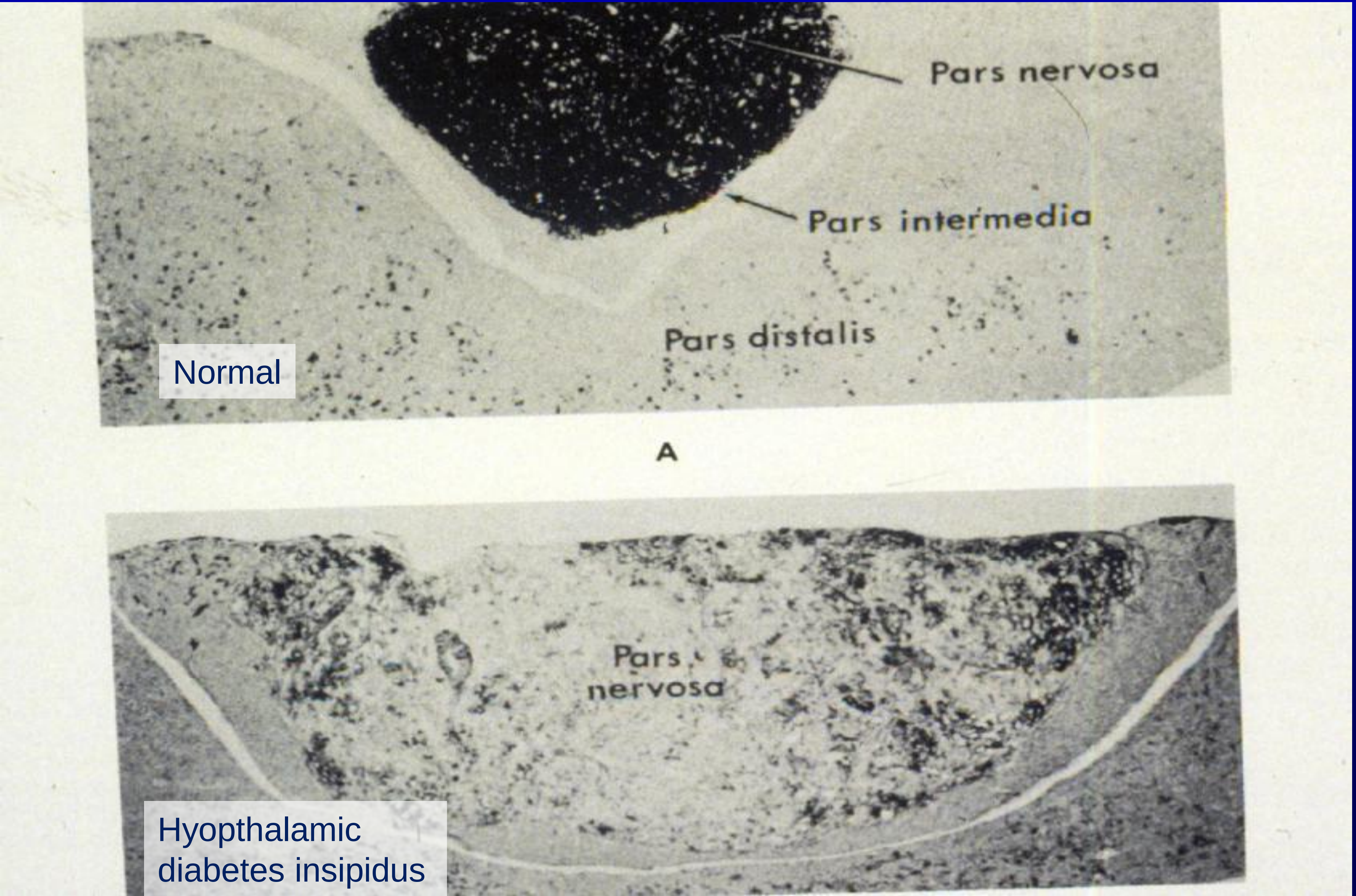
Pituitary – organ interaction

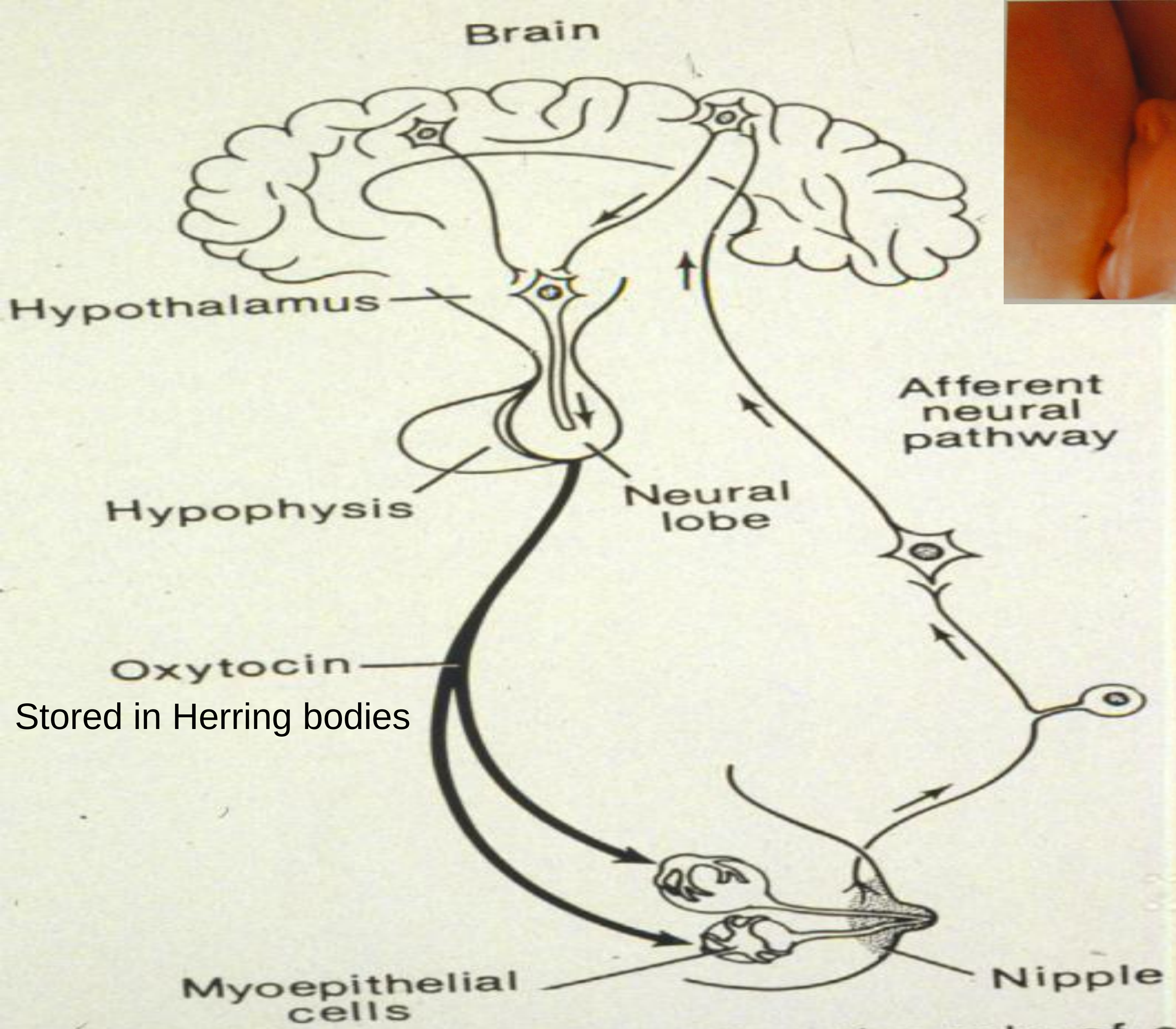


Pars Nervosa



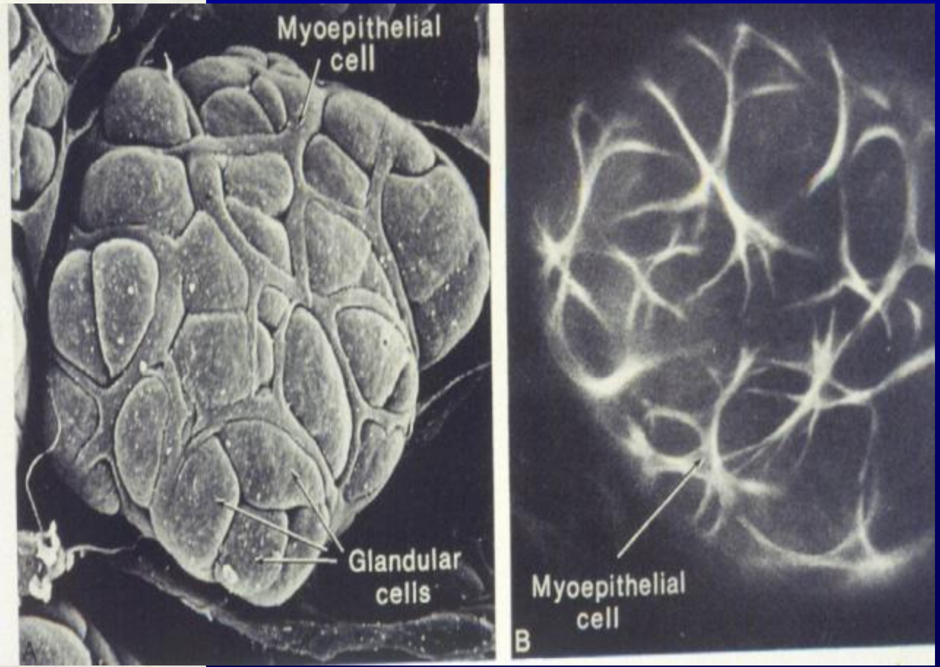
Pars Nervosa





re 17—17. Diagram illustrating the role of oxytocin
uckling reflex. Stimulation of the nipples generat

Nursing reflex stimulates brain to induce release of oxytocin which causes milk ejection by contraction of myoepitheilum around milk contained alveoli

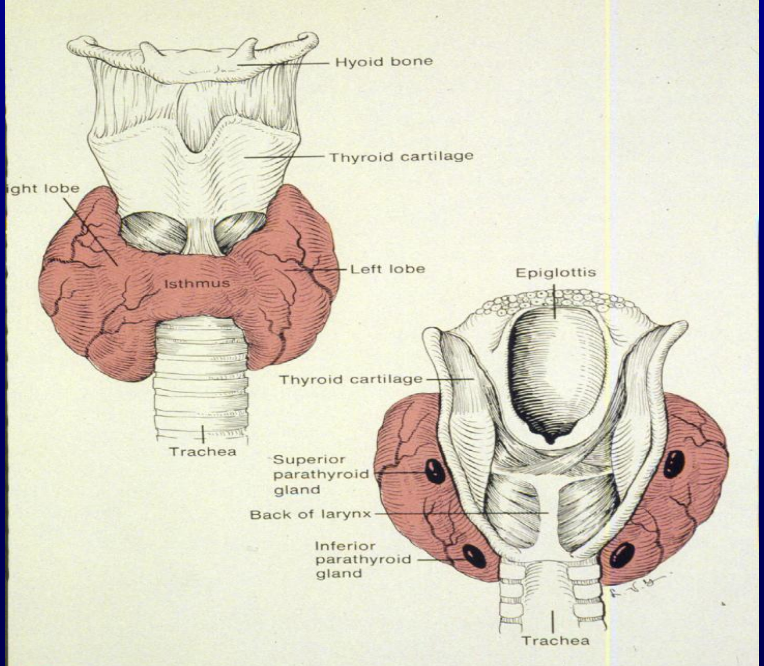


Thyroid Stimulating Hormone (TSH)

Physiological significance –
regulation of metabolism

The **thyroid** gland produces hormones that regulate the body's metabolic rate as well as heart and digestive function, muscle control, brain development, mood and bone maintenance. Its correct functioning depends on having a good supply of iodine from the diet.

www.yourhormones.info/glands/thyroid-gland/



28-6
ior (left) and posterior (right) views of anatomical relationship of thyroid and pa
d glands

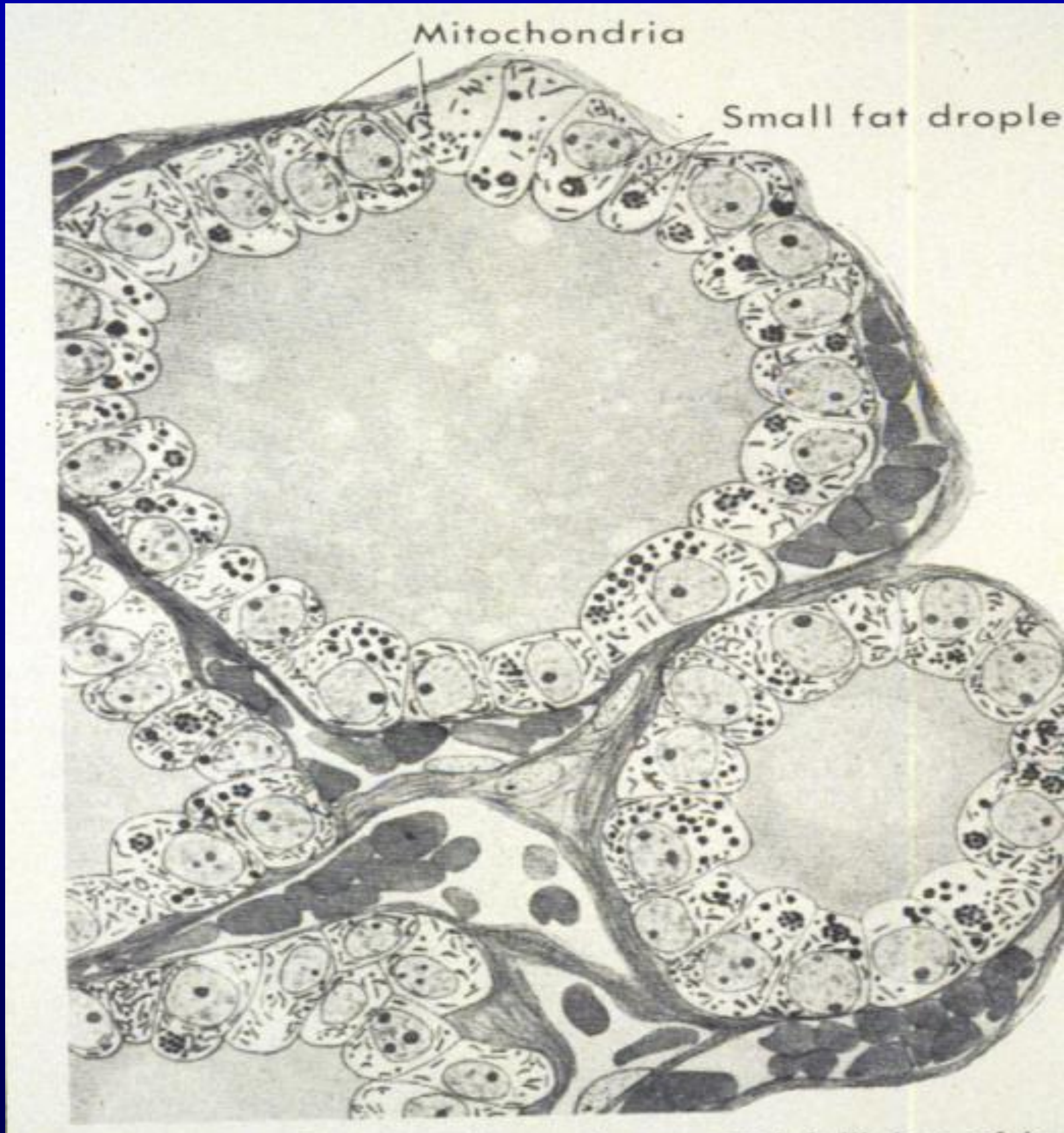
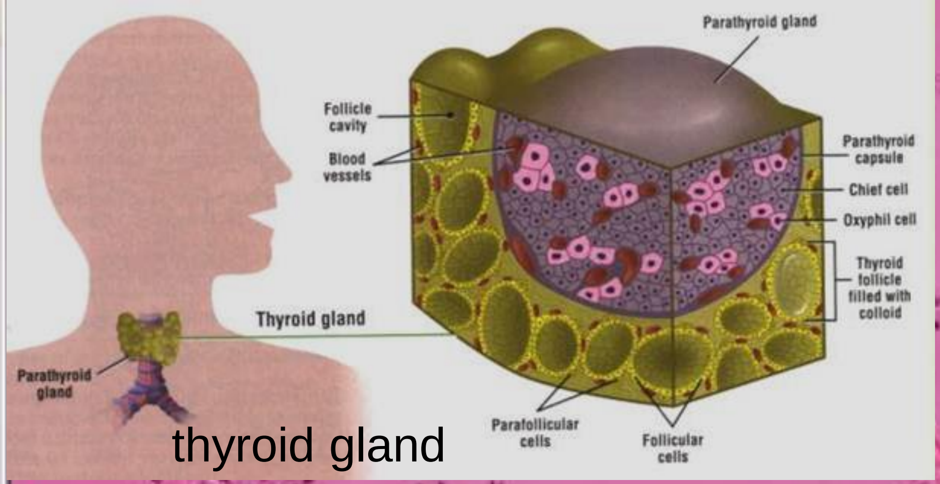


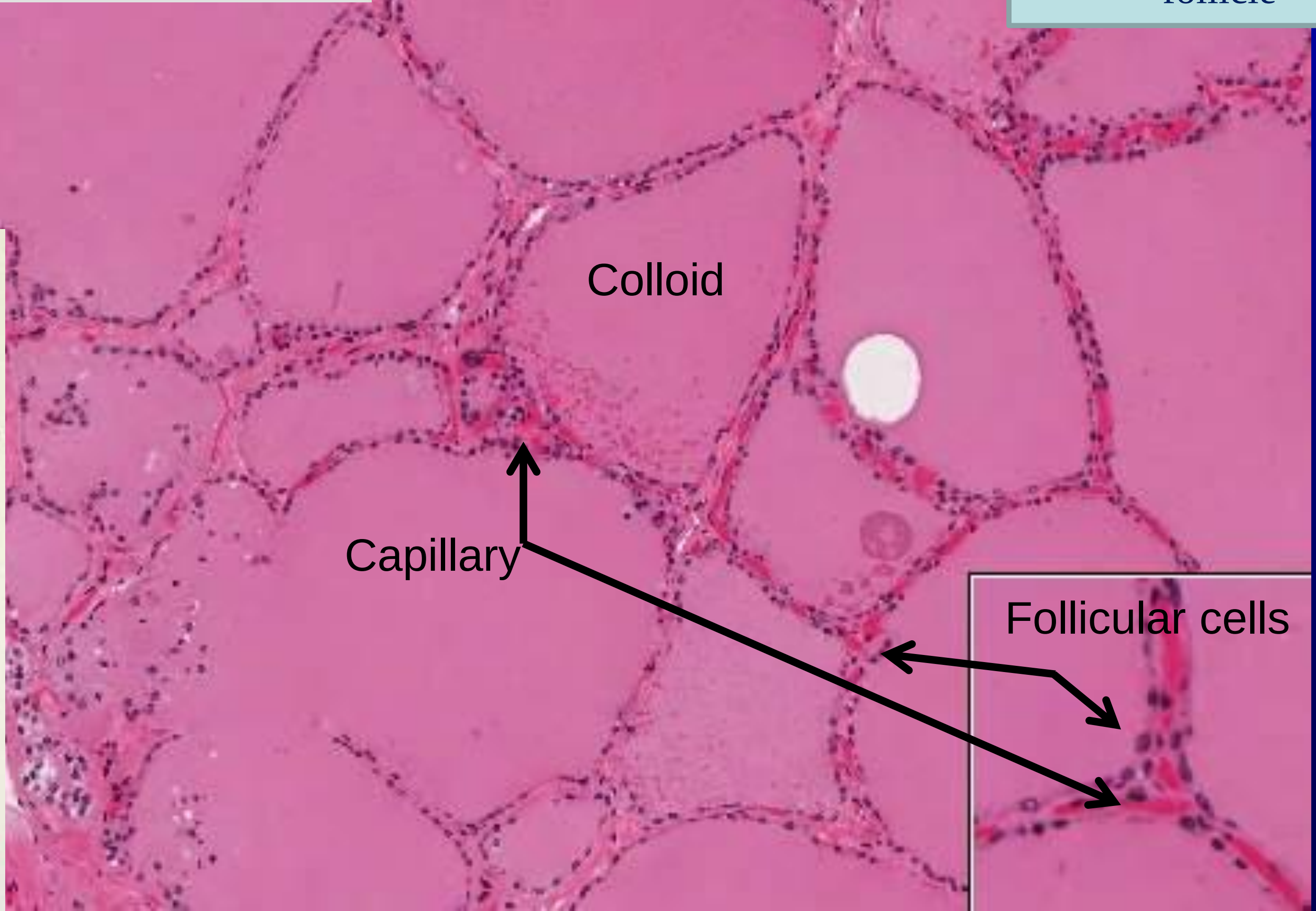
Figure 18–4. Section through several follicles of hu

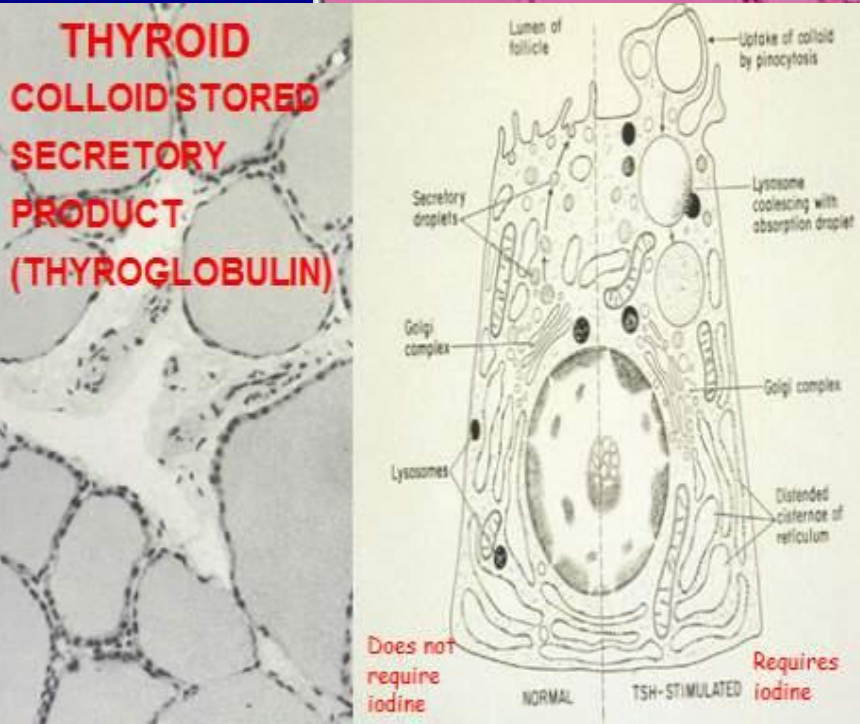
Thyroid gland

Follicle – no outlet

1. Colloid
2. Follicular cells
3. Capillaries in CT around follicle







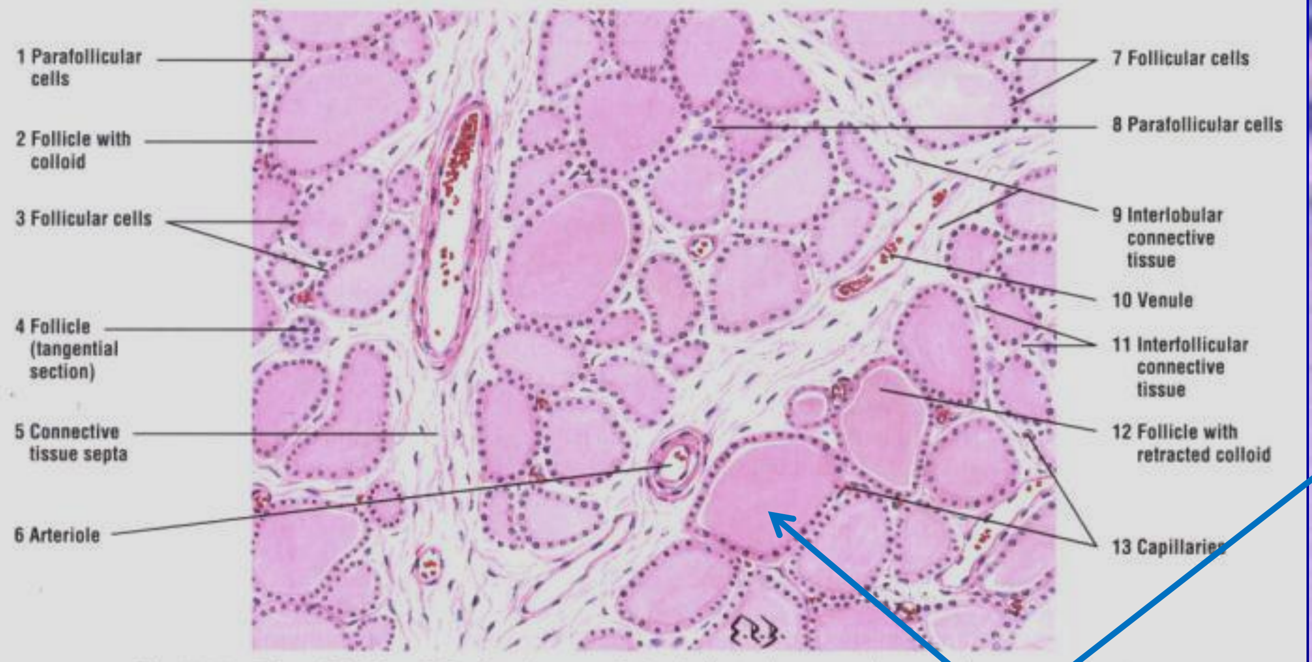


Fig. 16-5 Thyroid Gland: Canine (general view). Stain: hematoxylin-eosin. Low magnification.

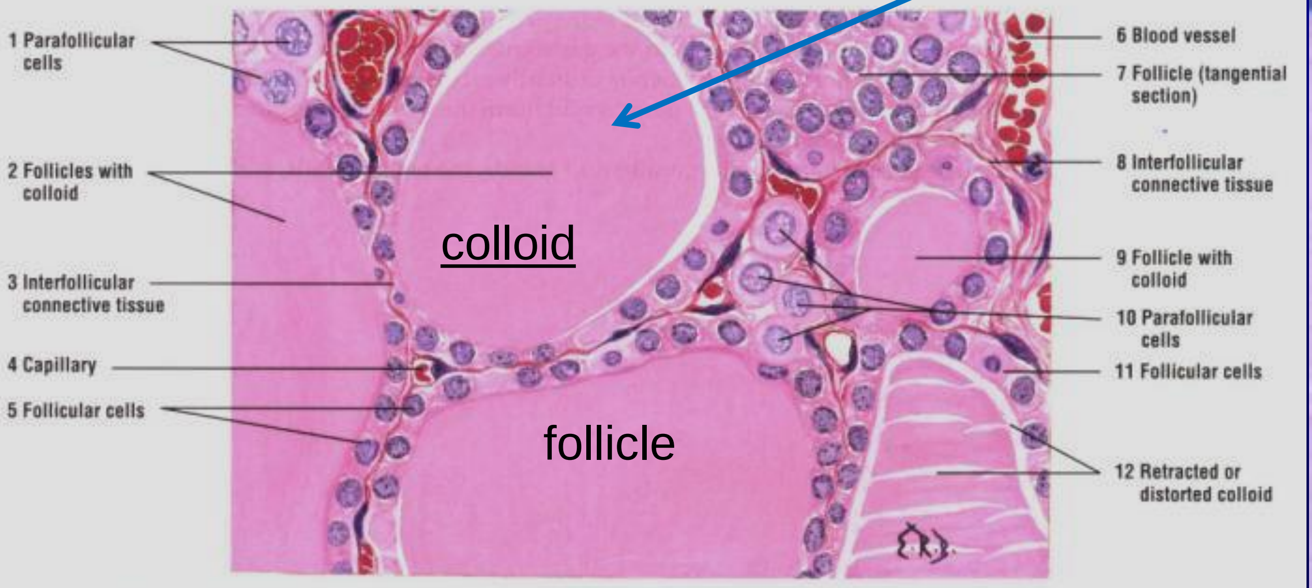
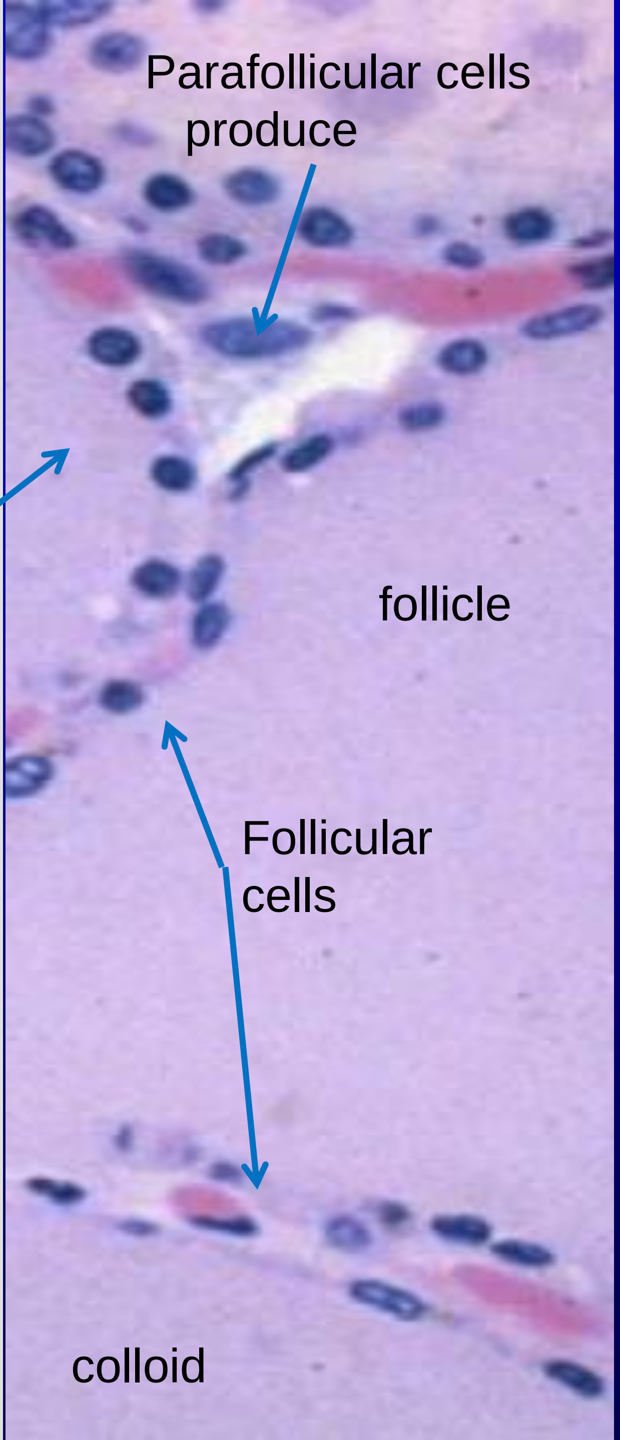


Fig. 16-6 Thyroid Gland Follicles: Canine (sectional view). Stain: hematoxylin-eosin. High magnification.

EROSCHENKO ATLAS OF HISTOLOGY with FUNCTIONAL CORRELATIONS



Thyroid – follicular cells

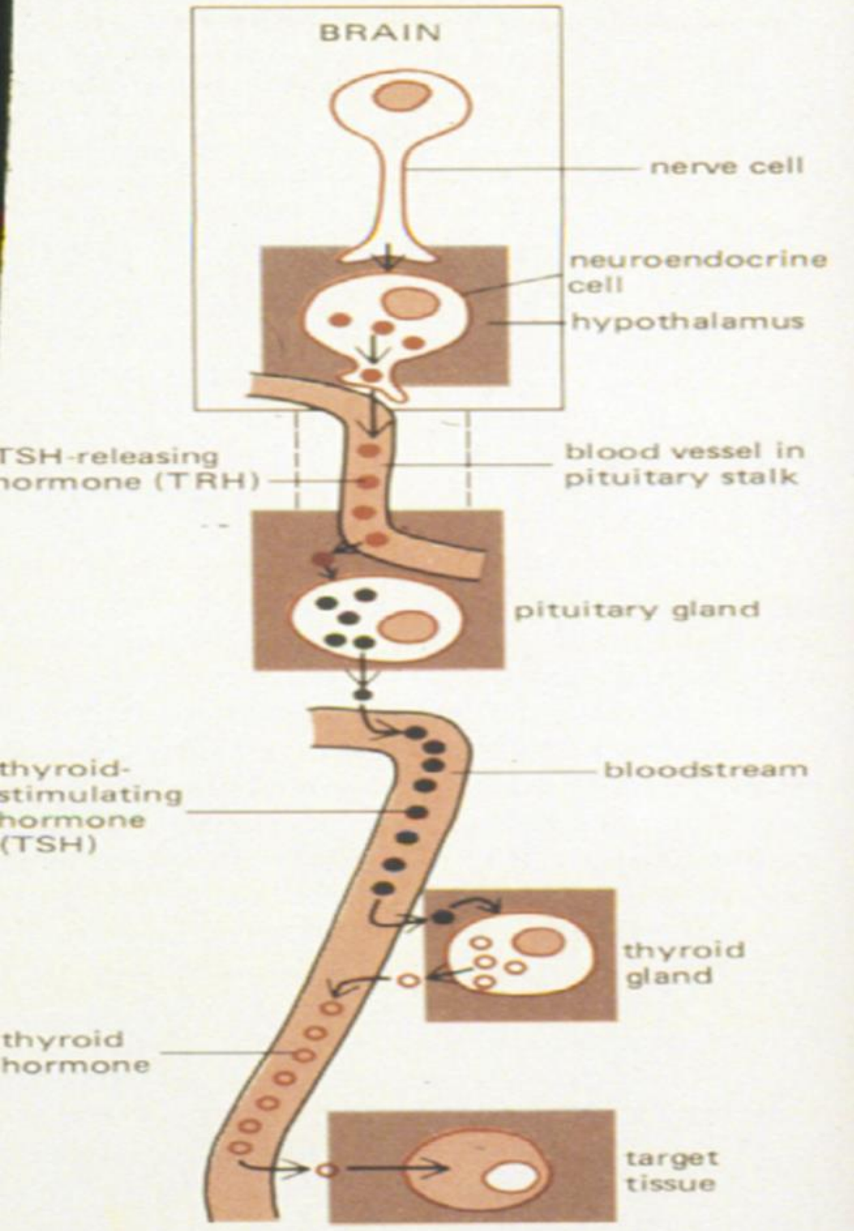
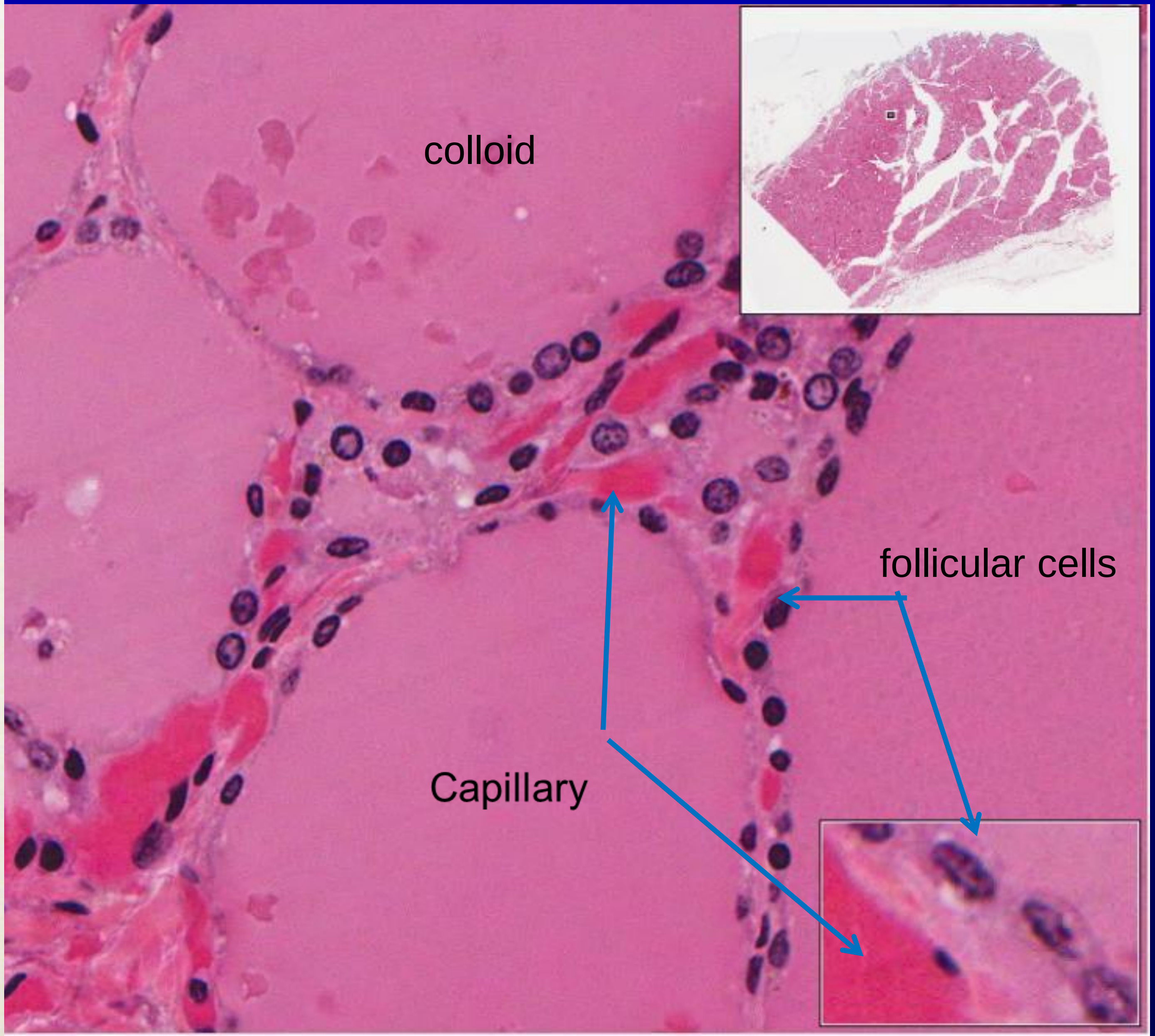
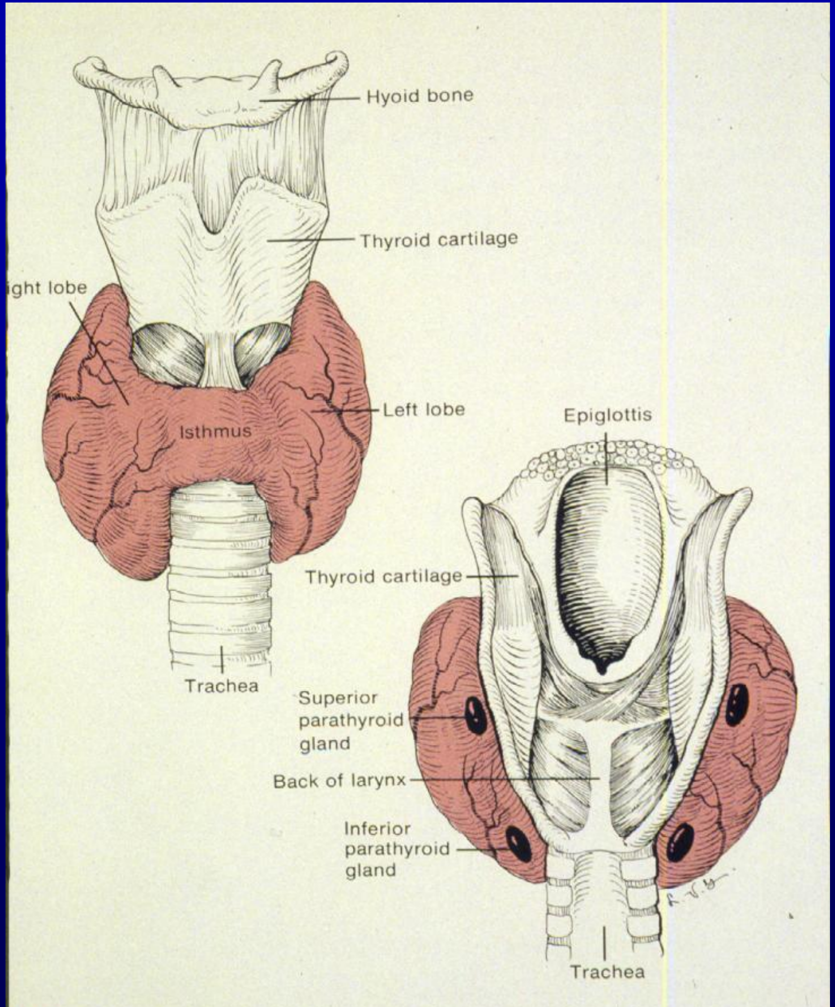


Figure 12—4 Thyroid hormone secretion is regulated indirectly by the nervous system. When stimulated by nerve cells in higher centers of the brain, specific neuroendocrine cells in the hypothalamus secrete TSH-releasing

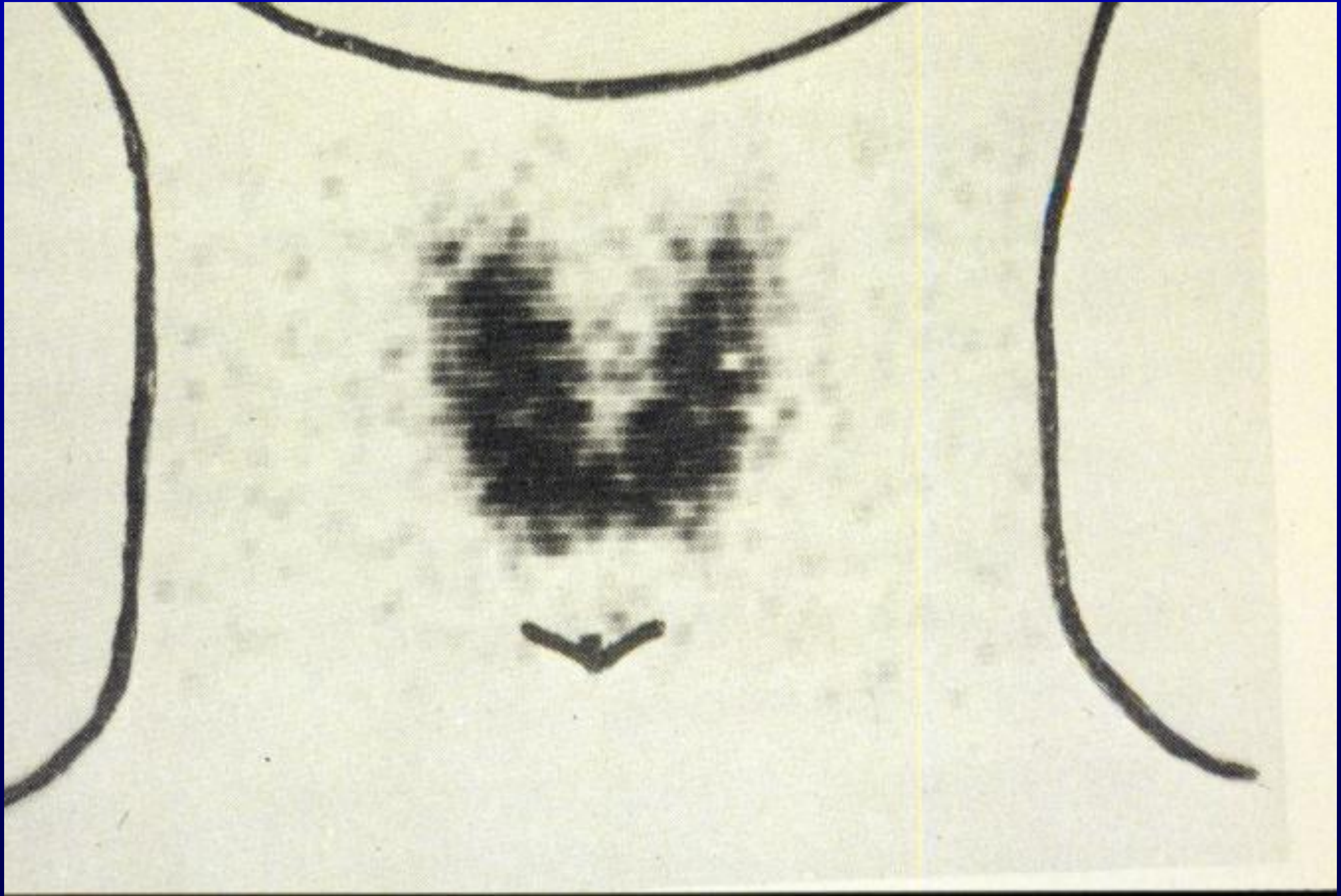


184

Thyroid



28-6
ior (left) and posterior (right) views of anatomical relationship of thyroid and pa
d glands



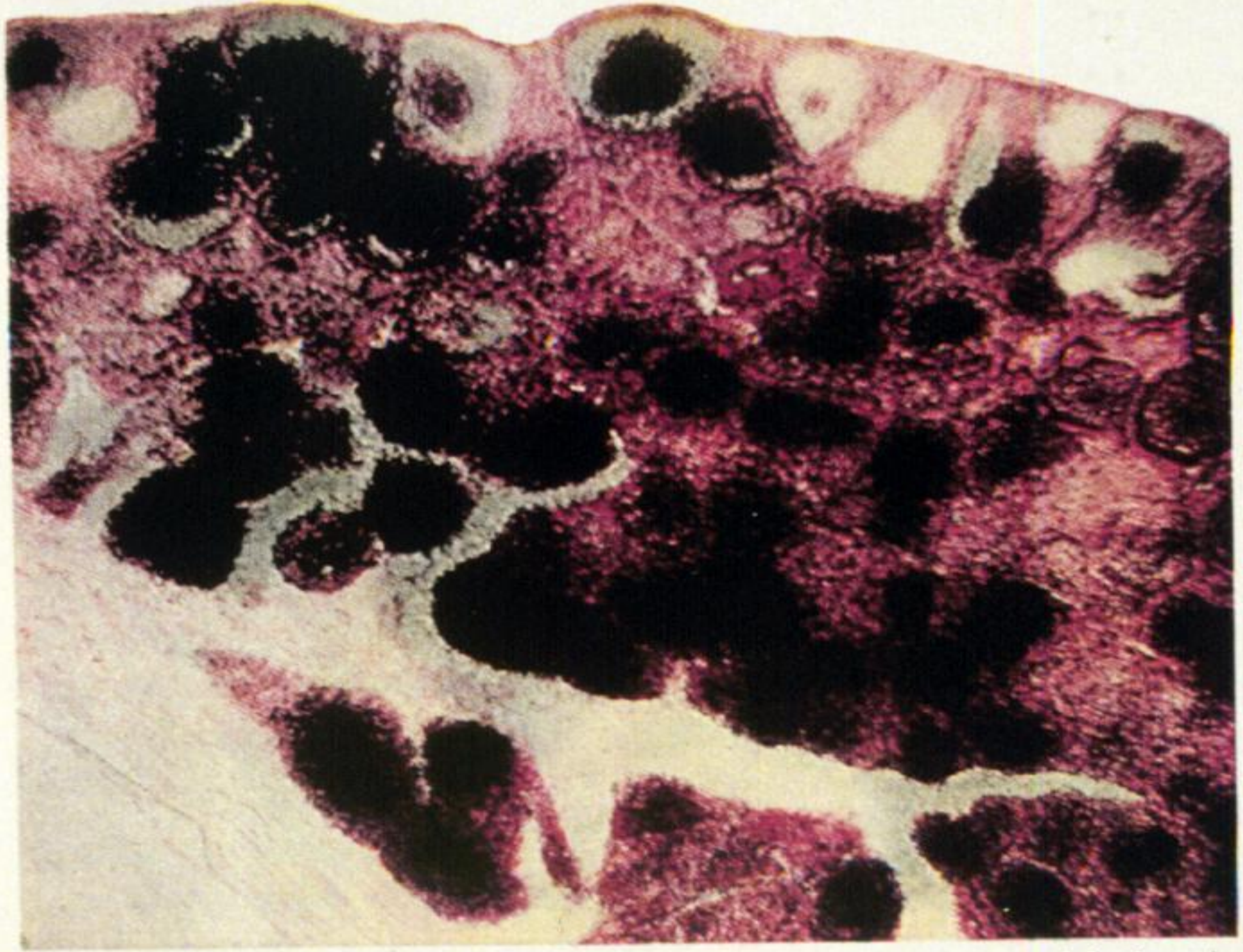
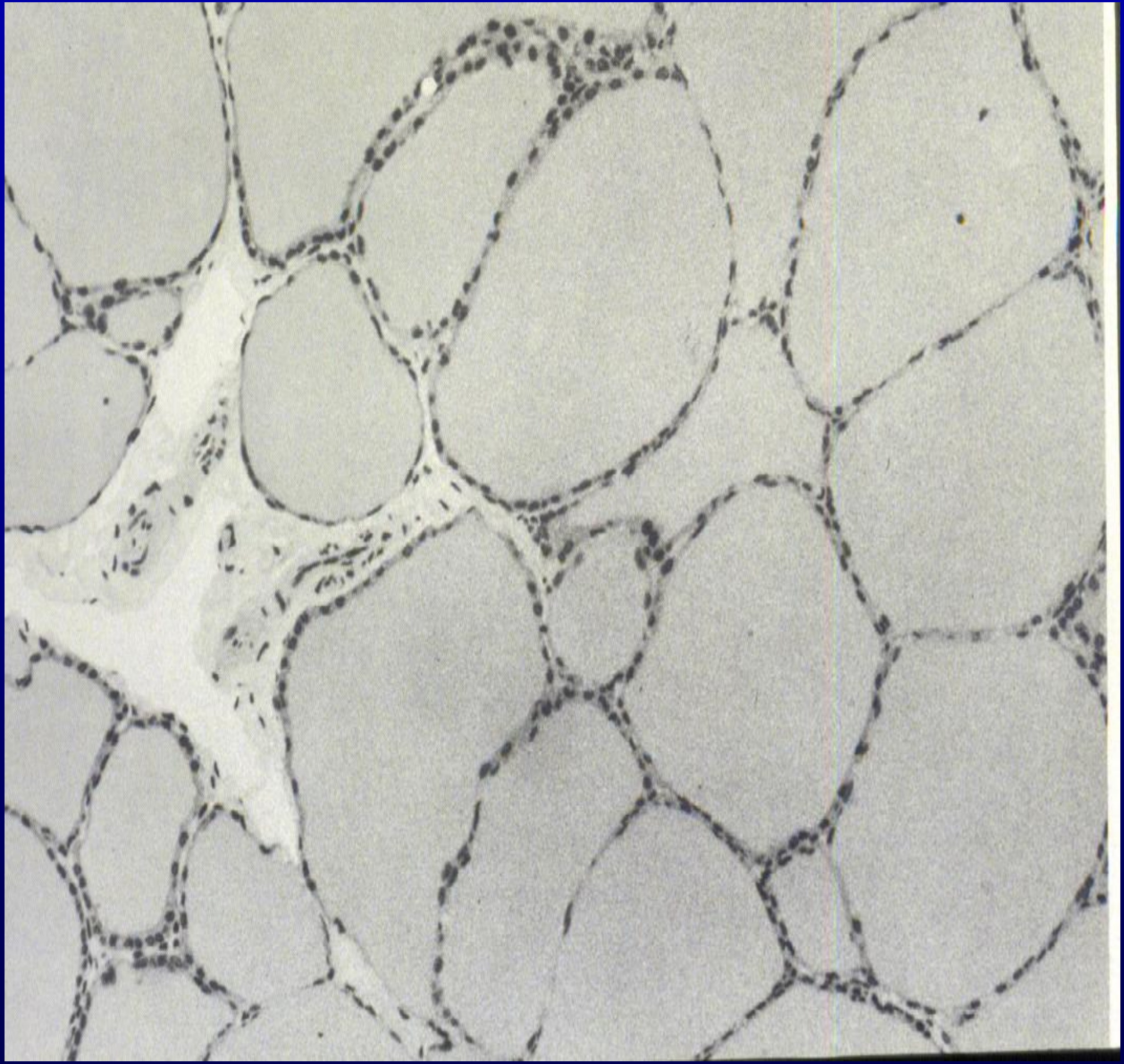


Figure 18–6. Low-power photomicrograph of thyroid gland of a rat previously injected with ^{131}I. The blackened areas represent sites of deposition of radioactive isotope in the colloid. There is great variation in the content of the isotope

Thyroid

Thyroid gland microanatomy

Follicles and highly vascularized



Mechanism for release of secretory products

Merocrine secretion – exocytosis w/o loss of surface membrane

Apocrine secretion – loss of part of apical cytoplasm and some plasma membrane

Holocrine secretion – release of whole cell

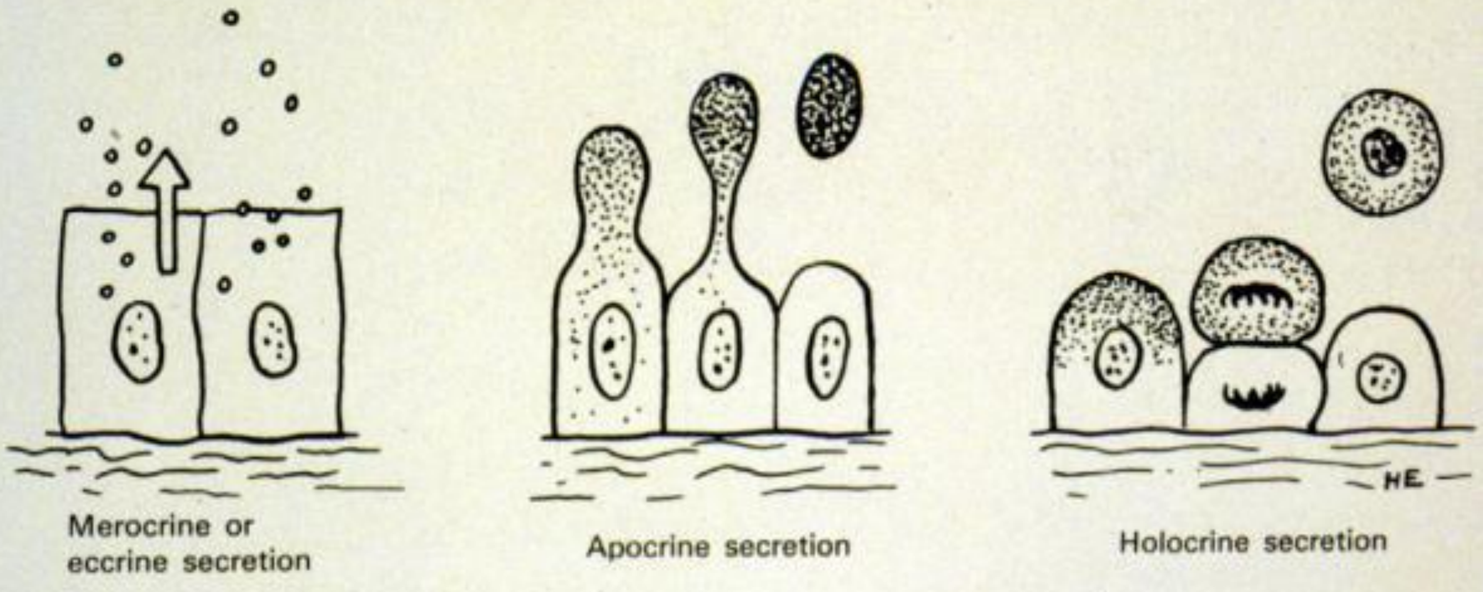
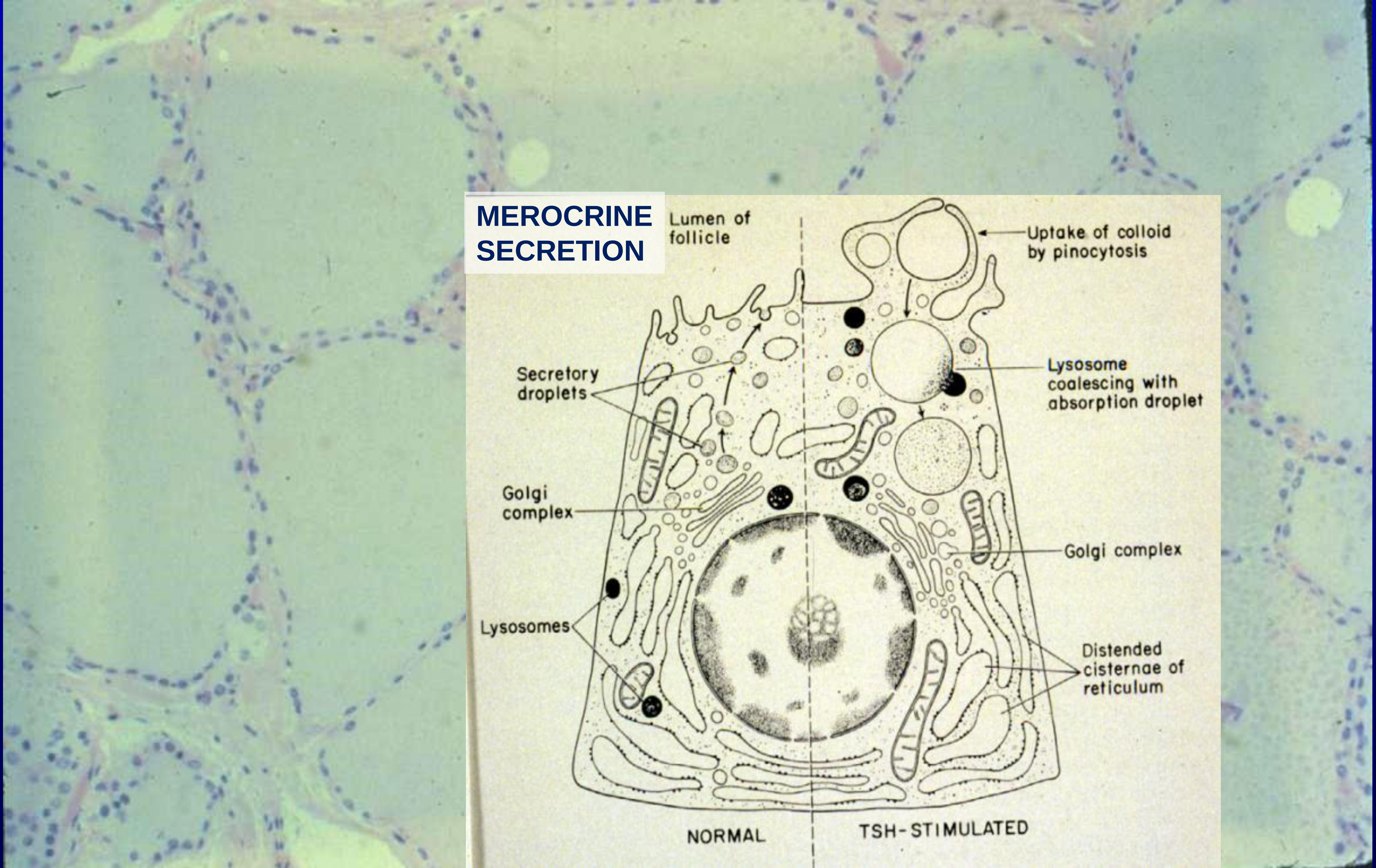


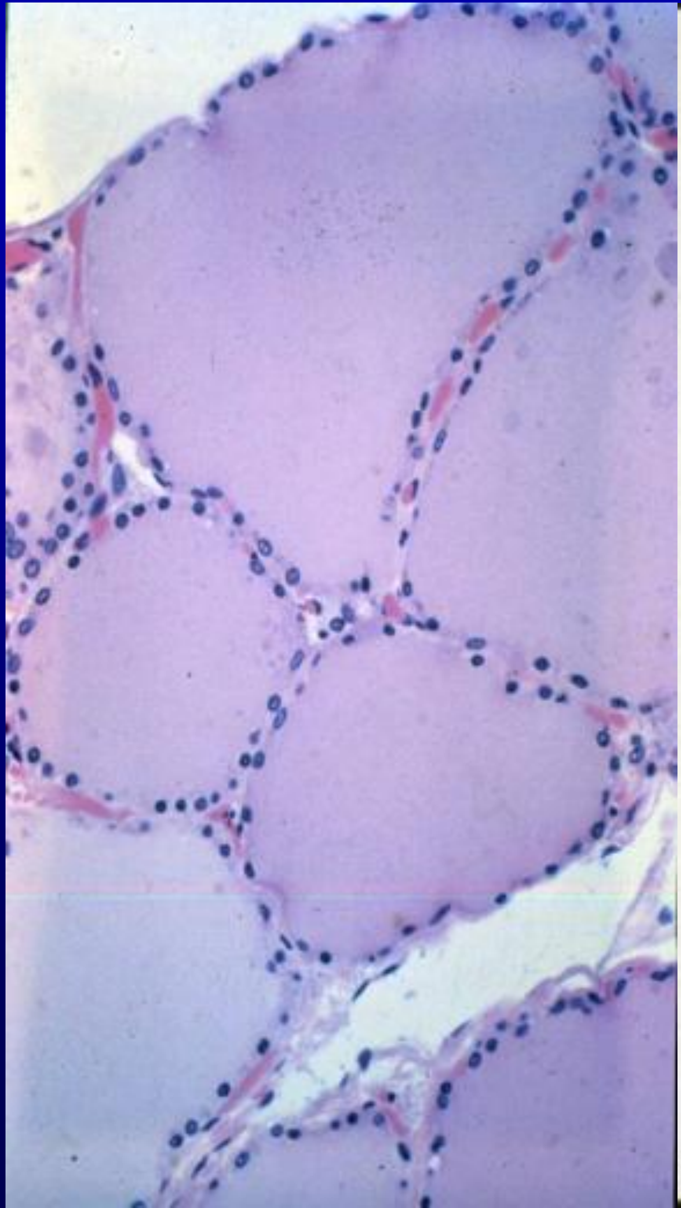
Fig. 8-20. Merocrine, apocrine and holocrine modes of secretion.

MEROCRINE SECRETION



Thyroid

Colloid stored secretory product (thyroglobulin)



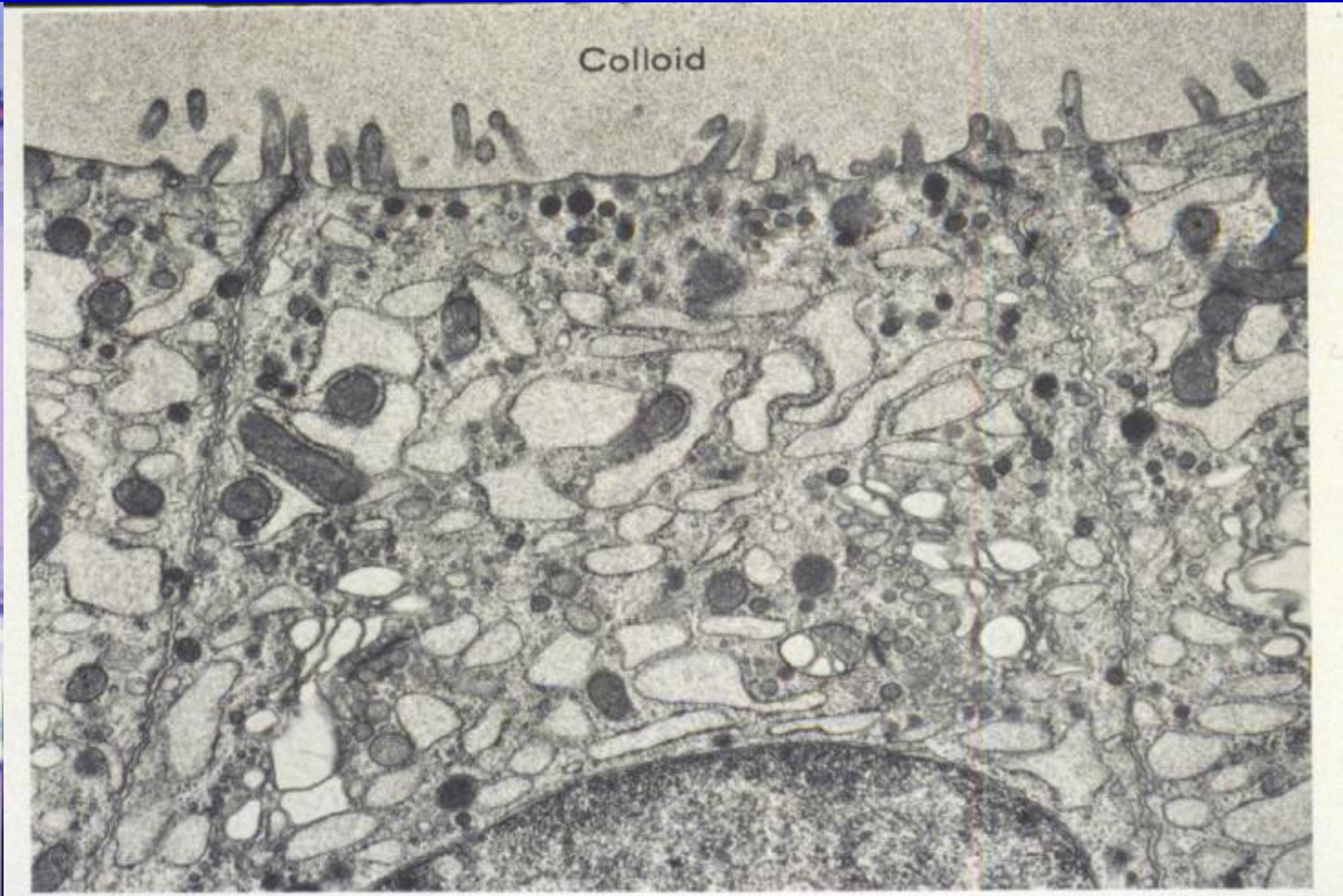
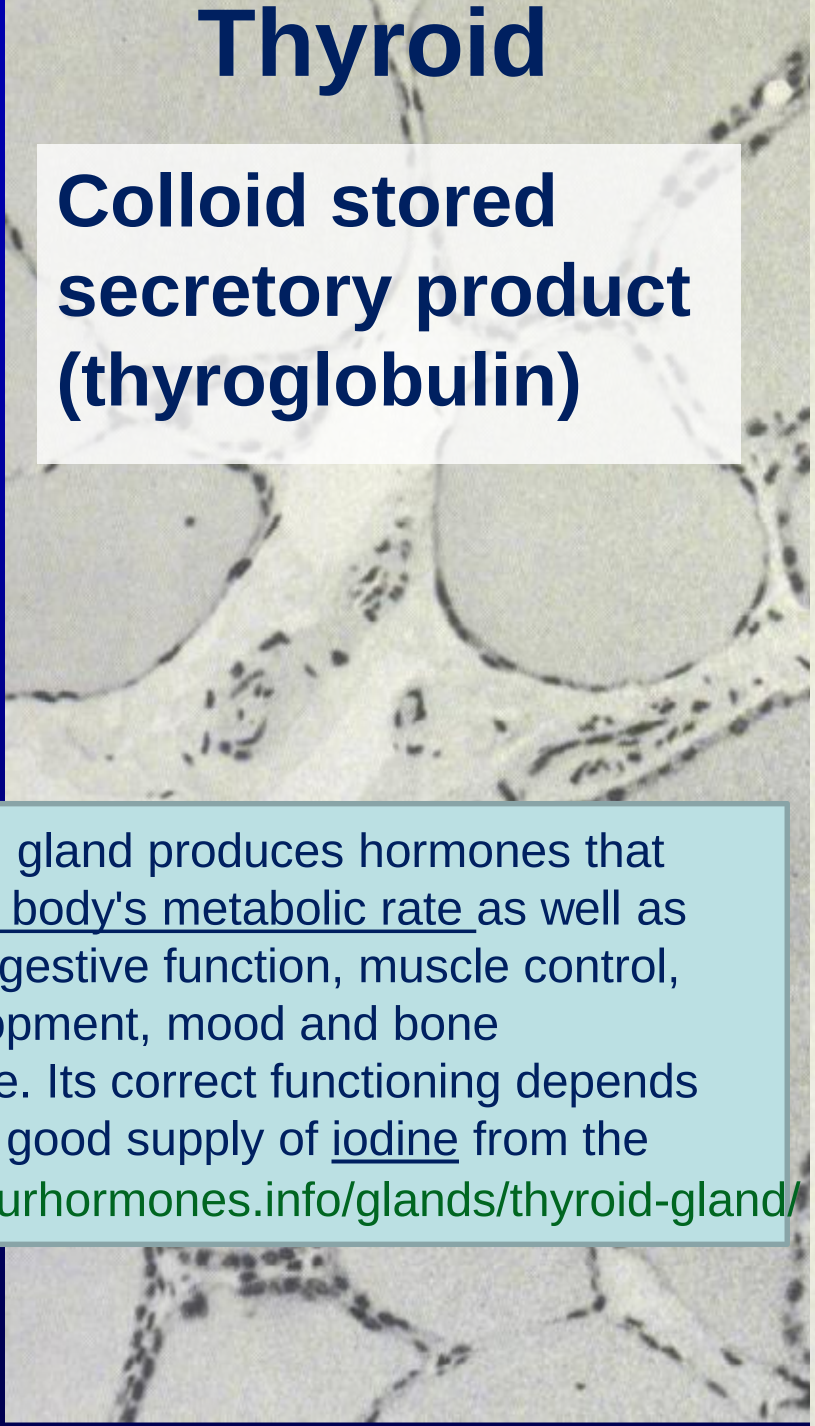


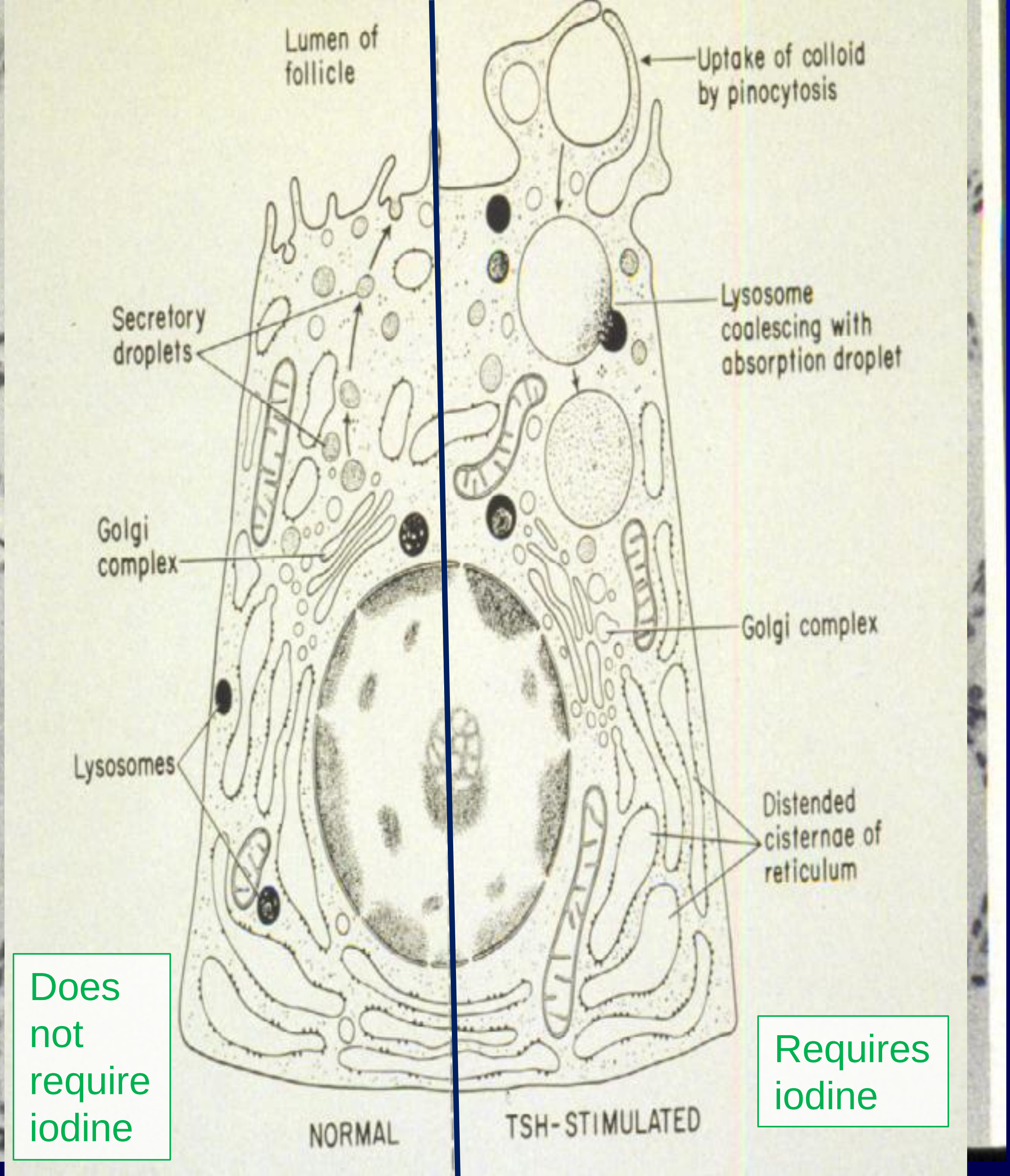
Figure 18–6. Electron micrograph of the apical half of an epithelial cell from rat thyroid gland. The free surface of the

Thyroid



Colloid stored secretory product (thyroglobulin)

The **thyroid** gland produces hormones that regulate the body's metabolic rate as well as heart and digestive function, muscle control, brain development, mood and bone maintenance. Its correct functioning depends on having a good supply of iodine from the diet.www.yourhormones.info/glands/thyroid-gland/



Does not require iodine

Requires iodine

Thyroid Gland Diseases

Goiter - accumulation of
thyroglobulin with
iodine deficiency

Graves disease –
hyperthyroidism
IgG immunoglobulin
with long-acting thyroid
stimulation

Figure 18–4. Section through several follicles of hu

Thyroid stimulating hormone (TSH)

Negative feedback

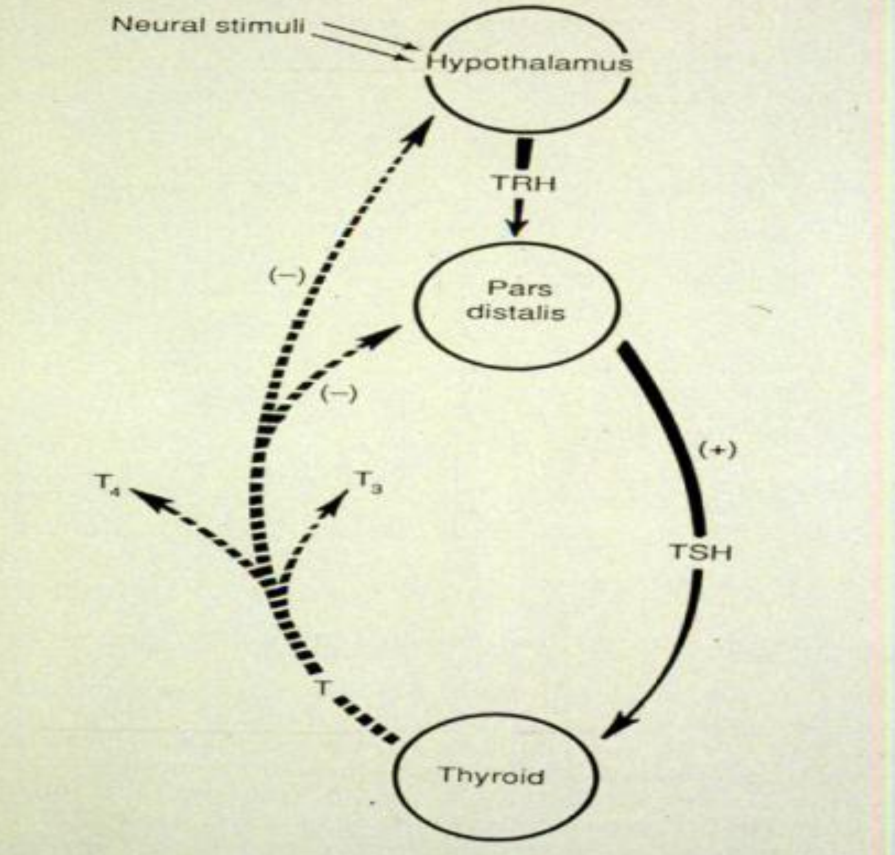


Figure 20–7. Relationship between the hypothalamus, the hypophysis, and the thyroid. Thyrotropin-releasing hormone (TRH) promotes secretion of thyrotropin (TSH), which regulates the synthesis and secretion of the...

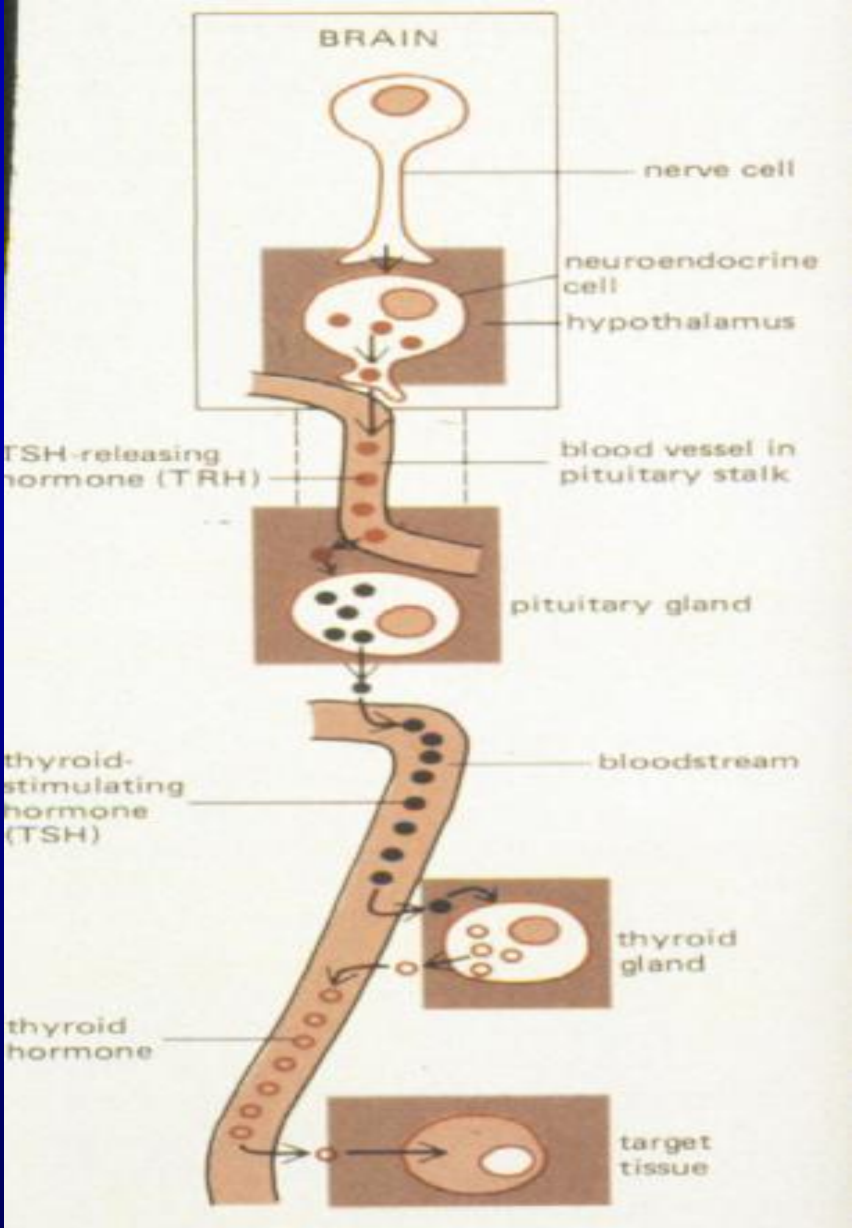
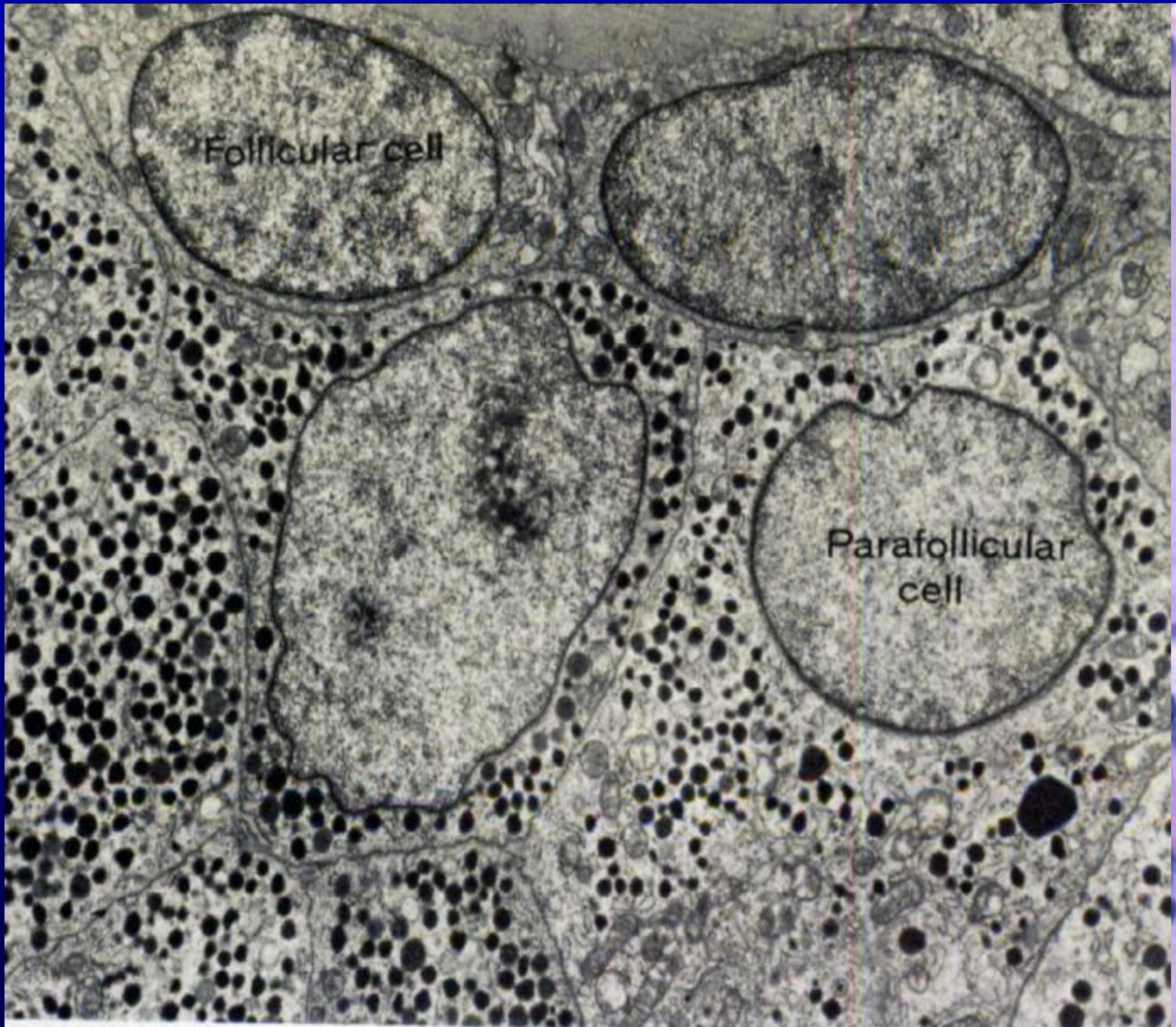


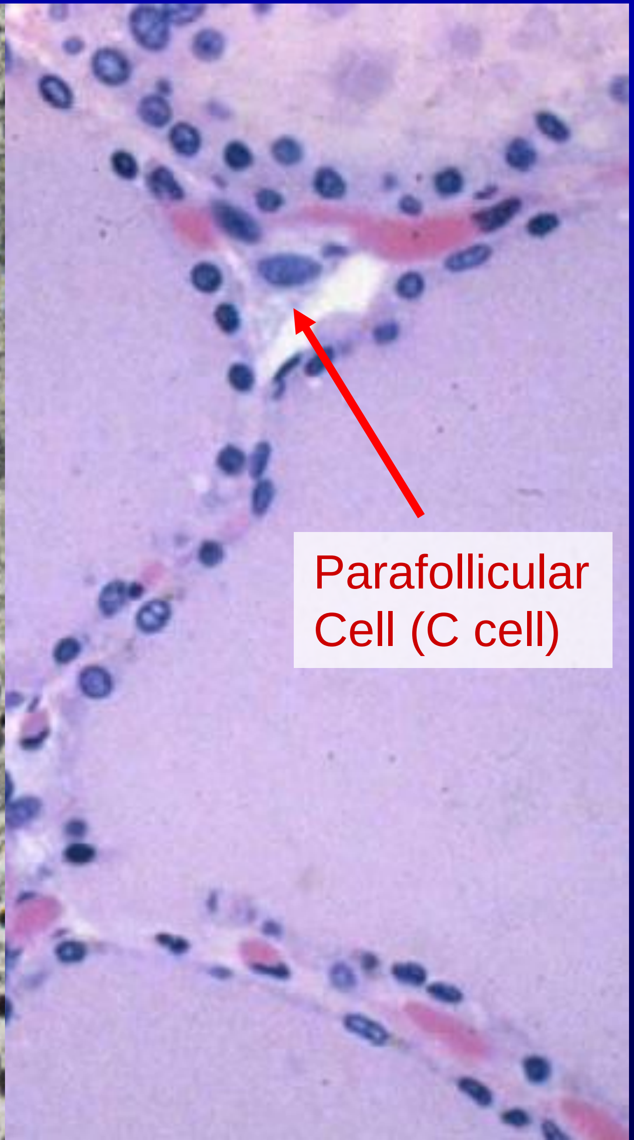
Figure 12–4 Thyroid hormone secretion is regulated indirectly by the nervous system. When stimulated by nerve cells in higher centers of the brain, specific neuroendocrine cells in the hypothalamus secrete TSH-releasing

Cell metabolism, heart and digestive function, muscle, brain, and bone

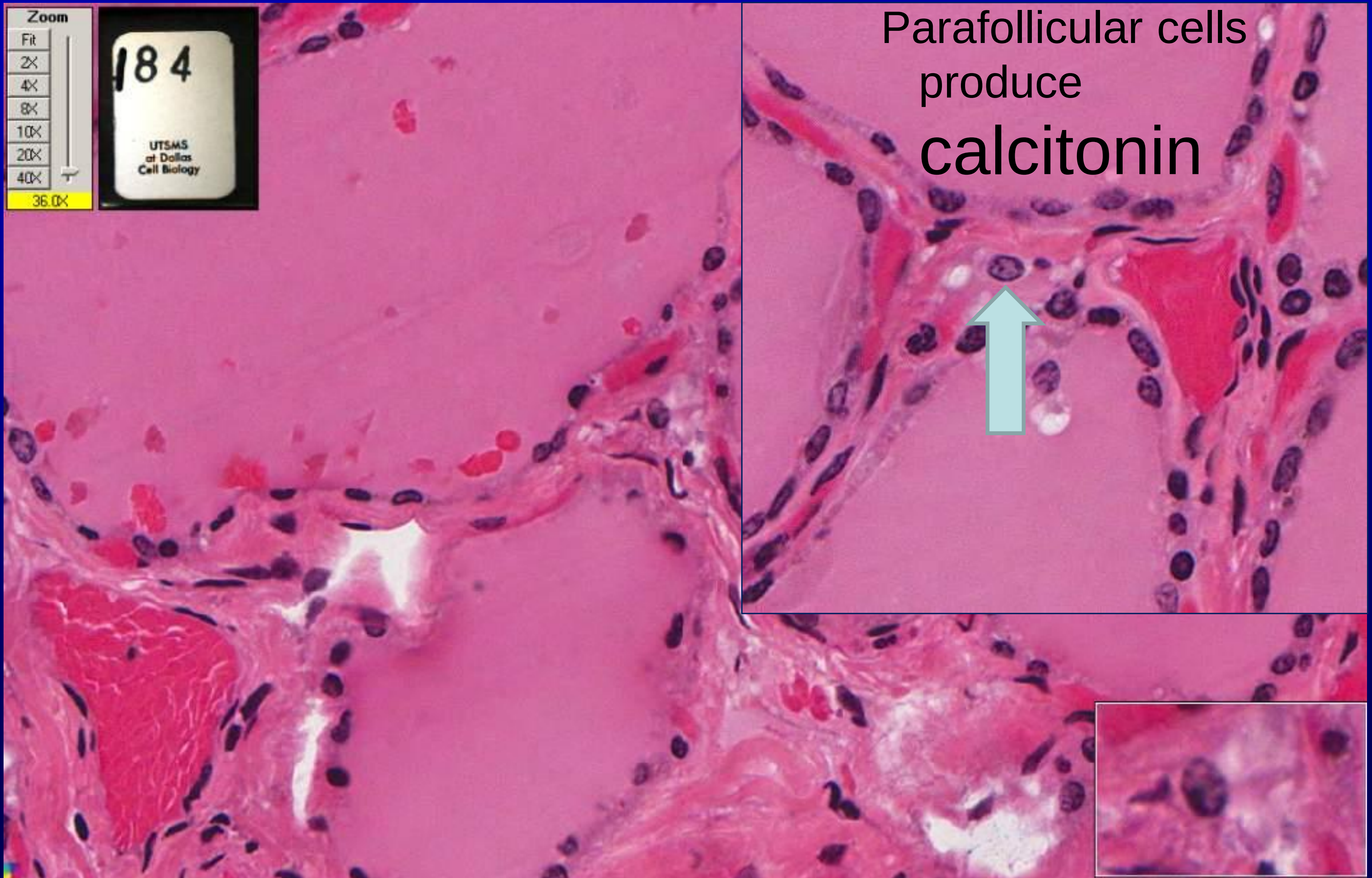
Parafollicular cells

Calcitonin





Thyroid –parafollicular cells



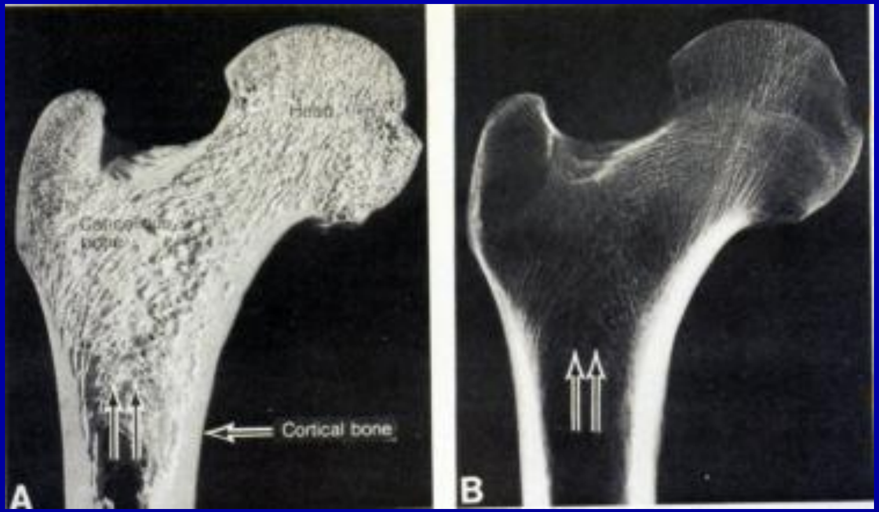
Functions of Bone

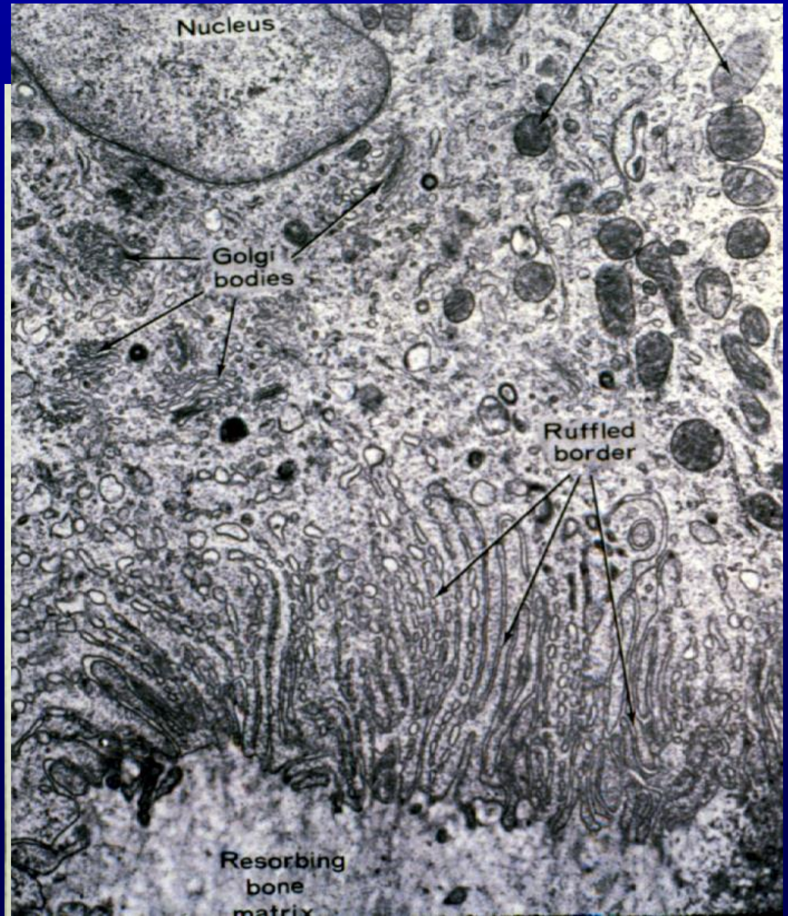
Calcium Regulation

- Parathyroid hormone (stimulates osteoclast production)

- Calcitonin (removes osteoclast's ruffled boarder which prevents resorption

- Remember that these hormones are involved in tight regulation of free Ca^{++} as 1/4 of free Ca^{++} in blood is exchanged each minute.





Endocrine secretions

Stored in granules

Stored extracellularly

Immediate release with no storage

pituitary

Protein in cell

thyroid

Thyroglobulin outside cell in colloid of follicle

adrenal

Steroid pass through cell

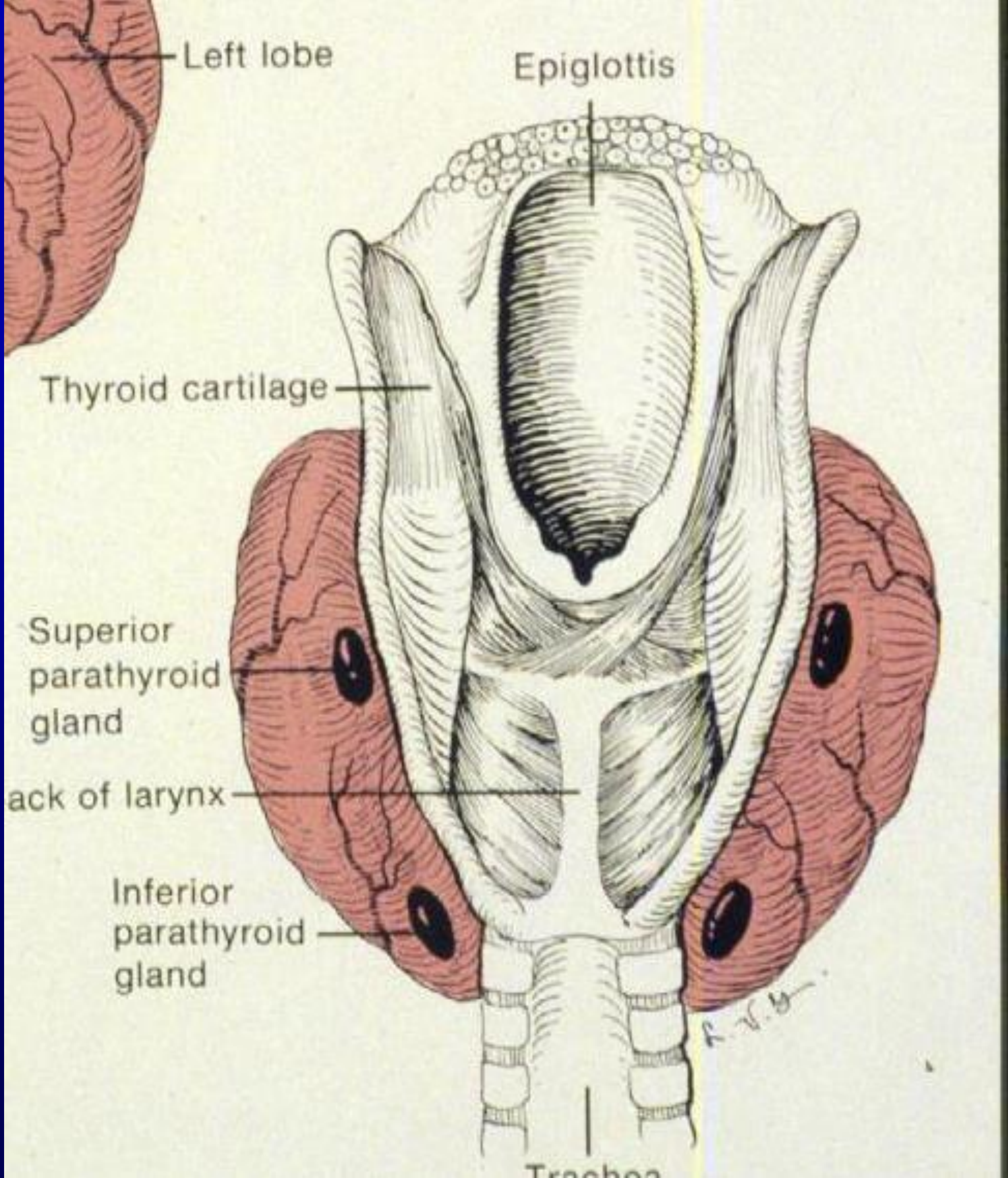
Parathyroid Gland

Gross anatomy

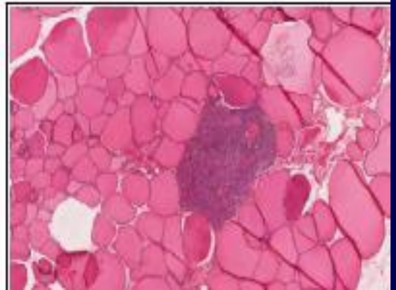
Physiological significance

Microanatomy

- <u>Chief cells</u>
  - Parathyroid hormone
  - Secretion control
- <u>Oxyphil cells</u>
  - function unknown

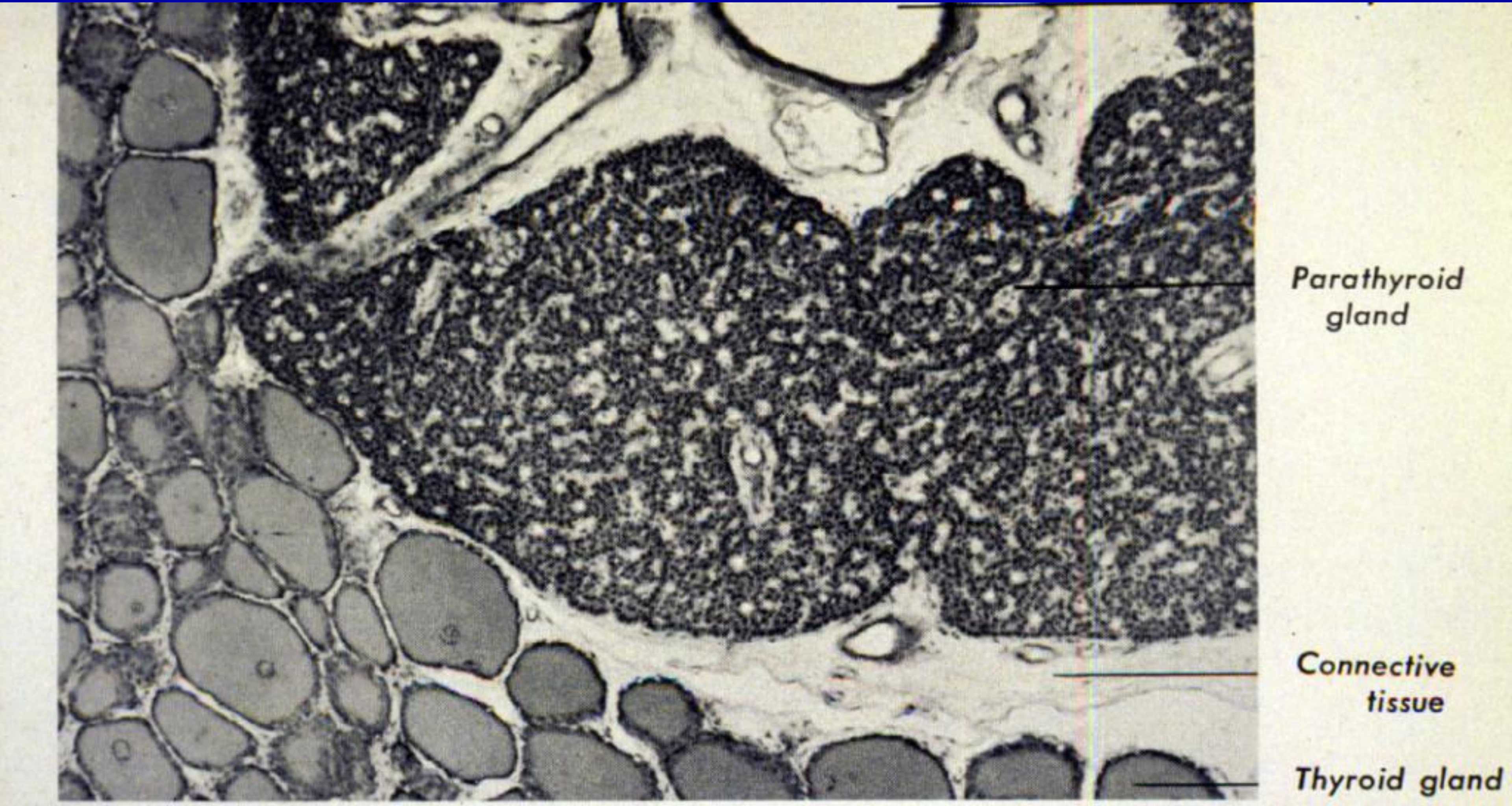


Parathyroid Gland



Parathyroid Gland

Microanatomy



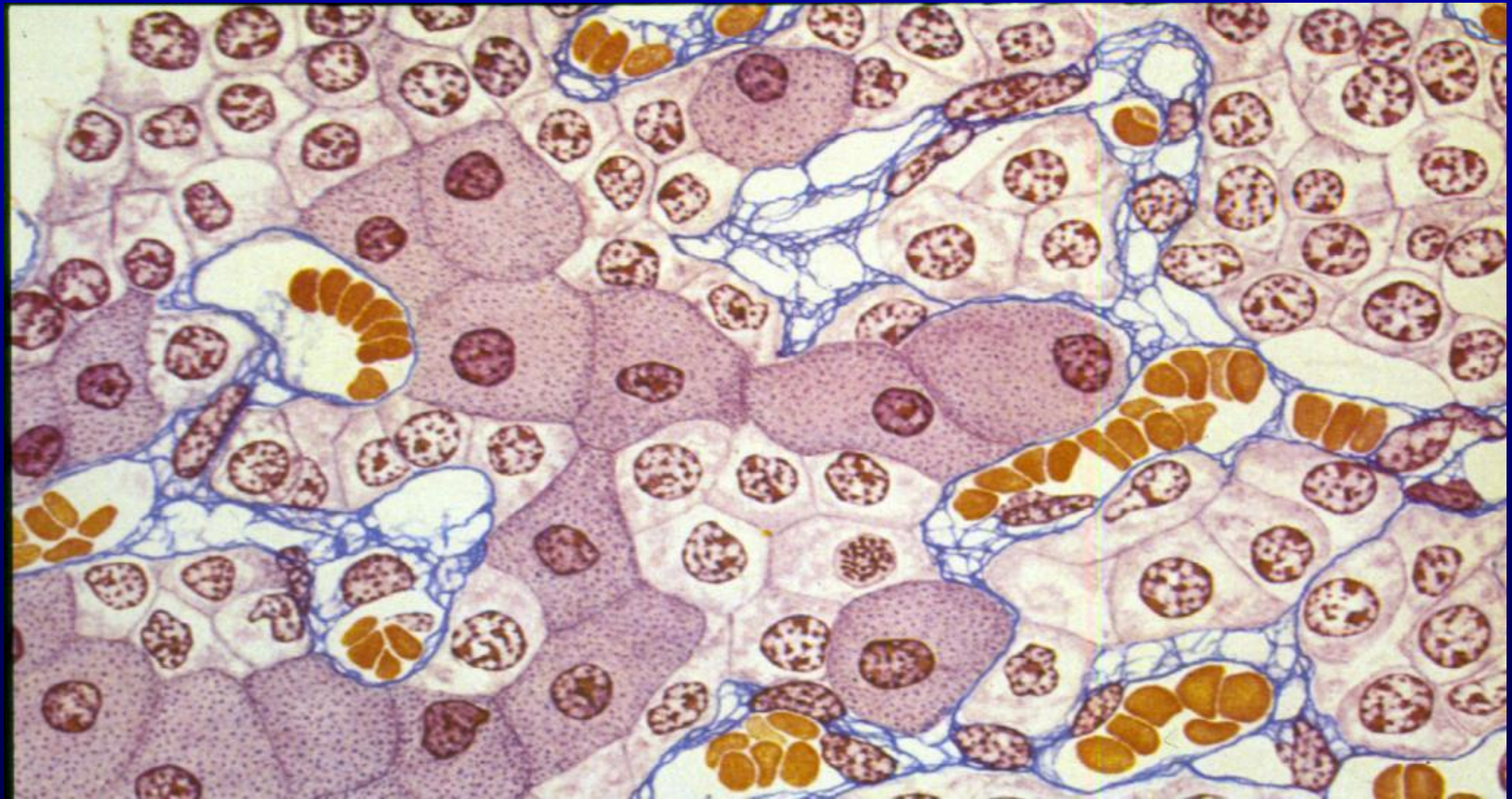
re 19–1. Photomicrograph of section of thyroid and parathyroid glands of *Macacus rhesu*

Chief cells of the Parathyroid Gland

Parathyroid Hormone

Secretion control

Oxyphil cells

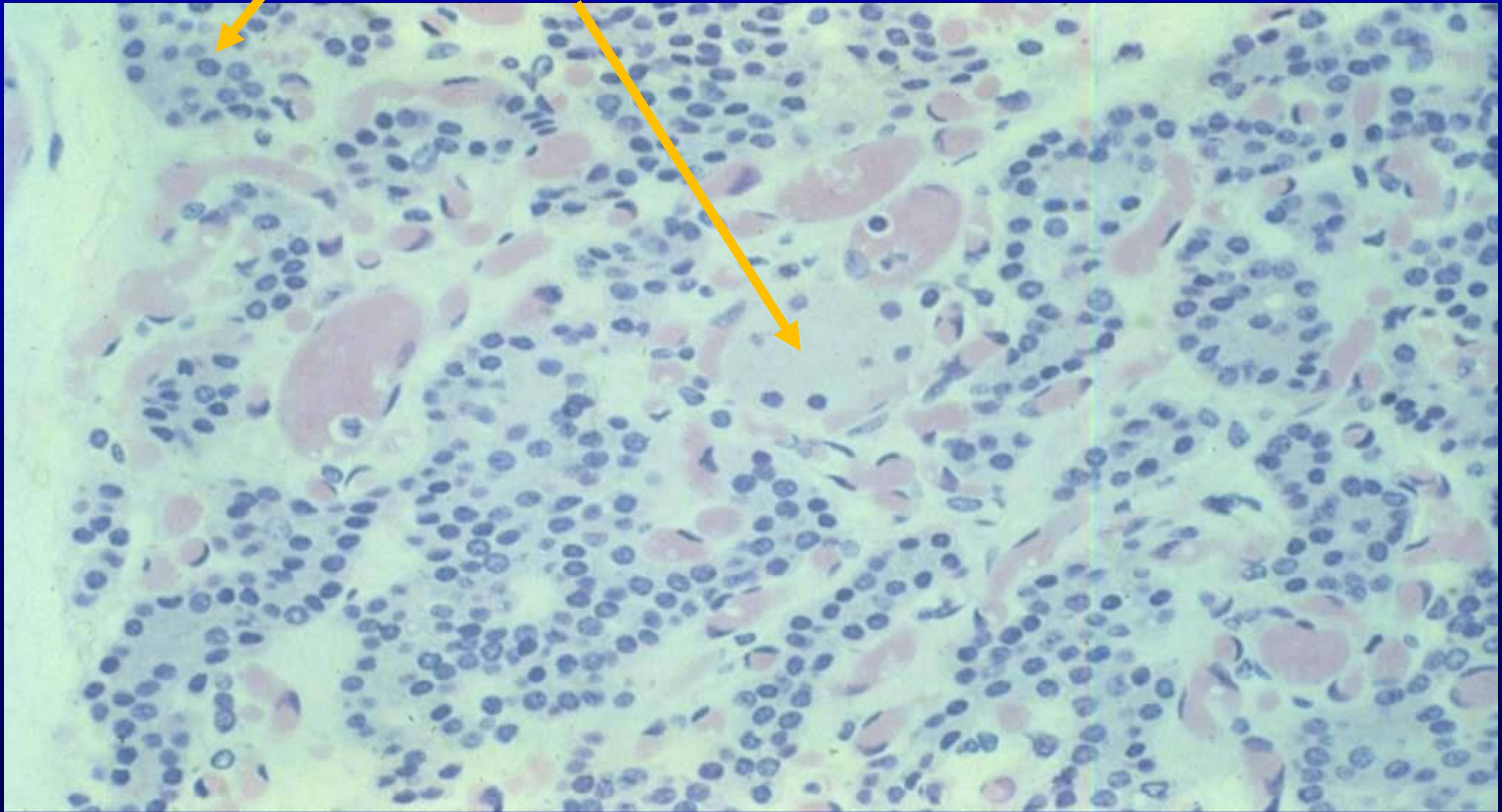


Chief cells of the parathyroid gland

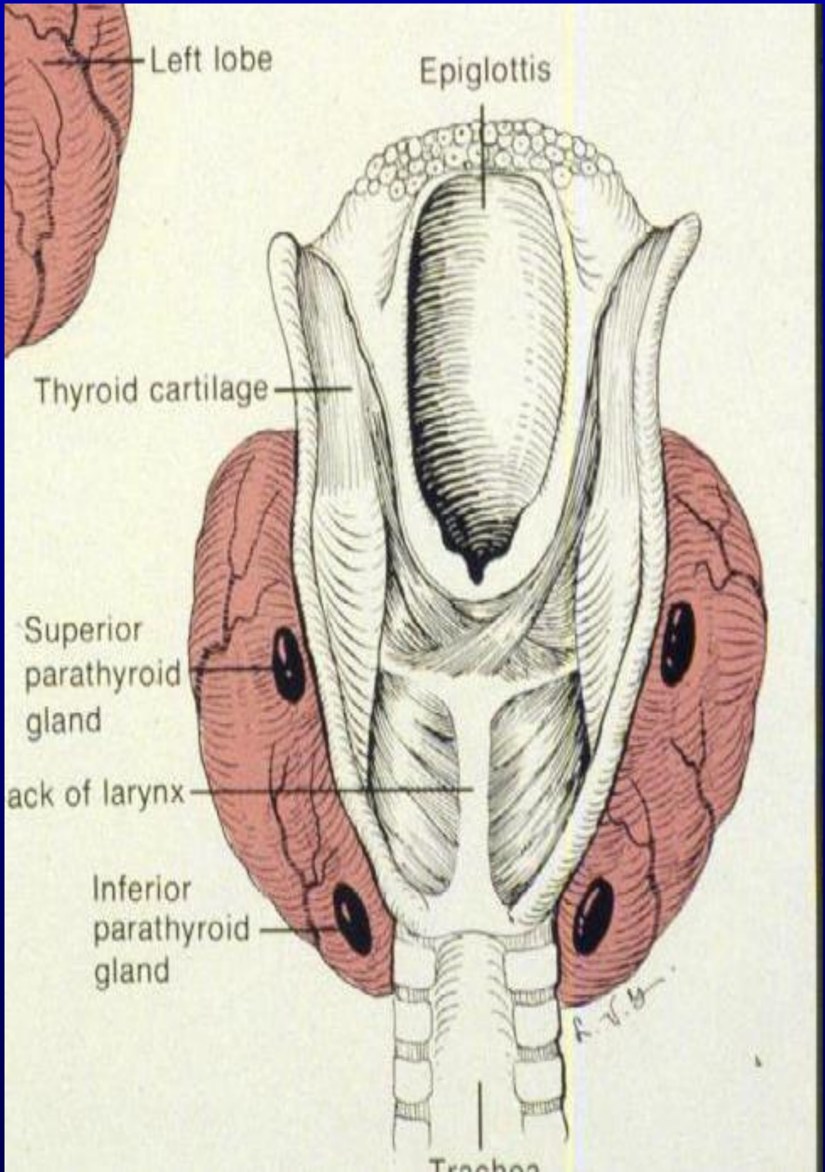
parathyroid hormone

secretion control

Oxyphil cells



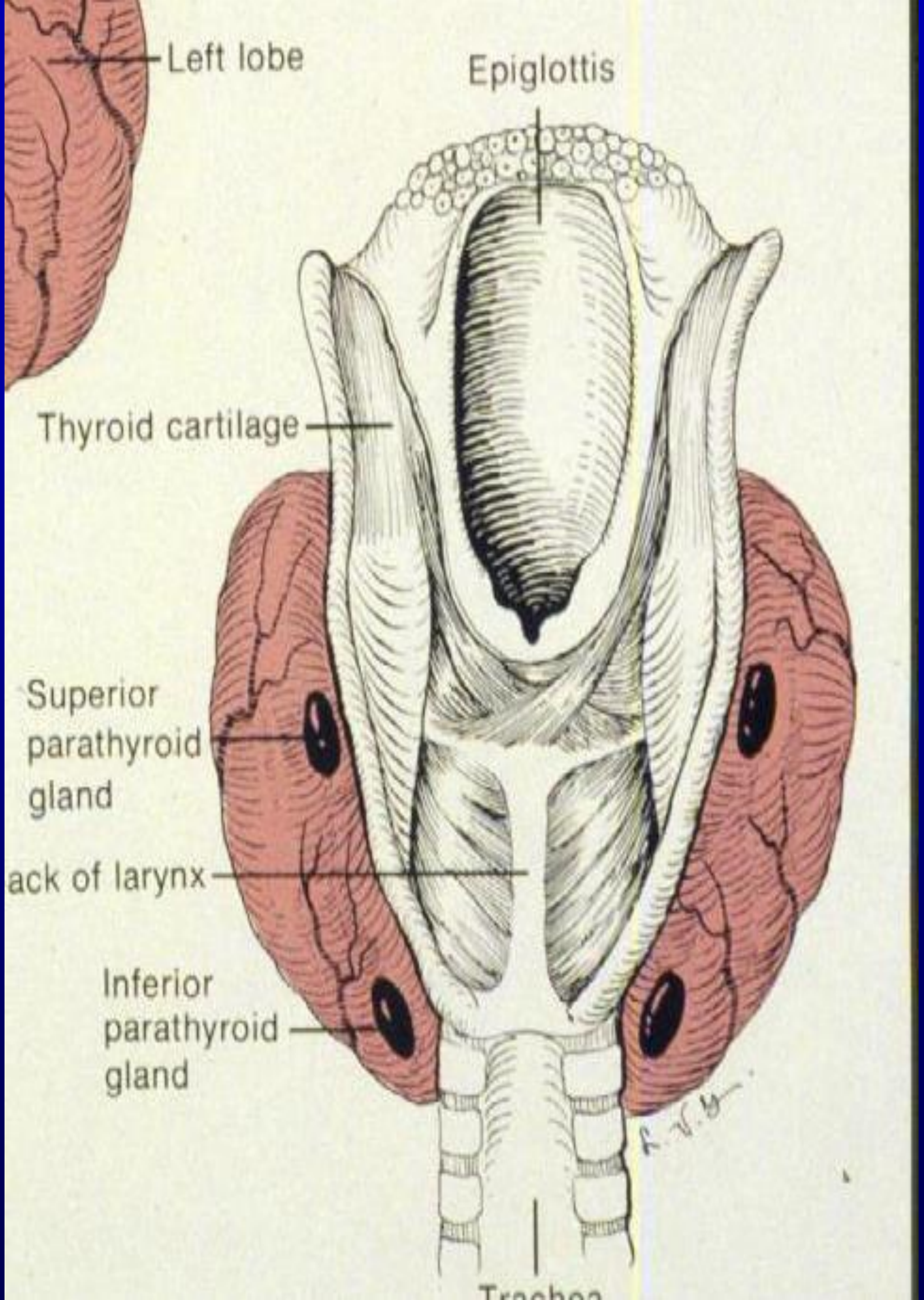
Parathyroid Gland



e 19–5. Photomicrograph of parathyroid glan
ey injected intravenously with India ink to show

Parathyroid Glands

- Parathyroid hormone (PTH) acts on
  - bones (*osteocytes / osteoclasts*), kidneys (*increase reabsorption of distal tubules*), and intestines (*increase calcium absorption*) to maintain tight control of calcium concentrations in the extracellular fluid (8.5 – 10.5 mg/100 ml).
- Calcium necessary for muscle contractions, glandular secretions, blood coagulation, and key enzymes of intermediary metabolism.
- Removal of gland results in violent spasm of skeletal muscle (tetany) and ultimately death.

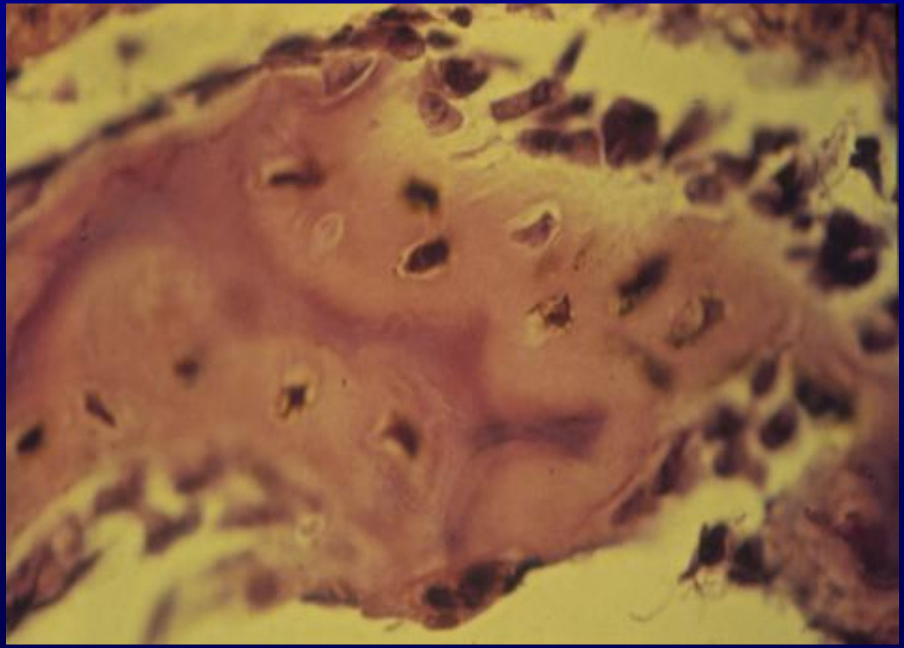


Parathyroid Glands

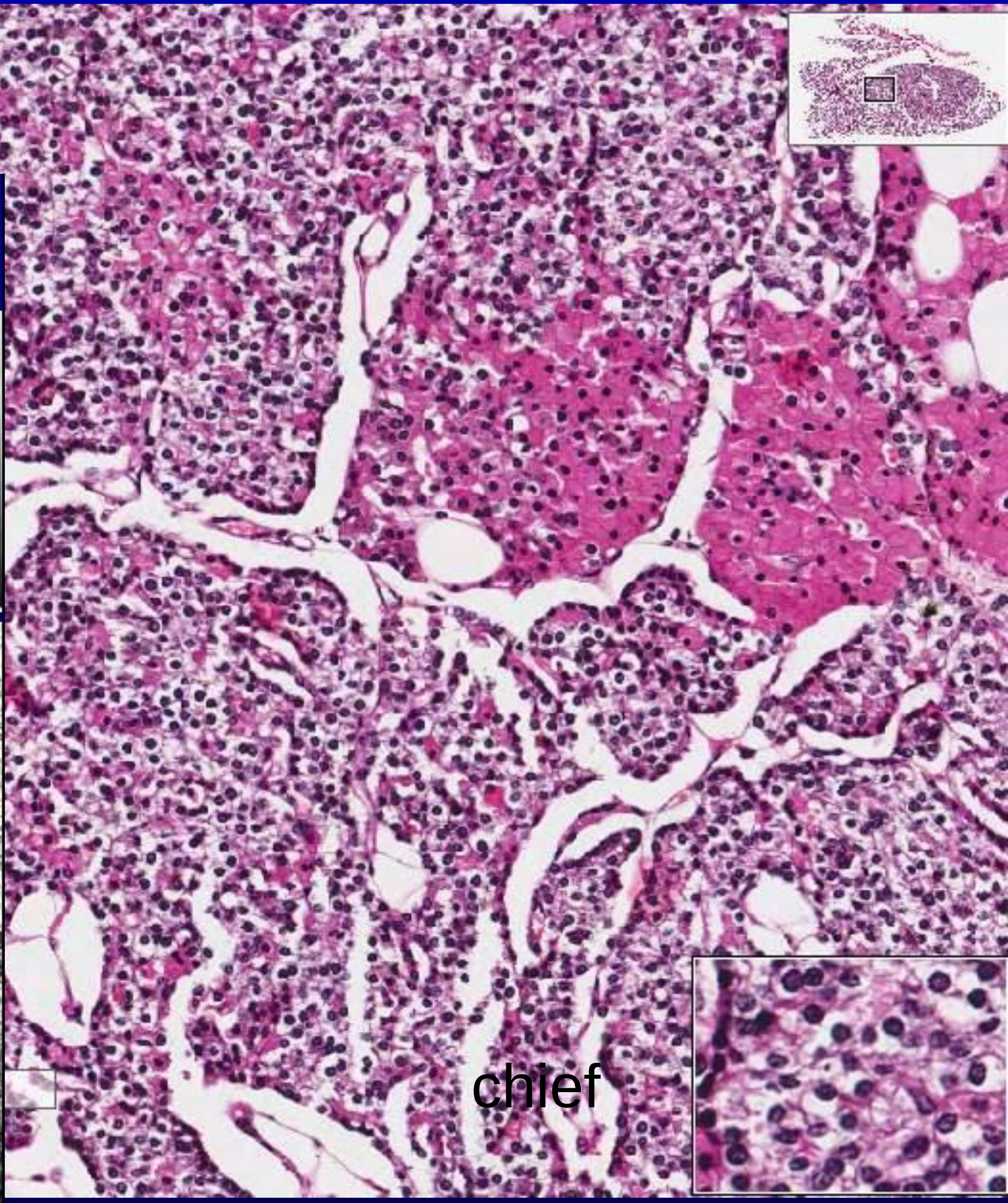
Parathyroid hormone (PTH) acts on bones

Osteocytic osteolysis: mobilize calcium by osteocytes – increase calcium concentrations in minutes

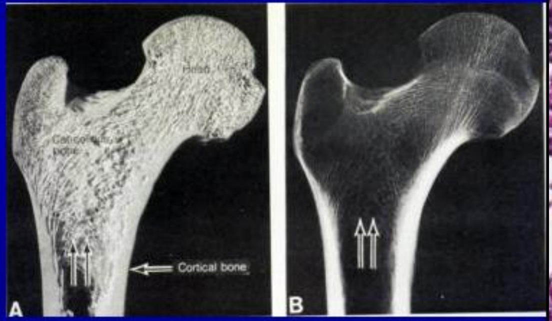
Osteoclastic bone resorption: caused by prolonged hypocalcemia – coalescence of precursor cells to form additional osteoclasts– many hours to reach effective levels of calcium released



Parathyroid – chief cells



Functions of Bone



Calcium Regulation

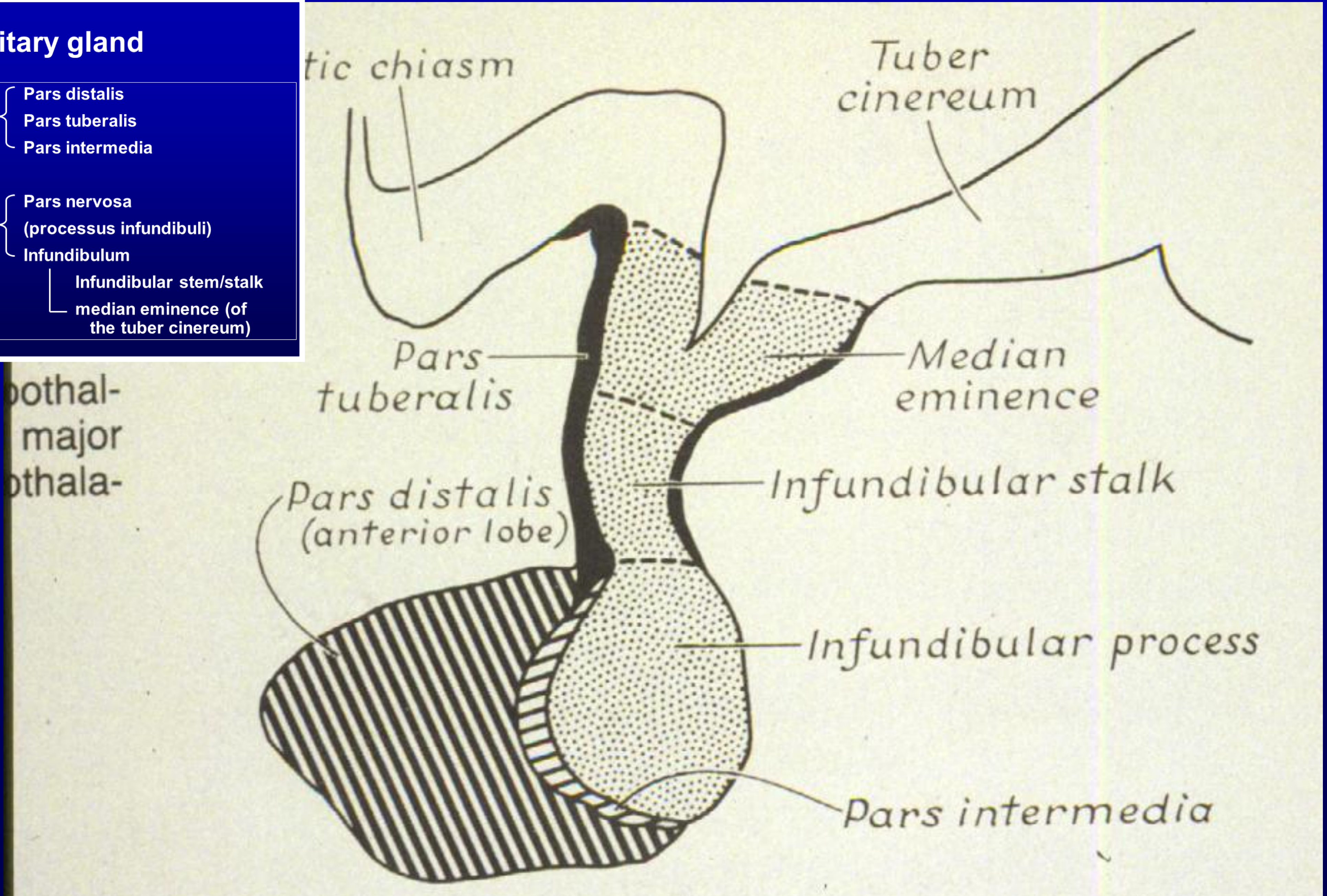
- **Parathyroid hormone (stimulates osteoclast production)**
- **Calcitonin (removes osteoclast's ruffled boarder which prevents resorption**
- **Remember that these hormones are involved in tight regulation of free Ca^{++} as 1/4 of free Ca^{++} in blood is exchanged each minute.**

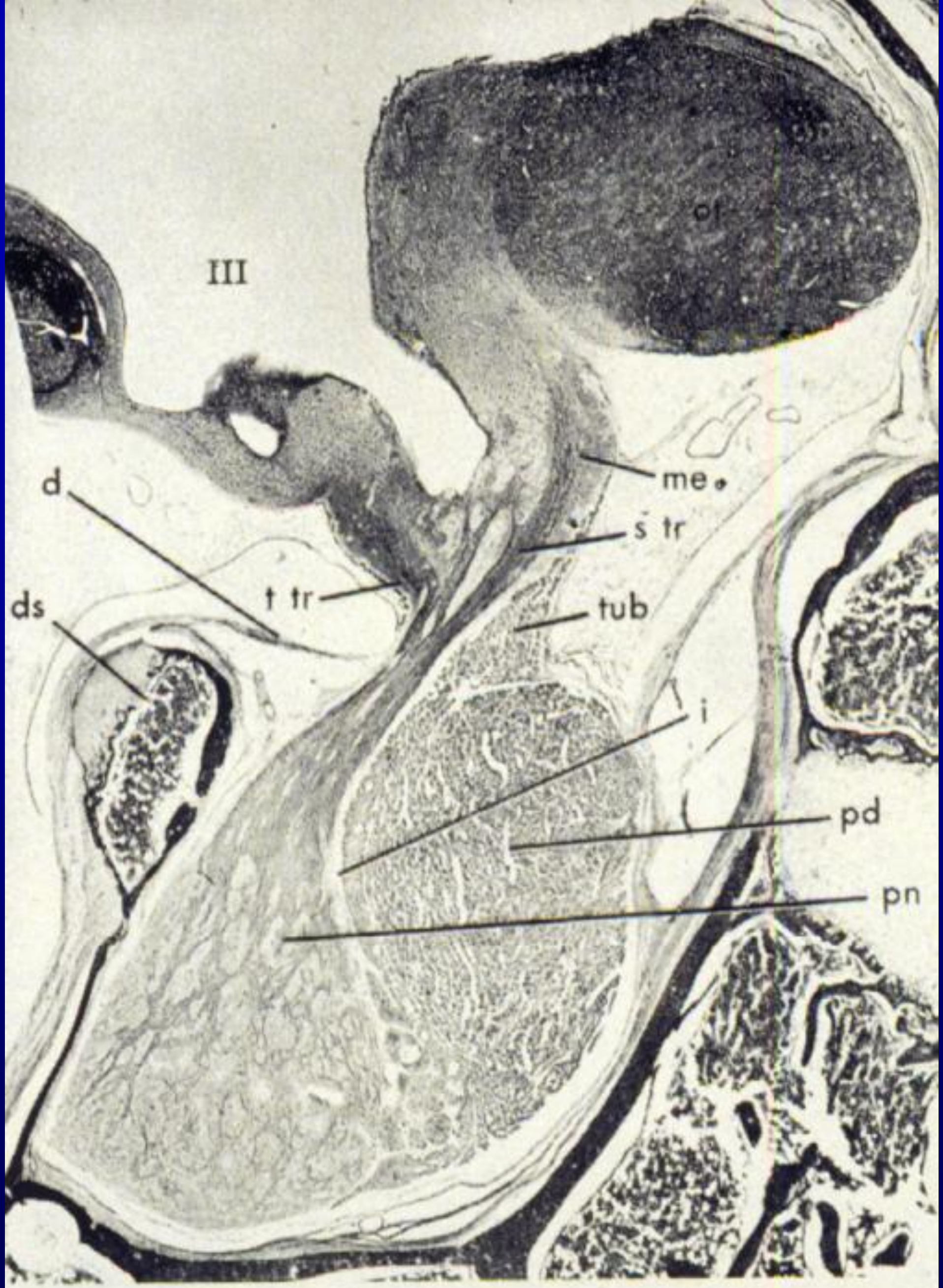
Osteoporosis due to hyperparathyroidism

Adenohypophysis **Pituitary Gland** Neurohypophysis

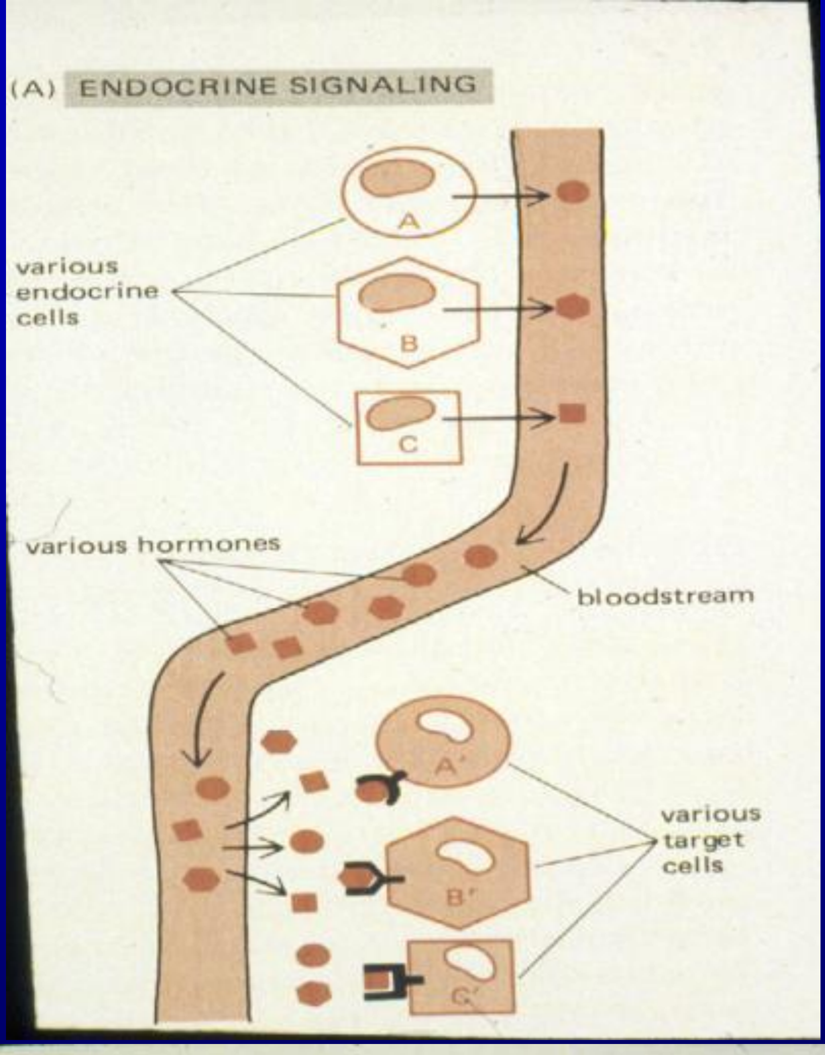
Pituitary gland

- **Adenohypophysis**
  - Pars distalis
  - Pars tuberalis
  - Pars intermedia
- **Neurohypophysis**
  - Pars nervosa (processus infundibuli)
  - Infundibulum
    - Infundibular stem/stalk
    - median eminence (of the tuber cinereum)





29–14 The primate neurohypophysis. Sagittal section of the neurohypophysis of a



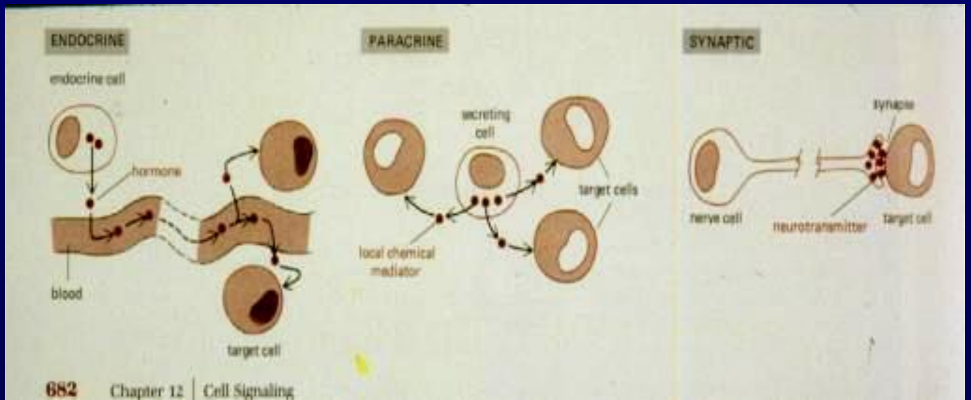


Table 20–1. Secretory cells of the pars distalis.

Cell Type	Stain Affinity	Hormone Produced	Main Physiologic Activity	Secretory Granules in Humans	Hypothalamic Releasing Hormones	Hypothalamic Inhibiting Hormones
Somatotropic cell	Acidophilic	Somatotropin (growth hormone).	Acts on growth of long bones via somatomedins synthesized in liver.	Numerous, round or oval; 300–400 nm diameter.	Somatotropin-releasing hormone (SRH).	Somatostatin.
Mammotropic cell	Acidophilic	Prolactin.	Promotes milk secretion.	200 nm; increases in size during pregnancy and lactation (600 nm).	Prolactin-releasing hormone (PRH).	Prolactin-inhibiting hormone (PIH).
Gonadotropic cell	Basophilic	Follicle-stimulating hormone (FSH) and luteinizing hormone (LH) in same cell type.	FSH promotes ovarian follicle development and estrogen secretion in female and stimulates spermatogenesis in male. LH promotes ovarian follicle maturation and progesterone secretion in female, Leydig cell stimulation and androgen secretion in male.	250–400 nm.	Gonadotropin-releasing hormone (GnRH). According to some authors there are 2 releasing hormones: FRH and LRH (follicle- and lutein-releasing, respectively).	
Thyrotropic cell	Basophilic	Thyrotropin (TSH).	Stimulates thyroid hormone synthesis, storage, and liberation.	Small granules, 120–200 nm.	Thyrotropin-releasing hormone (TRH).	
Corticotropic cell	Basophilic	Corticotropin (ACTH).	Stimulates secretion of adrenal cortex hormones.	Large granules, 400–550 nm.	Corticotropin-releasing hormone (CRH).	

Next time

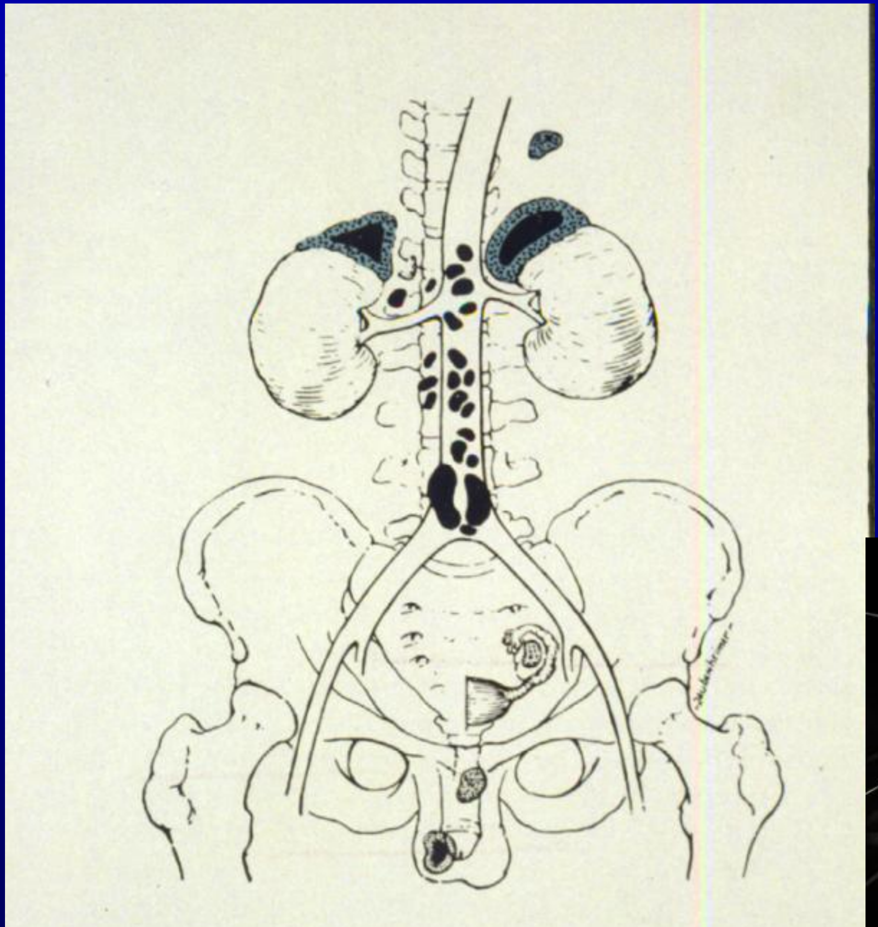
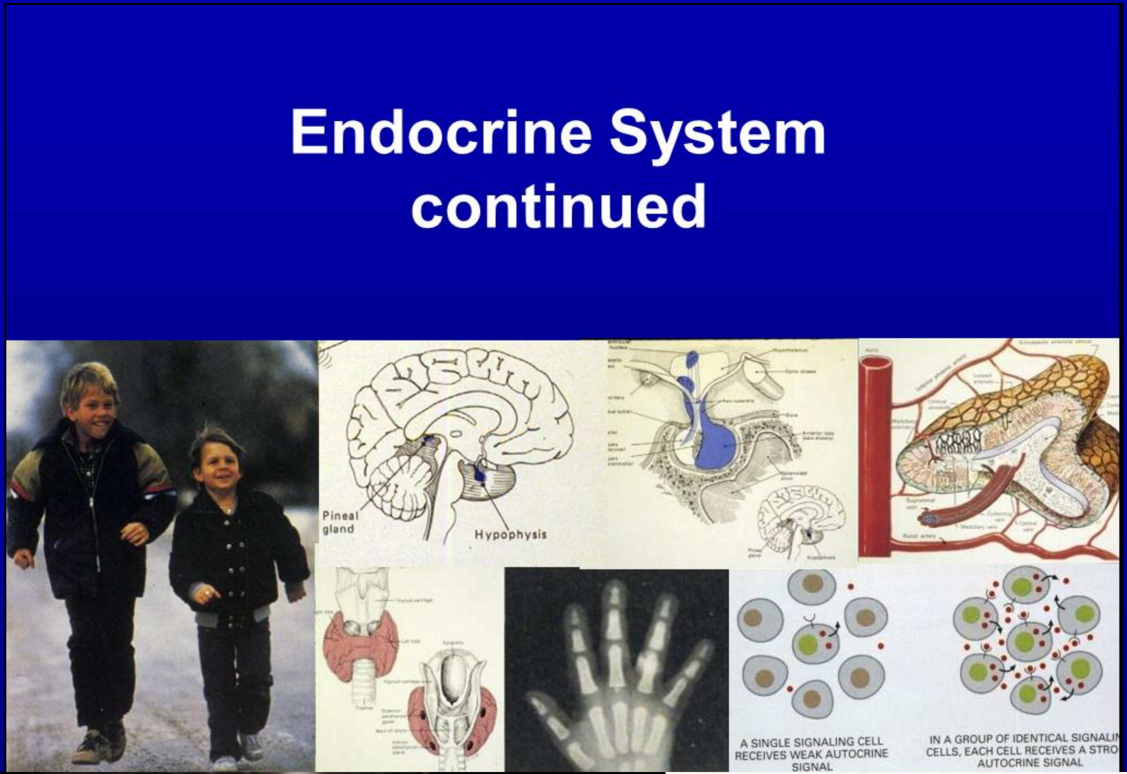
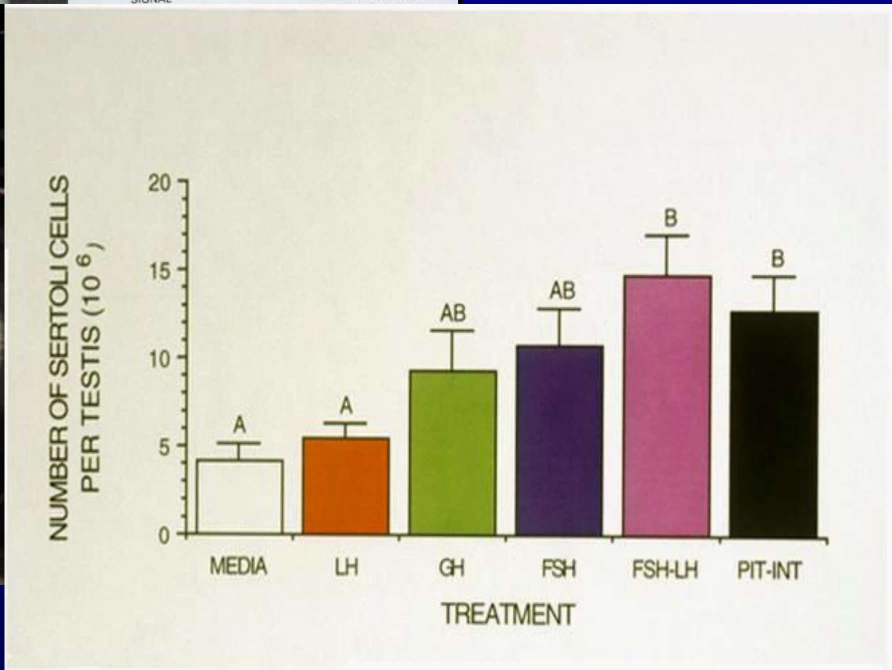


Figure 21–1. Human adrenal glands. Adrenocortical tis-
sue is shown stippled; adrenal medullary tissue is shown
black. Note the location of adrenals at the superior pole of
each kidney. Also shown are extra-adrenal sites where
cortical and medullary tissues are sometimes found. (Re-





Many illustrations in these VIBS Histology YouTube videos were modified from the following books and sources: Many thanks to original sources!

- Bruce Alberts, et al. 1983. Molecular Biology of the Cell. Garland Publishing, Inc., New York, NY.
- Bruce Alberts, et al. 1994. Molecular Biology of the Cell. Garland Publishing, Inc., New York, NY.
- William J. Banks, 1981. Applied Veterinary Histology. Williams and Wilkins, Los Angeles, CA.
- Hans Elias, et al. 1978. Histology and Human Microanatomy. John Wiley and Sons, New York, NY.
- Don W. Fawcett. 1986. Bloom and Fawcett. A textbook of histology. W. B. Saunders Company, Philadelphia, PA.
- Don W. Fawcett. 1994. Bloom and Fawcett. A textbook of histology. Chapman and Hall, New York, NY.
- Arthur W. Ham and David H. Cormack. 1979. Histology. J. S. Lippincott Company, Philadelphia, PA.
- Luis C. Junqueira, et al. 1983. Basic Histology. Lange Medical Publications, Los Altos, CA.
- L. Carlos Junqueira, et al. 1995. Basic Histology. Appleton and Lange, Norwalk, CT.
- L.L. Langley, et al. 1974. Dynamic Anatomy and Physiology. McGraw-Hill Book Company, New York, NY.
- W.W. Tuttle and Byron A. Schottelius. 1969. Textbook of Physiology. The C. V. Mosby Company, St. Louis, MO.
- Leon Weiss. 1977. Histology Cell and Tissue Biology. Elsevier Biomedical, New York, NY.
- Leon Weiss and Roy O. Greep. 1977. Histology. McGraw-Hill Book Company, New York, NY.
- Nature (http://www.nature.com), Vol. 414:88,2001.
- A.L. Mescher 2013 Junqueira's Basis Histology text and atlas, 13th ed. McGraw
- Internet images and videos on biological presentations

Gunther von Hagens' BODY WORLDS The Anatomical Exhibition of Real Human Bodies

Library
of Congress


IBRARY OF CONGRESS


LIBRARY OF CONGRESS