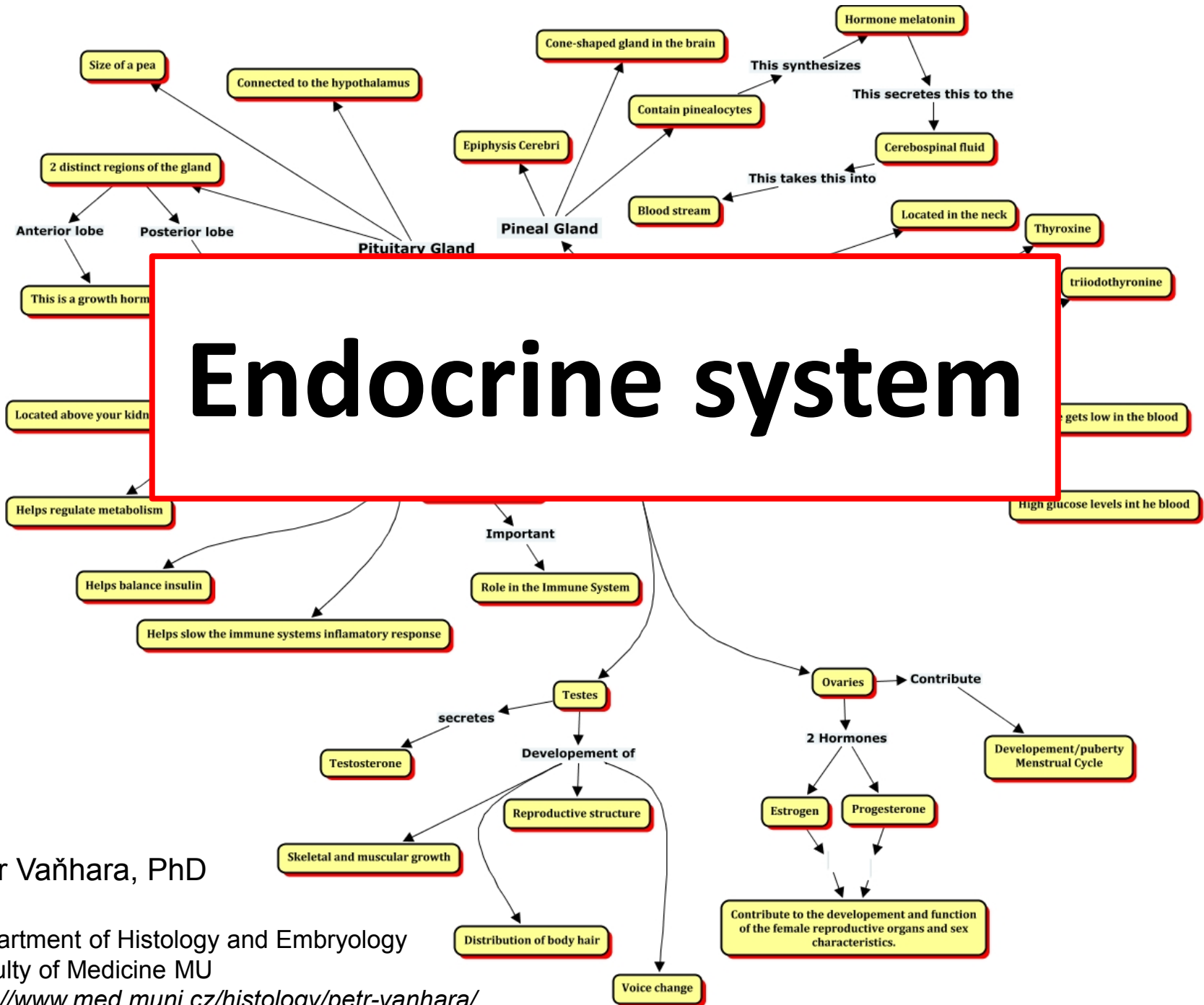
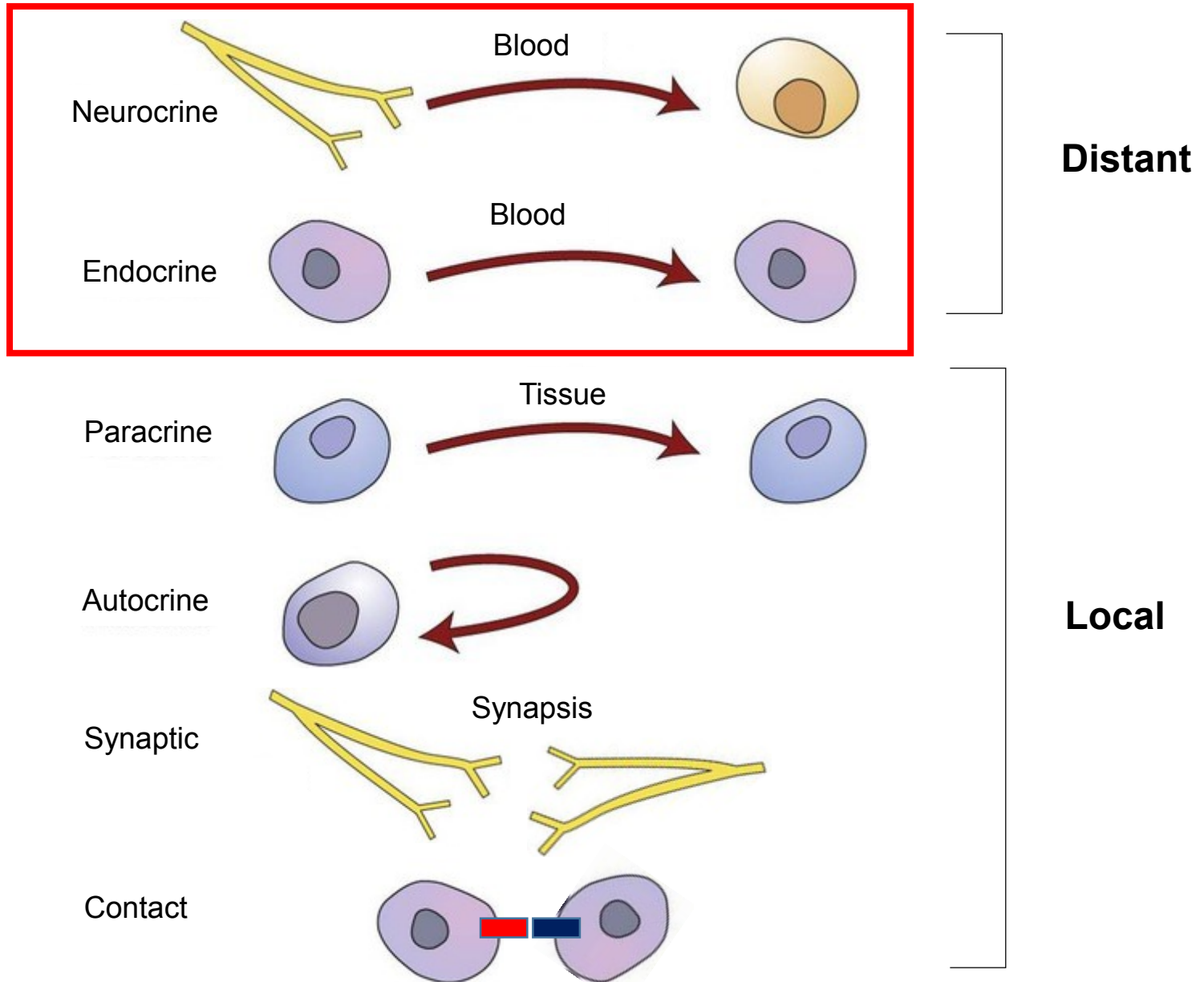


Endocrine system



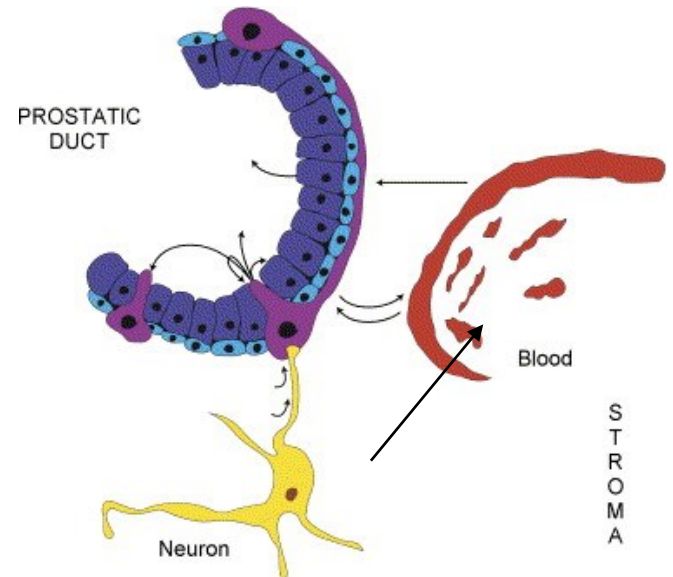
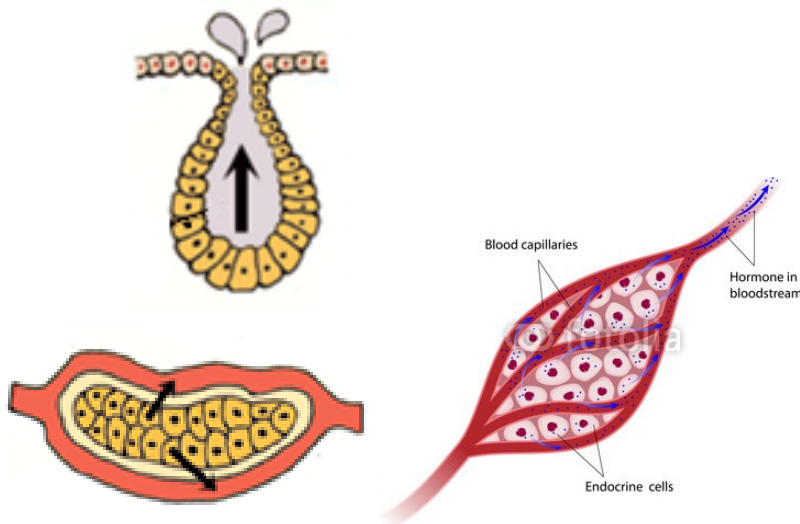
Petr Vaňhara, PhD
Department of Histology and Embryology
Faculty of Medicine MU
<http://www.med.muni.cz/histology/petr-vanhara/>

Intercellular communication



General properties of endocrine organs

- **Endocrine organs** (e.g. pituitary, thyroid, parathyroid, adrenal)
- **Endocrine tissue within other organs**
(pancreas, gonads, kidneys, placenta)
- **Isolated endocrine cells** (DNES, APUD)
- **Neuroendocrine cells**
- **Common developmental scheme**
 - invagination of epithelia, contact with original tissue lost during development
 - absence of exocrine ducts



General properties of endocrine organs

- C.t. capsule + septs
- Trabecules of glandular epithelium, follicles or clusters of glandular cells

or

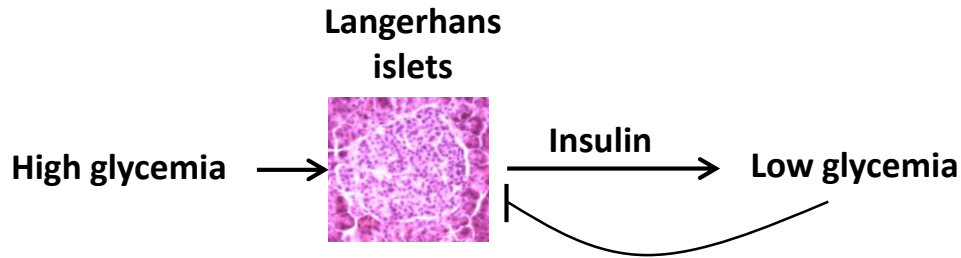
- Neurosecretory cells

- Capillary network
 - Fenestrated capillaries
 - Sinusoids

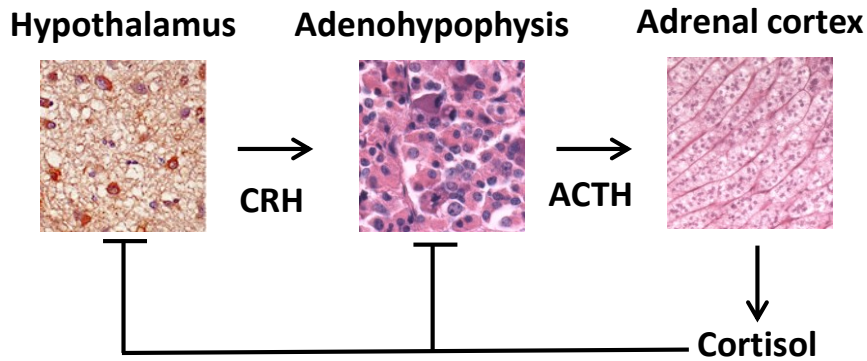
- Merocrine secretion
 - not only hormones – endocrine gland is *sensu lato* also liver

Regulation of hormone secretion

1. Negative feedback by change of metabolic state

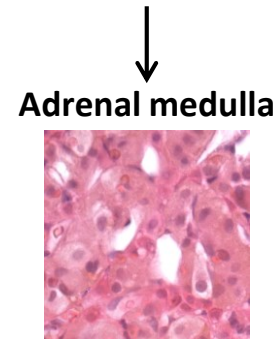


2. Negative feedback by increased concentration of secreted hormone



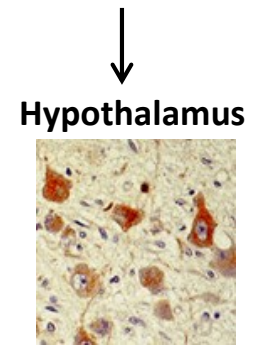
3. Nerve system – direct innervation

CNS (sympathicus)



Adrenalin

CNS



Neurohypophysis

ADH

General properties of hormones

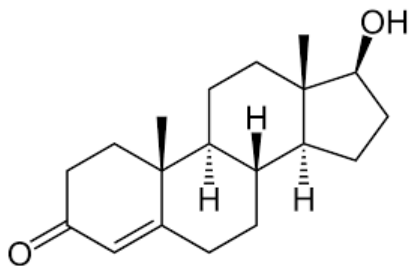
- hormones are chemical messengers delivered by bloodstream to target cells and tissues
- chemical nature of hormone determines its function

- classification
 - **water soluble**
 - **water insoluble**

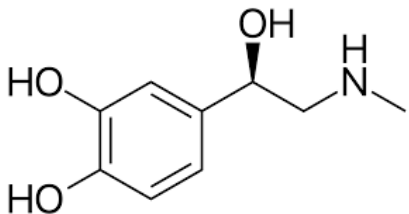
 - **surface receptors**
 - **nuclear receptors**

General properties of hormones

- **steroids** – hydrophobic, intracytoplasmic or nuclear receptors (sex hormones, corticoids)
- **proteins and polypeptides** – hydrophilic, plasma membrane receptors (insulin, pituitary hormones, PTH, ...)
- **aminoacids** and their amine derivatives (adrenalin, noradrenalin, thyroxin)

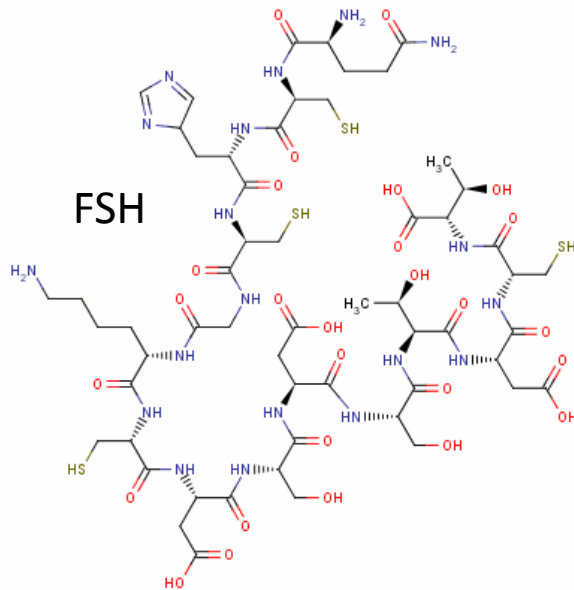


Testosterone

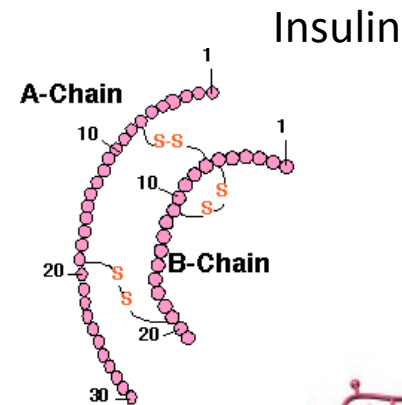


Adrenaline

4-[(1R)-1-hydroxy-2-(methylamino)ethyl]benzene-1,2-diol

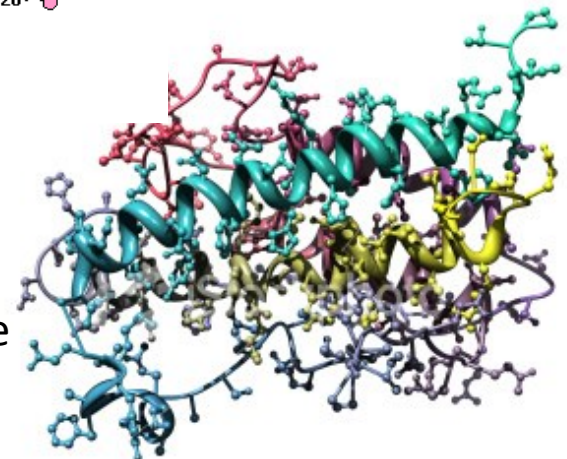


FSH

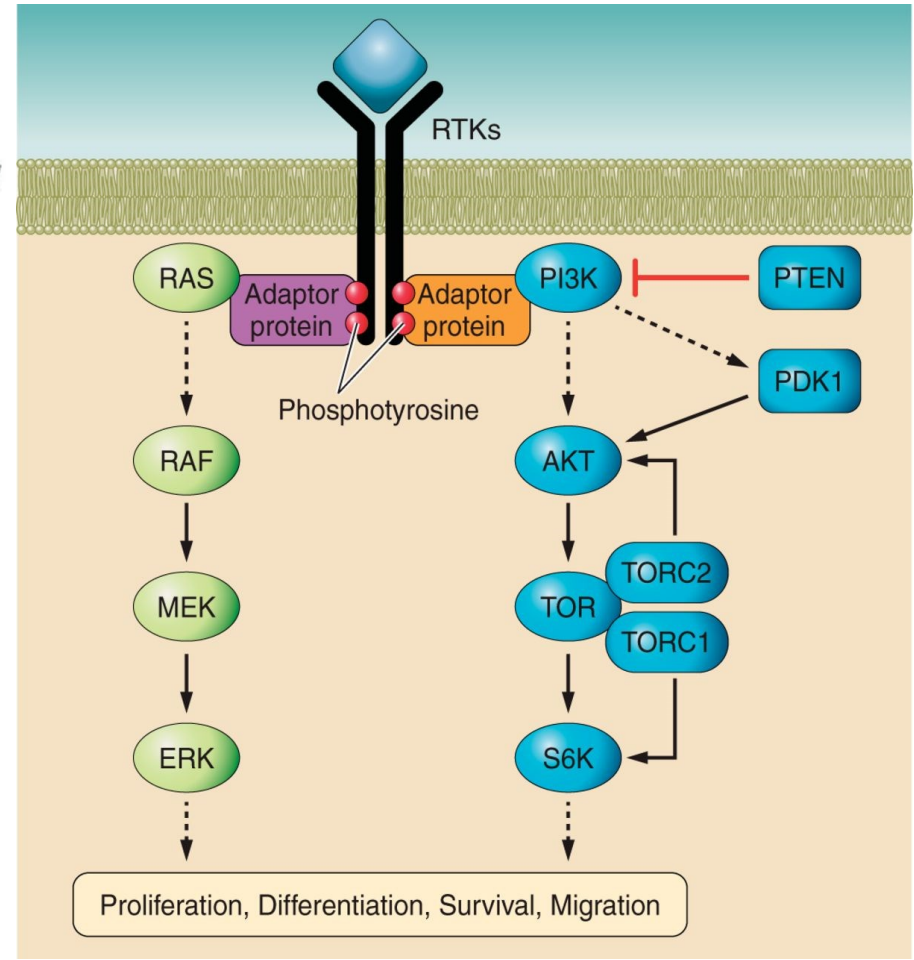
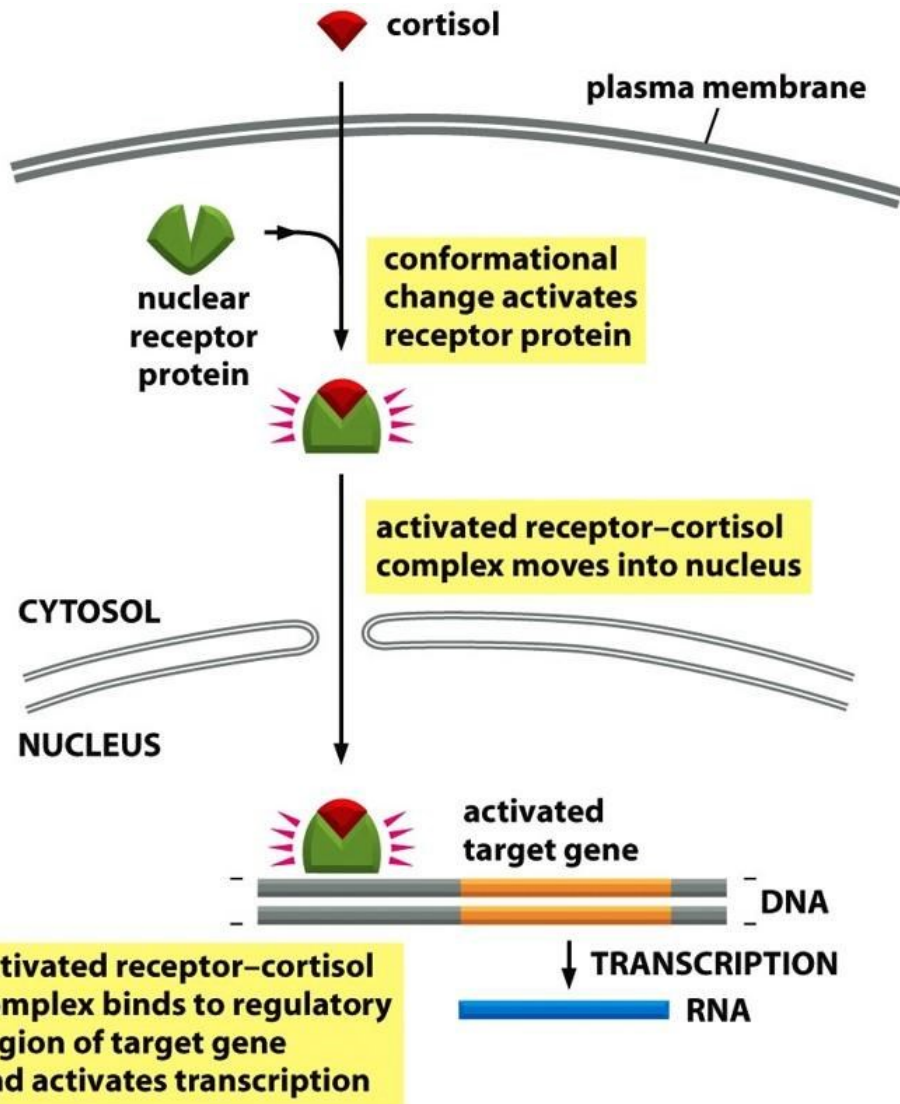


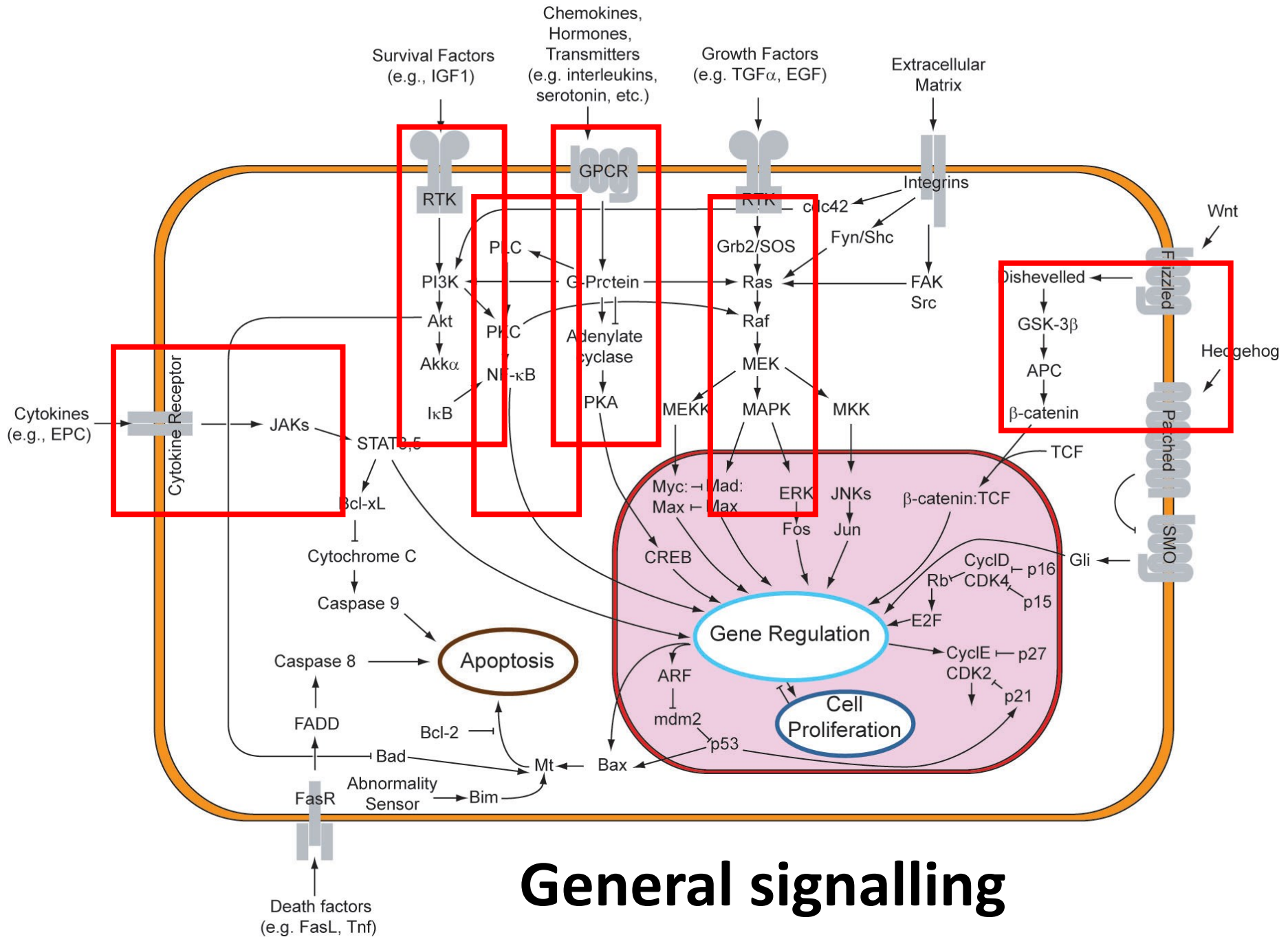
Insulin

Growth hormone

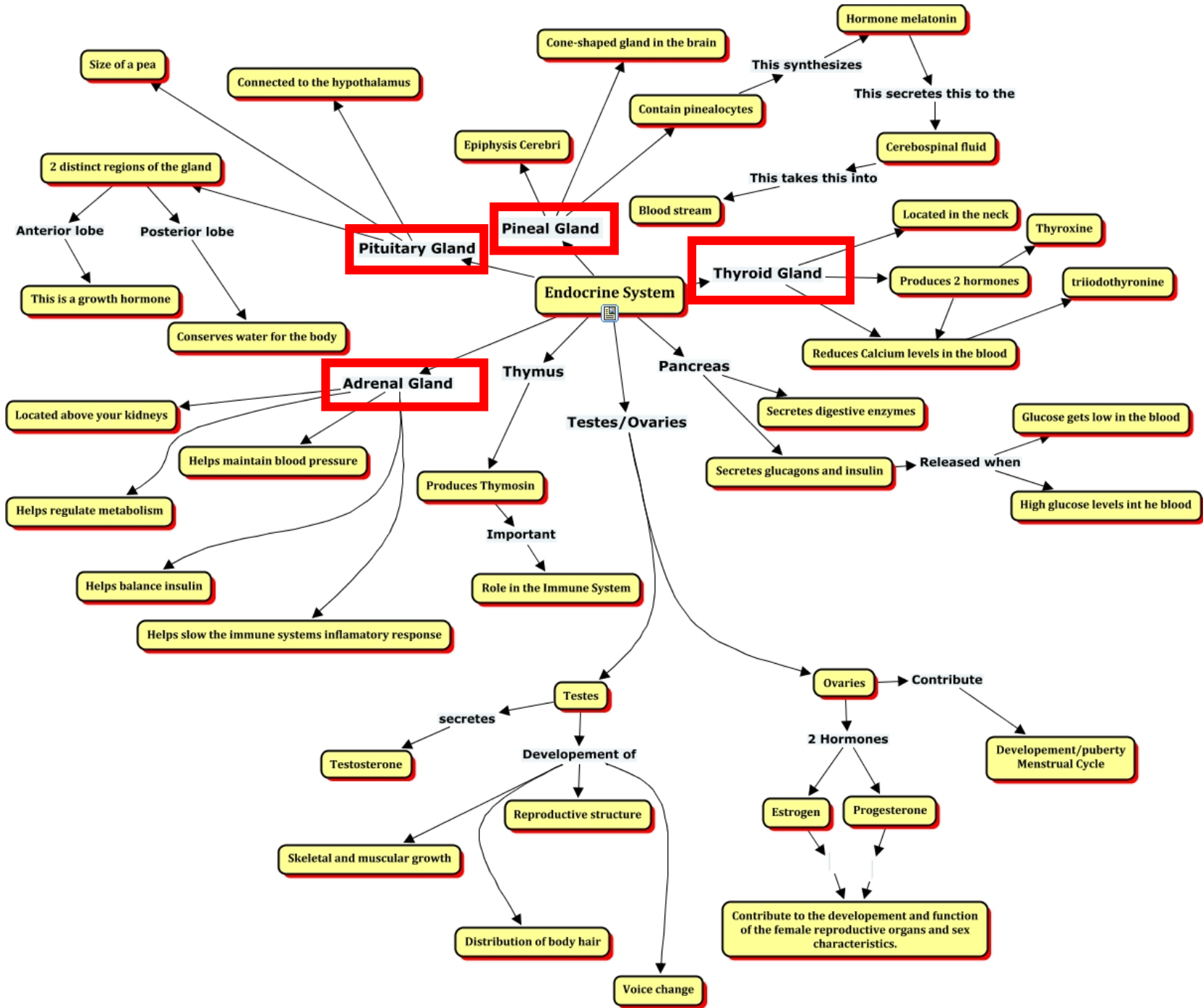


General signalling





General signalling



Pituitary gland (*gl. pituitaria*)



Corpus callosum

Hypothalamus

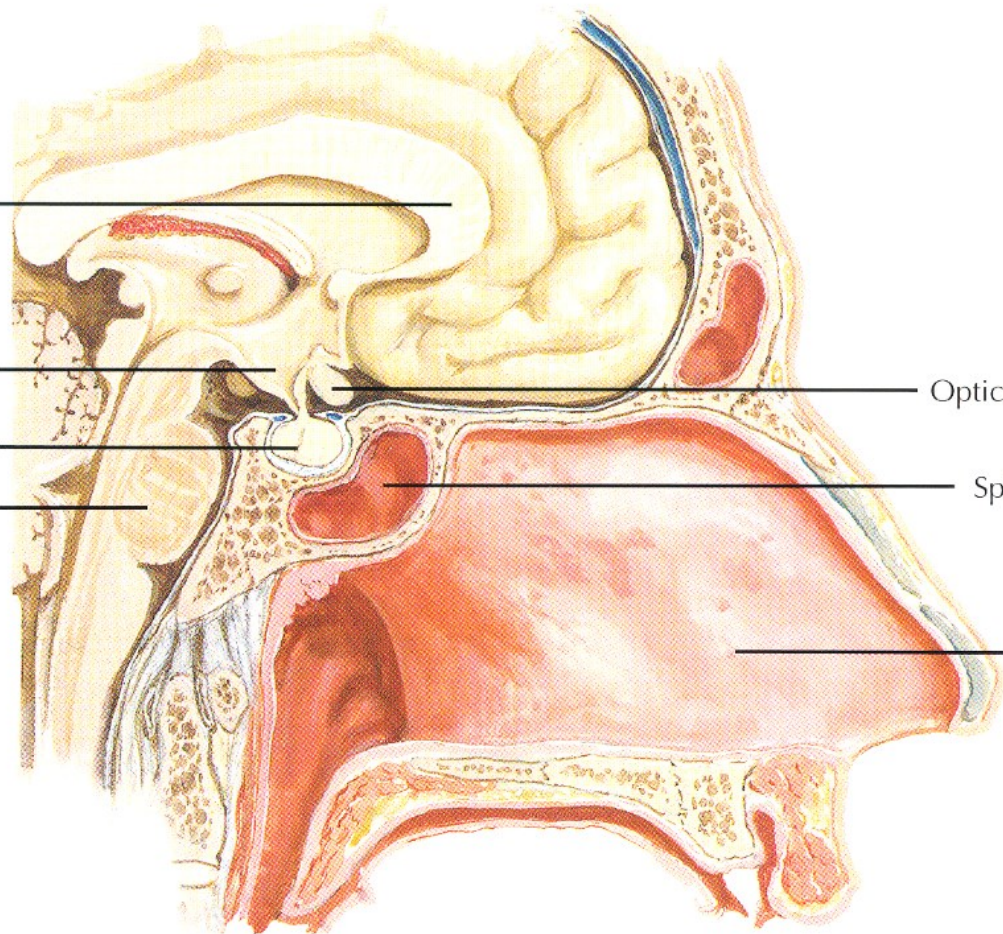
Pituitary gland

Brainstem (pons)

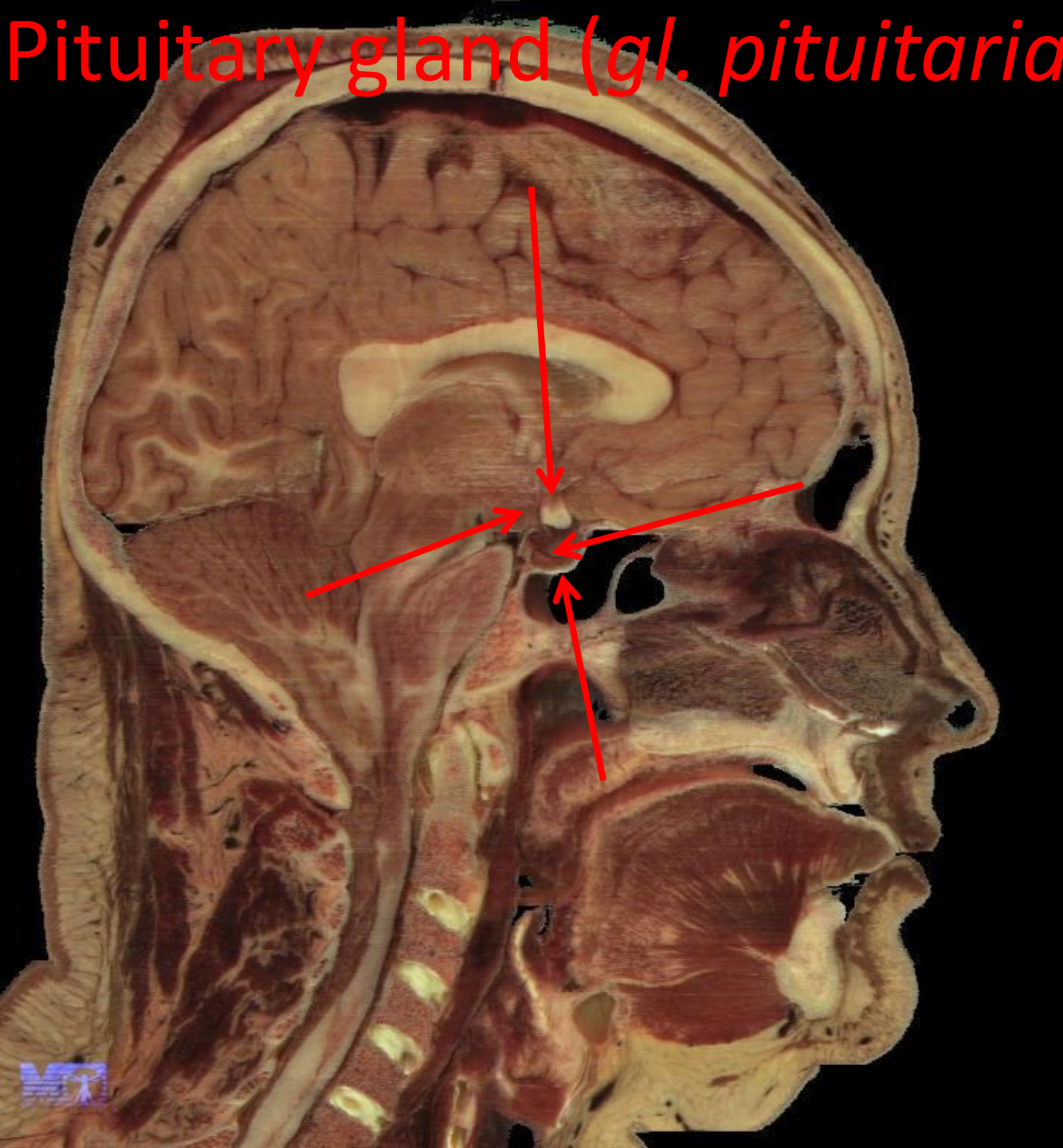
Optic chiasm

Sphenoid sinus

Nasal septum

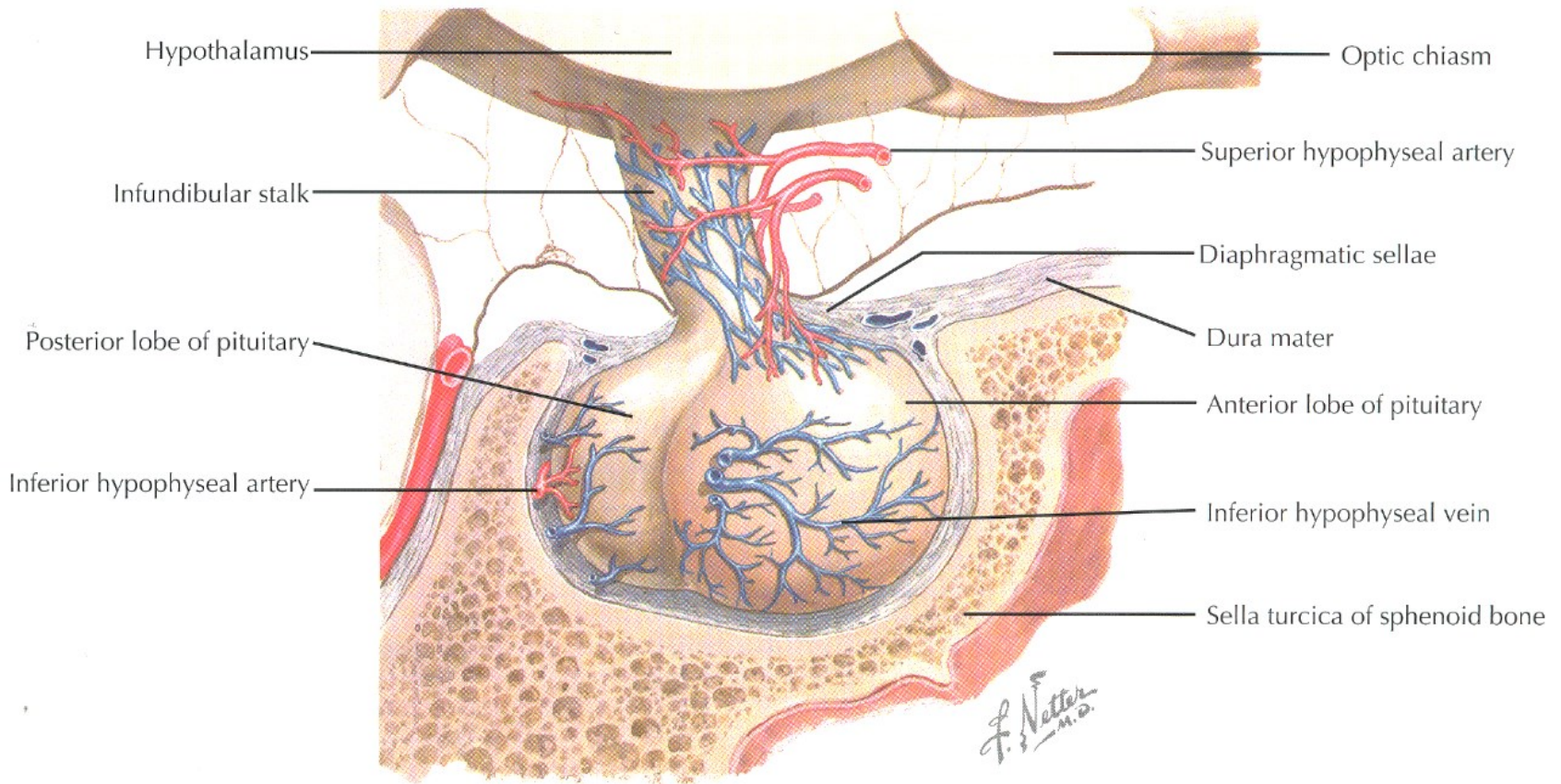
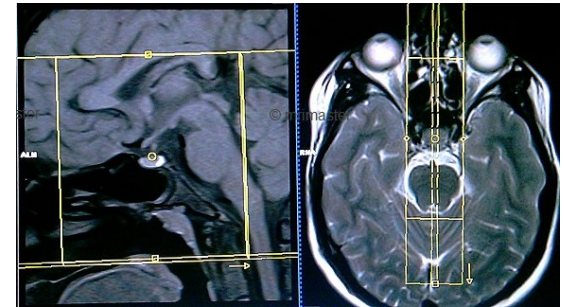


Pituitary gland (*gl. pituitaria*)



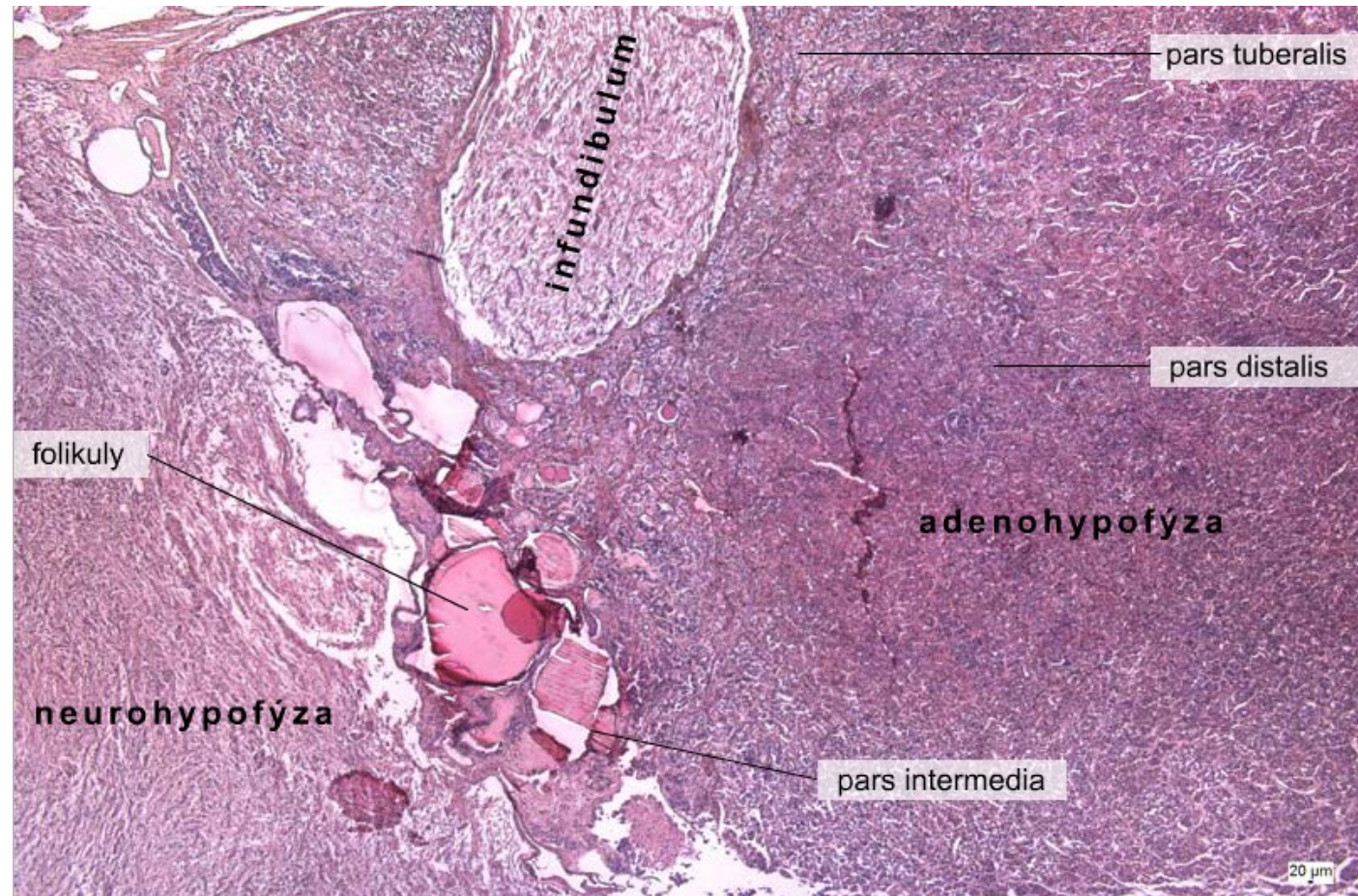
- hypothalamus
- sella turcica
- fossa hypophysialis
- optic chiasm

Pituitary gland (*gl. pituitaria*)



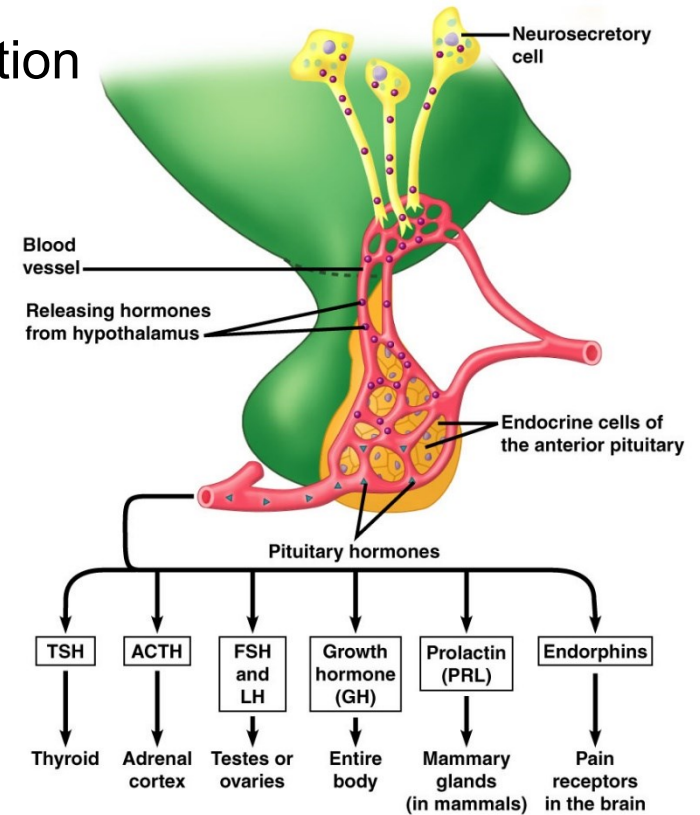
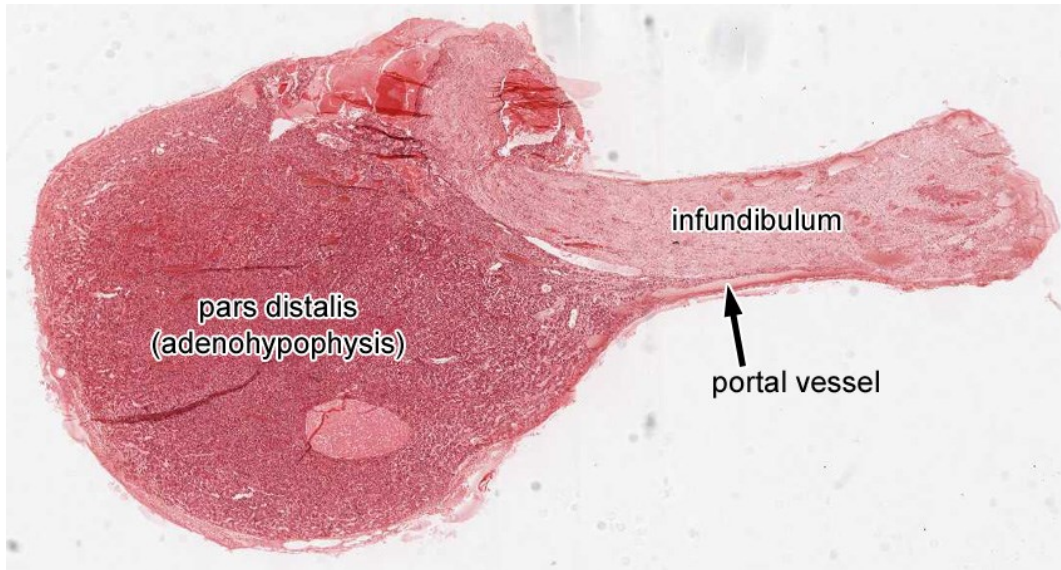
Pituitary gland (*gl. pituitaria*)

- adenohypophysis (*pars distalis*, *pars tuberalis*, *pars intermedia*)
- neurohypophysis (*pars nervosa*)
- *infundibulum*, *eminencia mediana*



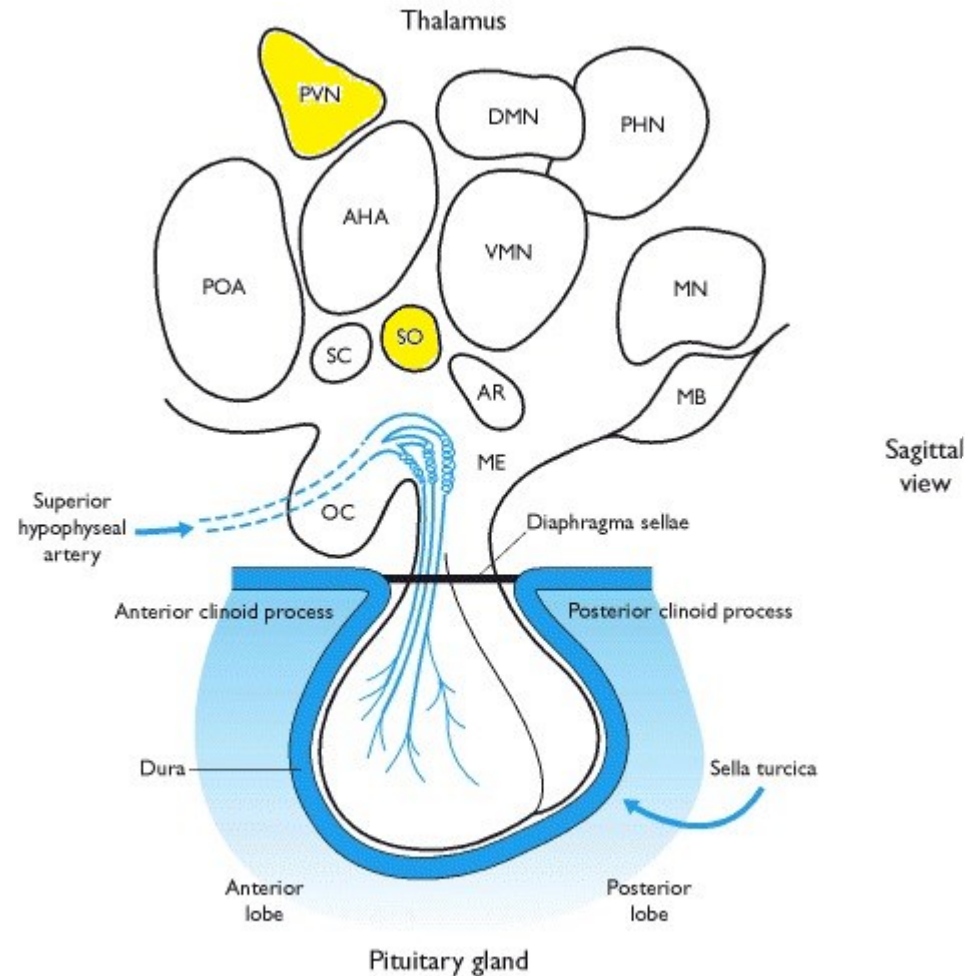
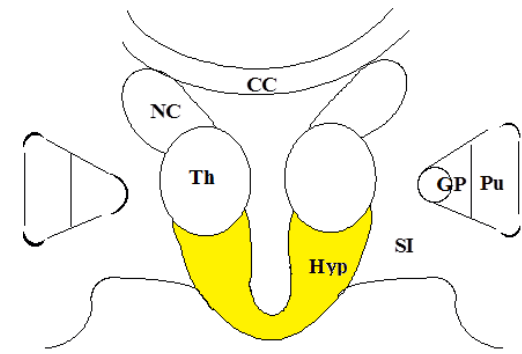
Pituitary gland (*gl. pituitaria*)

- adenohypophysis - glandotropic hormones, prolactin, GH
- neurohypophysis - hypothalamic hormones - ADH, oxytocin
- anatomical and functional association with hypothalamus
- capillary systems and neuroendocrine secretion

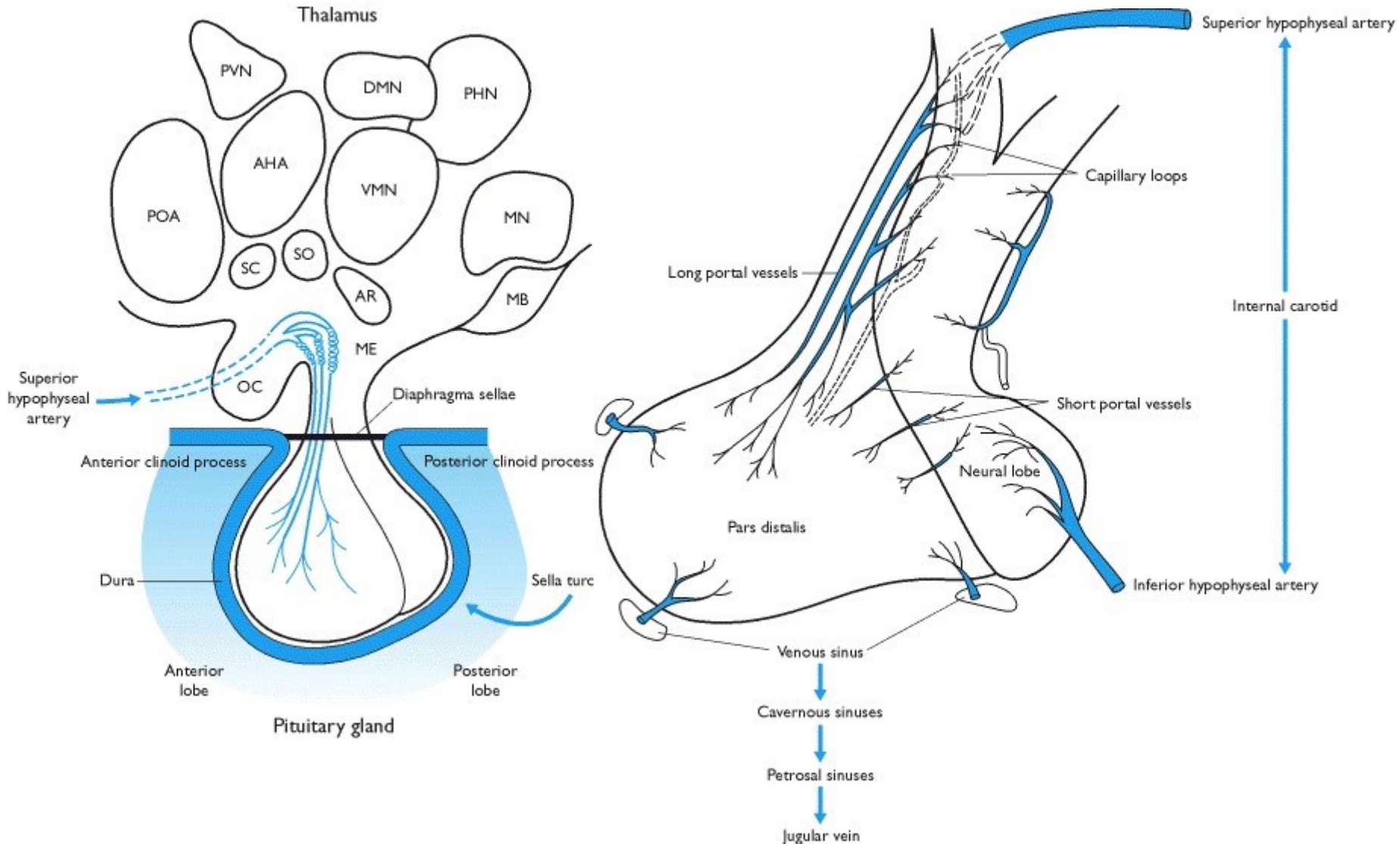


Hypothalamus

- small region of diencephalon
- complex neuroarchitecture
- core of the limbic system
- complex functions
 - regulation of temperature, emotions, eating behavior, circadian rhythms
 - hormonal regulation controlled by various stimuli (osmoreception, concentration of nutrients, electrolytes, systemic functions - pain)
- hypothalamic nuclei
 - *n. supraopticus, n. paraventricularis*
 - magnocellular neurons - *tractus hypothalamo-hypophysialis*
 - parvocellular neurons - capillaries in *eminentia mediana*



Hypothalamo-hypophyseal system



Mechanism of neurosecretion and the blood flow

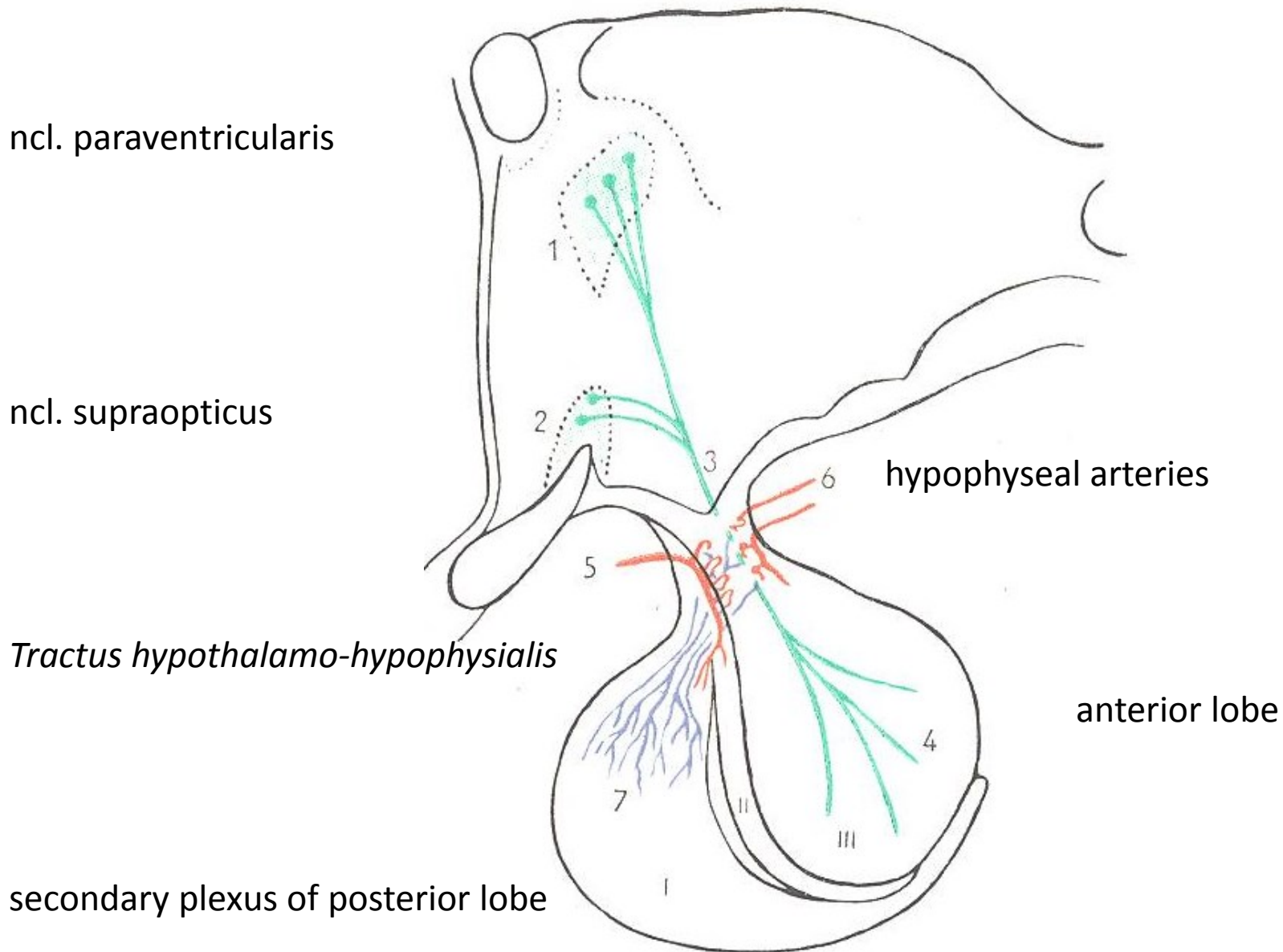
Tractus hypothalamo-hypophysialis

- axons of magnocellular neurons in *nucleus supraopticus* and *paraventricularis*
- terminating on fenestrated capillaries in neurohypophysis
- synthesis of prohormones → during axonal transportation maturation
- capillary plexus from *arteria hypophysialis* inferior (branch of *a. carotis interna*) → *sinus cavernosus*

Hypophyseal portal system

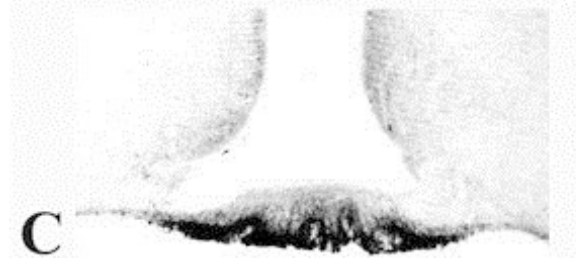
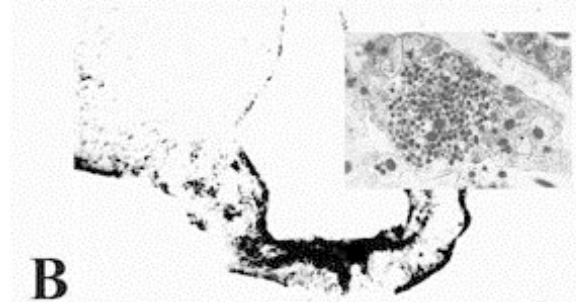
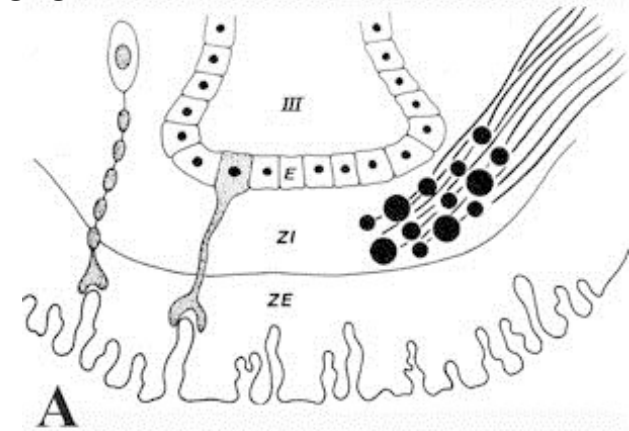
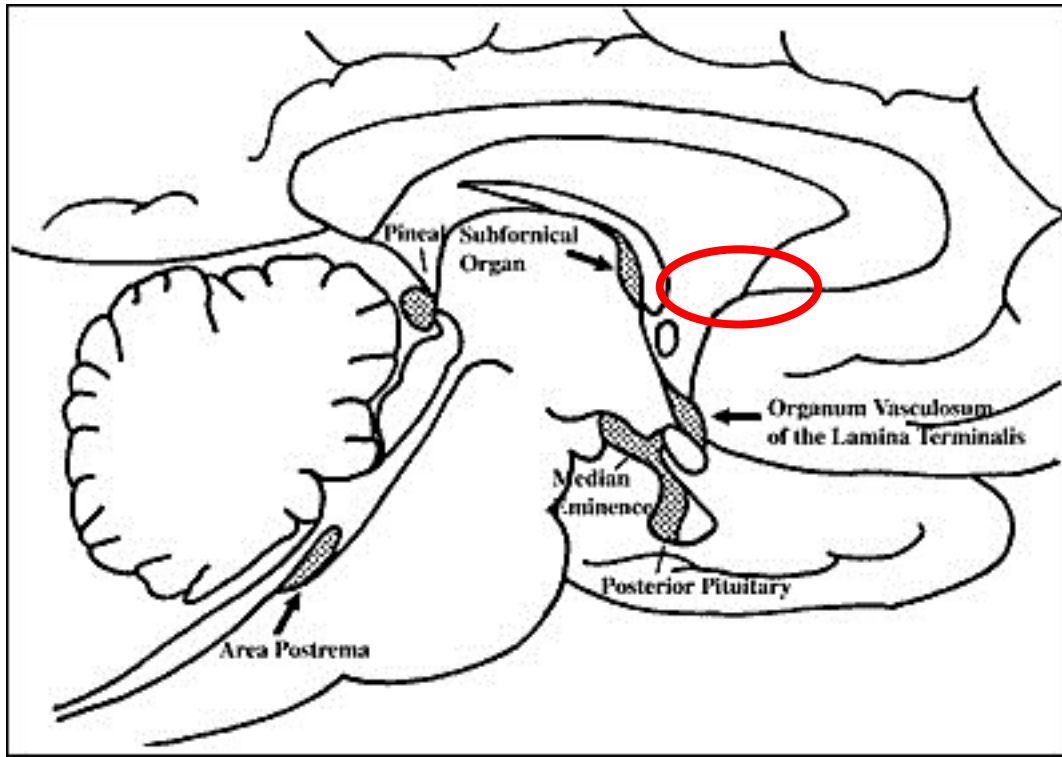
- parvocellular neurons e.g. in *nucleus arcuatus*, *preopticus*, *paraventricularis* and *nuclei tuberales*
- axonal transport onto primary capillary plexus in ***eminentia mediana*** (from anterior and posterior superior hypophyseal arteries) → hypophyseal portal veins → secondary capillary plexus in adenohypophysis → inferior hypophyseal portal veins → *vv. jugulares internae*

Capillary systems of hypophysis

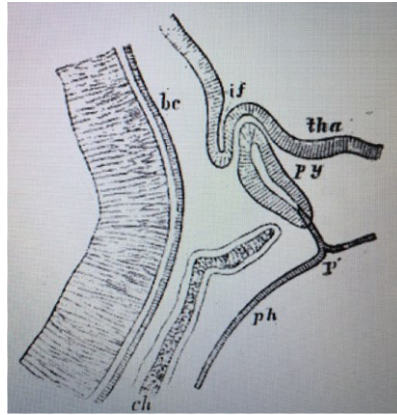


Eminentia mediana

- elevated part of tuber cinereum, (detachment of infundibulum p. nervosa)
- neurohemal area - hematoencephalic barrier is open here
- fenestrated capillaries with large perivascular spaces



Martin Heinrich Rathke (1793 – 1860)



Ueber die Entstehung der Glandula pituitaria.

Von
HEINRICH RATHKE.

Schon längst bemerkte ich bei mehreren Thieren in einer sehr frühen Zeit des Fruchtlebens, bei Säugethieren namentlich geraume Zeit früher, als sich der Gaumen bildet, ganz hinten in der Mundhöhle, unterhalb der Grundfläche des Schädels eine kleine unregelmässig rundliche Vertiefung, die der Schleimhaut des Mundes angehörte und offenbar eine dünnwandige Aussackung derselben war. Lange aber wusste ich sie nicht zu deuten, zumal da ich sie bei älteren Embryonen, wenn ich die Mundhöhle untersuchte, nicht mehr wiederfand. Endlich ward ich gewahr, dass diese Vertiefung den ersten Schritt zur Bildung des Hirnanhanges (Gland. pituitaria) bezeichnet.

Bevor ich nun aber das weitere Verhalten derselben schildere, sehe ich mich genöthigt ein Paar Worte über den Schädel vorzuschicken. Der Stern von der Chorda dorsalis reicht, wie es allen Anschein hat, vielleicht bei allen Wirbelthieren nur bis zwischen die beiden Knorpelkapseln, welche bei den mit einem Knochenskelett versehenen Thieren zu den

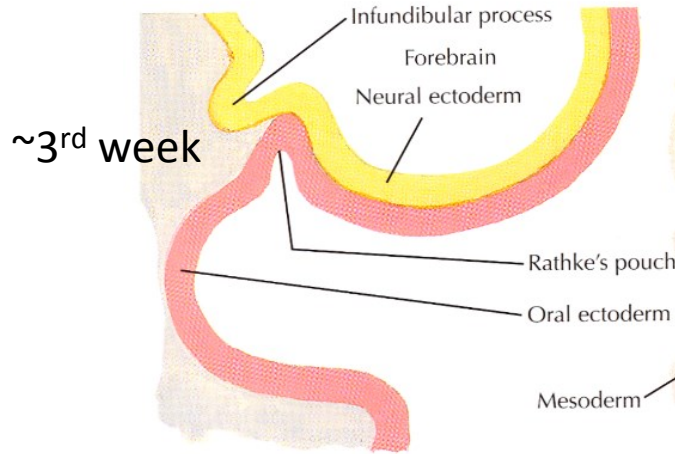
- Physician, anatomist, embryologist, zoologist
- One of founding fathers of modern embryology

"For a long time I have observed in several animals ... a small irregularly rounded depression which belongs to the mucous membrane of the mouth, of which it is clearly a thin-walled outpocketing. ... Finally I saw that this depression represents the first step in the formation of the pituitary gland" (p. 482).

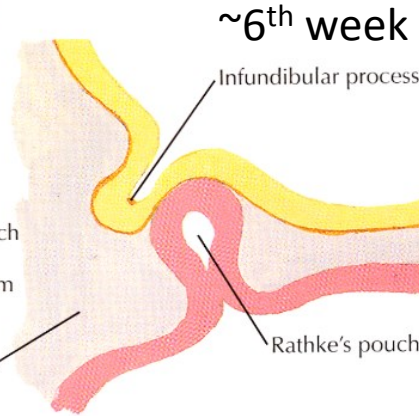
Rathke, H. : *Ueber die Entstehung der glandula pituitaria*. Arch, f. Anat., Phys. und wiss. Med. S. 482-85. **1838**

Embryonic development of pituitary gland

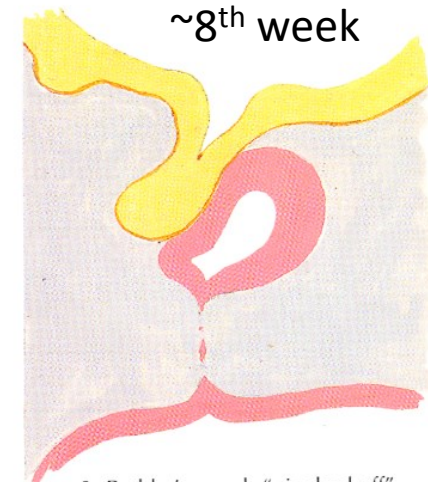
- Ectoderm of stomodeum (Rathke's pouch)
- Neuroectoderm of ventral wall of diencephalon



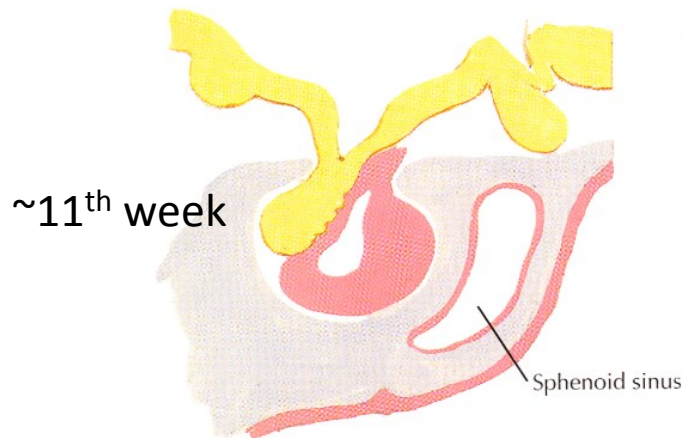
1. Beginning formation of Rathke's pouch and infundibular process



2. Neck of Rathke's pouch constricted by growth of mesoderm



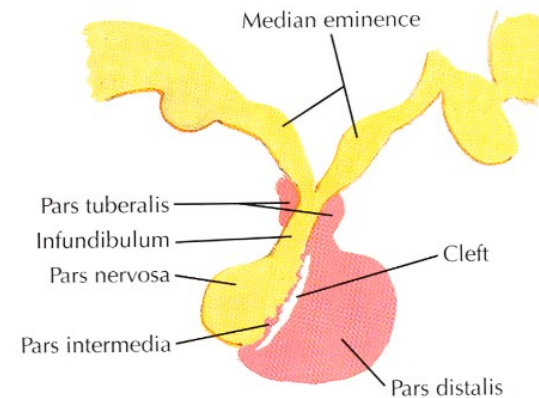
3. Rathke's pouch "pinched off"



4. "Pinched off" segment conforms to neural process, forming pars distalis, pars intermedia and pars tuberalis

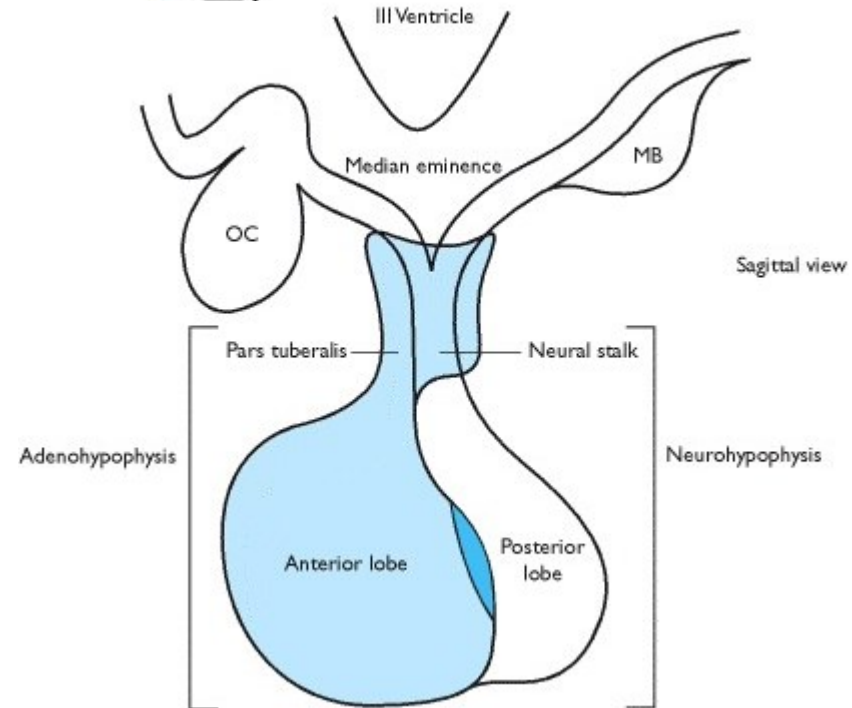
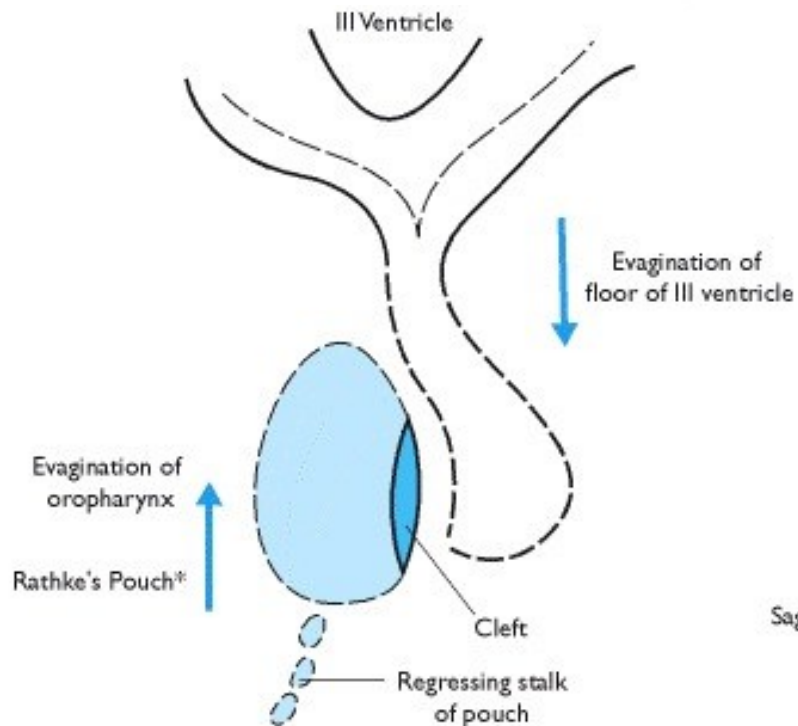
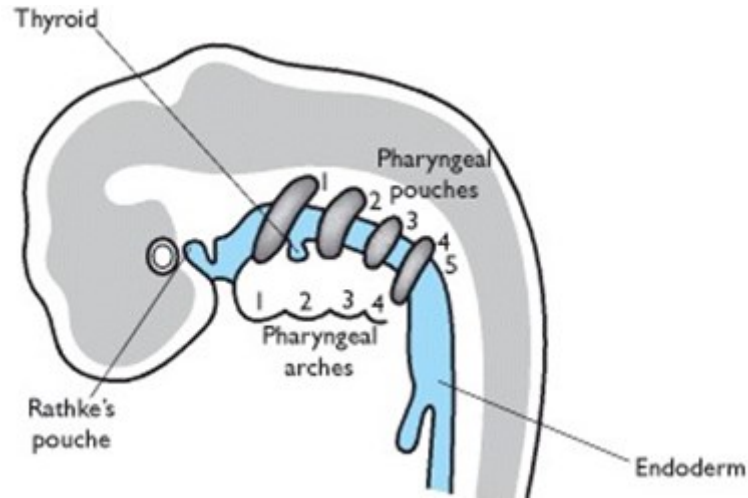
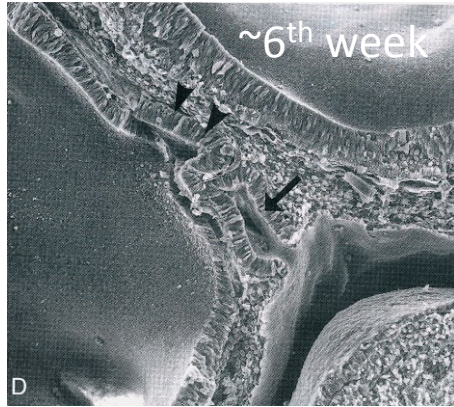


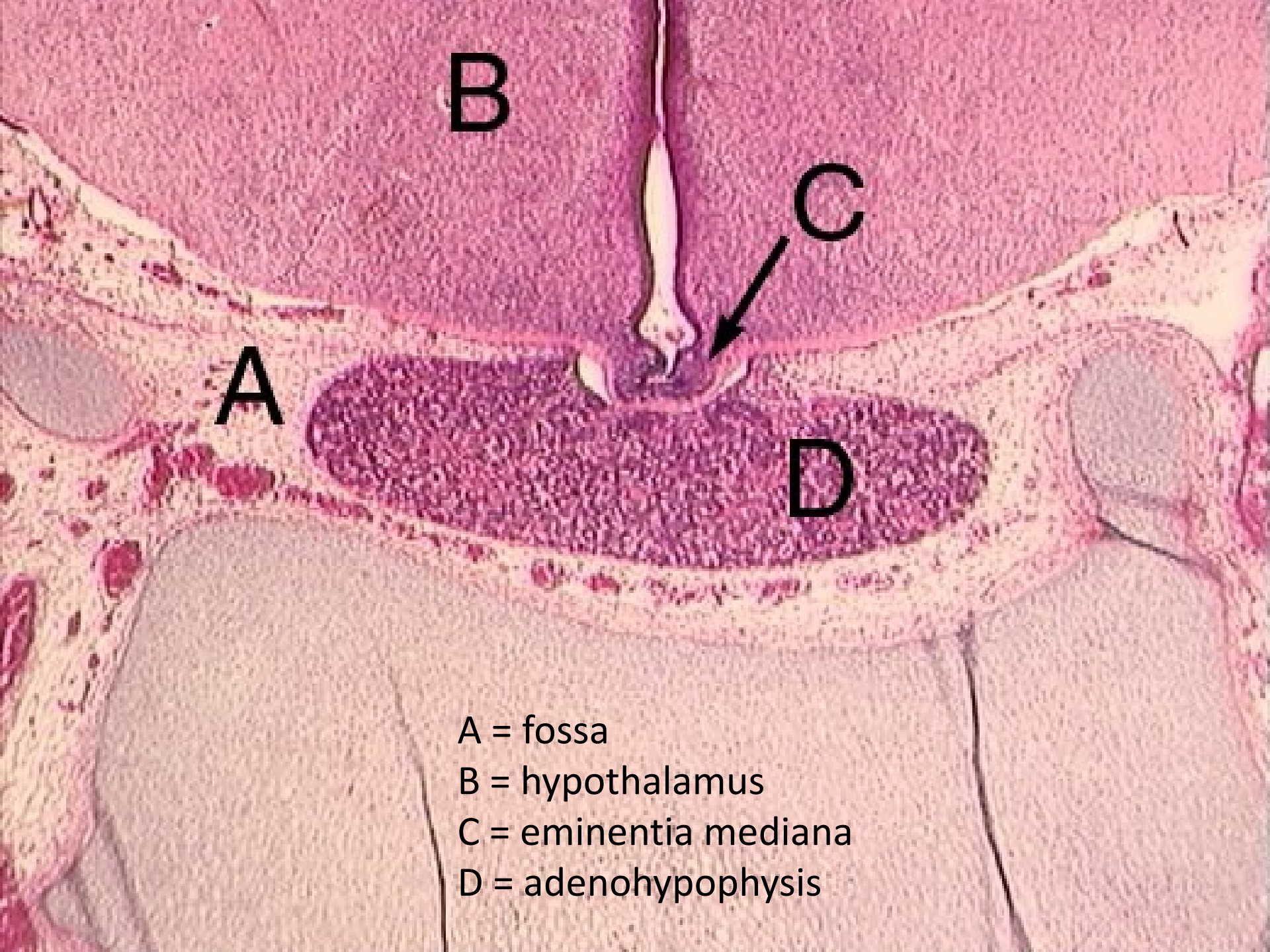
5. Pars tuberalis encircles infundibular stalk (lateral surface view)



6. Mature form

Embryonic development of pituitary gland





A = fossa
B = hypothalamus
C = eminentia mediana
D = adenohypophysis

Adenohypophysis (anterior lobe)

Chromophilic cells

Acidophils

Nonglandotropic

- direct effect on target tissues

Basophils

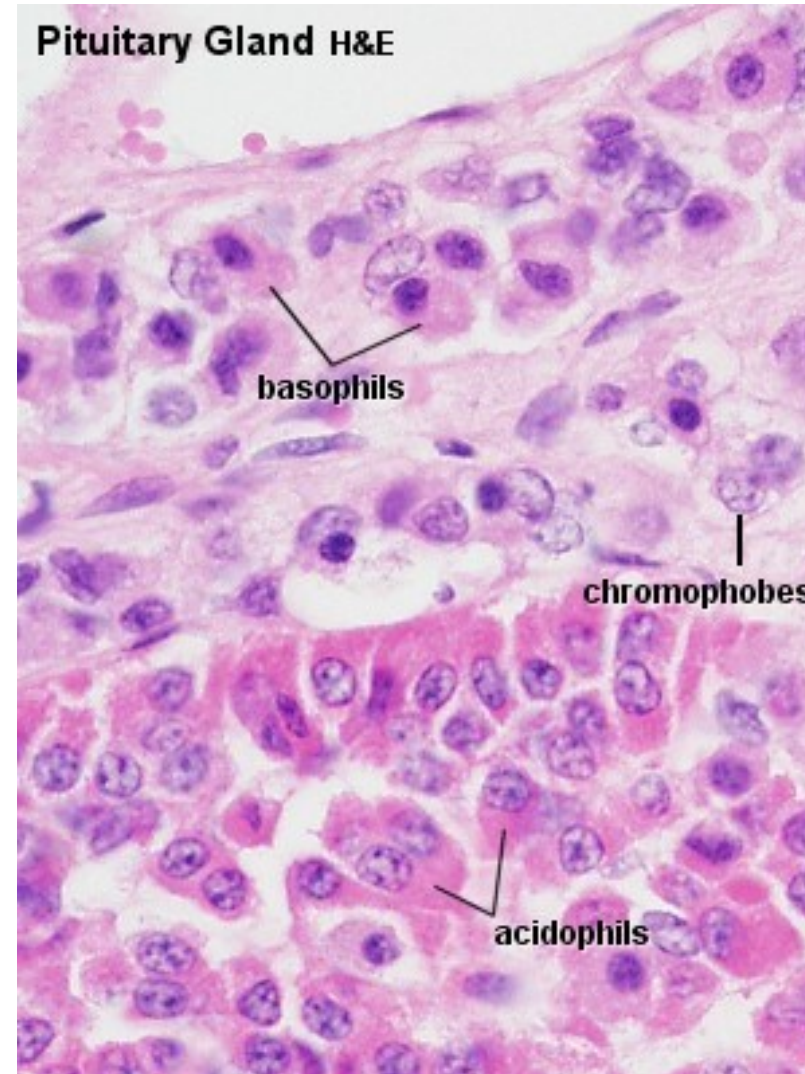
Glandotropic

- regulation of other endocrine glands

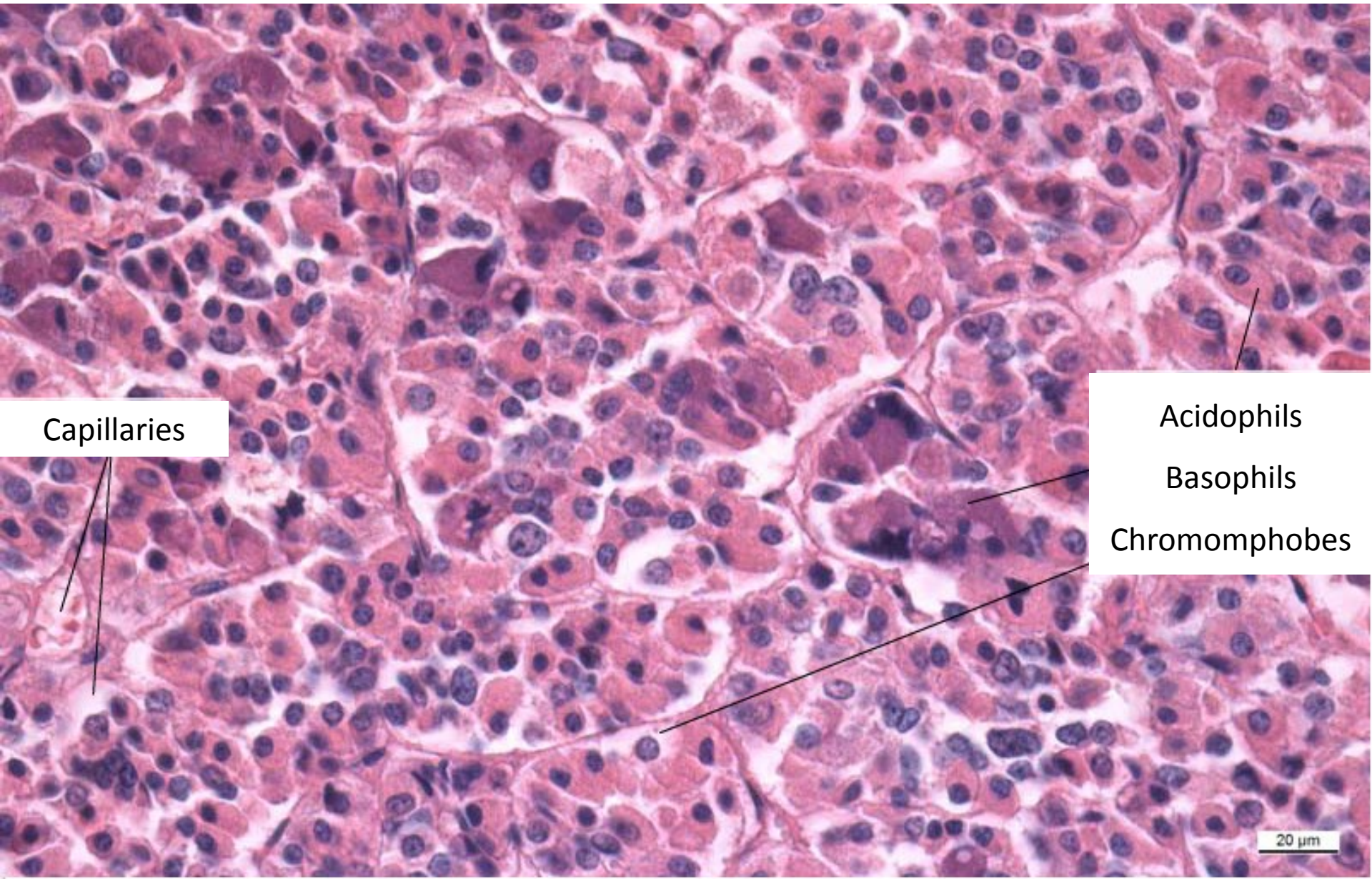
Chromophobic cells

- undifferentiated cells
- degranulated ("empty") chromophils
- stromal cells

Folliculo-stellate cells (FS-cells)



Adenohypophysis (anterior lobe)



Capillaries

Acidophils

Basophils

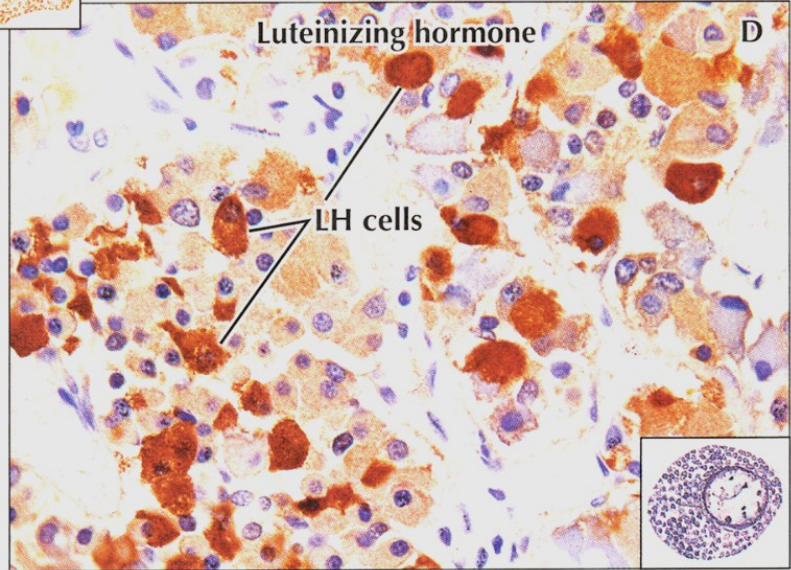
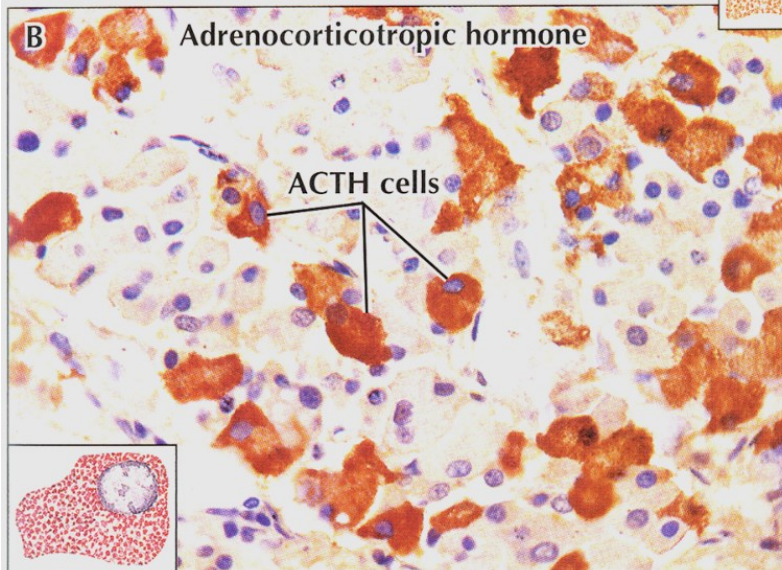
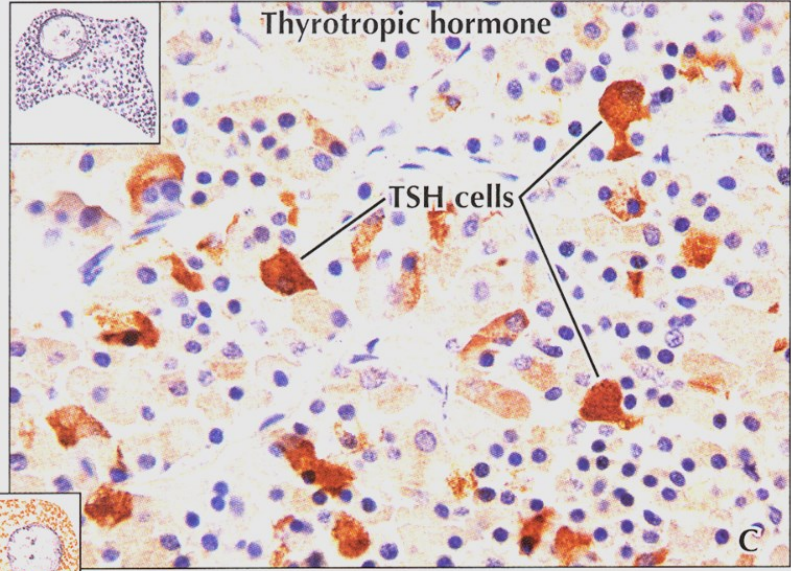
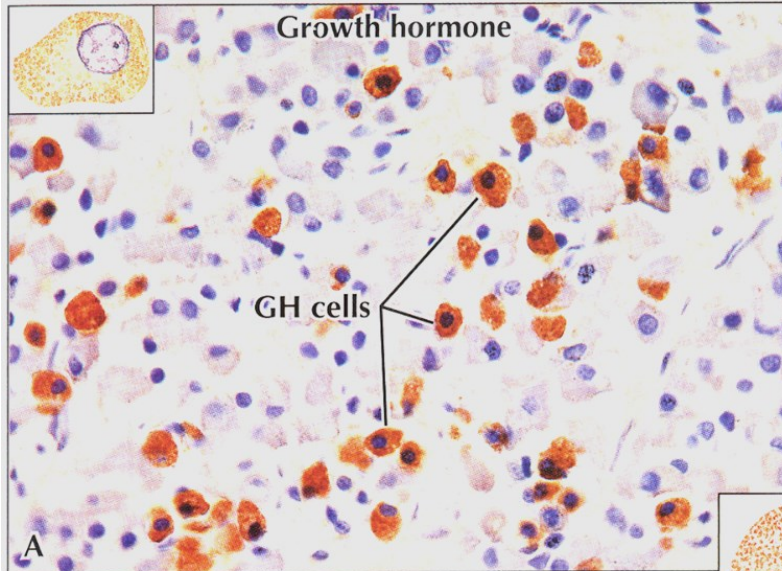
Chromomphobes

20 μm

Adenohypophysis (anterior lobe)

Acidophils producing GH

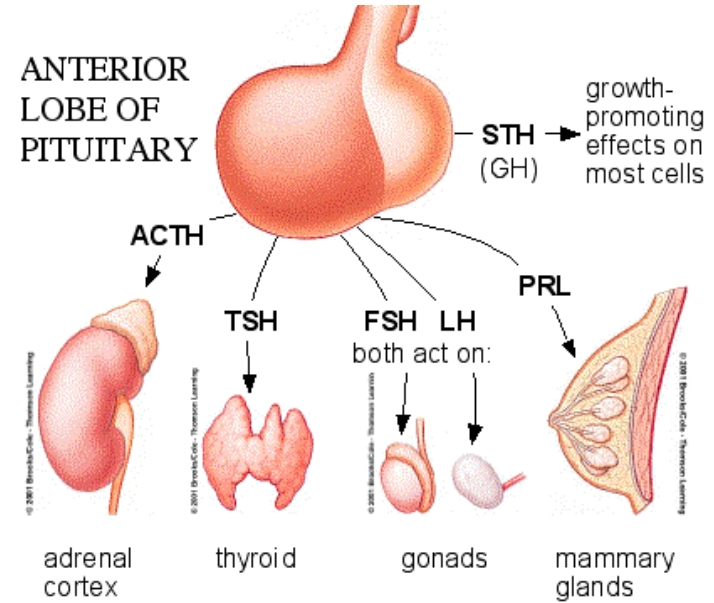
Basophils producing glandotropic hormones



BASOPHILS PRODUCING GLANDOTROPIC HORMONES

”FLAT PEG”

- FSH
- LH
- ACTH
- TSH
- Prolactin
- Endorphins
- Growth hormone



Pro-opio-melanocortin (POMC)

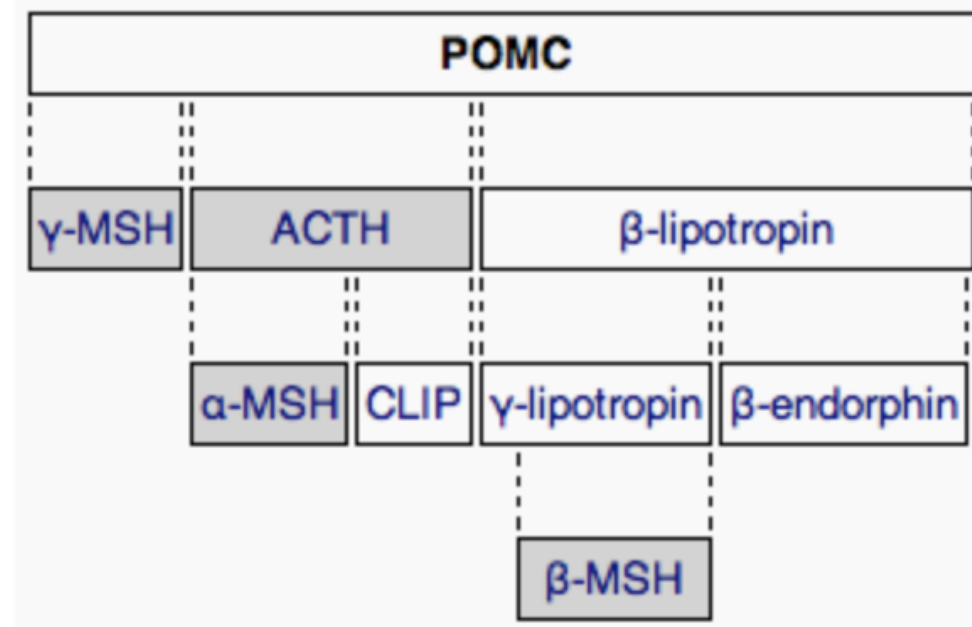
rough ER → pre-prohormon
produced by various tissues

cleavage to

- ACTH (target: adrenal cortex → kortisol)
- MSH (target: melanocytes - mostly in paracrine way)
- lipotropin (lipolysis, steroidogenesis)
- endorphins

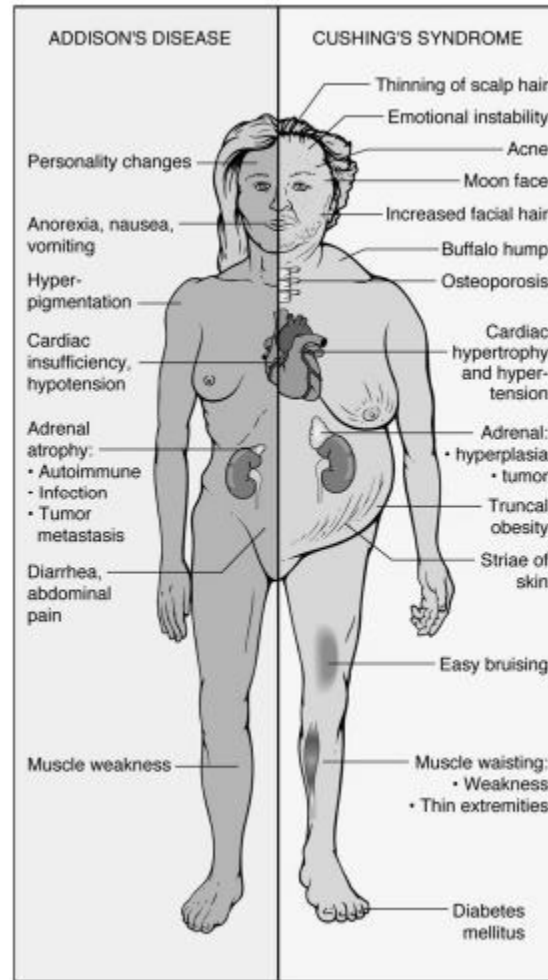
”FLAT PEG”

- FSH
- LH
- **ACTH**
- TSH
- Prolactin
- **Endorphins**
- Growth hormone

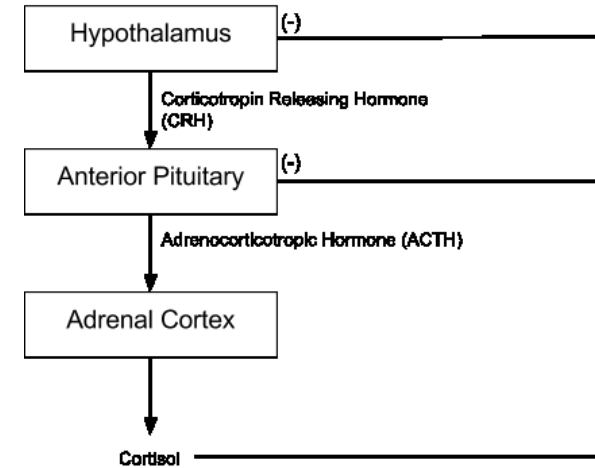
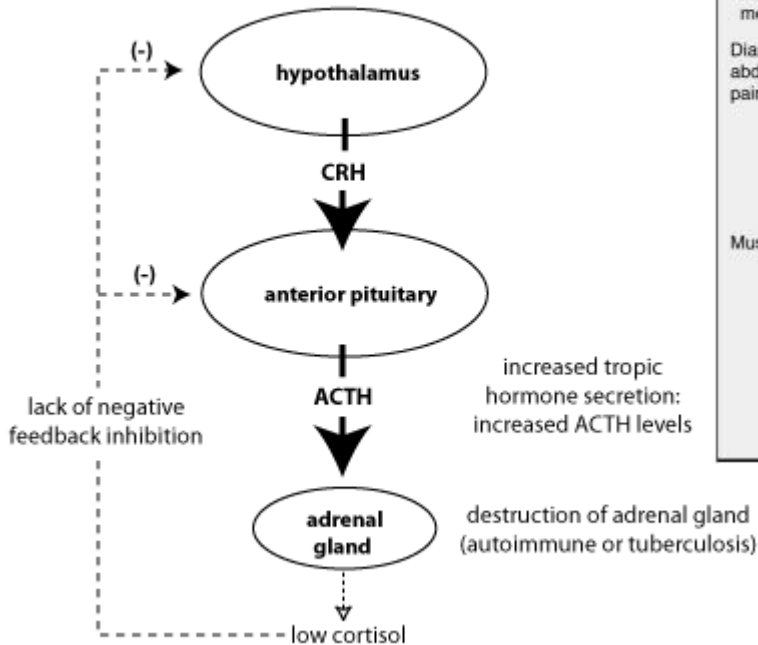


Corticotrophs hypofunction

Corticotrophs hyperfunction



Addison's Disease



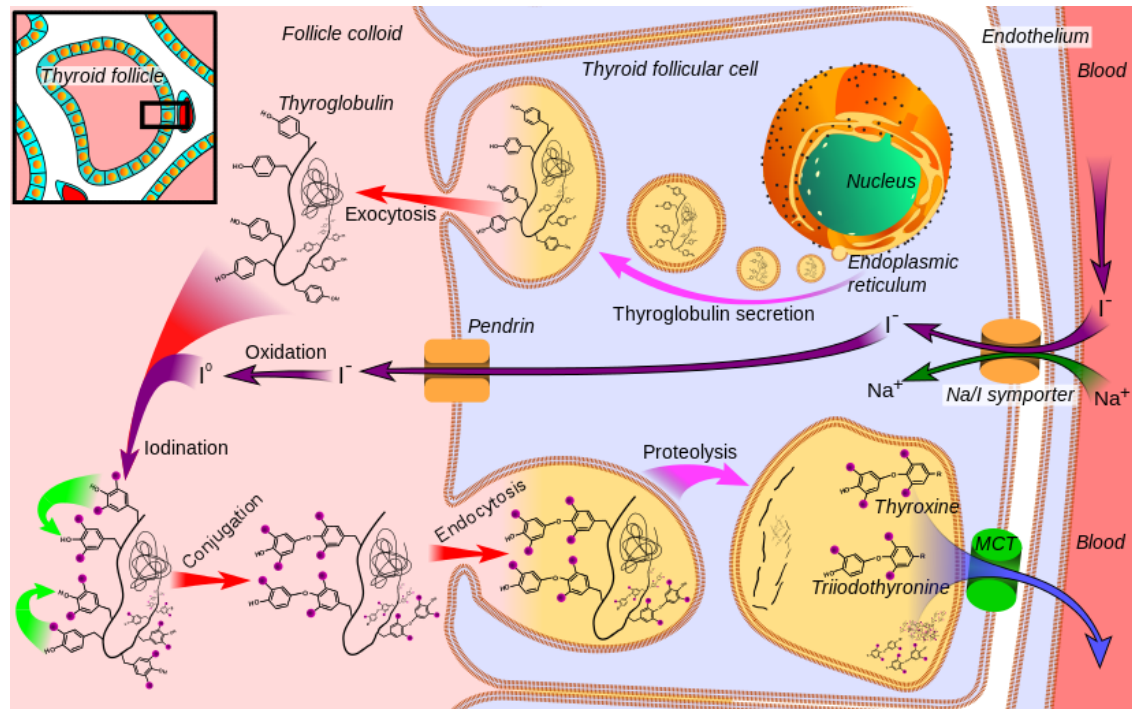
FSH (folitropin), LH (lutropin)

- gonadotropic cells of adenohypophysis stimulated by GnRH
- glycoproteins, 30kDa
- heterodimer, two noncovalent bound subunits (**a/α** - common for - LH, FSH, TSH, hCG, **b/β** - specific)
- FSH receptor (testes, ovarium, uterus) G-protein coupled receptor
 - glycosylated extracellular domain of 11 leucine rich repeats specific to FSH
 - after ligand binding, activation of G-protein and cAMP signaling
 - alternative activation of MAPK cascade (ERK)
 - complex signaling response (prostaglandins, PLPc, NO)

	FSH	LH
ovarium	follicle development (FSHR in m. <i>granulosa cells</i>)	ovulation, development of corpus luteum, production of androgens in thecal cells
testes	spermatogenesis, FSHR in Sertoli cells	production of testosterone in Leydig cells (expression of LHR)
extragonadal	FSHR in secretory endometrium of luteal phase uterus (endometrial functions, embryo-endometrial interactions)	uterus, seminal vesicles, prostate, skin... unknown function

TSH, thyrotropin

- thyrotropic cells of adenohypophysis stimulated by TRH
- production of T4 (thyroxin) a T3 (triiodothyronin) by thyroid gland
- glycoprotein, 28,5 kDa, heterodimer, two noncovalent bound subunits (a, b)
- TSH receptor on thyroid follicular cells
- G-protein signaling → adenylylcyklase → cAMP
- cAMP → iodide channels (pendrin), transcription of thyreoglobulin, endo- and exocytic pathway
- cross-reactivity with hCG → in pregnancy - alterations in synthesis of thyroid hormones (gestational hyperthyroidism)



GH, somatotropin, growth hormone

- somatotropic cells of adenohypophysis stimulated by GHRH (somatocrinin)
- several molecular isoforms (alternative splicing), ~20-24 kDa
- broad spectrum of target cell types and physiological circuits
 - transcription of DNA, translation of RNA, proteosynthesis
 - lipid use (fatty acid mobilization, conversion to acetyl-CoA)
 - inhibition of direct use of glucose, stimulation of glukoneogenesis
 - transmembrane transport of aminoacids
 - proteosynthesis in chondrocytes and osteoblasts, proliferation, osteogenesis
- GHR in various tissues
 - RTK, JAK-STAT
- somatomedins
 - small proteins (MW 7,5 kDa), IGF-like
 - produced by liver
- various pathologies associated with GH

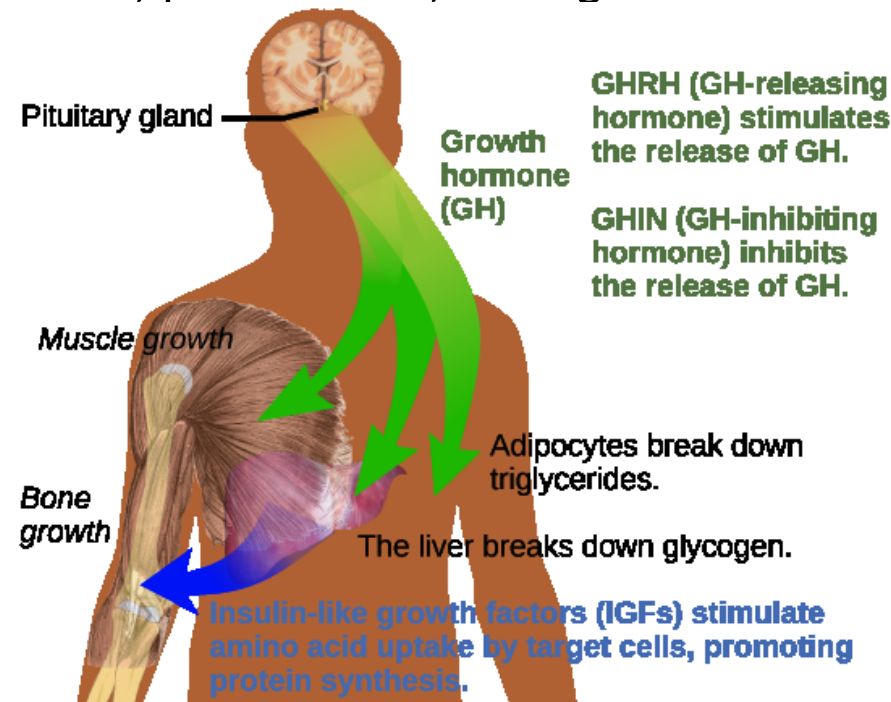


Table 2. Nonclassical Anterior Pituitary Substances and Cell(s) of Origin

Substances	Cell Types
PEPTIDES	
ACTIVIN B, INHIBIN, FOLLISTATIN	F,G
ALDOSTERONE STIMULATING FACTOR	UN
ANGIOTENSIN II (ANGIOTENSINOGEN, ANGIOTENSIN I CONVERTING ENZYME, CATHEPSIN B, RENIN)	C,G,L,S
ATRIAL NATURETIC PEPTIDE	G
CORTICOTROPIN-RELEASING HORMONE-BINDING PROTEIN	C
DYNORPHIN	G
GALANIN	L,S,T
GAWK (CHROMOGRANIN B)	G
GROWTH HORMONE RELEASING HORMONE	UN
HISTIDYL PROLINE DIKETOPIPERAZINE	UN
MOTILIN	S
NEUROMEDIN B	T
NEUROMEDIN U	C
NEUROPEPTIDE Y	T
NEUROTENSIN	UN
PROTEIN 7B2	G,T
SOMATOSTATIN 28	UN
SUBSTANCE P (SUBSTANCE K)	G,L,T
THYROTROPIN RELEASING HORMONE	G,L,S,T
VASOACTIVE INTESTINAL POLYPEPTIDE	G,L,T
GROWTH FACTORS	
BASIC FIBROBLAST GROWTH FACTOR	C,F
CHONDROCYTE GROWTH FACTOR	UN
EPIDERMAL GROWTH FACTOR	G,T
INSULIN-LIKE GROWTH FACTOR I	S,F
NERVE GROWTH FACTOR	UN
PITUITARY CYTOTROPIC FACTOR	UN
TRANSFORMING GROWTH FACTOR ALPHA	L,S,G
VASCULAR ENDOTHELIAL GROWTH FACTOR	F
CYTOKINES	
INTERLEUKIN-1 BETA	T
INTERLEUKIN-6	F
LEUKEMIA INHIBITORY FACTOR	C,F
NEUROTRANSMITTERS	
ACETYLCHOLINE	C,L
NITRIC OXIDE	F

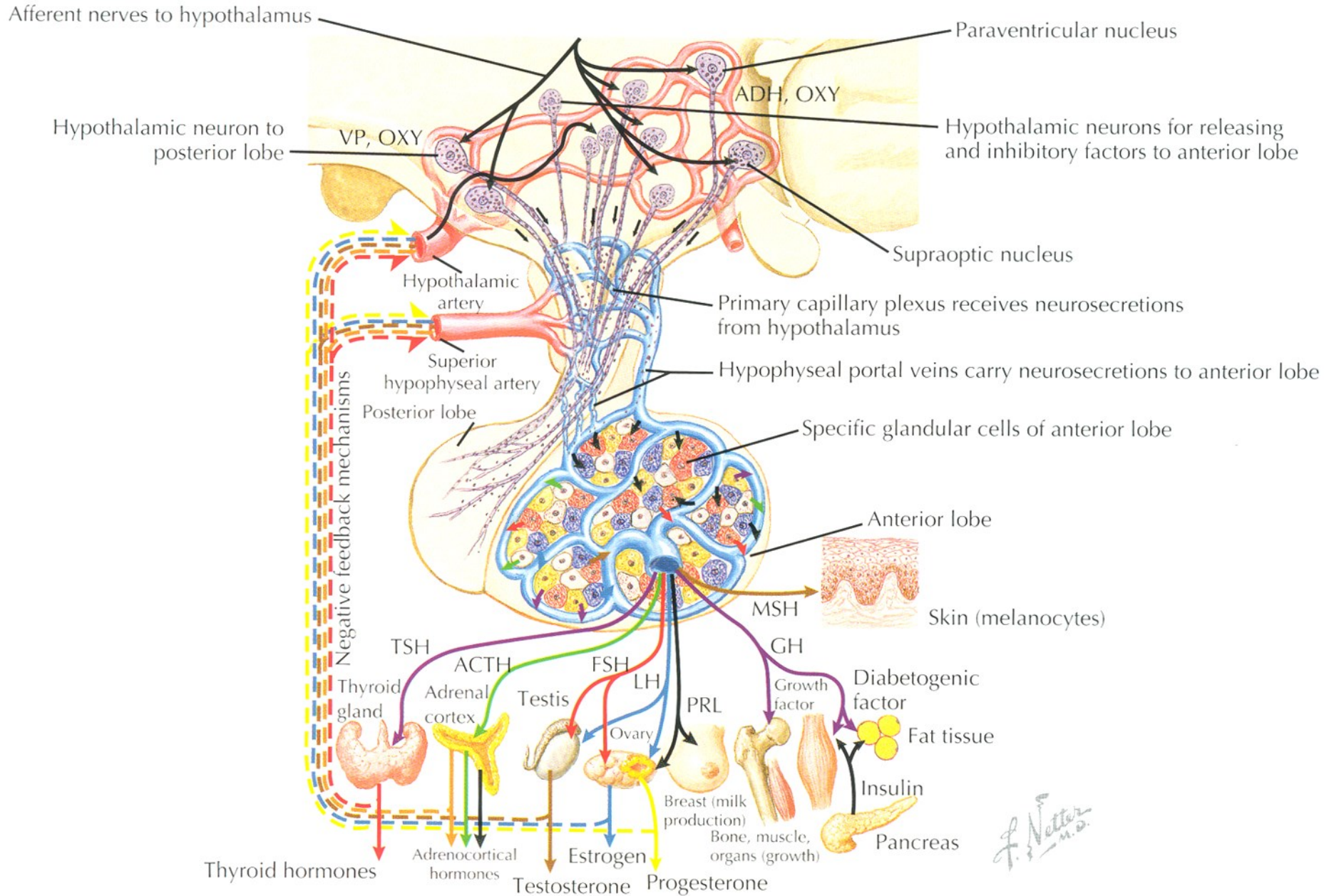
C = corticotroph, F = folliculostellate cell, G = gonadotroph, L = lactotroph,
S = somatotroph, T = thyrotroph, UN = unknown

Clinical links

Hypophyseal tumors

- compression of surrounding structures (optic chiasma)
- hyperfunction of endocrine component
 - prolactinoma - galactorrhea
 - hypogonadism (alterations of GnRH)
 - gigantism - acromegaly
 - nanism





F. Netter M.D.

Posterior hypophysis (neurohypophysis)

nonmyelinated nerve fibers

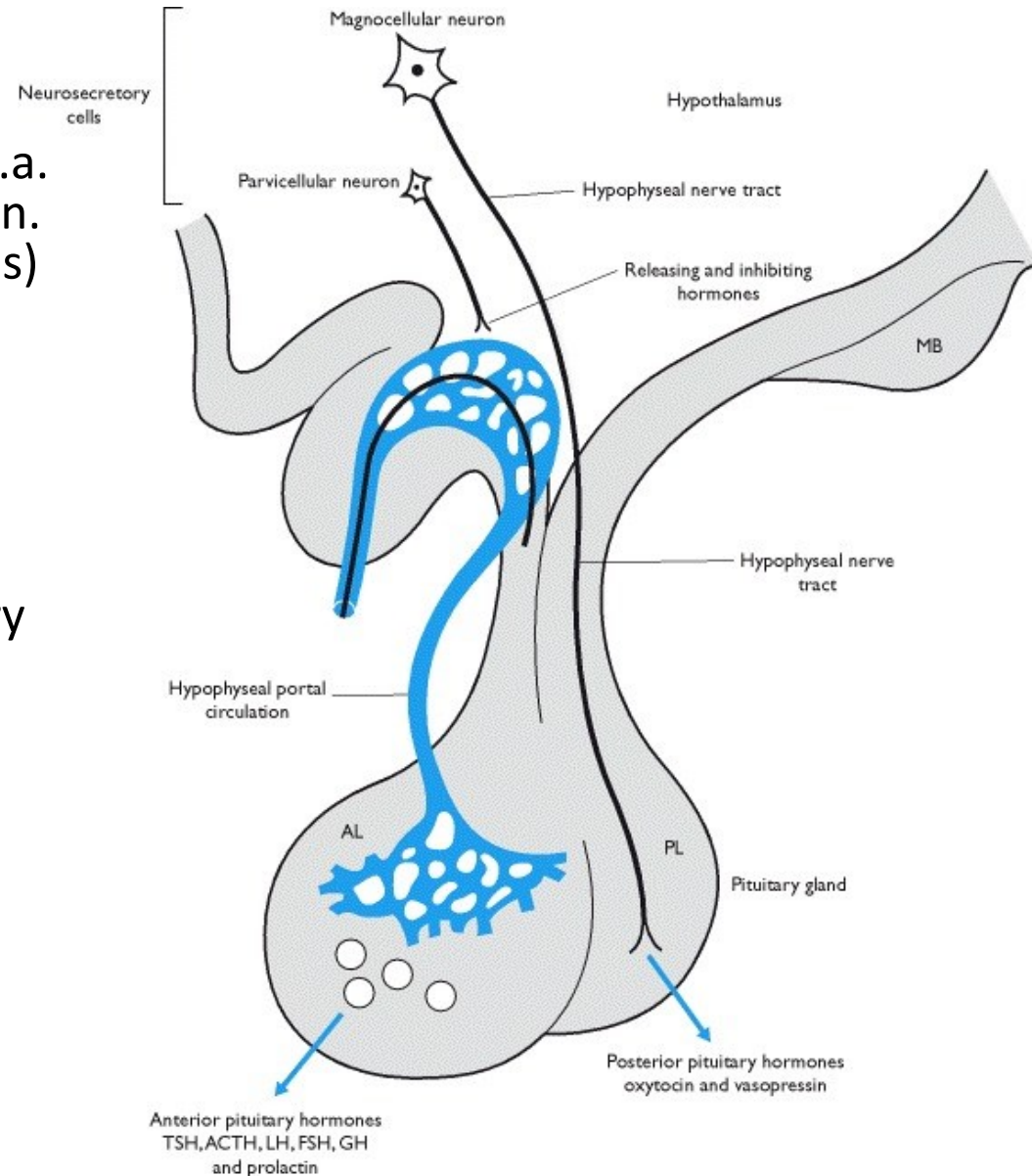
– axons of neurosecretory cells (c.a. 100 000) of hypothalamic nuclei (n. supraopticus and paraventricularis)

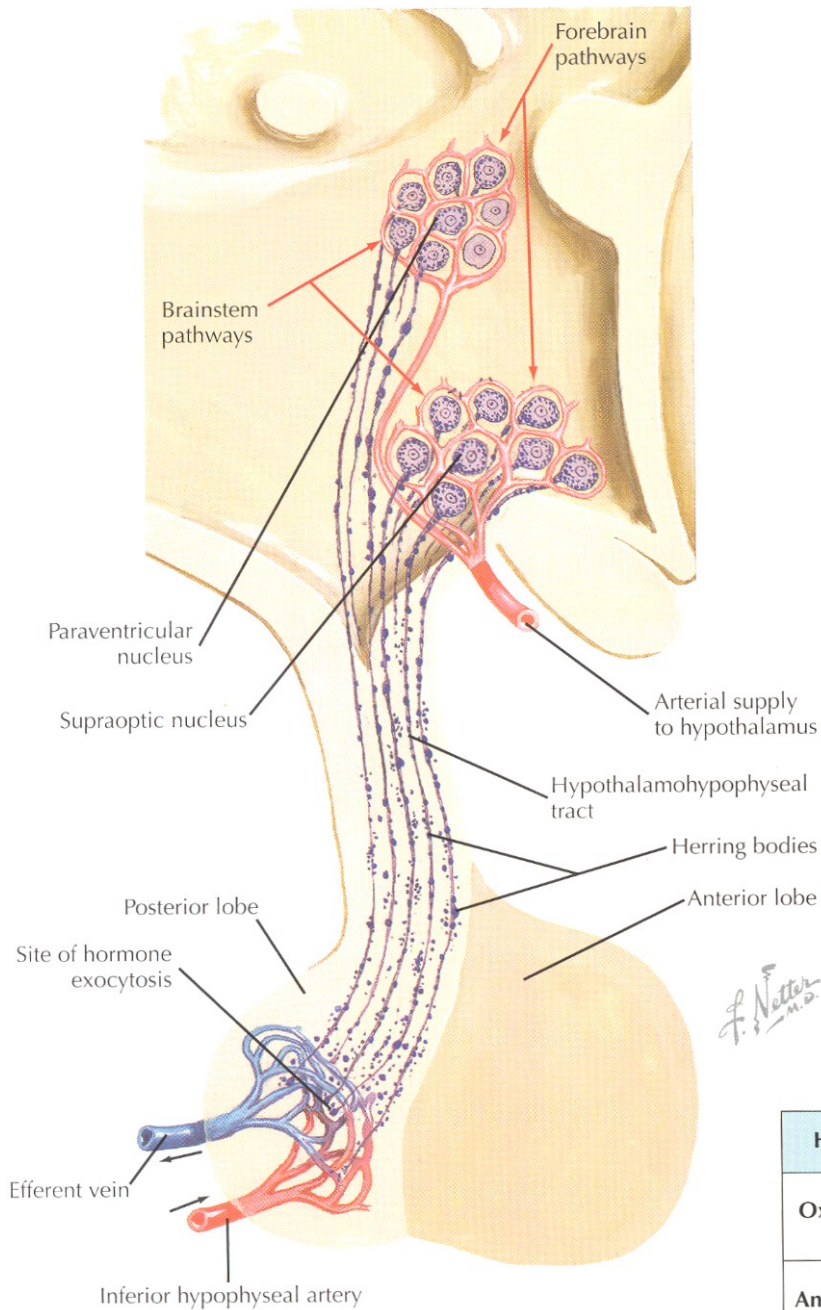
pituicytes (neuroglia)

- astrocyte-like (intermediate filaments, GFAP)
- local control of secretion from neurosecretory termini
- Herring bodies – neurosecretory endings – dilatation close to capillaries

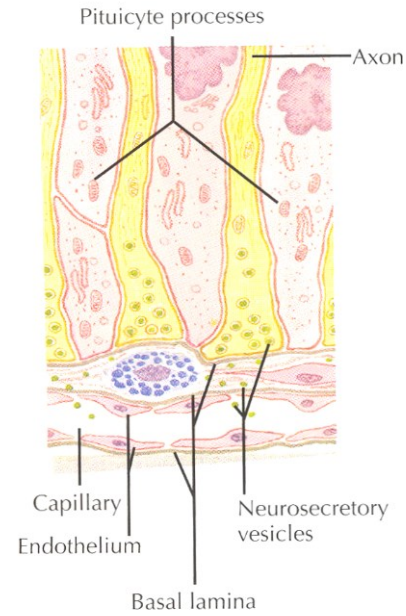
Hormones

- oxytocin (OT)
- antidiuretic hormone (ADH, vasopressin)

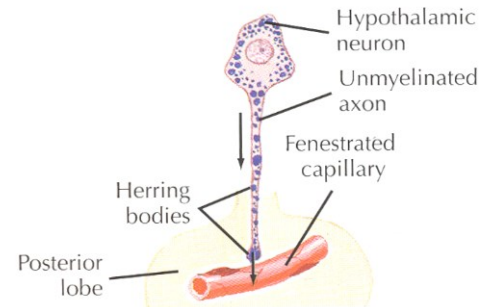




▼ Neurosecretory Ending (posterior pituitary).

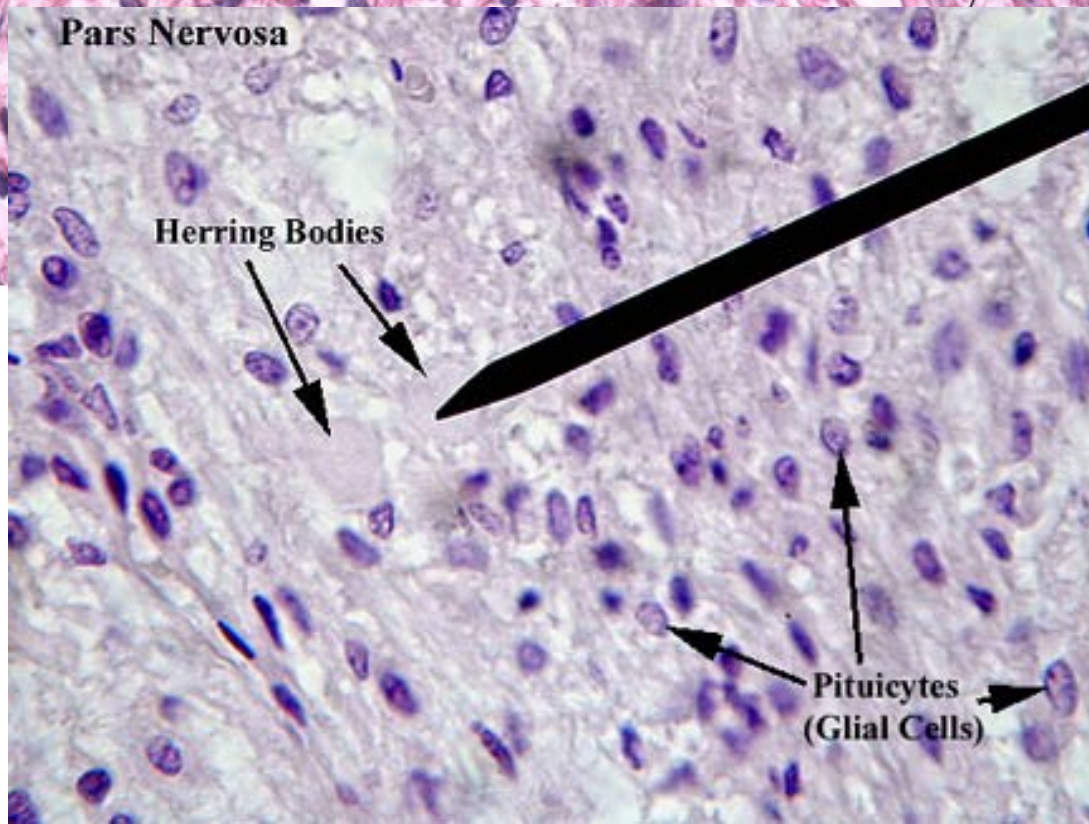
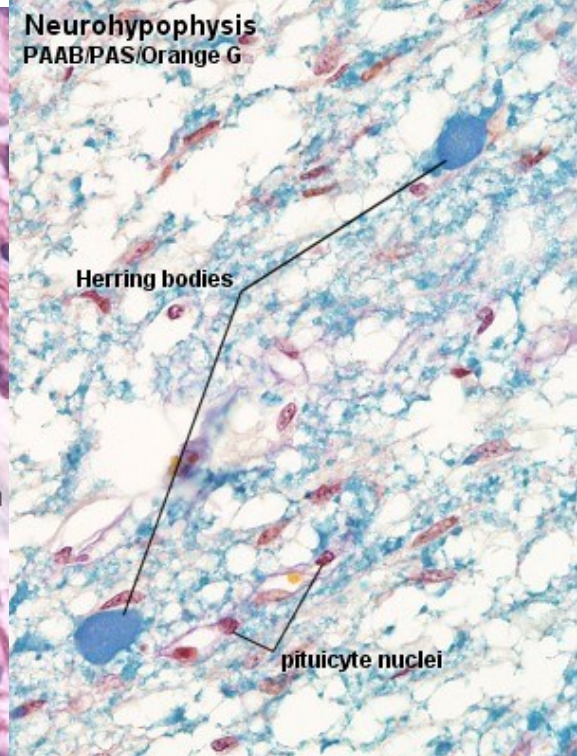
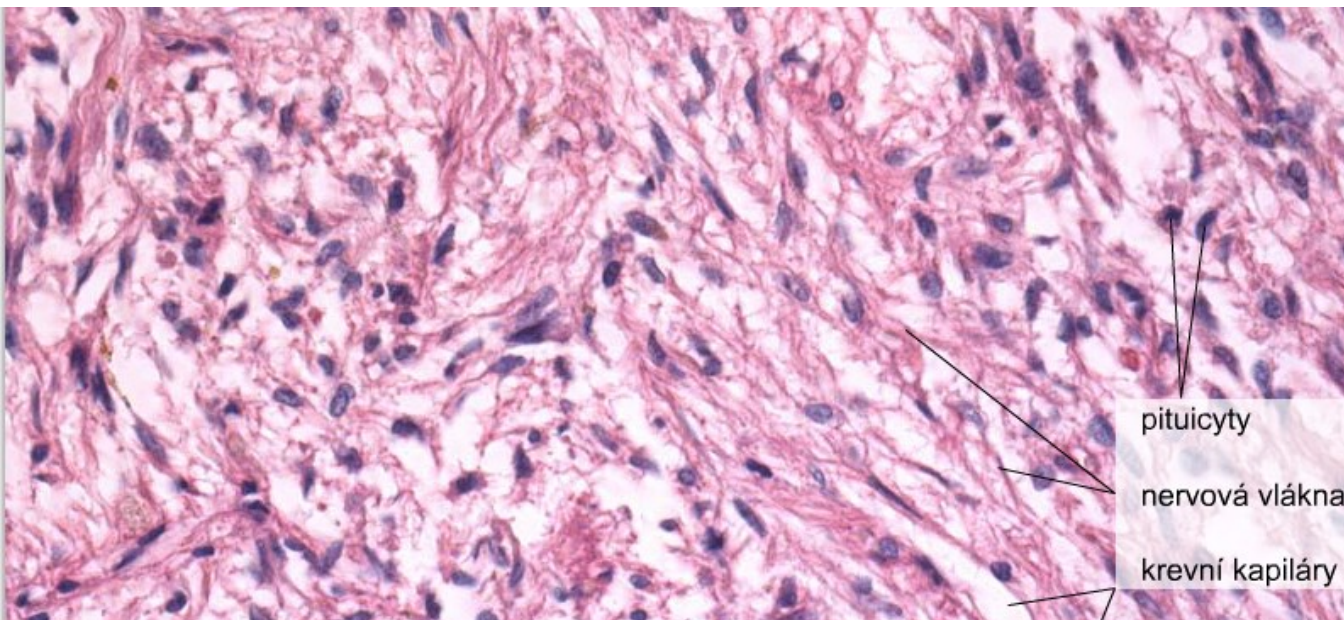


▼ Origin of ADH.



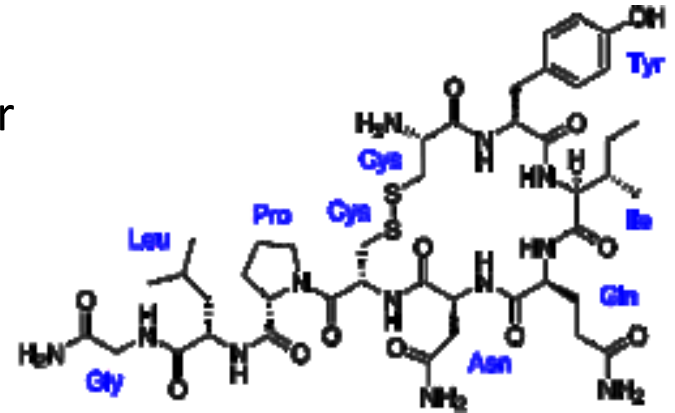
F. Netter M.D.

Hormone	Principal Action	Principal Nucleus of Origin
Oxytocin (OXY)	Uterine contraction, milk ejection	Paraventricular
Anti-diuretic hormone (ADH)	Water excretion in kidney, arteriolar constriction	Supraoptic



Oxytocin

- nonapeptide
- magno-cellular supraoptic and paraventricular hypothalamus
- OR - G-coupled receptor
- lactation reflex
- uterine contraction
- social behavior



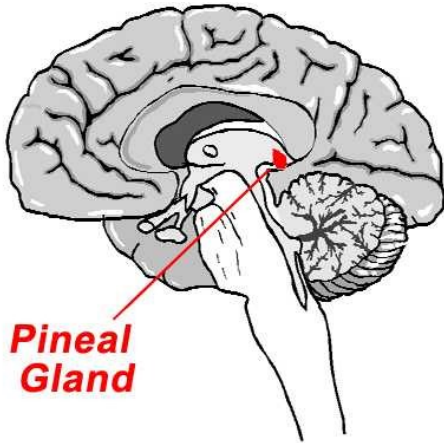
Vasopressin

- nonapeptide
- retention of water
- effective in collecting duct and distal convoluted tubule (aquaporine translocations)
- blood pressure regulation by affecting t. media
- diabetes insipidus, hypernatremia, polyuremia

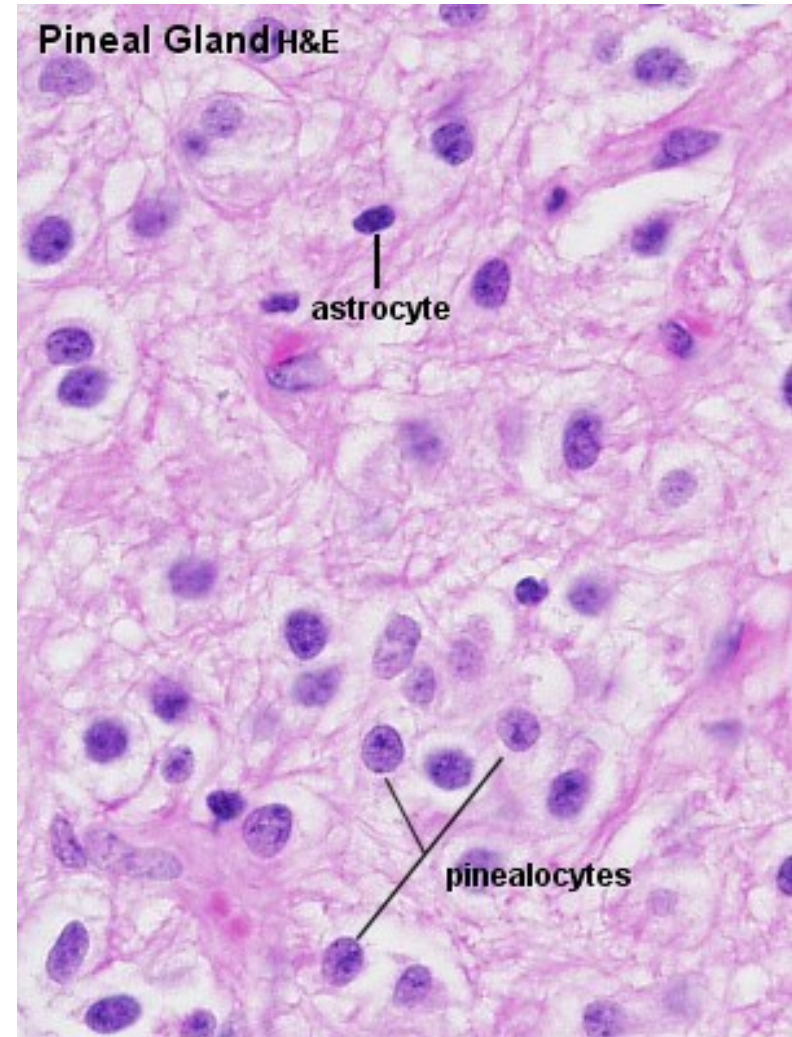


Anatomy			Microscopic anatomy		Hormones and target tissues			
Anterior lobe (adenohypophysis)	pars distalis	<p>superior hypophyseal arteries</p> <p>→ primary capillary plexus at eminentia mediana</p> <p>→ hypophyseal portal veins → secondary capillary plexus</p>	trabecular epithelium in cords and clusters, reticular fibers; agranular folliculo-stellate cells with so far unclear function		lack hormonal activity			
			chromophobes	undifferentiated cells degranulated chromophilic cells stromal cells				
			pars tuberalis	Rathke's cysts	chromophils	acidophilic nonglandotropic	mammotropic cells	small polypeptides
	somatotropic cells	somatostatin (GHIH) ↓ GHRH → somatotropin (STH)					directly liver and growth plates other tissues via somatomedins	
	pars intermedia	Rathke's cysts	basophilic glandotropic	corticotropic cells		glycoproteins	CRH → ACTH, MSH	adrenal cortex → cortisol melanocytes
				thyrotropic cells	TRH → TSH		thyroid → thyroxin, T3	
	gonadotropic cells	GnRH → FSH (ICSH), LH		gonads → androgens, estrogens, progesterone				
Posterior lobe (neurohypophysis)	eminetia mediana → infundibulum	<p>inferior hypophyseal arteries</p> <p>→ capillary plexus in neurohypophysis</p>	<p>nonmyelinated axons of hypothalamic neurons n. supraopticus, n. paraventricularis (tractus hypothalamohypophysialis), pituitocytes</p>		small peptides	ADH	tubulus reuniens, ductus colligens t.media of vessels	
	pars nervosa					oxytocin	myometrium of uterus during gravidity myoepithelium of lactating mammary gland	

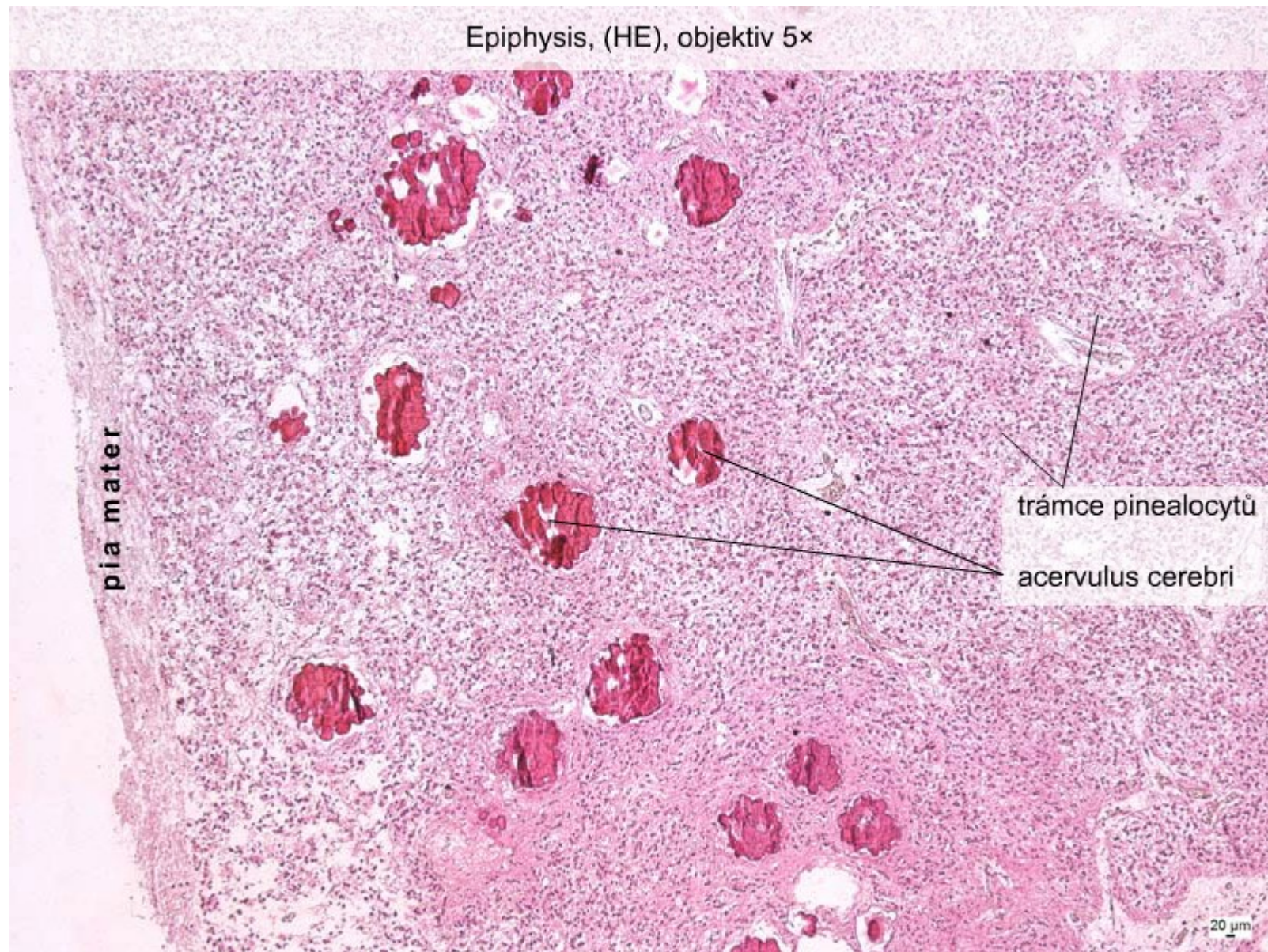
Epiphysis (*c. pineale*)



- epithalamus
- c.t. capsule continuous to pia mater
- thin c.t. septa
- nonmyelinated nerve fibers
- **pinealocytes** (95%, large, pale, round nuclei)
- interstitial neuroglia (astrocytes, dark, elongated nuclei)
- *acervulus cerebri*
- melatonin



Epiphysis, (HE), objektiv 5×



pia mater

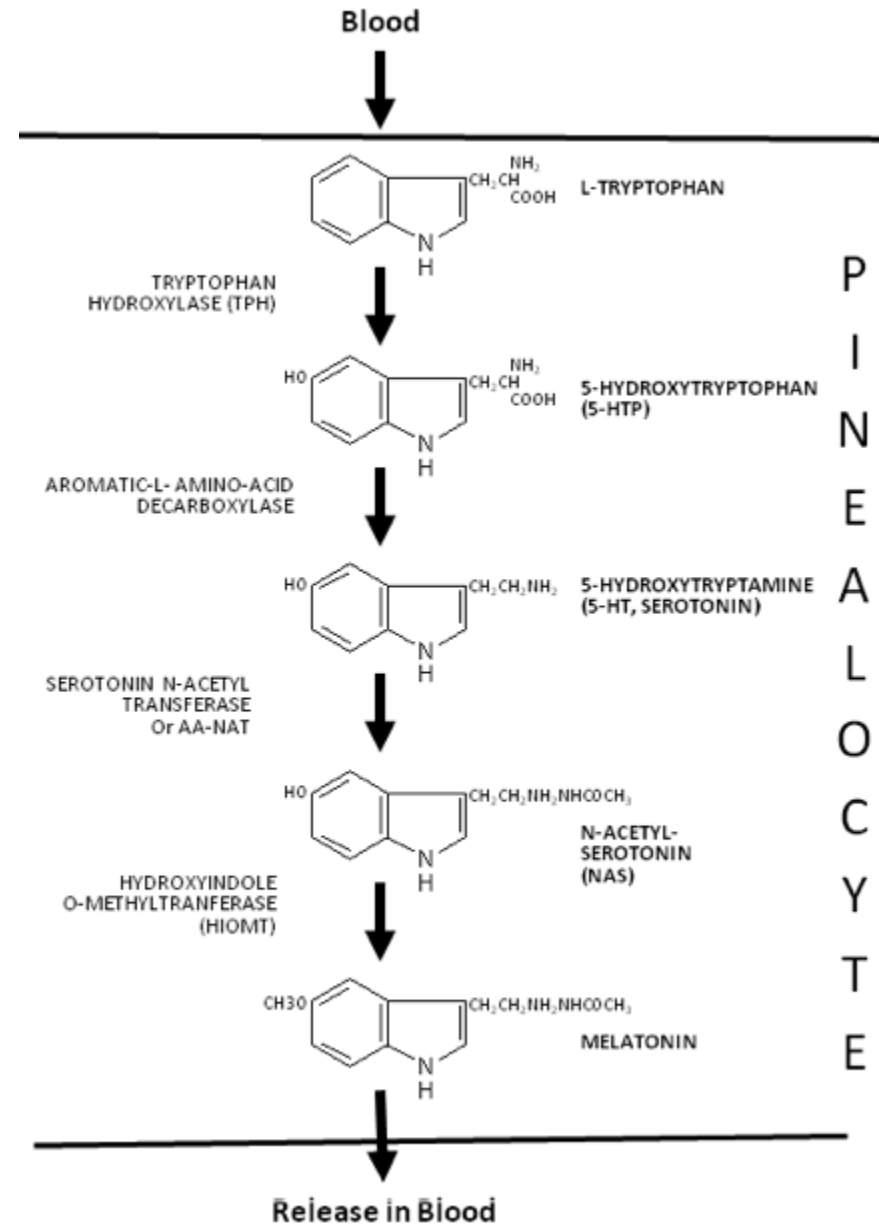
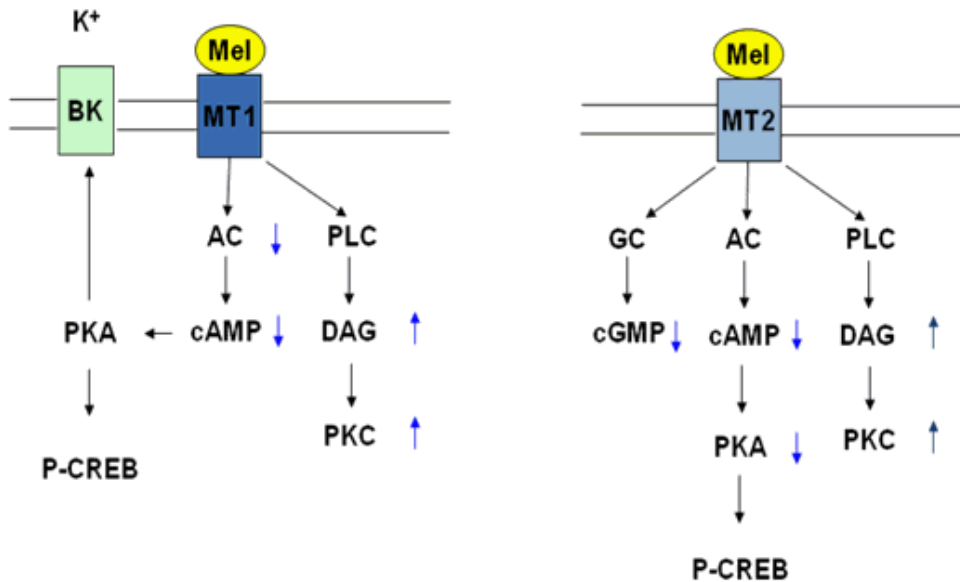
trámce pinealocytů

acervulus cerebri

20 μm

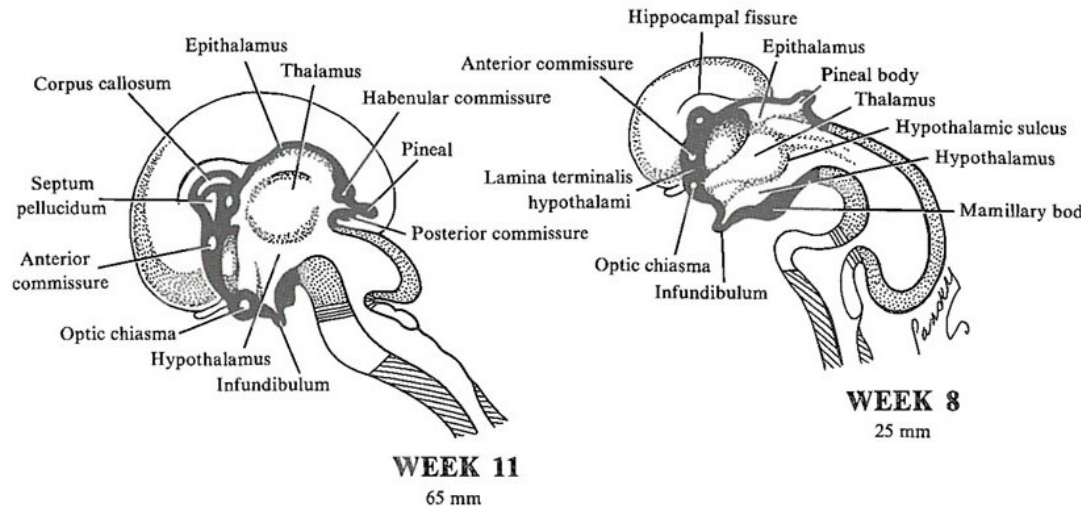
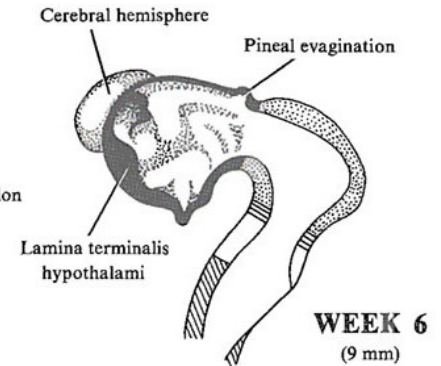
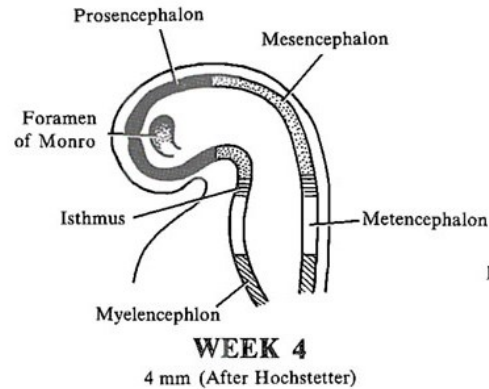
Epiphysis (*c. pineale*)

- pinealocytes
- star-like, modified neurons in trabecules
- association with fenestrated capillaries
- neurosecretory dilatations
- nonvisual photoreception



Embryonic development of epiphysis (*c. pineale*)

- thickening of caudal part of ependyma that does not contribute to development of choroid plexus at the roof of diencephalon
- neuroectoderm



Thyroid gland (*gl. thyroidea*)

- Follicular cells → thyroid hormones (T3, T4)
- **C cells** → calcitonin

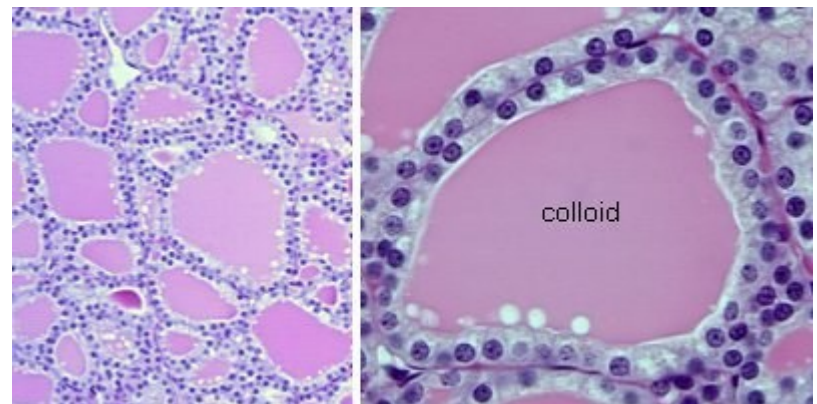
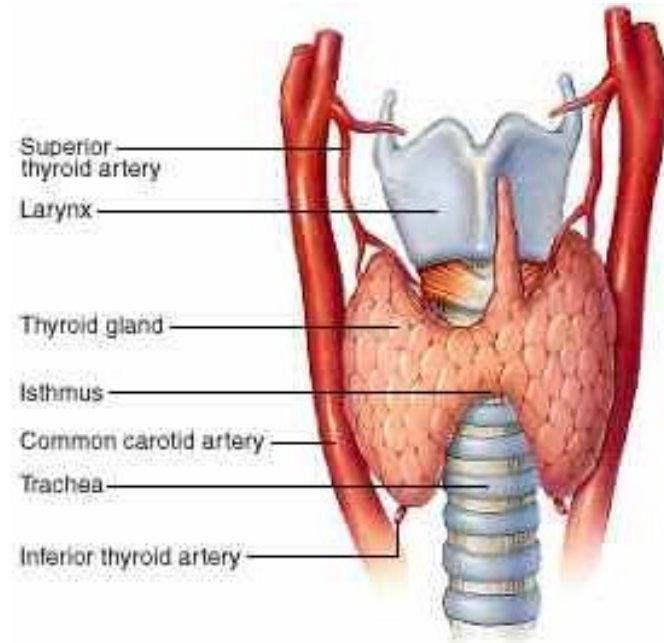
C.t. capsule, septa

Lobes → lobuli - follicles

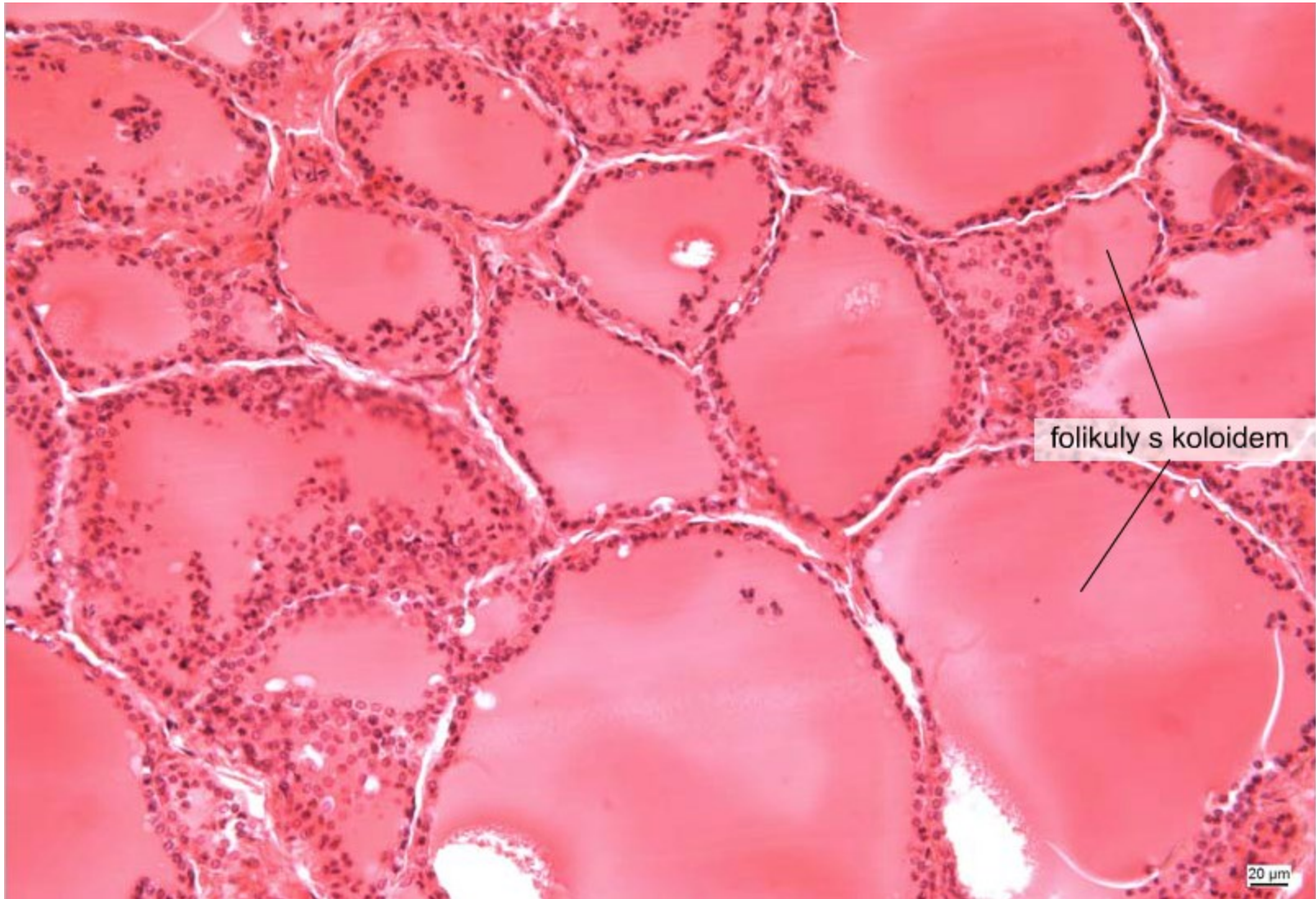
Follicles (50 μm - 1 mm)

- separated by interstitial loose collagen c.t.
- simple epithelium (flat to cubic, according to secretory activity)
- colloid

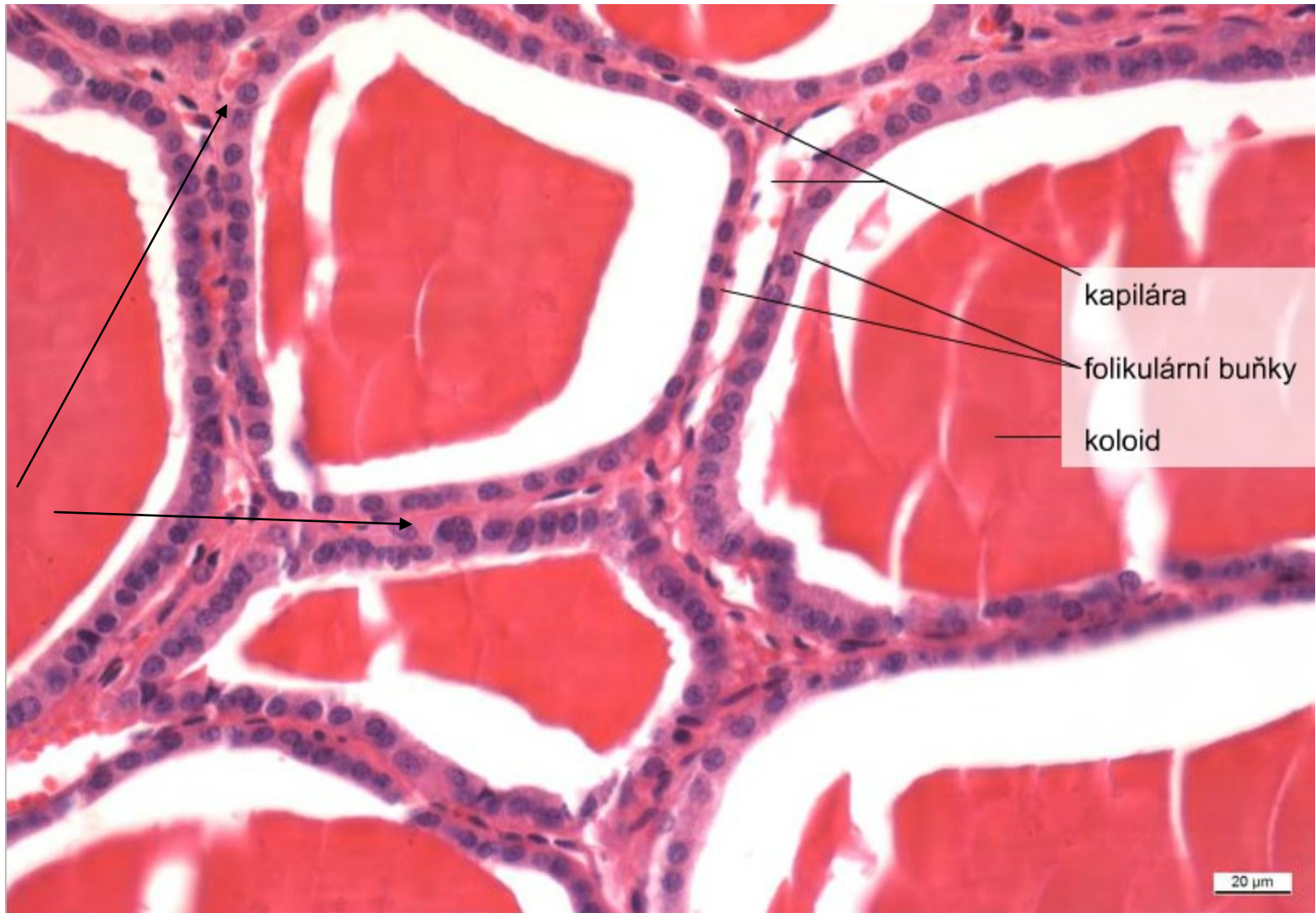
Capillary network from thyroid arteries



Thyroid gland - follicles



Thyroid gland - follicles



C-cells

kapilára

follikulární buňky

koloid

20 μm

Follicular cells and C-cells (parafollicular)

Synthesis of T3 and T4

T4 synthesis in thyroid

- sodium-iodide symporter transports two Na^+ and one I^- across the basement
- I^- is moved across the apical membrane into the colloid of the follicle.
- thyroperoxidase oxidises $2 \text{I}^- \rightarrow \text{I}_2$.
- thyroperoxidase iodinates the tyrosyl residues of thyroglobulin
- (TSH) stimulates the endocytosis of the colloidal content
- endocytic vesicles + lysosomes, lysosomal enzymes cleave T_4 from the iodinated thyroglobulin
- exocytosis

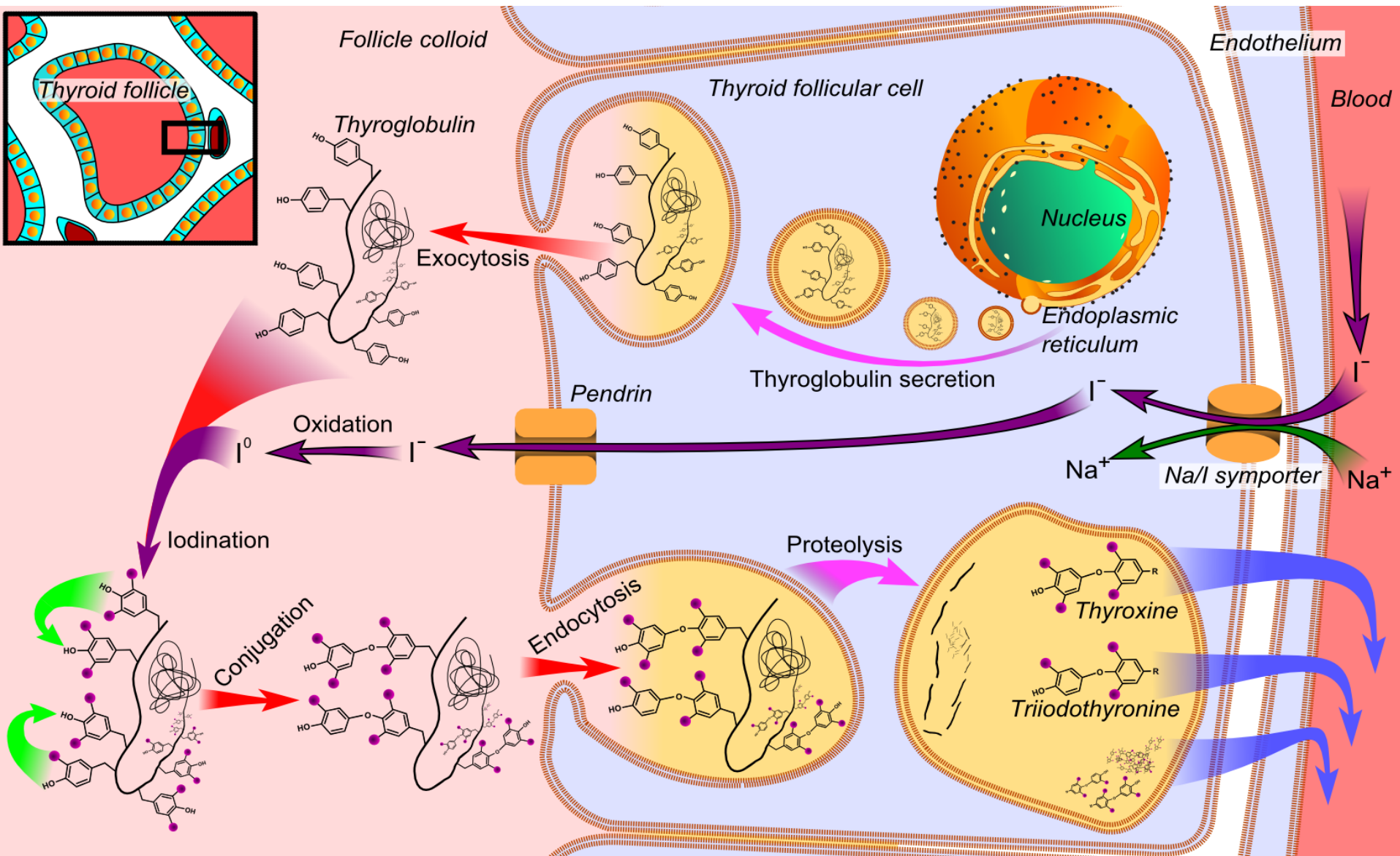
T3 synthesis from T4

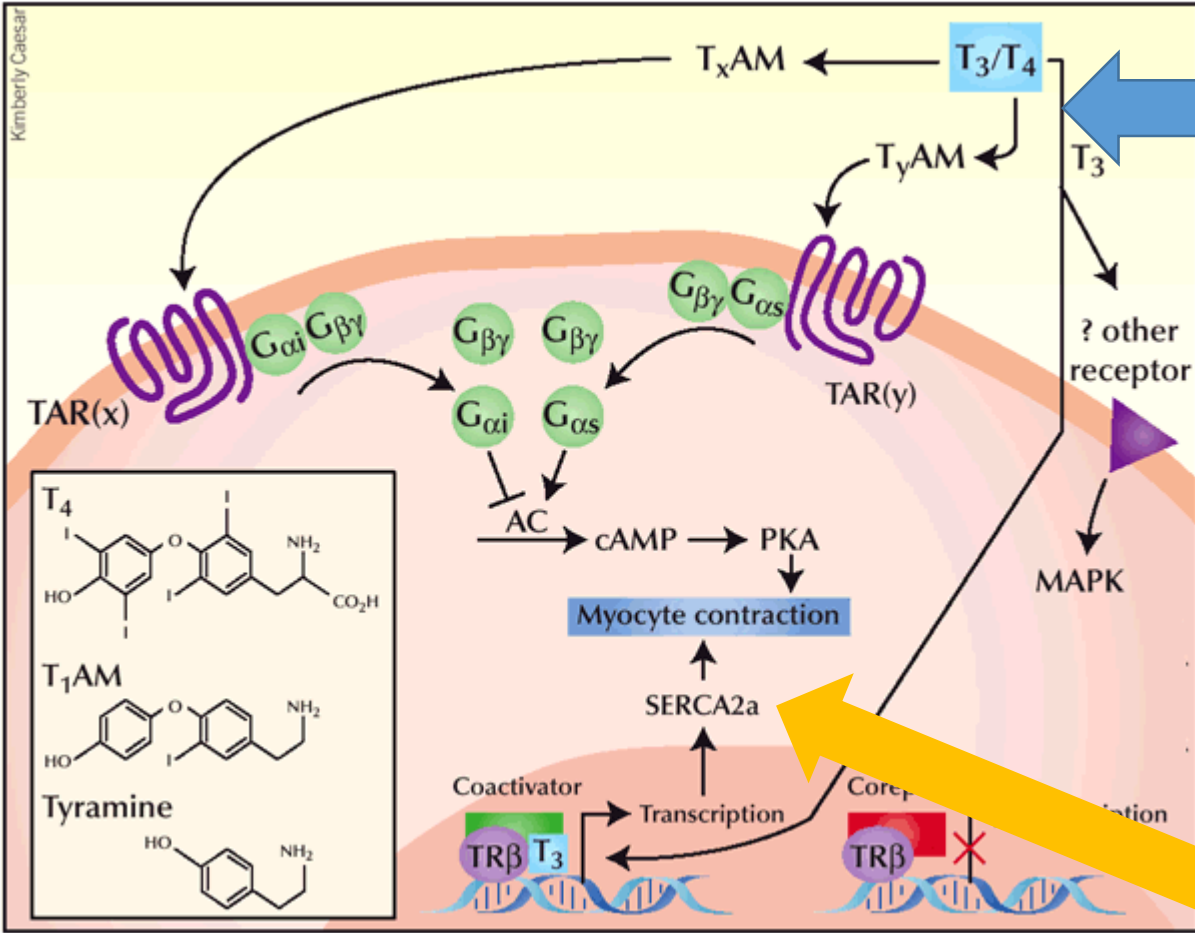
- T4 half-life in blood 6.5 days, T3 2.5 (T4 is a reservoir for T3)
- deiodination by tissue specific deiodinase enzymes generates T3

thyreoglobulin

triiodothyronin T_3

tetraiodothyronin (thyroxin) T_4





Canonical T3 pathway

Alternative T3 pathway

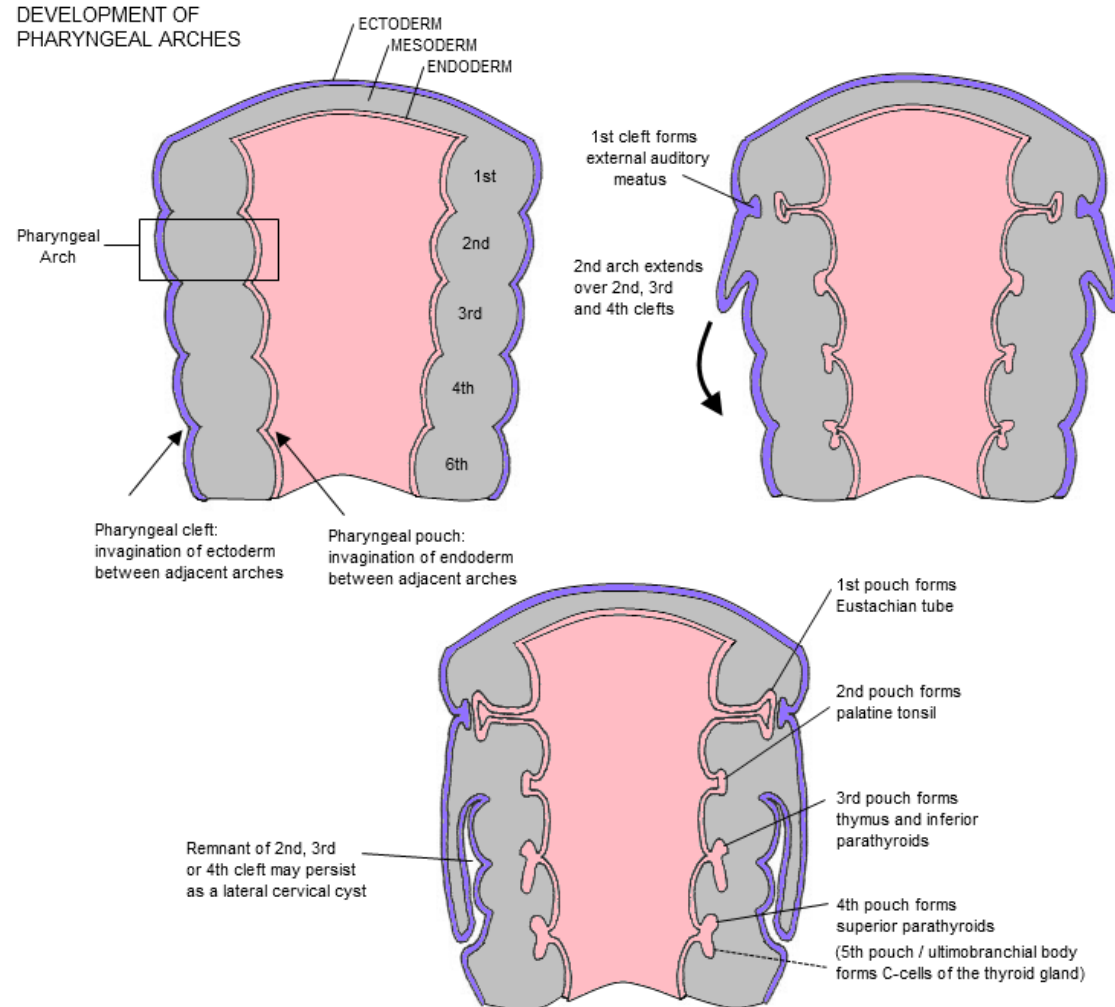
C cells of thyroid

Neuroendocrine cells

- pale staining
- epithelial basis, under basal lamina no contact with colloid
- derived from neural crest
- associate with ultimobranchial body, (derivative of the 4th pharyngeal pouch)

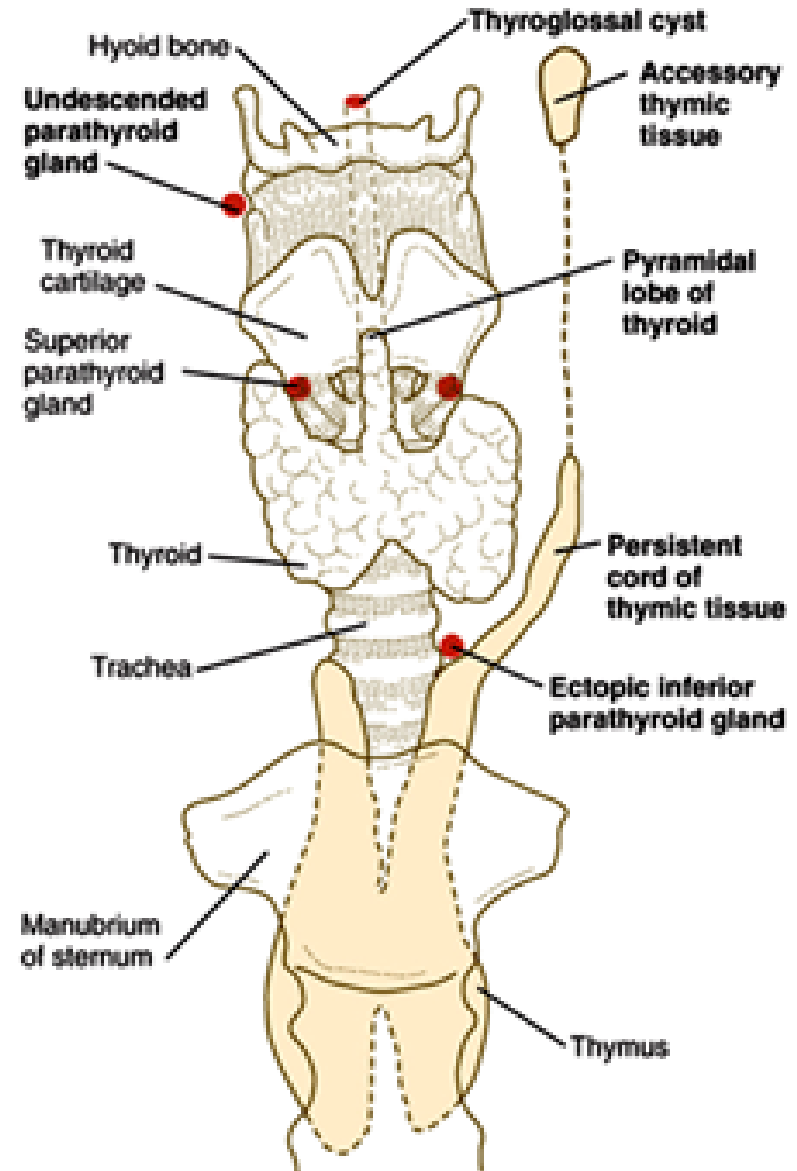
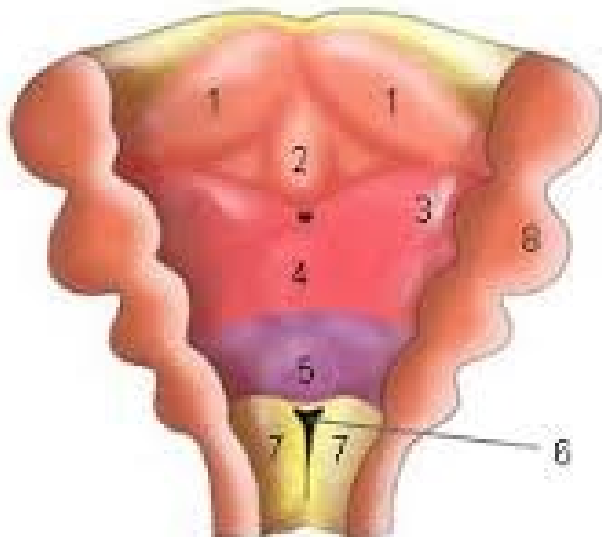
Calcitonin

- inhibition of osteoclasts



Thyroid development

- endodermal proliferation of pharyngeal floor
- hypobranchial eminence and foramen caecum
- bilobed diverticulum
- ductus thyreoglossus



Parathyroid gland (gl. parathyreoidea)

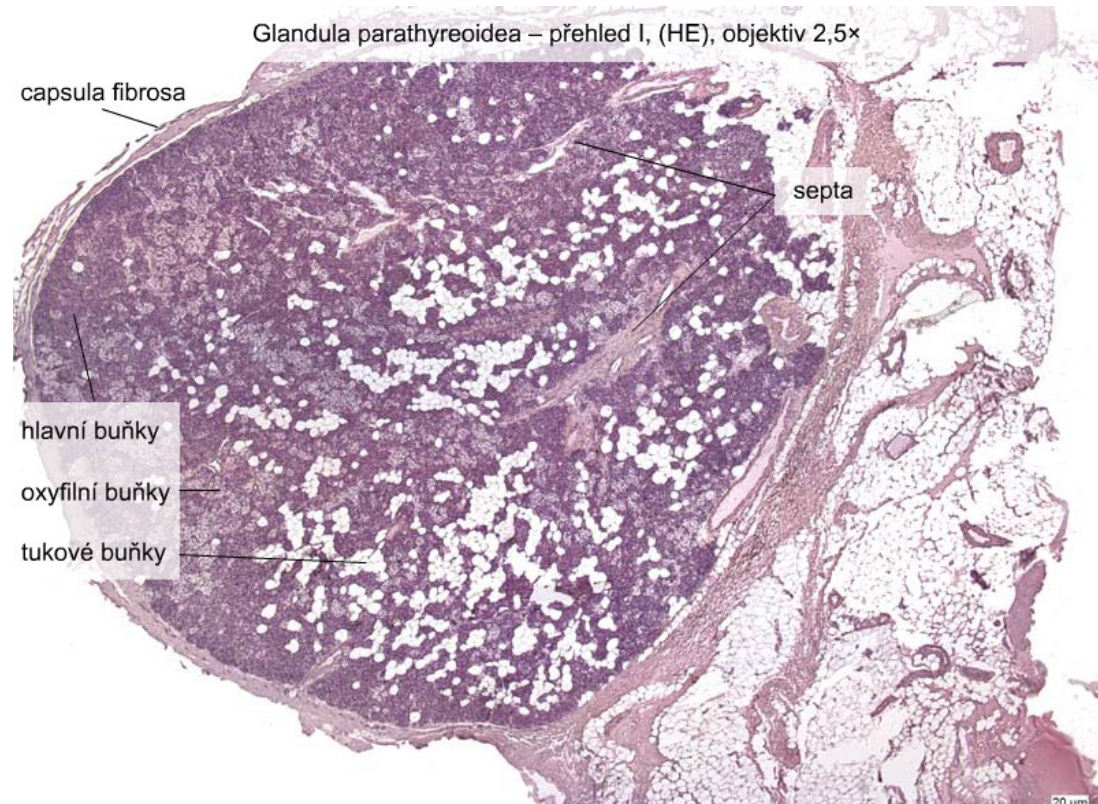
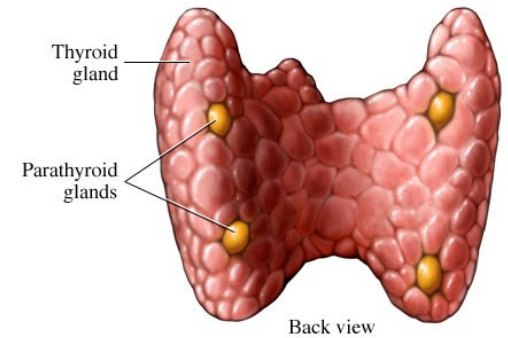
6 mm, 130 mg

c.t. capsule and septa

Capillary network

Cords and clusters of glandular cells

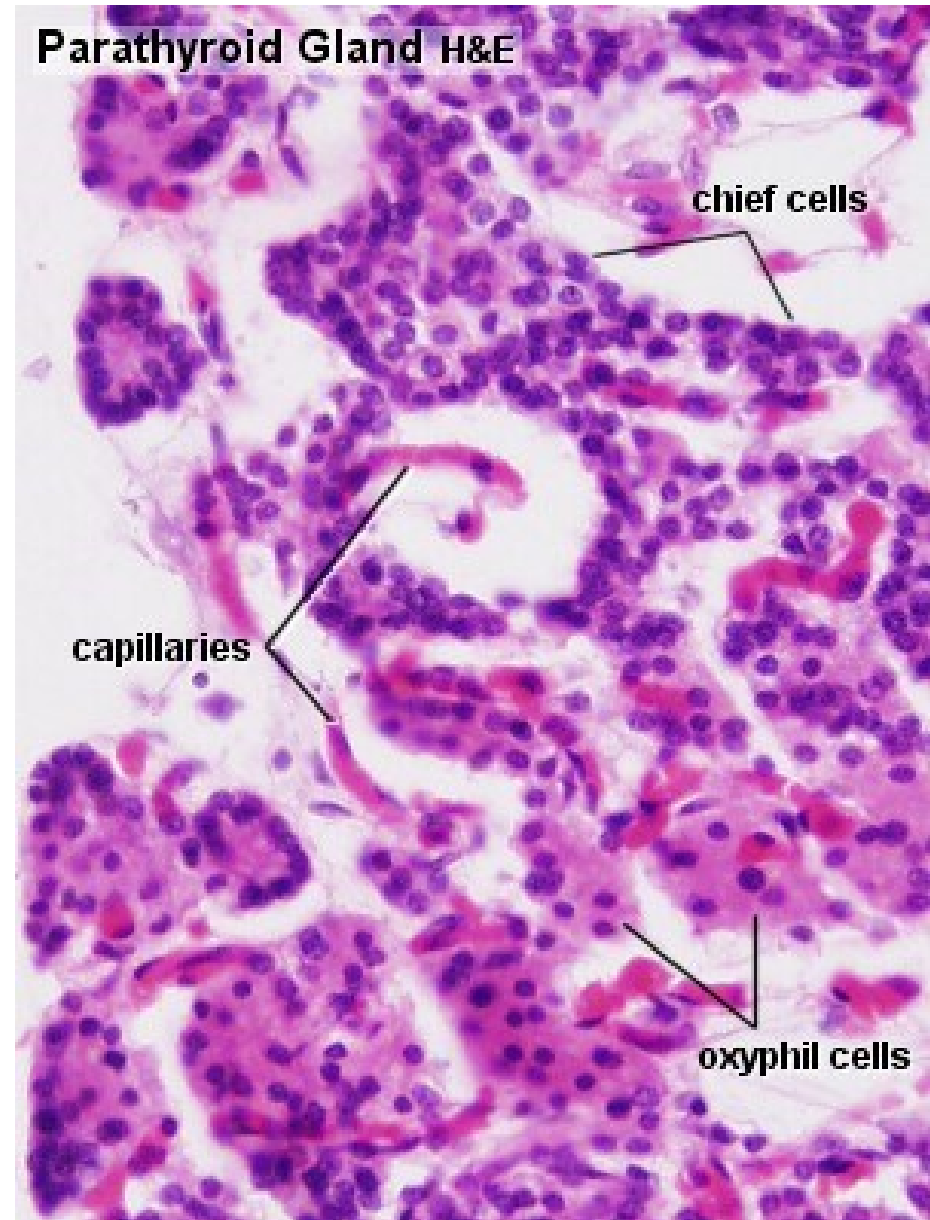
- Chief
- Oxyphilic
- Adipose



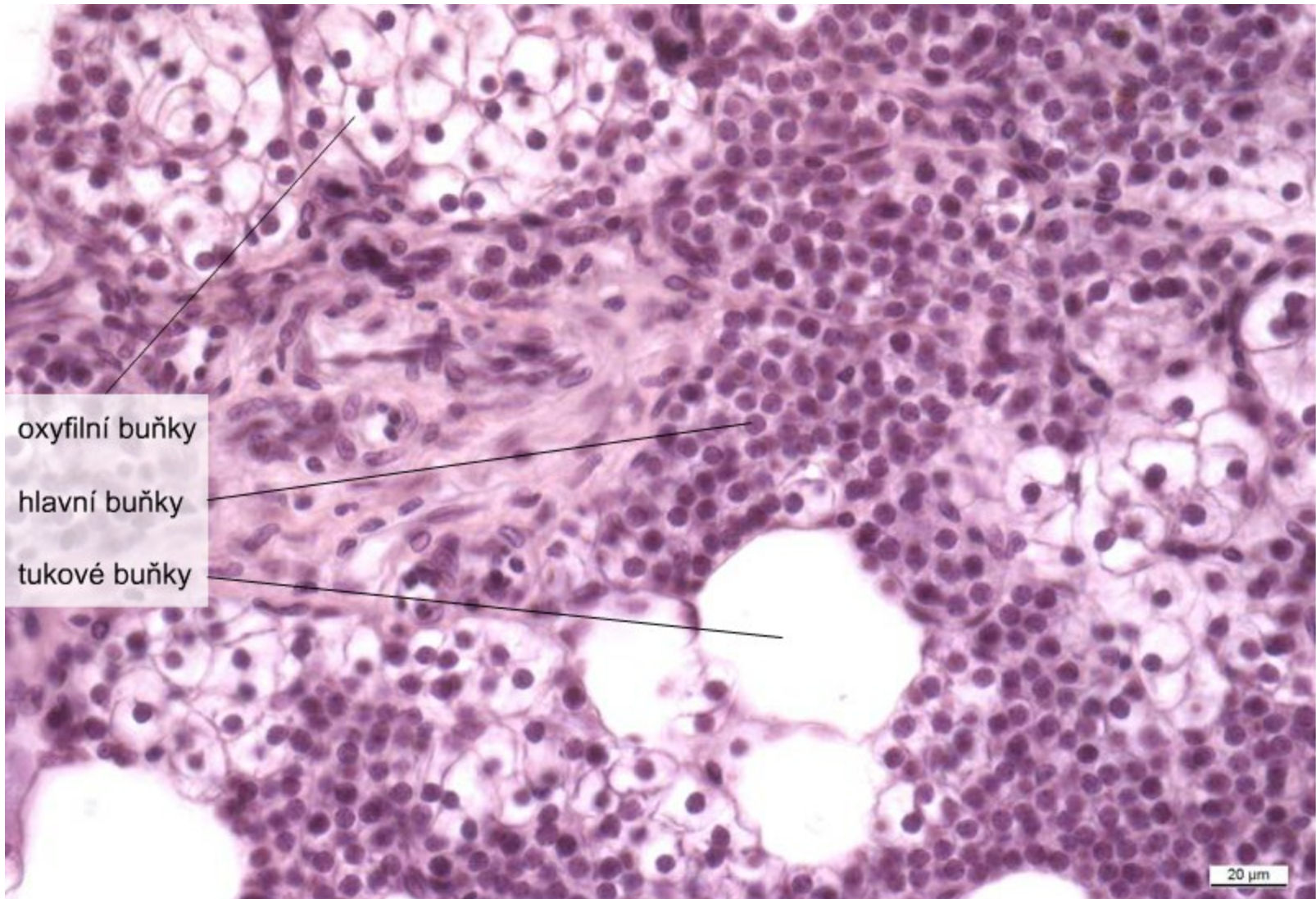
Parathyroid gland (gl. parathyreoidea)

- **Chief**
 - most abundant
 - small cells (7-10 μ m, big nucleus
 - mildly acidophilic
 - PTH – calcium metabolism

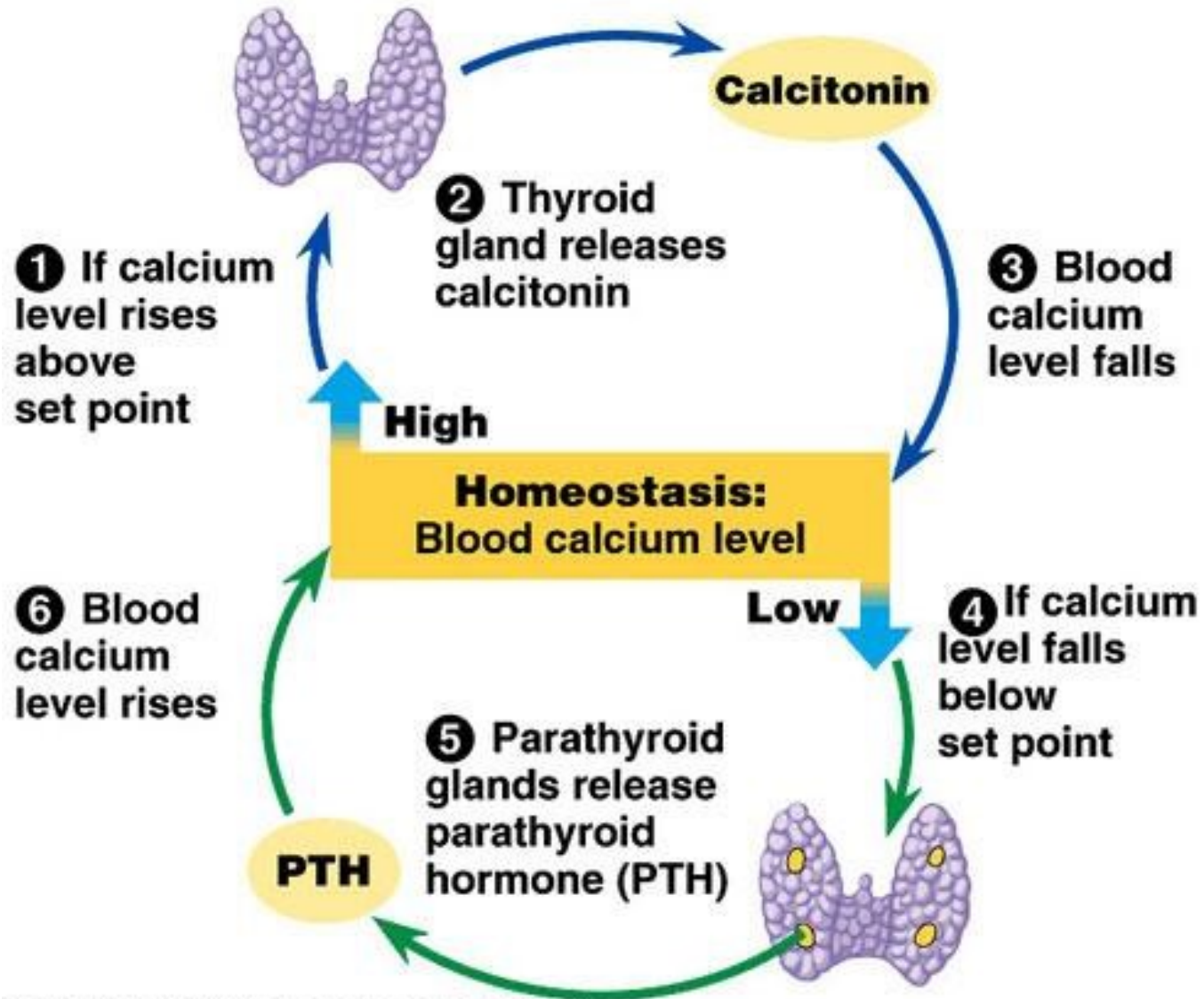
- **Oxyphylic**
 - large, polyhedral,
 - strongly acidophilic
 - round nucleus
 - glycogen



Parathyroid gland (gl. parathyreoidea)



PTH vs. calcitonin

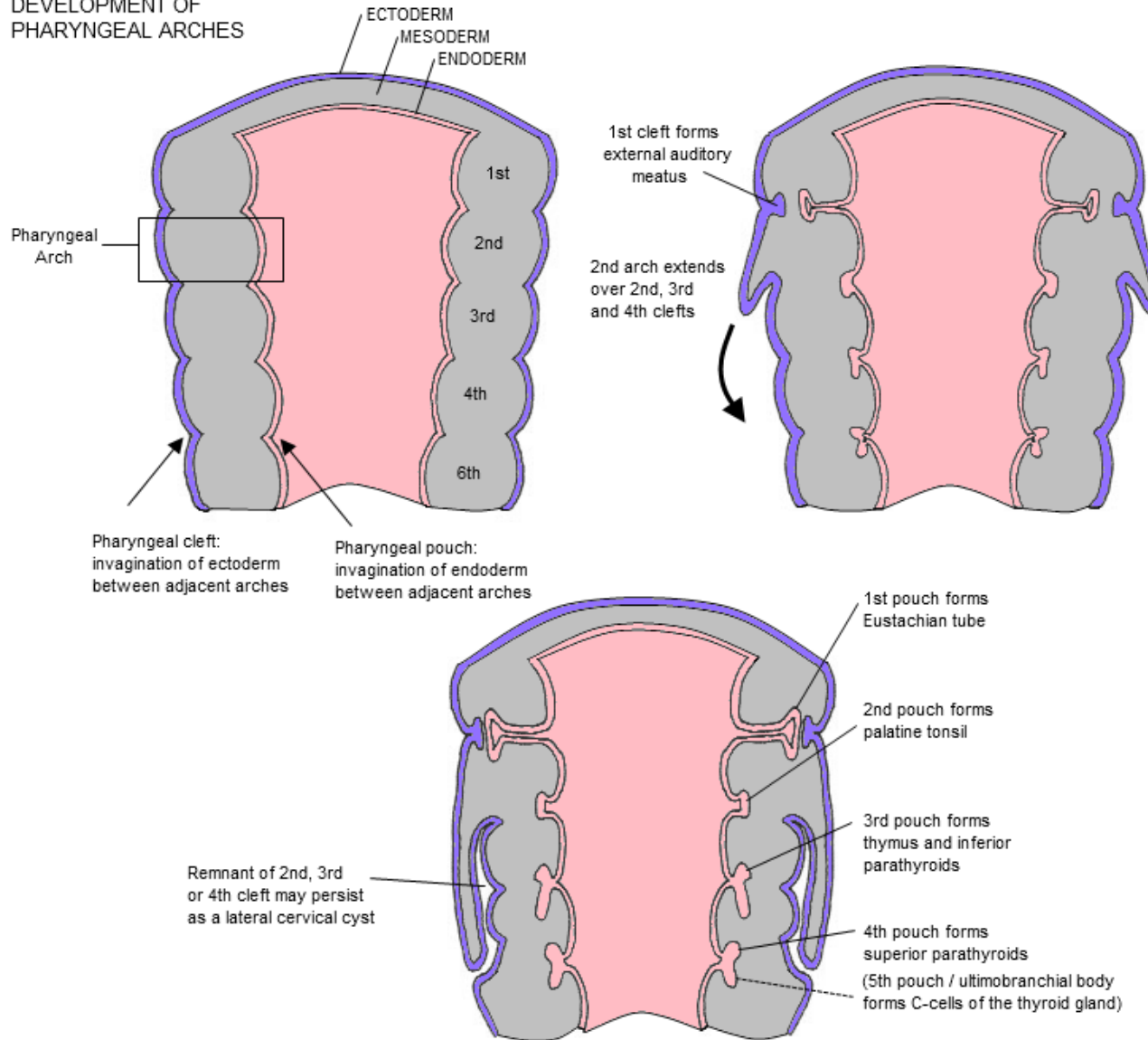


Embryonic development of parathyroid gland

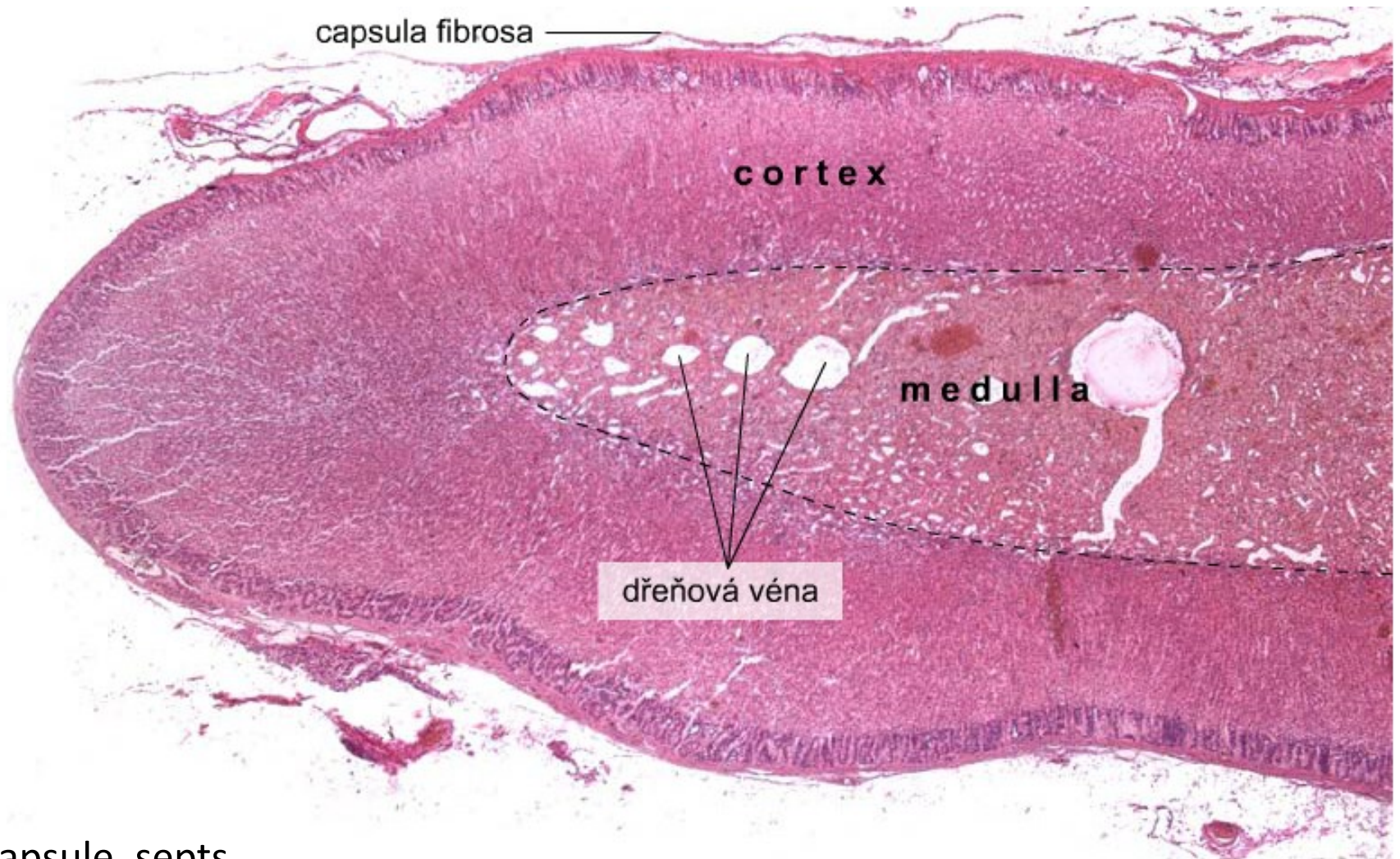
- glandulae parathyroideae superiores from endoderm of 4th pharyngeal pouch
- glandulae parathyroideae inferiores from dorsal process of 3th pharyngeal pouch
- together with thymus descend to lower poles of thyroid
- ectopic PTH gland in thymus or mediastinum

Embryonic development of parathyroid gland

DEVELOPMENT OF PHARYNGEAL ARCHES



Adrenal gland (*corpus suprarenale*)



c.t. capsule, septa

capillary plexus

Adrenal development

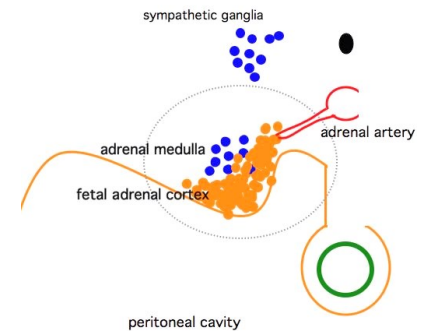
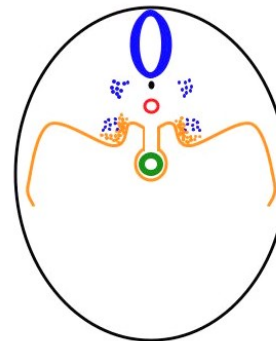
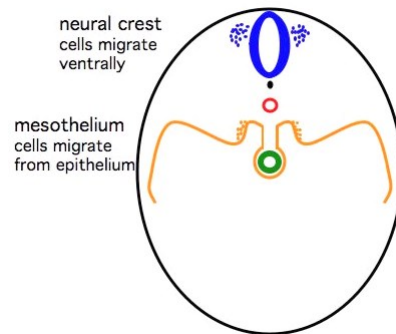
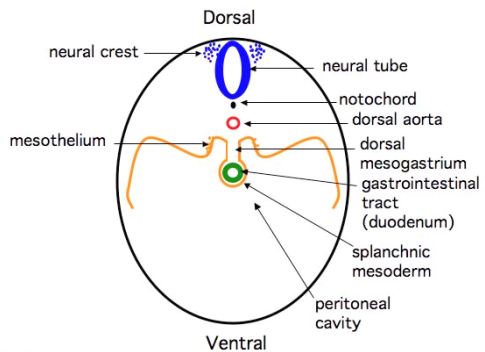
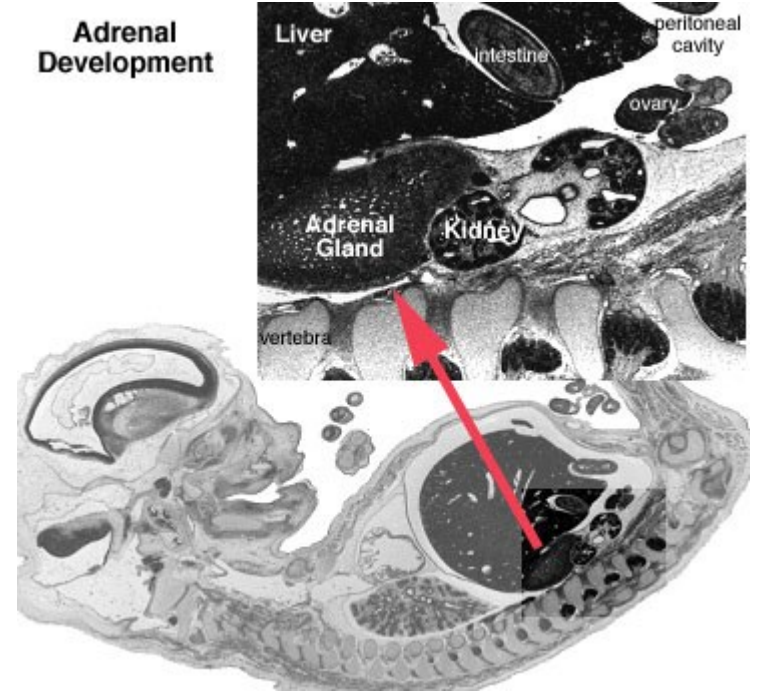
cortex

- mesoderm
- mesothelium, coelomic epithelium

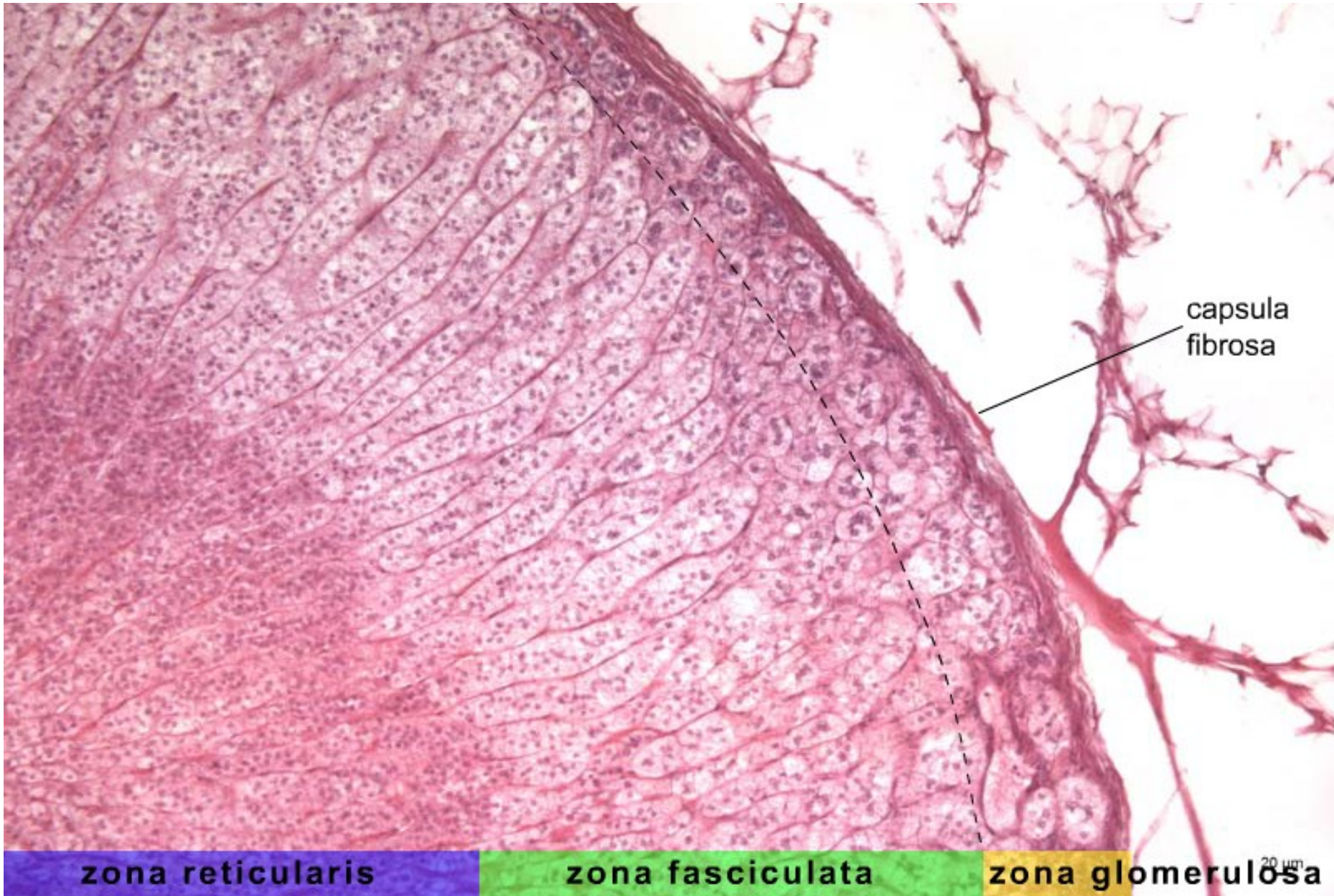
medulla

- neural crest

Adrenal Development

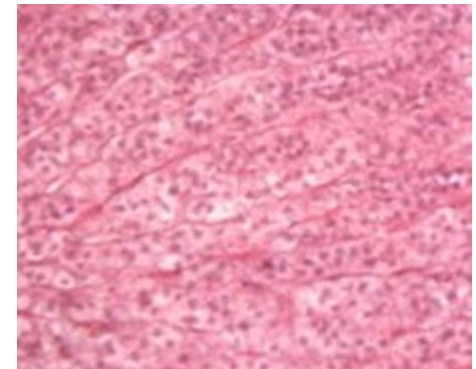
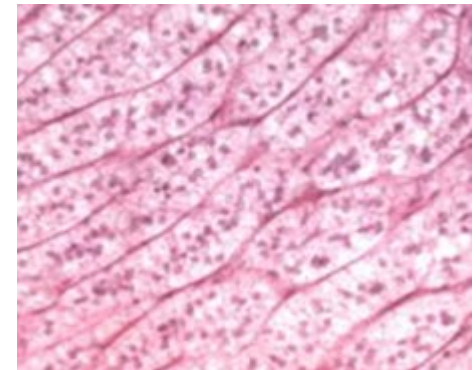
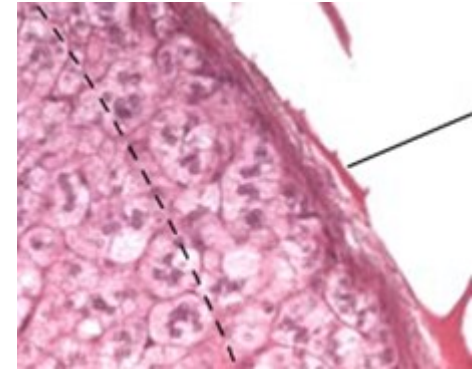


Adrenal cortex



Adrenal cortex

- **Zona glomerulosa (1/10)**
 - thin layer under capsule
 - relatively small cells in coiled glomeruli
 - not abundant lipid droplets
 - **mineralocorticoids**
- **Zona fasciculata (6/10)**
 - radially arranged trabecules
 - lipid droplets in cytoplasm
 - **glucocorticoids**
- **Zona reticularis (3/10)**
 - branched trabecules
 - small, acidophilic cells
 - lipofuscin
 - **androgen precursors**

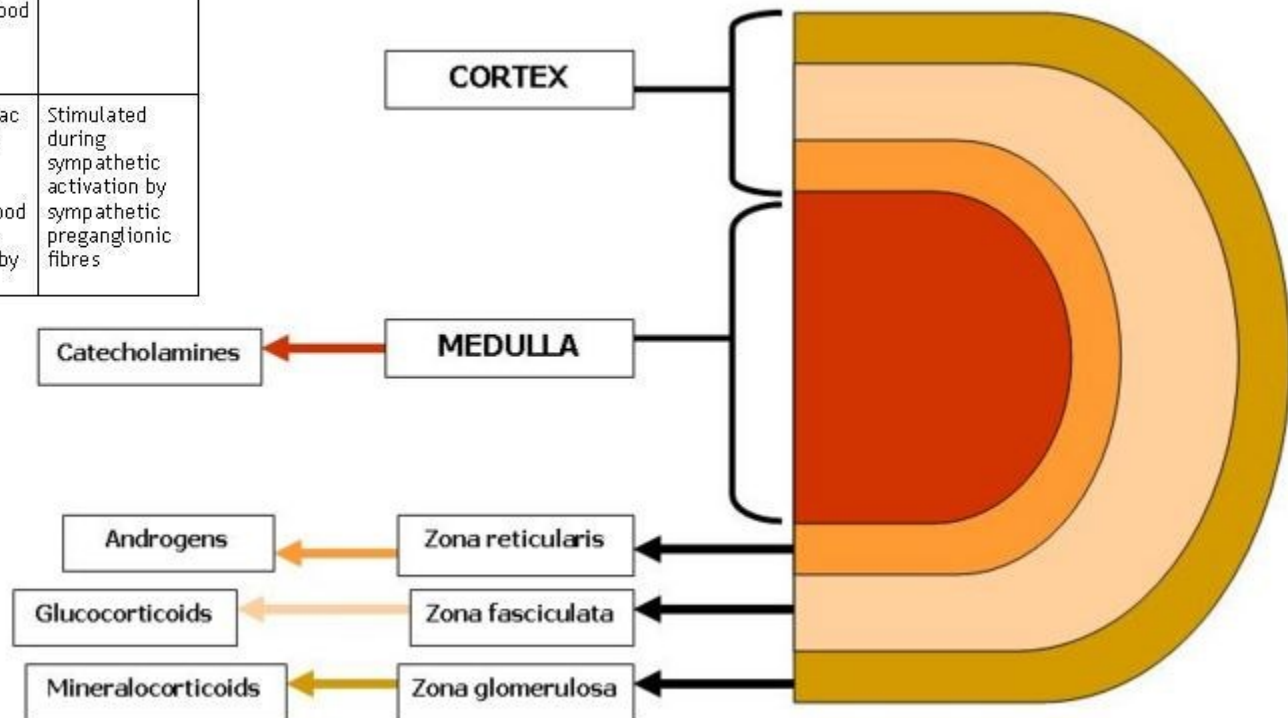


Adrenal cortex hormones

- Steroids produced in cortex = CORTICOSTEROIDS
- Steroidogenic cells
 - SER, lipid droplets, mitochondria
 - *mineralocorticoids*
 - *glucocorticoids*
- Aldosteron – *zona glomerulosa*
- Kortisol – *zona fasciculata*
- Androgens, estrogens, progesteron – *zona reticularis*

Adrenal cortex hormones

Region/ Zone	Hormone(s)	Primary Targets	Hormonal Effects	Regulatory Control
Cortex <i>Zona glomerulosa</i>	Mineralocorticoids (primarily aldosterone)	Kidneys	Increase renal reabsorption of Na ⁺ and water (especially in the presence of ADH and accelerate urinary loss of K ⁺)	Stimulated by angiotensin II, elevated plasma K ⁺ , or a fall in plasma Na ⁺ ; inhibited by ANP and BNP
<i>Zona fasciculata</i>	Glucocorticoids [cortisol (hydrocortisone), corticosterone]	Most cells	Release amino acids from skeletal muscles and lipids from adipose tissues; promote peripheral utilization of lipids; anti-inflammatory effects	Stimulated by ACTH from an anterior lobe of pituitary gland
<i>Zona reticularis</i>	Androgens	Most cells	Not important in adult men; encourages bone growth, muscle growth, and blood formation in children and women	Stimulated by ACTH
Medulla	Epinephrine, norepinephrine	Most cells	Increases cardiac activity, blood pressure, glycogen breakdown, blood glucose levels; releases lipids by adipose tissue	Stimulated during sympathetic activation by sympathetic preganglionic fibres



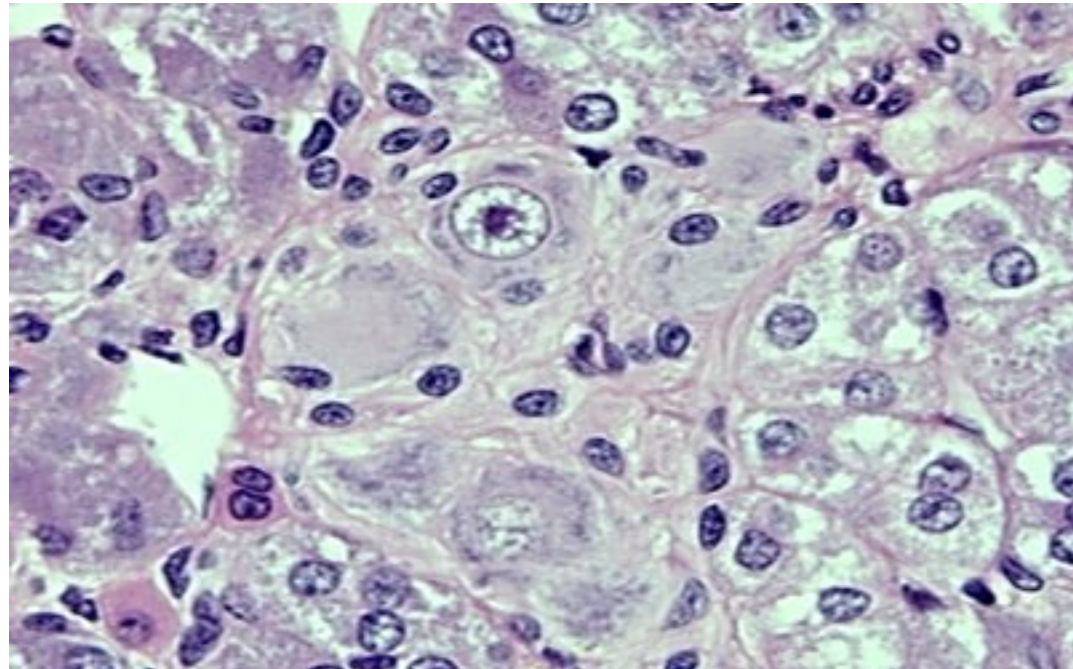
Adrenal medulla

Clusters of glandular cells in reticular c.t.

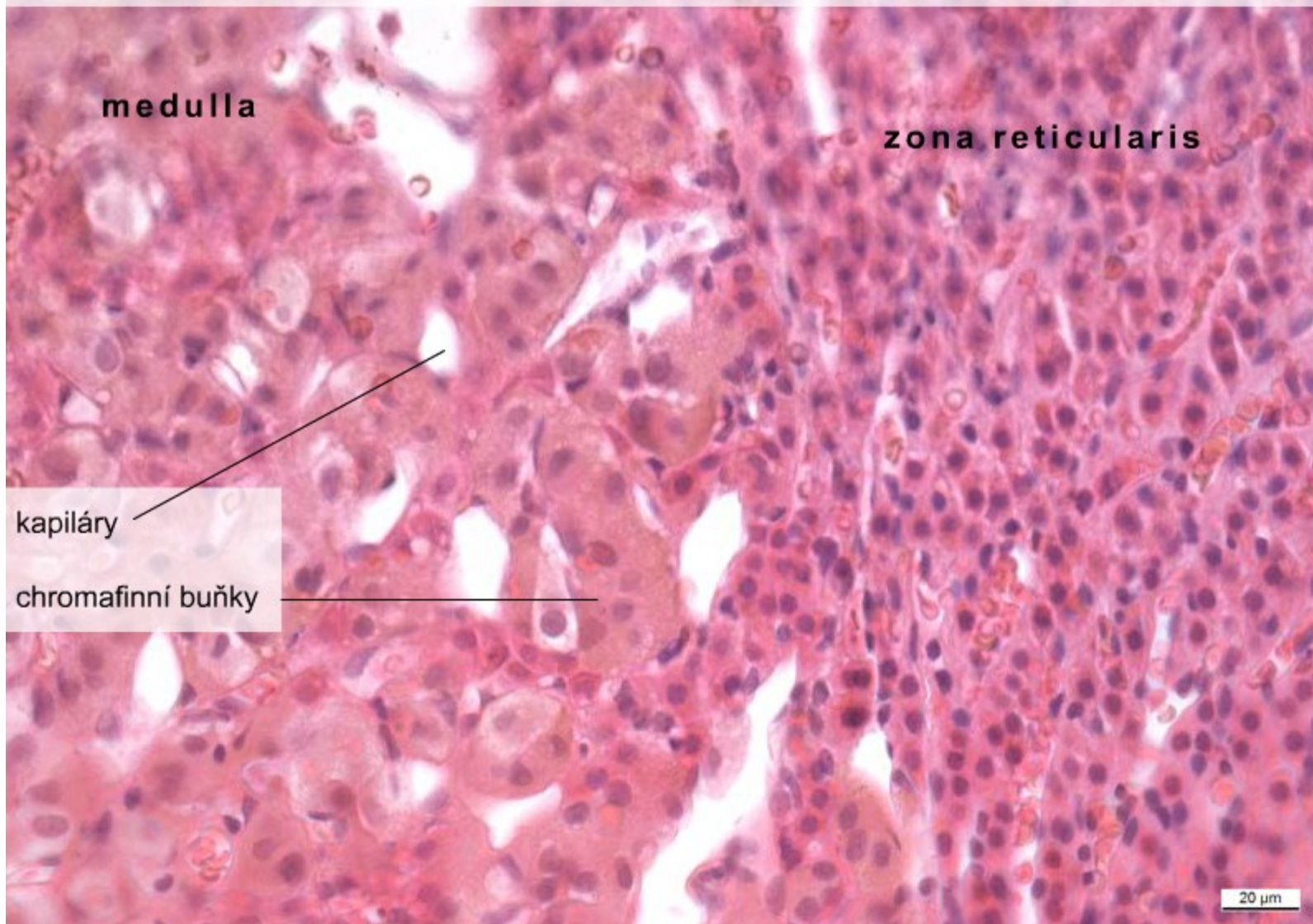
- chromaffin cells – modified postganglionic neurons
- ganglionic cells
- capillaries, venules, nerve fibers

- **adrenaline and noradrenaline**

Neural crest origin



Corpus suprarenale – medulla, (HE), objektiv 40×



medulla

zona reticularis

kapiláry

chromafinní buňky

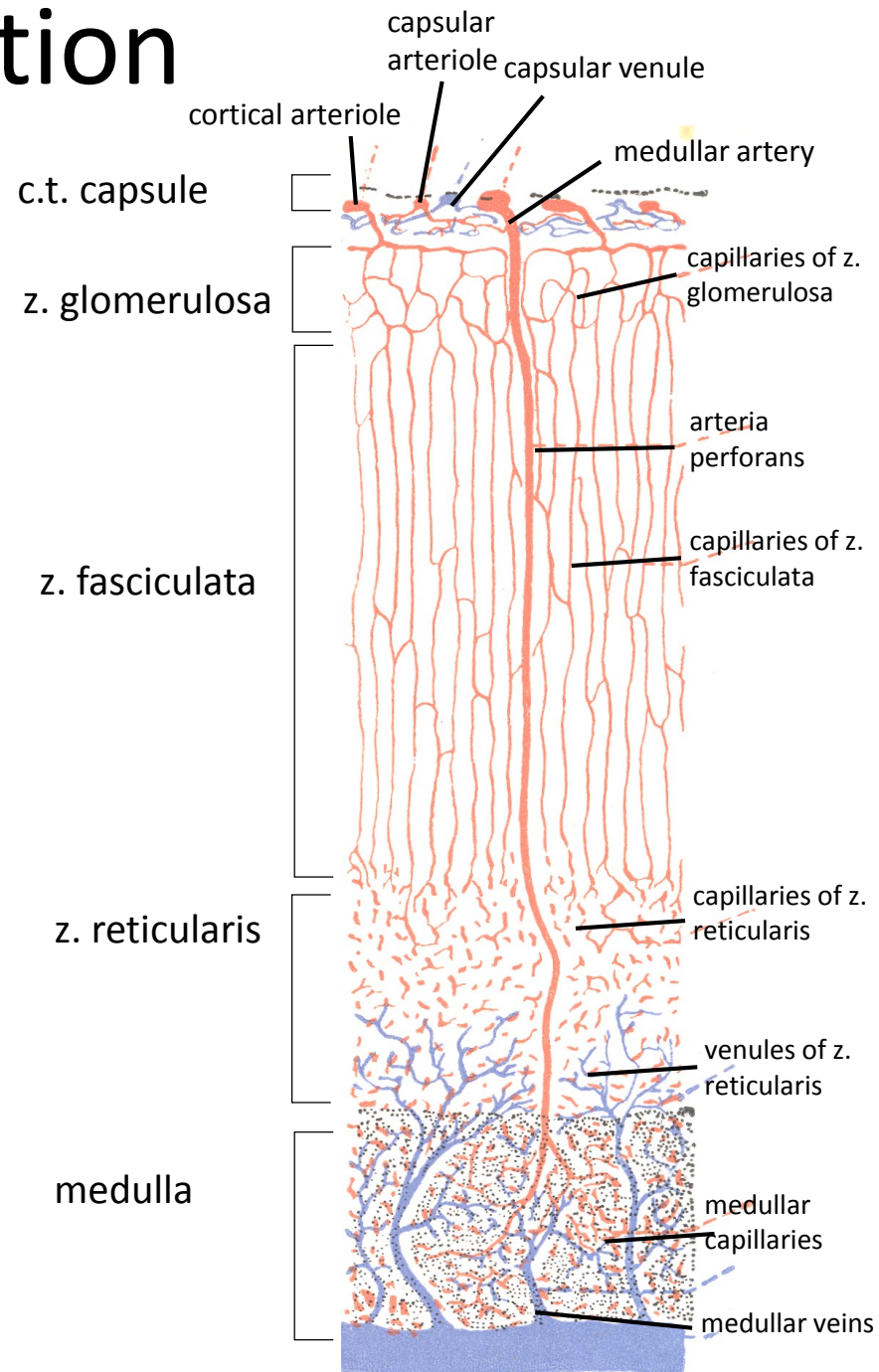
20 μm

Adrenal vascularisation

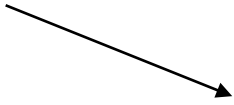
arteriae suprarenales (3) → arterial plexus in cortex under c.t. capsule → radially oriented fenestrated sinusoid capillaries continuous with medullar capillaries → medullar veins → *v. suprarenalis*

three arterial regions

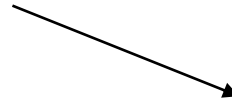
- 1) c.t. capsule and superior parts of cortex
- 2) radial capillaries of cortex continuing to medulla
- 3) medullar capillaries from *aa. perforantes*



Stress

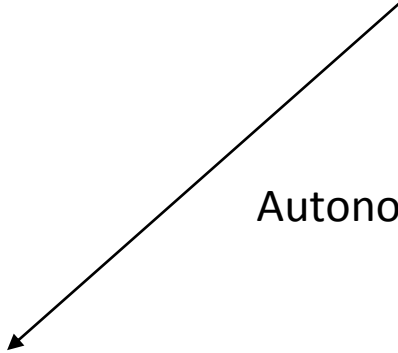


Hypothalamus



Pituitary gland

Autonomic nerve system



Adrenal medulla

ACTH



Adrenal cortex

Adrenaline

- blood pressure, vasoconstriction, heart rate...



Fight or Flight

Kortisol

- glycogen lysis
- stabilization of glucose levels
- suppression of immune system



Adaptation, regeneration

Adrenal hormones

Region (zone)		Hormone	Target tissue	Hormonal effect	Control
Cortex	Zona glomerulosa	Mineralocorticoids (aldosteron)	Kidney	Increased renal reabsorption of Na ⁺ and water Synergic to ADH Excretion of K ⁺	renin-angiotensin system, high level of K ⁺ low level of Na ⁺
	Zona fasciculata	Glucocorticoids (hydrocortison)	Most cells	Release of aminoacids from muscles and lipids from fat tissue, peripheral utilization of lipids, antiinflammatory effects	Stimulation by ACTH
	Zona reticularis	Androgens (dehydroepiandrosterone)	Most cells	In adult males not significant Children and women growth of bones, muscles, hematopoiesis	Stimulation by ACTH
Medulla		Epinefrine, norepinefrine	Most cells	Increased heart activity, centralization of circulation, bronchodilatation, glycogenolysis, regulation of glycemia	Sympaticus

Langerhans islet of pancreas



Paul Langerhans
1847 – 1888)

Beiträge
zur mikroskopischen Anatomie der
Bauchspeicheldrüse.

INAUGURAL-DISSERTATION,

ZUR
ERLANGUNG DER DOCTORWÜRDE

IN DER

MEDICIN UND CHIRURGIE

VORGELEGT DER

MEDICINISCHEN FACULTÄT

DER FRIEDRICH-WILHELMS-UNIVERSITÄT

ZU BERLIN

UND ÖFFENTLICH SO VORGELESEN

am 18. Februar 1869

VON

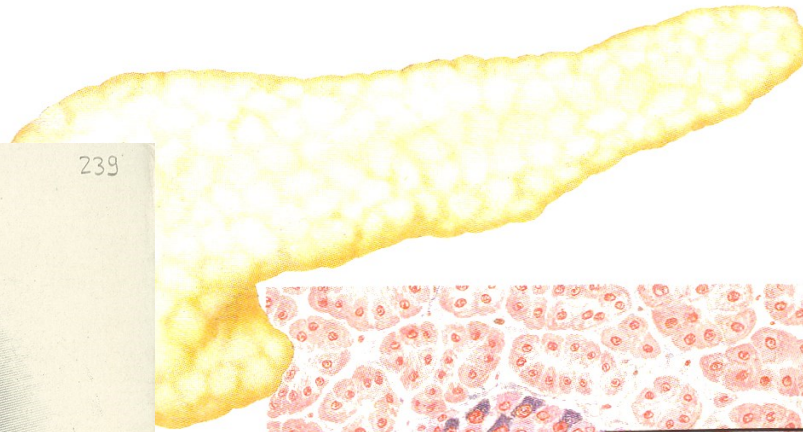
Paul Langerhans
aus Berlin.

OPPONENTEN:

O. Locquet de Mars, Dd. med.
O. Soltmann, Dd. med.
Paul Ruge, Stud. med.

BERLIN.

BLUMBERGSCHE BUCHDRUCKEREI VON GUSTAV LANGB.



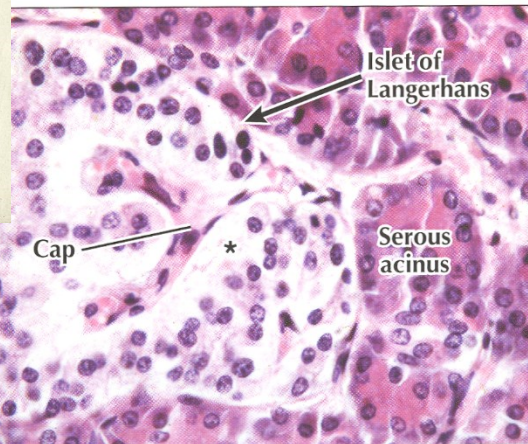
Beta cell
Alpha cell
Sinusoid
Serous
acinus



PROFESSEUR LAGUESSE

Prof. d'Histologie à la Faculté de Médecine de Lille.

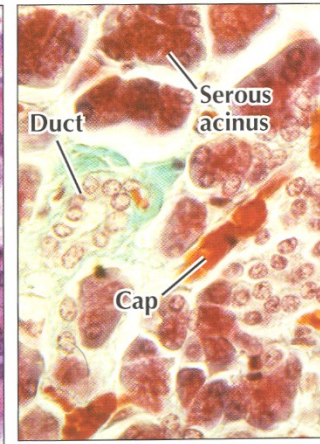
DESCHENS, éditeur.



Islet of
Langerhans

Cap

Serous
acinus



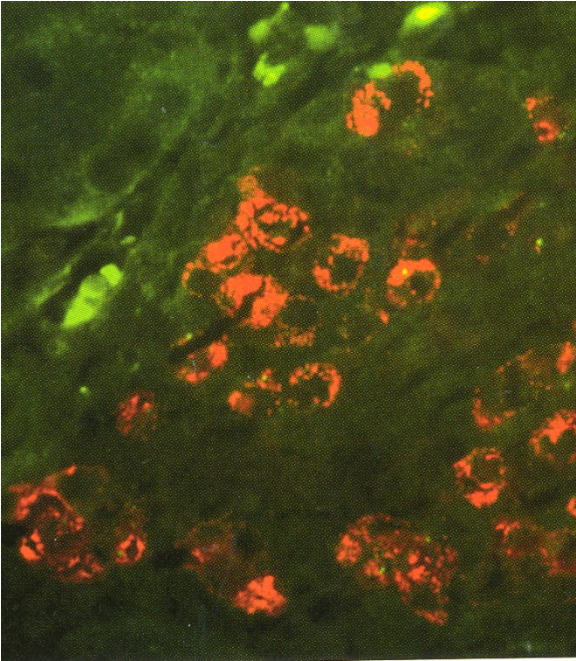
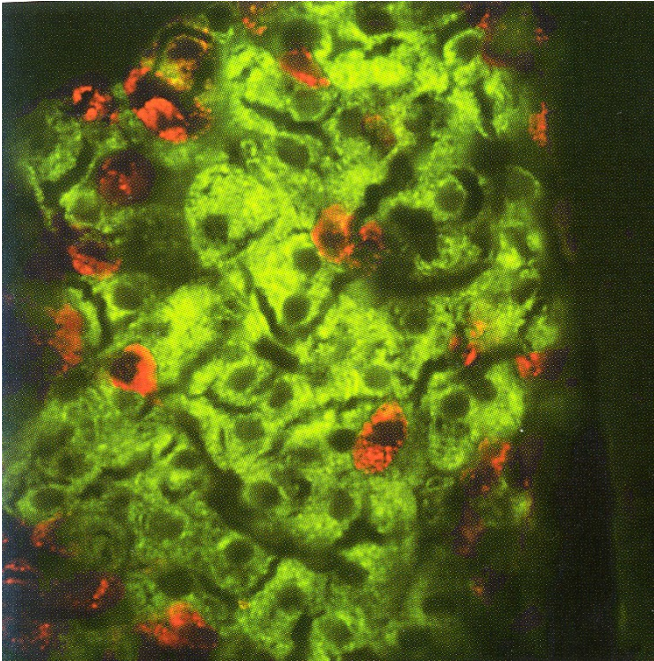
Duct

Serous
acinus

Cap

Laguesse E. Sur la formation des
ilots de Langerhans dans le
pancreas. Comptes Rend Soc Biol
1893;5 (Series 9k.819-20

Langerhans islets of pancreas



B-cells producing insulin



Ab-anti insulin –Alexa Fluor

A-cells producing glucagon



Ab-anti glukagon –Texas Red

Thank you for attention

Comments and questions:

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