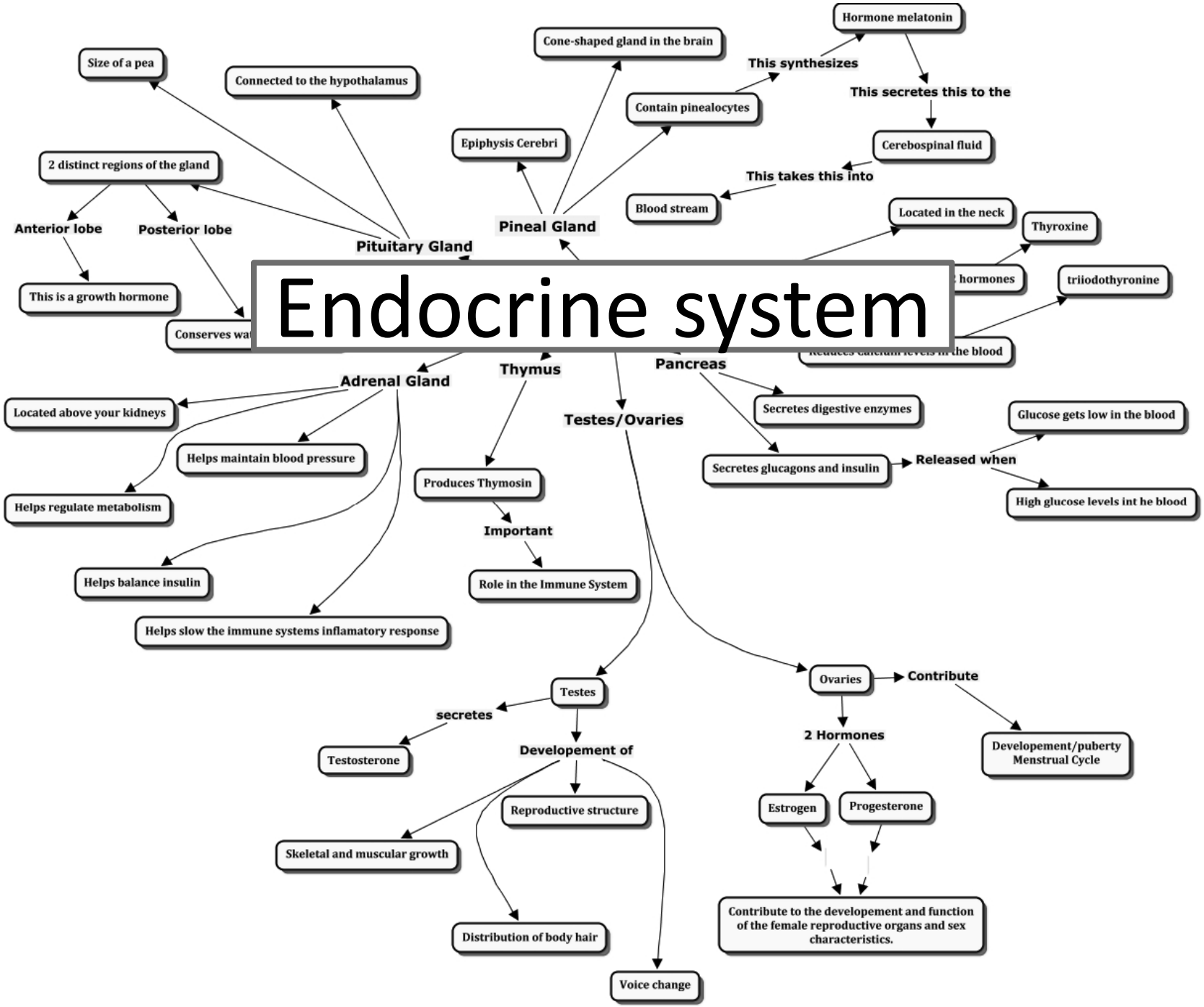
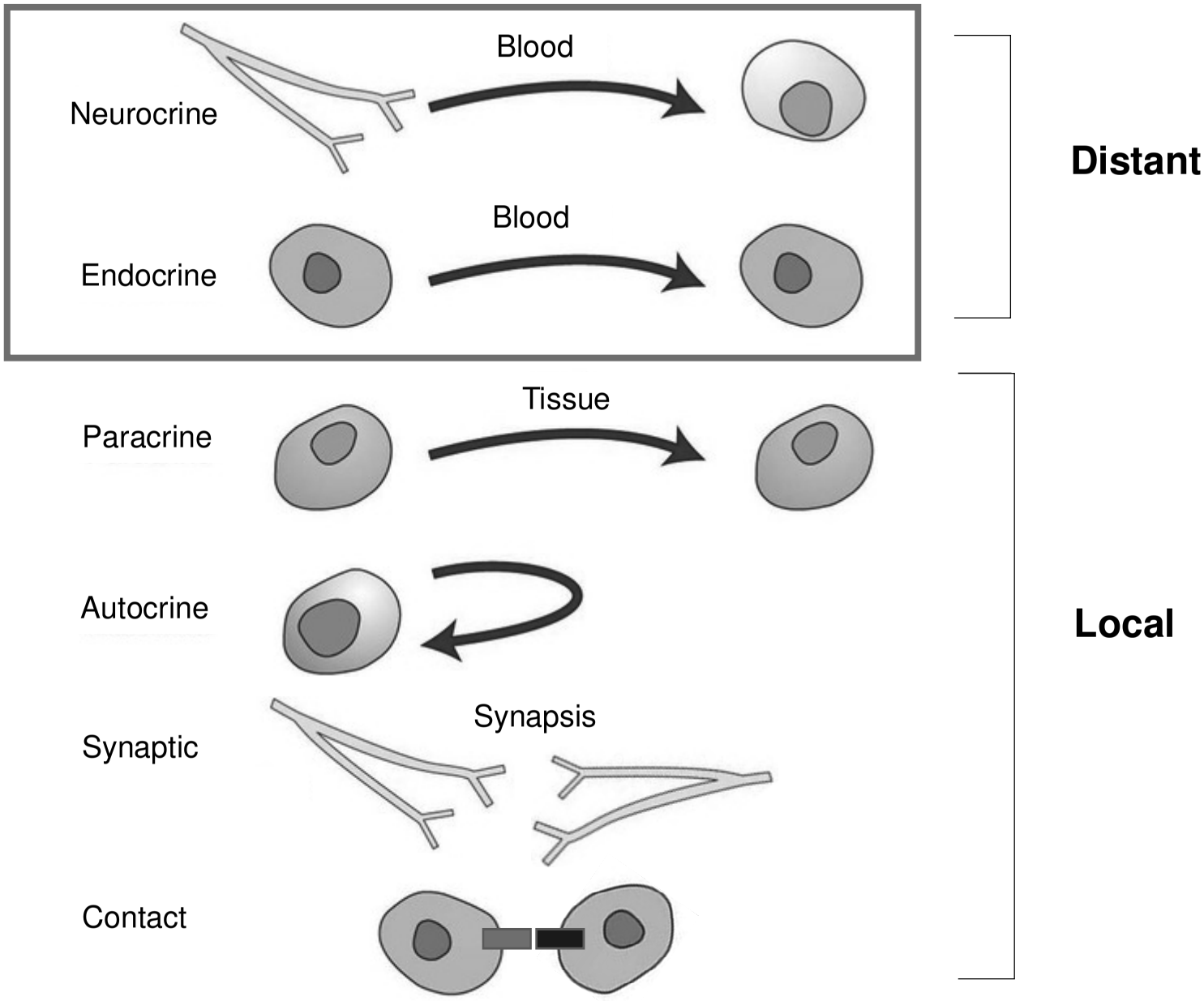

Endocrine system
Pituitary Gland
Size of a pea
Connected to the hypothalamus
2 distinct regions of the gland
Anterior lobe
Posterior lobe
This is a growth hormone
Pineal Gland
Cone-shaped gland in the brain
Epiphysis Cerebri
Contain pinealocytes
This synthesizes
Hormone melatonin
This secretes this to the
Cerebospinal fluid
This takes this into
Blood stream
Located in the neck
Thyroxine
triiodothyronine
Adrenal Gland
Located above your kidneys
Helps maintain blood pressure
Helps regulate metabolism
Helps balance insulin
Helps slow the immune systems inflamatory response
Thymus
Produces Thymosin
Important
Role in the Immune System
Pancreas
Secretes digestive enzymes
Secretes glucagons and insulin
Released when
Glucose gets low in the blood
High glucose levels int he blood
Testes/Ovaries
Testes
secretes
Testosterone
Developement of
Reproductive structure
Skeletal and muscular growth
Distribution of body hair
Voice change
Ovaries
Contribute
Developement/puberty
Menstrual Cycle
2 Hormones
Estrogen
Progesterone
Contribute to the developement and function of the female reproductive organs and sex characteristics.

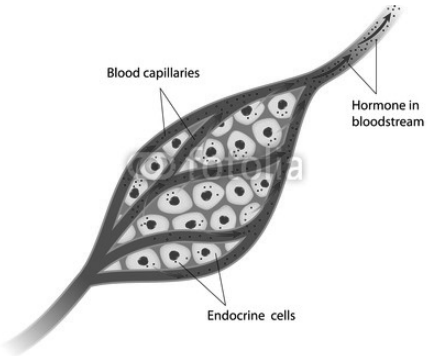
Intercellular communication

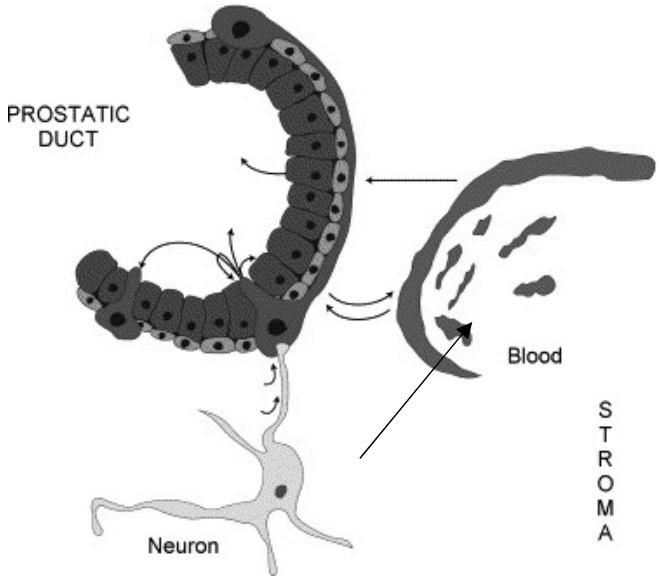


General properties of endocrine organs

- **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, losing contact with the original tissue
- ducts absents





General properties of endocrine organs

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

or

- **Neurosecretory cells**

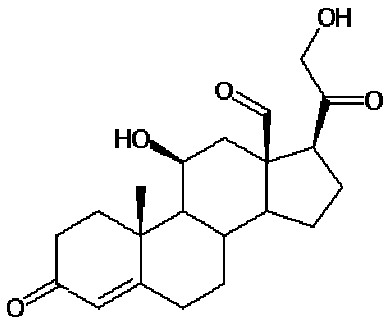
- **Capillary network**
  - Fenestrated capillaries
  - Sinusoids

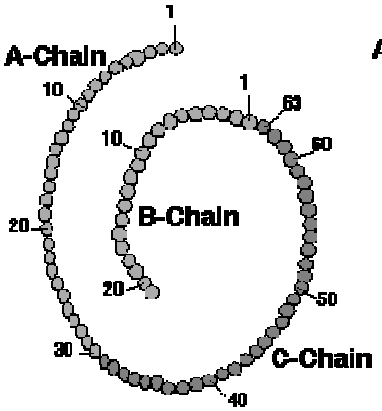
- **Merocrine secretion**

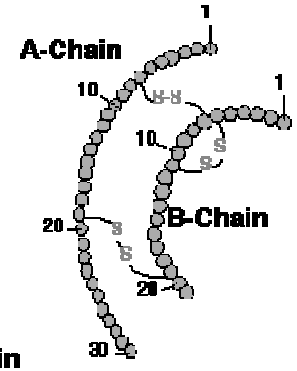
- not only hormones – endocrine gland is *sensu lato* also liver

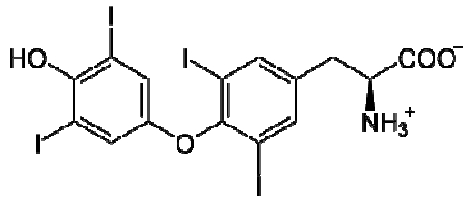
General properties of hormones

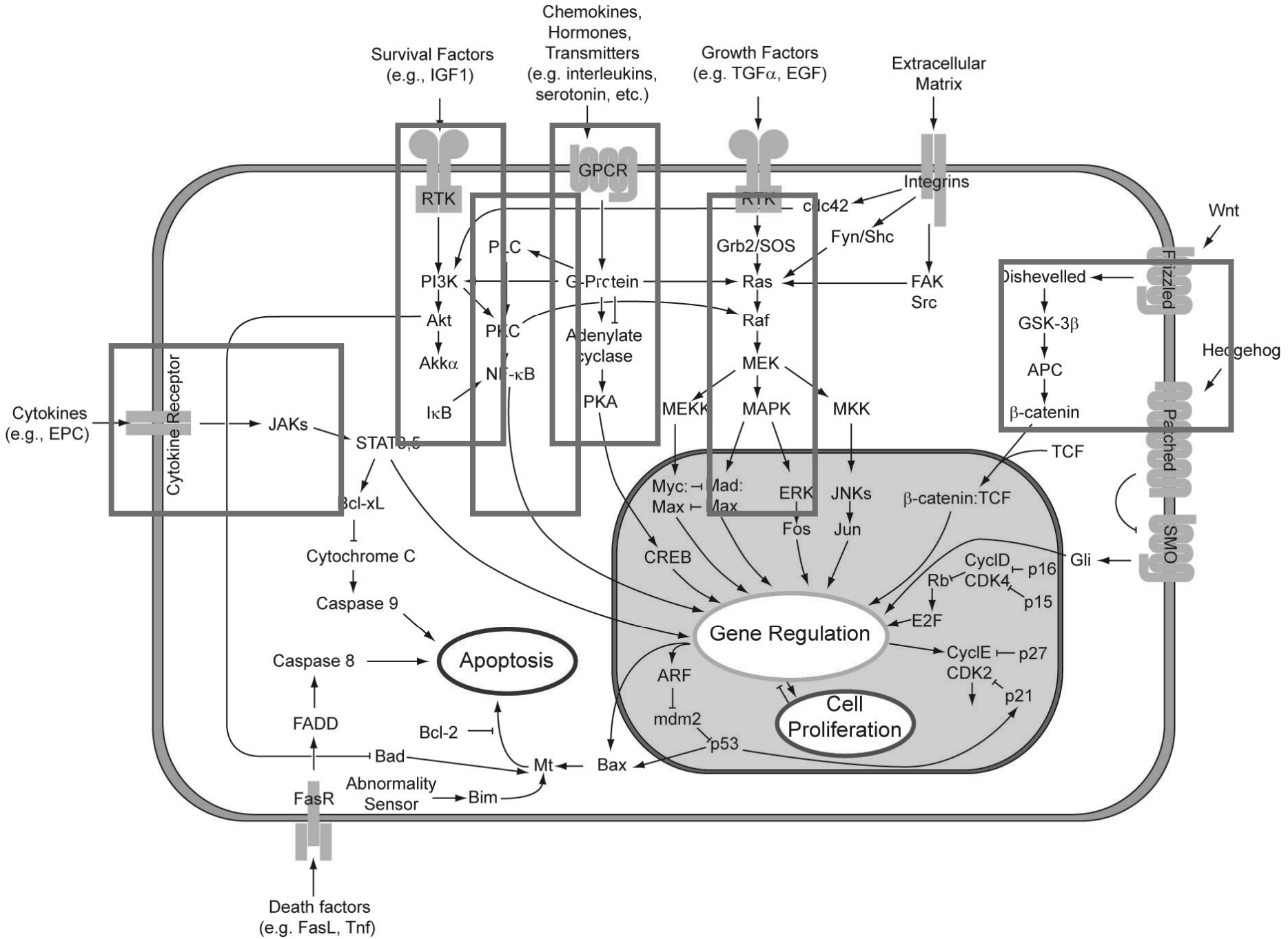
- **steroids** – hydrophobic, intracytoplasmic or nuclear receptors (sex hormones, corticoids)
- **proteins and polypeptides** – hydrophilic, plasma membrane receptors (insulin, pituitary hormones, PTH, …)
- **aminoacids** and their derivatives (adrenalin, noradrenalin, thyroxin)



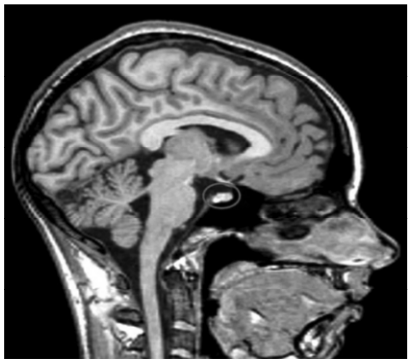


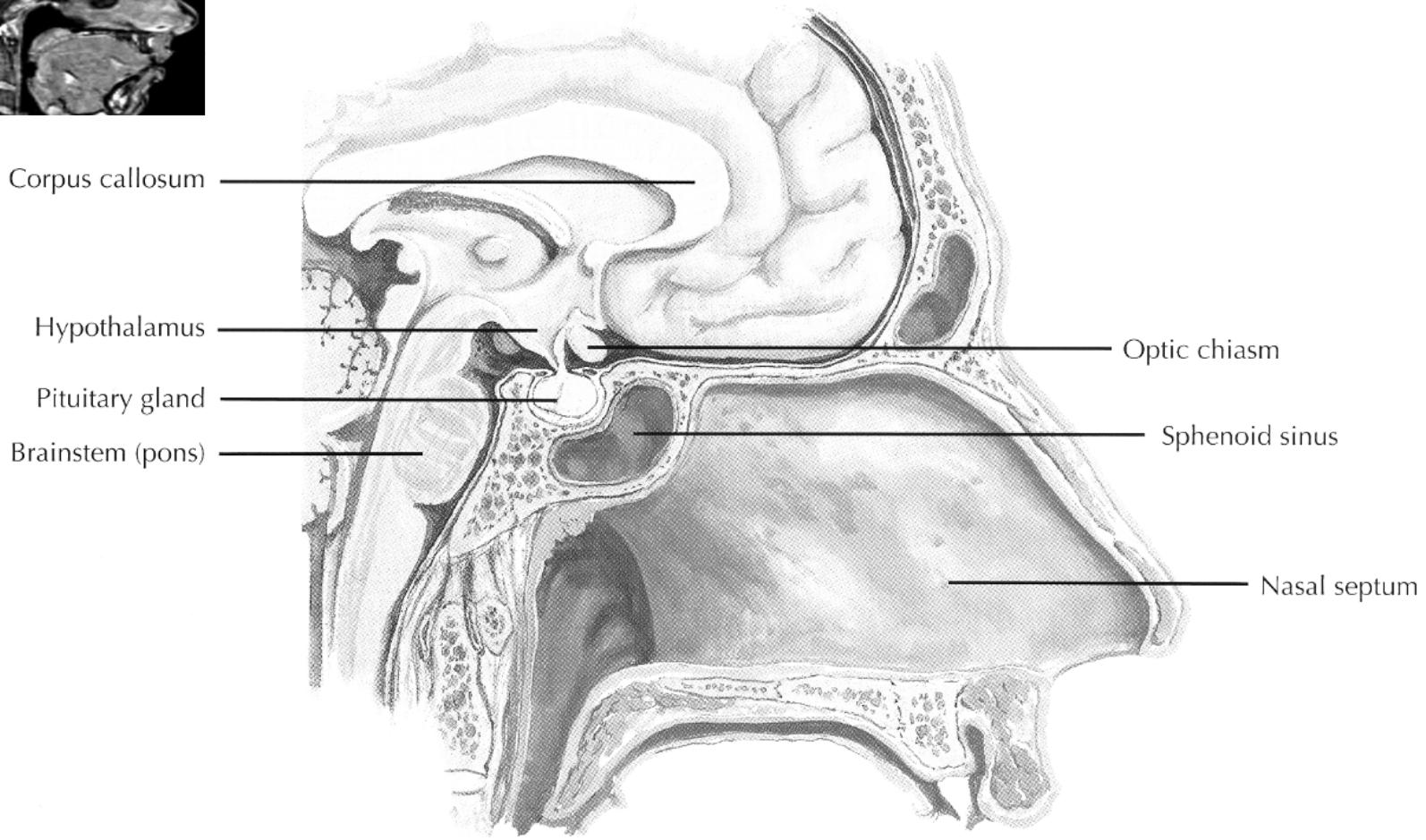





Survival Factors
(e.g., IGF1)
Chemokines,
Hormones,
Transmitters
(e.g. interleukins,
serotonin, etc.)
Growth Factors
(e.g. TGFα, EGF)
Extracellular
Matrix
RTK
GPCR
RTK
Integrins
cdc42
Fyn/Shc
Grb2/SOS
PLC
PI3K
G-Protein
Ras
FAK
Src
Akt
PKC
Adenylate
cyclase
Raf
Akkα
NF-κB
MEK
IκB
PKA
MEKK
MAPK
MKK
Wnt
Frizzled
Dishevelled
GSK-3β
APC
β-catenin
Hedgehog
Patched
SMO
Cytokines
(e.g., EPC)
Cytokine Receptor
JAKs
STAT3,5
TCF
Bcl-xL
Myc:
Max
Mad:
Max
ERK
JNKs
β-catenin:TCF
Fos
Jun
Cytochrome C
CREB
Gli
CyclD
Rb
CDK4
p16
p15
Caspase 9
E2F
Gene Regulation
Caspase 8
Apoptosis
CyclE
p27
ARF
CDK2
p21
mdm2
Cell
Proliferation
FADD
Bcl-2
p53
Bad
Mt
Bax
FasR
Abnormality
Sensor
Bim
Death factors
(e.g. FasL, Tnf)

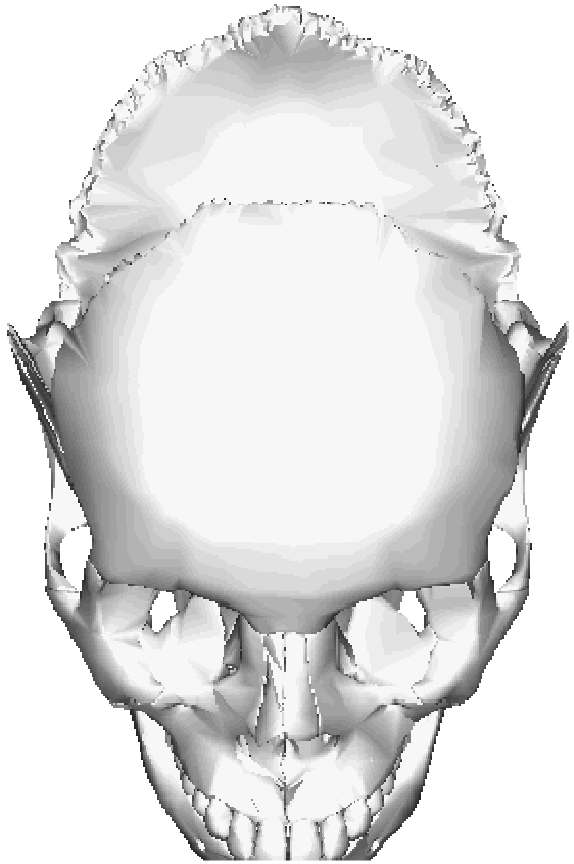
Pituitary gland (*gl. pituitaria*)

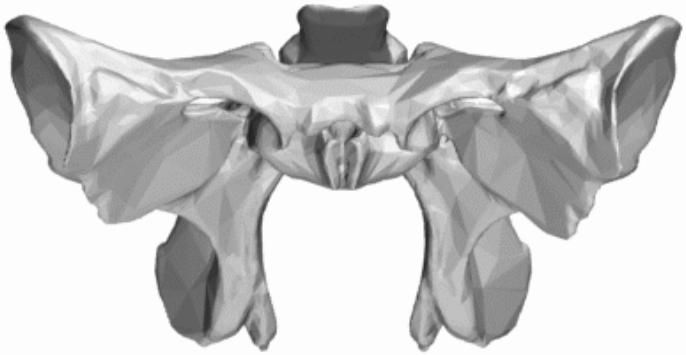




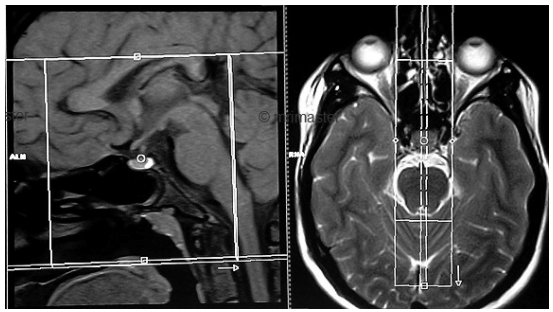
Pituitary gland (*gl. pituitaria*)

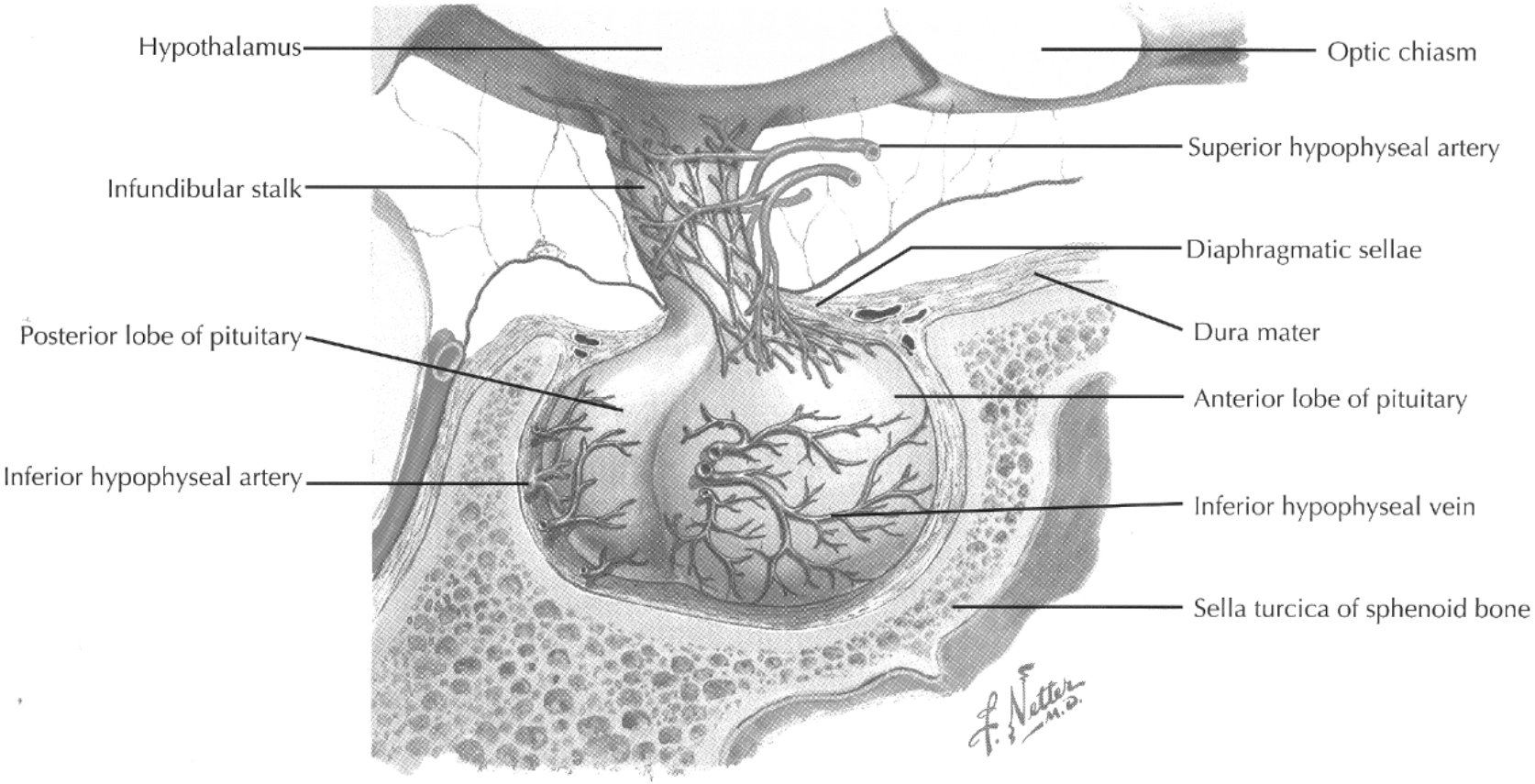
- sphenoid bone
- sella turcica
- fossa hypophysialis





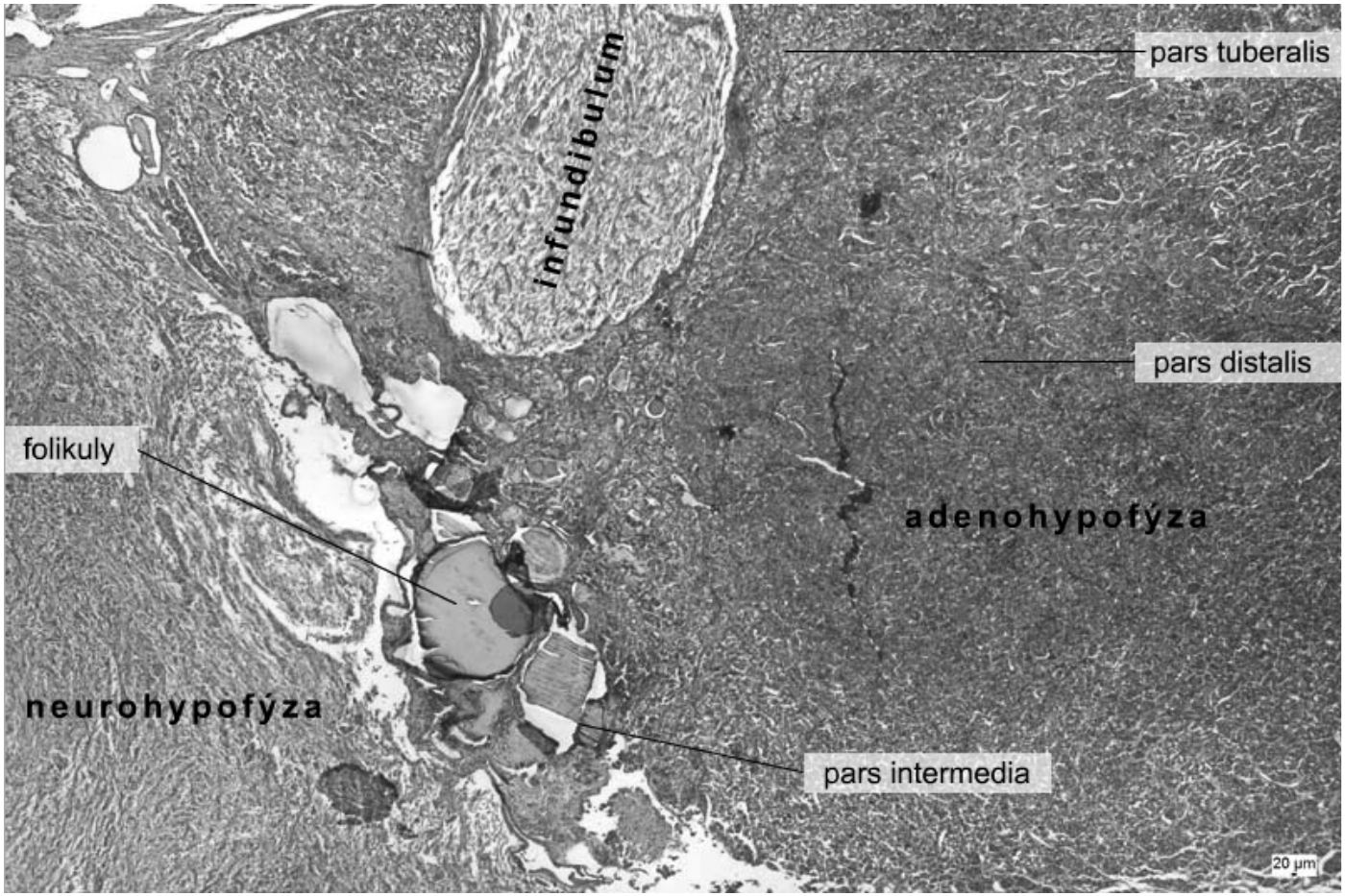
Pituitary gland (*gl. pituitaria*)





Pituitary gland (*gl. pituitaria*)

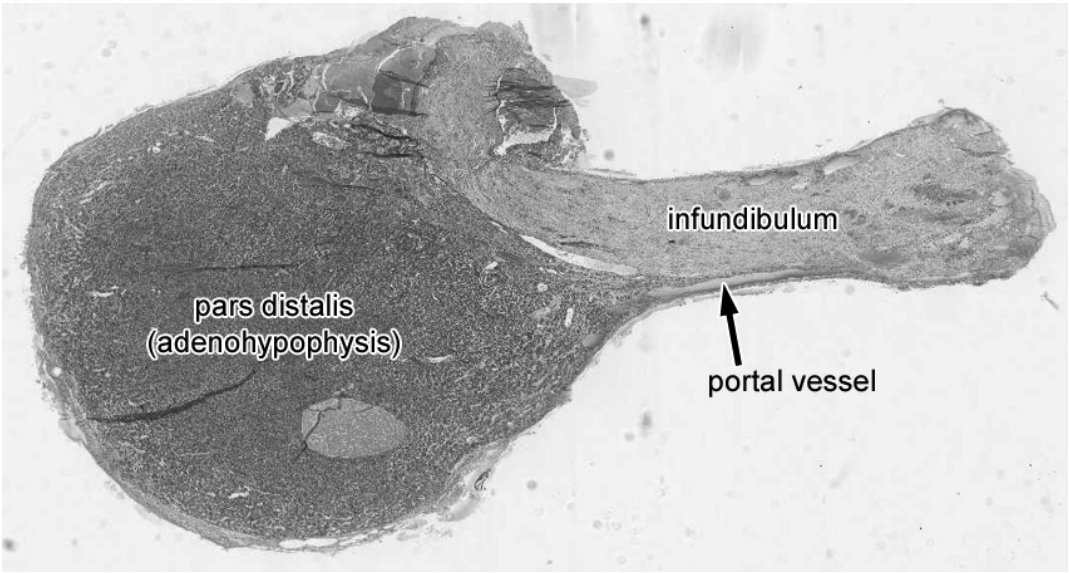
- adenohypophysis (*pars distalis, pars tuberalis, pars intermedia*)
- neurohypophysis (*pars nervosa*)
- *infundibulum, eminentia mediana*

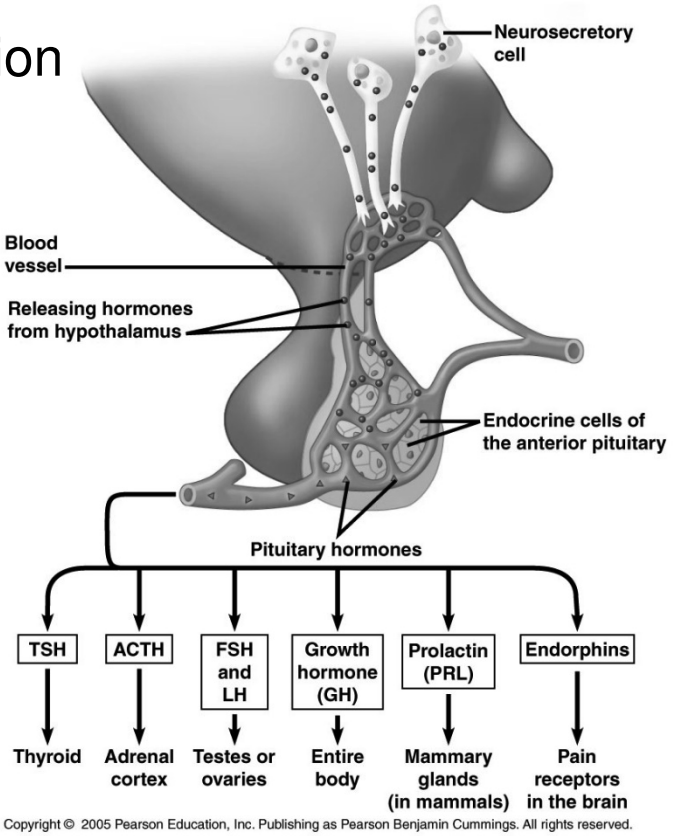


Pituitary gland (*gl. pituitaria*)

- adenohypophysis - glandotropic hormones, prolactin, GH
- neurohypophysis - hypothalamic hormones - ADH, oxytocin

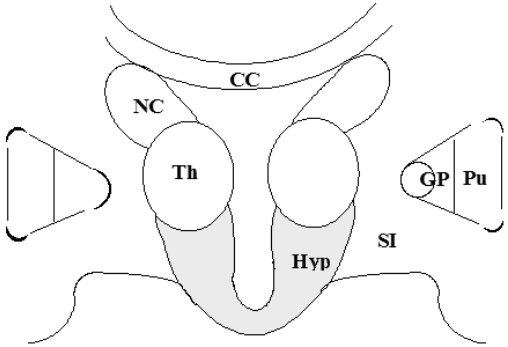
- anatomical and functional association with hypothalamus
- capillary systems and neuroendocrine secretion

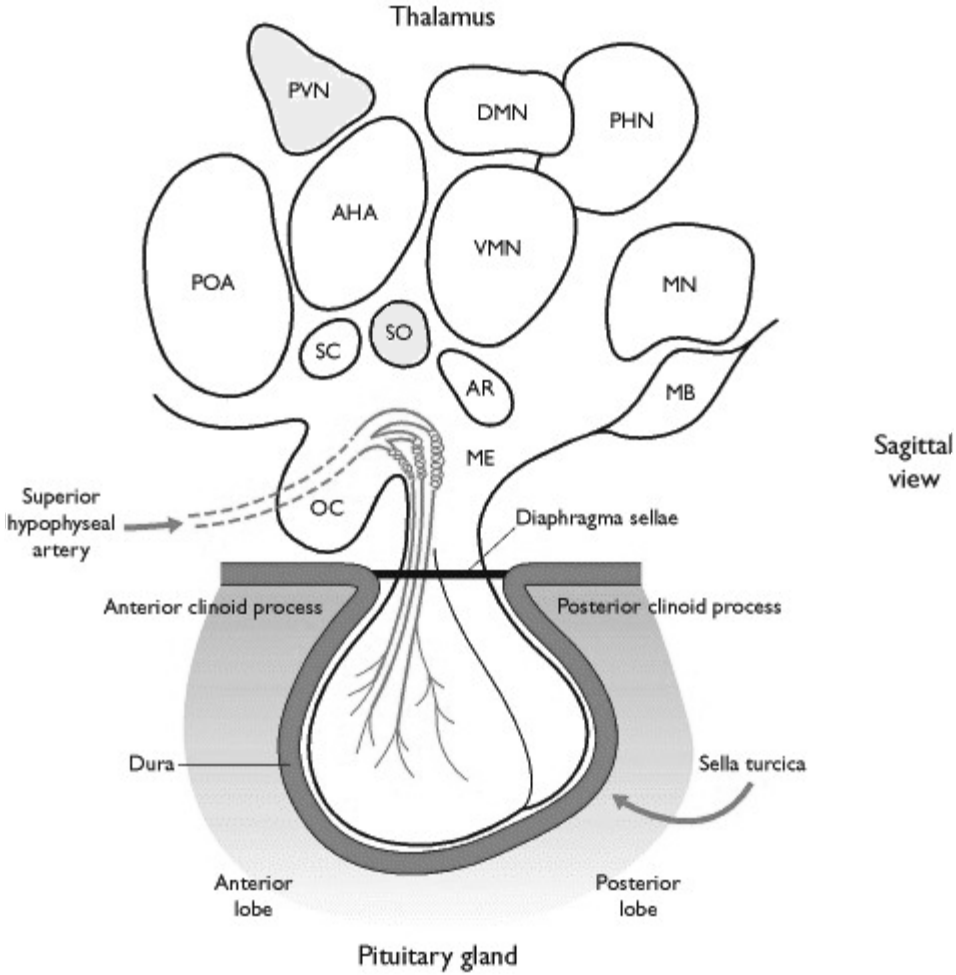




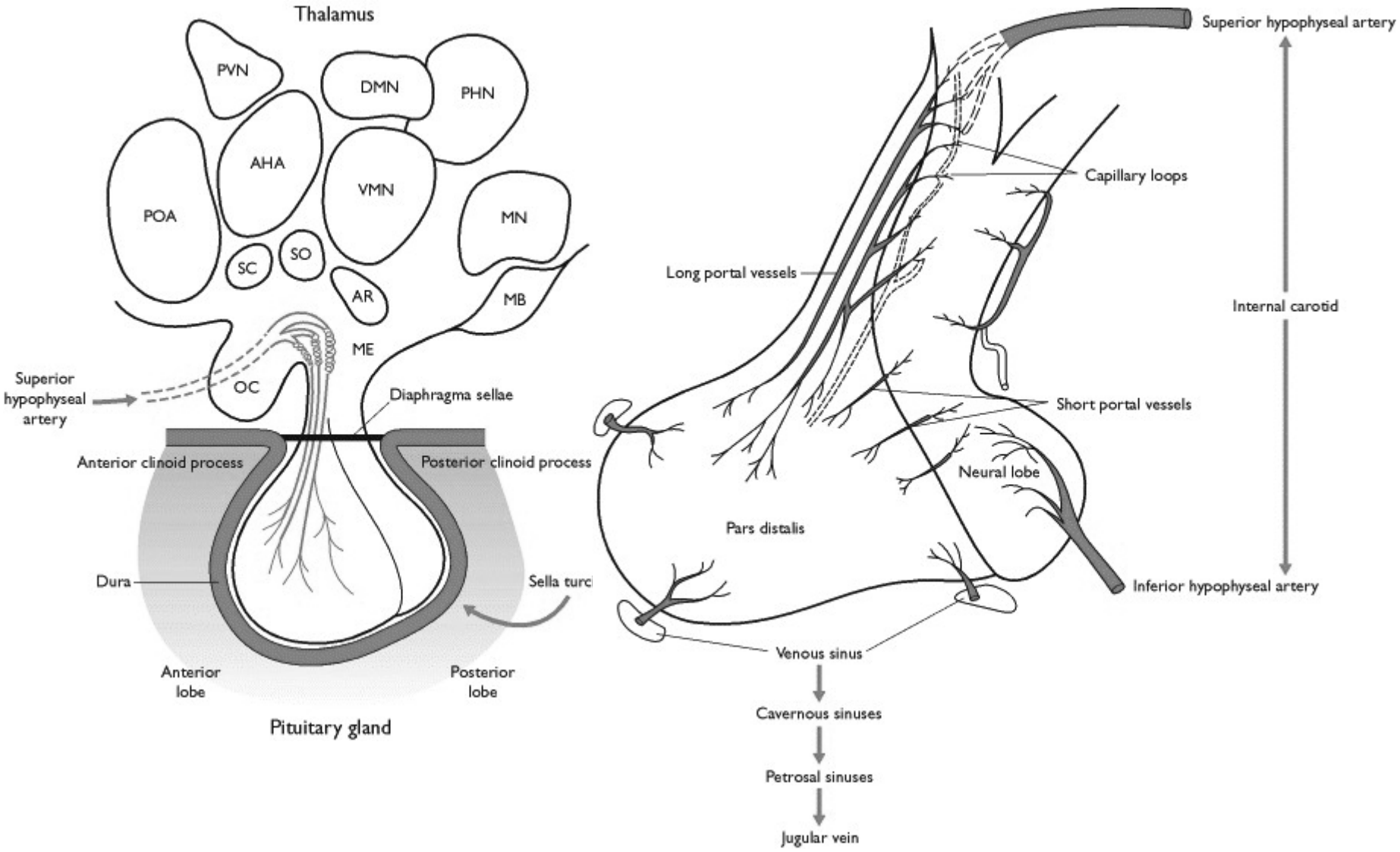
Hypothalamus

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





Hypothalamo-hypophyseal system



Mechanism of neurosecretion

Tractus hypothalamo-hypophysialis

- axons of magnocelullar neurons in nucleus supraopticus and paraventricularis
- terminating on fenestrated capillaries in neurohypophysis
- synthesis of prohormones → during axonal trasnportion maturation
- capillary plexus from arteria hypophysialis inferior (branch of arteria 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

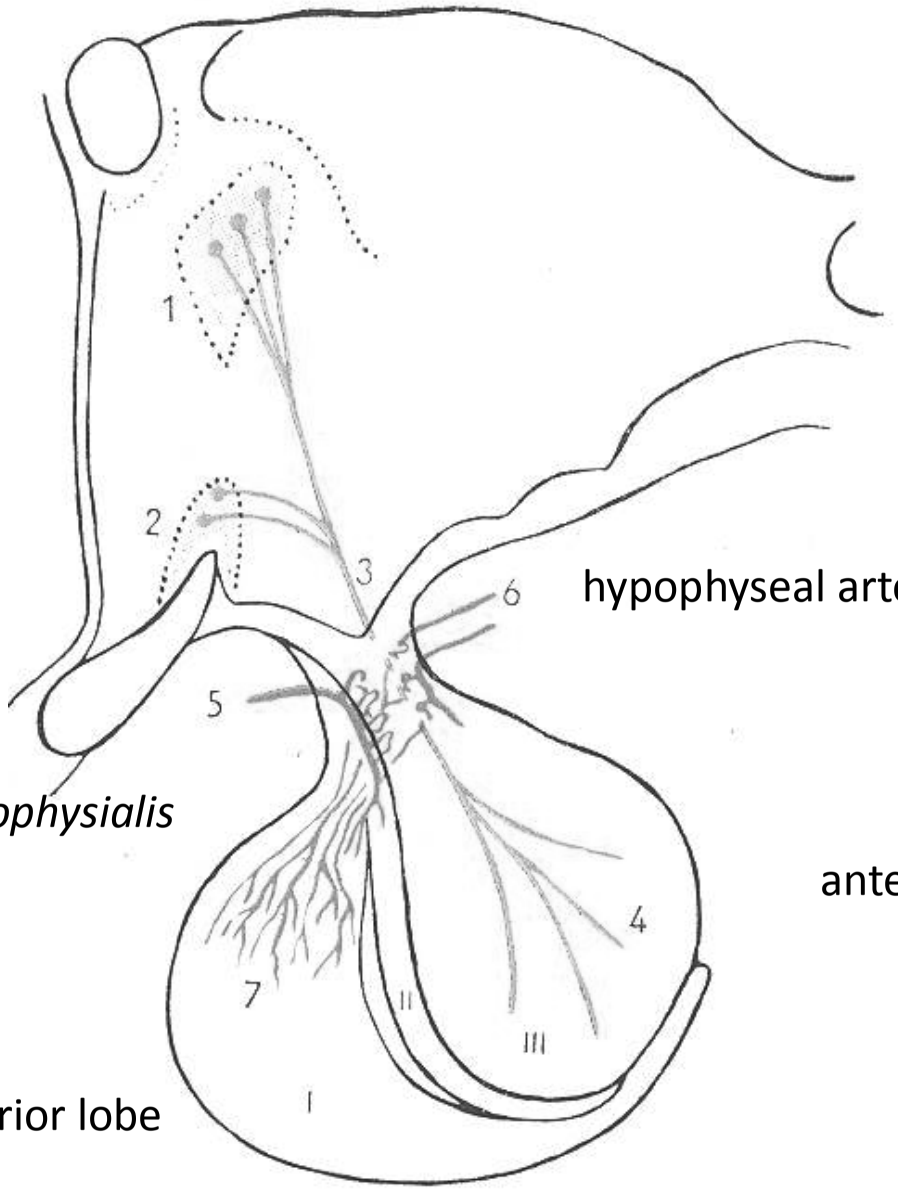
Capillary system of hypophysis

ncl. paraventricularis

ncl. supraopticus

Tractus hypothalamo-hypophysialis

secondary plexus of posterior lobe

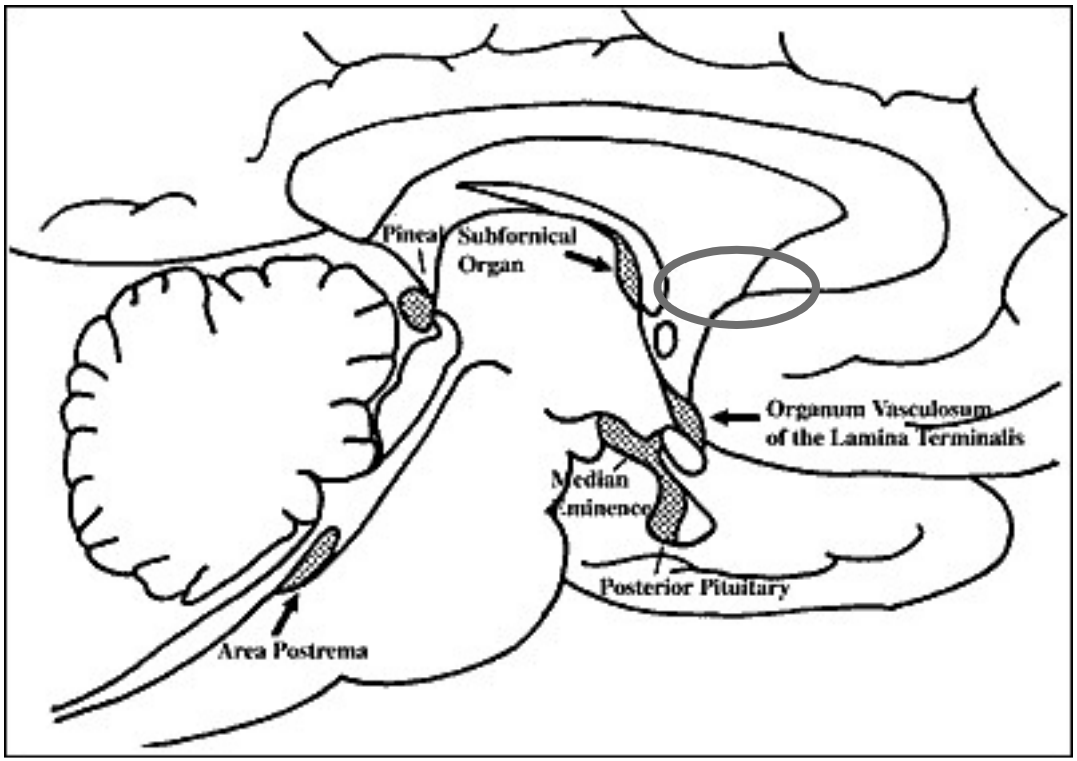


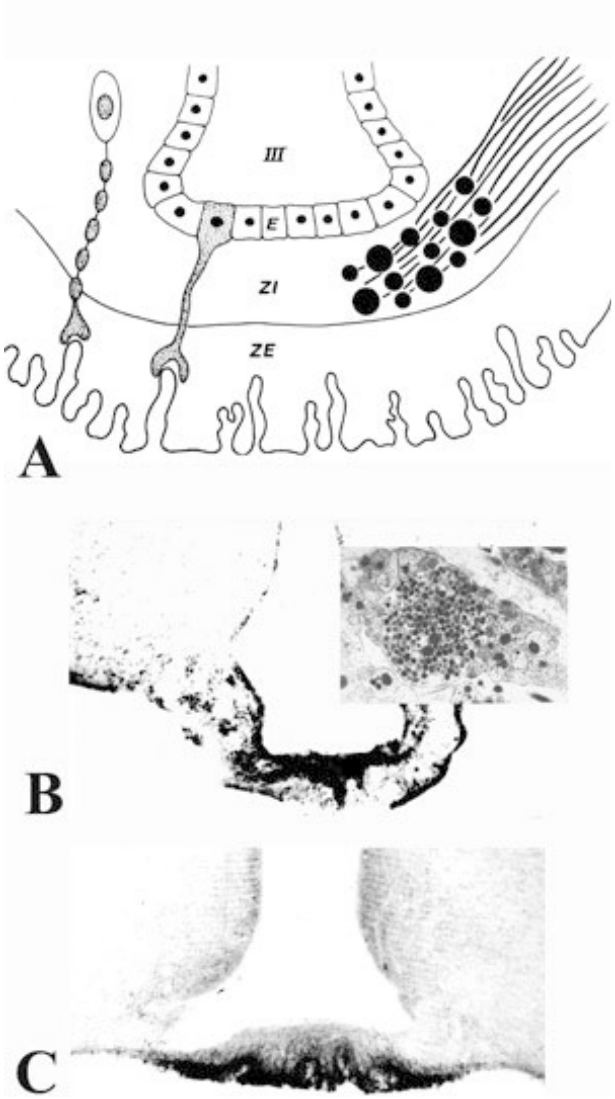
hypophyseal arteries

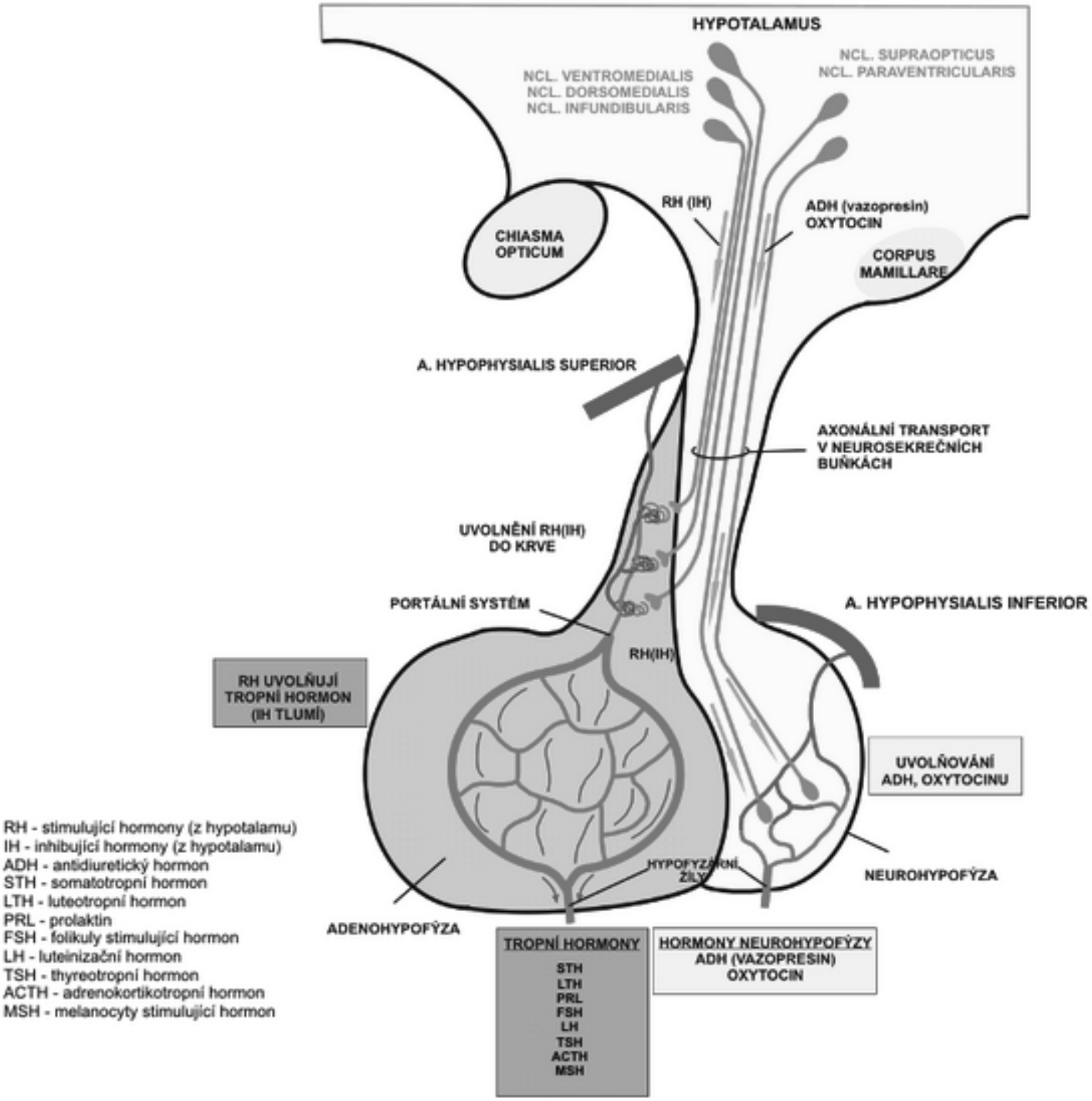
anterior lobe

Eminentia mediana

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



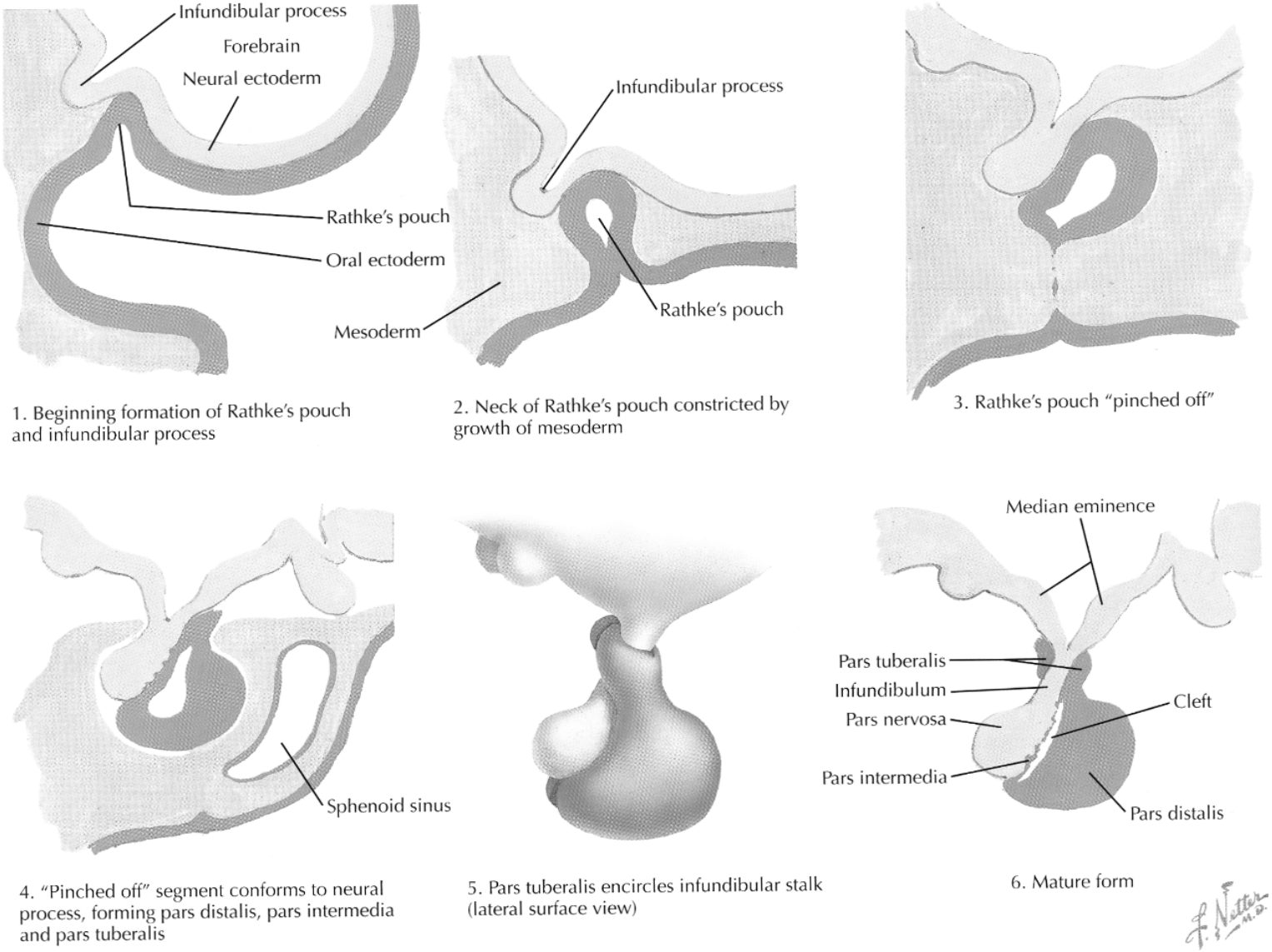




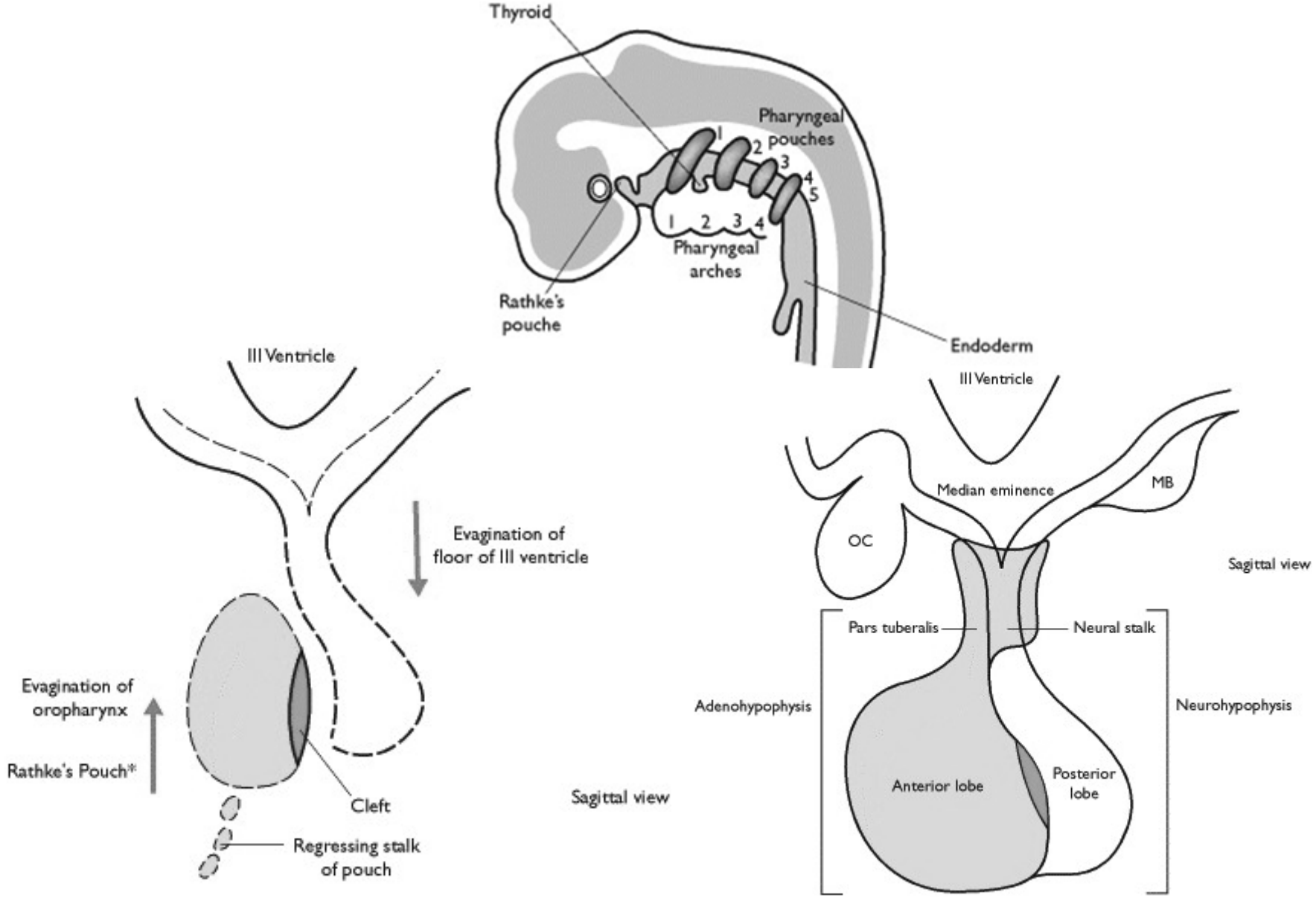
RH - stimulující hormony (z hypotalamu)
IH - inhibující hormony (z hypotalamu)
ADH - antidiuretický hormon
STH - somatotropní hormon
LTH - luteotropní hormon
PRL - prolaktin
FSH - folikuly stimulující hormon
LH - luteinizační hormon
TSH - thyreotropní hormon
ACTH - adrenokortikotropní hormon
MSH - melanocyty stimulující hormon

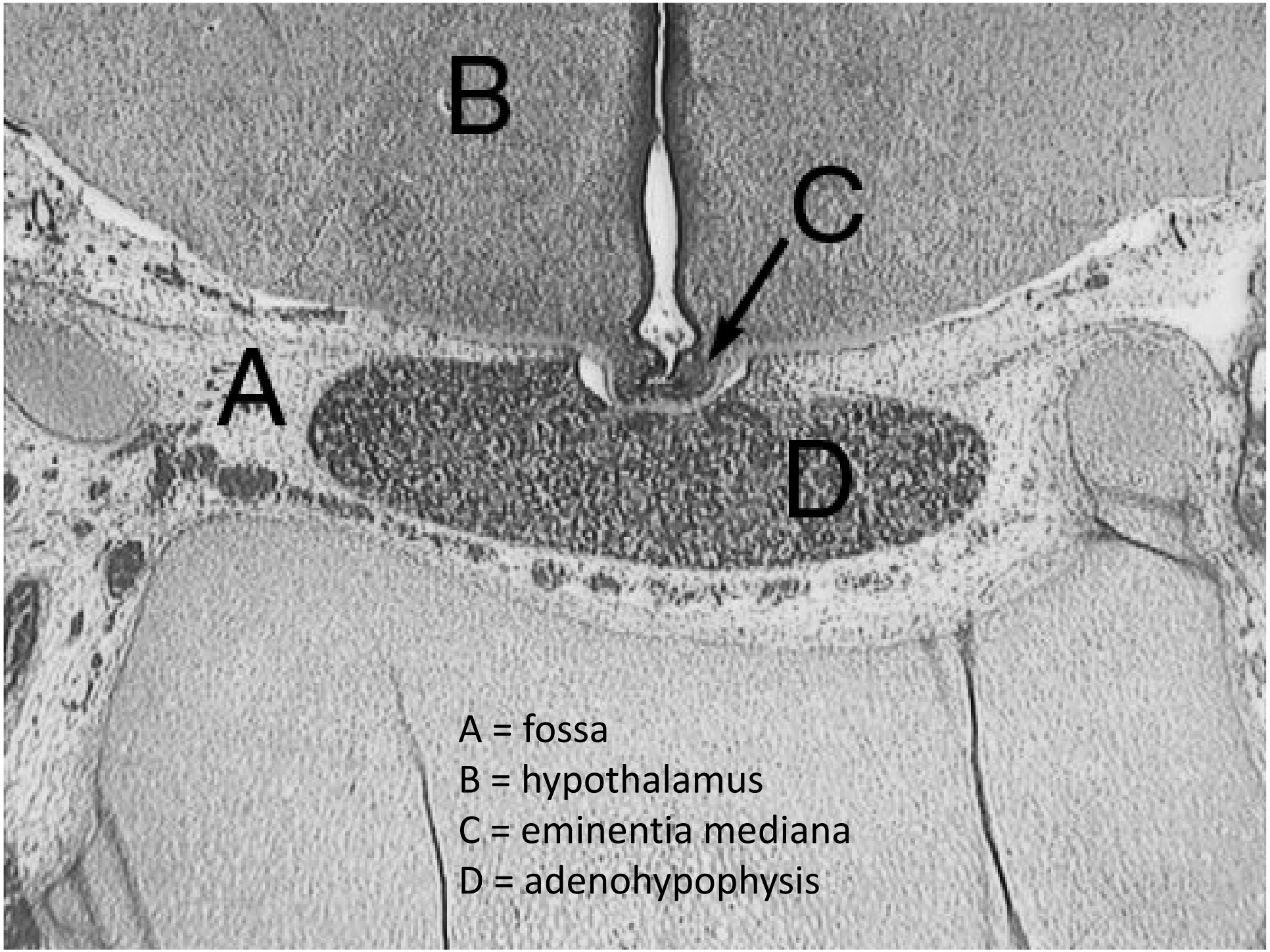
Embryonal development of pituitary gl.

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



Embryonal development of pituitary gl.




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

Adenohypophysis (anterior lobe)

Chromophilic cells

Acidophils

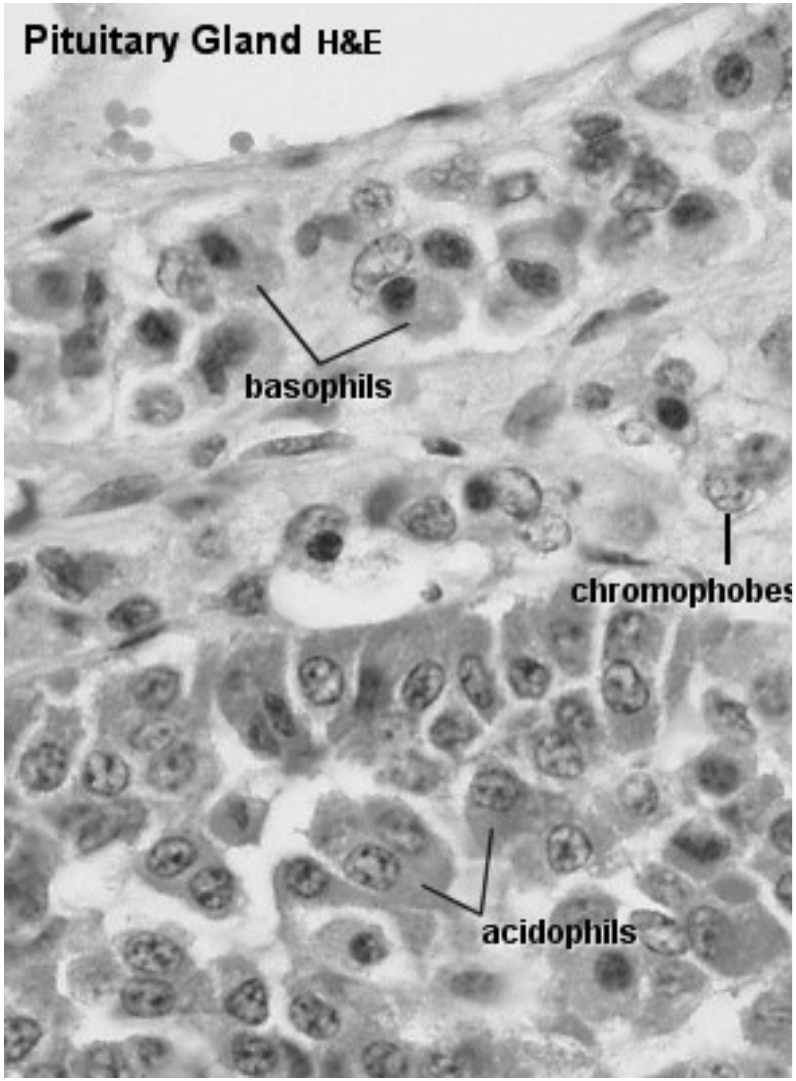
Nonglandotropic

- direct effect on target tissues

Bazophils

Glandotropic

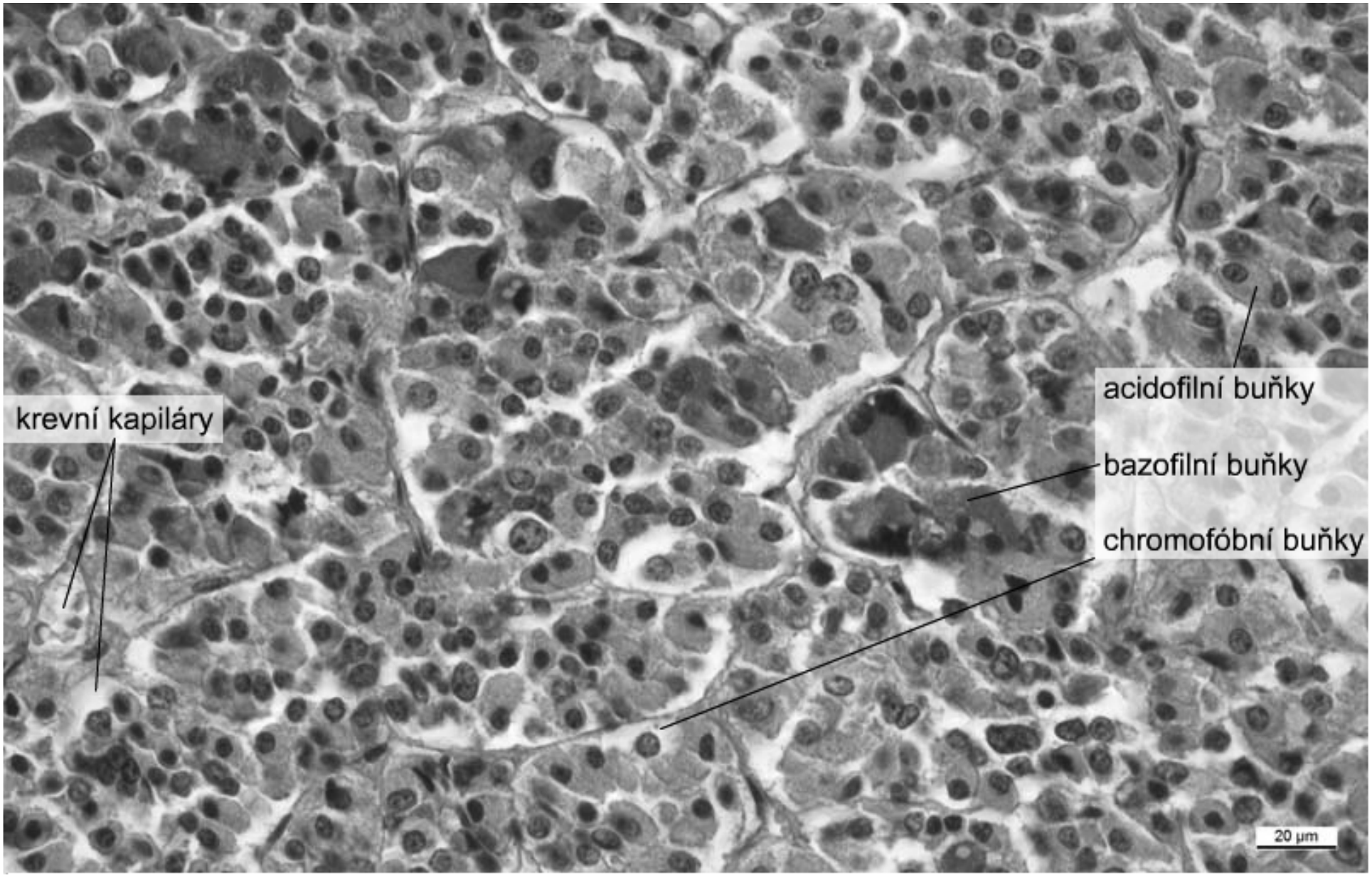
- regulation of other endocrine glands



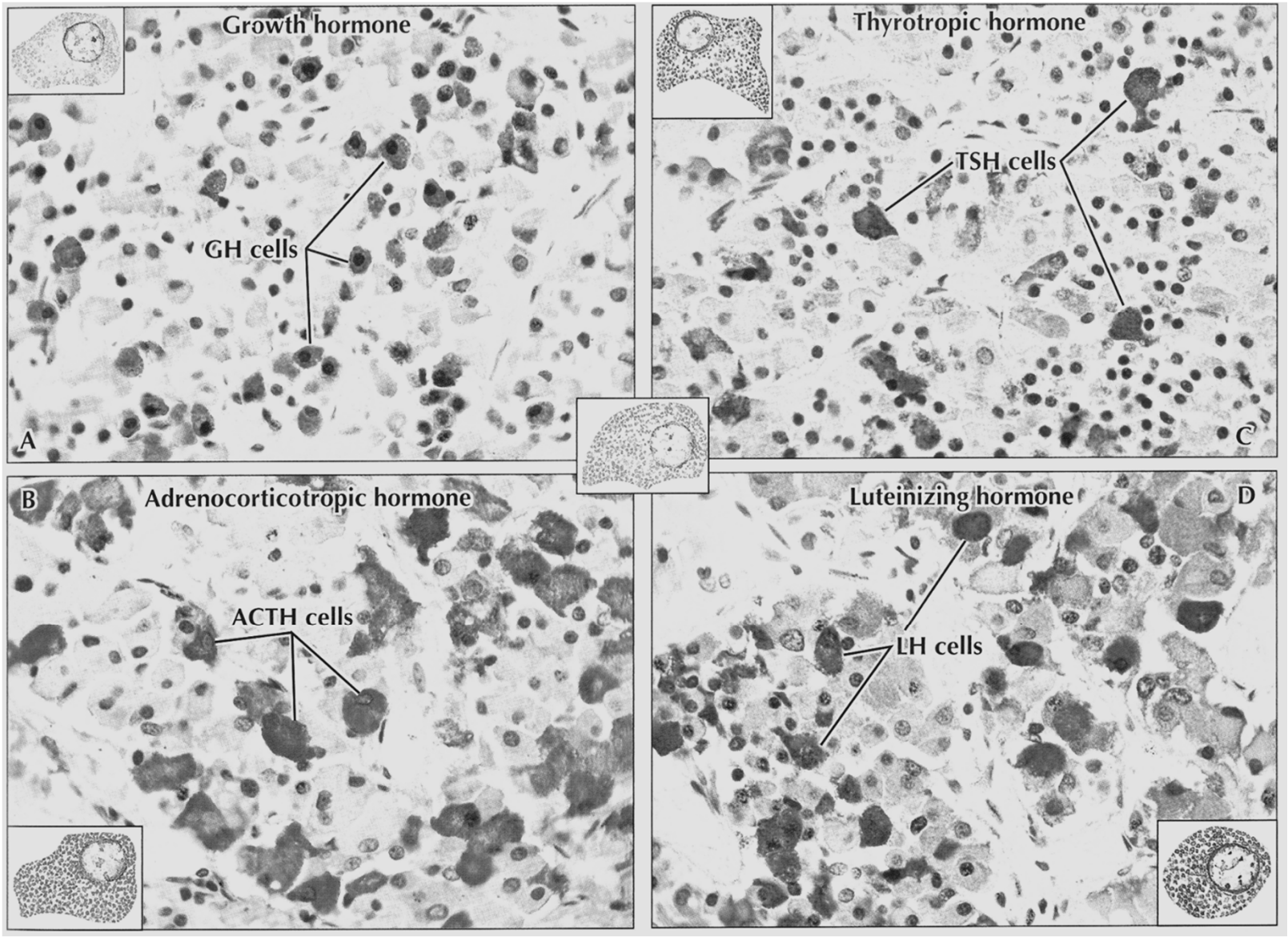
Chromophobic cells

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

Adenohypophysis (anterior lobe)

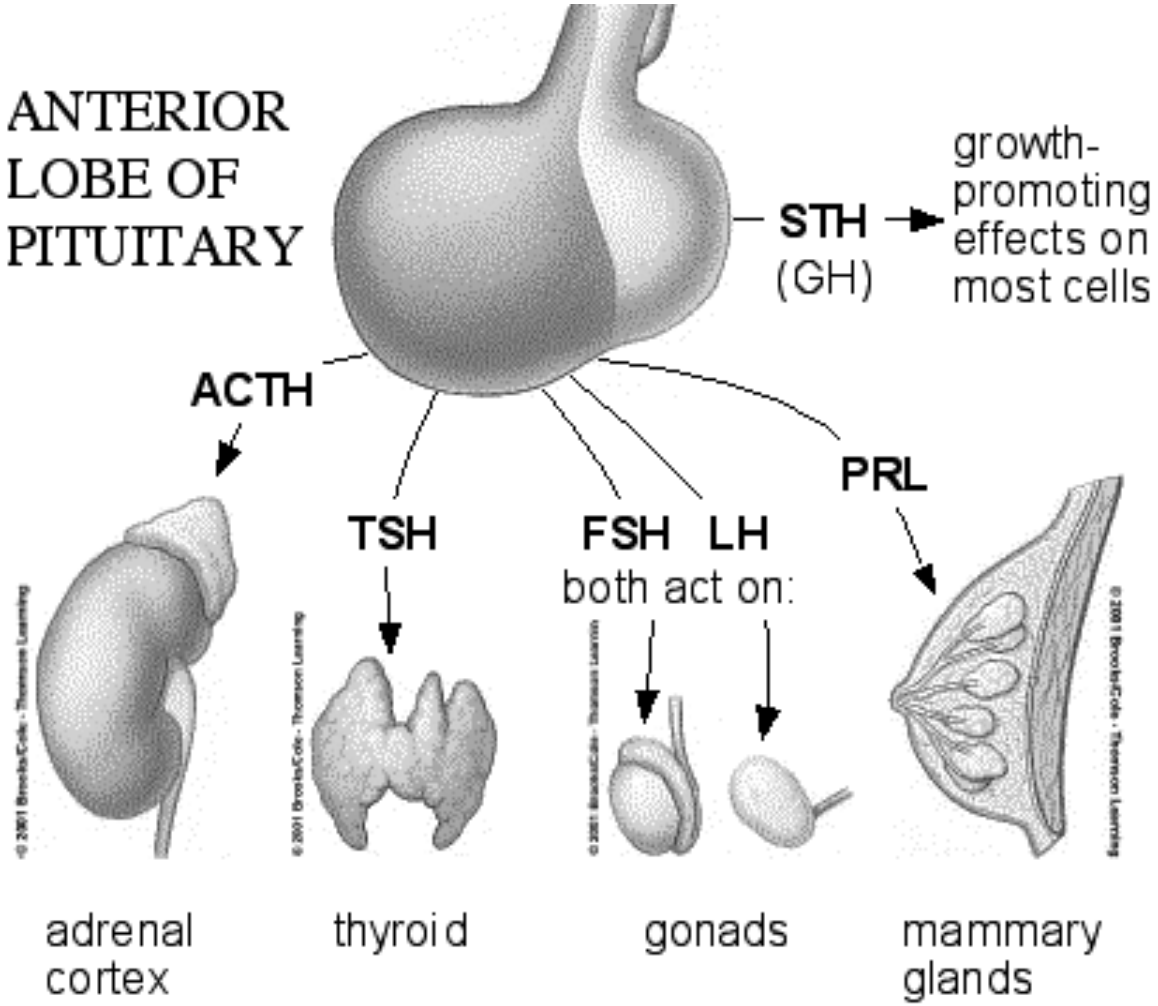


Adenohypophysis (anterior lobe)



”FLAT PEG”

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

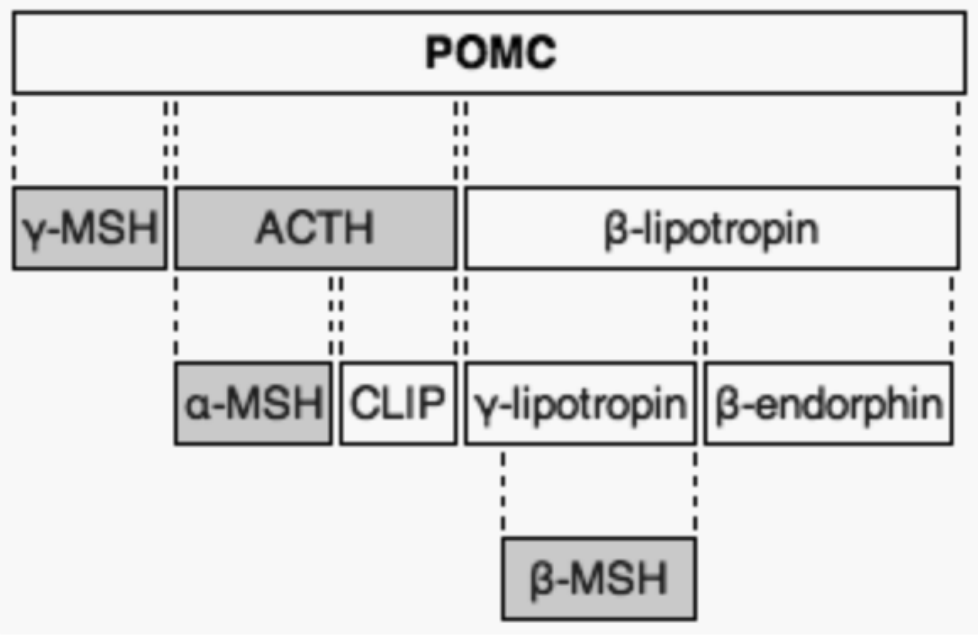


Pro-opio-melanocortin (POMC)

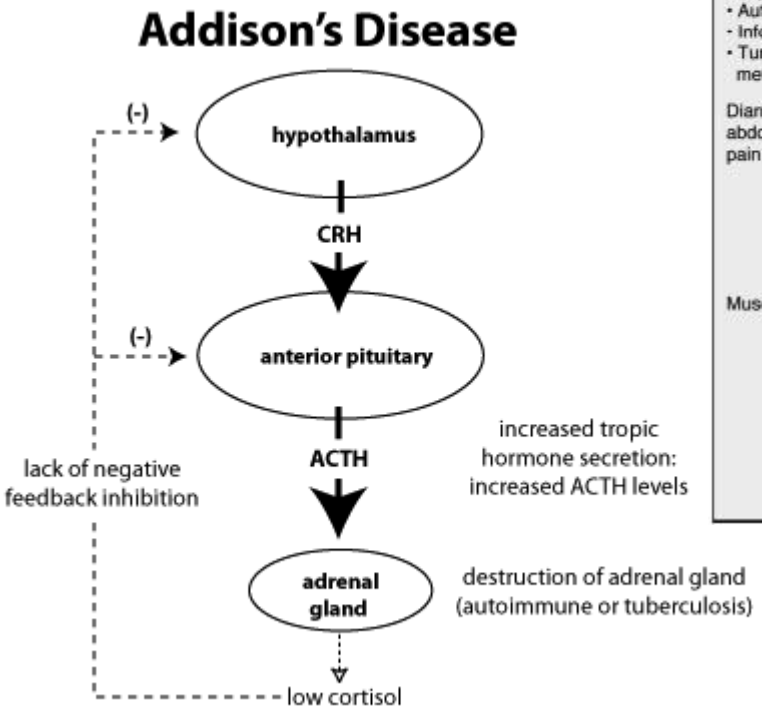
rough ER → pre-prohormon
produced by various tissues

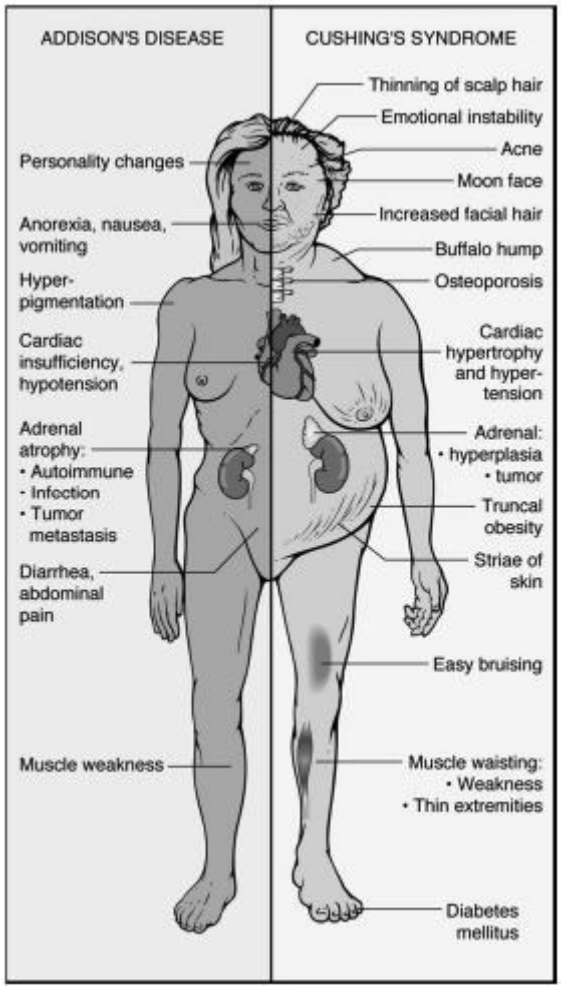
cleavage to

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

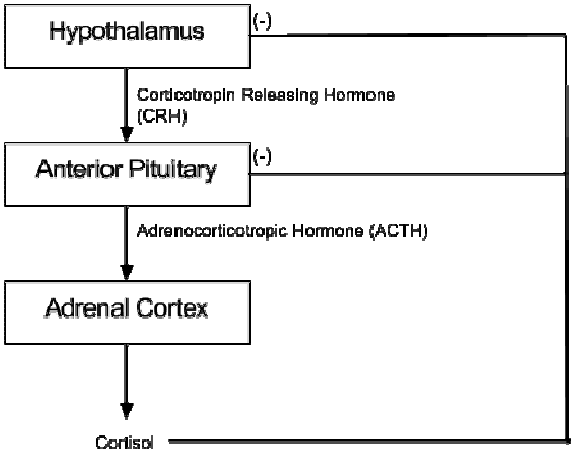


Corticotrophs hypofunction





Corticotrophs hyperfunction



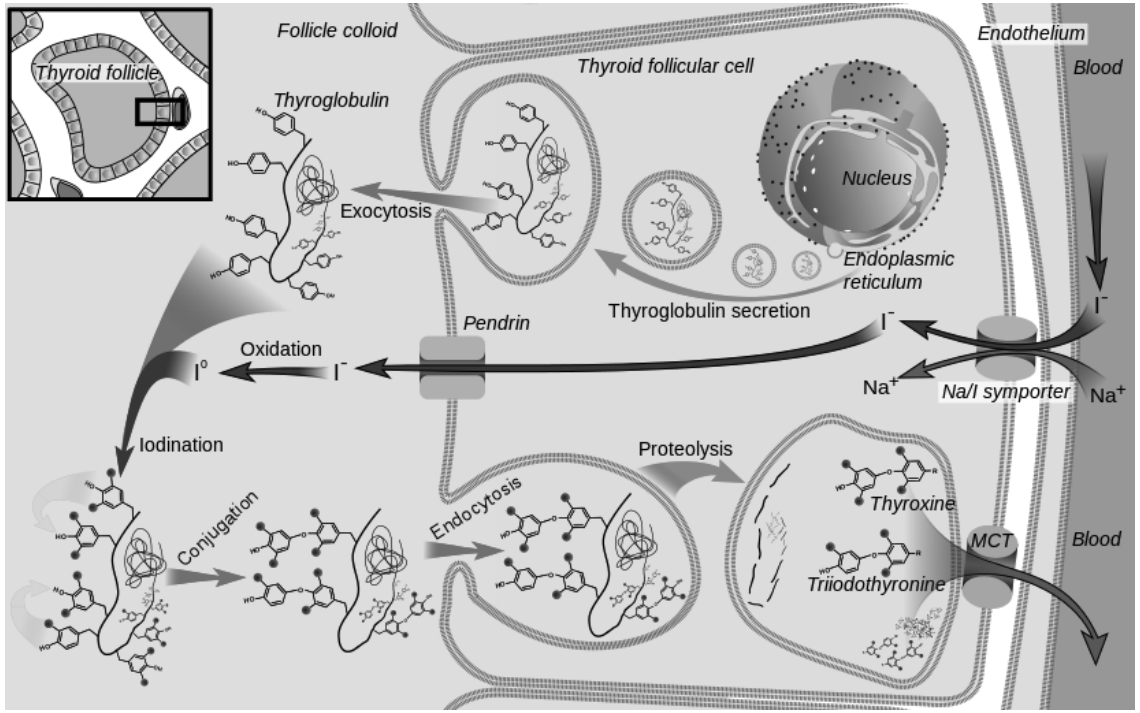
FSH (folitropin), LH (lutropin)

- 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. *granulosa cells*)	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

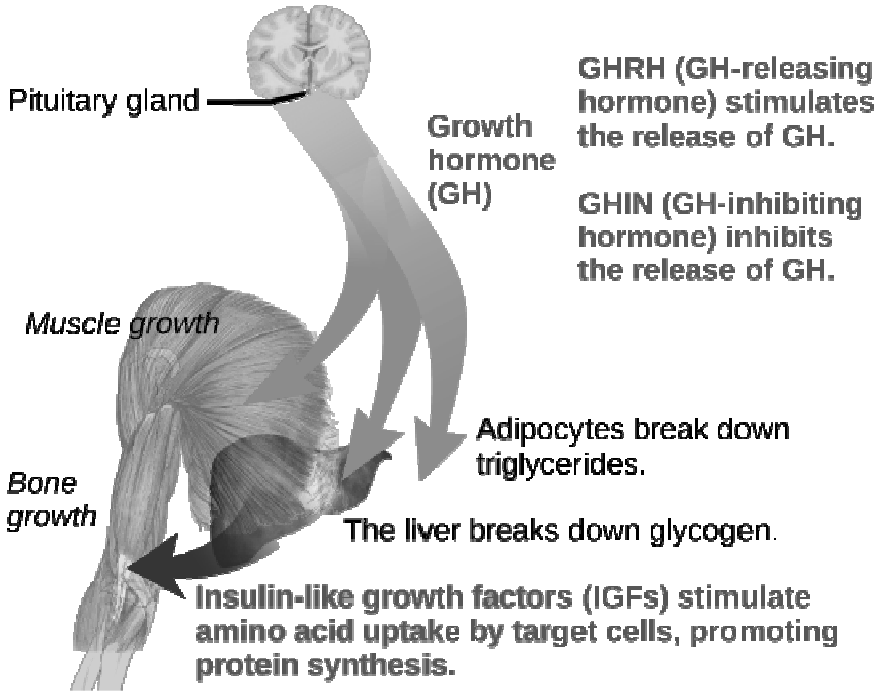


Table 2. Nonclassical Anterior Pituitary Substances and Cell(s) of Origin

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 POLTPEPTIDE	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

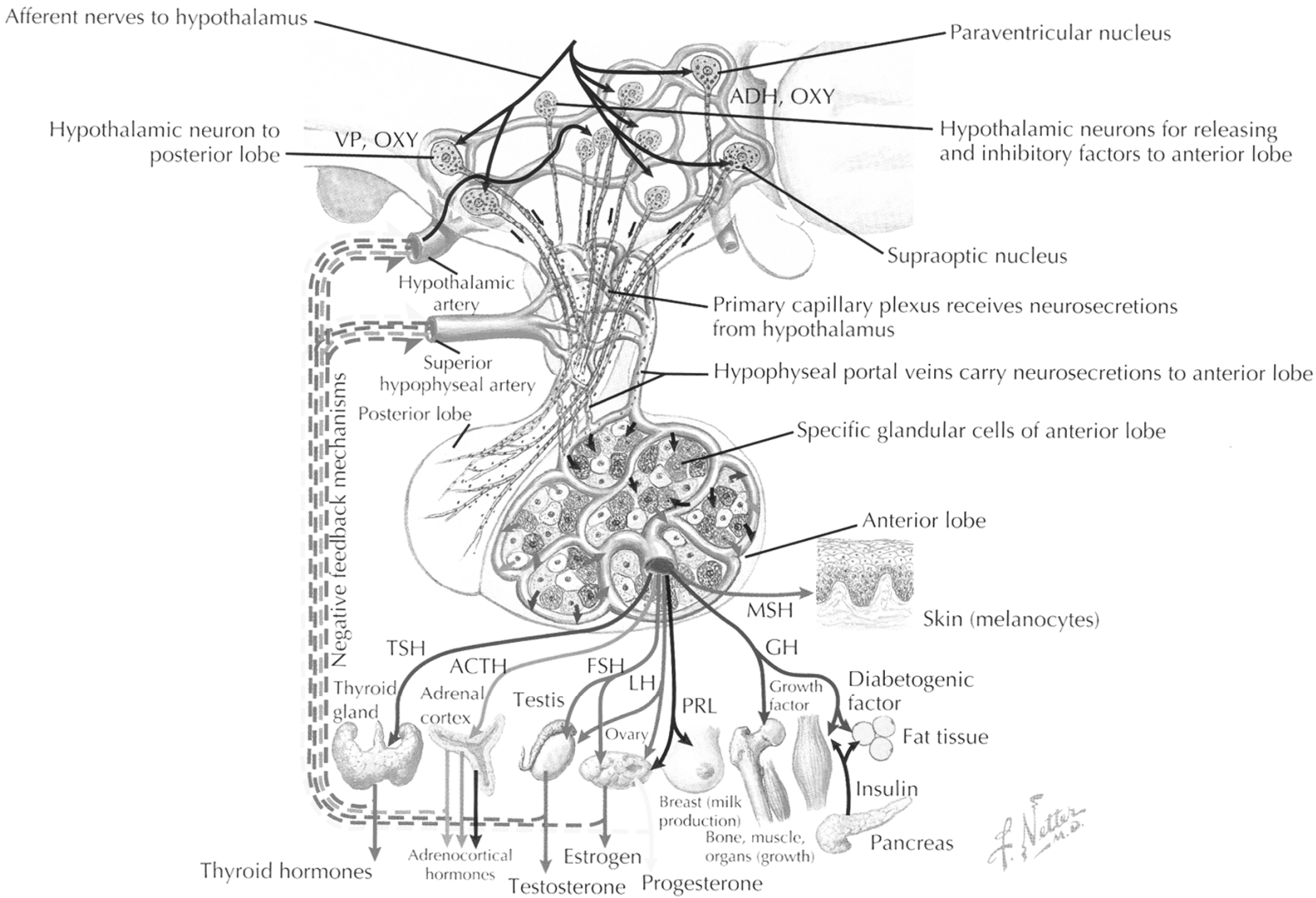
Clinical links

Hypophyseal tumors

- compression of surrounding structures (optic chiasma)

- hyperfunction of endocrine component

  - prolactinoma - galactorrhea
  - hypogonadism (alterations of GnRH)
  - gigantism - acromegaly
  - nanism


Afferent nerves to hypothalamus
Paraventricular nucleus
ADH, OXY
Hypothalamic neuron to posterior lobe
VP, OXY
Hypothalamic neurons for releasing and inhibitory factors to anterior lobe
Supraoptic nucleus
Hypothalamic artery
Primary capillary plexus receives neurosecretions from hypothalamus
Superior hypophyseal artery
Hypophyseal portal veins carry neurosecretions to anterior lobe
Posterior lobe
Specific glandular cells of anterior lobe
Negative feedback mechanisms
Anterior lobe
MSH
Skin (melanocytes)
TSH
ACTH
FSH
LH
PRL
GH
Thyroid gland
Adrenal cortex
Testis
Ovary
Growth factor
Diabetogenic factor
Fat tissue
Insulin
Breast (milk production)
Bone, muscle, organs (growth)
Pancreas
Thyroid hormones
Adrenocortical hormones
Estrogen
Testosterone
Progesterone

Posterior hypophysis (neurohypophysis)

nonmyelinated nerve fibers

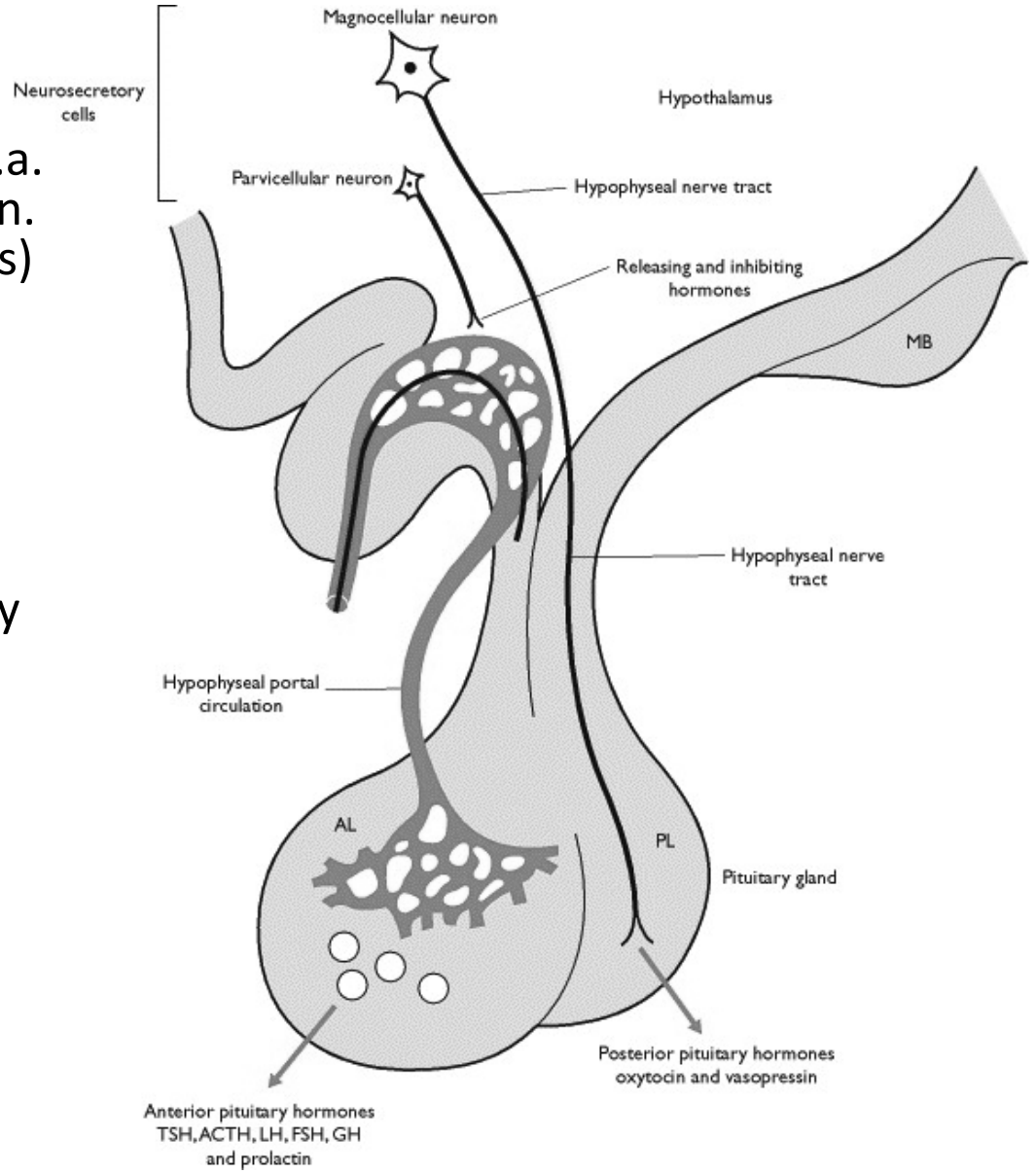
– axons of neurosecretory cells (c.a. 100 000) of hypothalamic nuclei (n. supraopticus and paraventricularis)

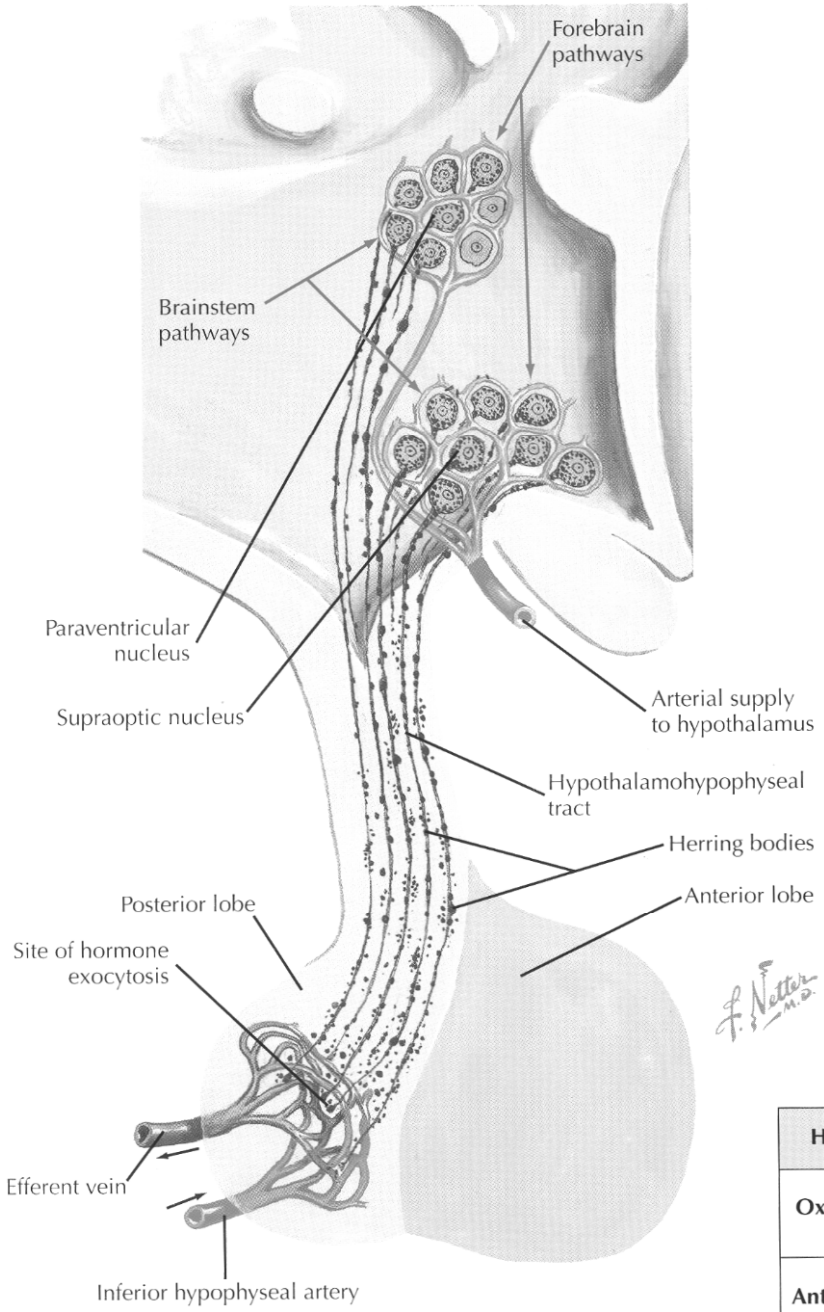
pituicytes (neuroglia)

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

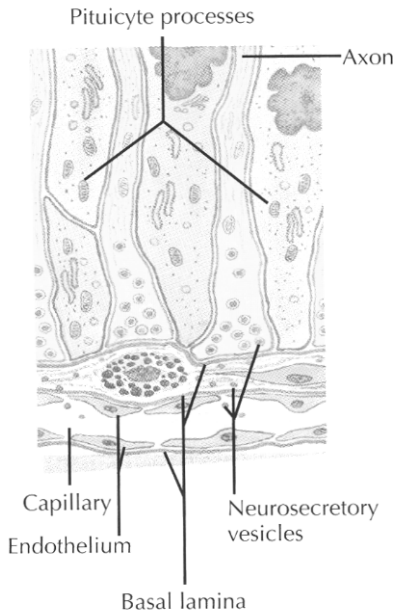
Hormones

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

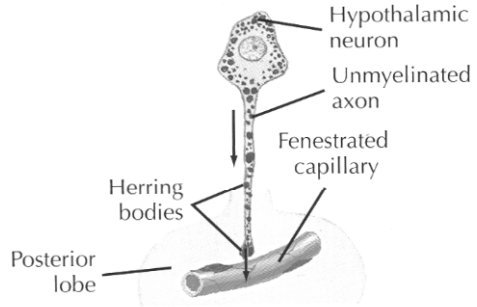




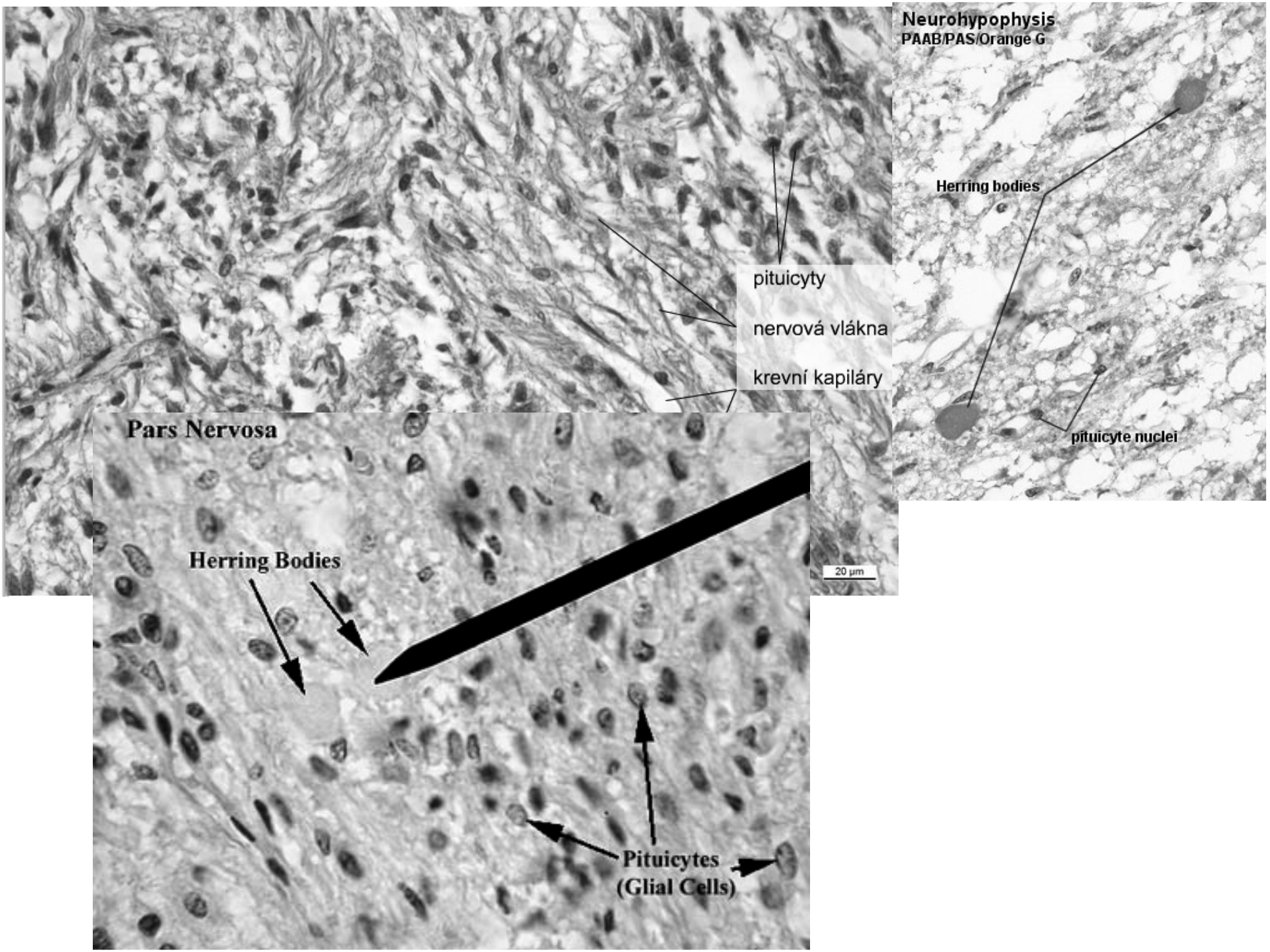
▼ **Neurosecretory Ending (posterior pituitary).**



▼ **Origin of ADH.**

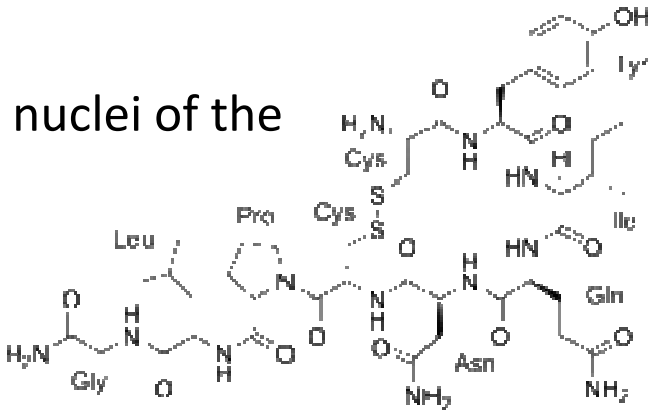


Hormone	Principal Action	Principal Nucleus of Origin
Oxytocin (OXY)	Uterine contraction, milk ejection	Paraventricular
Anti-diuretic hormone (ADH)	Water excretion in kidney, arteriolar constriction	Supraoptic


pituicyty
nervová vlákna
krevní kapiláry
Pars Nervosa
Herring Bodies
20 µm
Pituicytes
(Glial Cells)
Neurohypophysis
PAAB/PAS/Orange G
Herring bodies
pituicyte nuclei

Oxytocin

- nonapeptide
- magno-cellular supraoptic and paraventricular nuclei of the 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

<table>
<tr><th colspan="3">Anatomy</th><th colspan="3">Microscopic anatomy</th><th colspan="3">Hormones and target tissues</th></tr>
<tr><td rowspan="5">Anterior lobe (adenohypophysis)</td><td rowspan="3">pars distalis</td><td rowspan="4">superior hypophyseal arteries → primary capillary plexus → hypophyseal portal veins + inferior hypophyseal arteries → secondary capillary plexus → hypophyseal portal veins → vv. jugulares internae</td><td colspan="3">trabecular epithelium in cords and clusters, reticular fibers</td><td colspan="3"></td></tr>
<tr><td>chromophobes</td><td colspan="2">undifferentiated cells
degranulated chromophilic cells
stromal cells</td><td colspan="3">lack hormonal activity</td></tr>
<tr><td rowspan="3">chromophils</td><td rowspan="2">acidophilic
nonglandotropic</td><td>mammotropic cells</td><td rowspan="2">small polypeptides</td><td>dopamin (PIH)
⊥
(PRF → prolactin</td><td>mammary gland in gravidity and lactations</td></tr>
<tr><td>somatotropic cells</td><td>somatostatin (GHIH)
⊥
GHRH → somatotropin
(STH)</td><td>directly liver and growth plates other tissues via somatomedins</td></tr>
<tr><td>pars tuberalis</td><td rowspan="2">basophilic
glandotropic</td><td>corticotropic cells</td><td rowspan="3">glycoproteins</td><td>CRH → ACTH, MSH</td><td>adrenal cortex → cortisol
melanocytes</td></tr>
<tr><td rowspan="2">pars intermedia</td><td rowspan="2">Rathke’s cysts</td><td>thyrotropic cells</td><td>TRH → TSH</td><td>thyroid → thyroxin, T3</td></tr>
<tr><td>gonadotropic cells</td><td>GnRH → FSH (ICSH), LH</td><td>gonads → androgens, estrogens, progesterone</td></tr>
<tr><td rowspan="2">Posterior lobe (neurohypophysis)</td><td>eminentia mediana → infundibulum</td><td rowspan="2">anterior and posterior superior hypophyseal arteries →

primary capillary plexus, fenestrated capillaries</td><td colspan="2" rowspan="2">nonmyelinated axons
of hypothalamic neurons n. supraopticus, n. paraventricularis (tractus hypothalamohypophysialis),
pituicytes</td><td rowspan="2">small peptides</td><td>ADH</td><td>tubulus reuniens, ductus colligens t.media of vessels</td></tr>
<tr><td>pars nervosa</td><td>oxytocin</td><td>myometrium of uterus during gravidity
myoepithelium of lactating mammary gland</td></tr>
</table>

BREAK

To study the effects of the hypothalamo-pituitary-adrenal axis, groups of mice were injected with different hormones. Group A mice were injected with cortisol to mimic effects of Cushing's syndrome. Group B mice were injected with hormone X. Group C mice were injected with a saline solution. Blood samples were later taken from the various groups and average hormone levels were measured and recorded in Table 1.

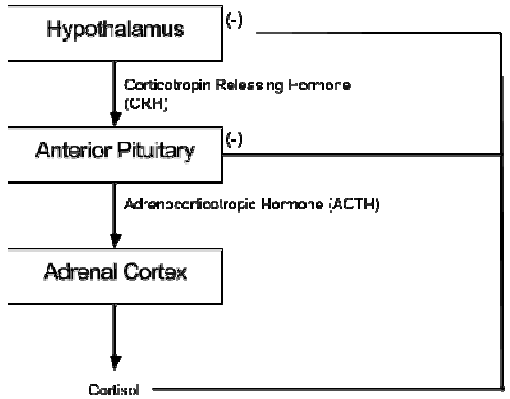


Table 1. Levels of hormones (in nmol/L) found in blood sample taken from experimental mice groups.

	CRH	ACTH	Cortisol
Group A	20	150	900
Group B	45	430	760
Group C	30	230	400

According to the results of the experiment, which is the most likely identity of hormone X?

Please choose from one of the following options.
- CRH, because Group C's concentration of ACTH and cortisol is lower than that of the control group.
- ACTH, because Group B's concentration of ACTH and cortisol is higher than that of the control group.
- ACTH, because Group C's concentration of ACTH and cortisol is lower than that of the control group.
- **CRH, because Group B's concentration of ACTH and cortisol is higher than that of the control group.**

Why does a pituitary adenoma cause a patient to have an excess level of cortisol?

Please choose from one of the following options.
- It increased the size of the hypothalamus.
- Its cells did not respond to CRH.
- **Its cells did not respond normally to cortisol.**
- It decreased the level of ACTH circulating in the body.

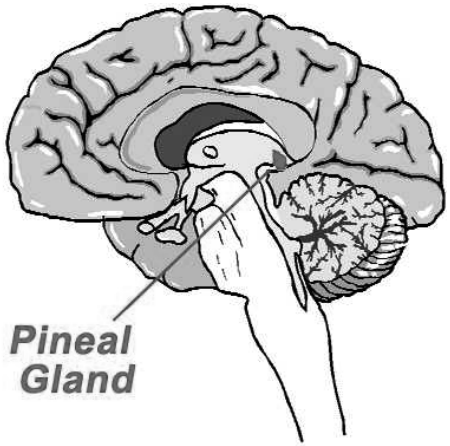
Which of the following would exacerbate the symptoms of Cushing's disease?

Please choose from one of the following options.
- Somatic cells not responding to cortisol.
- Taking a glucocorticoid receptor antagonist.
- Radiation therapy to treat a pituitary adenoma.
- **Taking glucocorticoids to treat asthma.**

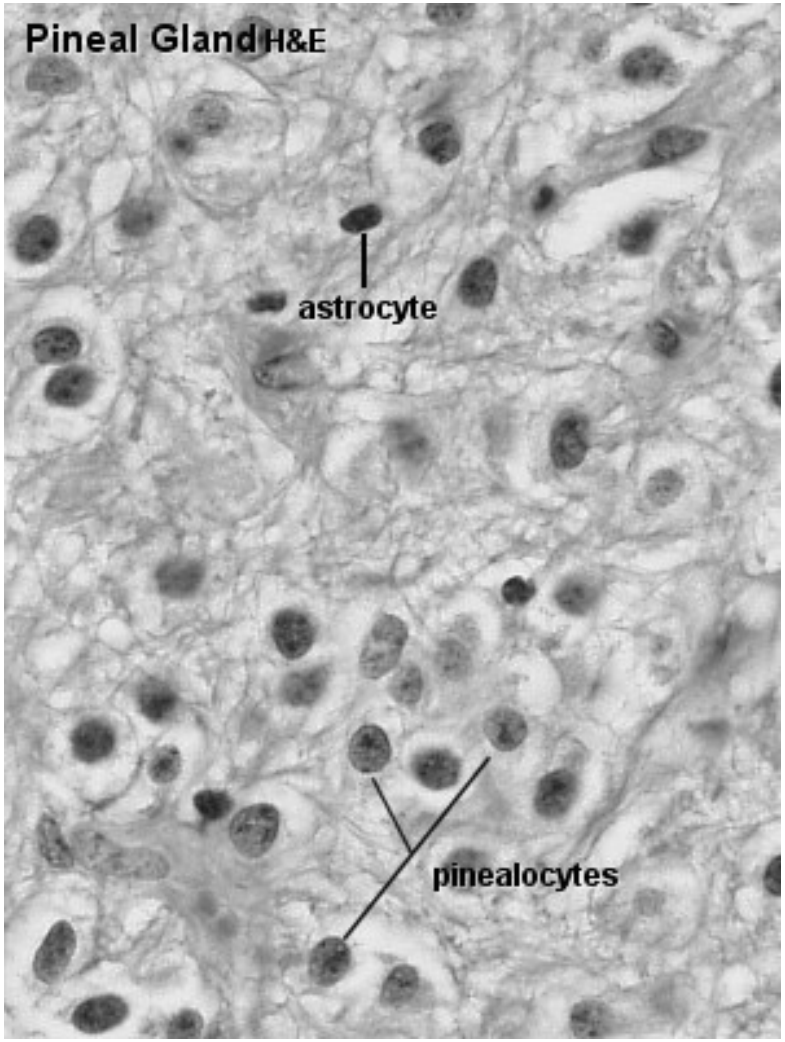
Which of the following can result in a chronic increase in a patient's ACTH and CRH levels?

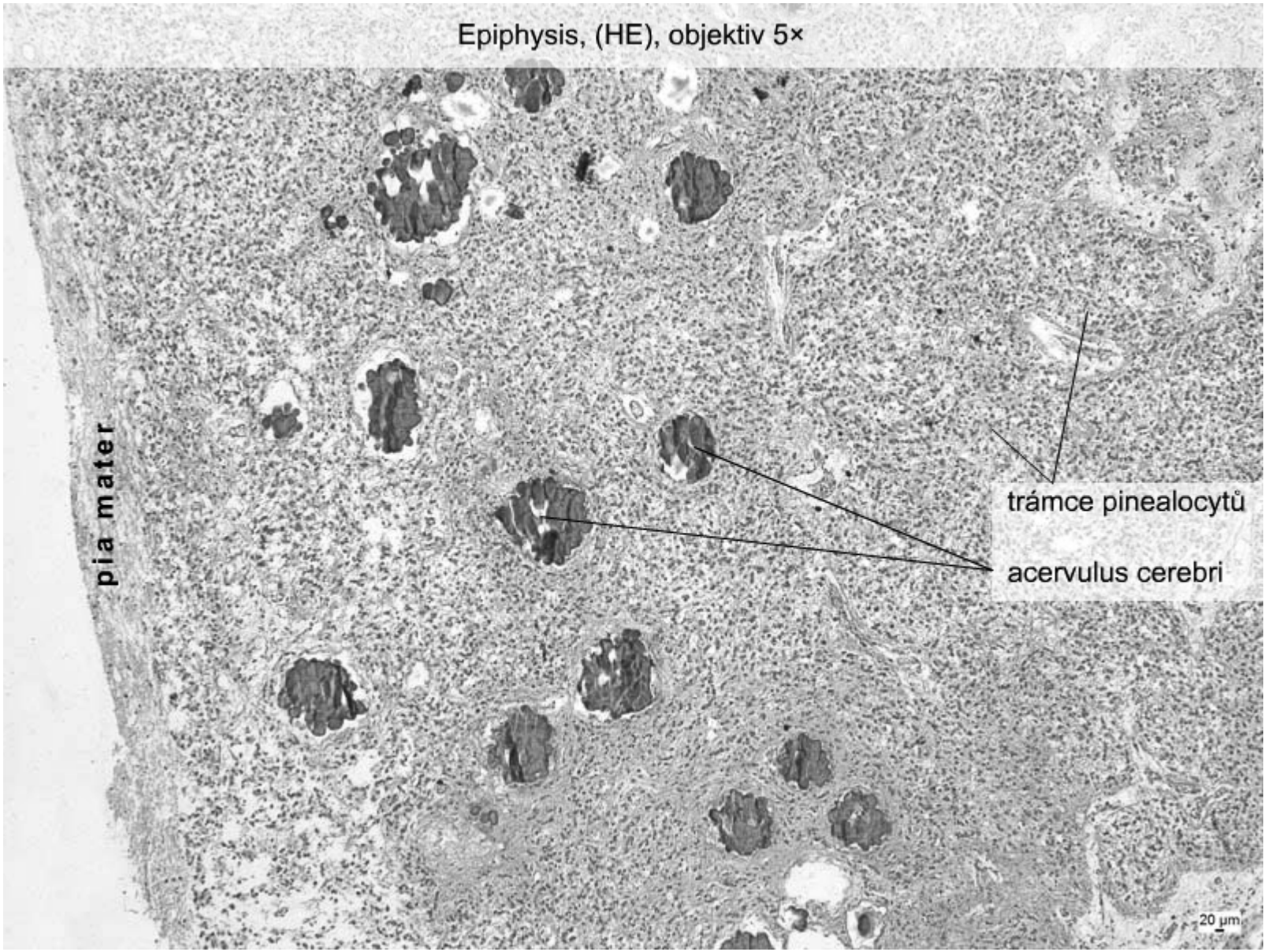
- Pituitary tumor.
- **Destruction of the adrenal glands.**
- Taking medicinal glucocorticoids, such as prednisone.
- Hypersecretion of cortisol from the hypothalamus.

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

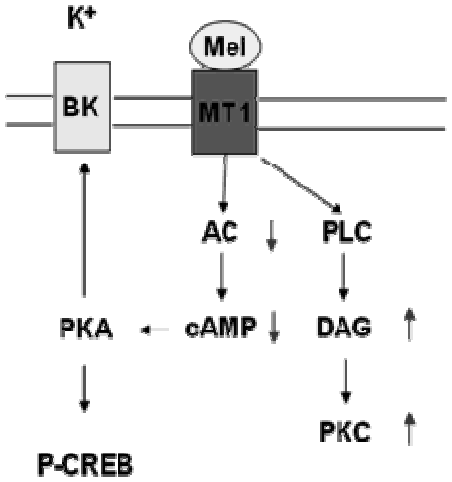


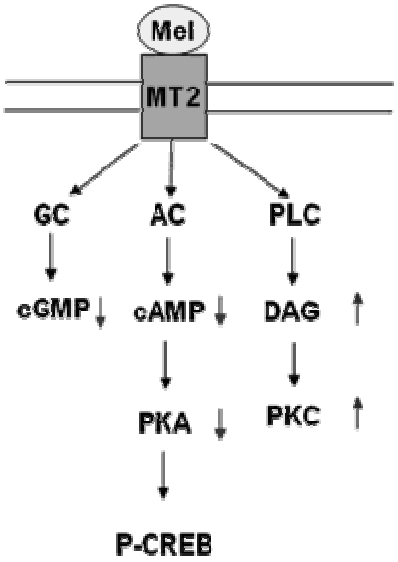

Epiphysis, (HE), objektiv 5×
pia mater
trámce pinealocytů
acervulus cerebri
20 µm

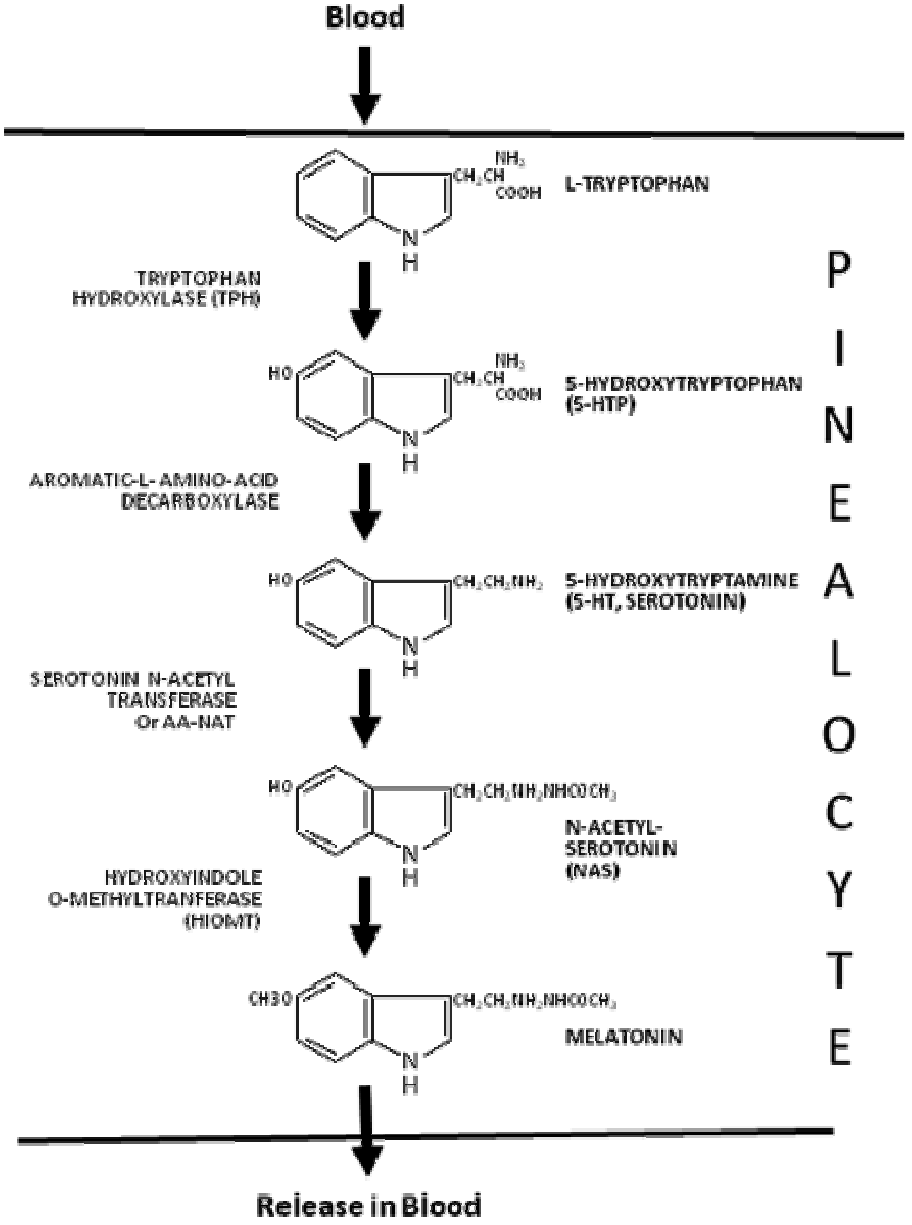
Epiphysis (*c. pineale*)

- **pinealocytes**

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

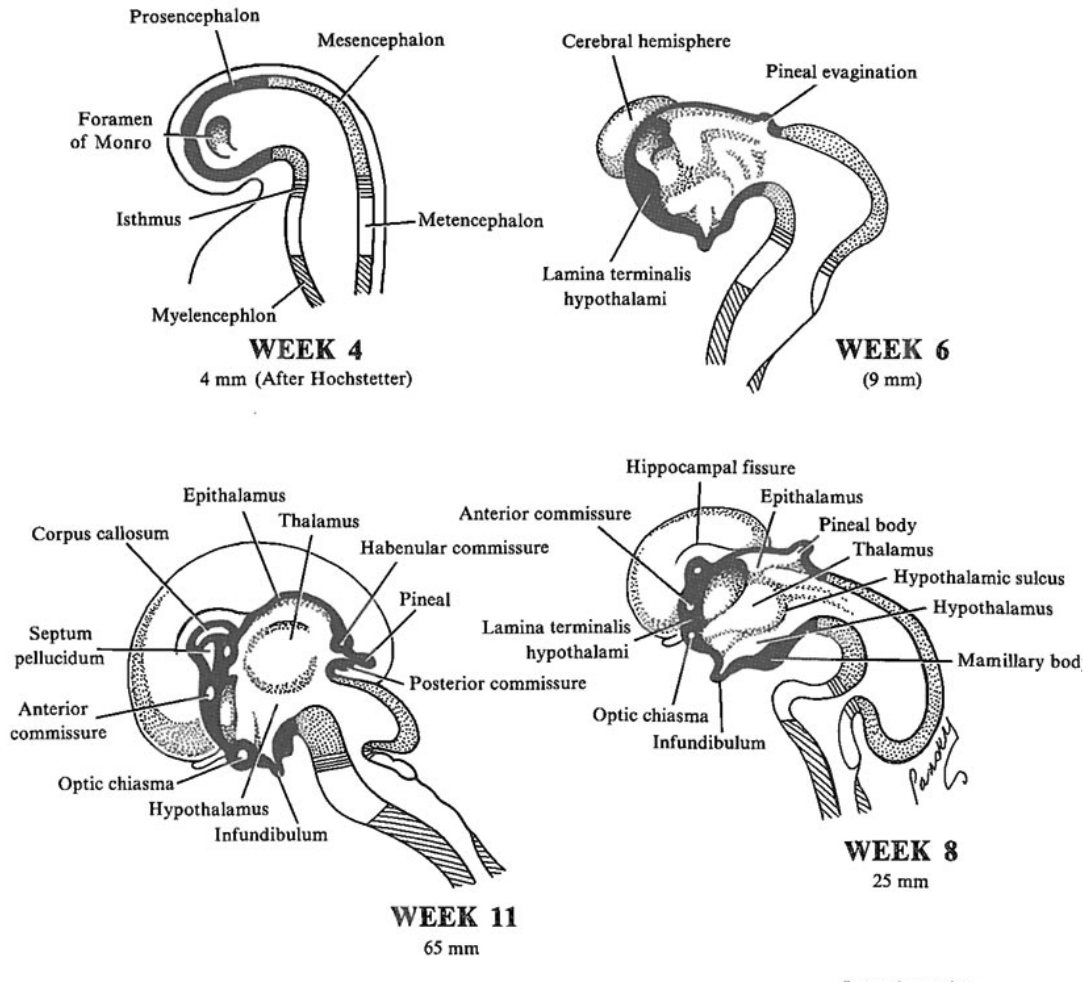






Embryonic development of epiphysis (*c. pineale*)

- 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

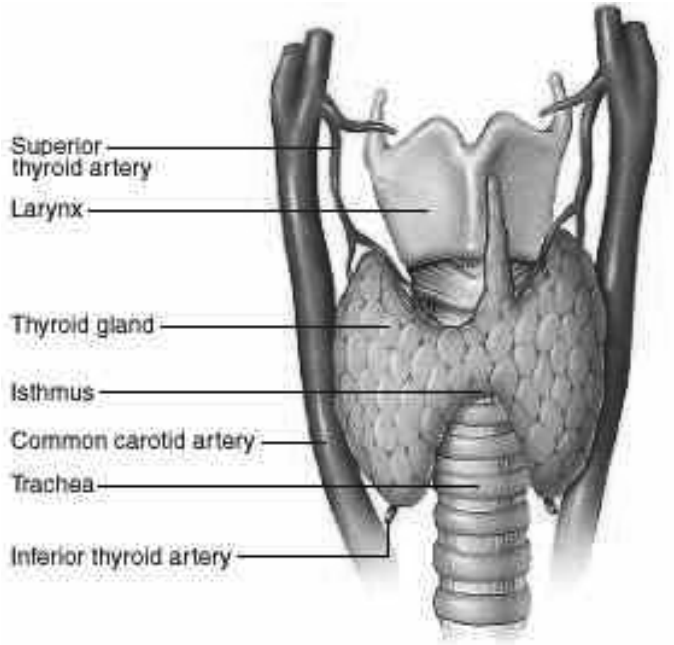
C.t. capsule, septs

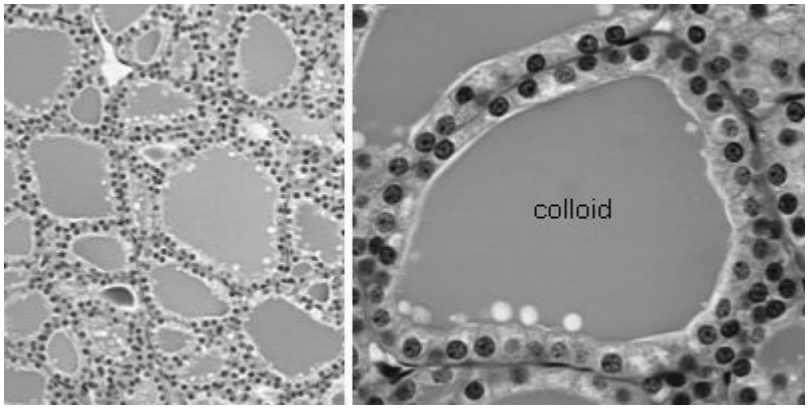
Lobes → lobuli - follicles

Follicles (50 µm -1 mm)

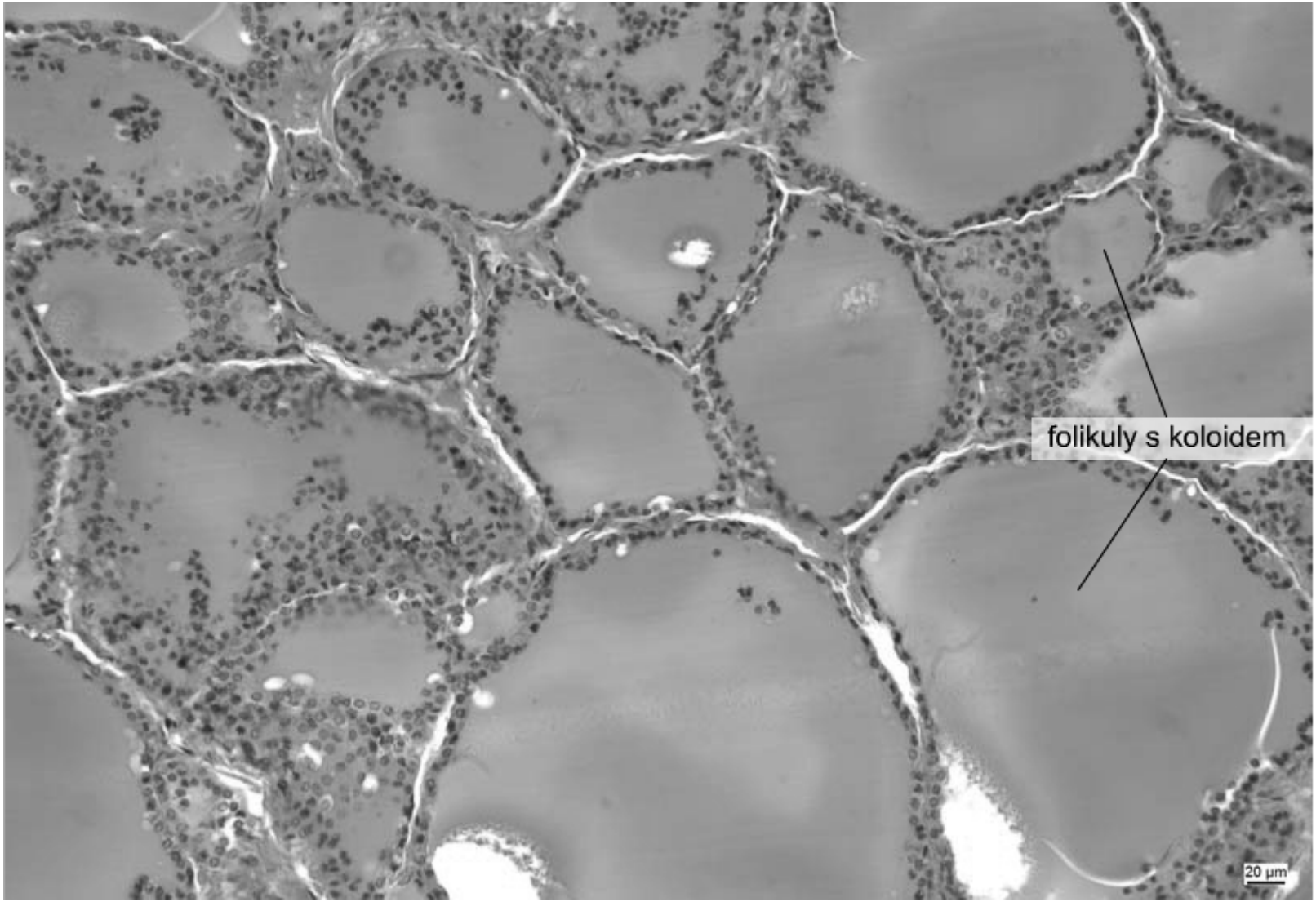
- separated by interstitial loose collagen c.t.
- simple epithelium (flat to cubic, according to secretory activity)
- colloid

Capillary network from thyroid arteries

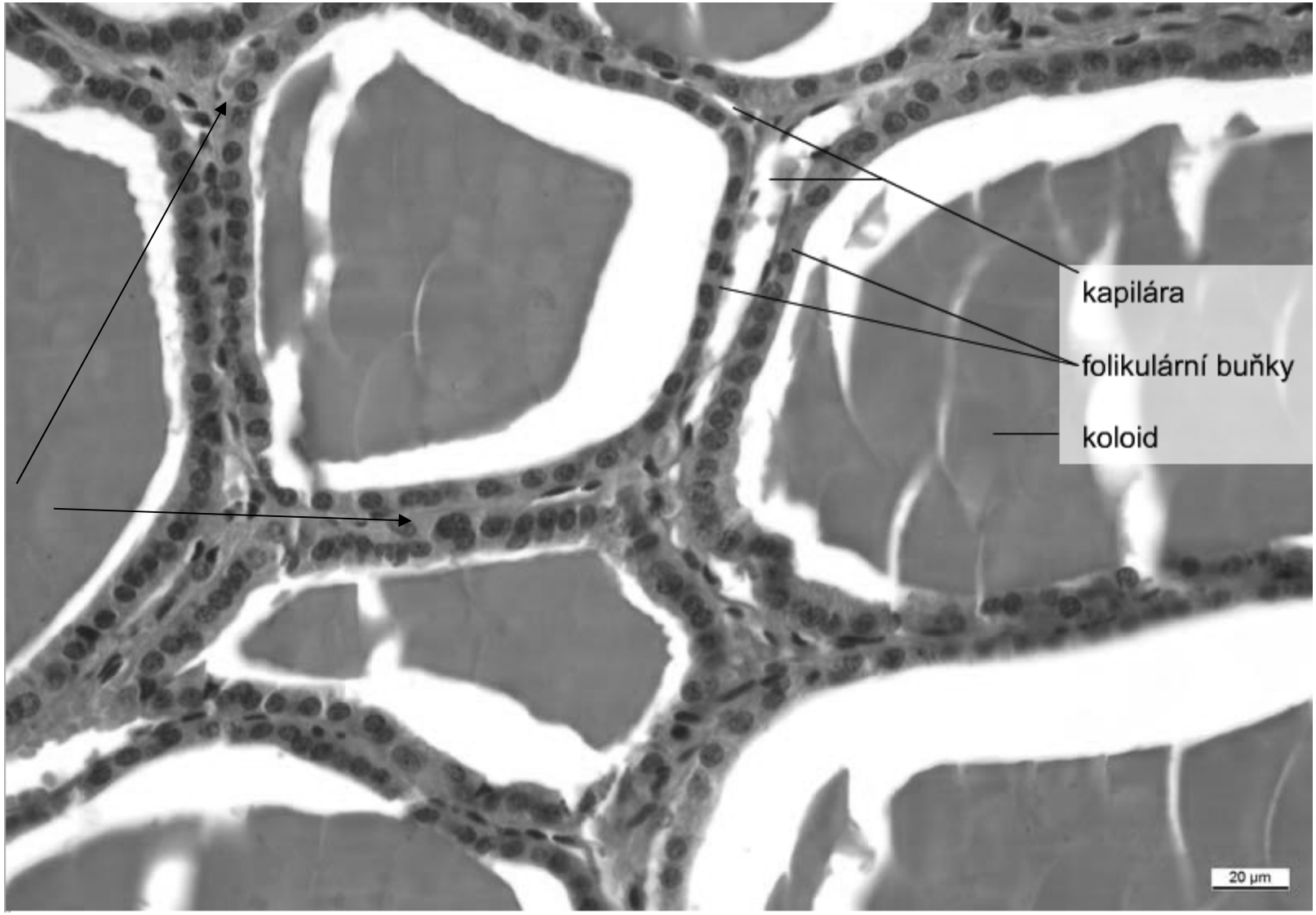




Thyroid gland - follicles



Thyroid gland - follicles



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 $I^- \rightarrow I_2$.
- 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

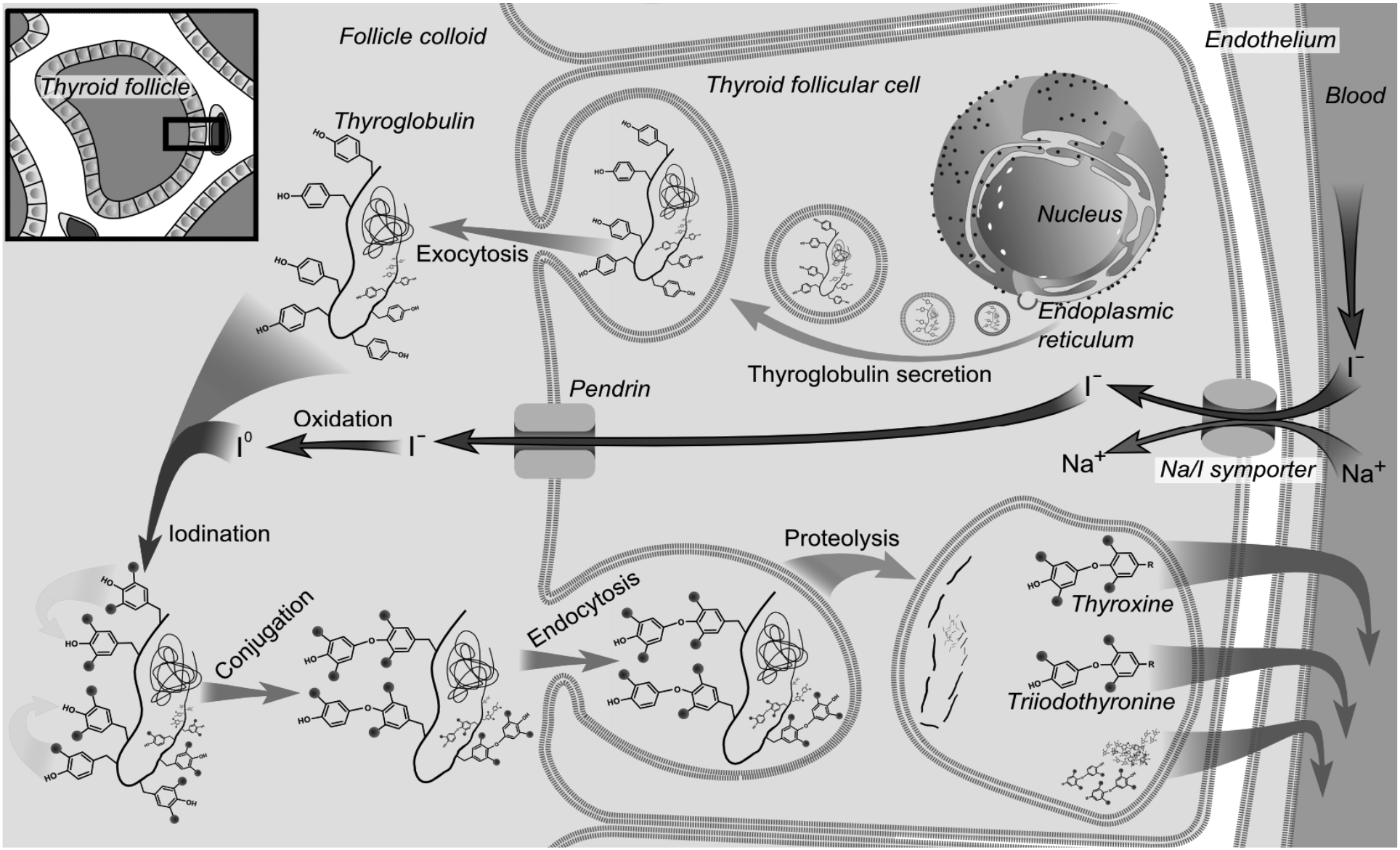
T3 synthesis from T4

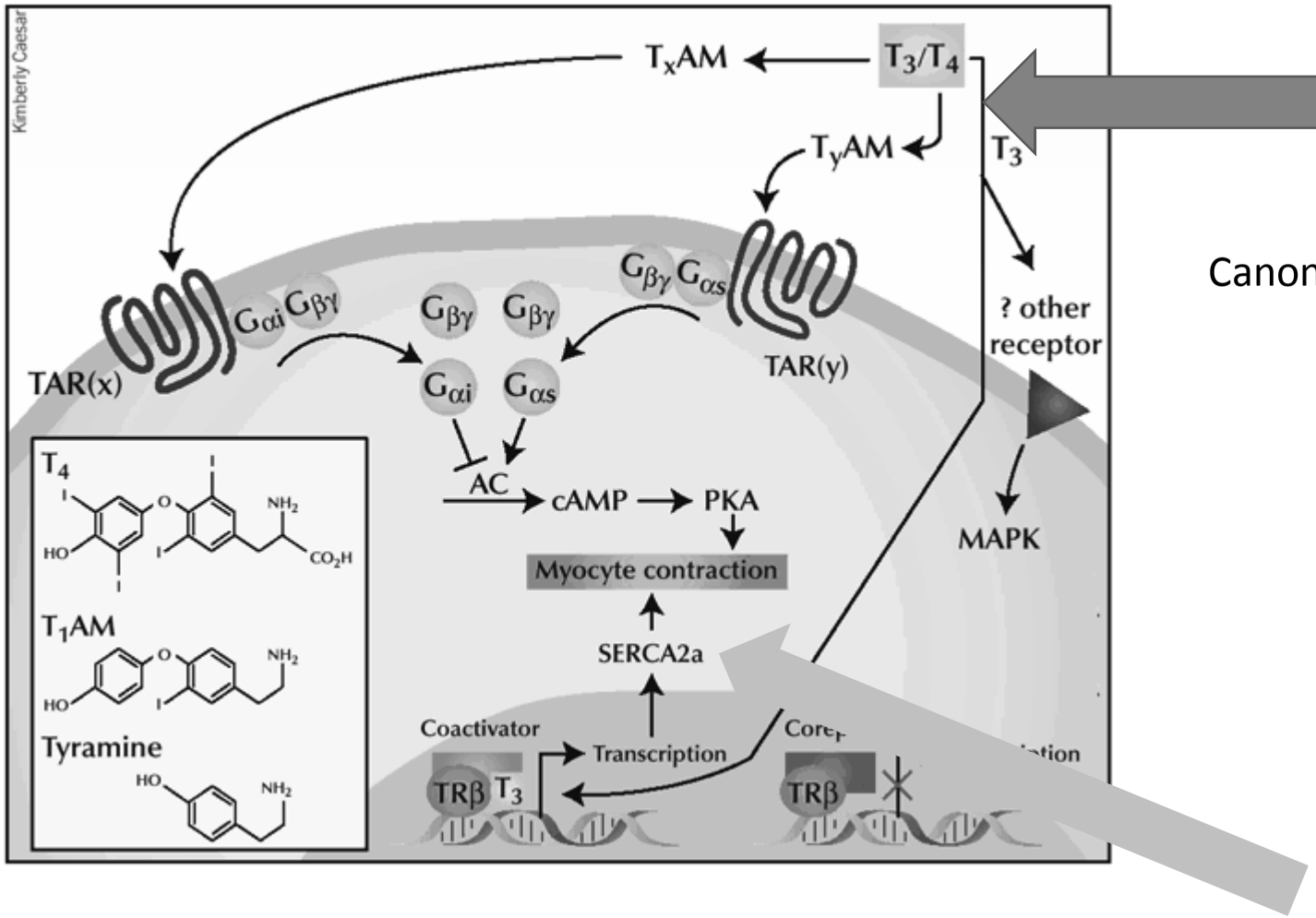
- T4 half-life in blood 6.5 days, T3 2.5 (T4 is a reservoir for T3)
- deiodination by tissue specific deiodinase enzymes generates T3

thyreoglobulin

triiodothyronin T_3

tetraiodothyronin (thyroxin) T_4





Canonical T3 pathway

Alternative T3 pathway

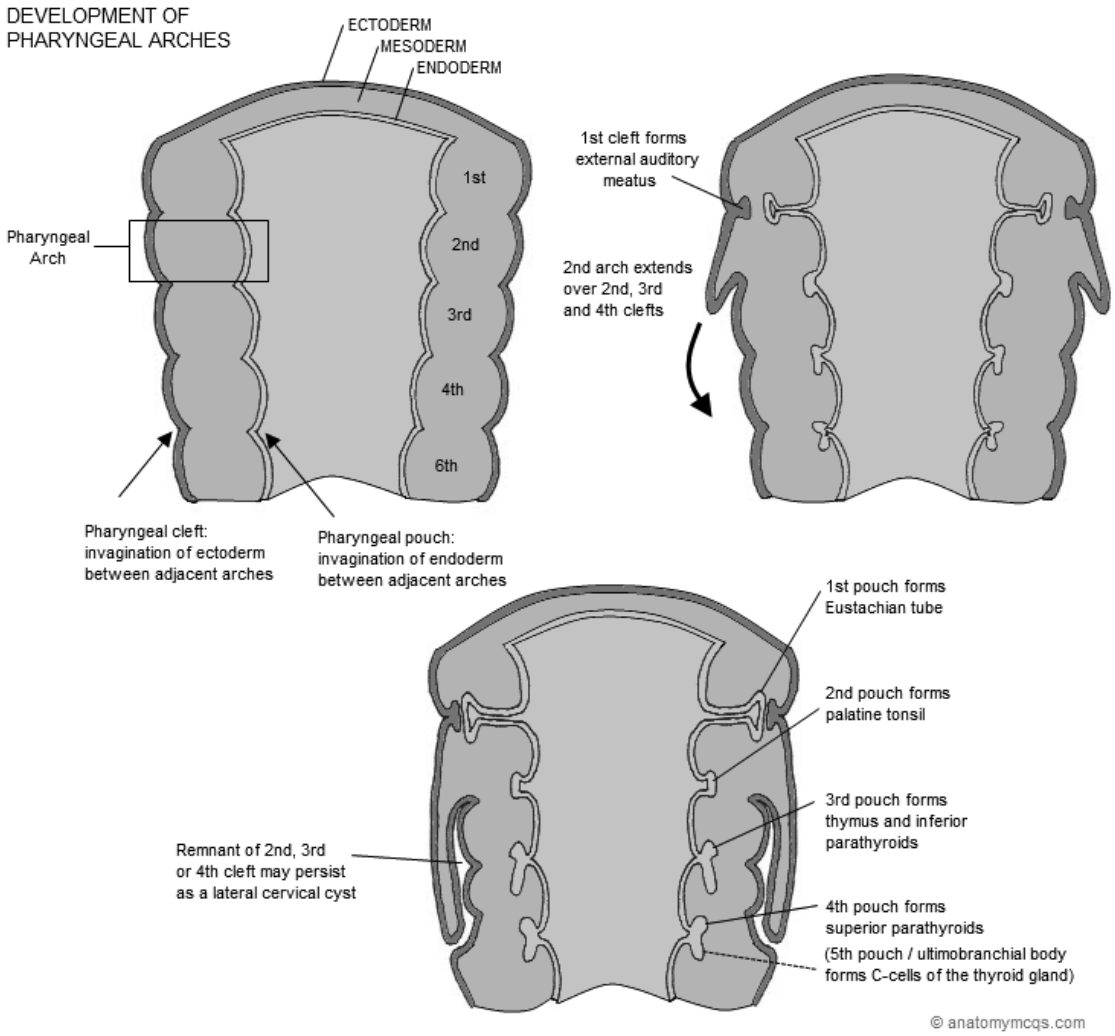
C cells of thyroid

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)

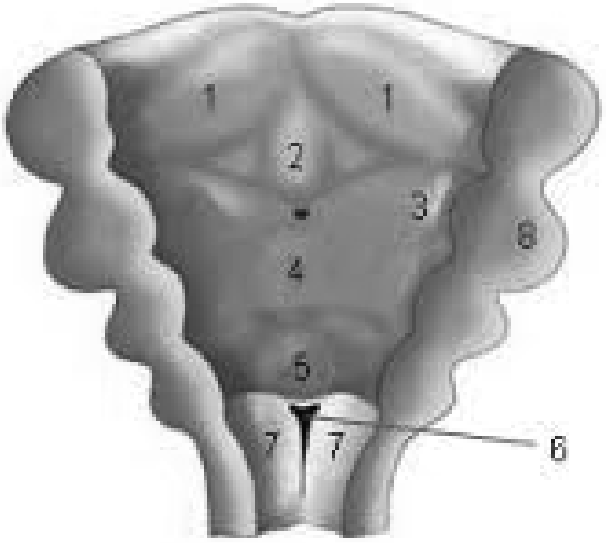
Calcitonin

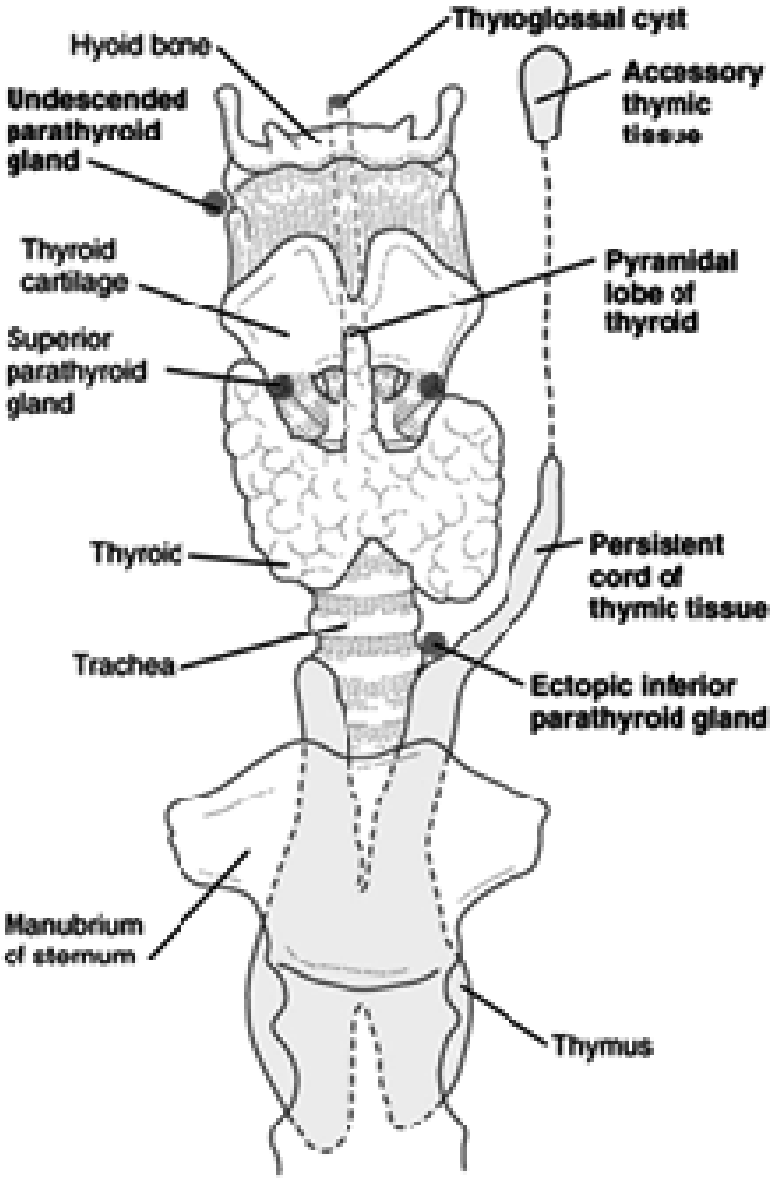
- inhibition of osteoclasts



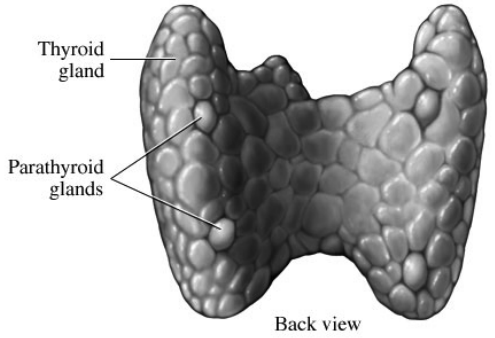
Thyroid development

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





Parathyroid gland (gl. parathyreoidea)



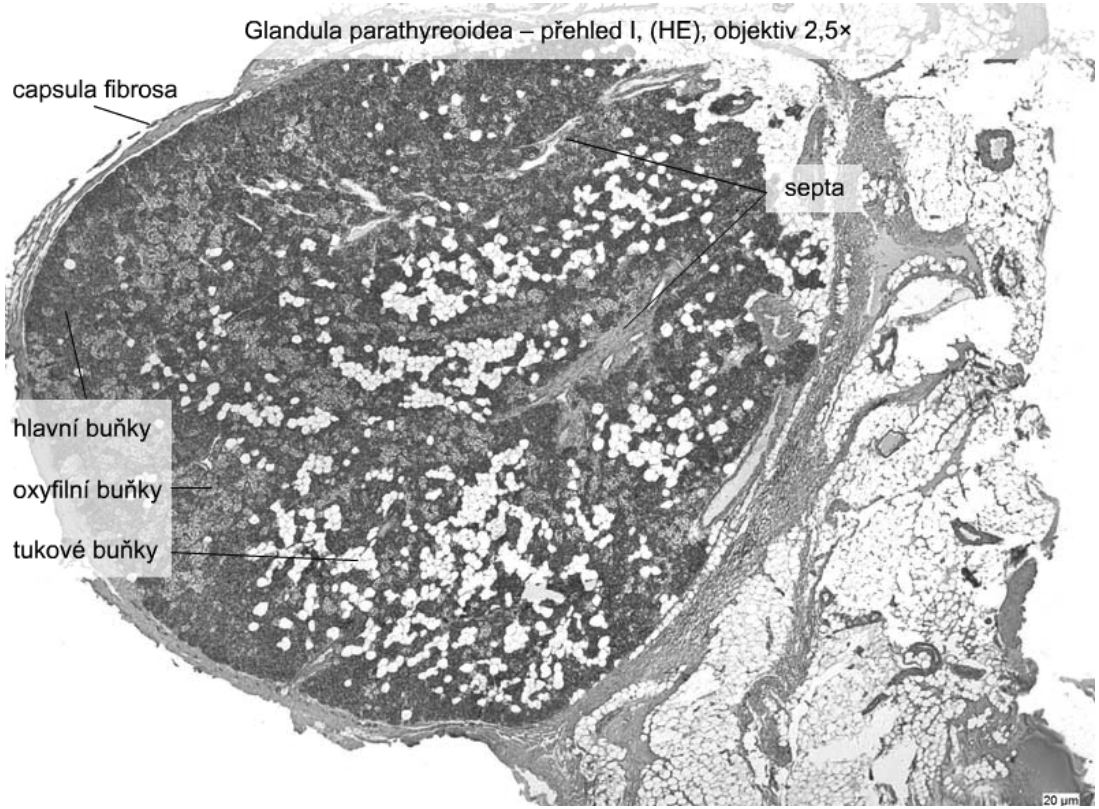
6 mm, 130 mg

c.t. capsule and septs

Capillary network

Cords and clusters of glandular cells

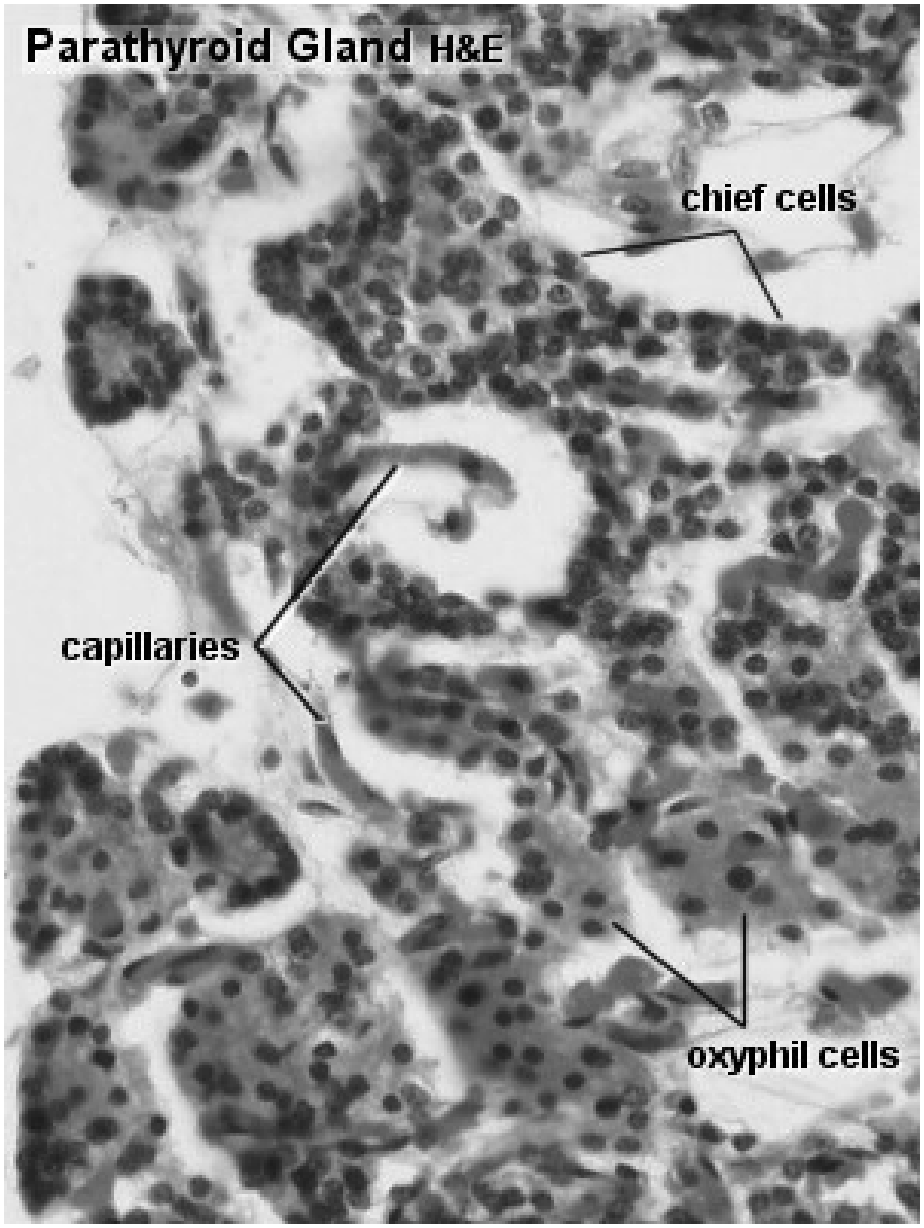
- Chief
- Oxyphilic
- Adipose



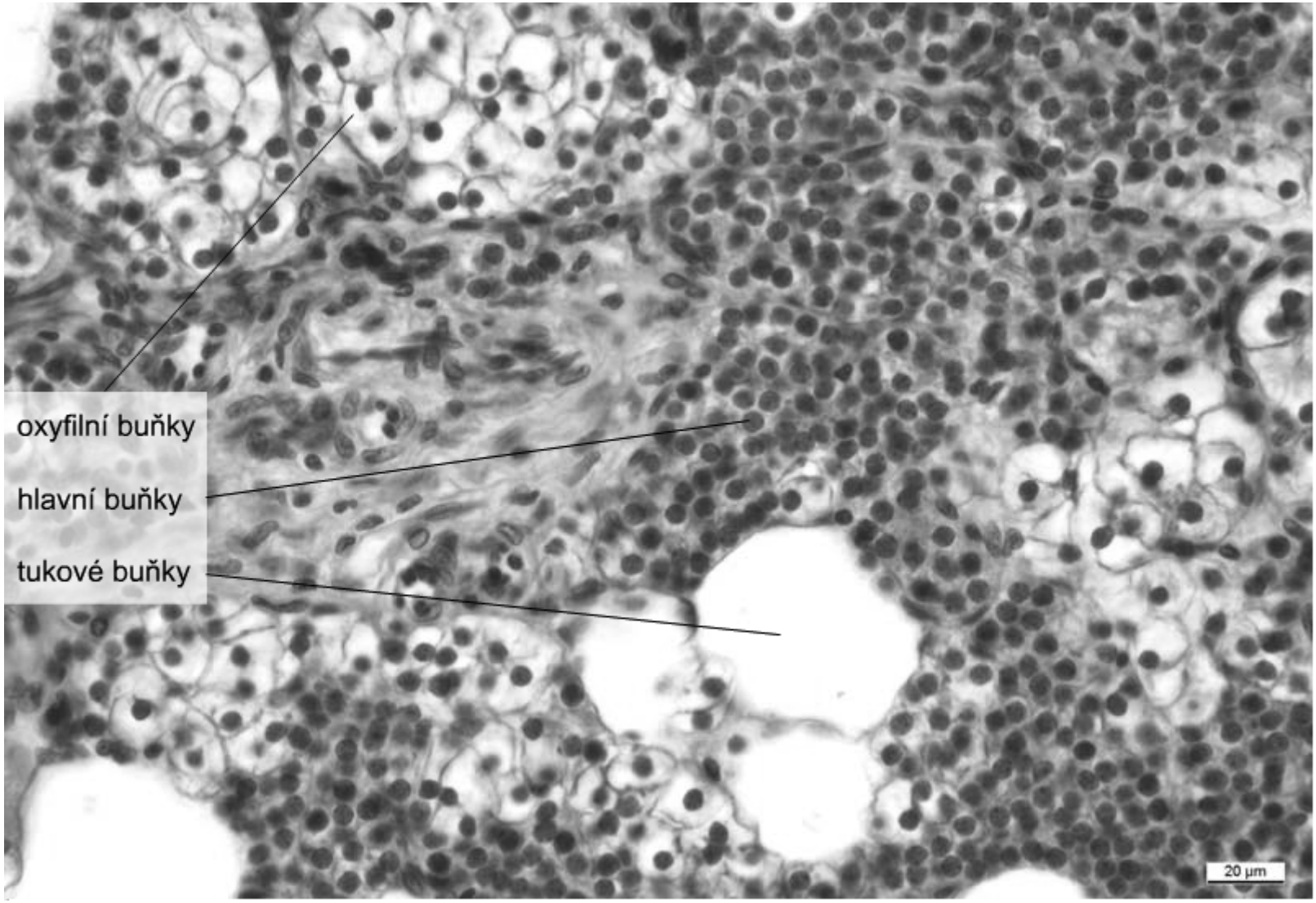
Parathyroid gland (gl. parathyreoidea)

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

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

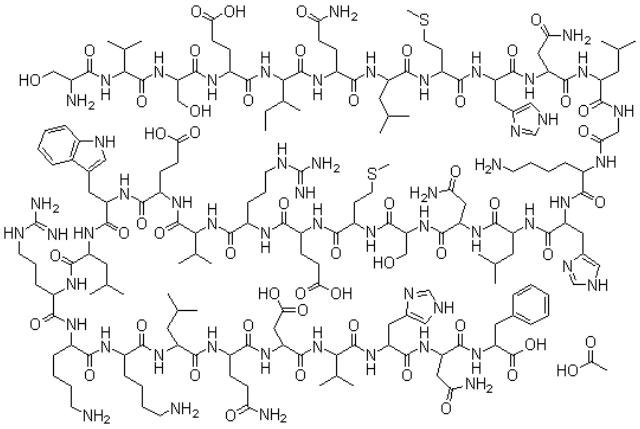


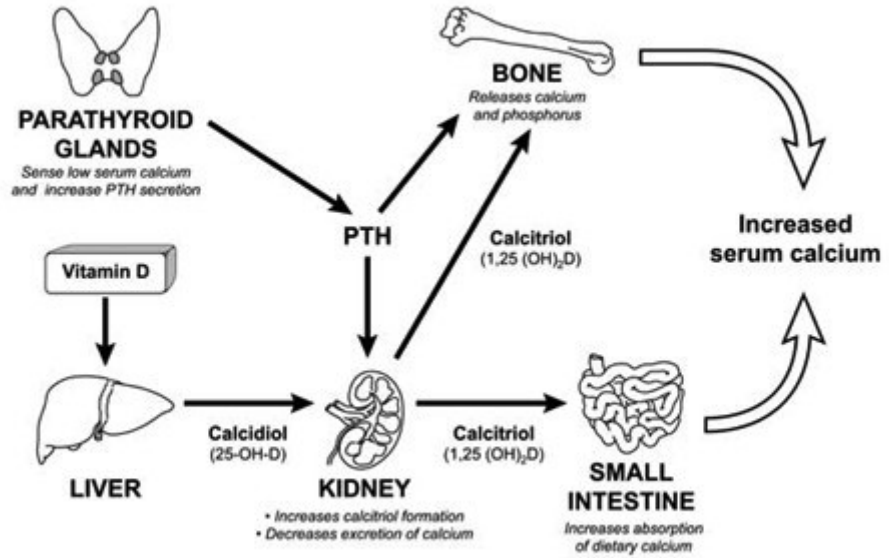
Parathyroid gland (gl. parathyreoidea)



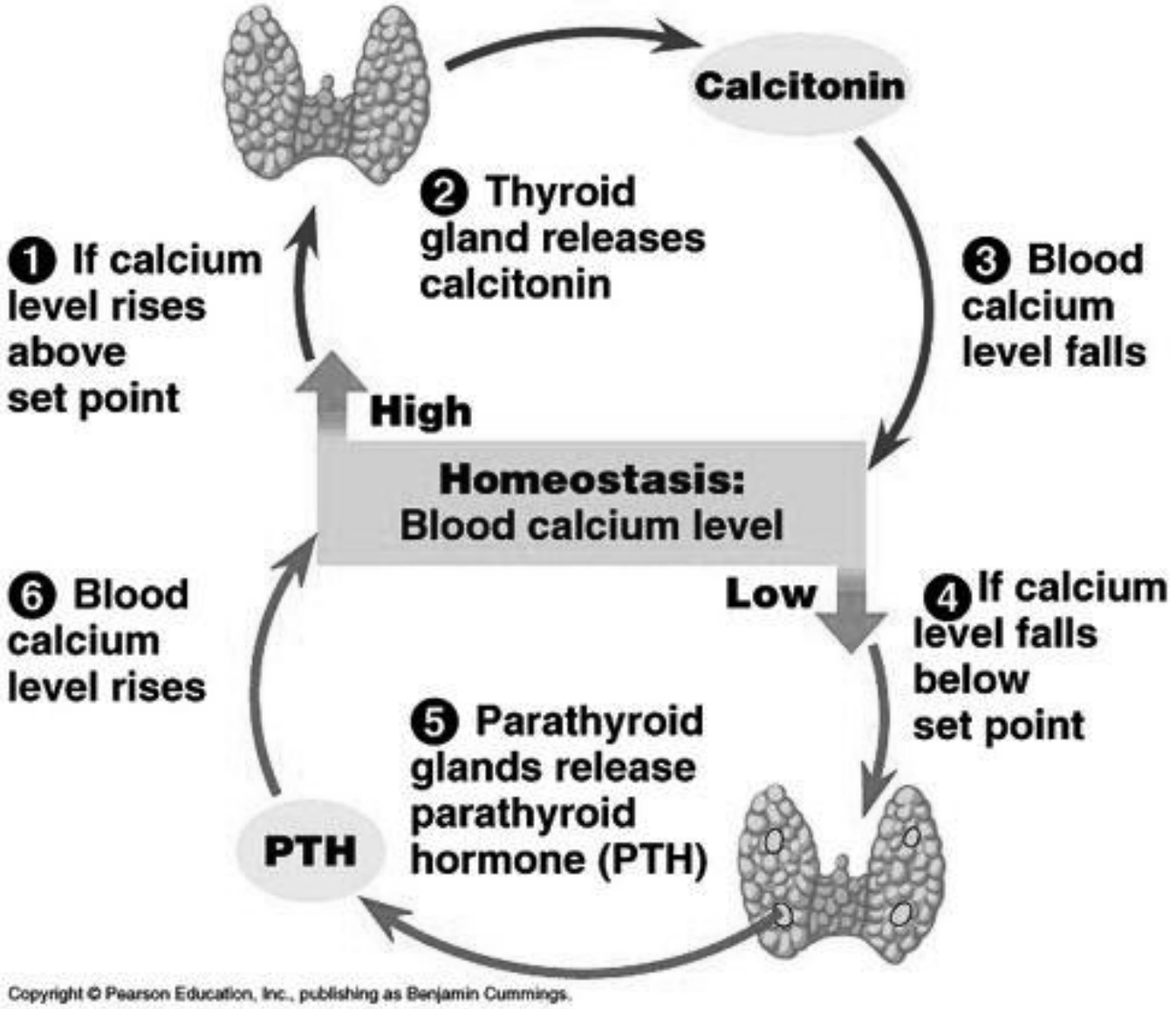
Parathyroid hormone (PTH, parathormone, parathyrin)

- 84 aminoacids
- stimulates resorption by osteoclasts
- enhances resorption of calcium and magnesium in distal tubules and thick ascending limb
- enhances absorption in the intestine (via vD3)





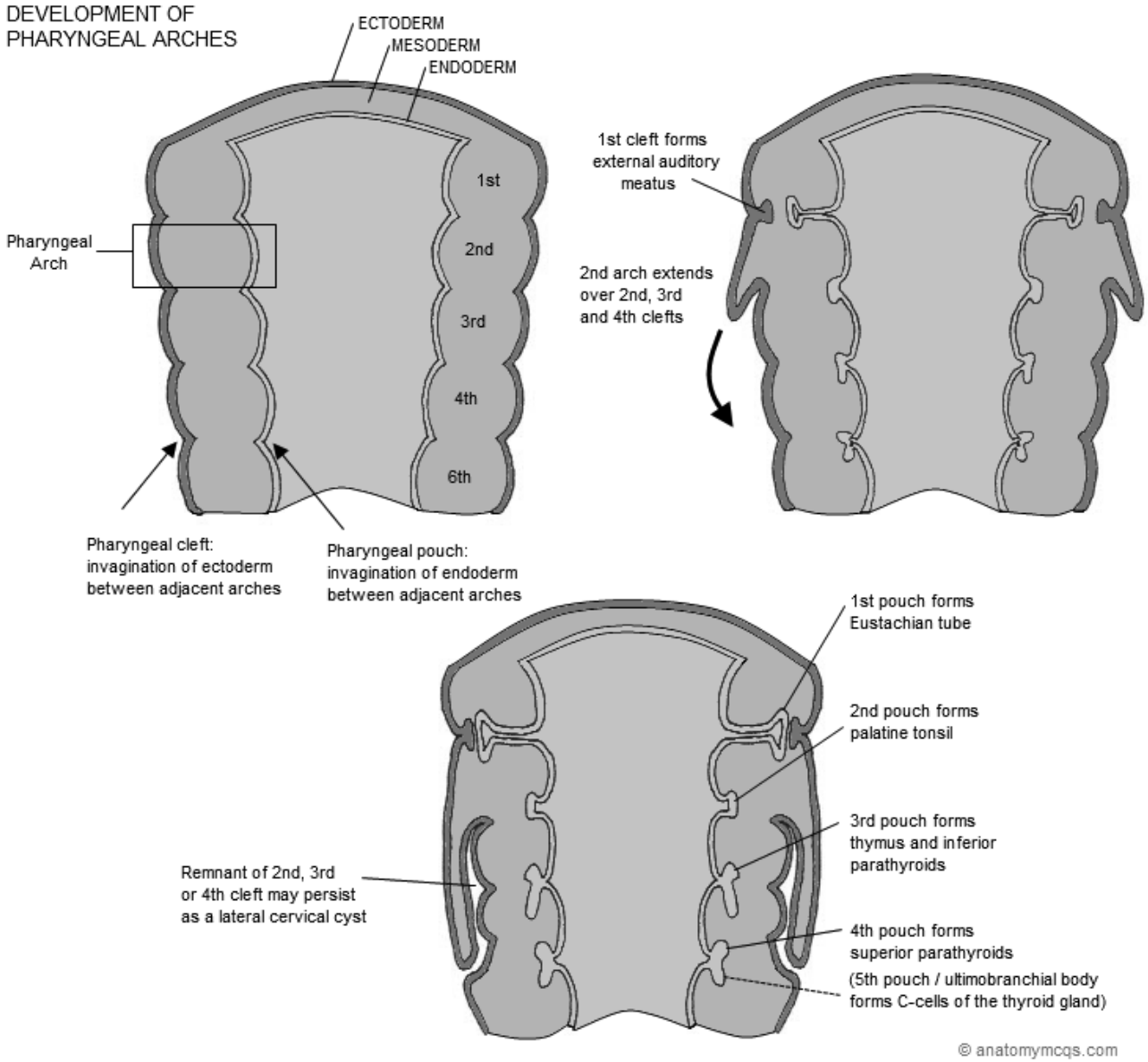
PTH vs. calcitonin



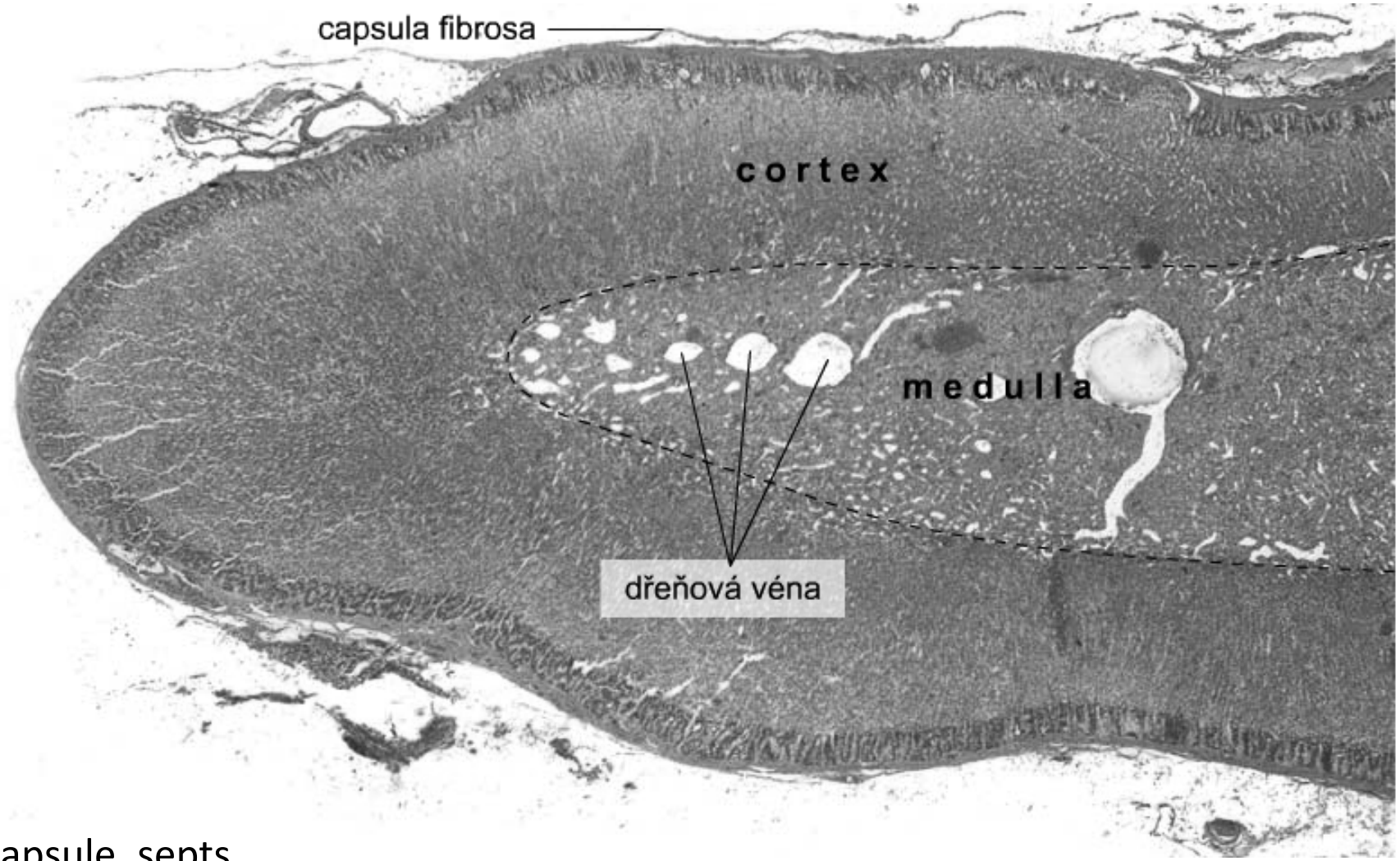
Embryonic development of parathyroid gland

- 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



Adrenal gland (*corpus suprarenale*)



c.t. capsule, septs

capillary plexus

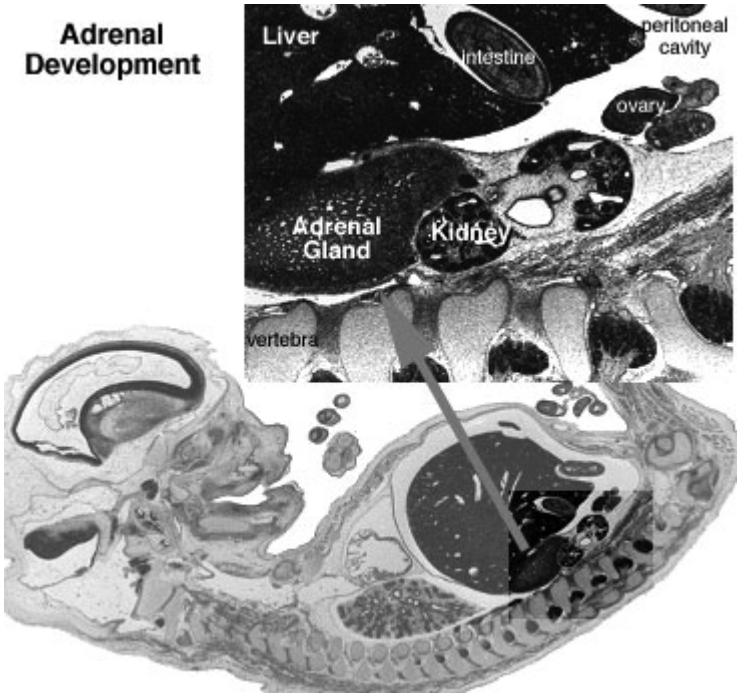
Adrenal development

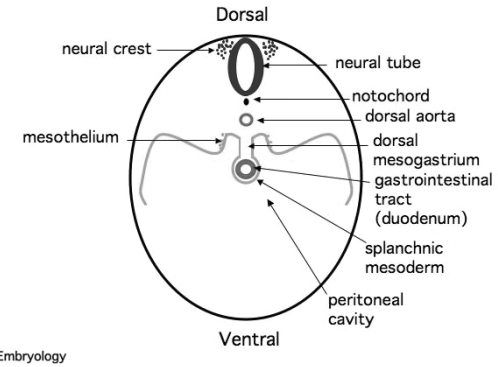
cortex

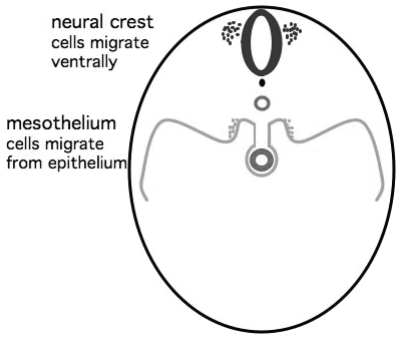
- mesoderm
- mesothelium, coelomic epithelium

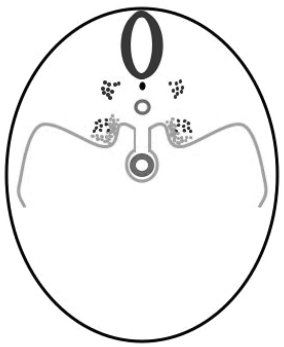
medulla

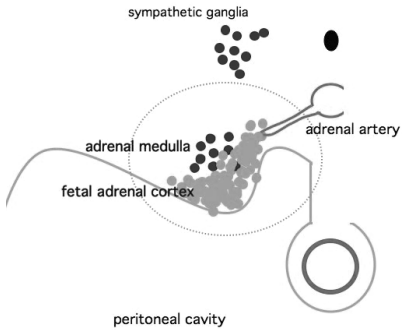
- neural crest



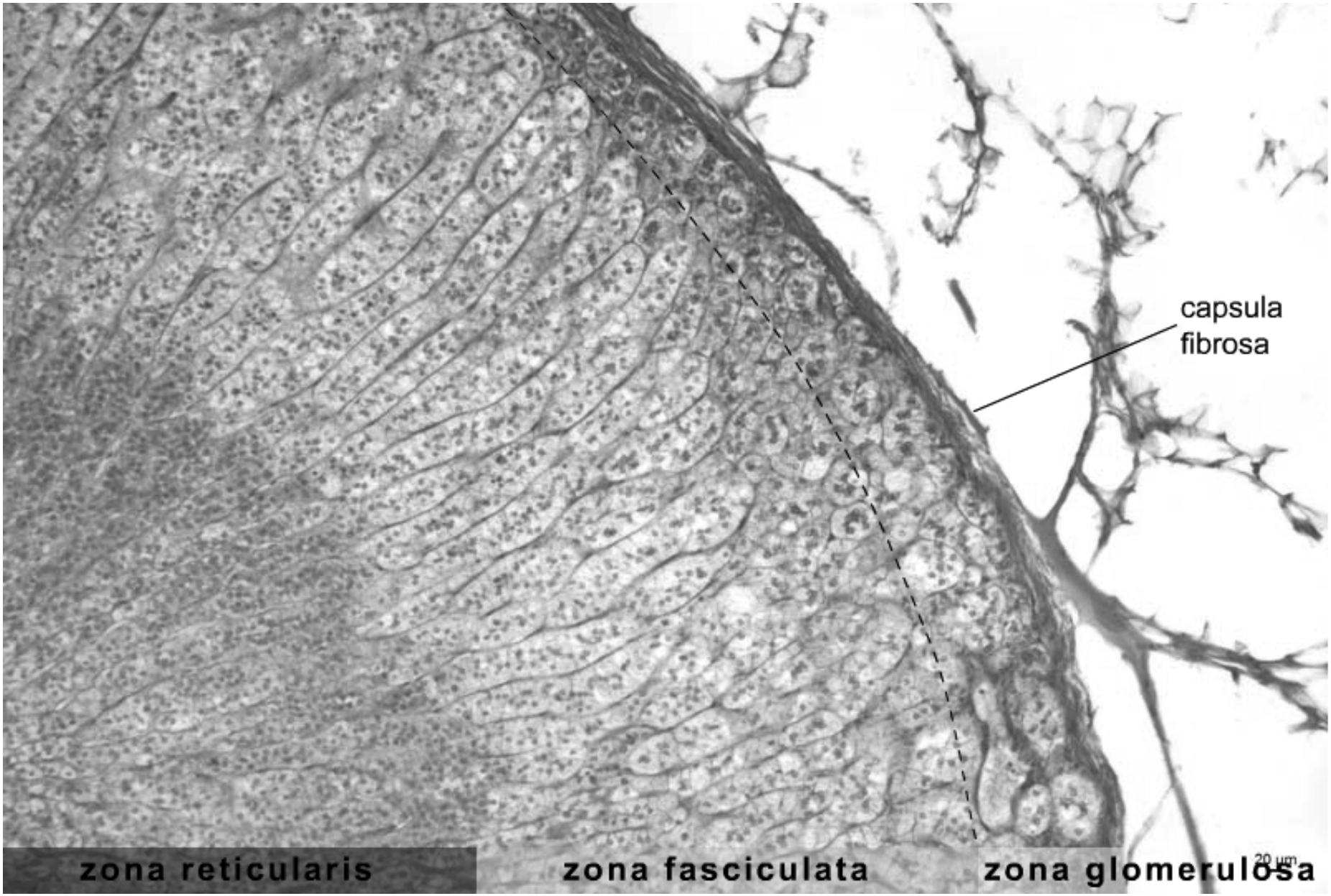








Adrenal cortex

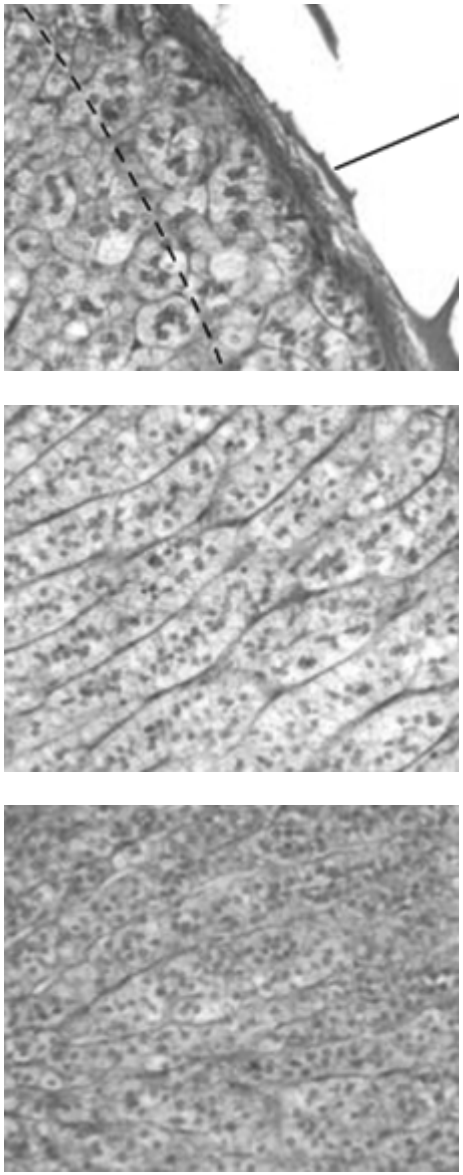


Adrenal cortex

- **Zona glomerulosa (1/10)**
- thin layer under capsule
- relatively small cells in coiled glomeruli
- not abundand 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**



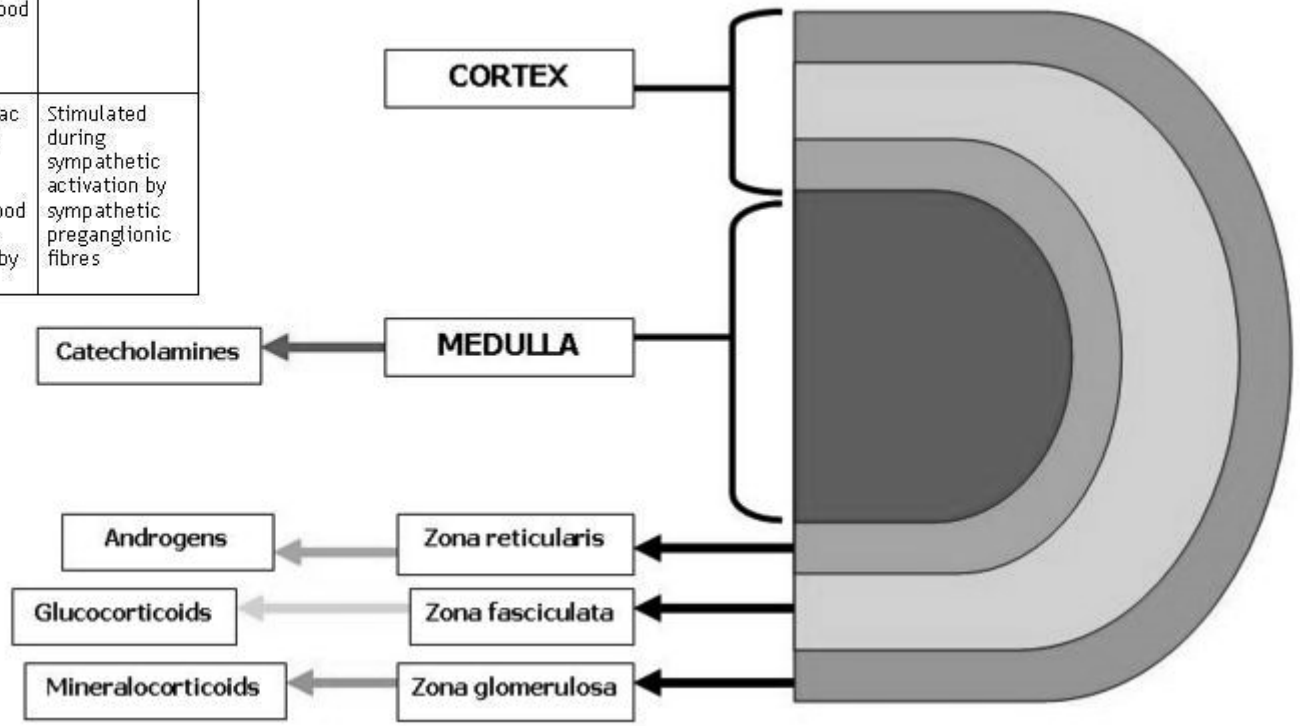
Adrenal cortex hormones

- Steroids produced incortex = 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 *Zona glomerulosa*	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 antiotebnsin II, elevated plasma K+, or a fall in plasma Na+; inhibited by ANP and BNP
Zona fasiculata	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 anterior lobe of pituitary gland
Zona reticularis	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



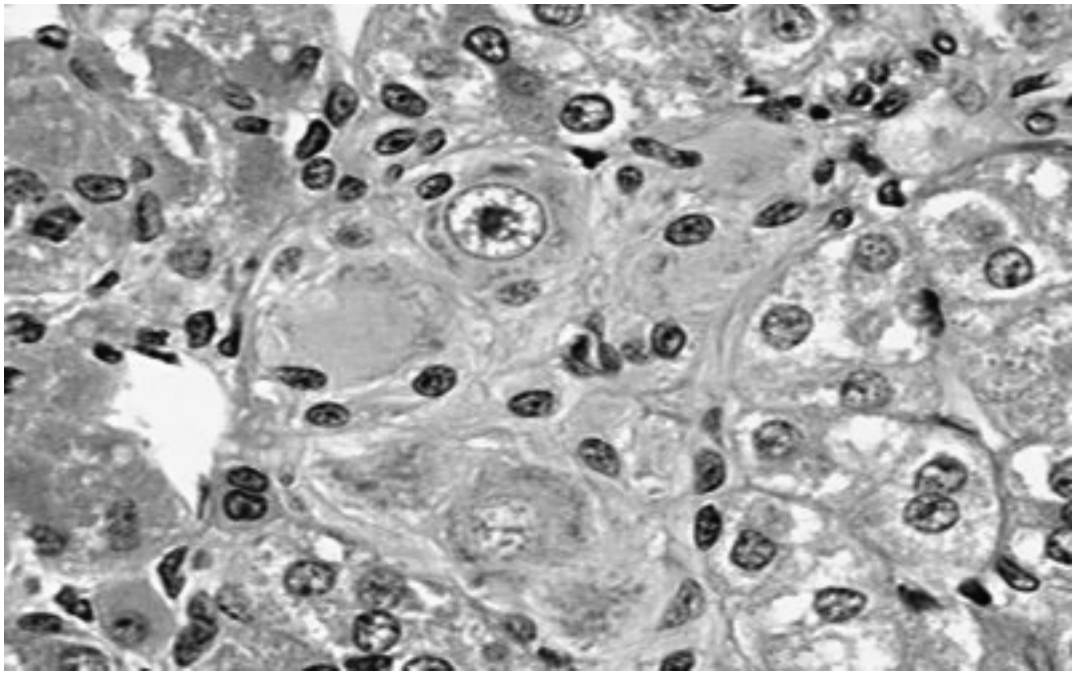
Adrenal medulla

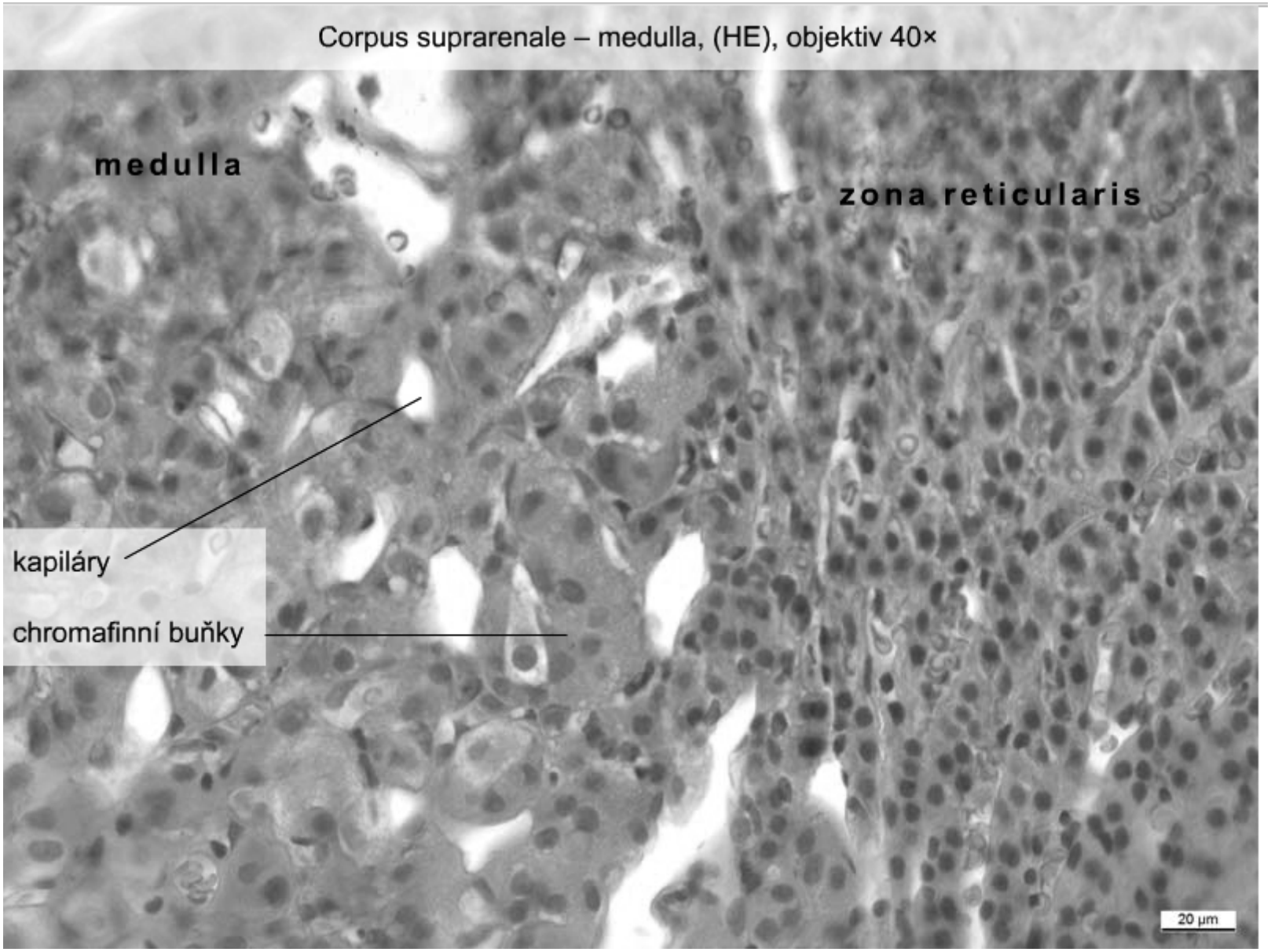
Clusters of glandular cells in reticular c.t.

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

- **adrenaline and noradrenaline**

Neural crest origin



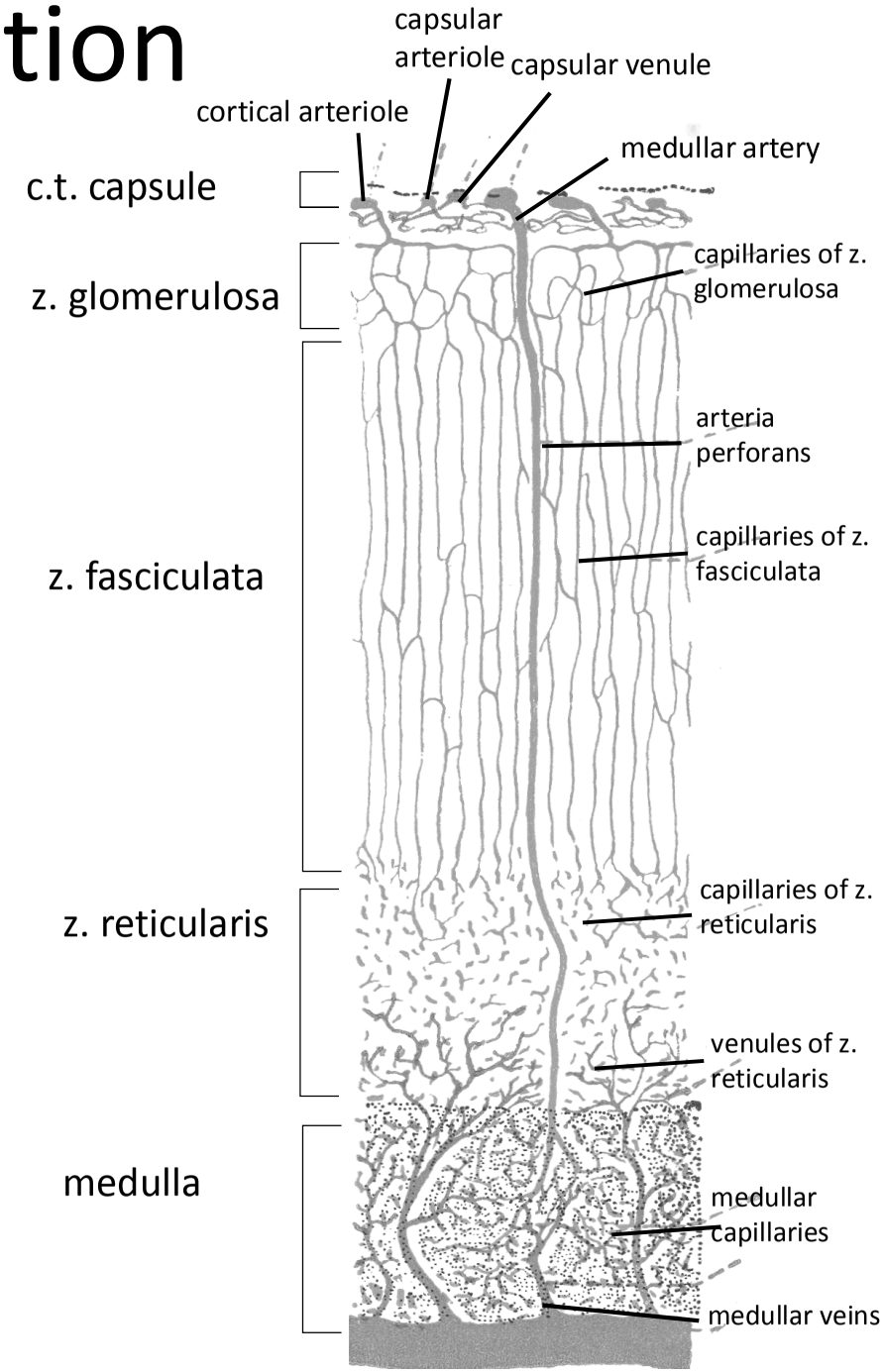

Corpus suprarenale – medulla, (HE), objektiv 40×
medulla
zona reticularis
kapiláry
chromafinní buňky
20 µm

Adrenal vascularisation

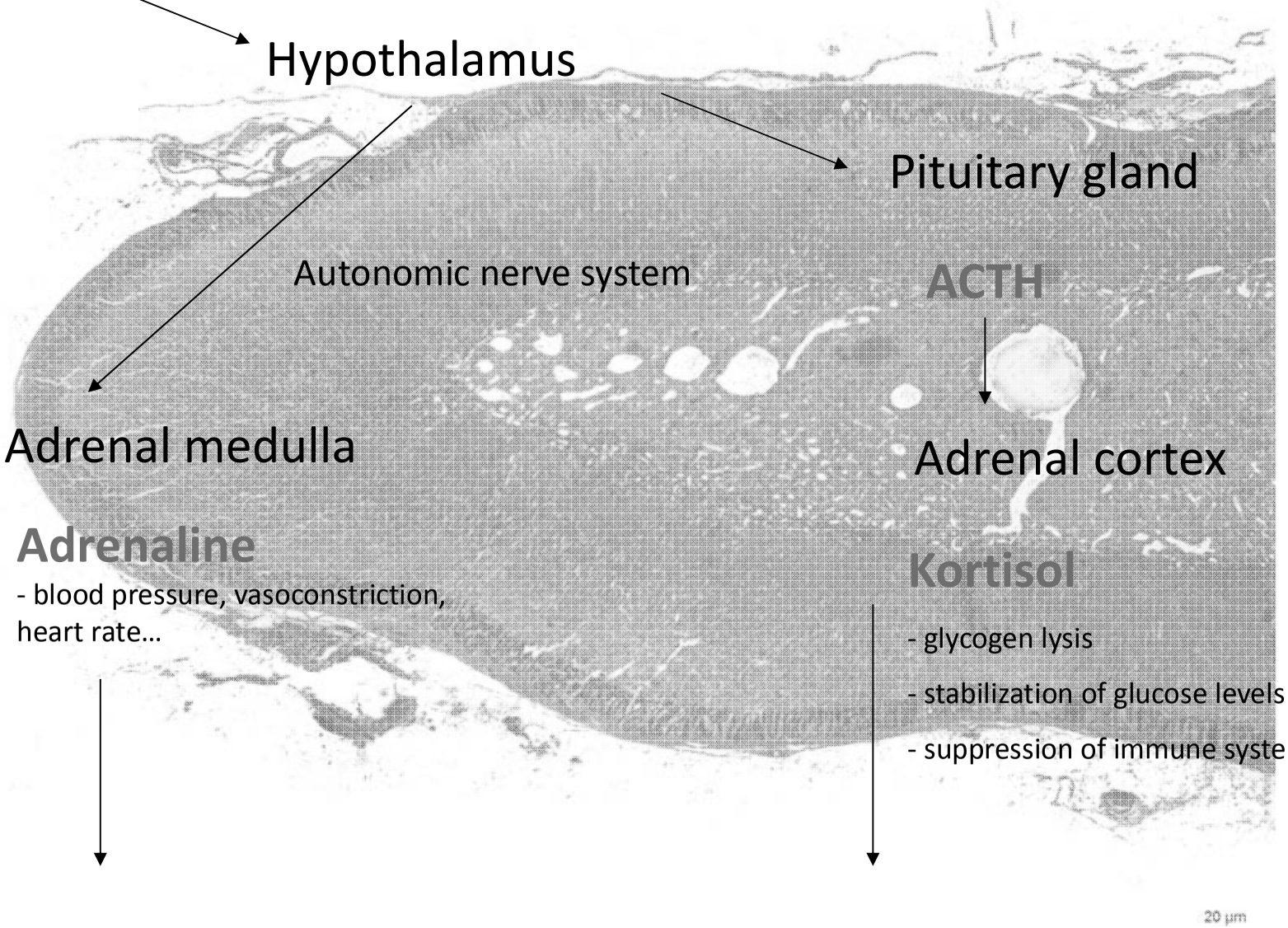
arteriae suprarenales (3) → arterial plexus in cortex under c.t. capsule → radially oriented fenestrated sinusoid capillaries continuous with medullar capillaries → medullar veins → *v. suprarenalis*

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*



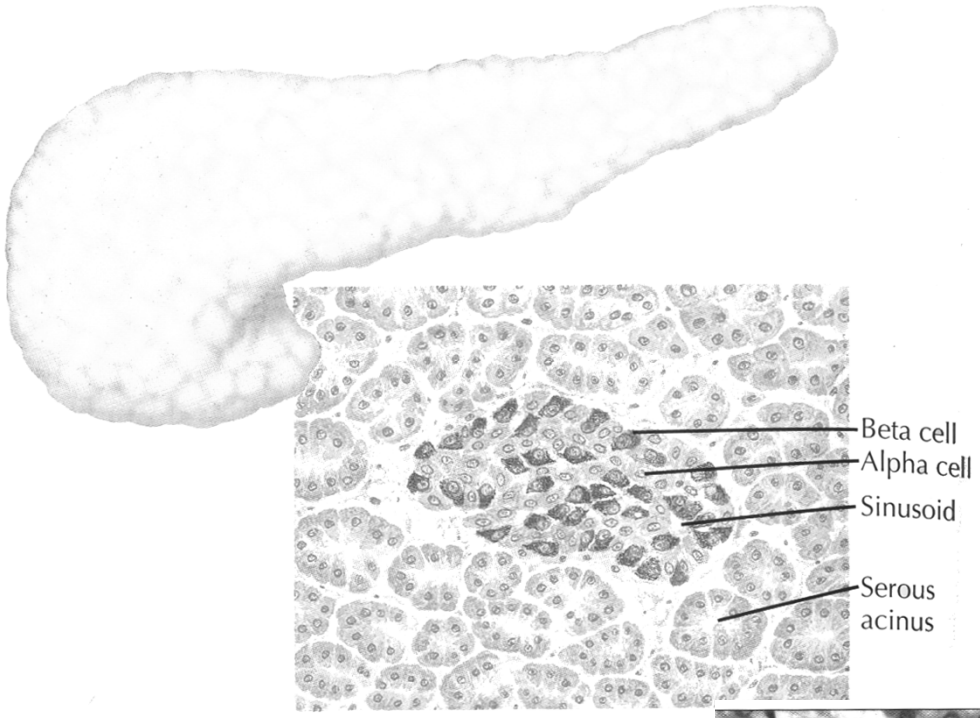
Stress

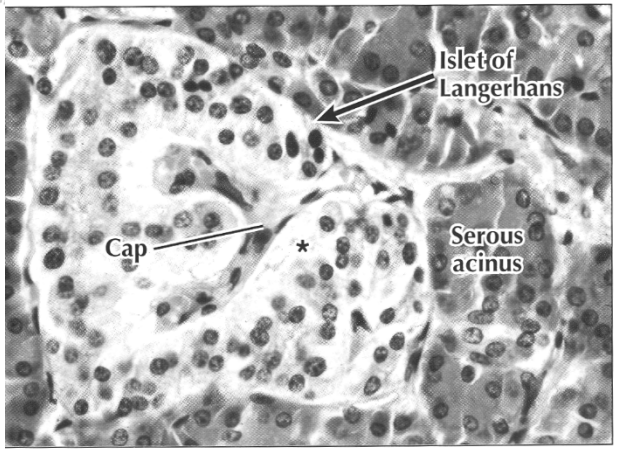


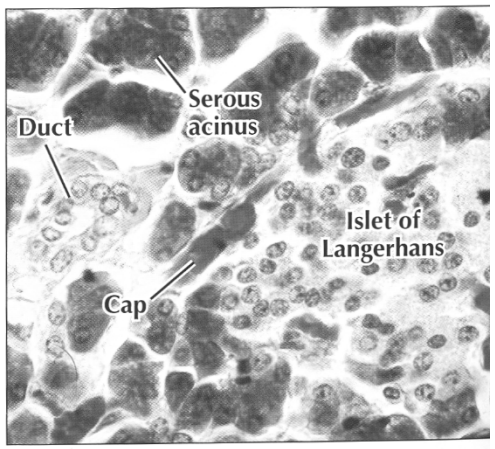
Fight or Flight

Adaptation, regeneration

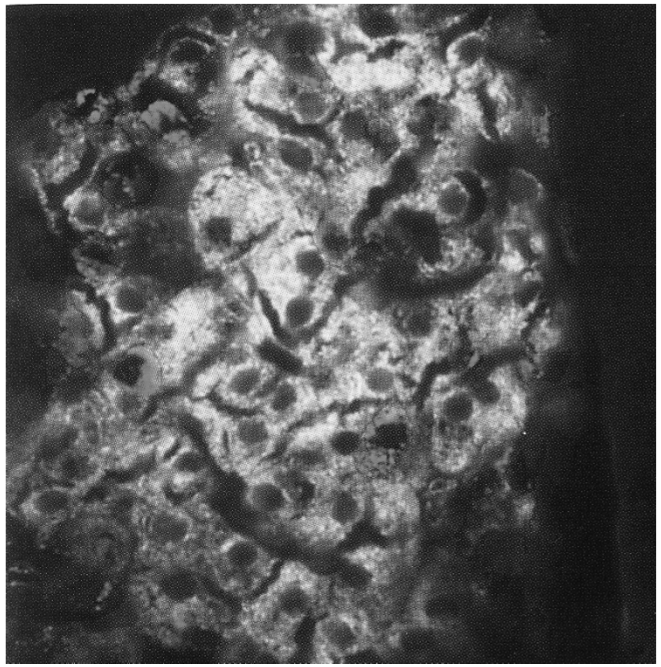
Langerhans islet of pancreas

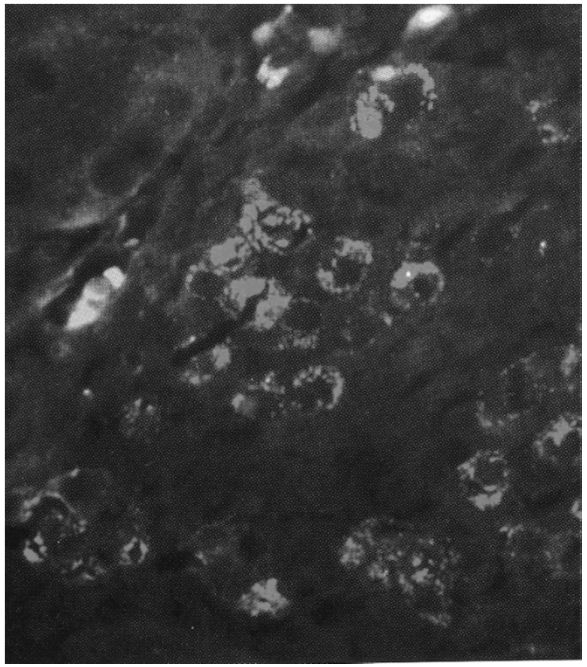






Langerhans islets of pancreas





B-cells producing insulin

Ab-anti insulin –Alexa Fluor

A-cells producing glucagon

Ab-anti glukagon –Texas Red

Thank you for attention