



# Endocrine system- system of glands

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Endo – inside

Krino – secrete



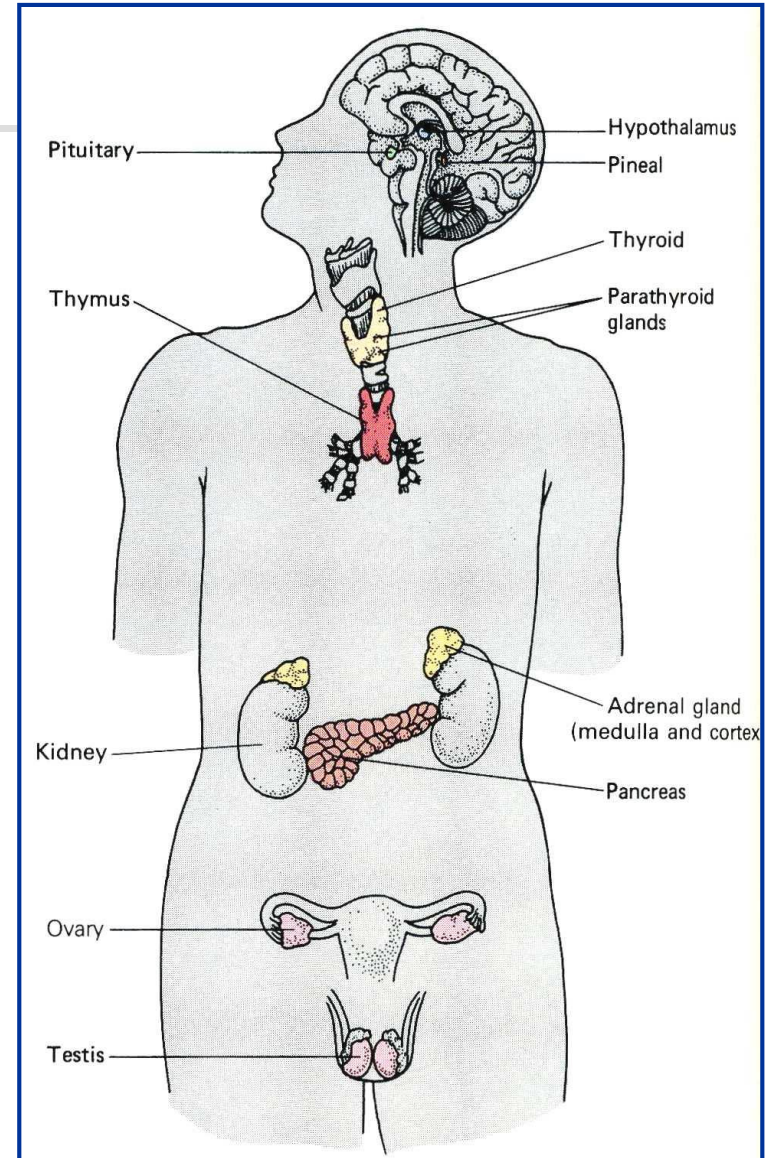
# The regulatory systems of the body

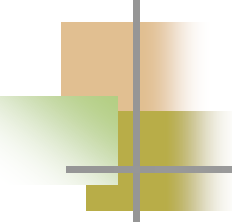
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- nervous system
- endocrine system  
(system of humoral regulation)

# The endocrine system

- endocrine glands
- groups of endocrine cells
- single endocrine cells



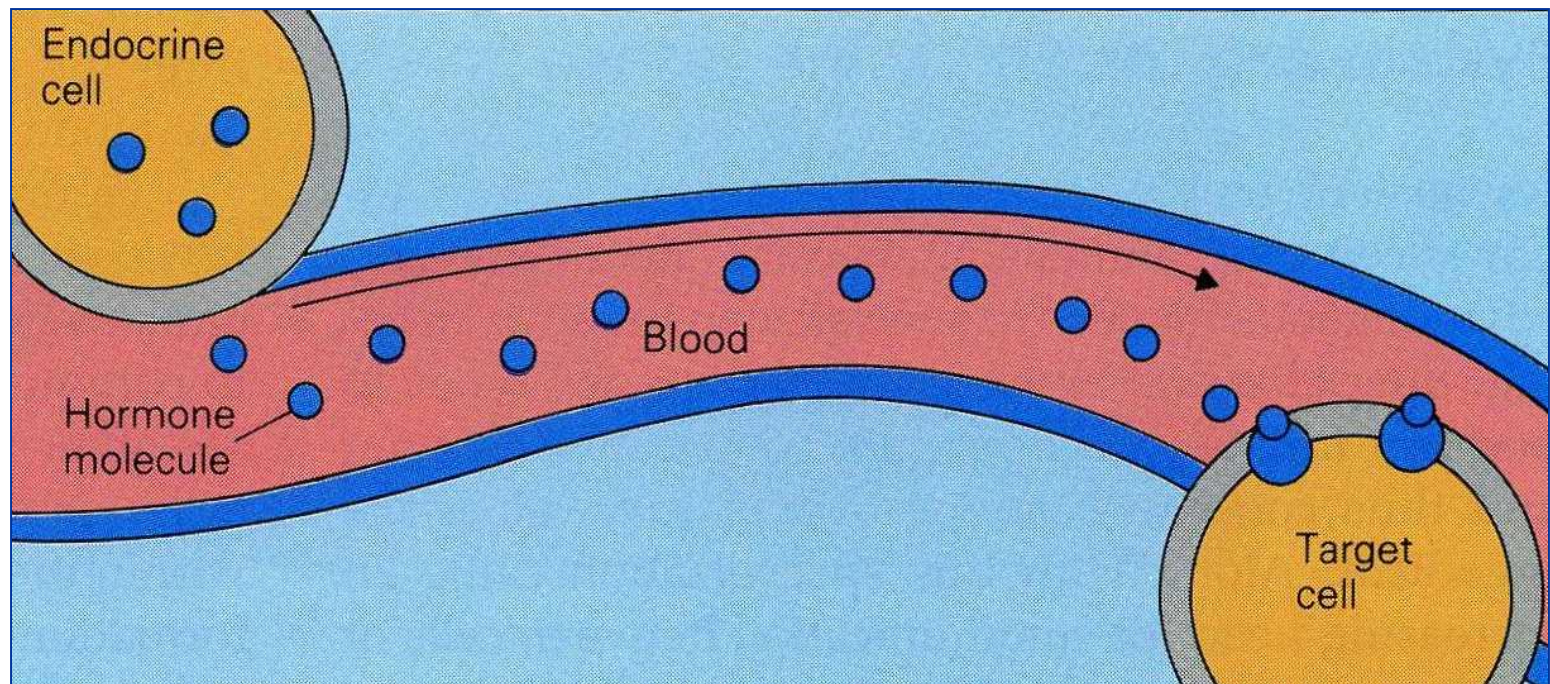
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- Glands have ducts
  - They produce **hormones**

**Hormao** (greek) – «inducing, stimulating»  
(1902 year, Starling and Bayliss)



# Hormones:

- Highly active substances
- Are secreted into the bloodstream
- Act on remotely located target organs





# Hormones can be:

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- **Water-soluble substances**

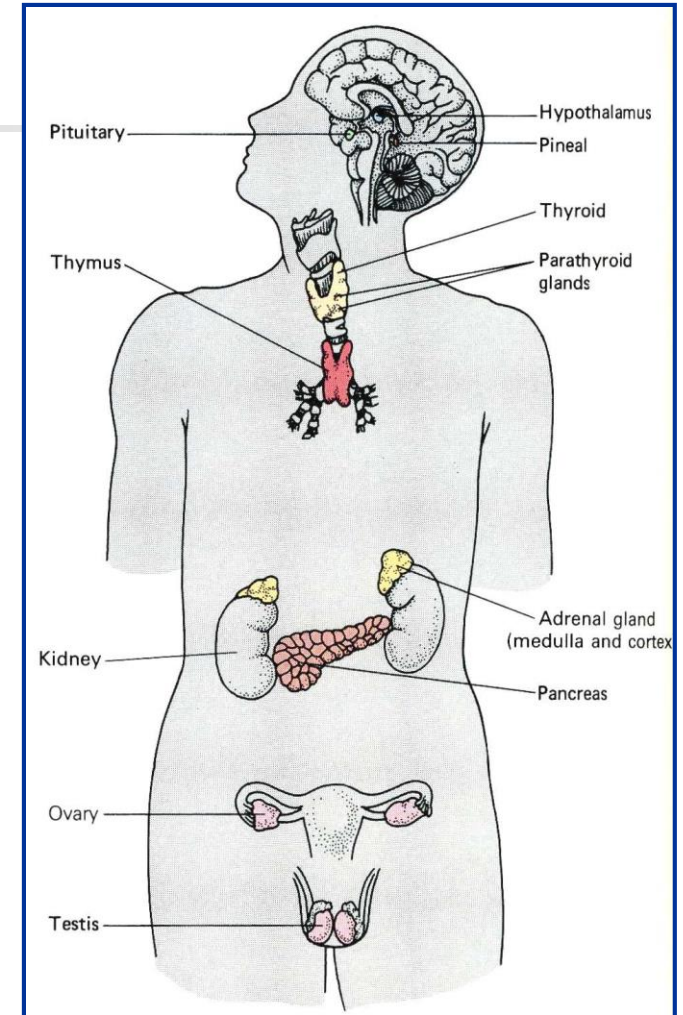
- Receptor - on the cell membrane
- The binding to the receptor → cascade of reactions → activation of certain enzymes

- **Fat-soluble substances**

- Receptor - in the cytoplasm
- The binding to the receptor → cascade of reactions → expression of certain genes

# The glands

- Hypothalamus
  - Hypophysis
    - Gonads
    - Suprarenal glands
    - Thyroid gland
- Parathyroid glands
- Pancreas
- Epiphysis
- Thymus



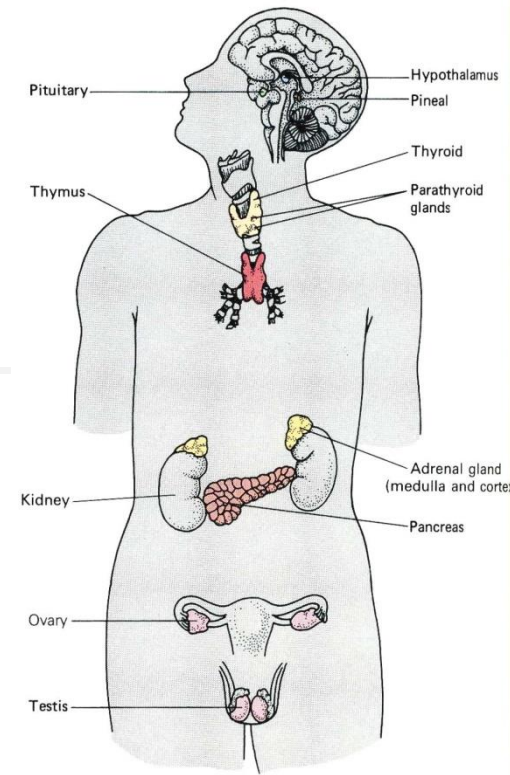


# Hypothalamus-Hypophysis-Gland system

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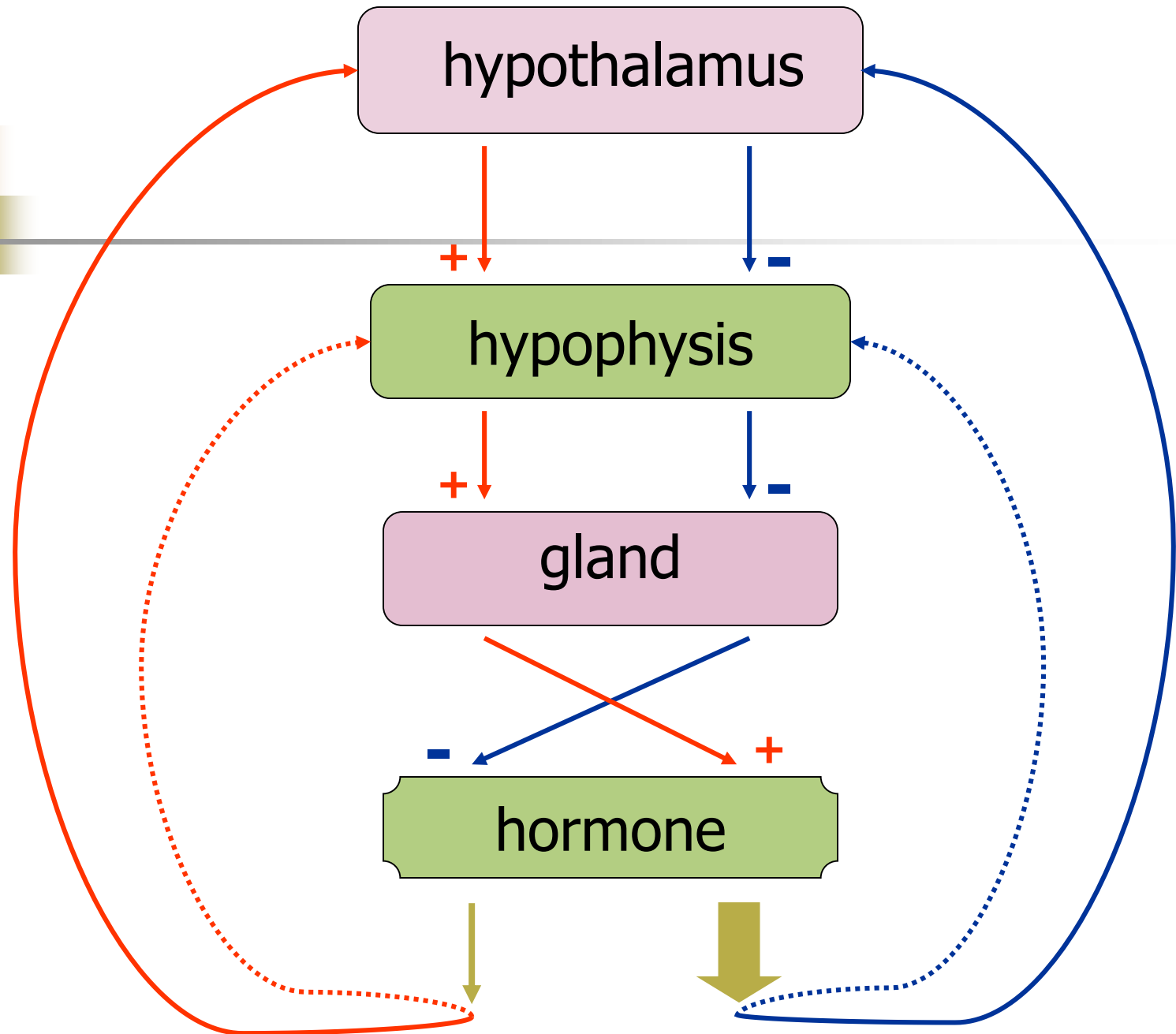
Negative feedback  
mechanism

# Hypothalamus



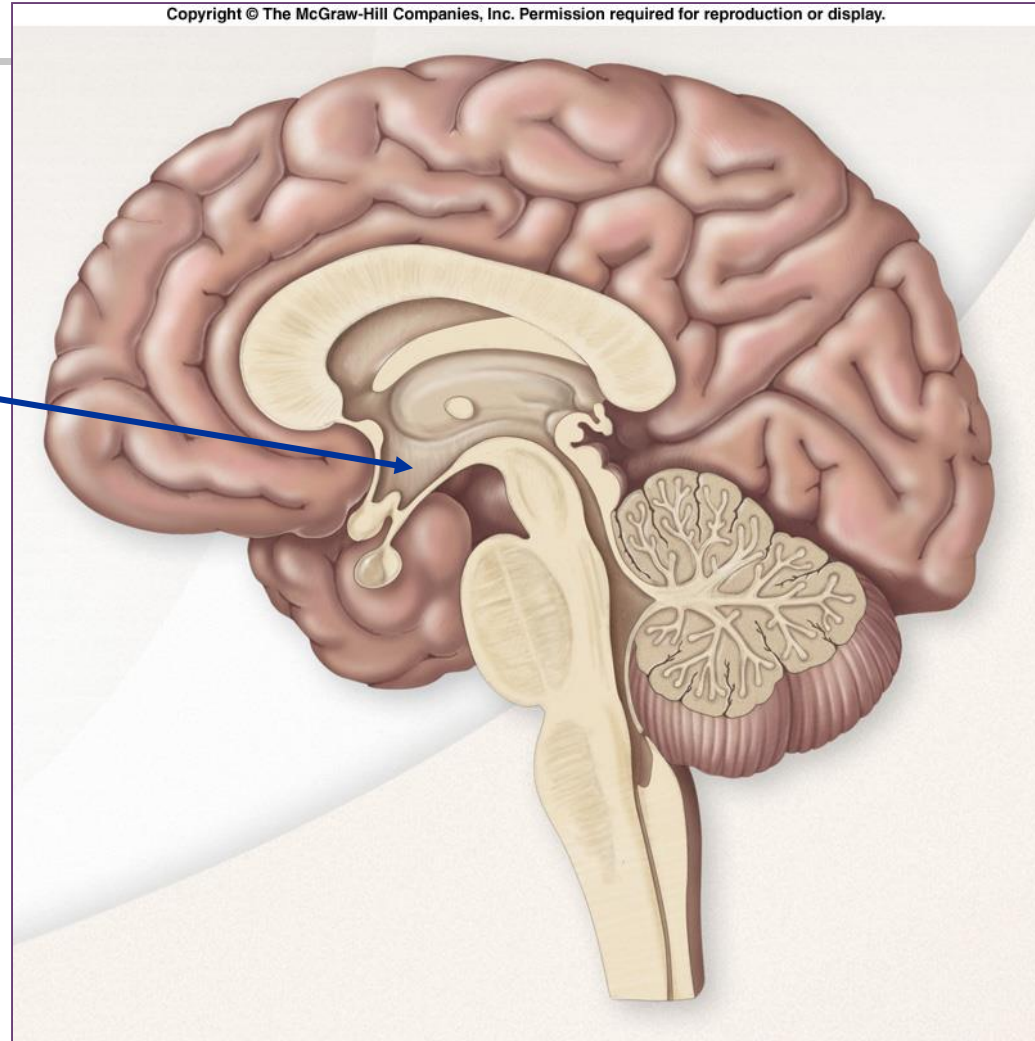
- Produces **releasing hormones** which stimulate or suppress the production of **hypophyseal (pituitary) hormones**
- **Pituitary** (tropic **hormones** ) act on the **glands** (sex, thyroid, adrenal cortex)
- Secretion of releasing hormones is regulated by blood levels of **hormones of the endocrine glands** according to **negative feedback** mechanism





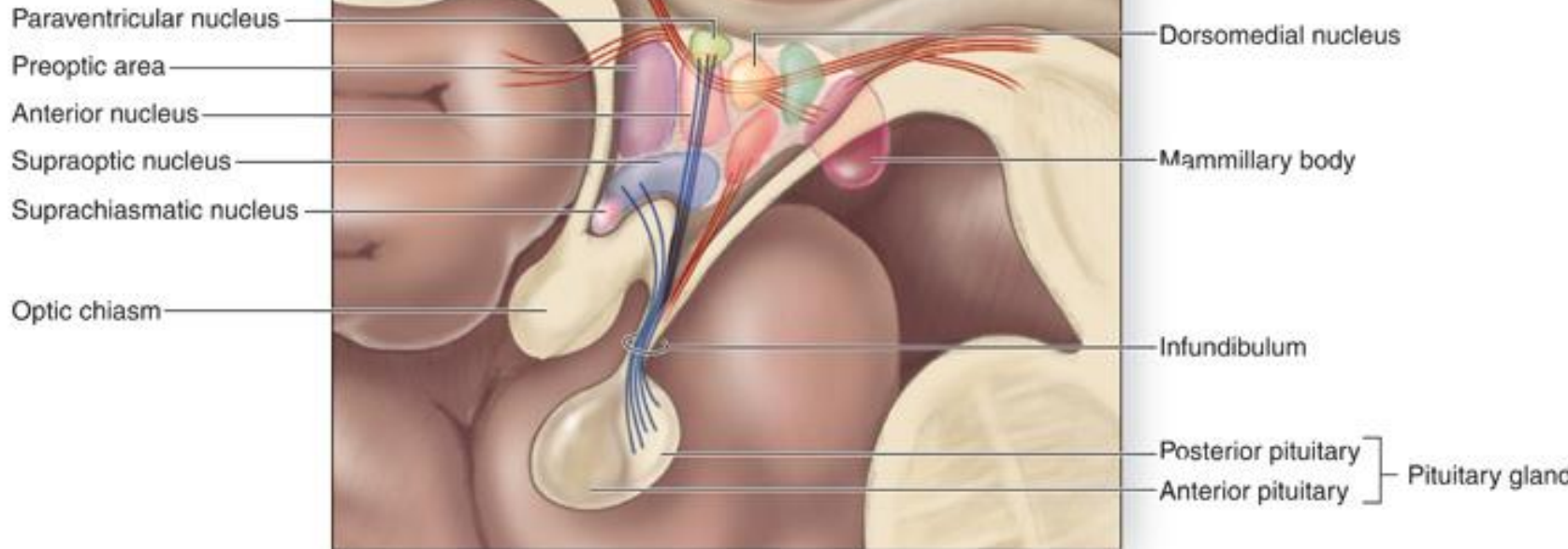
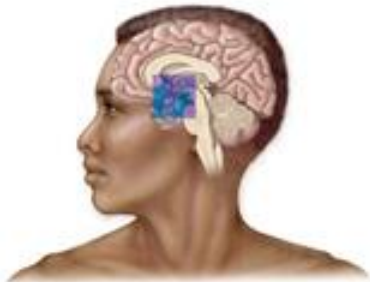
# Hypothalamus

- Part of the brain (diencephalon)
- Important center of neuro-humoral regulation



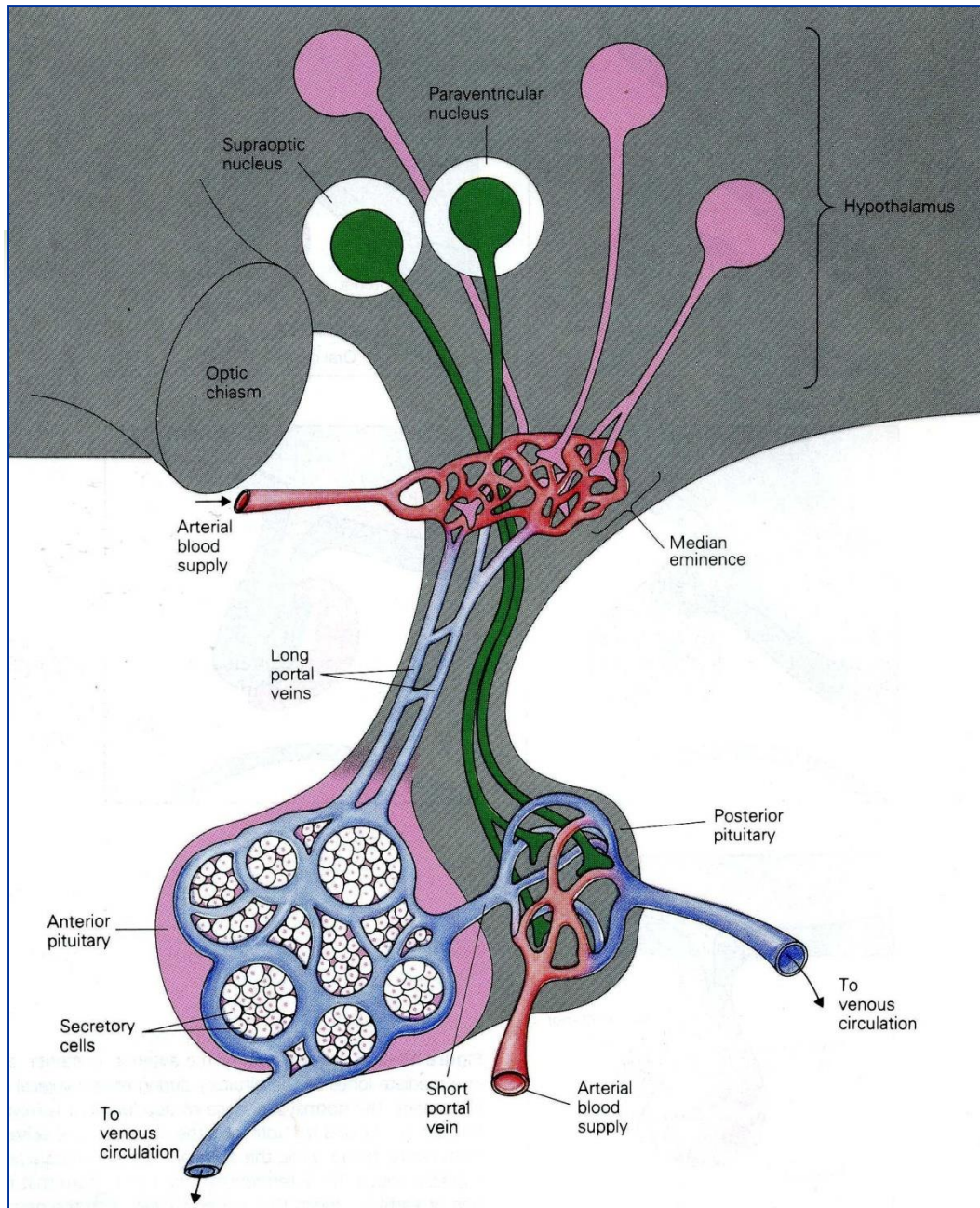
# The hypothalamus is composed of nuclei (bodies of neurons)

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Sagittal section of hypothalamus



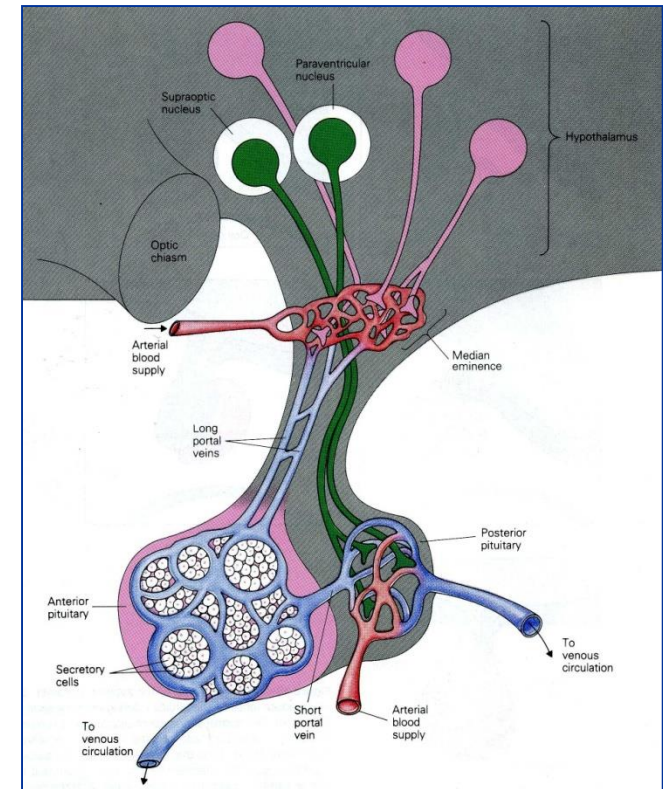


## ■ Neurons produce hormones:

- Acting (influencing) on the hypophysis
- Acting on target organs

# Hormones acting on the hypophysis (releasing hormones)

- Get to the hypophysis through the bloodstream
- Are divided into:
  - Stimulatory (liberins)
  - Inhibitory (statins)



# Stimulatory

# Inhibitory

- **Thyroliberin-**

TSH secretion

- **Corticoliberin-**

secretion of ACTH

- **Gonadoliberin-**

secretion of FSH, LH

- **Somatoliberin-**

secretion of somatotrophic hormone

- **Prolactoliberin-**

prolactin secretion

- **Somatostatin –**

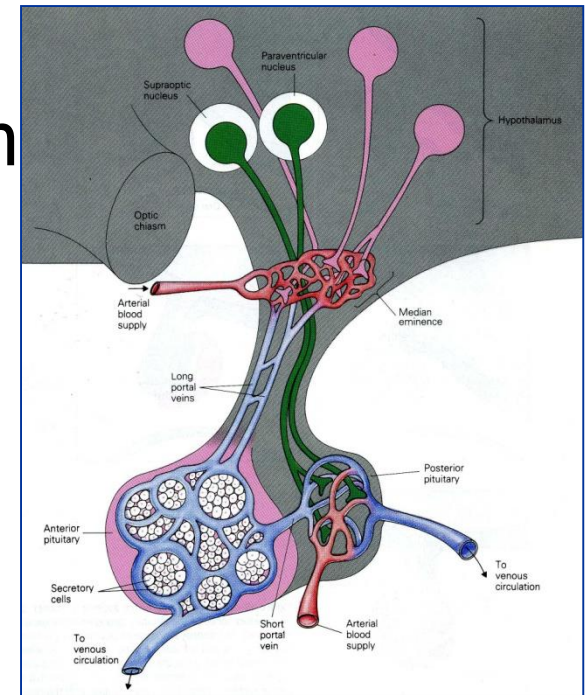
secretion of somatotrophic hormone

- **Prolactostatin–**

prolactin secretion

# Hormones acting on target organs

- Are produced by **supraoptic** and **paraventricular** nuclei of the hypothalamus
- Are stored in the hypophysis (get there via axons )
- Are secreted into the bloodstream from the hypophysis:
  - **Vasopressin (ADH)**
  - **Oxytocin**

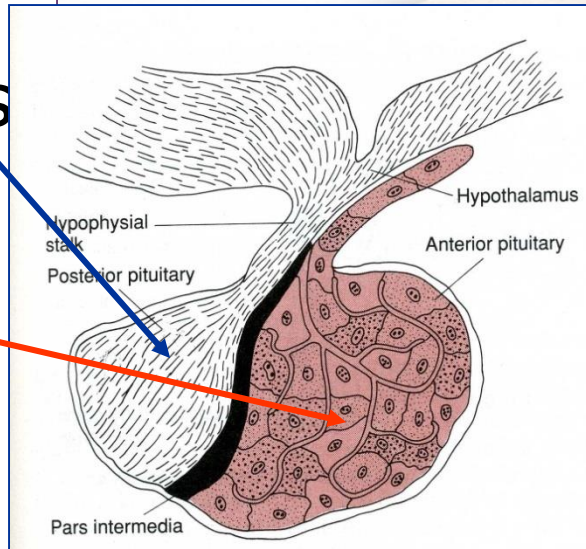
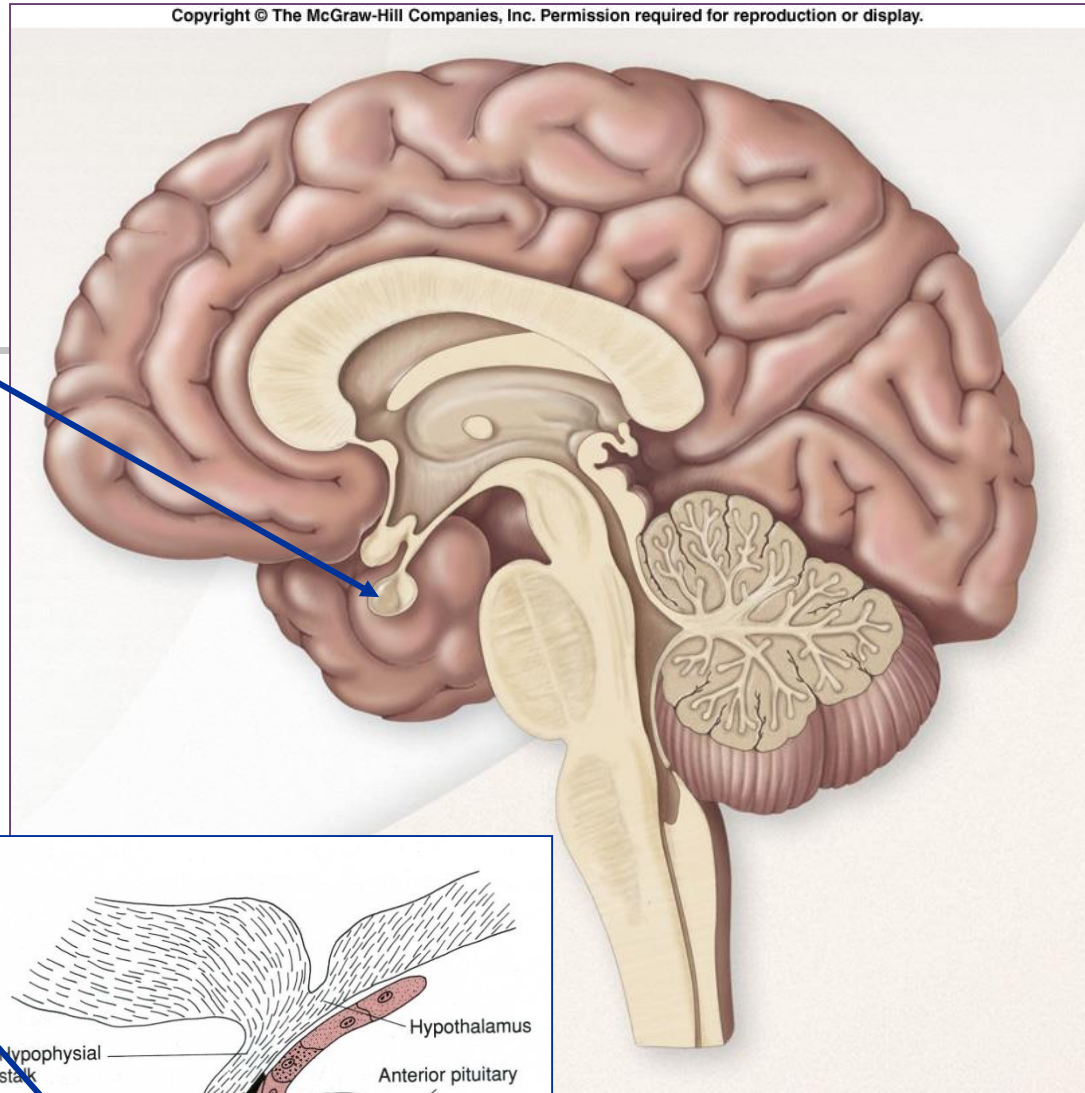




# Hypophysis (pituitary gland)

- Develops from two sources:

- Diencephalon -  
neurohypophysis
- Pharynx (Rathke's  
pouch)-  
adenohypophysis



# Neurohypophysis



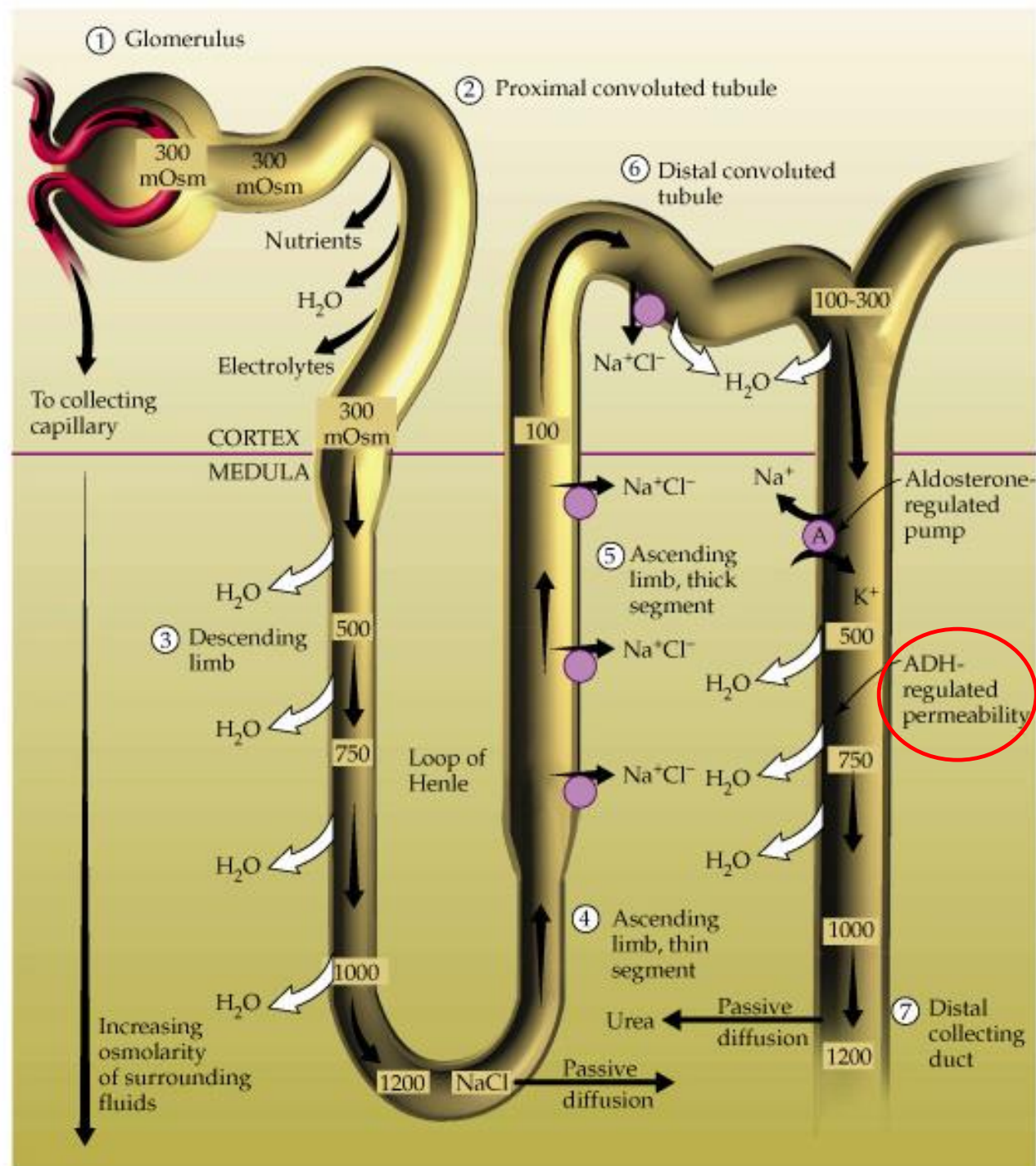
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- Stores and secretes two hormones of the hypothalamus:
  - Vasopressin (ADH)
  - Oxytocin

# Vasopressin

- Increases the reabsorption of water in the collecting ducts (water retention → increase of circulating blood volume and blood pressure)

- Increases the vascular SMC (increase of BP)





# Oxytocin

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- Increases uterus SMC (orgasm, menstruation, childbirth)
- Increases SMC of ducts of mammary glands (Milk allocation at feeding)





# Oxytocin

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- Maternal behavior
- Marital behavior
- Love, empathy, compassion, kindness, altruism, the ability to communication

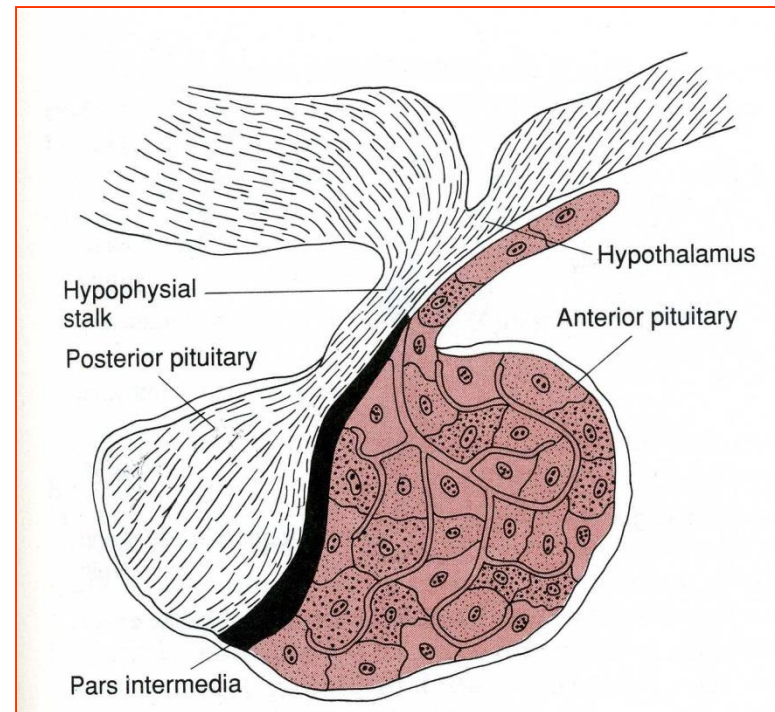
# Adenohypophysis

- Produces hormones that act on:

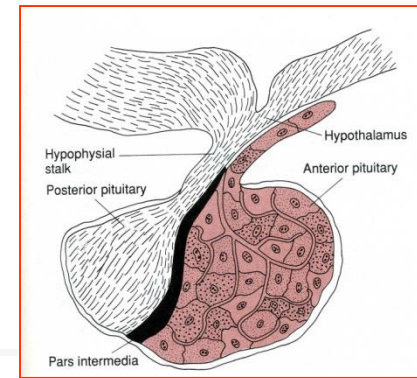
- endocrine glands  
(tropic hormones)
- target cells

- Parts of the adenohypophysis:

- The intermediate part
- Anterior part



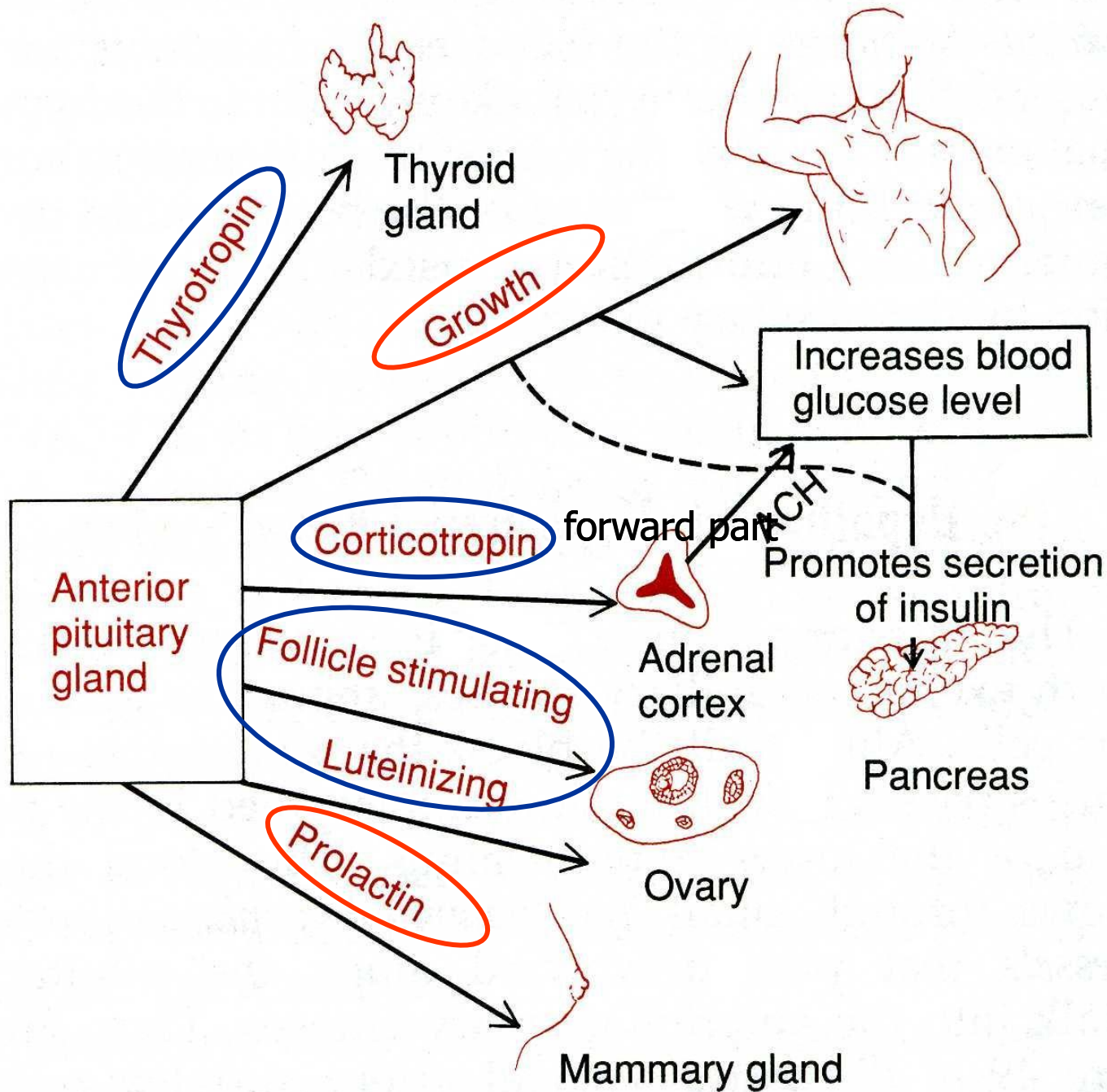
# The intermediate part



## ■ Melanocyte-stimulating hormone

- Stimulates synthesis and secretion of melanin by melanocytes of the skin, hair, eyes





**Forward part**



# The Hypothalamo - Pituitary Axis

## Brain Influence

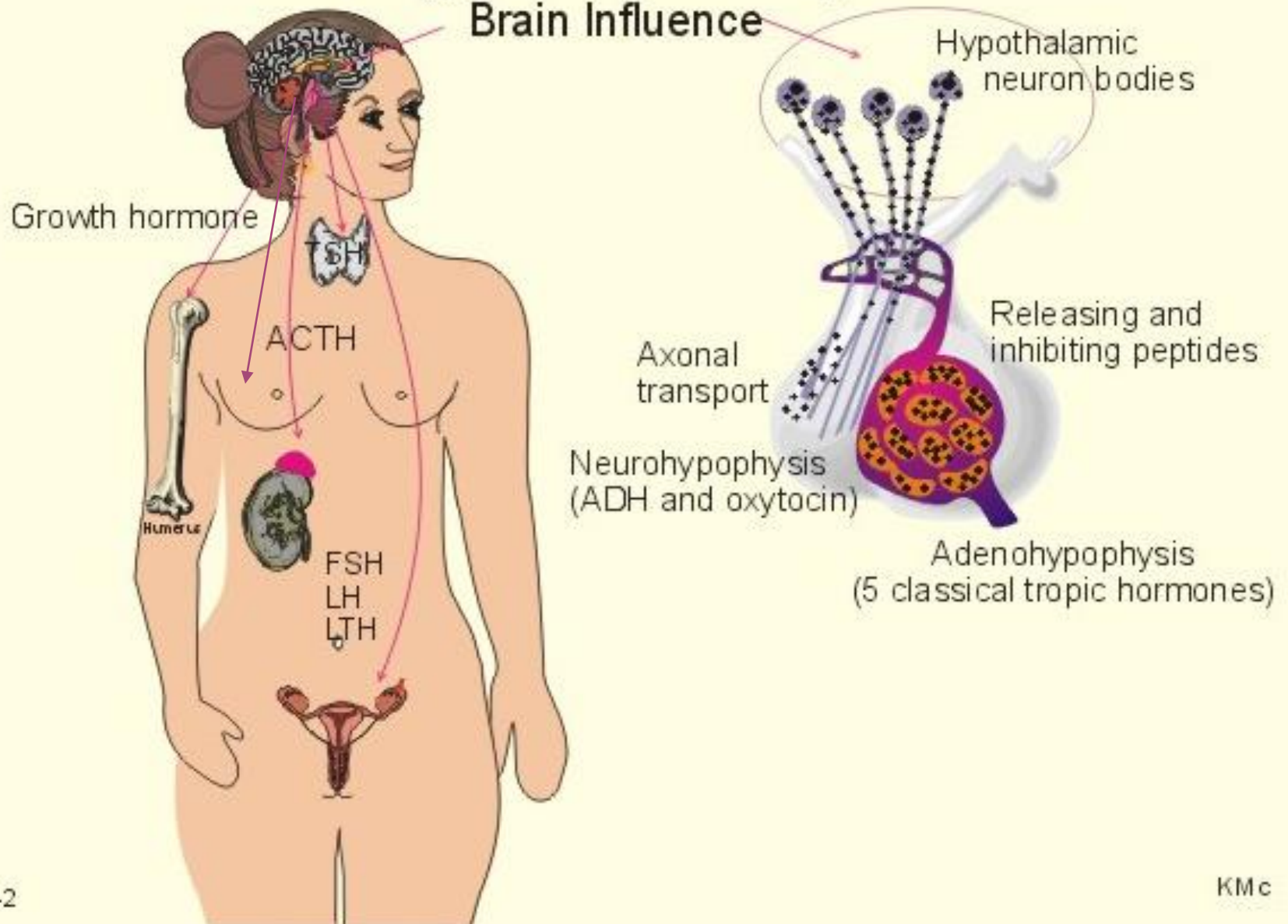


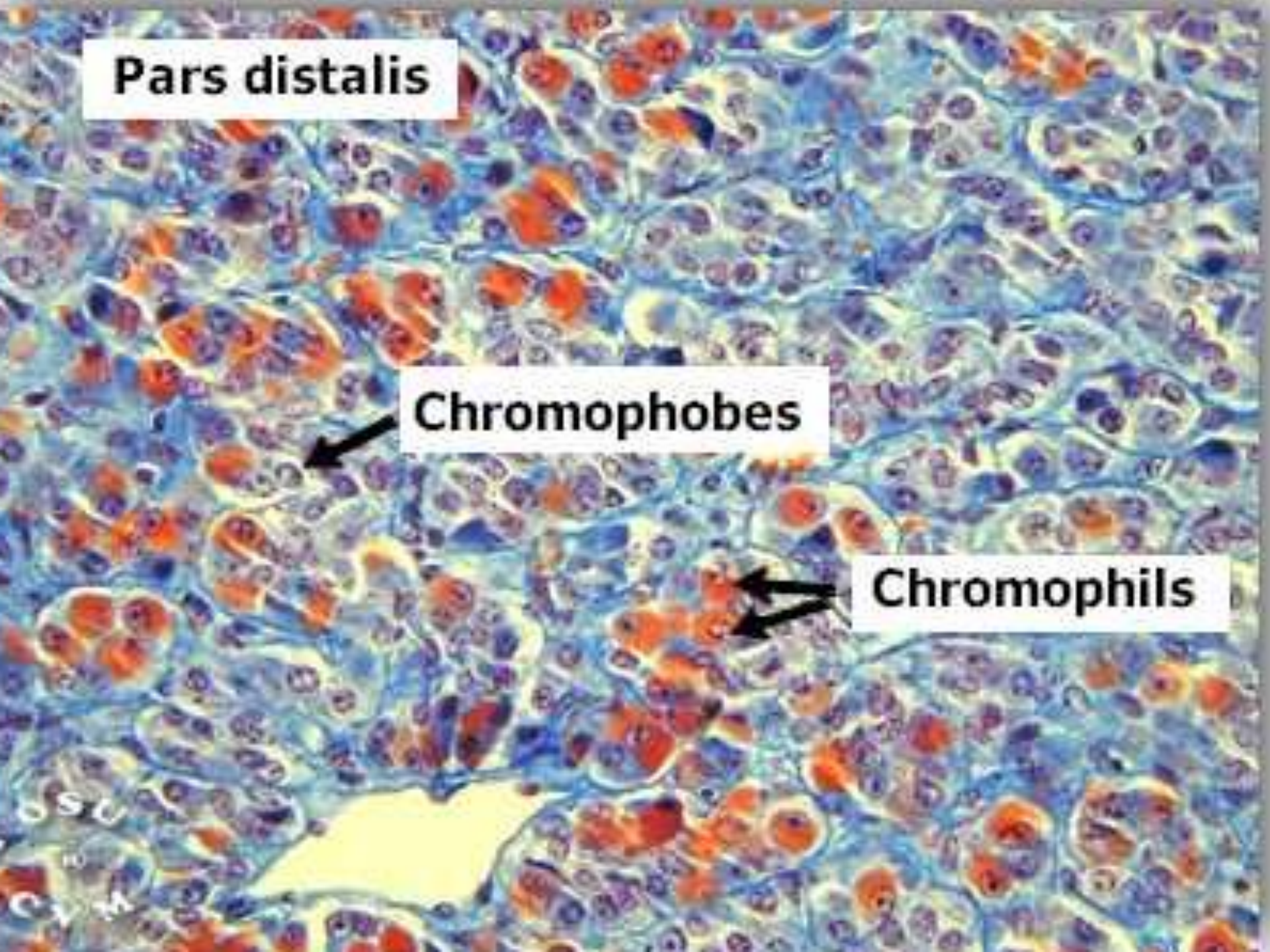
Fig. 26-2



**Pars distalis**

**Chromophobes**

**Chromophils**





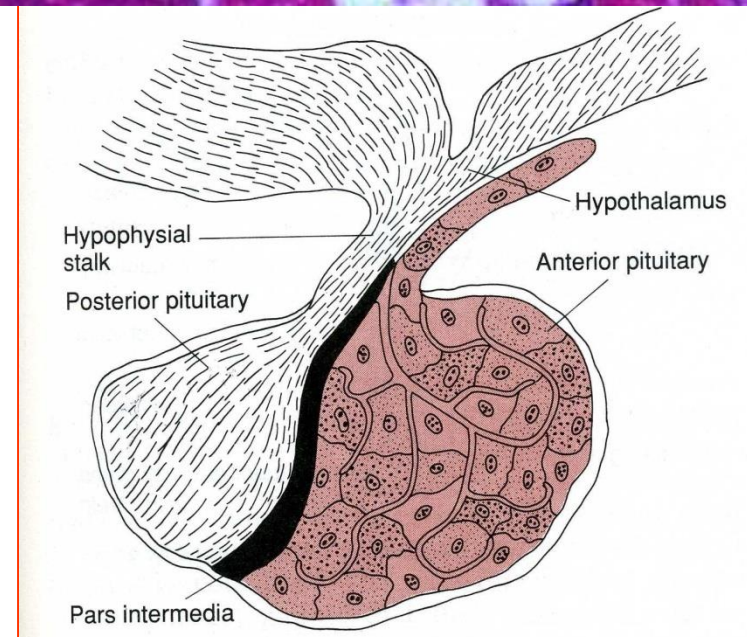
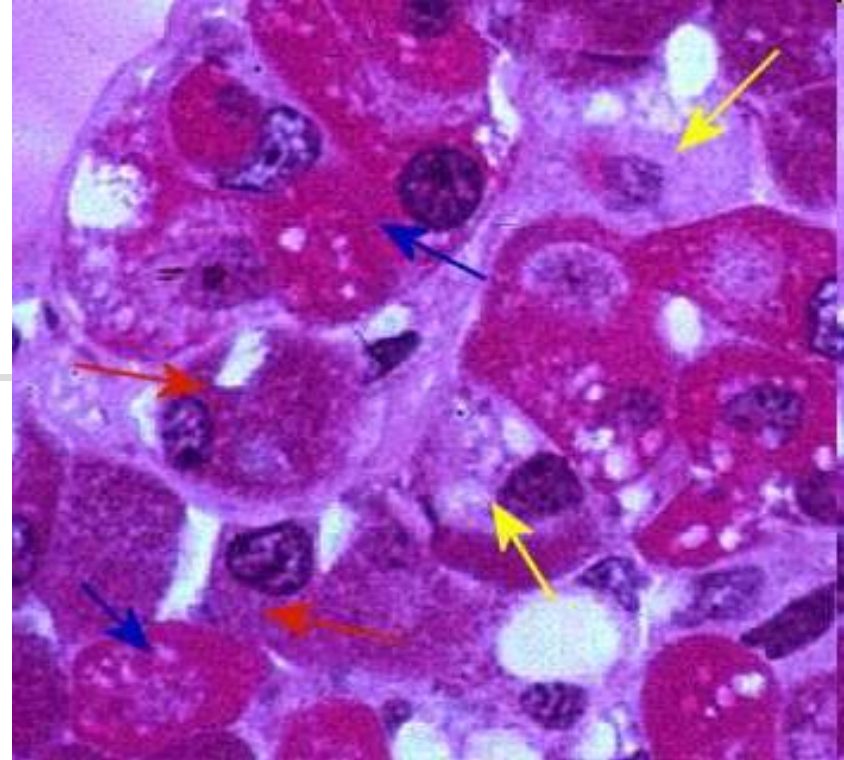
# Anterior part

- **Acidophiles**

- STH (somatotropic)
- Prolactin (lactotropic)

- **Basophils**

- FSH and LH (gonadotropic)
- TSH (thyreotropic)
- ACTH (kortikotropic)





# Somatotropic hormone

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- Enhances cell division and growth:
  - Enhances the synthesis of protein
  - Uses fatty acids as an energy source
  - Stores glucose as glycogen
- Increases the proliferative activity of cells in the growth zone of long bones and bone mineralization

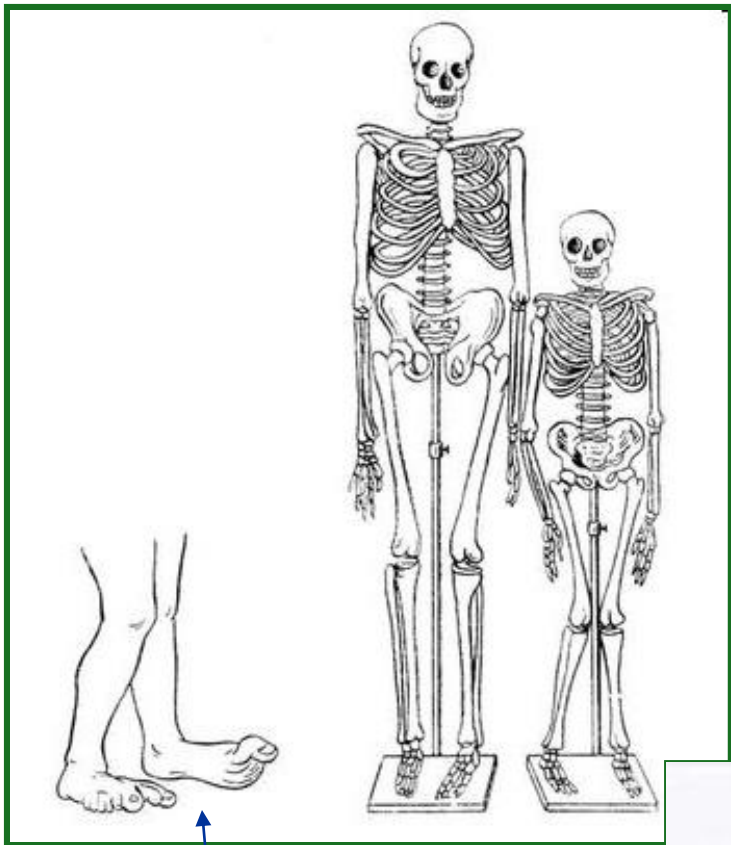


# Disturbances of somatotropic hormone secretion



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- **Increased production:**
  - in children - gigantism
  - in adults - acromegaly
- **Decrease in production** - pituitary dwarfism (nanism)



acromegaly



286 cm, 200 kg

**The girl of 15 years**

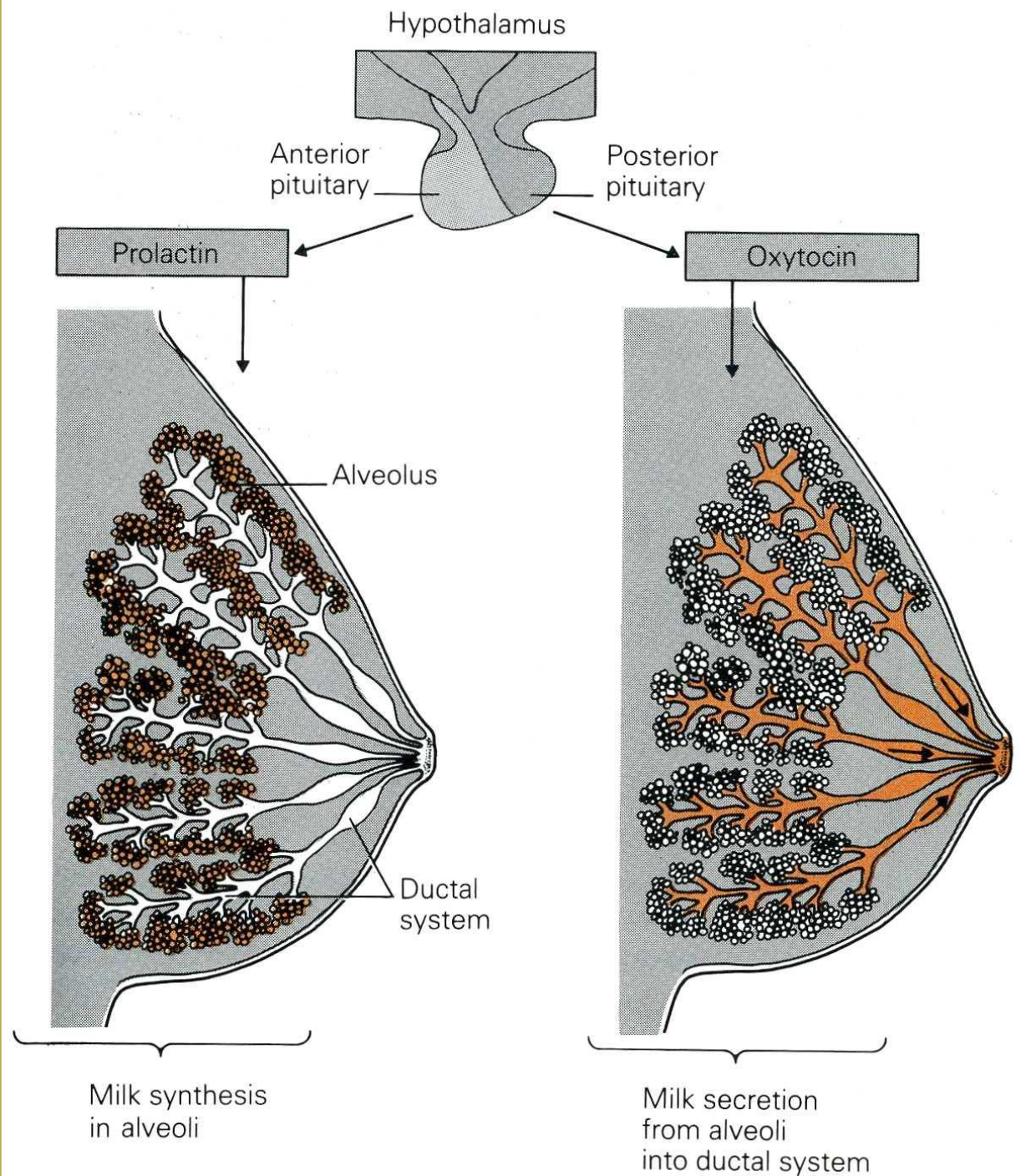




# Prolactin

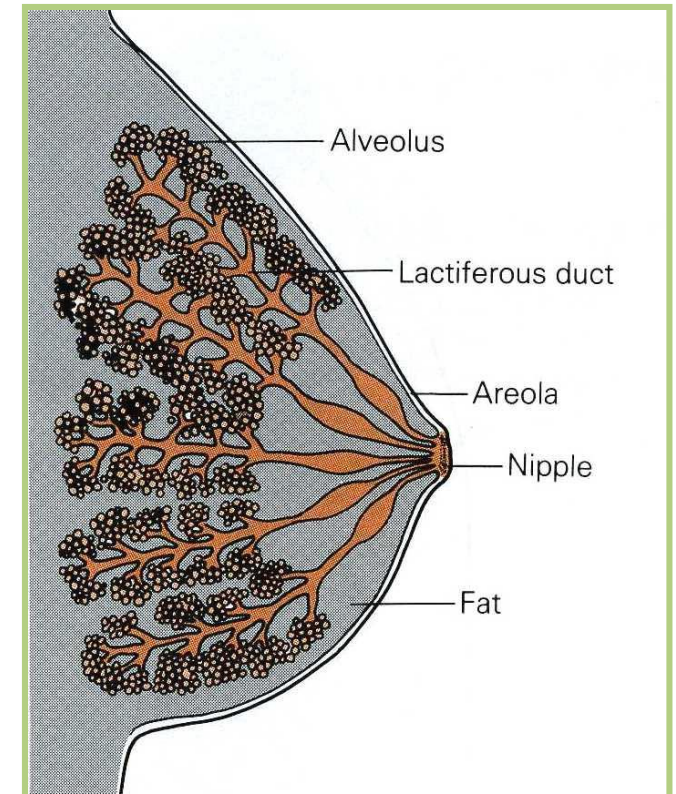
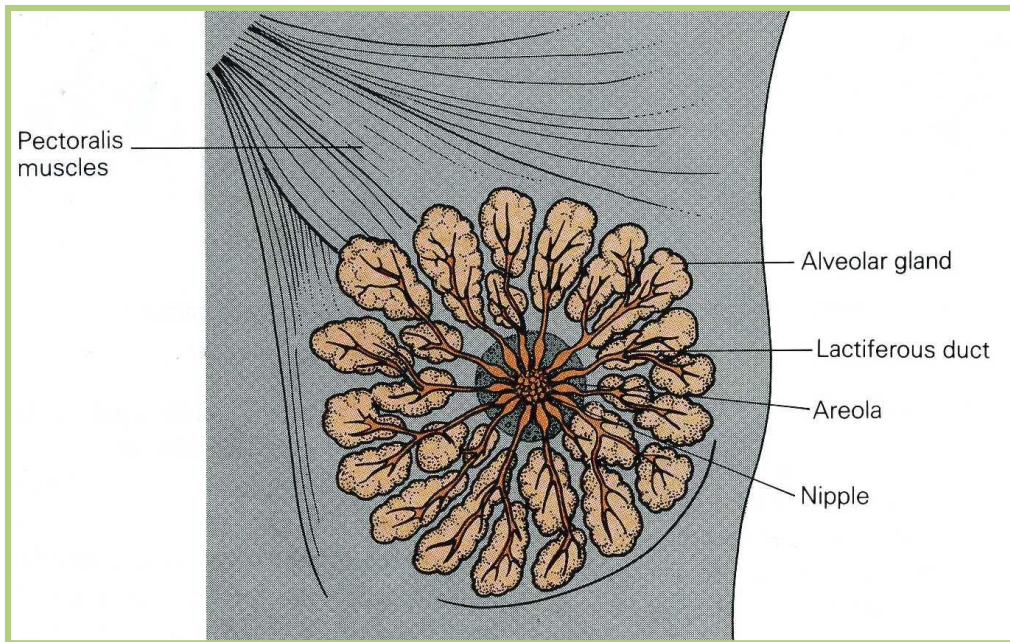


- Stimulates **milk secretion** by cells of the mammary gland



# The mammary glands

- Complicated alveolar-tubular glands
- Derivatives of the sweat glands





# Development of mammary glands

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- **Estrogens** - growth of the stroma and ducts, fat deposition
- **Progesterone** - development of the lobules and alveoles
- The main growth - during pregnancy (all hormones)



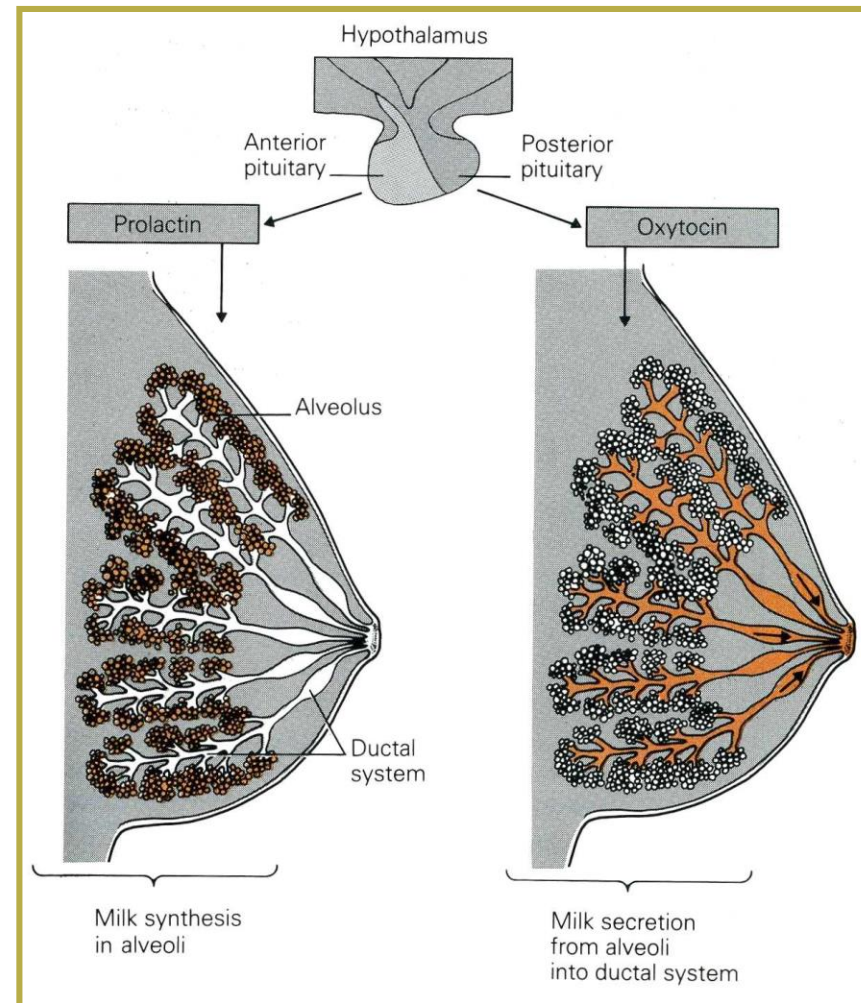
# Prolactin

- During pregnancy, prolactin effect is suppressed by estrogens and progesterone – every day is allocated a few ml of colostrum
- After delivery, levels of estrogens and progesterone decreases sharply and lactation begins

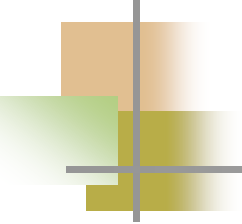


# Oxytocin

- Hypothalamic hormone
- Causes a increase in alveolar SMC of the mammary gland and milk excretion into the ducts
- Oxytocin is stimulated by applying a baby to the mammary gland





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- 
- A few weeks after delivery prolactin level falls to normal
  - Each latch baby to mammary glands increases the level of prolactin and oxytocin for 10-20 times, providing milk for the next feeding



Hormone levels (arbitrary units)

Estrogen

Progesterone

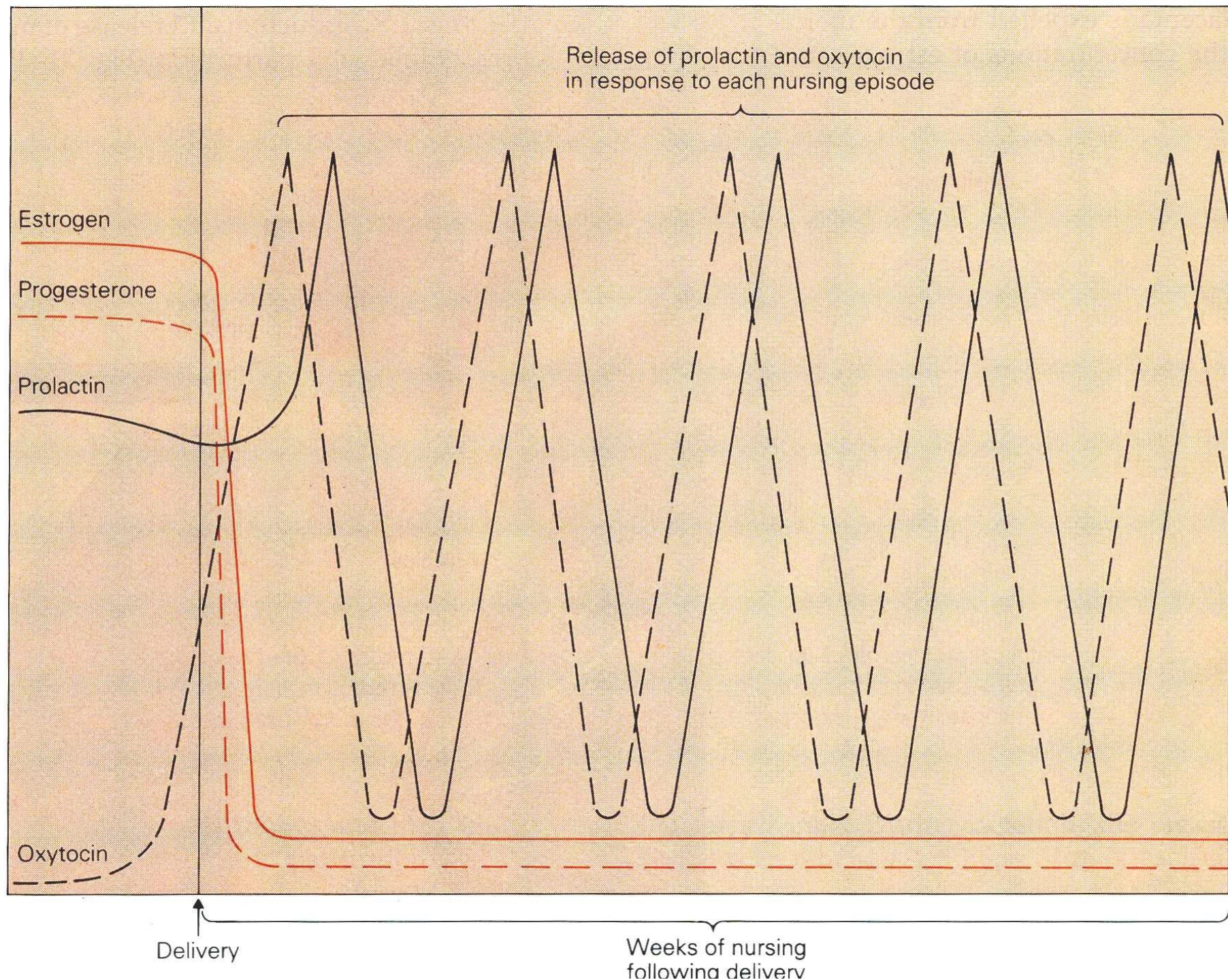
Prolactin

Oxytocin

Release of prolactin and oxytocin  
in response to each nursing episode

Delivery

Weeks of nursing  
following delivery









# FSH – Follicle Stimulating Hormone

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- **In females** is responsible for cyclic changes on ovaries
- **In males** is responsible for spermatogenesis (stimulates cells of Sertoli inducing the production of ABP (androgen-binding protein), inhibin and activin)





# LH- Luteinising Hormone

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- **In females:**
  - Induces ovulation
  - Takes part in transformation of follicle cells into the cells of corpus luteum
- **In males** stimulates Leydig cells inducing testosterone production



# Female reproductive glands

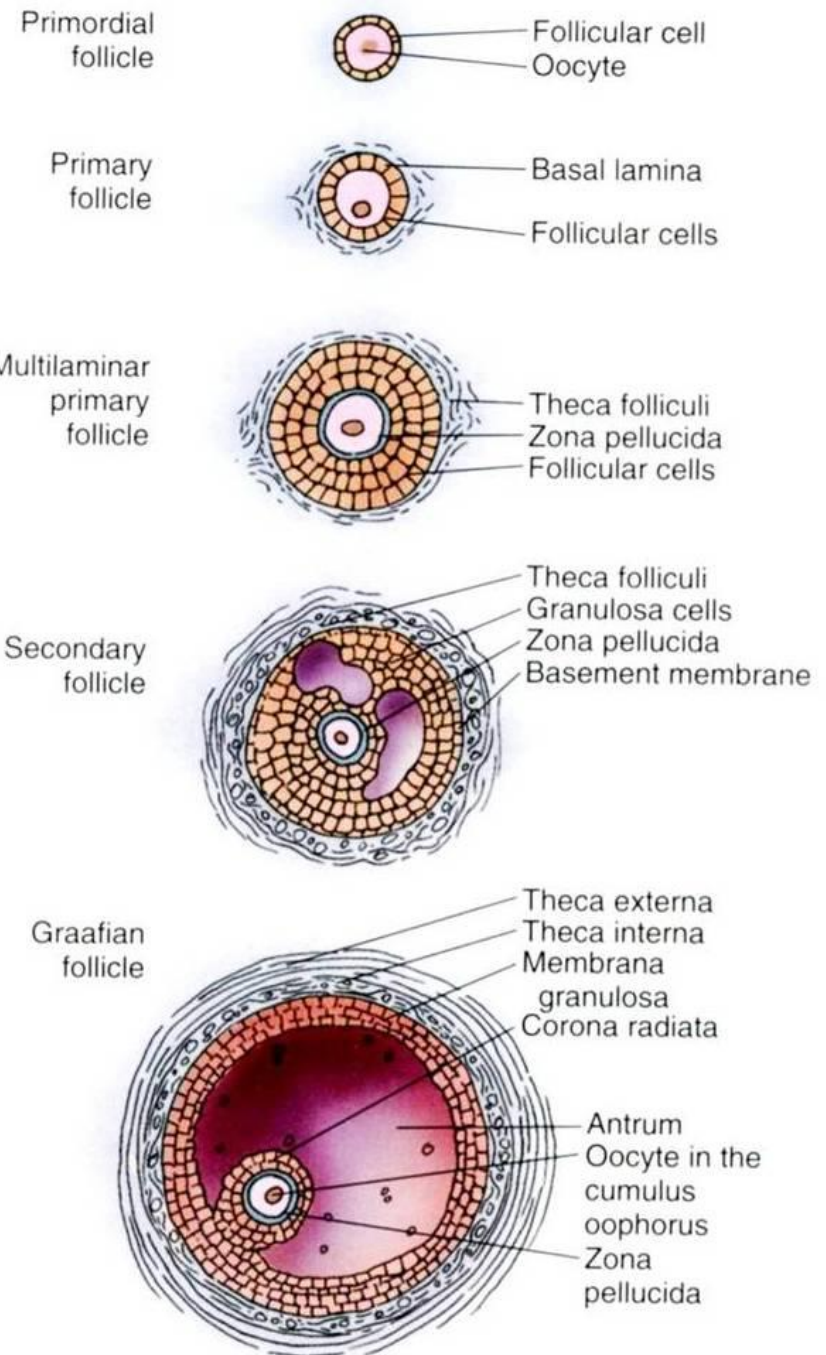
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- Exocrine function – ova
- Endocrine function – female sex hormones

# Ovarian hormones

## ■ Estrogens

## ■ Progesteron





# Estrogens

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- Growth of sex organs
- Maturation of uterine and vaginal mucosa
- Growth of mammary glands (growth of ducts and stroma, accumulation of fat)
- Growth of bones in length, however, fast “closing” of growth zones
- Female type of fat accumulation
- Development of skin blood vessels (increased bleeding in case of superficial cuts)





# Progesterone

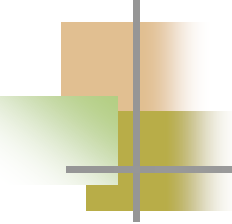
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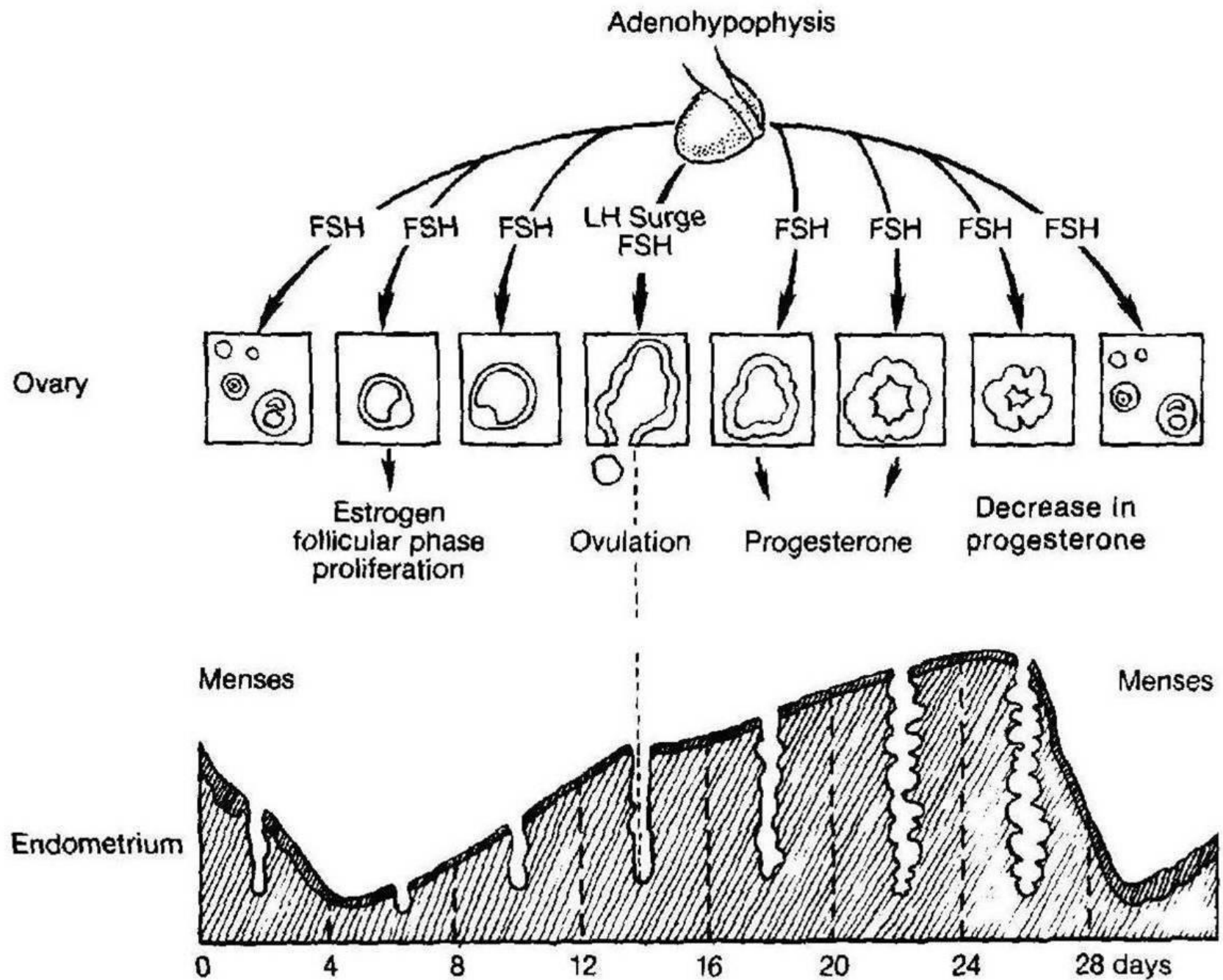
- Stimulates uterine glands secretion
- Prepares endometrium for implantation of fetus
- Stimulates development of secretory parts (lobules and alveoles) of mammary glands (without secretion)



# Ovarial-Menstrual Cycle

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- 
- 
- **Ovarial cycle** – cyclic changes in the ovary
  - **Menstrual cycle** – cyclic changes in the uterus







# Follicular phase (1-14 days of cycle)

- Hypothalamus – gonadoliberin



- Hypophysis – FSH

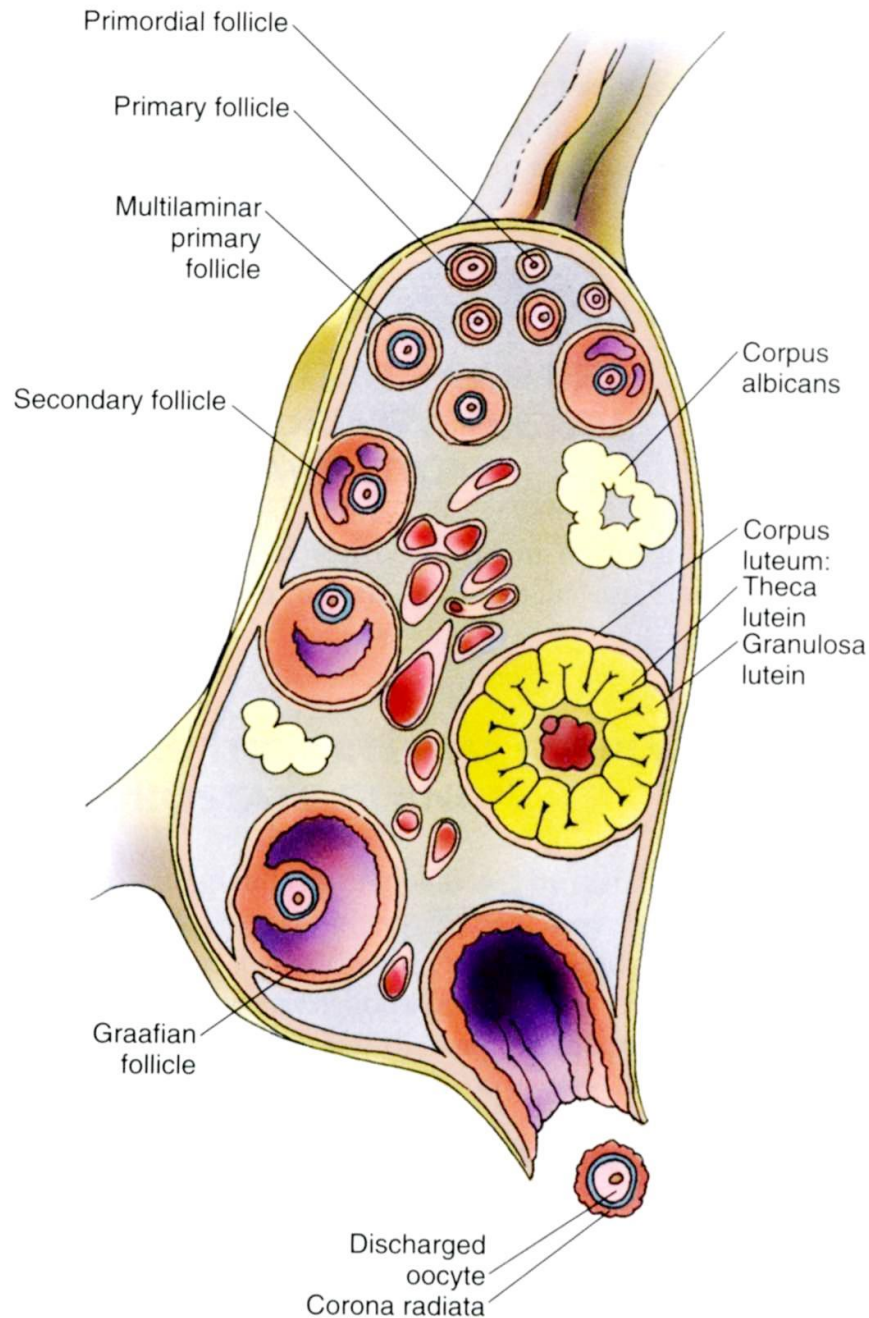


- Follicular cells of ovary



estrogens:

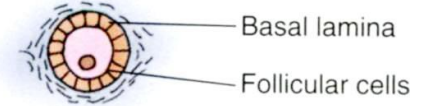
- Ovary – follicle maturation
- Uterus – restoration of endometrium



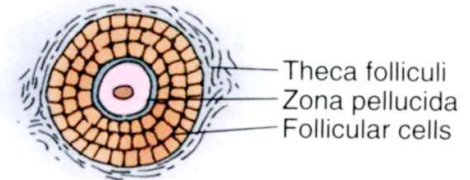
Primordial follicle



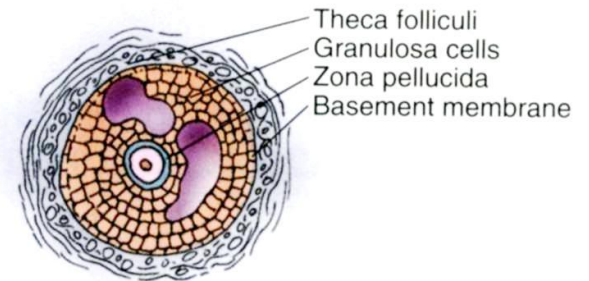
Primary follicle



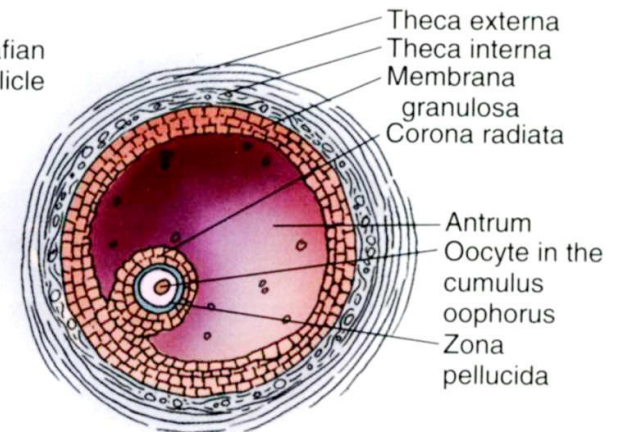
Multilaminar primary follicle



Secondary follicle

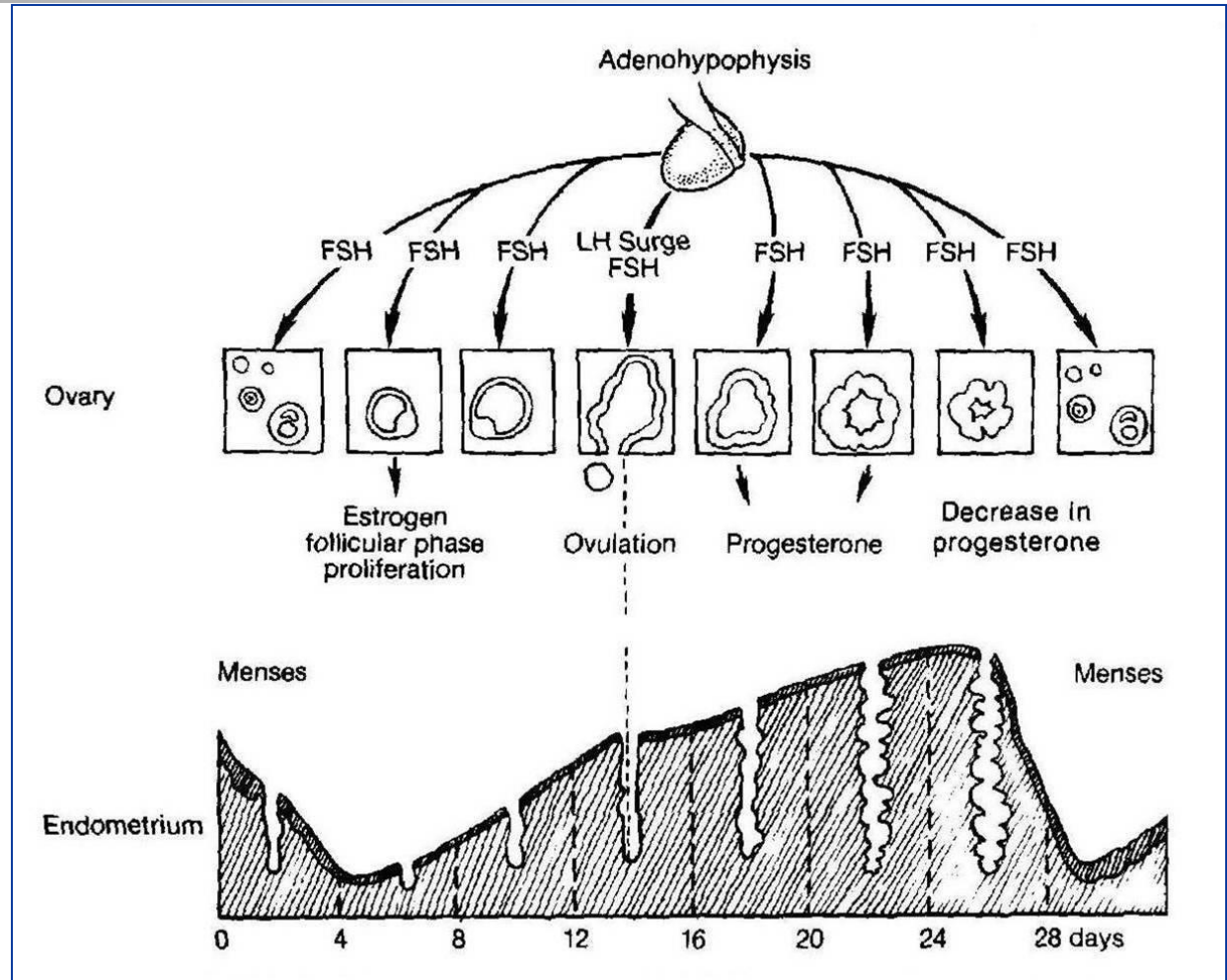


Graafian follicle



# Ovulation(14<sup>th</sup> day)

On the top of  
**FSH** secretion  
and **LH** release





# Luteine phase (15-28<sup>th</sup> days of cycle)

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- Hypothalamus – gonadoliberein

■ Hypophysis– LH

- Follicular cells luteinization

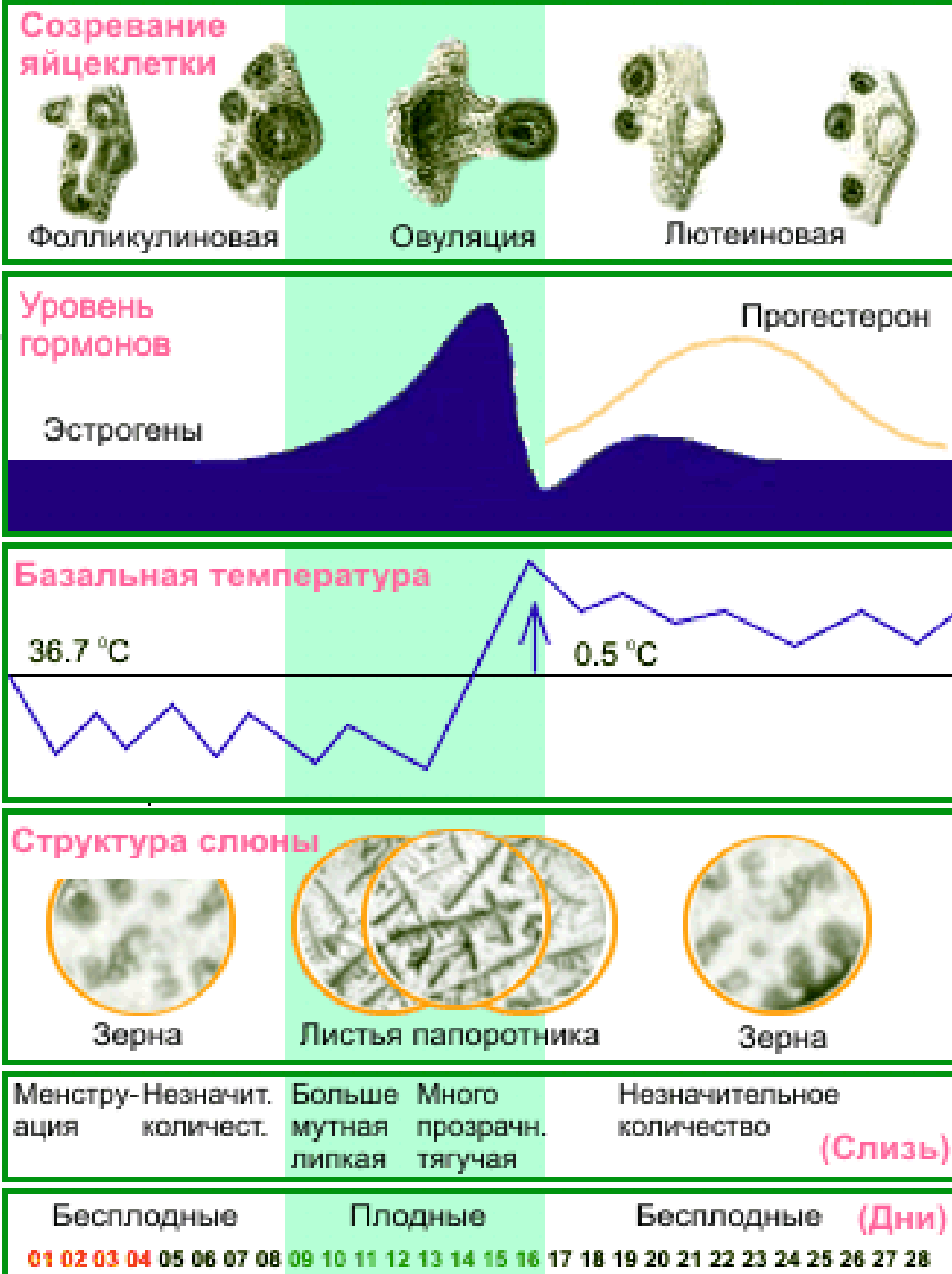
■ progesterone + estrogens:

- Preparing of endometrium for the implantation of foetus



# Определение дней, оптимальных для оплодотворения

- Расчет дней овуляции
- Измерение базальной температуры
- Изменения слюны
- Изменения шеечной слизи

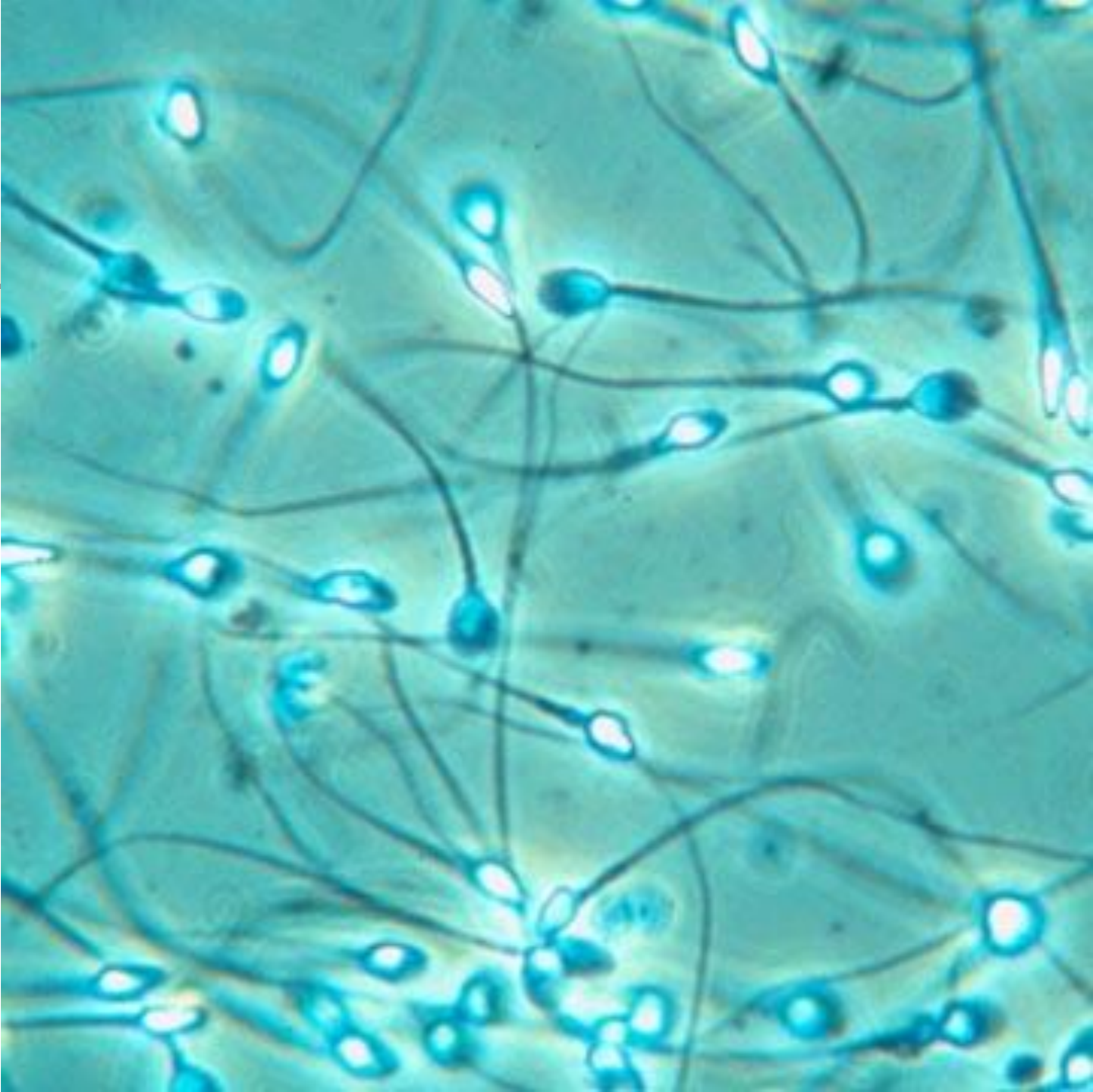


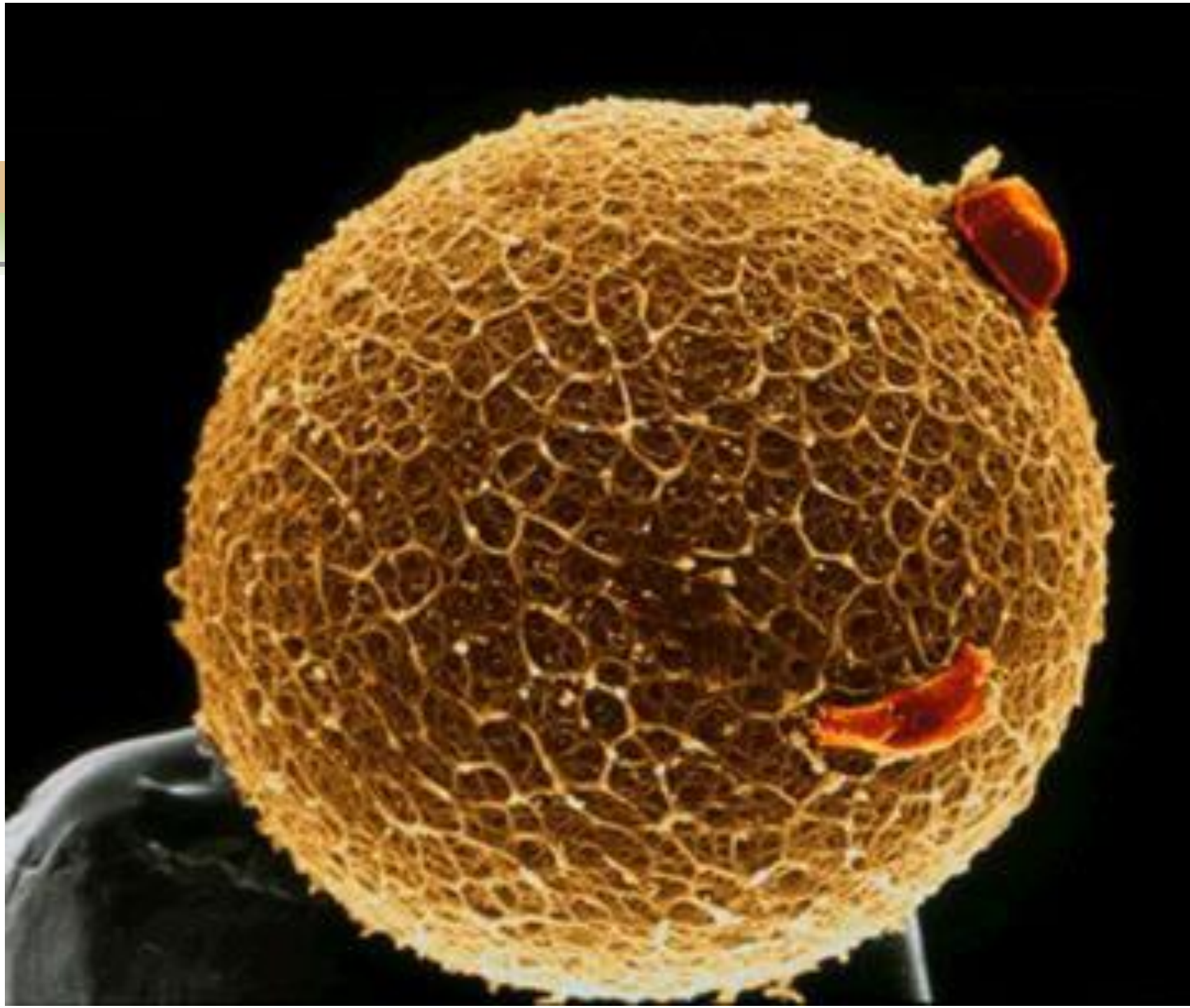
# Fertilization hasn't happened



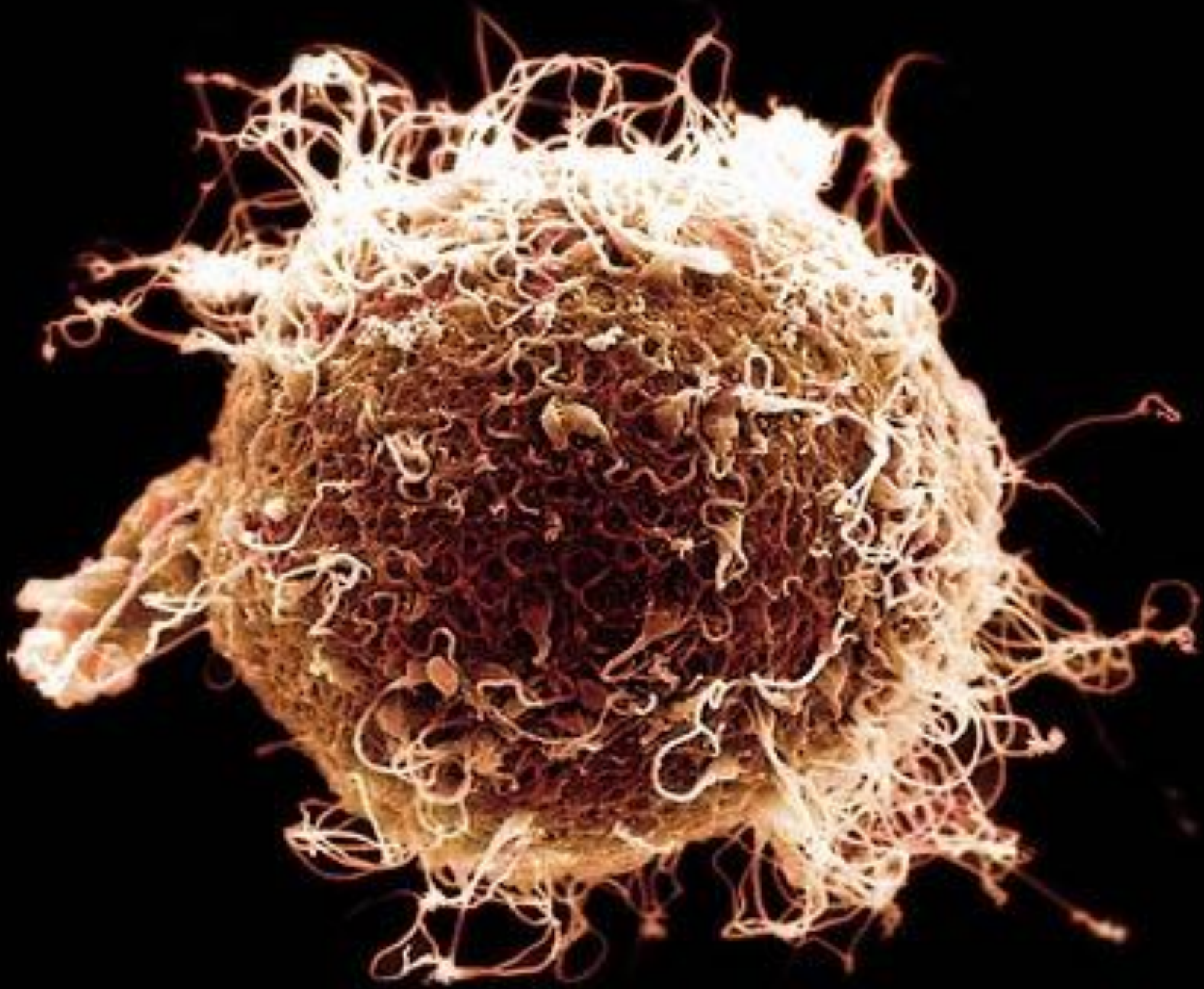
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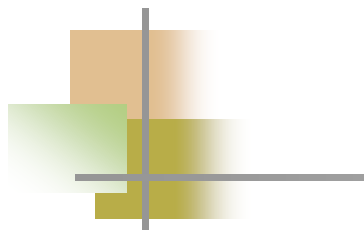
- Regression of corpus luteum – levels of hormones decrease sharply – constriction of uterine spiral arteries – necrosis and rejection of the endometrium (menstruation)



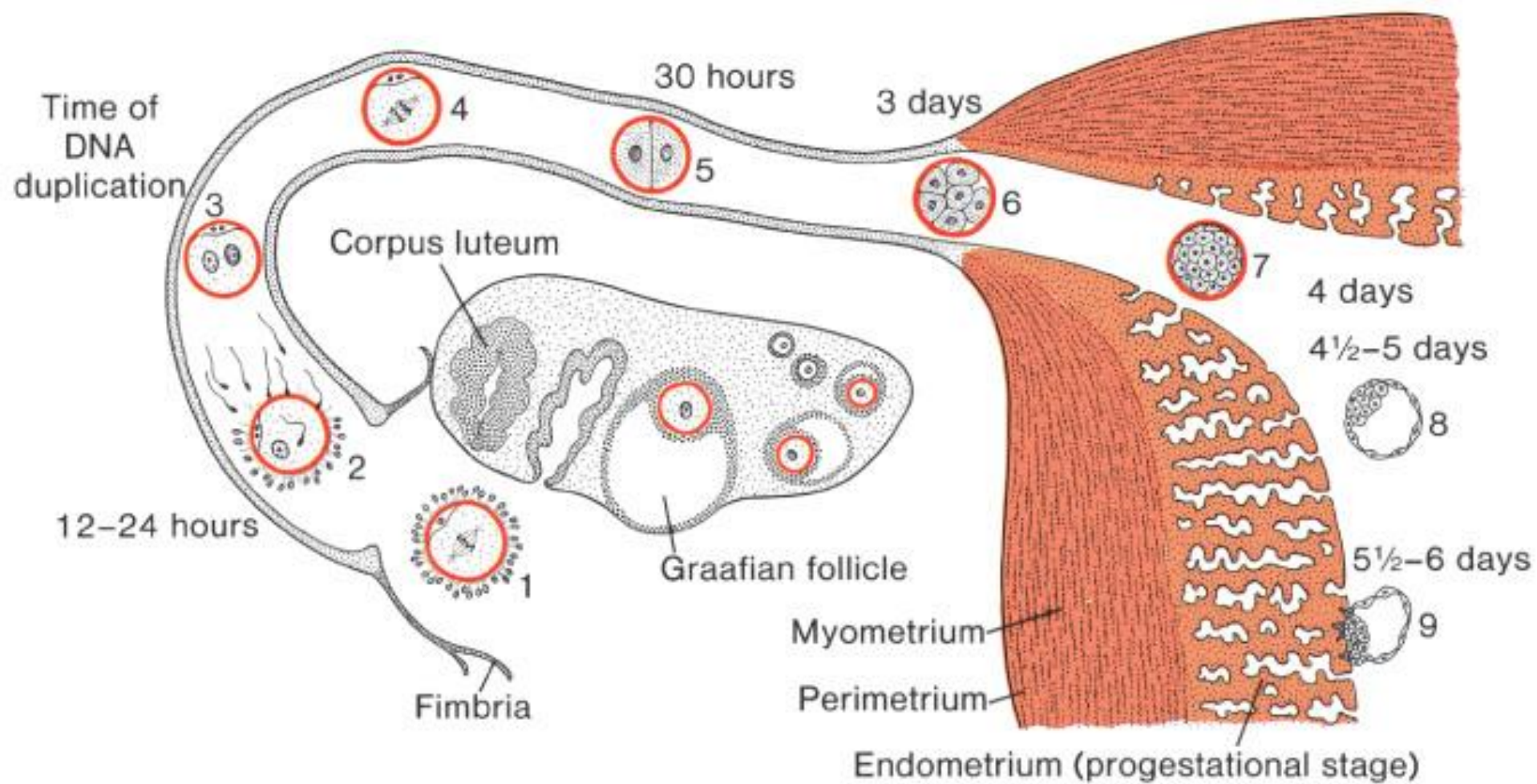








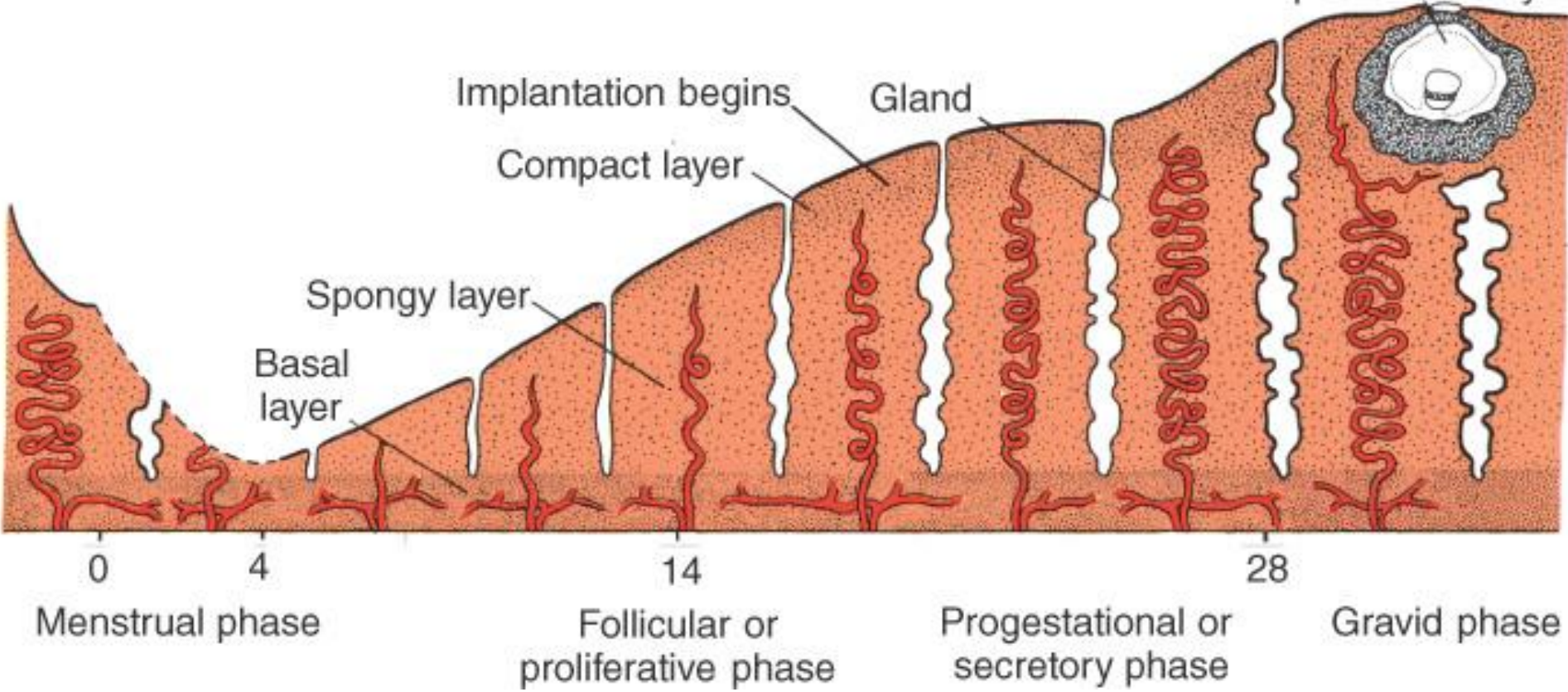
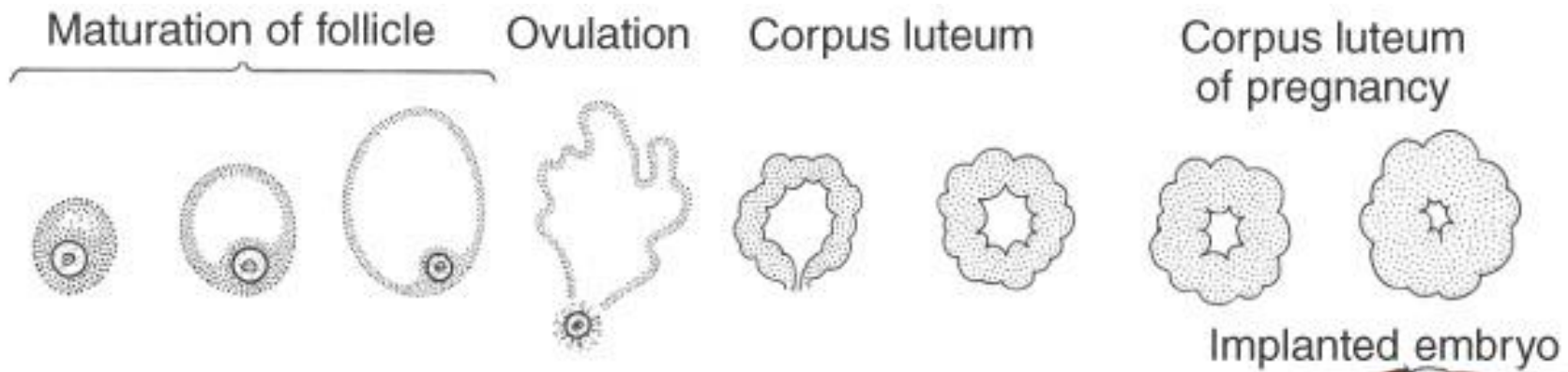




# Fertilization occurred

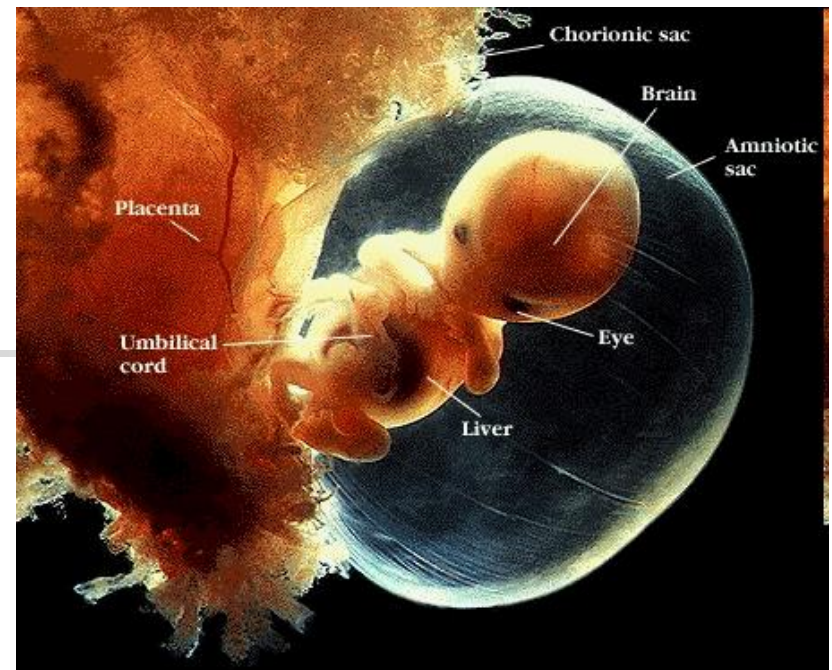
- Human chorionic gonadotropin prolongs life of corpus luteum – hormones of corpus luteum prolong pregnancy



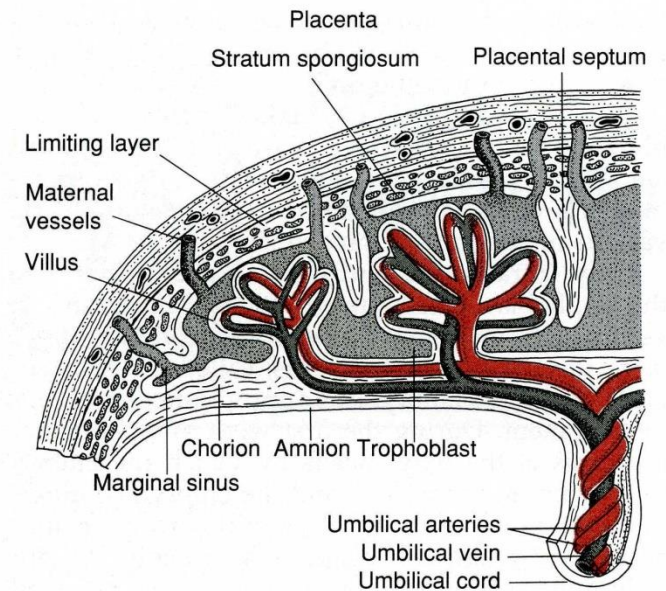
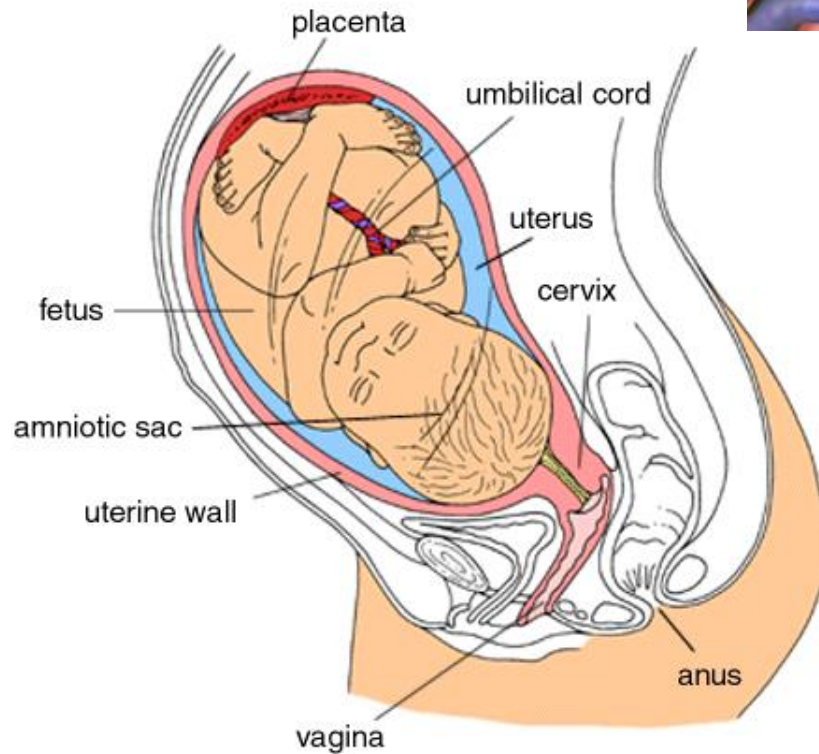
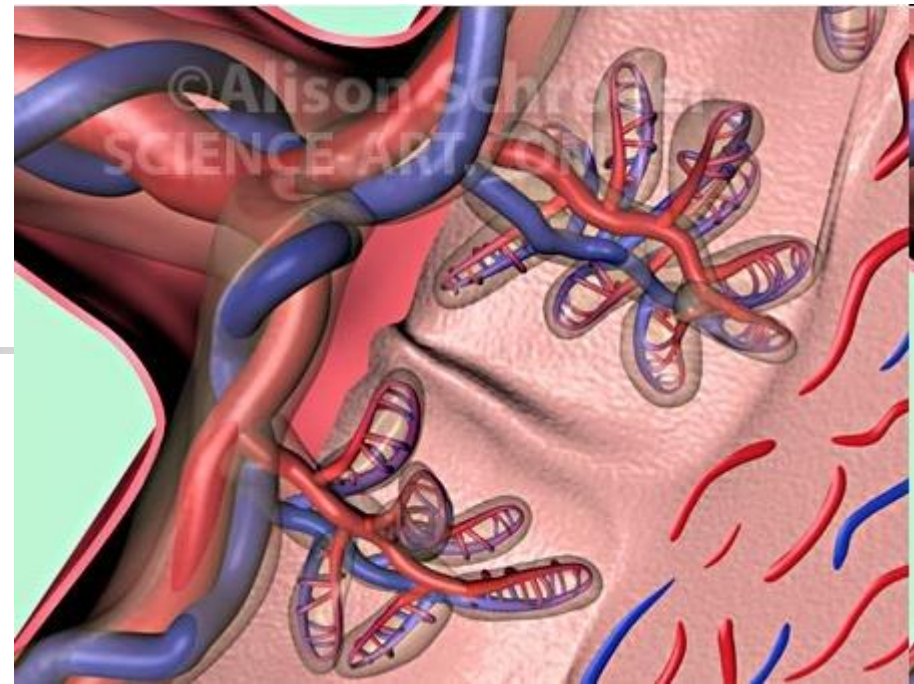
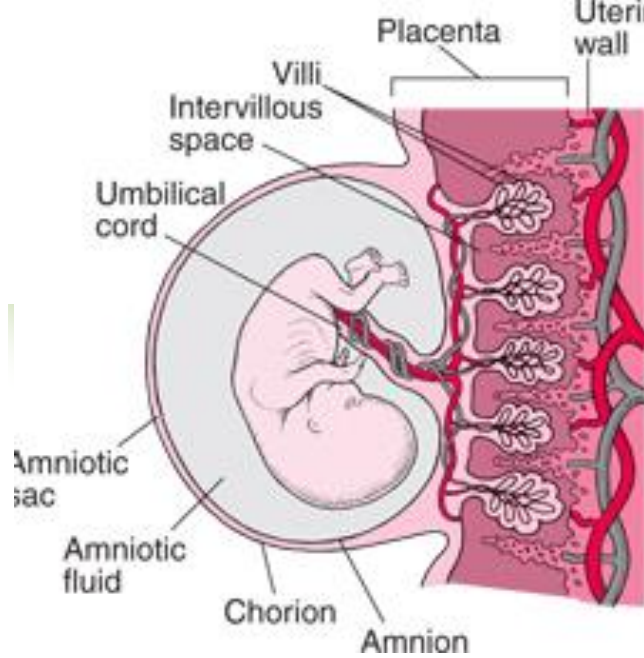




# Placenta



- Provides the foetus with oxygen and nutrition
- Excretes carbon dioxide and metabolism products from the foetus
- Produces hormones

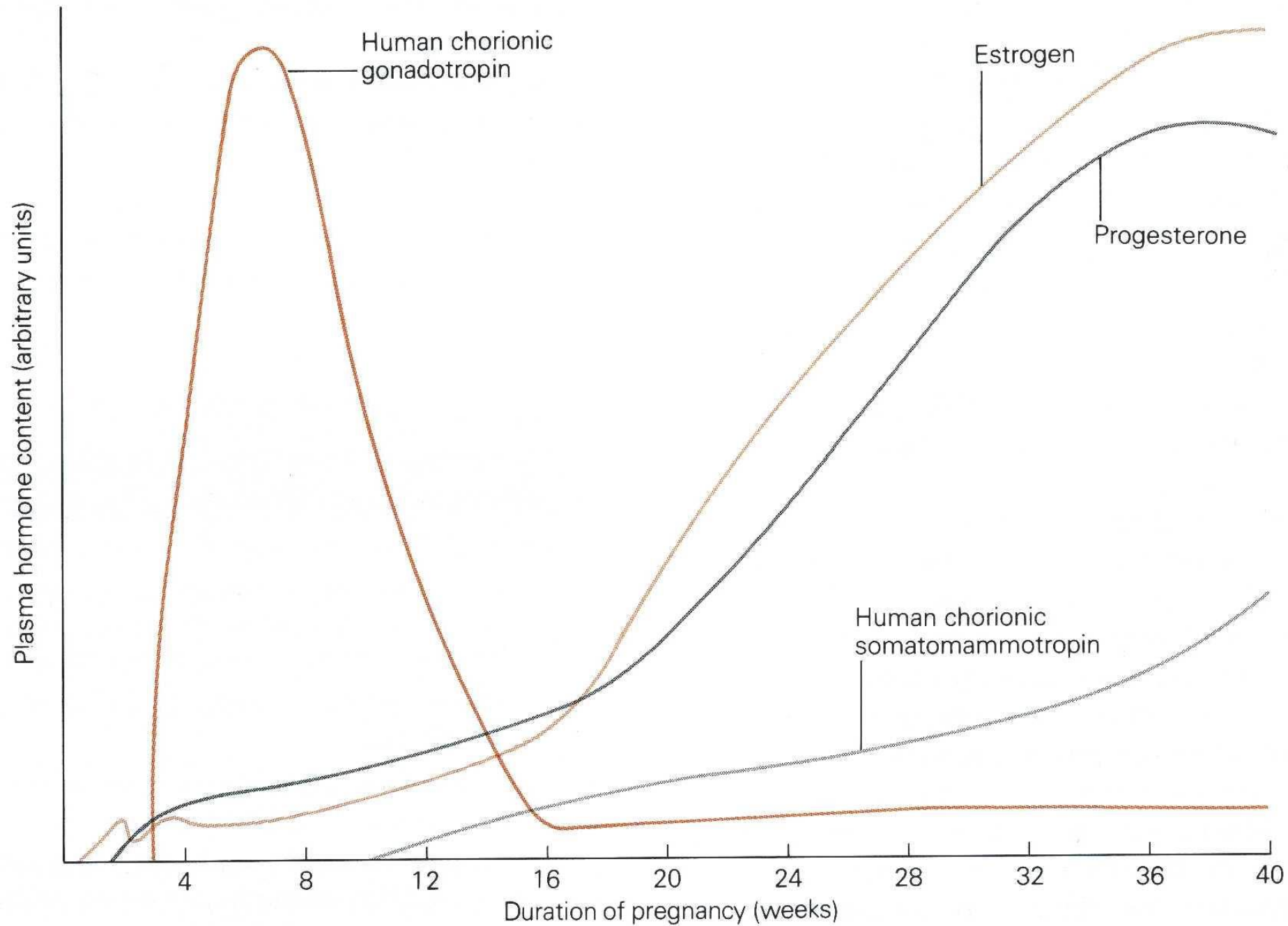




# Hormones of pregnancy

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- Human Chorionic Gonadotropin (HCG)
- Estrogens
- Progesterone
- Human chorionic somatomammotropine (placental lactogene)







# Chorionic gonadotropin

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- First time can be found 8 days after fertilization (pregnancy test)
- is very common with LH in its structure and functions
- Stimulates corpus luteum – pregnancy is prolonged
- Stimulates Leydig cells of foetus – testosterone – development of boy (male)



# Estrogens

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## **During pregnancy:**

- Growth of uterus
- Growth of mammary glands (ducts)
- Growth of external genital organs
- Relaxation and increased elasticity of pelvic ligaments, ligaments of sacro-iliac joint and pubic symphysis



# Progesterone

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## During pregnancy:

- Depression of mother's immune response against foetus
- Decrease of uterine SMC contractibility
- Suppression of lactation



# Chorionic somatomammotropin

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- Development of mammary gland
- Growth of foetus
- Mother's glucose goes primarily to the foetus (fat plays a role of additional source of energy in mother's body)

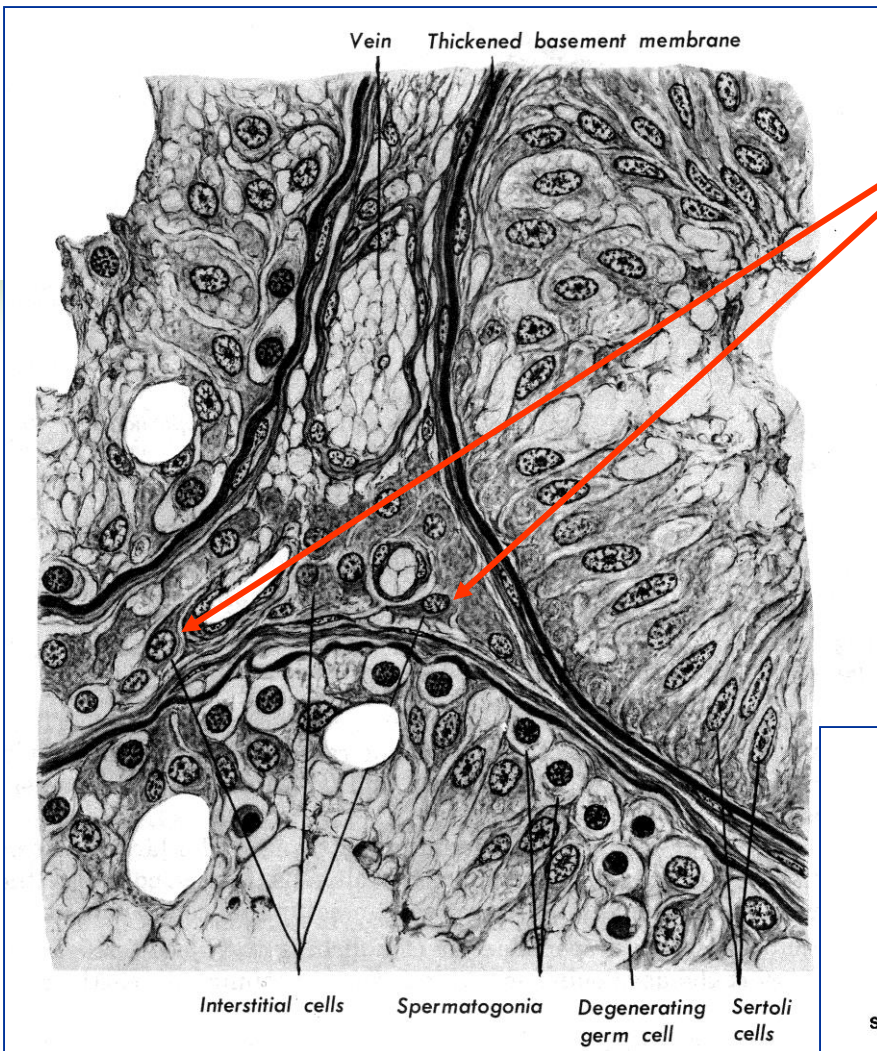




# Male sex glands

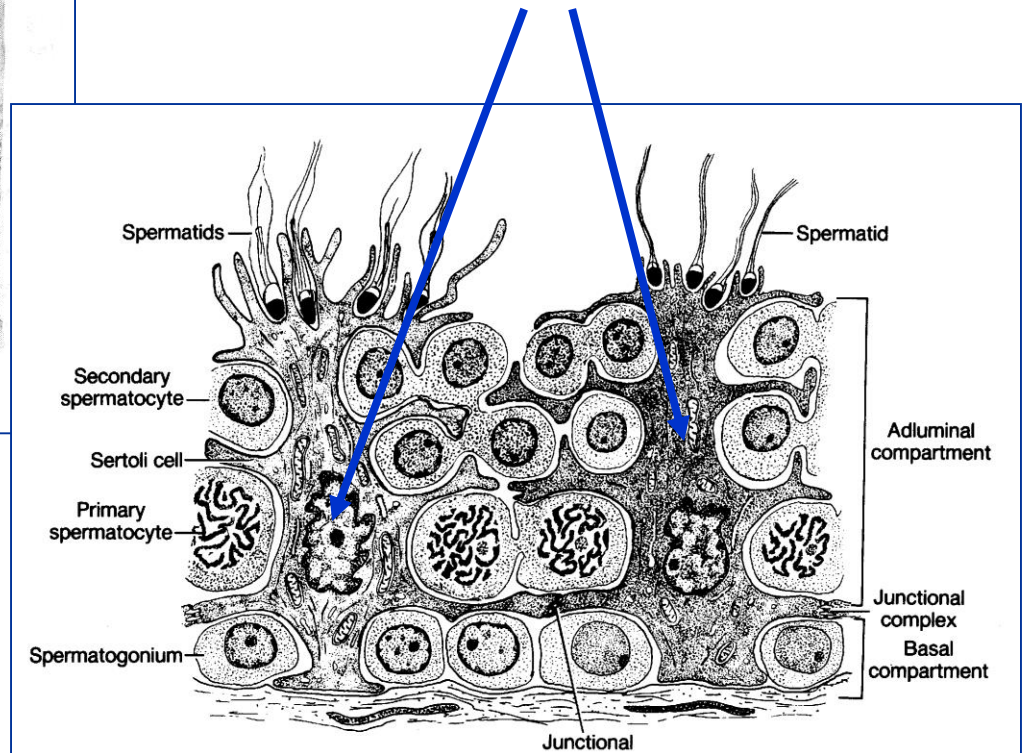
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- Exocrine function - sperm
- Endocrine function - male sex hormones

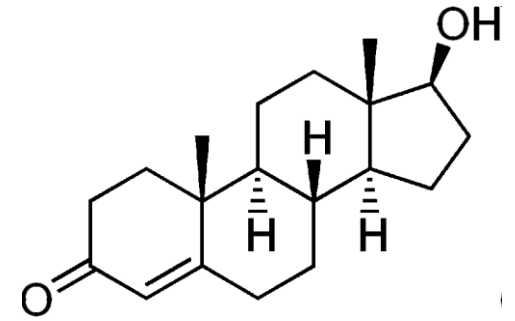


- Interstitial Leydig cells  
(testosterone)

- Sertoli cells (ABP, inhibin, activin)



# Testosterone



- Necessary for the **sperm maturation**
- Produced by Leydig cells under the **LH** influence (in prenatal period - under the HCG influence)
- **Testosterone** suppresses secretion of gonadoliberein by hypothalamus



# Testosterone

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- The development of male fetus
- Lowering (descent) of testicles into the scrotum





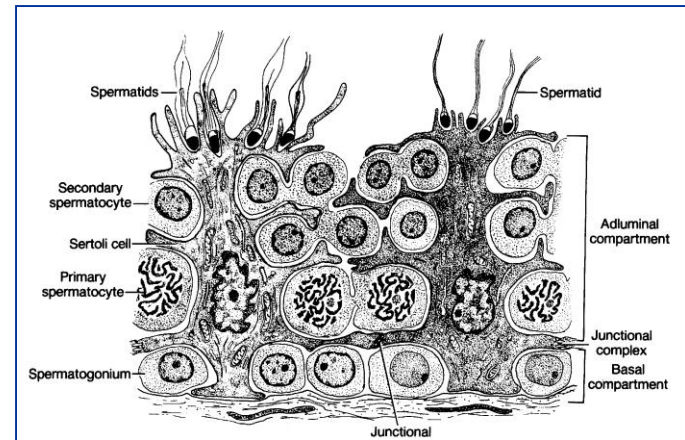
# Testosterone

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- The growth of sex organs
  - Man's type of hair distribution (and hair loss in case of genetic predisposition)
  - Bone growth in length and increase of bone density, but rapid closure of growth zones
  - The growth of the larynx ("breaking" of voice)
  - Enhanced production of sebum
  - Protein synthesis and muscle growth (anabolic effect)
  - Stimulation of production of red blood cells
  - Ability to make decisions

# Regulation of spermatogenesis

- FSH stimulates Sertoli cells for the development of androgen-binding protein (ABP)
- ABP provides a high level of testosterone around spermatogenic epithelium
- Sertoli cells produce inhibin and activin, regulating the FSH secretion





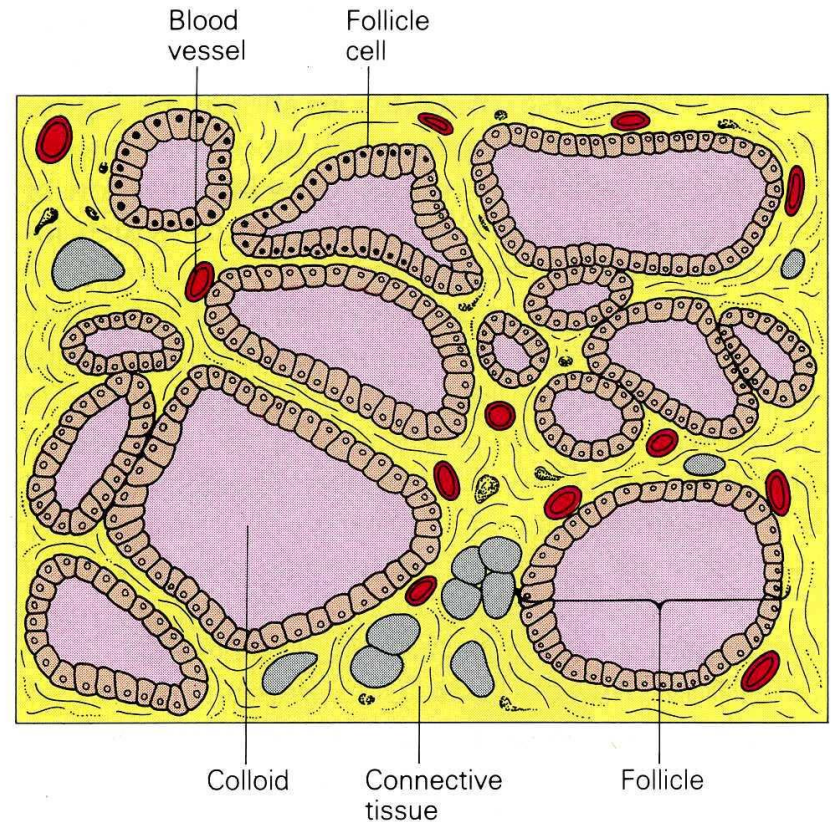
# TSH-Thyroid-Stimulating Hormone

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- Stimulates **follicular thyroid cells** for the synthesis and secretion of thyroxine and 3-iodothyronine

# Thyroid gland

- Contains two types of cells:
  - Follicular (A-cells)
  - Parafollicular (C-cells)







# Follicular cells

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- Form a wall of bubbles– follicles йод
- Under the influence of TSH :
  - Cells produce iodine- containing hormones - T3, T4 and thyroglobulin
  - Thyroglobulin - the storage form of iodine-containing hormones, it is the colloid in the follicle
  - T3 and T4 are secreted into the bloodstream



# Effects of Iodine-containing hormones

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- Stimulation of growth
- Development and maturation of the brain
- Stimulation of heartbeats and breathing
- Stimulation of the metabolism:
  - Protein synthesis
  - Mobilization and synthesis of fats
  - Storage of glucose

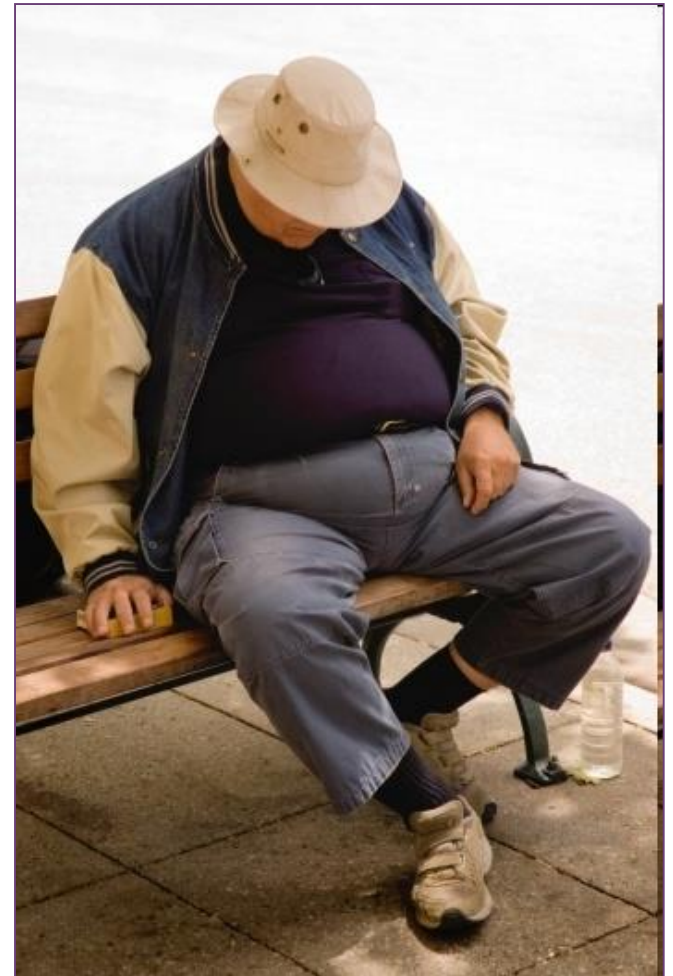
# Violations of secretion of Iodine-containing hormones

- Increased production - hyperthyroidism



# Violations of secretion of Iodine-containing hormones

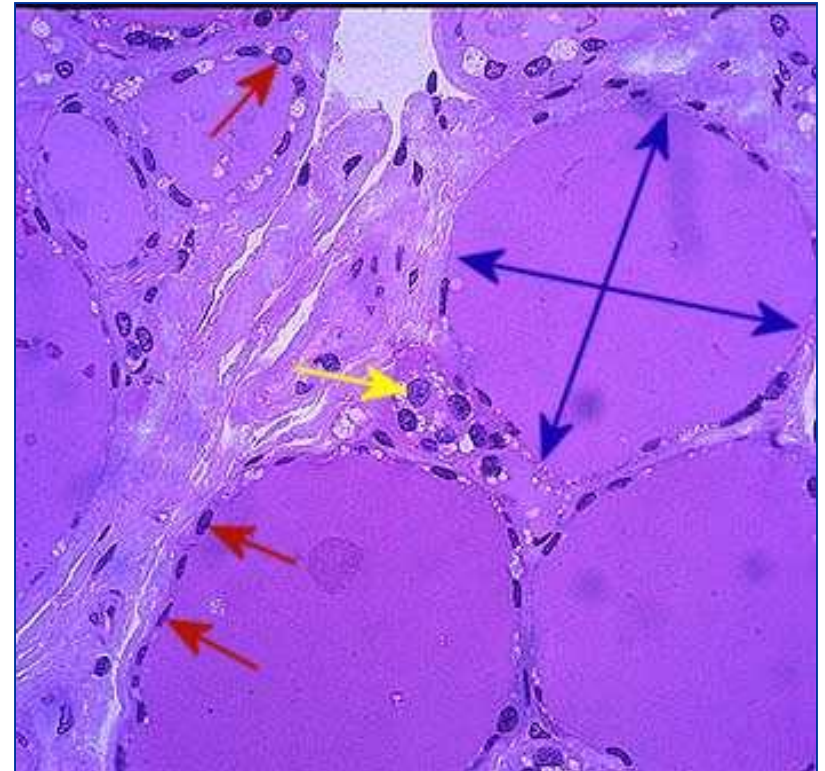
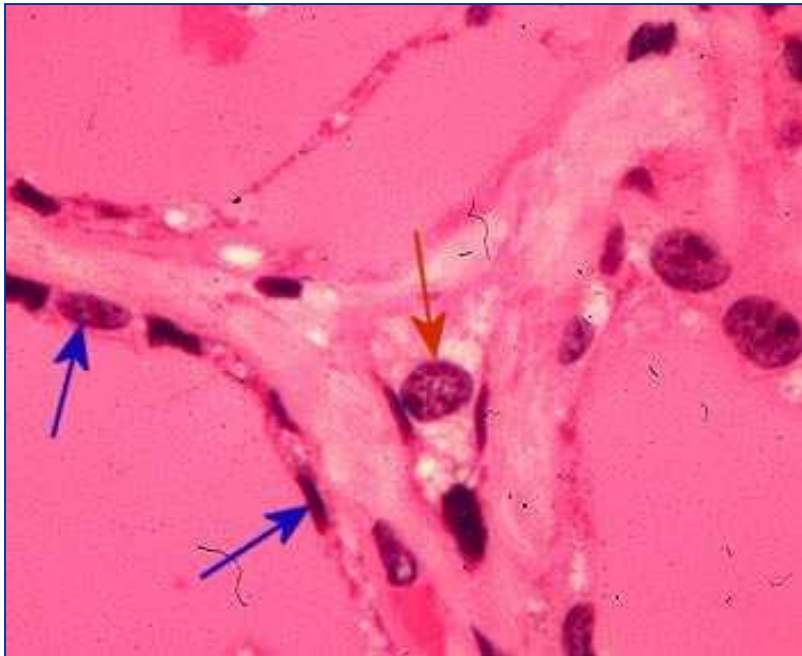
- Decreased production:
- Hypothyroidism (miksedema) in adults
- Cretinism in children





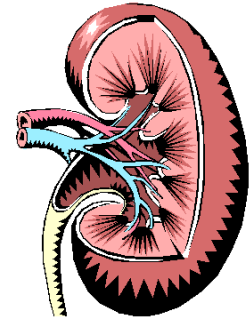
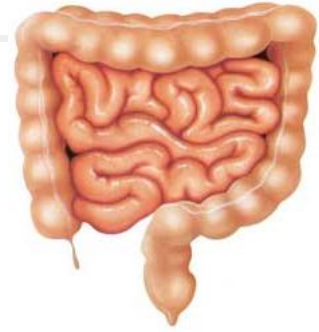
# Parafollicular cells

- Single cells located between the follicles
- Produce **calcitonin** (thyrocalcitonin)



# Calcium

- Absorption in the gut
- Reabsorption in the kidney
- Destruction of the bone





# Parafollicular cells

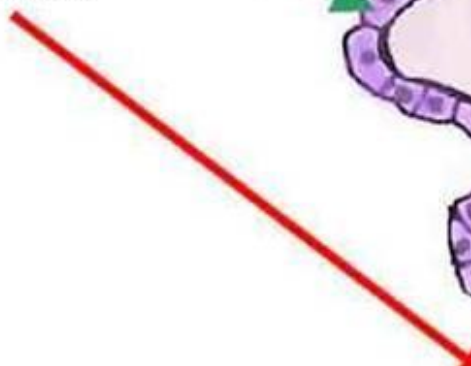
---

- Calcitonin secretion is stimulated by high levels of calcium in the blood
- Calcitonin blocks osteoclasts and bone resorption-**the level of calcium in the blood decreases**

**повышение кальция  
в крови**



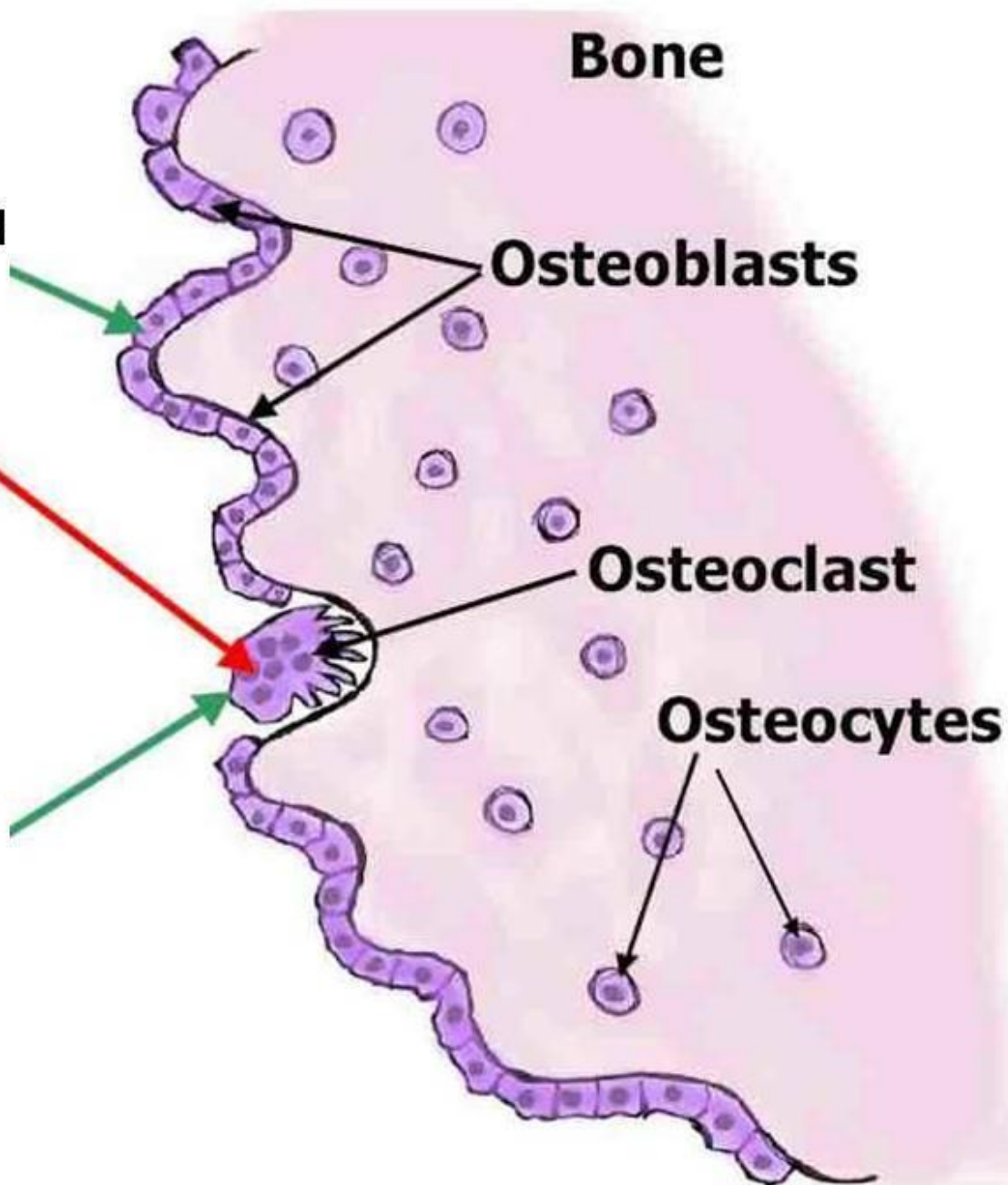
**повышение секреции  
кальцитонина**



**повышение секреции  
паратгормона**



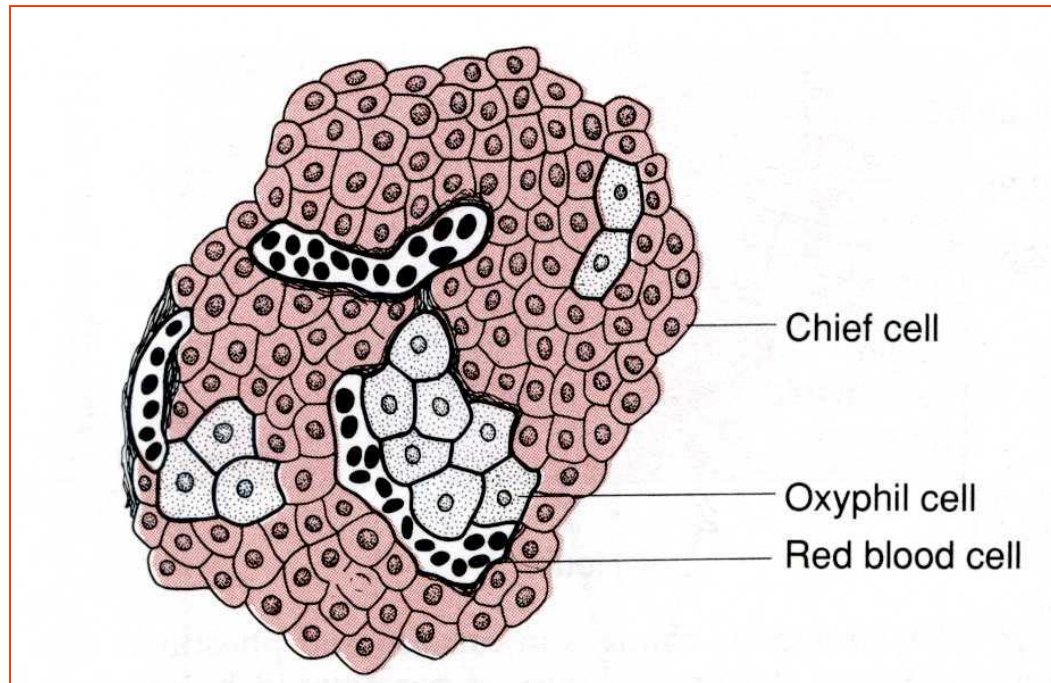
**снижение кальция  
в крови**

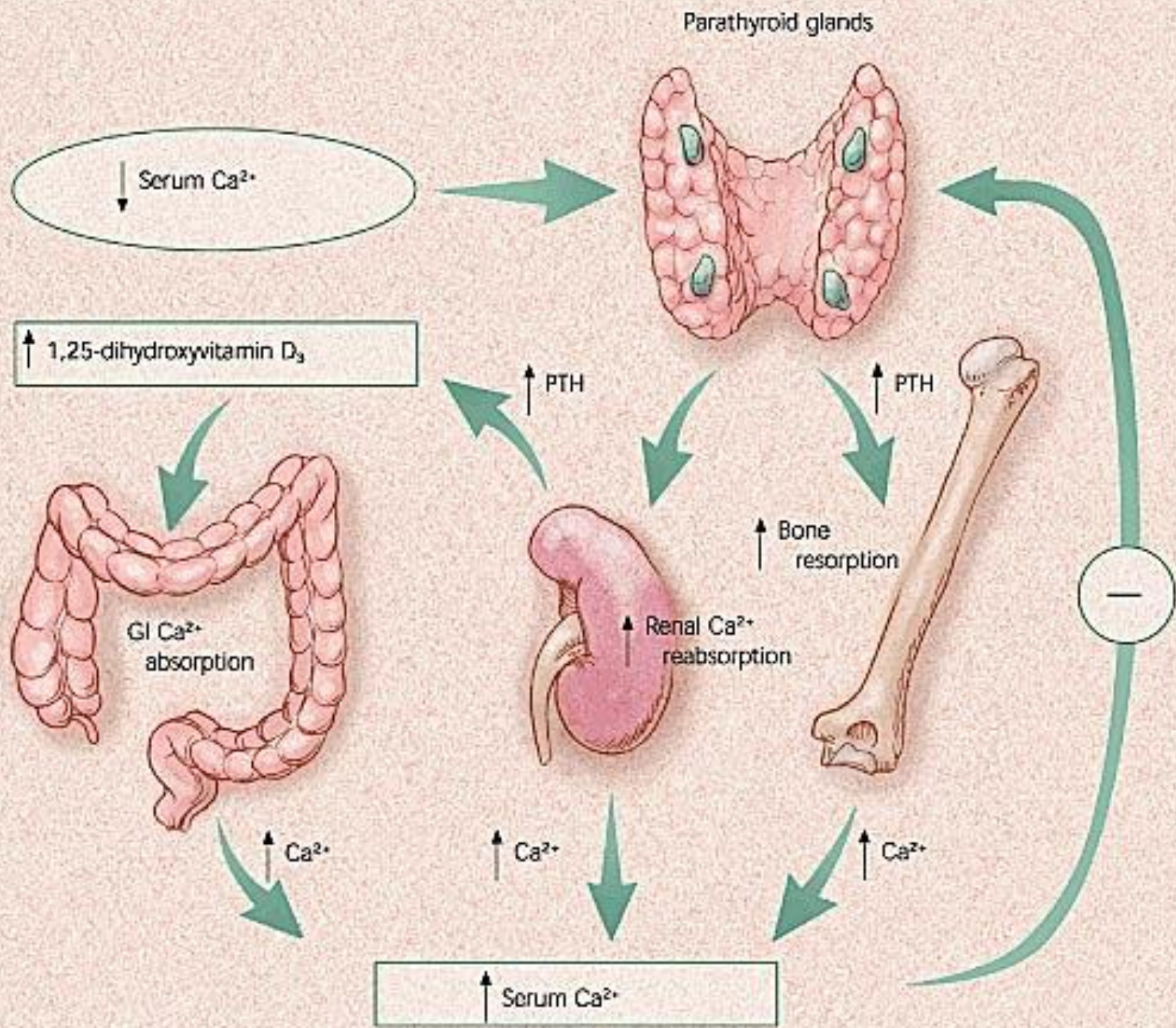




# Parathyroid gland

- The main cells of glands secrete **parathyroid hormone (PTH)**









# Parathyroid gland

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- PTH secretion is stimulated by low level of calcium in the blood
  - PTH converts vitamin D to its active form- increases calcium absorption in the gut
  - PTH increases reabsorption of calcium in kidney
  - PTH stimulates osteoclasts and bone resorption

**Calcium level in blood raises**



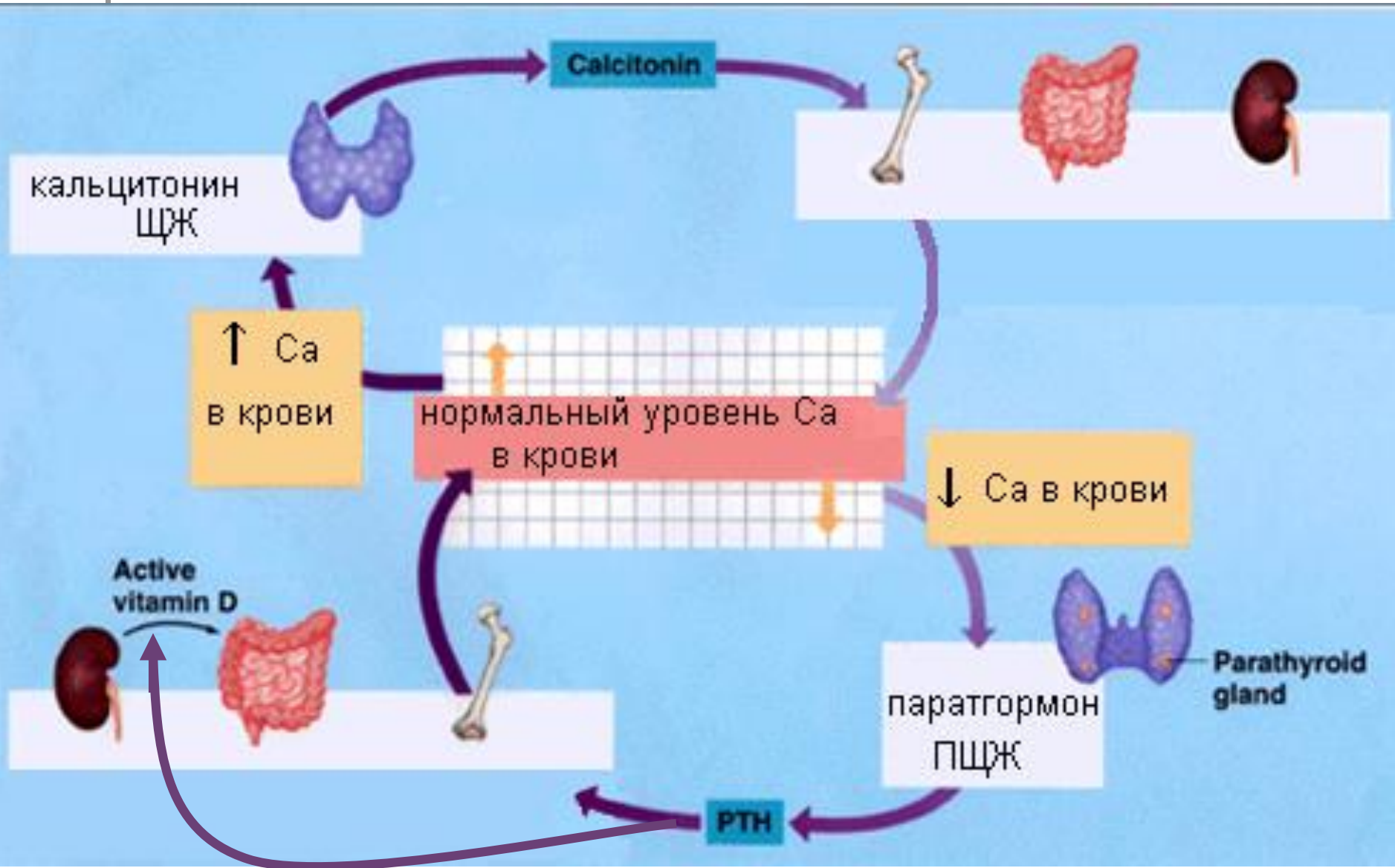
# Vitamin D

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- Is produced in skin
- Is activated in liver (1) and in kidney (2)
- Activation in the kidney occurs under the action of PTH
- The active form enhances calcium absorption in the gut



# Regulation of calcium level in blood





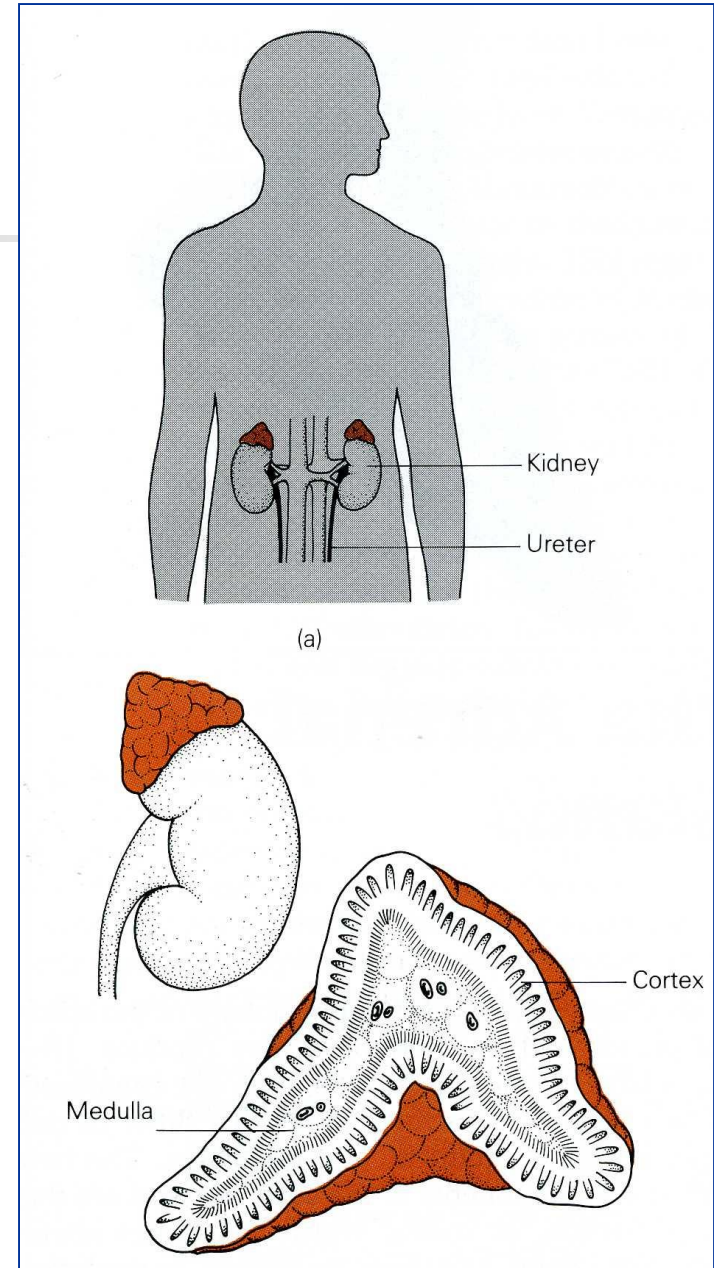
# ACTH- AdrenoCorticoTropic Hormone

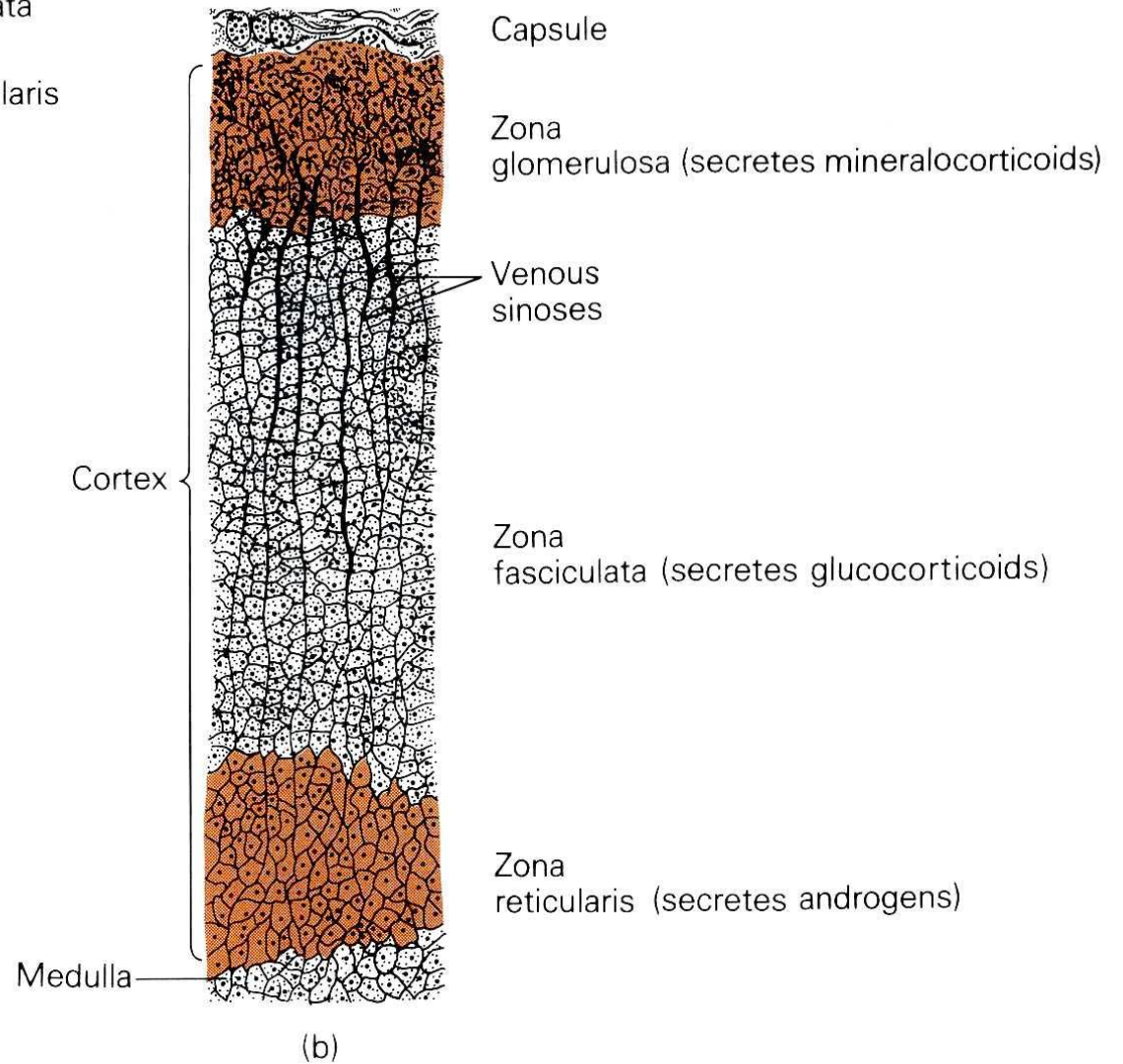
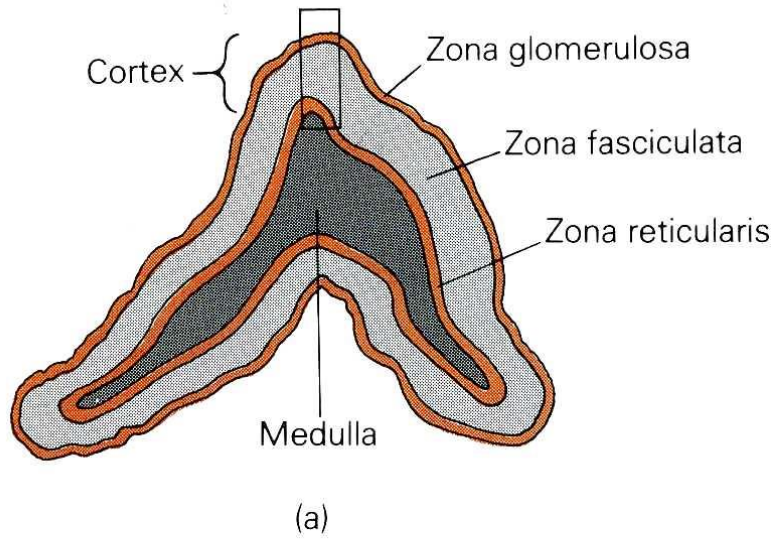
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- Stimulates **the adrenal cortex cells** to synthesis and secretion of **steroid hormones**

# Adrenal glands

- The cortex (from the mesoderm)
- The medulla (from the neural crest, sympathetic ganglion)

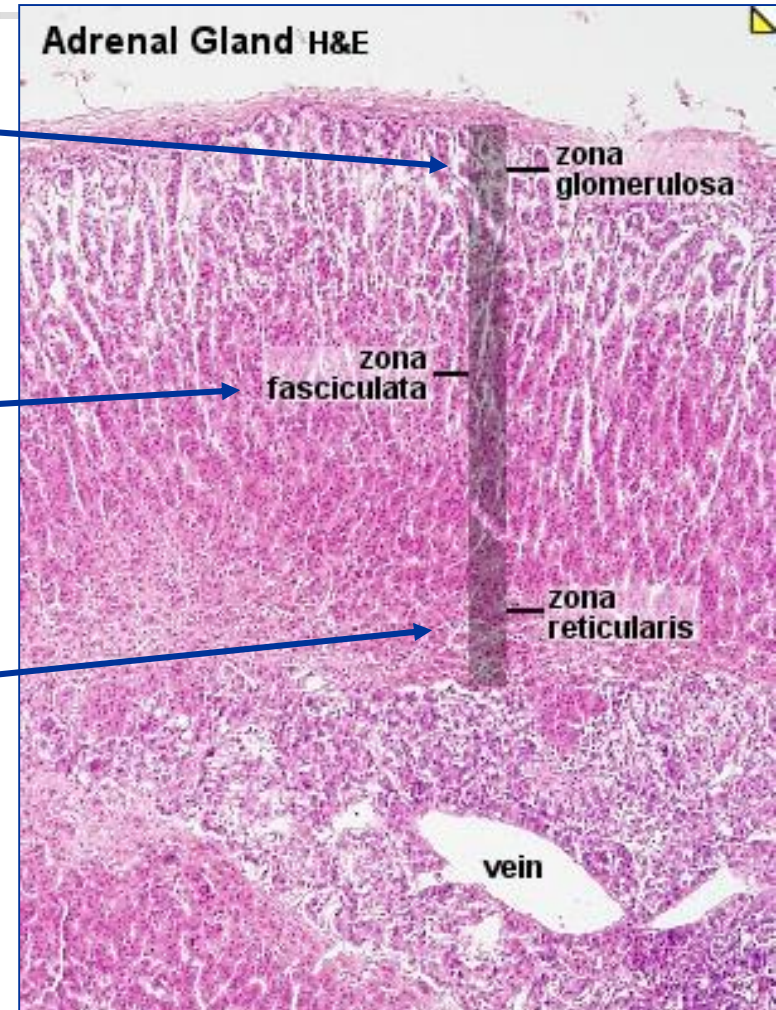






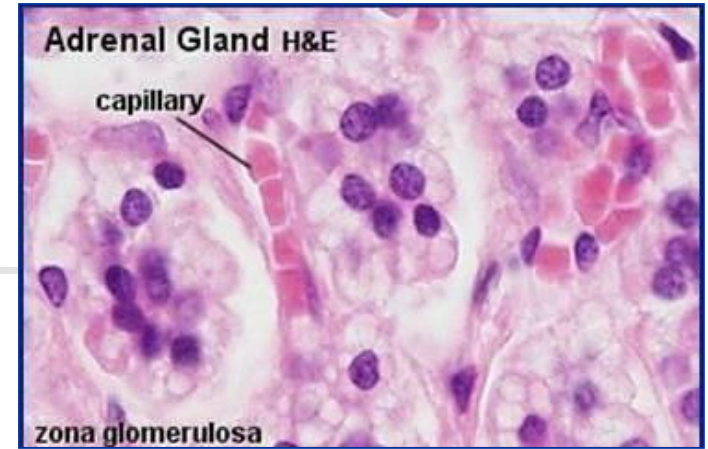
# The adrenal cortex

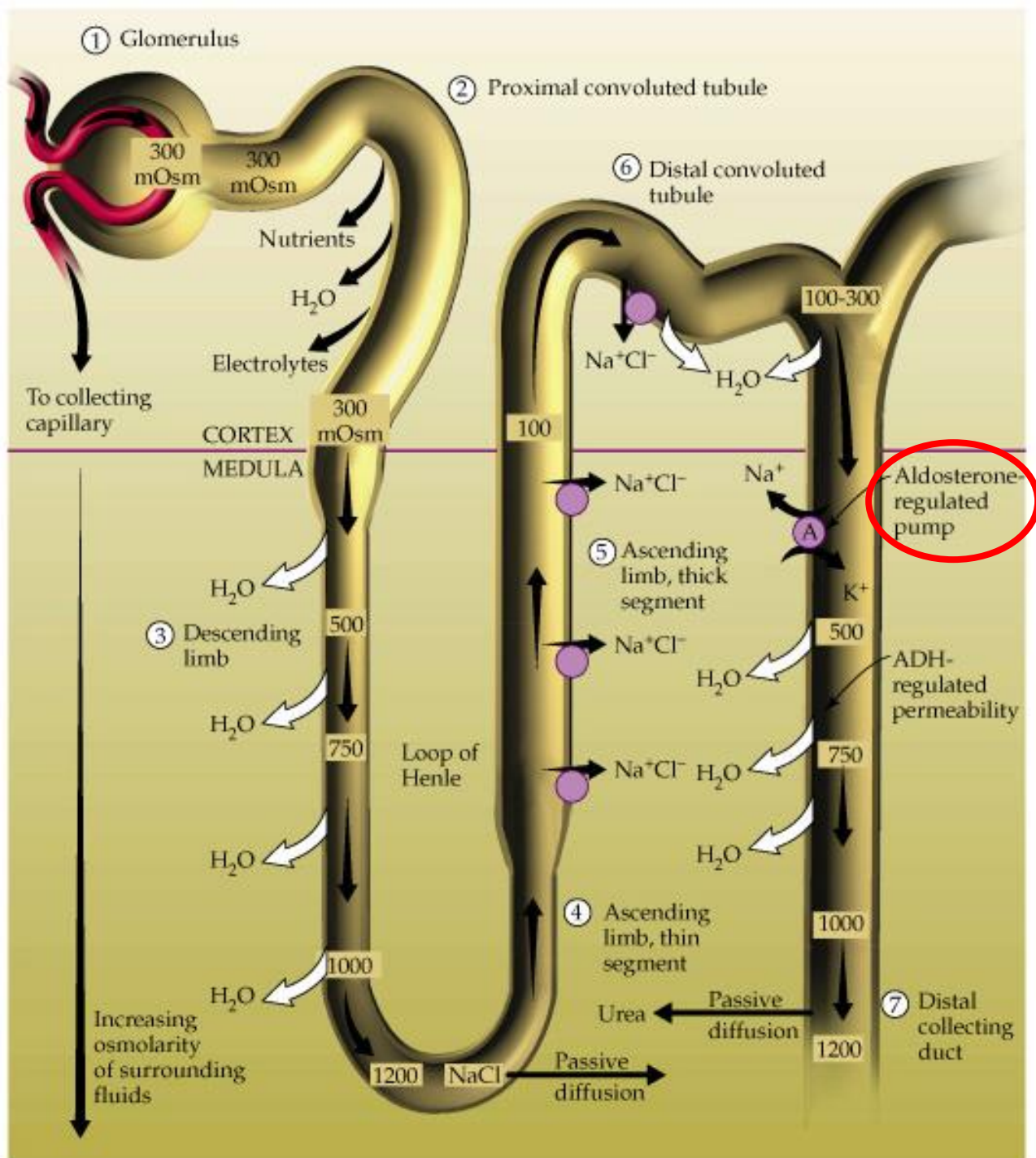
- Glomerular area  
mineralocorticoids  
(aldosterone)
- Beam area  
glucocorticoids  
(cortisol)
- Reticulated area  
sex hormones



# Aldosterone

- Aldosterone secretion is stimulated by angiotensin -2 and ACTH
- Aldosterone promotes sodium reabsorption and potassium secretion in the distal convoluted tubules

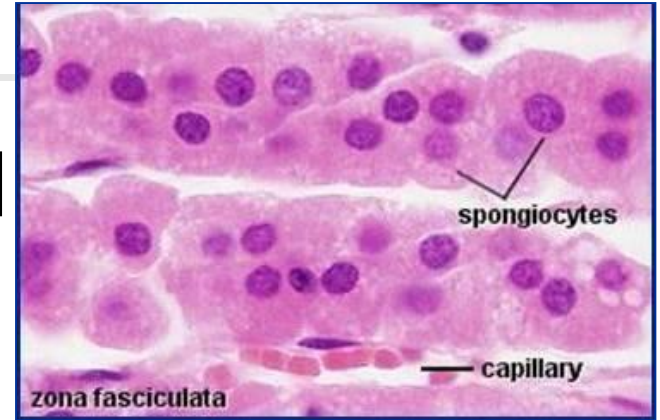




# Glucocorticosteroids

## (glucocorticoids)

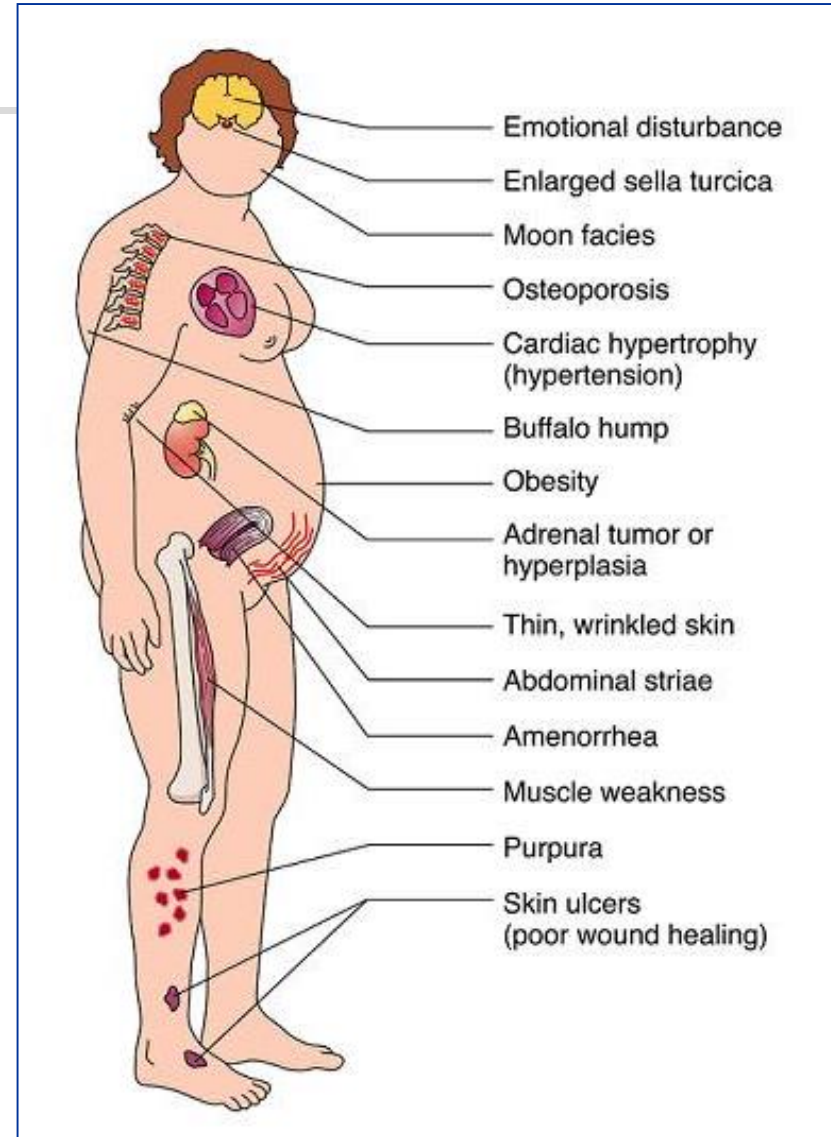
- Increase sugar level in blood
- The destruction of the protein
- Mobilization and redistribution of the fat
- Increase vascular reactivity
- The suppression of inflammation and immunity





# Violations of the adrenal hormones production

## ■ Increased production - Cushing's syndrome



# Violations of the adrenal hormones production



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- Decreased production- Addison's syndrome:
  - Weakness
  - Decreased blood pressure
  - Skin pigmentation
  - Depression



# Medulla

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- Production of hormones stimulated by sympathetic neurons endings
  - **Epinephrine**
    - Stimulation intensity and frequency of the heart contractions
    - Vasoconstriction of the skin and organs
    - Relaxation of bronchial, intestinal SMCs
    - Insulin suppression, glucagon stimulation
  - **Norepinephrine**
    - Stronger effect on blood vessels, weaker-on everything else



# Kidney hormones

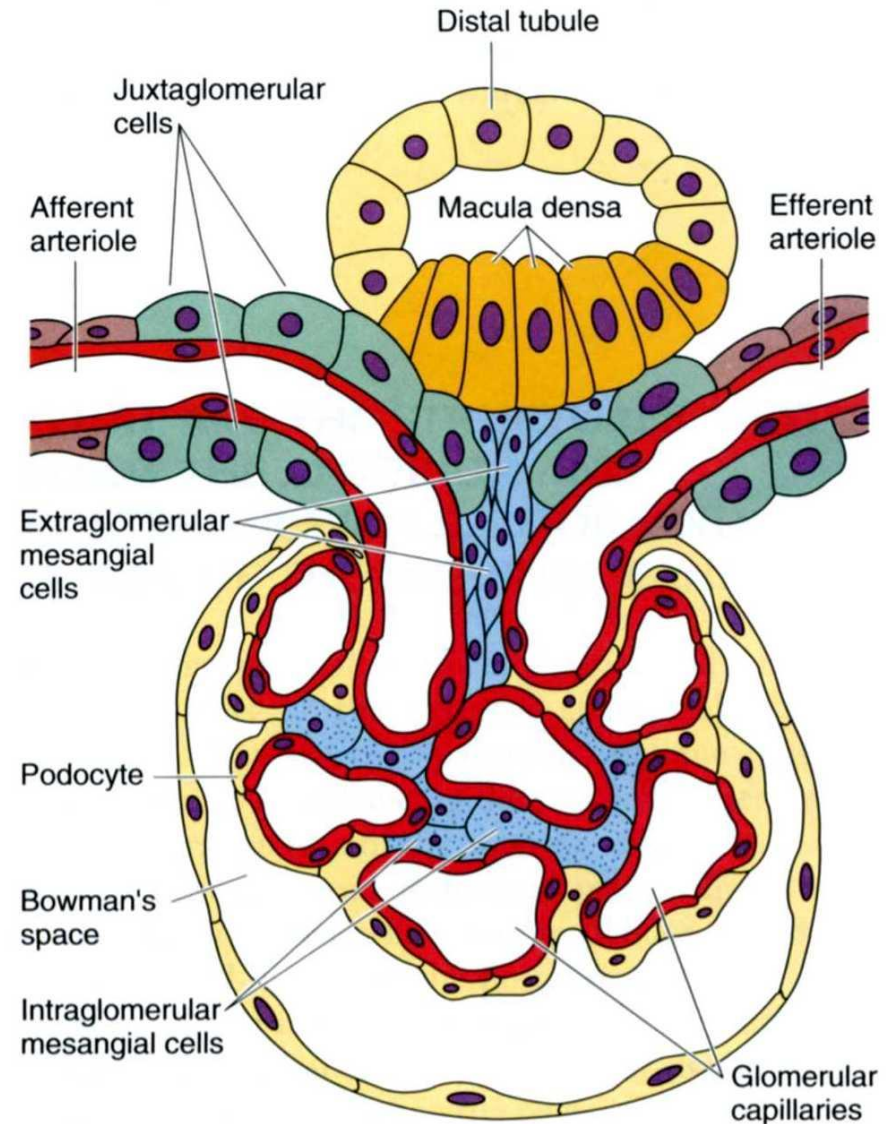
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- Renin
- Erythropoietin



# Juxtaglomerular apparatus (JGA)

- The cells of bringing arteriole
- The cells of the distal tubule ( tight spot)
- mesangial cells



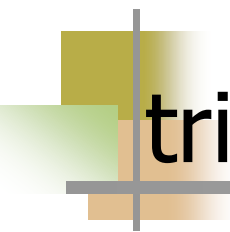


# The function of the JGA

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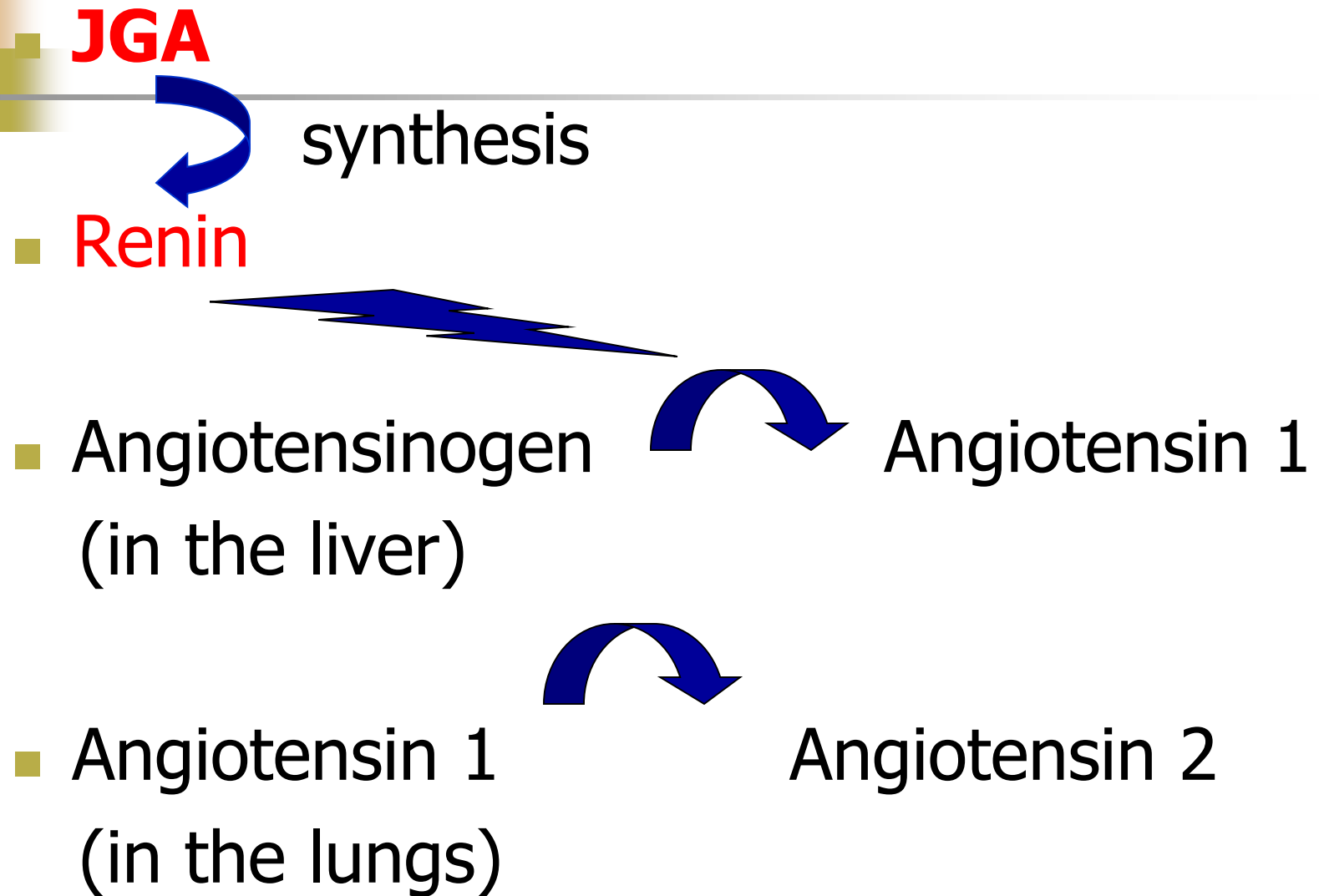
- Produce renin in case of:
  - Decreasing the blood pressure (decrease of the stretching of the bringing arteriole wall) and/or
  - Increasing the concentration of sodium in the lumen of the distal tubules (pick up the solid spot cells)

# Renin



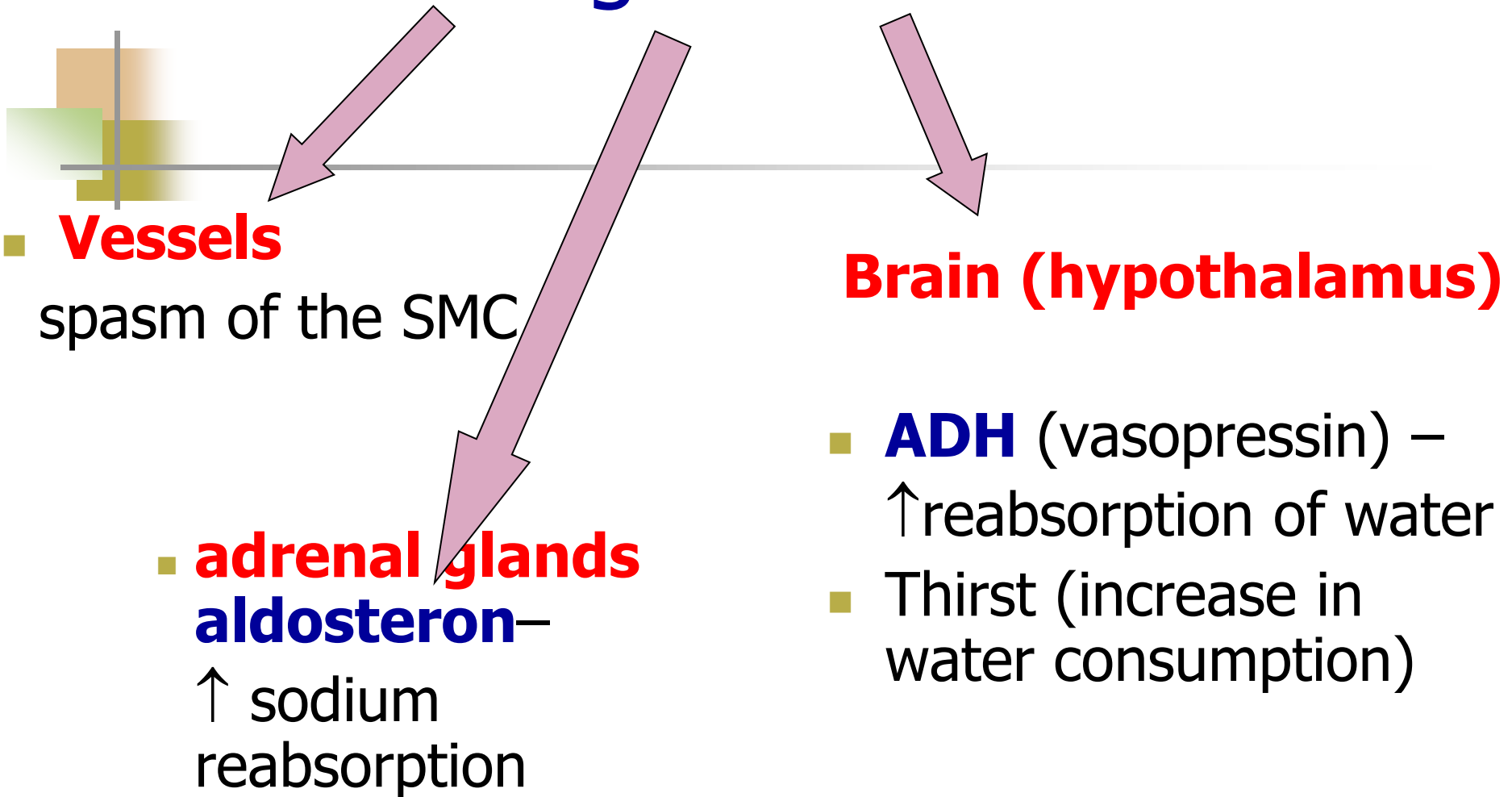
triggers a cascade of reactions leading  
to increased **Blood Pressure**

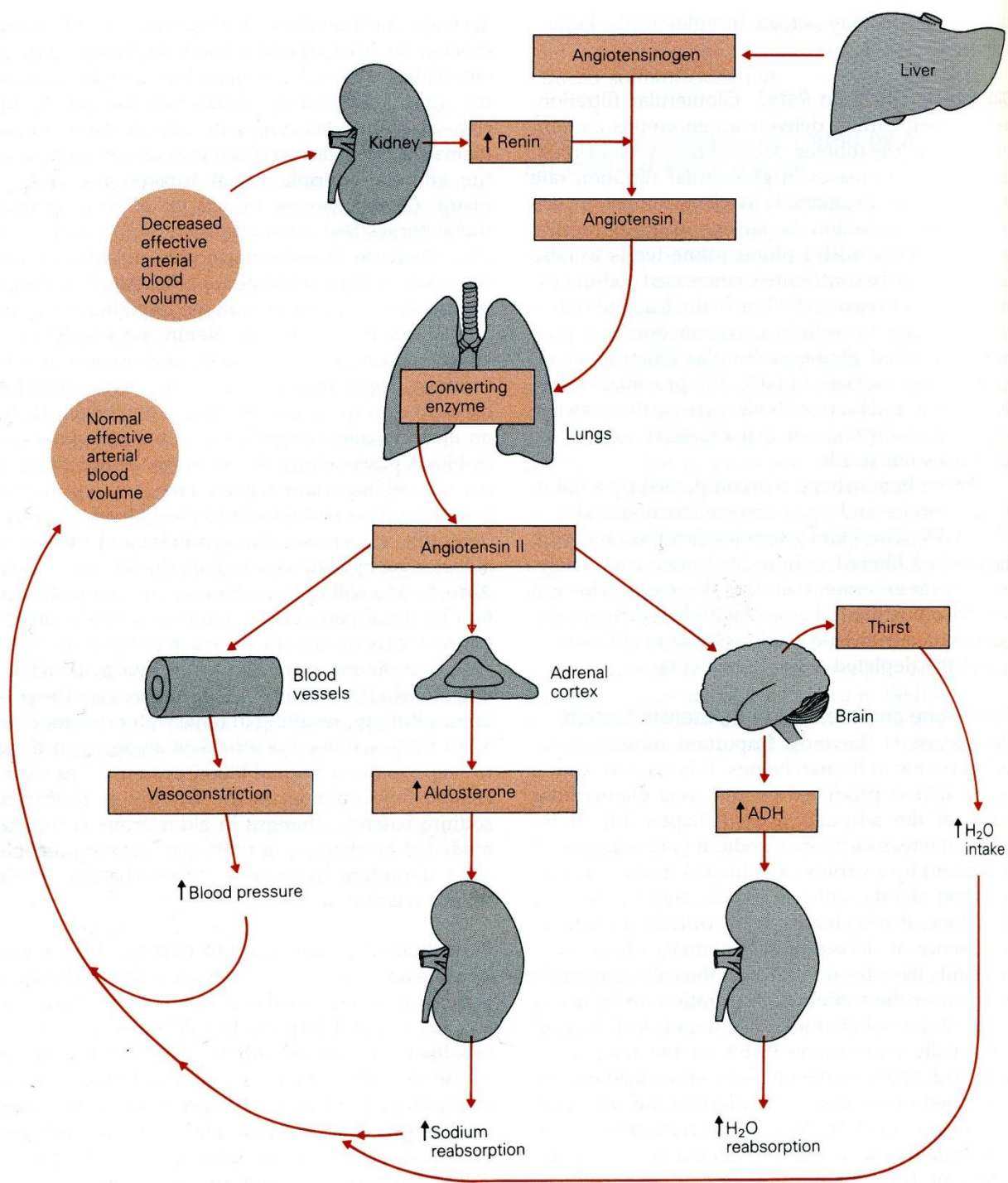
# Decrease in Blood Pressure:





# Angiotensin 2







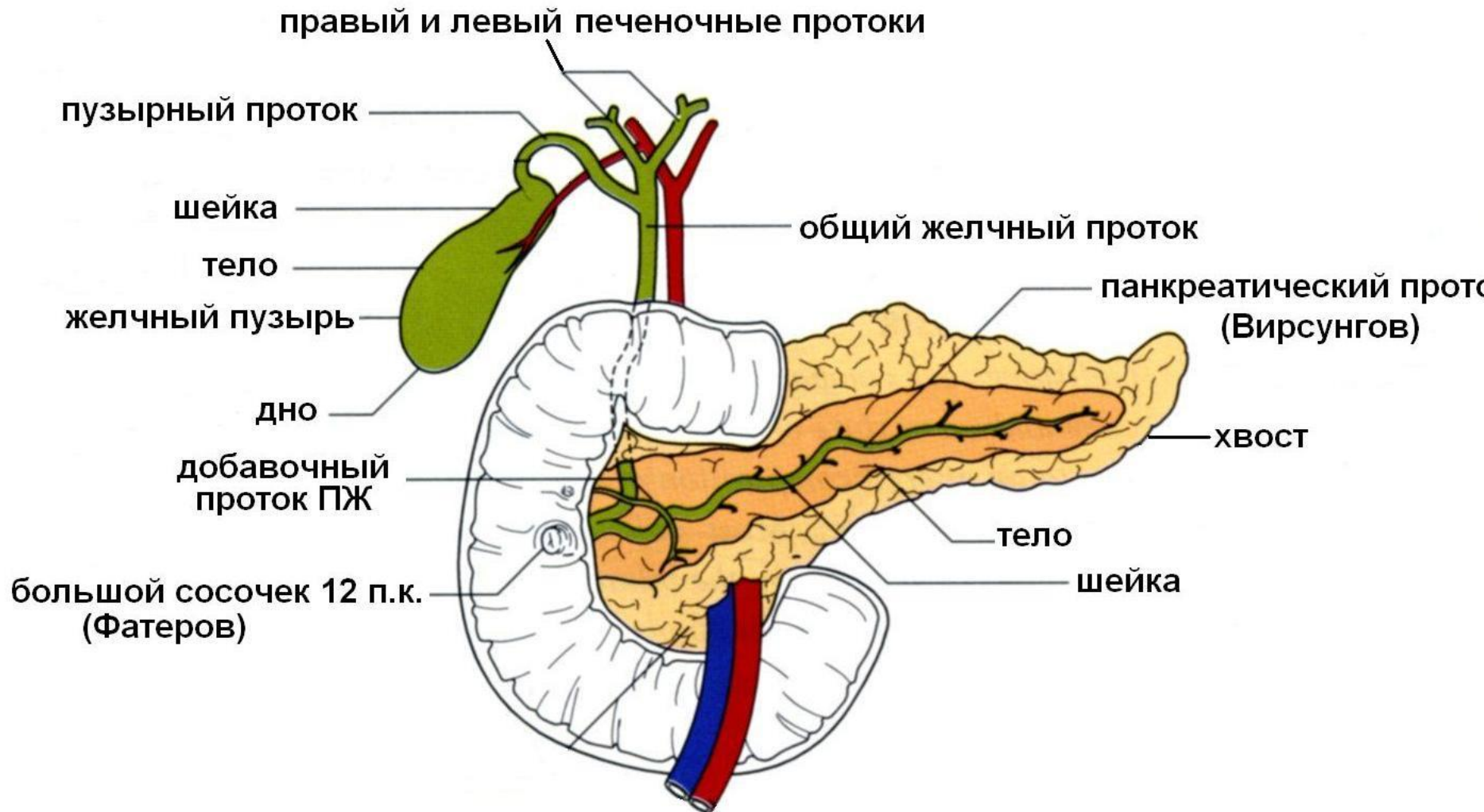
# Atriopeptin

## (sodium uretical factor)

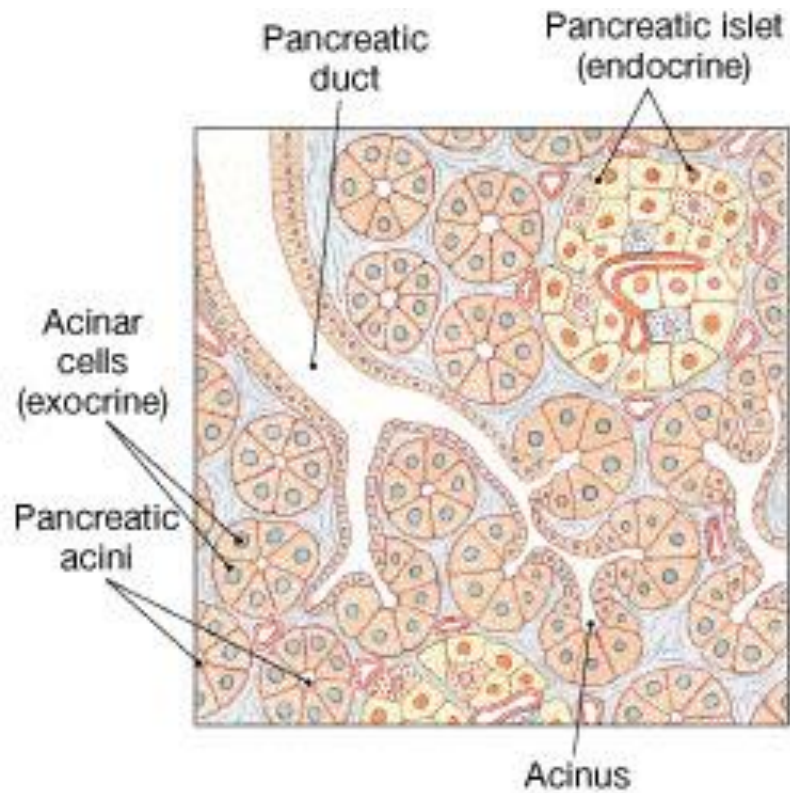
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- Produced by atrial myocytes in response to high blood pressure
- **Effects - decreasing blood pressure:**
  - Reduced sodium reabsorption in the dist. tubules
  - Acceleration of filtering
  - The suppression of the renin and aldosterone synthesis

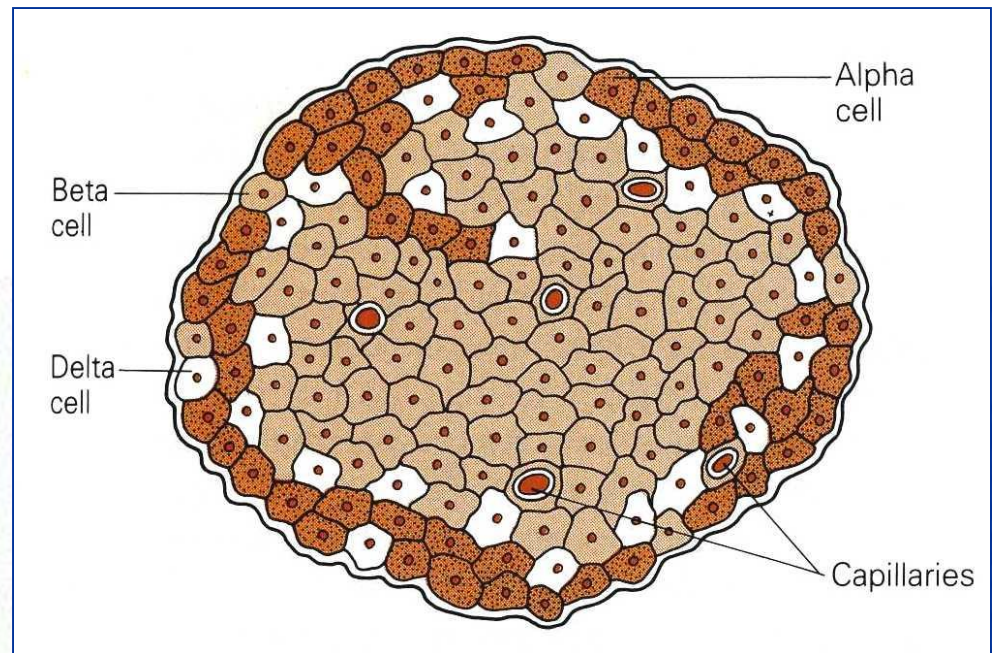
# Pancreas



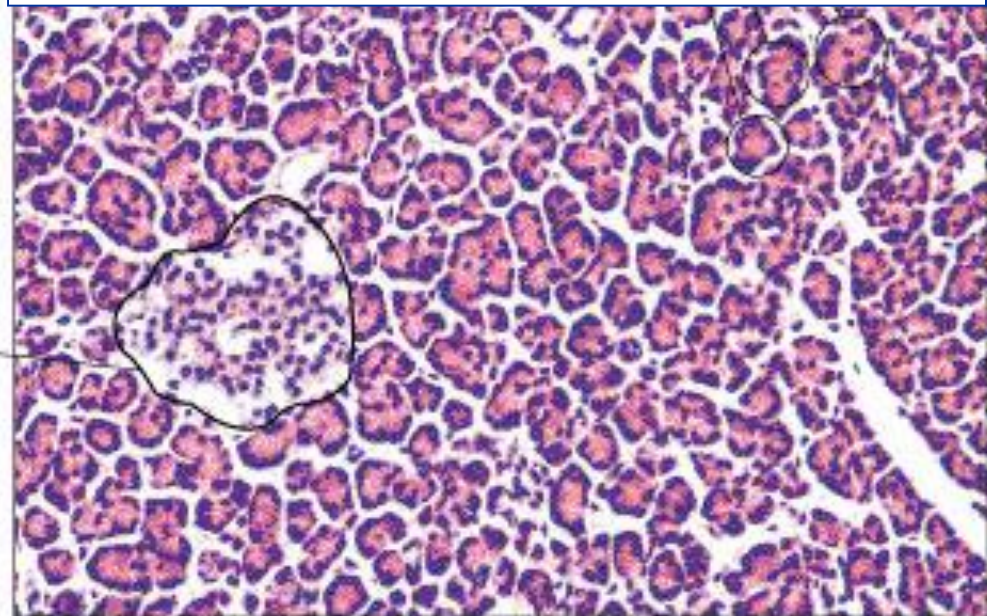




**(b) Pancreatic histology**



Pancreatic islet (endocrine)

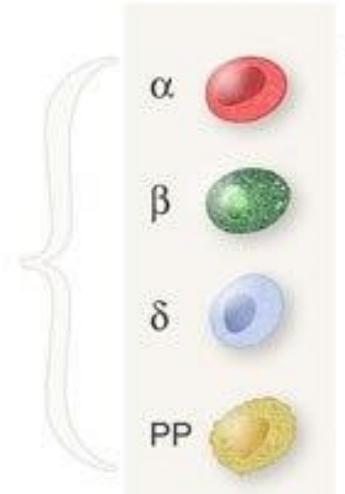
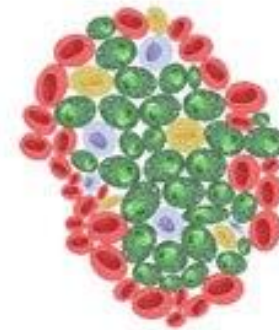


**(c) Exocrine and endocrine cells (LM x 120)**

# Cells of the Langerhans islets

- $\beta$ -cells (insulin)
- $\alpha$ -cells (glucagon)
- $\Delta$ -cells (somatostatin)
- F-cells (pancreatic polypeptide)

Traditional islet





# Insulin - the anabolic

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- **Decreases the blood glucose level:**
  - Carries glucose from the blood into the cells
  - «Excess» glucose stores as glycogen (in liver and muscles)
- Puts the fat from the blood into fat cells
- Stimulates the synthesis and deposition of fatty acids
- Stimulates the synthesis and deposition of protein

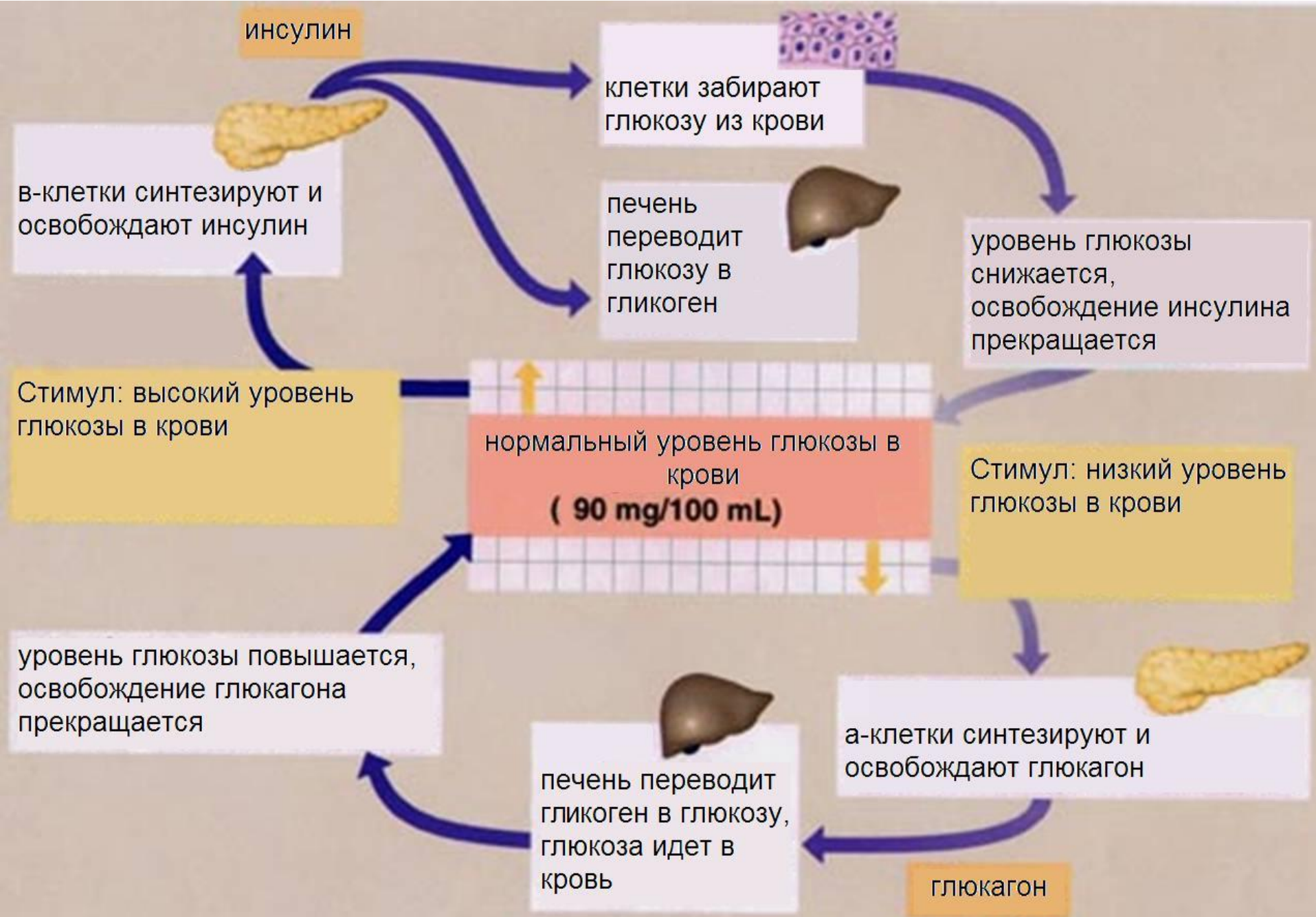


# Glucagon – the katabolik

---

- Raises the blood glucose levels:
  - Stimulates the release of glucose from glycogen ( glycogenolysis )
  - Stimulates the formation of glucose from fat and protein (gluconeogenesis)
    - Stimulates the breakdown of fat (lipolysis)
    - Stimulates the breakdown of protein







# Other hormones

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## ■ Somatostatin

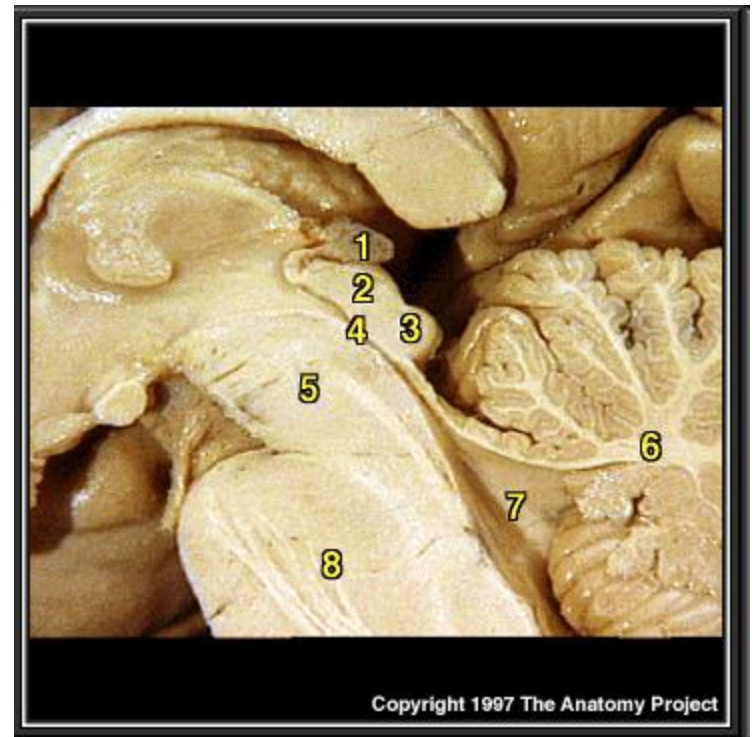
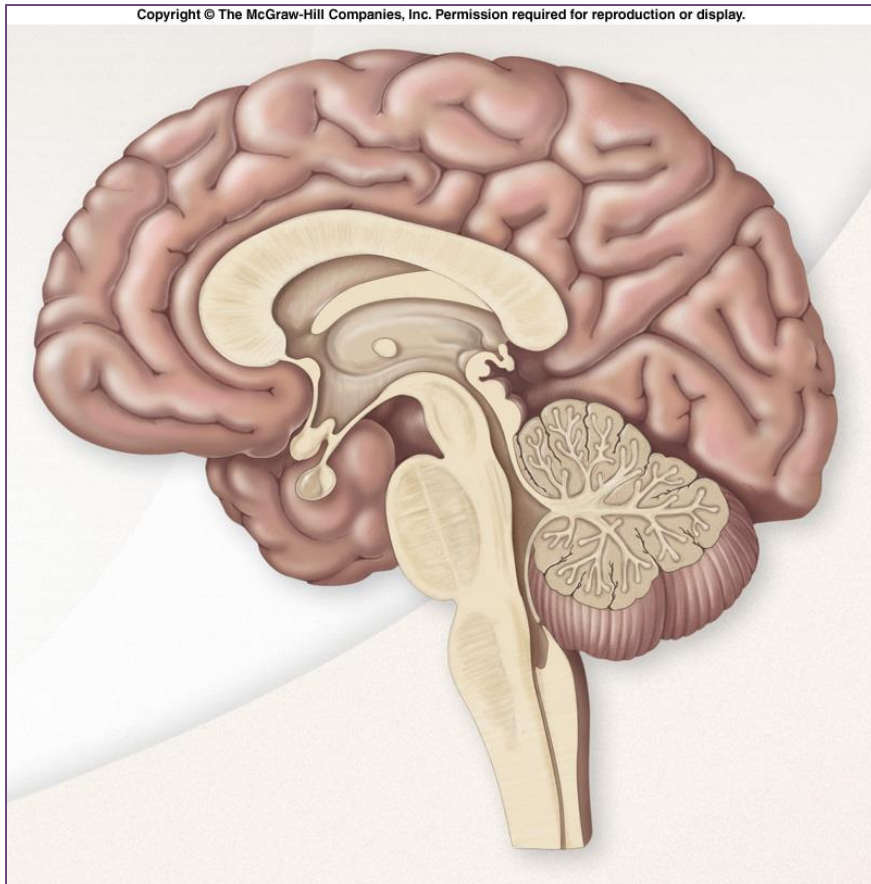
- An analogue of the hypothalamic somatostatin
  - Inhibits the secretion of growth hormone in the pituitary
  - Regulates the secretion of insulin and glucagon in the islets cells

## ■ Pancreatic polypeptide

- Suppresses the external secretion function of the pancreas

# Epiphysis

- Part of the diencephalon (1)





# Hormones

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- The precursor — **serotonin** (in the daytime, it needs glucose and ultraviolet irradiation )
  - Sleep, appetite, mood, emotion
  - Algesia
  - Sexual arousal and inhibition
- **Melatonin** (in the nighttime from the serotonin)
  - The regulation of circadian (daily, seasonal) rhythms
  - The suppression of the gonadotropic hormones secretion by the pituitary
  - Antitumor activity

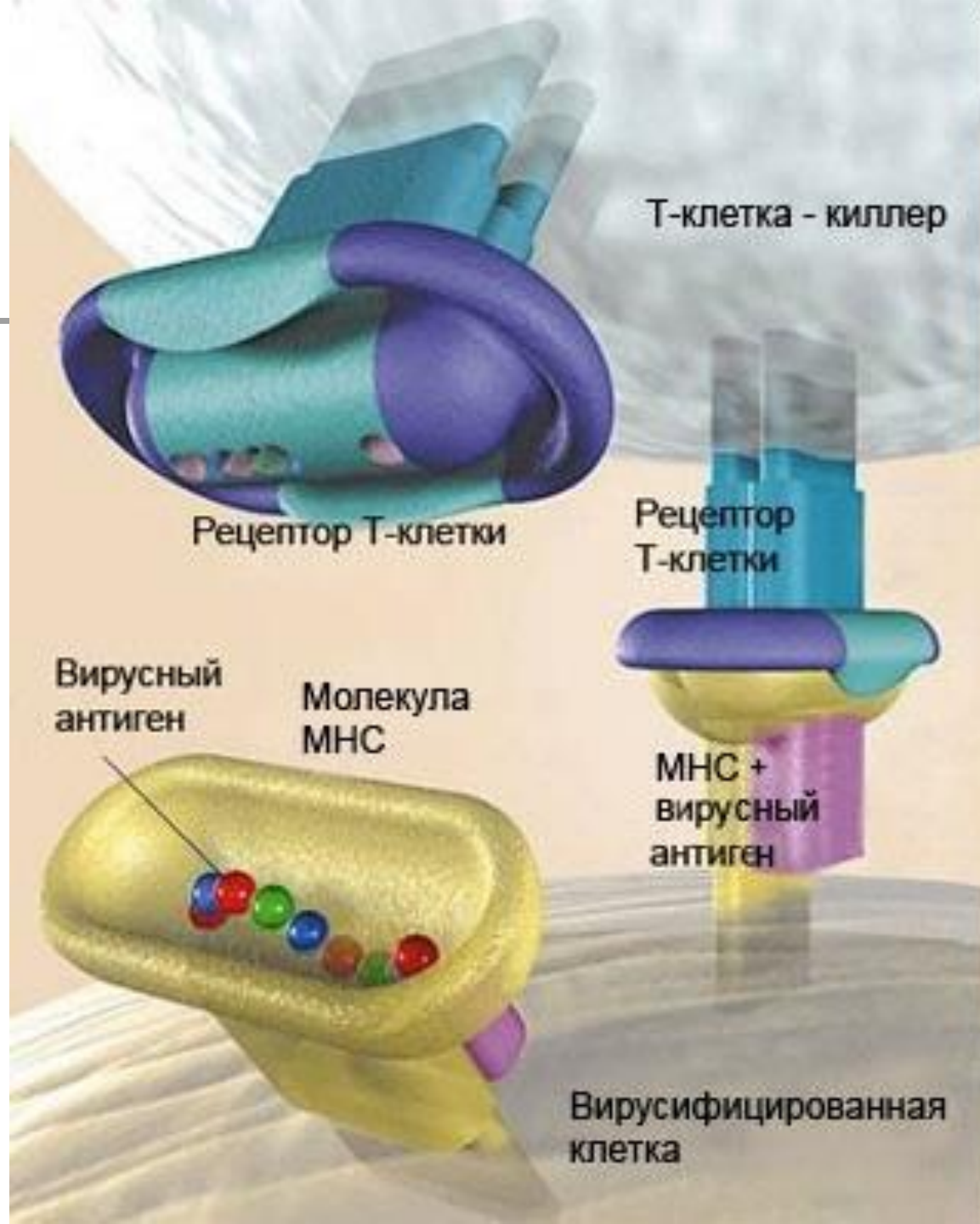


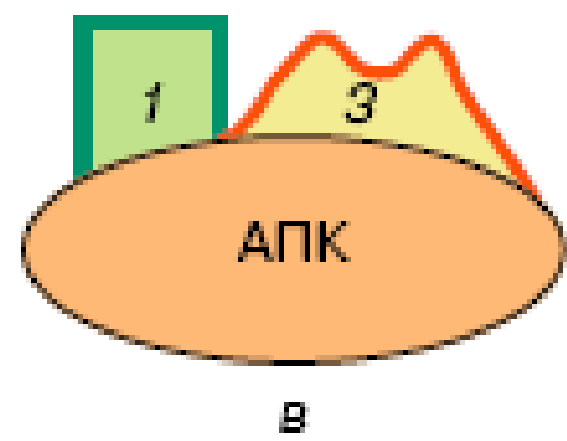
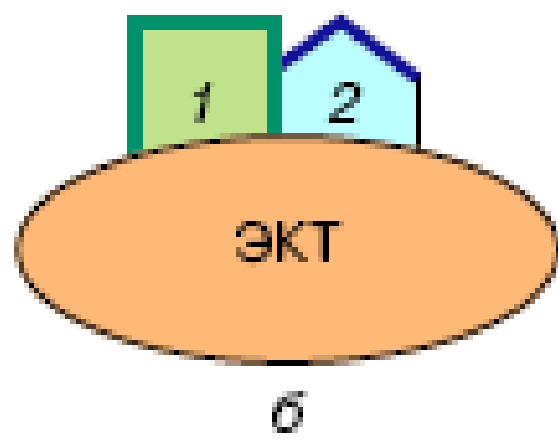
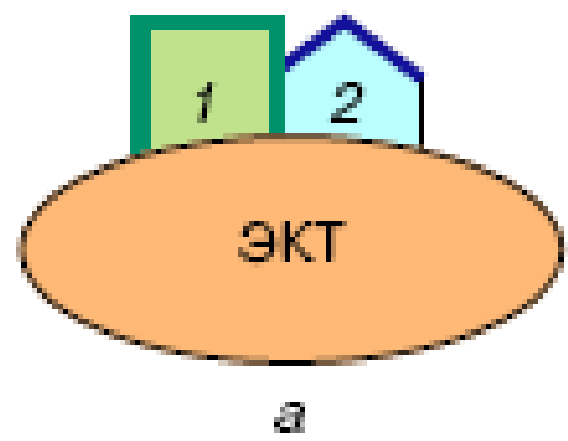
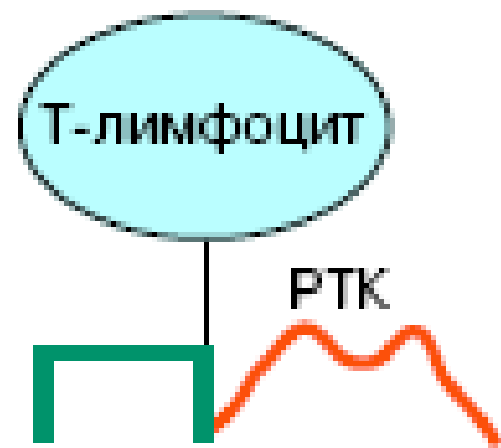
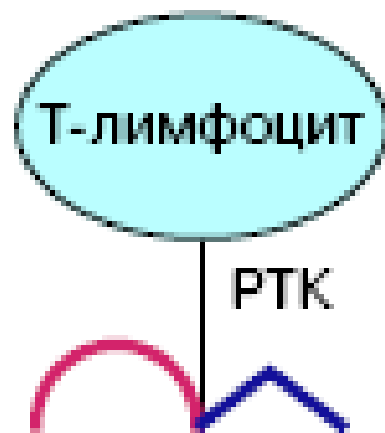
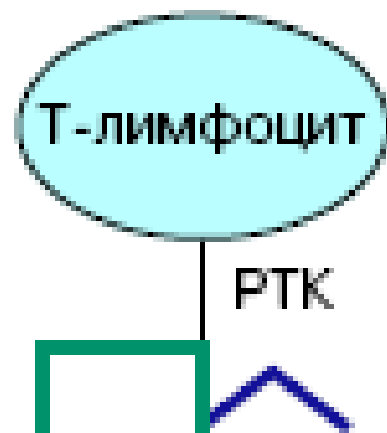
# Thymus



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- There is a differentiation and training of T-lymphocytes in the thymus
- The process is regulated by the thymus epithelial cells hormones- **thymopoietins**
- The function of the thymus is inhibited by glucocorticoids

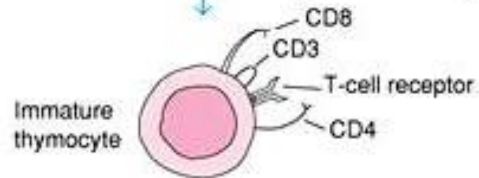




Thymocyte from bone marrow



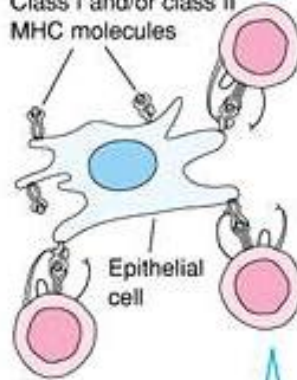
Rearrangement of TCR genes



Positive selection of cells whose receptor binds MHC molecules

Death by apoptosis of cells that do not interact with MHC molecules

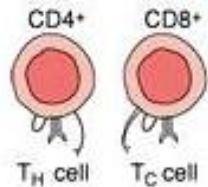
Class I and/or class II MHC molecules



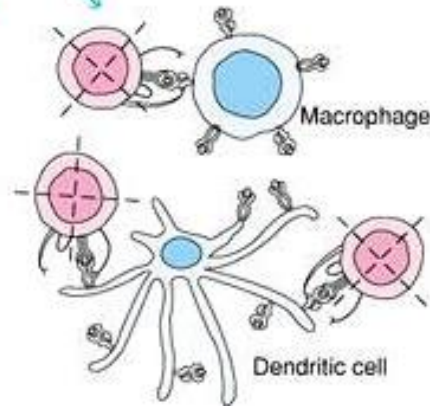
Epithelial cell

THYMIC CORTEX

Negative selection and death of cells with high-affinity receptors for self-MHC or self-MHC + self-antigen

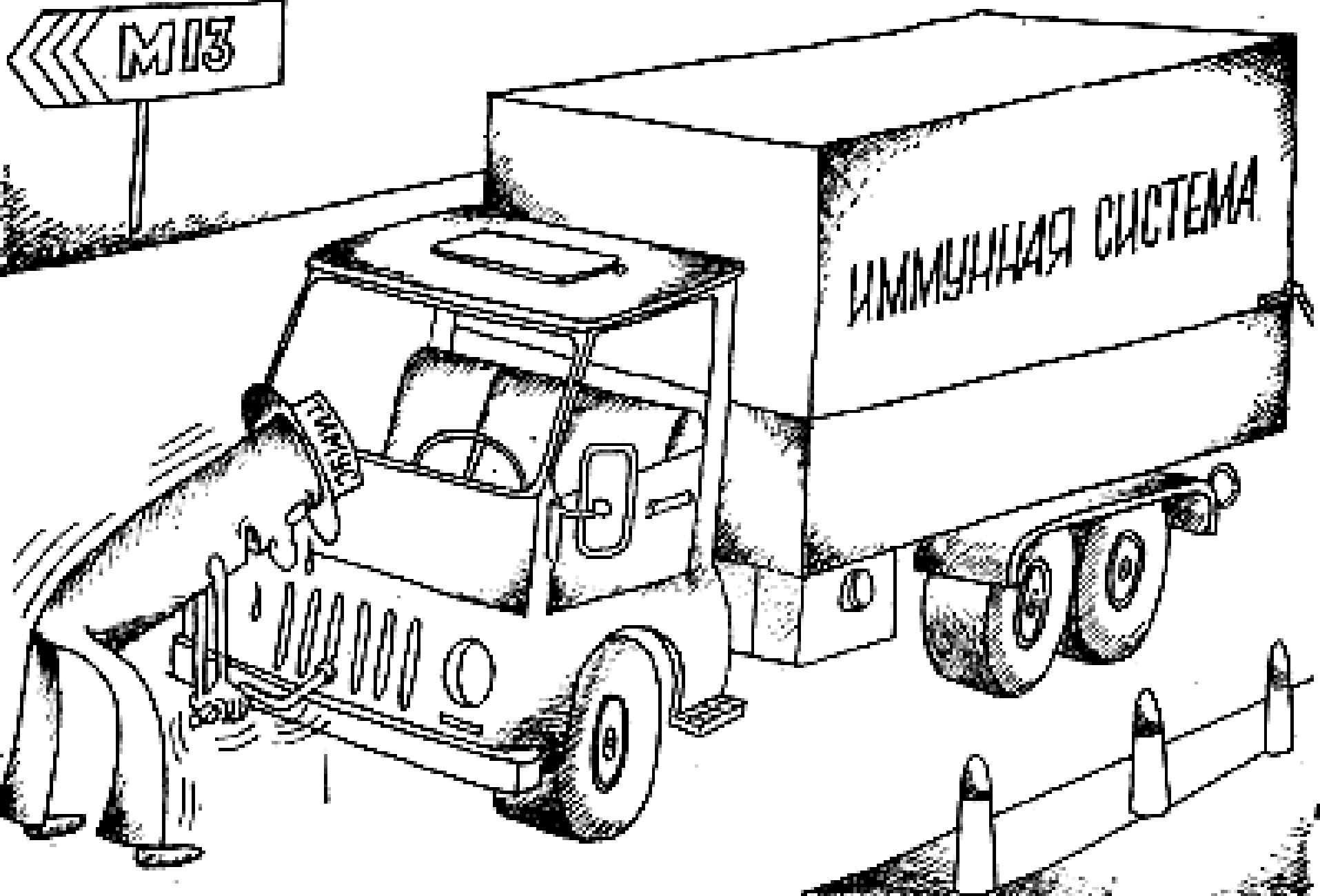
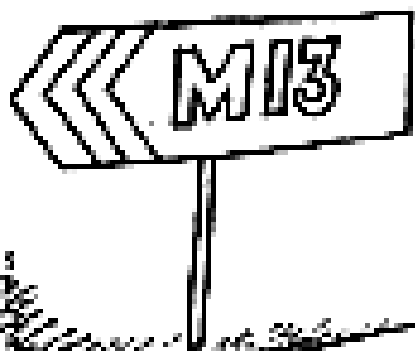


Mature CD4<sup>+</sup> or CD8<sup>+</sup> T lymphocytes



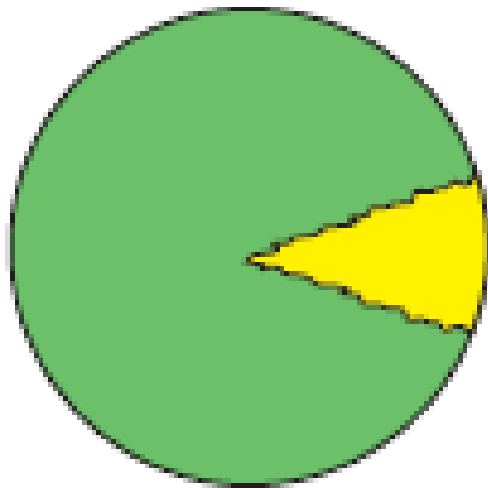
THYMIC MEDULLA



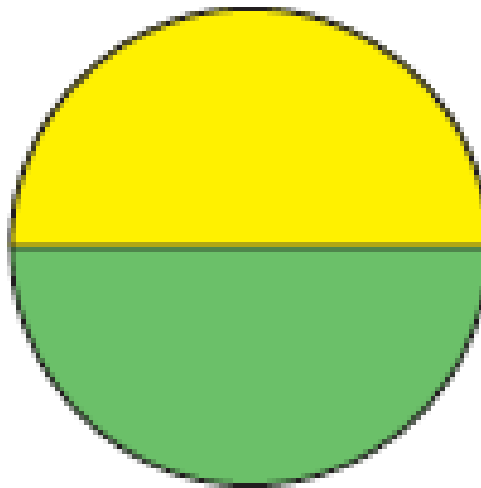




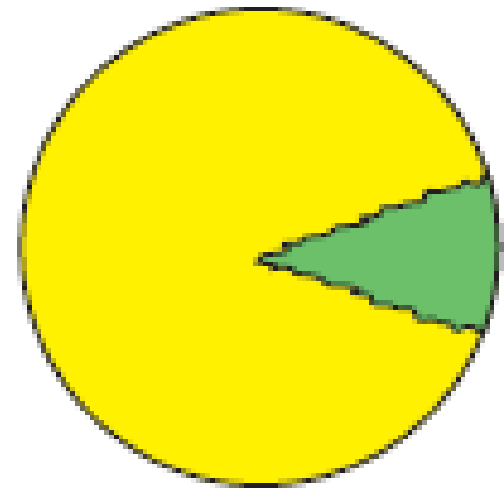
# Involution of the thymus



1 год



20 лет



50 лет