Endocrine system

Pineal Gland
- Cone-shaped gland in the brain
- Located in the brain
- Contains pinealocytes
- Synthesizes hormone melatonin
- Secretes melatonin
- Cerebrospinal fluid

Pituitary Gland
- Anterior lobe
- Posterior lobe
- Connected to the hypothalamus
- Size of a pea
- 2 distinct regions of the gland
- Helps maintain blood pressure
- Helps regulate metabolism
- Helps balance insulin
- Helps slow the immune system's inflammatory response

Adrenal Gland
- Located above your kidneys
- Helps maintain blood pressure
- Helps regulate metabolism
- Helps balance insulin
- Helps slow the immune system's inflammatory response

Thymus
- Role in the immune system
- Produces thymosin

Pancreas
- Secretes digestive enzymes
- Secretes glucagon and insulin

Testes/Ovaries
- Secretes testosterone
- Development of reproductive structure
- Skeletal and muscular growth
- Distribution of body hair
- Voice change
- Ovaries: 2 hormones
- Testes: development/puberty, menstrual cycle
- Contribute to the development and function of the female reproductive organs and sex characteristics
- Estrogen
- Progesterone

Thyroxine: triiodothyronine
Intercellular communication

- **Neurocrine**: Blood
- **Endocrine**: Blood
- **Paracrine**: Tissue
- **Autocrine**: Tissue
- **Synaptic**: Synapsis
- **Contact**: Local

Distant

Local
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)
Pituitary gland (*gl. pituitaria*)

- sphenoid bone
- sella turcica
- fossa hypophysialis
Pituitary gland (*gl. pituitaria*)

- Hypothalamus
- Optic chiasm
- Superior hypophyseal artery
- Diaphragmatic sellae
- Dura mater
- Anterior lobe of pituitary
- Posterior lobe of pituitary
- Inferior hypophyseal artery
- Inferior hypophyseal vein
- Sella turcica of sphenoid bone
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 rhythms
  - 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 magnocellular neurons in nucleus supraopticus and paraventricularis
- terminating on fenestrated capillaries in neurohypophysis
- synthesis of prohormones $\rightarrow$ maturation during axonal transportation
- capillary plexus from arteria hypophysialis inferior (branch of arteria carotis interna $\rightarrow$ v. lobi posterioris

**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) $\rightarrow$ hypophyseal portal veins (venae portales hypophysiales) $\rightarrow$ secondary capillary plexus in adenohypophysis $\rightarrow$ v. lobi anterioris $\rightarrow$ sinus cavernosus $\rightarrow$ v. jugularis interna
Capillary system of hypophysis

ncl. paraventricularis

ncl. supraopticus

Tractus hypothalamo-hypophysialis

hypophyseal arteries

anterior lobe

secondary plexus of posterior 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.
A = fossa
B = hypothalamus
C = eminentia mediana
D = adenohypophysis
Adenohypophysis (anterior lobe)

Chromophilic cells

**Acidophils**

Nonglandotrophic
- direct effect on target tissues

**Bazophils**

Glandotrophic
- 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 → cortisol)
• MSH (target: melanocytes - mostly in paracrine way)
• lipotropin (lipolysis, steroidogenesis)
• endorphins
FSH (folitropin), LH (lutropin)

- gonadotropic cells of adenohypophysis stimulated by GnRH
- glycoproteins, 30kDa
- heterodimer, two noncovalent bound subunits (α/α - common for - LH, FSH, TSH, hCG, β/β - specific)
- FSH receptor (testes, ovary, 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)

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

- thyrotropic cells of adenohypophysis stimulated by TRH
- production of T4 (thyroxin) and T3 (triiodothyronin) by thyroid gland
- glycoprotein, 28.5 kDa, heterodimer, two noncovalent bound subunits (α, β)
- 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>
<thead>
<tr>
<th>Substances</th>
<th>Cell Types</th>
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<tbody>
<tr>
<td><strong>PEPTIDES</strong></td>
<td></td>
</tr>
<tr>
<td>ACTIVIN B, INHIBIN, FOLLISTATIN</td>
<td>F, G</td>
</tr>
<tr>
<td>ALDOSTERONE STIMULATING FACTOR</td>
<td>UN</td>
</tr>
<tr>
<td>ANGIOTENSIN II (ANGIOTENSINOGEN, ANGIOTENSIN I CONverting ENZYME, CAThePSIN B, RENIN)</td>
<td>C, G, L, S</td>
</tr>
<tr>
<td>ATRIAL NATURETIC PEPTIDE</td>
<td>G</td>
</tr>
<tr>
<td>CORTICOTROPIN-RELEASING HORMONE-BINDING PROTEIN</td>
<td>C</td>
</tr>
<tr>
<td>DYNORPHIN</td>
<td>G</td>
</tr>
<tr>
<td>GALANIN</td>
<td>L, S, T</td>
</tr>
<tr>
<td>GAWK (CHROMOGANIN B)</td>
<td>G</td>
</tr>
<tr>
<td>GROWTH HORMONE RELEASING HORMONE</td>
<td>UN</td>
</tr>
<tr>
<td>HISTIDYL PROLINE DIKETOPIPERAZINE</td>
<td>UN</td>
</tr>
<tr>
<td>MOTILIN</td>
<td>S</td>
</tr>
<tr>
<td>NEUROMEDIN B</td>
<td>T</td>
</tr>
<tr>
<td>NEUROMEDIN U</td>
<td>C</td>
</tr>
<tr>
<td>NEUROPEPTIDE Y</td>
<td>T</td>
</tr>
<tr>
<td>NEUROTENSIN</td>
<td></td>
</tr>
<tr>
<td>PROTEIN 7B2</td>
<td>G, T</td>
</tr>
<tr>
<td>SOMATOSTATIN 28</td>
<td>UN</td>
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<tr>
<td>SUBSTANCE F (SUBSTANCE K)</td>
<td>G, L, T</td>
</tr>
<tr>
<td>THYROTROPIN RELEASING HORMONE</td>
<td>G, L, S, T</td>
</tr>
<tr>
<td>VASOACTIVE INTESTINAL POLYPEPTIDE</td>
<td>G, L, T</td>
</tr>
<tr>
<td><strong>GROWTH FACTORS</strong></td>
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</tr>
<tr>
<td>BASIC FIBROBLAST GROWTH FACTOR</td>
<td>C, F</td>
</tr>
<tr>
<td>CHONDROCYTE GROWTH FACTOR</td>
<td>UN</td>
</tr>
<tr>
<td>EPIDERMAL GROWTH FACTOR</td>
<td>G, T</td>
</tr>
<tr>
<td>INSULIN-LIKE GROWTH FACTOR I</td>
<td>S, F</td>
</tr>
<tr>
<td>NERVE GROWTH FACTOR</td>
<td>UN</td>
</tr>
<tr>
<td>PITUITARY CYTOTROPIC FACTOR</td>
<td>UN</td>
</tr>
<tr>
<td>TRANSFORMING GROWTH FACTOR ALPHA</td>
<td>L, S, G</td>
</tr>
<tr>
<td>VASCULAR ENDOTHELIAL GROWTH FACTOR</td>
<td>F</td>
</tr>
<tr>
<td><strong>CYTOKINES</strong></td>
<td></td>
</tr>
<tr>
<td>INTERLEUKIN-1 BETA</td>
<td>T</td>
</tr>
<tr>
<td>INTERLEUKIN-6</td>
<td>F</td>
</tr>
<tr>
<td>LEUKEMIA INHIBITORY FACTOR</td>
<td>C, F</td>
</tr>
<tr>
<td><strong>NEUROTRANSMITTERS</strong></td>
<td></td>
</tr>
<tr>
<td>ACETYLCHOLINE</td>
<td>C, L</td>
</tr>
<tr>
<td>NITRIC OXIDE</td>
<td>F</td>
</tr>
</tbody>
</table>

C = corticotroph, F = folliculoestellate 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
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 neurosecretory termini
- Herring bodies – neurosecretory endings – dilatation close to capillaries

Hormones
- oxytocin (OT)
- antidiuretic hormone (ADH, vasopresin)
Neurosecretory Ending (posterior pituitary).

- Pituicyte processes
- Axon
- Capillary
- Endothelium
- Neurosecretory vesicles
- Basal lamina

Origin of ADH.
- Hypothalamic neuron
- Unmyelinated axon
- Fenestrated capillary
- Herring bodies

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Principal Action</th>
<th>Principal Nucleus of Origin</th>
</tr>
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<tbody>
<tr>
<td>Oxytocin (OXY)</td>
<td>Uterine contraction, milk ejection</td>
<td>Paraventricular</td>
</tr>
<tr>
<td>Anti-diuretic hormone (ADH)</td>
<td>Water excretion in kidney, arteriolar constriction</td>
<td>Supraoptic</td>
</tr>
</tbody>
</table>
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>
<thead>
<tr>
<th>Anatomy</th>
<th>Microscopic anatomy</th>
<th>Hormones and target tissues</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anterior lobe (adenohypophysis)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pars distalis</td>
<td>superior hypophyseal arteries $\rightarrow$ secondary capillary plexus $\rightarrow$ hypophyseal portal veins + inferior hypophyseal arteries $\rightarrow$ secondary capillary plexus $\rightarrow$ hypophyseal portal veins $\rightarrow$ vv. jugulares internae</td>
<td>chromophobes&lt;br&gt;undifferentiated cells&lt;br&gt;degranulated chromophilic cells&lt;br&gt;stromal cells&lt;br&gt;lack hormonal activity</td>
</tr>
<tr>
<td>pars tuberalis</td>
<td></td>
<td>dopamin (PIH) $\perp$&lt;br&gt;(PRF $\rightarrow$ prolactin) &lt;br&gt;directly liver and growth plates other tissues via somatomedins</td>
</tr>
<tr>
<td>pars intermedia</td>
<td></td>
<td>somatostatin (GHIH) $\perp$&lt;br&gt;GHRH $\rightarrow$ somatotropin (STH)</td>
</tr>
<tr>
<td><strong>Posterior lobe (neurohypophysis)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>eminentia mediana $\rightarrow$ infundibulum</td>
<td></td>
<td>ADH $\perp$&lt;br&gt;myometrium of uterus during gravidity&lt;br&gt;myoepithelium of lactating mammary gland</td>
</tr>
<tr>
<td>pars nervosa</td>
<td></td>
<td>oxytocin</td>
</tr>
<tr>
<td></td>
<td>anterior and posterior superior hypophyseal arteries $\rightarrow$ primary capillary plexus, fenestrated capillaries</td>
<td>nonmyelinated axons&lt;br&gt;of hypothalamic neurons n. supraopticus, n. paraventricularis (tractus hypothalamohypophysialis), pituicytes</td>
</tr>
</tbody>
</table>
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 (c. pineale)

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

![Diagram of Melatonin production](attachment:melatonin.png)

- L-TRYPTOPHAN
- TRYPTOPHAN HYDROXYLASE (TPH)
- 5-HYDROXYTRYPTOPHAN (5-HTP)
- AROMATIC-L-AMINO-ACID DECARBOXYLASE
- 5-HYDROXYTRYPTAMINE (5-HT, SEROTONIN)
- SEROTONIN N-ACETYL TRANSFERASE OR AA-NAT
- HYDROXYINDOLE O-METHYLTRANSFERASE (HOMT)
- N-ACETYL-SEROTONIN (NAS)
- RELEASE IN BLOOD
- MELATONIN
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 $2 \text{I}^- \rightarrow \text{I}_2$.
- 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) $T_4$
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. parathyreoeidea)

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 (7-10µm, big nucleus
  - mildly acidophilic
  - PTH – calcium metabolism

- **Oxyphylic**
  - large, polyhedral,
  - strongly acidophilic
  - round nucleus
  - glycogen
Parathyroid gland (gl. parathyreoidea)
Parathyroid hormone (PTH, parathormone, parathyrinin)

- 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

1. If calcium level rises above set point
2. Thyroid gland releases calcitonin
3. Blood calcium level falls
4. If calcium level falls below set point
5. Parathyroid glands release parathyroid hormone (PTH)
6. Blood calcium level rises

Homeostasis: Blood calcium level
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**

- **Pharyngeal cleft:** invagination of ectoderm between adjacent arches
- **Pharyngeal pouch:** invagination of endoderm between adjacent arches

**Ectoderm**

- 1st cleft forms external auditory meatus
- 2nd arch extends over 2nd, 3rd, and 4th clefts

**Mesoderm**

- Remnant of 2nd, 3rd, or 4th cleft may persist as a lateral cervical cyst

**Endoderm**

- 1st pouch forms Eustachian tube
- 2nd pouch forms palatine tonsil
- 3rd pouch forms thymus and inferior parathyroids
- 4th pouch forms superior parathyroids (5th pouch / ultimobranchial body forms C-cells of the thyroid gland)

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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 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 incortex = CORTICOSTEROIDS
• Steroidogenic cells
  - SER, lipid droplets, mitochondria
  - mineralocorticoids
  - glucocorticoids

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

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

\textbf{three arterial regions}

1) c.t. capsule and superior parts of cortex  
2) radial capillaries of cortex continuing to medulla  
3) medullar capillaries from \textit{aa. perforantes}
STRESS

Hypothalamus

Pituitary gland

Adrenal medulla

Adrenaline
- blood pressure, vasoconstriction, heart rate...

CNS (sympathicus)

Adrenal cortex

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

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