1. Autonomic nervous system (ANS) – nomenclature
2. Topographic organization and structural features of ANS
3. Main subdivisions of the ANS:
   ✓ sympathetic nervous system
   ✓ parasympathetic nervous system
   ✓ enteric nervous system
4. Sympathetic (thoracolumbar) nervous system
5. Parasympathetic (craniosacral) nervous system
6. Enteric (intrinsic) nervous system
7. Neurotransmitters, receptors and some ANS drugs
8. Autonomic innervation of the eye and salivary glands
9. Autonomic plexuses in the thoracic cavity:
   ✓ cardiac plexus
   ✓ pulmonary plexus
   ✓ thoracic aortic plexus
10. Autonomic plexuses in the abdomen – primary and secondary
    ✓ abdominal aortic plexus
    ✓ coeliac (solar) plexus
11. Autonomic plexuses in the pelvis – primary and secondary
    ✓ inferior hypogastric plexus
Definition and nomenclature

- **Autonomic Nervous System (ANS):**
  - part of the peripheral nervous system

- **autonomic** = auto (self) + nomos, _Gr. νόμος_ (law)
  - reflex, involuntary actions
  - automatic, independent, unconscious system

- **innervation of:**
  - viscera
  - glands
  - blood vessels
  - nonstriated (smooth and cardiac) muscles

- **synonyms:** **visceral (vegetative) nervous system**

- **main function** – control system to maintain life:
  - regulation and control of visceral functions
    - reproduction
    - vital body processes – circulation, digestion, secretion and excretion etc.
Structural organization

- **two-neuron efferent system** (visceral efferent neurons):
  - first *(preganglionic)* neuron – inside the CNS
  - second *(postganglionic)* neuron – in a ganglion or plexus of neurons

- Perikarya of visceral afferent neurons:
  - in dorsal root (spinal) ganglia
Main subdivisions

- tripartite integrated system (Langley, 1921):
  - sympathetic nervous system
  - parasympathetic nervous system
  - enteric nervous system (ENS)
Structural and neurochemical differences

- **Sympathetic nervous system:**
  - equal pre- and postganglionic fibers
  - autonomic ganglia proximally located
  - preganglionic fibers – cholinergic (ACh)
  - postganglionic fibers – adrenergic (A, NA)

- **Parasympathetic nervous system:**
  - longer pre- vs. postganglionic fibers
  - autonomic ganglia located nearby targets or within their walls (intramural ganglia)
  - preganglionic fibers – cholinergic (ACh)
  - postganglionic fibers – cholinergic (ACh)
Functional considerations

- **parasympathetic reactions:**
  - generally localized and **anabolic** – day-to-day internal processes and behavior
  - conservation of body energies during rest, preparing us to go to sleep and digest

- **sympathetic reactions:**
  - mass responses – **catabolic**
  - mobilize body energies in stressful situations, preparing us for fight, flight or fright

**NB:** antagonistic actions of both components to maintain homeostasis!
Parasympathetic nervous system

- craniosacral division:
  - cranial region:
    - cranial nerves III, VII, IX, X
  - sacral region:
    - spinal cord segments S2-S4

- Cranial nerves:
  - III, VII, IX, X
# Sacral division

## Organs and Their Innervation

<table>
<thead>
<tr>
<th>Organ</th>
<th>Preganglionic Neuron Level</th>
<th>Postganglionic Neuron Site</th>
<th>Effect of Stimulation</th>
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<tr>
<td>Distal colon</td>
<td>S2–S4</td>
<td>Intramural ganglion</td>
<td>Enhanced peristalsis</td>
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<td>Urinary bladder</td>
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<td>Hypogastric plexus</td>
<td>Inhibition of anal sphincter</td>
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<td>Genitals</td>
<td>S2–S4</td>
<td>Hypogastric plexus (pelvic plexus)</td>
<td>Contraction of bladder wall</td>
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<td>Inhibition of urethral sphincter</td>
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<td>Vasodilation, penile/clitoral erection</td>
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</tbody>
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*Parasympathetic outflow (via pelvic splanchnic nerves)*
Sympathetic nervous system

- thoracolumbar division – Th1-L2 segments:
  - preganglionic sympathetic axons
    - intermediolateral column of spinal cord
  - paravertebral sympathetic ganglia
    - sympathetic chain (trunk)
  - prevertebral sympathetic ganglia
    - celiac ganglion
    - superior mesenteric ganglion
    - inferior mesenteric ganglion
two symmetrical ganglionated cords:

- **cervical part – 3 ganglia:**
  - superior cervical ganglion – 2.5-3 cm
    - jugular nerve
    - laryngopharyngeal and superior cardiac branches
    - internal and external carotid branches
  - middle cervical ganglion (60%) – 0.7-0.8 cm
    - thyroid and middle cardiac branches
  - inferior cervical ganglion ⇒ in 75% cervicothoracic (stellate) ganglion – up to 2.8 cm
    - inferior cardiac branch

- **thoracic part – 11-12 segmentally arranged ganglia**
  - greater splanchnic nerve – ganglion VI-IX
  - lesser splanchnic nerve – ganglion X-XI
  - lowest (renal) splanchnic nerve – ganglion XII

- **lumbar part – 3-4 segmentally arranged ganglia**
  - 4 lumbar splanchnic nerves

- **sacral (pelvic) part – 4-5 segmentally arranged ganglia**
  - sacral splanchnic nerves

- **terminal ganglion impar** – anterior to the coccyx

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**Prof. Dr. Nikolai Lazarov**
Prevertebral sympathetic ganglia

- **celiac ganglion** *(semilunar or solar ganglia):*
  - largest ganglion in the ANS
  - postganglionic sympathetic neurons
  - paired, with variable position:
    - upper part joined with greater splanchnic nerve
    - lower part receives lesser splanchnic nerve ⇒ renal plexus

- **aorticorenal ganglion**
  - lower part of celiac ganglion ⇒ kidney, ureters

- **phrenic ganglion**
  - small ganglion on the diaphragm
  - located at the junction of the right phrenic nerve

- **superior mesenteric ganglion**
  - close to the origin of the superior mesenteric artery
  - unpaired, innervates part of the large intestine

- **inferior mesenteric ganglion**
  - several small bodies
  - close to the origin of the inferior mesenteric artery
  - innervate part of the large intestine
Enteric nervous system

- embedded in the walls of the:
  - esophagus
  - stomach
  - small intestine
  - colon
- triggered to act when the walls of the hollow organs are stretched by food

This local nervous system, referred to as intrinsic or enteric nervous system (ENS), functions independently of the CNS and is influenced by the ANS in a limited way.

It controls the motility, exocrine and endocrine secretions, local blood flow, and also modulates immune and inflammatory processes of GI tract.

NB: neither sympathetic nor parasympathetic!
Enteric nervous system

Plexus submucosus internus

Plexus submucosus externus

Plexus myentericus

Prof. Dr. Heinz-Juergen Krammer,
University Hospital of Heidelberg at Mannheim, Germany
The myenteric plexus (of Auerbach) primarily controls digestive tract motility [strength & frequency]

The submucous plexus (of Meissner) regulates mucosal movements and epithelial cell function [mucosal gland secretion]
- internal submucosal plexus (the true plexus of Meissner)
- external submucosal plexus (the plexus of Schabadasch)
Autonomic transmitters and receptors

- **Cholinergic transmission:**
  - release acetylcholine (ACh)
  - two types of acetylcholine receptors:
    - nicotinic receptors ($nAChR$, also known as “ionotropic" receptors)
    - muscarinic receptors ($mAChR$, also known as “metabotropic" receptors)
Cholinergic drug effects

Cholinergic drugs

- Pupillary constriction Near vision
  - Eye
- Salivation
  - Salivary glands
- Constriction Secretion
  - Bronchi
- Slowing
  - Heart
- Gastric secretion increased Colic
  - GI tract
- Diarrhea
- Voiding of urine
  - Bladder

Anticholinergic drugs

- Pupillary dilatation Far vision
  - Anticholinergic drugs
- Dry mouth
  - Anticholinergic drugs
- Relaxation Sticky dry
  - Anticholinergic drugs
- Acceleration
  - Anticholinergic drugs
- Gastric secretion reduced Constipation
  - Anticholinergic drugs
- Retention of urine
  - Anticholinergic drugs
Autonomic transmitters and receptors

Adrenergic transmission:

- release noradrenaline (norepinephrine)
- two types of adrenergic receptors:
  - α-receptors ⇒ excitatory responses
    - pharmacologically $\alpha_1$- and $\alpha_2$-receptors
  - β-receptors ⇒ cause inhibition
    - pharmacologically $\beta_1$- and $\beta_2$-receptors
Adrenergic nerve endings
Enteric neurotransmitters

- amines
  - acetylcholine – excitatory
  - noradrenaline – inhibitory (norepinephrine)
  - adrenaline (epinephrine)
  - serotonin (5-Hydroxytryptamine)

- amino acids
  - GABA

- purines
  - ATP

- gaseous messengers
  - nitric oxide
  - carbon monoxide

- NANC neurotransmitters

NB: enteric transmitters = CNS neurotransmitters
Is really there a brain in the gut?

- here are some reasons...

“The fate of a nation has often depended on good or bad digestion of a prime minister”

Prof. Dr. Nikolai Lazarov

Voltaire
Is really there a brain in the gut?

Two brains are better than one, especially if you are hungry!
Structural organization

- aggregations (a network) of autonomic nerves and ganglia:
  - situated in the thoracic, abdominal and pelvic cavities
  - innervate the thoracic, abdominal and pelvic viscera
  - pass along branches of the arterial blood vessels
  - composed of sympathetic, parasympathetic, and sensory fibers
Autonomic innervation of the eye

- **sympathetic innervation** – SCG of sympathetic trunk:
  - dilator muscle of the iris
  - tarsal muscle
  - orbital muscle (of Müller)

- **parasympathetic innervation** – oculomotor (CN III)
  - parasympathetic fibers ⇒ ciliary ganglion ⇒ short ciliary nerves:
    - sphincter muscle of the iris ⇒ constriction of the pupil
    - ciliary muscle ⇒ eye accommodation (near vision)

} Horner’s syndrome
Autonomic innervation of the salivary glands

- secretory fibers in cranial parasympathetic nerves

- parasympathetic innervation:
  - facial nerve:
    - pterygopalatine ganglion ⇒ lacrimal gland, palatine and nasal glands
    - submandibular ganglion ⇒ submandibular and sublingual glands
  - glossopharyngeal nerve:
    - pharyngeal plexus, lingual branches
    - tympanic nerve ⇒ lesser petrosal nerve ⇒ otic ganglion ⇒ auriculotemporal nerve ⇒ parotid gland

- sympathetic innervation – SCG of sympathetic trunk:
  - deep petrosal nerve ⇒ pterygopalatine ganglion ⇒ lacrimal gland
  - external carotid plexus ⇒ external carotid nerves ⇒ submandibular ganglion ⇒ submandibular and sublingual glands
  - external carotid nerves ⇒ otic ganglion ⇒ parotid gland
Plexuses in the thoracic cavity

- **cardiac plexus** – contain both afferent and efferent fibers:
  - **superficial (ventral) part** – cardiac ganglion:
    - formed by cardiac branch of SCG of sympathetic trunk and cervical cardiac branches of vagus
    - gives branches to the deep part of the plexus, to the right coronary plexus and to the left anterior pulmonary plexus
  - **deep (dorsal) part**:
    - formed by cervical and upper thoracic sympathetic ganglia, cardiac branches of vagus and recurrent laryngeal nerves
    - right half supplies right anterior pulmonary plexus, right atrium and part of left coronary plexus
    - left half supplies left atrium, left anterior pulmonary plexus and greater part of left coronary plexus
Plexuses in the thoracic cavity

- **pulmonary plexus** – branches from the vagus and sympatheticus:
  - anterior part:
    - formed by cardiac branches of the SCG and vagus
  - posterior part:
    - formed by rami of the cardiac branches of the vagus, from the cardiac plexus and Th2-Th6 sympathetic ganglia
  - gives branches to the bronchi, pulmonary and bronchial vessels

- **thoracic aortic plexus** – branches to the oesophagus
Primary plexuses in the abdominal cavity

- **coeliac (solar) plexus** – the largest autonomic plexus, located at Th12-L1:
  - surrounds the coeliac artery and root of superior mesenteric artery
  - unites the coeliac ganglia
  - joined by greater and lesser splanchnic nerves

- **abdominal aortic plexus** ↔ **intermesenteric plexus**
Secondary plexuses in the abdomen

- phrenic plexus
- hepatic plexus
- left gastric plexus
- splenic plexus
- suprarenal plexus
- renal plexus → ureteric plexus
- testicular/ovarian plexus
- superior mesenteric plexus
- inferior mesenteric plexus
- superior hypogastric plexus
Gastric plexuses
Hepatic and splenic plexuses
Suprarenal and renal plexuses
Superior and inferior mesenteric plexuses

Vegetativer Innervationsbereich des Plexus mesentericus superior am Darm

Vegetativer Innervationsbereich von Plexus mesentericus und hypogastricus inferior am Darm
Ovarian/testicular plexuses
Primary plexuses in the pelvis

- **inferior hypogastric (pelvic) plexus:**
  - hypogastric nerves – sympathetic innervation
  - pelvic splanchnic nerves – parasympathetic innervation
Secondary plexuses in the pelvis

- **common (male&female) plexuses:**
  - middle and inferior rectal plexuses
  - vesical plexus

- **autonomic plexuses in the male:**
  - prostatic plexus
  - plexus of the deferent duct

- **autonomic plexuses in the female:**
  - uterovaginal plexus
  - vaginal nerves – parasympathetic
Autonomic innervation of male genitals

- innervated by both somatic and autonomic nerve fibers
- **somatic innervation:**
  - pudendal nerve
- **autonomic innervation** – parasympathetic and sympathetic fibers:
  - pelvic plexus ⇔ cavernous nerve ⇔ penis
Autonomic innervation of male genitals

- innervated by both somatic and autonomic nerve fibers
- **somatic innervation:**
  - pudendal nerve
- **autonomic innervation** – parasympathetic and sympathetic fibers:
  - pelvic plexus ↔ cavernous nerve ↔ penis

1. **Erection.** Psychic stimulation of the central parasympathetic pathway activates selected preganglionic neurons (P) to pelvic ganglia supplying parasympathetic fibers to the internal pudendal artery, where muscarinic and vasoactive intestinal polypeptide receptors cause the artery to relax, allowing blood to distend the penile cavernous tissue spaces. Cholinergic fibers also cause the relaxant transmitter nitric oxide to be released from the lining epithelium of the cavernous spaces.

2. **Secretion.** Parasympathetic ganglia in the walls of the prostate and seminal vesicles are stimulated to cause glandular secretion (via muscarinic receptors on the acini). These secretions contribute 80% of total semen volume.

3. **Emission.** Psychic stimulation of the central sympathetic pathway activates preganglionic neurons to pelvic ganglia supplying fibers to \( \alpha_1 \) receptors on the smooth muscle of vas deferens, seminal vesicles, prostate, and internal urethral sphincter.

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Autonomic innervation of female genitals

Prof. Dr. Nikolai Lazarov
Clinical notes

- the overall functional status of the body:
  - vital body processes are autonomic reflex responses;
  - many somatic-visceral and visceral somatic reflexes;
  - metabolic and mechanical irritations of autonomic nerve fibers cause different pathologic conditions;
  - an appreciation of the nuclei, fiber pathways and resulting reflex deficits from injuries are useful as a diagnostic aid in exploring the diffuse distribution of the autonomic system;
  - changes in cutaneous sudomotor and vasomotor reflexes, changes in skin temperature, and increased skin resistance to passage of a minute electric current indicate the involvement of sympathetic nerve fibers;
  - a knowledge of dermatomal and peripheral nerve distributions often can provide additional evidence to substantiate both the location and level of a nerve injury.
Thank you...