Autonomic Nervous System

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ANS: Homeostatic Balance

- Controls:
  - Smooth muscle, heart muscle
  - Glands and adipose tissue
- Antagonist branches
  - Parasympathetic
    - “Rest and Digest”
    - Refreshing and resting state
  - Sympathetic
    - “Fight or flight!”
    - Functions requiring energy
Dual interaction in ANS

Homeostasis is a dynamic balance between autonomic branches.

Rest-and-digest

Fight-or-flight

Parasympathetic activity

Sympathetic activity
Autonomic control systems

- Hypothalamus
- Pons
- Medulla
Autonomic pathways: Communication in the body

1. Sensory input
   - Hypothalamic receptors
   - Somatic and visceral sensory neurons

2. Brain stem, Hypothalamus
3. Limbic system, Cerebral cortex

4. Autonomic response
5. Endocrine response
6. Behavioral response
Autonomic pathways: Two efferent neurons

CNS → Preganglionic neuron → Ganglion → Postganglionic neuron → Target tissue
Semptatik-Parasemptatik Yolların Karşılaştırılması

**Semptatik Pathway**
- CNS
- Cholinergic preganglionic neuron
- Cholinergic nicotinic receptor
- Autonomic ganglion
- Adrenergic postganglionic neuron
- Adrenergic receptor (a or b)
- NE
- Target tissue

**Parasympathetic Pathway**
- CNS
- Cholinergic preganglionic neuron
- Cholinergic nicotinic receptor
- Autonomic ganglion
- Cholinergic postganglionic neuron
- Cholinergic muscarinic receptor
- ACh
- Target tissue
Parasympathetic System: Overview

- **Preganglionic neurons from**
  - Brain stem (III, VII, IX, X)
  - Lower spinal cord (S2-S4) [Craniosacral syst.]
    - Transmitter: ACh
- **Ganglion:**
  - Near target
  - **Nikotinic** synapses
- **Postganglionic neuron (long) → target tissue receptors (muskarinic ACh)**
Parasympathetic System: Overview

PREGANGLIONİK NÖRONLAR

Beyin sapı çekirdekleri

GANGLİONLAR

Siliyer gang.

Pterigopalatin; submandibular ganglionlar

Otok ganglion

İntramural ganglionlar

Osmatik ganglionlar

HEDEF DOKULAR

İç göz kasları (pupil ve mercek)

Nasal, ter ve tükürk bezleri

Parotis bezi

Boyun, göğüs ve çoğu karnın organları

Karın boşluğu alt bölgesi organları

P.S.S. PARASEMPATİK BÖLÜM

P.A.N. PREGANGLİONİK

S2-S4 çekirdekleri

Pelvik sinirler

İntramural ganglionlar

ANAHİSAR

Preganglionik

Postganglionik
Effects of the parasympathetic system

- Constriction (contraction)
  - Pupil
  - Bronchiols (airways of the lungs)
- Slows down the heart
- Activates:
  - Digestive system
  - Insulin secretion
  - Urine formation and excretion
  - Erection
Effects of the parasympathetic system

- Short duration (Rapid ACh metabolism)
- **Paradoxic Fear Response**
  - In excessive fear and anxiety;
    - Abnormal over-activation of parasympathetic nerves
    - *Vasovagal syncop*
  - Partial or total loss of micturation and defecation control
Sympathetic System: “Fight or Flight” response

- Preganglionic neuron *(short)*
  - From T1-L2 (Thoracolumbar system)
  - Transmitter: ACh (Cholinergic)

- Ganglia
  - Sympathetic chain, collateral ganglion, adrenal medulla*

- Postganglionic neuron *(long)*
  - Transmitter: Norepinefrine
Sympathetic System: “Fight or Flight” response
Sympathetic System: Anatomical features
Stimulatory effects of Sympathetic System

- Dilation of pupil
- Saliva rich in mucus (*salivation*) ↑
- Heart rate and stroke volume ↑
- Dilator effects:
  - Blood vessels
  - Bronchioles
  - Cathecolamine secretion ↑
  - Fat breakdown ↑
  - Ejeculation
Inhibitory effects of Sympathetic System

- Digestion
- Pankreatic secretions
- Micturation
Organs receiving ONLY Sympathetic nerves:

- Adrenal medulla – increase secretion
- Hair follicle muscles (m. arrector pili) - contraction
- Sweat glands – increase secretion
- Kidneys – Renin secretion
- Fat tissue – Release of fatty acids
- Majority of blood vessels - contraction
Antagonistically controlled organs:

- Eyes (pupil)
- Livary glands
- Heart
- Circulatory system
- Digestive system
  - Sphyncters, level of activity, secretory glands, liver
- Urinary vesicle
  - Sphyncters and vesicle contraction
# Receptors of ANS – Overview

<table>
<thead>
<tr>
<th>Receptor</th>
<th>Location</th>
<th>Response</th>
<th>Mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Adrenergic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>α1</td>
<td>Widespread</td>
<td><strong>Stimulatory</strong></td>
<td>I.C. Ca(^2+) ↑</td>
</tr>
<tr>
<td>α2</td>
<td>Sympathetic-parasympathetic endings</td>
<td><strong>Inhibitory</strong></td>
<td>cAMP ↓</td>
</tr>
<tr>
<td>β1</td>
<td>Heart, kidney, liver, adipose tissue</td>
<td><strong>Stimulatory</strong></td>
<td>Enzyme activation</td>
</tr>
<tr>
<td>β2</td>
<td>Heart, skeletal muscle, small intestines and lung vessels</td>
<td><strong>Inhibitory, relaxing</strong></td>
<td>Enzyme activation</td>
</tr>
<tr>
<td><strong>Cholinergic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nicotinic</td>
<td>ANS ganglia, NMJ</td>
<td><strong>Stimulatory</strong></td>
<td>Opens Na+ channels</td>
</tr>
<tr>
<td>Muscarinic</td>
<td>Parasympathetic and <em>cholinergic</em> sympathetic endings</td>
<td><strong>Varies</strong></td>
<td>Enzyme activation → [K⁺]</td>
</tr>
</tbody>
</table>
Synapses in the ANS

Axon of postganglionic autonomic neuron

Vesicle containing neurotransmitter

Mitochondrion

Varicosities

Smooth muscle cells
Synthesis:
Tyrosine $\rightarrow$ DOPA $\rightarrow$ Dopamine $\rightarrow$ Norepinephrine $\rightarrow$ Epinephrine (in adrenal medulla)

Degredation:
- MAO (*monoamine oxidase*)
- COMT (*catechol-o-methyl transferase*)
- Effect lasts a few seconds
- *Effect of ACh lasts 20 milliseconds*
**Synthesis and recycling of NE**

1. Action potential arrives at the varicosity.
2. Depolarization opens voltage-gated Ca²⁺ channels.
3. Ca²⁺ entry triggers exocytosis of synaptic vesicles.
4. NE binds to adrenergic receptor on target.
5. Activity ceases when NE diffuses away from the synapse.
6. NE is transported back into the axon.
7. NE can be taken back into synaptic vesicles for re-release.
8. NE is metabolized by monoamine oxidase (MAO).

**KEY**
- NE (norepinephrine)
Effects of Sympathetic System – Epinefrine and NE

• Adrenaline (epinephrine, E)
  • Increases the activity of the heart
  • Increases metabolism
  • Dilates the bronchi

• Noradrenaline (norepinephrine, levarterenol, NE)
  • Constricts the blood vessels
  • Increases the blood pressure
Adrenoreceptors

Classification of adrenoreceptors

\[ \alpha \]
- \( \alpha_{1A} \)
- \( \alpha_{1B} \)
- \( \alpha_{1D} \)
- \( \alpha_{2A} \)
- \( \alpha_{2B} \)
- \( \alpha_{2C} \)

\[ \beta \]
- \( \beta_1 \)
- \( \beta_2 \)
- \( \beta_3 \)
Adrenoreceptors

Generally:

- **β₁**: Stimulator
- **β₂**: Inhibitor-relaxing
  *The most abundant β receptor*
- **β₃**: Lipolytic *(in adipose tissue)*

- **α₁**: Stimulator
  *The most abundant α receptor*
- **α₂**: Inhibitory
Autonomic receptor mechanisms: \( \beta_1 \) Adrenergic Receptors – Stimulating effect

Target Cell
Autonomic receptor mechanisms: $\alpha_2$ Adrenergic Receptors – Inhibition

Target Cell
Autonomic receptor mechanisms: Muscarinic receptors

Target Cell
<table>
<thead>
<tr>
<th>Effector Organ</th>
<th>Parasympathetic Response **</th>
<th>Sympathetic Response</th>
<th>Adrenergic Receptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pupil of eye</td>
<td>Constricts</td>
<td>Dilates</td>
<td>α</td>
</tr>
<tr>
<td>Salivary glands</td>
<td>Watery secretion</td>
<td>Mucus, enzymes</td>
<td>α and β&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Heart</td>
<td>Slows rate</td>
<td>Increases rate and force of contraction</td>
<td>β&lt;sub&gt;1&lt;/sub&gt;</td>
</tr>
<tr>
<td>Arterioles and veins</td>
<td>—</td>
<td>Constricts Dilates</td>
<td>α β&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Lungs</td>
<td>Bronchioles constrict</td>
<td>Bronchioles dilate</td>
<td>β&lt;sub&gt;2&lt;/sub&gt;*</td>
</tr>
<tr>
<td>Digestive tract</td>
<td>Increased motility and secretion</td>
<td>Decreased motility and secretion</td>
<td>α β&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Exocrine pancreas</td>
<td>Increases enzyme secretion</td>
<td>Decreases enzyme secretion</td>
<td>α</td>
</tr>
<tr>
<td>Endocrine pancreas</td>
<td>Stimulates insulin secretion</td>
<td>Inhibits insulin secretion</td>
<td>α</td>
</tr>
<tr>
<td>Adrenal medulla</td>
<td>—</td>
<td>Secretes catecholamines</td>
<td>—</td>
</tr>
<tr>
<td>Kidney</td>
<td>—</td>
<td>Increases renin secretion</td>
<td>β&lt;sub&gt;1&lt;/sub&gt;</td>
</tr>
<tr>
<td>Urinary bladder</td>
<td>Release of urine</td>
<td>Urinary retention</td>
<td>α β&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
<tr>
<td>Adipose tissue</td>
<td>—</td>
<td>Fat breakdown</td>
<td>β</td>
</tr>
<tr>
<td>Sweat glands</td>
<td>—</td>
<td>Localized sweating</td>
<td>α</td>
</tr>
<tr>
<td>Male and female sex organs</td>
<td>Erection</td>
<td>Ejaculation (male)</td>
<td>α</td>
</tr>
<tr>
<td>Uterus</td>
<td>Depends on stage of cycle</td>
<td>Depends on stage of cycle</td>
<td>α β&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

**All parasympathetic responses are mediated by muscarinic receptors.**

*Hormonal epinephrine only*
Adrenal Medulla: A sympathetic ganglion

Adrenal cortex is a true endocrine gland.

Adrenal medulla is a modified sympathetic ganglion.

The chromaffin cell is a modified postganglionic sympathetic neuron.

Epinephrine is a neurohormone that enters the blood.

Spinal cord

Preganglionic sympathetic neuron

Blood vessel

ACh

Adrenal medulla

To target tissues
Adrenal Medulla: A sympathetic ganglion

• After sympathetic stimulation:
  • Catecholamine release to the bloodstream
    • Epinephrine (adrenaline) 80%
    • Norepinephrine (noradrenaline) 20%
    • Dopamine (trace)
  • Target:
    • Multiple targets
    • Distant targets; 10 x prolonged effect
Adrenergic drugs

- Sympathomimetic
  - Epinephrine and NE
  - Ephedrine, Tyramine, Amphetamine: Increase in NE secretion
  - Tricyclic antidepressants
    - Delay in NE degradation
Adrenergic drugs

• Sympatholytic
  • Reserpine
    • Decreases the synthesis and storage of NE
    • Used as a sedative
  • Beta blockers
    • Propranolol, atenolol
      • Negative inotropic and chronotropic effects

• Beta blockade inhibits renin and thus aldosterone release... Which result in: hyponatremia and hyperkalemia
Cholinergic drugs

- *Parasympathomimetic*
  - ACh cannot be used (breaks down rapidly)
  - Muscarinic antagonists
    - Pilocarpine: Dilates the Schlemm’s canal.
- *Nicotinic*
  - Nicotine: Stimulates all ANS and skeletal muscles
- AChe Inhibitors: Diisopropyl fluorophosphate (DFP), Physotigmin, Neostigmin (*in myastenia gravis, glaucoma etc*)
Anticholinergic drugs

- Parasympatholytic
  - Atropine (from “atropa belladonna”)
    - Muscarinic antagonist
- Areas of use
  - Pupillar dilataion
  - To dry the mucosa
  - Antidote for nerve gas (sarin)
Summary of efferent pathways: Somatic and autonomic control

- Somatic motor pathway
- Parasympathetic pathway
- Sympathetic pathways
- Adrenal sympathetic pathway

**Autonomic Pathways**

- CNS
- Ganglion
- Nicotinic receptor
- Muscarinic receptor
- Skeletal muscle

**Autonomic Effectors:**
- Smooth and cardiac muscles
- Some endocrine and exocrine glands
- Some adipose tissue

**KEY**
- ACh = acetylcholine
- E = epinephrine
- NE = norepinephrine
That’s all… Any questions ? ? ?

Quote of the day

“When I get a little money I buy books; and if any is left, I buy food and clothes.”

(Erasmus) 😊