◉Sheet ○Slides

Number

12

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the last lecture, we have studied the differences between the two divisions of the ANS: *sympathetic and parasympathetic* pathways which work together in controlling and regulating involuntary activities in the body . So what are the similarities?

Anatomic characteristics of ANS :

1) Neural structure : both division have two types of neurons :
a. **The preganglionic neuron** starts from the brain or spinal cord to the ganglia , then its axon synapses with the second neuron.
b. **The ganglionic neuron (postganglionic)** starts the ganglia after synapses with the first neuron , then its axon extends to the effector organ .

Adrenal gland is an exception : there is no two neurons ! only one neuron passes from the spinal cord to the adrenal gland and synapses with **endocrine cells** in the Adrenal medullae called chromaffin cells results in releasing "in the blood" :

- epinephrine (adrenaline) as a *hormone* which is acting on the activity of other structures and cells in the body
- norepinephrine (noradrenaline) function as *neurotransmitter* .

*The pathway from the origin to the effector organ is called the **Axe**. The Axe in both types consists of two neurons.

2) Organization of synapses :

- SNS : has convergence and divergence in its synapses , so :
  - ✓ *it can receive inputs from upper, lower and middle segments*
  - ✓ *its reactions are almost diffusible .*
- PNS : don't have convergence and divergence in its synapses , so its reactions are limited (localized) .

Physiological characteristics of ANS :

1. **speed of onset:** ANS can produce dramatic changes in the level of activity of organs they innervate within seconds . *The response happens immediately with stimulation .*
2. **Autonomic nature:** functions and the regulation by this system occur without conscious control , you have **reflexes** activate the reactions of the ANS .
3. **Tonic activity** (for each division): the balance between sympathetic and parasympathetic activity . For example , at the same time **Autonomic Tone** can be :

a. Increasing the level of activity of the SNS = Increasing the rate of generating action potentials.
b. Decreasing the level of activity of the PNS = Decreasing the rate of generating action potentials .

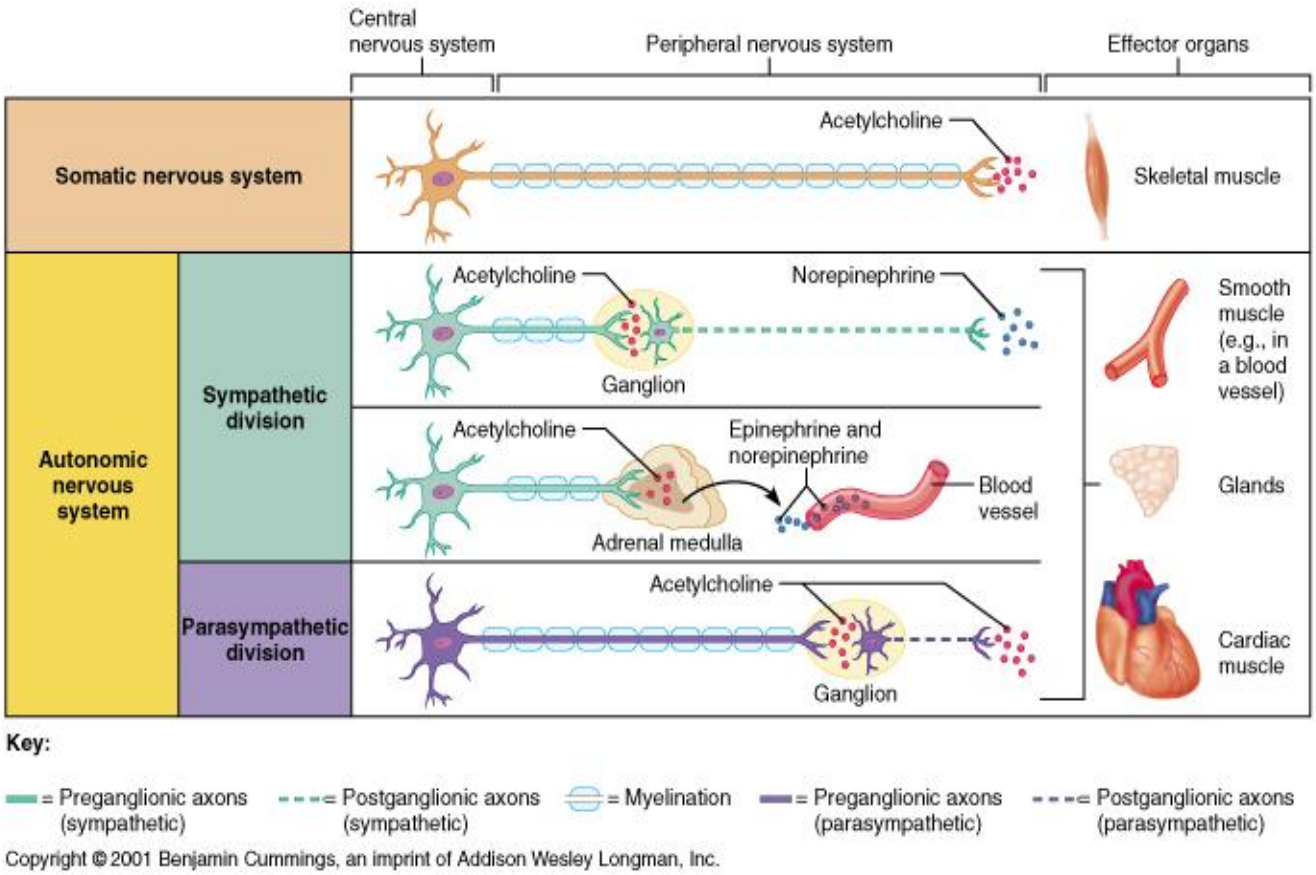
So, the autonomic system is continually active.

Note : some tissues and organs are *widely distributed tissues* , have **only sympathetic innervation** (no parasympathetic to work in opposition to sympathetic) because we need a system with high-diffuse effects , these structures include :

Most blood vessels , sweat glands , the kidneys and the Adrenal medullae . Still they have tonic activity :

a. An increase in sympathetic tone has one effect .
b. A decrease in sympathetic tone has the opposite effect .

all neurons generate action potentials at certain *rate* = (*number of action potentials / unit of time*) . So both SNS and PNS do that !



Effects of the sympathetic stimulation

1. **Controlling the blood pressure :** <u>in many ways</u> The SNS can do that ; one of them is *to change the diameter of vessels (a diffused control)* , blood vessels supplying skeletal muscle are major players , so we can get :
   I. *vasoconstriction* to increase the blood pressure.
   II. *vasodilation* to decrease the blood pressure .

In addition to that the effect on heart also contributes in regulation of blood pressure.

2. **Body temperature :** by effecting **cutaneous blood vessels** and **sweat glands.**
   - Vasodilation to lose heat from the body , vasoconstriction to keep heat in it.
   - Sweating evaporates water from the body , that causes losing heat .

The main function of the SNS is (fight-and-flight reactions) by effecting the different systems in our body , including :

3. **Cardiovascular system:** effecting vessels results in **redistribution of blood** by :
   - Enhancing blood flow to skeletal muscle.
   - Reducing blood flow to the skin and mesentery.
4. **Heart** : by increasing the heart rate and the force of contraction , increasing cardiac output (volume of blood pumped per minute).

5. **Respiratory system :** by relaxation of bronchial smooth muscles which results in bronchodilation (increasing in the diameter of bronchi so getting more air flow) to get more oxygen . This is necessary effect during fight or flight reactions .

6. **Digestive system :** inhibition of motility and secretion. (Results in dry mouth due to low salivation).

7. **Metabolic effects :** the SNS stimulation increases the following : mobilization of glucose , lipolysis and metabolic rate “the activity of metabolism reaction” . we need nutrients to have energy for the muscles and fight-and-flight reactions .

"Glucose is stored in the form of glycogen in our bodies.”

Effects of the parasympathetic stimulation

1. **Cardiovascular system :** reducing the heart rate by effecting the conductive tissue , without any change in the contractility of the heart muscle or the vessels .

How does PNS effect the heart rate ? By acting on Na+ channels :

Decreasing the permeability of Na+ results in a slow heart rate because we get slow depolarization , which is affected by the parasympathetic nervous system . While Increasing the permeability of Na+ results in fast heart rate which is affected by the sympathetic nervous system.

2. **Gastrointestinal system** : increases motility and secretory activity.
3. **Glands :** increases secretory activity in the digestive glands: like salivary glands, pancreas as a gland, other secretory cells, or glands in the gastrointestinal tract, all these glands and their activities are controlled by the parasympathetic , ***except sweat glands they <u>are not</u> under the control of PNS .***

4. **Heart** : decreases the rate of contraction (bradycardia) .
5. **Pupil** : controls pupil diameter → (regulates the amount of light falling on retina).

- ❖ Miosis: when there is a high intensity of light directed towards the pupil, the pupil becomes constricted in order to reduce the amount of light.
- ❖ Mydriasis: when the eye is under little amount of light, the pupil gets dilated , that allows more amount of light to enter the eye .

6. **Lens :** accommodation of it for near vision , you have to change the convexity of your lens according to the distance, to adapt your eyes to the required distance.
7. **Urinary bladder :** Voiding it (micturition) . Doesn't happen always , it can have some sympathetic effects .

The molecular basis of physiological actions of ANS

The molecular components which are involved in the ANS reactions :

1. *<u>The neurotransmitters</u>* which are released by the ANS neurons .

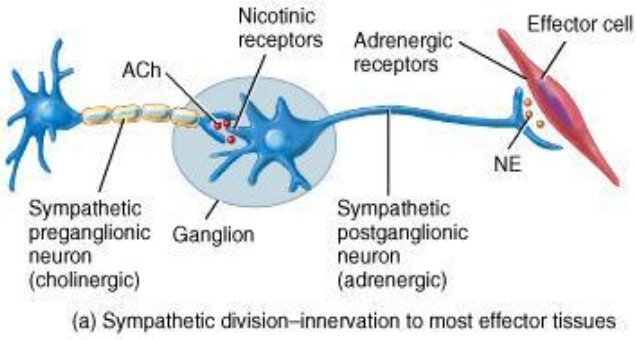
2. *<u>The receptors</u>* of these neurotransmitters.

When a neurotransmitter binds to its receptor, an action potential is generated in the second neuron (or excitable tissue) by the activation of Na+ channels

Neurotransmitters and receptors **AT GANGLION** :

1- **In both** sympathetic and parasympathetic divisions, the preganglionic fibers release **Acetylcholine** as neurotransmitters .

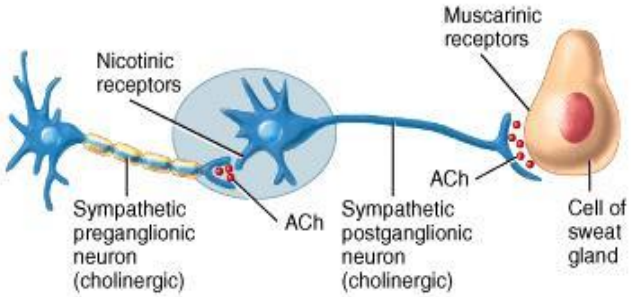
2- **In both** of them , The Acetylcholine is acting on receptors called **Nicotinic receptors** , which is located in the postsynaptic membrane of the second neuron .



(a) Sympathetic division–innervation to most effector tissues

*Why are they called nicotinic receptors 》

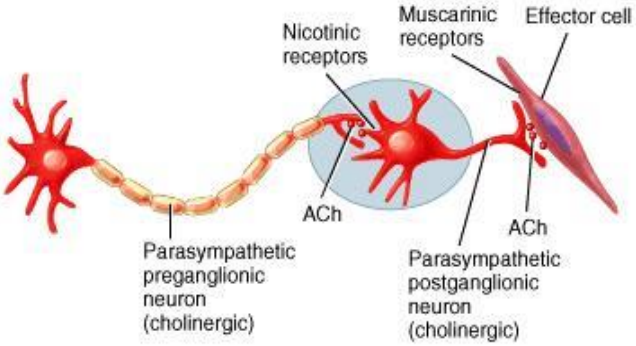
》 nicotine can bind to and activate that receptor not only acetylcholine.



(b) Sympathetic division–innervation to most sweat glands

Neurotransmitters and receptors **AT THE EFFECTOR CELLS :**

a- In sympathetic division, the second neuron releases *norepinephrine* as a neurotransmitter, its receptors are called *adrenergic receptors*



(c) Parasympathetic division

Exception : Fibers of the sympathetic system which innervate *sweat glands*, they release *acetylcholine*, which binds to *muscarinic receptors* so they are sympathetic but acting like parasympathetic.

b- In parasympathetic division, the second neuron as well as the first neuron releases *Acetylcholine* as a neurotransmitter , its receptors are called *muscarinic receptors.*

*Why they are called muscarinic receptors 》》Muscarin : is a substance we can easily find in toxic mushroom , it can bind to muscarinic receptors.

Mushroom Intoxication : if someone ate toxic mushroom , all of the parasympathetic reactions would start to happen. As muscarin binds to its receptors , The PNS is stimulated and affect all the body ; such as decreasing heart rate , increasing the gastrointestinal activity (hyper-salivation) , contracting the pupil , tearing and **increasing sweat** although sweating is considered to be under the control of the sympathetic nervous system, yet its receptors are muscarinic.

1- Muscarinic Receptors (M1-M5) :

These receptors are divided into either excitatory or inhibitory receptors:

a. Inhibitory receptors : (M2 , M4)

- *M2 in the heart :* decreasing the heart rate when it is stimulated .

G protein → increasing the activated K+ channel → slow the rate of depolarization (so we get hyperpolarization)

- *Other inhibitory receptors:*
  Gi → reduces the activity of adenylyl Cyclase → reduces cAMP (Inhibition)

Remember that : Increasing of cAMP in the heart inhibits K+ channels and activated Na+ channels

b. Excitatory Receptors: (M1, M3, M5)

Found on ***smooth muscle*** , ***glands*** and ***gastrointestinal tract*** are coupled with Gq protein phospholipase C .

This enzyme *increases production of inositol-1,4,5-trisphosphate (IP3) ,* which results in releasing calcium ions and thus having contracted muscles.

So we either have inhibition or excitation depending on the type of receptors we are having.

If a patient ate toxified mushroom : that causes the Stimulation of tissues with muscarinic receptors . **To reverse the effects of that ,** muscarinic receptors **are blocked** by using **Atropin** a medication that binds to muscarinic receptors and prevent Ach from acting on these receptors .

Activation of muscarinic receptors (symptoms of mushroom intoxication) :

- Stimulation of secretory activity: salivation, tearing, sweating, nasal and bronchial secretion.

- Increase gastrointestinal tract motility → vomiting and diarrhea.
- Contraction of urinary bladder → urination.
- Slowing of the heart → Bradycardia.

Blocking of Muscarinic Receptors by ATROPIN:

Atropin locks up all the muscarinic receptors , it is given to the patient in the form of injections "many of them until we noticed the effects of the medication" :

- Inhibition of glandular secretions : that causes dry mouth, dry eyes, and dry nasal passages.
- Tachycardia. (Increase heart rate).
- Loss of pupillary light reflex : Mydriasis
- Loss of ability to focus the lens for near vision.

*we use atropin to get a dilated pupil during the examination of eyes.

2- Adrenergic receptors : (alpha & beta)

These receptors respond to both epinephrine (adrenaline hormone) and norepinephrine (a neurotransmitter , is released by the **SNS**) by different effects and acting on different subtypes :

a. **Alpha receptors** : divide into alpha1 & alpha2 receptors .
   - Alpha 1: (Excitatory) are located in smooth muscle cells in some vessels and arterioles . When Alpha 1 is stimulated by releasing of adrenaline , *constriction* of the vessels occurs through the usual mechanism : the activation of PLC increases IP3 .
   - Alpha 2 : (Inhibitory) are located at the neuron terminals . When alpha 2 are stimulated by releasing epinephrine , the norepinephrine secretion is reduced and thus having inhibitory effect.
   - Alpha 2 Heteroreceptors : (Inhibitory) are located over neurons that are not releasing norepinephrine . *nonadrenergic

If someone was injured, would he/she feel the pain at that time ?

No ; because at this situation , most of the axons that are transmitting pain sensation are releasing epinephrine, reducing transmission of pain during activity to the CNS , and with relaxation, pain starts to be transmitted gradually.

b. Beta receptors:

- Beta 1 receptors : (Excitatory) are found in the heart , *so increasing the heart rate and the force of constriction of its muscles .*
- Beta 2 receptors : (Inhibitory) are found on tracheal and bronchial smooth muscle, in the gastrointestinal tract, and on smooth muscles of blood vessels supplying skeletal muscles to cause **relaxation** and **dilation**
  Gs activates Adenylyl cyclase so increases cAMP

* Patient with asthma suffers **constriction in the bronchioles**, and needs epinephrine which binds to beta 2 receptors and results in bronchodilation.

BE CARFUL : the asthmatic patients must be given epinephrine to dilate the bronchioles ; you have to be careful as **they might have tachycardia**. The epinephrine results in higher heart rate ; because epinephrine activates all beta and alpha receptors which include beta 1, so you should watch his heart rate so it doesn't reach dangerous levels.

Catecholamines : are epinephrine (EP) and norepinephrine (NE).

Different receptors have different affinity to the neurotransmitters : some receptors have more affinity to the EP than they have for NE ." You don't have to know them"

*Something is good to know :

In medication we use selective blockers to target one subtype of receptors , for example we have a selective blocker for beta 1 that doesn't target or block beta 2 and any other receptors , *actually it is prescribed for patients with hypertension.*

It's always your choice ! 💪

It's not too late ! ✌

Be what you want to be ❤