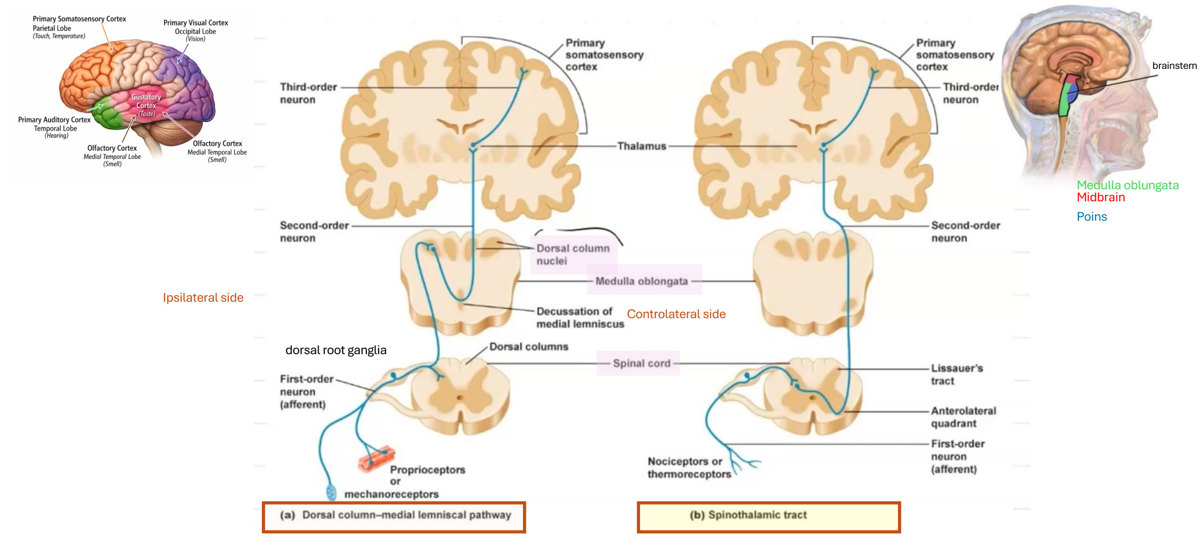
Somatosensory Pathways

Afferent way



Mechanoreceptive Information
- Touch
- Proprioception

travel along the ipsilateral side

Nociceptive information
- Pain

Thermoreceptive information
- Temperature

travel along the controlateral side

Somatosensory pathways distinguish two ways for information to travel. Both are ascending pathways, and both use three neurons (1st, 2nd, and 3rd order). The two pathways are called:
Lemniscal pathway (dorsal column–medial lemniscus)
Spinothalamic pathway (anterolateral)

Lemniscal pathway

The first-order neuron has a receptor (for example, a mechanoreceptor). Its other end enters the spinal cord, and its cell body is located in the dorsal root ganglia (pseudounipolar neuron).
Once it enters the spinal cord, it travels along the dorsal columns (hence the name of the pathway), ascending on the ipsilateral side.
When it reaches the level of the medulla (medulla oblongata), it synapses with a second-order neuron, at the level of the dorsal column nuclei.
The second-order neuron decussates, meaning it crosses to the opposite side (contralateral), at the level of the medial lemniscus. From there, it ascends to the thalamus, where it synapses with a third-order neuron.
The third-order neuron then projects to the primary somatosensory cortex.

Spinothalamic pathway

Here we start with a primary neuron that has a free nerve ending. Its cell body is also located in the dorsal root ganglia. Once it enters the spinal cord, it synapses with a second-order neuron (a projection neuron of the spinal cord), which decussates and ascends along the contralateral side of the spinal cord. It reaches the thalamus, where it synapses with a third-order neuron that projects to the primary somatosensory cortex.

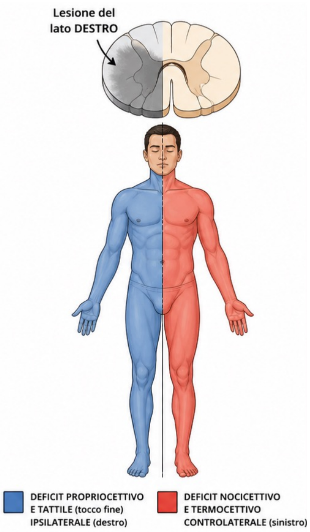
Therefore, proprioceptive information travels along the ipsilateral side of the spinal cord, while nociceptive and thermoreceptive information travel along the contralateral side.
In the case of a spinal lesion, there will be a tactile and proprioceptive deficit on the ipsilateral side, while nociceptive and thermoreceptive deficits will appear on the contralateral side.

Lesion of the RIGHT side of the spinal cord (e.g., at the thoracic level)

Right side (same side as the lesion):

has poor sense of limb position
→ **loss of proprioception**

has difficulty recognizing objects by touch
→ **loss of fine touch**



Left side (opposite to the lesion):

does not feel pain
→ **loss of nociception**

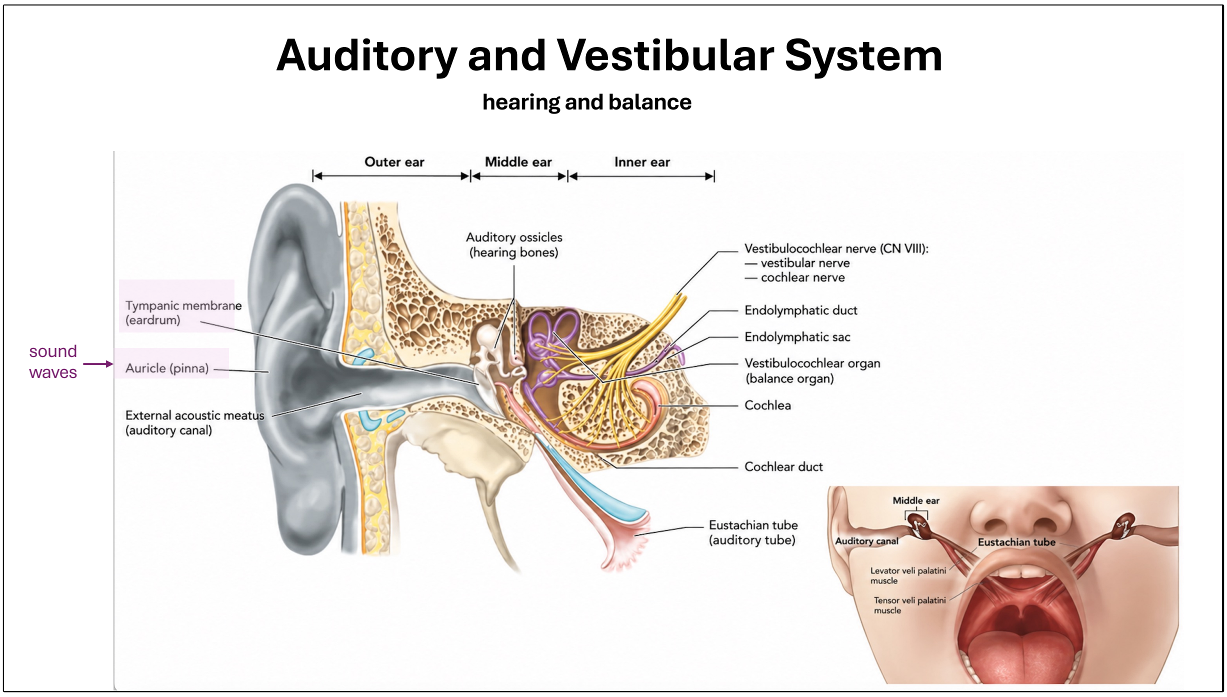
does not feel temperature (hot/cold)
→ **loss of themoreception**

Example: lesion on the RIGHT side
What happens on the side of the body where the lesion is (right side)?

Right side (same side as the lesion):

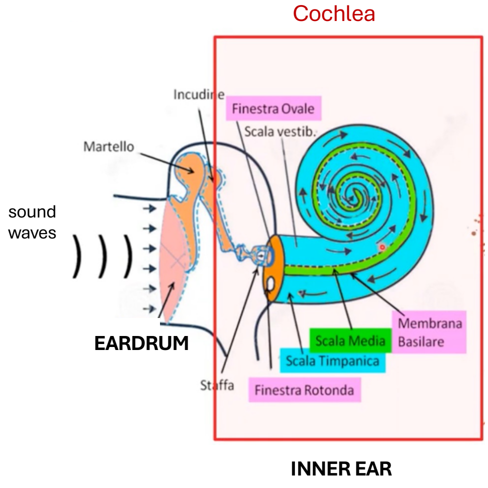
The patient:
has poor sense of limb position → **loss of proprioception**
has difficulty recognizing objects by touch → **loss of fine touch**
Example:
If the patient closes their eyes and you move the right foot, they cannot tell its position.

Left side (opposite to the lesion):
The patient:
does not feel pain
does not feel temperature (hot/cold)
Example:
If you pinch or touch the left leg with something hot, the patient does not feel it well.



The ear is the organ responsible for two different sensory systems: hearing and balance. The balance system is called the vestibular system.
The ear is made of structures located inside the temporal bone and is divided into three parts: outer ear, middle ear, and inner ear.
The inner ear contains the sensory receptors for both hearing and balance, so it is the true sensory organ.
In simple terms, the auricle (pinna) collects sound waves and sends them to the eardrum, which starts to vibrate.
These vibrations are transmitted through the small bones of the middle ear (ossicles) to the inner ear.
The middle ear contains air that comes from the pharynx through the Eustachian tube.
This tube connects the middle ear to the pharynx and allows drainage of secretions and air passage to equalize pressure.
You can experience this, for example, when going up a mountain: your ears feel blocked, and by swallowing, the pressure is balanced again.

Auditory



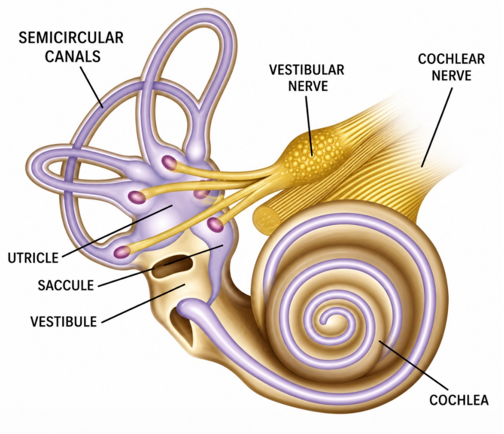
Tonotopic organization

The inner ear contains the cochlea, a spiral-shaped structure.
Sound waves enter the cochlea and set a fluid in motion. This movement causes a membrane to vibrate. On top of this membrane are located the hair cells.
What happens next?
The stereocilia bend → mechanosensitive potassium (K^+) channels open → potassium enters the cell → the cell becomes activated → a neural signal is generated.

The signal is then transmitted through the cochlear nerve (first-order neuron), which enters the brainstem and synapses with second-order neurons. From there, the signal is relayed to the central nervous system, ultimately reaching the auditory cortex, where it is perceived as sound.
Different sounds activate different regions of the cochlea:
high-frequency sounds → base
low-frequency sounds → apex
This organization is known as tonotopic organization.

The auditory system is bilateral, meaning that the signal is distributed to both sides of the brain. As a result, damage on one side can be partially compensated by the other. Therefore, central lesions do not typically cause complete deafness, because of this bilateral processing.

Vestibular



In the inner ear there are also the structures of the vestibular system:
the semicircular canals, the utricle, and the saccule.

These structures contain hair cells that detect:
- head movements
- acceleration

allowing the maintenance of balance.

The signals are transmitted through
the **vestibular nerve** (first-order neuron)
to the **central nervous system**, where they are processed.

The vestibular system is bilateral, but the signals coming from the left and right sides are compared. Therefore, the vestibular system works by comparing left and right.
Consequence:
if one side is damaged → strong imbalance
vertigo, nausea, loss of balance
because the brain receives "asymmetric" signals

Gustatory

Taste receptors are located in the **taste buds** on the tongue, which **are specialized epithelial cells**.

Signal transduction depends on the type of taste:

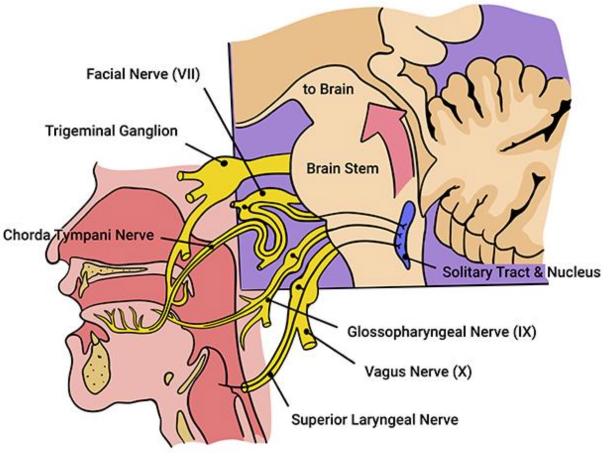
Salty / sour
direct entry of ions (Na^+ or H^+)

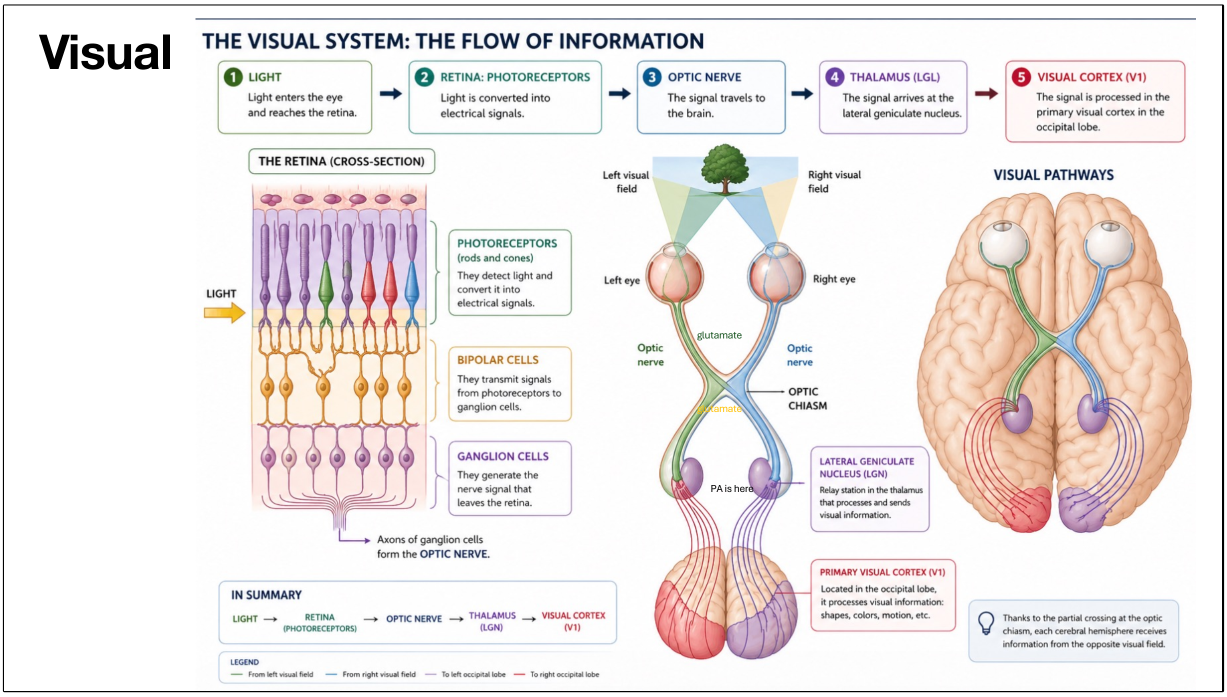
Sweet / bitter / umami
metabotropic receptors (GPCR)
→ intracellular cascade

Final result:
Depolarization followed by:
opening of Ca^{2+} channels
release of neurotransmitter

→ activation of the first-order neuron such as:

Facial nerve → anterior part of the tongue
Glossopharyngeal nerve → posterior part
Vagus nerve → epiglottis





In the retina there are specialized neurons with receptors called photoreceptors.

Photoreceptors:
composed of rods and cones.

They contain the pigment **rhodopsin**, which absorbs photons.Rhodopsin changes shape and activates a protein called transducin, which in turn activates PDE (a phosphodiesterase) that reduces cGMP levels. cGMP is essential for the activity of Na^+ channels in the retina.

Final effect:
closure of these channels
hyperpolarization
reduced release of glutamate released from photoreceptors to bipolar cells

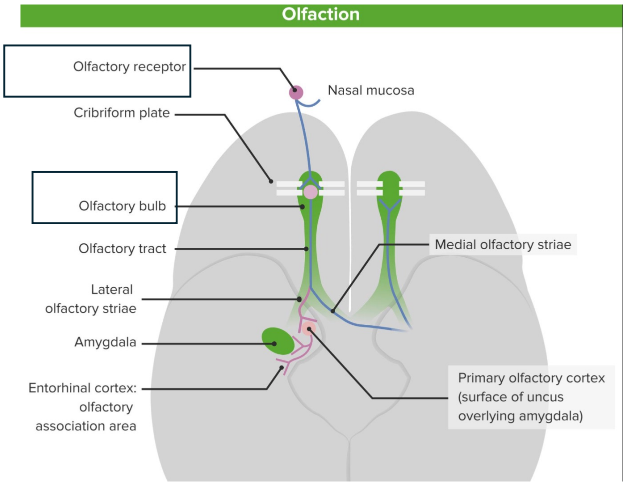
Olfactory

Smell starts in the **nasal cavity** (olfactory receptors)

Receptors (GPCR) bind odor molecules
→ **electrical signal is generated**

Signal → **olfactory bulb** (first processing is occurring) here we have neurons releasing glutamate and gamma-aminobutyric acid (GABA)

Signal → **olfactory cortex** (no thalamus first)



The olfactory system is strongly connected to the limbic system
which explains why smells are often linked to emotions and memories.

The sense of smell starts in the nasal cavity, where we find specialized neurons called olfactory receptors. These receptors are real neurons and contain metabotropic receptors (GPCR) that bind odor molecules. When an odor molecule binds, an intracellular cascade is activated and an electrical signal is generated.

The signal is then transmitted to the olfactory bulb, where the first processing occurs. From the olfactory bulb, the signal travels directly to the olfactory cortex. Unlike other sensory systems, the olfactory pathway does not pass through the thalamus first. The olfactory system is strongly connected to the limbic system, which explains why smells are often linked to emotions and memories.