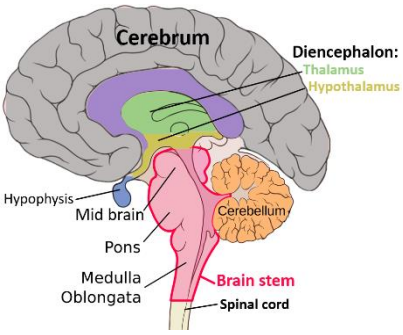
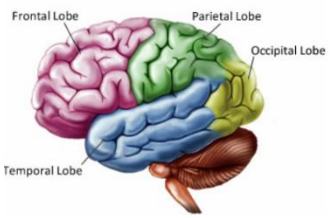
Test exam 2014-2015

1/ Name 5 main substructures of the brain



- Cerebellum
- Hippocampus
- Midbrain
- Cerebrum (*under the cerebellum, cerebral cortex*), divided into 4 lobes → frontal, parietal, occipital and temporal
- Medulla (*regulates involuntary functions like breathing, swallowing and heart rate*)
- Pons (*serves as a bridge btw various parts of the NS*)



2/ What is the typical value of the resting potential of a neuron? Describe briefly the mechanism which generates the resting membrane potential.

-70 mV → The negative resting membrane potential is determined by leak channels only permeable to K^+ ions.

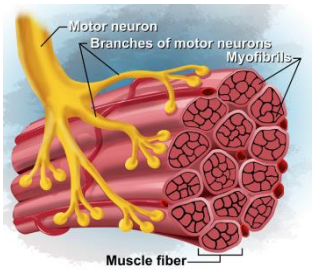
3/ Name the 2 ionotropic receptors which are localized on the postsynaptic side of most glutamatergic synapses. Which of the 2 receptors activates faster?

Ionotropic = ligand-gated ion channels

- AMPA receptor → faster
- NMDA receptor

4/ What is a motor unit?

Motor neuron + all of the skeletal muscle fibers innervated by the neuron's axon terminal



Test exam 2015-2016

1/ Briefly describe the mechanism which creates the gradient of Na^+ and K^+ ions btw the inside and the outside of the cell. What are the resulting approximate intracellular and extracellular concentrations of these 2 ions?

The Na^+/K^+ ATPase is the pump which creates the principal ion gradient over the cell membrane. At each transport cycle, 2 K^+ ions flow into the cell and 3 Na^+ ions flow out of the cell. This process requires the transformation of one ATP molecule into an ADP molecule. (*active transport*)

mV	*Intracellular* []	*Extracellular* []
K^+	140	3
Na^+	10	145

2/ Which neurotransmitter mediates transmission at the nerve-muscle synapse and what happens to it after it is released from the motor axons?

Acetylcholine → after liberation in the synaptic cleft, the neurotransmitter opens channels on the postsynaptic neuron, and this leads to depolarization of the muscle cell. ACh is then degraded by glial uptake of enzymatic degradation.

ACh binds to nicotinic acetylcholine receptor (nAChR)

3/ G-protein coupled receptors (GPCR) can be subdivided into three important classes (Gs, Gi, Gq). Identify the correct statement:

GPCR coupled to Gi:

- activate the enzyme phospholipase C
- inhibit the enzyme Adenylate Cyclase
- inhibit the enzyme phospholipase C

4/ Explain the process of primary sensory transduction in a touch receptor cell; that is, how the primary mechanical stimulus is transduced into a membrane potential response of the cell. Where are the touch receptor cells located, and in which compartment of those cells does this process take place?

Sensory transduction is the process of converting the energy of a stimulus into an electrical signal. Afferent fiber terminals that detect and transmit touch sensory stimuli (mechanoreceptors) are often encapsulated by specialized receptor cells (Ruffini corpuscle, Pacinian, etc.)

The mechanoreceptors have their nucleus in the DRG and have two ends of the axon: one near the skin which transmits the signal from the periphery toward the spinal cord, and another one which transmits the signal toward medulla.

A. Deformation of the capsule leads to a stretching of the membrane of the afferent fiber, increasing the probability of opening mechanosensitive ion channels. These are non- selective cation channels (Na+, K+).

B. Opening of the mechanosensitive ion channels leads to depolarization of the afferent fiber: graded response, receptor potential

C. If the afferent is sufficiently depolarized (*above threshold ~ -50mV*), voltage-gated Na^+ channels open and an AP is generated at the end of the axon, near the skin.

5/ In which auditory brainstem nucleus do the axons of auditory nerve fibers end, and form synapses?

- medial nucleus of the trapezoid body
- thalamus
- cochlear nucleus
- inferior colliculus

a) The auditory nerve fibers (*axons of the spiral ganglion cells in the cochlea*) enter the brainstem, where it innervates the cochlear nucleus.
b) Neurons in cochlear nucleus (*brainstem*) send ascending projections to the superior olivary complex (SOC) in the midbrain. SOC receives signals from 2 different ears while cochlear nuclei receive inputs from SGN from the ipsilateral side.
c) Neurons in SOC send projections to nuclei in the inferior colliculus in the midbrain, which then send projections to the auditory thalamus.
d) Neurons in the auditory thalamus send projections to primary auditory cortex A1.

Test exam 2018-1019

1/ Explain the principal signaling steps during transmitter release at an excitatory synapse, starting with the action potential in the presynaptic neuron, and ending with the excitatory postsynaptic potential in the postsynaptic cell.

- Glutamate is loaded into synaptic vesicles via vesicular transporter VGlut
- AP invades the presynaptic neuron
- Depolarization caused by entering AP causes presynaptic Ca^{2+} voltage-gated channels to open which causes an influx of Ca^{2+} ions into the presynaptic cell
- Ca^{2+} sensor synaptotagmin senses the Ca^{2+} ions and triggers the fusion of the neurotransmitter filled vesicles with the membrane
- The transmitters are released in the synaptic cleft via exocytosis
- The transmitters bind to receptor AMPAR and NMDAR on the postsynaptic membrane causing an opening of those channels
- The postsynaptic current flow EPSC (*movement of charges, Na^+ and K^+ ions*) causes an excitatory postsynaptic potential EPSP in the postsynaptic cell
- Removal of glutamate by glia uptake via EATT terminates the action of glutamate in the synaptic cleft

2/ Identify two examples of ligand-gated ion-channels permeable to Na^+ and K^+ ions

- GABA-receptor
- glutamate receptor of the AMPA subtype
- Voltage-gated Na^+ channel
- nicotinic acetylcholine-receptor (AChR)
- muscarinic acetylcholine-receptor
- metabotropic glutamate receptor

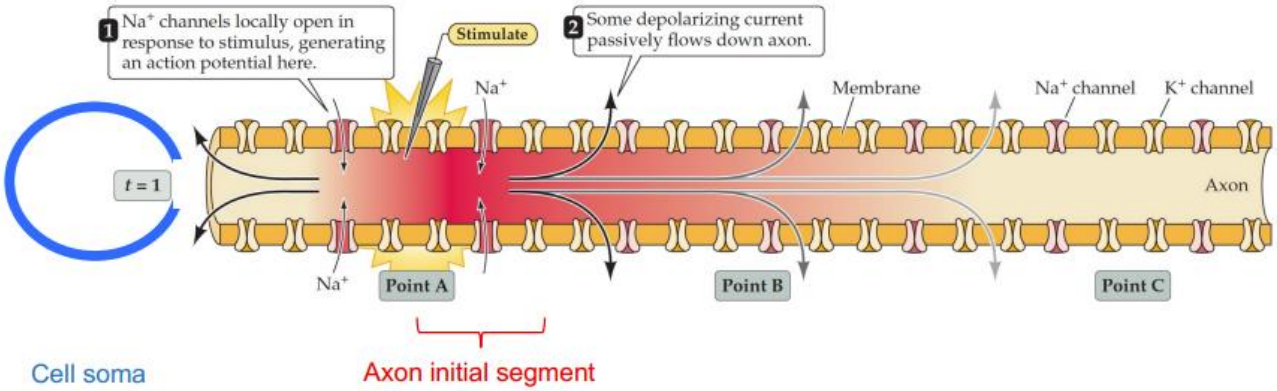
3/ Explain the primary sensory transduction of auditory signals in inner hair cells (IHCs). The flow of which ion, through what type of ion channel, depolarizes the IHC?

Depolarization of IHC = K^+ influx though mechanosensitive cation-selective hcMet channels

- a sound wave is emitted somewhere in the world
- the wave is focused on the outer ear, transmitter and amplified by the middle ear
- the energy of the sound wave moves the fluids in the inner ear
- that movement is sensed by the stereocilia sitting on top of the inner hair cells
- stereocilia bend
- tip links stretch which opens hcMet K^+ channels
- depolarization of the IHC causes Ca^{2+} channels to open at the base of the IHC resulting in a local Ca^{2+} influx
- this causes the release of glutamate transmitter in the synaptic cleft (*same mechanism as for chemical synapses in the brain*)
- the transmitter will bind on specific receptors of the postsynaptic afferent nerve
- new current generates an AP which is transmitter all the way up to the brain

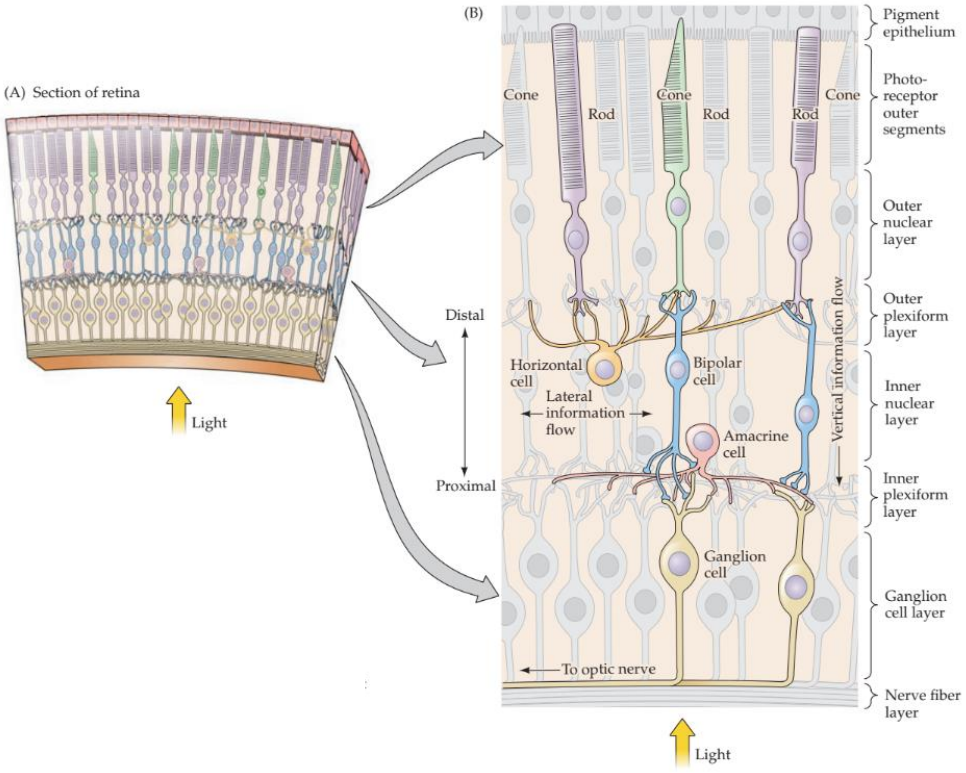
1/ How is the action potential generated, and propagated along the axon? Describe the role of two important voltage-gated currents in this process. Make a drawing that shows the action potential, and when during the action potential each current flows (*with their correct directions*)

APs are generated at the axon initial segment, near the soma, when the threshold V_m is reached. A stimulus creates a transient increase in the permeability of the neuronal membrane to Na^+ which initiates the AP. This depolarization causes the depolarization of the neighboring Na^+ channels which triggers a new AP. This cycle continues until the AP has reached the end of the axon. So, the AP flows passively downstream of the stimulus. Upstream the stimulus, Na^+ channels are inactivated while K^+ channels open. This causes a repolarization of the membrane potential and so the axon becomes refractory in that region.



Test exam 2014-2015

1/ **Make a drawing which shows the basic connections between photoreceptors, bipolar cells and retinal ganglion cells in the retina**.



Explain how the information flows to an "ON-center retinal ganglion cell" and to an "OFF-center retinal ganglion cell".

- ON-retinal ganglion cell = photoreceptor →(sign inverting) glutamate on mGluR6 and TRPM1 = hyperpolarized in darkness and depolarized in light
- OFF-retinal ganglion cell = photoreceptor → (sign conserving) glutamate on AMPA kainate = depolarized in darkness and hyperpolarized in light

Photoreceptors are hyperpolarized (-65 mV) in light and depolarized in darkness (-40 mV)

Which cell type fires action potentials and which does not? Only RGCs fire AP

Which neuron type in the output neuron of the retina? Retinal ganglion cells (RGC)

2/ **What is a motor unit**?

A motor unit is as alpha motor neuron together with all the muscle fibers it innervates. It is the smallest unit of muscle that can be controlled by the brain. When a motor neuron sends a signal to a motor unit, all of the fibers in the unit contract at the same time, producing a coordinated movement.

Test exam 2015-2016

1/ **What is the receptive field of a sensory neuron**?

It is a specific part of the sensory environment to which the neuron responds.

Briefly describe the organization of the receptive field of an ON-retinal ganglion cell.

The receptive field of an ON-retinal ganglion cell is organized into 2 distinct regions:

- The center = region of the RF that, when stimulated, causes the neuron to generate an AP and send a signal to the brain ON-center
- The surround = region of the RF that, when stimulated, causes the neuron to inhibit its activity and decrease the likelihood of generating an AP OFF-surround

This organization is important for detecting edges and boundaries in the visual environment.

Test exam 2018-2019

1/ **Please identify the two correct statements**:

- Color vision is enabled by rods that are located in the fovea of the retina
- Color vision is enabled by cones that located in the periphery of the retina
- In humans there are two opsins, long (L)- and short (S)-wave opsins expressed in cone photoreceptors
- In humans there are three opsins, long (L), medium (M) and short (S) wave opsins expressed in cone photoreceptors
- In humans there are three opsins, long (L), medium (M) and short (S) wave opsins expressed in rod photoreceptors
- Color vision is enabled by cones that are located in the fovea of the retina

Fovea = dense amount of cones = scotopic vision

Test exam 2019-2020

1/ **Name the principal layers of the neocortex**. **Which is the layer that receives input from the thalamus and from which layer occurs an important output**?

L1 to L6. L4 is the major input layer from the thalamus (LGN). L2/3 is the layer that makes the computations. It receives input from L4 and gives output to L5. L6 and L5 are the major output layer. L5 (descending) to superior colliculus. L6 (descending, cortico-thalamic) to visual thalamus LGN

!! the LGN is the lateral geniculate nucleus and is a structure in the thalamus.

VISION:

1) **What is accommodation**

Dynamic changes in the refractive power of the lens

It is the action of contraction of the ciliary muscles which decreases the tension on the Zonule fibers and makes the lens more concave (*curved*). Increases the refractive index of the lens. It helps in seeing near objects. An incapacity to accommodate the eye is the cause of many eye problems in older people. Because with age the eye muscles become weaker. So many parents have to put the book far from them in order to read what you showed them!

2) **What is the effect of color blindness**

Color blind people are unable to distinguish the colors of objects. It is a defect of the cones. People see the world with less shades of colors. It affects more men than women. Lack of one of the photoreceptors

3) **Describe the green-red opponent system**

There are 3 types of cones: S (blue), M (green) and L (red). The gene that encodes for S is located alone on chromosome 7 while genes coding for M and L are both located on chromosome X. So, it can happen that there are some crossovers, and one has a hard time distinguishing between red and green features. More a problem in men because they cannot compensate for the error on the X chromosome.

- Deuteranopia = one of the 2 chromosomes has 2 M genes and the other one has 0
- Deuteranomalous trichromat = unequal crossing over some part of the L is on the other chromosome

4) **Describe the organization of the receptive field of neurons in the primary visual cortex. Which hypothesis can be made to explain this shape**

The receptive field of neurons in the primary visual cortex encodes simple features like edges and orientation. There are 2 types of cells:

- Simple cells = receptive field has a bar in the middle which is ON and the surrounds are OFF
- Complex cells = can have more complex forms, respond more vigorously to moving bars for instance

The responses of cortical neurons are tuned to the orientation of edges, with a bar-like receptive field. The peak in the tuning curve is referred to as the neuron's preferred orientation and it has the highest rate of AP discharge. All edge orientations are equally represented in V1. As a result, a given orientation in a visual scene appears to be encoded in the activity of a distinct population of orientation-selective neurons.

A hypothesis is that the bar like receptive fields of these simple cells can be formed by combining the receptive fields of a series of LGN arranges in a line.

MOVEMENT CONTROL BY THE SPINAL CORD

1) **What is the distribution of motor neurons in the ventral horn of the spinal cord**

The motor neurons innervating distal muscles (like arms) are placed on the periphery of the ventral horn of the spinal cord, laterally. Those innervating more proximal muscles (like shoulders) are located medially in the ventral horn of the spinal cord.

2) **What is the difference and the role of alpha and gamma neurons**

Both are lower motor neurons.

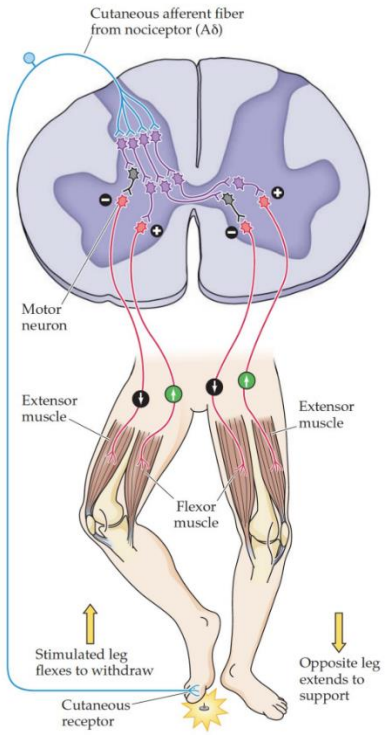
- Alpha motor neurons = innervate the striate muscle fibers that generate the forces needed for posture and movement
- Gamma motor neurons = innervate specialized muscle fibers (muscle spindles) that are sensory receptors, sensors for posture and proprioception

3) **Explain the flexion crossed extension reflex**

Mediates the withdrawal of a limb from painful stimulus!

- Stimulation of the nociceptive sensory fibers
- Excitation of ipsilateral flexor muscle
- Inhibition of ipsilateral extensor muscle
- Contralateral extensor muscle is excited
- Contralateral flexor muscle is inhibited

This reflex provides postural support during withdrawal of the affected limb from the painful stimulus.



- A tack stimulates right foot
- Right foot is retracted (flexion)
- Left foot is extended (extension)

Note the role of **inhibition** here!

MOVEMENT CONRTOL BY CORTEX AND BASAL GANGLIA:

1) **What are the 2 main descending motor systems to the spinal cord**

The corticospinal tract and the medial motor system via the brainstem

2) **What happens if you stimulate electrically specific sites in M1**

You get a movement. Motor map organized around ethologically relevant categories of motor behaviors (*hand to mouth, defensive, climbing*).

3) **What is the preferred direction of a neuron in M1 and what is a population vector**

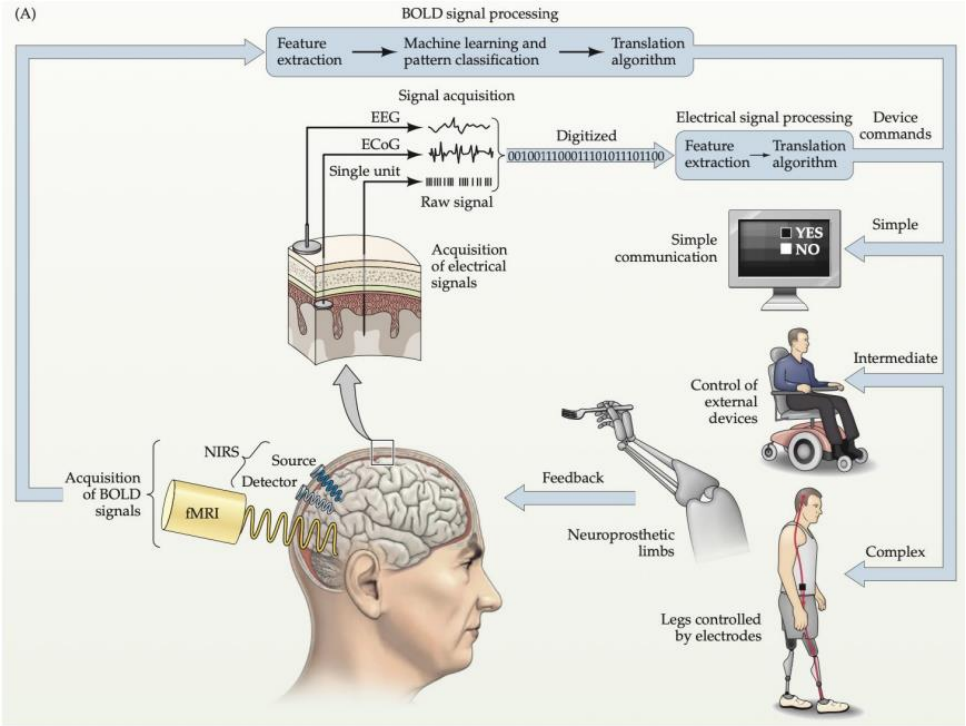
The direction in response to which the neuron fires. The neuron only fires when the movement is carried in a particular direction. A population vector is the direction of the mean AP of the considered neuron. It indicated where the preferred direction of the neuron is.

4) **What are the possible causes of Parkinson's disease**

We observe a degeneration of SNpc dopaminergic neurons. Aggregation of α-synuclein in neurons (*formation of Lewy bodies*). MPTP intoxication (*MPP^+ is uptaken by dopaminergic neurons and leads to inhibition of mitochondrial function, leading to neuronal death…*).

5) **What are the main applications of BMIs**

Communication, control of external devices, neuroprosthetics limbs, etc..



LEARNING AND MEMORY:

1) **What are the difference association cortices and their purposes**

- Parietal → attending stimuli in external and internal environments WHERE
- Frontal → short term memory, working memory, Phineas Gage, planning of purposeful behaviors
- Temporal → long-term declarative/explicit memory
- *Occipital → vision*

2) **How can you test the working memory of monkeys**

Delay response task. Show the monkey in which box the food is, then close the screen for a short time (10s to 3 min), then open it again and let the monkey take the food if it could remember where it was placed.

3) **What are the two major mechanism that could contribute to the persistent firing of neurons in the prefrontal cortex during the delay period**

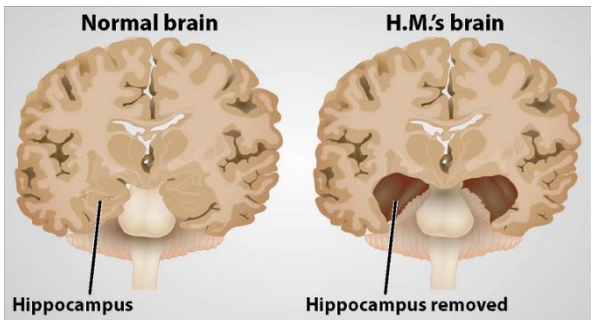
- the intrinsic membrane high electrical properties of those delay neurons. Indeed, for some neurons, a small brief electrical stimulation can lead to persistent firing that lasts for seconds or even minutes after the end of the stimulus
- excitatory neural networks leading to reverberatory activity, long-range connections between distinct regions of the brain or local circuits sustain firing

4) **What are the 4 distinct operations that involve explicit memories**

- Encoding
- Storage
- Consolidation
- Retrieval

5) **Describe the case of patient H.M. What did we learn thanks to him**

HM had a bilateral medial temporal lobectomy, so an excision of the lobe. His hippocampus was cut out. Attempt to heal his epilepsy.



He could not form new long-term memories but his memories from before the intervention and his working short-term memory was unaffected. So, we learned that the hippocampus and the temporal lobe are important for the creation of new long-term explicit memories.