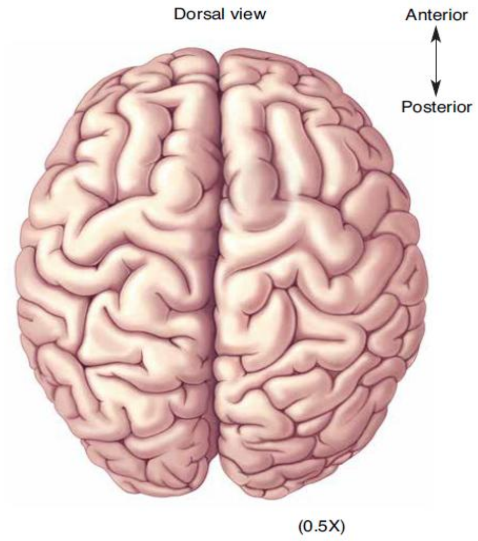
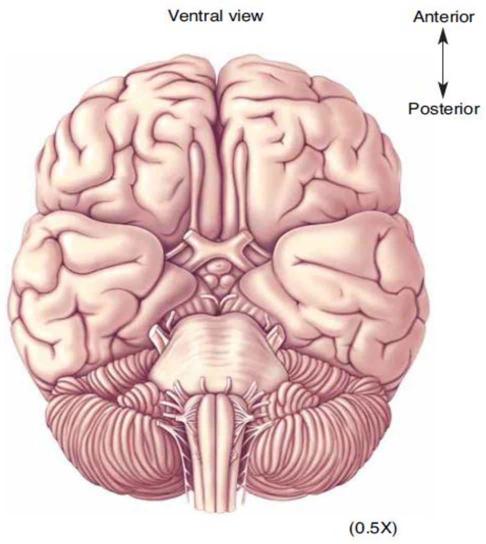
Chapter 2

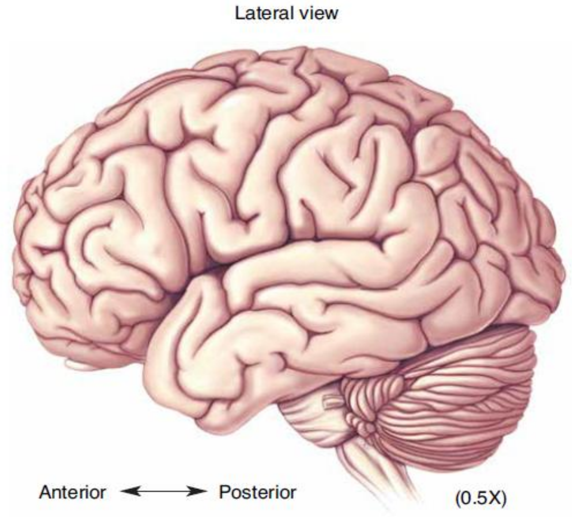
Origin of EEG

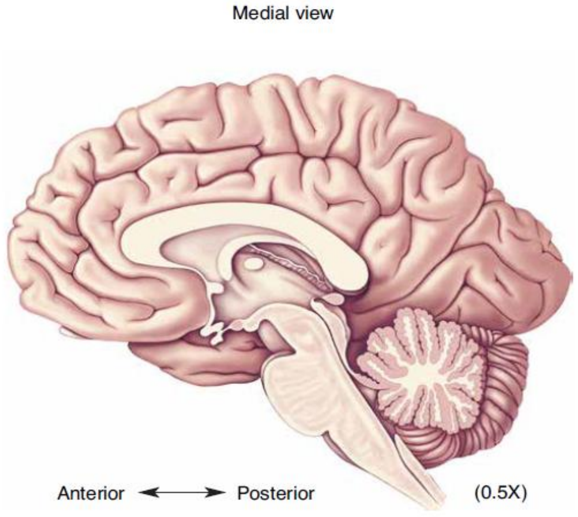
Brief Introduction to Brain anatomy





Imagine that you hold in your hands a human brain that has been dissected from the skull. It is wet and spongy, and weighs about 1.4 kilograms (3 pounds). Looking down on the brain's dorsal surface reveals the convoluted surface of the cerebrum. Flipping the brain over shows the complex ventral surface that normally rests on the floor of the skull.





Holding the brain up and looking at its side—the lateral view—shows the "ram's horn" shape of the cerebrum coming off the stalk of the brain stem. The brain stem is shown more clearly if we slice the brain right down the middle and view its medial surface. In the part of the guide that follows, we will name the important structures that are revealed by such an inspection of the brain.

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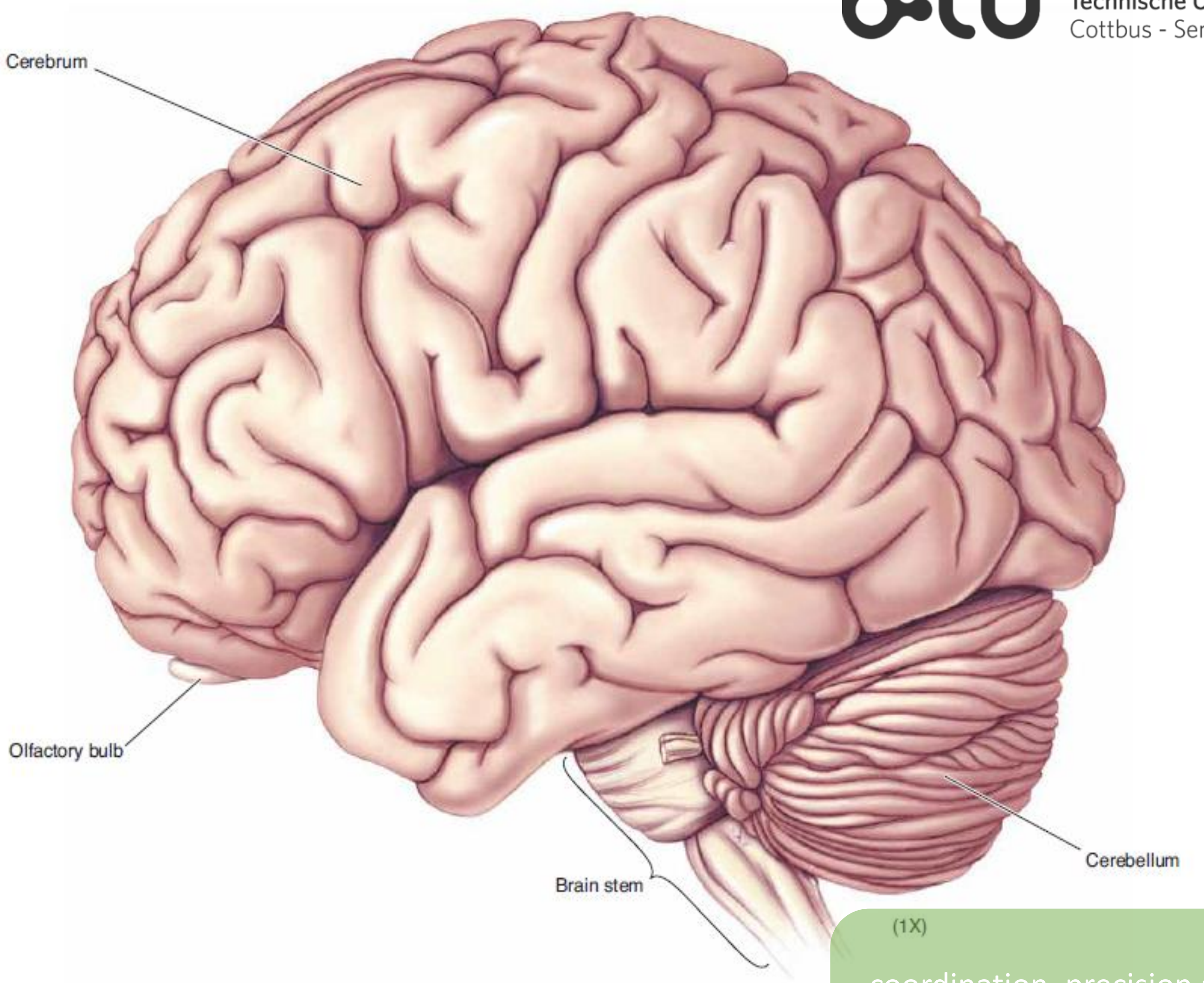
Brief Introduction to Brain anatomy…

Gross inspection reveals the three major parts:
the **large cerebrum**, the brain stem that forms its stalk, and the rippled **cerebellum**. The diminutive olfactory bulb of the cerebrum can also be seen in this lateral view.



coordination, precision and timing of movements, as well as in motor learning

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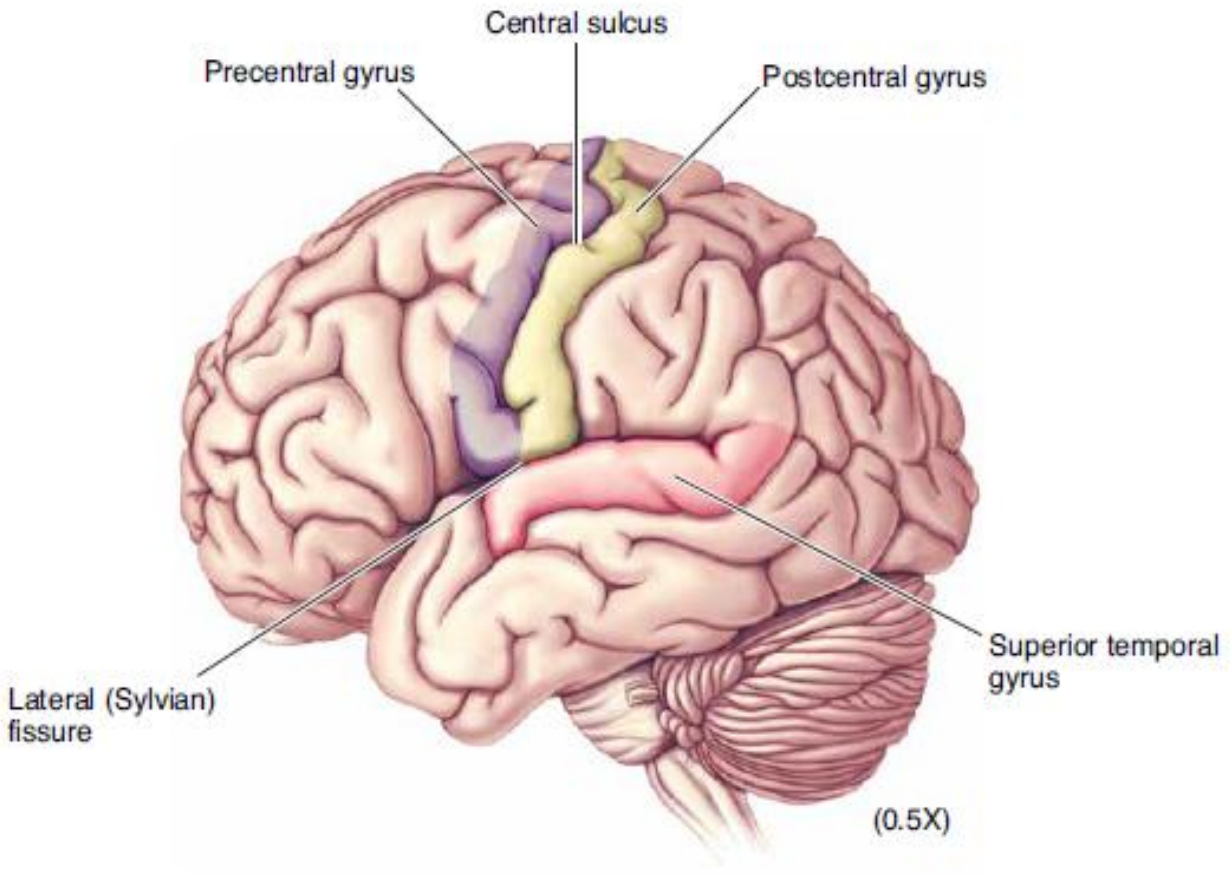
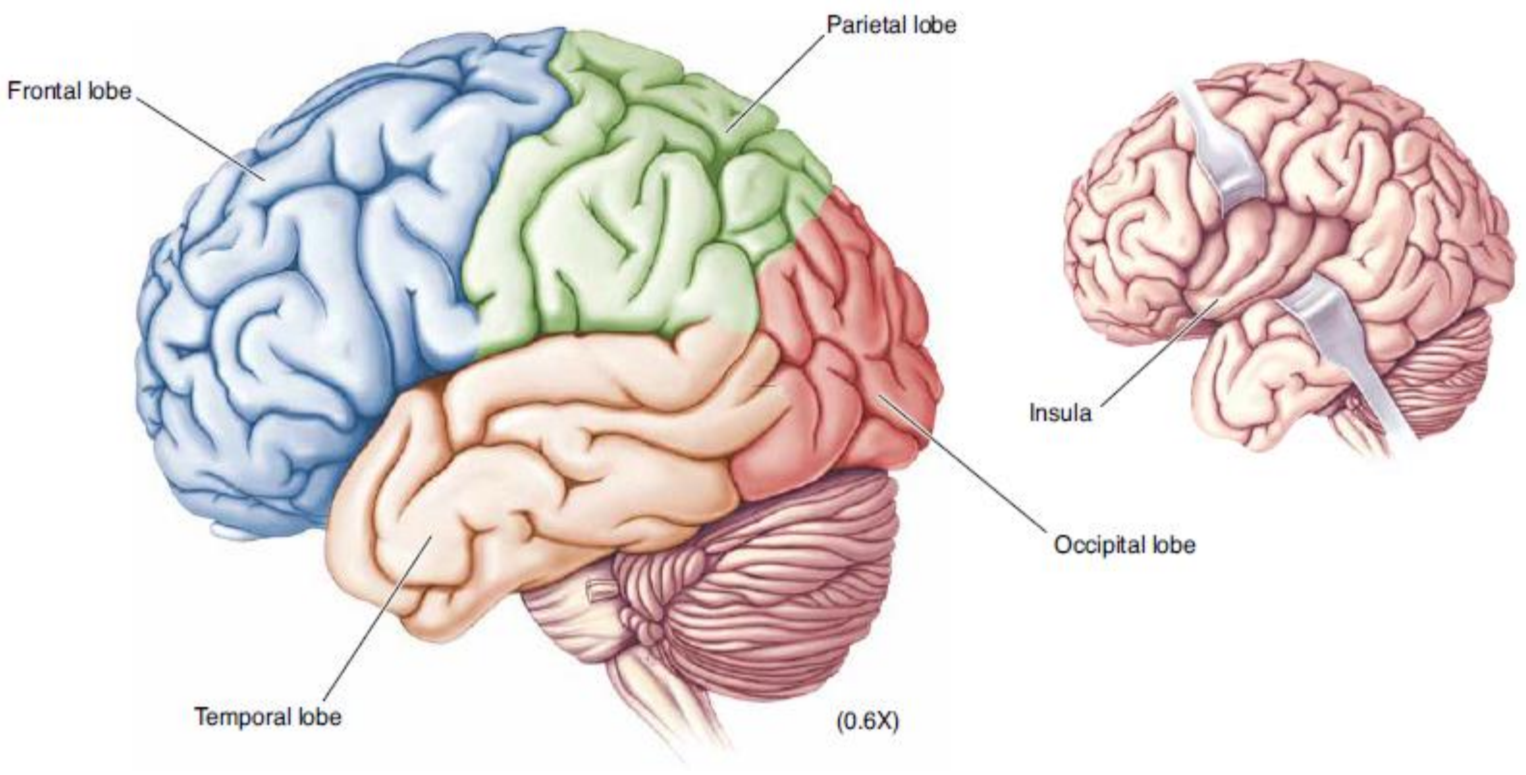
Brief Introduction to Brain anatomy …

Selected Gyri, Sulci, and Fissures. The cerebrum is noteworthy for its convoluted surface. The **bumps are called *gyri***, and the **grooves are called *sulci*** or, if they are especially deep, **fissures**. The precise pattern of gyri and sulci can vary considerably from individual to individual, but many features are common to all human brains. Some of the important landmarks are labeled here. Notice that the **postcentral gyrus** lies immediately posterior to the **central sulcus**, and that the precentral gyrus lies immediately anterior to it. The neurons of the postcentral gyrus are involved in **somatic sensation** (touch), and those of the precentral gyrus control **voluntary movement** . Neurons in the superior temporal gyrus are involved in **audition**).



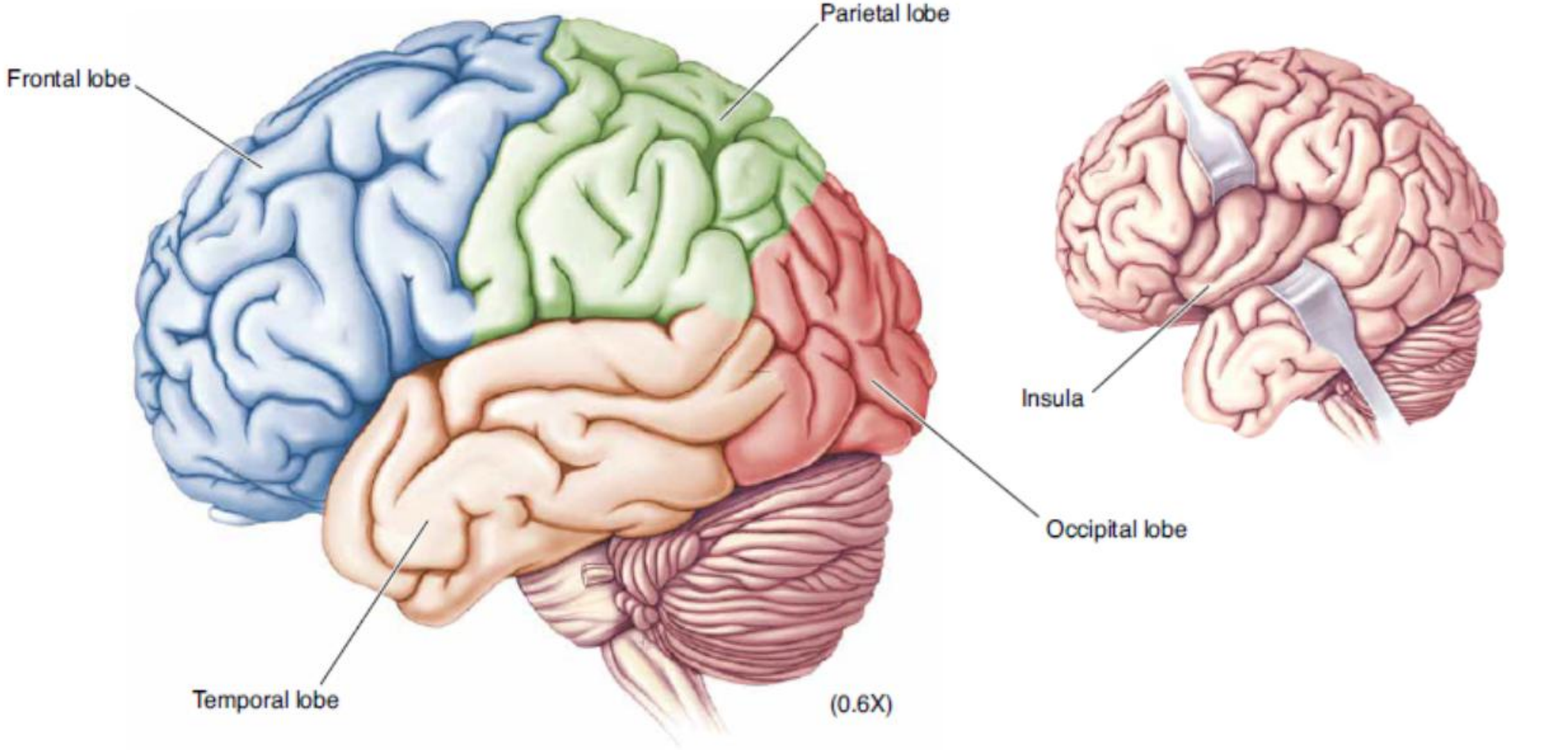
Cerebral Lobes and the Insula

By convention, the cerebrum is subdivided into lobes named after the bones of the skull that lie over them. The central sulcus divides the frontal lobe from the parietal lobe. The temporal lobe lies immediately ventral to the deep lateral (Sylvian) fissure.
The occipital lobe lies at the very back of the cerebrum, bordering both parietal and temporal lobes. A buried piece of the cerebral cortex, called the *insula* (Latin for “island”), is revealed if the margins of the lateral fissure are gently pulled apart (inset). The insula borders and separates the temporal and frontal
lobes.



Frontal lobe

Primary motor cortex	**Voluntary** movements
Motor Association cortex	**Planning , Sequencing** and **Execution** of movement
Frontal eye field	**Voluntary** eye movements
Pre frontal cortex	**memory, learning, personality, reasoning, judgment, Decision making**



Broca's area	**Speech production**

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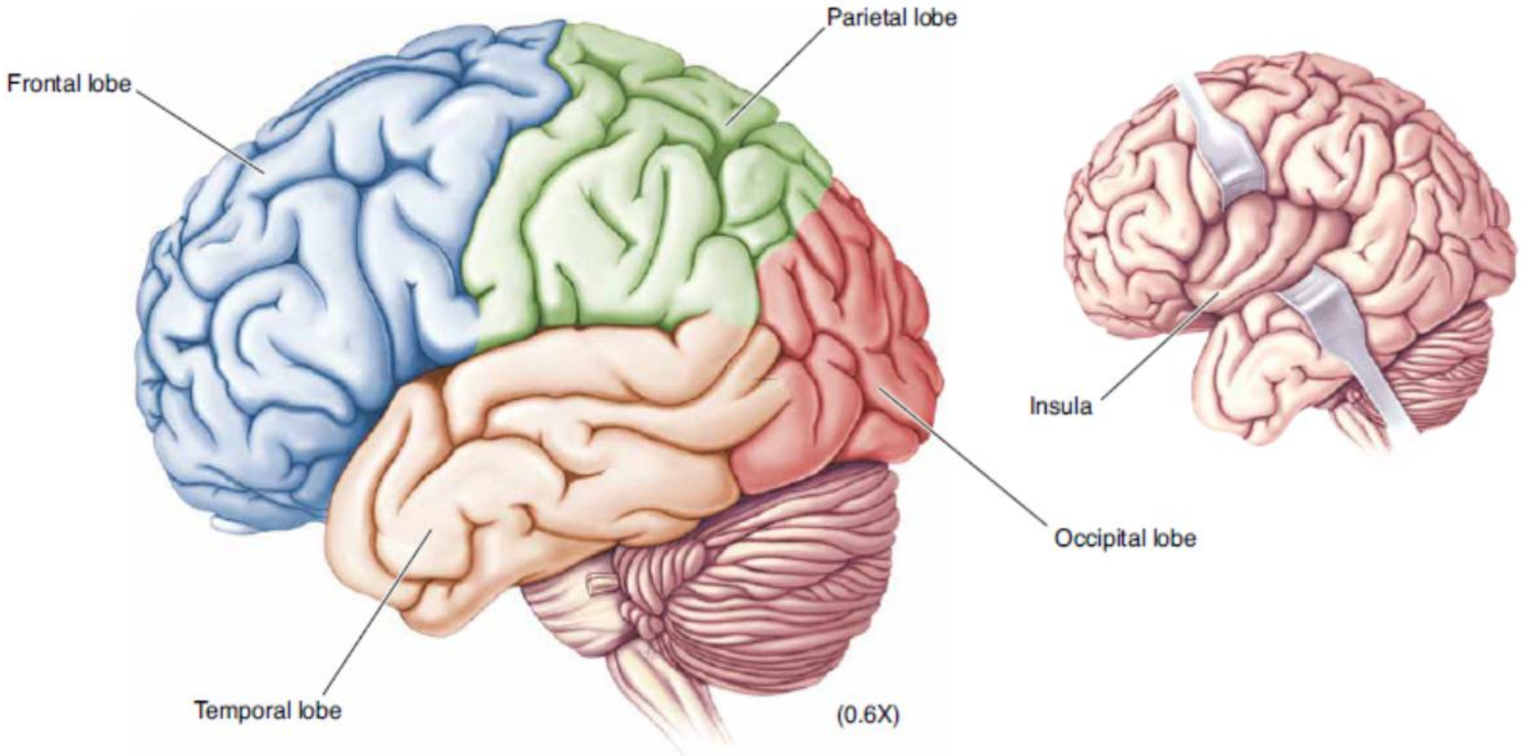
Temporal lobe

Primary auditory cortex	Perception of sound (pitch , frequency, location)
Auditory Association cortex	**Analyzes and , recognition of sound**
Wernicke's Area	Language comprehension
Primary Olfactory cortex	**Awareness of smell**



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Parietal lobe

Primary somatosensory cortex

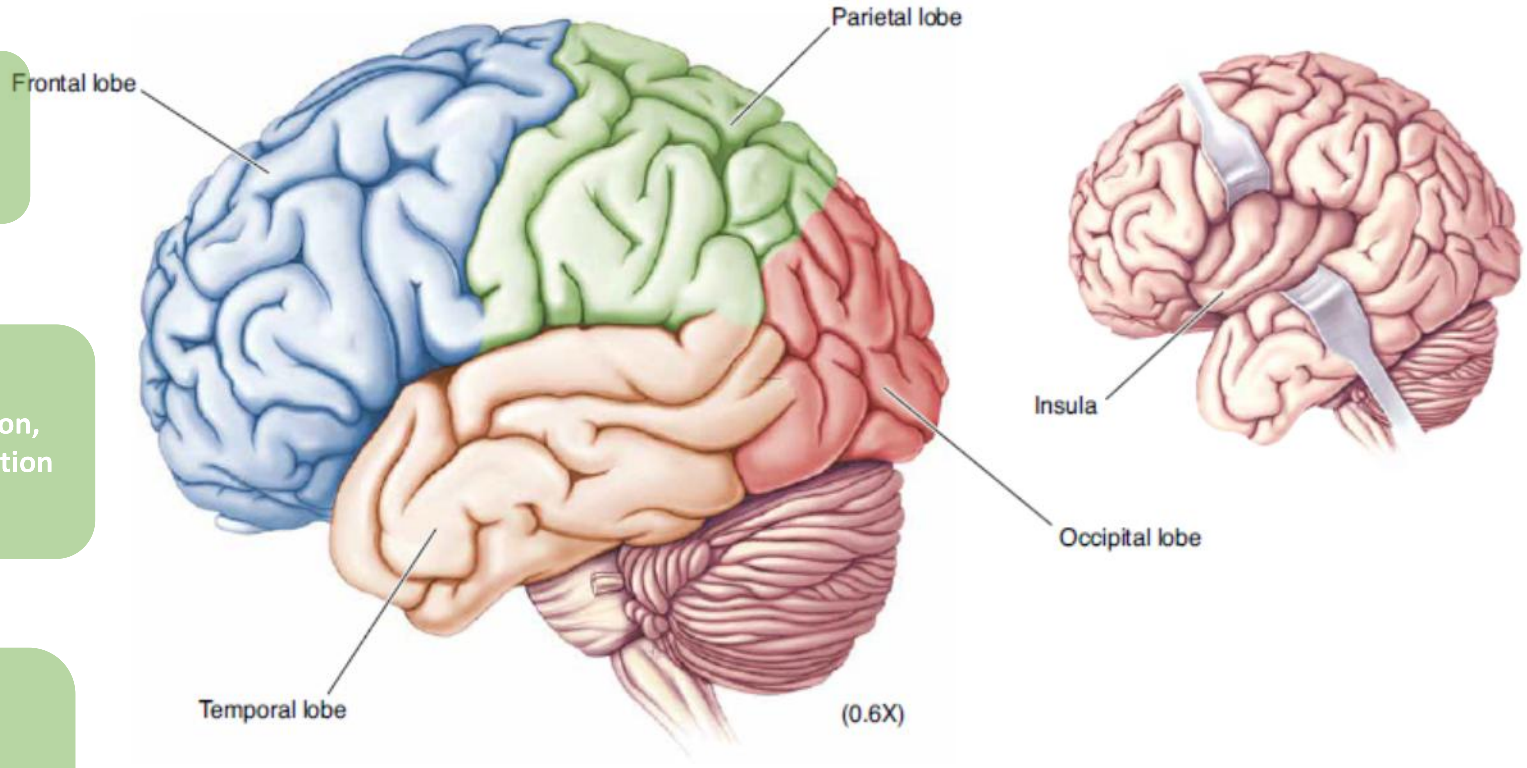
Awareness of somatosensory sensation (Pressure, vibration…)

Primary somatosensory Association cortex

Analyzes of somatic sensation, Recognition of somatic sensation

Posterior Association Area

Multi modal Association (auditory, visual, and somatosensory pathway)
Spatial coordination
Communication with other areas



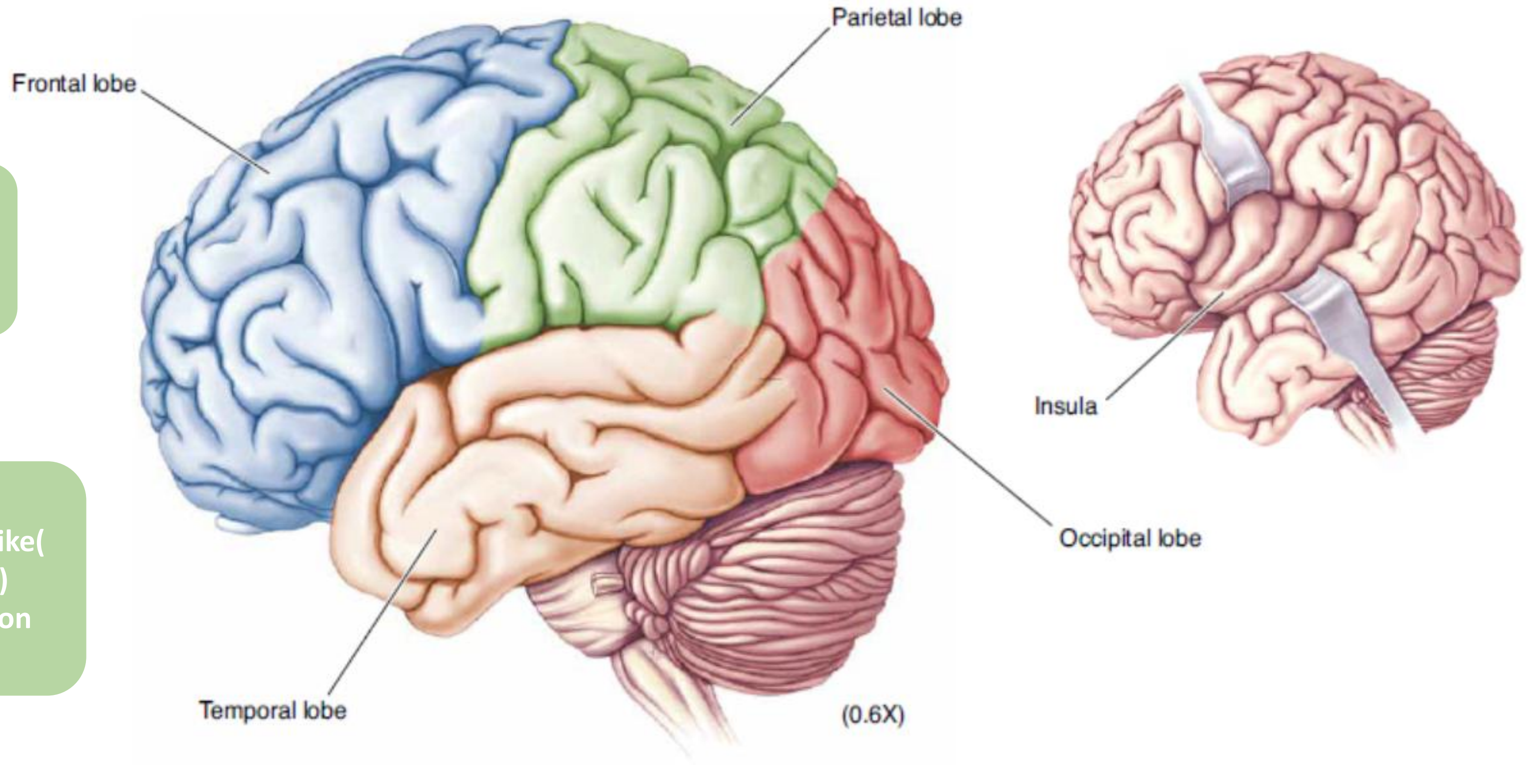
Occipital lobe

Primary visual cortex

Awareness of visual stimuli

visual Association cortex

Analyzes of visual sensation like(color, angle, movements,…)
Recognition of visual sensation



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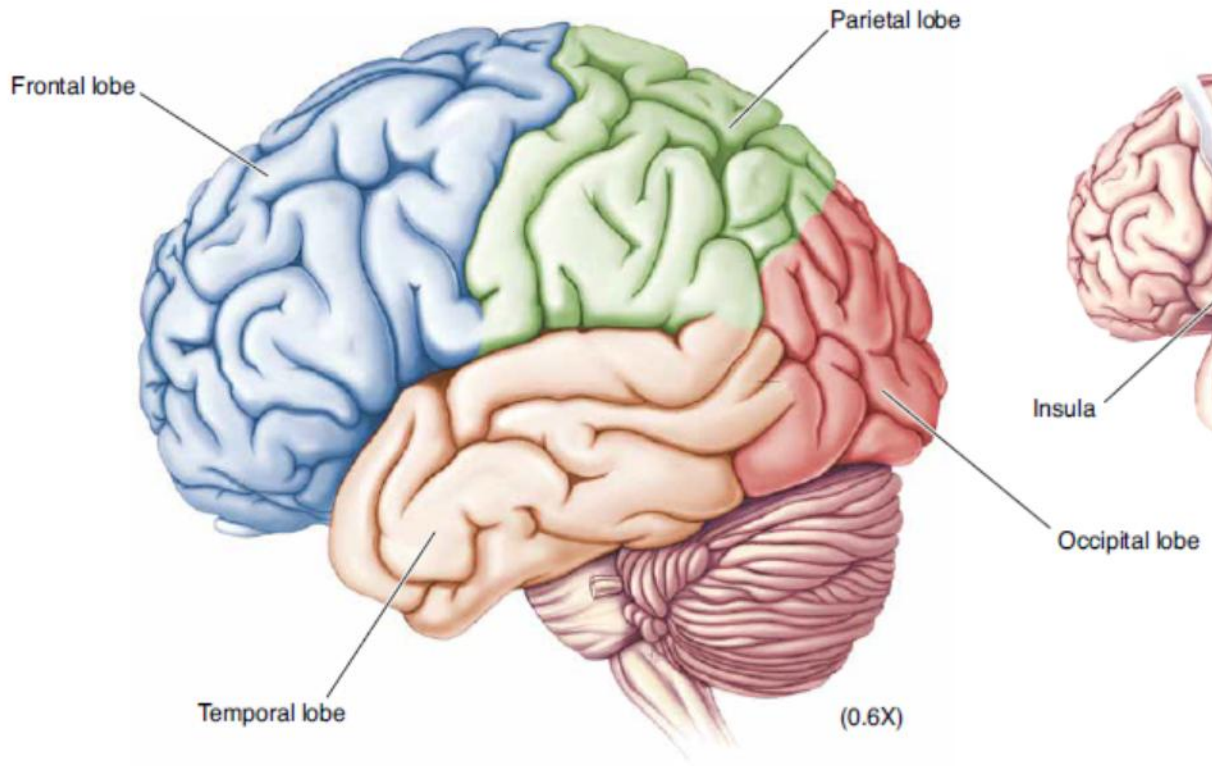
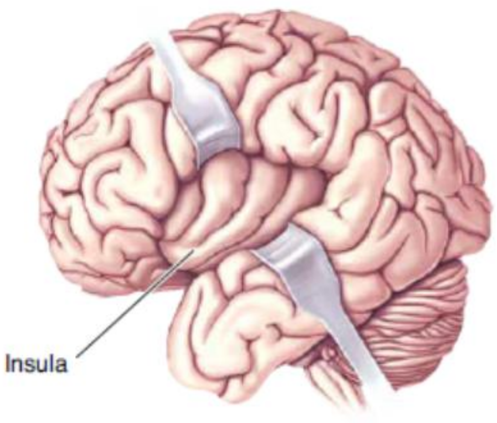
Insula





Gustation cortex	Awareness of tastes
Association Gustation cortex	Analyzes of tests sensation
Visceral sensation	Sensation of pain receptor of the thoracic, pelvic, or abdominal viscera (organs)

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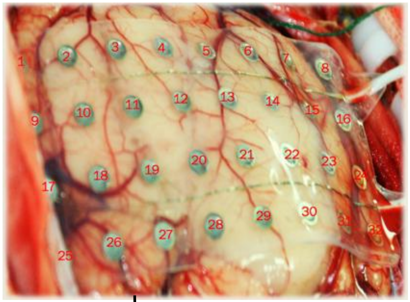
Methods for Neural signal recording

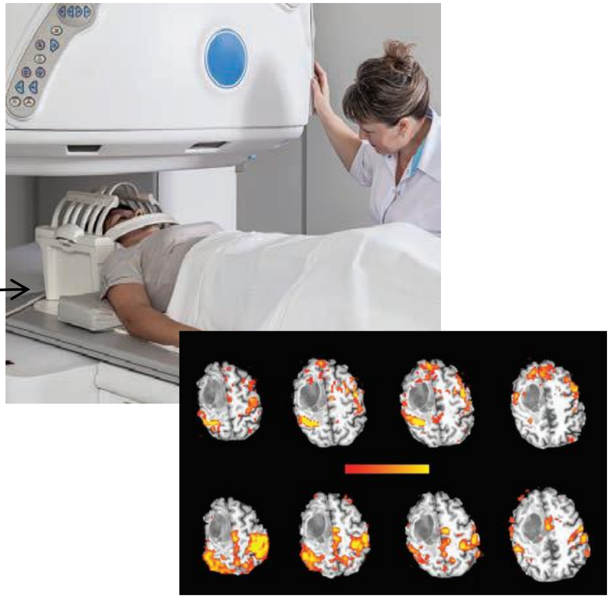
Electroencephalography

Magnetoencephalography

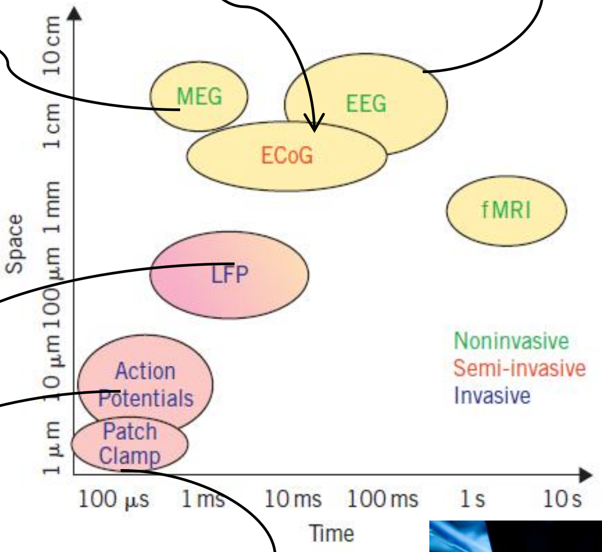
Electrocorticography

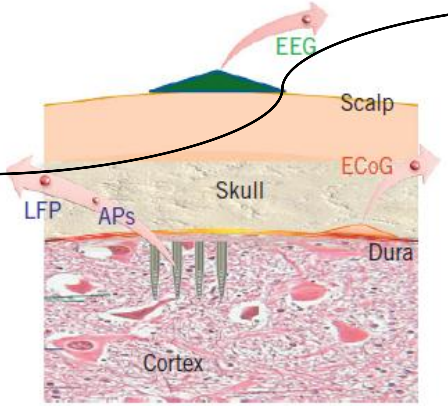


Functional magnetic resonance imaging

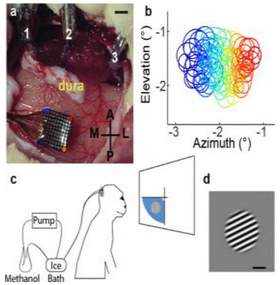


This technique relies on the fact that cerebral blood flow and neuronal activation are coupled

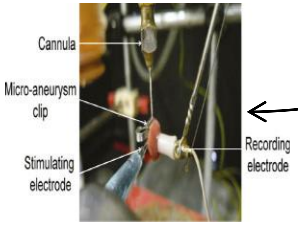




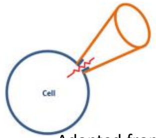
Till S. Hartmann, 2019, Fig1



Extracellular electrical potentials

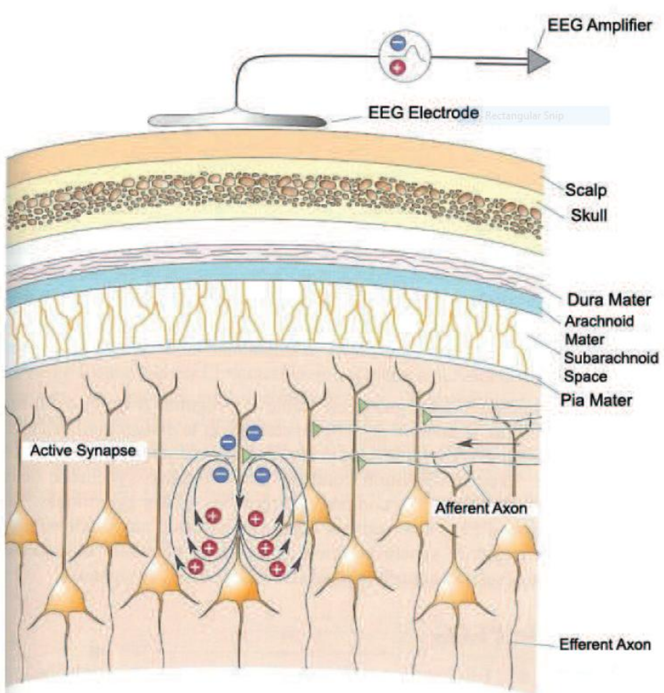


Gary Tse ,Fig2, 2016

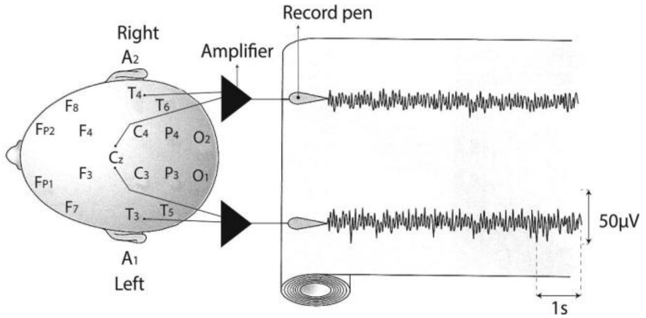


Adopted from Fig1.1 of Statistical Signal Processing for Neuroscience and Neurotechnology Edited by Karim G. Oweiss

Origin of EEG



M. F. Bear, B. W. Connors, and M. A. Paradiso. Neuroscience: Exploring the Brain.



Bastos-Filho, Teodiano Freire, ed. *Introduction to Non-invasive EEG-based Brain-computer Interfaces for Assistive Technologies*. CRC Press, 2020.

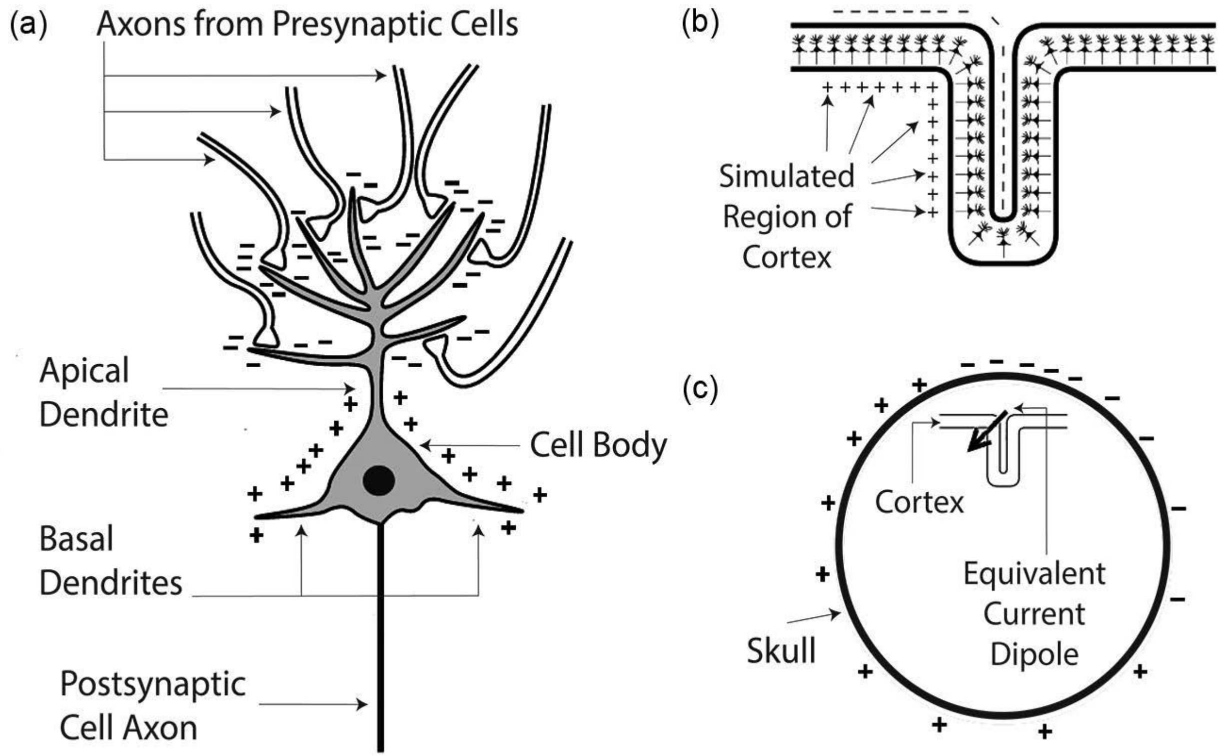
The EEG mainly records the extracellular currents that arise as a consequence of synaptic activity in dendrites of neurons in the cerebral cortex.

The extracellular electric field is mainly generated by the postsynaptic potential (PSP) that may be excitatory postsynaptic potential (EPSP) or inhibitory postsynaptic potential (IPSP).

When the AP reaches postsynaptic dendrites, it causes a current flow that enters through the synapse to the postsynaptic dendrites of the next neuron.

Pyramidal cells (mostly excitatory) are main contributors to the formation of the electrical field lead to EEG are spatially aligned perpendicularly to the cortex.

Origin of EEG …



The dipole of an individual neuron is impossible to be measured by electrodes on the scalp; however, under specific conditions, the dipoles of many neurons are added, generating a resulting field that can be measured on the scalp.

(a) Bipolar configuration of the electric field of pyramidal neuron during a PSP.

(b) bipolar configuration of the electric field of a pyramidal neurons of an active cortical region.

(c) equivalent current dipole of the active cortical region

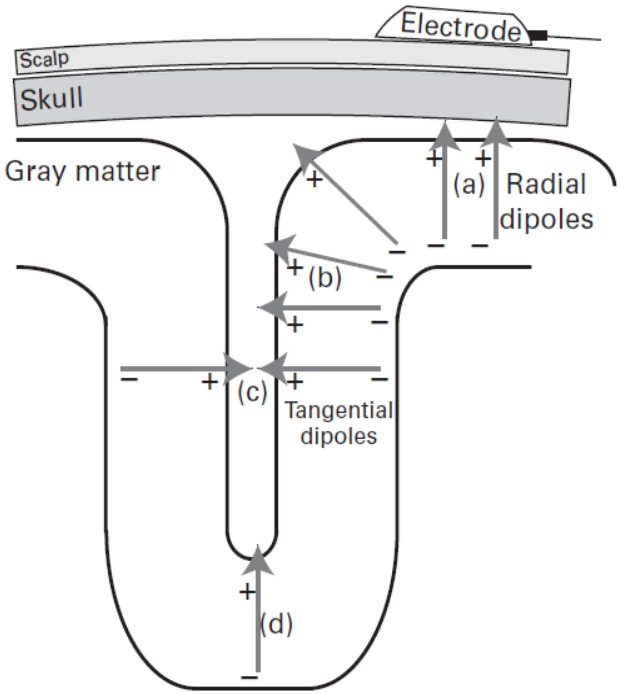
Origin of EEG …

Illustration of dipoles in different orientations with respect to the skull.

(a) These dipoles will contribute the strongest signal to EEG.

(b,C) These dipoles are unlikely to be measured because the dipoles on opposing sides of the sulcus produce electrical fields that are likely to cancel each other.

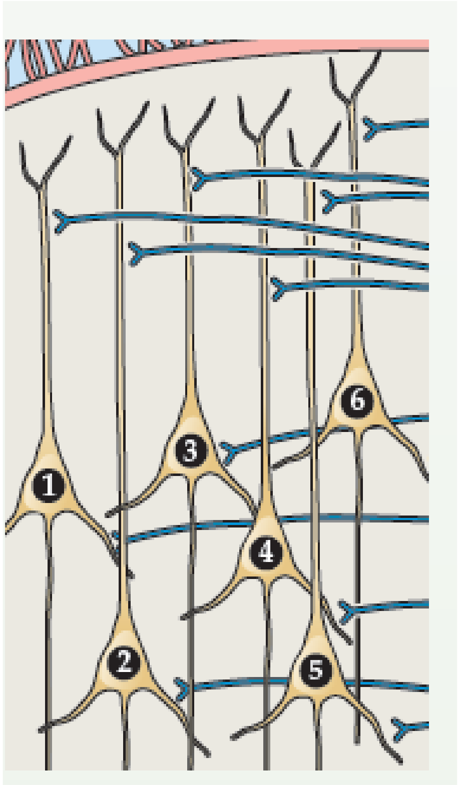
(d) These dipoles will make a smaller contribution to EEG than dipole (a) because it is further away from the electrode.

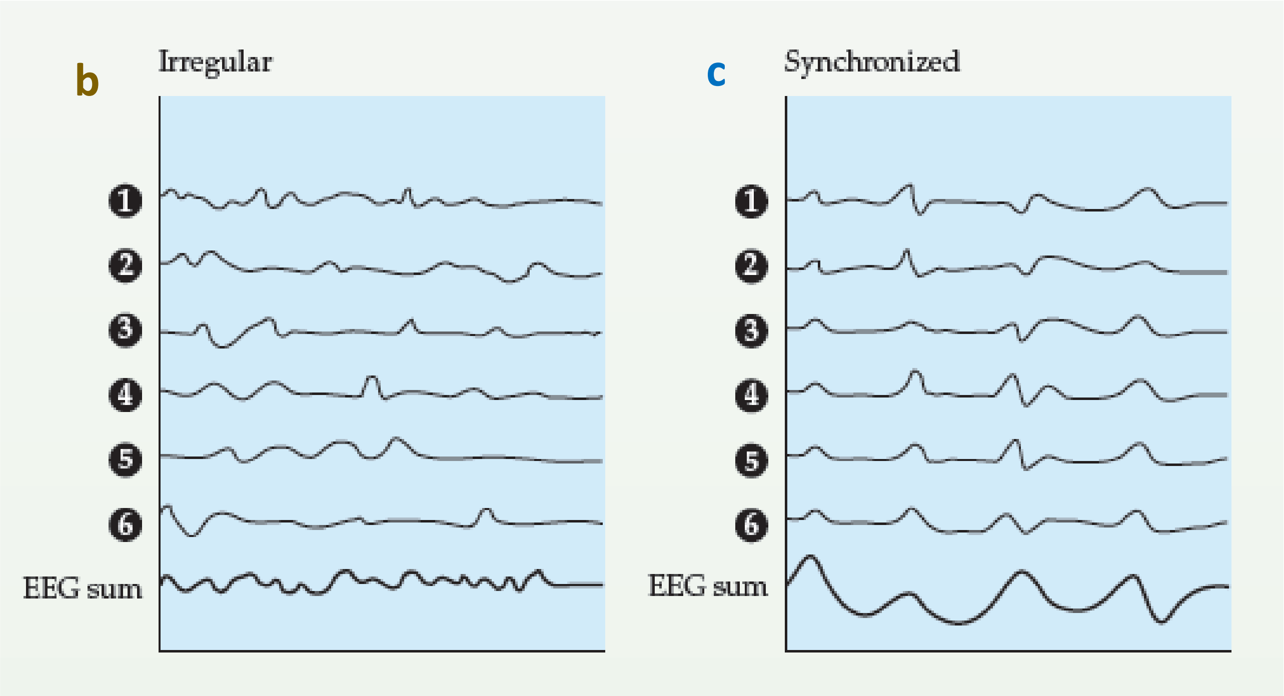


inspired by figure 1 of Scherg 1990

Origin of EEG ...

a





(a) six pyramidal neurons wherein the PSP is measured between a pair of sensors at their extremities (gray triangles).

(b) The neurons are activated in irregular time intervals and the summed PSP activity of all six neurons has small amplitude.

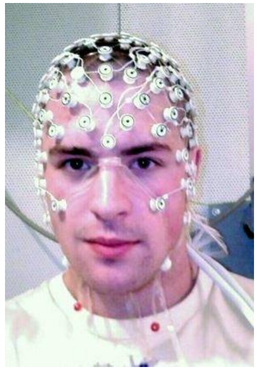
(c) The neurons are activated synchronously; thus, the summed PSP activity of all six neurons has high amplitude.

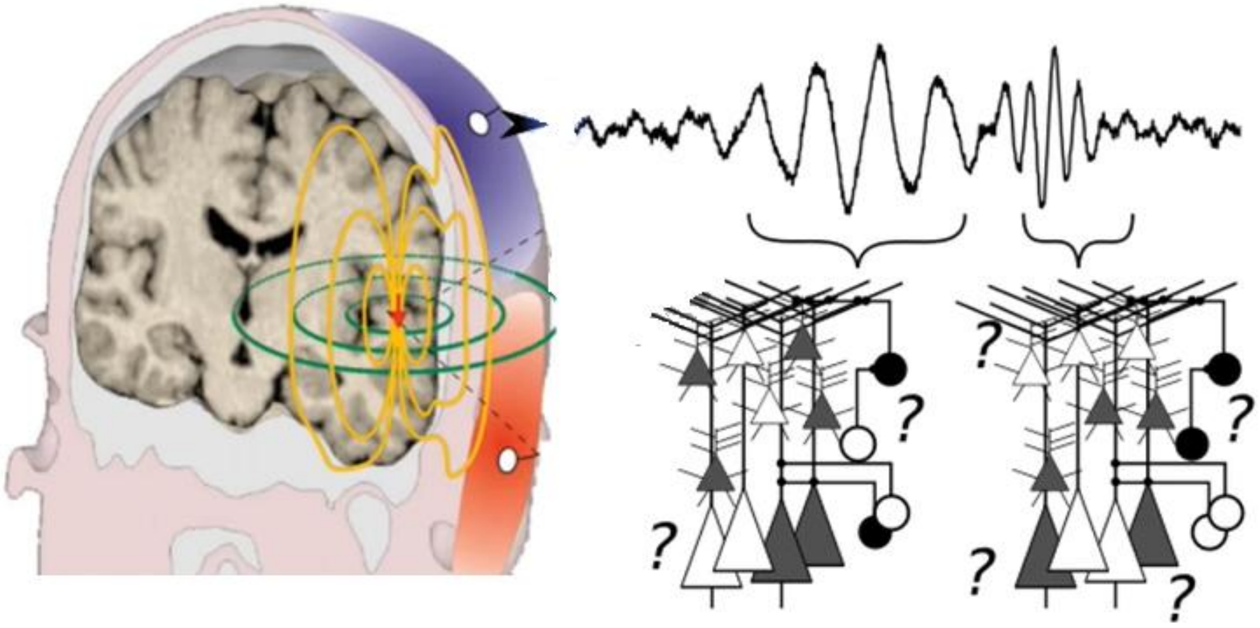
If the neurons are randomly oriented, the positivity of a dipole would be canceled by the negativity of the adjacent dipole.

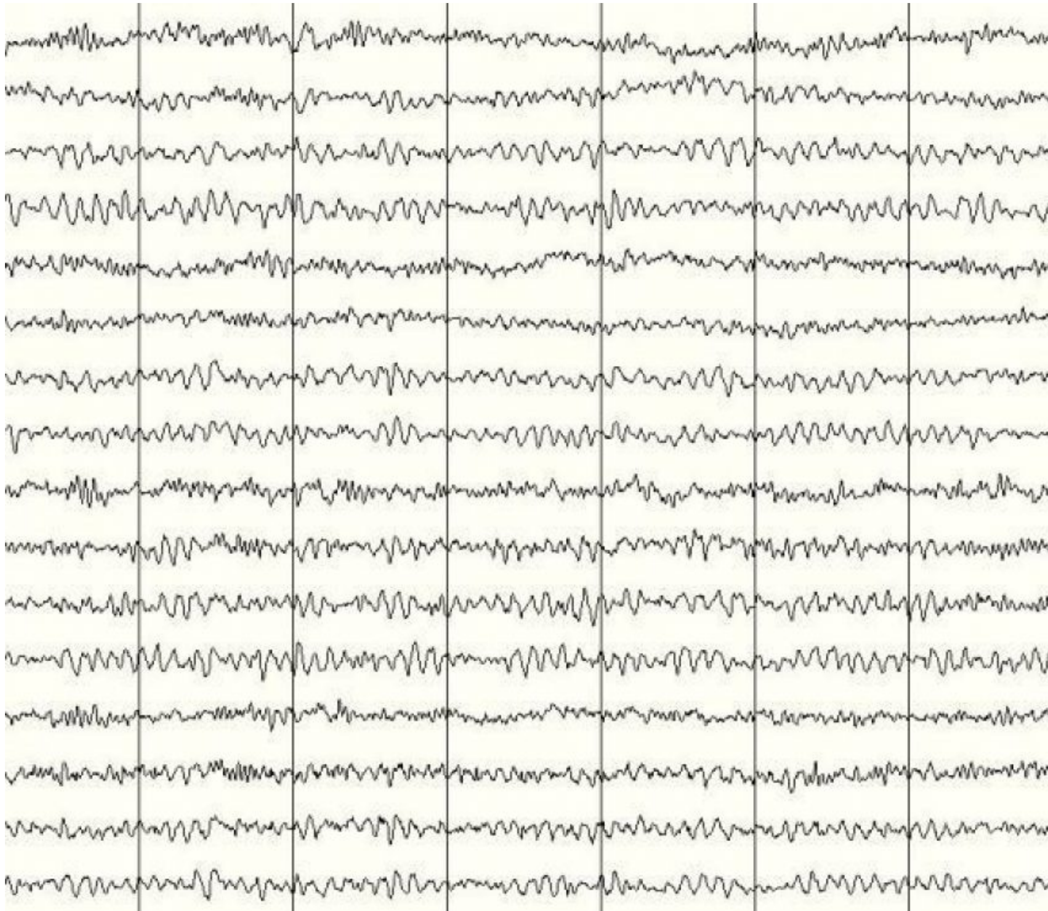
if a neuron is stimulated by an excitatory neurotransmitter, and an adjacent neuron is stimulated by an inhibitory neurotransmitter, the dipoles will have opposite orientations and cancel each other.

If many neurons having similar orientations and the same type of neurotransmitter are stimulated at approximately the same moment, then the dipoles will be added and their activity may be measured on the scalp

Content of EEG ???







Why EEG

The use of EEG in practical applications has steadily increased and is expected to continue to increase. Indeed, EEG has many advantages over the other methods to study brain functions, as follows:

- EEG is perfectly noninvasive, without any exposure to radiation or high magnetic field
- EEG is direct measure of electrical brain activity
- EEG devices can be made small and portable
- EEG has high temporal resolution (The temporal resolution match the speed of cognition).
- EEG has very rich information allow for physiologically inspired analysis (Oscillation, synchronization, connectivity ,….)
- EEG can be recorded in an open environment
- EEG is economical