# Electroneugram

# ▪ Electroneurogram (ENG)

- ENG measures electrical activity of neurons in the central nervous system (brain, spinal cord) or peripheral nervous system.
  - done by placing an electrode in the neural tissue to record neuron action potential of one or a group of neurons

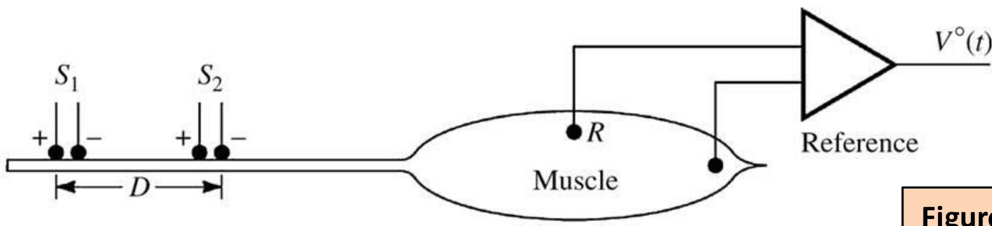
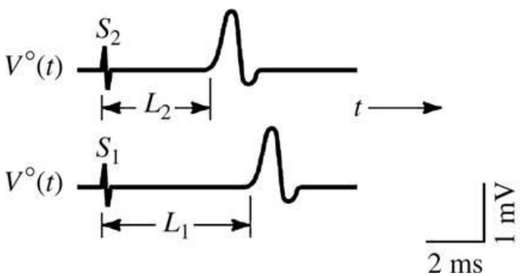



**Figure..:** Measurement of neural conduction velocity via measurement of latency of evoked electrical response in muscle. **The nerve was stimulated at two different sites a known distance D apart.**




$$\text{Velocity} = u = \frac{D}{L_1 - L_2}$$

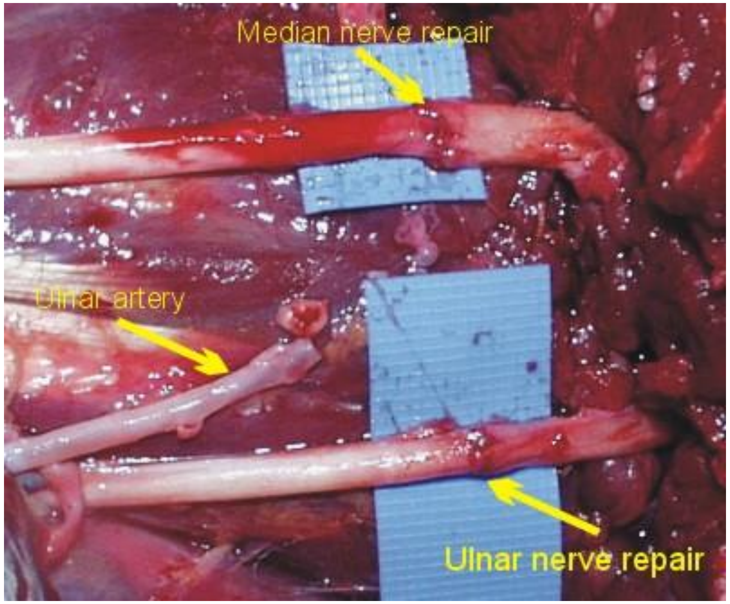
u : Conduction velocity
D : Distance between electrodes
$L_1$: Time of longer latency
$L_2$: Time of shorter latency

- Subtraction of the shorter latency from the longer latency gives the conduction time along the segment of nerve between the stimulating electrodes.

# Electroneurogram (ENG)-(Cont.)

- the conduction velocity of the nerve has clinical value e.g., conduction velocity in a regenerating nerve fiber is slowed following nerve injury.

- In other words, <u>conduction velocity can show nerve regenerating</u> following nerve injury.




- Recording of these signals can be done using concentric needle electrode or surface electrodes.

# Electroneurogram (ENG)-(Cont.)

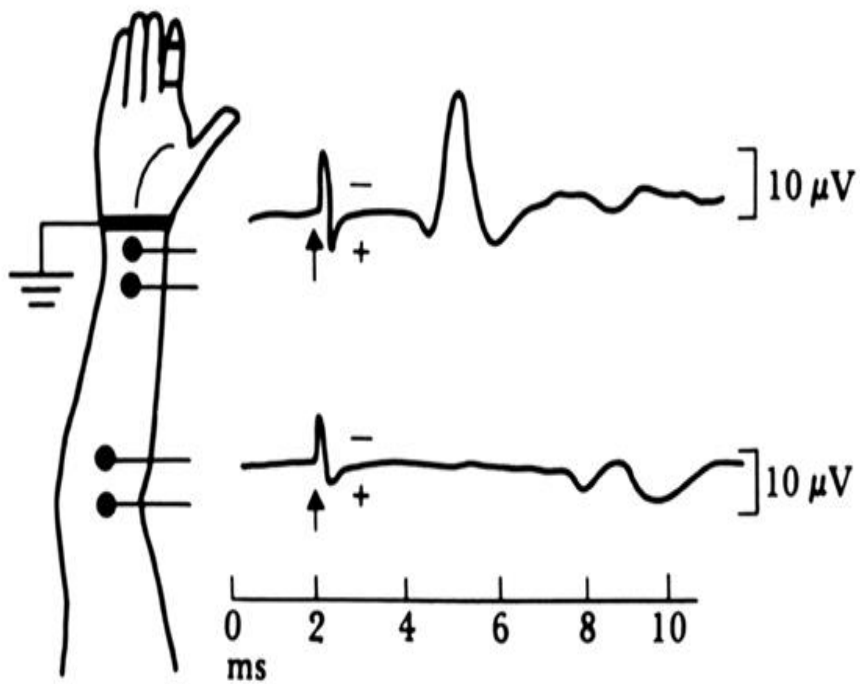
- Important parameters to be observed for diagnosing peripheral nerve disorder :
  - Conduction velocity and latency,
  - Characteristics of field potentials evoked by stimulated nerve.
    - For instance; amplitude of field potentials of nerve fibers < extracellular potentials from muscle fibers.

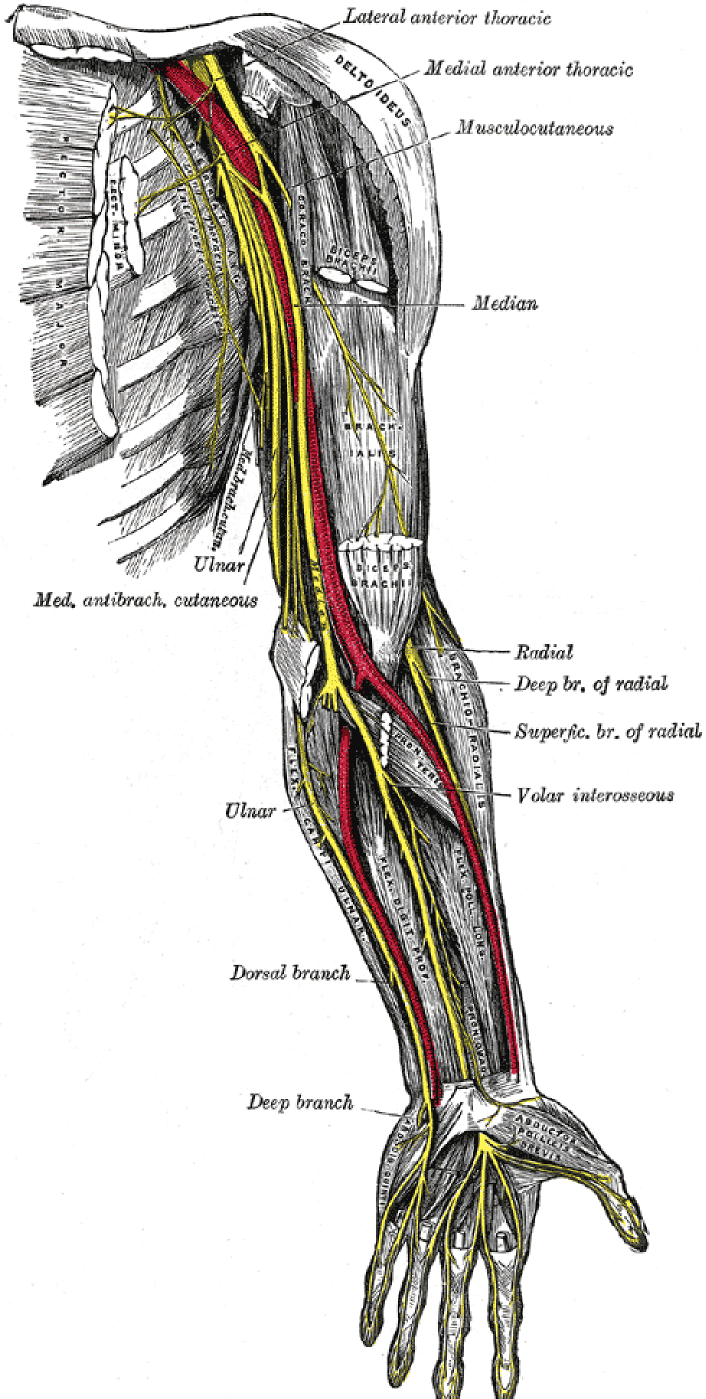
- Application of ENG includes studies on the following fields:
  - Sensory nerve field potentials.
  - Motor-nerve conduction velocity.
  - Reflexly evoked field potentials.

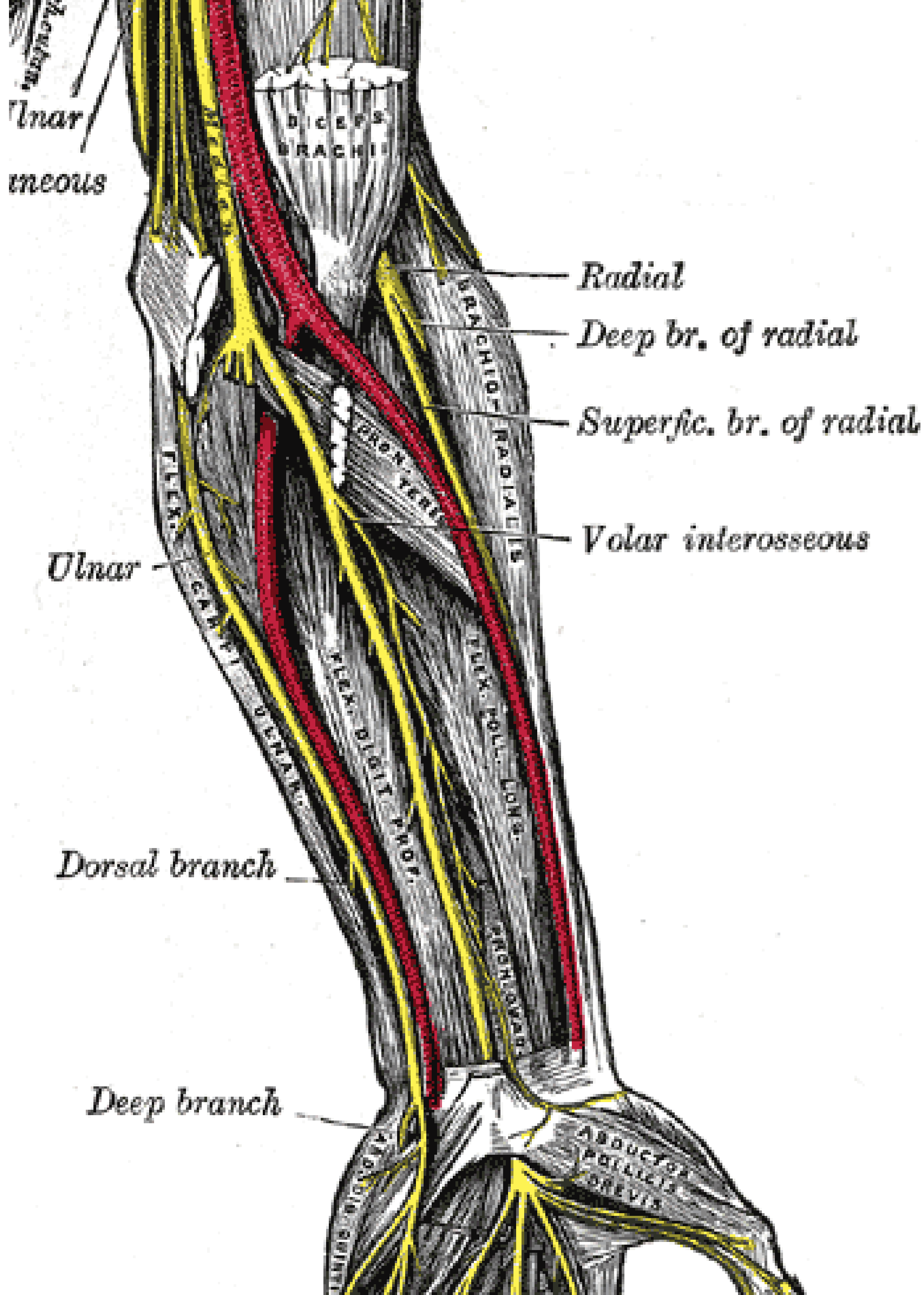
# Electroneurogram (ENG)-(Cont.)

## Sensory Nerve Field Potential

- Measured by applying stimulus on the sensory nerve.
- Ring-stimulating electrodes applied to the fingers.
- ground is placed at the wrist between the stimulating and recording electrodes.
- Known distance allow computation of conduction velocity of sensory nerve.
- Examples:
    - For ulnar nerve, potentials can be recorded from different sites along the course of the nerve as high as the armpit.
    - For median nerve, potentials can be recorded at or above the elbow




Lateral anterior thoracic
Medial anterior thoracic
DELTOIDEUS
Musculocutaneous
Median
Ulnar
Med. antibrach. cutaneous
Radial
Deep br. of radial
Superfic. br. of radial
Volar interosseous
Ulnar
Dorsal branch
Deep branch


Ulnar
BICEPS BRACHII
Radial
Deep br. of radial
Superfic. br. of radial
BRACHIO-RADIALIS
PRON. TERES
Volar interosseous
Ulnar
FLEX. CARPI ULNAR.
FLEX. DIGIT. PROF.
FLEX. POLL. LONG.
Dorsal branch
Deep branch
ABDUCTOR POLLICIS BREVIS

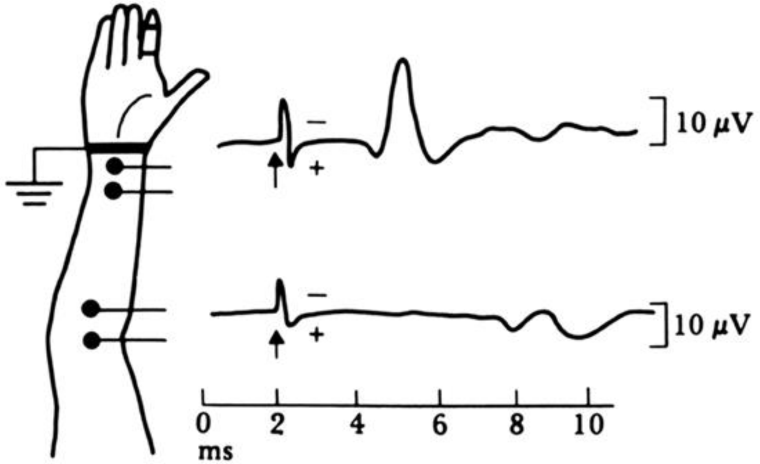
# Electroneurogram (ENG)-(Cont.)

## Sensory Nerve Field Potential

- Long stimulation pulse results in:
  - Muscle contractions
  - Limb movements
  - Undesired signals (artifacts)

- To overcome these problems, a brief but intense stimulus such as square pulse of approximately 100 V amplitude with a duration of 100 to 300 μs may be applied.

- Such a stimulus excites the large, rapidly conducting sensory nerve fibers but not small pain fibers or surrounding muscle.




Sensory nerve action potentials evoked from median nerve of a healthy subject at elbow and wrist after stimulation of index finger with ring electrodes.

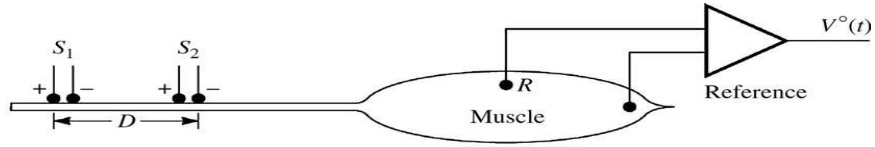
- The potential magnitude at the wrist is much larger than delayed potential recorded at the elbow.
- Considering the median nerve to be of the same size and shape at the elbow as at the wrist, we find that the difference in magnitude and waveshape of the potentials is due to the size of the volume conductor at each location and the radial distance of the measurement point from the neural source.

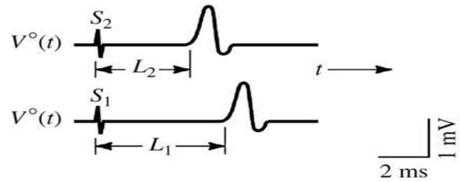
# Electroneurogram (ENG)-(Cont.)

## Sensory Nerve Field Potential

- Clinically, these field potentials are recorded using
  - high-gain,
  - high-input-impedance differential preamplifiers with good common-mode rejection (CMRR) ratio.
- Desirable stimulus:
  - 100V amplitude,
  - Duration of 100-300μs.
- Why do we need these characteristics?
  - Excites large, rapidly conducting sensory nerve fibers.
  - Does not elicit pain fibers and surrounding muscle.
- Diagnose peripheral nerve disorders.

# Electroneurogram (ENG)-(Cont.)



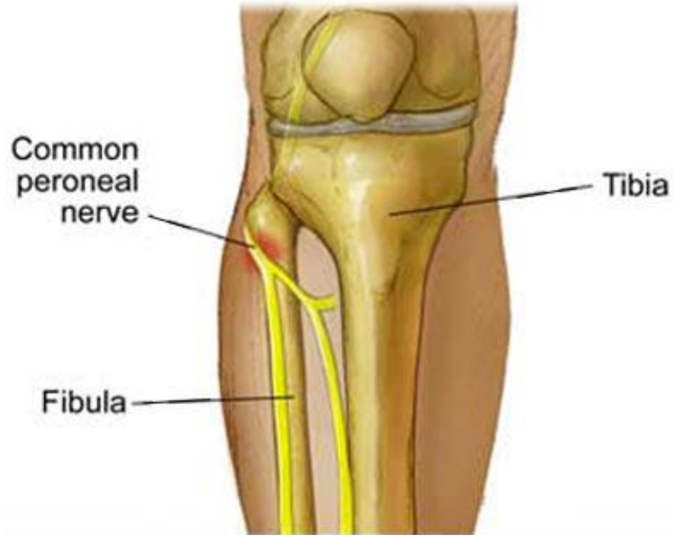




$$\text{Velocity} = u = \frac{D}{L_1 - L_2}$$

## ➢ Motor-Nerve Conduction

- Conduction velocity of motor nerves can be measured using the similar method used for sensory nerve field potential.

**For Example;** the peroneal nerve of the left leg may be stimulated first behind the knee and second behind the ankle. A muscular response is obtained using surface or needle electrodes from the side of the foot.



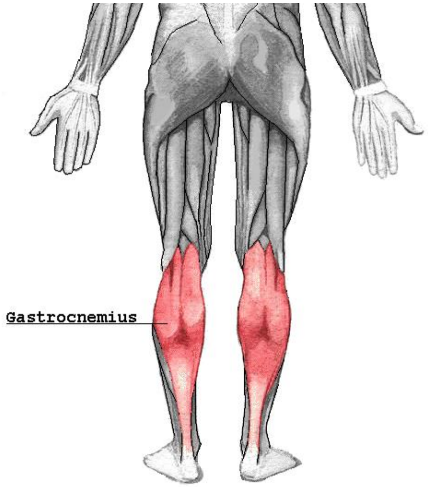
# Electroneurogram (ENG)-(Cont.)

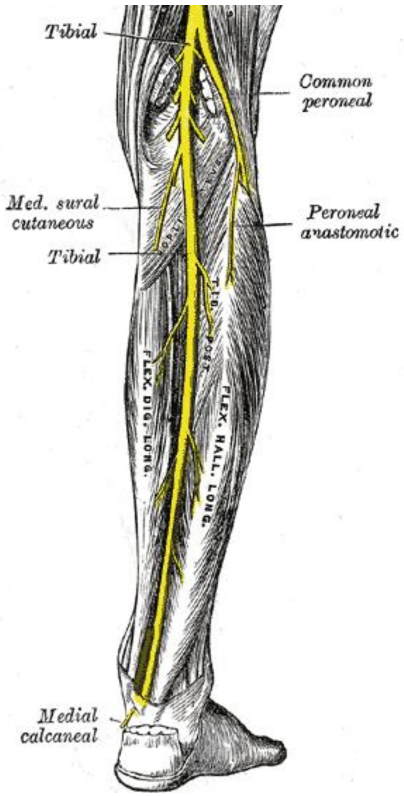
## ➢ Reflexly Evoked Field Potential

- When a peripheral nerve is stimulated and an evoked field potential is recorded in the muscle it supplies (M wave), it is sometimes possible to record a second potential that occurs later than the initial response (H wave).

**For example:**

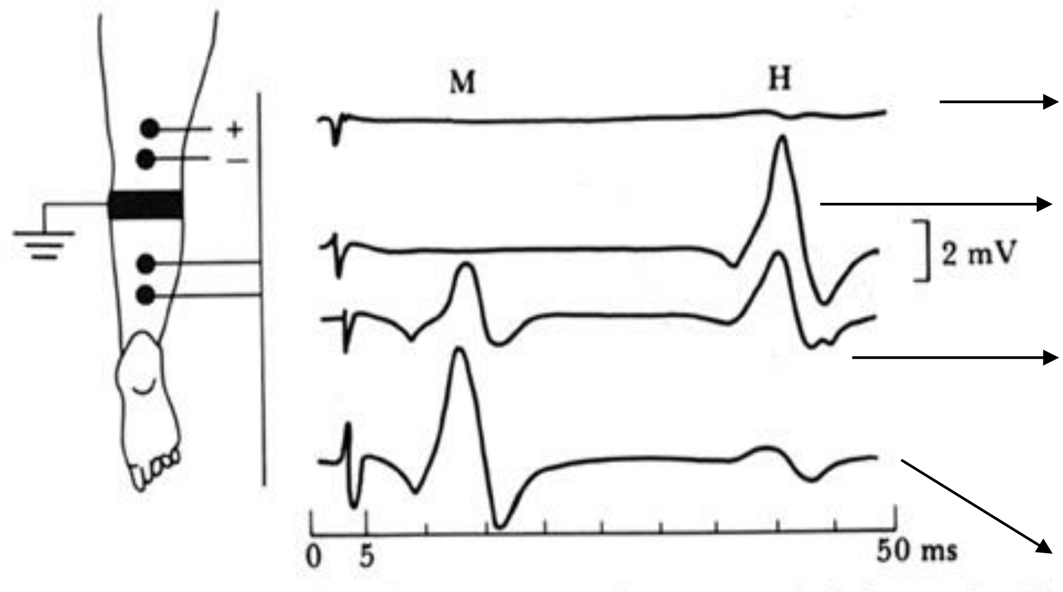
- Stimulated nerve: posterior tibial nerve
- Muscle: gastrocnemius



# Electroneurogram (ENG)-(Cont.)

## ➢ Reflexly Evoked Field Potential




**<u>No stimulus</u> stimulus**

**<u>Low intensity stimulus</u>** stimulate only the large sensory fibers that conduct toward the CNS. No M wave

**<u>Medium intensity stimulus</u>** stimulate smaller motor fibers in addition to the large sensory fibers. Motor fibers produce a direct muscle response the M wave.

**<u>With strong stimuli</u>**, the excited motor fibers are in their refractory period so only the M wave is produced.

**The H reflex** : The four traces show potentials evoked by stimulation of the medial popliteal nerve with pulses of increasing magnitude (the stimulus artifact increases with stimulus magnitude). The later potential or H wave is a low-threshold response, maximally evoked by a stimulus too weak to evoke the muscular response (M wave). As the M wave increases in magnitude, the H wave diminishes.

# Electroencephalogram

# Electroencephalogram (EEG) - A Brief Background

- The study of the brain function has been revolutionized by the introduction of various imaging modalities in recent years :
  - Positron Emission Tomography (PET)
  - Single Photon Emission Computed Tomography (SPECT)
  - Magnetic Rezonans Imaging (MRI)

- These modalities extend information inferred from an electrophysiological investigation by providing detail information on anatomy and blood flow in different regions of the brain.

- **EEG signals are also powerful tool in the diagnosis brain functions**.
  - Diagnosis of diseases such as;
    - Epilepsy
    - sleep disorders
    - dementia
    - real-time monitoring the progress of patients brain activities in the operating theatre
    - monitoring the progress of patients in a coma with encephalopathies in the intensive care unit

**is possible with EEG signals .**

# The Nervous System

- The nervous system gathers, communicates, and processes information from various parts of the body and assures that both internal and external changes are handled rapidly and accurately.

- The nervous system is commonly divided into two subsystem

  - The **Central Nervous System**-CNS (consists of the brain and the spinal cord)
  - The **Peripheral Nervous System**-PNS (connects the brain and the spinal cord to the body organs and sensory systems)

- The two systems are closely integrated because sensory input from the PNS is processed by the CNS, and responses are sent by the PNS to the organs of the body.

  - The nerves transmitting signals to the CNS are called *Sensory Nerves*.
  - The nerves transmitting signal from the CNS are called *Motor Nerves* since these signals may elicit muscle contraction.

# The Nervous System- (Cont.)

- Another important division of the nervous system is based on its functionality:
  - **The *somatic* nervous system** (includes those nerves which controls muscle activity in reponse to conscious commands)
  - **The *autonomic* nervous system** (regulates the bodily activities which are beyond conscious contol, e.g. cardiac activity,muscle activity in internal organs)
- The autonomic nervous system actually consists of two subsystems which operate against each other:
  - ***sympathetic* nervous system** - fight or flight -
  - ***parasympathetic* nervous system** – rest and relax –
- Both these subsystems innervate the same organs and acts so as to maintain the correct balance of the interval organ environment.
  - For example, regulation of heart rate during exercise or fear

# Neurons

- The basic functional units of the nervous system is nerve cell which is called **neuron.**

- The neuron communicates information to and from the brain.

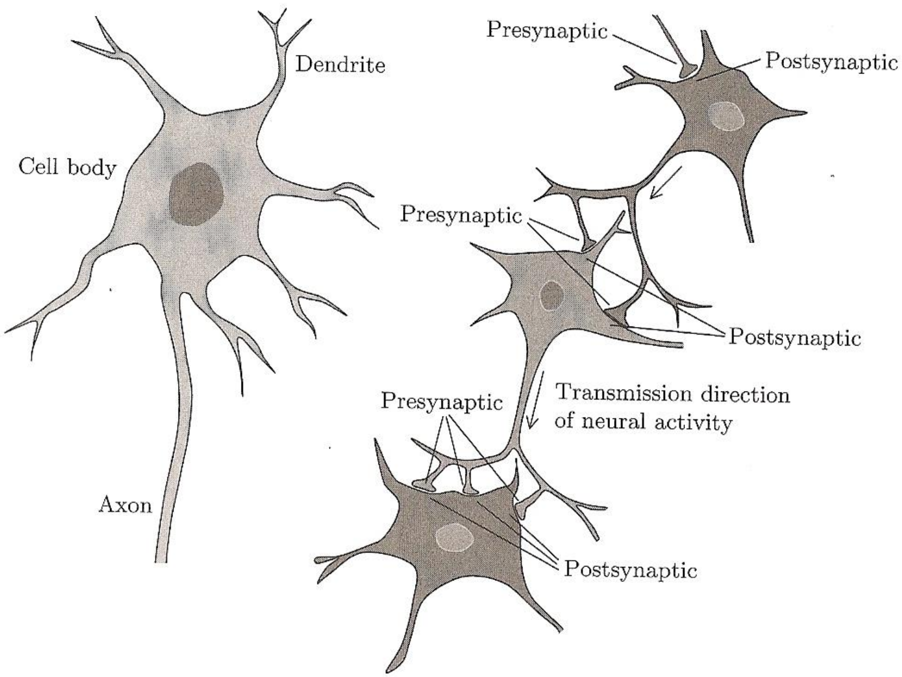
- <u>All nerve cells are collectively referred to as neurons </u>although their size, shape, and functionality may differ widely.

- <u>Three types of neurons </u>can be defined with reference to functionality:

  - ***sensory* neurons**, connected to sensory receptors
  - ***motor* neurons**, connected to muscle
  - ***inter*neurons**, connected the other neurons

# Neurons- (Cont.)

- Archetypal neuron consists of a cell body, the *soma*, from which two types of structures extend:
  - the dendrites
  - the axon




- Dendrites can consist of as many as several thousands of branches, with each branch receiving a signal from another neuron.

- The axon is usualy a single branch which transmits the output signal of the neuron to various parts of the nervous system.

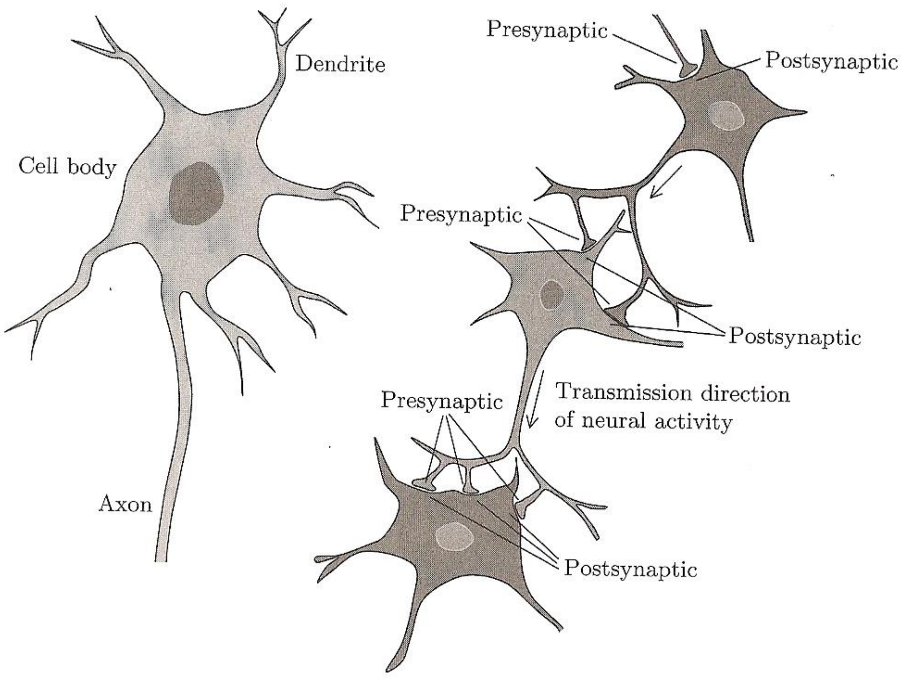
- The length of an axon ranges from less than 1 mm to longer than 1 m.
- Dendrites are rarely longer than 2 mm.

# Neurons- (Cont.)

- The transmission of information from one neuron to another takes place at the ***synapse***, a junction where the terminal part of the axon contacts another neuron.

- The signal initiated in the soma, propagates through the axon encoded as a short, pulse-shaped waveform, i.e., the action potential.

- Although the signal is initially electrical, it is converted in the presynaptic neuron to a chemical signal (neurotransmitter) which diffuses across the synaptic gap and is subsequently reconverted to an electrical signal in the postsynaptic neuron.

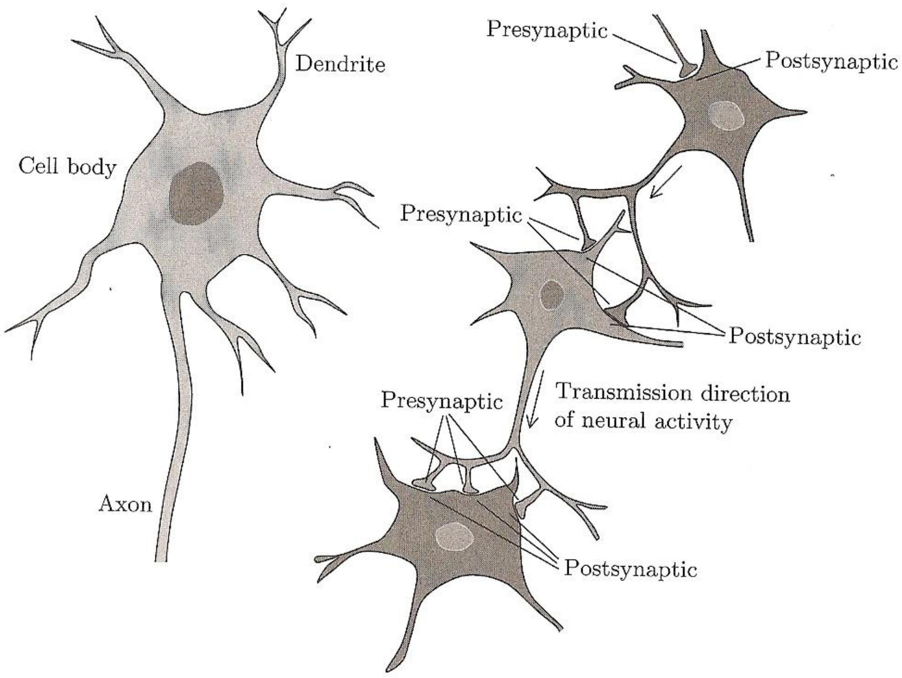


# Neurons- (Cont.)

- Summation of the many signals received from the synaptic inputs is performed in the postsynaptic neuron.

- The amplitude of the summed signal depends on the total number of input signals and how closely these signals occur in time; the amplitude decreases when the signal become increasingly dispersed in time.

- The amplitude of the summed signal must exceed a certain threshold in order to make the neuron fire an action potential.

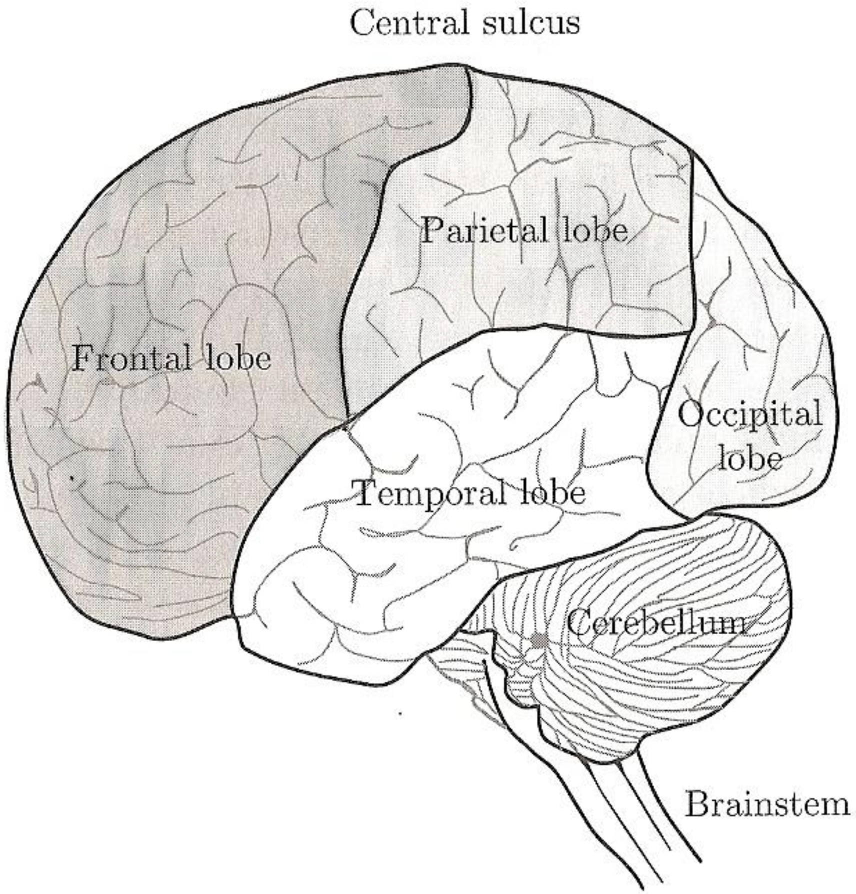


# The Cerebral Cortex

- The cerebral cortex is the most important part of the CNS.

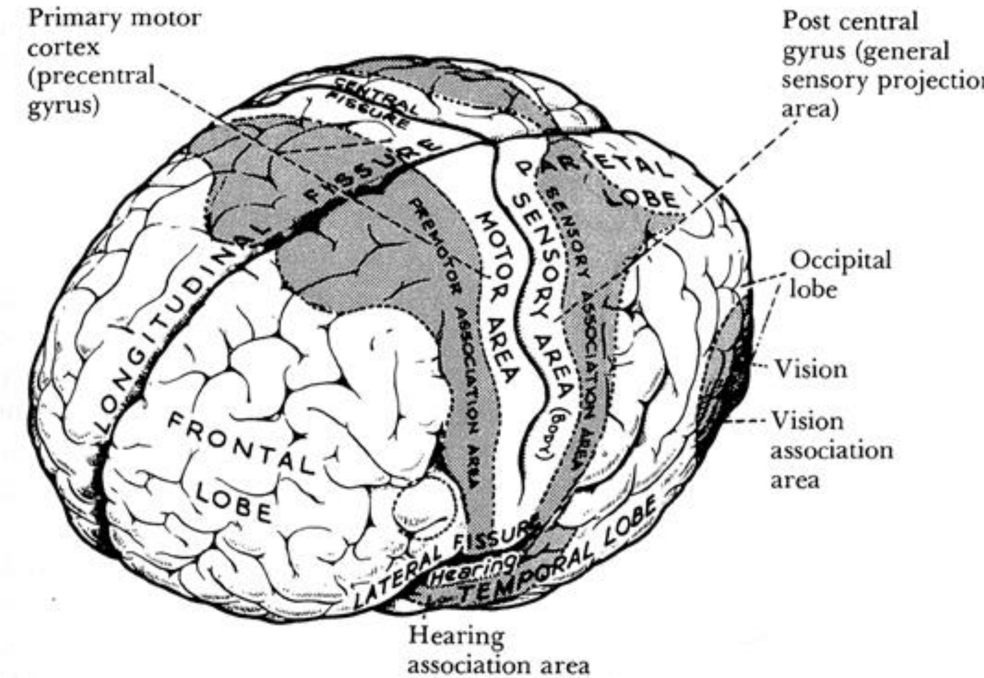
- Different regions of the cortex are responsible for processing vital functions such as

    - sensation,
    - learning,
    - voluntary movement,
    - speech,
    - perception.



# The Cerebral Cortex- (Cont.)

- The cortex consists of two symmetrical hemispheres- left and right- which are seperated by the deep central sulcus.
- Each hemisphere are divided into four different lobes



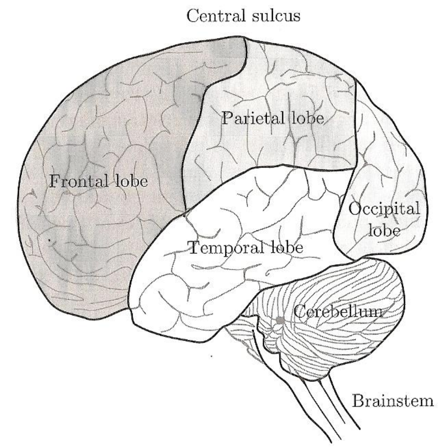

  - Temporal lobe→auditory cortex
  - Occipital lope→visual cortex
  - Parietal lobe→somatic sensory cortex
  - Frontal lobe→ Voluntary movement such as speech, finger movement

## EEG Rhythms and Waveforms

- Signals recorded from the scalp have
  - amplitudes ranging from a few microvolts to approximately 20-200uv
  - a frequency content ranging from 0.5 to 30-40 Hz.

- Electroencephalographic rhythms, also refered to as background rhythms, are conventionally classified into five different frequency bands.
  - Delta rhythm, < 4 Hz.
  - Theta rhythm, 4-7 Hz.
  - Alpha rhythm, 8-13 Hz.
  - Beta rhythm, 14-30 Hz.
  - Gamma rythme, >30 Hz.

# EEG Rhythms and Waveforms- (Cont.)




## Wave group of the normal cortex

- **Alpha wave**
  - 8 to 13 Hz, 20-200 μV,
  - Recorded mainly at the occipital region,
  - disappear when subject is sleep, change when subject change focus.
- **Beta wave** (I and II)
  - 14 to 30Hz, sometimes – especially during intense mental activity- as high as f=50Hz,
  - Beta I disappear during brain activity while beta II intensified,
  - Recorded mainly at the parietal and frontal regions.
- **Theta wave**
  - 4 to 7 Hz,
  - Appear during emotional stress such as disappointment and frustration,
  - Recorded at the parietal and temporal regions .
- **Delta wave**
  - < 4 Hz,
  - occur in deep sleep, and independent of activity,
  - Occur solely within the cortex, independent of activities in lower regions of the brain.

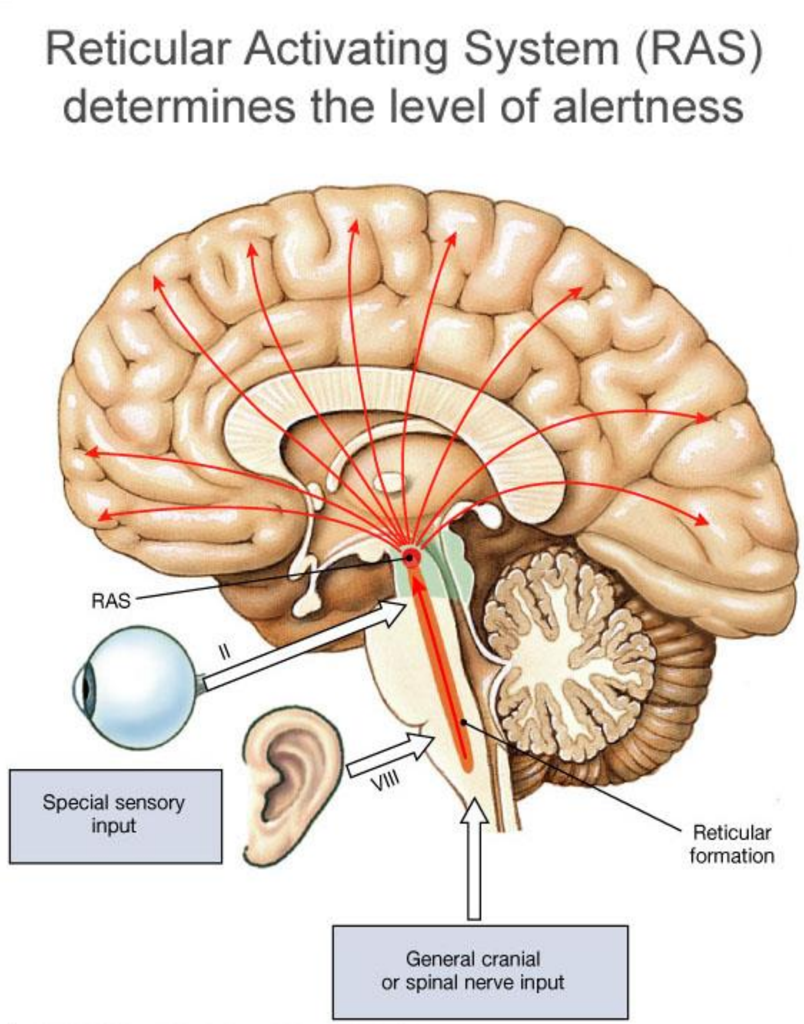
# EEG Rhythms and Waveforms- (Cont.)

- **Synchronization** is the underline process that bring a group of neurons into unified action. Synaptic interconnection and extracellular field interaction cause Synchronization.

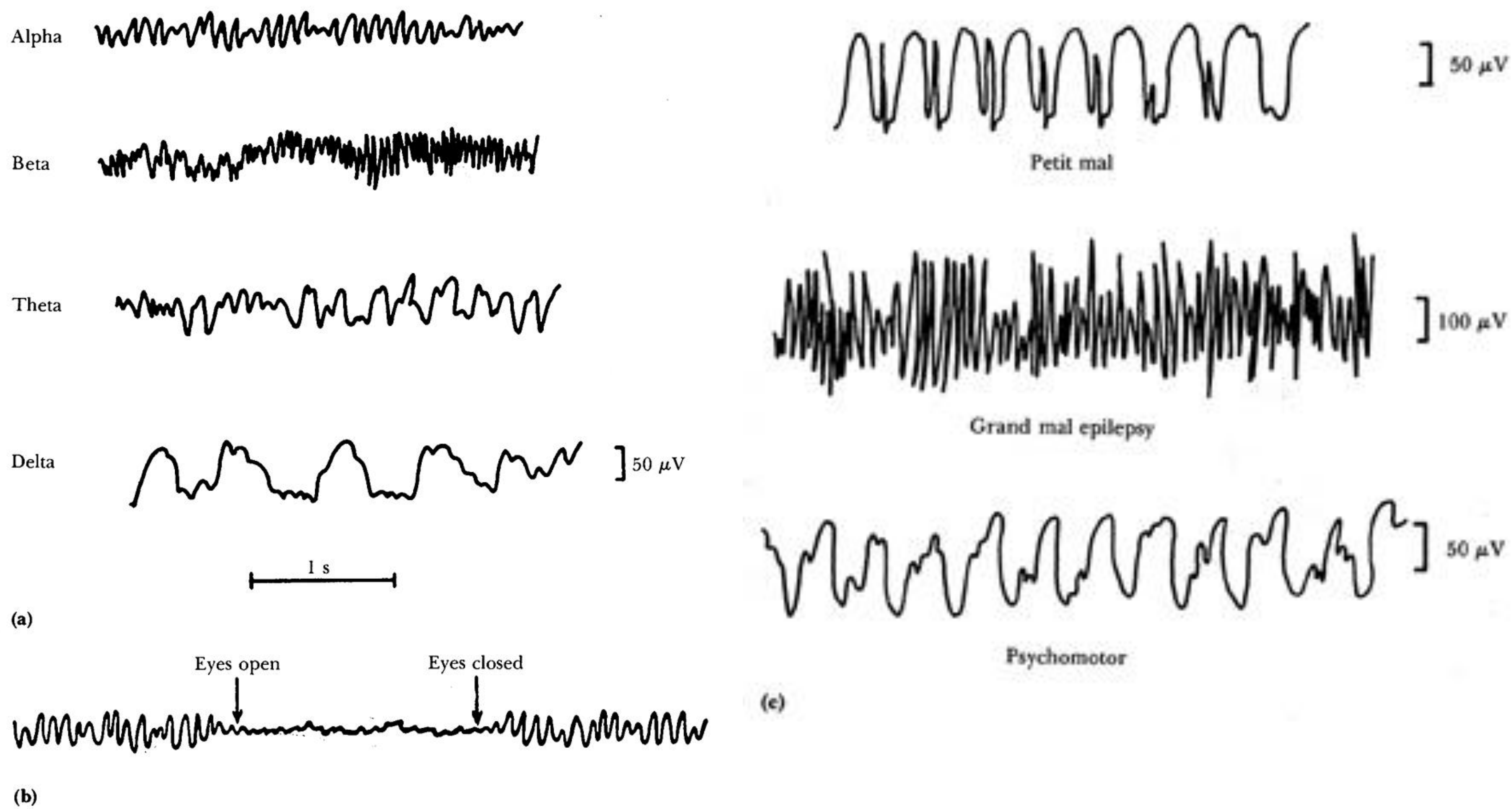
- Although various regions of the cortex capable of exhibiting rhythmic activity, they require trigger inputs to excite rhythmicity. The **reticular activation system** (RAS) provide this pacemaker function.

# Reticular Activating System

- Network in brain stem
- RAS is responsible for sleep/wake behavior and arousal
- Arouses and activates cerebral cortex
- Controls overall degree of cortical alertness or level of consciousness:
  - maximum alertness
  - wakefulness
  - sleep
  - coma



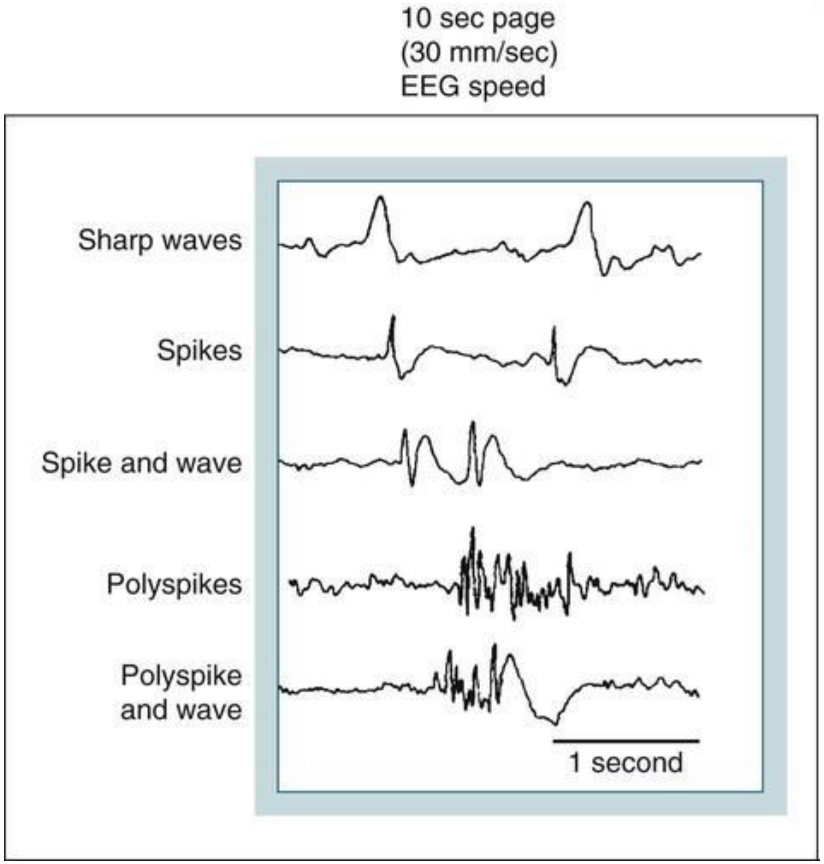
# EEG Rhythms and Waveforms- (Cont.)




(a) Different types of normal EEG waves.
(b) Replacement of alpha rhythm by an asynchronous discharge when patient opens eyes.
(c) Representative abnormal EEG waveforms in different types of epilepsy.

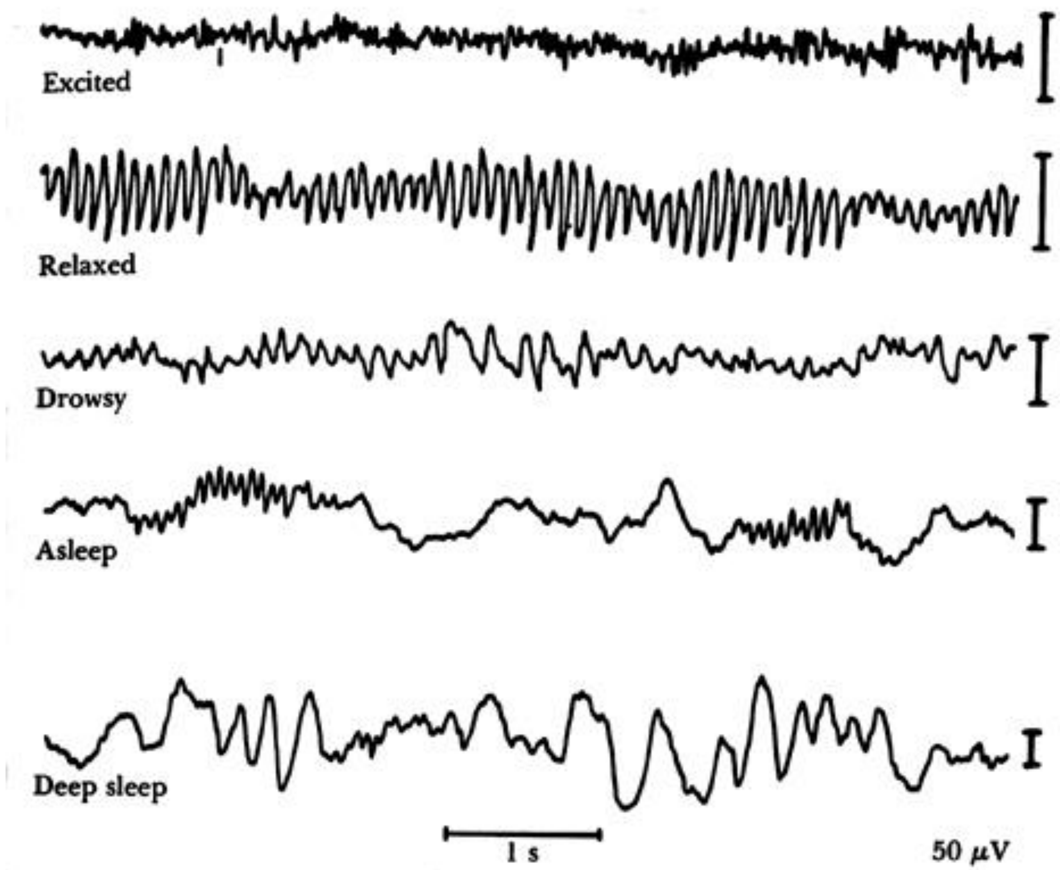
# EEG Rhythms and Waveforms- (Cont.)

- Spikes and Sharp Waves (SSWs)
  - Transient waveforms standing out from the background EEG
  - Irregular, unpredictable temporal occurance pattern
  - Indicates a deviant neuronal behavior often found in patients suffering from epileptic seizures.
  - Spike → 20 to 70 ms
  - Sharp wave → 70 to 200 ms

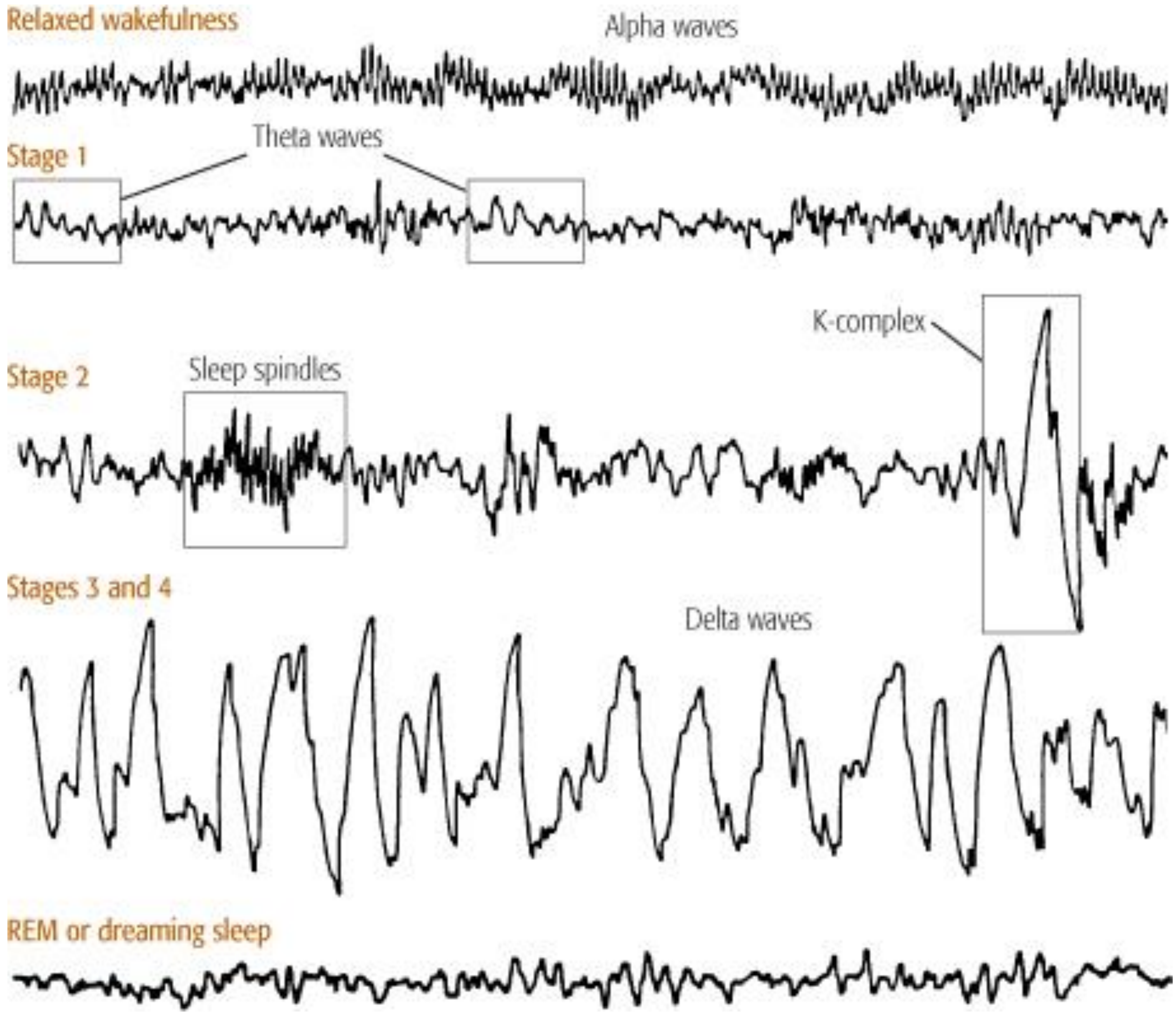


# EEG Rhythms and Waveforms- (Cont.)

- **Sleep rhythms**




**The electroencephalographic changes that occur as a human subject goes to sleep** (The calibration marks on the right represent 50 mV).



Relaxed wakefulness
Alpha waves
Theta waves
Stage 1
K-complex
Stage 2
Sleep spindles
Stages 3 and 4
Delta waves
REM or dreaming sleep

## ➢ Characteristics of the four Non-REM sleep stages and the REM sleep

| Sleep Stage | sleep depth | waveforms |
|---|---|---|
| 1 | Drowsiness | From alpha dropouts to vertex waves |
| 2 | Light sleep | Vertex waves, spindles, K complexes |
| 3 | Deep sleep | Much slowing, K complexes, some spindles |
| 4 | Very deep sleep | Much slowing, some K complexes |
| REM | REM sleep | Desynchronization with faster frequencies |

- <u>Non-REM sleep state (stage 1-4)</u> associated with resting of the brain and the bodily functions.

- <u>REM sleep state</u>; the eyes move rapidly back and forth in an erratic pattern. Rapid eye movement sleep corresponds to an active brain, so the EEG resembles the awake brain where the beta rhythms show higher proportions.

# Recording Techniques

- The clinical EEG is commonly recorded using the International 10/20 system, which is a standardized system for electrode placement.

- This recording system employs <u>21 electrodes</u> attached to surface of the scalp at locations defined by certain anatomical reference points; the numbers 10 and 20 are percentages signifying relative distances between different electrode locations on the skull perimeter.

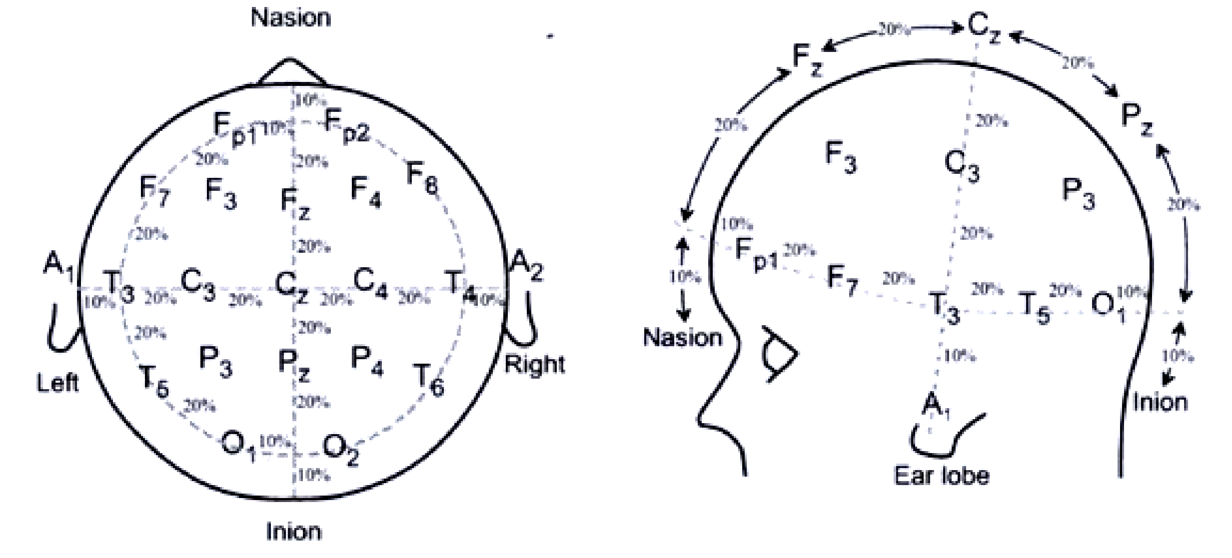
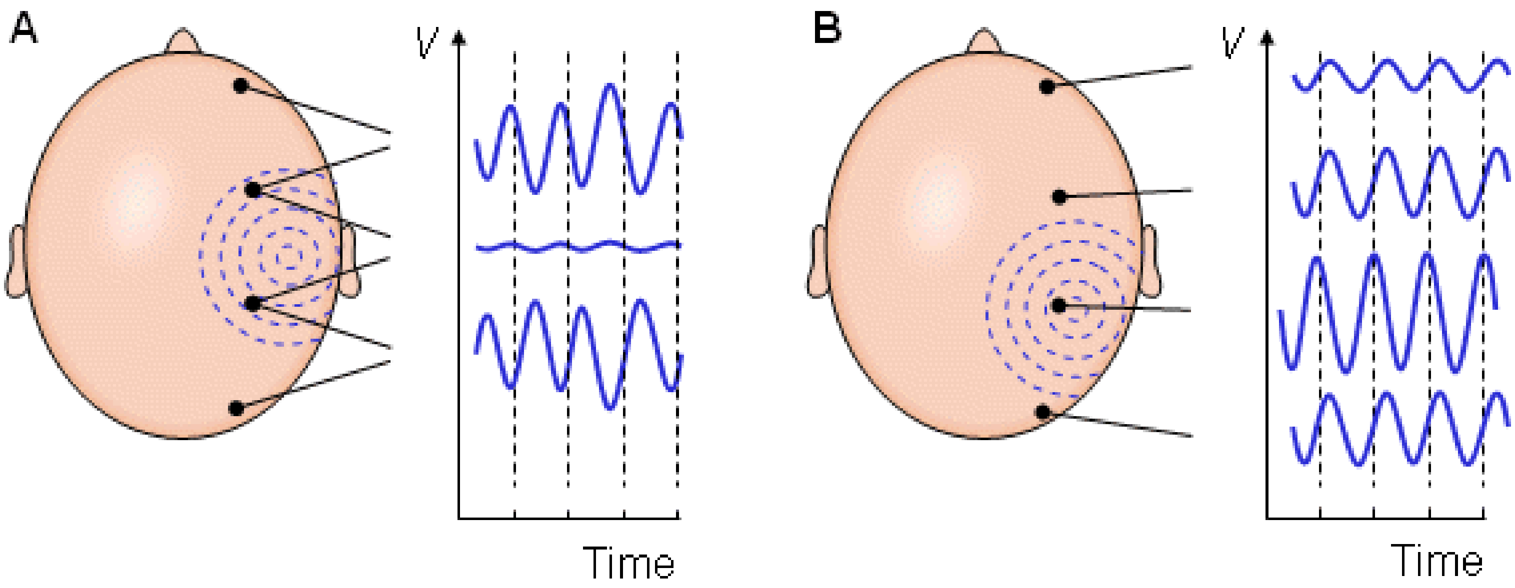



Figure 2.7: The International 10/20 system for recording of clinical EEG's. The anatomical reference points are defined as the top of the nose (nasion) and the back of the skull (inion). The letters F, P, C, T, O and A denotes frontal, parietal, central, temporal, occipital and auricle, respectively. Note that odd-numbered electrodes are on the left side, even-numbered on the right side, and z (zero) in the midline.

## ▪ International Federation 10-20 System

**Type of electrode connections**

1- Between each member of a pair (bipolar)
2- Between one monopolar lead and a distant reference
3- Between one monopolar lead and the average of all.



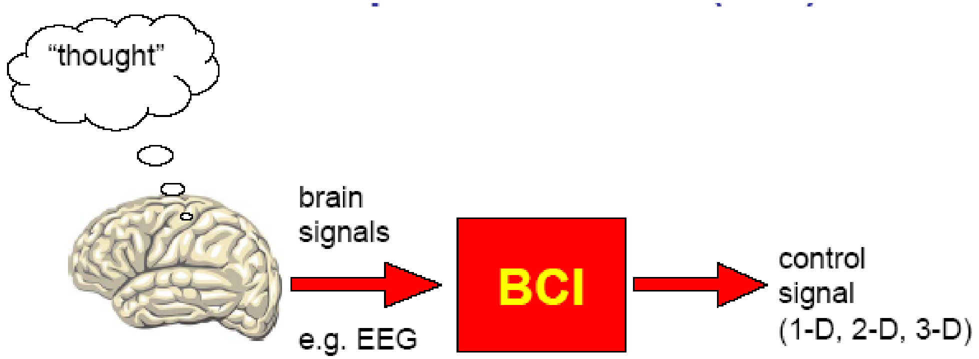

(A) Bipolar and (B) unipolar measurements. Note that the waveform of the EEG depends on the measurement location.

# Some Examples for EEG Applications

## Ambulatory EEG:

- 24 h recording
- Should identify moments of onset of seizure
- Can be used to predict the seizure. Patient can then take appropriate measures
- Great amount of data
- Many sources of noise/artifacts
  - Signal processing is beneficial

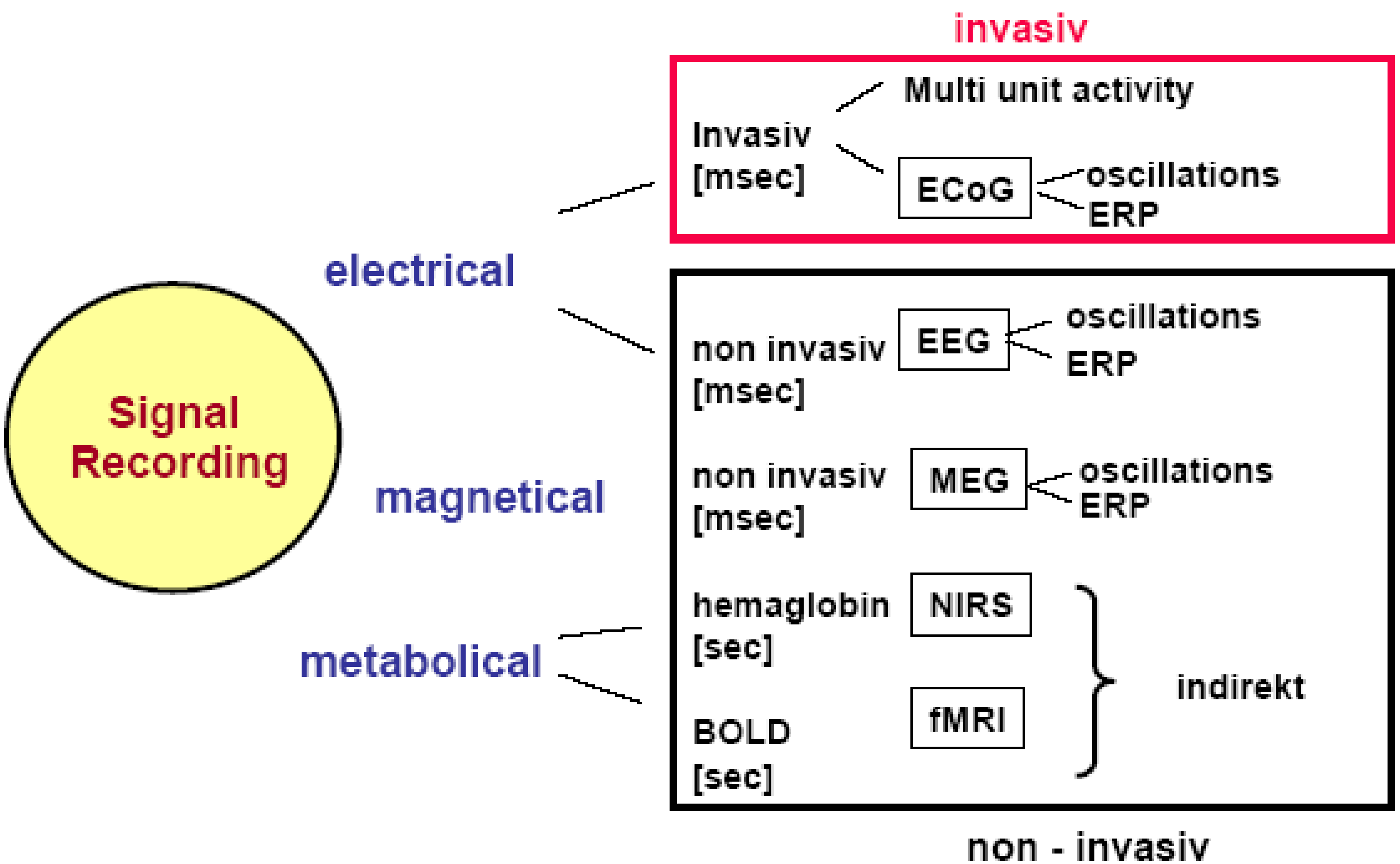
## Brain Computer Interface



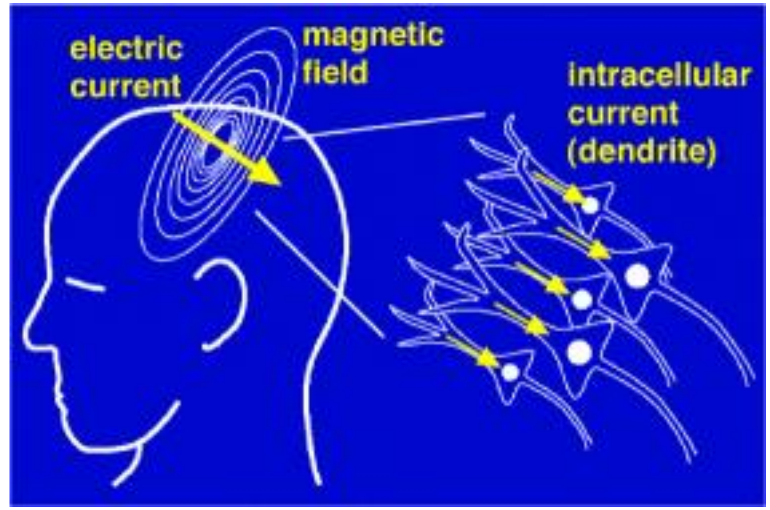

- A BCI is a non-muscular information channel for sending messages and commands from the brain to the external world.
- A BCI analyses and classifies brain signals online and in real-time.

# Brain Computer Interface (BCI)- (Cont.)

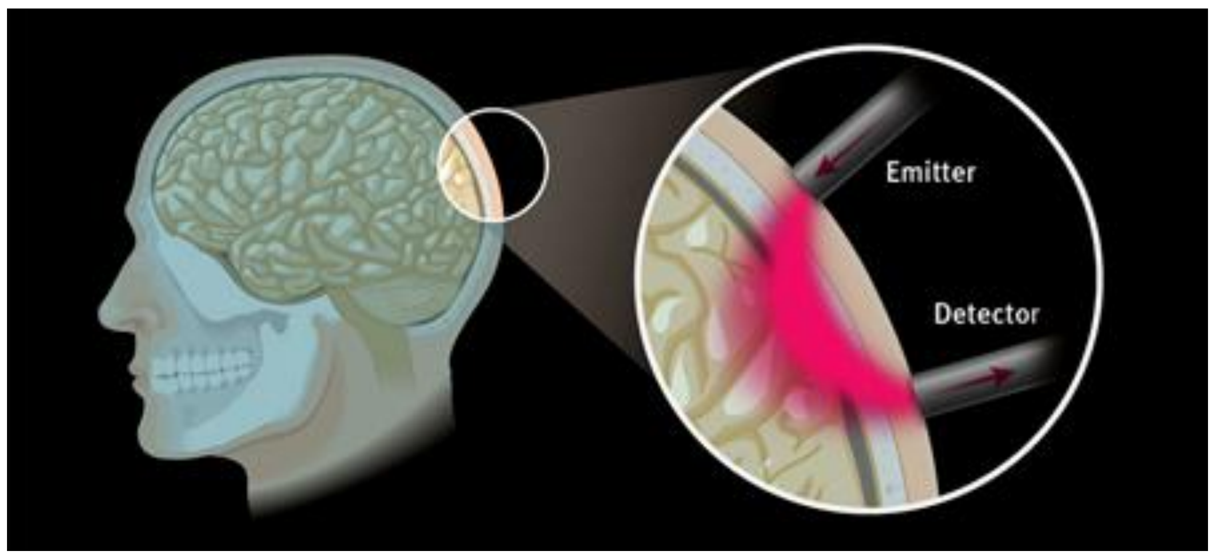
- There are several techniques for measuring brain activities such as magnetoencephalogram (MEG), near infrared spectroscopy (NIRS), electrocorticogram (ECoG), functional magnetic resonance imaging (fMRI), and electroencephalography (EEG).



- **Magnetoencephalography (MEG)** is a non-invasive neurophysiological technique that measures the magnetic fields generated by neuronal activity of the brain, using very sensitive magnetometers.



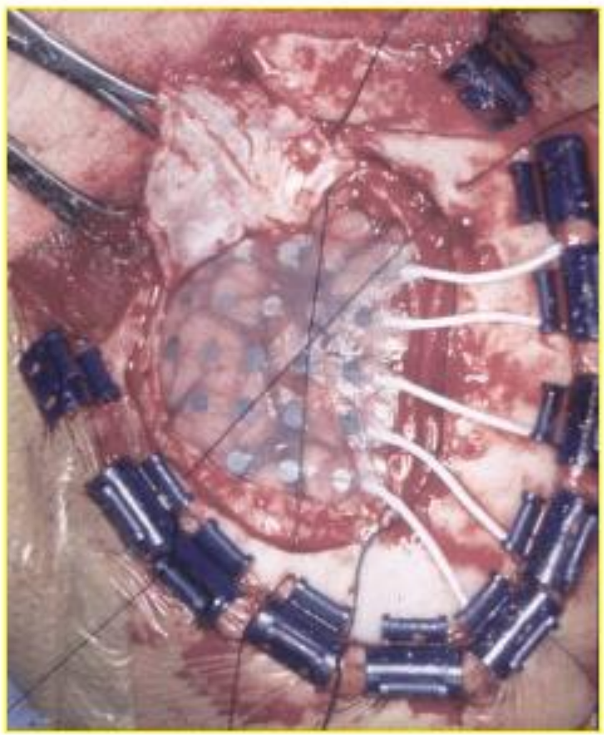

- **Functional Near Infrared Spectroscopy (fNIRS**), which detects changes in the absorption of the optical signal in response to a stimulus and provides a map of the areas where the changes occur. The changes in the optical signal (time scale > 100 ms), are due to local variations of oxy- and deoxy-hemoglobin concentrations.

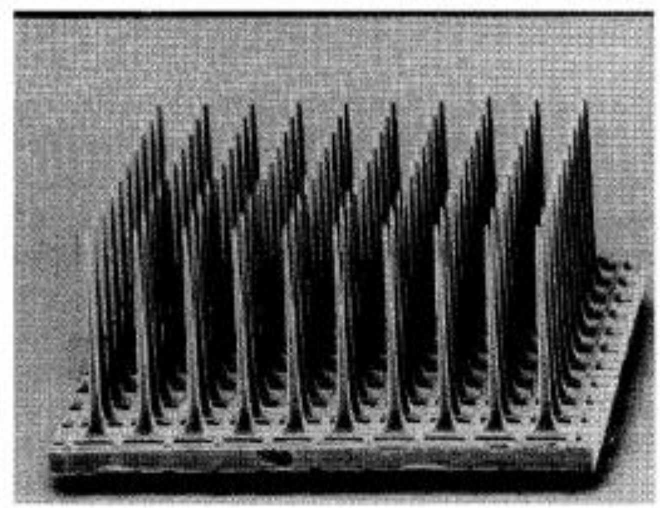


# Brain Computer Interface (BCI)- (Cont.)

- When electrodes are placed on the exposed surface (cortex) of the brain, the electrical activity of the brain is also recorded and  the recording is called an electrocorticogram (ECoG).

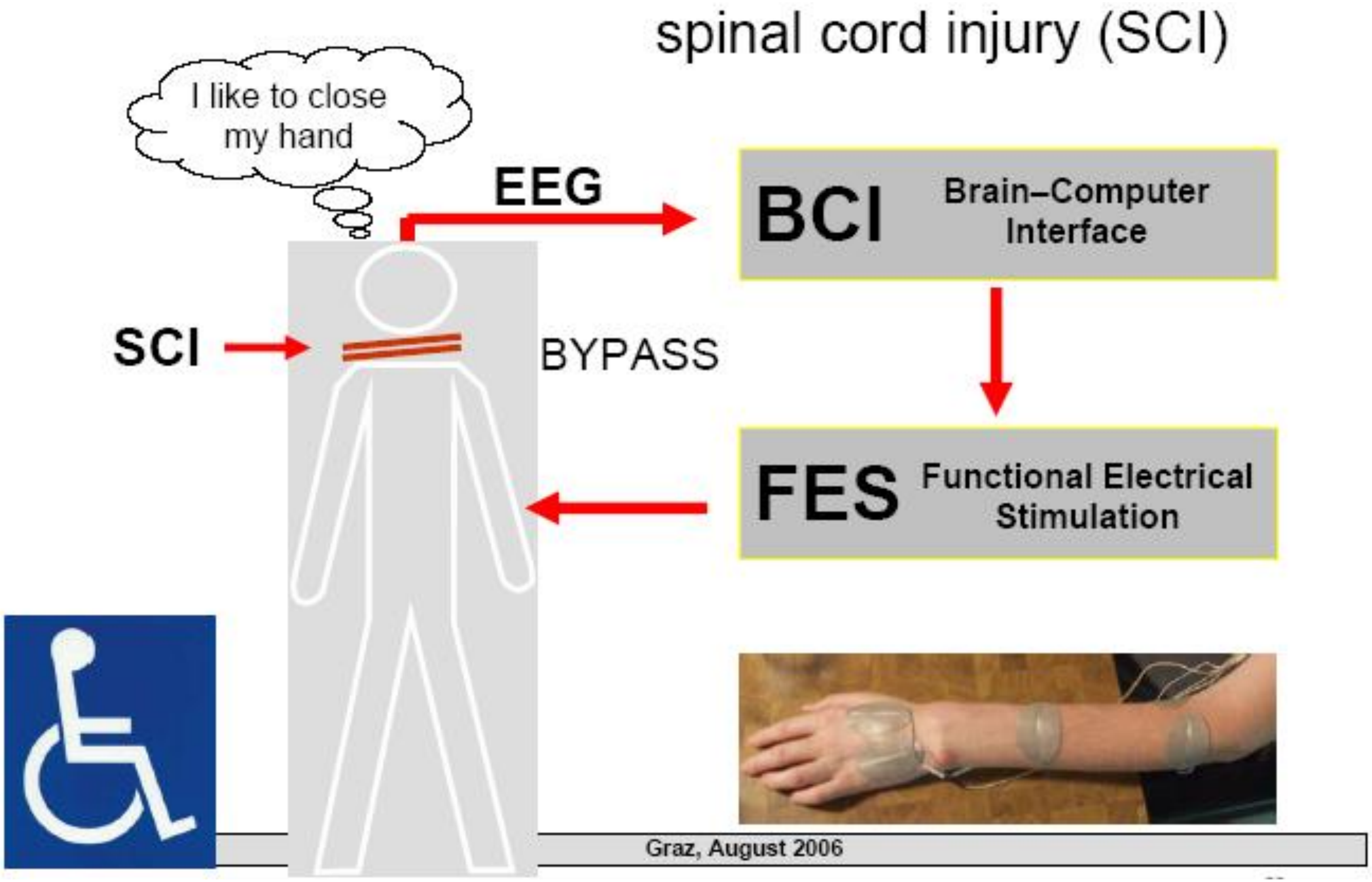
ECoG / Intracortical rec.





Utah array

# Brain Computer Interface (BCI)- (Cont.)



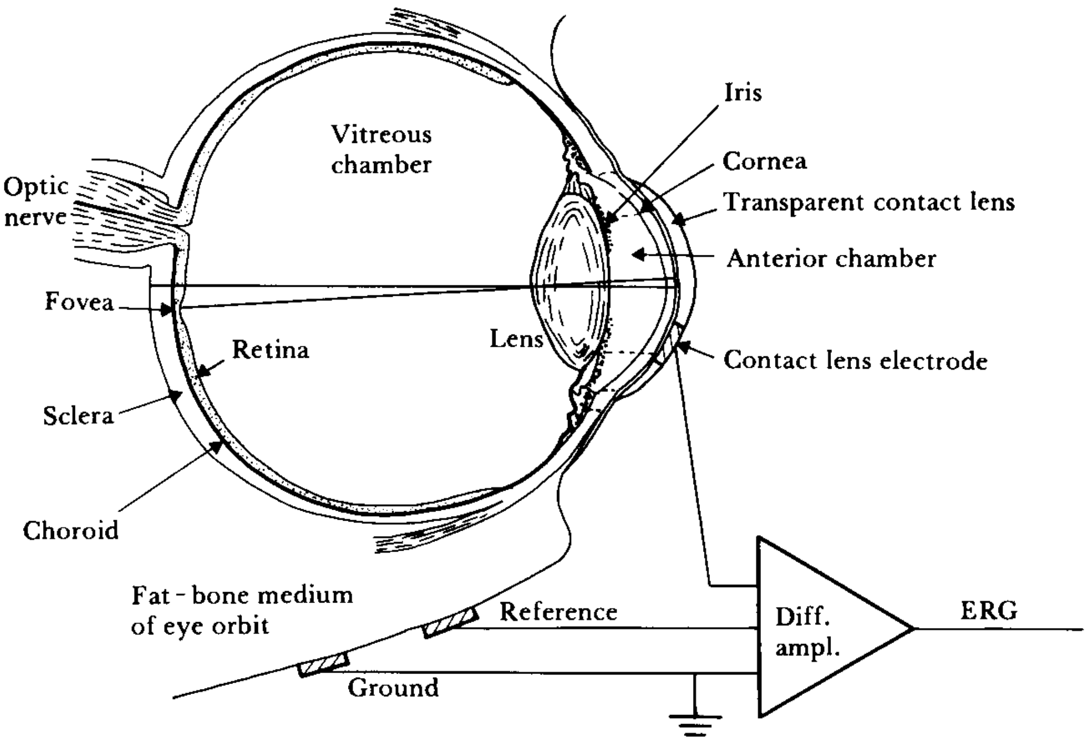
# Electroretinogram (ERG)

## ▪ *Electroretinogram (ERG)*

- The normal eye is an approximately spherical organ about 24 mm in diameter.
- The **retina**, located at the back of the eye, **is the sensory portion of the eye.**

- ERG is a recording of the <u>temporal sequence of changes in potential in the retina</u> when stimulated with a brief flash of light.

- A transparent contact lens contains one electrode and the reference electrode can be placed on the right temple.



# Electroretinogram (ERG)-(Cont.)

- When the retina is stimulated with a brief flash of light, a characteristic temporal sequence of changes in potential can be recorded between an exploring electrode—placed either on the inner surface of the retina or on the cornea—and an indifferent electrode placed elsewhere on the body (usually the temple, forehead, or earlobe).

- These potential changes are collectively known as the electroretinogram (ERG).

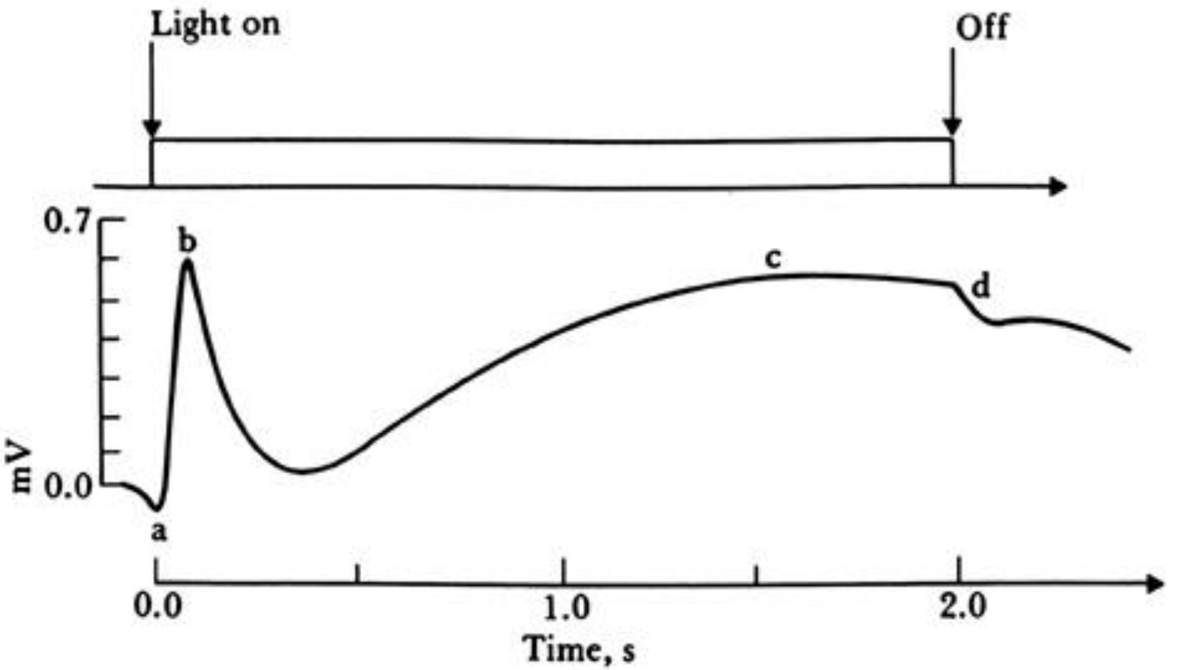
some corneal ERG electrodes

Ag/AgCl electrode embedded in a special contact lens used as the exploring electrode

- The saline-filled contact lens is in good contact with the cornea, which is very thin and in intimate contact with the aqueous fluid medium of the inner eye.
- The contact lens is usually well tolerated by the subject and permits long examinations without discomfort.

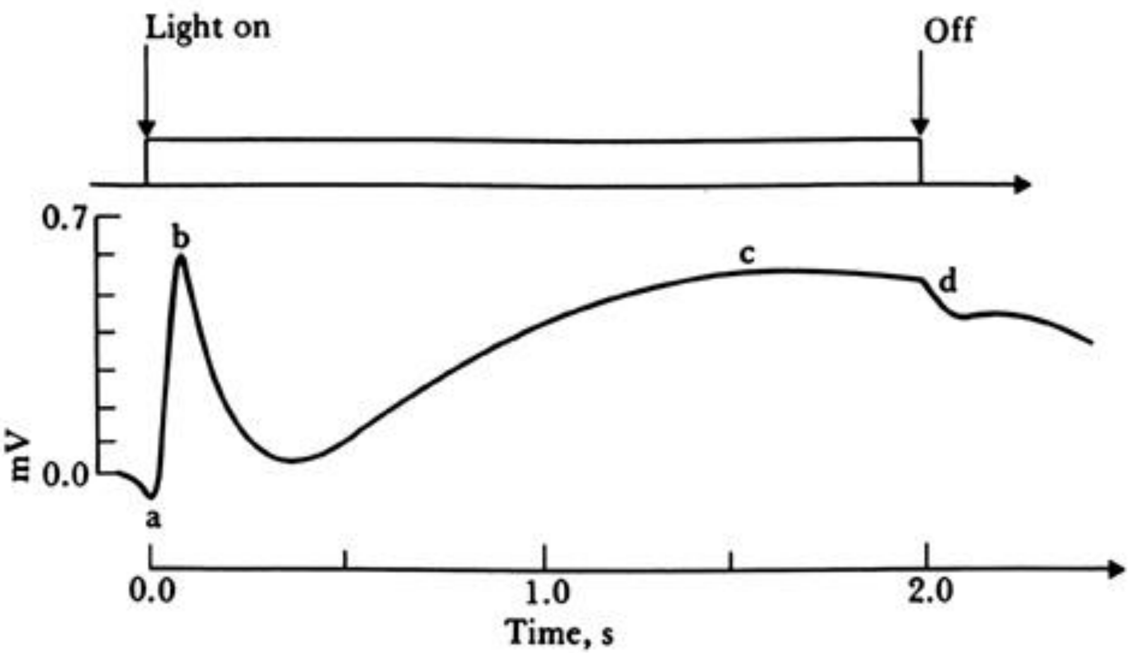
# Electroretinogram (ERG)-(Cont.)

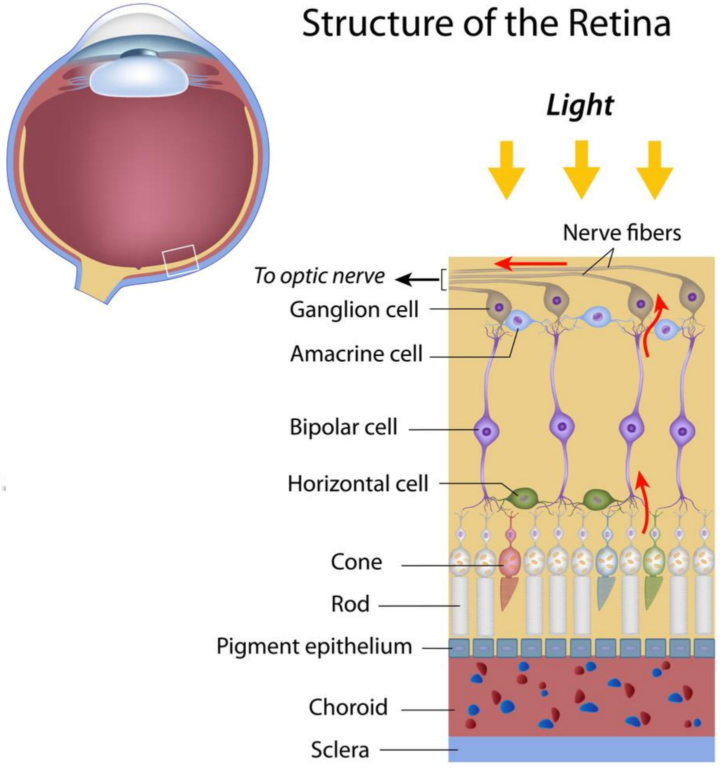
- A typical ERG waveform in response to a 2 s light flash was shown below.




- The four most commonly identified components of the ERG waveform (the a, b, c, and d waves) are common to most vertebrates, including humans.

# Electroretinogram (ERG)-(Cont.)




- The a-wave reflects the general physiological health of the photoreceptors in the outer retina.
- The b wave is generated by activity of the bipolar and ganglion cells of the inner layers of the retina and the b-wave reflects the health of the inner layers of the retina.
- The c wave is not generated by the retina itself, but rather by the pigment epithelial layer. It is generated from the retinal pigment epithelium mainly in response to rod photoreceptors.
- The d wave is the off-response of the retina to the light stimulus.

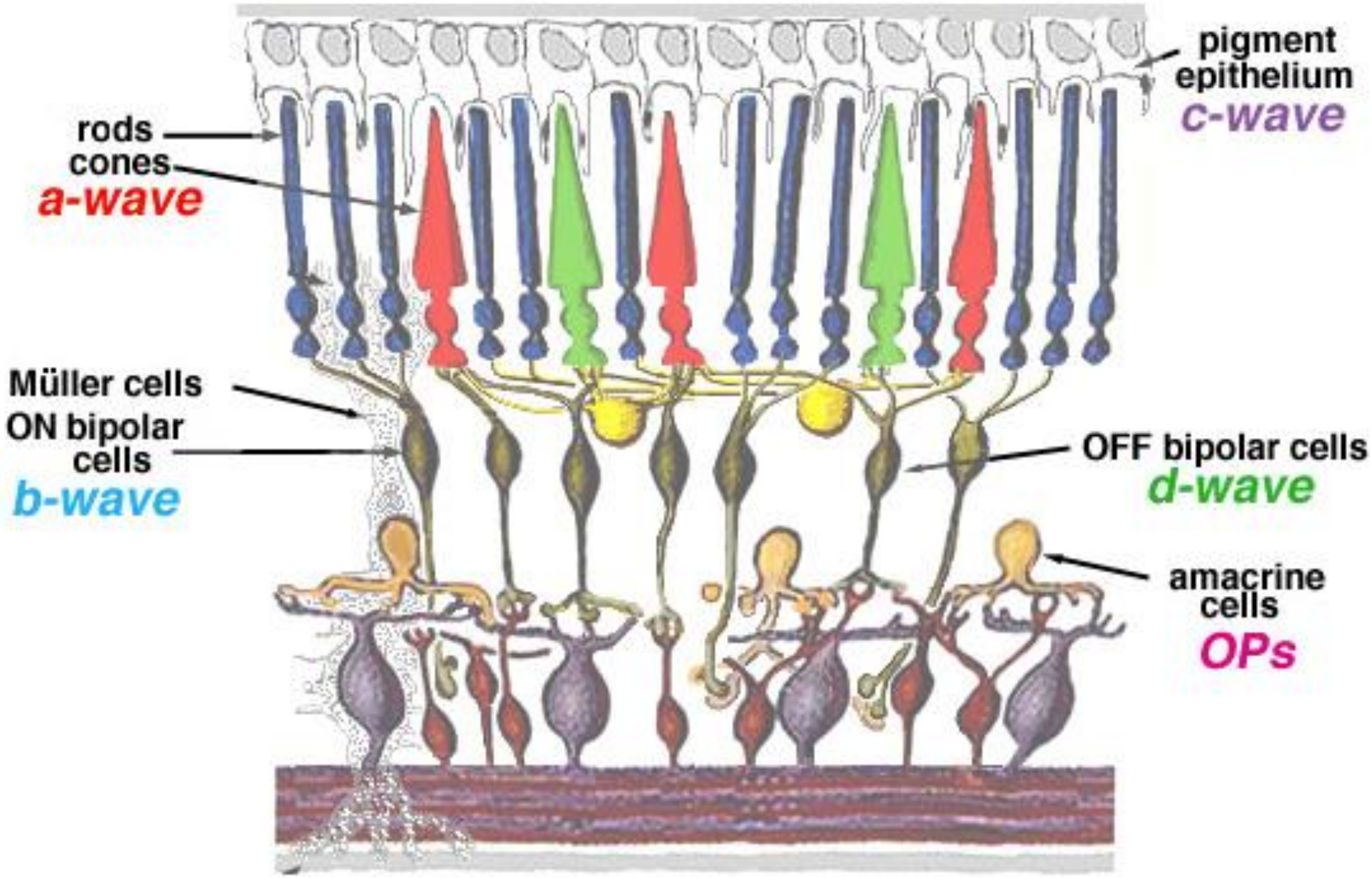



*Fig.3 Cartoon of the retina to show where the major components of the ERG originate.*

# Electro-oculogram (ORG)

# Electro-oculogram (EOG)

- In addition to the transient potential recorded as the ERG, there is a steady corneal–retinal potential.

- EOG is the recording of the corneal-retinal potential to determine the eye movement.

- One can measure the potential between the two electrode to determine the horizontal or vertical movement of the eye by placing two surface electrodes to the left and right of the eye (e.g., on the nose and the temple) or above and below of the eye.

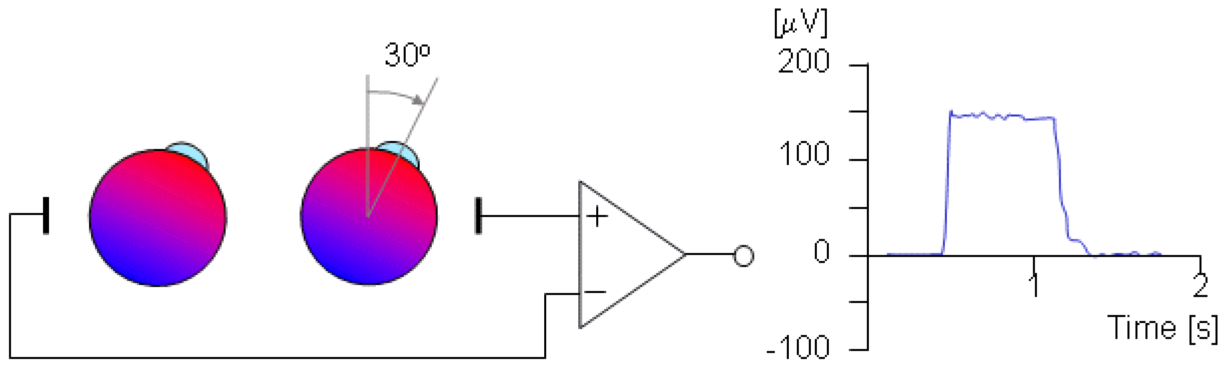
- The potential is zero when the gaze is straight ahead.

- The EOG is frequently the method of choice for recording eye movements in sleep and dream research, in recording eye movements from infants and children, and in evaluating reading ability and visual fatigue.

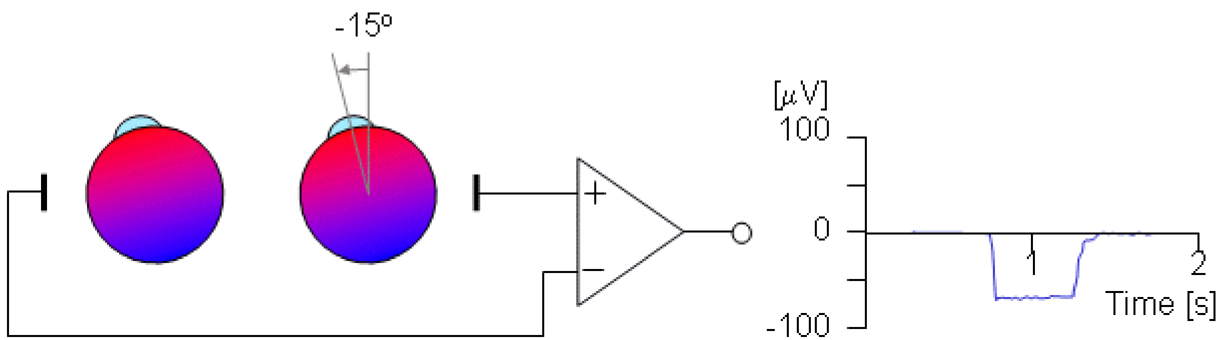
# Electro-oculogram (EOG)- (Cont.)

Fig. 44. Placement of the electrodes for recording an EOG.

# *Electro-oculogram (EOG)- (Cont.)*




Eyes moving 30º to the right




Eyes moving 15º to the left