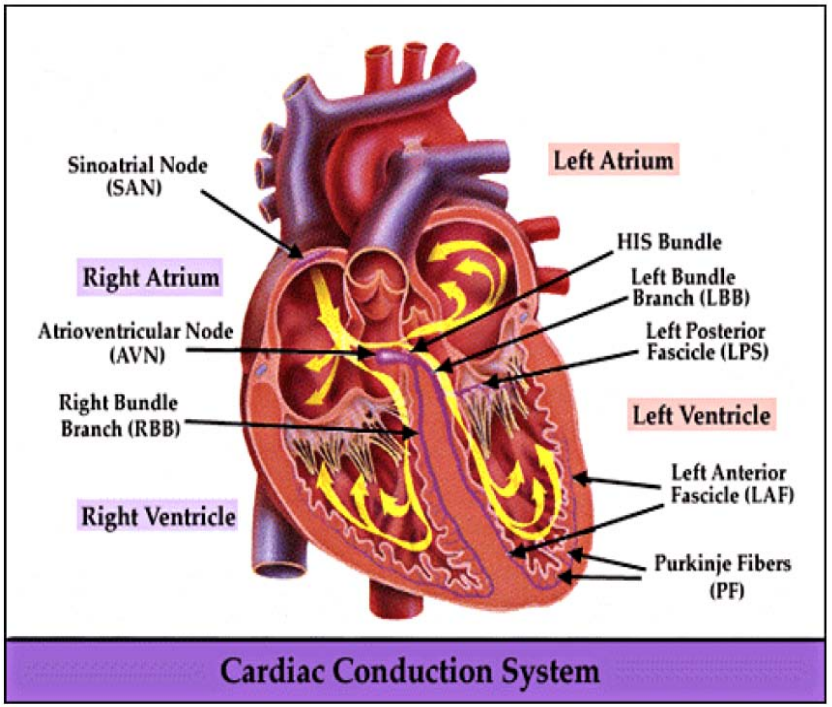
Electro---Grams

Voltage and Frequency Ranges for Some Important Parameters That Are Measured in the Human Body

Parameter sensor location	Voltage range	Frequency range (Hz)
Electrocardiography (ECG)	0.5–4 m V	0.01–250
Skin electrodes		
Electroencephalography (EEG)	5–200 μV	DC–150
Scalp electrodes		
Electrogastrography (EGG)		
Skin–surface electrodes	10–1000 μV	DC–1
Stomach–surface electrodes	0.5–80 mV	DC–1
Electromyography (EMG)	0.1–5 mV	DC–10,000
Needle electrodes		
Electrooculography (EOG)	50–3500 μV	DC–50
Contact electrodes		
Electroretinography (ERG)	0–900 μV	DC–50
Contact electrodes		
Nerve potentials	0.01–3 mV	DC–10,000
Surface or needle electrodes		

ElectroCardioGram

Cardiac Conduction System



http://library.med.utah.edu/kw/ecg

The Action potential that started from the SA (sinoatrial) node (동방결절) propagates down to atrium to reach the Atrioventricular node (심방결절).

The separation between the atrium and ventricle is called the Atirioventrical Ring (방실환) and acts as an insulation (with only 0.05 m/sec conduction velocity). This has a critical function of allowing a delay about 0.1 sec which is enough to finish atrial contraction before ventricular contraction starts.

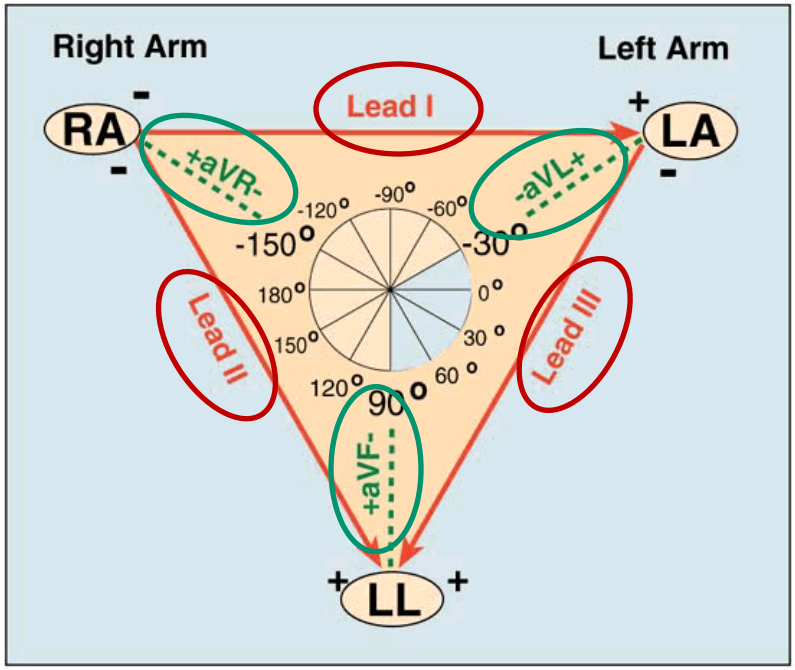
(The conduction velocity is about 1m/sec within the atrium and ventricle)

The AP travels from the AV node through His' bunble at a speed of 4m/sec to arrive at the Purkinje network in the right and left branches of the central septum. Here the conduction is at 5m/sec and the entire ventricular muscle contracts almost simultaneously.

The Einthoven Triangle

Pacemaker voltage: The repetitive depolarization state in the SA node.

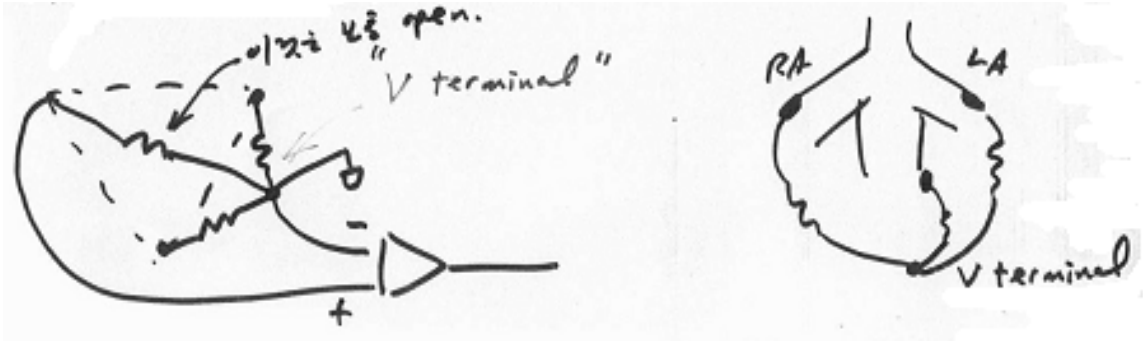
The propagation of the AP in the heart can be presented as a dipole vector that moves within the Einthoven Triangle drawn by him to record the ECG by the standard limb lead method(사지유도방식).



Lead Connections

Standard Line Lead: Bipolar measurement

Augmented Lead: Unipolar measurement

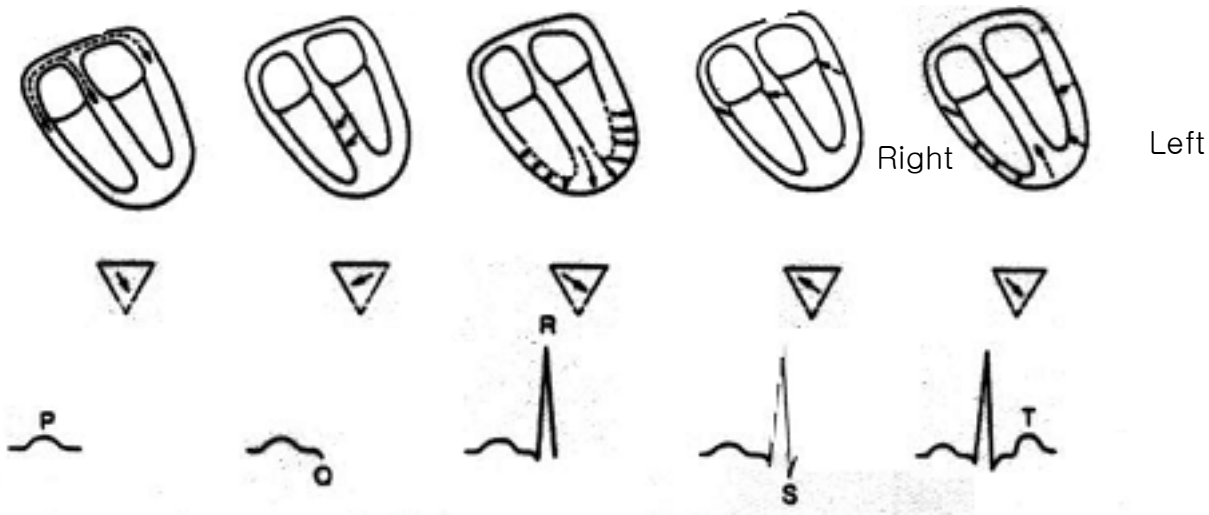


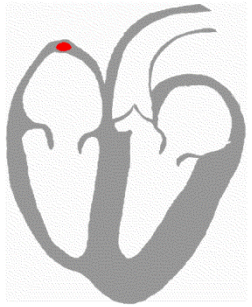
Heart as a Dipole Vector (at lead 2)

- **(P)** The AP that started from SA node propagates to the atrium then reaches to the AV node. The direction of the vector is bottom left.
- **(QRS)** The AP in the ventricle starts from the interventricular septum at the center and propagates to both left and right. The direction of vector is bottom right. (Q phase, phase 1)

  The depolarization continues to propagate from center to outside of the ventricle. Vector direction is to the bottom left. (R, phase 2)

  The last place to be excited is the top and posterior side of the septum. The vector points to top and right. (S, phase 3)
- **(T)** The repolarization in the ventricle propagates from the outer wall to the inner wall. This is opposite to the direction of R wave but considering the polarity of the dipole, the vector directs to bottom and left.



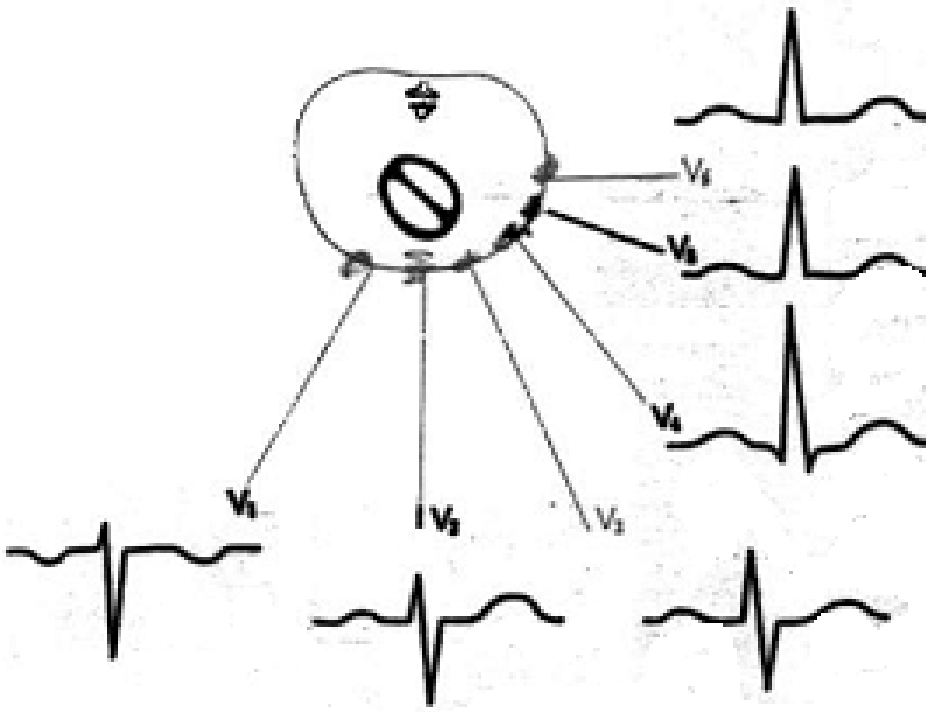


Source: Wikipedia

Precordial lead and Standard 12 lead

Precordial lead(or chest lead) records the ECG by looking at the heart from the transverse plane and records the ECG with larger magnitude.

Including the standard line leads, augmented leads, and precordial leads, there are 12 leads total and the system is called the Standard 12 lead system.

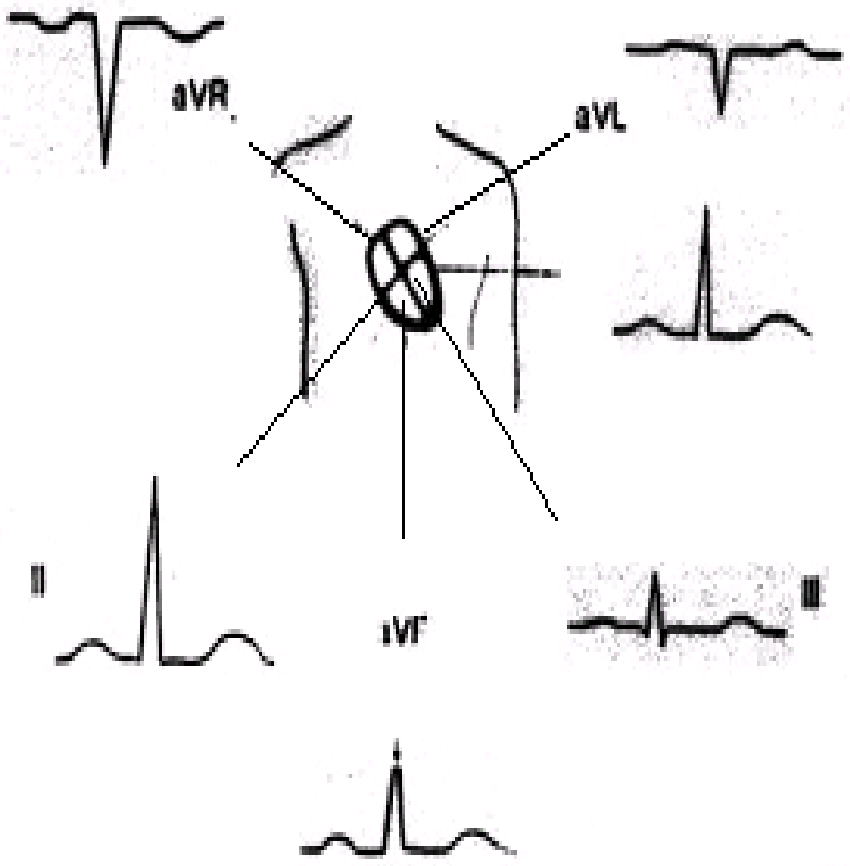


For 12 lead ECG placement, see

http://www.youtube.com/watch?v=GUIKXnot-1k

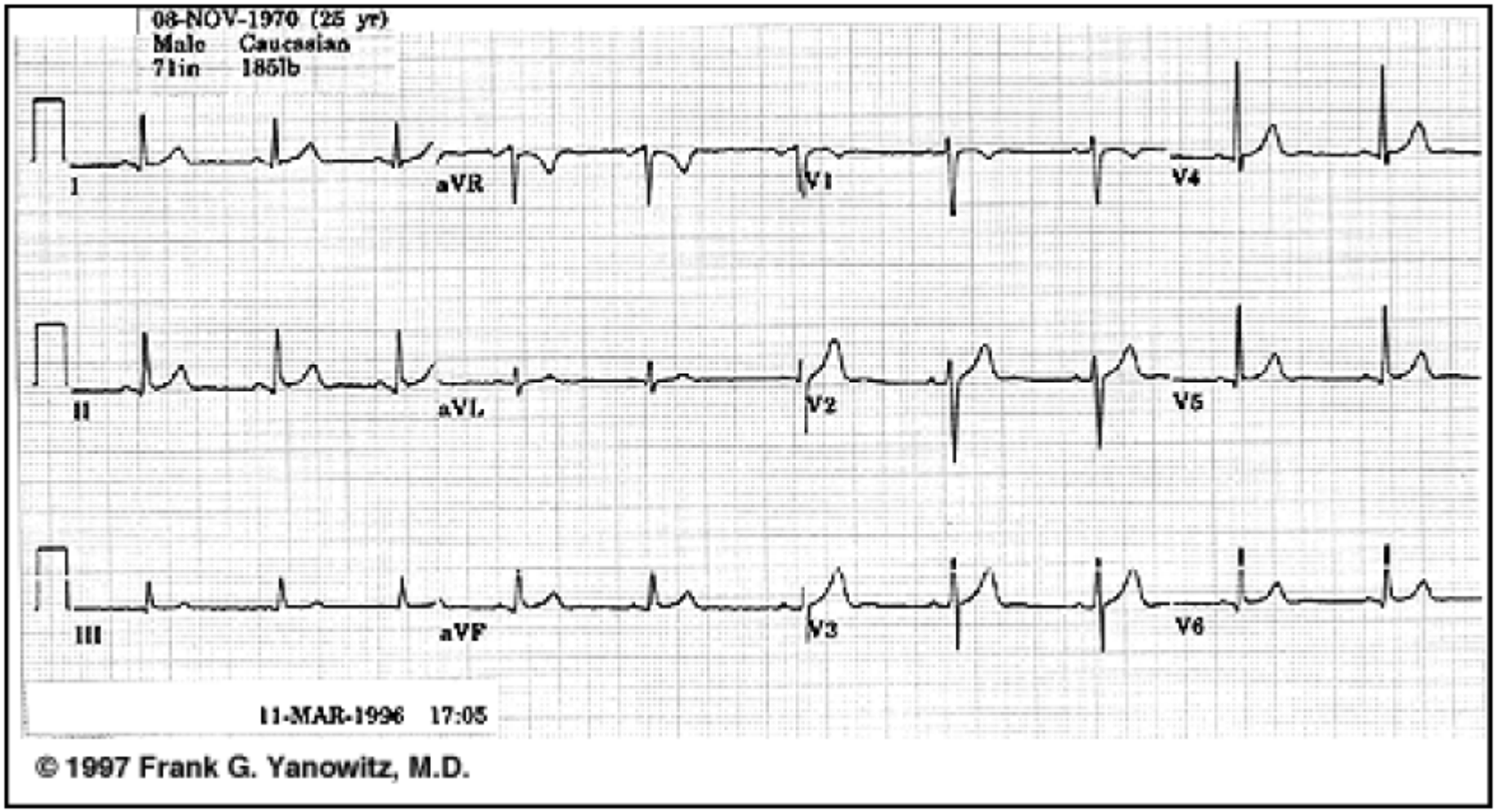
ECG dependency on leads

- Lead II: sees the main vector almost in parallel → largest positive P,R,T waves, very small negative Q, S waves.
- Lead I & aVF: not parallel to the main vector → mostly positive but, small
- Lead III: faces the main vector at almost right angle→ small QRS wave,
- aVL: slightly opposite direction → negative QRS wave.
- aVR: truly opposite direction → large negative R wave, small negative P & T waves



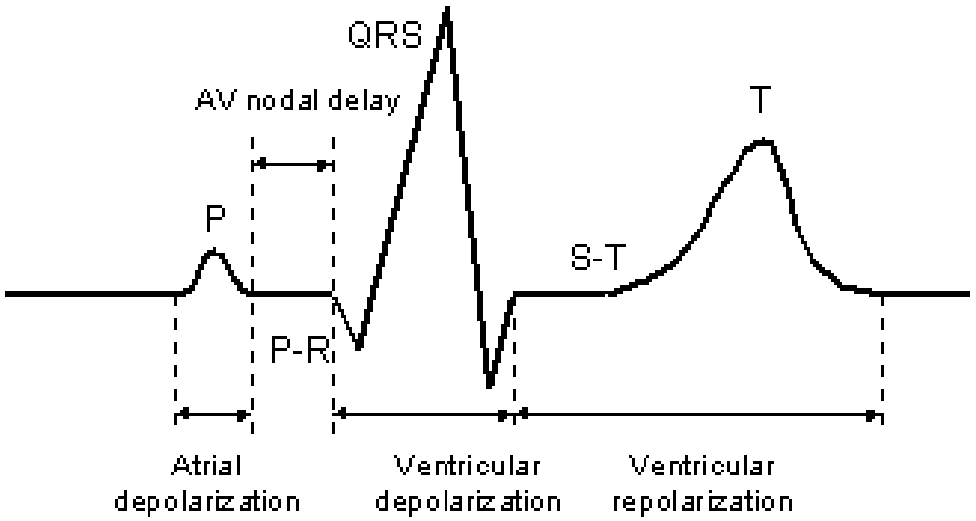
- Lead I: RA (-) to LA (+)
- Lead II: RA (-) to LL (+)
- Lead III: LA (-) to LL (+)
- aVR: RA (+) to [LA & LL] (-)
- aVL: LA (+) to [RA & LL] (-)
- aVF: LL (+) to [RA & LA] (-)

Normal ECG


08-NOV-1970 (25 yr)
Male Caucasian
71in 185lb
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
11-MAR-1996 17:05
© 1997 Frank G. Yanowitz, M.D.

Diagnosis

Diagnosis parameter: heart output, output under stress, anatomy electrical conductivity, blood pressure, valve leakage...



For example)

If, QRS duration is too long

- Incomplete right or left bundle branch block (SA→AV bundle fiber)
- Inverted T (repolorization problem; shorter AP at ventricular apex than at ventricular base)

For more Diagnosis of cardiac diseases, see http://library.med.utah.edu/kw/ecg

Normal variability in 12 lead ECG

- Measurements
  - Heart rate: 60 - 90 bpm
  - PR interval: 0.12 - 0.20 sec
  - QRS duration: 0.06 - 0.10 sec
  - QT interval: QTc ≤ 0.40 sec

Fibrillation and Defibrillation

Fibrillation(세동): In normal, once an action potential is initiated, a new action potential cannot be initiated for the refractory period. But, in arrhythmia (부정맥) patients, there is uncoordinated contraction of the cardiac muscle of the ventricles in the heart, making them quiver rather than contract properly. Ventricular fibrillation is especially a cause of cardiac arrest (심장마비; Do not get confused with Heart Attack (심장발작, 경색)) . The condition can often be reversed by the resuscitation (소생술) or an electrical defibrillator (제세동기).

For BiVentricular Degibrillator Implantation

see from 10 minute point of or-live.com video:

http://www.youtube.com/watch?v=fE13wVvt8Gg

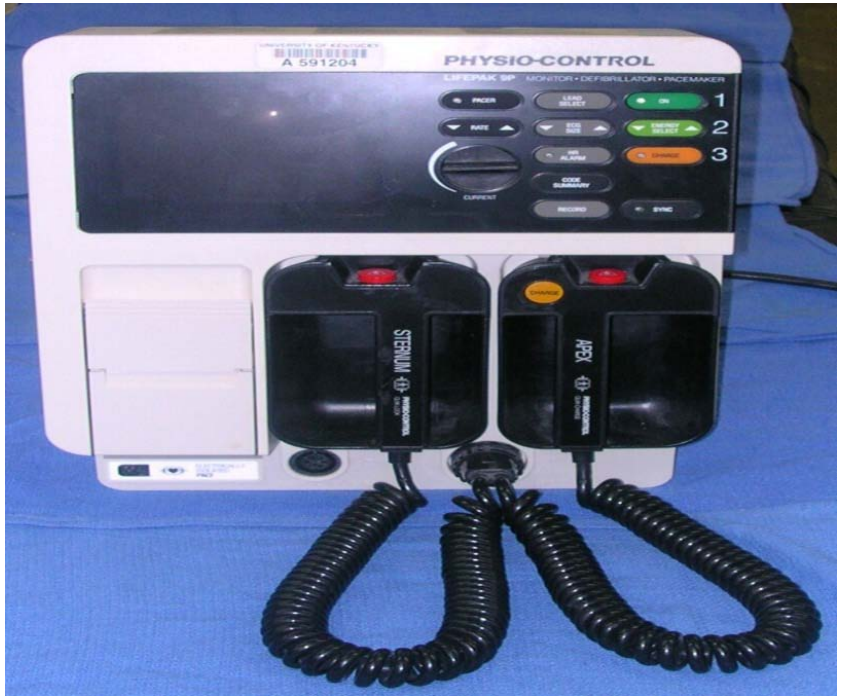
Implantable cardioverter-defibrillator (ICD)

A small battery-powered electrical impulse generator

implanted in patients who are at risk of sudden cardiac death due to ventricular fibrillation.

The device is programmed to detect cardiac arrhythmia and correct it by delivering a jolt of electricity

Defibrillator



Other Biopotentials

EMG

EEG

Visually Evoked Potentials

Auditorily Evoked Potentials

ElectroMyoGram

What is an electromyogram(EMG) ?

- A test that is used to record the electrical activity of muscles.
- EMGs can be used to detect abnormal muscle electrical activity that can occur in many diseases and conditions, such as amyotrophic lateral sclerosis (ALS) (also known as Lou Gehrig disease).

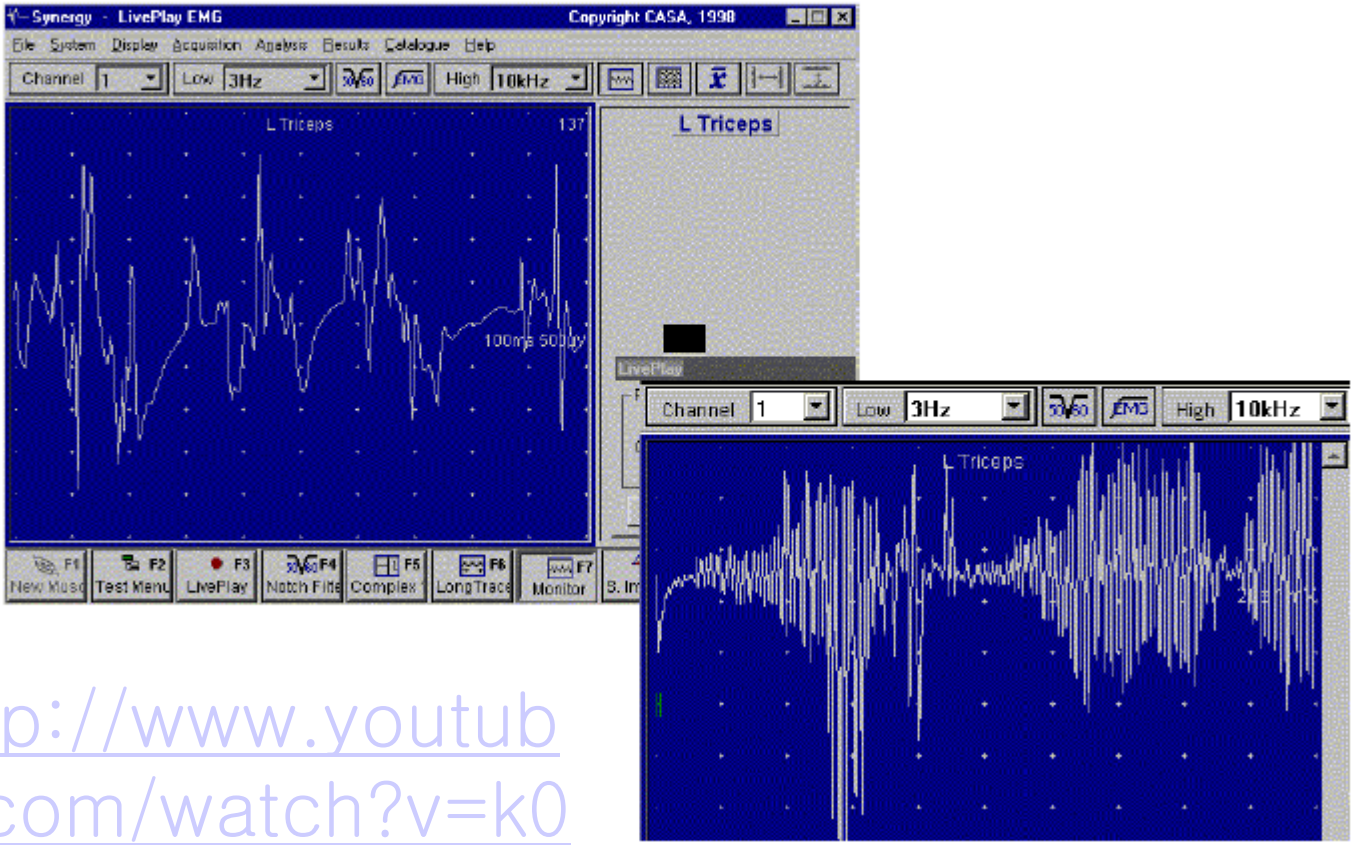
Why is an EMG test done?

- For patients with unexplained muscle weakness.

What kinds of EMG are there?

- *Intramuscular EMG* (the most commonly used type) involves inserting a needle electrode through the skin into the muscle whose electrical activity is to be measured.
- *Surface EMG* (SEMG) involves placing the electrodes on (not into) the skin overlying the muscle to detect the electrical activity of the muscle.

EMG Waveform



http://www.youtube.com/watch?v=k0uSpYd_Ics

ElectroEncephaloGram

1.A graphic recording of electrical activity of the brain, usually of the cerebral cortex, but sometimes of lower areas, recorded from electrodes placed on the surface of the scalp.

2.A graphic (voltage vs. time) depiction of the brain's electrical potentials (brain waves) recorded by scalp electrodes. It is used for diagnosis in neurologic and neuropsychiatric disorders and in neurophysiological research. Sometimes used interchangeably with electrocorticogram and depth record, in which the electrodes are in direct contact with brain tissue.

http://www.youtube.com/watch?v=3eZTAAIt3QU

http://www.youtube.com/watch?v=M9XVm-ks1ME

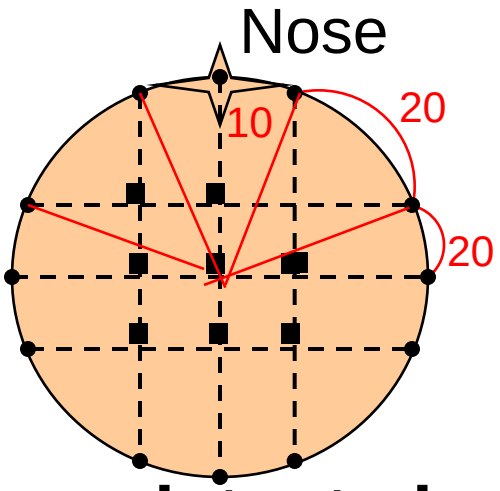
http://www.youtube.com/watch?v=C4H-0eLVZAk

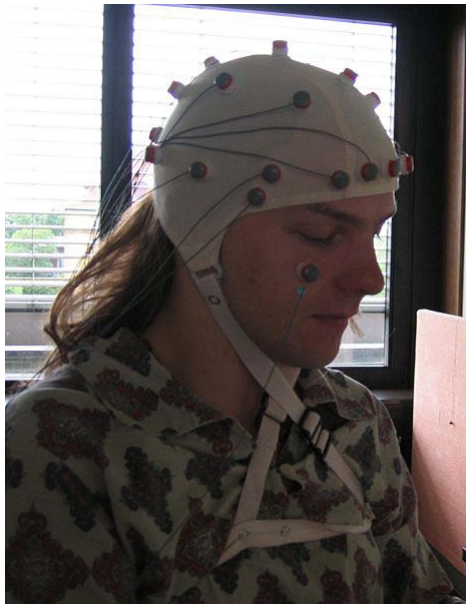
EEG

- EEG configuration

  21 electrodes, z~10kΩ max

Top view





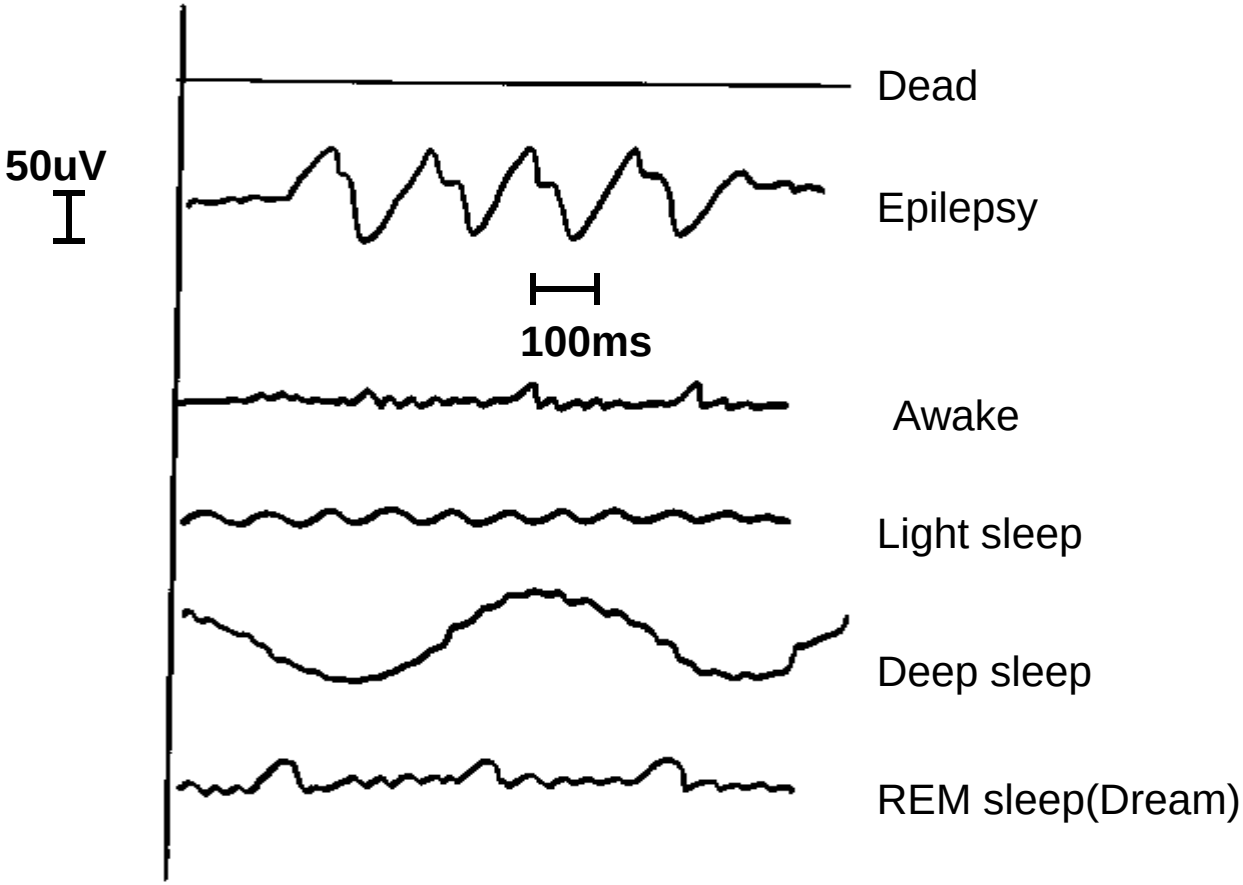
32 channel EEG

Each electrode can detect circles of 1cm diameter.

Intensity of the signal $\alpha \propto 1/r^2$

EEG

Wave	δ θ α β γ
	0 ~ 4 ~ 8 ~ 13 ~ 22 ~ 30



EEG source

Scalp EEG measures summated activity of post-synaptic currents.
While it is post-synaptic potentials that generate the EEG signal, it is not possible to determine the activity within a single dendrite or neuron from the scalp EEG. Rather, surface EEG is the summation of the synchronous activity of thousands of neurons that have similar spatial orientation, radial to the scalp. Currents that are tangential to the scalp are not picked up by the EEG. The EEG therefore benefits from the parallel, radial arrangement of apical dendrites in the cortex. Because voltage fields fall off with the fourth power of the radius, activity from deep sources is more difficult to detect than currents near the skull.
Scalp EEG activity is composed of multiple oscillations. These have different characteristic frequencies, spatial distributions and associations with different states of brain functioning (such as awake vs. asleep). These oscillations represent synchronized activity over a network of neurons. The neuronal network underlying some of these oscillations are understood (such as the thalomocortical resonance underlying sleep spindles), while many others are not (e.g., the system that generates the posterior basic rhythm still defies understanding).

EEG and MEG

Electroencephalography (EEG) and magnetoencephalography (MEG) are non-invasive techniques for detecting and localizing electrical activities of the central nervous system. EEG systems measure the electric potentials induced on the surface of the scalp using electrodes (see Fig. 1). MEG systems measure the magnetic fields emanating from the brain with SQUID biomagnetometers (SQUID is a Superconducting QUantum Interference Device.)(see Fig. 2).

Both EEG and MEG are non-invasive, have good temporal resolution, and directly yield information about neurologic functions. Compared with EEG, MEG is more robust to modeling inaccuracy, more comfortable, has a smaller procedural cost (shorter preparation time), but is also more expensive.

EEG and MEG can be used in clinical applications such as seizure source localization in epilepsy, fatal medicine, psychiatry, or in neuroscience to analyze sensorimotor or cognitive functions of the brain.

Fig. 1: 128 channel EEG system (courtesy of Electrical Geodesics).

Fig. 2: (a) 143 channel MEG system. (b) Illustration of the MEG sensor array. The contours correspond to the magnitude of the field induced by the source. (courtesy of VSM MedTech Ltd.)

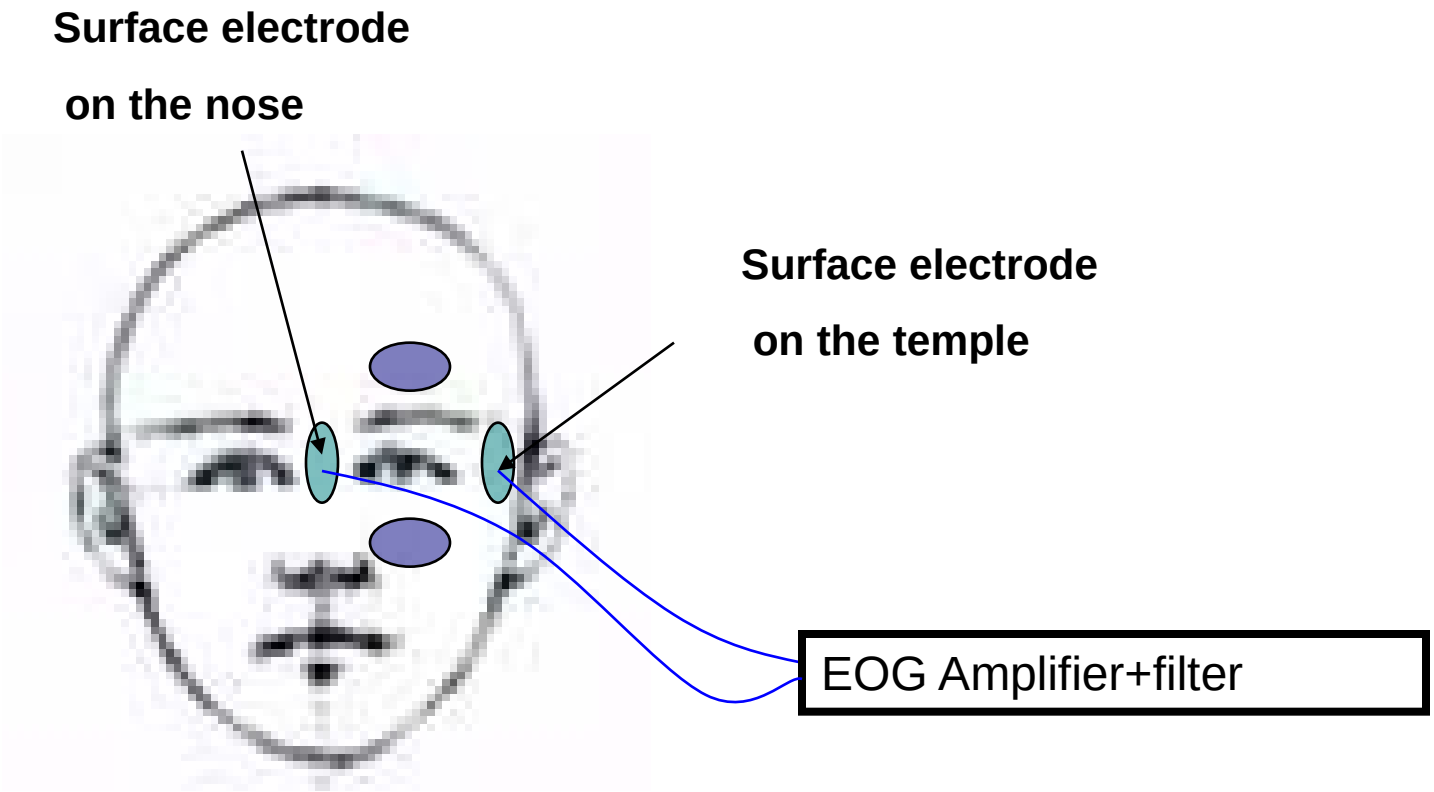
Biopotentials related with Vision

- EOG : Eye battery Measurement

  Record Resting Potential of Retina while allowing subject to see two points with fixed distance alternately

- ERG : electrical response of retina to optical stimulation
- Visually Evoked Potential (VEP) and EEP (from retina prosthesis)

Electro-Oculogram



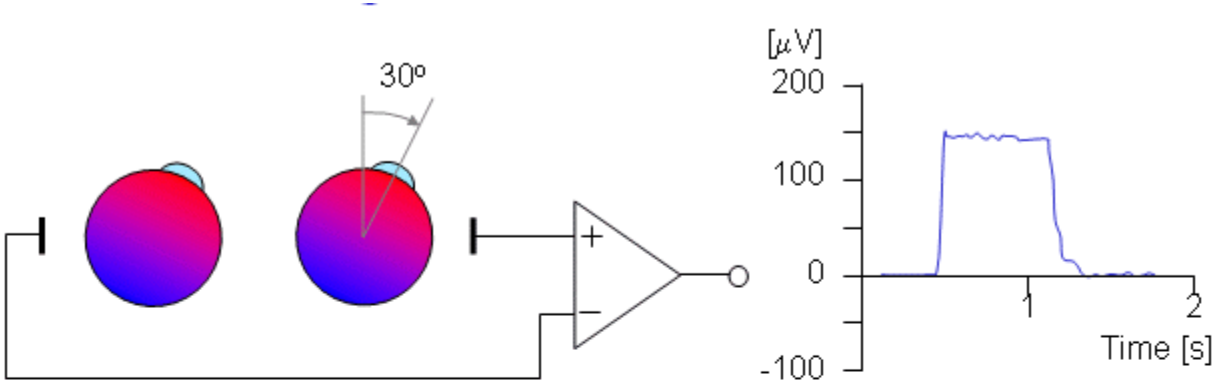
EOG

- Emil du Bois-Reymond (1848): First observation that the cornea of the eye is electrically positive relative to the back of the eye.
- Elwin Marg named the electrooculogram in 1951
- Geoffrey Arden (Arden et al. 1962) developed the first clinical application.

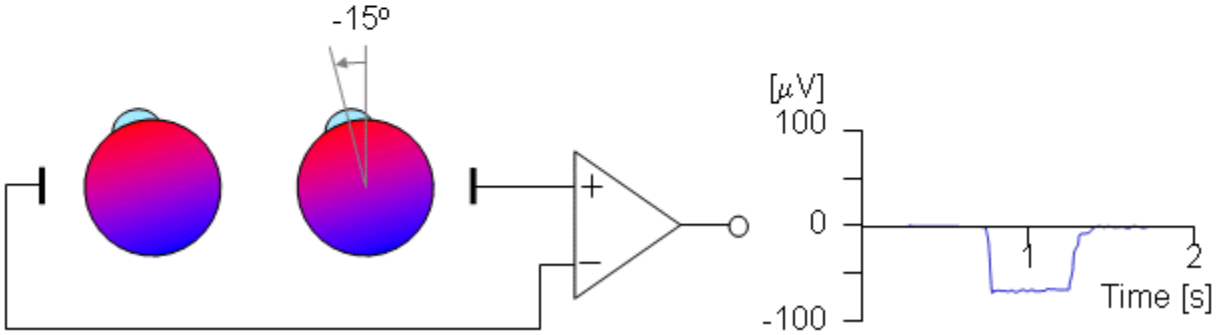
EOG

- behaves as if it were a single dipole oriented from the retina to the cornea.
- well established and are in the range of 0.4 - 1.0 mV .
- Eye movements thus produce a moving (rotating) dipole source.
- Can be used for the measurement of eye movement.

EOG



Eyes moving 30º to the right



Eyes moving 15º to the left

Clinical EOG

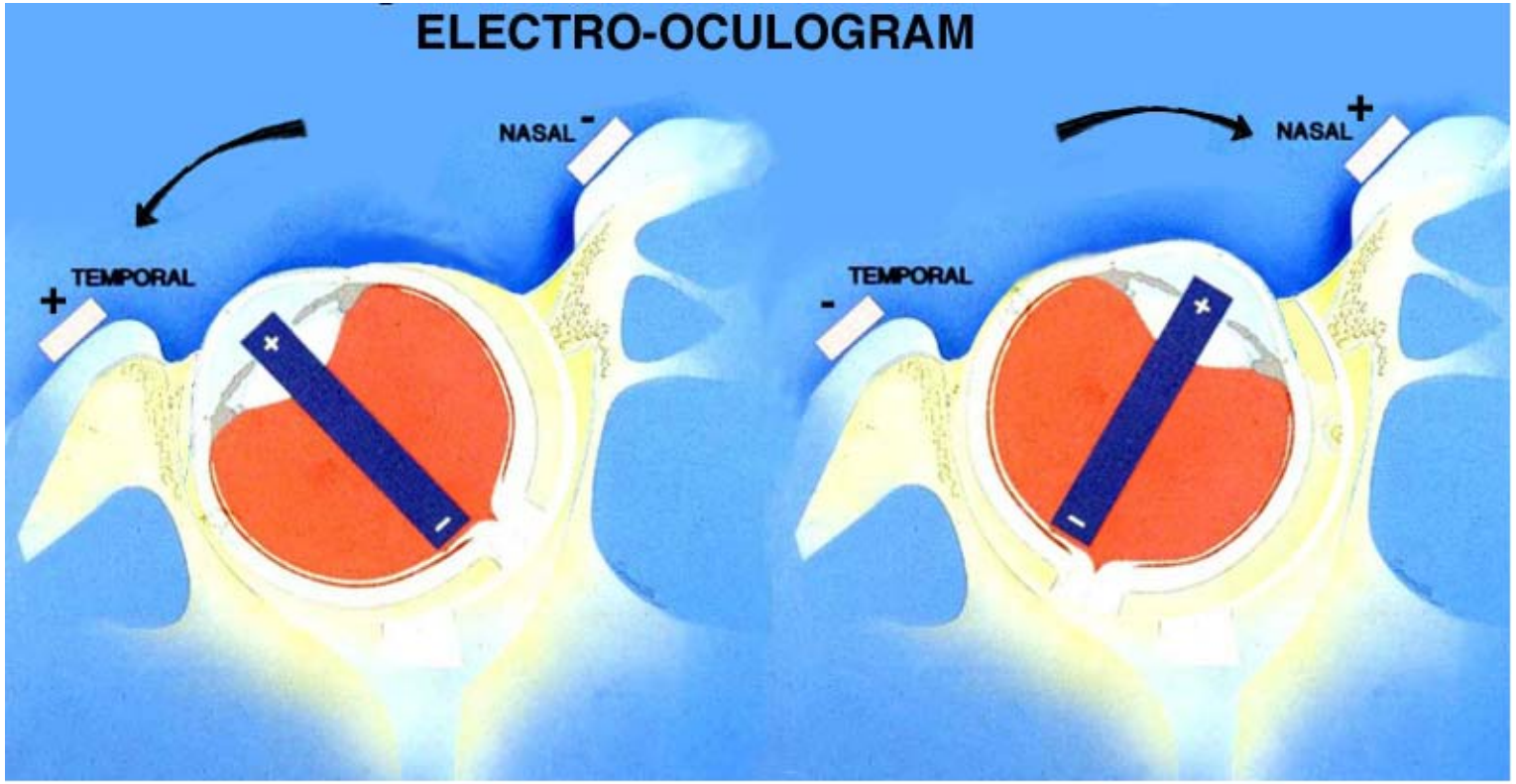


Fig. 45. How the EOG potential is measured as the eyes turn towards and away from the skin electrodes.

Measuremant of the clinical EOG

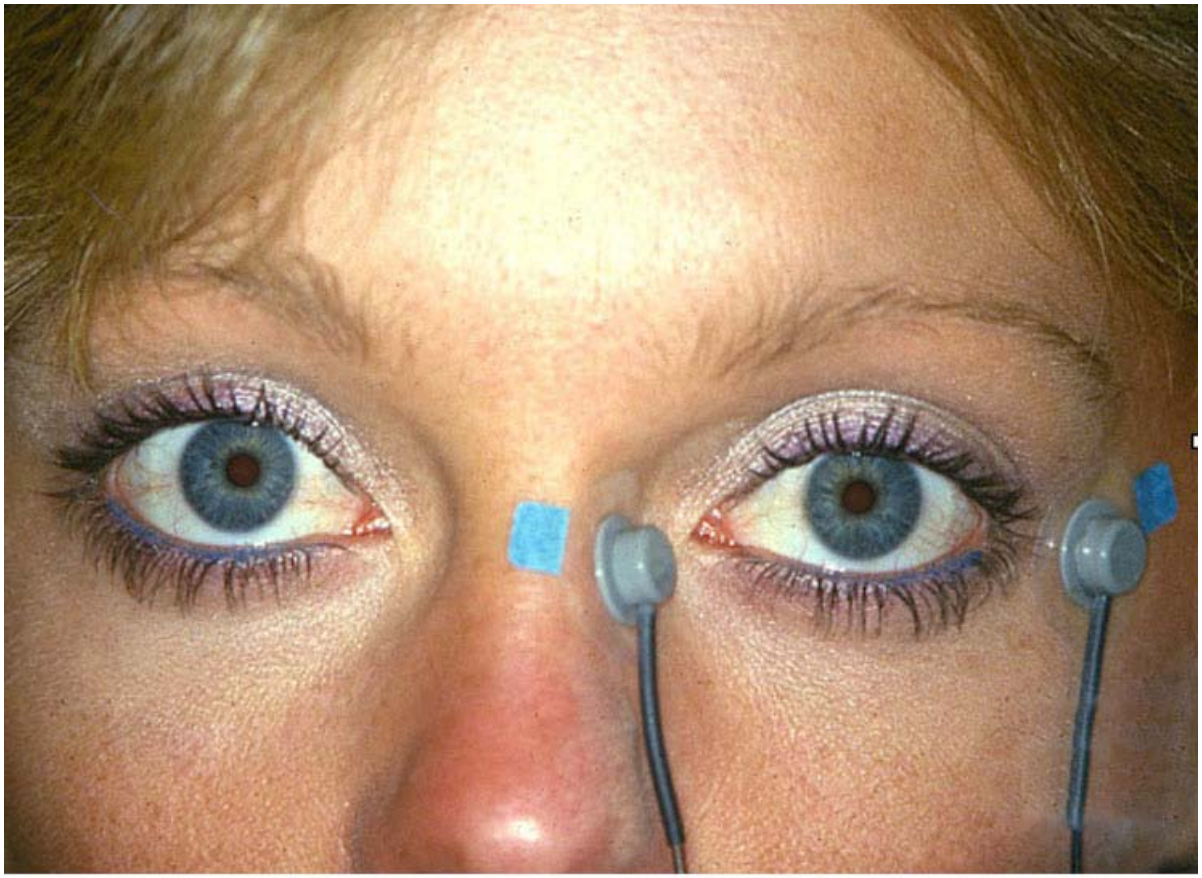


Fig. 44. Placement of the electrodes for recording an EOG.

Measuremant of the clinical EOG

A ground electrode is attached usually to either the forehead or earlobe.

Either inside a Ganzfeld, or on a screen in front of the patient, small red fixation lights are place 30 degrees apart .

The distance the lights are separated is not critical for routine testing.

Ganzfeld used in Clinical EOG

Fig. 46. Ganzfeld used for stimulating EOG recordings.

The standard EOF method

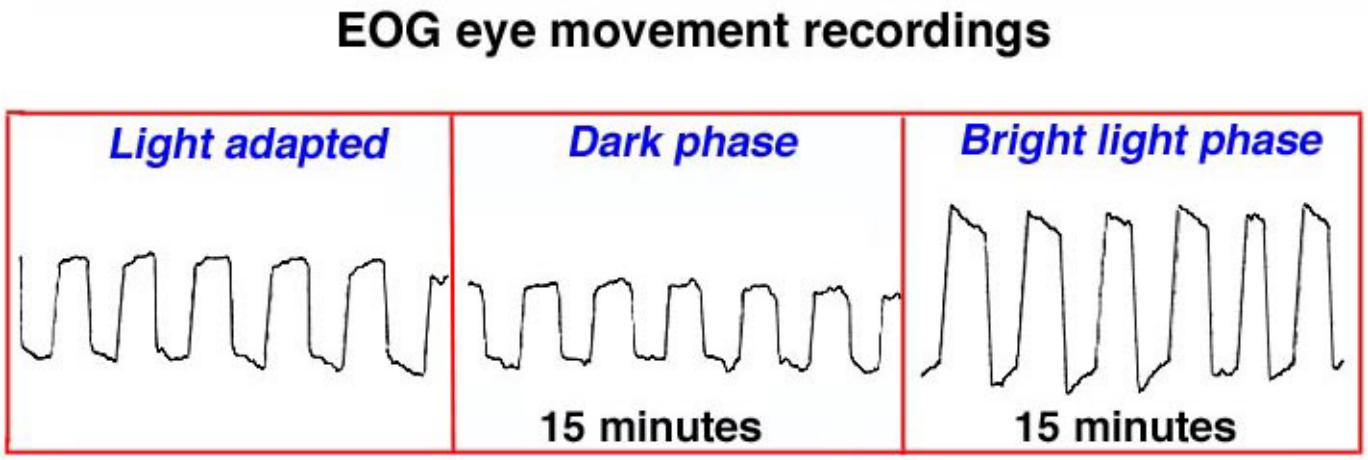


Fig. 47. Light adapted pre-EOG, dark adaptation phase and light-rise phase.

The standard EOG method

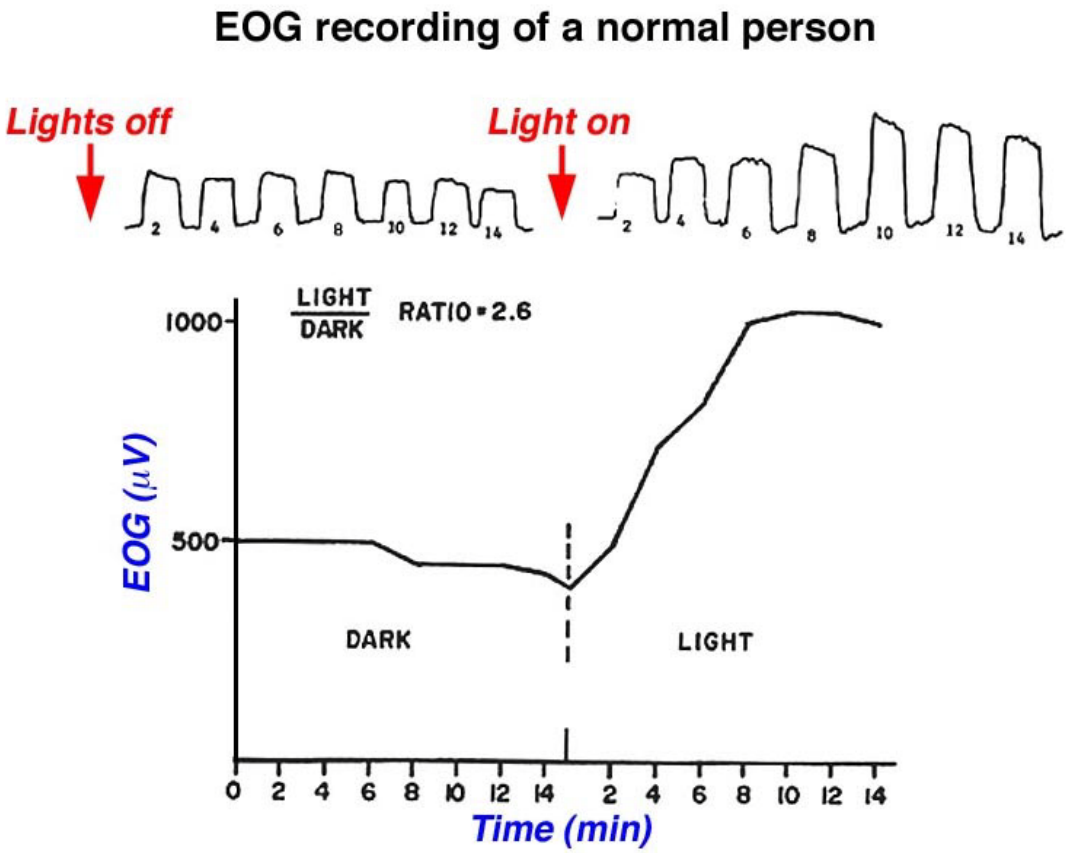


Fig. 48. Normal EOG recording.

EOG in Best's disease

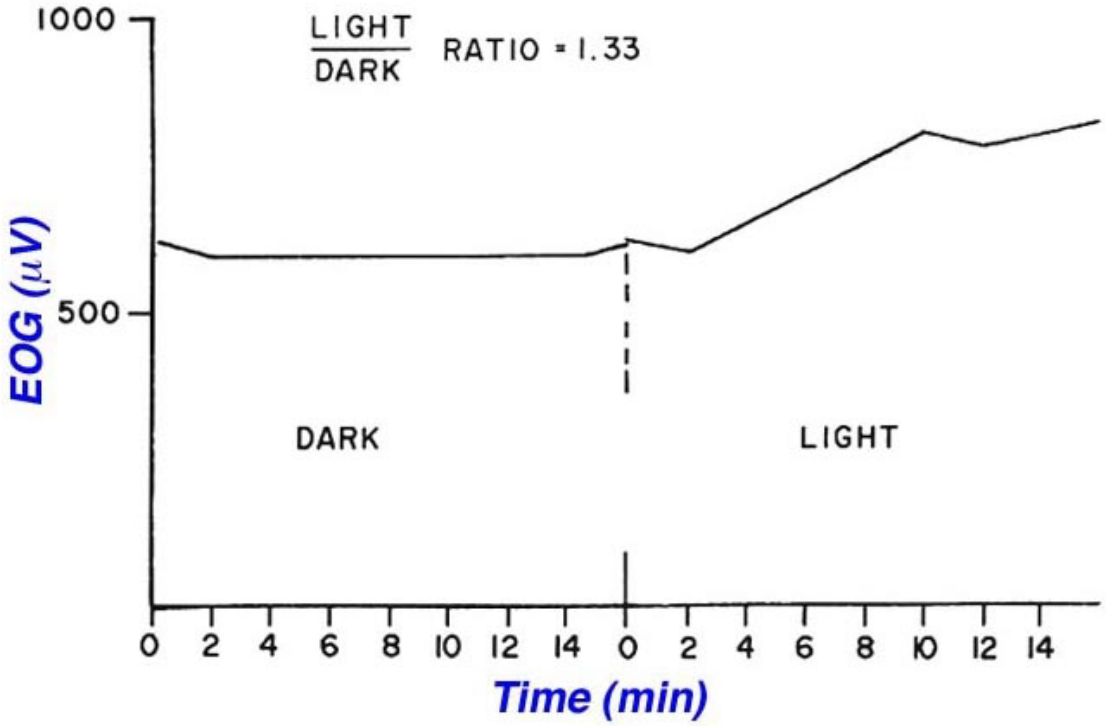


Fig. 49. EOG from a patient with Best's disease.

BEST's Disease

- Initially a recording of eye movements and eye position identifies abnormal electrical potential.
- At the second stage (usually between 10-25 years of age), typical yellow spots, sometimes accompanied by material leaking into a space by the retina, can be observed; an observation called "egg-yolk" lesion.
- When part of the lesion becomes absorbed this is identified as stage three.
- At the fourth stage, when the "egg-yolk" breaks up, in a process referred to as "scrambled-egg", sight will probably be affected.
- The fifth and final stage is when the condition causes the most severe sight loss.

Fundus photo: BEST's Disease

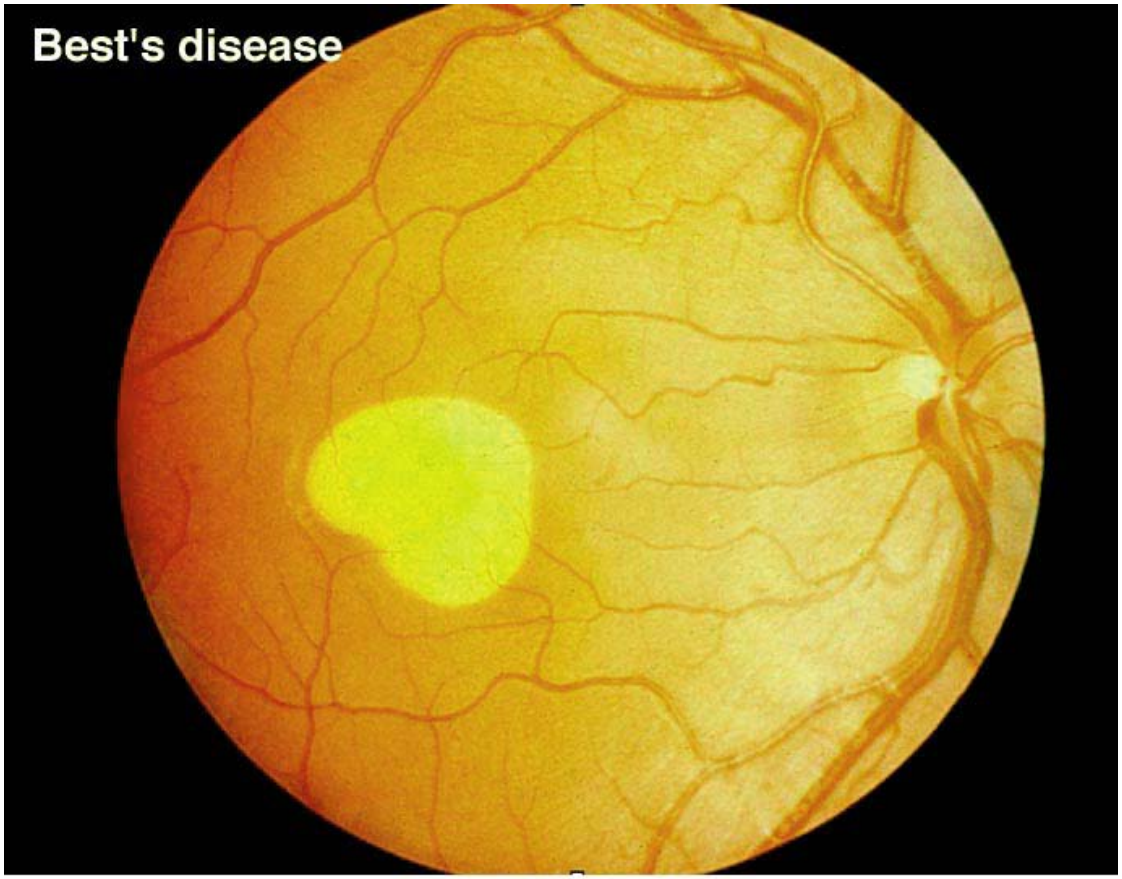
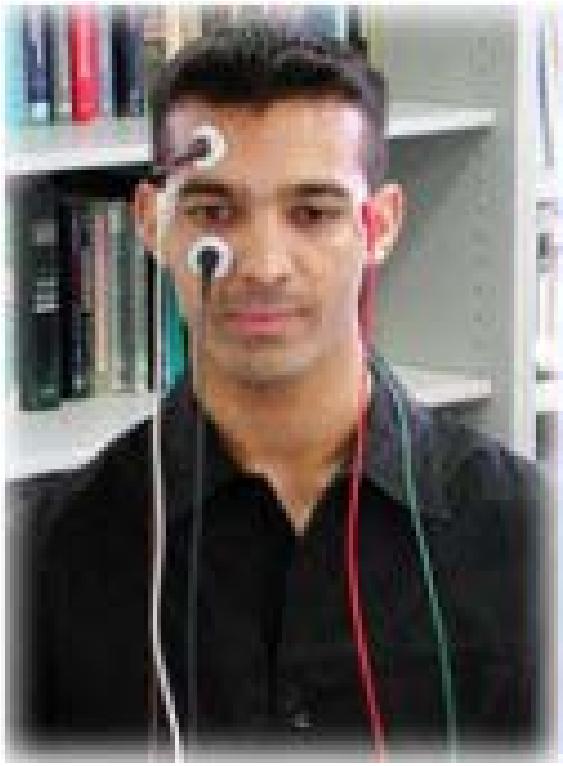
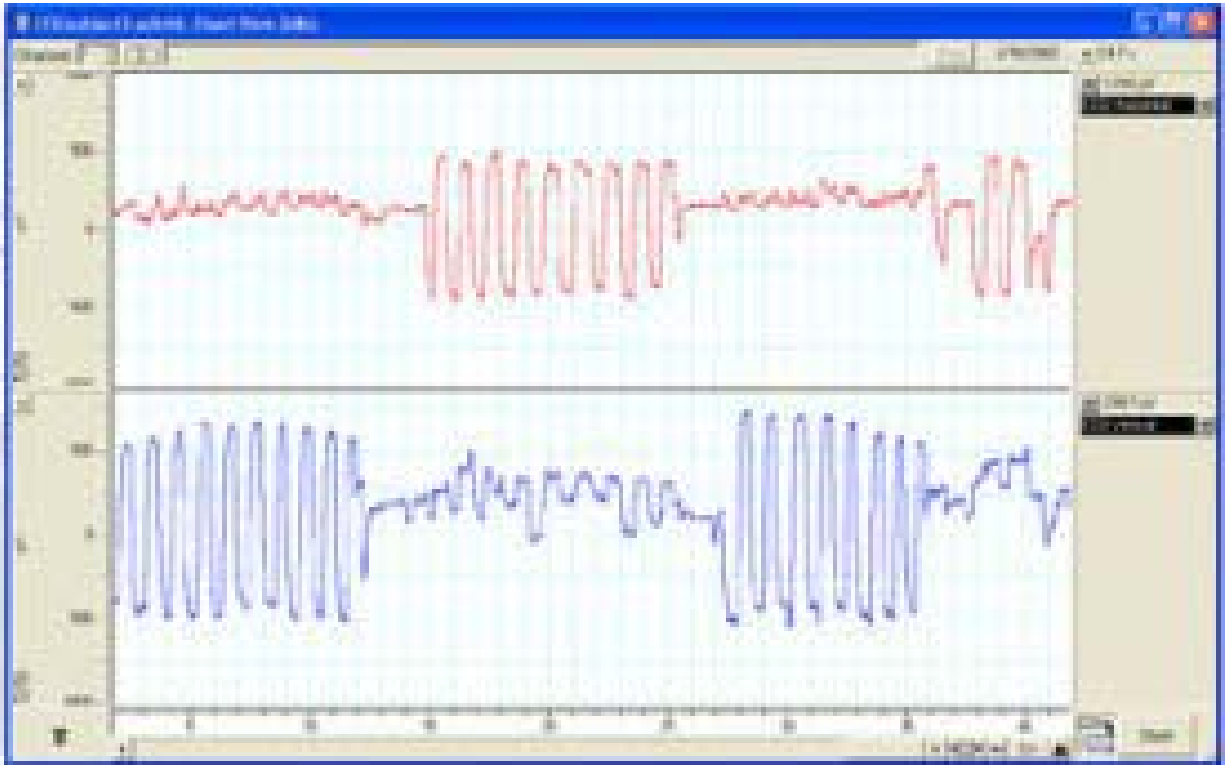


Fig. 50. Fundus photo of a patient with Best's disease.



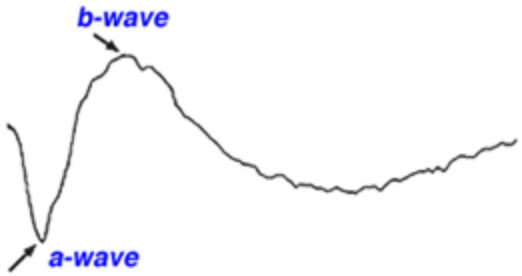


Electroretinogram & Visual Evoked Potential

ERG

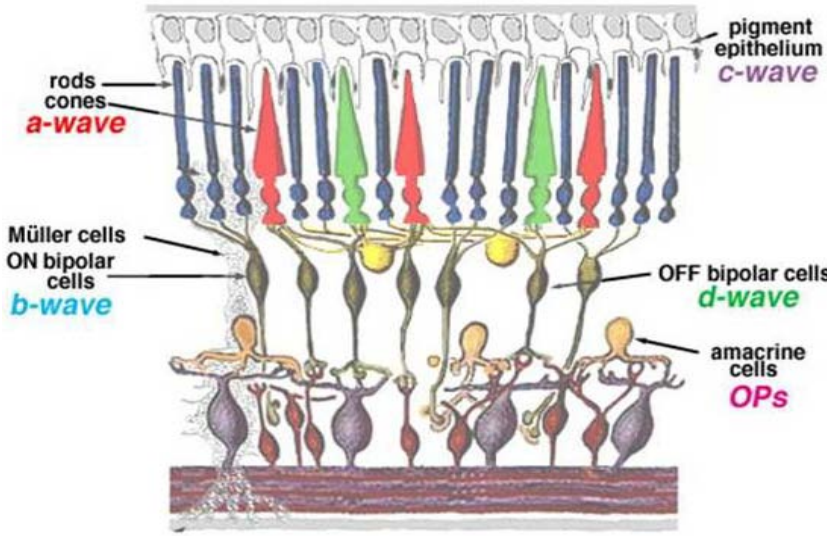
The global or full-field electroretinogram (ERG) is a mass electrical response of the retina to photic stimulation.

The intense flash of light elicits a biphasic waveform recordable at the cornea.

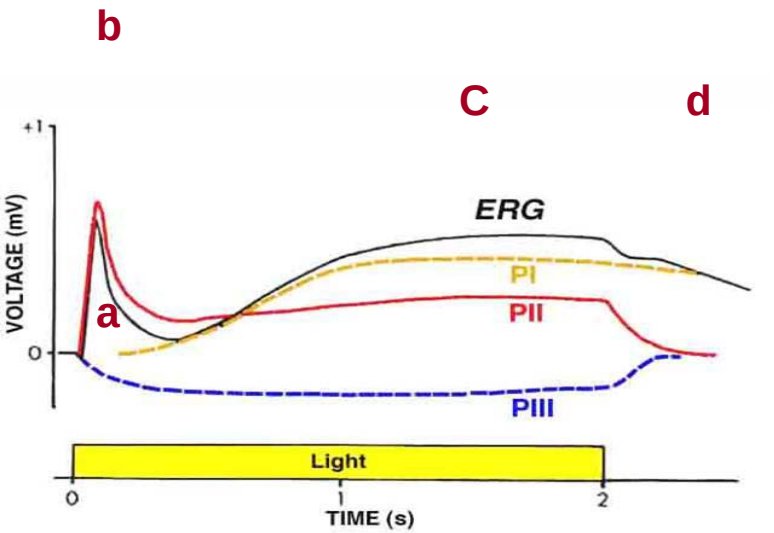


The basic waveform of the ERG

ERG Parameters and Major Components



Retina layer



The ERG of a cat in response to a 2 sec light stimulus.

PI, PII, and PIII waveforms are isolated by depending the state of anesthesia.

ERG measures

Two principal measures of the ERG waveform are taken: 1) The amplitude of the a-wave from the baseline to the negative trough of the a-wave, and the amplitude of the b-wave measured from the trough of the a-wave to the following peak of the b-wave; and 2) the time from flash onset to the trough of the a-wave and the time from flash onset to the peak of the b-wave .

The ERG Parameters Measured in the Ophthalmic Clinic

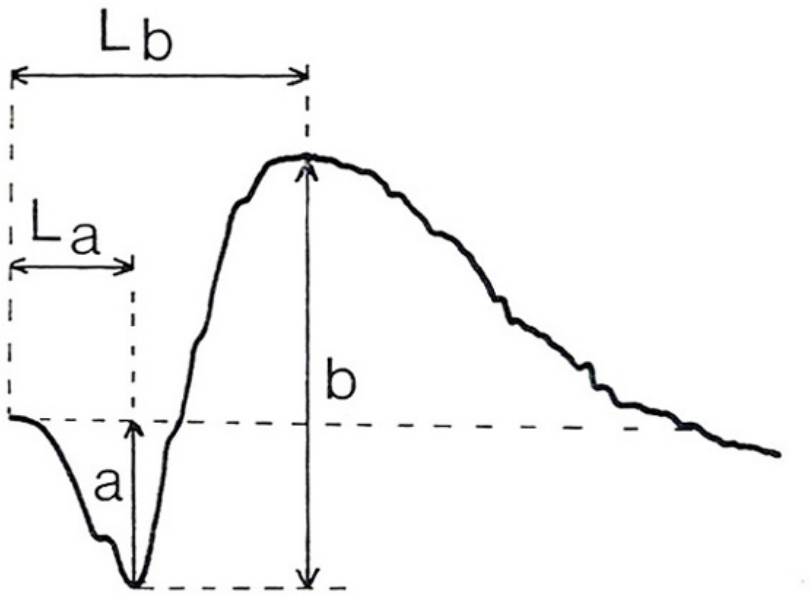
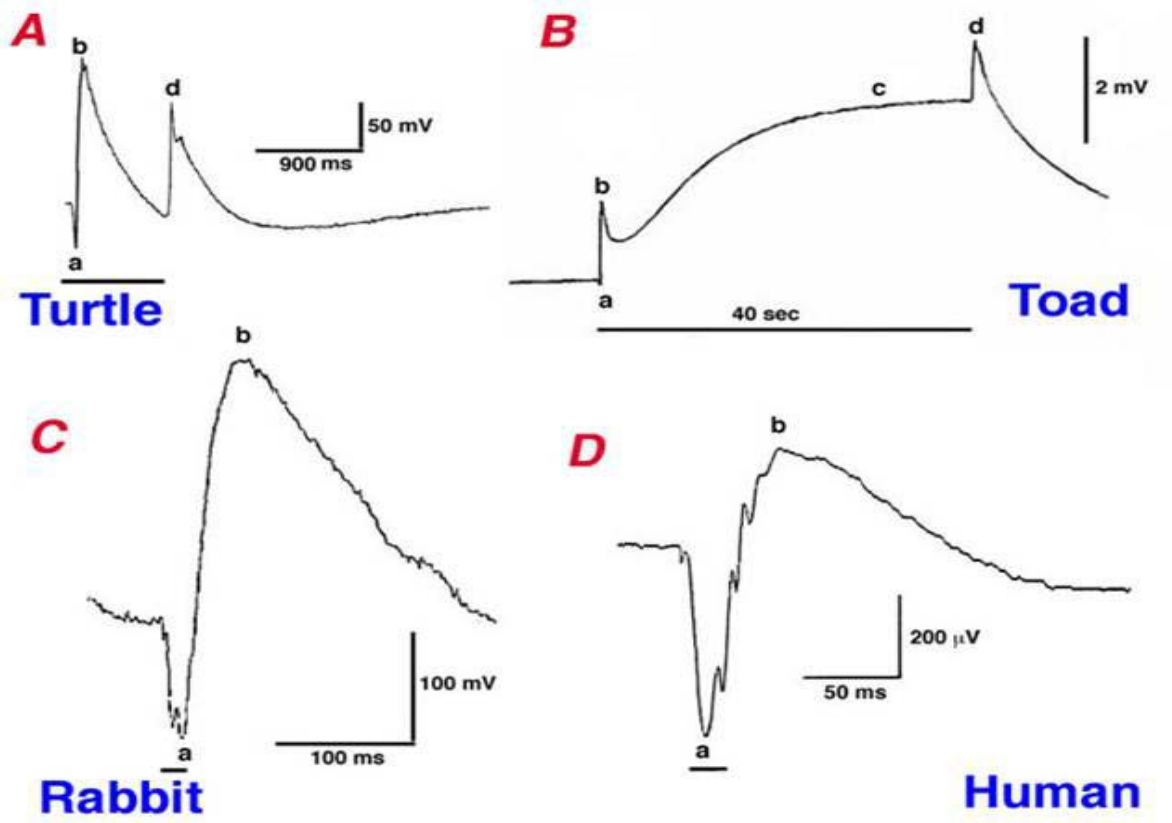


Fig. 21. The ERG parameters that are customarily measured in the ophthalmic clinic for electrodiagnosis. The size of the a-wave is measured from the baseline to the trough of the wave. The size of the b-wave is measured from the trough of the a-wave to the peak of the b-wave. The time-to-peak for both waves (La and Lb) is determined from stimulus onset to the trough or peak of the waves.

ERG Responses from Different Species



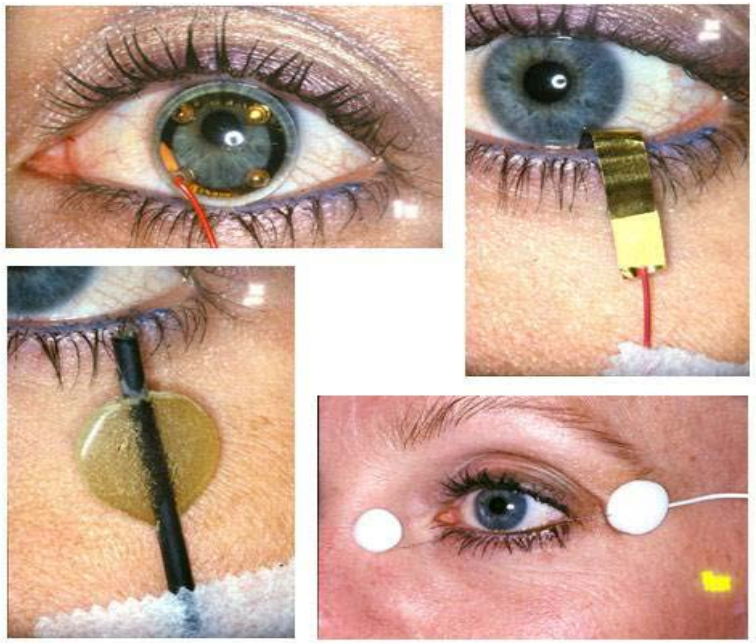
ERG recording electrodes

There are a number of corneal ERG electrodes that are in common use.

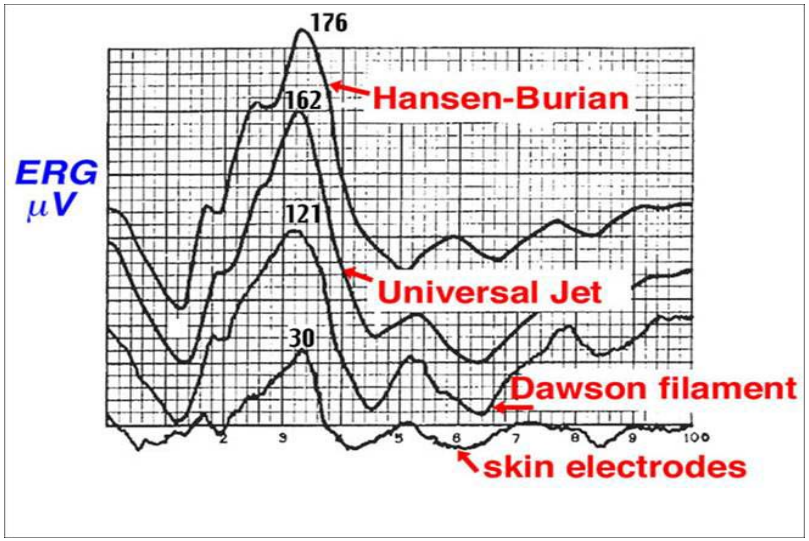
Some are speculum structures that hold the eye open and have a contact lens with a wire ring that "floats" on the cornea supported by a small spring .

Some versions use carbon, wire or gold foil to record electrical activity.

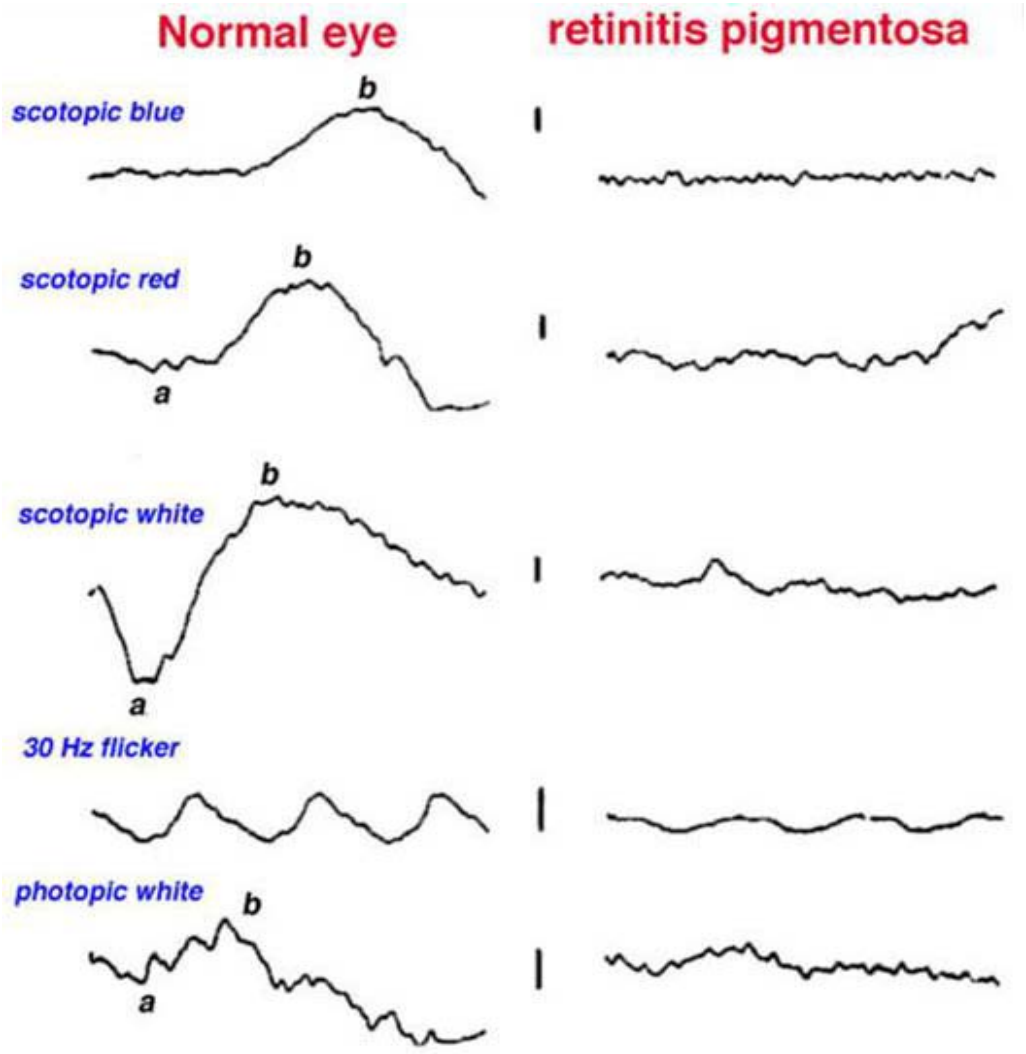
Typical ERGs as Recorded with Different Electrodes



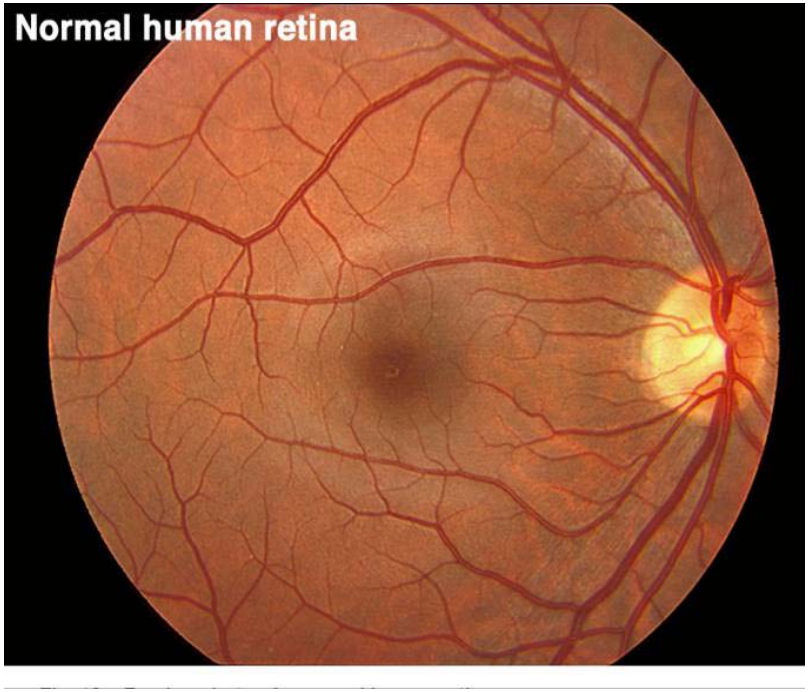
some corneal ERG electrodes

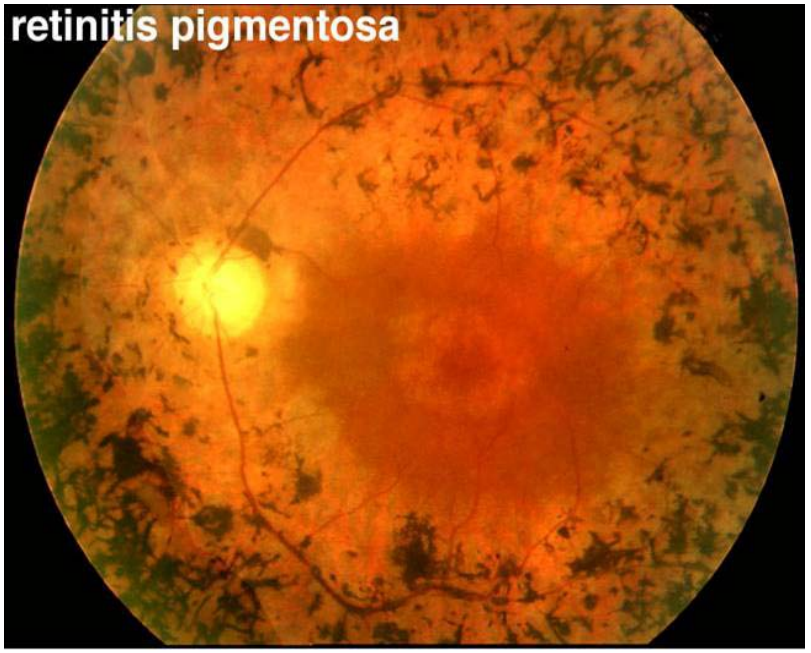


ERGs from Normal Subject and RP Patient

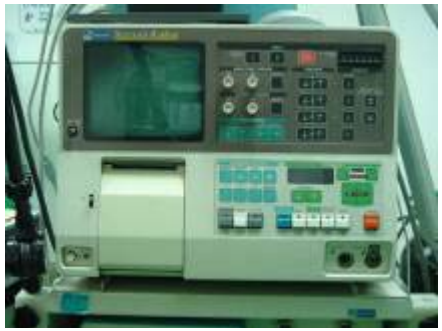


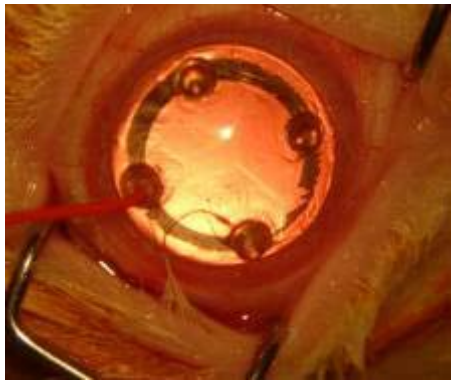
Fundus Photo of Human Retina

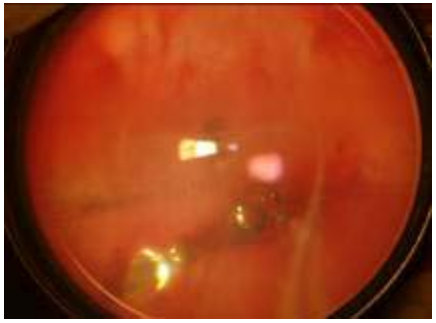


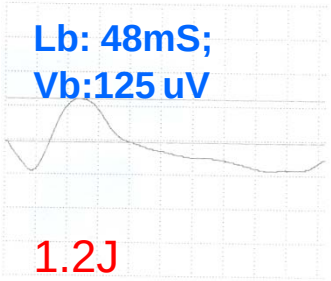


ERG & EERG (Electrically Evoked ERG)









1.2J Flash (a)

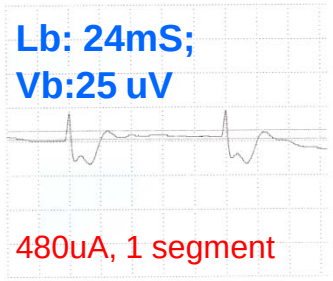
20mS/DIV

100uV/DIV

High Cut: 30Hz

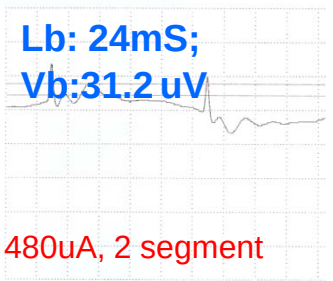
Low Cut: 0.5Hz

Recording Condition



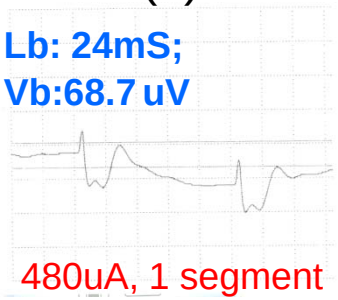
480uA, 1 segment

(b)



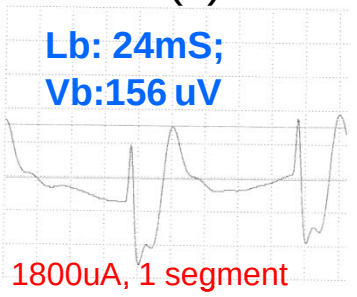
480uA, 2 segment

(c)



480uA, 1 segment

(d)



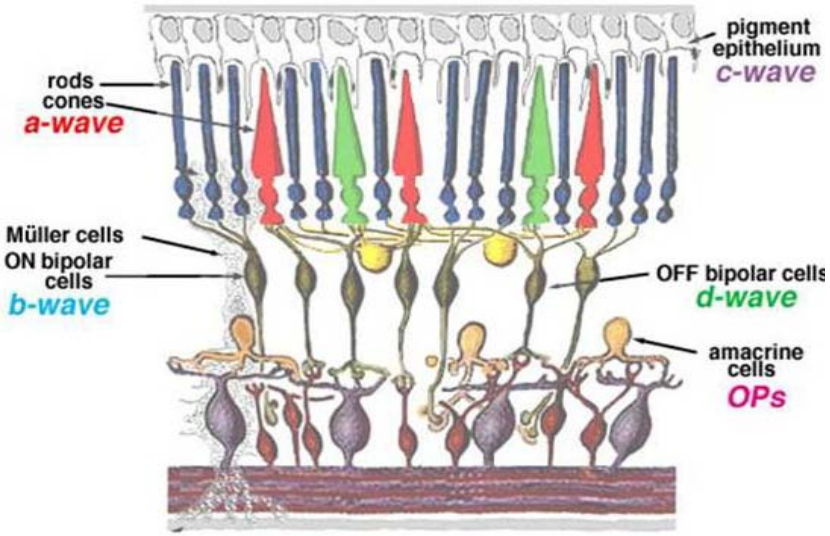
1800uA, 1 segment

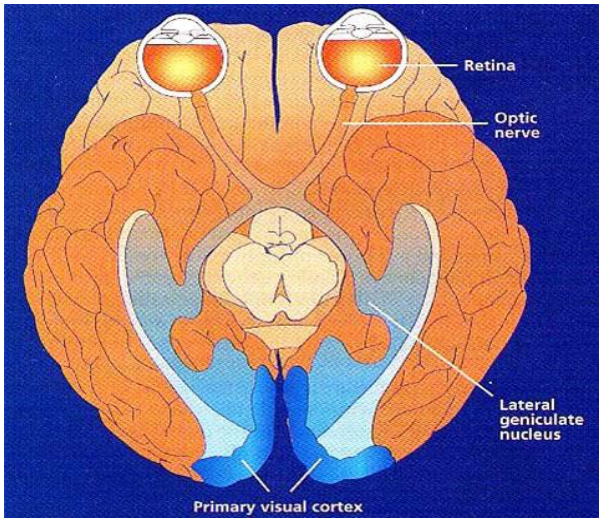
(e)

(b), (c): subretinal stimulation; (d), (e): epiretinal stimulation

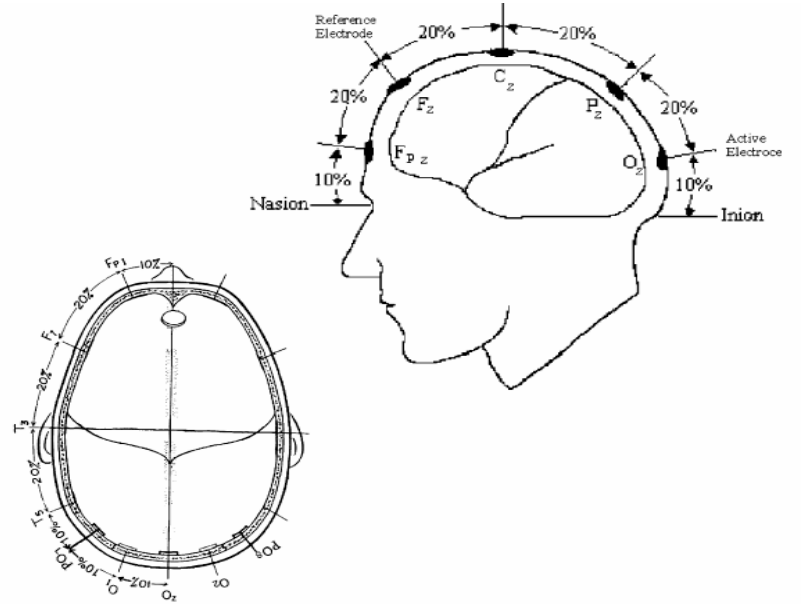
Visual Evoked Potential

The Retina and Visual System

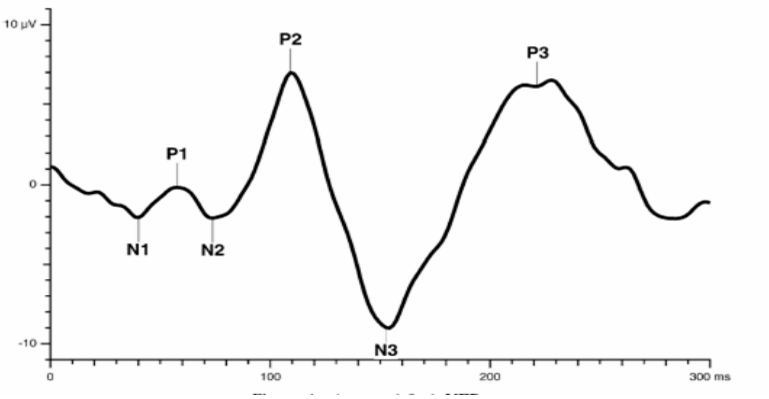




VEP Recording

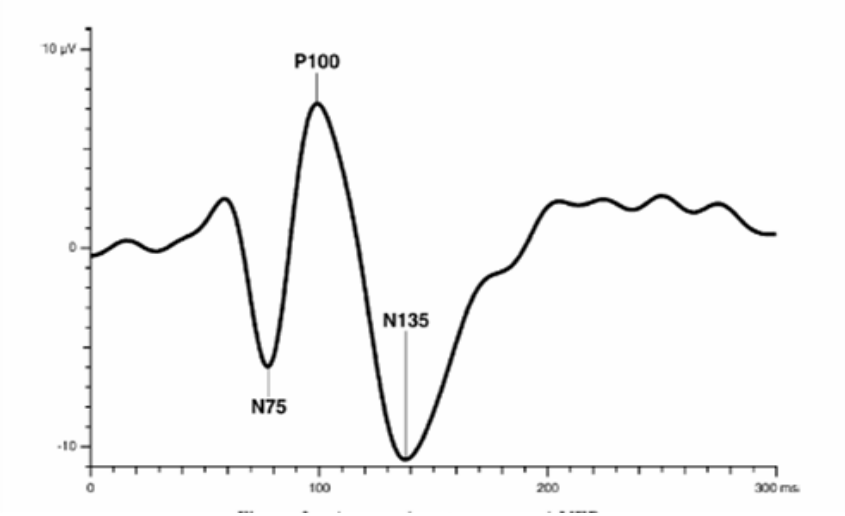


Electrode Location

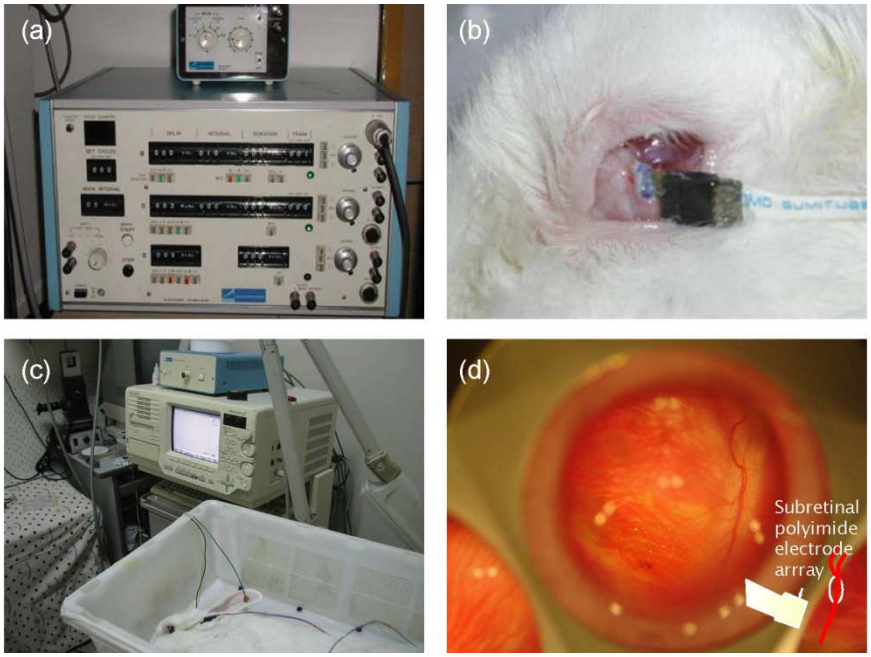


A normal flash VEP

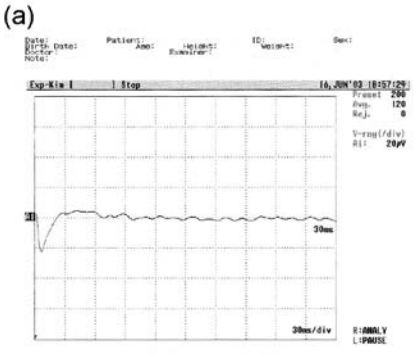
A Pattern Reversal VEP



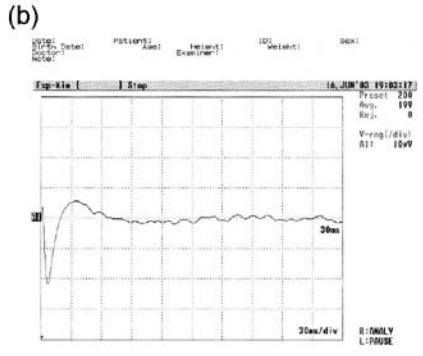
Electrically Evoked Potentials



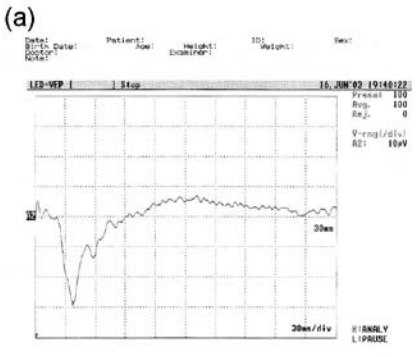
Subretinal Electrical Stimulation



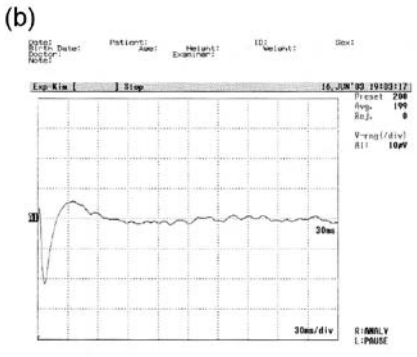
EEP, 1 mA



EEP, 2.5mA



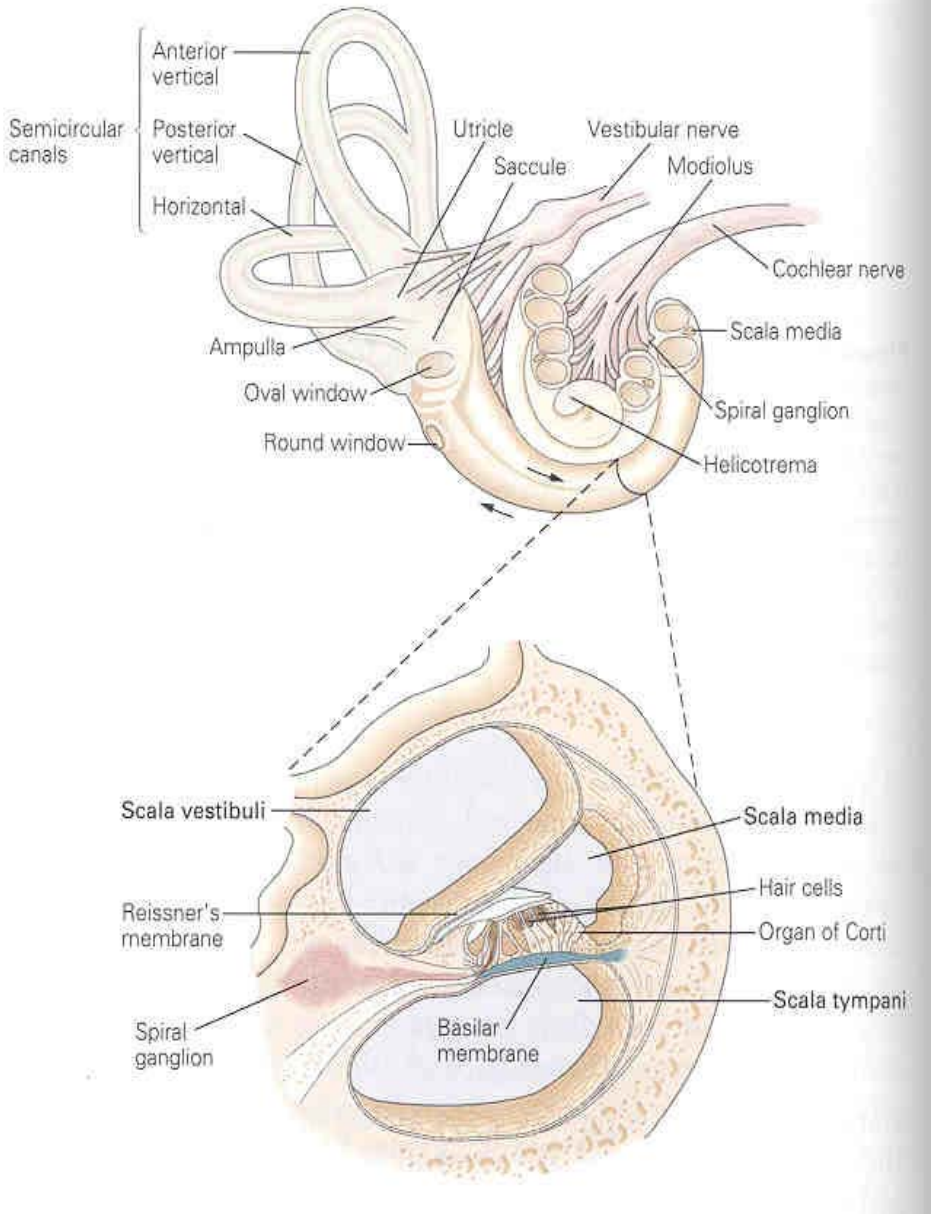
VEP

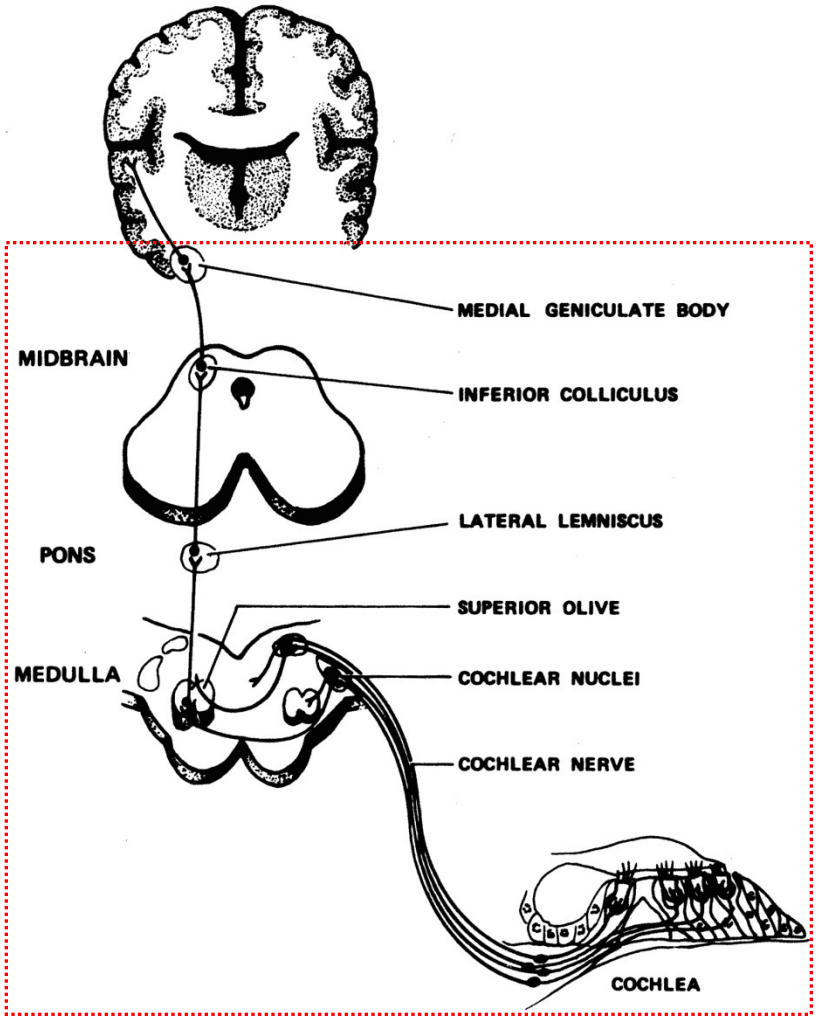


EEP, 2.5mA

Biopotentials related with Hearing

Auditory Pathway





Sources of ABR
(lower part of auditory system)

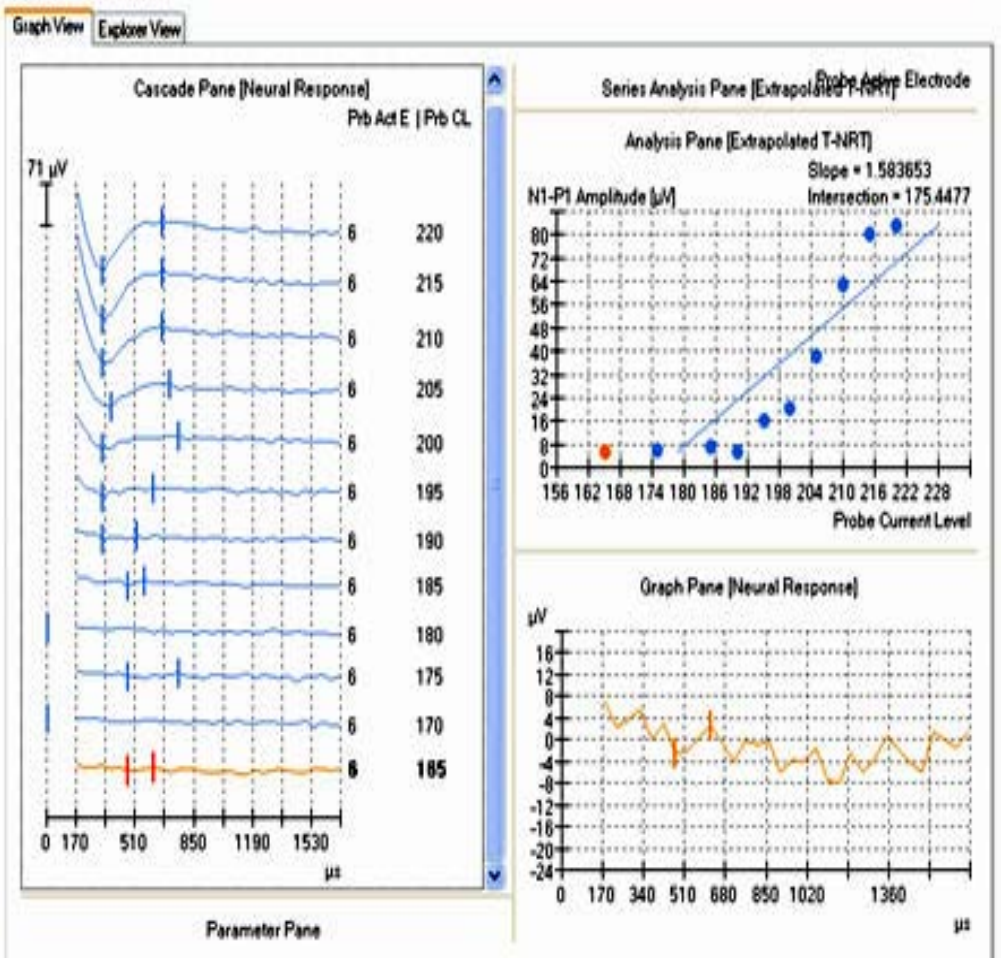
(Electrically Evoked) Compound Action Potential (ECAP)

- **Electrically evoked potentials of auditory neurons.**
  - Very short latency (0.2 to 0.5msec)
  - Artifact removal is the most important techniques for successful ECAP measure

- **Cochlear stimulating electrodes are used as recording electrodes**

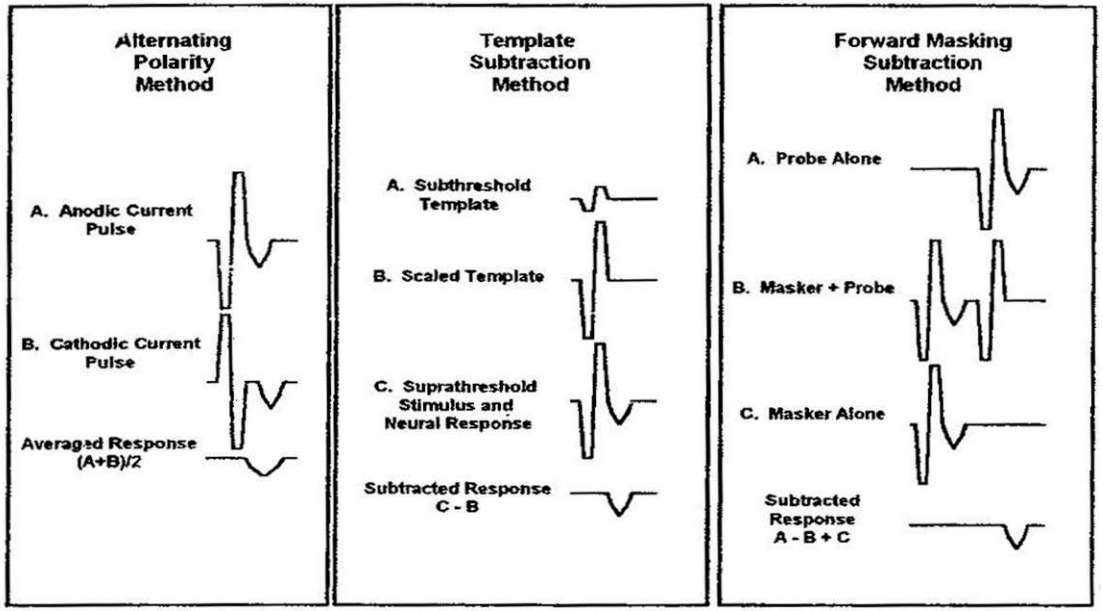
- **Every Cochlear Implant Manufacturers offer functions for ECAP measure/analysis**

(1) Cochlear Corp.
  – “NRT(Neural Response Telemetry)”
(2) Advanced Bionics
  - “NRI (Neural Response Imaging)”
(3) Med-El
  - “ART(Auditory nerve Response Telemetry)”



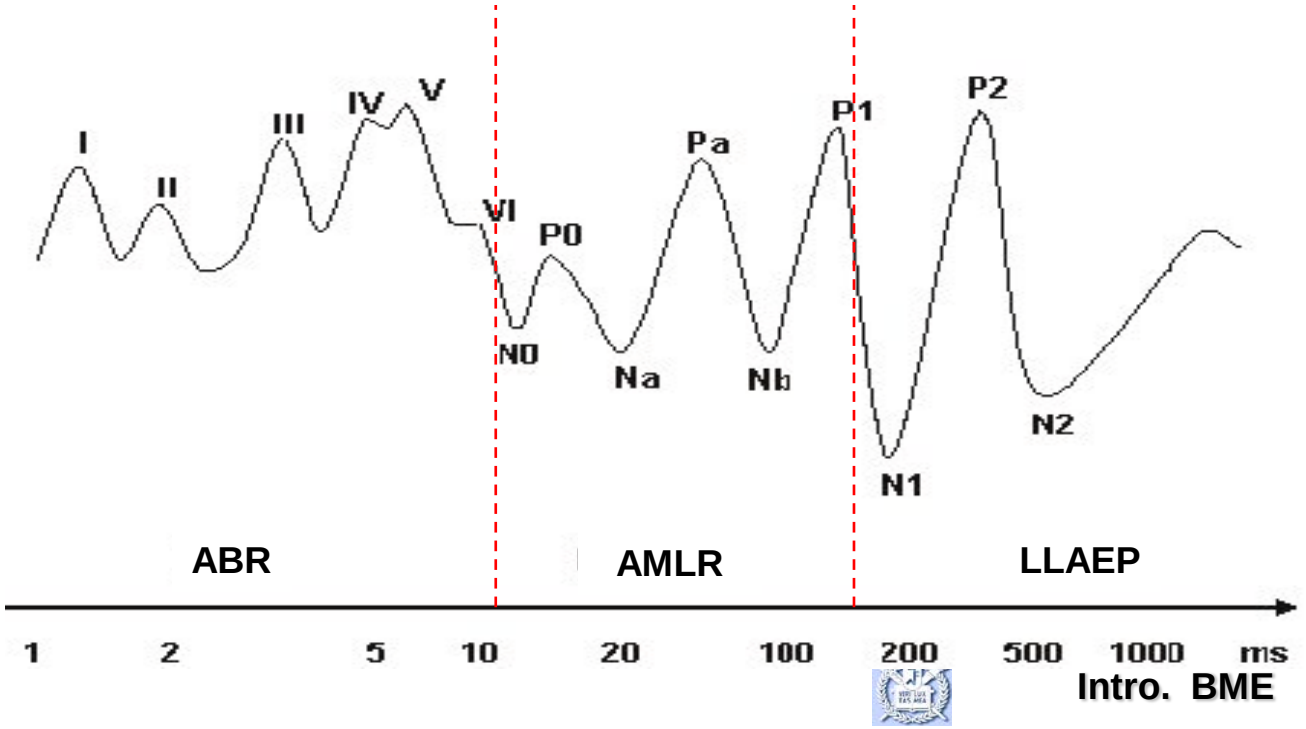
Artifact Removal in ECAP measure

- **Alterating stimulus polarity (Brown *et al*.,1990)**
  - relatively simple approach (used by Advanced Bionics Corp.)
  - underlying assumption : “the neural response is identical either anodic or cathodic leading pulses.”
    (but not always true (Van den Honert and Stypulkowski, 1987, Miller et al., 1998)
- **Template subtraction (Miller *et al*., 1998)**
  - use subthreshold response as a template (very linear and acurate amplifier is needed)
  - can be used with wide range of stimulus duration.
- **Two-pulse subtraction (Brown *et al*., 1990, Abbas *et al*., 1999)**
  - the most commonly used (Ineraid → Cochlear Corp., → Advanced bionics)
  - uses forward masking paragigm (refractory characteristic of neurons)
  - need careful optimization of amplifier gain and another parameters



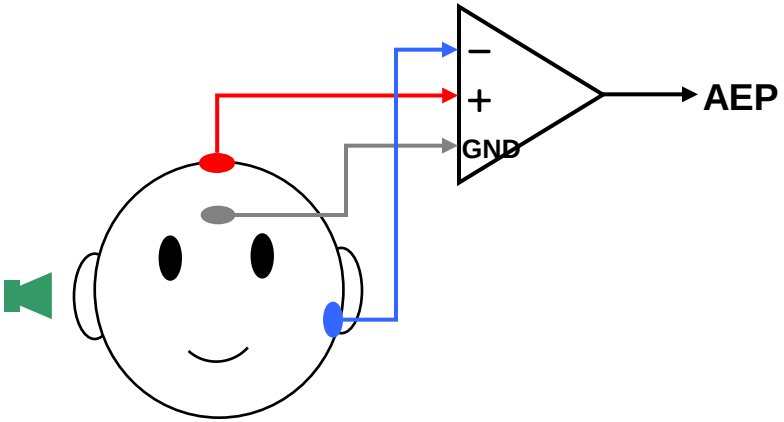
Auditory Evoked Potential (AEP)

- **ABR, AMLR, LLAEP, etc.**
- **Tests are far field recordings of neurophysiological responses to auditory stimulation…in a bioelectric background!**
- **Can be measured using acoustic sound or electrical stimulation (C.I.)**
- **Used to identify auditory dys-synchrony (auditory neuropathy), a dysfunction of neural pathways**



AEP Measure

- **AEP can be measured non-invasively**
  - scalp electrode is used.
- **Setup for AEP measure**
  (1) Recording electrode – scalp electrode
  (2) Stimulator
  - for acoustic stimulation : speaker
    (click or tone-burst sound)
  - for electrical stimulation : C.I. or other stimulator
  (3) Acquisition hardware
  - Amplification, filtering
  - data recording/analysis



Typical electrode montage for AEP measure
Vertex : non-inverting input
Forehead : groung
Contralateral earlobe : inverting input

Auditory Brainstem Response (ABR)

- **Most well known AEP**

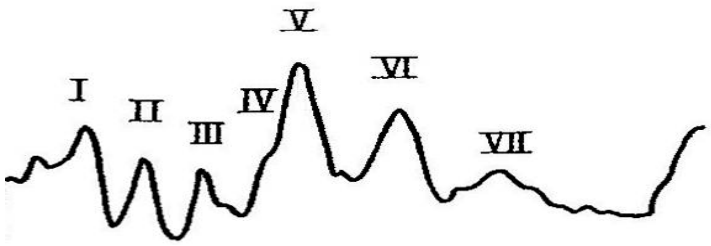
  - Primarily used to evaluate neurological disorders at level of auditory nerve and brainstem

- **ABR (first described by Jewett and Williston, 1971)**
  - Short latency (~10msec) evoked potential
  - ABR measure can access lower part of the auditory system
  - Amplitude ranges a few uV

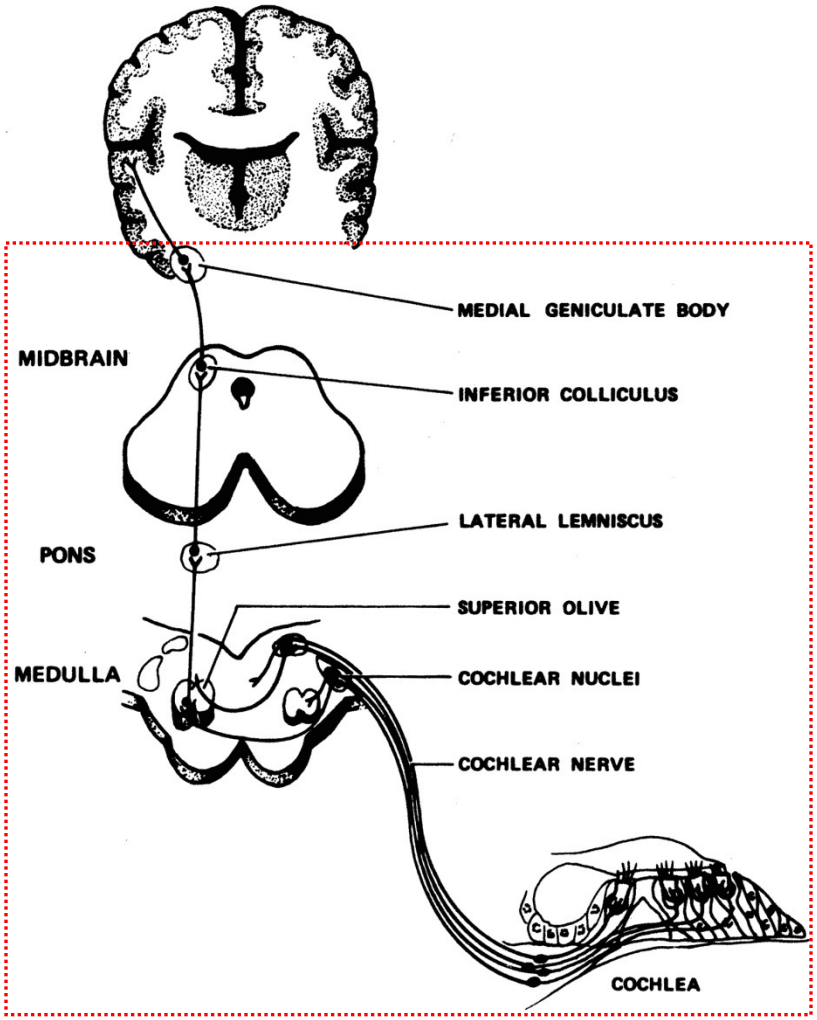
- **ABR consists of 7 peaks**

  Wave I - compound action potential of cochlear nerve
  Wave II – proximal region of cochlear nerve
  Wave III – cochlear nucleus
  Wave IV – superior olivery complex
  Wave V – lateral lemniscus
  Wave VI and VII – inferior colliculus

(Presence of Wave V found to be reliable estimate of hearing ability in 2K-4K Hz range)



Typical ABR waveform



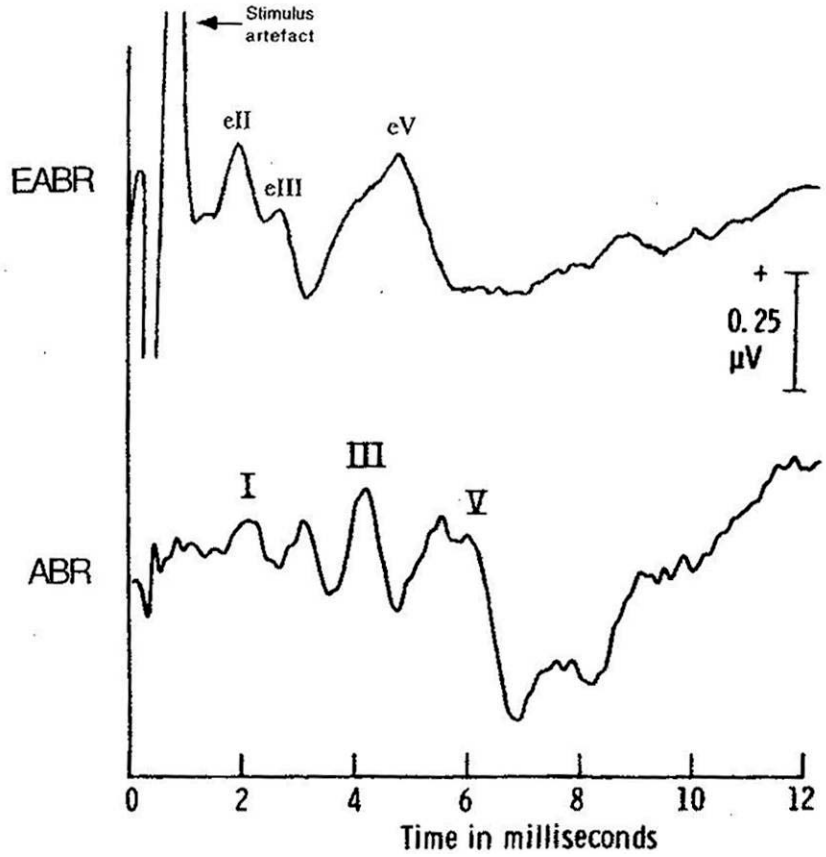
Sources of ABR
(lower part of auditory system)

ABR vs. EABR

- **EABR (Electrically evoked ABR)**
  : ABR evoked by electrical stimulation (such as C.I.)

- **EABR has similar characteristic to ABR**
  - same auditory processes are used.

- **Some importane differences**
  (1) Wave eI is usually obscured.
  - due to stimulation artifact
  (2) Shorter latency
  - EABR arise 1.0~1.5msec earlier than ABR
  - Electrical stimulus bypasses the transmission process of sound.



Typical response wave forms for the ABR and the EABR

Intensity series of ABR and EABR