Other Biopotentials

EMG

EEG

Visually Evoked Potentials

Auditorily Evoked Potentials

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		

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).

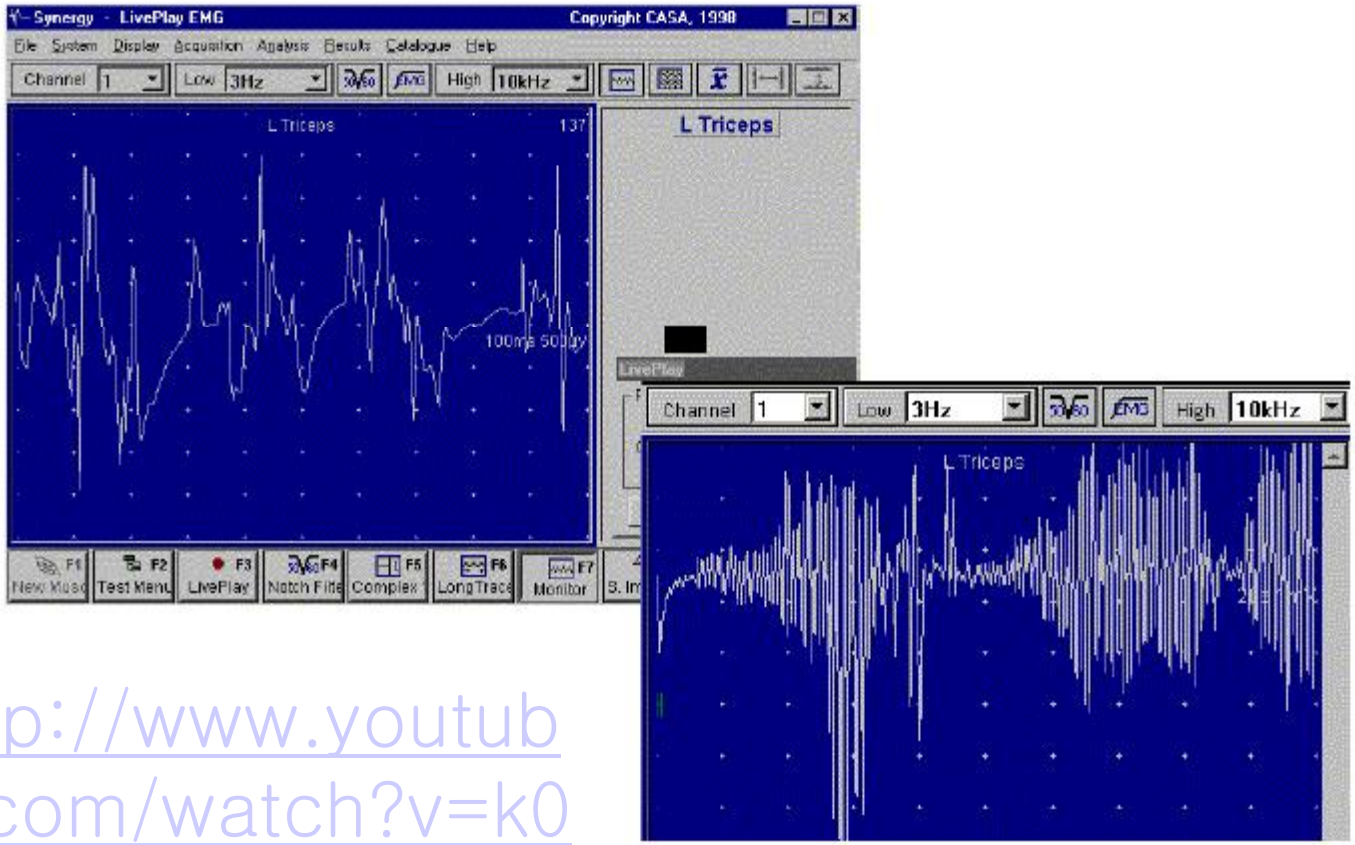
Why is an EMG test done?

- 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

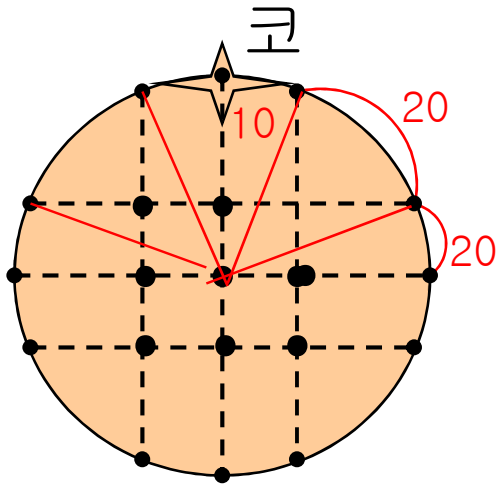
http://www.youtube.com/watch?v=C4H-0eLVZAk

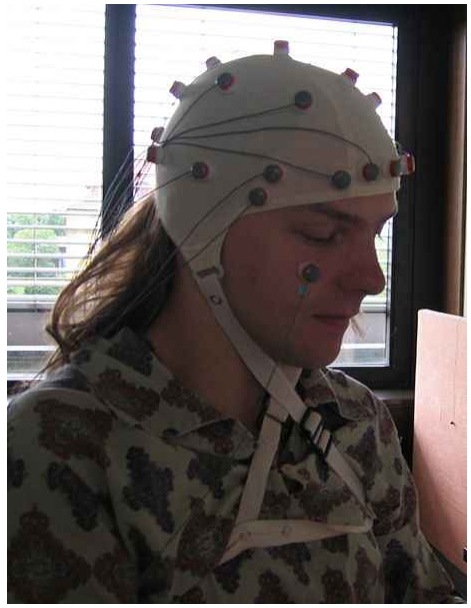
EEG

- EEG configuration

  21 electrodes, z~10kΩ max

Top view





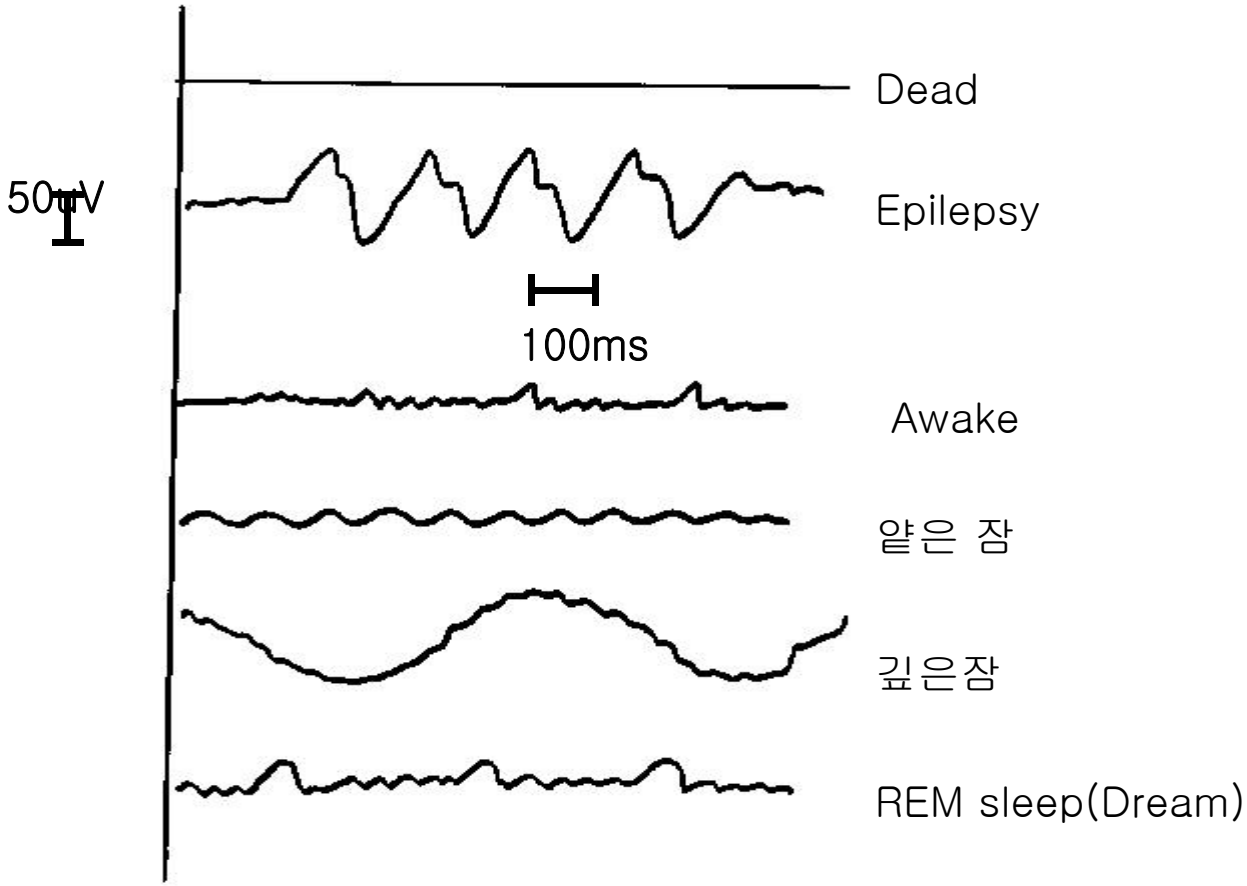
32 channel EEG

각 전극은 1cm 직경 정도의 면적을 봄.

신호강도 $\alpha \propto 1/r^2$

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.)

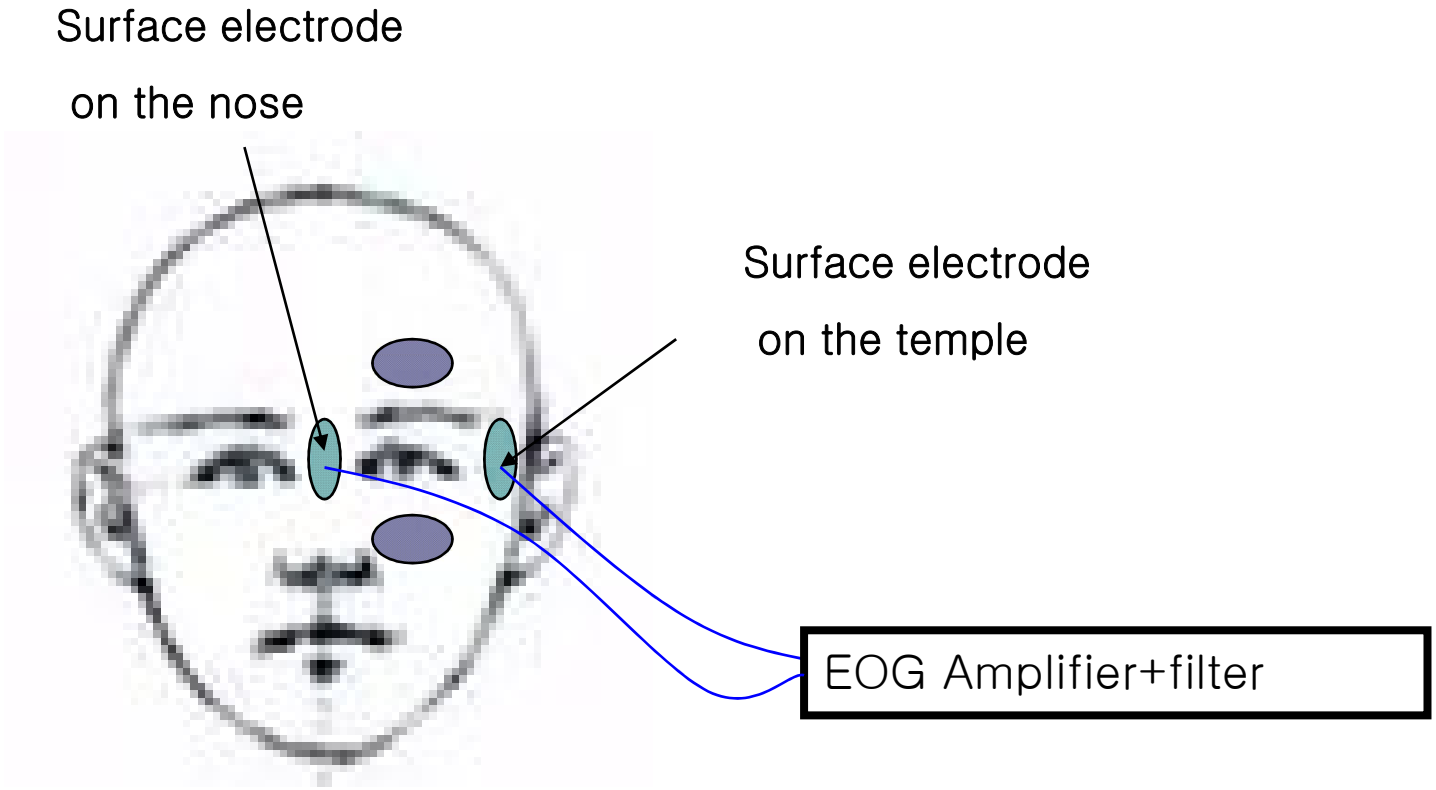
Biopotentials related with Vision

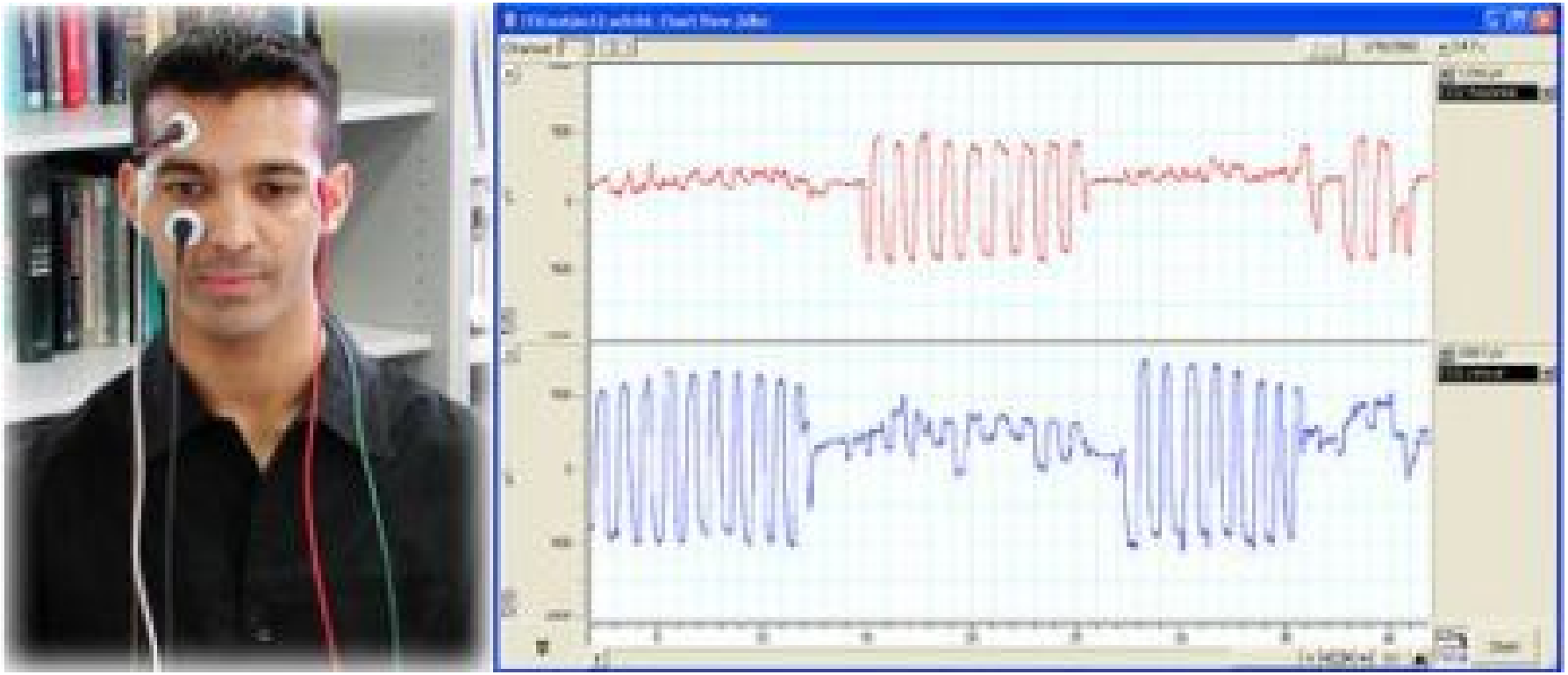
- EOG : 안전도, eye battery 측정

  일정한 거리의 두 점을 교대로 보게 하면서 뇌파 기록

- ERG : 망막전계, 광자극에 의한 망막의 전기적 반응 계측
- Visually Evoked Potential (VEP) and EEP (from retina prosthesis)

Electro-Oculogram

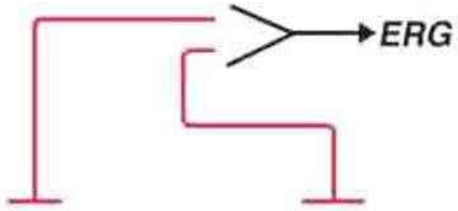


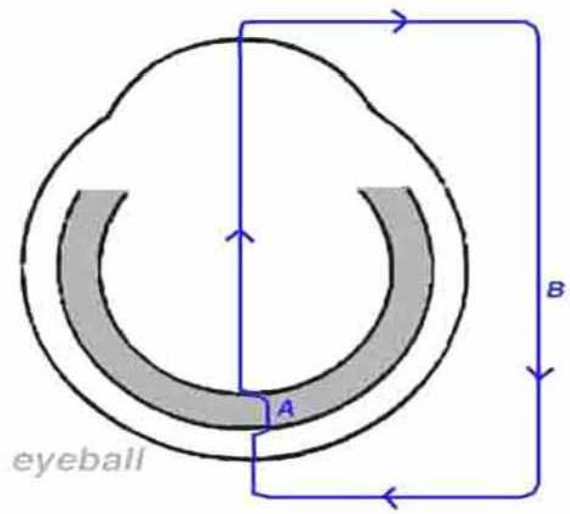


http://www.adinstruments.com/education/experiments/applications/Electrooculogram--EOG--Recordings/

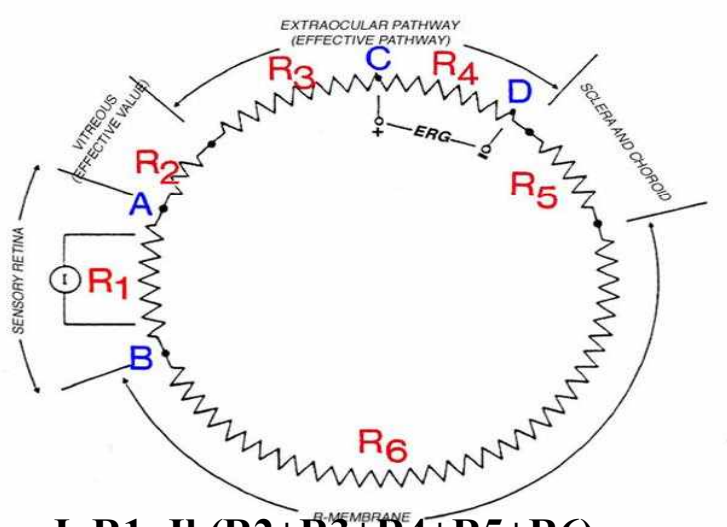
Electroretinogram & Visual Evoked Potential

The Electrical Basis of ERG Recordings





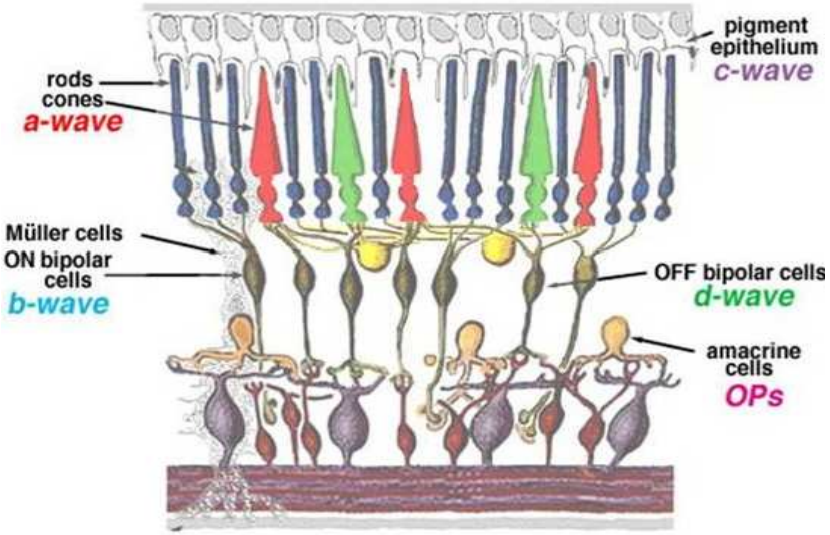
Current pathway following light stimulation



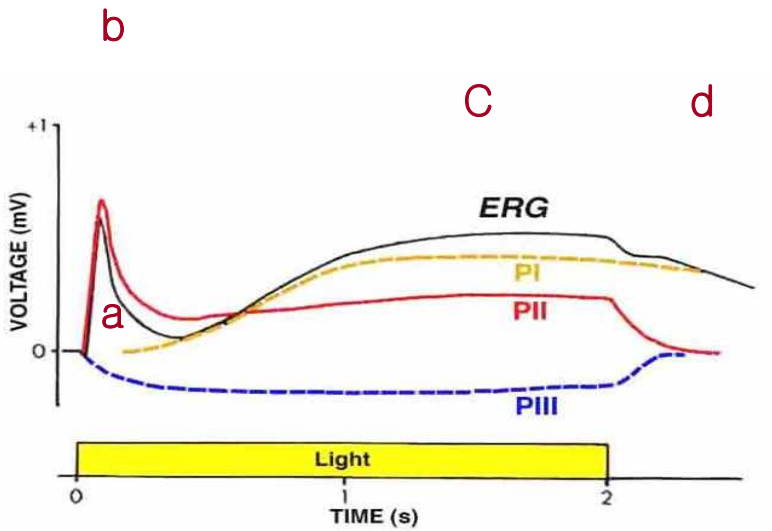
IaR1=Ib(R2+R3+R4+R5+R6)

An equivalent electrical circuit of the eye

ERG Parameters and Major Components



Retina layer



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

Pl, Pll, and Plll waveforms are isolated by depending the state of anesthesia.

The ERG Parameters Measured in the Ophthalmic Clinic

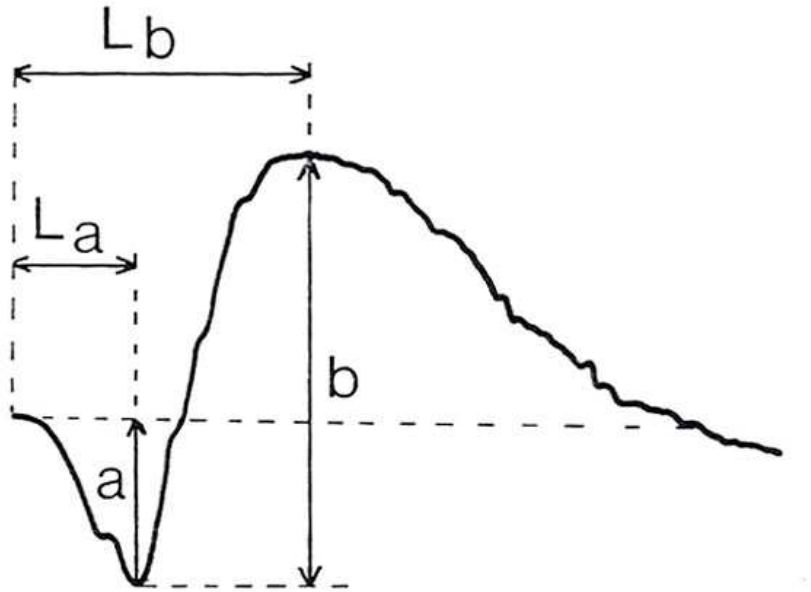
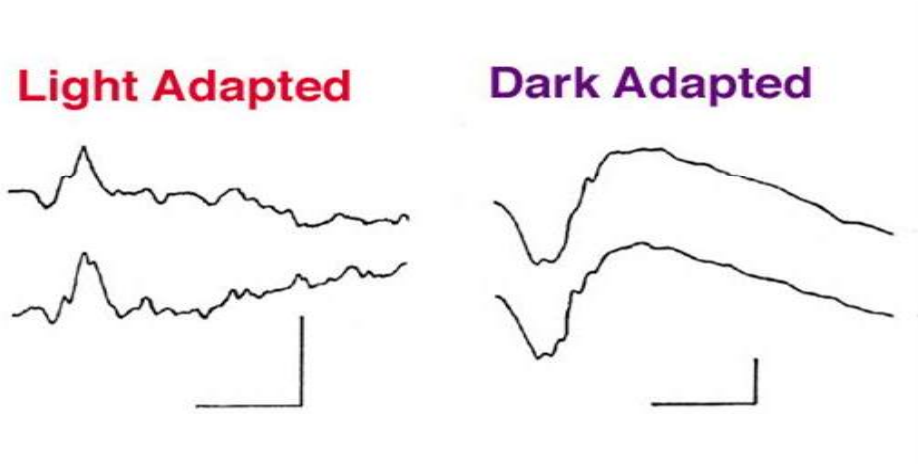


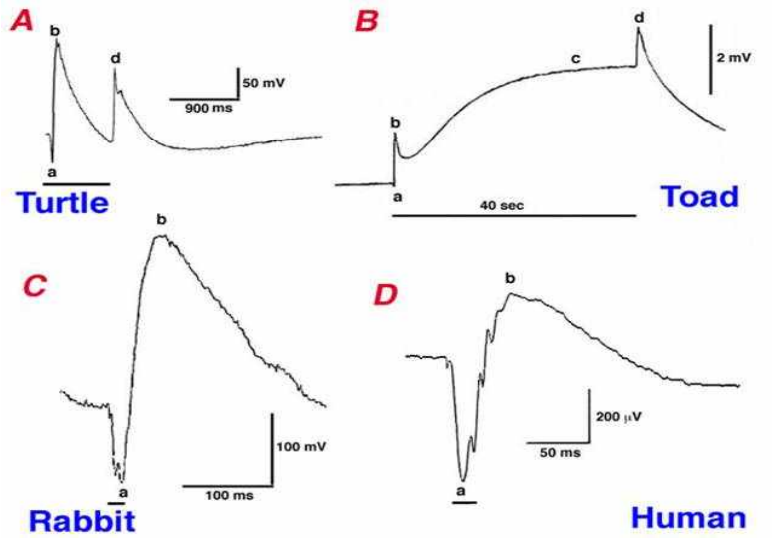
Fig. 21. The ERG parameters that are customarily measured in the ophthalmic clinic for electrodiagnosis. The size of the a-wave is measured from the baseline to the trough of the wave. The size of the b-wave is measured from the trough of the a-wave to the peak of the b-wave. The time-to-peak for both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

ERG Responses from different light Adaptation

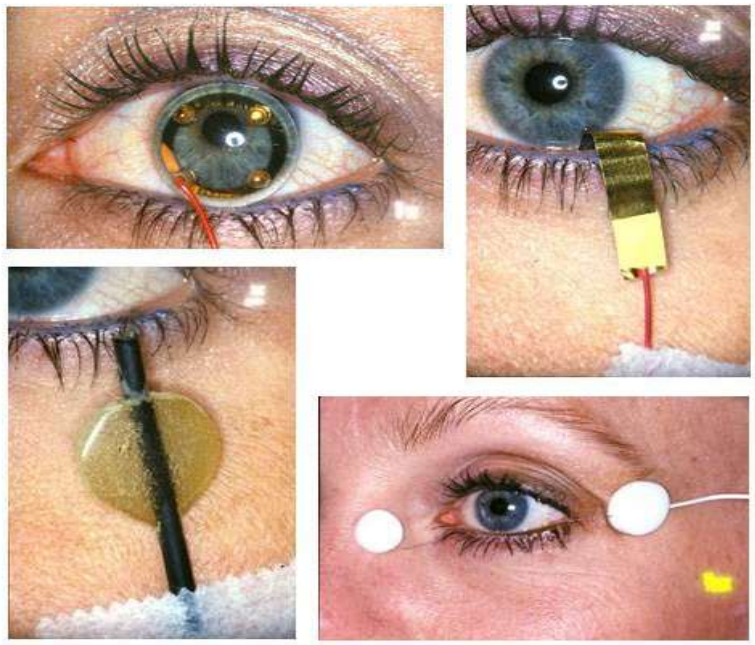


The same light stimulus was used.

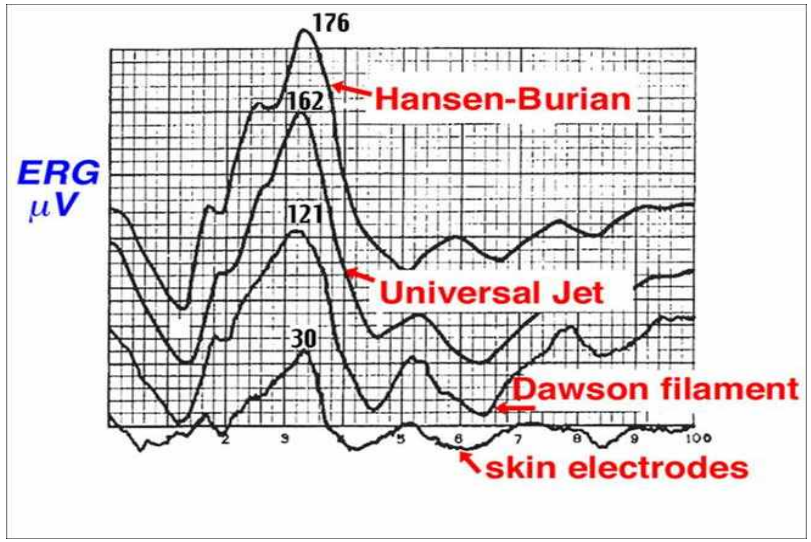
ERG Responses from Different Species



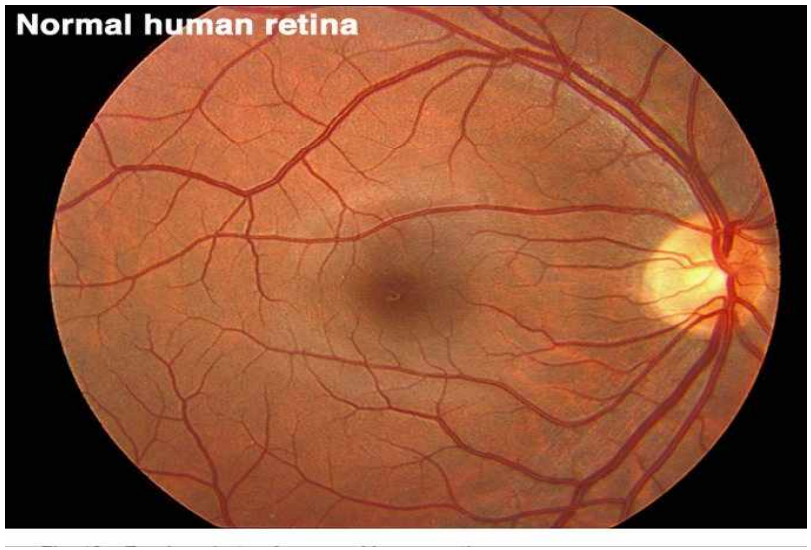
Typical ERGs as Recorded with Different Electrodes

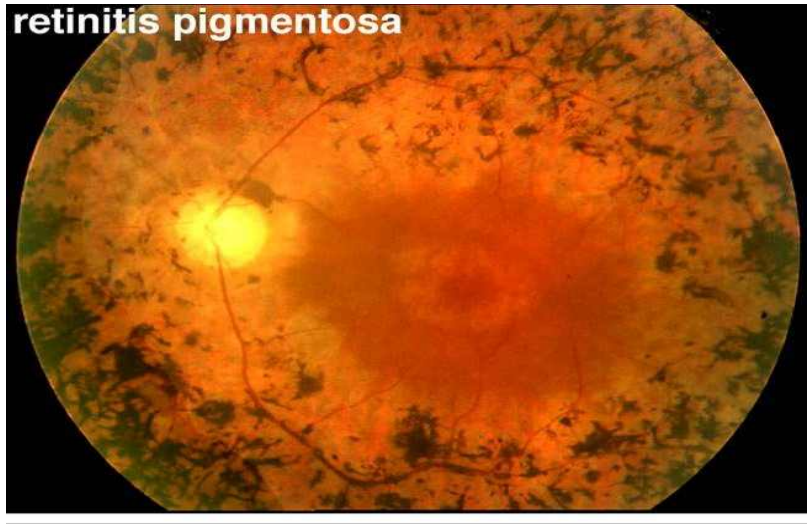


some corneal ERG electrodes

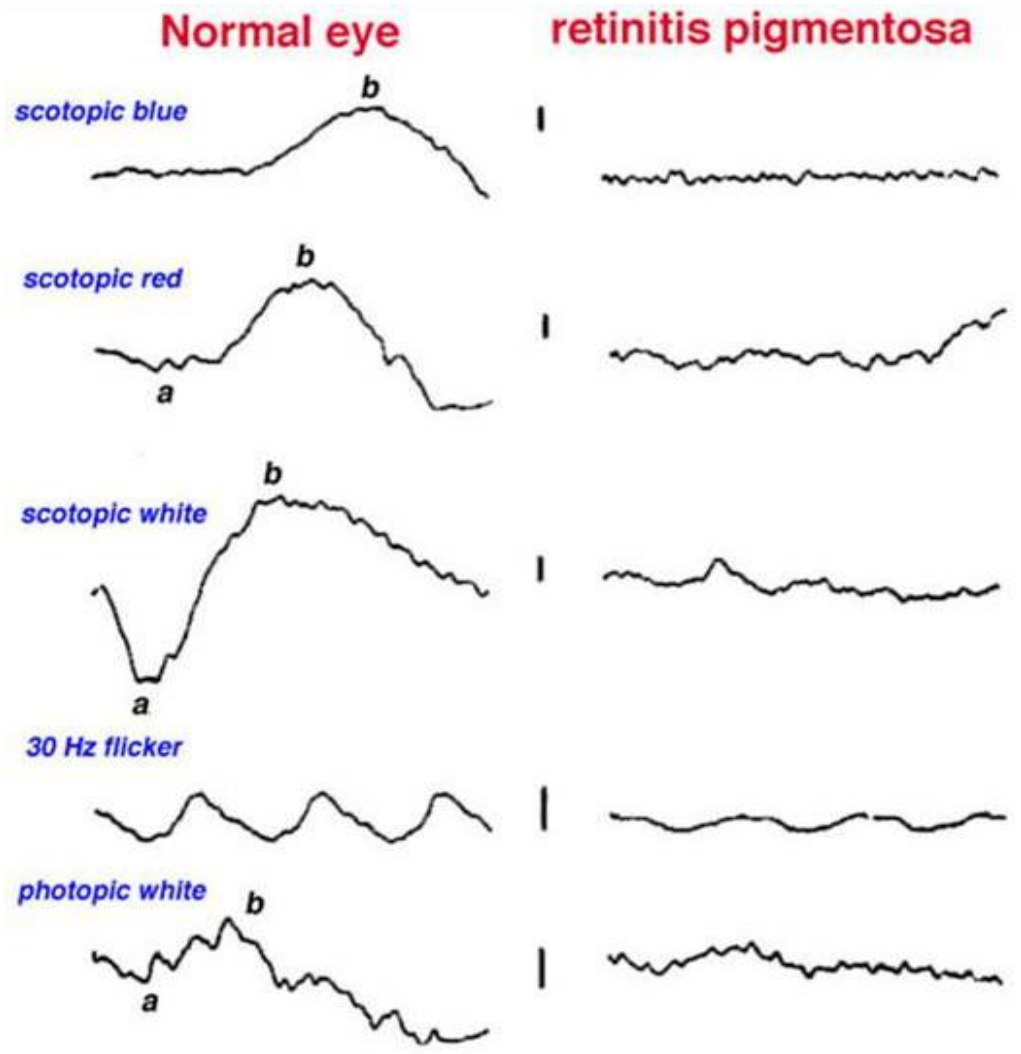


Fundus Photo of Human Retina

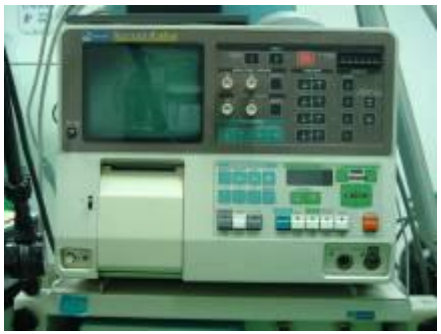


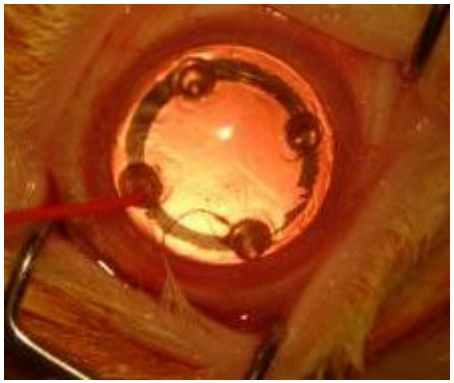


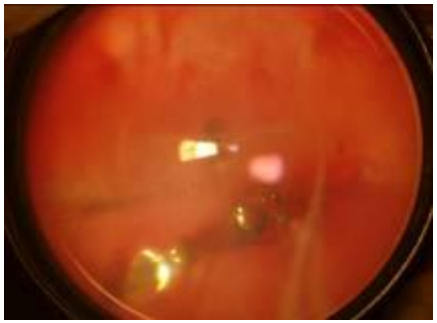
ERGs from Normal Subject and RP Patient

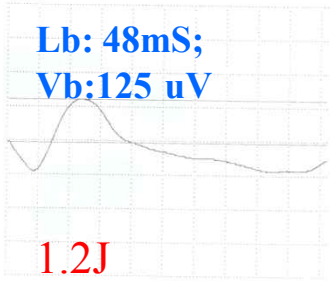


ERG & EERG (Electrically Evoked ERG)









(a)

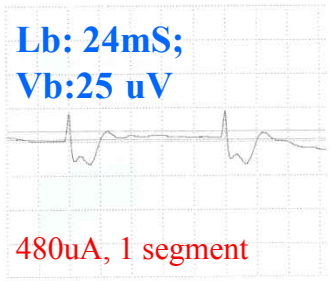
20mS/DIV

100uV/DIV

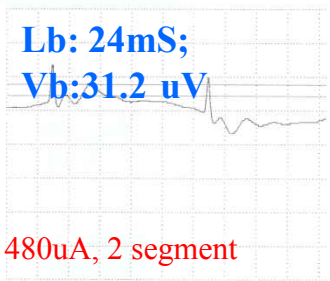
High Cut: 30Hz

Low Cut: 0.5Hz

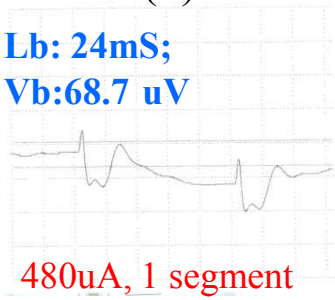
Recording Condition



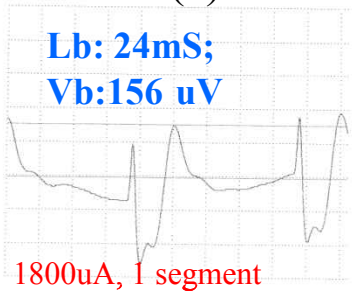
(b)



(c)



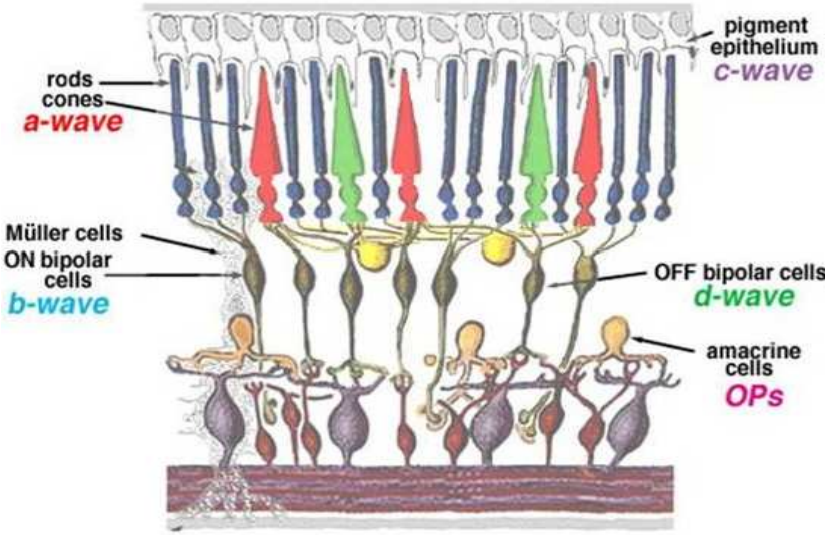
(d)

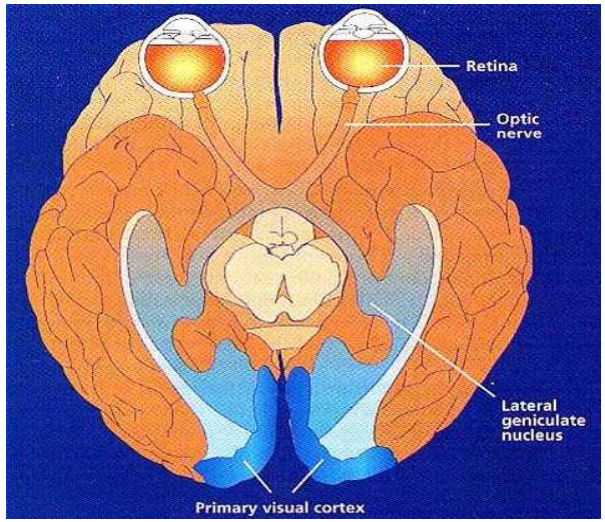


(e)

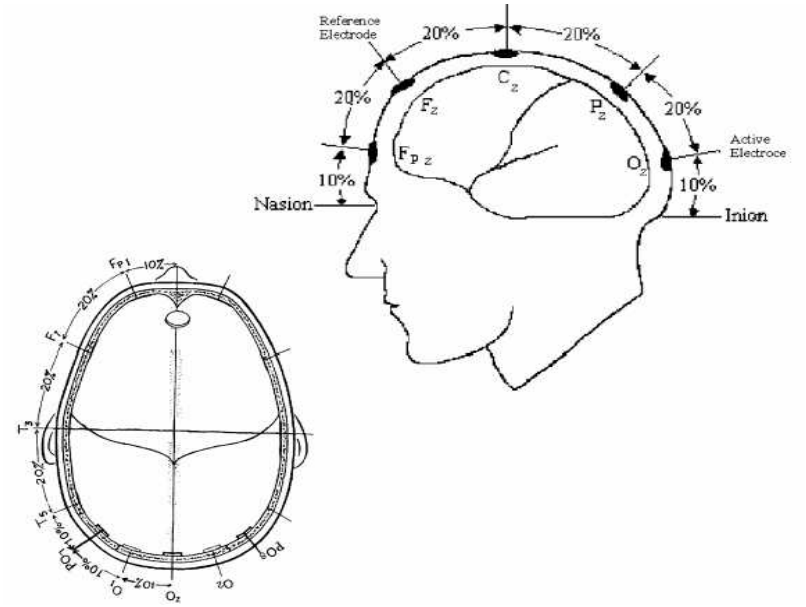
(b), (c): subretinal stimulation; (d), (e): epiretinal stimulation

The Retina and Visual System

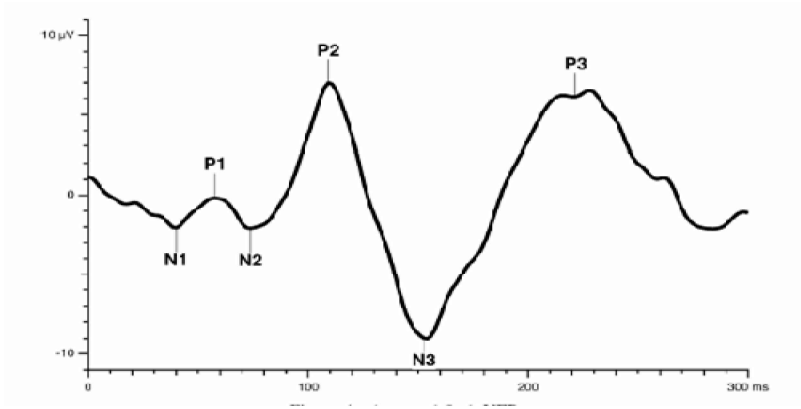




VEP Recording

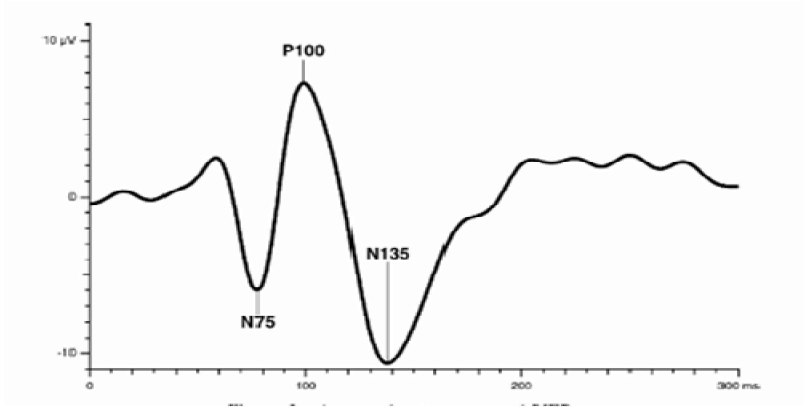


Electrode Location

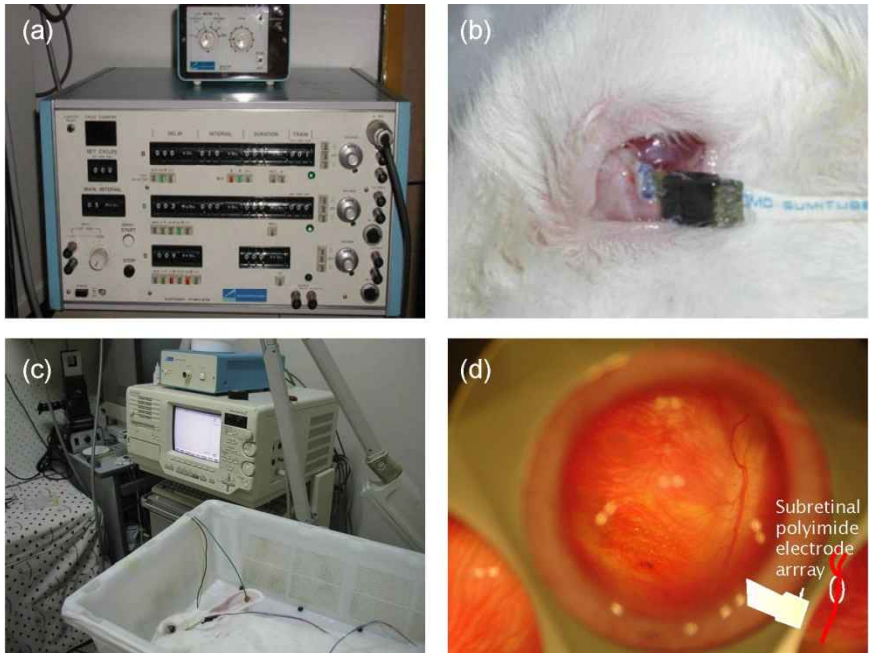


A normal flash VEP

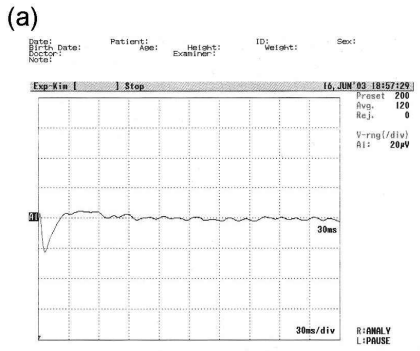
A Pattern Reversal VEP



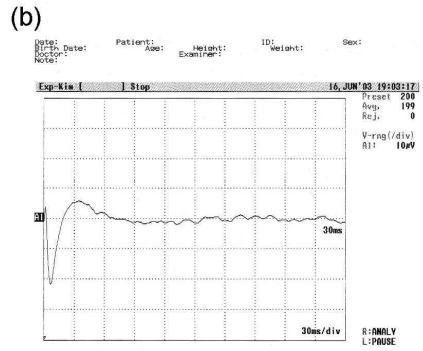
Electrically Evoked Potentials



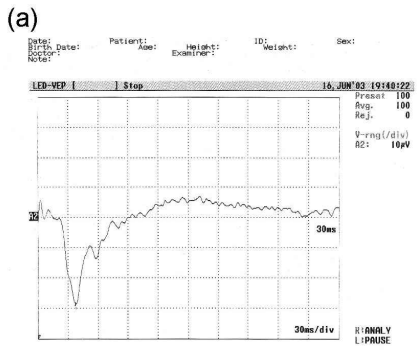
Subretinal Electrical Stimulation



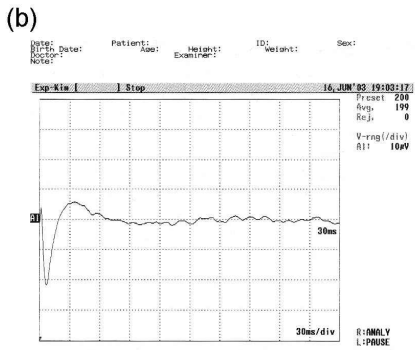
EEP, 1 mA



EEP, 2.5mA



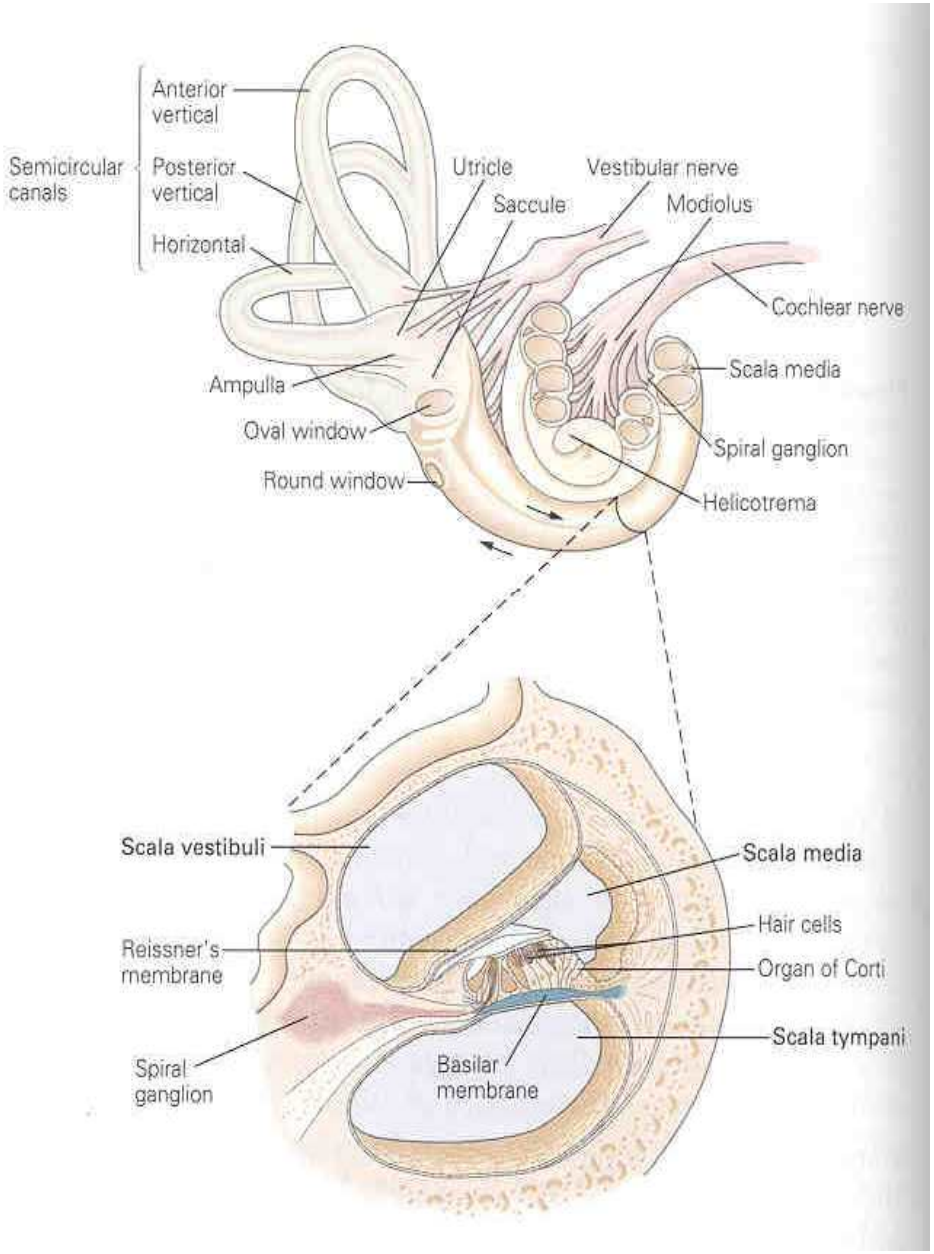
VEP

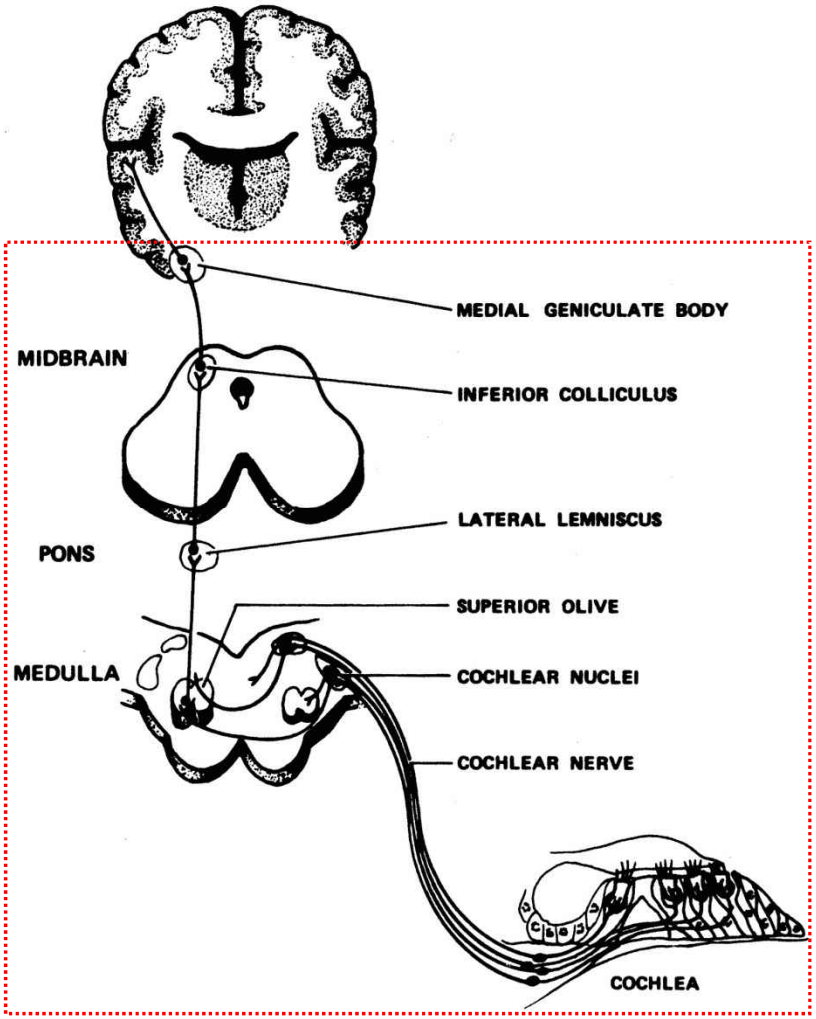


EEP, 2.5mA

Biopotentials related with Hearing

Auditory Pathway





Sources of ABR
(lower part of auditory system)

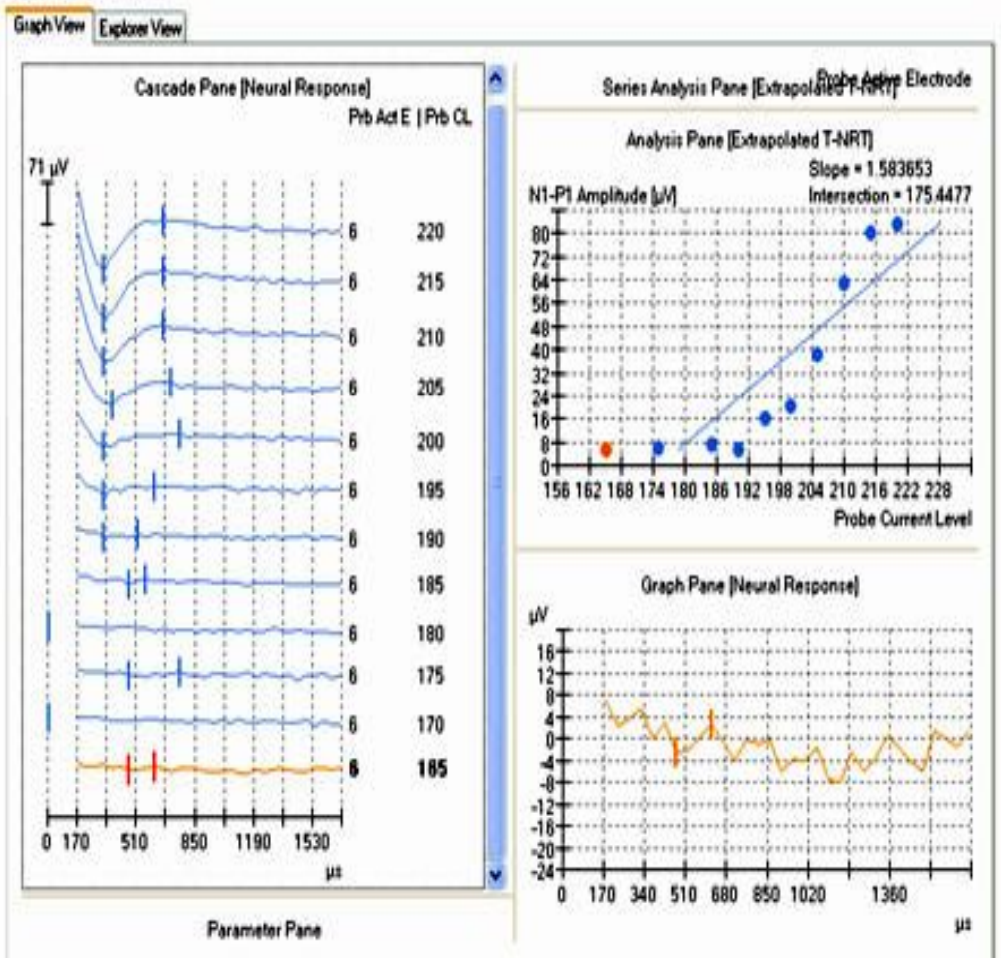
Comopound Action Potential (ECAP)

- **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**

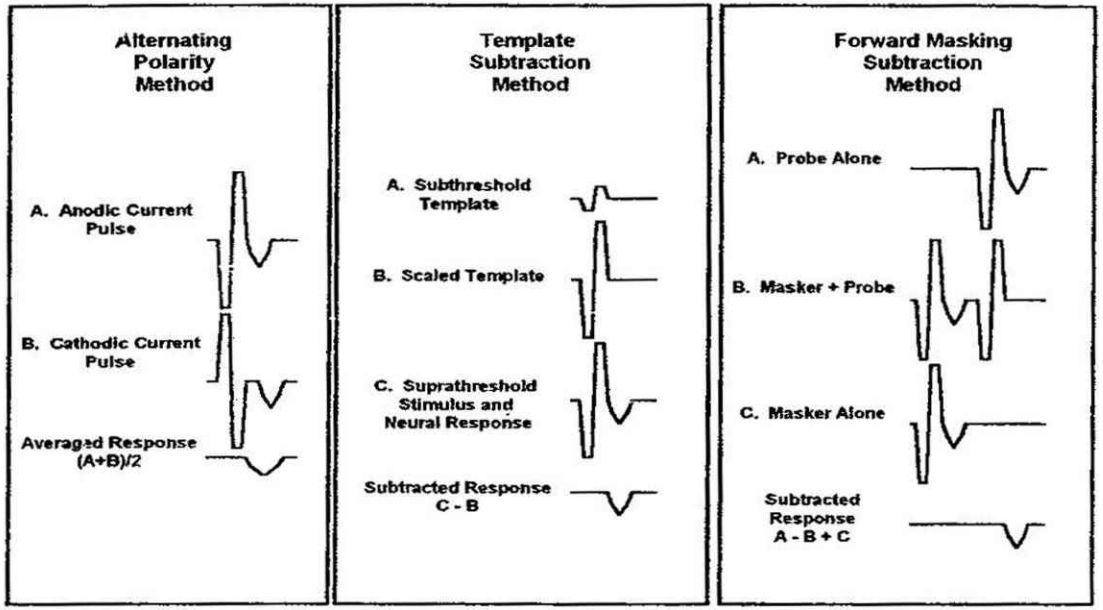
- **Every Cochlear Implant Manufacturers offer functions for ECAP masure/analysis**

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



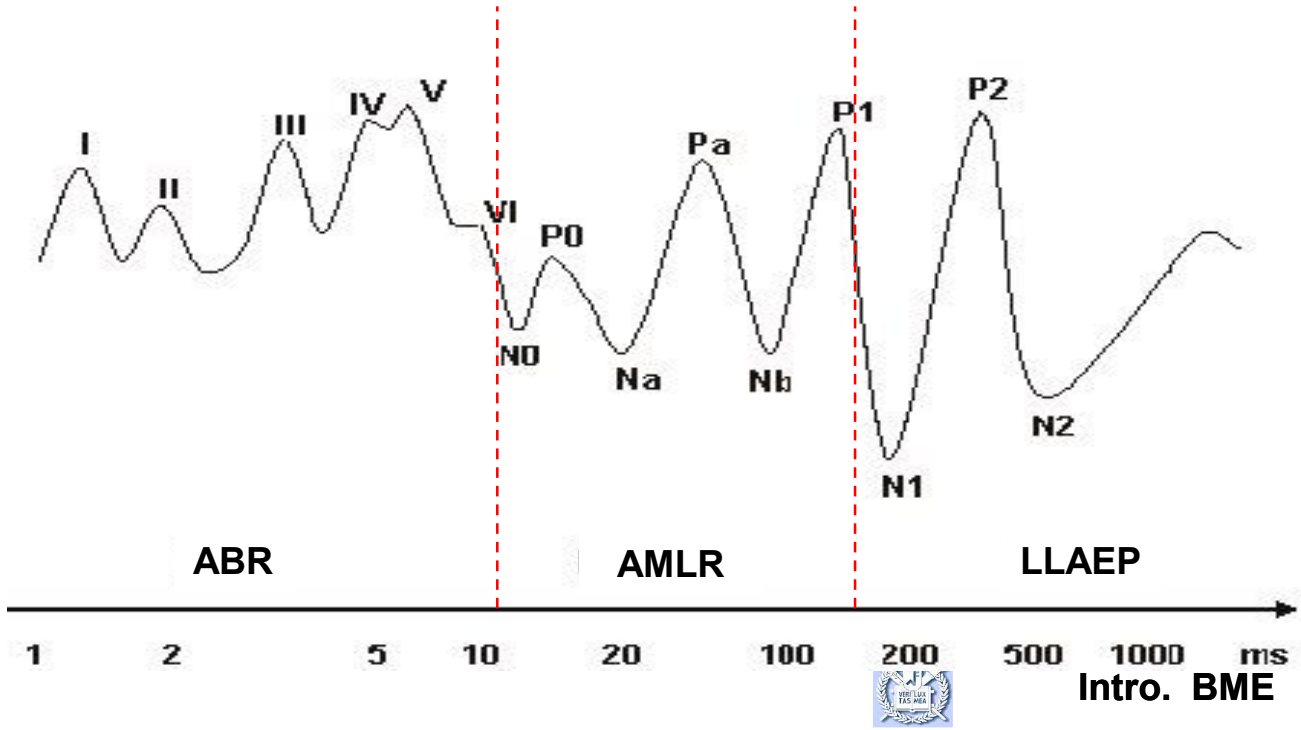
Artifact Removal in ECAP measure

- **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



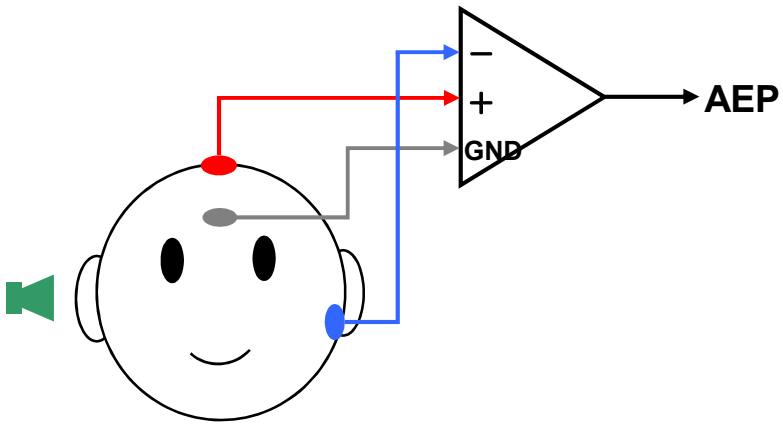
Auditory Evoked Potential (AEP)

- 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**

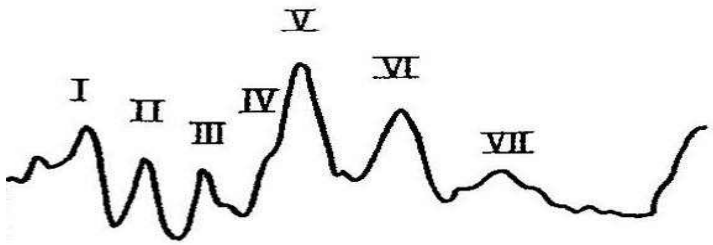
  - Primarily used to evaluate neurological disorders at level of auditory nerve and brainstem

- **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

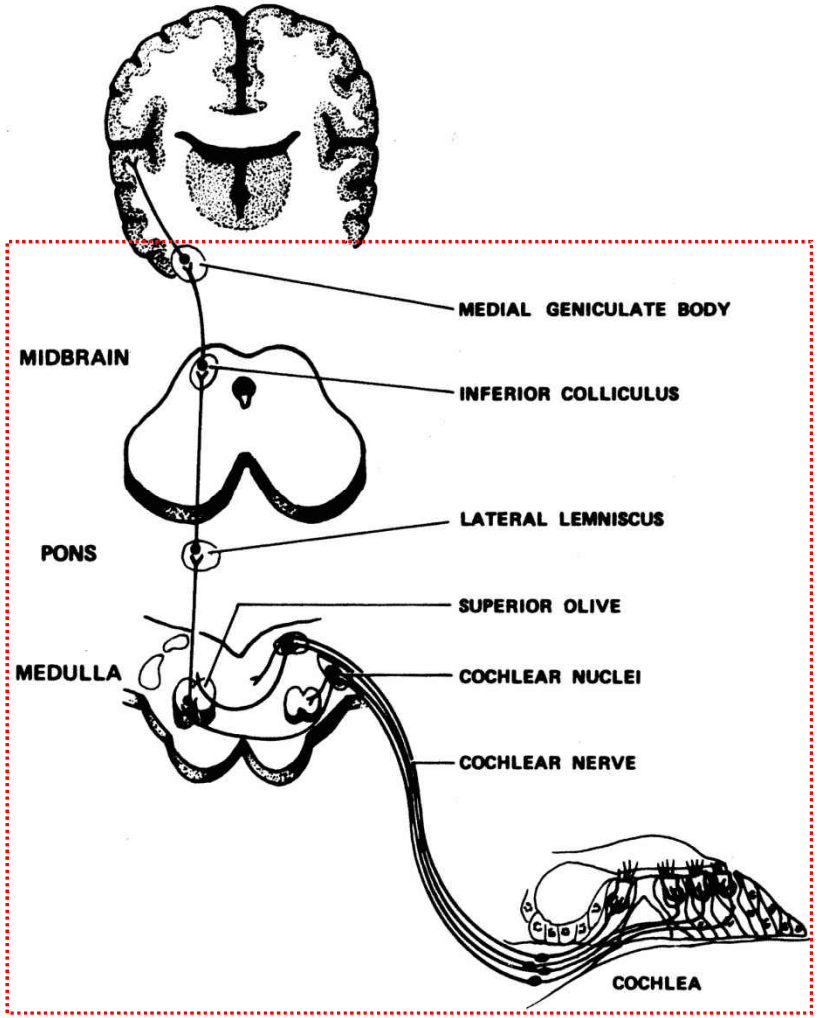
- **ABR consists of 7 peaks**

  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



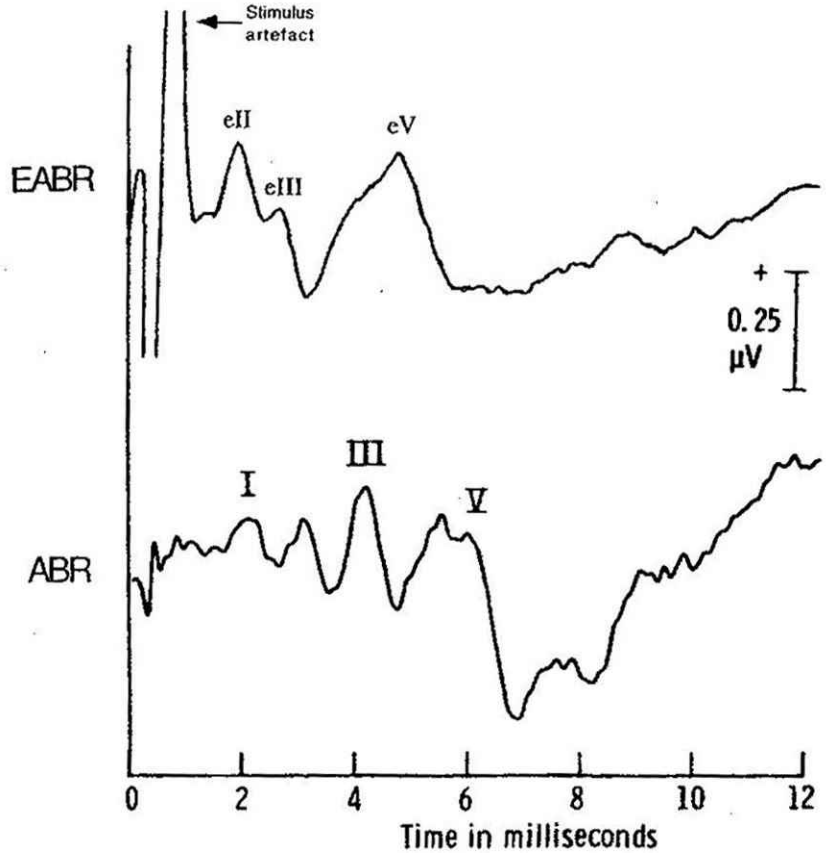
Sources of ABR
(lower part of auditory system)

ABR vs. EABR

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

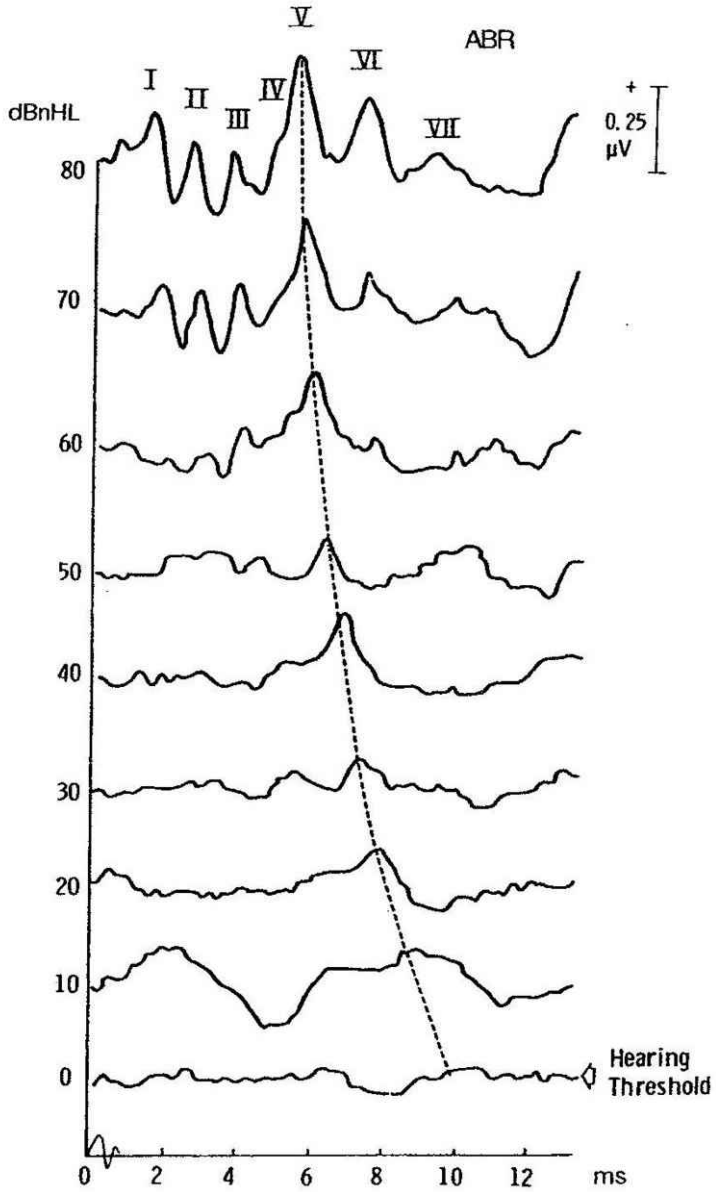
- **EABR has similar characteristic to ABR**
  - same auditory processes are used.

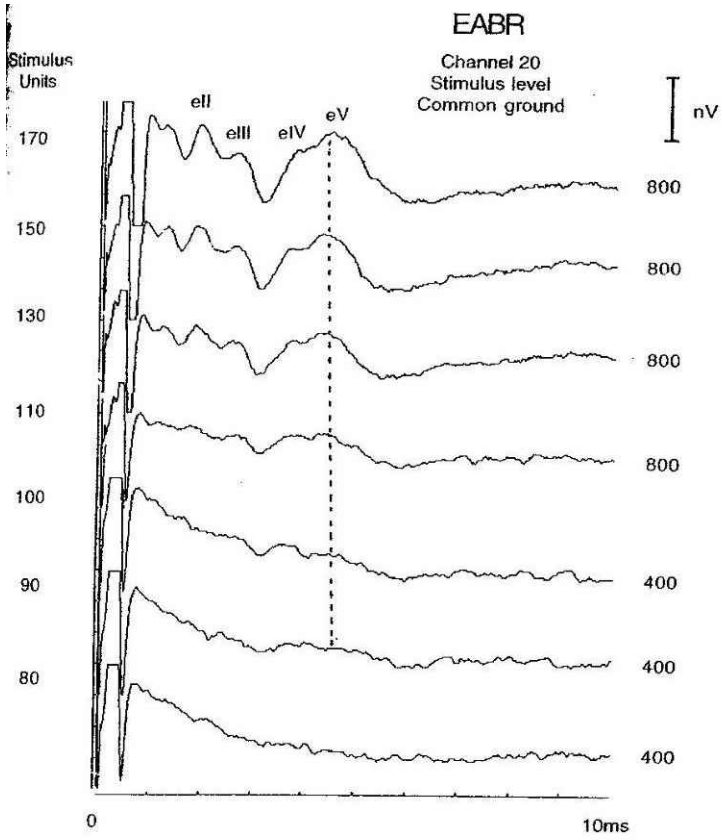
- **Some importane differences**
  (1) Wave eI is usually obscured.
  - due to stimulation artifact
  (2) Shorter latency
  - EABR arise 1.0~1.5msec earlier than ABR
  - Electrical stimulus bypasses the transmission process of sound.



Typical response wave forms for the ABR and the EABR

Intensity series of ABR and EABR





Other AEPs – AMLR, LLAEP, etc.

- AMLR Auditory Middle Latency Response

- LLAEP Long-Latency Auditory Evoked Potential
  - P300 Event Related Response

- On-going studies regarding clinical utility of these tests continue…

- Most recorded since 1960s
  : Not in widespread use outside of research sites

Auditory Middle Latency Response (AMLR)

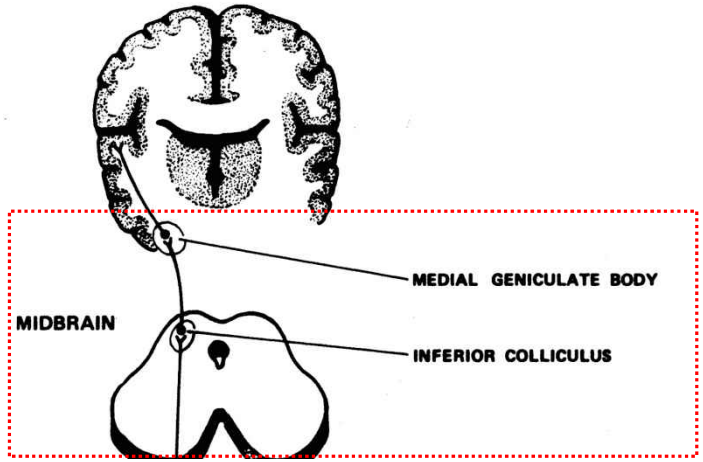
- **AMLR**
  - AEP that occurs after the ABR
  - Typical latency : 10msec ~ 100msec

- **AMLR contains larger and broader peaks than those of ABR**

  - Na,Pa, Nb, Pb(o P1) peaks
  (This form of representation is introduced by Goldstein and Rodman, 1967)
  - Pa is mostly used for checking auditory function (often compared to wave V of ABR)
  - Pb is highly variable and may not appear in normal subjects

- **AMLR measure is helpful in studying central auditory function in patient with language, speech and learning**

  - Neural generator of AMLR
  (1) subcortical portion of the auditory pathway that develops early
  (2) cortical portion that developes later



Sources of AMLR

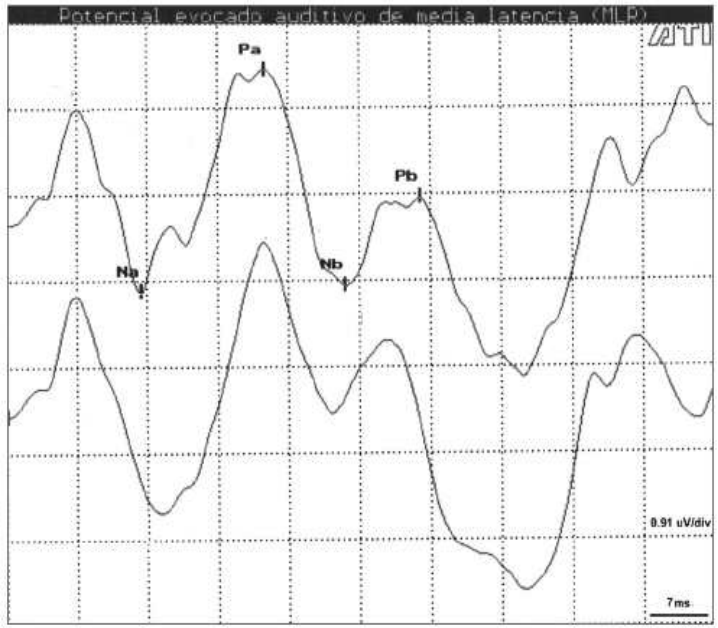


Figure 1. AMLR recording at 70 dBNA with replication.
Key: mV= microvolts; ms = milliseconds.

Long Latency Auditory Evoked Potential (LLAEP)

LLAEP is results of cognitive processing

- related with cognitive function of brain rather
  (than with physical sensory input)
- P300 event related potential is mostly invested by researchers

P300 event-related potential (Sutton et al, 1965)

- Positive peak with latency around 300msec after stimulation
- late cognitive component

Clinical use of P300

- diagnosis of
  (1) epilepsy, (2) Alzheimer disease,
  (3) obsessive-compulsive disorder, etc.