ELEC ENG 3BB3:

Cellular Bioelectricity

Notes for Lecture 26

Thursday, March 13, 2014

Electroencephalography (EEG):

EEG signals are field potentials measured on the surface of the skull.

These field potentials result from a large number of microcurrent sources working synergistically.

The microcurrent sources can be generated from propagating action potentials or synaptic activity.

Brain Wave Recordings

- Recorded extra-cellularly from scalp (EEG)
- Recorded extra-cellularly from surface of cortex (ECOG)
- Recorded extra-cellularly from deep structures (electroneurogram)

EEG (cont.):

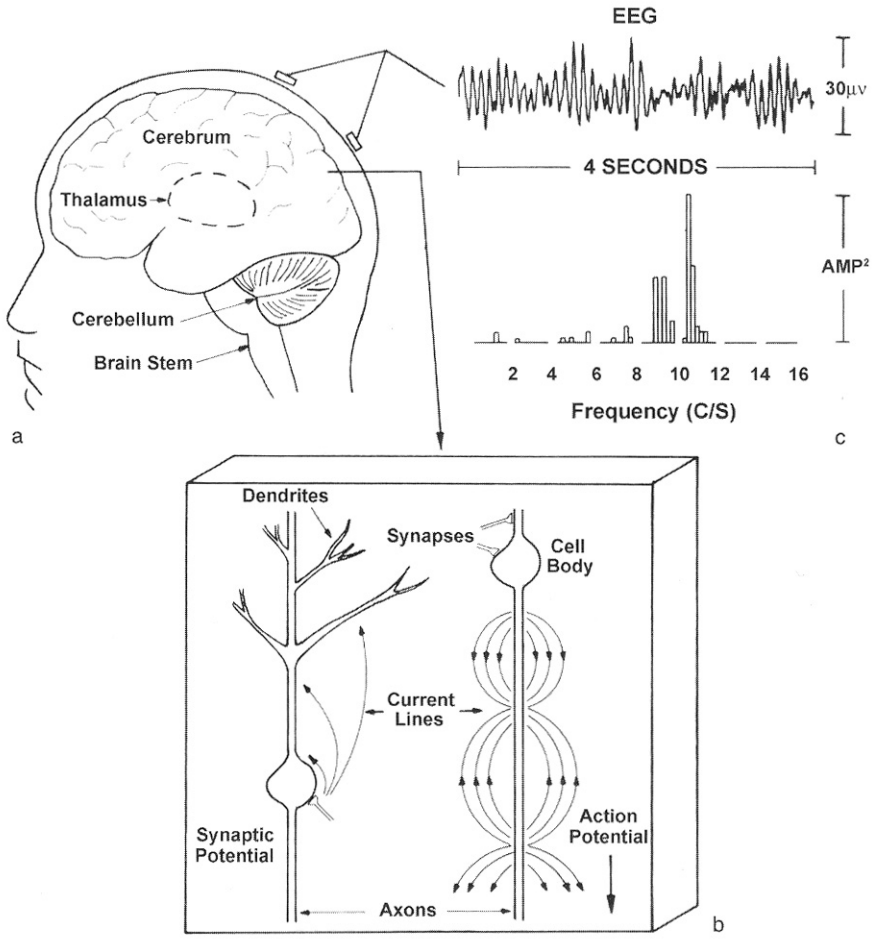


Figure 1-1 (a) The human brain. (b) Section of cerebral cortex showing microcurrent sources due to synaptic and action potentials. Neurons are actually much more closely packed than shown, about 10^5 neurons per mm^2 of surface. (c) Each scalp EEG electrode records space averages over many square centimeters of cortical sources. A four-second epoch of alpha rhythm and its corresponding power spectrum are shown.

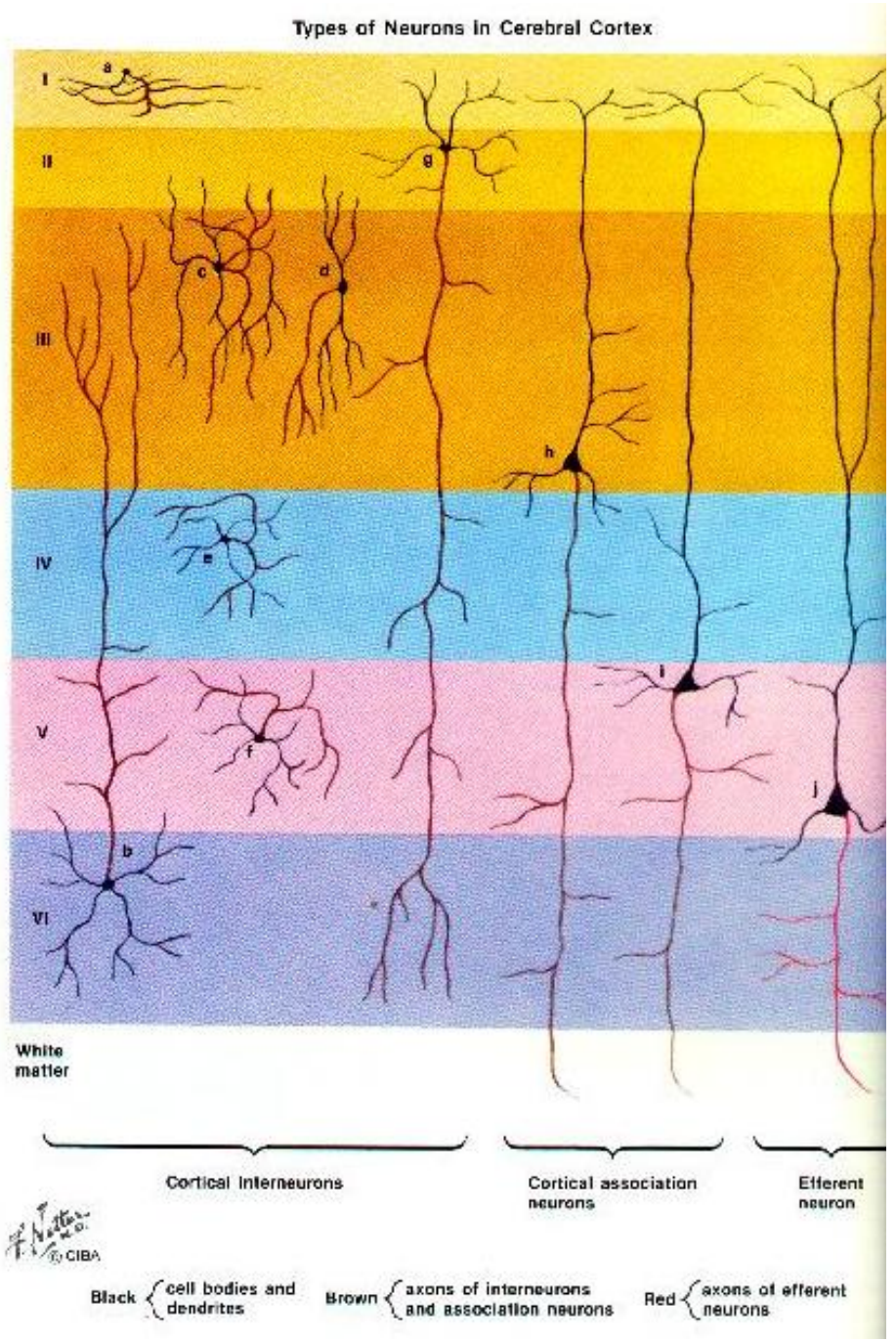
(from Nunez & Srinivasan)

Source of EEG Signal

- Only cerebral cortex contributes to EEG
- Organized vertically in 6 layers (I to VI)
- Includes about 10^{10} neurons
- Individual action potentials travelling along neuron axons are too small to be measured on scalp
- Each neuron has 10’s of thousands of synapse at its dendrites which are usually horizontally aligned
- Inward +ve current flow at excitatory synapses (EPSP)
- Outward +ve current flow at inhibitory synapses (IPSP)
- Viewed as current dipoles
- Sum of these flows creates synaptic fields

EEG (cont.):

Corticocortial fibers are closest to the skull surface.



Cortical Contributions

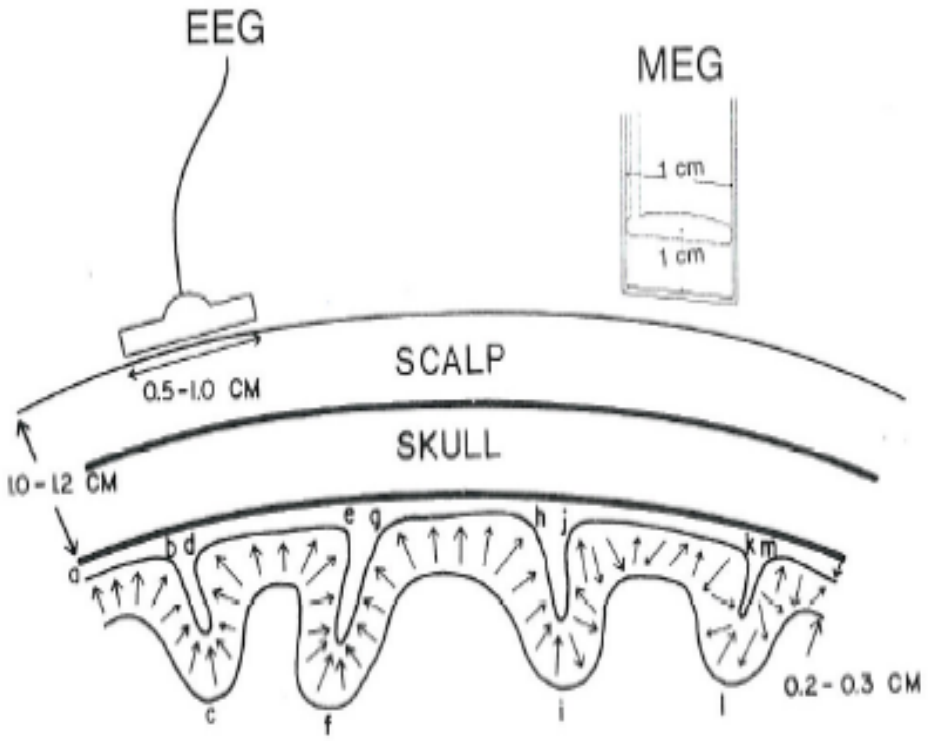
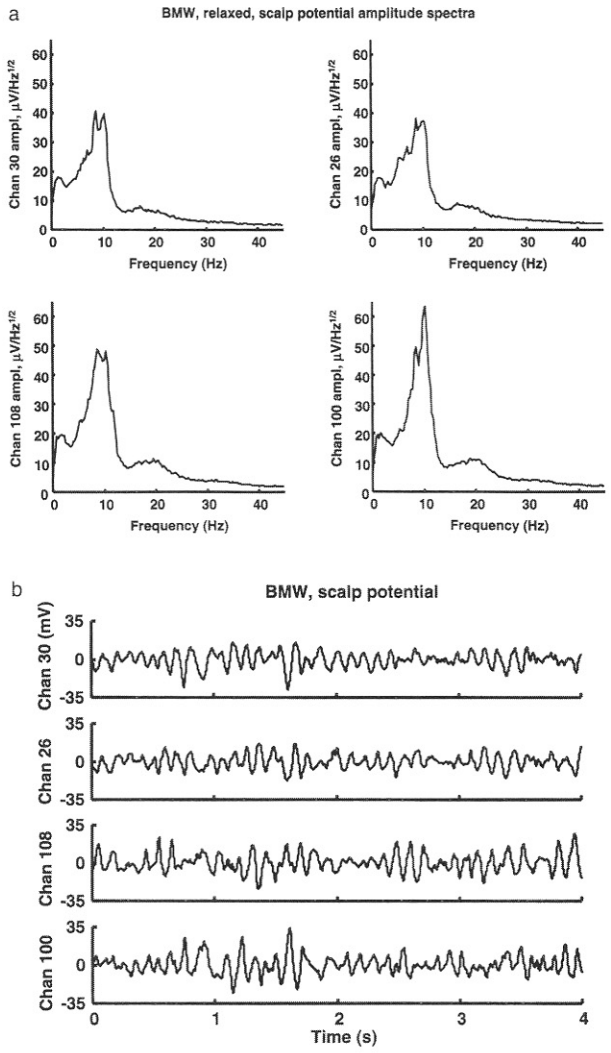


Figure 2-3 Neocortical sources can be generally pictured as *dipole layers* (or "dipole sheets," in and out of cortical fissures and sulci) with mesosource strength varying as a function of cortical location. EEG is most sensitive to correlated dipole layer in gyri (regions ab, de, gh), less sensitive to correlated dipole layer in sulcus (region hi), and insensitive to opposing dipole layer in sulci (regions bcd, efg) and random layer (region ijklm). MEG is most sensitive to correlated and minimally apposed dipole layer (hi) and much less sensitive to all other sources shown, which are opposing, random, or radial dipoles. Modified version reproduced with permission from Nunez (1995).

Spectral analysis (cont.):

Rhythm/ wave:	**Frequency range: (Hz)**	**Brain state:**
Alpha	8 – 13	prominent with closed eyes and with relaxation
Beta	> 13	prominent during awake activity *and deep sleep*
Theta	3.5 – 7.5	normally seen in sleep
Delta	< 3	normally seen in deep sleep

Spectral analysis of spontaneous EEG signals:



The frequency of spontaneous EEG oscillations can be indicative of brain state.

(from Nunez & Srinivasan)

Figure 1-4 (b) Alpha rhythm recorded from a healthy 25-year-old relaxed male with eyes closed using a neck electrode as reference. Four seconds of data are shown from four scalp locations (left frontal-30; right frontal-26; left posterior-108; right posterior-100). Amplitudes are given in μV. (a) Amplitude spectra for the same alpha rhythms shown in (b) but based on the full five-minute record to obtain accurate spectral estimates. Amplitudes are given in μV per root Hz. Frequency resolution is 0.25 Hz. The double peak in the alpha band represents oscillations near 8.5 and 10.0 Hz. These lower and upper alpha band frequencies have different spatial properties and behave differently during cognitive tasks as shown in chapter 10.

Neuronal Connections

- Most connections are short < 1mm
- Long distance pathways also exist (1 to 15 cm)
- Two hemispheres connected through corpus callosum 10^8 fibres
- Transmission times could be as little as 1 ms for short connections or 3 – 10 ms for longer.

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Instrumentation (EEG Electrodes)

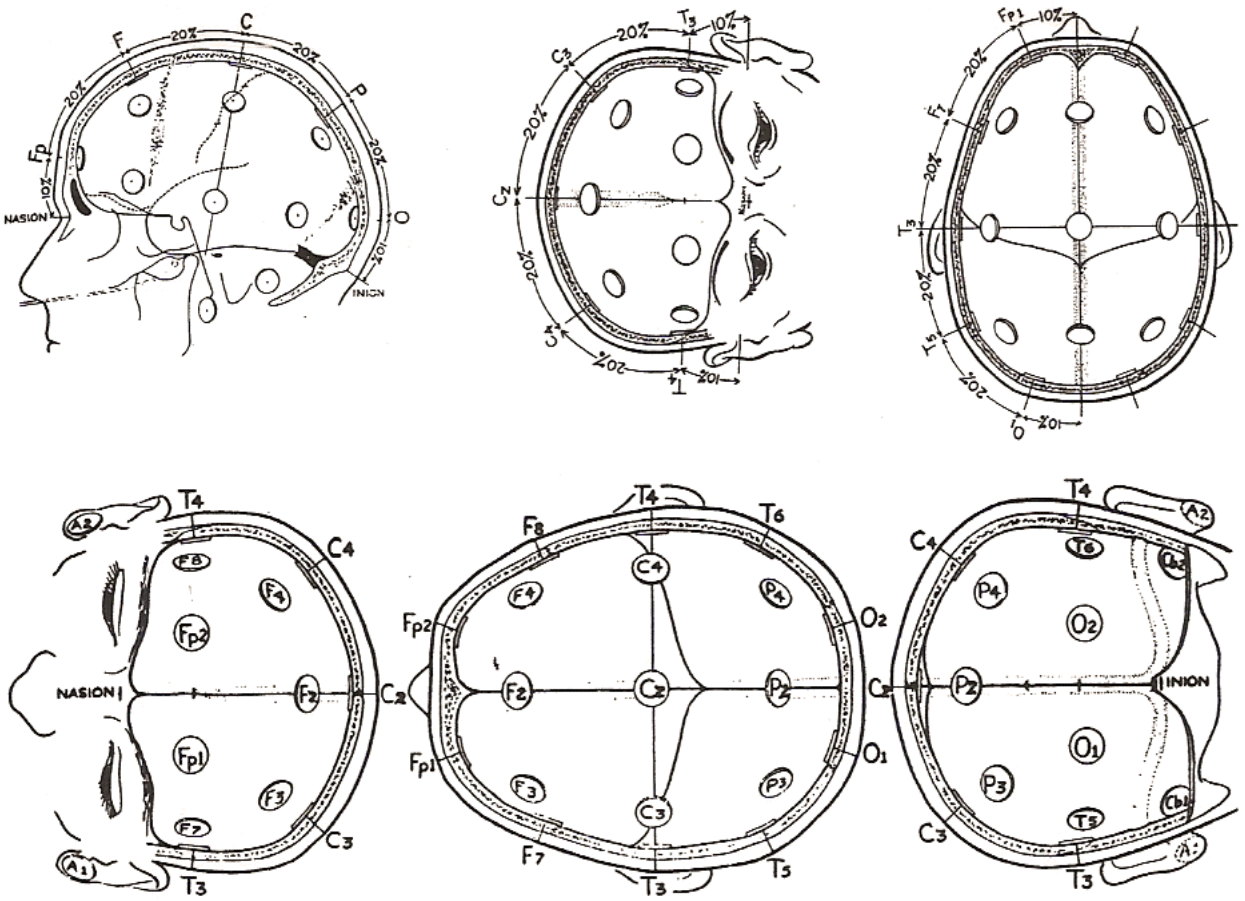


Figure 4.28 **The 10-20 electrode system** This system is recommended by the International Federation of EEG Societies. (From H. H. Jasper, "The Ten-Twenty Electrode System of the International Federation in Electroencepha-

Electrode Placement

Multi-electrode recording:

EEG electrode caps allow simultaneous recording of large numbers of EEG signals.

Cortical Electrodes

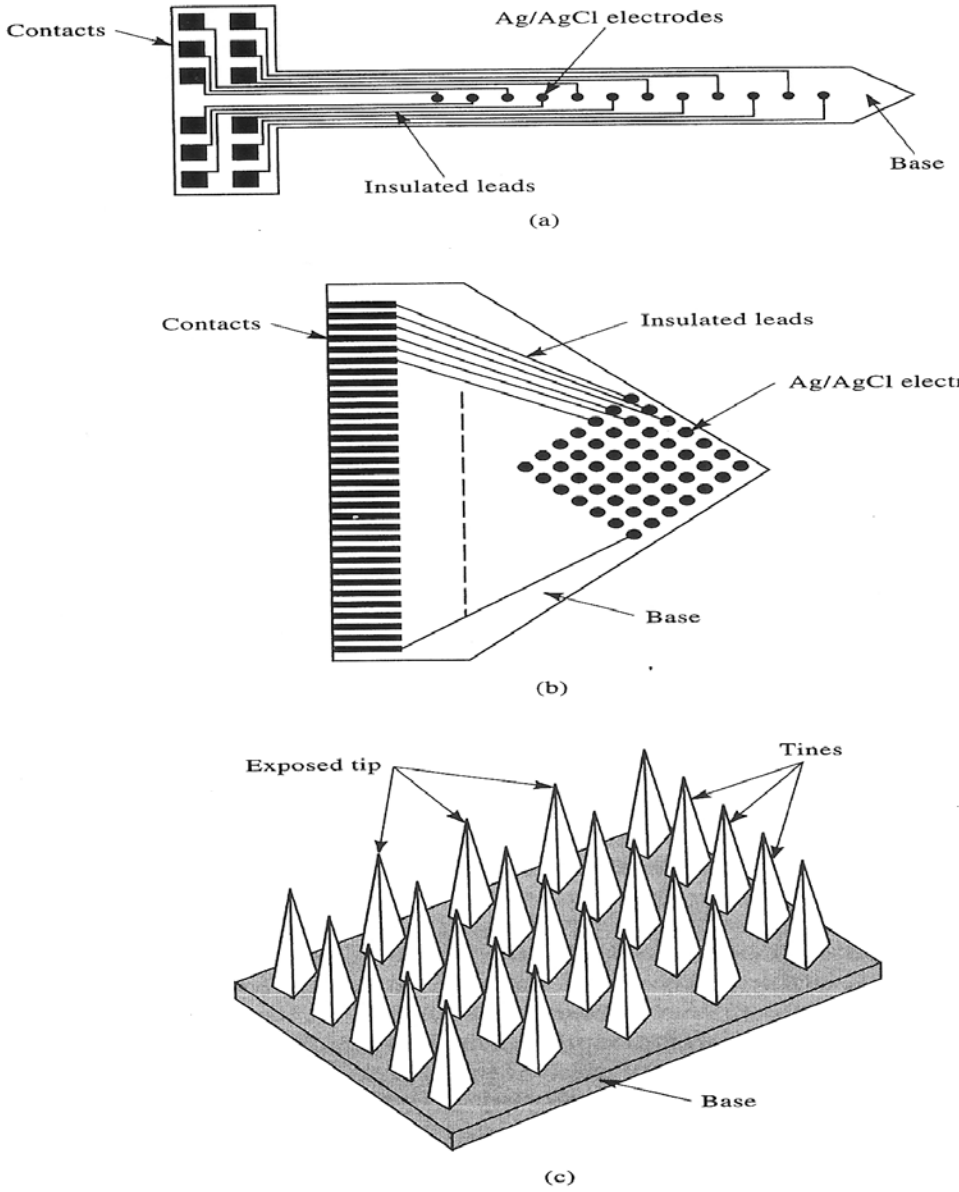


Figure 5.16 Examples of microfabricated electrode arrays. (a) One-dimensional plunge electrode array (after Mastrototaro *et al.*, 1992), (b) Two-dimensional array, and (c) Three-dimensional array (after Campbell *et al.*, 1991).

Amplifier Connections

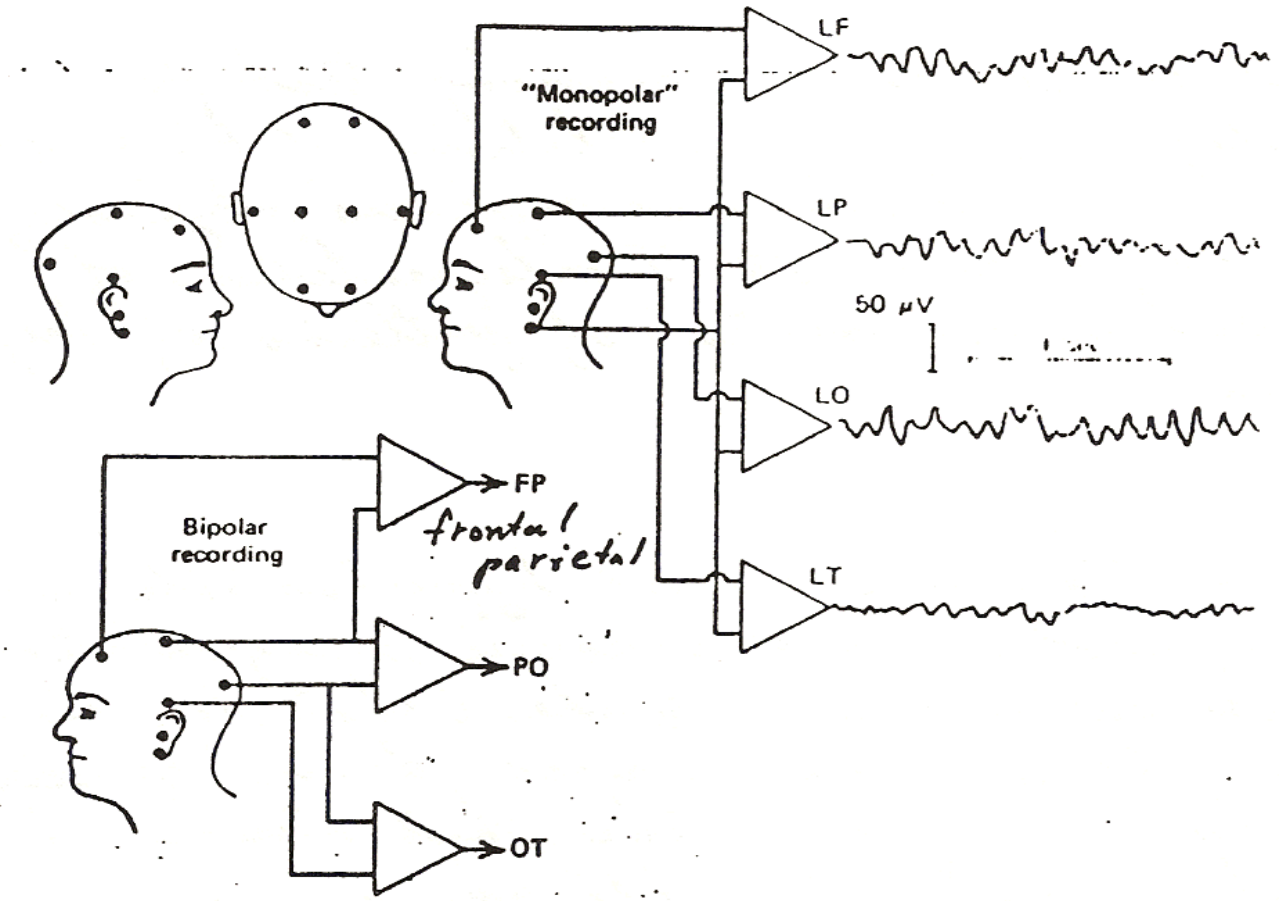
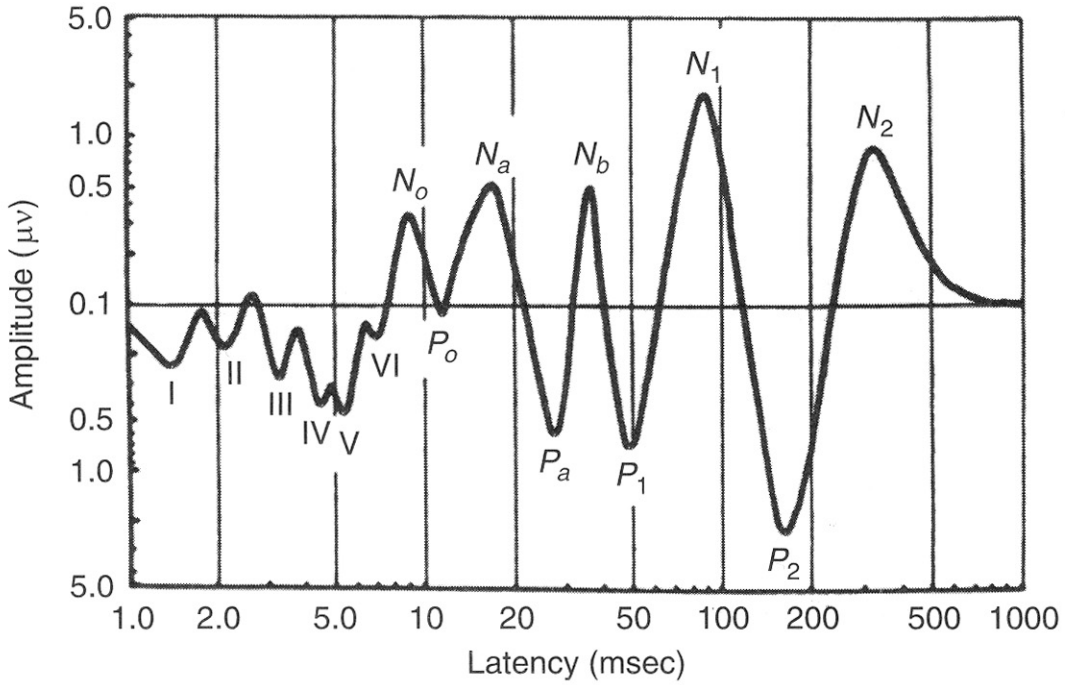


Figure 11-52. Method of connecting the recording channels for "monopolar" and bipolar recording. With "monopolar" recording, the reference electrode is on the earlobe, chin, or neck

Evoked potentials:

Averaging of EEG signals in response to a repeated stimulus gives an *evoked potential*.

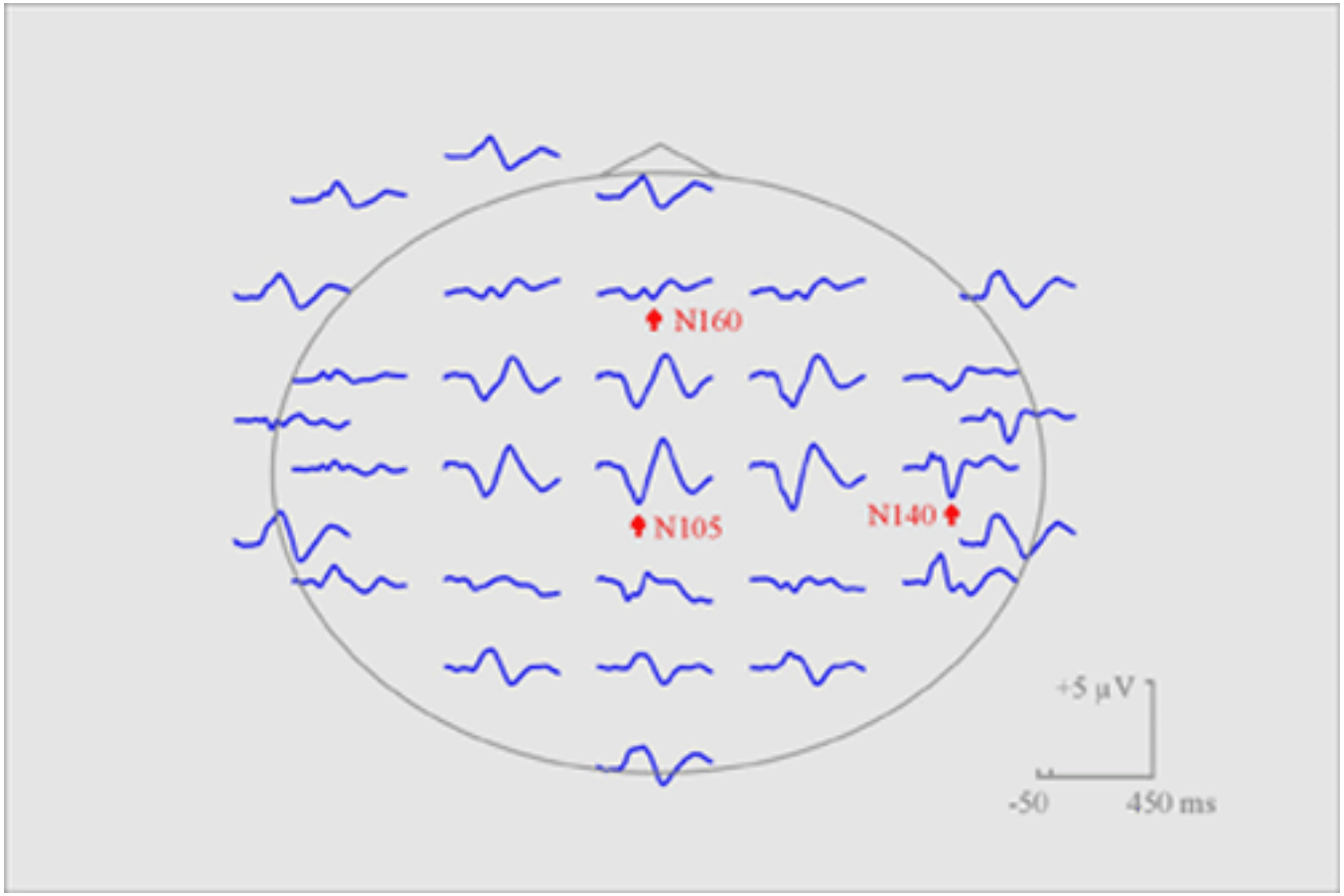


(from Nunez & Srinivasan)

Figure 1-17 The auditory evoked potential waveform as recorded from the human scalp. A subject is presented with a series of up to several thousand tones or clicks and the time-locked EEG is averaged over the stimuli to remove the (much larger) spontaneous EEG. The first few ms of the waveform is also known as the brainstem averaged evoked response (BAER). Physiologists have assigned standard labels to each peak (N_1, P_2, and so forth). Reproduced with permission from Picton et al. (1974).

Multi-electrode recording (cont.):

Example auditory evoked potentials at different electrode positions on the skull —



Epilepsy

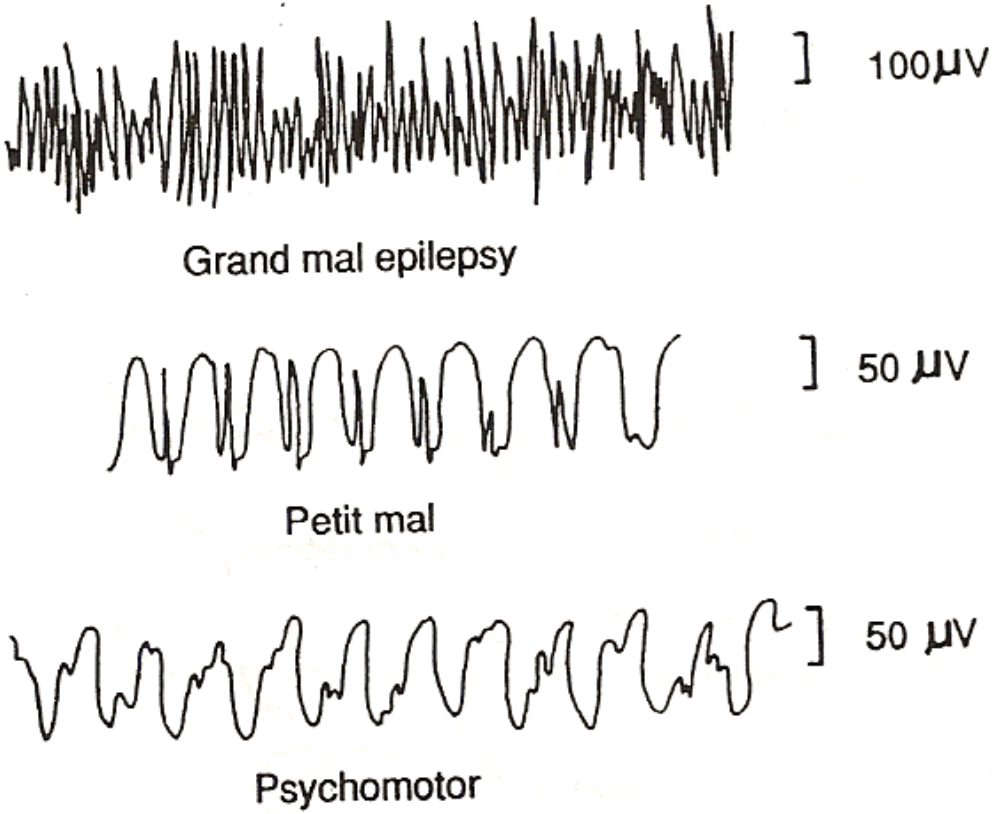
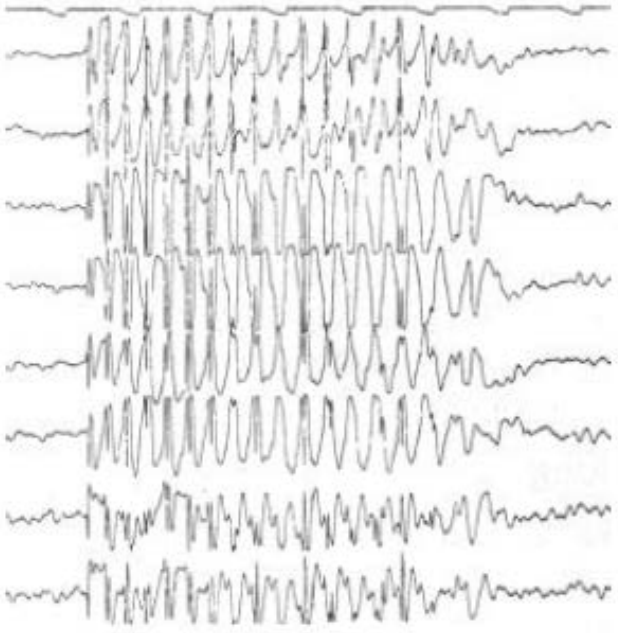


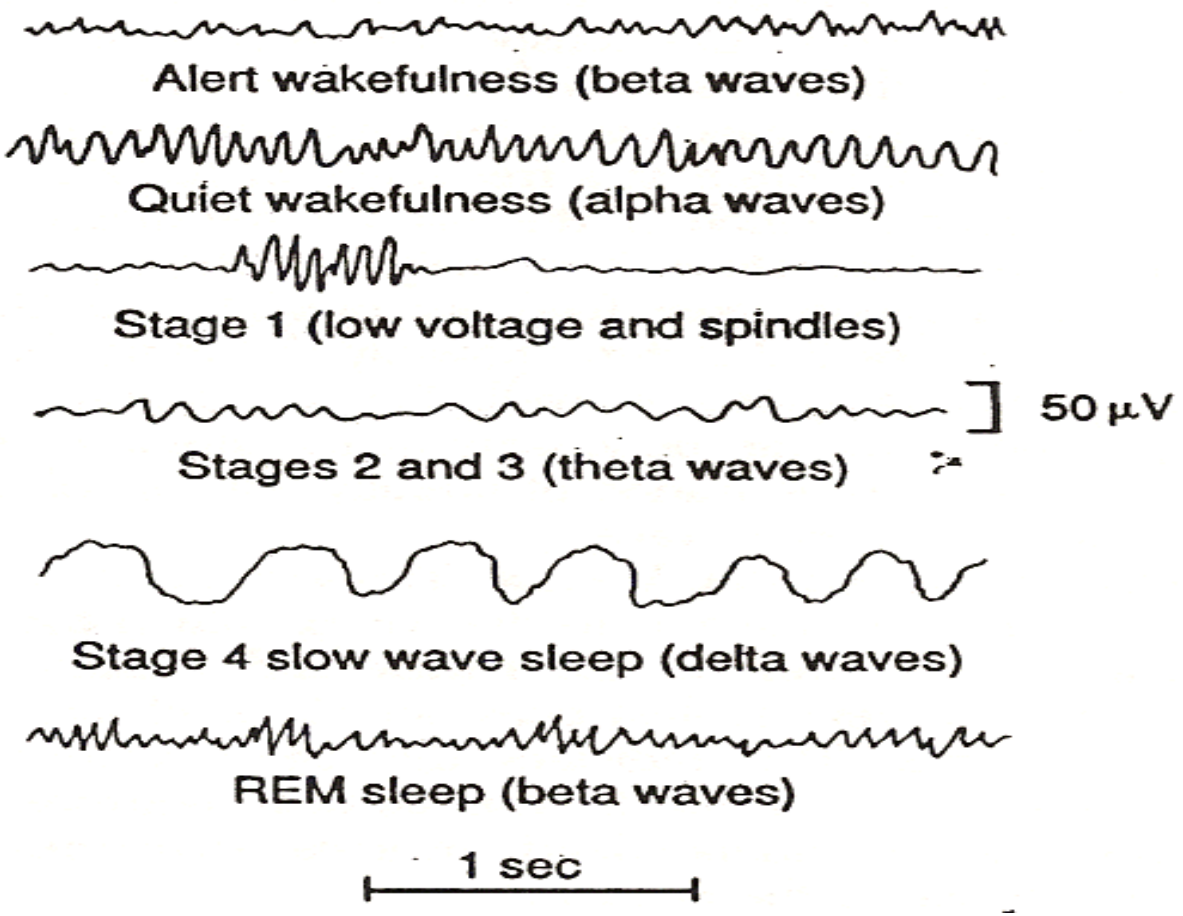
Figure 59–5. Electroencephalograms in different types of epilepsy.

Epilepsy EEG Signal

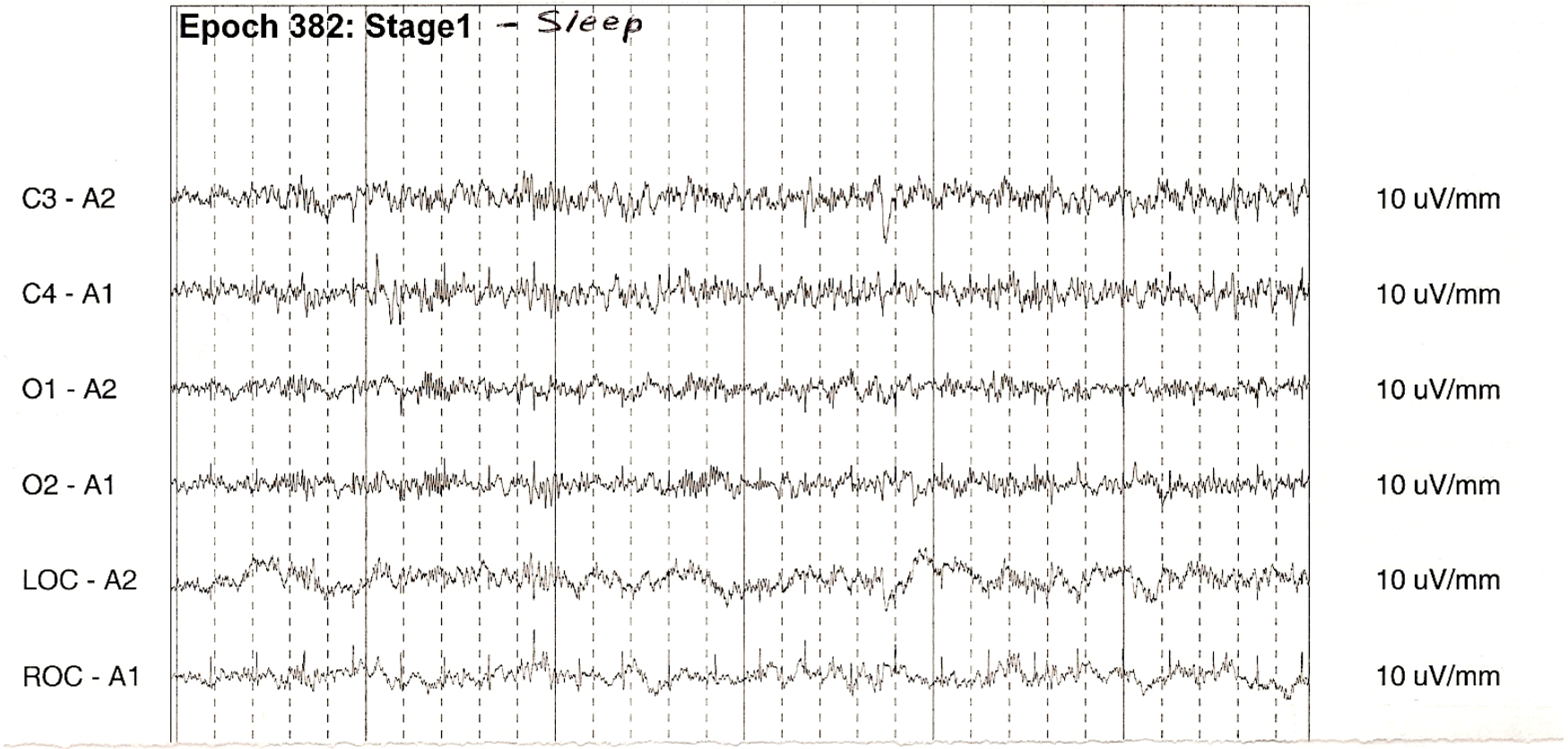
- Spikes
  - response to stimuli
  - Epileptic seizures
  - higher frequency content
  - Up to 100 Hz



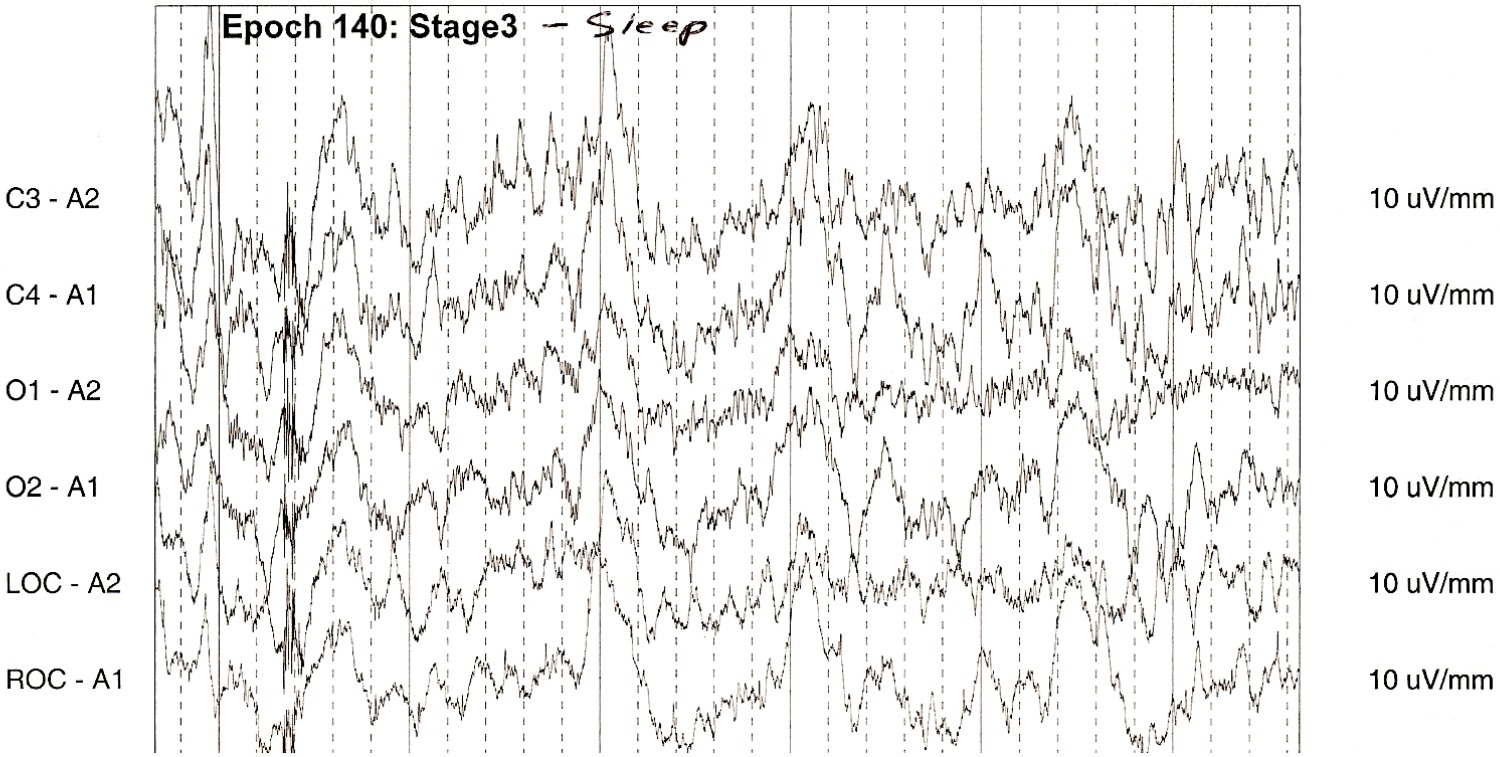
Sleep Staging



Stage 1


Epoch 382: Stage1 – Sleep
C3 - A2
C4 - A1
O1 - A2
O2 - A1
LOC - A2
ROC - A1
10 uV/mm
10 uV/mm
10 uV/mm
10 uV/mm
10 uV/mm
10 uV/mm

Stage 3


Epoch 140: Stage3 – Sleep
C3 - A2
C4 - A1
O1 - A2
O2 - A1
LOC - A2
ROC - A1
10 uV/mm
10 uV/mm
10 uV/mm
10 uV/mm
10 uV/mm
10 uV/mm