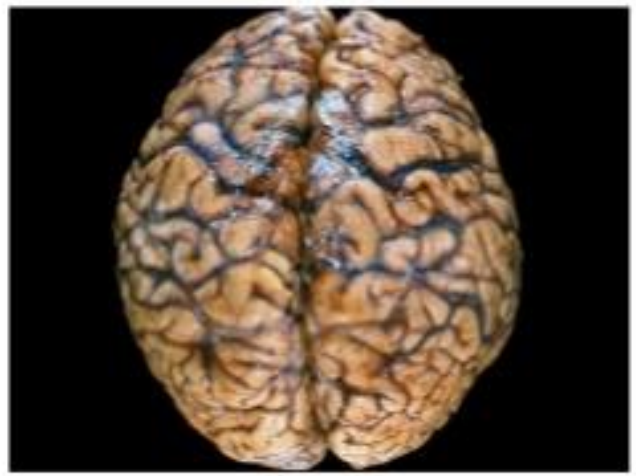
به نام خدا

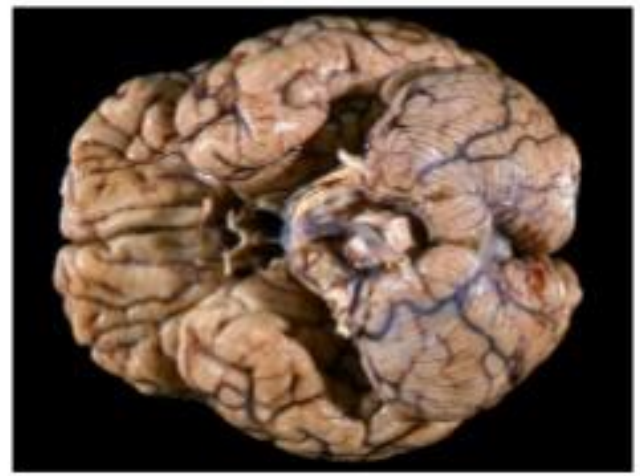
# EEG:

Electroencephalogram

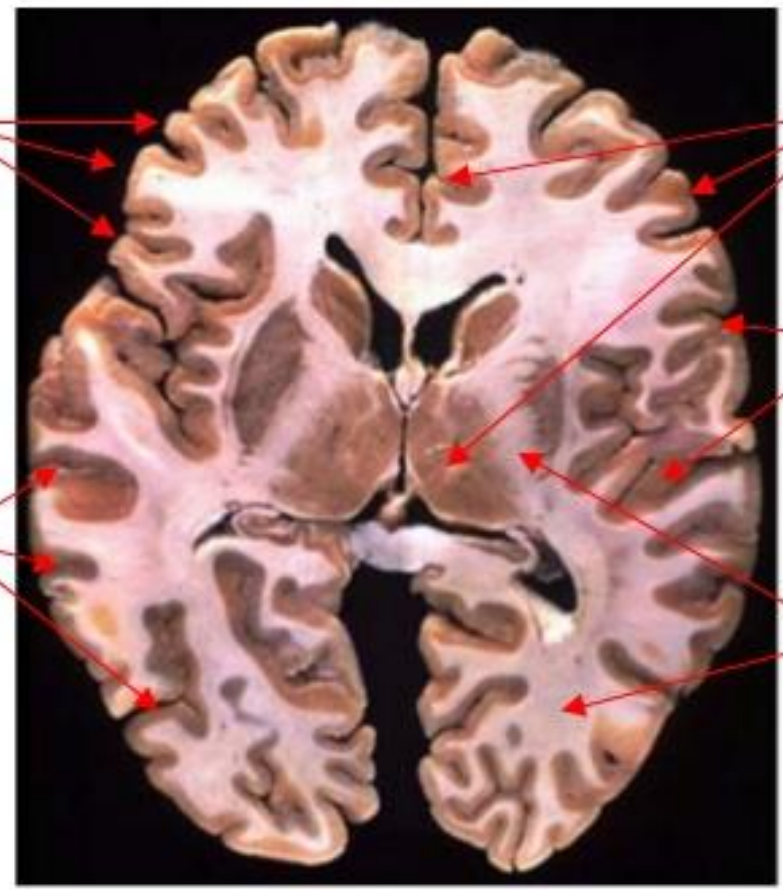
- EEG = a measure of cerebral electrical activity
  - The generator sources for EEG waves are within the cerebral cortex
  - Electrical activity recorded on the scalp is produced by extracellular current flow associated with summated excitatory and inhibitory postsynaptic potentials (EPSPs and IPSPs)
  - Individual action potentials do not contribute directly to EEG activity

# Outer Surface of Human Brain





# Axial Slice through Human Brain




**Gray Matter**
= Neuron cell bodies & dendrites

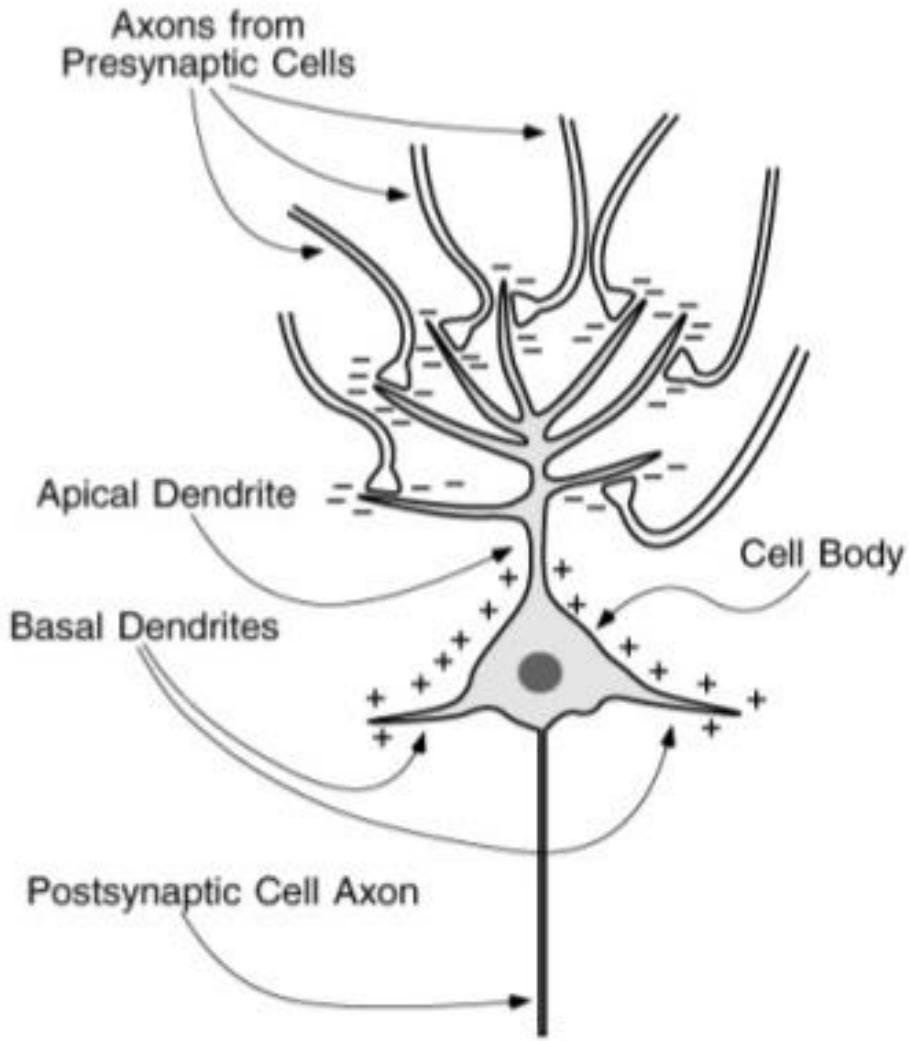
**Cortex**
= Outer layer of gray matter

**White Matter**
= Myelin (=fat)-covered axons

# Single pyramidal cell in cortex

For brain electrical activity to be detectable through skull, must be strong signal summed over many neurons

- All behaving similarly at same time
- All oriented in same way
- So negative and positive don't cancel each other out when summed




**Pyramidal Cells** in the cortex have the right properties

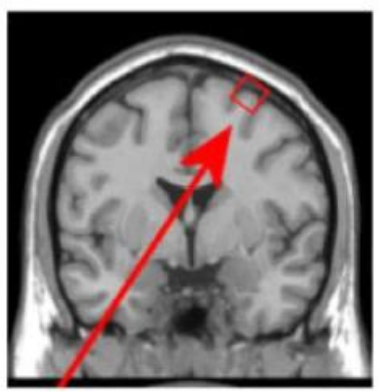
- EPSP – produces a change in membrane permeability within a select portion of the cell membrane resulting in a net influx of + ions that depolarizes the cell
- IPSP – selective activation of either $Cl^-$ or $K^+$ channels resulting in a net outward ionic current with hyperpolarization of the cell

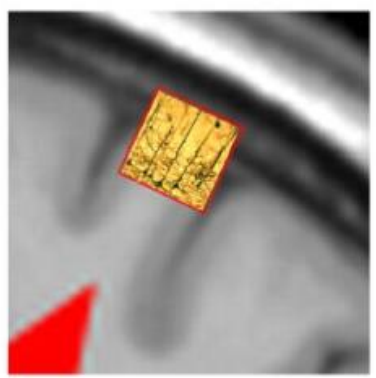
# EEG: A Reflection of Current

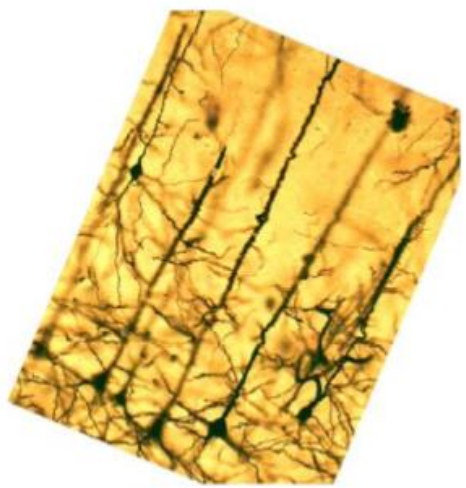
- Spontaneous EEG activity occurs when currents flow across charged neuronal membranes
- An EEG waveform reflects a summation of PSPs from thousands or even millions of cortical neurons
- The EEG represents the "average" behavior of large neuronal aggregates
- The current flow from positive to negative is arranged in a dipole

# What is electroencephalography (EEG)?

- "It is generally accepted that the EEG reflects activity originating in the brain" (Coles & Rugg, 1995, Electrophysiology of Mind)
- EEG reflects voltages generated (mostly) by excitatory postsynaptic potentials from apical dendrites of massively synchronised neocortical pyramidal cells.







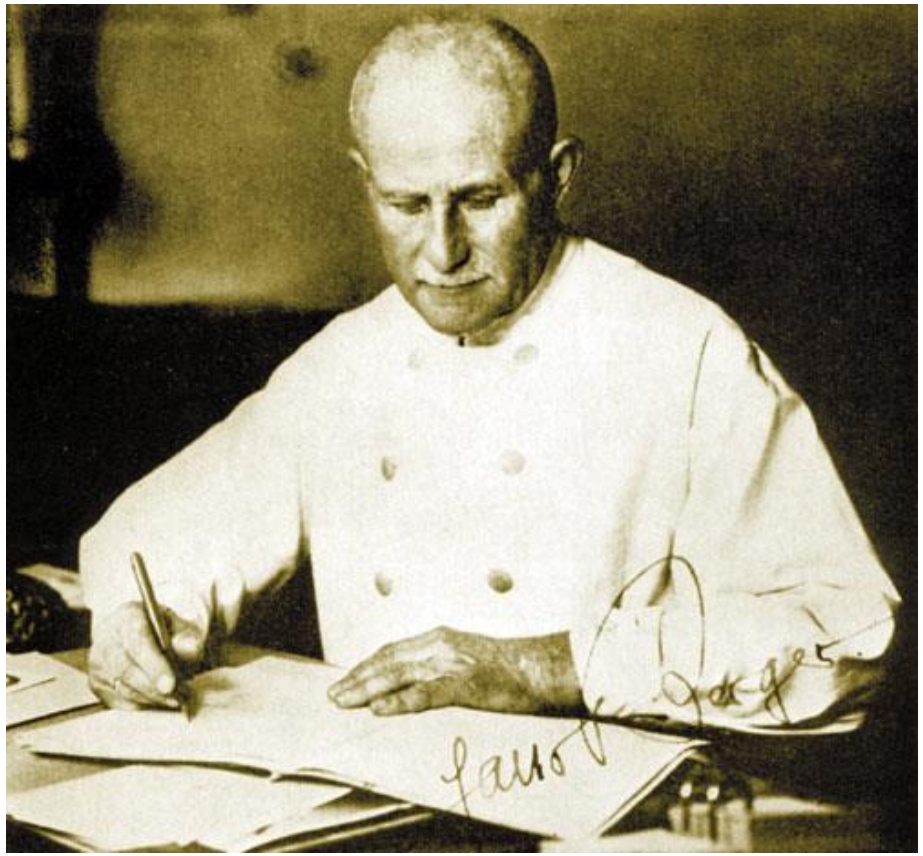
# Interim summary

- What EEG measures:
  - Excitatory and inhibitory PSP at apical dendrites of many synchronised cortical neurons.
- What EEG does **not** measure:
  - Single neurons
  - Asynchronous activity
  - Glial cells
  - Subcortical structures

## Factors Affecting EEG Waveforms

- Voltage of the cortical discharge
- Area involved in synchronous activity
- Degree of synchrony
- Location of the dipole generators in relation to the convolutions of the cortical mantle.

# History



**1929: Hans Berger** developed the electroencephalography (=graphic representation of the difference in voltage between two different cerebral locations plotted over time) following the studies of Richard Caton in non-human animal species.

He described the human alpha and beta rhythms

# Über das Elektrenkephalogramm des Menschen.

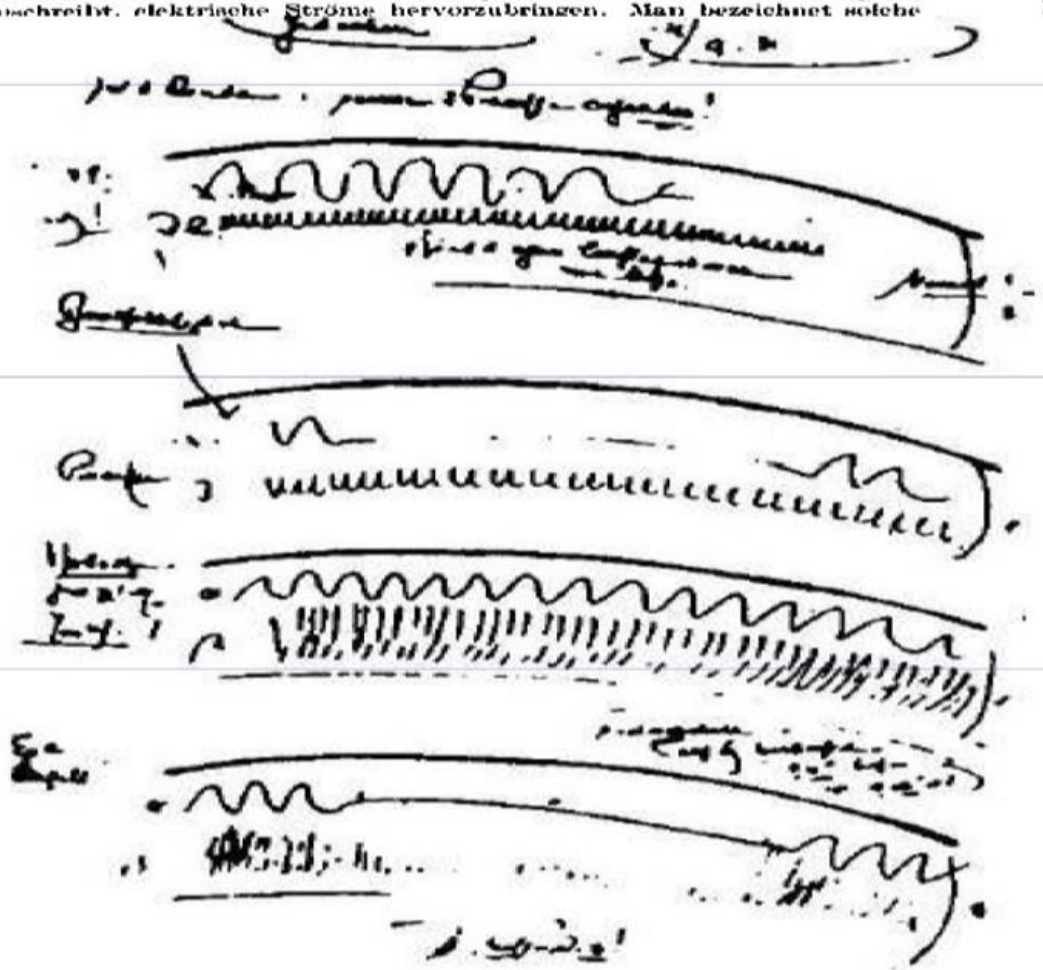
Von

Professor Dr. **Hans Berger**, Jena.

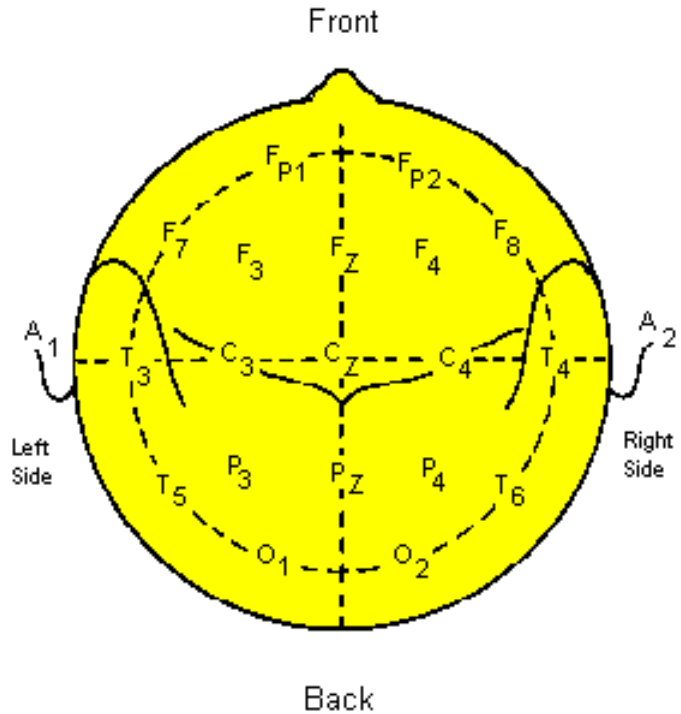
(Mit 17 Textabbildungen.)

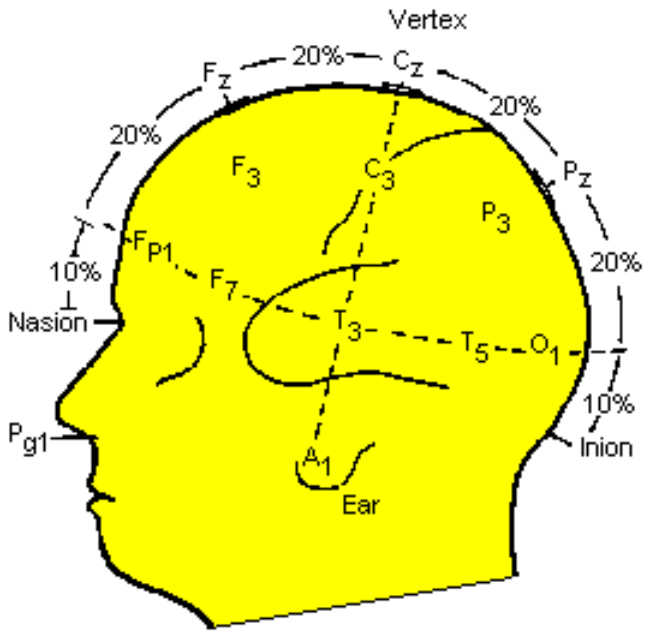
*(Eingegangen am 22. April 1929.)*

Wie *Garten* [1], wohl einer der besten Kenner der Elektrophysiologie, mit Recht hervorgehoben hat, wird man kaum fehlgehen, wenn man jeder lebenden Zelle tierischer und pflanzlicher Natur die Fähigkeit zuschreibt, elektrische Ströme hervorzubringen. Man bezeichnet solche

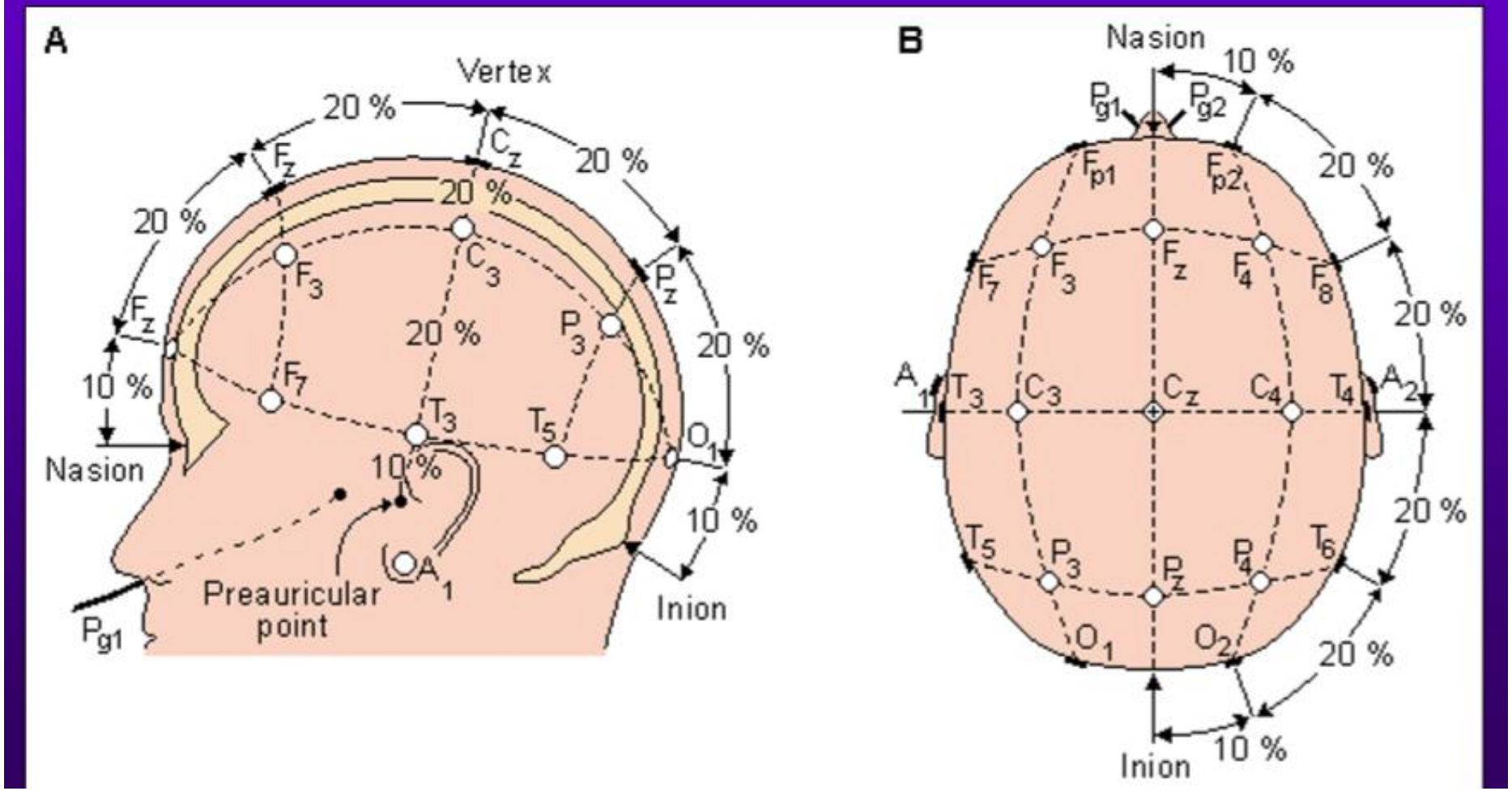


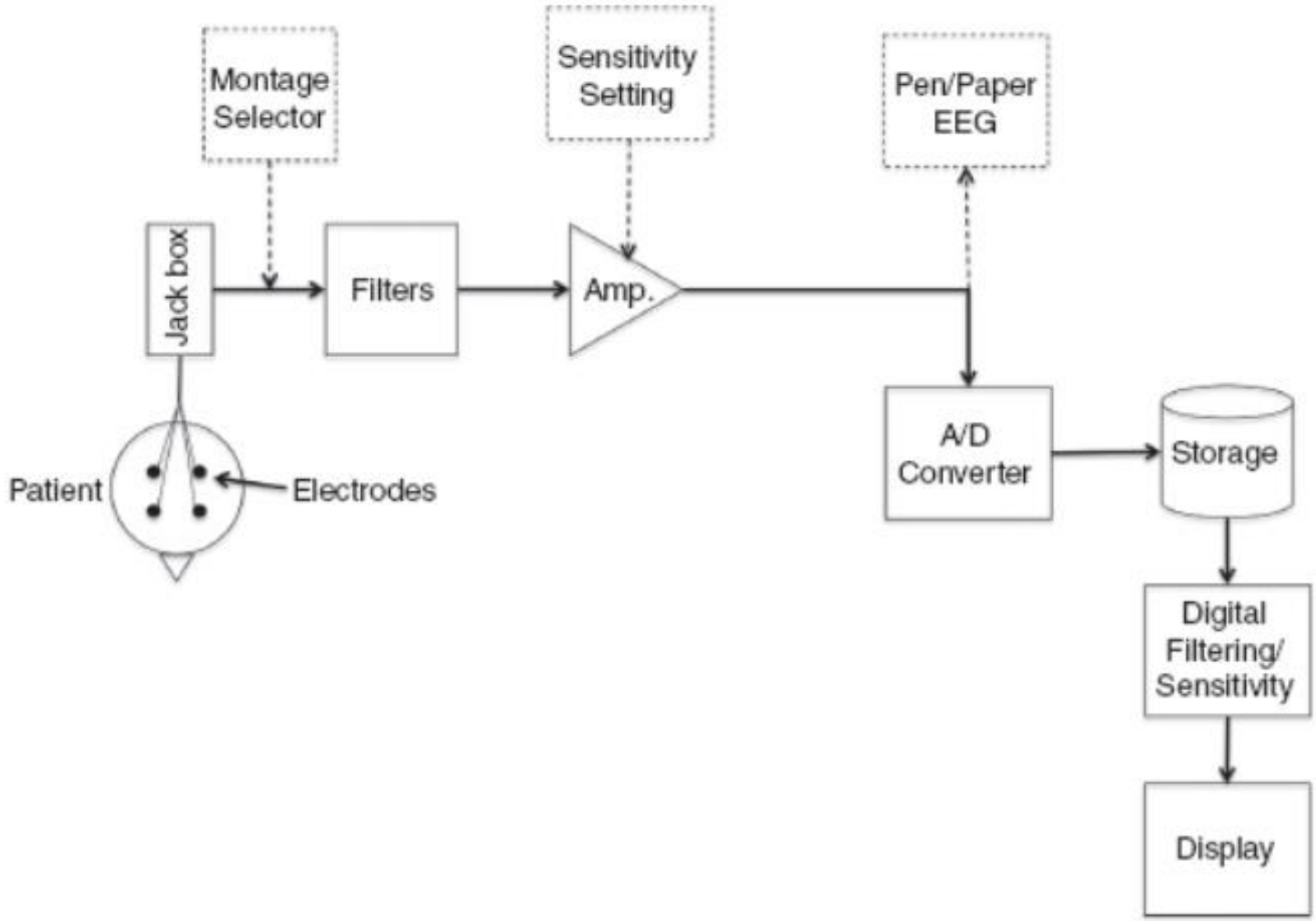
# 10/20 System of EEG Electrode Placement



# The 10/20 System




Montage Selector
Sensitivity Setting
Pen/Paper EEG
Jack box
Filters
Amp.
Patient
Electrodes
A/D Converter
Storage
Digital Filtering/ Sensitivity
Display

# Filters

- “an electronic device comprised of capacitors and resistors that discriminate against a particular frequency or band of frequencies”
- Act by:
  1. Attenuating input signals by decreasing the amplitude gradually
  2. Shifting input signal peak in time (phase shift)

  - Does NOT alter the frequency of input signals

Note: R’s impede all freqs equally, C’s have the filtering effect in that they impede slower freqs more than fast

# Filters in the Electroencephalogram

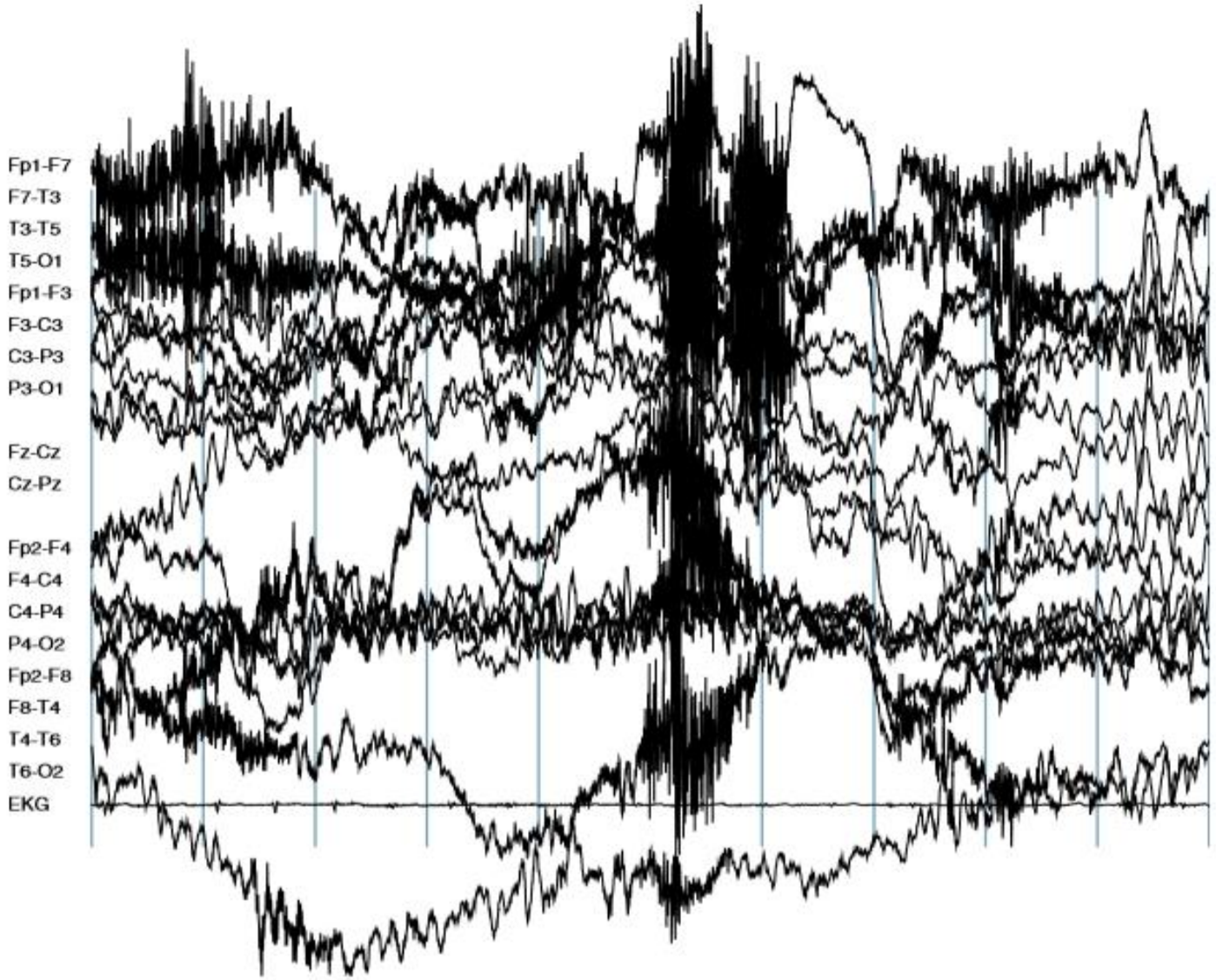



**Figure 7-1** This EEG page was obtained without the explicit use of filters. Muscle artifact obliterates much of the temporal chains (the top four and bottom four EEG channels). The baselines of certain channels fluctuate so widely that they often obliterate other channels. Note that the bottom two channels even dip below the electrocardiogram channel. Compare to Figure 7-2.

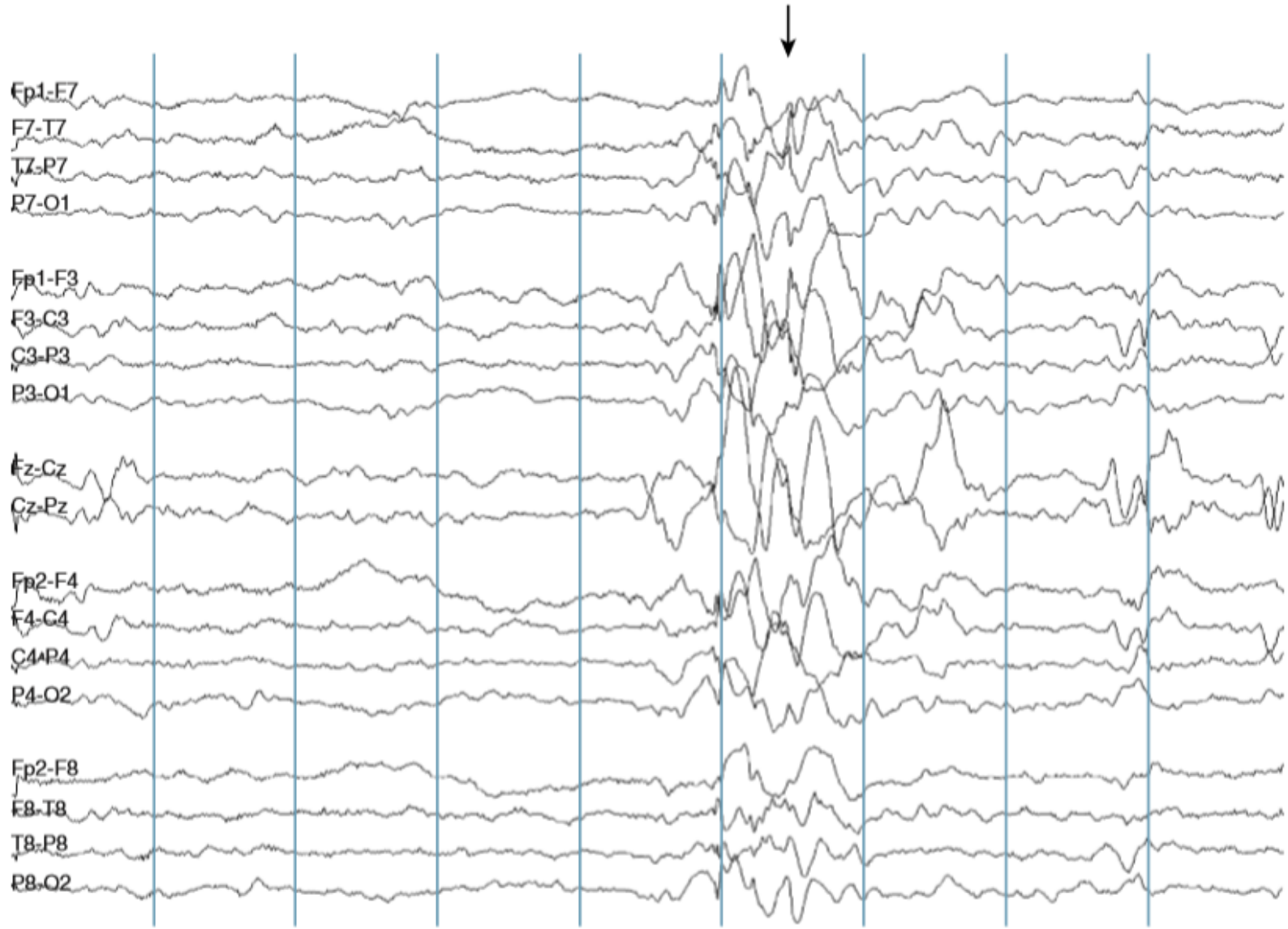
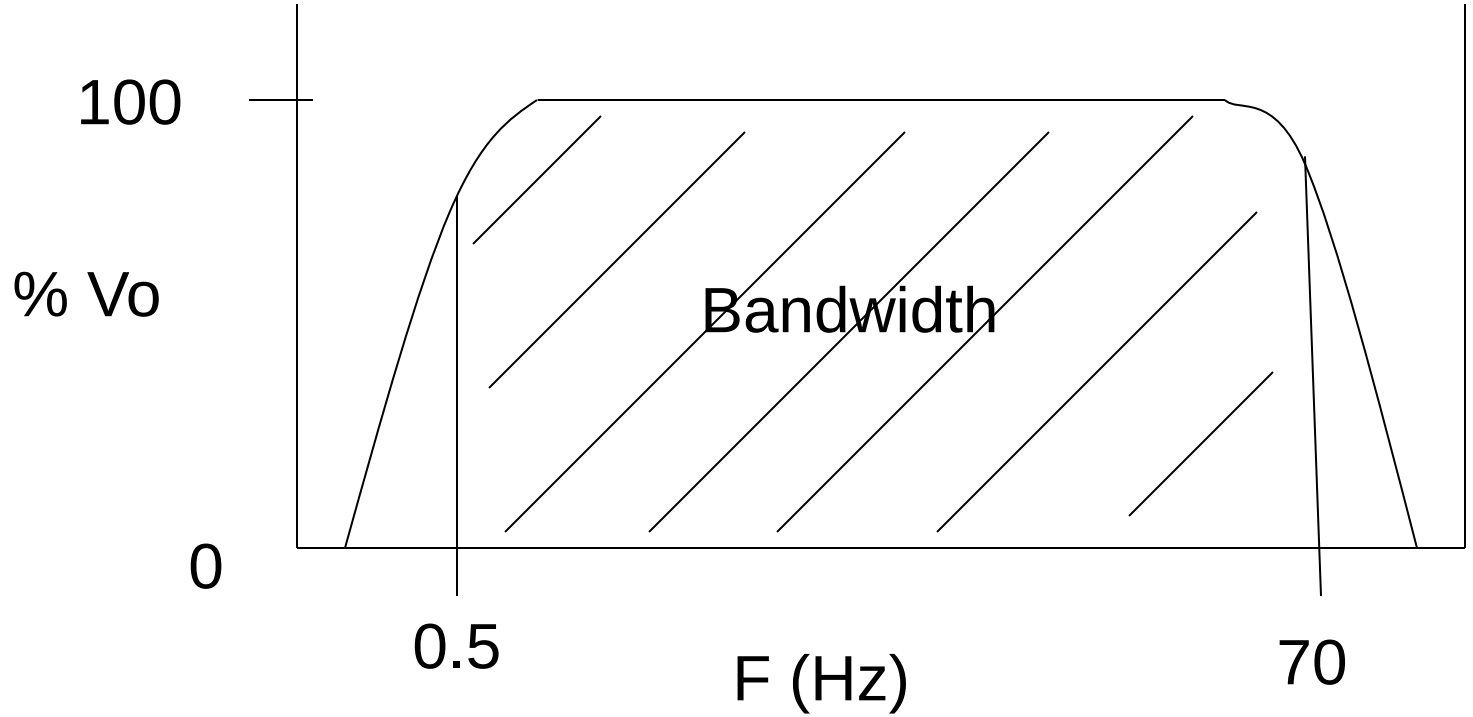



**Figure 7-3** This recording is made during a transition from Stage I to Stage II sleep using the standard low filter setting of 1 Hz. A burst of high-voltage slowing is seen during the sixth second (arrow). Inspection of the burst suggests the possibility that some spike activity may be intermixed, but a definite determination as to whether spike activity is truly present is difficult. Compare to same EEG signals displayed with different filter settings in Figure 7-4.

# Frequency Response Curve

- “graphical representation of the % amplitude output of a band of frequencies based on a set of low and high frequency filter settings



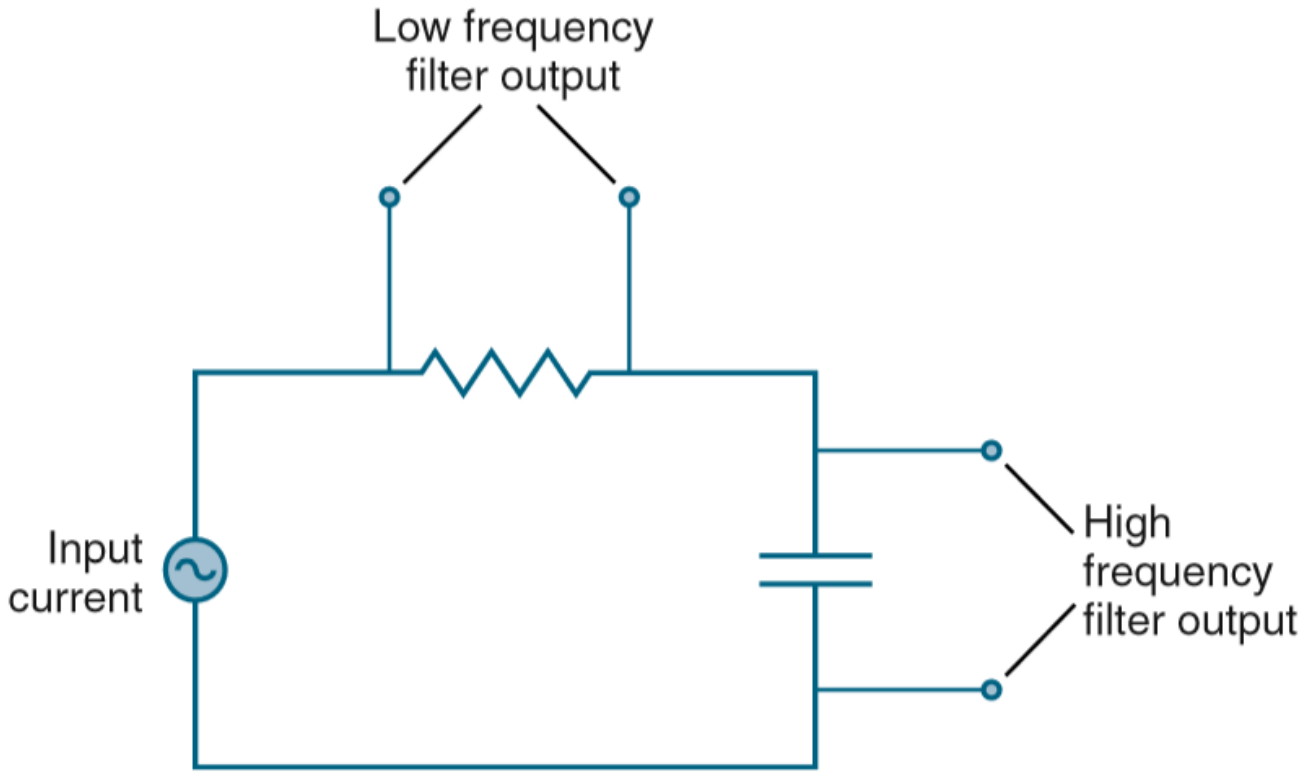



**Figure 7-27** The difference between HFF circuit design and LFF circuit design is that the filter output represents the voltage measured across the capacitor or the resistor, respectively. Circuit diagrams can show this either by exchanging the position of the resistor and the capacitor as in the previous figures or by changing the points of voltage measurement as in this figure.

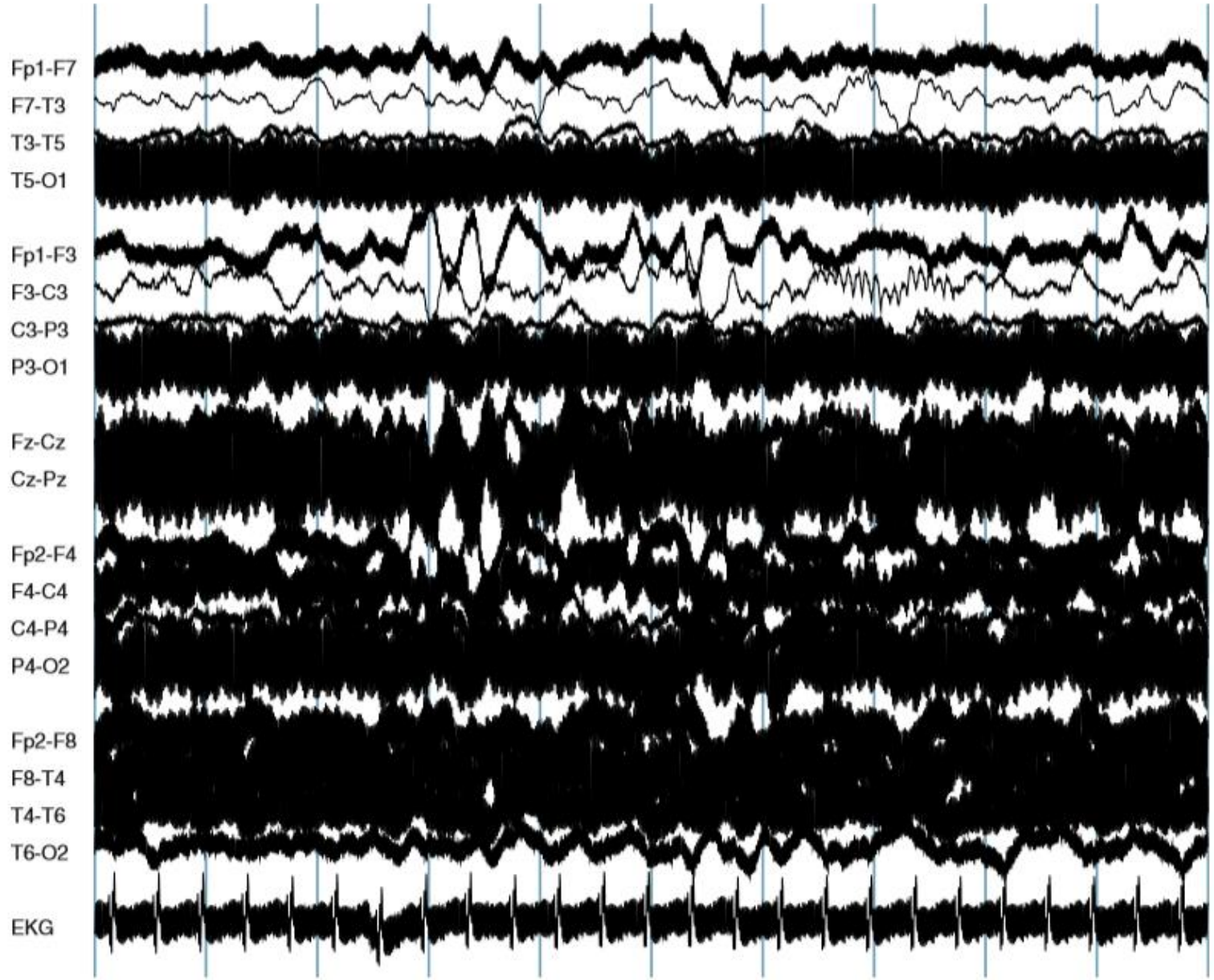
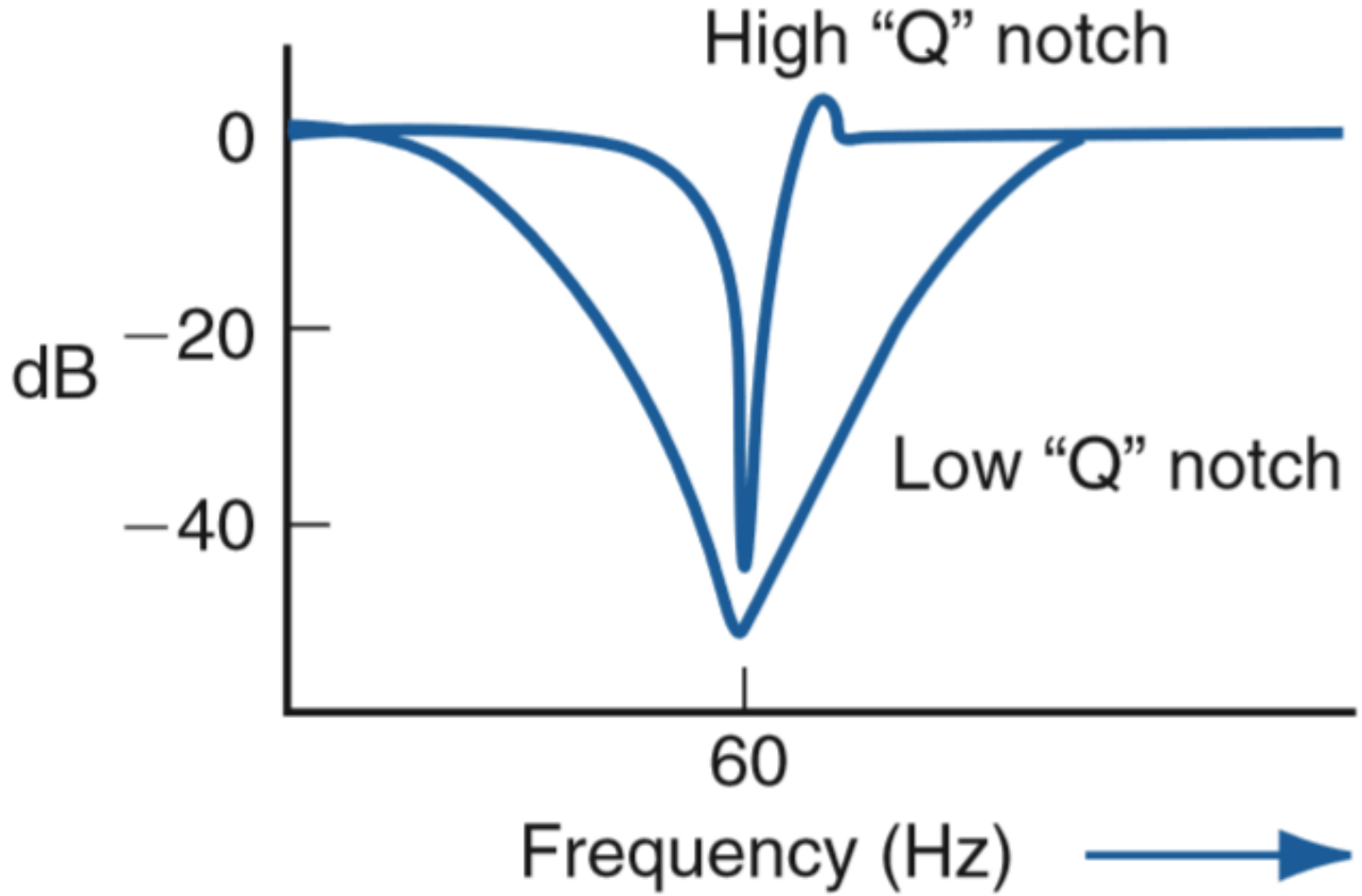



**Figure 7-19** Multiple channels in this tracing are obscured by 60-Hz artifact. In general, 60-Hz artifact can be distinguished from muscle artifact by its highly regular, sinusoidal appearance. Close examination of the waves sometimes allows a 60-Hz wave to be discerned, which in this example has the appearance of vertical ribbing. Also, notice that the amplitude of the artifact tends to stay steady in each channel. Compare to Figure 7-20.

# Notch Filter

Notch filters provide precise band-reject capability and are tuned for 50- or 60-Hz operation. The “Q” (quality) of a filter is a mathematical measure of its resonance. High-Q filters respond to a narrow but precise range of frequencies. They are used for 50- and 60-Hz notches because signals that are only a few Hertz above or below the notch frequency are passed transparently. Low-Q filters respond to a wide range of frequencies and are used for bandpass applications.


High “Q” notch
0
dB
−20
−40
Low “Q” notch
60
Frequency (Hz)

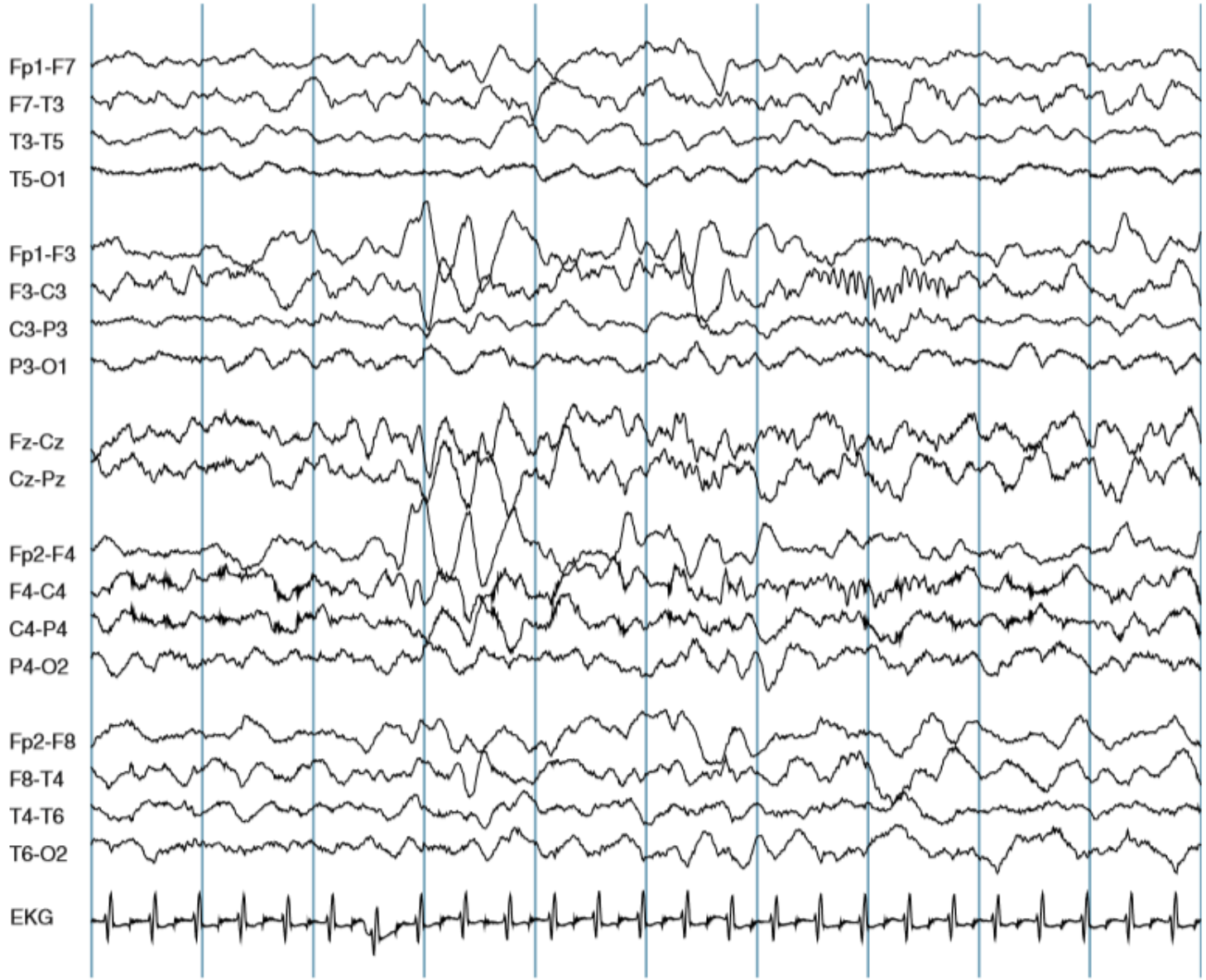



**Figure 7-21** The same page of EEG as was shown in Figure 7-18, this time displayed with the use of a 60-Hz notch filter. The notch filter has dramatically "cleaned up" the EEG tracing, and the page now looks fairly unremarkable. Now that the page has been filtered, there is little to suggest to the reader that several of the electrode contacts probably have impedance problems.

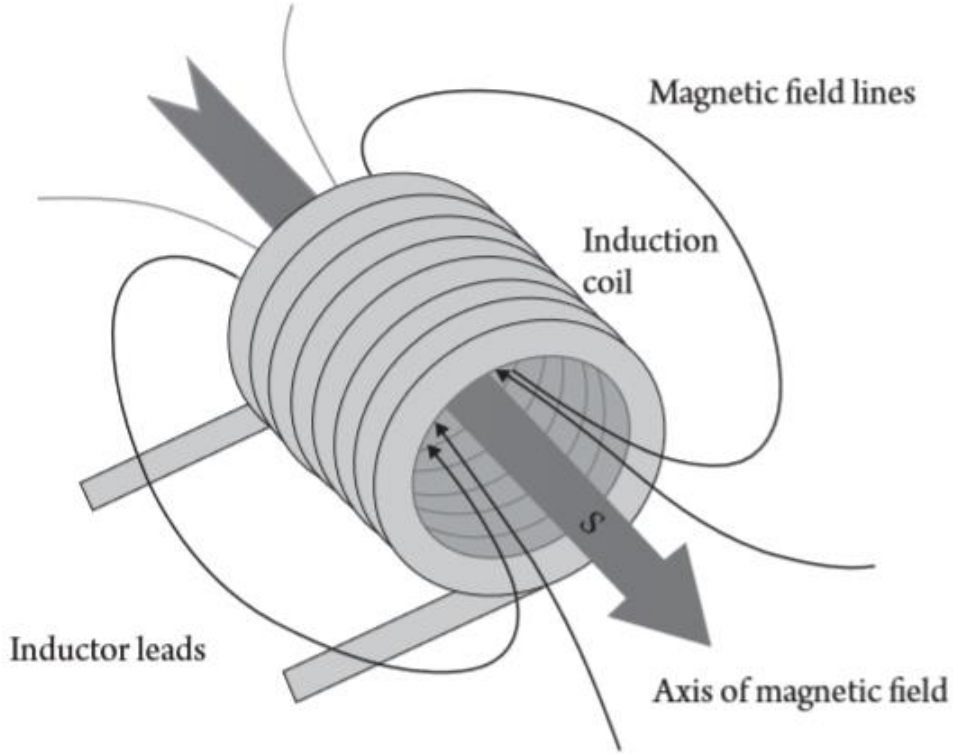



**Figure 2-8: Inductor.**
Diagram of an inductor coil. The coil of wire results in the magnetic fields being in effectively the same direction, producing summation of the fields. This makes for a powerful field that is dependent on the amount of current flowing through the coiled wire and the number of turns of the coil.

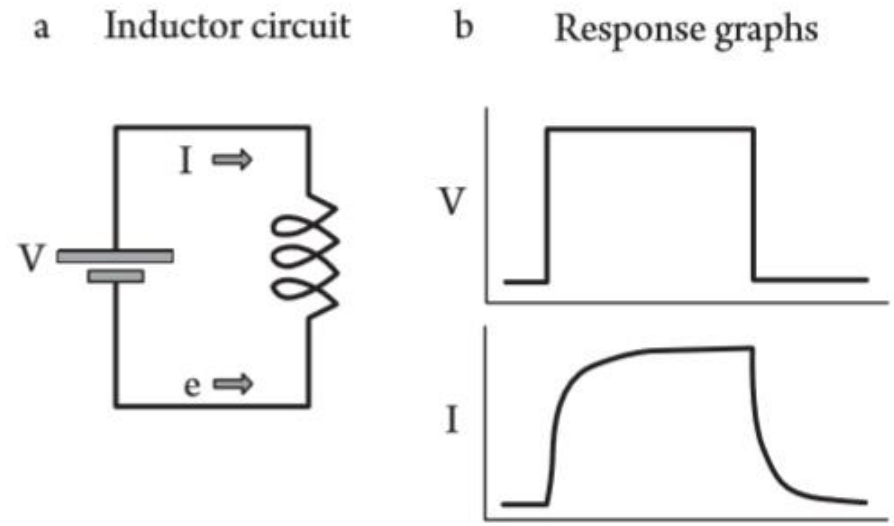



**Figure 2-9: Inductor Theory.**
a: Circuit diagram of a power supply (V), inductor, and current (I) flowing through the circuit. Electrons flowing through the inductor coil produce a magnetic field. b: Graph of the response to a step in voltage (V). The current builds up but more slowly than expected because some of the energy of the current flow is used to generate the magnetic field.

---

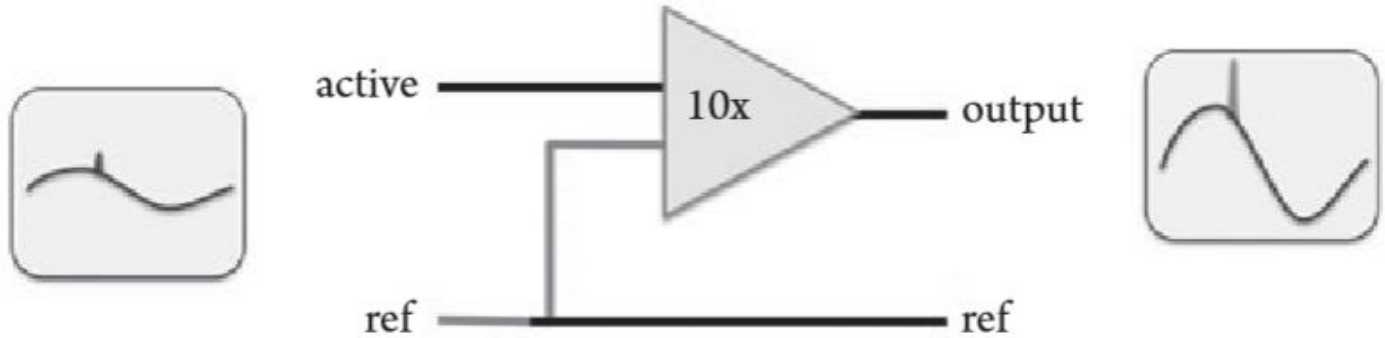
Inductors are especially important for radios and a

# 2. Differential Amplifier

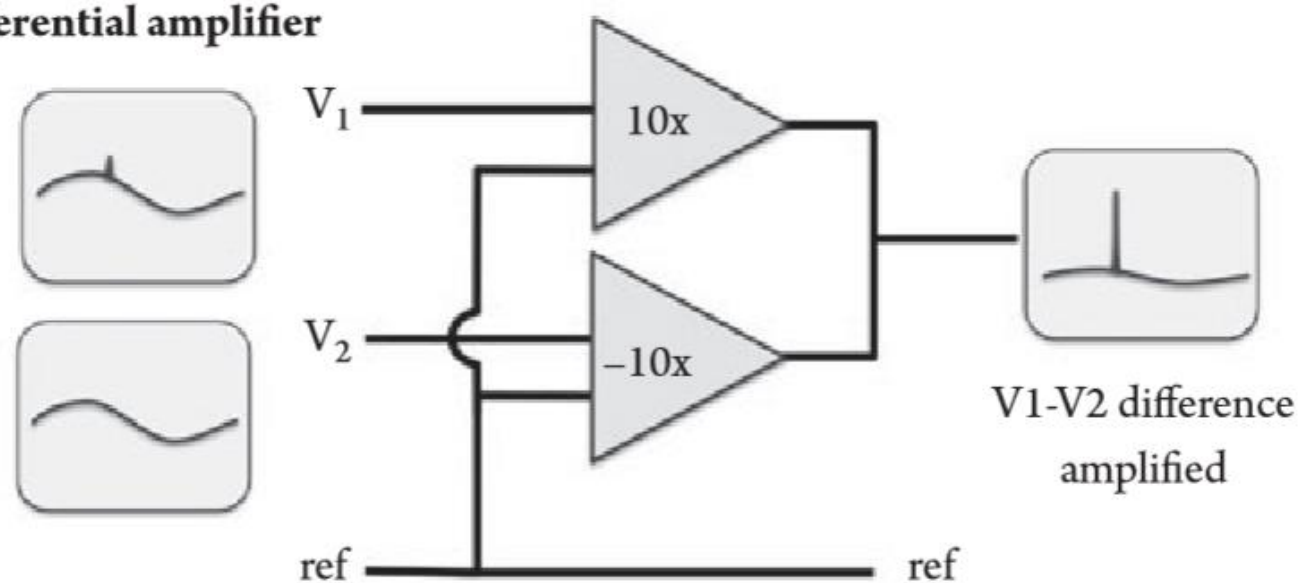
- Electronic device that discriminates against in-phase/common signals and amplifies out-of-phase/different signals
- Vo = the potential difference of two inputs

- CMRR (common mode rejection ratio): how well differential amplifiers can cancel common signals
  - Out-of-phase:In-phase
  - Can optimize CMRR by having low equal electrode impedances and a high amplifier impedance
  - EEG machines must have a MINIMUM CMRR ratio of 10000:1

**a Single-ended amplifier**




**b Differential amplifier**



# Analog to Digital Conversion

# Sampling

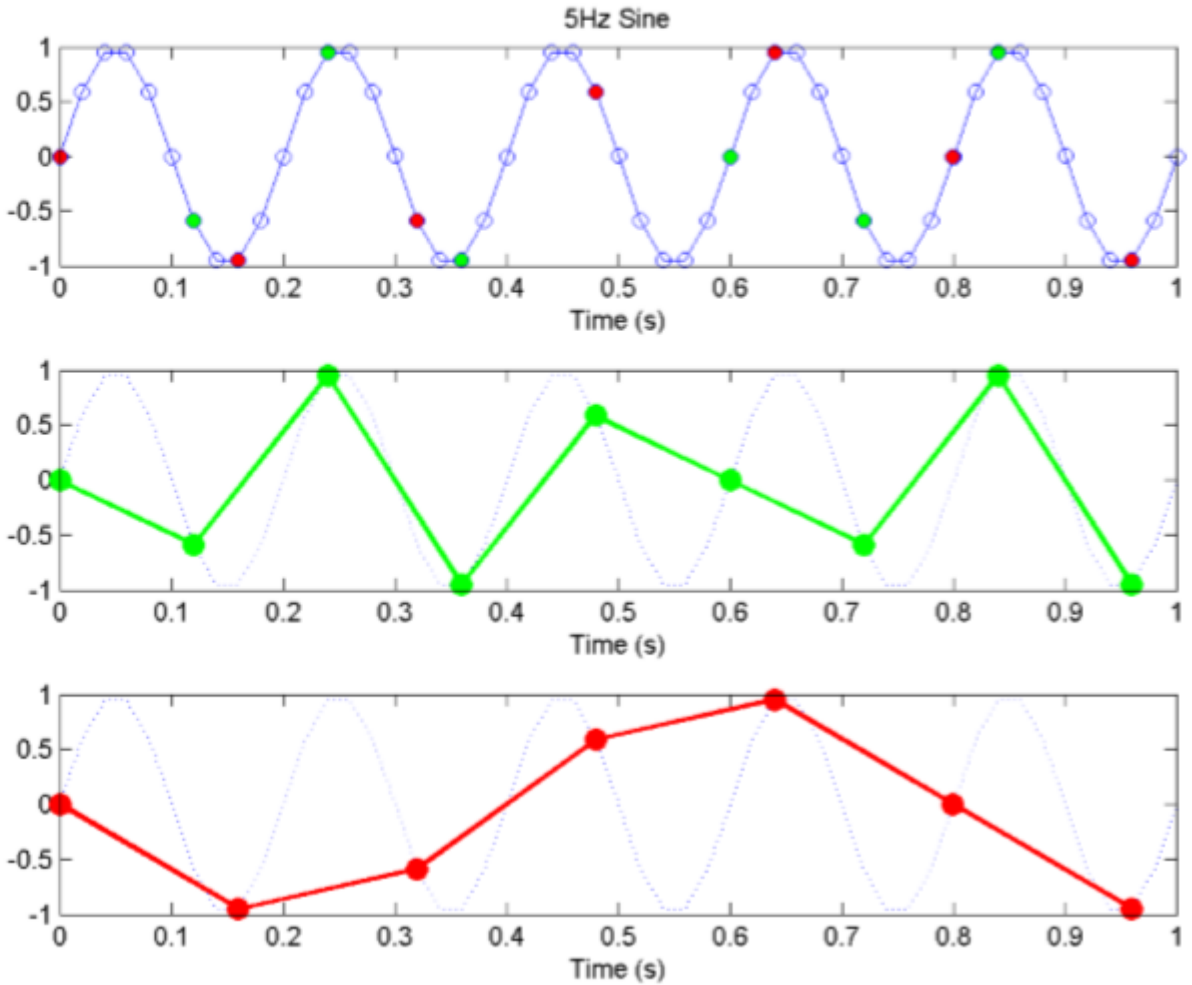
- Sampling interval determines temporal resolution
  - 0.01ms for BAEP
  - >=5msec for EEG
- Sampling frequency= reciprocal of sampling interval (Hz)
  - Determines temporal resolution
  - Determines maximum frequency that can be represented
    - Nyquist theorem= sampling theorem. If signal has 0-$f_N$ frequencies, the minimum sampling frequency for digital signal to represent the original signal freq content is $2f_N$
    - $f_N$ is Nyquist frequency= 1/ (2 x sampling interval) so for $f_{N=}$ 50Hz would sample at least at 100Hz and sampling interval is 0.01 sec or less
- Nyquist frequency = what need to avoid distortion. Need sampling frequency 3-5 x $f_N$ to give adequate resolution of details in digitized signal

# Aliasing

5 Hz wave

9 Hz sampling

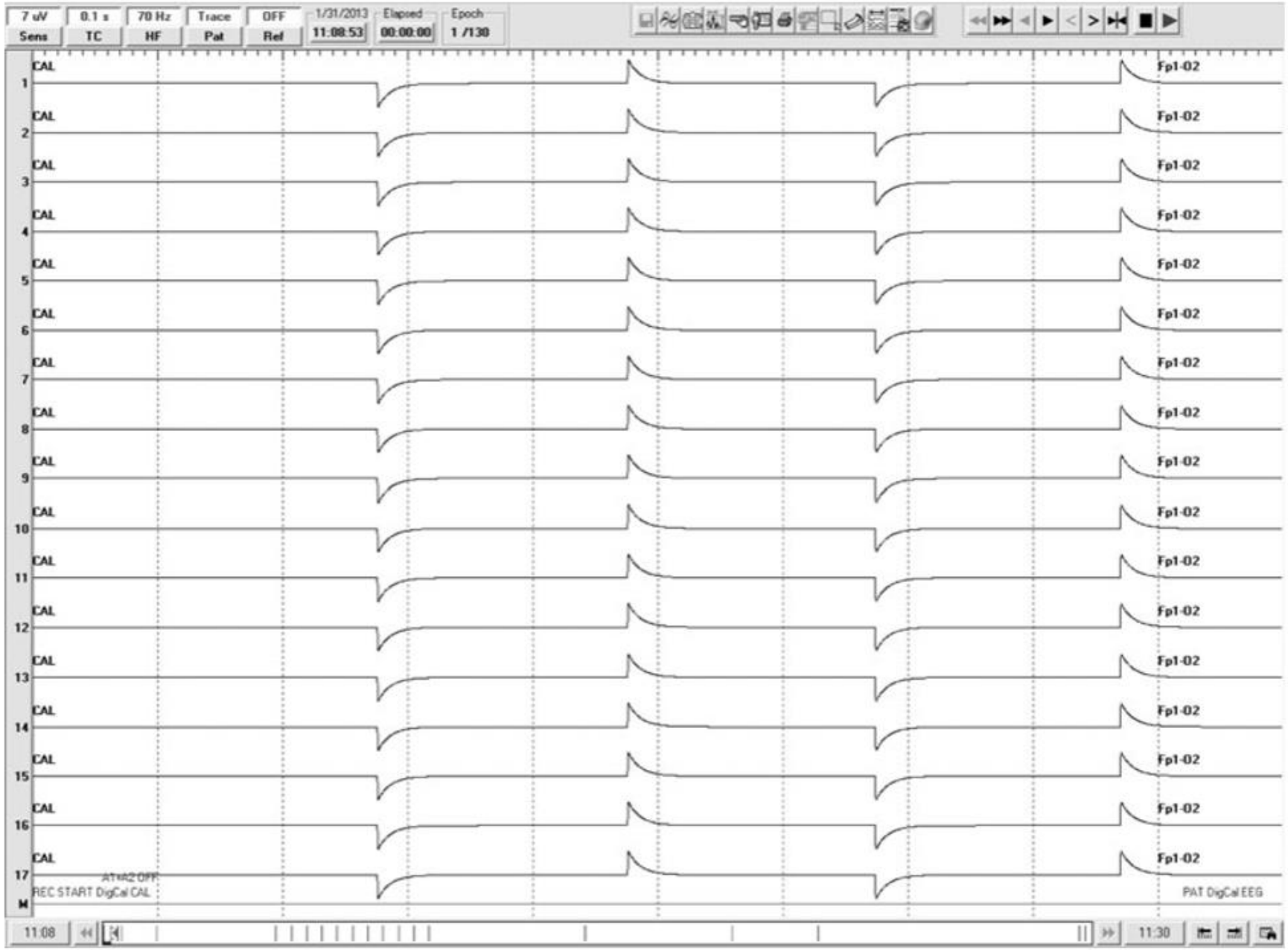
7 Hz sampling



# TC

TC gives the number of seconds it takes for a square wave to fall by 63% of its original value.

The amount of time it takes for the upswing of the square wave signal to rise to 63% of its final value in the case of high filters or the amount of time it takes for the square wave signal to decay by 63% of its initial value in the case of low filters is measured.


7 uV
Sens
0.1 s
TC
70 Hz
HF
Trace
Pat
OFF
Ref
1/31/2013
11:08:53
Elapsed
00:00:00
Epoch
1 /130
CAL
Fp1-O2
A1+A2 OFF
REC START DigCal CAL
PAT DigCal EEG
11:08
11:30