



# Bioelectric Signals of Interest in Sleep Medicine

Robertson Chapter 5



# Parameters Typically Evaluated by PSG

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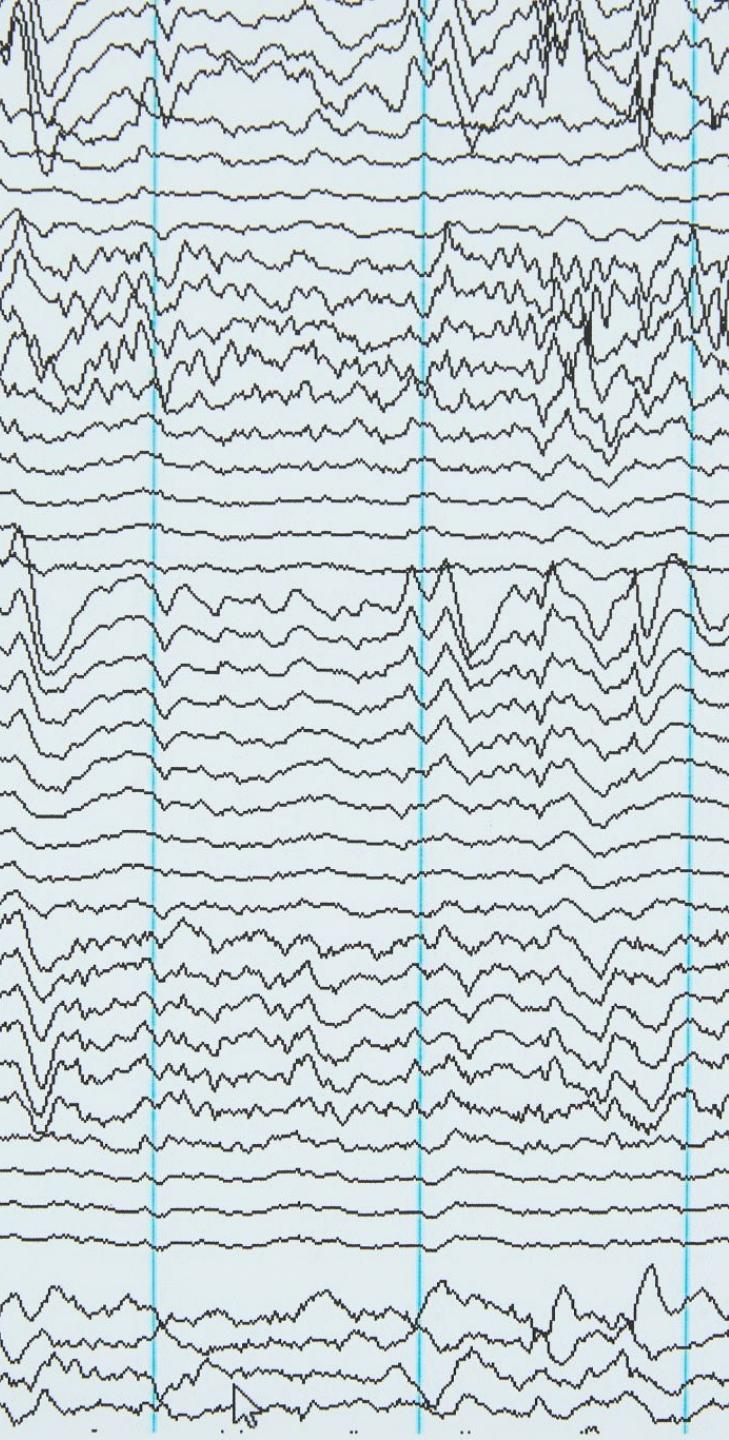
- 3 basic signal types:
  - Bioelectric
    - Rising and falling of electrical potentials at surface of body
      - Include EEG, EMG, EOG, and ECG
    - Transduced
    - Ancillary equipment
  - EEG, EMG, EOG, and ECG recorded using small cup electrodes



# Parameters Typically Evaluated by PSG

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- Transducer converts one form of energy into another form of energy
- Ancillary equipment is interfaced with the data acquisition system
  - Can be stand alone monitors or connected to PSG
  - Includes pulse oximeter, capnograph
    - Can be seen as numerical value, tracing on graph, or both

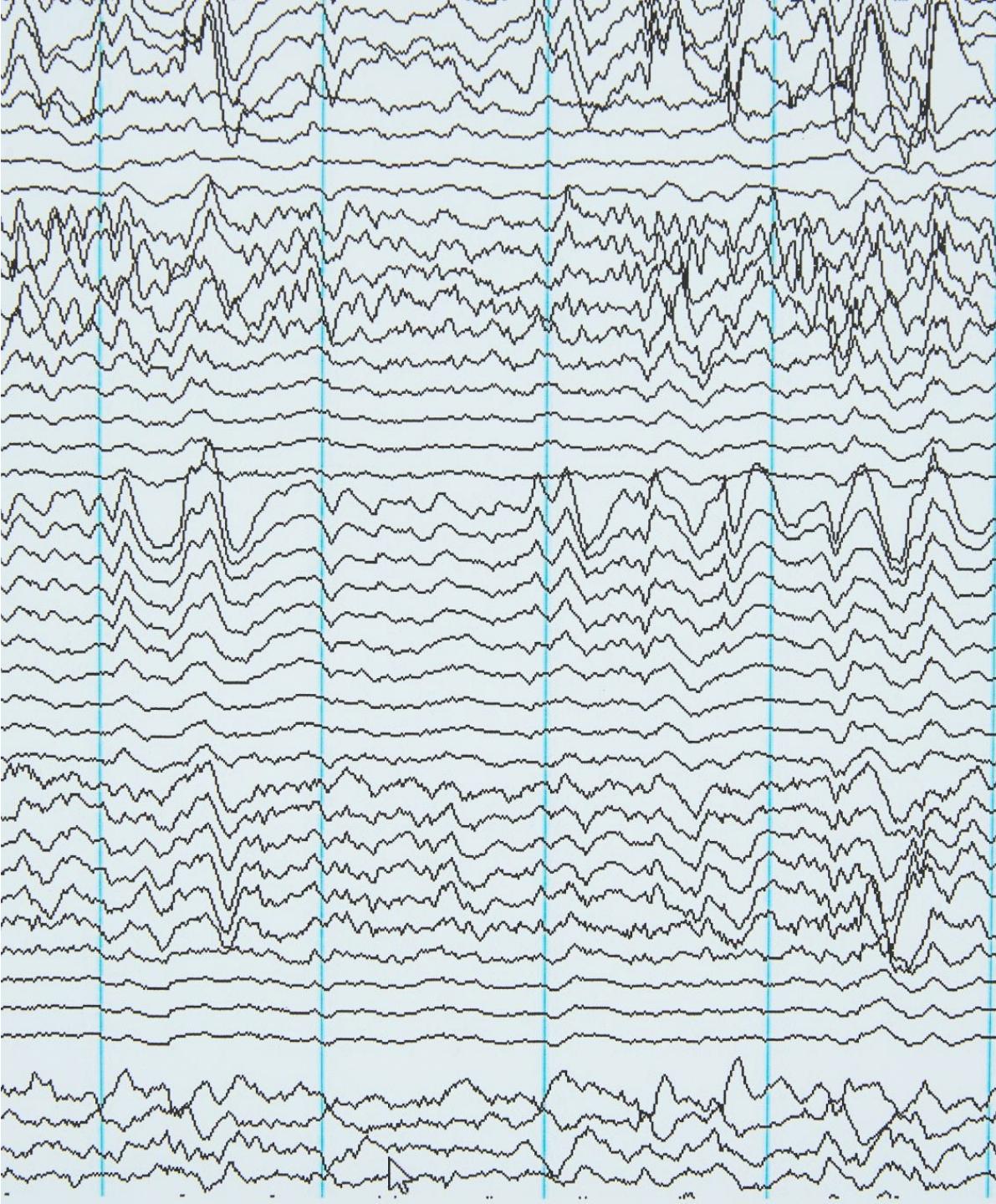


# EEG

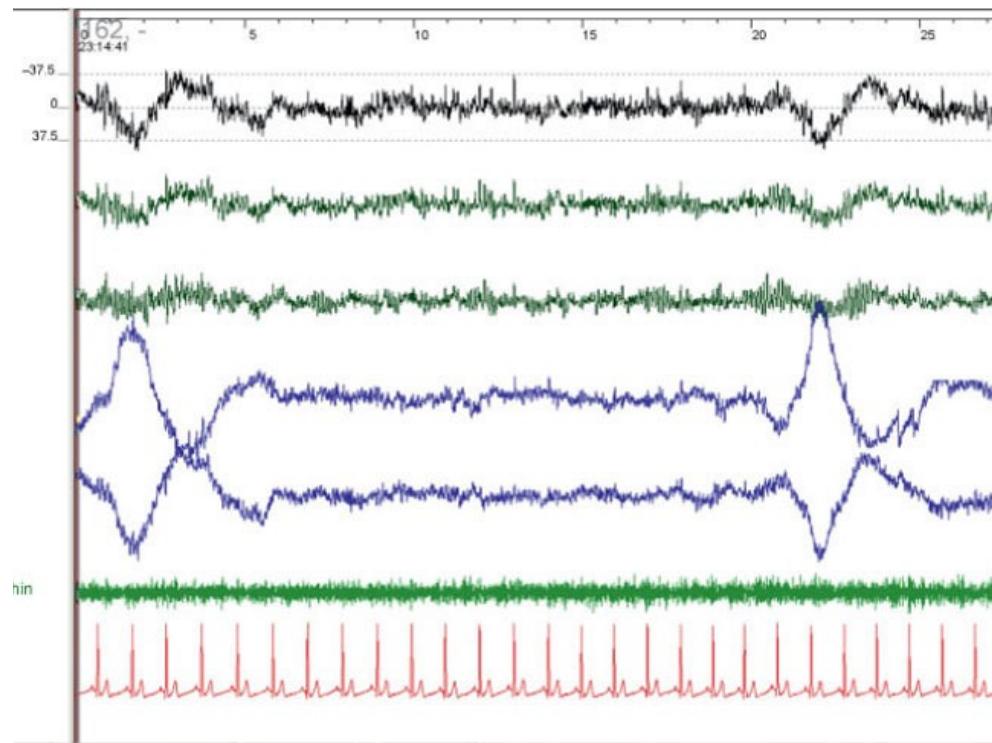
- Records amplitude, morphology, and frequency of encephalographic bioelectric signals for visual display
- Eye movements and muscle activity help to differentiate between sleep and wake and decipher NREM from REM sleep
- Heart activity and breathing provide additional info on sleep

# EEG

- Types of wave activity:
  - Alpha
  - Beta
  - Delta
  - Theta

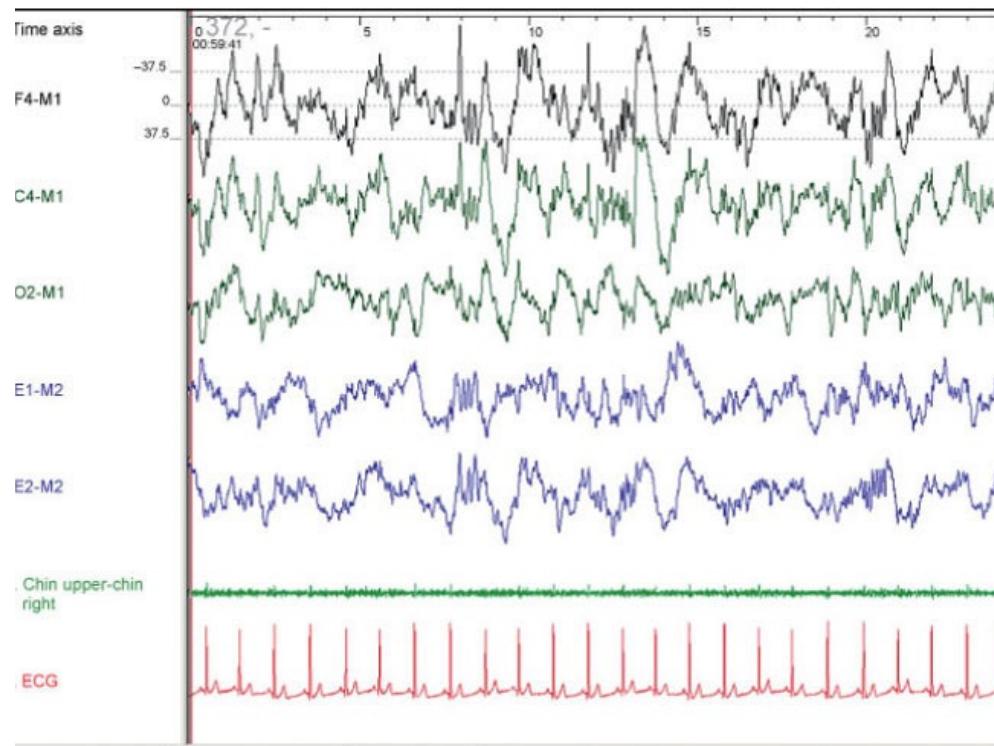


# Low-Amplitude, Mixed-Frequency (LAMF) Waves



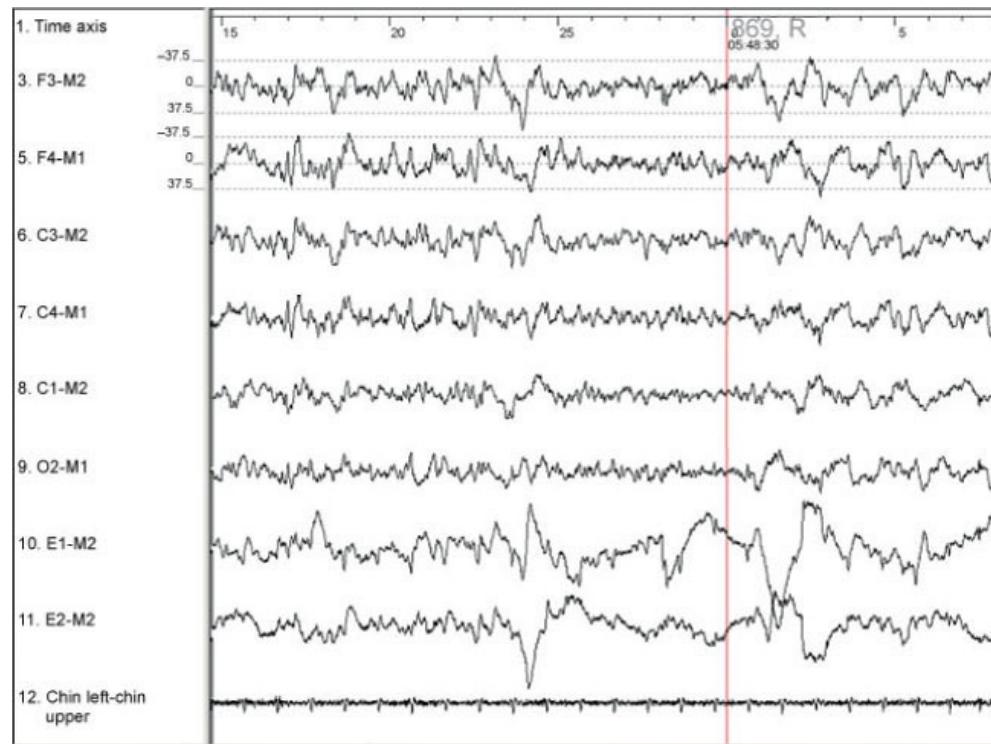
- Alpha waves
  - Frequency: 8-13 Hz
  - Prominent in occipital region
  - Amplitude: 10-150 uV
  - Seen with eyes closed but patient awake

# Low-Amplitude, Mixed-Frequency (LAMF) Waves



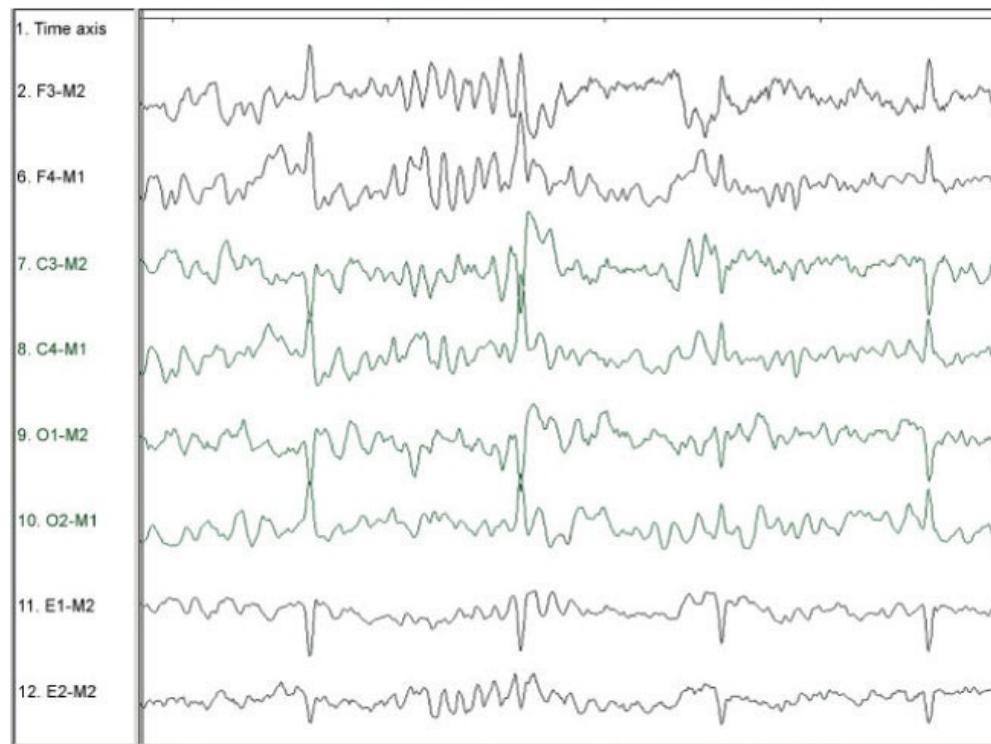
- Delta Waves
  - Frequency: 0.5-2 Hz
  - Prominent in frontal region
  - Scored as N3 sleep when 20% of epoch contains delta

# Low-Amplitude, Mixed-Frequency (LAMF) Waves



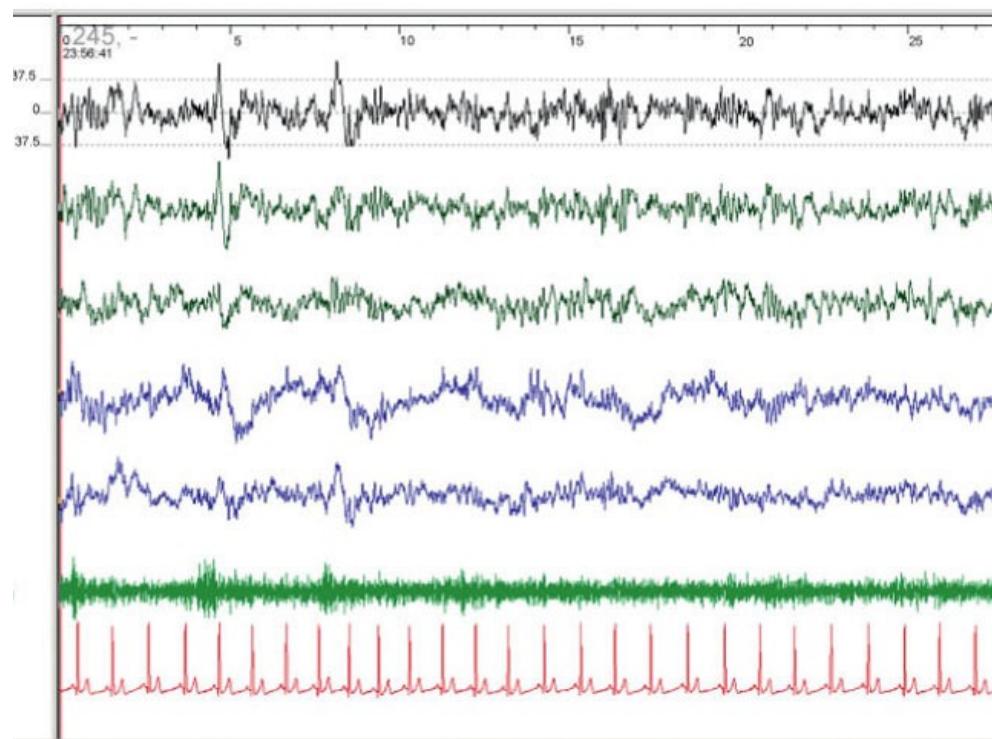
- Sawtooth Waves
  - Frequency: 2-6 Hz
  - Central region
  - Seen in REM

# Low-Amplitude, Mixed-Frequency (LAMF) Waves



- Sleep spindles
  - Frequency: 11-16 Hz
  - Central region
  - Last  $\geq 0.5$  second
  - Seen in N2 sleep

# Low-Amplitude, Mixed-Frequency (LAMF) Waves



- K complex
  - $\geq 0.5$  second in duration
  - Frontal region
  - Seen in N2



## Low-Amplitude, Mixed-Frequency (LAMF) Waves

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- Theta Waves
  - Frequency: 4-7 Hz
  - Temporal or Central regions
  - Seen in N1 and REM
- Vertex Sharp Waves
  - <0.5 second duration
  - Central region
  - Sharply contoured negative wave
  - Seen in latter part of N1 right before patient enters N2



# EOG

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- Records eye movement
- Slow eye movements (SEMs) often symbolize drowsiness and transitioning to sleep
  - Defined as conjugate, reasonably regular sinusoidal eye movements with initial deflection lasting more than 500 microseconds
  - Signify N1 sleep in non-alpha producing patients

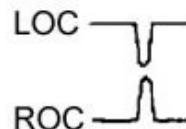
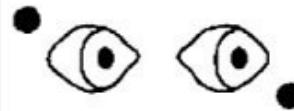
# EOG

- REM = Conjugate, irregular, sharply peaked eye movements with initial deflection lasting less than 500 microseconds
  - Seen in awake individuals and those in REM sleep
- Electrodes placed 1 cm below the LOC and 1 cm above the ROC

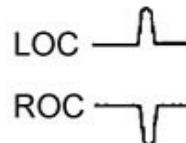
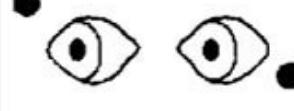
# EOG

Since the cornea (front of the eye) is relatively positive to the retina (back of the eye) there is an electrical potential difference when the cornea and retina move away from or toward the exploring electrode. When the cornea is closest to the electrode, a positive (downward) deflection is recorded, whereas when the retina is closest to the electrode a negative deflection results. This is illustrated on the attached graphic when the recommended EOG electrode placement of left inferior and right superior occulogram are utilized. In many sleep-testing facilities, both an inferior and superior electrode is placed for each eye to provide a back-up option for the EOG.

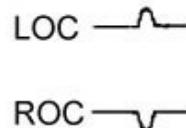
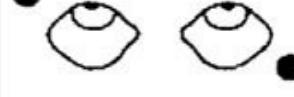
Looking left



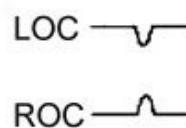
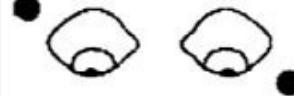
Looking right



Looking up



Looking down

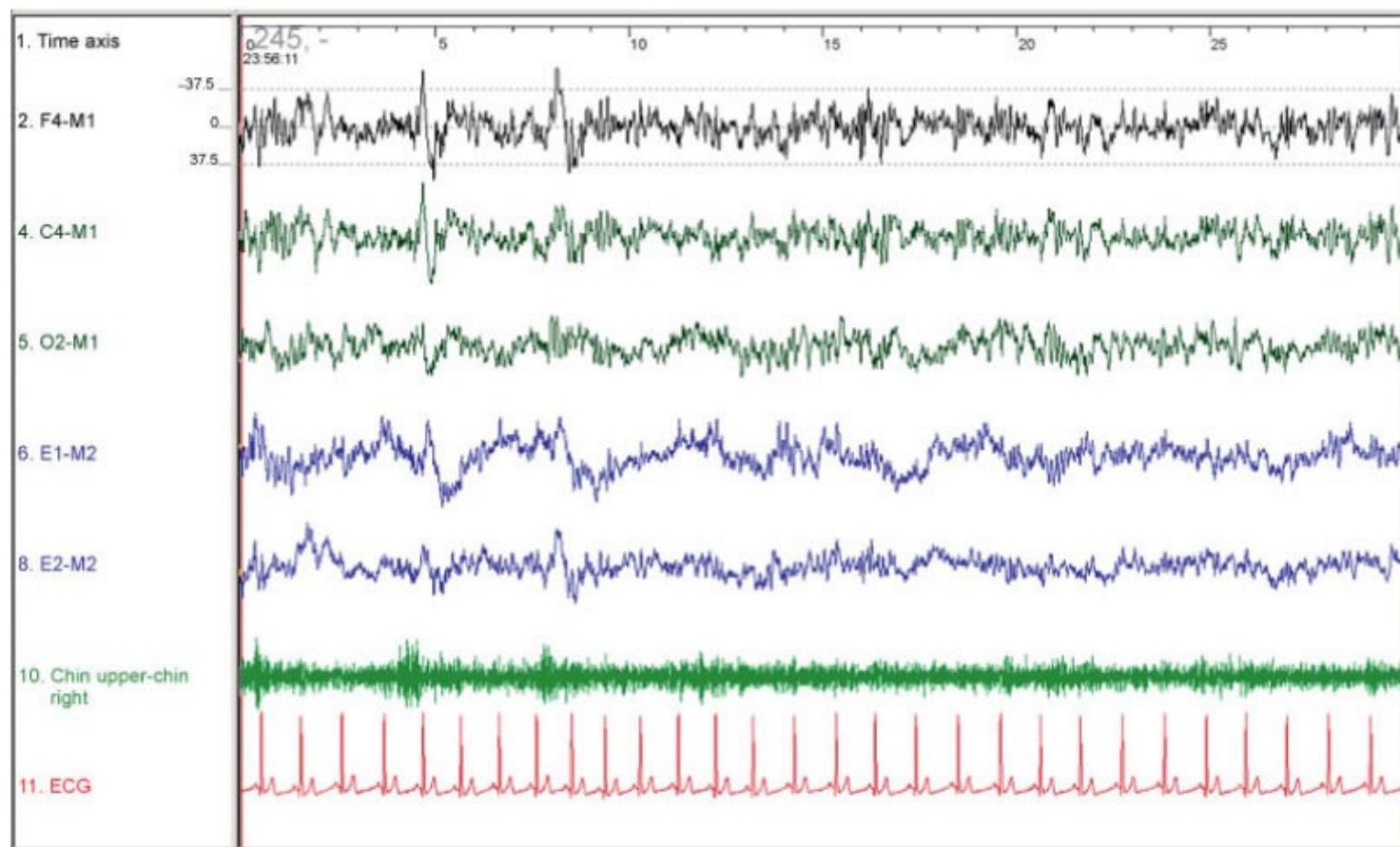




# EMG

- Measure of electrical potential difference generated by groups of skeletal muscle cells at rest and during activation
- Chin EMG
  - Chin tone disappears (atonia) during REM
  - Should have 3 electrodes
    - 2 to record, 1 as backup
    - One placed 2 cm above inferior edge of mandible on middle of chin, other 2 placed 2 cm below the inferior edge of mandible (one 2 cm to the left and other 2 cm to the right)

# Chin EMG

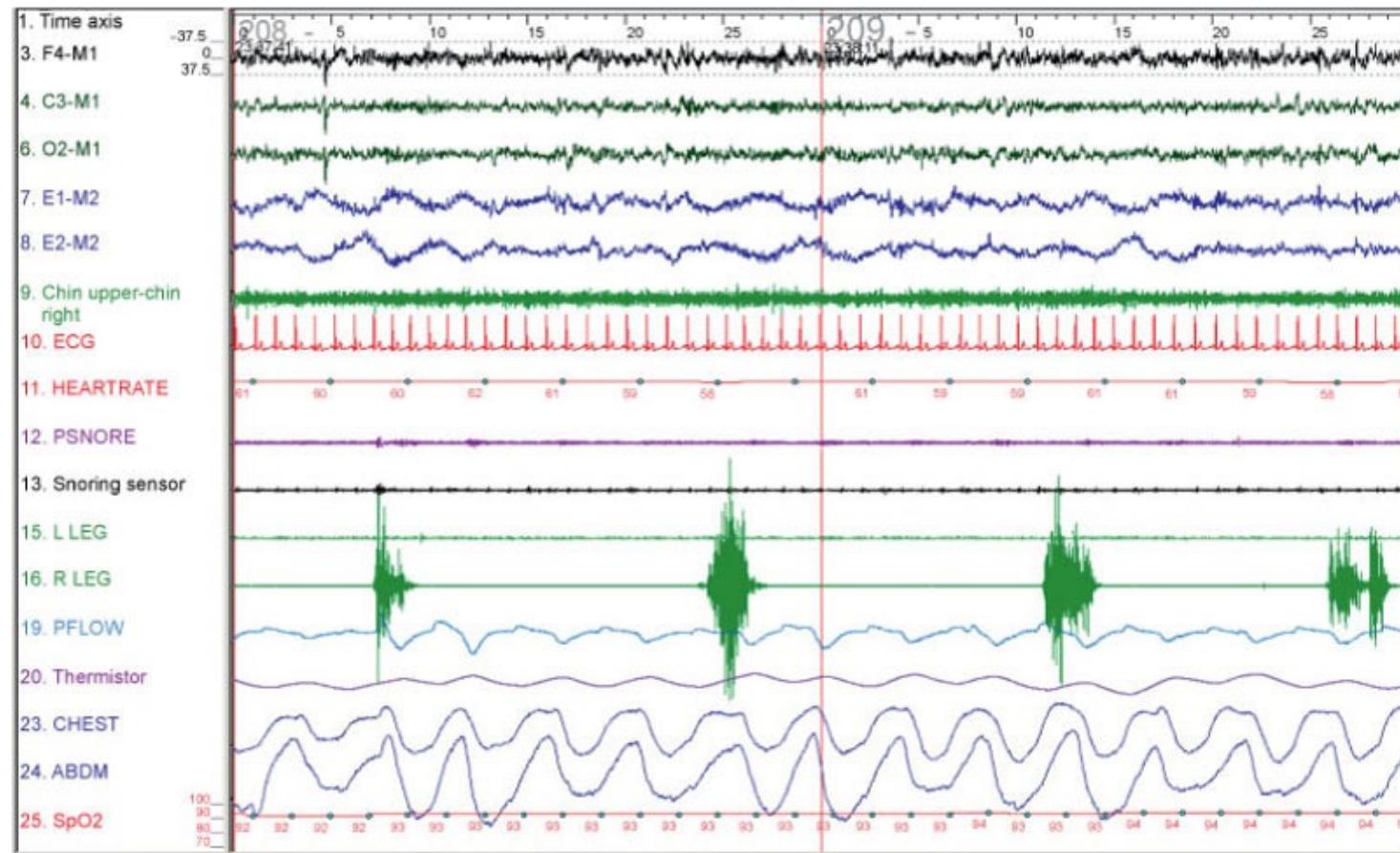


# EMG

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- Leg EMG
  - Gives info about leg movements and whether those movements impact sleep
  - Placed on anterior tibialis muscle 2-3 cm apart
    - Sometimes only use 1 electrode per leg rather than 2 electrodes
  - Impedance should be < 10,000 Ohms
  - Filters should be set to 10-100 Hz with sampling rate of 200-500 Hz

# Leg EMG





# Modified Lead II ECG

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- Documents changes in HR and ECG signal morphology related to sleep state, abnormal events, and/or underlying pathologic conditions
- P wave = Atrial depolarization and contraction
- QRS complex = Ventricular depolarization and contraction
- T wave = Ventricular repolarization or relaxation

# Modified Lead II ECG

- Lead placement
  - AASM recommends modified lead II
  - 1 lead below right clavicle, aligned with nipple
    - Plugged into the negative input on head box
  - 1 lead on lower left ribs, aligned with hip and arm pit
    - Plugged into positive input on head box

# Sleep/Wake States

- Sleep stages are scored in 30 second epochs
- Sleep stages:
  - Wake
  - N1
  - N2
  - N3
  - REM
- Epoch scored as the sleep stage that occupies over 50% of the epoch



# Overview of Sleep Stages

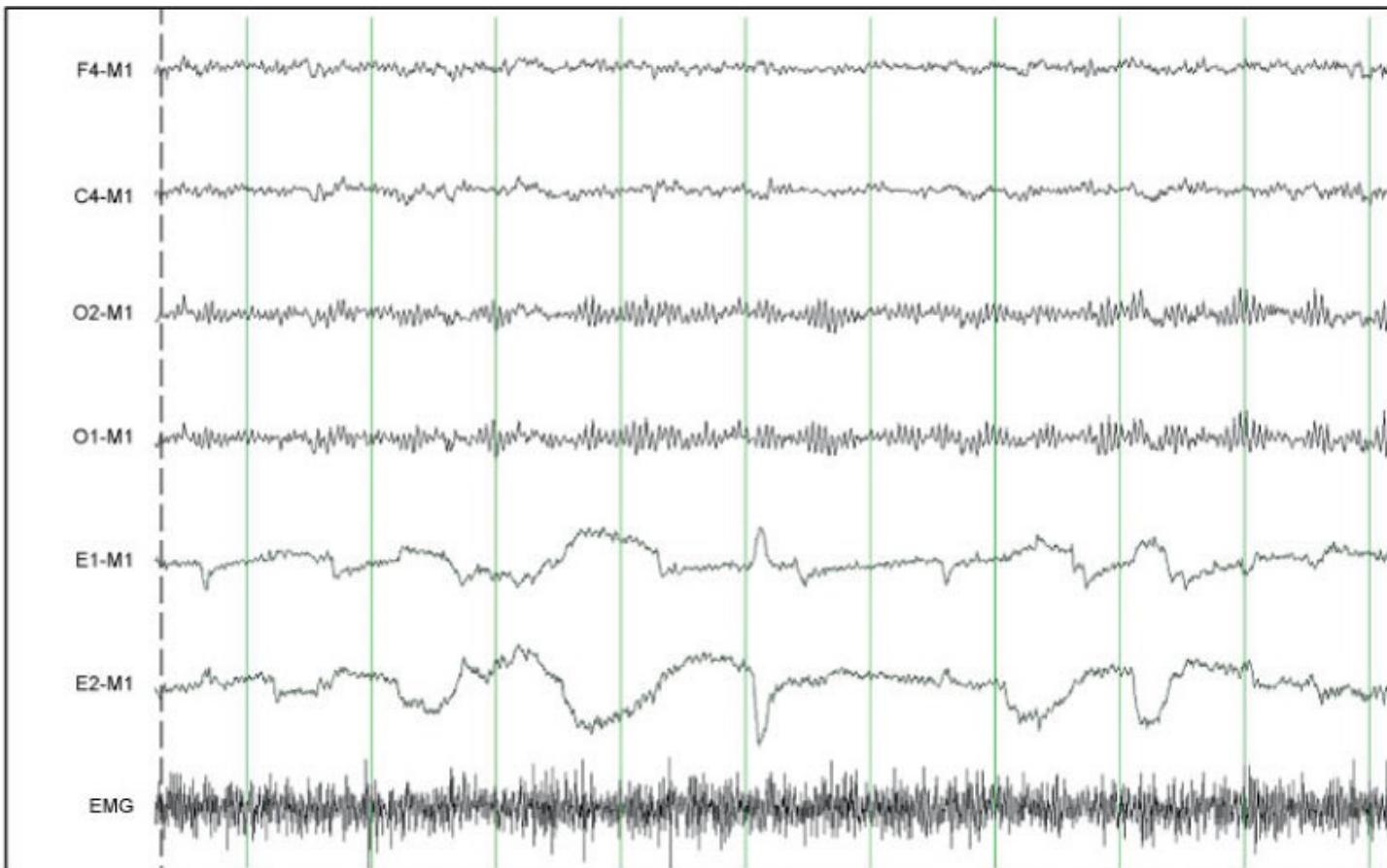
Properties	Stage W	Stage N1	Stage N2	Stage N3	Stage R
EEG	Eyes open: LAMF, little alpha; Eyes closed: LAMF with alpha	LAMF, theta, vertex sharp waves	LAMF, K complexes and sleep spindles	> 20% delta waves	LAMF, sawtooth waves
EOG	Eye blinks, under voluntary control, can see SEMs when drowsy	SEM	Occasional SEM	Usually no eye movements	REM—usually phasic
Chin EMG	Highest, and under voluntary control	High	Lower than N1	Lower than N2	Lowest, with periods of twitching

# Wake

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- EEG
  - > 14 Hz beta activity
    - Most prominent in frontal and central regions
  - 8-13 Hz alpha activity seen primarily in occipital region
    - Alpha amplitude higher when eyes are closed
- EOG
  - Conjugate eye movements consisting of slow phase followed by fast phase in opposite direction
  - Reading eyes, REM, and eye blinks with frequency of 0.5-2 Hz
  - SEMs during relaxed wakefulness

# Wake

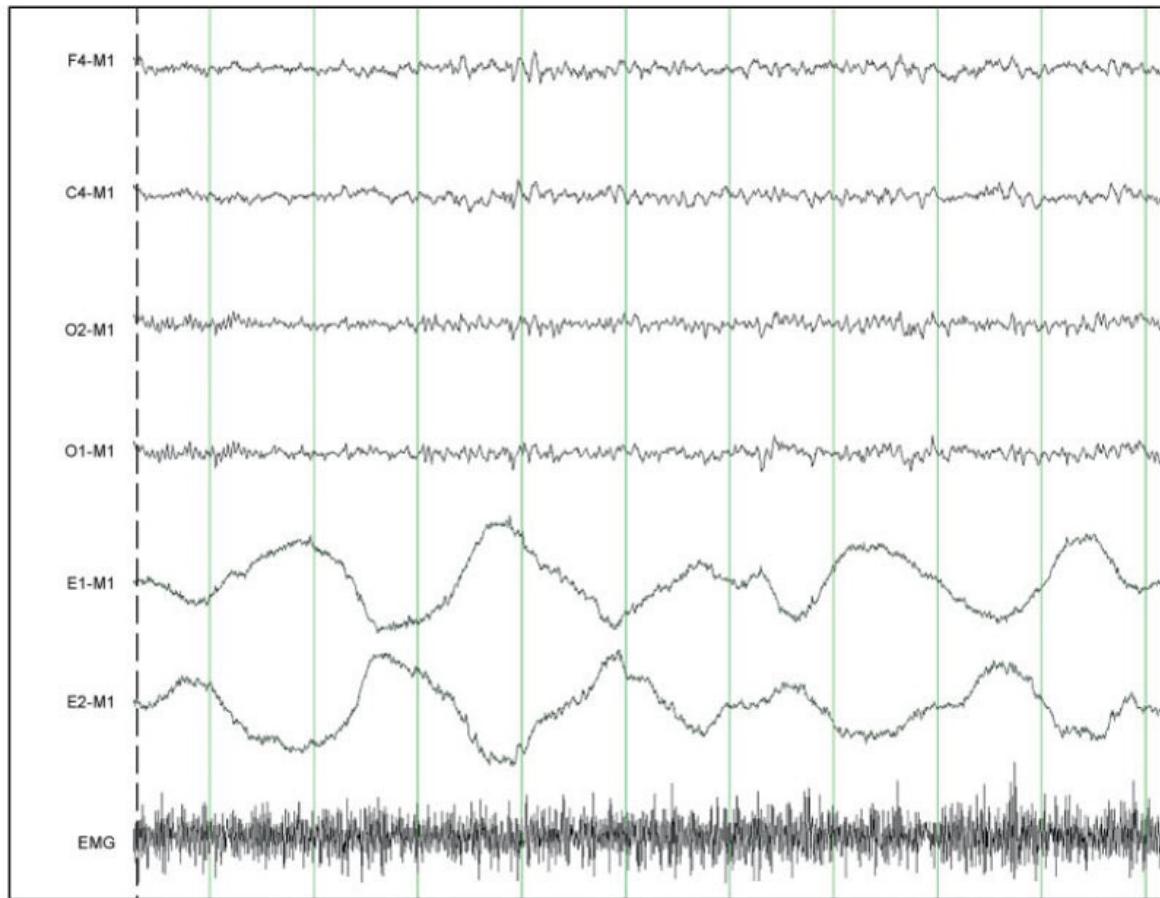


# Stage N1



- EEG
  - LAMF activity in the 4-7 Hz range
  - Vertical sharp waves
    - Usually in the latter portion of N1
- EOG
  - Slow eye movements

# Stage N1



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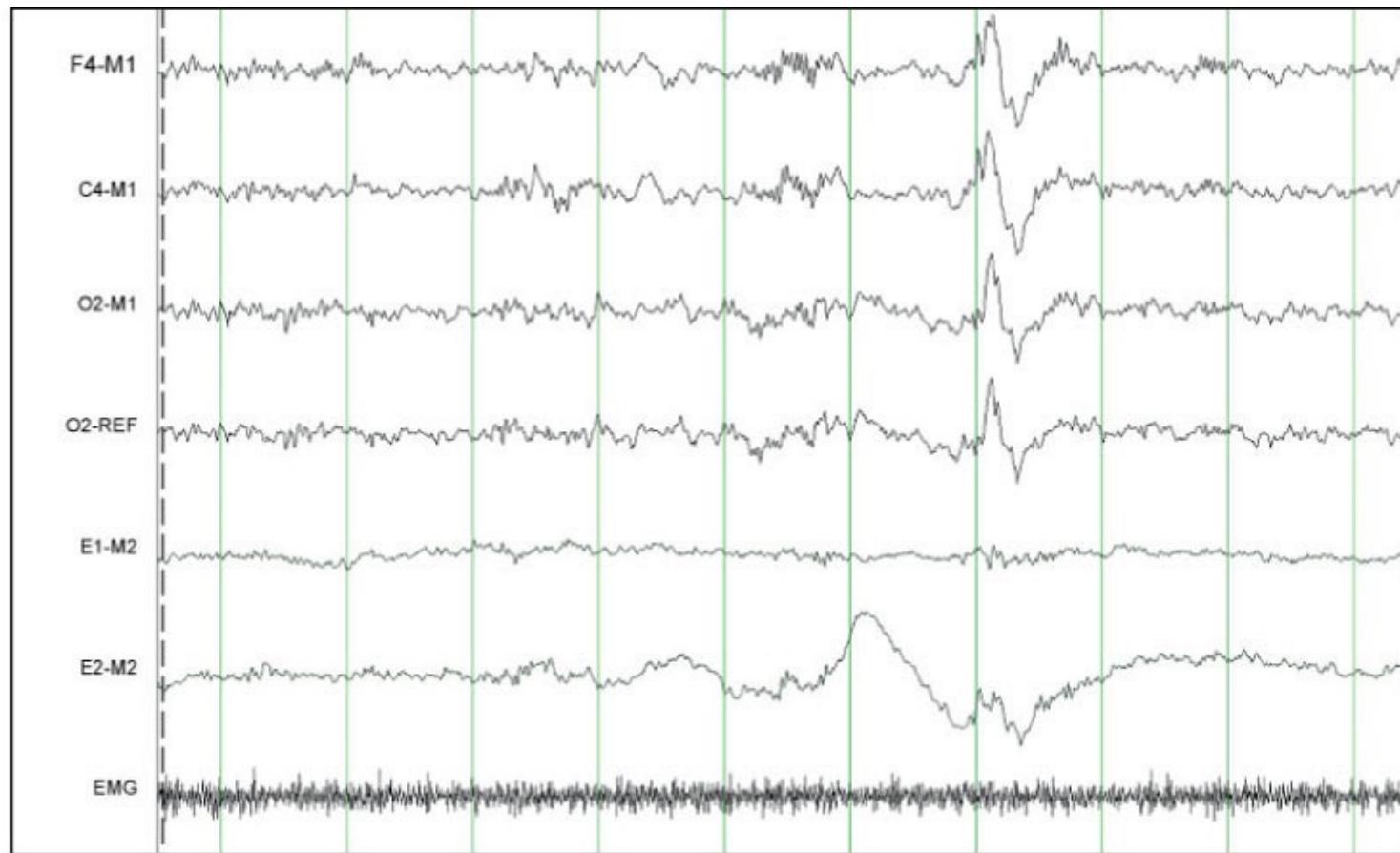


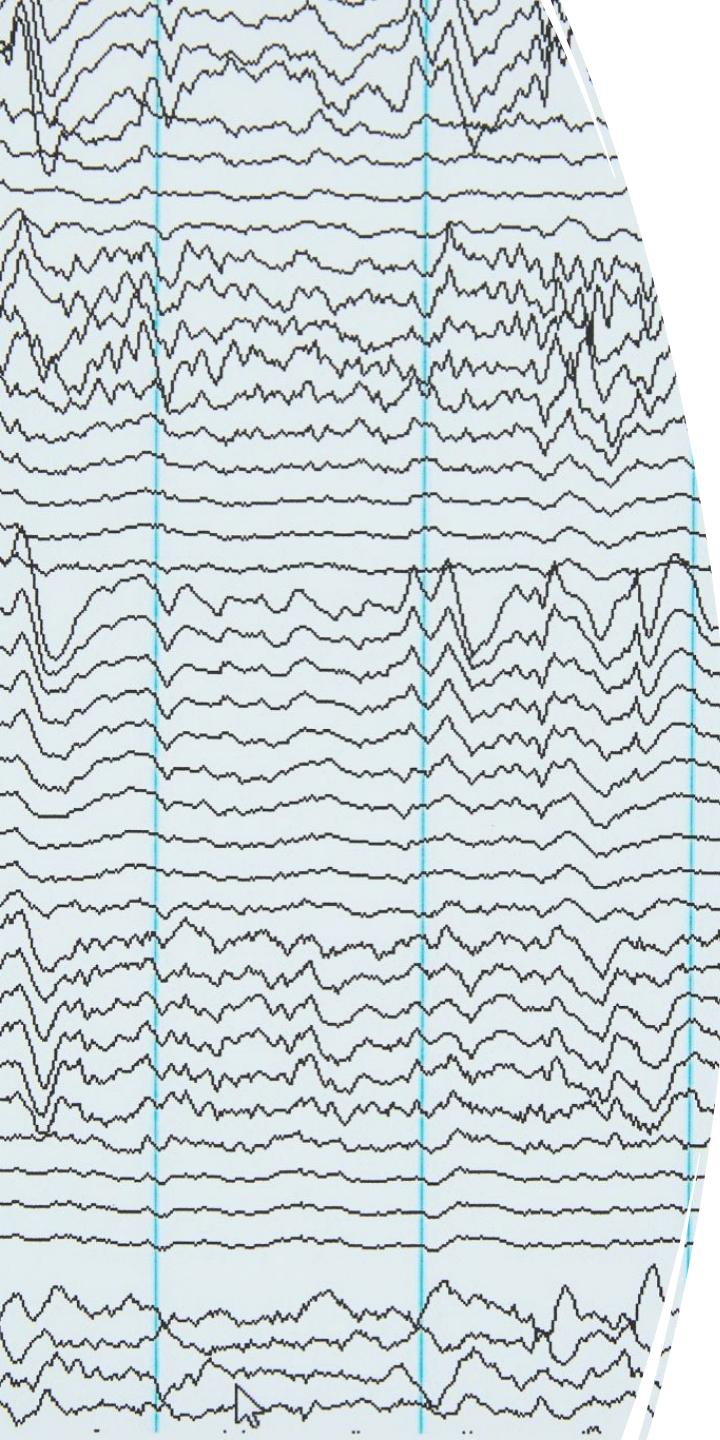
## Stage N2

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- EEG
  - Sleep spindles (12-14 Hz)
    - Maximal over central region
  - K complexes (0.5 second or longer)
    - Maximal over frontal region
  - LAMF
- EOG
  - Eye movements disappear

## Stage N2



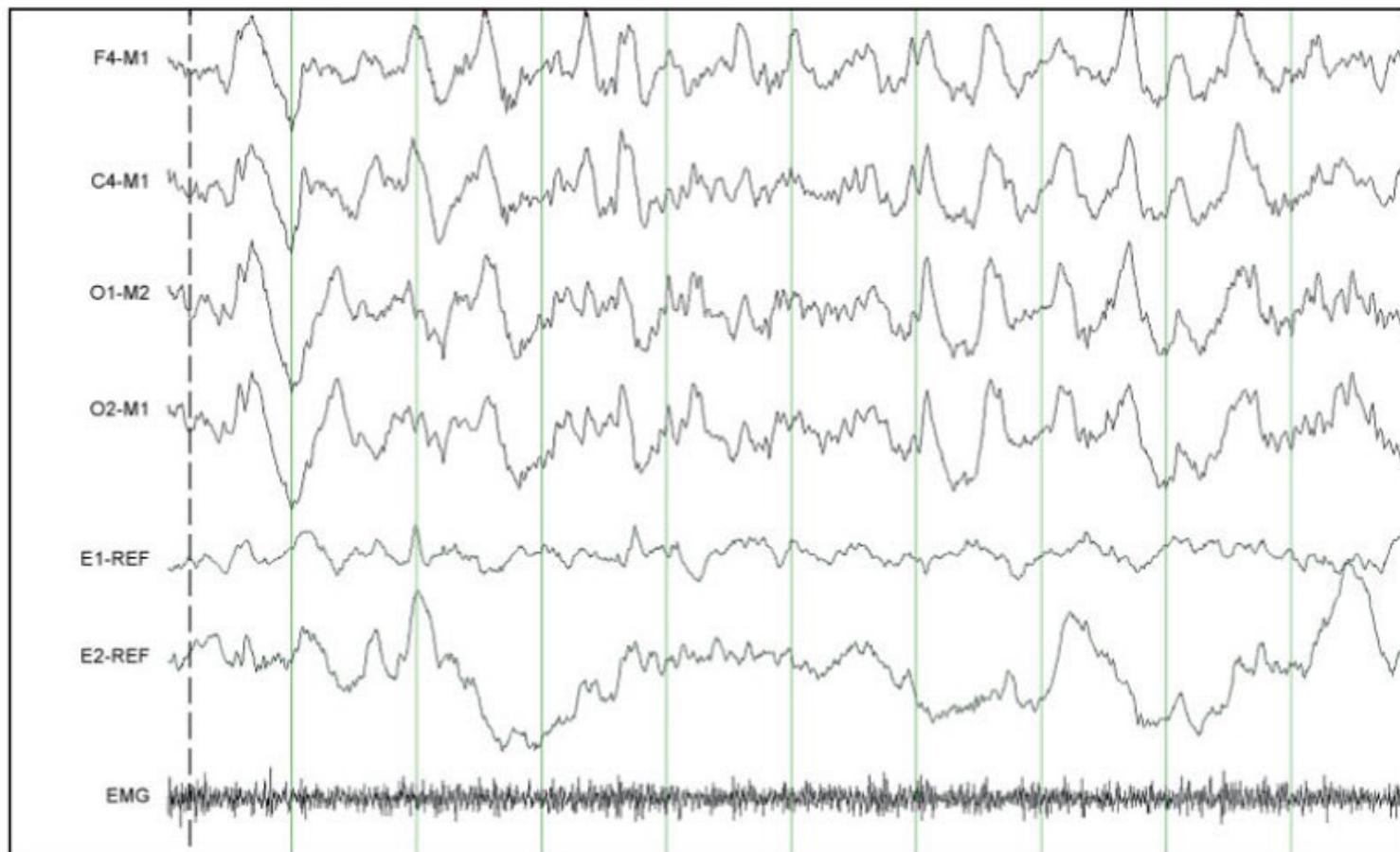


# Stage N3

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- EEG
  - Slow waves (delta waves) in 0.5-2 Hz range with peak-to-peak amplitude of > 75  $\mu$ V
    - Maximal in frontal region
    - Epoch must have  $\geq$  20% delta waves to be scored as N3
- EOG
  - Absent eye movements
- Chin EMG
  - Lower than N2

# Stage N3



# Stage R



- EEG
  - LAMF
  - Sawtooth waves
- EOG
  - Conjugate REMs that are sharply peaked and irregular
    - Initial deflection is < 500 ms
- Chin EMG
  - Lowest level of sleep study

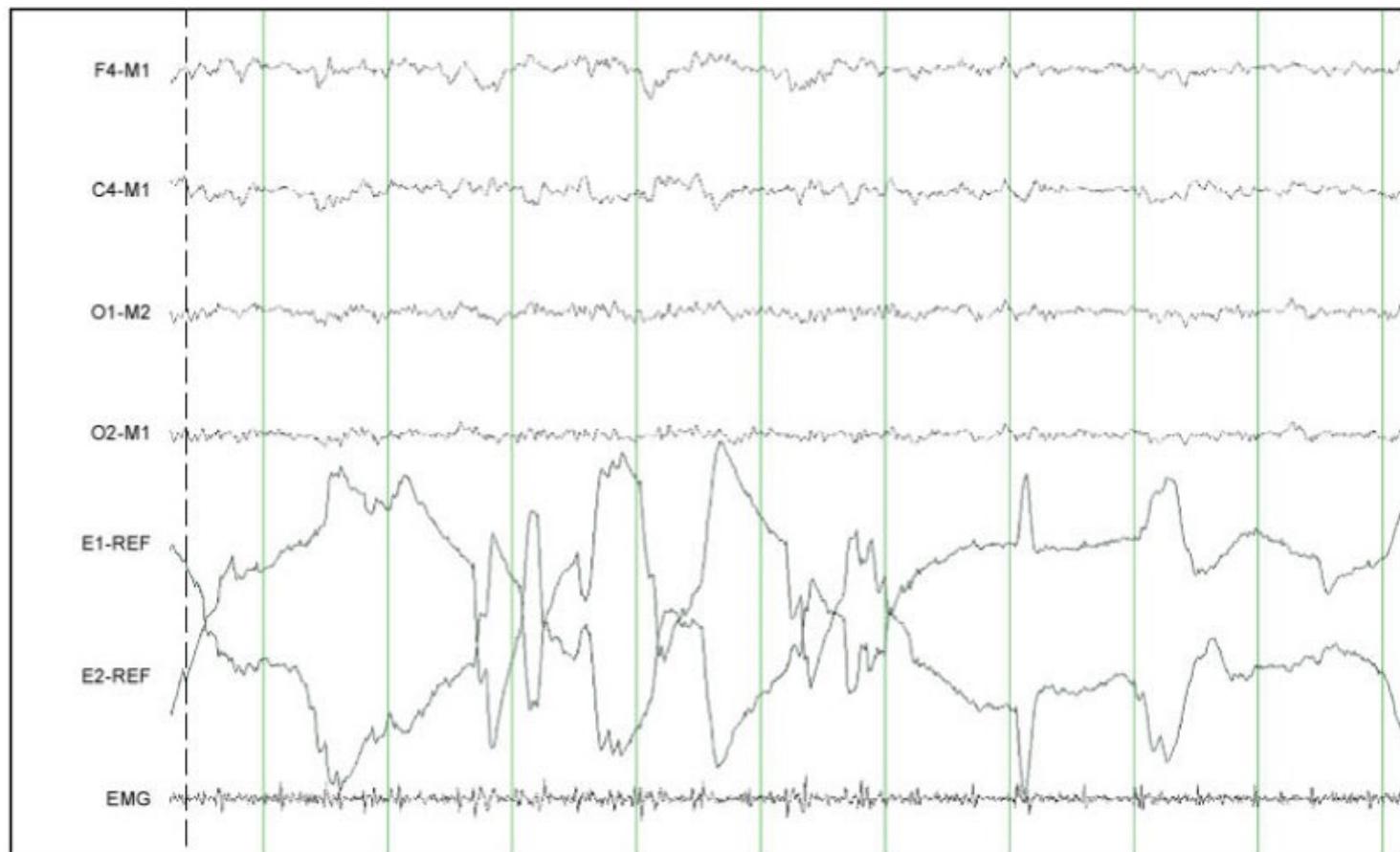


# Stage R

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- 2 types
  - Phasic
    - Has REMs and episodic EMG twitching
  - Tonic
    - No REMs and very low chin EMG

## Stage R



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