Spencer Dawson

Assessing Sleep

Methods for Assessing Sleep

- Simplest method: Questionnaires
  - Retrospective: past week, month, year, lifetime
  - Daily: Sleep diary
- What kinds of questions would you ask?

Common Questions About Sleep

- Did you nap during the day?
- Bed time and rise time → Time In Bed
- Time to fall asleep → Sleep Onset Latency
- Waking up during the night → Frequency of Night Awakenings and Wake After Sleep Onset
- Quality of Sleep
- Physical problems: breathing, pain, restlessness, temperature
- Use of alcohol or medication

Sleep Diary

	First day	*Second day*	*Third day*	*Fourth day*
Complete in morning				
Bedtime (date/time)	10:45 p.m. (4/10)			
Rise time (date/time)	7:00 a.m. (4/11)			
Estimated time to fall asleep	30 minutes			
Estimated number of awakenings and total time awake	5 times 2 hours			
Estimated amount of sleep obtained	4 hours			
Complete at bedtime				
Naps (number, time, and duration)	1 at 3:30 p.m. 45 minutes			
Alcoholic drinks (number and time)	1 drink at 8:00 p.m. 2 drinks at 9:00 p.m.			
List stresses of the day	Flat tire Argued with son			
Rate how you felt today 1 = Very tired/sleepy 2 = Somewhat tired/sleepy 3 = Fairly alert 4 = Wide awake	2			
Irritability level 1 = None 2 = Some 3 = Moderate 4 = Fairly high 5 = High	5			
Medications				

http://www.aafp.org/afp/2009/0115/afp20090115p125-f1.gif

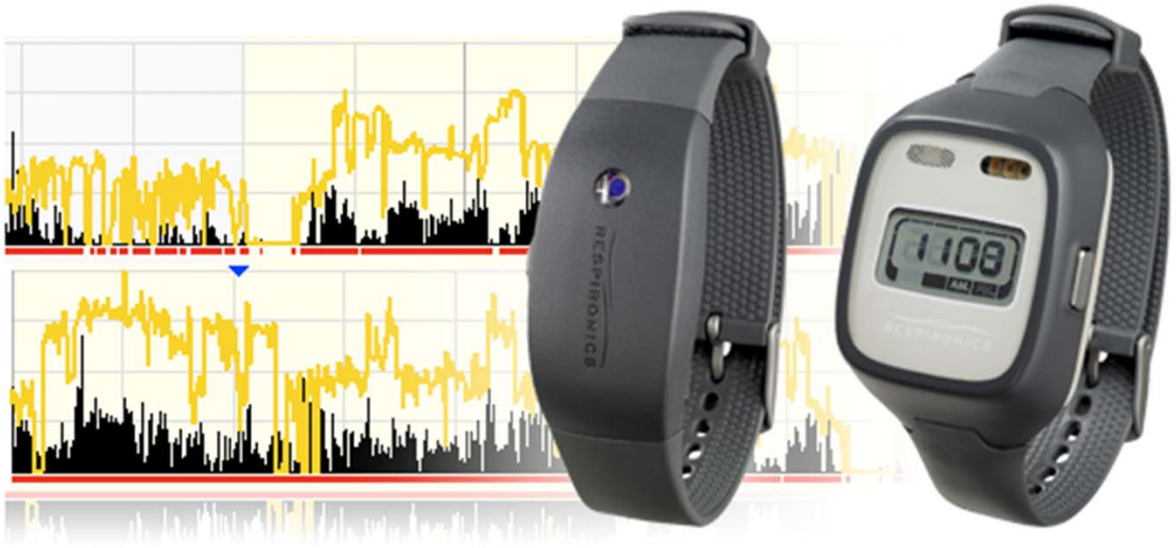
Observer Ratings

- Bed partner
- Roommate
- Nursing staff
- Sleep tech

http://3.bp.blogspot.com/_2TWdt7WJ_48/S96vqW_hNnI/AAAAAAAAAT8/NzHAt-8DL9c/s1600/funny-pictures-your-cat-watches-you-sleep.jpg

Actigraphy

- Small device worn on the wrist in adults
  - Accelerometer, light sensor (some models)
- Variable sampling rate: 15 seconds to 5 minutes, allowing recordings to range from days to months at a time



http://www.learnactiware.com/images/screenshots.png?1251392333

Standard Actigraphy Measures

- Sleep Onset Latency
- Time in Bed
- Total Sleep Time
- Number of Awakenings
- Wake After Sleep Onset

Actigraphy in Infants

- Actigraphs can be worn on infants' ankles
- Sleep problems in infants at risk for depression can be detected at 2 weeks of age

Armitage et al., 2009

Polysomnography

- Traditional laboratory sleep study
- Simultaneous recording of multiple sleep-related physiological measures

http://images.wikia.com/psychology/images/a/a6/Pediatric_polysomnogram.jpg

Polysomnography

- Three main measures:
  - EEG: electroencephalogram
  - EOG: electrooculogram
  - EMG: electromyogram
- These measures are used to determine different stages of sleep
- Additional measures used for detecting sleep disorders

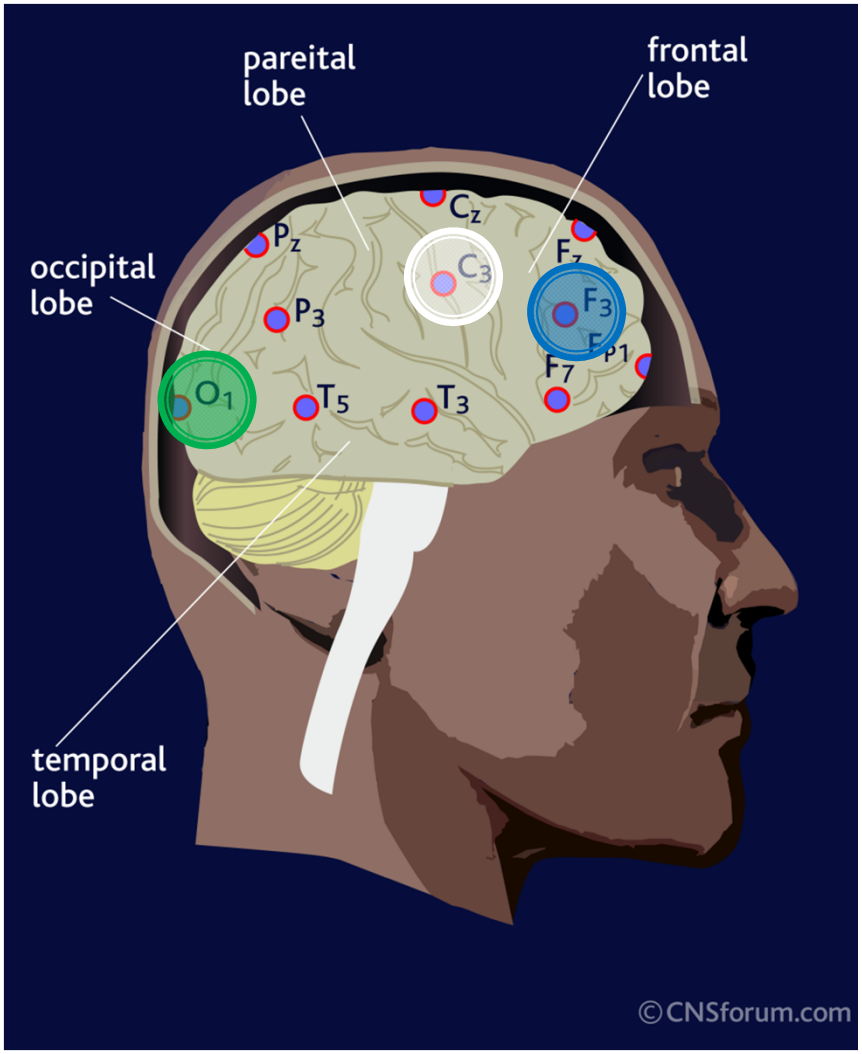
EEG in Polysomnography

- Individual electrodes – NO CAPS
  - High likelihood of slipping during sleep
  - In waking EEG studies, subjects sit upright
  - In sleep studies, subjects have pillows and roll around
- EEG and EOG are recorded with references
  - Contralateral mastoid (or earlobe)
- Filters: usually 0.3-70 Hz
- Sampling: usually 256 Hz or faster

http://www.astro-medinc.com/electrode.jpg

EEG in Polysomnography

- Frontal (F_3 and F_4) for delta
- Central (C_3 and C_4) for Sleep Spindles and K Complexes
- Occipital (O_1 and O_2) for alpha

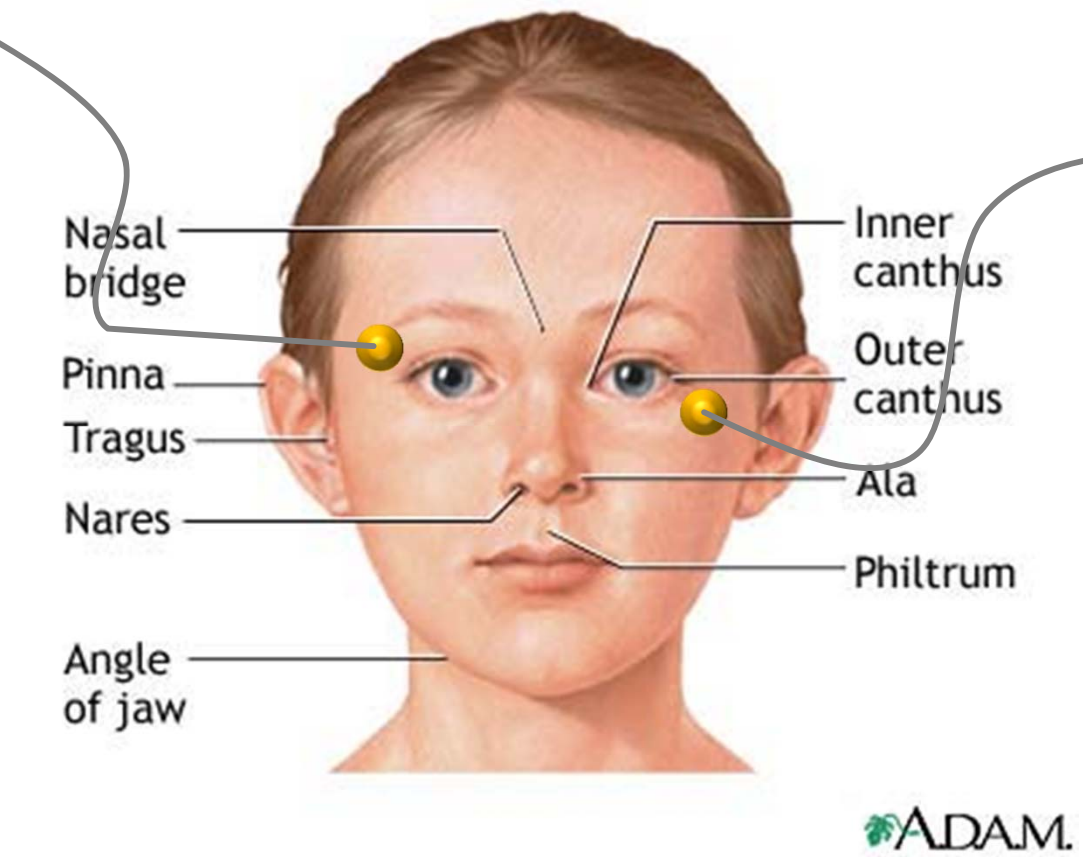


http://www.cnsforum.com/content/pictures/imagebank/hirespng/placement_EEG_leads.pn

EOG in Polysomnography

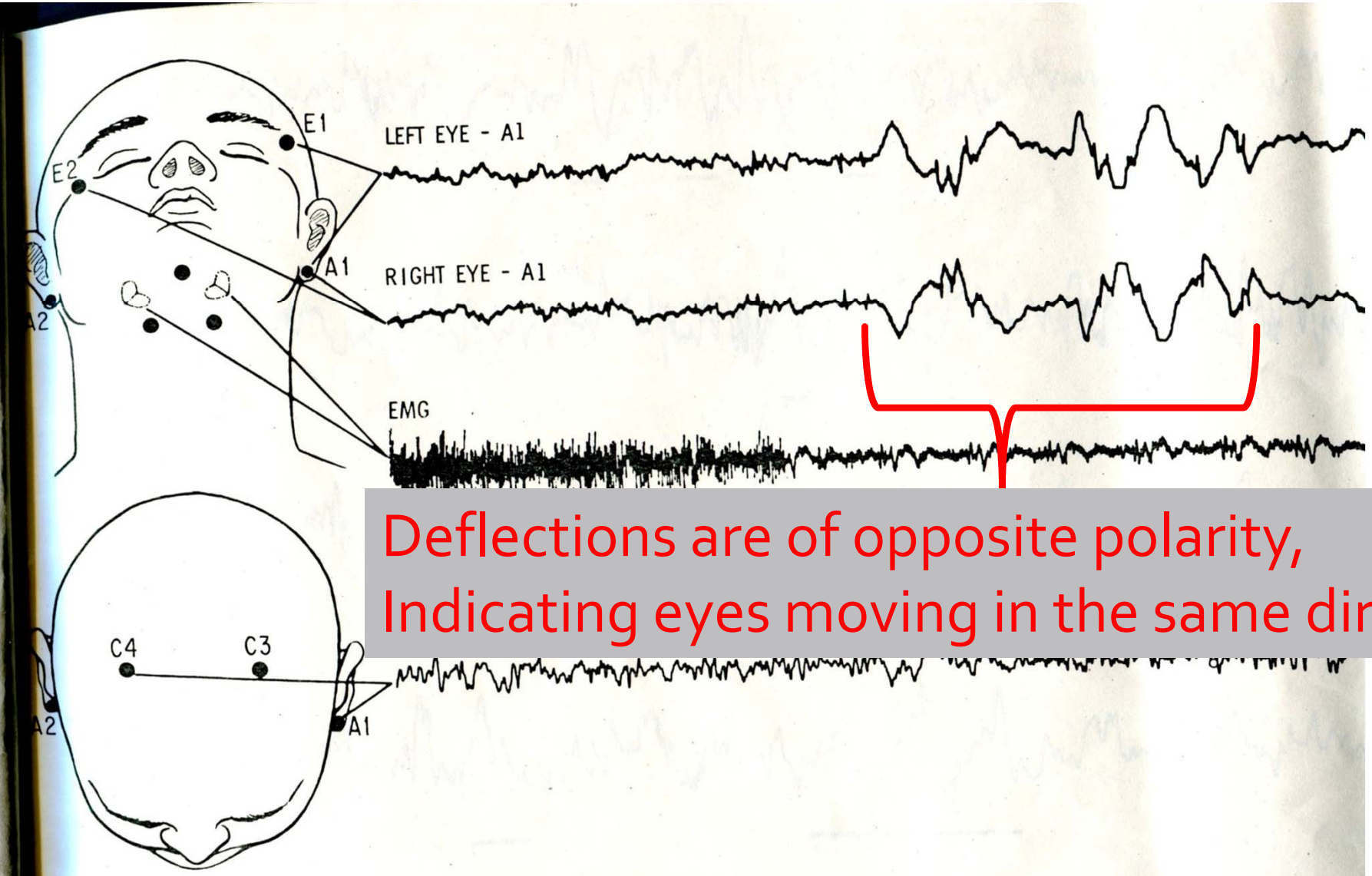
- From before: our eyes are polarized
- Eye movement generates electrical potentials
- In waking EEG these are annoying artifacts
- In polysomnography, these are helpful in distinguishing between stages of sleep

Placement of EOG electrodes



- Left Oculogram (LOC)
  - Below outer canthus
- Right Oculogram (ROC)
  - Above outer canthus
- Why?
  - When looking left or down, eyes move towards LOC and away from ROC
  - Opposite for looking right or up

http://www.nlm.nih.gov/medlineplus/ency/images/ency/fullsize/1095.jpg



Deflections are of opposite polarity,
Indicating eyes moving in the same direction

FIGURE 1

Upper drawing illustrates the placement of E1, E2, A1, and A2 electrodes for detection of eye movements and also shows two methods for recording tonic EMG from mental and submental muscle areas. Lower drawing illustrates the placement of C3, C4, A1, and A2 electrodes for EEG recording of sleep stages. (See text, pages 2-4). This epoc REM. Note relatively low voltage mixed f sharp decrease in the tonic EMG.

Rechtschaffen and Kales, 1968

EMG in Polysomnography

- In waking EMG, we want to know WHICH muscles are moving (e.g., corrugator, zygomatic) so we can infer emotion
- In measuring sleep, we want to know the level of muscle tension that changes during sleep
  - Best place to measure: under the chin

Alpha

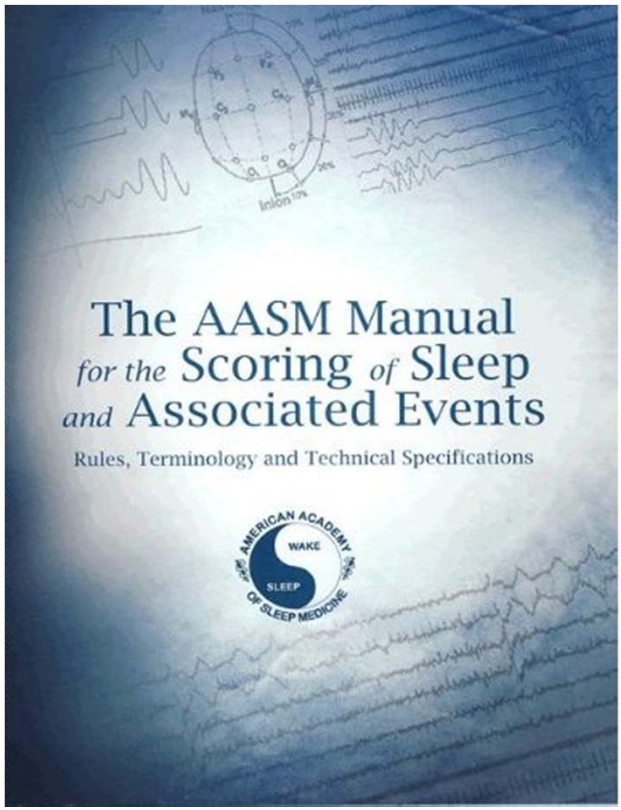
- What do we infer from alpha in wakefulness?
  - Relaxation or inactivity
  - A state in between wake and sleep
- If alpha is in between wake and sleep, what do you think alpha during sleep represents?
  - Increased arousal
  - Again, a state in between wake and sleep

Sleep Stages

- NREM: Non-Rapid Eye Movement Sleep
  - N1: transition stage, less than 10% of sleep time
  - N2: about 50% of all sleep time
  - N3: also known as slow wave sleep or deep sleep, about 20% of sleep time
- REM: Rapid Eye Movement sleep, about 20% of sleep time
- Non-sleep stages
  - Awake
  - Movement time (too much artifact from movement to determine sleep stage)

Scoring Rules

- Original rules: Rechtschaffen and Kales, 1968
  - Before that, inconsistent definitions and terminology
- New rules: American Academy of Sleep Medicine, 2007
  - Slight revision of R & K



Epochs

- Overnight polysomnography can typically range from 6 to 10 hours
- Like in EEG analysis, we use epochs to break down the data into manageable pieces
- Typical epoch length is 30 seconds
- Each epoch is assigned a sleep stage
  - What is the majority of the epoch? 14.9 seconds of wake and 15.1 seconds of sleep means all 30 seconds are counted as sleep

Criteria for Awake and N1

- Awake
  - EEG: high frequency, low amplitude activity
  - EOG: sharp eye movements
  - EMG: relatively high muscle tone, with increases related to movement
- N1
  - EEG: mixed frequency, low amplitude activity, less than 50% alpha
  - EOG: slow rolling eye movements
  - EMG: lower muscle tone than when awake

Transition from Wake to N1

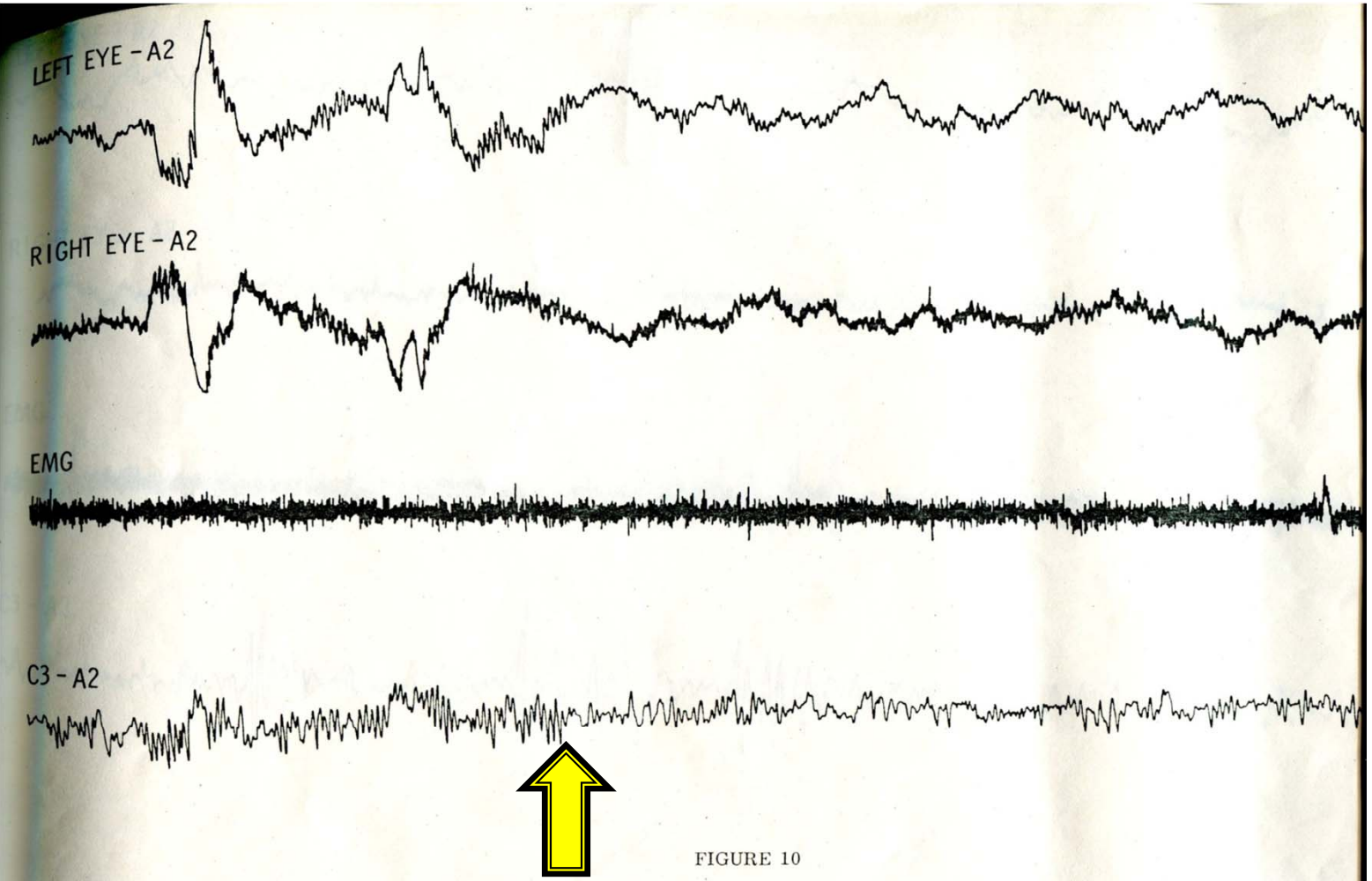


FIGURE 10

Stage 1. This illustrates the transition from Stage W to Stage 1 within a single epoch; REMs and alpha activity at the start of the epoch are followed by slow eye movements and the typical relatively low voltage, mixed frequency EEG of Stage 1 (much activity at 3-4 cps) later in the epoch. There are no vertex sharp waves, which is typical of the early minutes of Stage 1. At the end of the epoch, a REM and a burst of alpha activity signa W, but slightly more than half the epoch is Stage 1, and the accordingly. The relatively elevated EMG is maintained in Stage W to Stage 1.

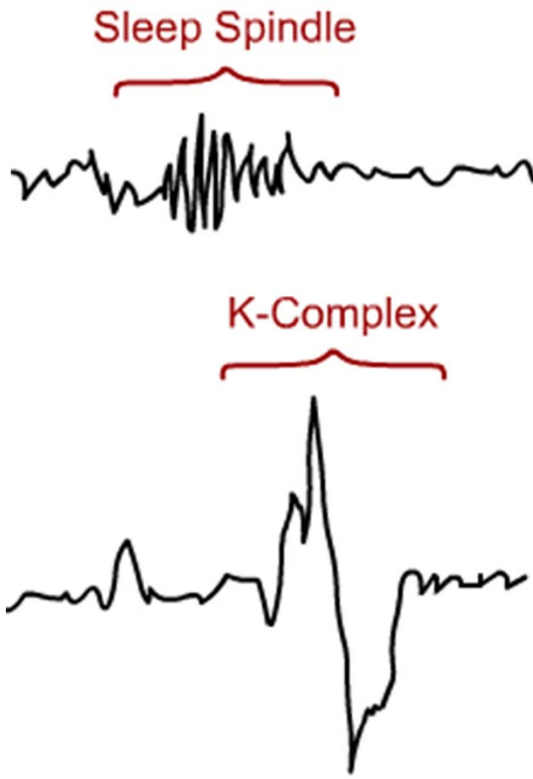
Eye movements slow down

EEG changes:
Alpha disappears

Rechtschaffen and Kales, 1968

Criteria for N2

- EEG: Sleep Spindles and/or K Complexes over a background of low amplitude, mixed frequency activity
  - Sleep Spindle: burst of 12-14 Hz activity 0.5 seconds or longer
  - K Complex: sharp negative inflection, followed by positive inflection and slow return to baseline, at least 75 microvolts amplitude and 0.5 seconds long
- EOG: generally no eye movements, but no specific criteria
- EMG: relatively low muscle tone



http://images.wikia.com/psychology/images/a/a8/Stage2sleep.png

N2

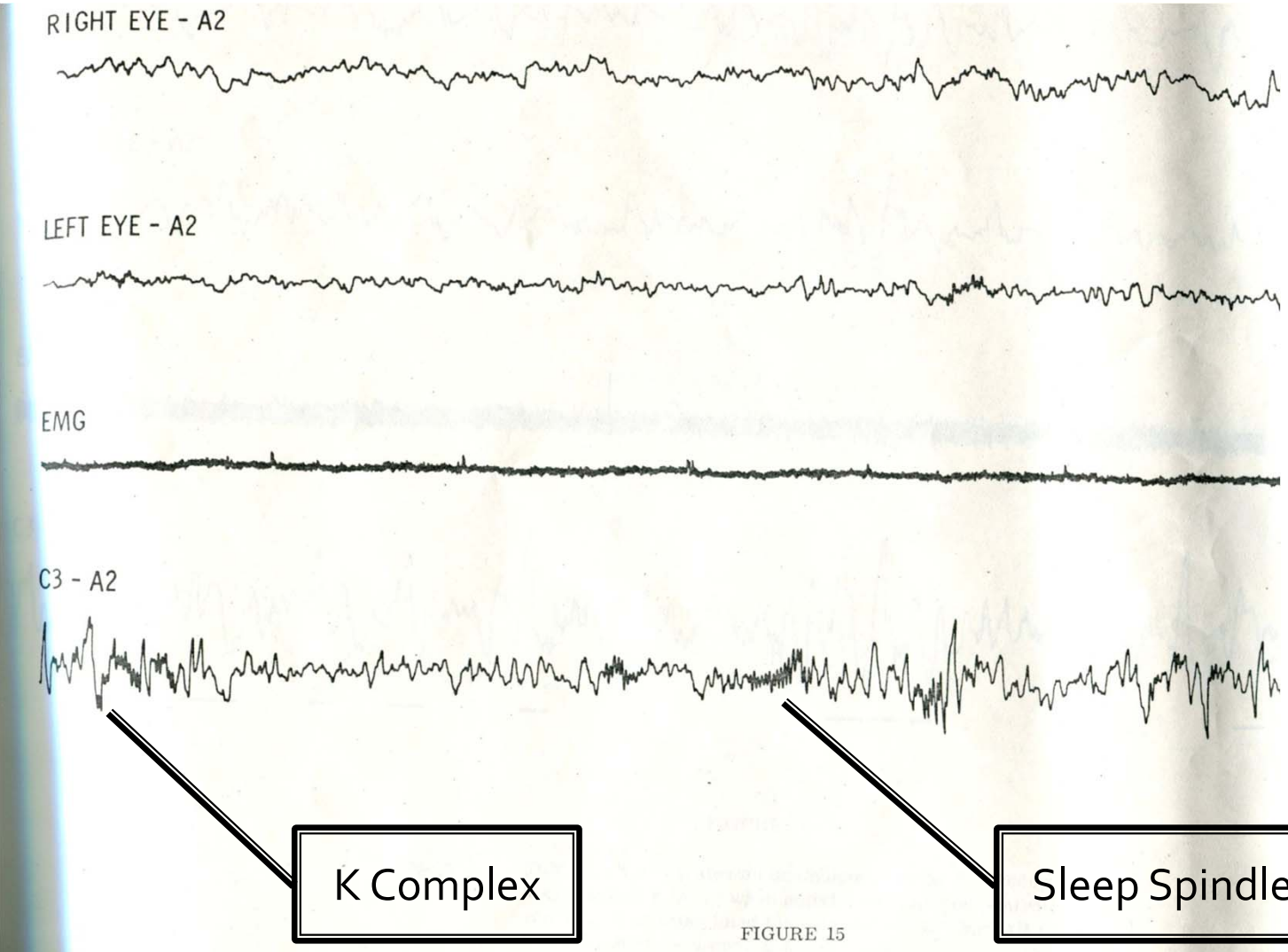


FIGURE 15

Stage 2. This illustrates Stage 2 with tonic EMG at the lowest level attained during the recording session.

Absence of eye movements

Presence of sleep spindles and K complexes

Rechtschaffen and Kales, 1968

Criteria for N3

- EEG: greater than 20% of the epoch consists of high amplitude slow waves
  - High amplitude slow waves are >75 microvolts in amplitude and 0.5-2.0 Hz in frequency
- EOG: generally no eye movements, but no specific criteria
- EMG: relatively low muscle tone

N3

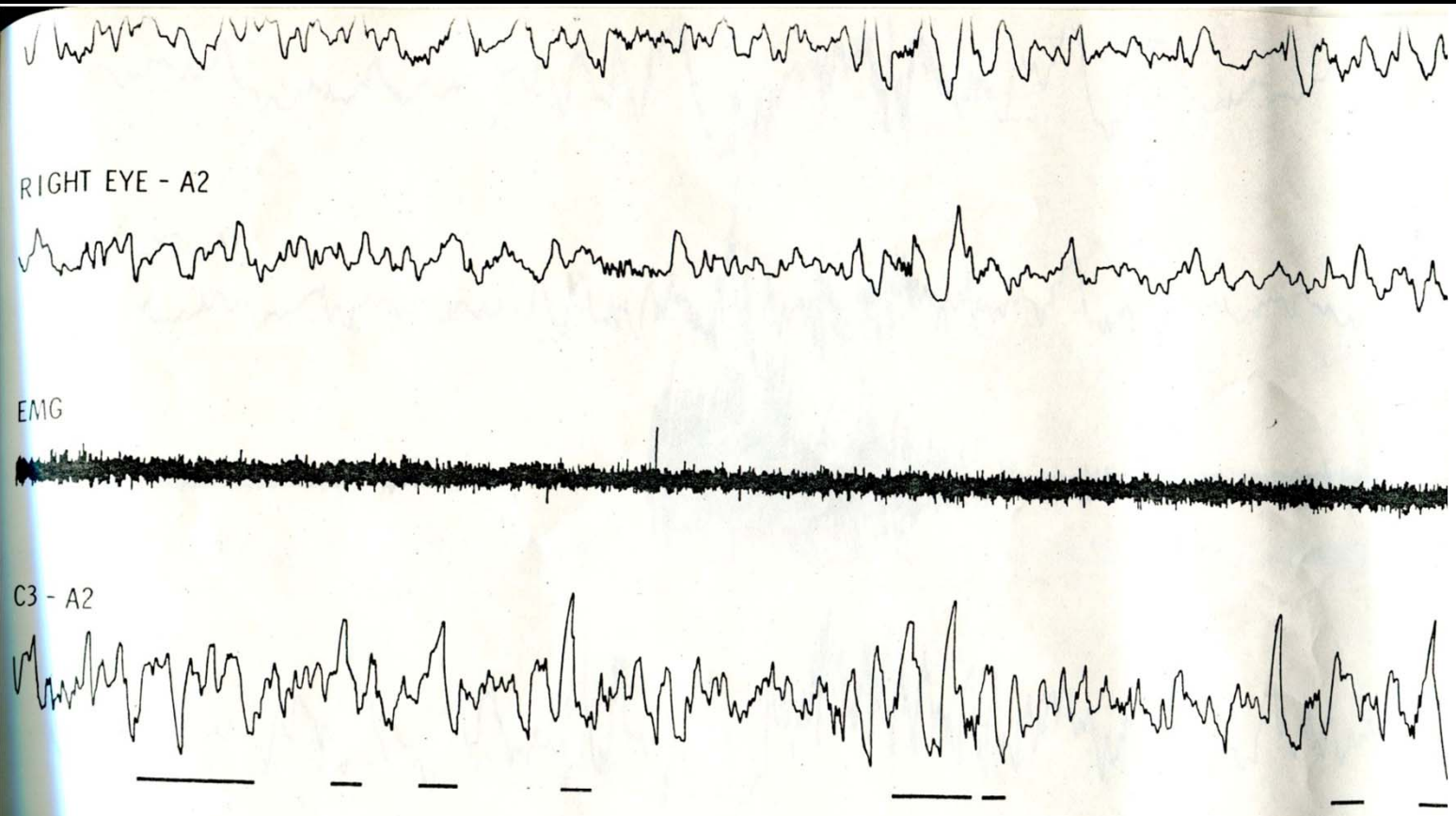


FIGURE 16

Stage 3. This epoch illustrates an unambiguous Stage 3. Acceptable high amplitude, slow wave activity occupies one-third of the record. It is underlined for emphasis in this and all the Stage 3 and Stage 4 epochs which follow.

EOG shows artifact from high amplitude EEG activity
Note that the deflections in LOC and ROC are in the same direction

High amplitude slow waves in EEG (underlined)

Rechtschaffen and Kales, 1968

Criteria for REM

- EEG: mixed frequency, low amplitude activity
  - ABSENCE of Sleep Spindles and K Complexes
- EOG: phasic bursts of rapid eye movements
- EMG: lowest muscle tone, almost complete inhibition of muscle activity

REM

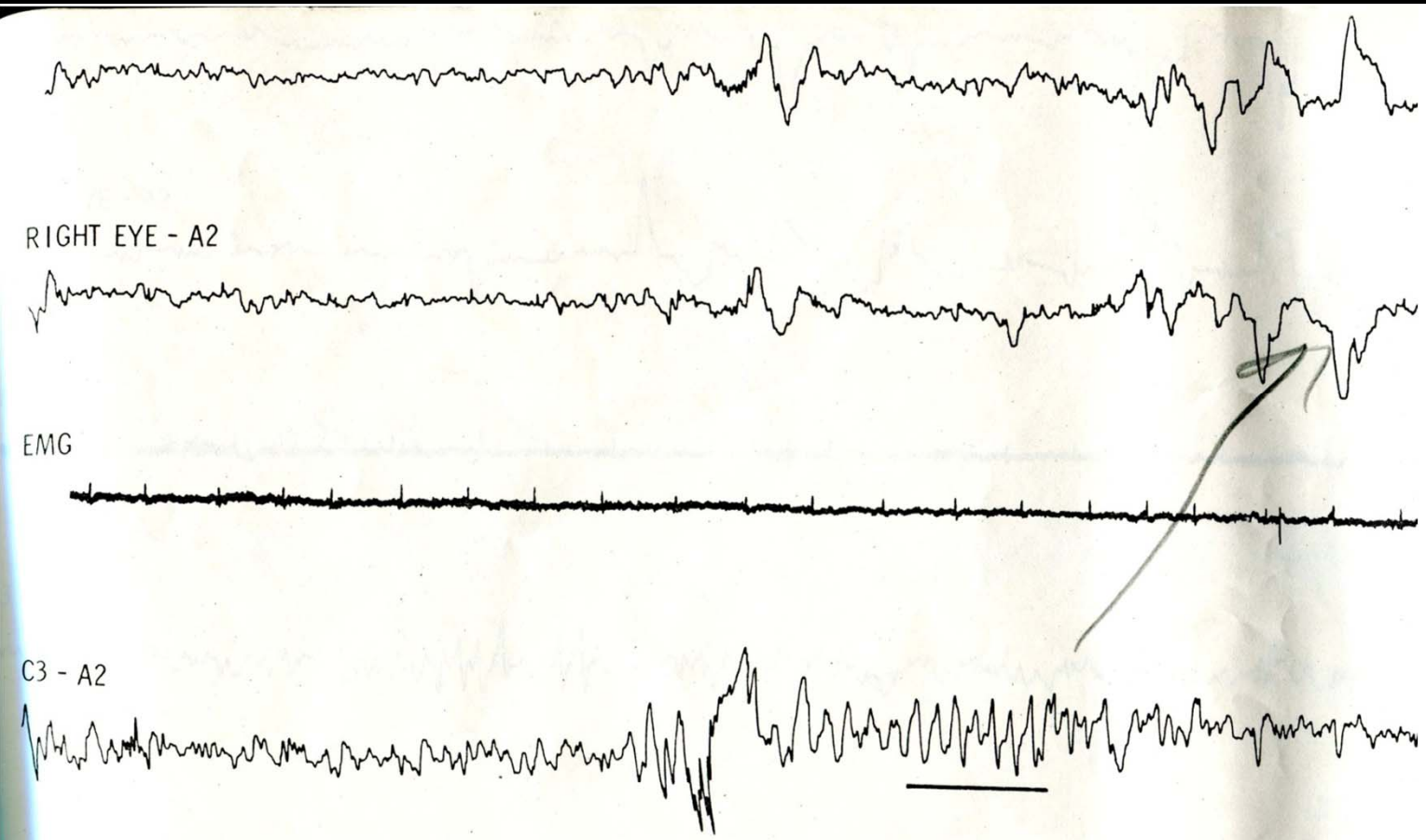


FIGURE 19

Stage REM. This epoch illustrates a transition between Stage 2 and Stage REM. The record had been Stage 2 for some time prior to this epoch. Just before the midpoint of the epoch, there is a clear sleep spindle followed by a K complex. Following the K complex are clear saw-tooth waves (underlined), which herald the appearance of REMs during the last third of the epoch. (Note that not all the saw-tooth waves have the distinctive no Stage REM is considered to have begun immediately af complex, and to continue for the remainder of the epoc Stage REM occupies just over 50% of the epoch; hence considered Stage REM. EMG is at the lowest level of

Rapid eye movements
Note opposite polarity in LOC and ROC

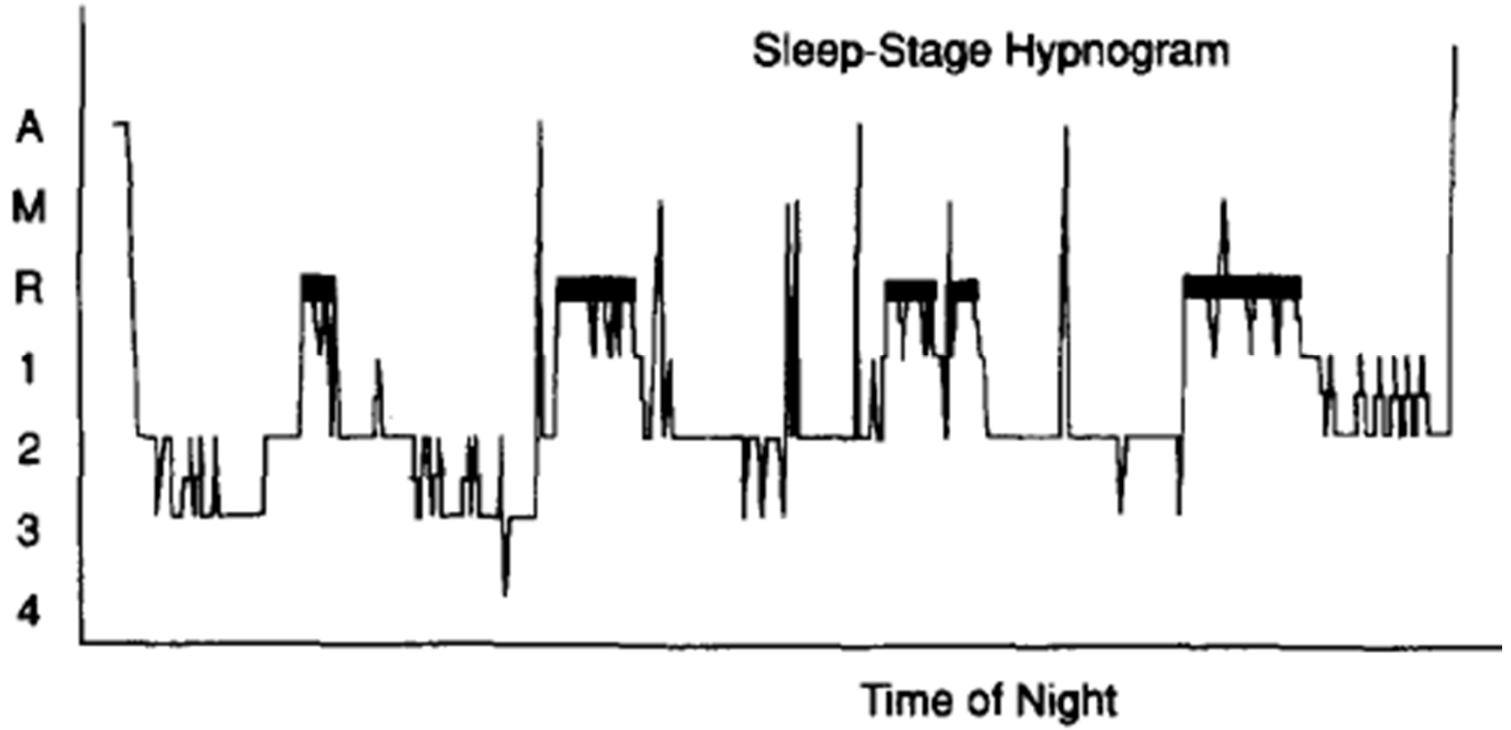
Low tonic EMG

Low amplitude, mixed frequency EEG

Sawtooth waves are also present (underlined), but are not required for REM

Hypnogram

- Sleep stages across the night are plotted to create a hypnogram
- This is a simple overview of a night's sleep



(Armitage, *Biological Psychiatry*, 1995)

Important Sleep Variables

- Sleep onset latency
- Sleep efficiency
- REM latency
- Percent of each sleep stage
- Number of awakenings
- Wake After Sleep Onset

Other Physiological Parameters

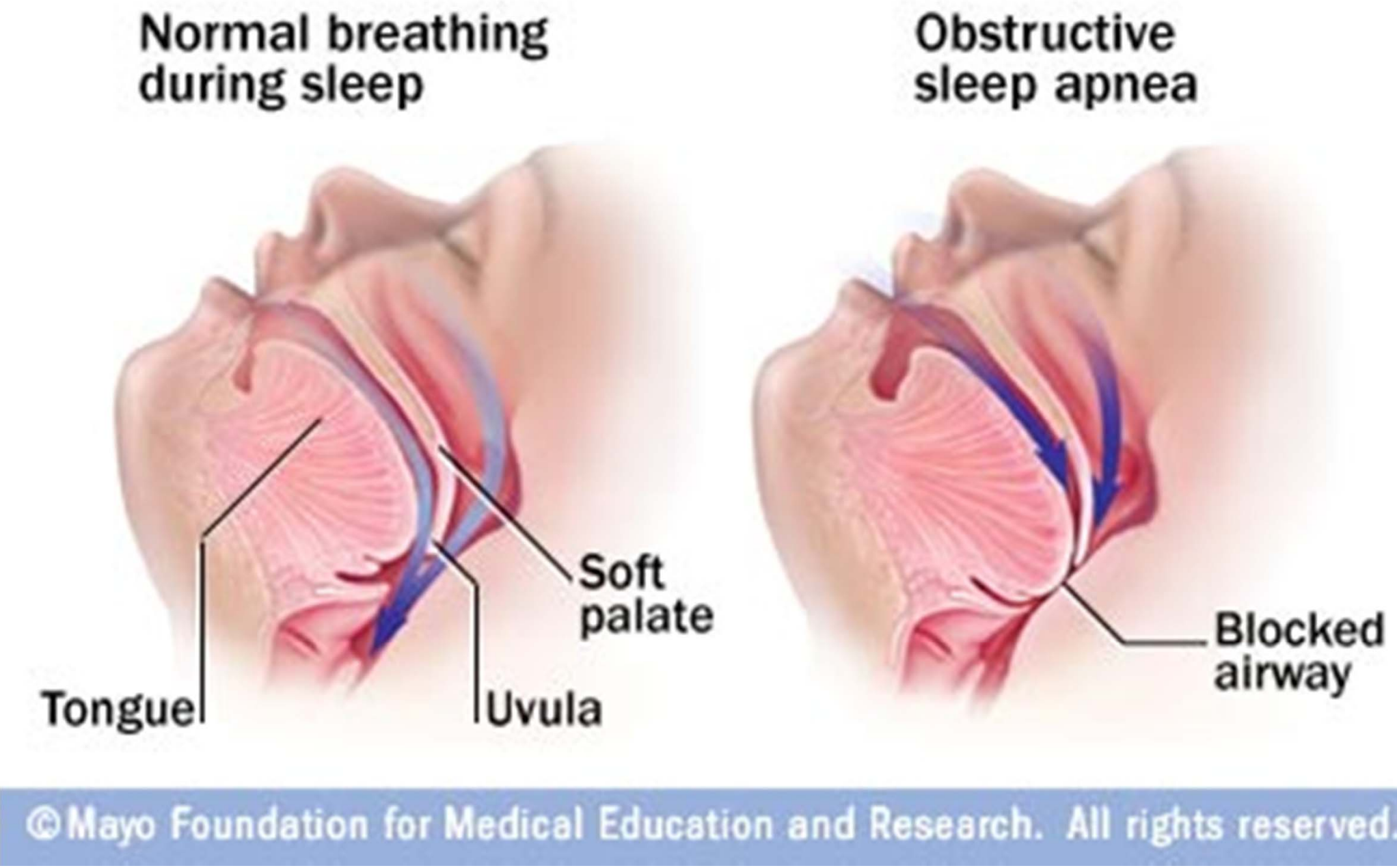
- Respiration
  - Respiratory effort with belts on ribcage and abdomen
  - Oral and nasal airflow with thermistor and pressure transducer
- Blood oxygen and pulse rate with pulse oximeter on finger
- Leg muscle activity with anterior tibialis EMG
- EKG (modified Lead II)
- Body position with sensor on belt and observation

Sleep Disorders

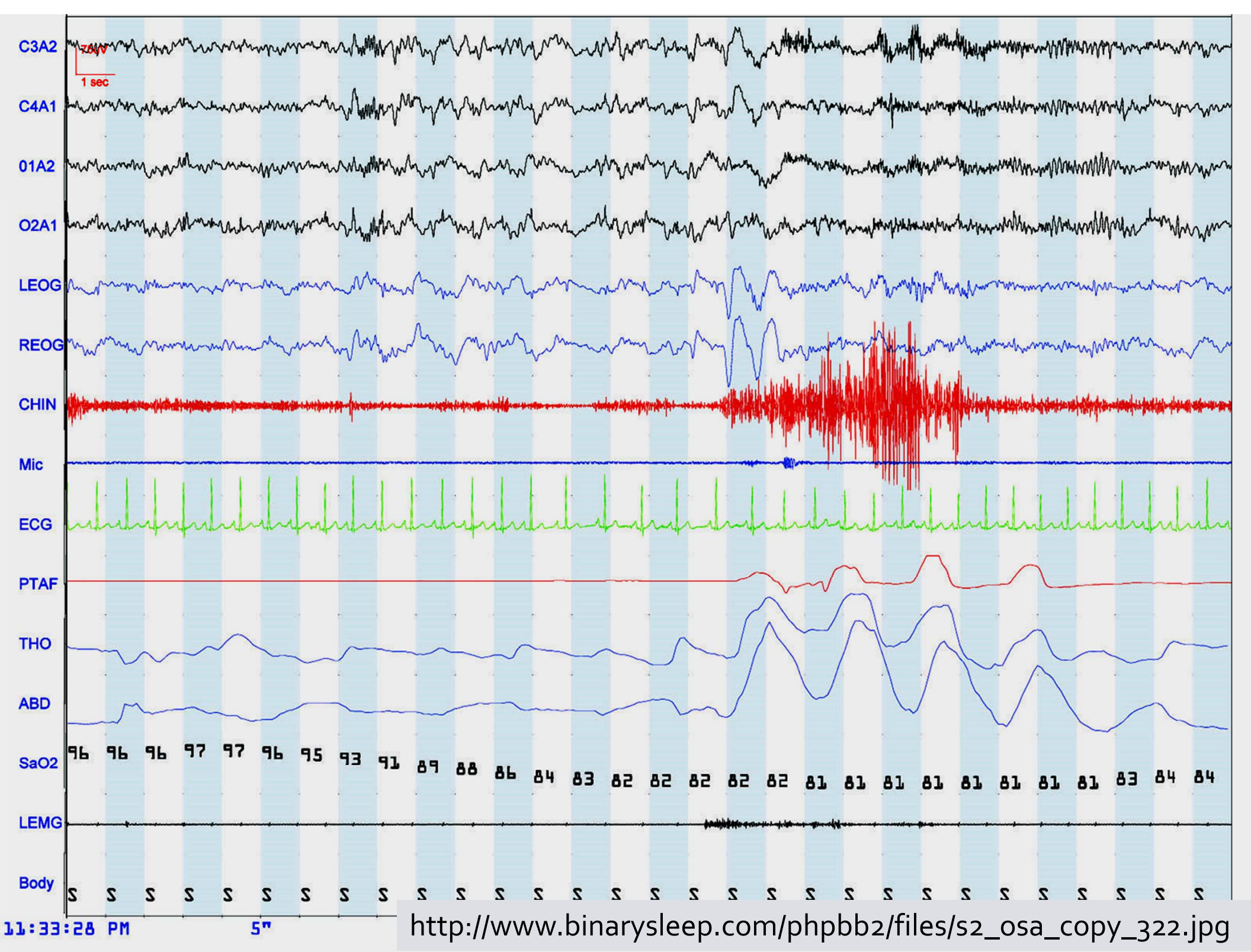
- Insomnia
  - Difficulty initiating sleep
  - Difficulty maintaining sleep
  - Early morning awakening
  - Nonrestorative sleep
- Multiple etiologies
  - Hyperarousal, learned behavior, secondary to another disorder, iatrogenic, poor sleep hygiene
- Multiple treatments
  - Drugs: proven short term, less evidence long term
  - Behavioral: proven in the short term AND long term!

Sleep Disorders

- Obstructive Sleep Apnea
  - Airway closes partially or entirely during sleep
  - Blood oxygen drops
  - Usually terminated by an arousal from sleep to resume breathing
  - Causes: being overweight (excess tissue), size and shape of airway, strength of airway muscles, inadequate innervation of airway muscles
  - Treatment: CPAP, which increases air pressure to hold airway open



http://www.mayoclinic.com/images/image_popup/sl7_sleep_apnea.jpg

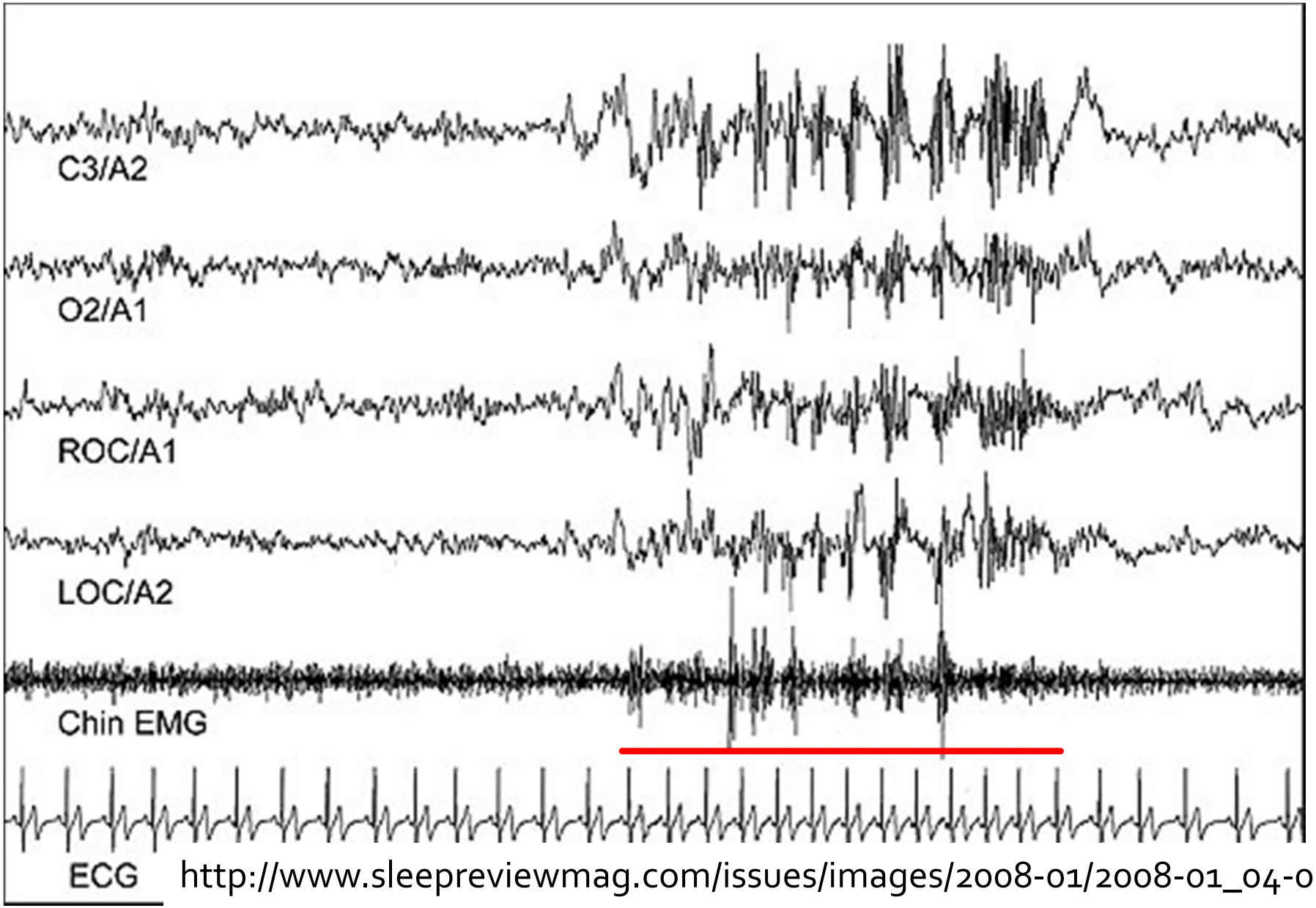


http://www.binarysleep.com/phpbb2/files/s2_osa_copy_322.jpg

Sleep Disorders

- Central Sleep Apnea: cessation of respiratory effort
  - Neurological or related to heart disease
- Periodic Limb Movement Disorder
  - Series of leg muscle twitches which can cause arousals from sleep
- Bruxism
  - Teeth grinding
  - Muscle activity can cause severe artifact in other channels

Bruxism



http://www.sleepreviewmag.com/issues/images/2008-01/2008-01_04-02.jpg

Moving Beyond Sleep Stages

- Sleep stages are nominal definitions
  - The main difference which holds up is the distinction between NREM and REM sleep
- A great deal of variability is ignored by sleep stages
- Divisions between N2 and N3 are arbitrary
  - Based solely on amount of high amplitude slow waves in an epoch

Where is the change from N2 to N3?

FIGURE 4

The top three tracings are Stage 2 and contain increasing percentages of high amplitude, slow wave activity but not enough to qualify for Stage 3. The [redacted] tracings contain increasing percentages of high amplitude, slow wave activity and qualify as Stage 3. The tracings depict 20 sec epochs recorded on a Grass Model IV-C electroencephalograph with a paper speed of 15 mm/sec, a time constant of 0.3 sec and a calibration of 50 μV/cm.

Rechtschaffen and Kales, 1968

Quantitative EEG Analysis

- Quantitative analysis of physiological data (especially EEG) can yield rich data
- Instead of discussing N2 and N3, we can state exactly how much delta power was generated by a subject
- We can analyze multiple frequency bands

Delta: 0 to <4.0 Hz

Theta: 4.0 to <8.0 Hz

Alpha: 8.0 to <12.0 Hz

Sigma: 12.0 to <16.0 Hz

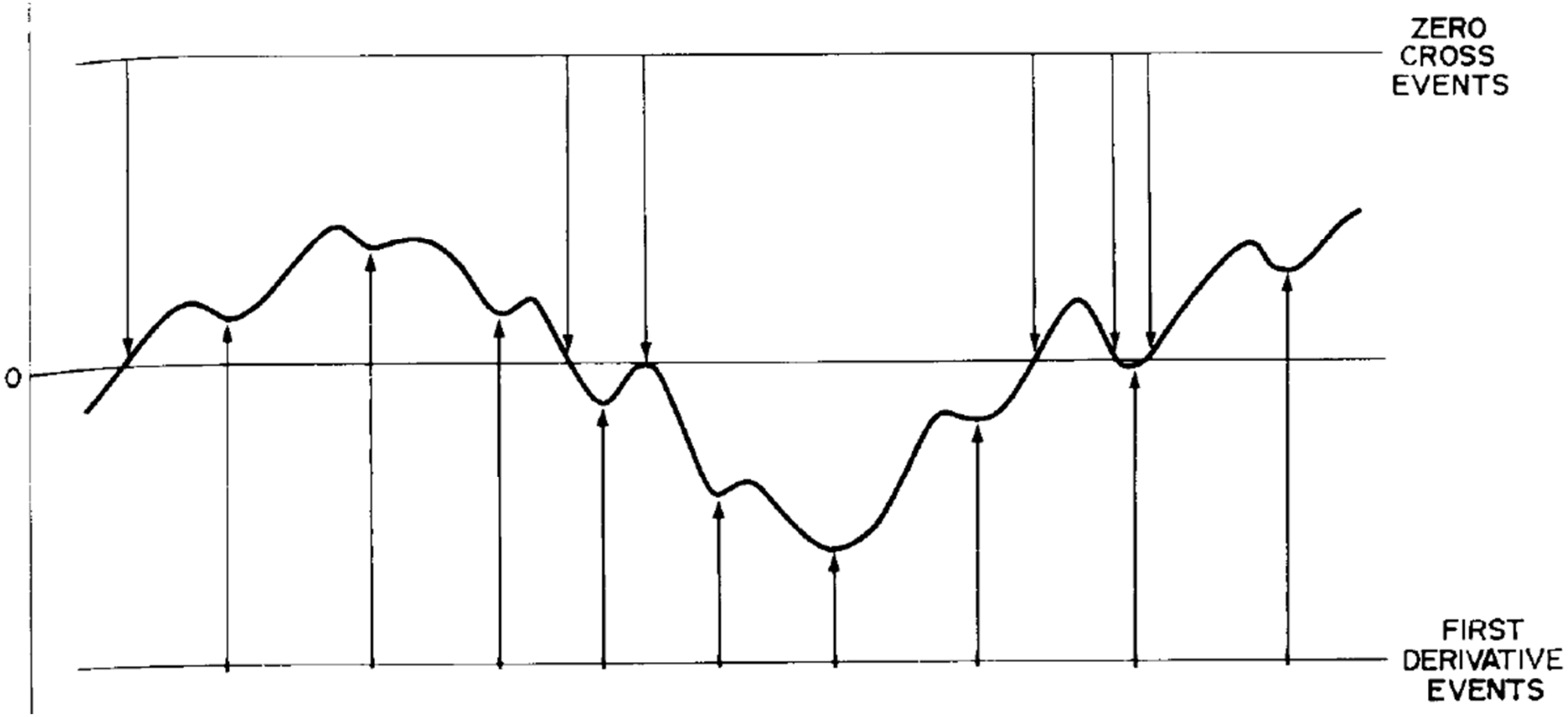
Beta: 16.0 Hz and above

NB: these frequency definitions vary between labs!

Types of Quantitative EEG Analysis

- Fourier Transform (frequency domain)
  - We have discussed this in waking EEG
  - In sleep, the computational technique is the same
- Period Analysis (time domain)
  - How often EEG signal crosses electrical baseline
  - How often there is a negative inflection in the EEG signal
  - Amplitude can also be calculated

Period Analysis

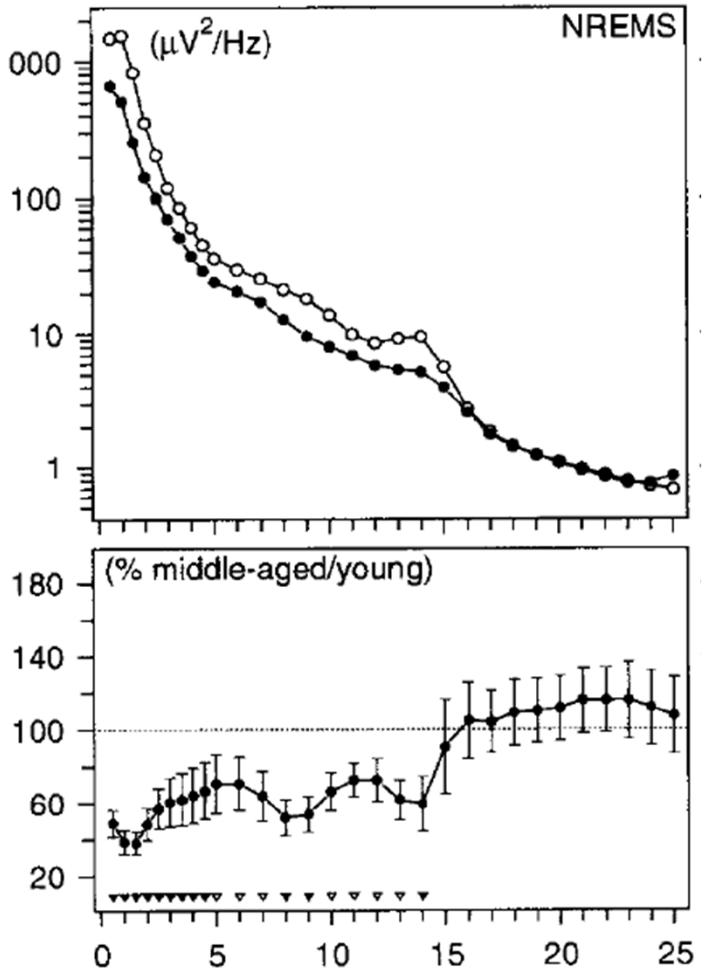


Zero cross is biased toward slow frequencies
First derivative (negative inflection) is biased toward faster frequencies

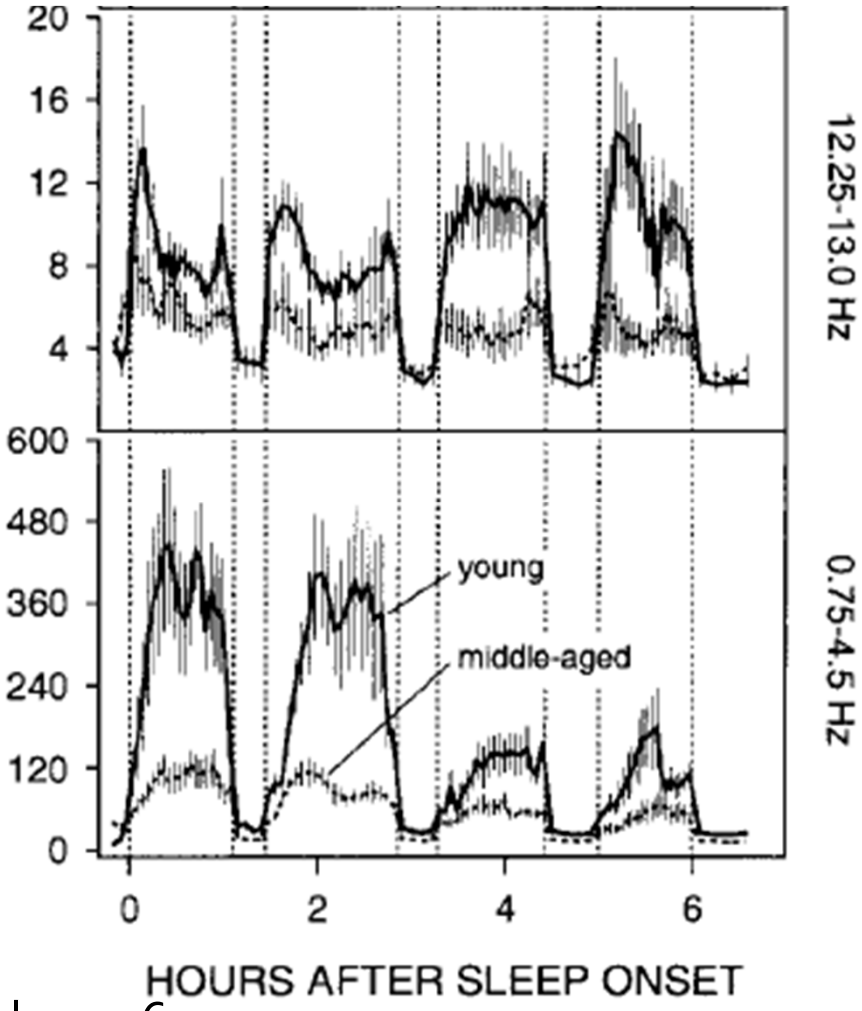
Hoffmann et al., 1979

Plotting Quantitative EEG Data

Power By Frequency



Power By Time



Landolt et al., 1996

Stage Scores and Quantitative Analysis

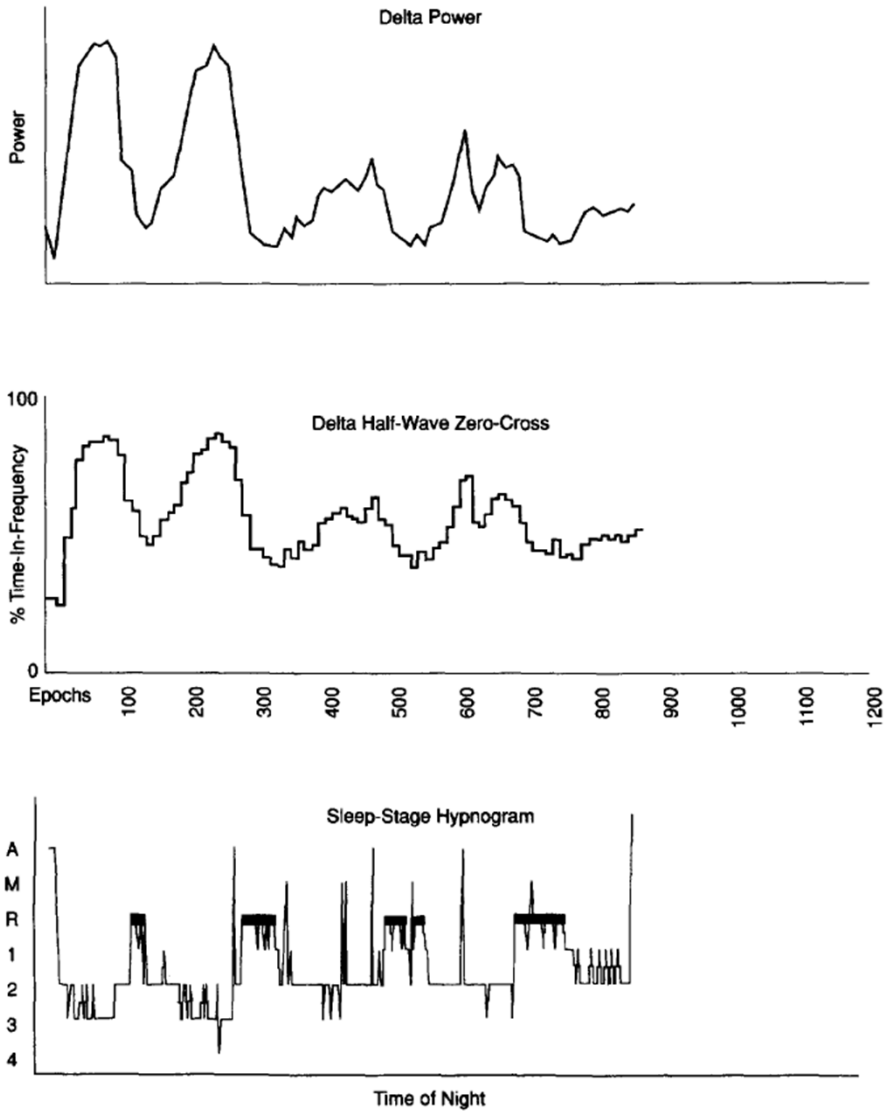


Figure 2. Comparison of delta (0.5 to <4 Hz) quantified by fast Fourier transforms (FFTs) (top), digital period analysis (DPA) (middle), and standard visual stage scoring (bottom).

Power Spectral Analysis

Period Analysis
- less popular than FFT
- Blockiness is an artifact of the plotting program

Visually Scored Sleep Stages
- Universally reported
- Blockiness is inherent in the analysis

(Armitage, *Biological Psychiatry*, 1995)

Frequency and Time Domain

Period Amplitude

Spectral Analysis

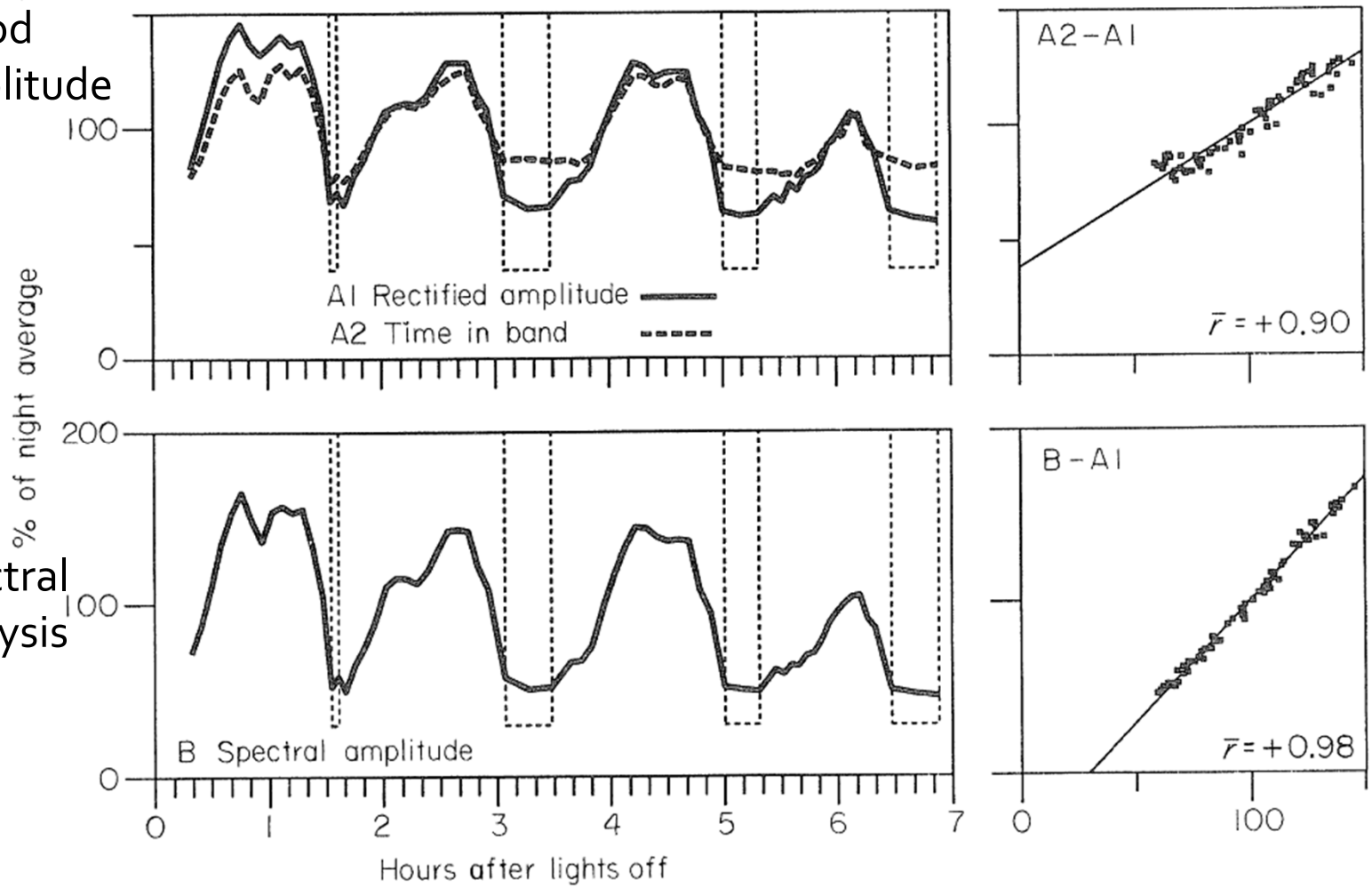
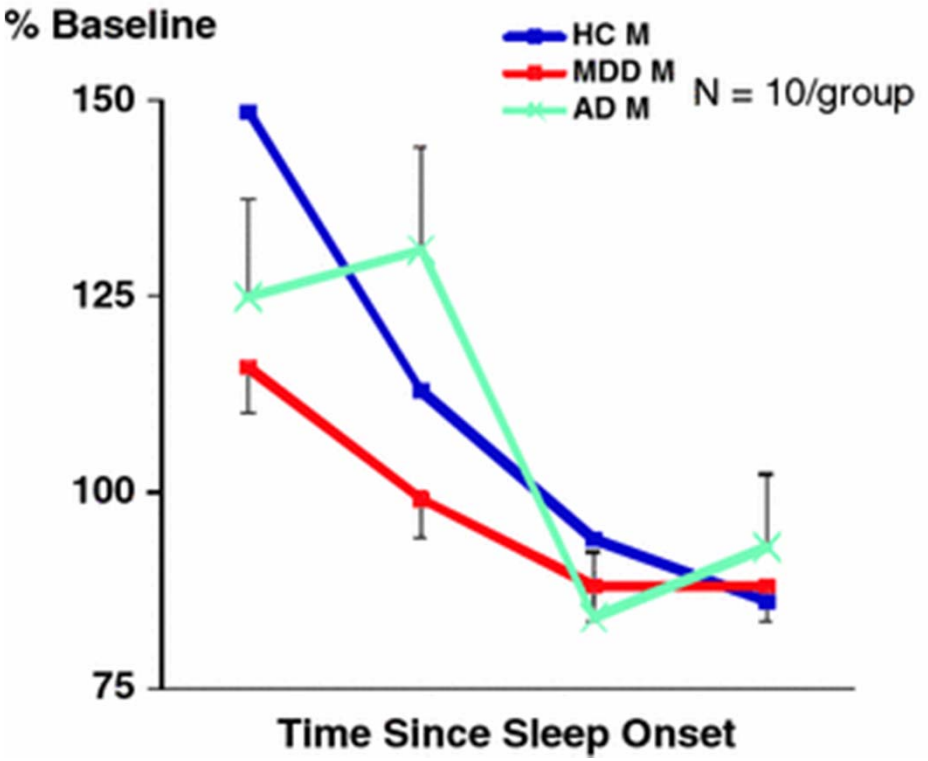


Figure 5. Comparison of variables derived from PAA (upper left) and PSA (lower left) in the low delta band (0.1–2.1 Hz). Synchronized average curves over all subjects ($N = 11$). REM sleep episodes are indicated by interrupted vertical lines. The right panels are scatterplots of pairs of the 68 average values constituting the curves in the left panels. Linear regression lines are indicated. Upper panel (A2–A1): time in band (vertical axis) *vs* rectified amplitude (horizontal axis). Lower panel (B-A1): spectral amplitude (vertical axis) *vs* rectified amplitude (horizontal axis). The indicated correlation coefficients ($\bar{r}$) are averages over 11 individual correlation coefficients ($N = 68$).

What To Do With This Data?

- Compute power of frequency bands across entire night, or in particular stages (e.g., REM or NREM
- Time course of delta power across the night



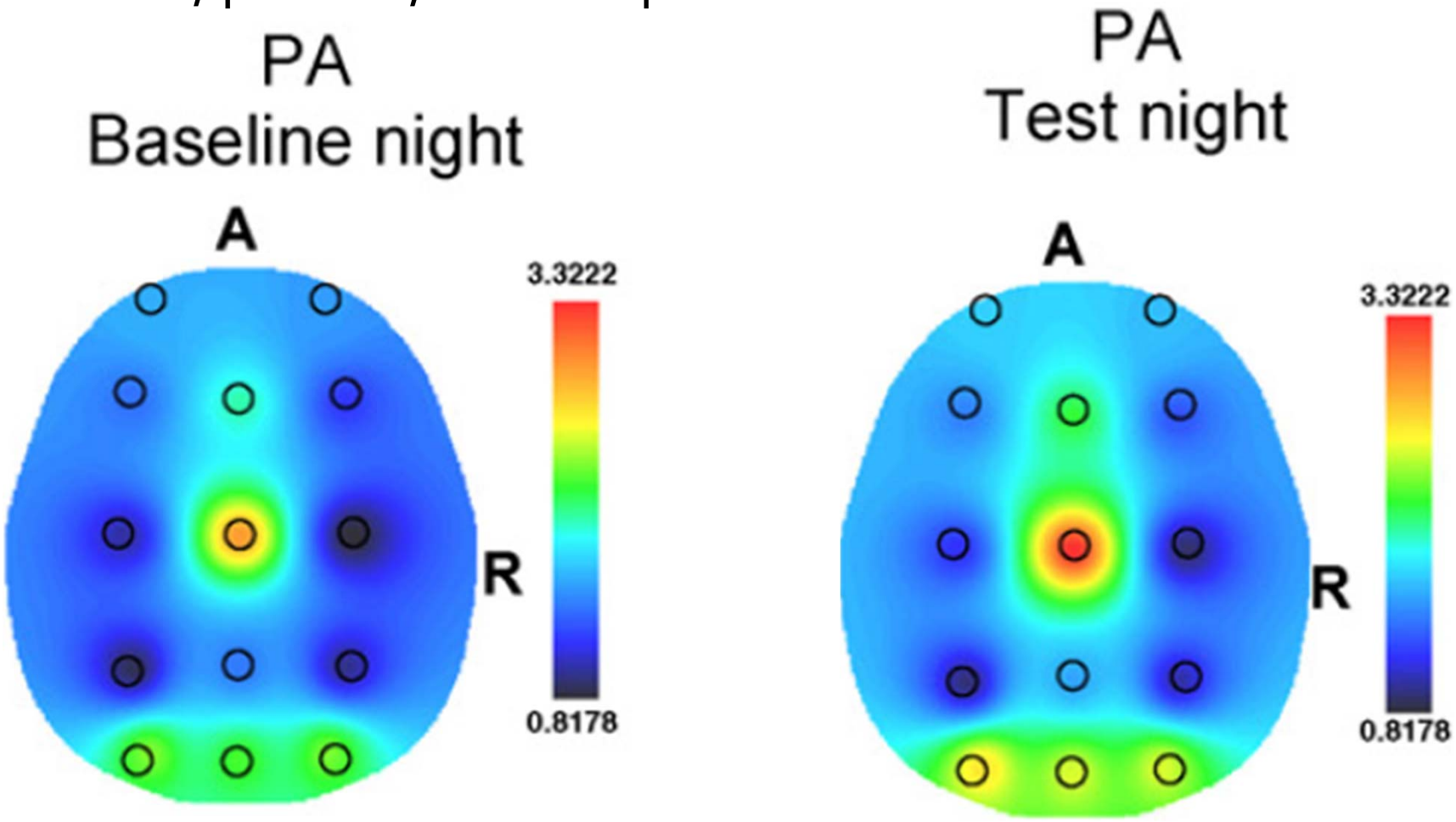
Brower et al., 2011

Want More EEG?

- While the standard montage for sleep studies contains only 6 EEG leads, more can be added
- Full 10-20 EEG montage can and is used regularly for nocturnal seizure studies and more in depth quantitative analysis

Changes in Theta Band During REM

After a learning task, theta power increases in frontal, central, parietal, and occipital leads



Fogel et al., 2007

Newer Methods

- These do NOT include measures of EEG ☹
- Home Sleep Apnea Testing
  - Respiratory channels
  - Pulse and blood oxygen
  - Body Position
- WatchPAT
  - Actigraphy
  - Pulse and blood oxygen
  - Peripheral Arterial Tone

http://www.kegohealthcare.ca/Products/Braebon_MediByte/Images1/MP8KN%20web%202.jpg

http://www.centerforsoundsleep.com/images/uars_watchPAT.jpg

Recapping Assessment Methods

- Questionnaires
- Observation
- Actigraphy
- Sleep Stage Scores
- Quantitative Analysis

Questions?

Special thanks to the faculty and staff of the University of Michigan Depression Center Sleep and Chronophysiology Laboratory for giving me my start in the scientific study of sleep and Dr. Richard Bootzin for continuing it

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