Scoring Sleep Stages: N2

AASM Stage N2 Definitions

- K complex: Well-delineated, negative, sharp wave immediately followed by a positive component standing out from the background EEG, with total duration of $\geq$0.5 seconds, and usually maximal in amplitude in the frontal derivations. For an arousal to be associated with a K complex, the arousal must either be concurrent with the K complex or commence no more than 1 second after the K complex ends

AASM Stage N2 Definitions

- Sleep spindle: Train of distinct sinusoidal waves with frequency 11-16 Hz (most commonly 12-14 Hz), with a duration of $\geq$0.5 seconds, and usually maximal in amplitude in the central derivations

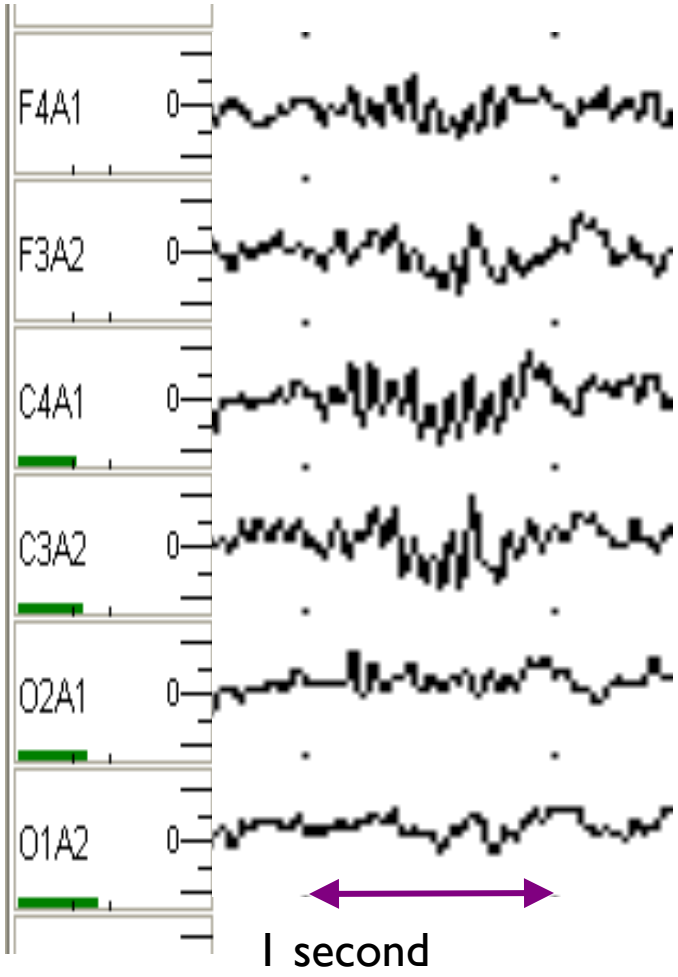
Sleep Stage N2

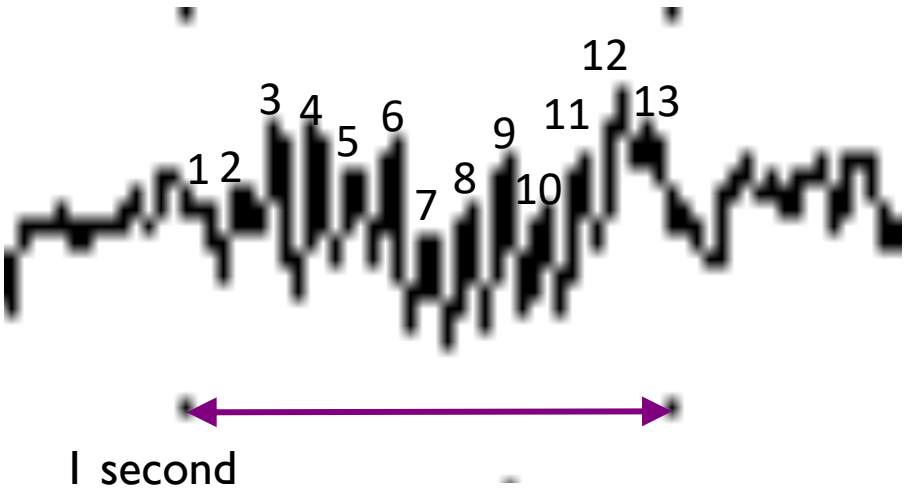
1. Contains sleep spindles, K complexes, or both
2. No more than 20% of epoch may contain slow wave activity
3. Eye movements are usually absent
4. N2 usually accounts for 40-50% of the major sleep period in adults

Sleep Spindles

- Sleep spindles occur with a frequency of 11 to 16 Hz and last greater than or equal to 0.5 seconds. The name derives from the overall shape of the activity, which may wax and wane to produce a burst of activity that looks like a spindle for yarn or thread. Spindles are thought to arise from reverberating activity between the thalamus and the cortex. Spindles are sinusoidal waves that are usually largest in the central regions but can occur frontally as well. Spindles may occur in or around K complexes. Compare the frequency and distribution of spindles to that of alpha activity to learn how to differentiate between the two rhythms.
- Amplitude seldom exceeds 50 uV in the adult. Sleep spindle morphology and intraburst frequency may vary with age.

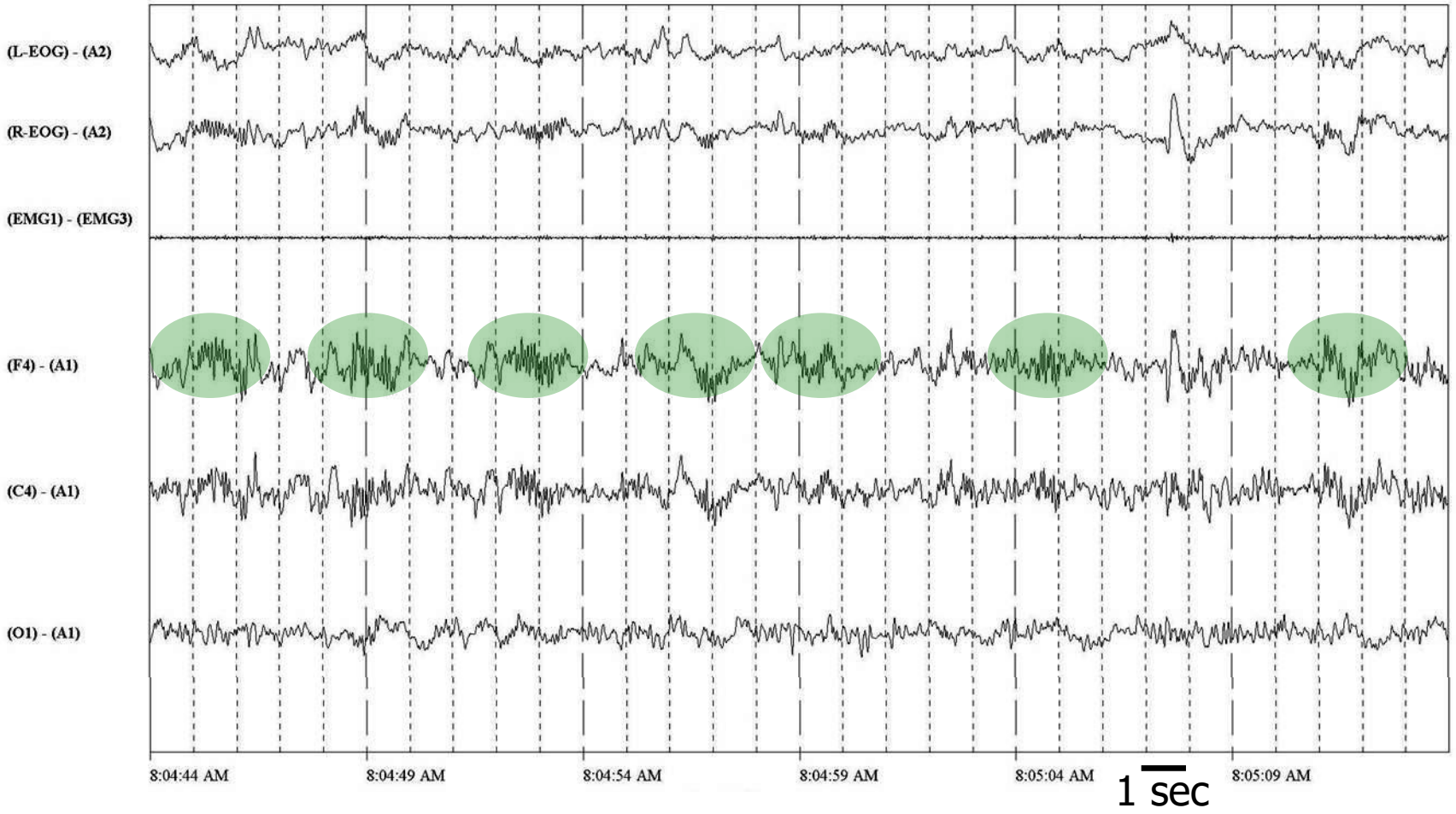
Sleep Spindles





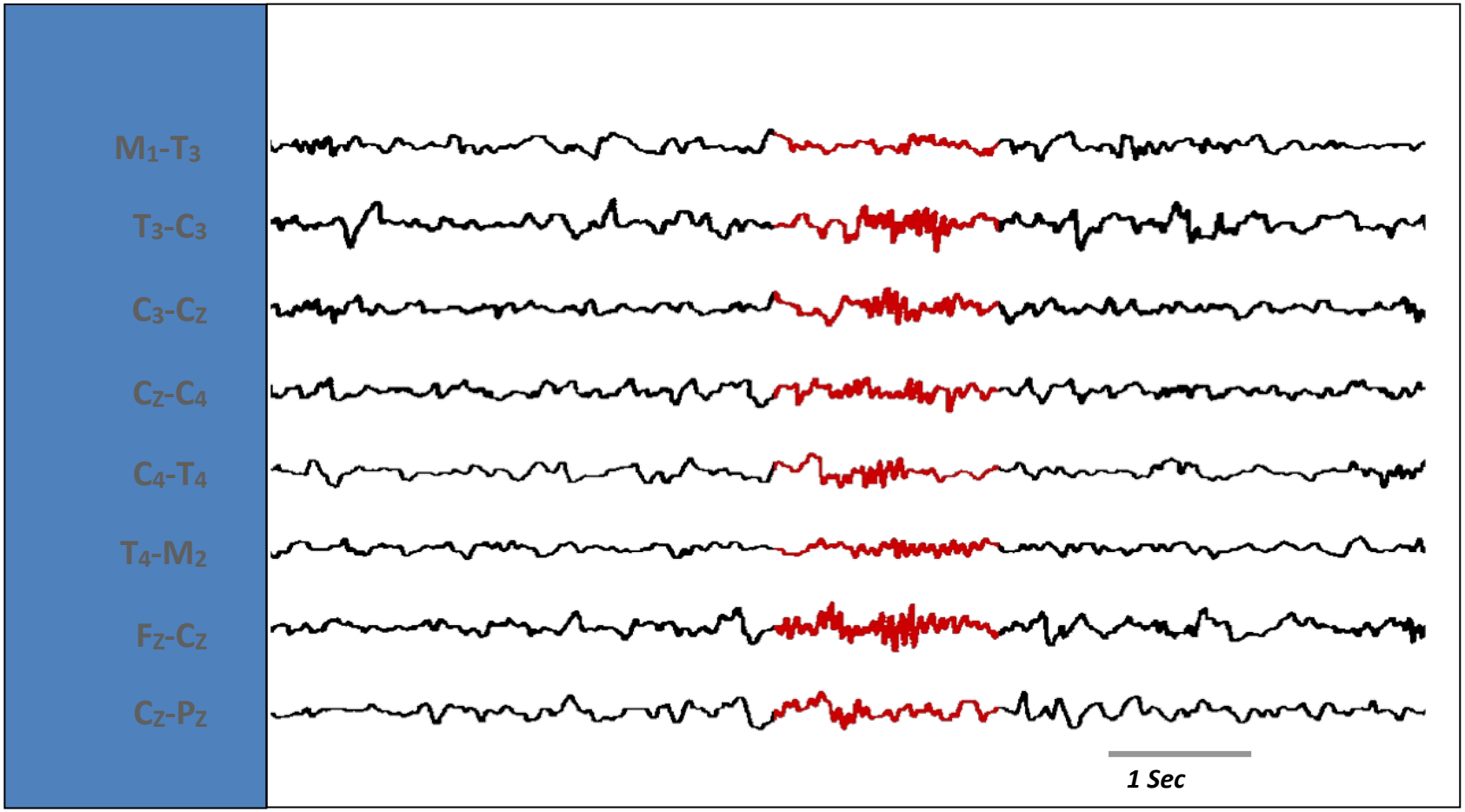
A train of distinct waves with frequency 11 – 16 Hz with a duration ≥ 0.5 seconds, usually maximal in amplitude using central derivations.

Sleep Spindles



Multiple sleep spindles are highlighted in green on this slide.

Sleep Spindles Distribution

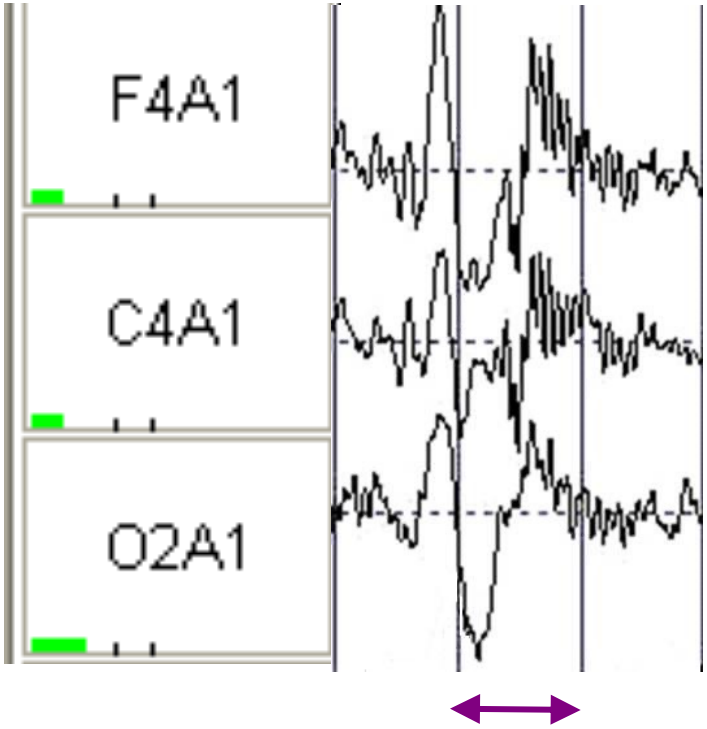


This illustration shows the scalp distribution of sleep spindle activity in a normal volunteer. We can see that the waveform (in red) is represented maximally at the central and frontal midline electrode pair. Common activity in the bipolar pairs shown here reduce amplitude; nonetheless, central derivations all reveal this event.

Sleep Spindles

- Sleep spindle activity is thought to be distributed through thalamocortical pathways. Sleep spindle activity is known to increase in response to benzodiazepines. The increase can be in the number of spindles, the duration of spindles, and/or the amplitude of spindles. Sleep spindles are one of the fundamental defining characteristics of sleep stage N2.

K Complex

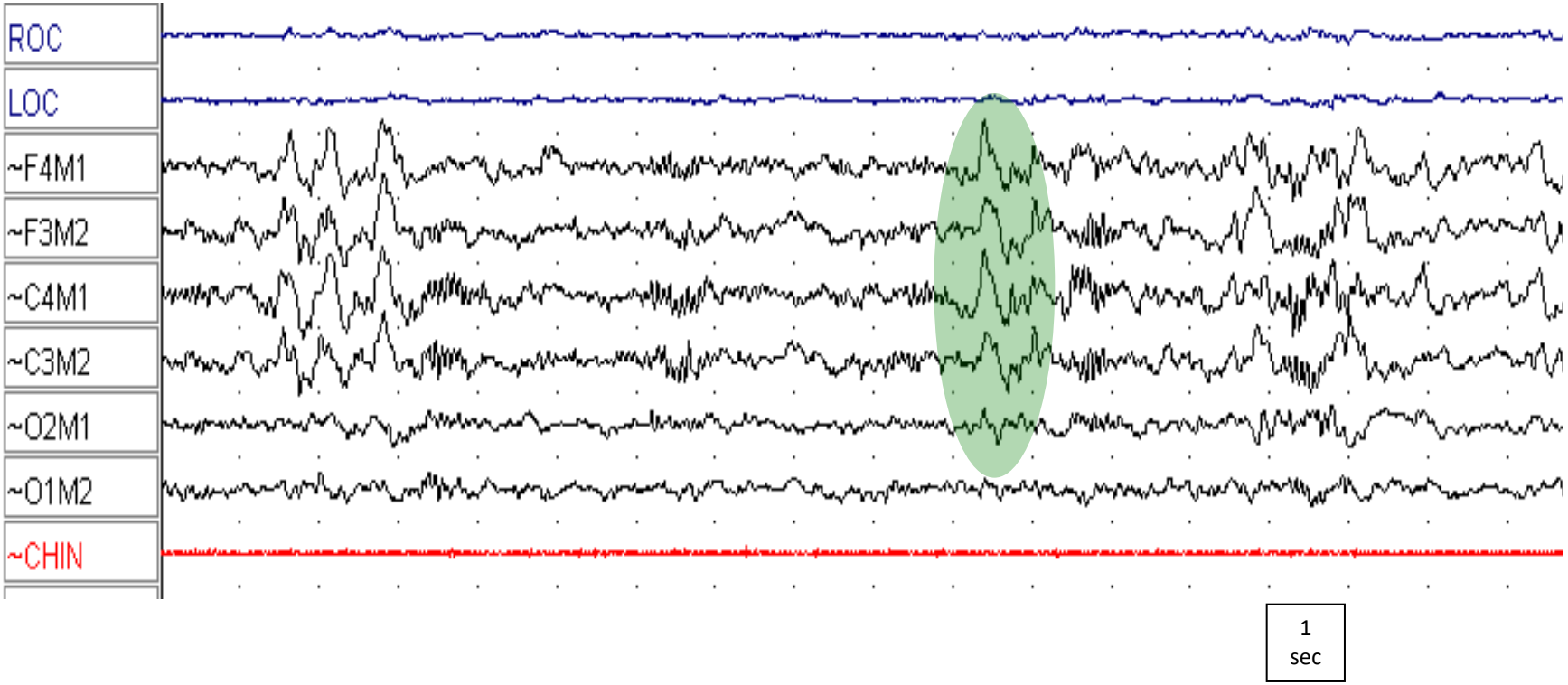


A well-delineated negative sharp wave immediately followed by a positive component standing out from the background EEG, with total duration ≥ 0.5 seconds, usually maximal in amplitude when recorded using frontal derivations.

1 second

A K complex starts with a negative sharp wave (upward deflection) followed by a positive component. Like the vertex wave, K complexes must stand out from the background activity. The total duration of the K complex must last 0.5 seconds or longer; the duration criterion distinguishes K complexes from vertex waves. Sleep spindles may precede, follow or occur during K complexes, but this is not a requirement for their identification.

K Complex

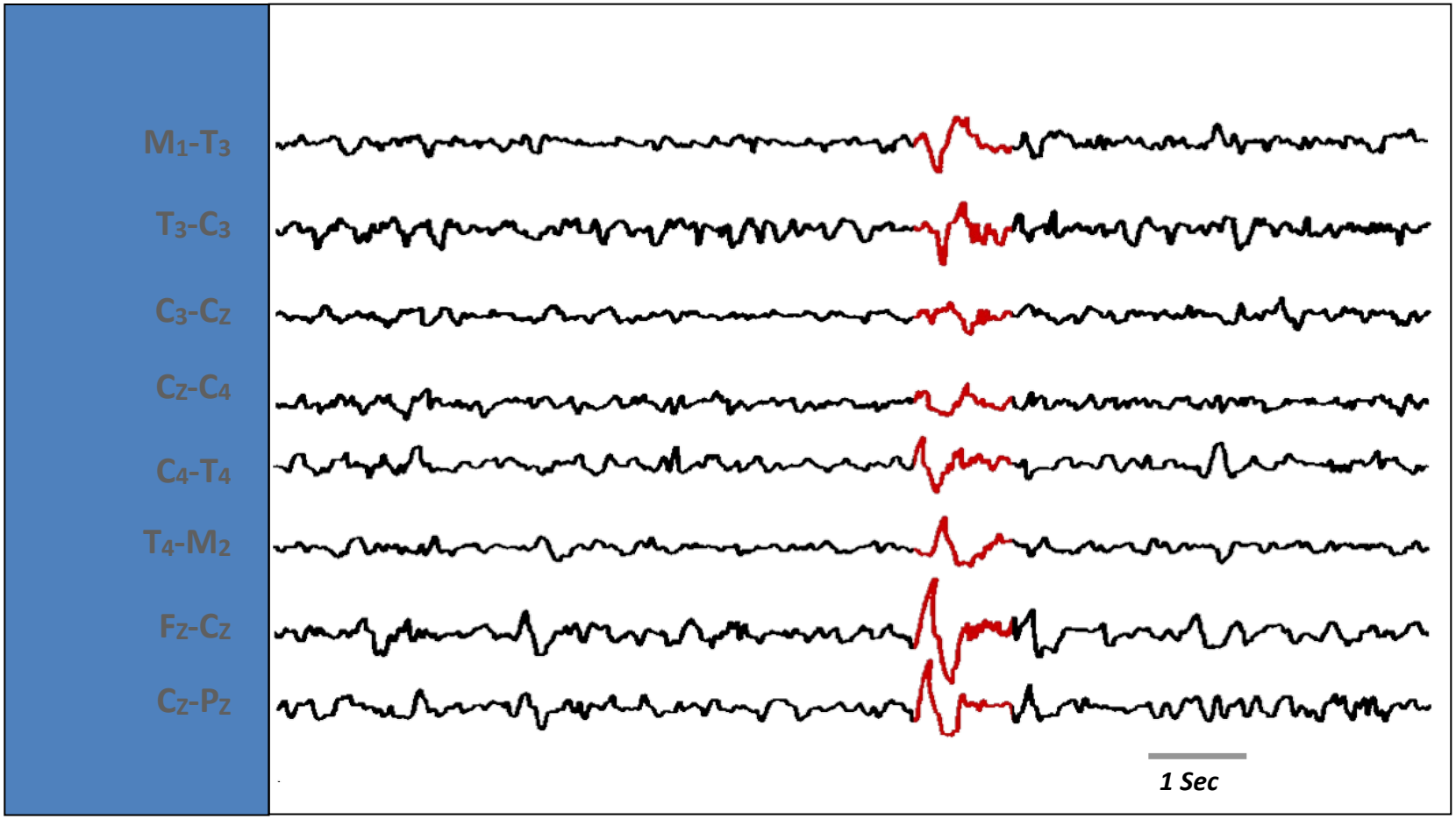


An example of a K complex is highlighted in green on this slide. The K complex is a high voltage (relative to background) biphasic slow or sharply contoured wave which is not an eye movement artifact. Eye movement artifact can usually be recognized by out-of-phase activity in ROC-M2 compared with LOC-M2.

K Complex

- When recorded with standard polysomnographic technique, a K complex has a well delineated negative sharp wave (upward deflection) which is immediately followed by a positive component (downward deflection). The total duration of the K complex should last 0.5 seconds or longer. If a sleep spindle occurs immediately after the positive component, it is considered part of the K complex. The K complex is generally maximal in recordings derived from the frontal regions. Although K complexes can occur in response to external stimuli, they frequently occur spontaneously.

K Complex Distribution



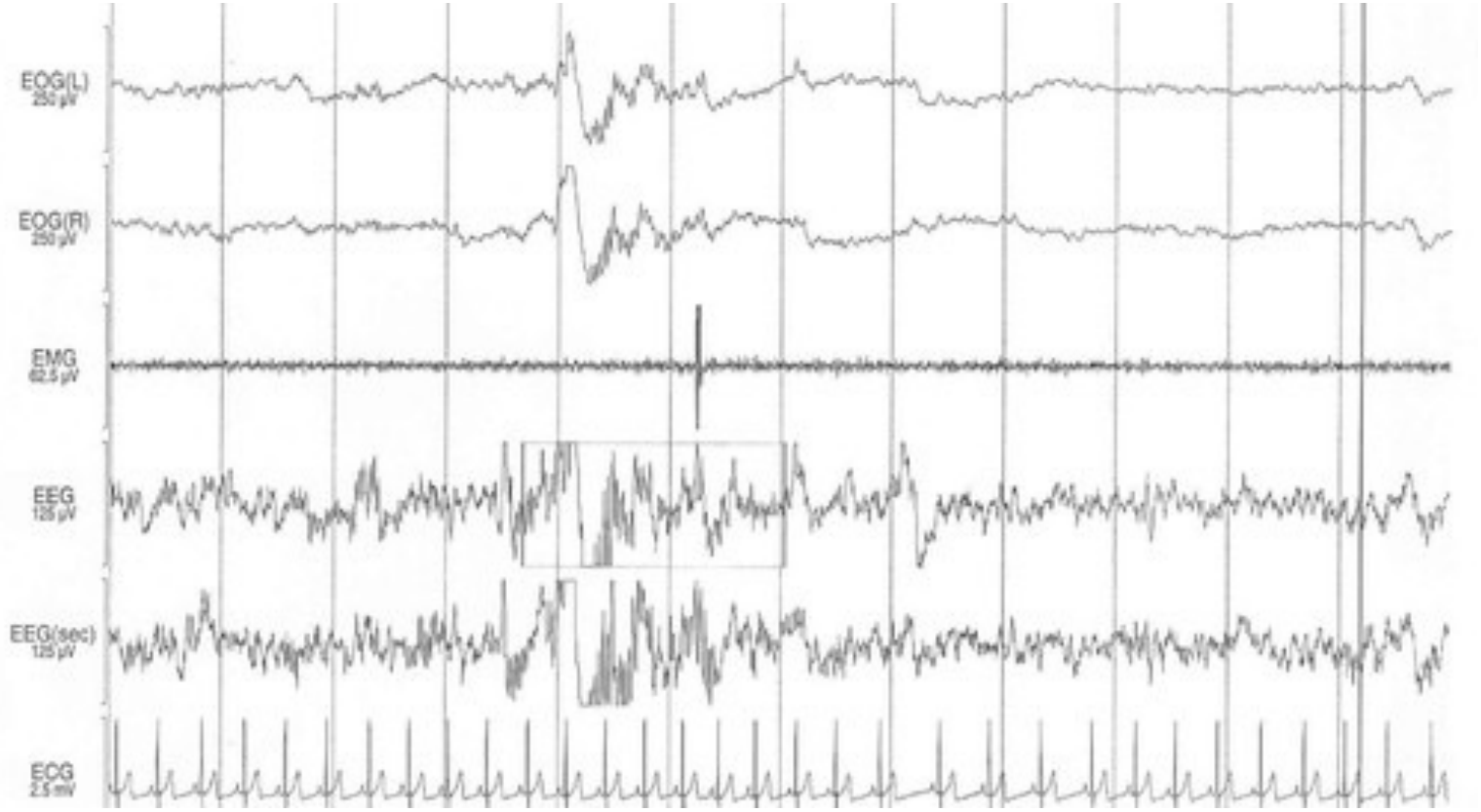
This illustration shows the scalp distribution of a K complex (in red) recorded from a normal volunteer. Maximum amplitude for the waveform occurs at the central and frontal midline electrode pair. In this recording, diminished amplitude is observed in intracentral lobe recordings due to common activity at both electrodes of the pair differentially amplified. Polarity reversals can be seen as recordings descend from the vertex to temporal derivations.

K Complex

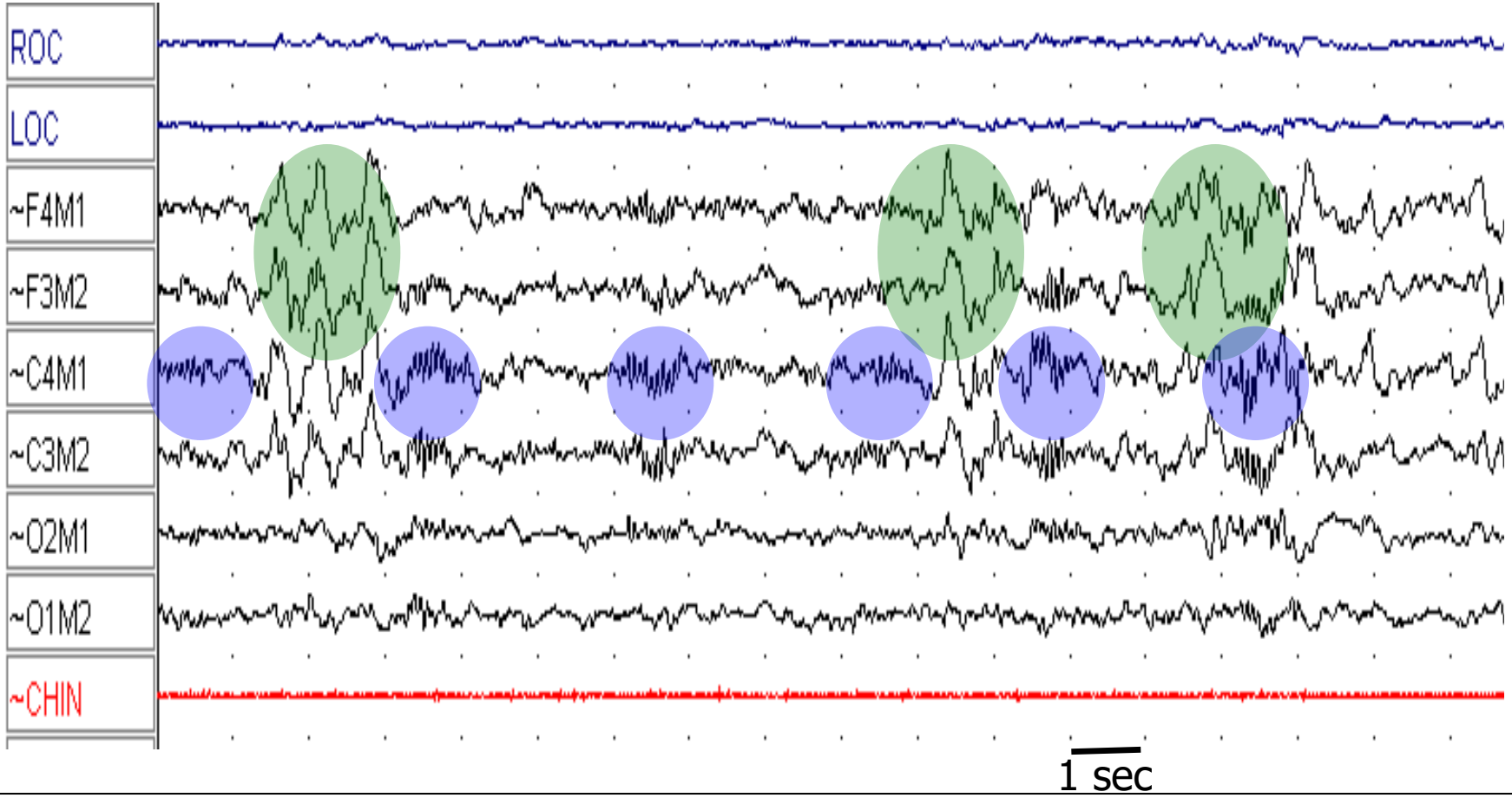
- Research indicates that arousals are more likely during a several minute interval following a K complex. The term K-complex is derived from research demonstrating that these waveforms would arise when researchers would knock on the door of a sleeping subject. Another phenomena, K alpha, has also been investigated with respect to arousal. K complex reduction may occur as a result of drug ingestion (e.g., benzodiazepines); aging-related decreases in K complex activity have also been reported.

K-Arousals

- For an arousal to be associated with a K complex, the arousal must be concurrent with the K complex or occur no more than 1 second after the K complex concludes



Sleep Stage N2



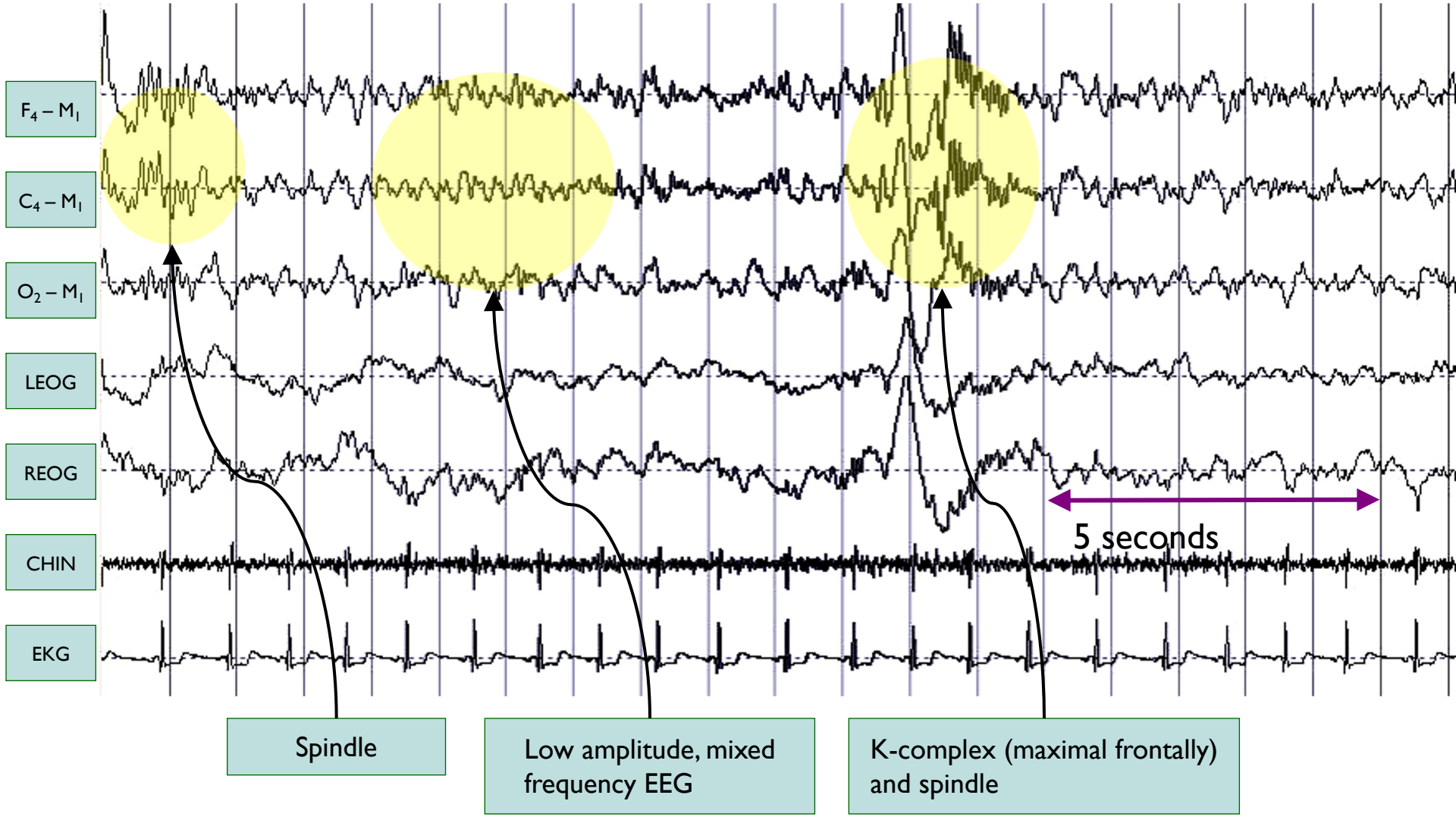
This slide shows an epoch scored as sleep stage N2. This 30-second polysomnographic tracing contains both sleep spindles (highlighted in blue) and a K complex (highlighted in green). Alpha rhythm has completely disappeared and there are no eye movements. EMG from submentalis shows reduced amplitude.

Stage Scoring Rules – N2

A. Begin scoring stage N2 if EITHER or BOTH of the following occur during the first half of the epoch or the last half of the previous epoch:
   - One or more K complexes unassociated with arousals
   - One or more sleep spindles

B. Score a given epoch as N2 if the majority meets criteria for N2.

Stage N2


$F_4 - M_1$
$C_4 - M_1$
$O_2 - M_1$
LEOG
REOG
CHIN
EKG
5 seconds
Spindle
Low amplitude, mixed frequency EEG
K-complex (maximal frontally) and spindle

Stage Scoring Rules – N2 (cont)

C. Continue to score epochs with LAMF EEG activity without K complexes or sleep spindles as stage N2 if they are preceded by epochs containing EITHER of the following without an intervening arousal:
    A. K complexes unassociated with arousals
    B. Sleep spindles.

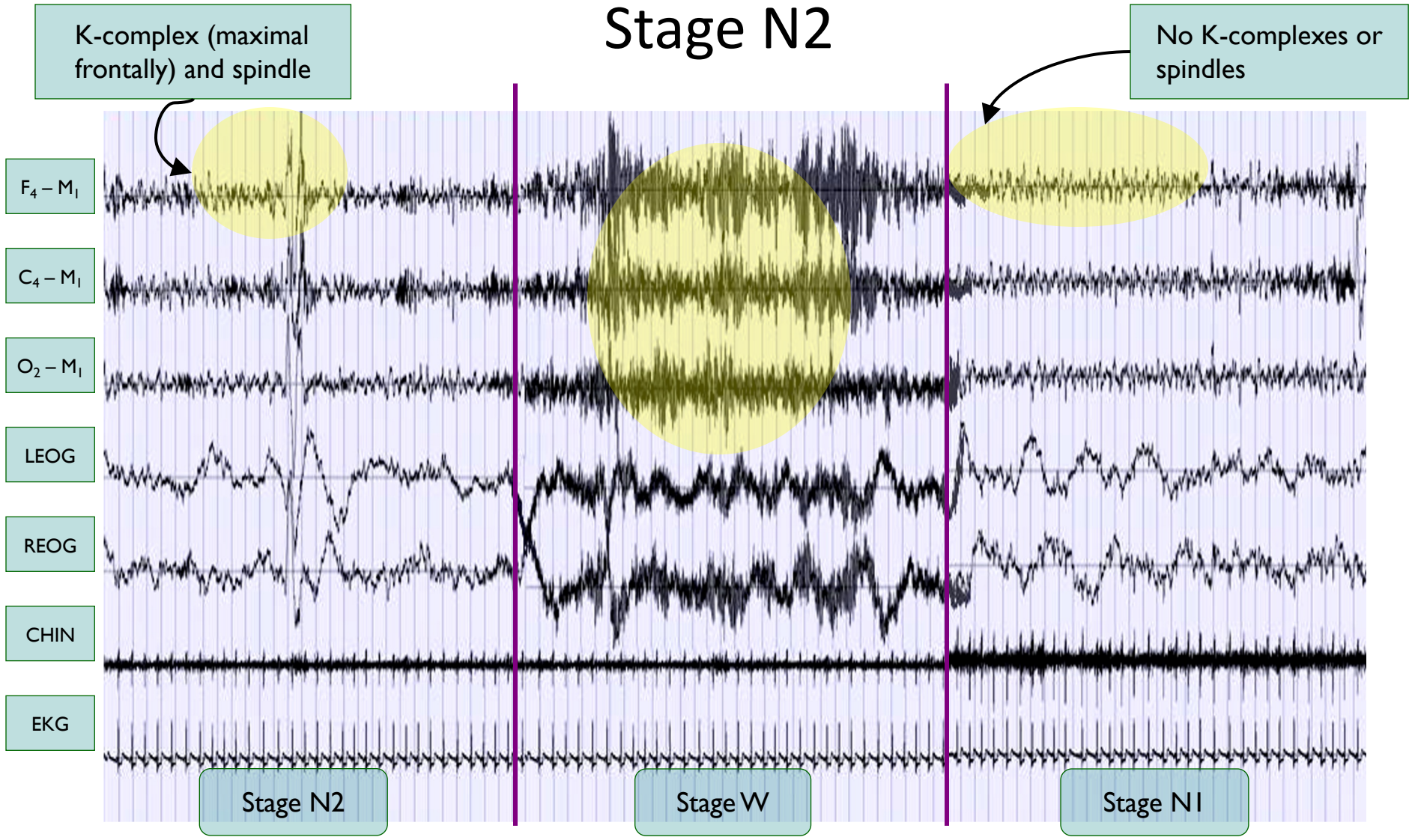
D. Epochs following an epoch of N3 that do not meet criteria for N3 are scored as N2 if there is no intervening arousal and the epoch does not meet criteria for Wake or REM.

Stage Scoring Rules – N2 (cont)

End stage N2 sleep when one of the following events occurs:

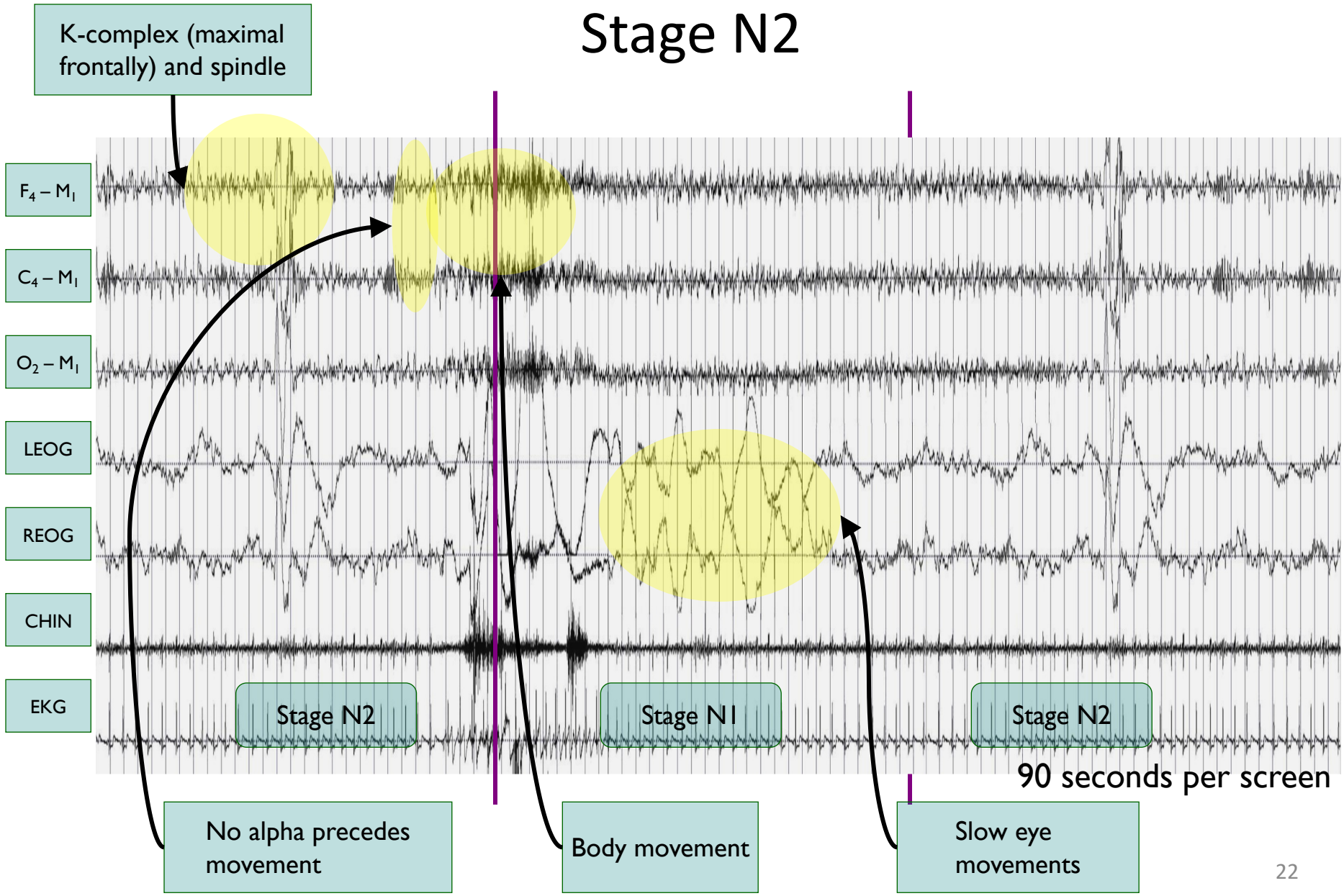
a. Transition to stage W
b. An arousal followed by LAMF EEG (change to stage N1 until a K complex unassociated with an arousal, or a sleep spindle occurs)
c. A major body movement followed by slow eye movements and LAMF EEG without non-arousal associated K complexes or sleep spindles
d. Transition to stage N3
e. Transition to stage R

Stage N2

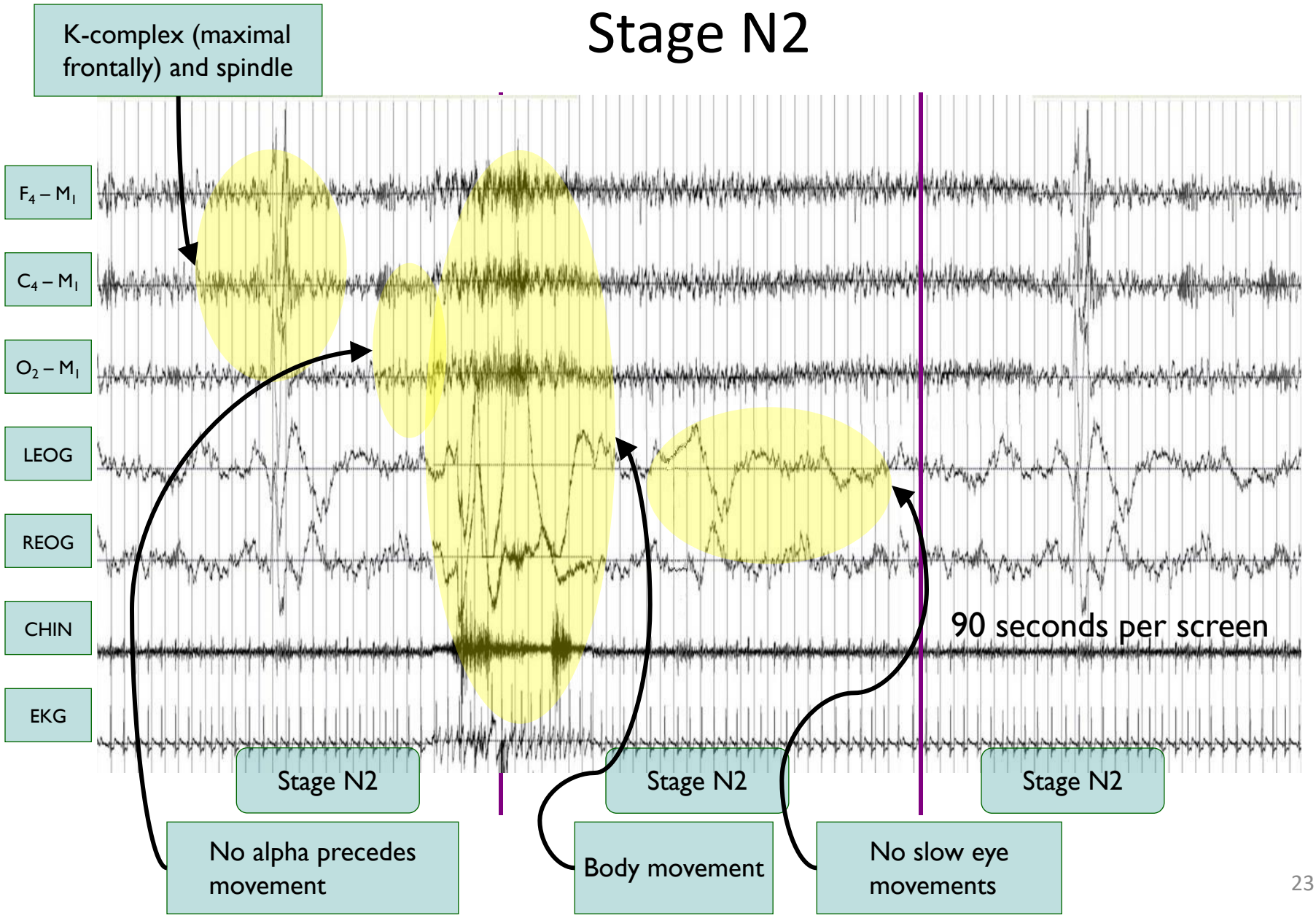


90 seconds per screen

Stage N2


K-complex (maximal frontally) and spindle
F4 – M1
C4 – M1
O2 – M1
LEOG
REOG
CHIN
EKG
Stage N2
Stage N1
Stage N2
90 seconds per screen
No alpha precedes movement
Body movement
Slow eye movements

Stage N2


K-complex (maximal frontally) and spindle
F4 – M1
C4 – M1
O2 – M1
LEOG
REOG
CHIN
EKG
90 seconds per screen
Stage N2
Stage N2
Stage N2
No alpha precedes movement
Body movement
No slow eye movements

Notes for N2

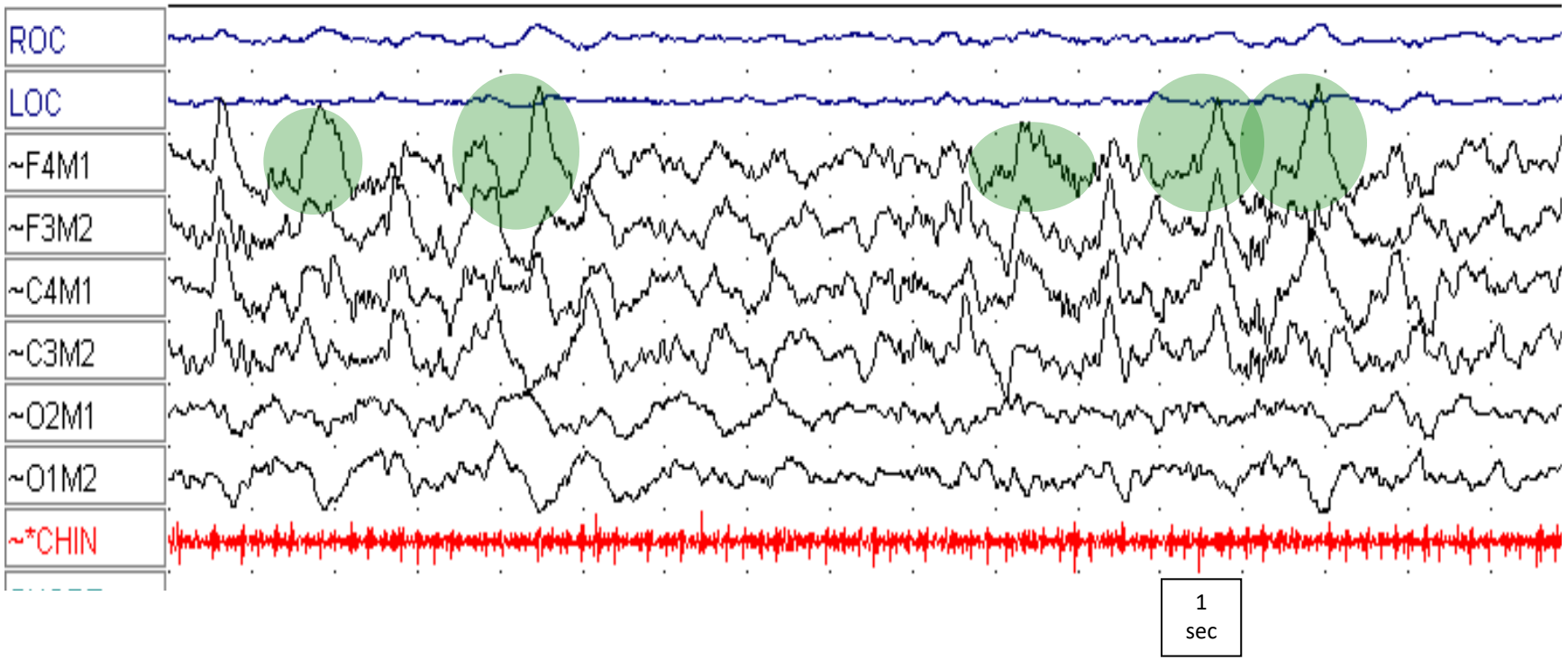
- Definite N2 contains K complexes and spindles
- Continue to score N1 for epochs with arousal-associated K complexes until they contain sleep spindles or K complexes not associated with arousals
- EOG usually shows no eye movements in N2, but some individuals may still have SEMs
- Chin EMG is of variable amplitude, but usually lower than Wake and may be as low as REM

Scoring Sleep Stages: N3

Slow Waves

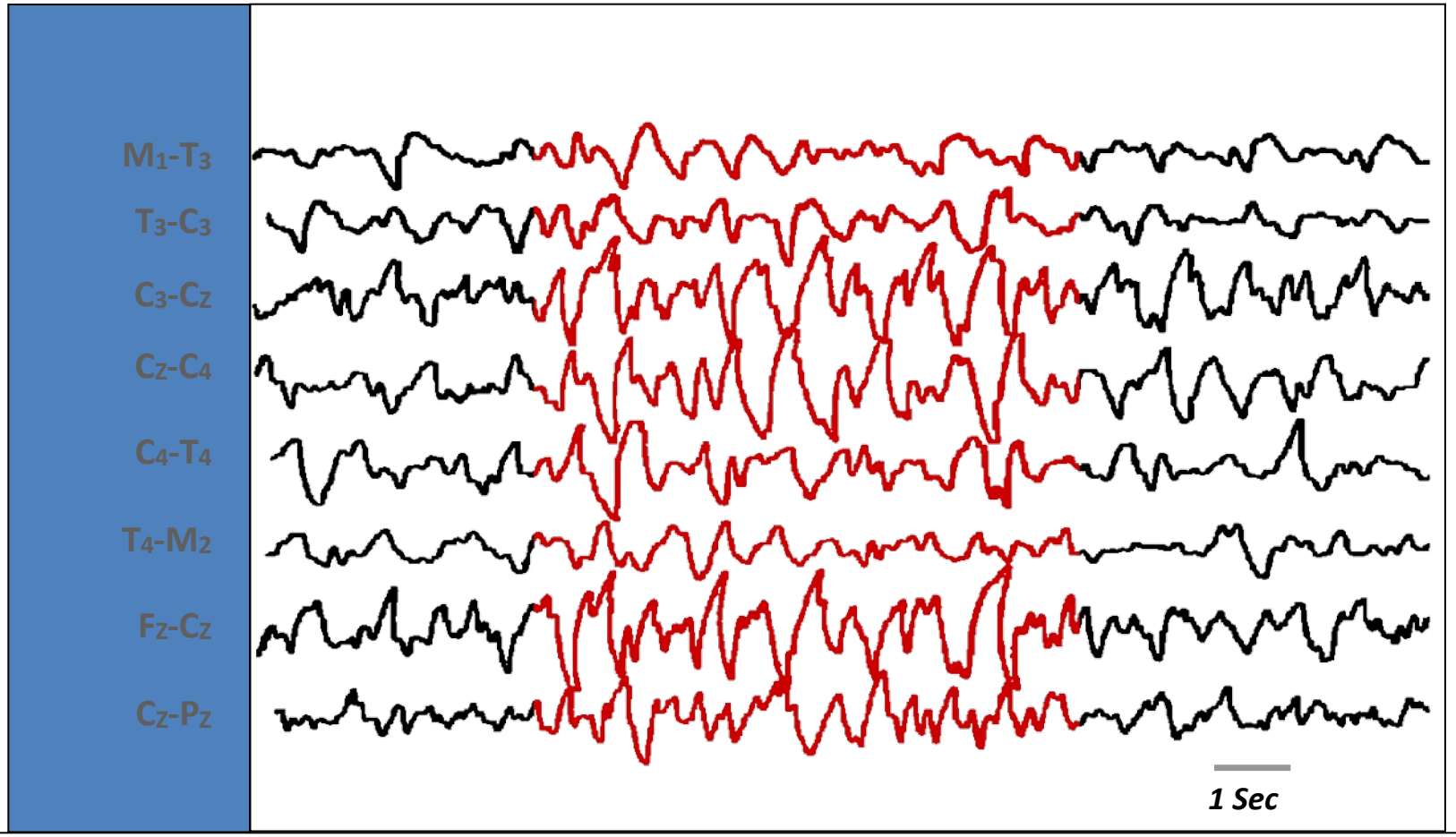
- In human sleep scoring, the minimum characteristics for scoring slow waves are conventionally 75 microvolts or greater in amplitude, and 0.5 Hz to 2 Hz in frequency. Slow waves are most prominent in the frontal leads.

Slow Waves



Slow waves are highlighted in green on this slide.

Slow Wave Distribution



Slow wave activity (shown in red on this slide) is maximal when recorded with monopolar frontal leads.

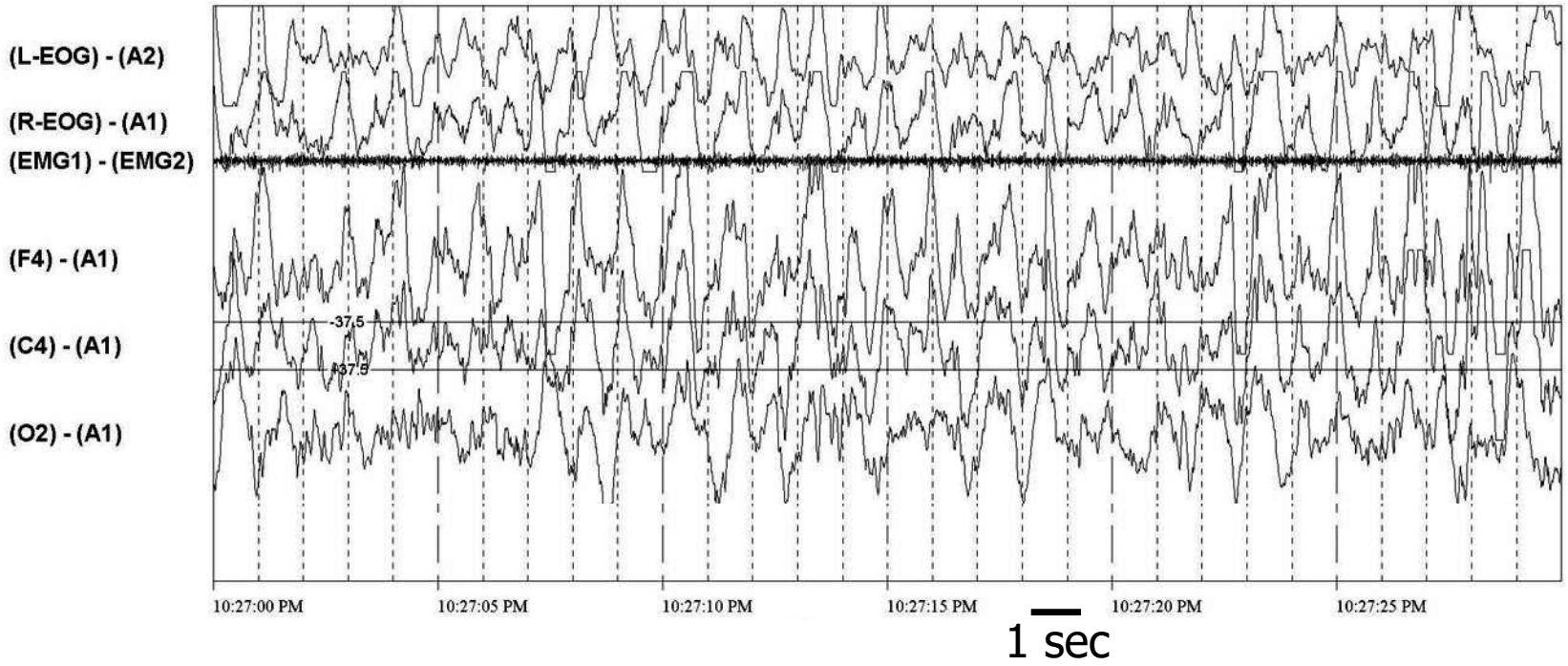
Slow Waves

- However, slow wave activity occurs prominently across all scalp derivations during slow wave sleep. Polarity reversals across hemispheres and across the dipole are obvious. Waves are typically high amplitude and "synchronized." Slow wave activity is the defining characteristic of sleep stage N3. Slow wave amplitude is so great in children, many laboratories "down calibrate" (reduce the sensitivity of) EEG channels to prevent pen blocking. Slow wave amplitude typically declines with advancing age.

Sleep Stage N3

1. High amplitude (> 75 uV over frontal region) slow waves constitute greater than 20% of the recording epoch
2. Sleep spindles may be present
3. Eye movements are absent

Sleep Stage N3

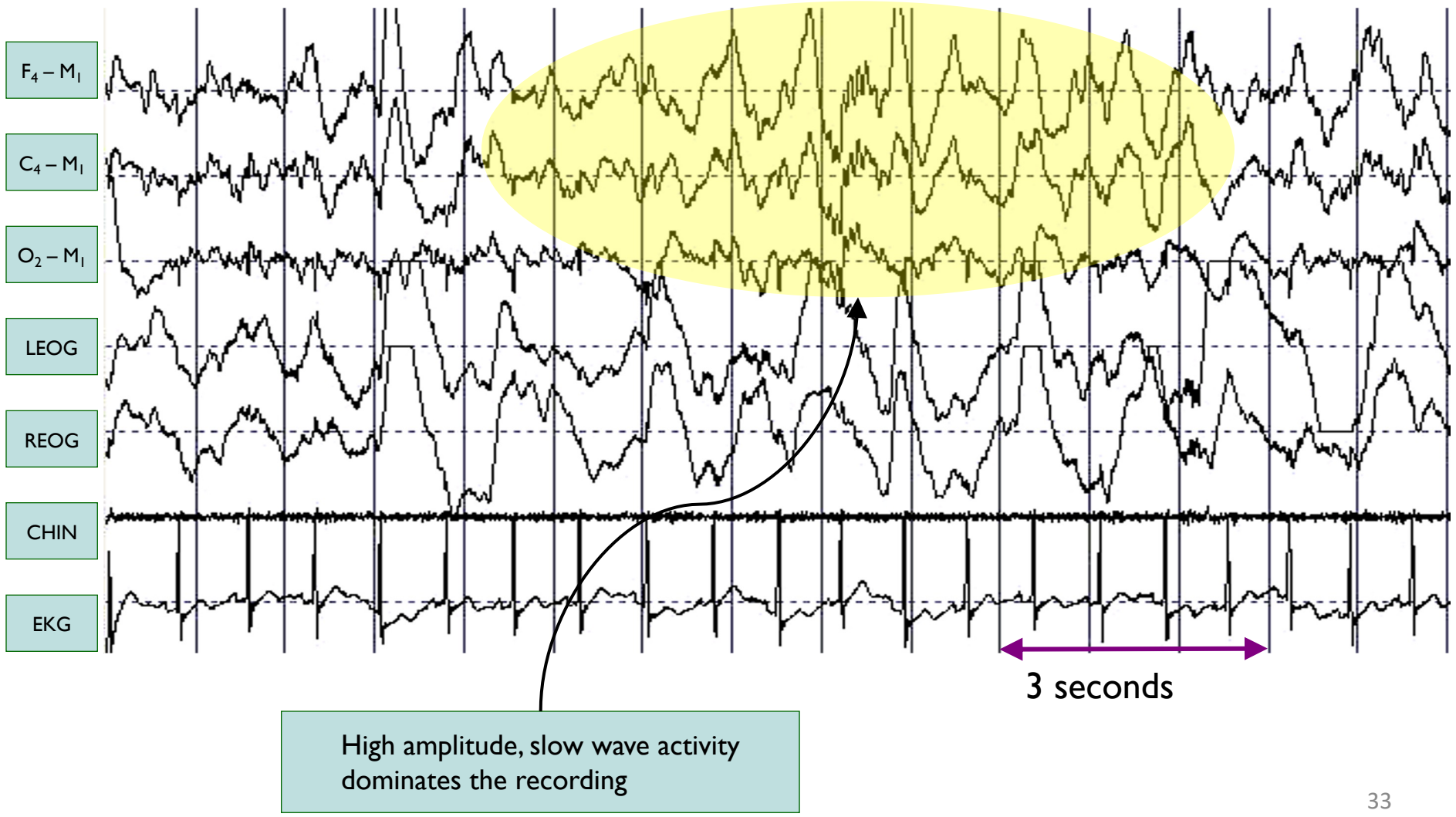


This slide provides an example of sleep stage N3. The 30-second polysomnographic epoch clearly meets criteria for classification as N3 sleep, with most of the EEG demonstrating large, slow waves. The activity in eye channels is also slow wave activity, present because outer canthi loci detect frontal lobe slow wave activity. The synchrony between eye channels and coherence with monopolar central lobe tracings rule out this activity as indicating eye movements. Submentalis EMG activity is reduced but still tonic.

Stage Scoring Rules – N3

A. Score stage N3 when ≥20% (6 seconds or more) of an epoch consists of slow wave activity, irrespective of age.

Stage N3


F4 – M1
C4 – M1
O2 – M1
LEOG
REOG
CHIN
EKG
3 seconds
High amplitude, slow wave activity dominates the recording

Notes for N3

- N3 represents slow wave sleep and replaces R&K's stage 3 and stage 4 sleep
- K complexes would be considered slow waves if they meet the definition of slow wave activity
- Seizure activity may look like delta waves, but this activity would not be N3 sleep
- Sleep spindles may persist in N3
- Eye movements not typically seen
- Chin EMG is of variable amplitude, often lower than N2 and sometimes as low as REM

Notes for N3

- Due to reported difficulty correctly identifying qualifying slow waves, 75 uV lines inserted in the recording or identification of delta waves by concurrent digital analysis, may assist the scorer.