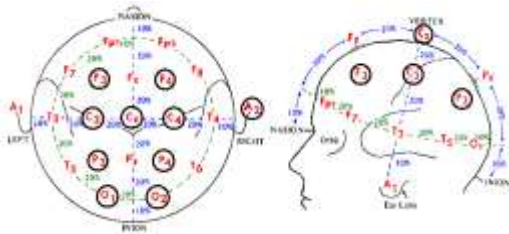


## Normal EEG in children

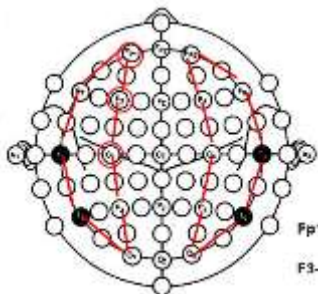
### EEG workshop

Sorawit Viravan

#### International 10-20 system



AP bipolar montage (double banana):  
for localization



## Electrode placement

- **International 10-20 system**
  - Minimum 21 electrodes
  - Odd-numbered electrodes are placed on the left side of the head, and even-numbered electrodes are placed on the right side of the head
  - Specific letters designate the anatomical area; for example "F" means frontal

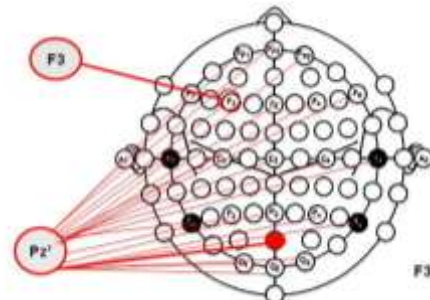


## Common Montage types

The difference in voltage between two electrodes

- **Bipolar:**
  - Each channel represents difference between 2 adjacent electrodes
  - AP bipolar
  - Coronal / transverse bipolar
- **Referential:**
  - Each channel represents the difference between a certain electrode and the designated reference position
  - ipsilateral ear
  - average
  - midline, etc.

Referential montage:  
for amplitude measurement



## EEG activity

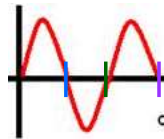
- Waveform
- Frequency
- Amplitude
- Polarity
- Timing

## Wave form

- Spike
  - Sharply contoured, duration 20-70 msec
- Sharp wave
  - Sharply contoured, duration 70-200 msec
- Sharp transient
  - Sharply contoured waveform
- Other morphology
  - spindles, arciform, saw-tooth

## Wave form

- Monophasic wave
  - Single deflection: up or down
- Diphasic wave
  - 2 components on opposite sides
- Polyphasic wave
  - 2 or more components of different direction



## Frequency

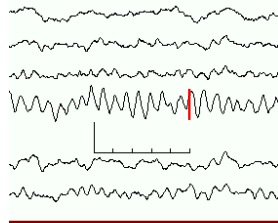
- Delta wave < 4 Hz
- Theta wave 4-7 Hz
- Alpha wave 8-13 Hz
- Beta wave > 13 Hz



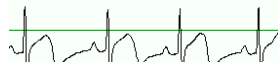
## Amplitude

Total vertical distance of wave

- Low < 20  $\mu$ V
- Medium 20-50  $\mu$ V
- High > 50  $\mu$ V



Affected by barriers



## Distribution

- Generalized / diffuse
- Lateralized
- Focal / localized

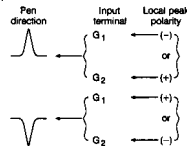
## Polarity

### Bipolar (input 1 – Input 2)

- Upward pen deflection
  - when input 1 is more negative than input 2
  - when input 2 is more positive than input 1
- Downward deflection
  - when input 1 is more positive than input 2
  - when input 2 is more negative than input 1

### Referential (Input 1 – Ref)

- negative is up and positive is down



## Timing

- Synchronous
- Bilaterally synchronous
- Asynchronous
- Independent

## Pediatric EEG

### EEG in newborn

- Post conceptional age
- Duration at least 60 minutes
- Awake / Active sleep / Quiet sleep
- Continuity / Synchrony
- Symmetry / Reactivity
- Normal specific EEG pattern

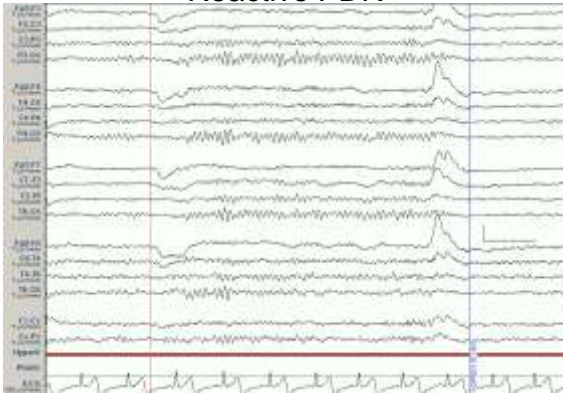
### Awake

- Posterior dominant rhythm (PDR)
- Posterior slow wave of youth (PSWY)
- Mu rhythm
- Beta activity
- Lambda wave
- Eye movement
- Artifact

### PDR

- Alert, eye-closed, in rest state
- First seen at 3 months of age
- Maximum posterior head region
- Reactivity
  - Attenuation with eye opening,  $\pm$  anxiety

## Reactive PDR



## PDR

- Higher amplitude over right hemisphere (< 50% difference) due to asymmetric skull thickness
- Amplitude ~ 50-100  $\mu$ V
- Decreasing amplitude with increasing age due to increased bone density of the skull

## PDR

Frequency in Children

3-4 months:	4 Hz
12 months:	5-6 Hz
2 years:	7 Hz
3 years:	8 Hz
9 years:	9 Hz
15 years:	10 Hz

## PSWY

- Slow activity intermixed with PDR
- Moderate voltage (<120% of normal alpha rhythm voltage)
- May be asymmetry
- Best seen in 8-14 years
- Block with eye opening
- Disappear with the alpha rhythm during drowsiness and light sleep

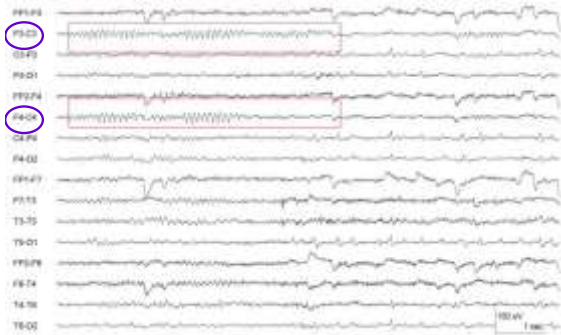
## PSWY



## Mu

- central arch-like rhythm of alpha frequency (usually 8-10 Hz)
- May be related to the functions of the sensorimotor cortex at rest
- Best seen between 8-16 years
- Asymmetrical
- Blocked unilaterally with movement of the contralateral extremity
- Not blocked by eye opening

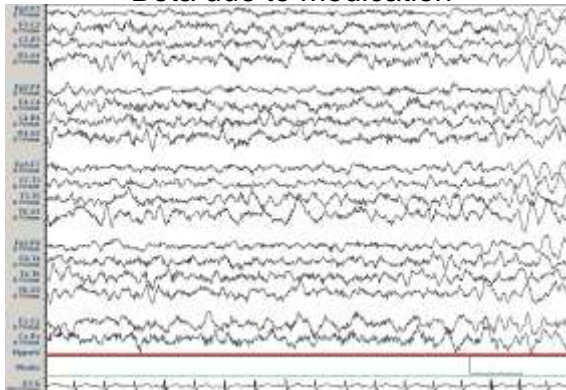
### Mu rhythm



### Beta

- Frequencies more than 13 Hz
- Amplitude < 20 uV, usually < 10 uV
- Three band
  - 18-25 Hz band (common)
  - 14-16 Hz band (less common)
  - 35-40 Hz band (rare)
- Increased by
  - Drugs eg. barbiturate, benzodiazepine, chloral hydrate (18-25 Hz > 14-16 Hz)

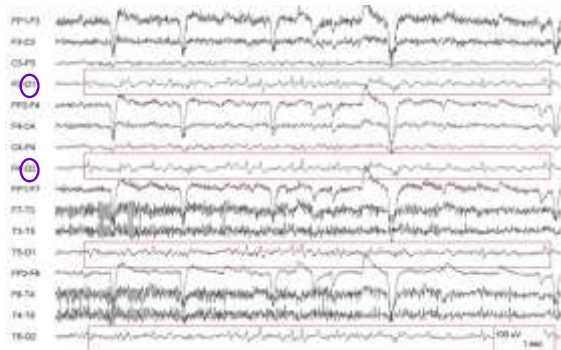
### Beta due to medication



### Lambda wave

- Surface positive, check mark-like wave
- Occipital region
- During eye opening
- Visually scanning at complex picture (ceiling, TV etc.) with saccadic eye movement
- Best seen in 2-15 years
- May be asymmetrical

### Lambda



### Eye movement (EM)

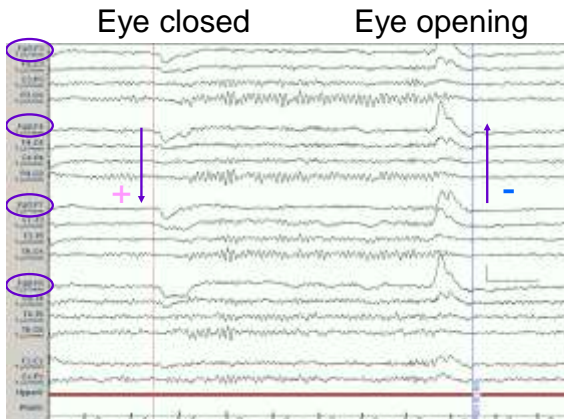
- Vertical EM (Fp1, Fp2)
- Eye opening
  - Eye closure
  - Eye blinking
- Horizontal EM (F7, F8)
- To the left
  - To the right

## Eye movement (EM)

- Cornea → positivity
- Retina → negativity
- Nearest electrode of the direction of EM will pick up positivity, the opposite electrode will pick up negativity

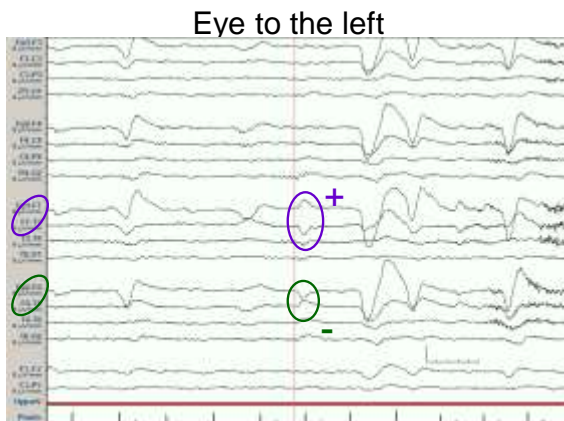
## Vertical EM

- Eye closure (relatively eyes go up)
  - Fp1 and Fp2 pick up positivity
  - downward deflection at Fp1-F7, Fp2-F8
- Eye opening (relatively eyes go down)
  - Fp1 and Fp2 pick up negativity
  - upward deflection at Fp1-F7, Fp2-F8

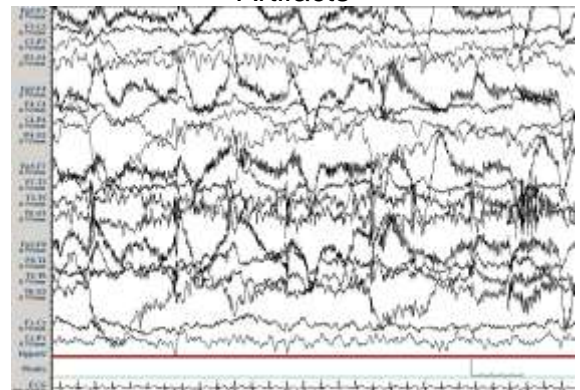


## Horizontal EM

- Eye turn to the left
  - F7 pick up positivity, F8 pick up negativity
  - positive phase reversal at F7 (Hole)
  - negative phase reversal at F8
- Eye turn to the right
  - F8 pick up positivity, F7 pick up negativity
  - positive phase reversal at F8 (Hole)
  - negative phase reversal at F7



## Artifacts



## Sleep

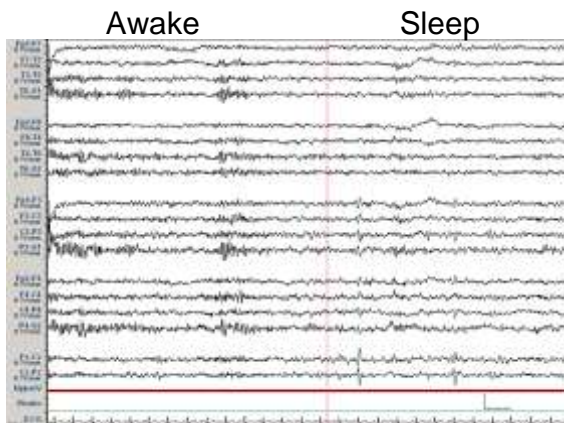
### Non-REM sleep

- Stage 1 (drowsiness)
- Stage 2
- Stage 3 & 4

### REM sleep

## Stage 1

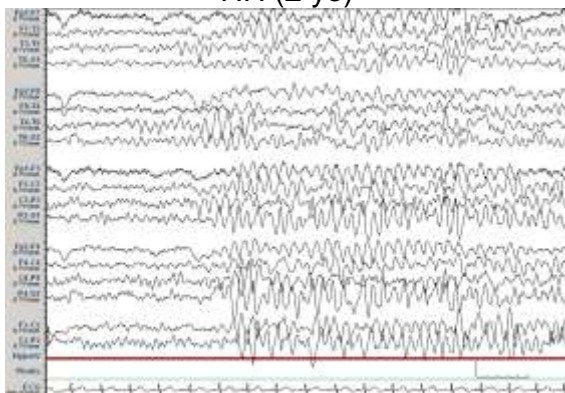
- Alpha drop out
- Hypnagogic hypersynchrony
- POSTs
- Beta activity
- Vertex wave



## Hypnagogic hypersynchrony

- Burst of generalized high voltage 3-5 Hz
- Maximum fronto-central
- Awake → sleep
- Begin 6 months
- Best seen 1-5 years
- Rare after 11-12 years
- Hypnapompic: sleep → awake

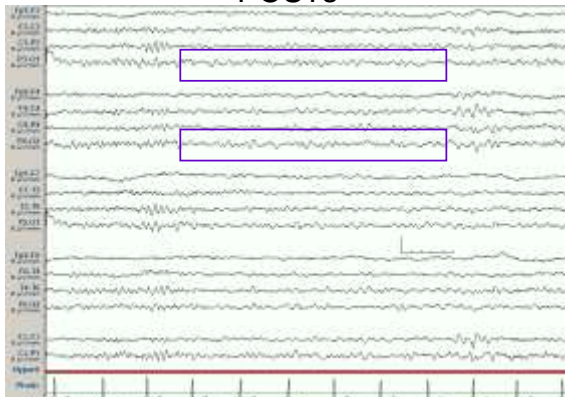
## HH (2 yo)



## POSTs

- Positive occipital sharp transients of sleep
- 4-5 Hz, checkmark-like, isolated or in trains
- Esp. daytime nap, arousal → return to sleep
- Commonly asymmetry
- Age 4-50 years
- Best seen 15-35 years

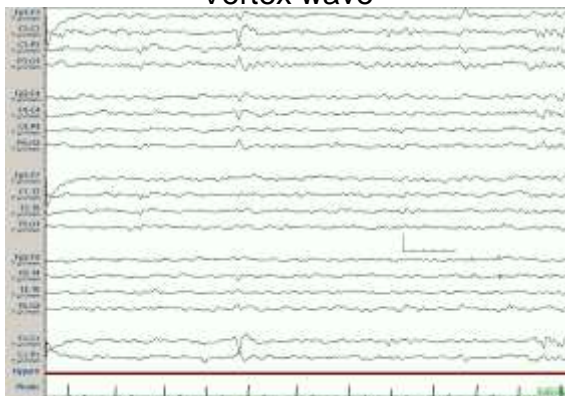
## POSTs



## Vertex wave

- Sharp transient maximum Cz (vertex)
- Begin 8 weeks post term
- Age 1-4 years; spiky and high amplitude
- Runs of vertex

## Vertex wave



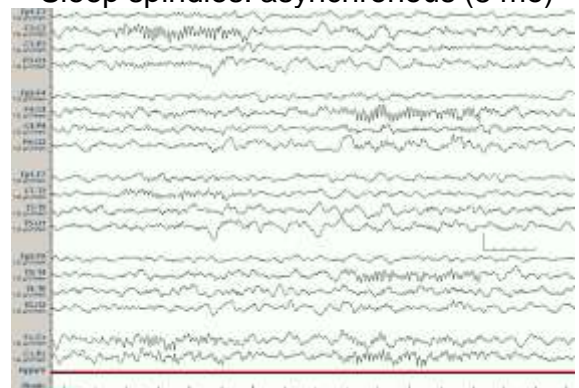
## Stage 2

- Sleep spindles
- K-complex
- Delta wave
- (Vertex, POSTs)

## Sleep spindles

- 11-14 Hz
- Maximum central, frontal (Cz, C3C4, F3F4)
- 2-5 seconds duration, may be spiky
- Lack of fusiform shape as in adult
- Begin 6-8 weeks post term; asynchronous but symmetrical
- Age 2 years; synchronous

## Sleep spindles: asynchronous (8 mo)

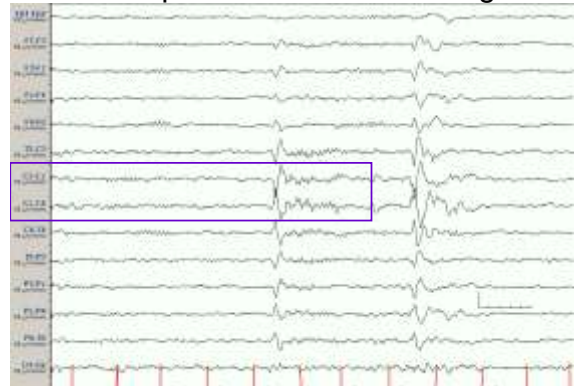




## K-complex

1. Vertex + spindles
  2. Biphasic high amplitude slow wave  
> 0.5 seconds duration
- Maximum Cz (vertex)
  - Begin 5 months

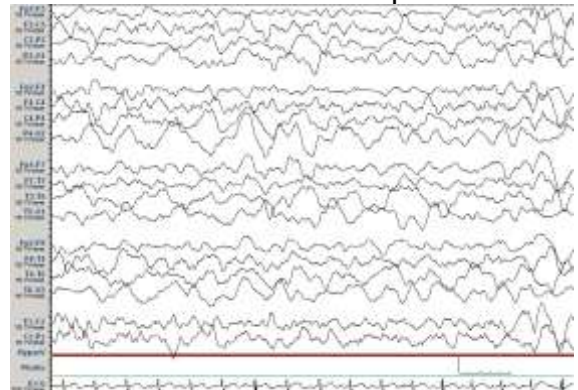
## K-complex: transverse montage



## Stage 3 & 4

- Delta activity
  - 20-50% → stage III
  - > 50% → stage IV
- (Sleep spindles)

## Slow wave sleep



## REM

- Sleep onset in newborn until 2.5 months, then NREM onset
- Rapid eye movement
- Relatively absent EMG
- Intermixed delta/theta, saw tooth appearance
- Rarely seen in routine pediatric EEG

## Arousal

- Brief arousal period from sleep
- Abrupt change of the background
- Biphasic slow wave: begin 3 mo
- 4-5 Hz: begin 7 mo
- 8-10 Hz: adolescent
- Usually 4-5 seconds or longer

## Photic stimulation

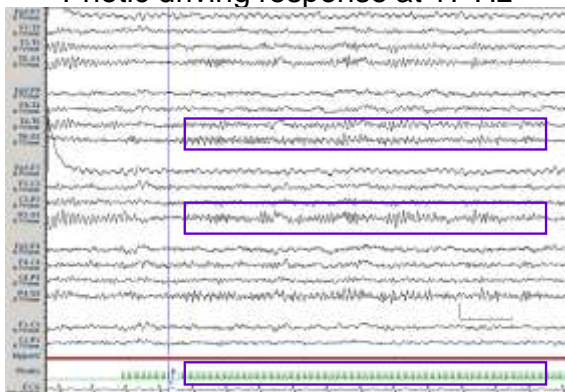
Done in dimly lit room, 30 cm away from eyes  
Frequency 1-30 Hz

- Visual evoked response
- Photo myogenic response
- Photic driving response

## Photic driving response

- Usually > 3 Hz
- Posterior head region
- Related to stimulus frequency
- Asymmetry is not associated with structural brain disease in the absence of other abnormalities

### Photic driving response at 17 Hz



## Hyperventilation test

- Duration 3 minutes; adequate
- Normal response: build up of diffuse, synchronous high voltage delta activity
- More prominent posteriorly in age < 8 yrs
- Change usually resolve within 60 seconds

### HV response (11 yo)

