The use of EEG in Epilepsy, Encephalopathy and Coma in Adults



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# **Electroencephalography (EEG)**

- Epilepsy and encephalopathy are clinically-based diagnoses but EEG is an extremely useful tool when used to bolster these clinical diagnoses.
- In good hands, EEG can be of immense benefit but, where used by inexperienced electroencephalographers, it may result in misdiagnosis and serious harm.



#### **Reading an EEG**

Effective reading of an EEG requires three elements:

- 1. Analysis of waveforms
- 2. Pattern recognition, and
- 3. Interpretation of these waveforms within the clinical context.



# **Brain Signal Generation**



### Origin of voltage changes within the cortex

The voltage changes within the cortex which are recorded on the scalp are primarily derived from the excitatory and inhibitory post-synaptic potentials (EPSPs and IPSPs) and <u>not</u> from the neuronal action potentials.

This is because, although action potentials are of much greater voltage, they are very brief, whereas the EPSPs and IPSPs are of much longer duration and are able to summate to create a signal capable of being detected on the surface of the scalp



## **The Role of Dendritic Palisades**



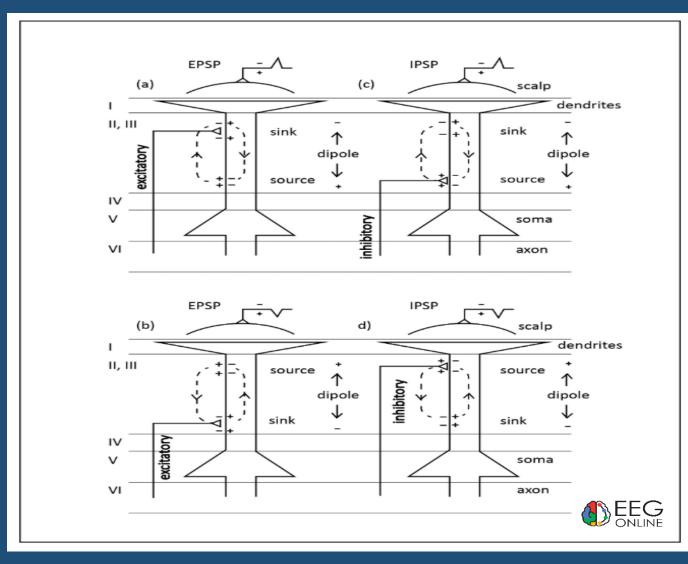
Science Photo Library

Summation of the voltages (EPSPs and IPSPs) is aided by the fact that the axons and dendrites of neurones are arranged in parallel in the cortex, referred to as dendritic palisades

www.sciencedirect.com

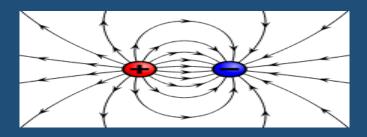


### **Dipoles**



It is mostly the EPSPs and IPSPs of the large pyramidal neurones with cell bodies in the cortical layers IV and V that generate the EEG

The positivity and negativity created can be viewed as a dipole, with current flow occurring between the poles.





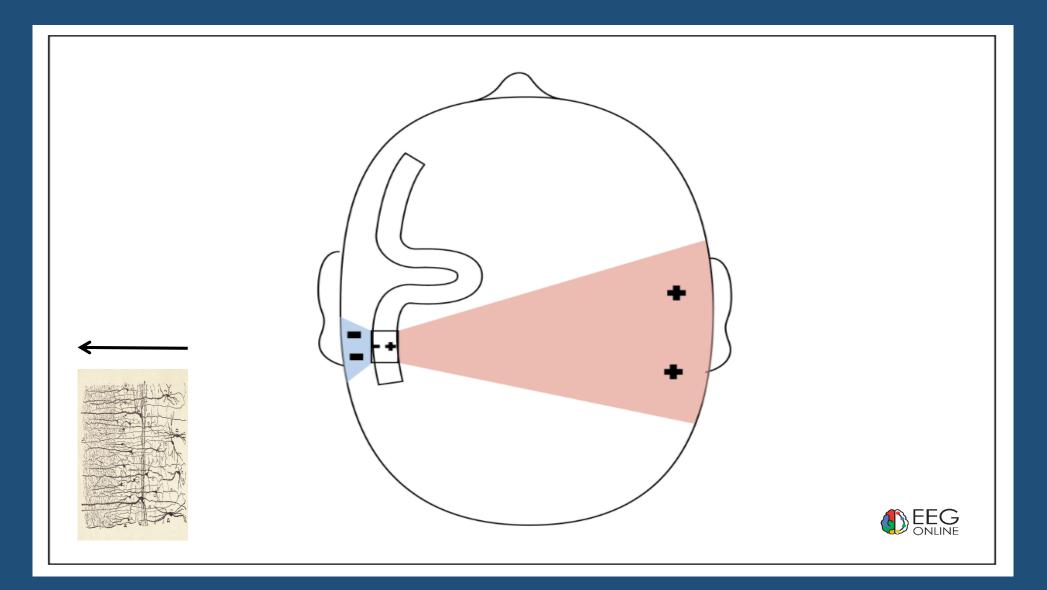
#### **Orientation of the Cortical Layer & Cancellation Effect**

# Orientation of the cortical layer generating the electrical potentials is important

For example, the summation of electrical potentials generated by dendritic palisades in one region of cortex may "cancel out" potentials generated in another if these regions are in an opposite orientation.

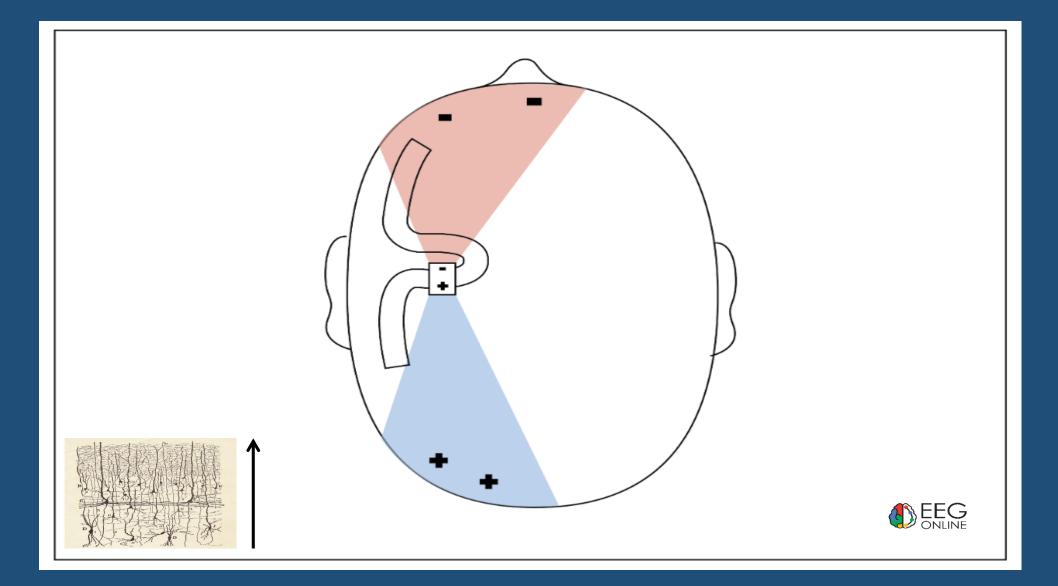






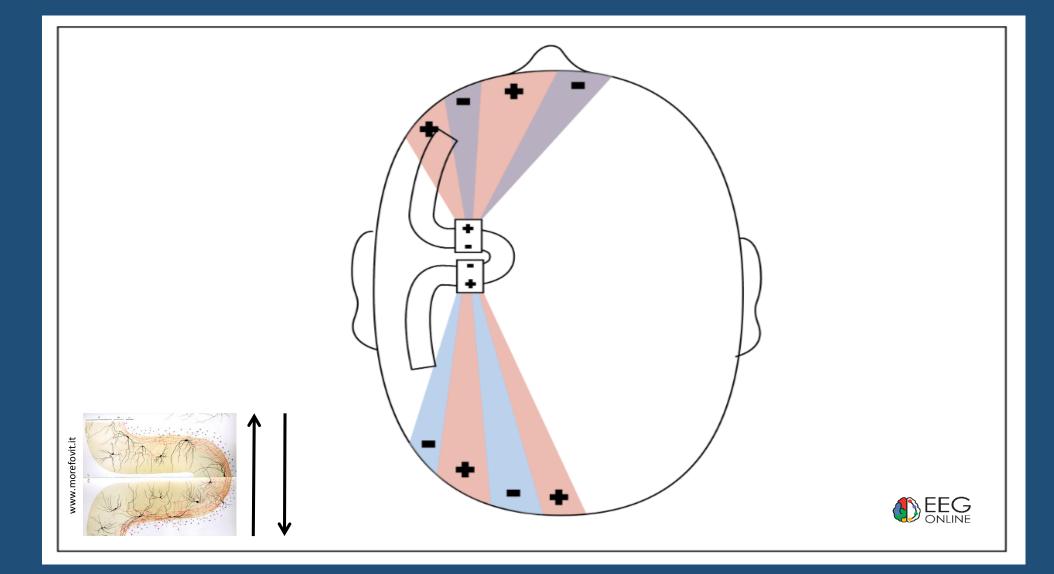
## **Tangential Dipole**



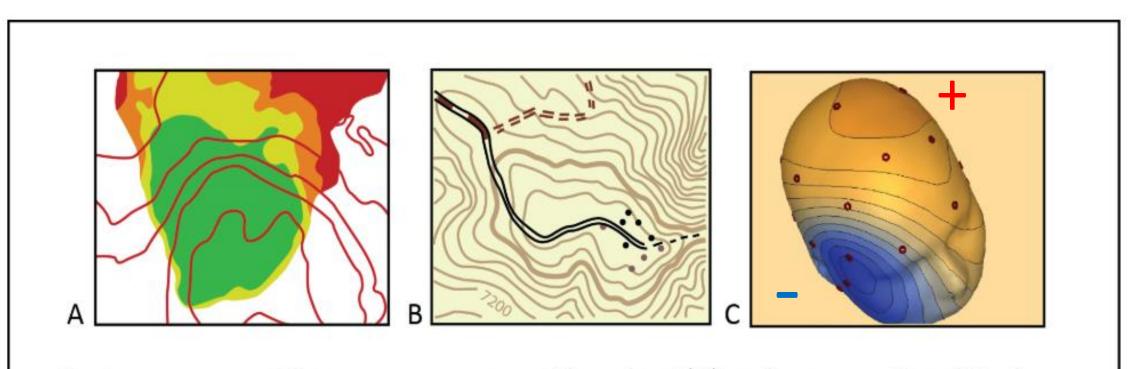


# **Opposing Tangential Dipoles**





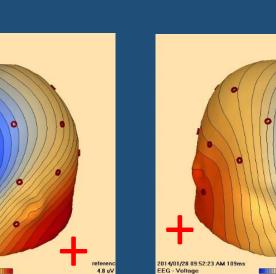
# **Electrical/Voltage Fields Represented as Contour Maps**

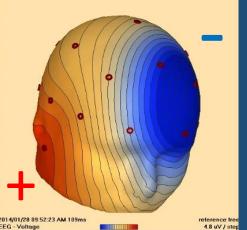


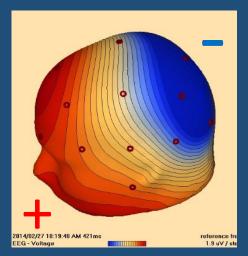
Contours representing pressure on a weather chart (A) and representing altitude on a topographical map (B). In (C), contours are used in a similar way to represent an electrical field on the surface of the brain.

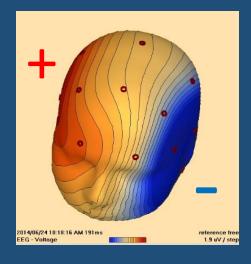


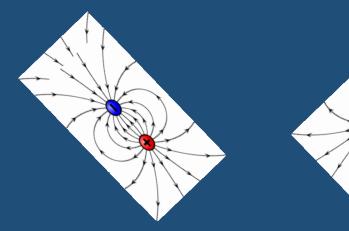
## **Electrical/Voltage Fields Represented as Contour Maps**





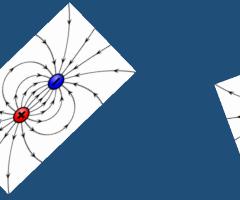


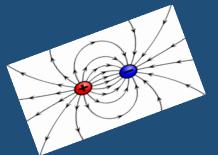


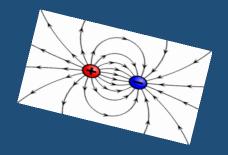


2013/06/11 03:28:19 PM 189ms

EG - Voltage



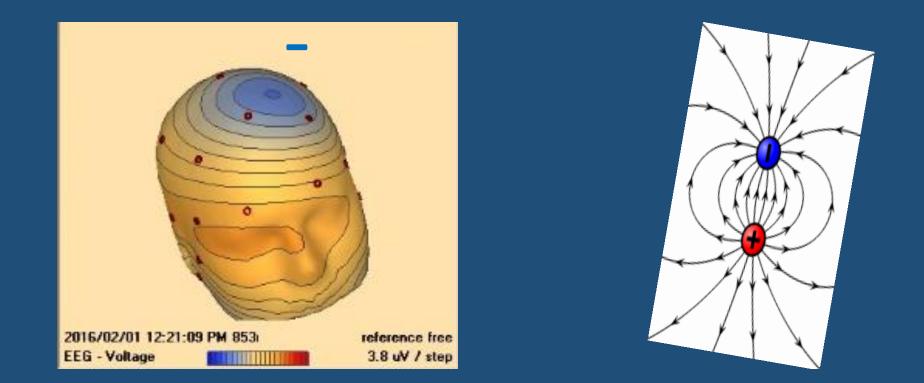








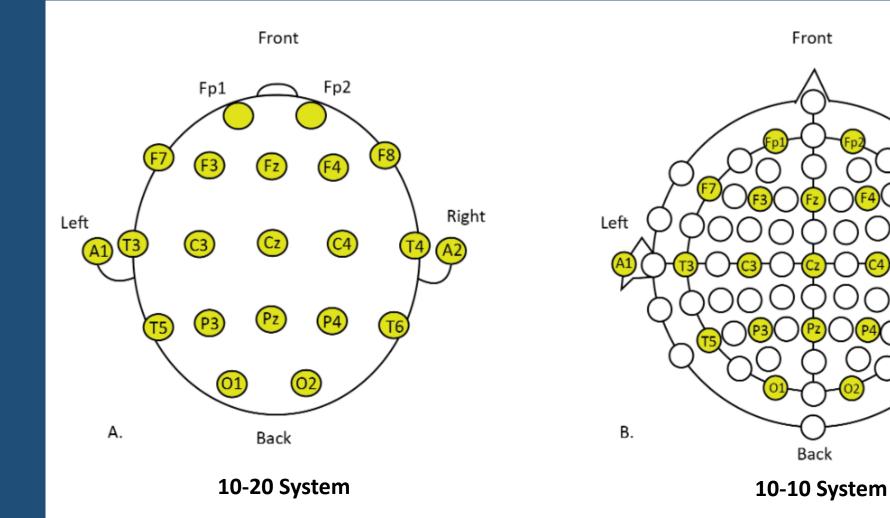
#### **Electrical/Voltage Fields Represented as Contour Maps**



A dipole with its negative pole on the cortical surface may have its positive pole hidden deep within the brain itself and this may not be detectable by scalp EEG

## Electrode Placement: 10-20 / 10-10 System



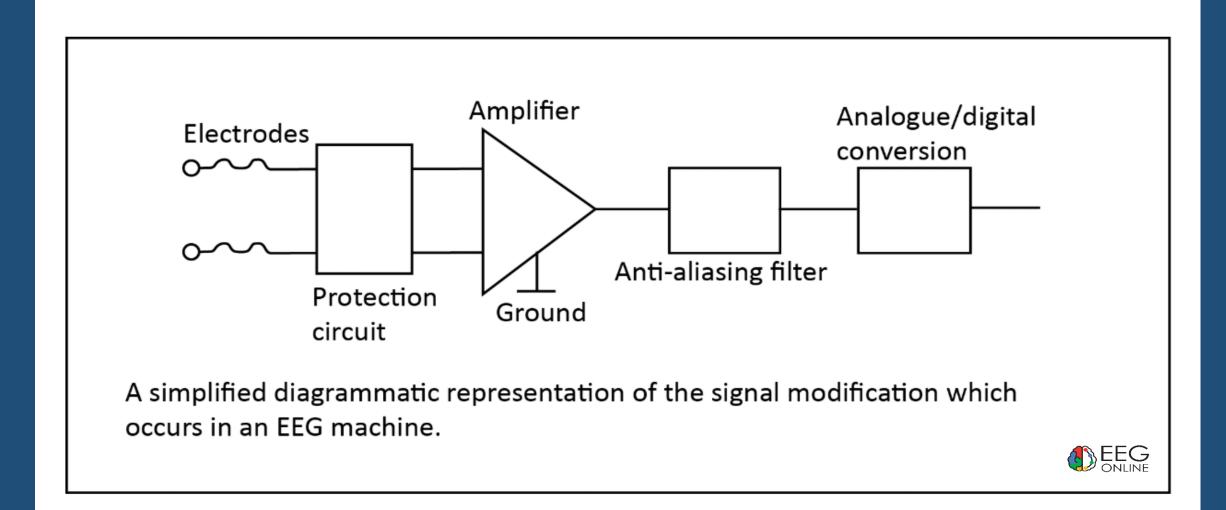




Right



## **Signal Processing**





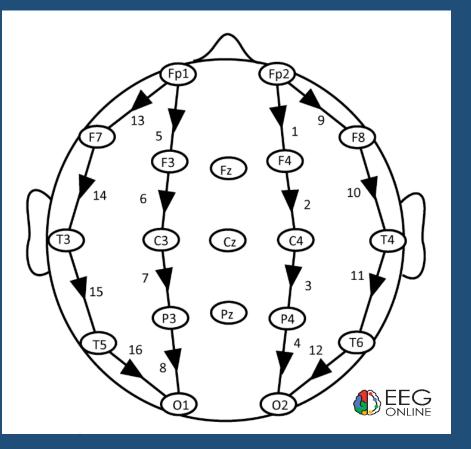
#### Montages

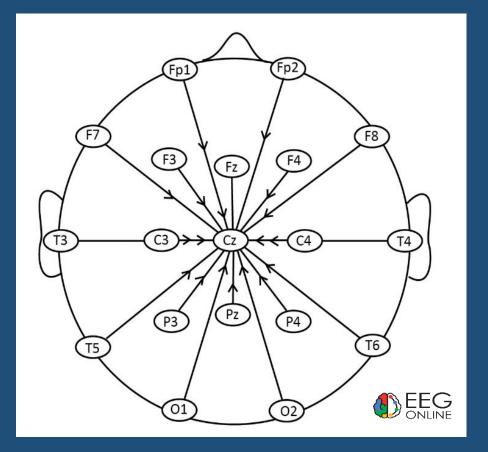
There are numerous ways one can connect scalp electrodes on the head and these different arrangements will result in different advantages and disadvantages. Each of these arrangements constitutes a "montage".

For instance, there are certain montages, which are particularly useful when analysing temporal lobe abnormalities and others which are better at identifying, respectively, frontal, paracentral or occipital abnormalities.



#### Montages



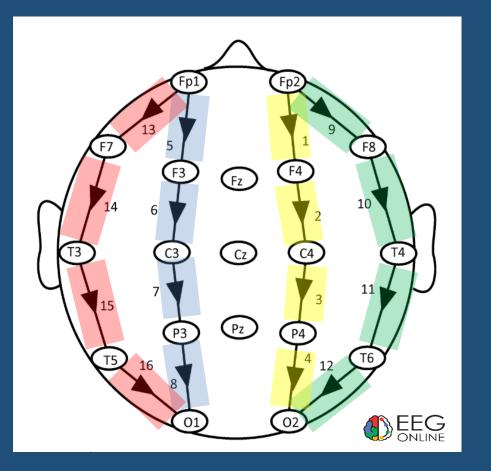


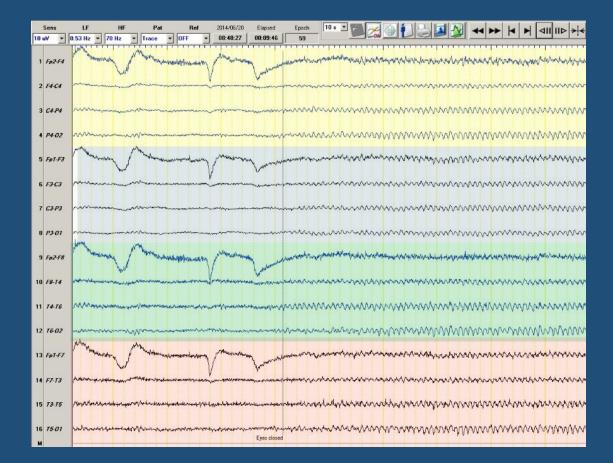
Longitudinal Bipolar Montage

**Cz-Common Reference Montage** 



## In this presentation: Only the Longitudinal Bipolar Montage will be used



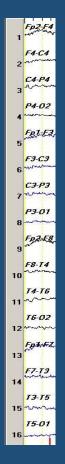


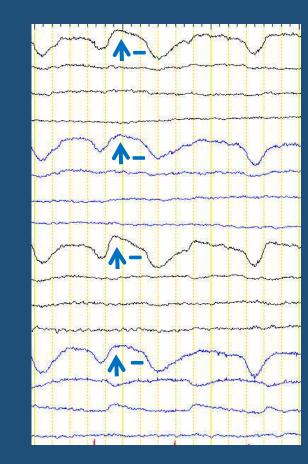


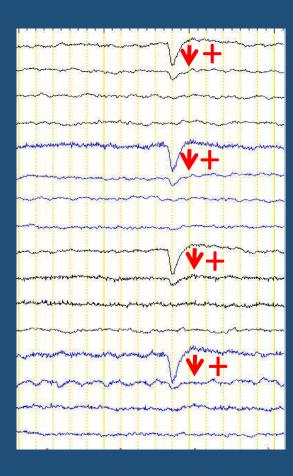
# **Polarity Convention**

7 uV	0.3 s	70 Hz	DBLBAN			2-Elapsed	
Sens	TC	HF	Pat	Ref	10:01:34	00:01:10	8 /105

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#### By convention:

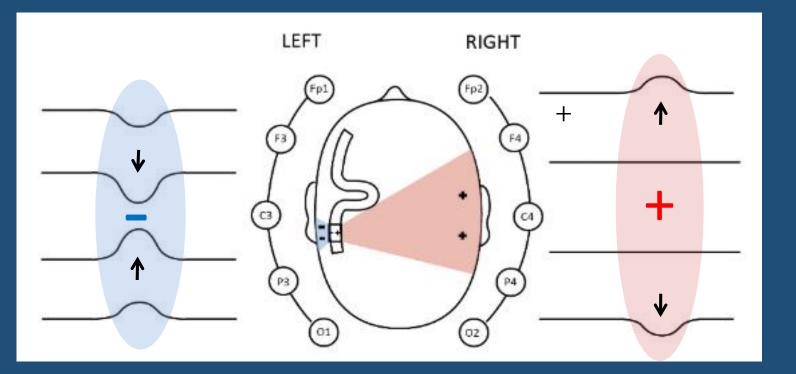
- upward deflections are negative
- downward deflections are positive

Eye movement Artefact A

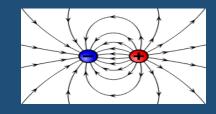
Eye movement Artefact B

#### Longitudinal Bipolar Montage: Radial Dipole





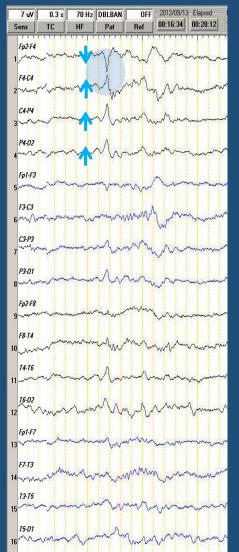
Note how the negative pole of the dipole on this montage results in deflections which move together while the more widely distributed positive pole results in deflections which move apart.

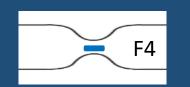


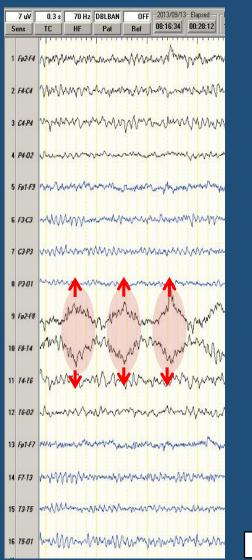
# Foci of Negative and Positive Charge on the Bipolar Montage

R











F8 Electrode Artefact



#### Most clinically relevant waveforms have a predominantly **negative polarity** at the surface of the brain and, consequently, most montages are designed to localize these regions of high negativity.



# Waveform Pattern Recognition and Interpretation



#### In order to successfully analyse and interpret the EEG, the reader must adopt an **unbiased and rigorously systematic approach**.



# It is best to analyse an EEG recording "BLIND"

- 1. Take note of the subjects age and state of vigilance
- 2. Take note of settings (sensitivity, paper speed and filtering)
- 3. Identify any artefacts
- 4. Beware of bias
- 5. Identify and assess the predominant background rhythm (posterior dominant rhythm)
- 6. Identify and assess any additional rhythms
- 7. Identify and assess any other waveforms of interest
- 8. Correlate your EEG findings with the reason for referral and clinical features





Sens	LF	HF	Pat	Ref	2015/12/03	Elapsed	Epoch	
7 uV	• 1.6 Hz •	70 Hz	Trace	OFF. •	09:03:47	00:07:23	45	

1 Fp2-F4	
2 F4-C4	
3 C4-P4	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
4 P4-02	www.www.www.www.www.www.www.www.www.ww
5 Fp1-F3	
6 F3-C3	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
7 C3-P3	manne manne manne
8 P3-01	mmmmmmmmm
9 Fp2-F8	······
10 FB-T4	and a second and a second and a second se
11 T4-T6	
12 T6-02	
13 Fp1-F7	
14 F7-T3	
15 T3-T5	and the second
16 75-01	
18 <i>X1-X2</i>	www.www.www.www.www.www.www.www.www.ww
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Normal

#### **Epileptiform**

#### Slowing

200



# The EEG of Normal Wakefulness



# Background / Posterior Dominant Rhythm (PDR)

Background rhythms of normal wakeful adult subjects are assessed in the **posterior regions of the head** and represent the summation of different cortically-generated rhythms of varying frequencies. These background rhythms are referred to as the **Posterior Dominant Rhythm** (PDR) and typically run at a frequency of between **8Hz and 14 Hz** which is referred to as the **Alpha Range** 



#### Normal Wakefulness: Alpha Posterior Dominant Rhythm (PDR)

	Sen:	LF	HF	- P	Pat	Ref	2015/12/08	Elapsed	Epoch	10 * 💌		• <b>!</b>	5		www.	studyE	EGonlin	e.com
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3	C4-P4	~~~~	www	Mm	m	MM	MMM	Man	mm	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	www	www	Mm	ww	ww	ww	www	www
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6	F3-C3	~~~	www	mm	~~~~	m	mm	MM	~~~~~	mm	~~~~~	www	~~~~	ww~	ww	~~~~	www	www
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16	T5-01	non	mm	mm	MMM	MM	mm	mm	mm	mm	mm	min	mm	MM	nn			

This is an example of a Normal Posterior Dominant Rhythm.

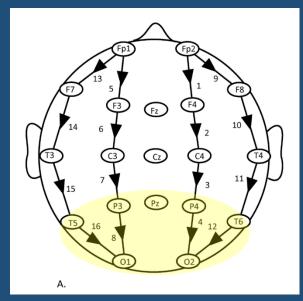
Note that it is symmetrical, rhythmical, sinsusoidal, largely confined to the posterior channels and runs in the alpha range (i.e. 8-14 Hz)



# Normal Wakefulness: Normal Alpha PDR (High Amplitude)

Sens 7uV ▼	LF 0.53 Hz 🔻	HF 70 Hz	Pat	Rel	<ul><li>2014/07/04</li><li>▼ 09:05:28</li></ul>	Elapsed 00:03:41	Epoch	10 s 💌	22	1000	www.studyEEGonline.com
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2 F4-C4											manna
3 <i>C4-P4</i>	MM	www	MAN	MM	mm	MANA	mm	MM	MAMM	mmm	MMMMMMMMM
4 <i>P4-02</i>	MM	MAM	AMAA	MMM	MAMAA	MANA	MMM	NM	MANANI	MANAMAN	www.www.www
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6 <i>F3-C3</i>	Www	~~~~	m	www	www	$\sim$	mun	n	www	Mumm	Man Man
7 <i>C3-P3</i>	Mm	www	NW	MMM	NMMM	MMM	hwn	mm	MMM	MMM	MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
8 <i>P3-01</i>	1/m	MM	AMA	WWW	WWW	MMM	MMM	(WWV)	MAMM	MINIMAN	www.www.www.www
9 <i>Fp2-F8</i>	man	mandal	www.	many	mannan	month	Margaren	moun	Mmmm	a the second second	have a second and a second and a second
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12 <i>T6-02</i>	MM	WM	MMM	MMM	WWW	NNN		[VMM]		MIMMIM	MMMMMMMM
13 <i>Fp1-F7</i>	Vww	mmm	www	mm	www.	man	nonun	mmun	manni	Mummer	man man man
14 <i>F7-T3</i>											mmmmmm
15 <i>T3-T5</i>	Mm	WWW	MM	WWW	MMM	MMM	mm	m	MMM	MMMM	www.wwwww
16 <i>75-01</i>	Mm	WW	MM	MMM	WWW	MW	MMM	IMM	MMMM	MUMMIM	NWWWWWWWW
18 <i>X1-X2</i>		l	lin	l	h	h	l	and	- hi	mlim	

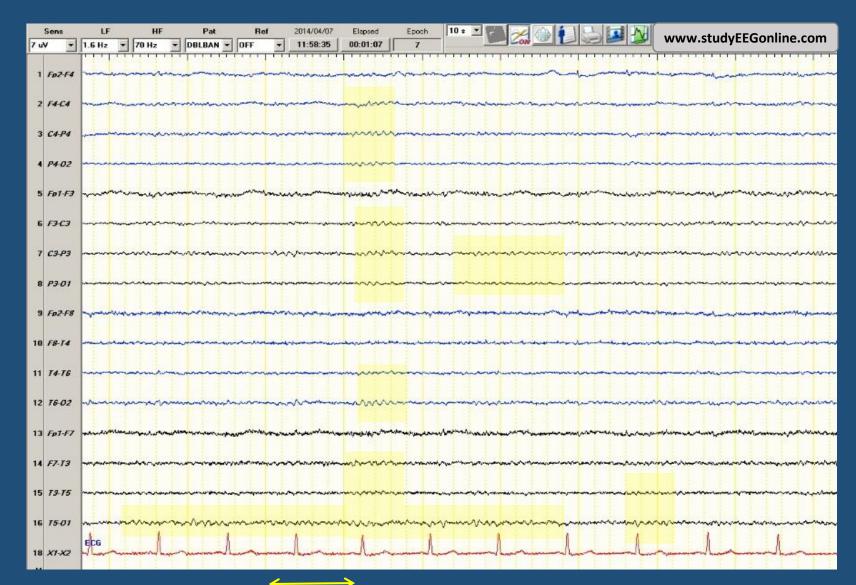
#### Normal, high amplitude 9-10 Hz alpha PDR



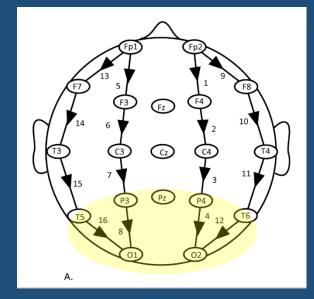




## Normal Wakefulness: Normal Alpha PDR (Low Amplitude)



#### Normal scanty, low amplitude 10-11 Hz alpha PDR



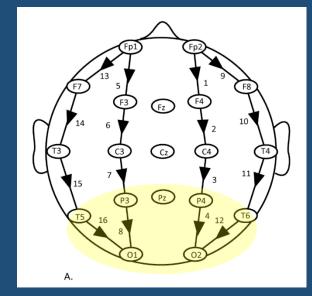
1 second

#### Normal Wakefulness: Reactive Alpha PDR





Normal reactive 9-10Hz alpha PDR, which attenuates on eye opening. Note eye blink artefacts in the second half of this epoch

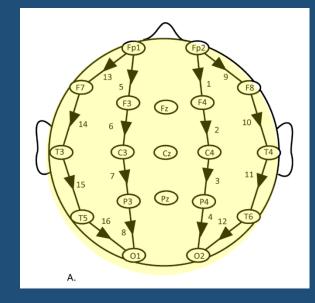




# Normal Wakefulness: Beta PDR

Sens	E LF	HF	Pat	Ref	2015/01/15	Elapsed 00:01:26	Epoch	10 s 💌			www.studyEEGonline.com
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#### Normal beta PDR running faster than 14 Hz.



1 second

#### **Slowing of the PDR: Normal Drowsiness vs. Abnormal**

10 uV 70 Hz 0.3 s 8 /116 00:01:19 13:42:18 Sens mmmmmmm Mammonton Prozensin Man Martin Ma minuman mann 16 15 07 Martin Ma Martin Mart

A PDR running slower than 8 Hz (i.e. in the theta or delta range) may be due to normal drowsiness or it may be pathological.

It is therefore very important to recognise the EEG features of drowsiness



# Normal Drowsiness / Somnolence

With the onset of drowsiness and subsequent progression to somnolence in normal adults, a number of characteristic changes occur sequentially in the electroencephalogram. These include alterations in, and eventual loss of, the alpha rhythm, the emergence of generalised slow waves, and the appearance of specific drowsiness- or sleep-associated electrographic waveforms such as sleep spindles, V-waves and K-complexes. Many of these waveforms may be mistaken for abnormalities.



#### Drowsiness: Drop-Out of Alpha

Sena	LF HF Pat Ref 2016/04/15 Elapsed Epoch 10 * 2016/04/15 Elapsed Epoch 10 * 2016/04/15 BB www.studyEEGonline.com
10 uV 👻	1.5 Hz T 120 Hz DBLBAN T OFF T 10:33:16 00:14:35 88
1 Fp2-F4	
2 F4-C4	man war
3 C4-P4	www.www.www.www.www.www.www.www.www.ww
4 P4-02	
5 Fp1-F3	www.mar.mar.mar.mar.mar.mar.mar.mar.mar.mar
6 F3-C3	www.www.www.www.www.www.www.www.www.ww
7 C3-P3	
8 <i>P3-01</i>	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
9 Fp2-F8	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
10 <i>F8-14</i>	many for a second and the second and
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12 <i>T6-02</i>	MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
13 Fp1-F7	www.www.www.www.www.www.www.www.www.ww
14 <i>F7-T3</i>	
15 <i>73-75</i>	
16 <i>75-01</i>	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

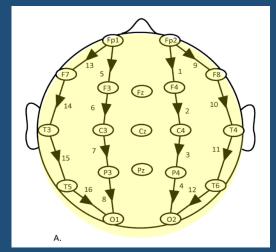
Typically, as a subject becomes drowsy, there is dropout of the alpha PDR which is replaced by generalised beta frequencies.



#### Drowsiness: Theta

Sena		LF	HF	Pa	it	Ref	2014/07/31	Elapsed	Epoch	10 : 💌	- 2				ww.stu	dvEEGor	line.com
7 uV	- 0.	53 Hz 🔻	70 Hz	DBLBA	N - OFF	-	11:57:48	00:03:49	23								
1 <i>Fp2</i>	-F4	~~~~	~~~~			~~~	~~~~~	~~~	~~~~	~~~~	~~~~	~~~~	~~~~	m	man	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
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This is followed by emergence of generalised slowing in the theta range (5-7 Hz)

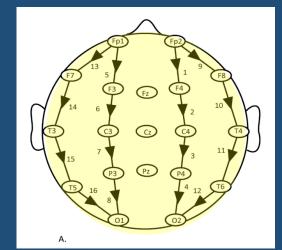




#### **Drowsiness: Delta and Arousal**

Sens	LF	HF	Pat	Ref	2014/05/24	Elapsed	Epoch	10 :			www.studyEEGonli	ine com
7 uV	• 0.53 Hz •	70 Hz	DBLBAN -	OFF -	14:08:45	00:12:21	75					
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The theta, in turn, is followed by slowing in the delta range (i.e. < 5Hz) consistent with slow wave sleep.



Generalised Delta Drowsiness

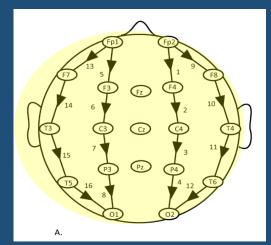
Arousal

#### **Arousal**



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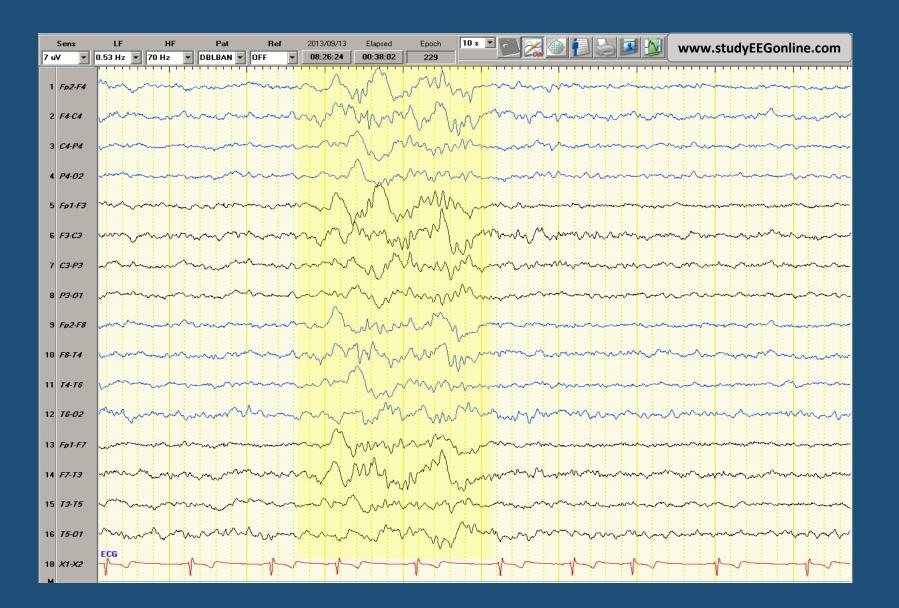
Occasionally, arousals may be preceded by waveforms associated with physiological sleep which may be erroneously regarded as pathological.



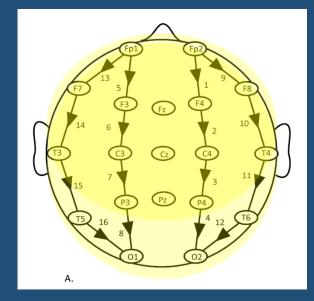
Somnolence

Arousal

#### Drowsiness & Somnolence: K-Complexes

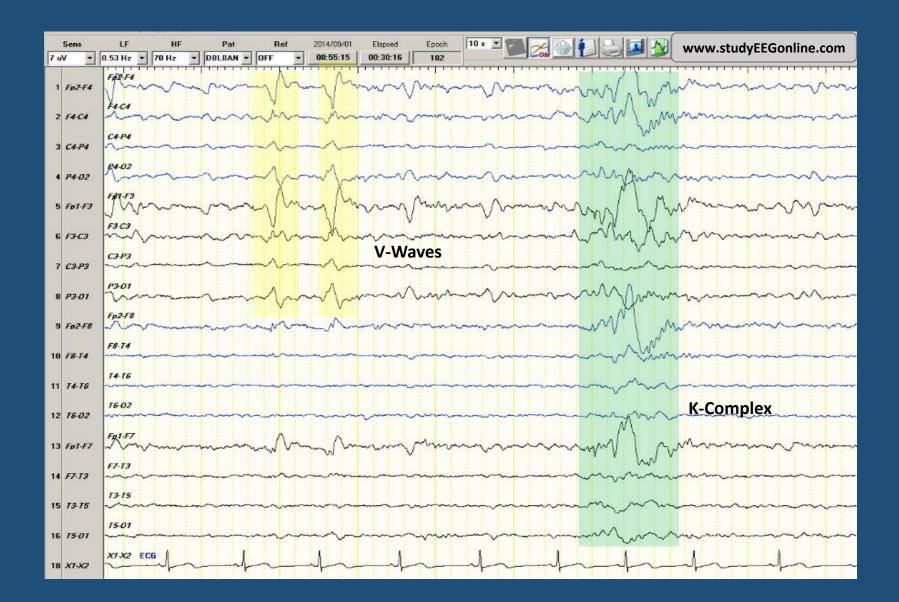


K-complexes which occur during somnolence may be dramatic and mistaken as pathological

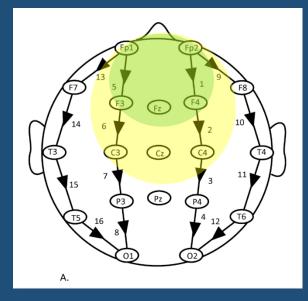




#### Drowsiness & Somnolence: Vertex (V)-Waves

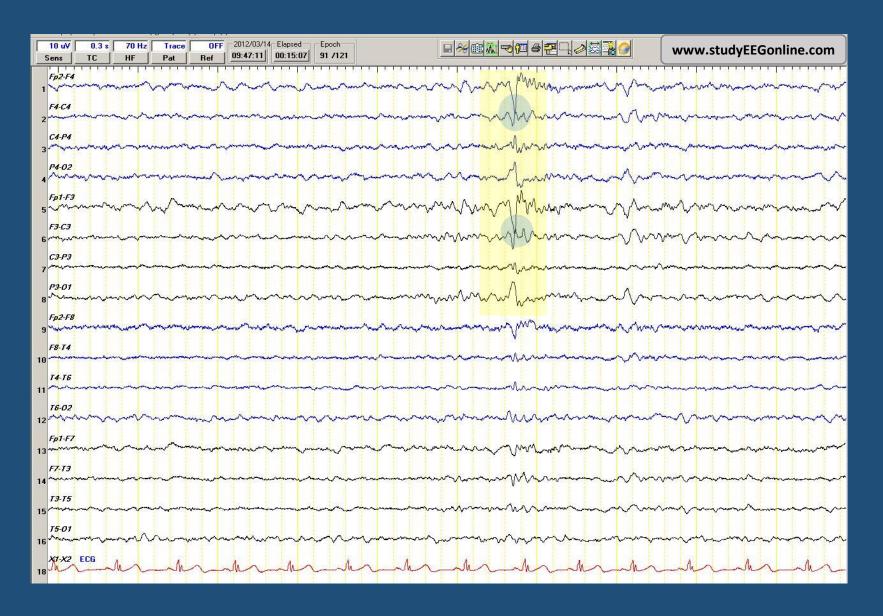


V-waves often have a sharply-contoured morphology which closely mimic epileptiform discharges

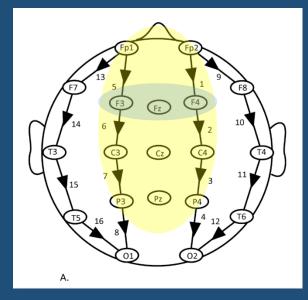




#### Drowsiness & Somnolence: Symmetrical Frontal (F)-wave



When "V"-waves phasereverse in the frontal channels they are often referred to as F-waves

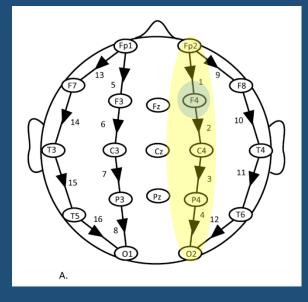




#### Drowsiness & Somnolence: Asymmetrical F-wave

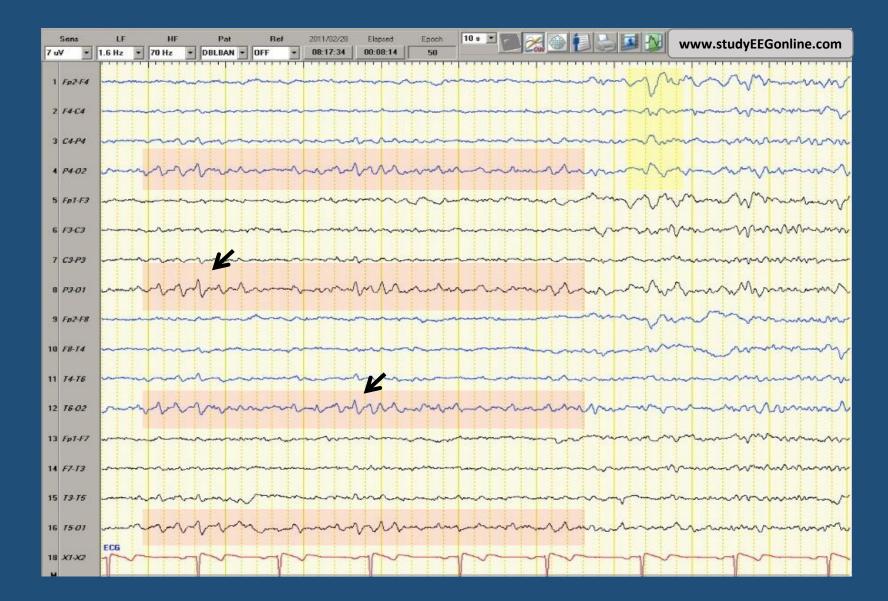


Importantly, V- and F-waves may occasionally be asymmetrical

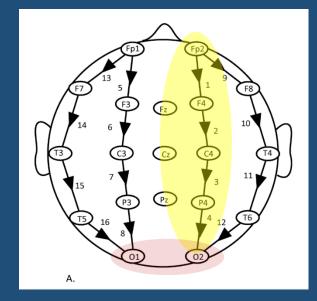




#### Drowsiness & Somnolence: **POSTS**



Posterior Occipital Sharp Transients of Sleep (POSTS) may be mistaken as evidence of epilepsy







The take home message is not to mistake normal physiological waveforms of drowsiness and sleep as epileptiform or pathological slowing.



### **The Abnormal EEG**



### **The Abnormal EEG**

**Epileptiform Waveforms:** 

Sharp Waves Spikes / Polyspikes Spike/Poly-spike/Sharp & Slow Wave Complexes

**Non-Epileptiform Waveforms:** 

**Abnormal Slowing** 



### **Epileptiform Waveforms**

The EEG is probably most commonly used to assist in diagnosing and characterising epilepsy. It may be especially helpful where conditions such as syncope, panic attack, hyperventilation, and TIAs, etc. present with clinical symptoms mimicking those of a seizure



### **Epileptiform Discharges**

#### Three features characterise epileptiform discharges:

- a) They should be sharply contoured
- b) They should be "superimposed upon" and "disrupt" the background rhythms
- c) They should have **credible electrical fields**



### A diagnosis of epilepsy is primarily based on clinical presentation

The presence of iterictal epileptiform discharges strongly support a clinical diagnosis of epilepsy

BUT

The absence of epileptiform discharges does not exclude a clinical diagnosis of epilepsy

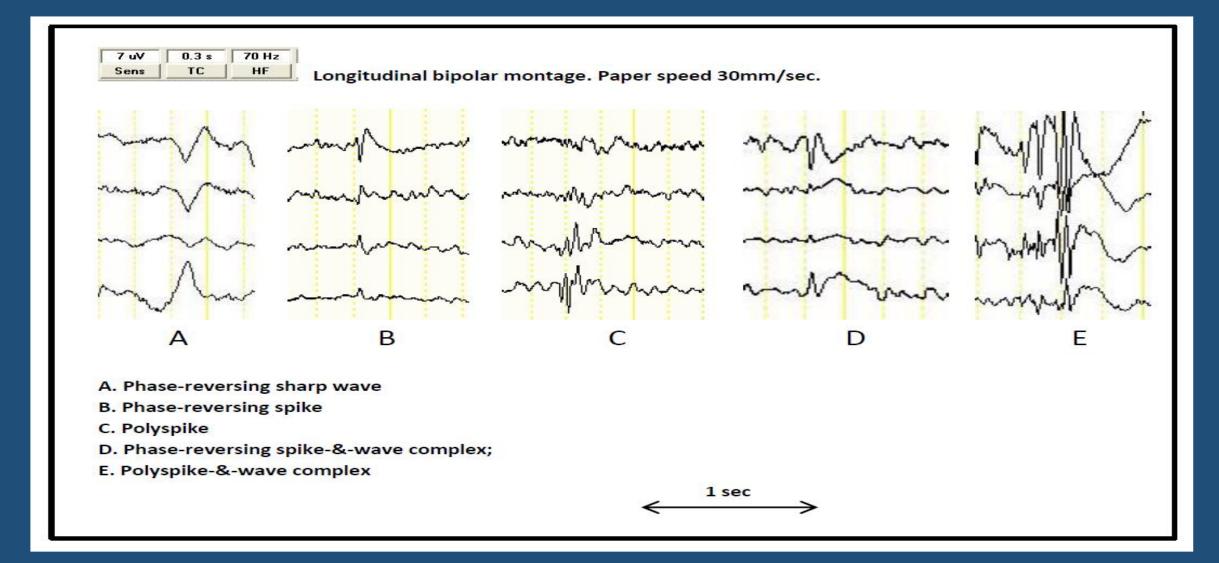


#### **Epileptiform Discharges: Focal vs Generalised**

Another useful role of EEG is to determine whether interictal epileptiform discharges are focal or generalised

This has important implications for both the **aetiology** and **management** of a patient with epilepsy

#### **Epileptiform Dischages** (longitudinal bipolar montage)





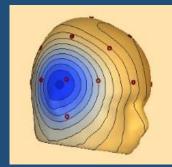
### **Focal Epileptiform Discharges**

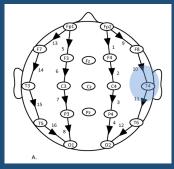


#### **Focal Spike-&-Slow Wave**

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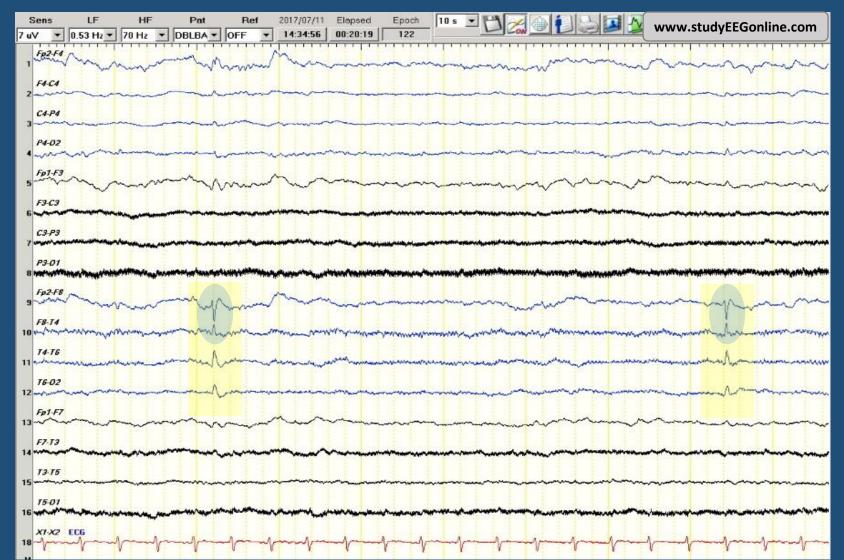
A focal spike is present, which phase-reverses at T4 in the right mid-temporal lobe



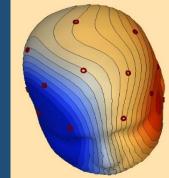


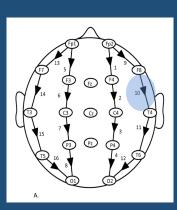






Two focal spikes are present, which phase reverse at F8 in the right anterior temporal lobe

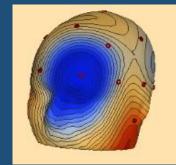


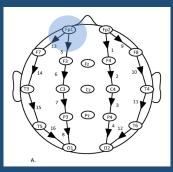


#### **Focal Spike-&-Slow Wave**

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A focal spike-&-slow wave discharge is present, which is maximal at Fp1 and F7 in the left frontal and left anterior temporal region.





#### Independent Multi-Focal Epileptiform Discharges



Independent multifocal epileptiform discharges are seen in both temporal lobes.





## **Generalised Epileptiform Discharges**

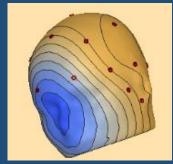
Generalised Epileptiform Discharges usually imply an inherited generalised form of epilepsy

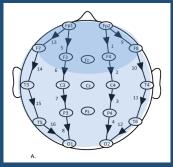


#### Generalised ("Typical") 3 Hz Spike-&-Slow Wave

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Generalised, but frontally-predominant, rhythmic, 3Hz spike-&slow wave discharge characteristic of Childhood Absence Epilepsy



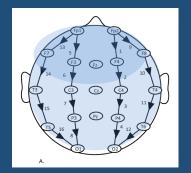




#### Generalised ("Atypical") 4-5 Hz Spike & Slow Wave

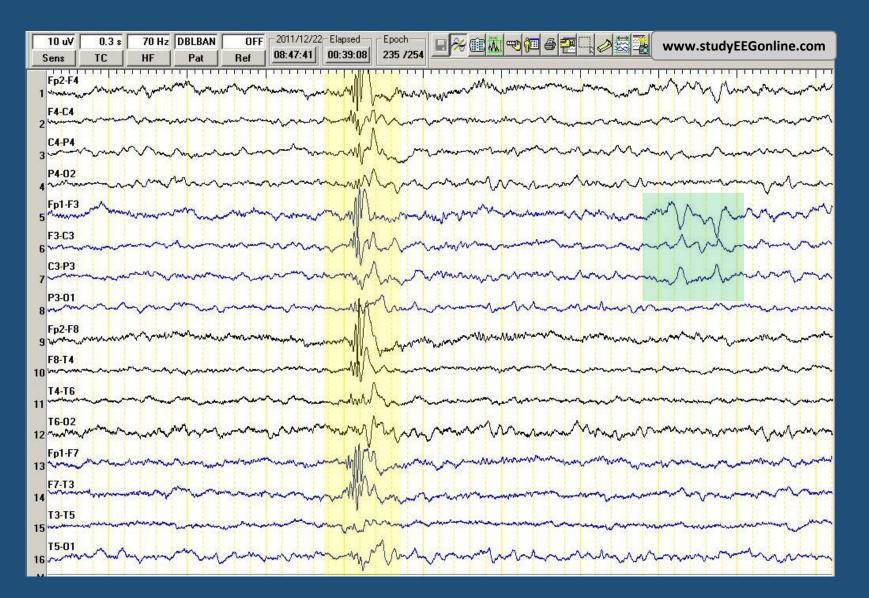
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Generalised, but frontally-predominant, atypical, 4-5 Hz spike-&-slow wave discharge characteristic Juvenile Myoclonic Epilepsy





#### **Generalised Polyspike-&-Slow Wave**

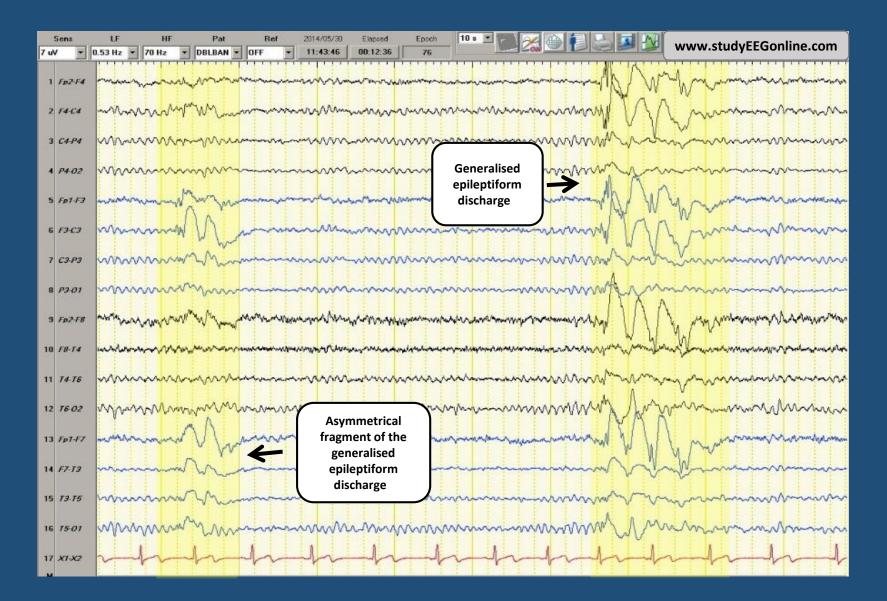


Generalised, frontallypredominant, polyspike-&-slow wave complex consistent with an Inherited Generalised Form of Epilepsy

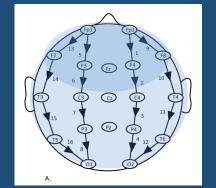
Note the asymmetrical V-waves resembling sharp waves (highlighted in green)



#### **Generalised Spike & Slow Wave: With Fragment**



Occasionally fragments of generalised epileptiform discharges may be seen, which may be confused with focal discharges.





# **Electrographic Seizures**



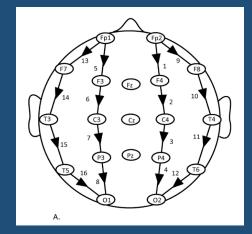
### **Generalised Seizure**



#### Generalised Seizure: Background

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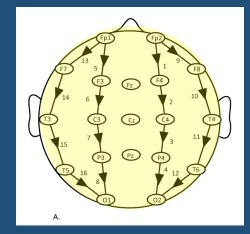
# Note the normal background





#### Generalised Seizure: Onset

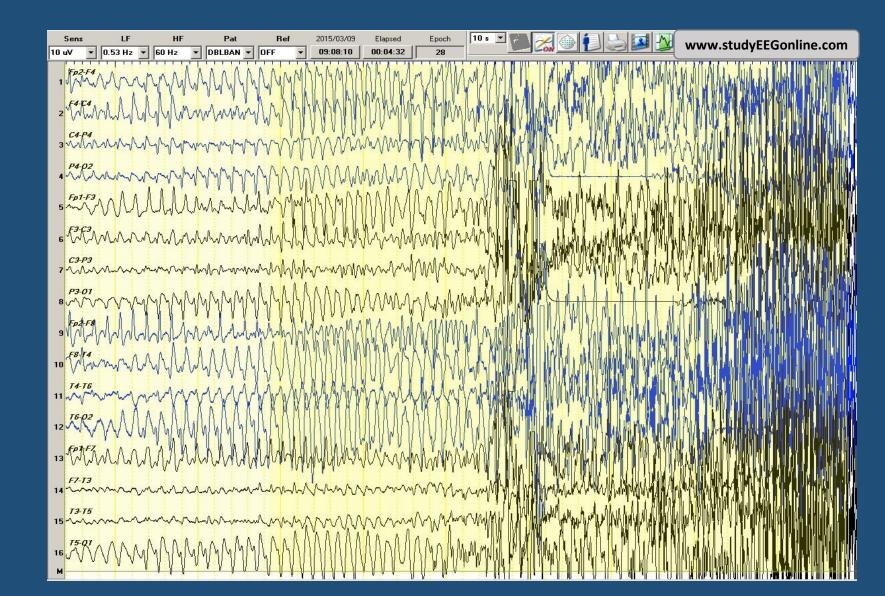
Simultaneous onset in all channels of a relatively high frequency, sharply contoured beta rhythm



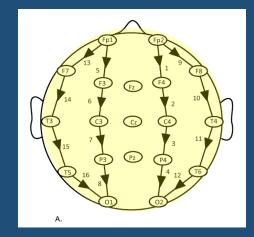
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#### Generalised Seizure: Evolution

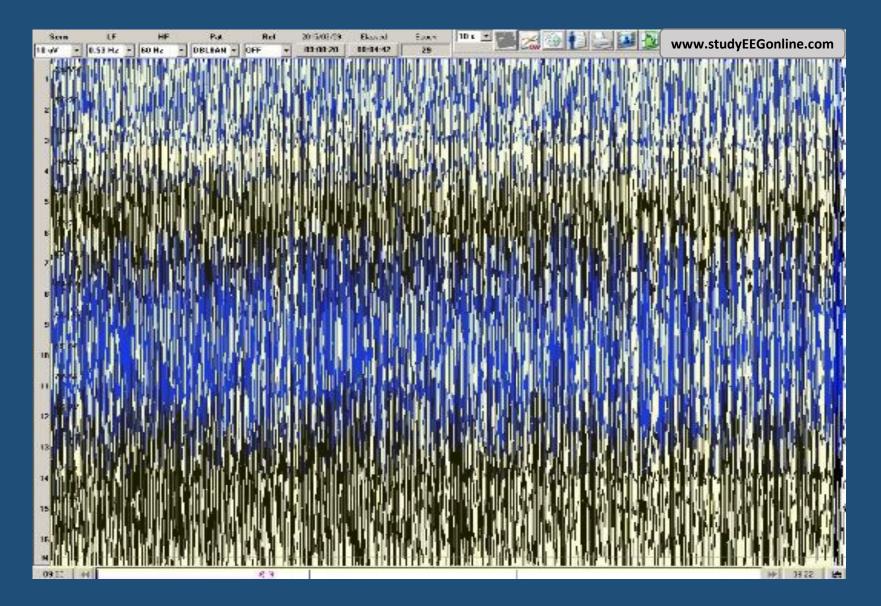


Gradual evolution (reducing frequency and increasing amplitude)

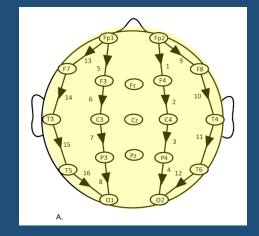




#### Generalised Seizure: Evolution

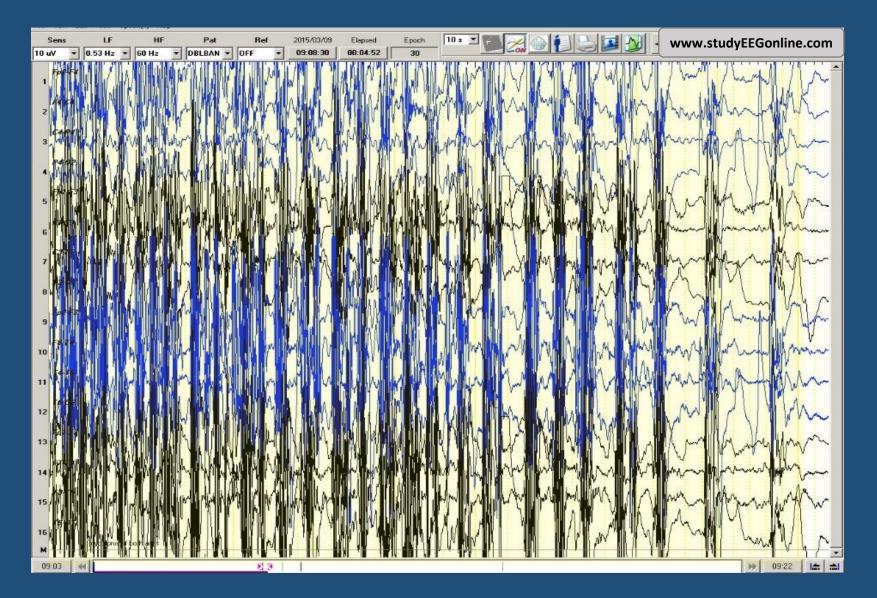


#### Muscle (EMG) artefact

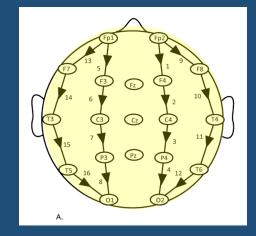




#### Generalised Seizure: Evolution

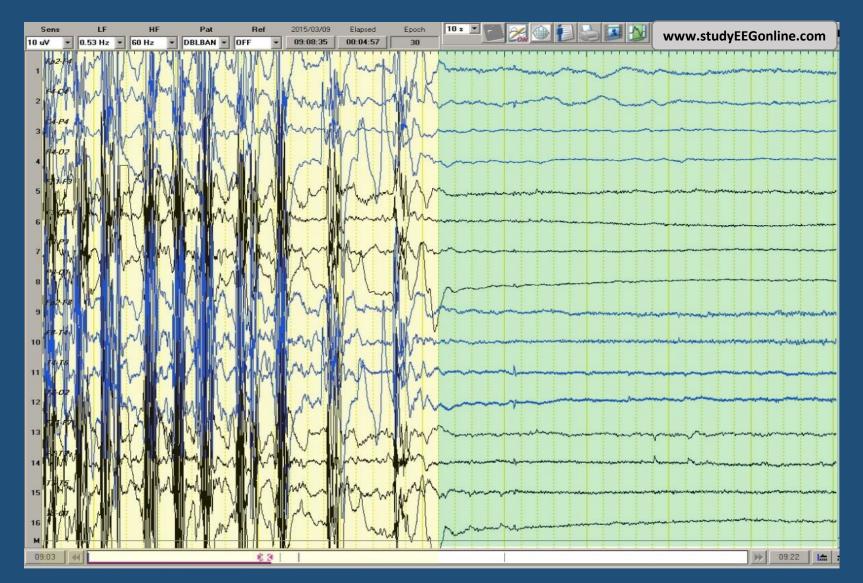


Continued evolution (reducing frequency) of discharges/EMG artefact





#### Generalised Seizure: Offset & Post-ictal Suppression



Continued evolution (reducing frequency) of discharges/EMG artefact and abrupt offset

Note post-ictal suppression



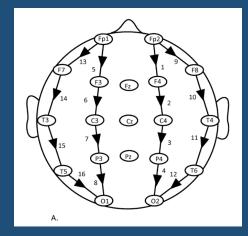
### Focal Seizure with Altered Awareness



#### Focal Seizure with Altered Awareness: Background

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# Note the normal background

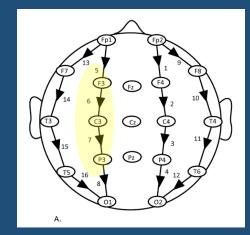




#### Focal Seizure with Altered Awareness: Onset

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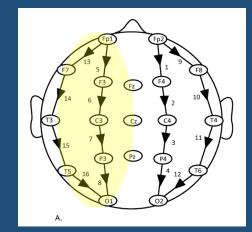
#### Gradual emergence of fast beta rhythm over F3, C3 and P3



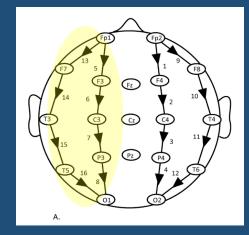


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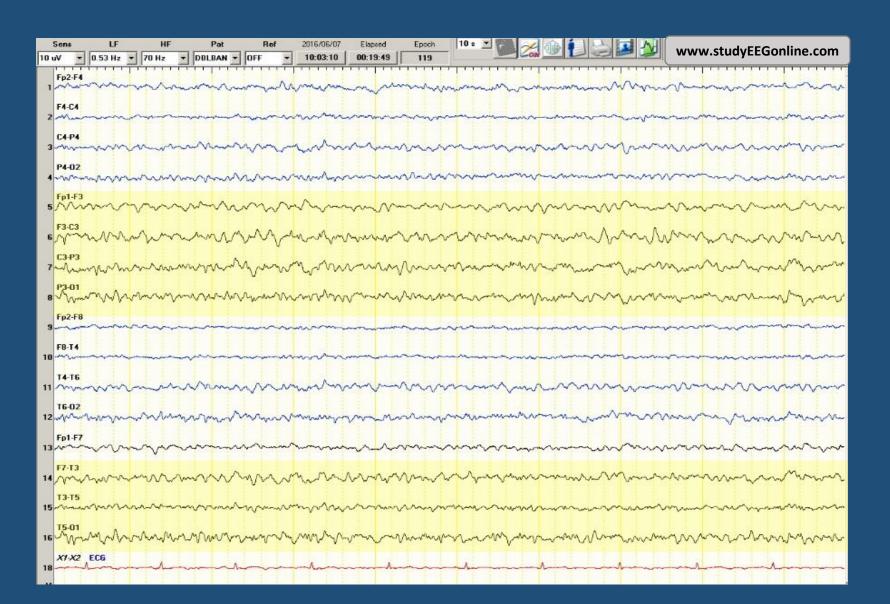
Gradual evolution (reducing frequency and increasing amplitude) and involvement of temporal channels

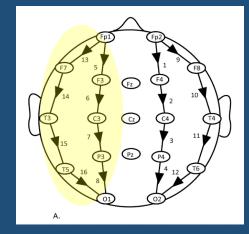


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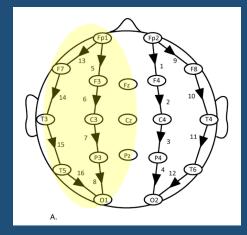




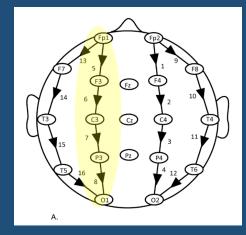




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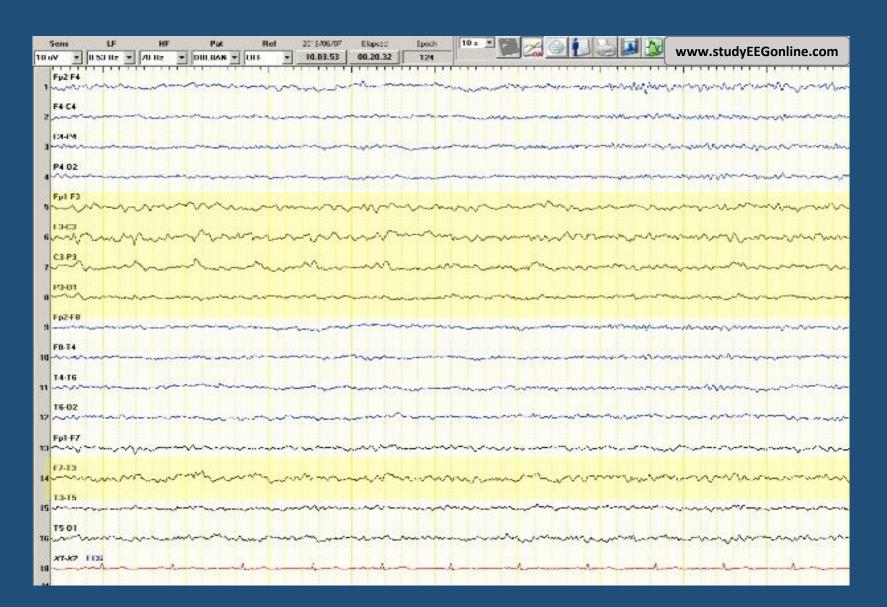


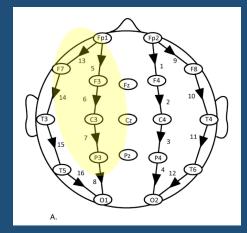
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#### Focal Seizure with Altered Awareness: Offset



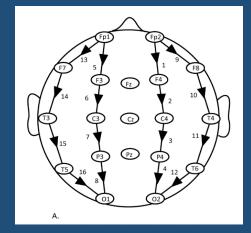




### Focal Seizure with Altered Awareness: Post-Ictal

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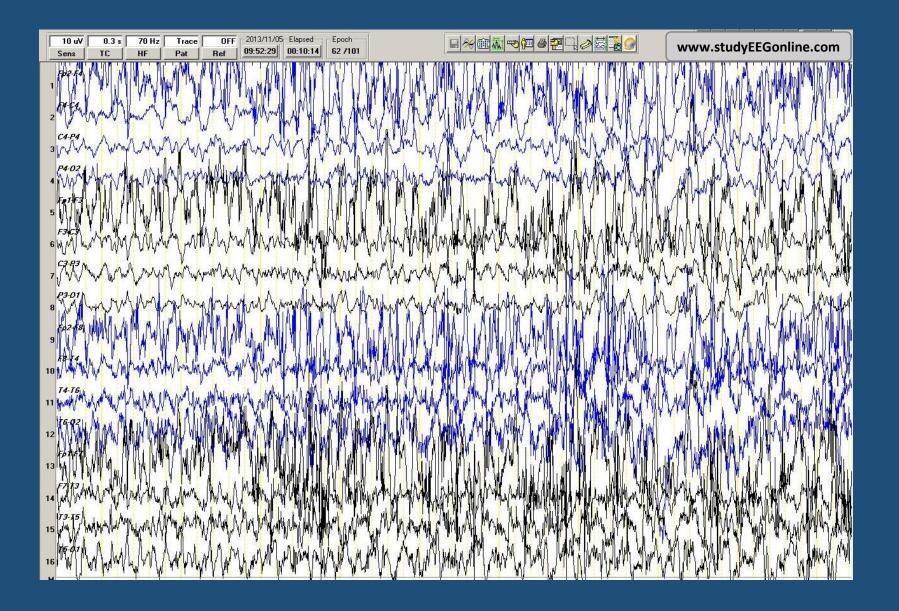
#### Back to **base-line**



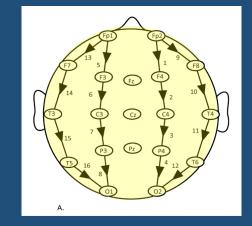


## **Status Epilepticus**

#### **Generalised Status Epilepticus**

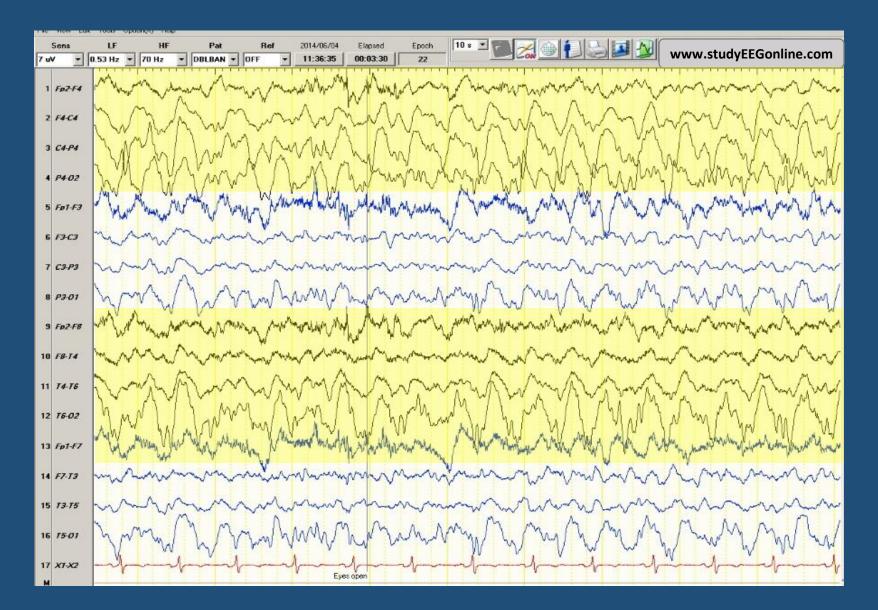


Continuous generalised epileptiform activity

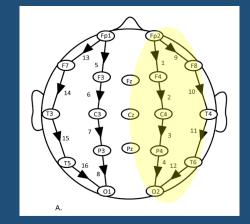




#### **Focal Status Epilepticus: Right Hemisphere**

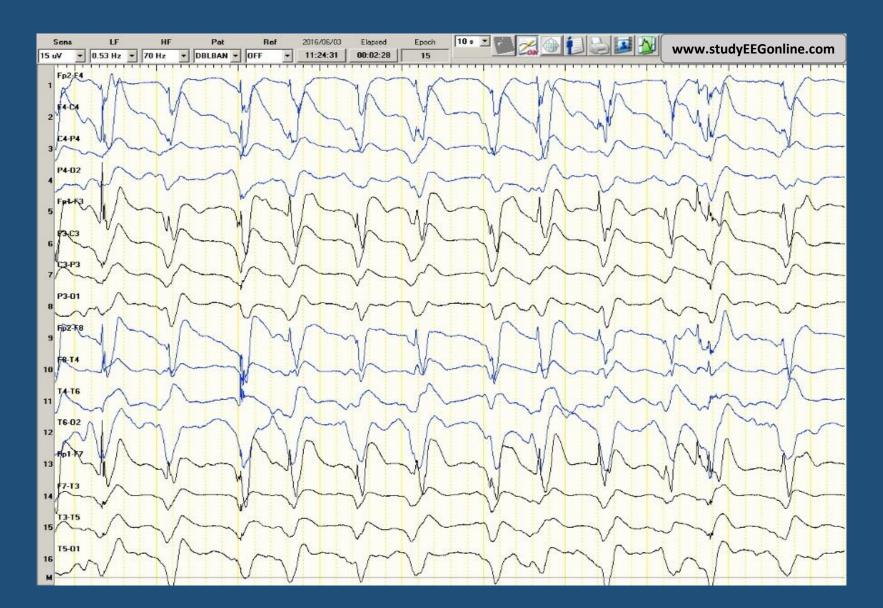


# Continuous focal epileptiform activity

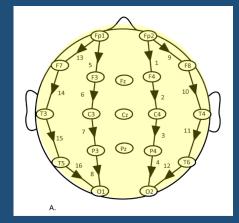




### **PEDS (Periodic Epileptiform Discharges)**



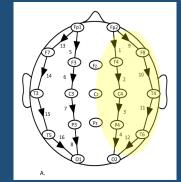
Continuous generalised periodic epileptiform discharges (PEDS)

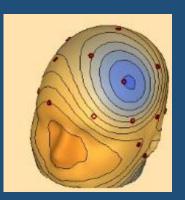


#### **PLEDS (Periodic Lateralised Epileptiform Discharges)**



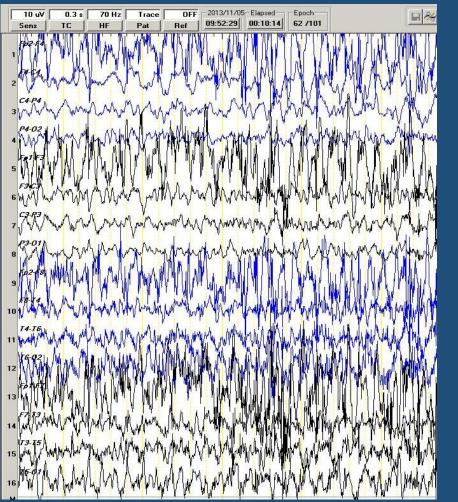
Continuous lateralised periodic epileptiform discharges (PLEDS)



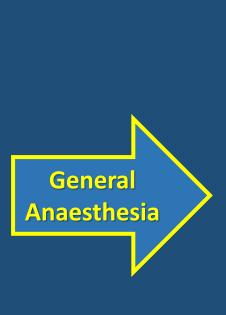


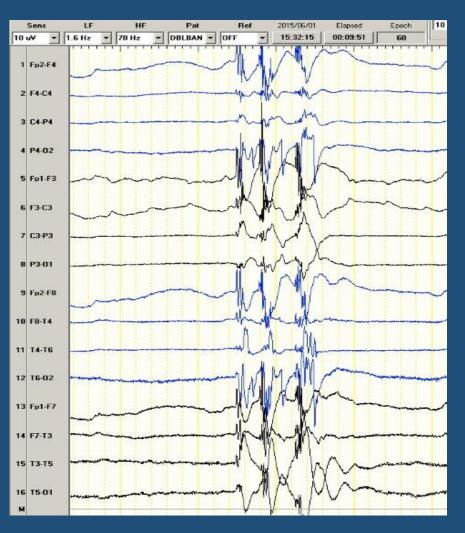


#### **Burst Suppression**



**Status Epilepticus** 





**Burst Suppression** 



## Non-Epileptiform EEG Abnormalities



Most non-epileptiform abnormalities of the EEG take the form of **slowing**; in other words transient waves or rhythms with frequencies lower than 8Hz and in the theta and delta ranges.

However, it is crucial to keep in mind that **not all slowing is pathological**. For instance, normal drowsiness and sleep are associated with physiological slowing of the EEG



#### **Unreactive Slowing**

As a rule of thumb:

- Generalised slowing is non-specific and indicates encephalopathy of many possible causes
- Focal slowing suggests focal cerebral dysfunction (e.g. stroke, tumour, focal encephalitis)
- The slower the rhythm, the more pathological it is (i.e. delta is more pathological than theta)



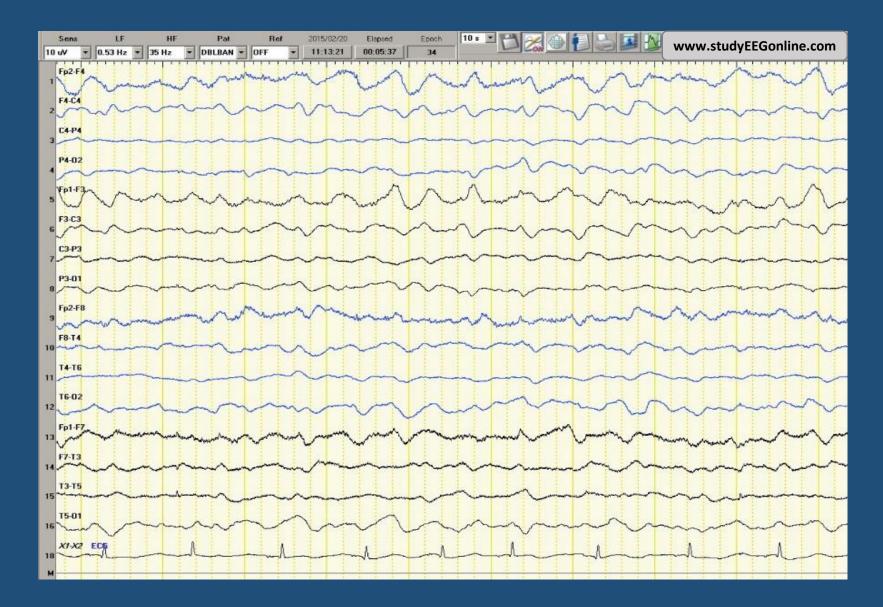
#### Generalised Slowing: Theta

7 uV v 0.53 Hz v 70 Hz v Trace v OFF v 09:45:43 00:13:24 81 www.studyEEGonline.com me a survey manual and and and a construction and 2 race NMM many have a second 1 P402 Martin Mart 5 F07 F3 warman warman warman warman and a warman war and a share and a share warman and a share warman warma s coop AMMANNA AMMANA 8 P301 hadrown which have a second which have 3 FOZER Manager and the second and t 13 EDT Manus Man Manus M 10 1201 Margan Marg hand the second 18 XT-X2

In this epoch the background (PDR) consists of generalised 6 Hz theta which is consistent with mild encephalopathy, unless the patient is drowsy.

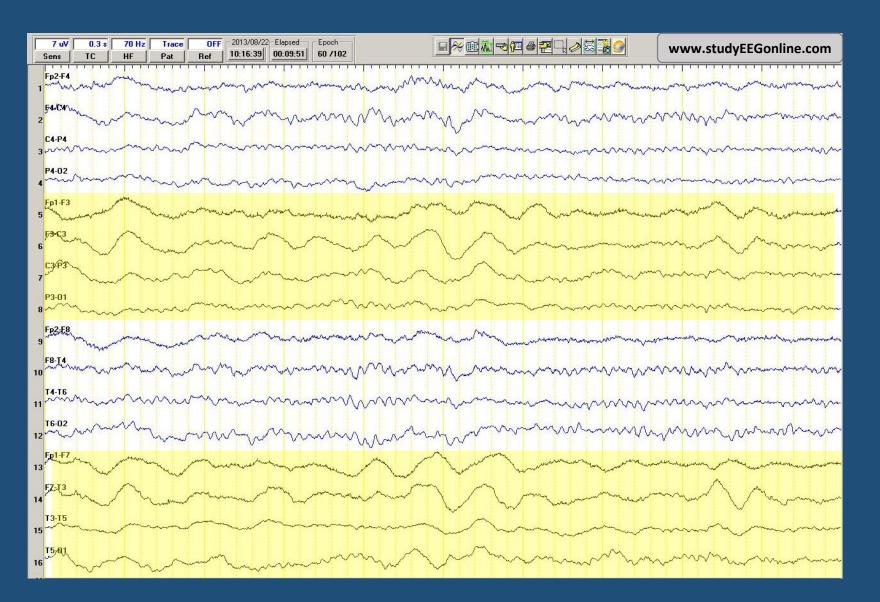


#### Generalised Slowing: Delta



In this epoch the background (PDR) consists of generalised 2-3 Hz delta which is consistent with moderate to severe encephalopathy, unless the patient is in slow wave sleep.

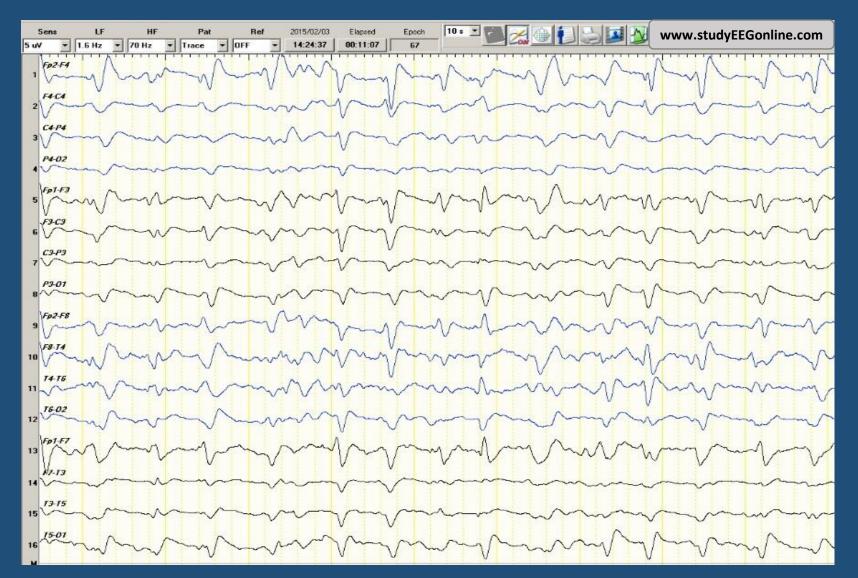
#### Focal Slowing: Left Hemisphere, Delta



Here focal 2-3 Hz delta affects all channels over the left side of the head. This suggests an underlying structural intracranial abnormality in the left hemisphere.



#### **Triphasic Waves**

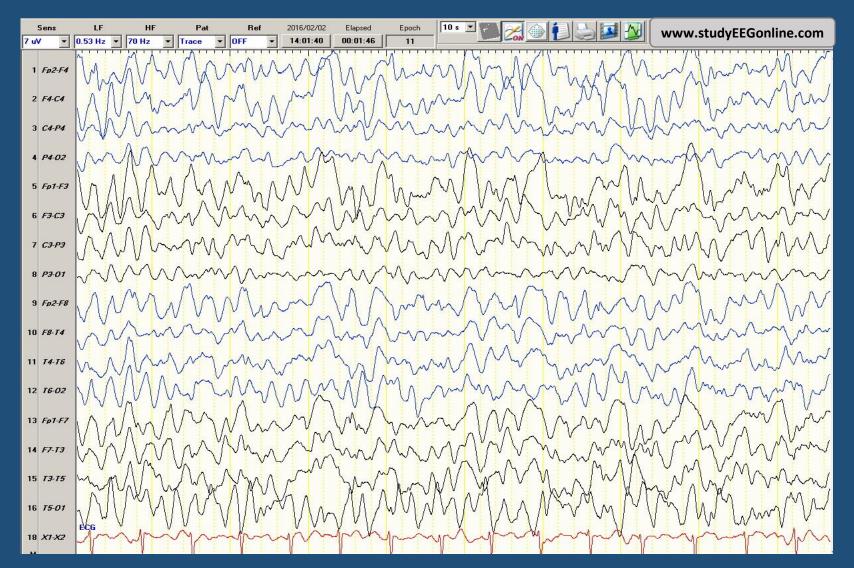


Triphasic waves are commonly associated with metabolic derangements and especially hepatic encephalopathy



## **Depression of Consciousness & Coma**

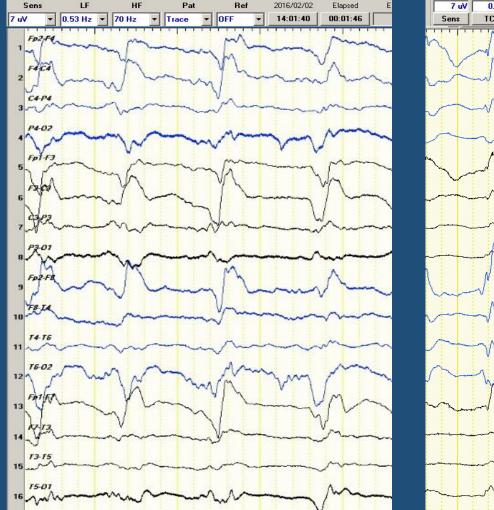
### Persistent, Unreactive, Polymorphic Delta



Persistent, generalised, unreactive, polymorphic delta activity is nonspecific but implies severe diffuse encephalopathy

#### **PEDS (Periodic Epileptiform Discharges)**







PEDS / PLEDS imply subclinical status epilepticus







#### Alpha Coma

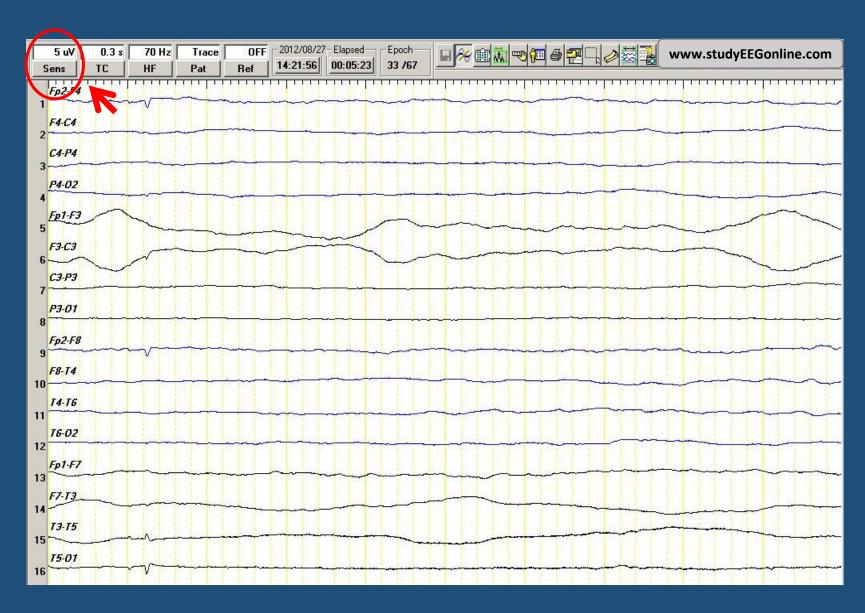
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**Unreactive to Painful Stimulus** 

Occasionally the EEGs of patients in severe coma may show generalised unreactive alpha frequencies.

This is typically associated with a poor prognosis

### **Suppression & Electro-cerebral Silence**



Suppression implies reduced cerebral activity while electro-cerebral silence indicates that no detectable electrical activity is present

It is important to keep in mind that suppression and electro-cerebral silence are not necessarily pathological, and may be reversibly induced in normal people by anaesthetic drugs, hypothermia, and some toxic states

#### What we have covered

#### The Basics of:

- Generation of Electrical Discharges in the Brain
- Electrical Fields & Dipoles
- Electrode Placement (10-20 and 10-10 System)
- Montages
- Normal EEG in Wakefulness and Drowsiness
- Epileptiform Waveforms
- Non-Epileptiform Waveforms.

#### What we have not covered



Many normal variants and artefacts closely resemble pathological waveforms and which can result in the wrong diagnosis and serious harm

#### With respect to reading EEGs...

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