NeuroTrace Study Guide

Domain: Domain I – Basic Concepts & Principles
Section: Neurophysiology & Seizure Mechanisms
Style: Conceptual but applied, exam-oriented

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1. Core Principles (Must Know)

EEG Reflects Postsynaptic Potentials, Not Action Potentials

- **EEG reflects postsynaptic potentials, not action potentials**
- Action potentials are too brief and small to be detected
- Postsynaptic potentials are slower and larger
- Many neurons must fire synchronously
- Scalp EEG detects synchronized activity

Large Numbers of Neurons Must Fire Synchronously

- **Large numbers of neurons must fire synchronously**
- Individual neurons cannot be detected
- Thousands of neurons must fire together
- Synchronization is essential
- Without synchronization, no EEG signal

Cortical Pyramidal Neurons Are Primary EEG Generators

- **Cortical pyramidal neurons are primary EEG generators**
- Pyramidal cells have vertical orientation
- Vertical orientation creates detectable fields
- Pyramidal cells are most numerous in cortex
- Other cell types contribute less

Key Principle

- **Synchronization determines EEG visibility**
- Synchronized activity is visible
- Desynchronized activity is not visible
- Degree of synchronization affects amplitude
- Synchronization patterns create rhythms

Practical Application

- Understand that EEG requires synchronization
- Know that postsynaptic potentials generate EEG
- Recognize that pyramidal cells are primary generators
- Appreciate that individual neurons are not detected

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2. EEG Signal Generation

Excitatory and Inhibitory Postsynaptic Potentials

Excitatory Postsynaptic Potentials (EPSPs)

- **Excitatory postsynaptic potentials (EPSPs):** Depolarizing potentials
- Make neurons more likely to fire

- Create positive or negative deflections
- Sum together to create larger signals
- Contribute to EEG activity

Inhibitory Postsynaptic Potentials (IPSPs)

- **Inhibitory postsynaptic potentials (IPSPs):** Hyperpolarizing potentials
- Make neurons less likely to fire
- Create opposite deflections
- Balance excitatory activity
- Contribute to EEG patterns

Vertical Orientation of Pyramidal Cells

- **Vertical orientation of pyramidal cells:** Key to EEG detection
- Pyramidal cells are oriented perpendicular to cortex
- Vertical orientation creates detectable fields
- Parallel orientation allows summation
- Creates large enough fields for scalp detection

Summation Across Cortical Columns

- **Summation across cortical columns:** Amplifies signals
- Many pyramidal cells in columns
- Synchronized activity sums together
- Creates larger, detectable signals
- Essential for scalp EEG detection

ABRET Emphasis

- **Deep structures are poorly represented on scalp EEG**
- Deep structures (thalamus, hippocampus) are far from scalp
- Distance attenuates signals
- Deep activity may not be visible
- Surface structures are better represented

Best Practice

- Understand that EEG requires synchronized, large populations
- Know that vertical orientation is essential
- Recognize that deep structures are poorly represented
- Appreciate that summation creates detectable signals

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3. Neuronal Synchronization

Normal Rhythms Arise from Synchronized Networks

- **Normal rhythms arise from synchronized networks**
- Alpha rhythm: Synchronized occipital activity
- Beta rhythm: Synchronized frontal activity
- Theta rhythm: Synchronized temporal activity
- Synchronization creates visible rhythms

Excessive Synchronization → Pathologic Rhythms

- **Excessive synchronization → pathologic rhythms**
- Too much synchronization is abnormal

- Creates epileptiform patterns
- May indicate hyperexcitability
- Can lead to seizures

Thalamocortical Circuits Influence Rhythm Generation

- **Thalamocortical circuits influence rhythm generation**
- Thalamus connects to cortex
- Thalamocortical loops create rhythms
- Sleep spindles: Thalamocortical activity
- Absence seizures: Thalamocortical hypersynchrony

Best Practice

- Understand that synchronization creates rhythms
- Know that excessive synchronization is pathologic
- Recognize thalamocortical role in rhythms
- Appreciate network-level activity

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4. Seizure Mechanisms (Basic)

Imbalance Between Excitation and Inhibition

- **Imbalance between excitation and inhibition**
- Normal: Balance between excitation and inhibition
- Seizure: Imbalance favoring excitation
- Too much excitation → hyperexcitability
- Too little inhibition → disinhibition

Hyperexcitable Neuronal Populations

- **Hyperexcitable neuronal populations**
- Neurons fire more easily
- Lower threshold for firing
- More likely to fire synchronously
- Creates epileptiform activity

Hypersynchrony Produces Epileptiform Discharges

- **Hypersynchrony produces epileptiform discharges**
- Excessive synchronization
- Large populations fire together
- Creates spikes and sharp waves
- Visible on EEG

EEG Correlate

- **Spikes and sharp waves reflect sudden synchronous depolarization**
- Spikes: Brief, synchronous depolarization
- Sharp waves: Slower, synchronous depolarization
- Both reflect hyperexcitability
- Both indicate seizure risk

Best Practice

- Understand that seizures involve imbalance
- Know that hyperexcitability creates epileptiform activity

- Recognize that hypersynchrony produces spikes
- Appreciate that EEG reflects network-level activity

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5. Focal vs Generalized Seizure Physiology

Type	Mechanism	EEG Correlate
Focal	Local cortical hyperexcitability	Focal spikes
Generalized	Widespread network involvement	Generalized spike-and-wave

Key Distinctions

Focal Seizures

- **Local cortical hyperexcitability:** Limited to one area
- Small population of hyperexcitable neurons
- Local synchronization
- Focal EEG patterns
- May spread to other areas

Generalized Seizures

- **Widespread network involvement:** Both hemispheres
- Large populations involved
- Widespread synchronization
- Generalized EEG patterns
- Thalamocortical networks involved

Best Practice

- Understand that focal = local, generalized = widespread
- Know that mechanisms differ
- Recognize that EEG patterns reflect mechanisms
- Appreciate that both involve hyperexcitability

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6. Factors Affecting EEG Expression

Age

- **Age:** Affects EEG patterns
- Children: Different patterns than adults
- Background frequency increases with age
- Epileptiform patterns vary with age
- Must use age-appropriate norms

Sleep

- **Sleep:** Affects EEG patterns
- Sleep stages create different patterns
- Sleep enhances epileptiform activity
- Sleep spindles are normal
- Must know sleep stage

Medications

- **Medications:** Affect EEG patterns
- Antiepileptic drugs may suppress activity
- Sedatives may create slowing
- Stimulants may increase activity
- Must know medication effects

Metabolic State

- **Metabolic state:** Affects EEG patterns
- Hypoglycemia: Slowing
- Hyperglycemia: Variable effects
- Metabolic encephalopathy: Diffuse slowing
- Must consider metabolic state

ABRET Trap

- **Absence of epileptiform discharges does not exclude epilepsy**
- Normal EEG does not rule out epilepsy
- Interictal EEG may be normal
- Seizures may not be captured
- Clinical correlation is essential

Best Practice

- Consider age, sleep, medications, metabolic state
- Know that normal EEG doesn't exclude epilepsy
- Understand that many factors affect EEG
- Appreciate that clinical correlation is essential

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7. Common ABRET Exam Traps

Trap 1: Thinking EEG Shows Individual Neuron Firing

- **Reality:** EEG shows synchronized populations
- **Trap:** May think EEG shows individual neurons
- **Solution:** Understand that EEG requires synchronization
- **ABRET focus:** EEG signal generation

Trap 2: Overestimating Deep Brain EEG Representation

- **Reality:** Deep structures are poorly represented
- **Trap:** May think deep structures are well represented
- **Solution:** Know that distance attenuates signals
- **ABRET focus:** EEG signal detection

Trap 3: Assuming Seizures Always Produce EEG Changes

- **Reality:** Some seizures may not show on EEG
- **Trap:** May assume all seizures show on EEG
- **Solution:** Know that some seizures are not visible
- **ABRET focus:** EEG limitations

Trap 4: Confusing Seizure Physiology with EEG Appearance

- **Reality:** Physiology and appearance are related but different
- **Trap:** May confuse mechanism with appearance
- **Solution:** Understand relationship between physiology and EEG

- **ABRET focus:** Physiology-EEG correlation

Trap 5: Not Understanding Synchronization Requirements

- **Reality:** Synchronization is essential for EEG
- **Trap:** May not understand why synchronization is needed
- **Solution:** Understand that individual neurons are not detected
- **ABRET focus:** EEG signal generation principles

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8. Case-Based Example

Scenario

Clinical Setting: Routine EEG for absence seizures
EEG Finding: Generalized spike-and-wave activity
Question: What is the physiologic basis?

Physiologic Basis

- **Thalamocortical hypersynchrony**
- Thalamus and cortex fire synchronously
- Widespread network involvement
- Excessive synchronization
- Creates generalized spike-and-wave

Teaching Point

- **EEG patterns reflect network-level physiology**
- EEG shows network activity, not individual neurons
- Patterns reflect underlying mechanisms
- Understanding physiology helps interpret EEG

ABRET Application

- Given generalized spike-and-wave → think thalamocortical
- Given focal spikes → think local hyperexcitability
- Given pattern → understand underlying physiology
- Must link physiology to EEG patterns

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9. Exam Readiness Checklist

Use this checklist to verify your understanding:

- [ ] Can explain EEG signal generation (postsynaptic potentials, synchronization)
- [ ] Can describe neuronal synchronization (normal rhythms, pathologic rhythms)
- [ ] Can link seizure mechanisms to EEG (hyperexcitability, hypersynchrony)
- [ ] Can avoid physiologic misconceptions (individual neurons, deep structures)
- [ ] Understand that EEG reflects postsynaptic potentials
- [ ] Know that large numbers of neurons must fire synchronously
- [ ] Recognize that pyramidal cells are primary generators
- [ ] Understand that synchronization determines visibility
- [ ] Know that deep structures are poorly represented
- [ ] Understand that absence of epileptiform doesn't exclude epilepsy

- [ ] Can distinguish focal vs generalized mechanisms
- [ ] Know factors affecting EEG expression

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10. Internal Cross-Links

Foundations

- **Neuroanatomy for EEG Localization:** Understanding brain structure
- **Basic Concepts:** Fundamental EEG principles

Patterns

- **Epileptiform Discharges:** How physiology creates epileptiform patterns
- **Focal vs Generalized:** How mechanisms differ
- **Diffuse Slowing:** How metabolic factors affect EEG

Cases

- **Seizure mechanism cases:** Cases explaining seizure physiology
- **EEG pattern cases:** Cases linking physiology to patterns

Quizzes

- **Neurophysiology MCQs:** Questions on EEG generation and mechanisms
- **Synchronization questions:** Questions on neuronal synchronization
- **Seizure mechanism questions:** Questions on seizure physiology

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Study Tips

1. **Memorize core principles:** Postsynaptic potentials, synchronization, pyramidal cells
2. **Learn signal generation:** EPSPs, IPSPs, vertical orientation, summation
3. **Understand synchronization:** Normal rhythms, pathologic rhythms, thalamocortical
4. **Know seizure mechanisms:** Imbalance, hyperexcitability, hypersynchrony
5. **Remember the principle:** Synchronization determines EEG visibility
6. **Know the traps:** Individual neurons, deep structures, always visible seizures
7. **ABRET focus:** Expect questions on signal generation, synchronization, and seizure mechanisms

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End of Study Guide

For additional practice, complete quiz questions tagged: eeg-generation, synchronization, seizure-mechanisms