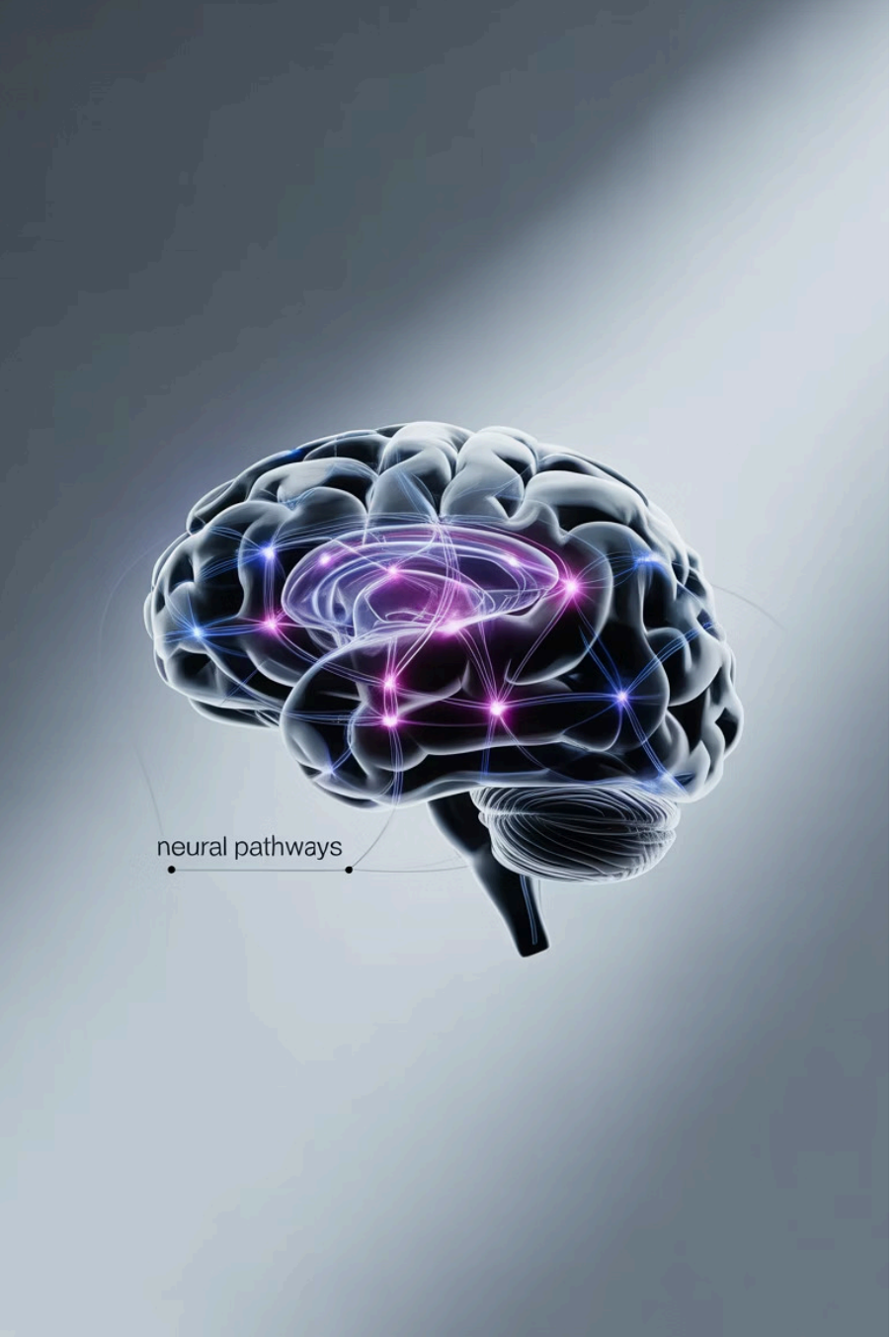


Biopsychology: The Biological Basis of Behaviour

Welcome to this comprehensive exploration of biopsychology, a fascinating field that examines how biological processes influence human behaviour and mental processes. Based on the AQA A-level specification (section 4.2.2), this presentation delves into the intricate workings of the nervous system, brain localisation, hormonal influences, and biological rhythms that govern our daily lives. Each slide includes examination-style questions to help you assess your understanding and prepare for assessments. By the end of this presentation, you'll have gained valuable insights into how our biology shapes our psychology, a crucial foundation for understanding human behaviour.

by Stephen Renwick

The Nervous System: Central and Peripheral Divisions

The nervous system is divided into two main components:

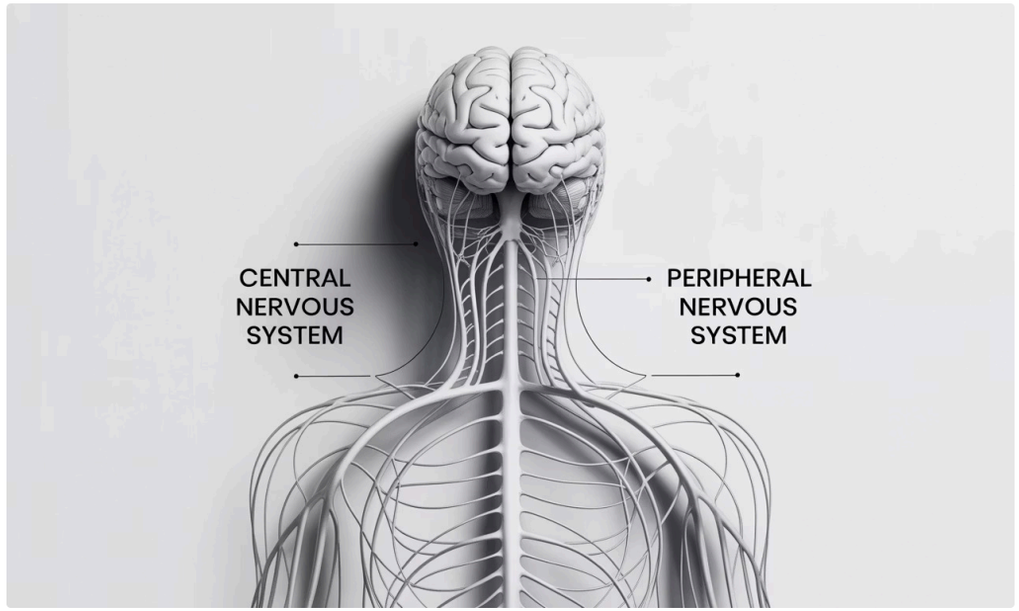
Central Nervous System (CNS): Comprises the brain and spinal cord. It acts as the control centre, processing information and coordinating responses.

Peripheral Nervous System (PNS): Consists of all nerves outside the CNS, connecting it to the rest of the body. The PNS is further divided into:

- **Somatic Nervous System:** Controls voluntary movements via skeletal muscles and processes sensory information.
- **Autonomic Nervous System:** Regulates involuntary functions and has two branches:

- *Sympathetic:* Activates the 'fight or flight' response, preparing the body for action.

- *Parasympathetic:* Promotes 'rest and digest' functions, conserving energy and maintaining normal bodily functions.



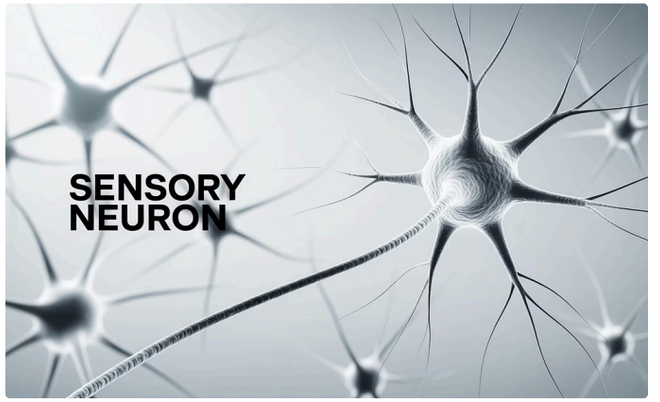
Examination Questions:

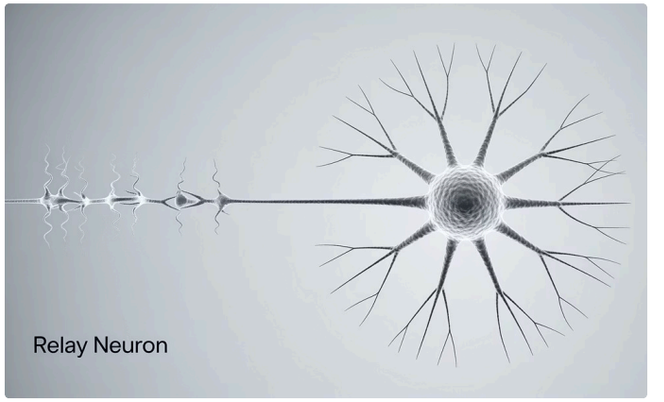
1. Outline the difference between the somatic and autonomic nervous systems. (4 marks)

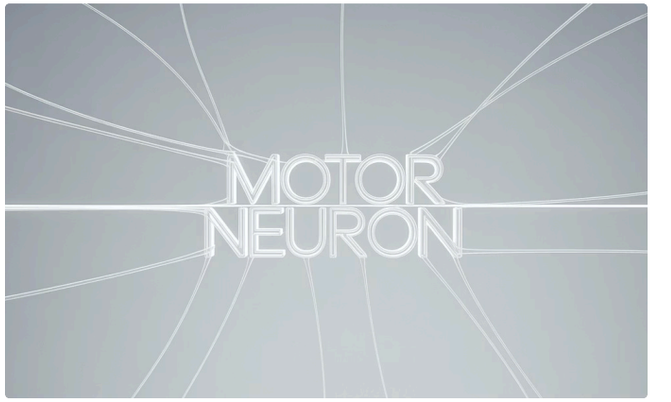
2. Explain how the sympathetic and parasympathetic branches of the autonomic nervous system differ in their effects on the body. (6 marks)

3. Describe the main functions of the central nervous system. (3 marks)

Neurons: Structure and Function







Sensory Neurons

Transmit information from sensory receptors to the CNS. They have a distinctive structure with the cell body offset from the main axon, creating a pseudounipolar appearance. Their dendrites connect to sensory receptors in the skin, muscles, and organs, while their axon terminals form synapses with interneurons or motor neurons in the spinal cord or brain.

Relay (Inter) Neurons

Found exclusively within the CNS, these neurons connect sensory and motor neurons, forming complex neural networks. They process and integrate information from multiple sources. Most neurons in the brain are interneurons, allowing for the complex processing that underlies cognition, memory, and emotion. They typically have shorter axons than sensory or motor neurons.

Motor Neurons

Transmit signals from the CNS to effector organs (muscles and glands). They have a multipolar structure with numerous dendrites receiving signals from interneurons or sensory neurons. Their long axons extend from the CNS to the peripheral effectors, enabling rapid transmission of action potentials that trigger muscle contractions or glandular secretions.

Examination Questions:

1. Compare and contrast the structure and function of sensory and motor neurons. (8 marks)

2. Explain why relay neurons are essential for complex behaviour. (4 marks)

3. Draw and label a typical motor neuron, explaining how its structure relates to its function. (6 marks)

Synaptic Transmission

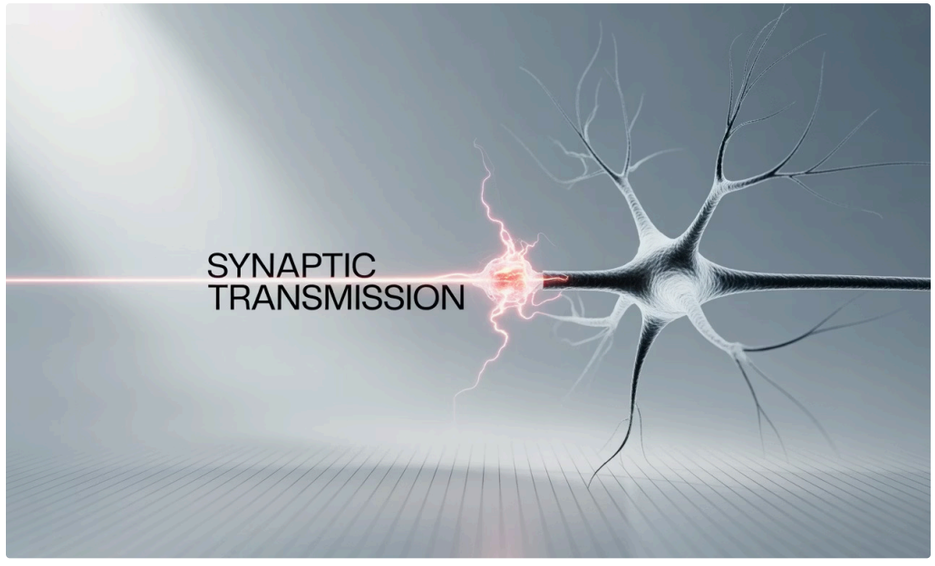
Synaptic transmission is the process by which neurons communicate with each other across a small gap called the synaptic cleft. This electrochemical process involves several steps:

1. An action potential travels along the presynaptic neuron's axon to the terminal button.
2. This triggers calcium channels to open, allowing Ca^{2+} ions to enter the terminal button.
3. Calcium ions cause synaptic vesicles containing neurotransmitters to fuse with the presynaptic membrane.
4. Neurotransmitters are released into the synaptic cleft via exocytosis.
5. Neurotransmitters diffuse across the cleft and bind to specific receptors on the postsynaptic membrane.
6. This binding can have either an excitatory or inhibitory effect on the postsynaptic neuron.

Excitation vs. Inhibition:

- **Excitatory neurotransmitters** (e.g., glutamate) increase the likelihood of an action potential in the postsynaptic neuron by causing depolarisation.

- **Inhibitory neurotransmitters** (e.g., GABA) decrease the likelihood of an action potential by causing hyperpolarisation.



Common Neurotransmitters:

- **Acetylcholine:** Involved in muscle movement, attention, and arousal
- **Dopamine:** Associated with reward, motivation, and motor control
- **Serotonin:** Regulates mood, appetite, and sleep
- **Noradrenaline:** Involved in alertness and the fight-or-flight response

Examination Questions:

1. Describe the process of synaptic transmission. (6 marks)

2. Explain the difference between excitatory and inhibitory neurotransmitters. (4 marks)

3. Discuss how drugs might affect synaptic transmission. (8 marks)

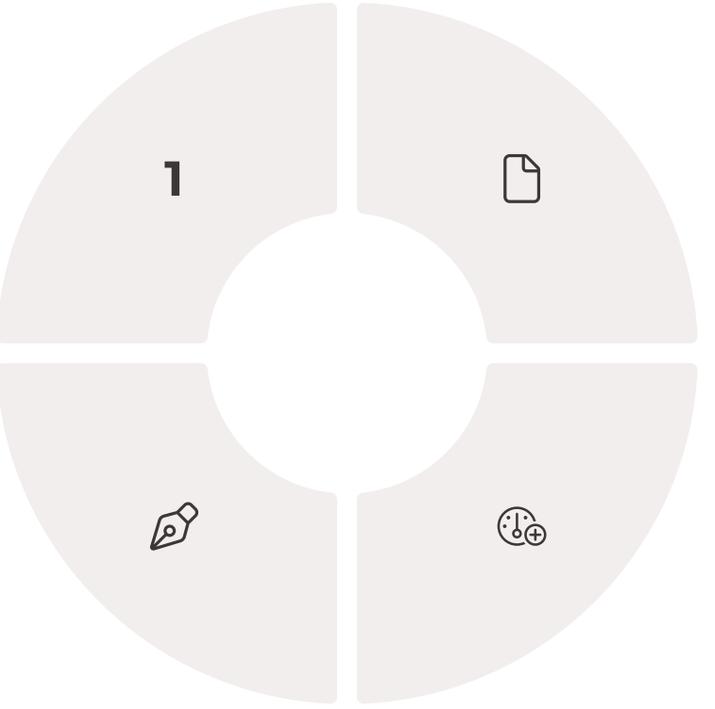
The Endocrine System: Glands and Hormones

Pituitary Gland

Often called the 'master gland', it controls other endocrine glands by releasing hormones that regulate their function. It produces growth hormone, prolactin, and hormones that control the thyroid, adrenal glands, and reproductive organs.

Adrenal Glands

Produce adrenaline, noradrenaline, and cortisol. Adrenaline and noradrenaline are involved in the fight-or-flight response, while cortisol helps regulate metabolism and the immune response.



Thyroid Gland

Produces thyroxine and triiodothyronine, which regulate metabolism, growth, and development. Thyroid hormones affect nearly every cell in the body, controlling how quickly the body uses energy and makes proteins.

Pancreas

Produces insulin and glucagon, which regulate blood glucose levels. Insulin decreases blood glucose by promoting its uptake into cells, while glucagon increases blood glucose by promoting glycogen breakdown in the liver.

Unlike the nervous system, which communicates via electrical impulses, the endocrine system uses chemical messengers (hormones) transported through the bloodstream. This results in slower but longer-lasting effects. Hormones bind to specific receptors on target cells, triggering changes in cellular activity.

Examination Questions:

1. Compare and contrast the communication methods of the nervous system and the endocrine system. (6 marks)

2. Explain the role of the pituitary gland in the endocrine system. (4 marks)

3. Describe how insulin and glucagon work together to maintain blood glucose homeostasis. (8 marks)

The Fight or Flight Response

The fight or flight response is a physiological reaction that occurs in response to a perceived threat or danger. It prepares the body to either fight the threat or flee to safety. This response involves both the nervous system and the endocrine system working together:

1. **Perception of threat:** The amygdala in the brain processes emotional responses and signals potential danger.
2. **Hypothalamus activation:** The hypothalamus activates two systems:
    - The sympathetic nervous system (part of the autonomic nervous system)
    - The adrenal-cortical system (part of the endocrine system)
3. **Sympathetic activation:** Nerve impulses travel to the adrenal medulla, triggering the release of adrenaline (epinephrine) and noradrenaline (norepinephrine).

The role of adrenaline:

- Increases heart rate and force of contractions
- Dilates airways to improve oxygen intake
- Redirects blood flow from digestive system to muscles
- Dilates pupils to improve vision
- Increases blood glucose levels for immediate energy
- Increases mental alertness

These physiological changes prepare the body for intense physical action, improving chances of survival in dangerous situations. However, chronic activation of this response due to ongoing stress can lead to health problems.

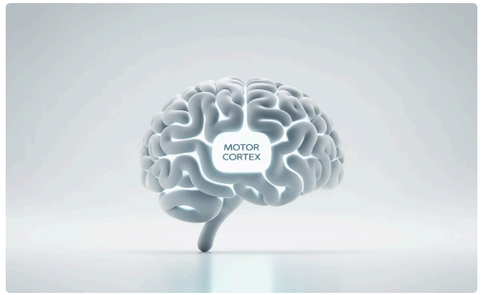
Examination Questions:

1. Describe the role of adrenaline in the fight or flight response. (6 marks)

2. Explain how the sympathetic nervous system and the endocrine system work together during the fight or flight response. (8 marks)

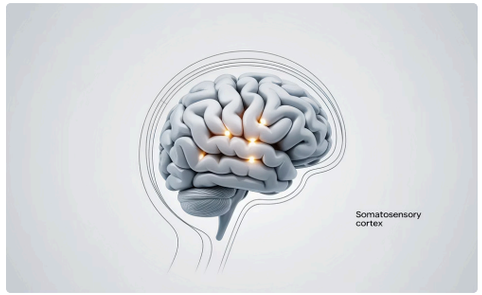
3. Discuss the potential negative effects of chronic activation of the fight or flight response. (6 marks)

Localisation of Function in the Brain



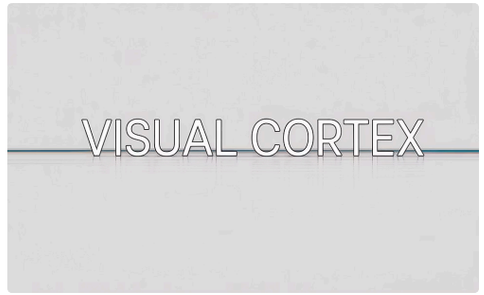
Motor Cortex

Located in the frontal lobe, the primary motor cortex controls voluntary movement. It is organised somatotopically (as a motor homunculus), with different areas controlling different body parts. The size of the cortical area devoted to a body part reflects the precision of movement required rather than the size of the body part.



Somatosensory Cortex

Located in the parietal lobe, this area processes sensory information from the body, including touch, temperature, and pain. Like the motor cortex, it is organised somatotopically (as a sensory homunculus), with proportionally larger areas dedicated to body parts with greater sensory sensitivity, such as the hands and face.



Visual Cortex

Located in the occipital lobe, the primary visual cortex processes visual information from the retina. Different areas process different aspects of vision, such as colour, motion, and form. The right visual cortex processes information from the left visual field and vice versa due to the crossing of optic nerves.

Auditory Cortex

Located in the temporal lobe, the primary auditory cortex processes sound information. It is organised tonotopically, with different frequencies processed by different neurons. The auditory cortex is involved in identifying sound sources, understanding speech, and appreciating music.

Examination Questions:

1. Explain what is meant by 'localisation of function' in the brain. (4 marks)

2. Describe the organisation of the primary motor cortex and explain why some body parts have larger representations than others. (6 marks)

3. Outline the functions of the visual cortex and explain how visual information is processed. (8 marks)

Language Centres and Hemispheric Lateralisation

Broca's Area

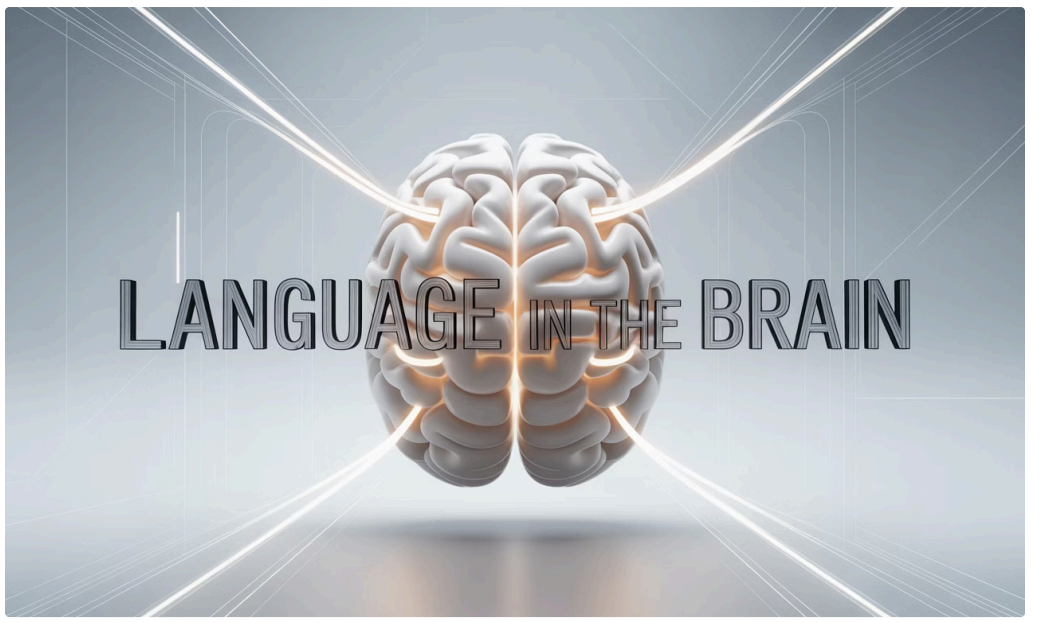
Located in the frontal lobe (usually in the left hemisphere), Broca's area is primarily responsible for speech production and language processing. Damage to this area results in Broca's aphasia, characterised by:

- Slow, effortful speech
- Difficulty forming grammatically correct sentences
- Relatively preserved comprehension
- Awareness of speech deficits, often leading to frustration

Wernicke's Area

Located in the temporal lobe (usually in the left hemisphere), Wernicke's area is primarily responsible for language comprehension. Damage to this area results in Wernicke's aphasia, characterised by:

- Fluent but meaningless speech
- Poor comprehension
- Use of made-up words (neologisms)
- Lack of awareness of speech deficits



Hemispheric Lateralisation

The brain is divided into two hemispheres, each specialising in different functions:

Left Hemisphere (typically dominant for):

- Language processing
- Logical and analytical thinking
- Sequential processing
- Mathematical calculations

Right Hemisphere (typically dominant for):

- Spatial awareness
- Face recognition
- Visual imagery
- Musical ability
- Emotional processing

Examination Questions:

1. Compare and contrast Broca's aphasia and Wernicke's aphasia. (8 marks)

2. Explain what is meant by 'hemispheric lateralisation' and give examples of functions that are lateralised. (6 marks)

3. Discuss the evidence for the localisation of language in the brain. (10 marks)

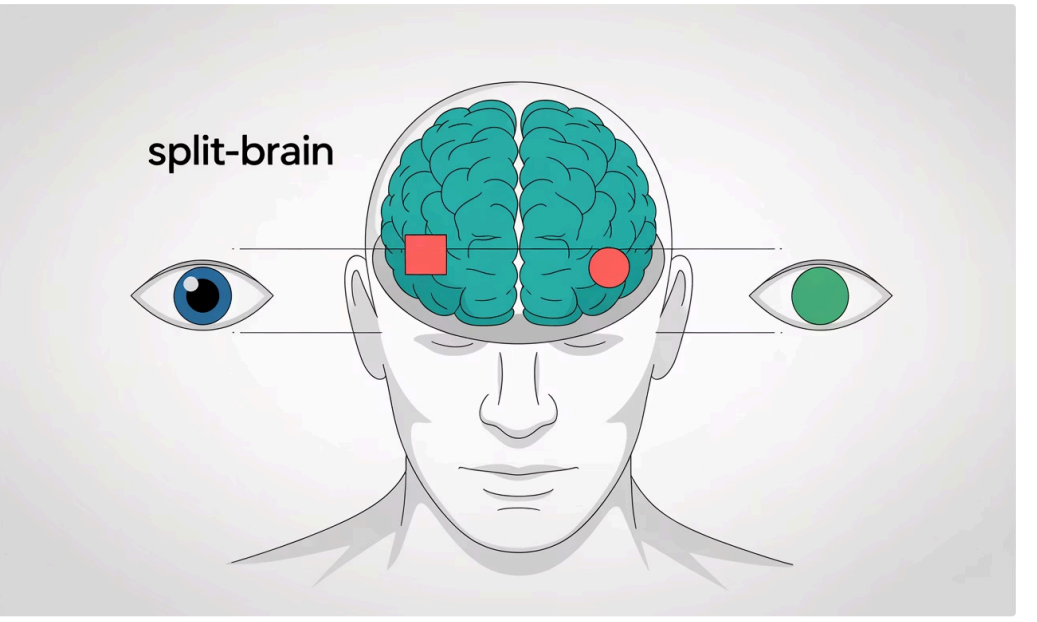
Split Brain Research

Split brain research has provided valuable insights into hemispheric specialisation. This research primarily involved patients who had undergone corpus callosotomy—a surgical procedure that severs the corpus callosum (the main connection between the two hemispheres) to treat severe epilepsy.

Roger Sperry and Michael Gazzaniga's Research:

In the 1960s, these researchers conducted experiments with split-brain patients that revealed:

- Information presented to one hemisphere could not be verbally reported if presented to the right hemisphere (which lacks language centres in most people).
- When an image was presented to the left visual field (processed by the right hemisphere), patients could not name the object but could select it with their left hand (controlled by the right hemisphere).
- When an image was presented to the right visual field (processed by the left hemisphere), patients could name the object but might not recognise it with their left hand.



Key Findings and Implications:

- Confirmed that the left hemisphere is typically dominant for language.
- Demonstrated that each hemisphere can function independently and has different capabilities.
- Suggested that consciousness might be divided in these patients, with each hemisphere having its own perceptions and responses.
- Revealed that the right hemisphere has limited language abilities but excels in spatial tasks.
- Showed that the corpus callosum is crucial for integrating information between hemispheres.

This research earned Sperry the Nobel Prize in Physiology or Medicine in 1981 and fundamentally changed our understanding of brain organisation.

Examination Questions:

1. Describe a typical experiment conducted with split-brain patients and explain what it reveals about hemispheric specialisation. (8 marks)

2. Evaluate the ethical implications of split-brain research. (6 marks)

3. Discuss how split-brain research has contributed to our understanding of consciousness. (10 marks)

Brain Plasticity and Recovery After Trauma

1

Neural Plasticity

The brain's ability to reorganise itself by forming new neural connections. This property allows the brain to adapt to new situations, learn new information, and recover from injury. Plasticity is greatest during childhood but continues throughout life.

Brain Trauma

Damage to the brain can occur through various means, including stroke, traumatic brain injury, or neurodegenerative diseases. The effects depend on the location and extent of damage, with some functions more likely to recover than others.

Recovery Mechanisms

Several mechanisms contribute to functional recovery: - Unmasking of existing but inactive pathways - Sprouting of new connections from undamaged neurons - Recruitment of adjacent brain areas to take over lost functions - Reorganisation of neural circuits

Rehabilitation

Targeted therapies can enhance recovery by promoting neuroplasticity: - Physical therapy for motor deficits - Speech therapy for language impairments - Cognitive rehabilitation for attention and memory - Constraint-induced movement therapy

Factors affecting recovery include age (younger brains typically show greater plasticity), the extent and location of damage, individual differences in brain organisation, and the timing and intensity of rehabilitation efforts. Recovery is typically greatest in the first few months after injury but can continue for years.

Research has shown that environmental enrichment and cognitive stimulation can enhance neuroplasticity and improve recovery outcomes. This has led to the development of various therapeutic approaches that aim to harness the brain's natural plasticity to promote functional recovery.

Examination Questions:

1. Explain what is meant by 'neuroplasticity' and describe how it contributes to recovery after brain injury. (8 marks)

2. Discuss factors that influence the extent of recovery following brain damage. (6 marks)

3. Evaluate the effectiveness of rehabilitation techniques in promoting recovery after brain injury. (10 marks)

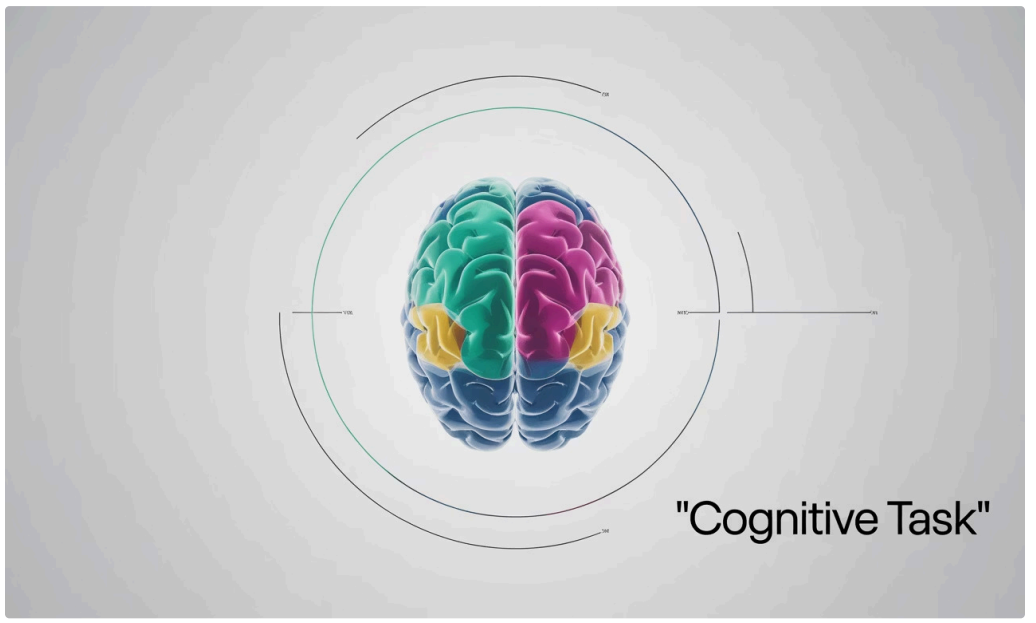
Scanning Techniques: fMRI

Functional Magnetic Resonance Imaging (fMRI)

fMRI is a neuroimaging technique that measures brain activity by detecting changes in blood flow. It works on the principle that when an area of the brain is in use, blood flow to that region increases to meet the demand for oxygen and nutrients.

How fMRI Works:

1. The scanner uses a strong magnetic field to align hydrogen atoms in the brain.
2. Radio frequency pulses temporarily disrupt this alignment.
3. As atoms return to alignment, they emit signals that are detected by the scanner.
4. Active brain regions require more oxygen, delivered by oxygenated haemoglobin.
5. Oxygenated and deoxygenated haemoglobin have different magnetic properties.
6. The scanner detects these differences (BOLD signal - Blood Oxygen Level Dependent).
7. Computer processing creates images showing which brain areas are active during specific tasks.



Advantages of fMRI:

- Non-invasive and uses no radiation
- Excellent spatial resolution (can pinpoint activity to within millimetres)
- Can create 3D images of brain activity
- Allows researchers to observe brain activity during cognitive tasks

Limitations of fMRI:

- Poor temporal resolution (several seconds delay in detecting changes)
- Measures blood flow as a proxy for neural activity, not direct neural activity
- Expensive and requires subjects to remain still in a confined space
- Data requires complex statistical analysis and interpretation

Examination Questions:

1. Explain how fMRI works to detect brain activity. (6 marks)

2. Discuss the strengths and limitations of using fMRI to study brain function. (8 marks)

3. Describe a research study that has used fMRI and explain what it revealed about brain function. (10 marks)

Scanning Techniques: EEGs and ERPs

Electroencephalogram (EEG)

An EEG records electrical activity in the brain using electrodes placed on the scalp. It measures voltage fluctuations resulting from ionic current flows within neurons.

How EEG Works:

1. Multiple electrodes are placed on the scalp in standardised positions.
2. These electrodes detect tiny electrical signals produced by neurons.
3. Signals are amplified and recorded as waveforms.
4. Different patterns of brain waves are associated with different states:

- **Alpha waves** (8-13 Hz): Relaxed wakefulness, closed eyes
- **Beta waves** (13-30 Hz): Alert, active concentration
- **Theta waves** (4-8 Hz): Drowsiness, meditation
- **Delta waves** (0.5-4 Hz): Deep sleep

Applications of EEG:

- Diagnosing epilepsy and sleep disorders
- Monitoring consciousness during surgery
- Studying sleep patterns
- Brain-computer interfaces

Event-Related Potentials (ERPs)

ERPs are measured brain responses that are the direct result of a specific sensory, cognitive, or motor event. They are calculated by averaging EEG activity time-locked to the presentation of a stimulus.

How ERPs Work:

1. A stimulus is presented multiple times while EEG is recorded.
2. The EEG segments following each stimulus are averaged together.
3. Random brain activity cancels out, leaving only the response related to the stimulus.
4. The resulting waveform shows components that reflect different stages of processing.

Common ERP Components:

- **P300:** Appears about 300ms after stimulus, associated with decision-making
- **N400:** Appears about 400ms after stimulus, associated with semantic processing
- **P600:** Appears about 600ms after stimulus, associated with syntactic processing

Examination Questions:

1. Describe how an EEG records brain activity and explain what the different brainwave patterns indicate. (8 marks)

2. Explain how event-related potentials (ERPs) are measured and what they can tell us about cognitive processing. (6 marks)

3. Compare and contrast EEG and fMRI as techniques for studying brain function. (10 marks)

Post-Mortem Examinations and Other Brain Study Methods

Post-Mortem Examinations

The study of brain tissue after death has been fundamental to our understanding of brain structure and function. This approach allows direct observation of brain anatomy and pathology.

Key aspects:

- Allows detailed examination of brain structure at cellular and molecular levels
- Can reveal abnormalities associated with neurological and psychiatric disorders
- Provides information about neurodegenerative diseases like Alzheimer's and Parkinson's
- Historical cases like Phineas Gage and HM have provided valuable insights into brain function

Limitations:

- Cannot observe brain function or activity
- May not reflect the brain's condition during life
- Ethical considerations regarding consent and tissue use

Transcranial Magnetic Stimulation (TMS)

TMS is a non-invasive procedure that uses magnetic fields to stimulate nerve cells in the brain. It can be used to study brain function by temporarily disrupting activity in specific brain regions.

Applications:

- Creating 'virtual lesions' to study the role of specific brain regions
- Investigating brain connectivity
- Therapeutic applications for depression and other disorders

Advantages:

- Non-invasive and generally safe
- Good temporal resolution
- Can establish causal relationships between brain regions and functions

Positron Emission Tomography (PET)

PET scans use radioactive tracers to measure metabolic activity in the brain, providing information about brain function.

How it works:

- A radioactive tracer is injected into the bloodstream
- The tracer emits positrons that are detected by the scanner
- Areas with higher metabolic activity show greater tracer concentration

Applications:

- Studying neurotransmitter systems
- Investigating metabolic changes in neurological disorders
- Monitoring treatment effects

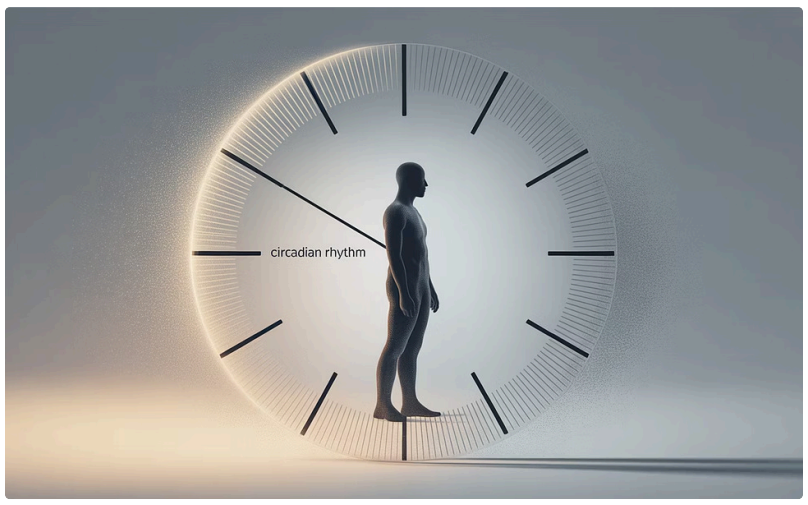
Examination Questions:

1. Discuss the contribution of post-mortem examinations to our understanding of brain function. (8 marks)

2. Compare and contrast two different methods for studying the brain, evaluating the strengths and limitations of each. (10 marks)

3. Explain how transcranial magnetic stimulation (TMS) can be used to investigate brain function. (6 marks)

Biological Rhythms: Types and Characteristics



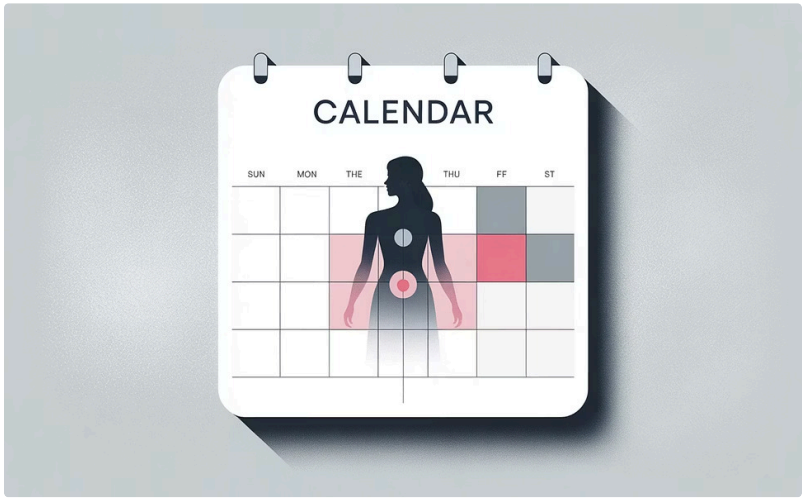
Circadian Rhythms

Duration: Approximately 24 hours

Examples:

- Sleep-wake cycle
- Body temperature fluctuations
- Hormone secretion (e.g., cortisol, melatonin)
- Alertness and cognitive performance

Circadian rhythms are regulated primarily by the suprachiasmatic nucleus (SCN) in the hypothalamus, which acts as the body's master clock. These rhythms help organisms anticipate and prepare for regular environmental changes.



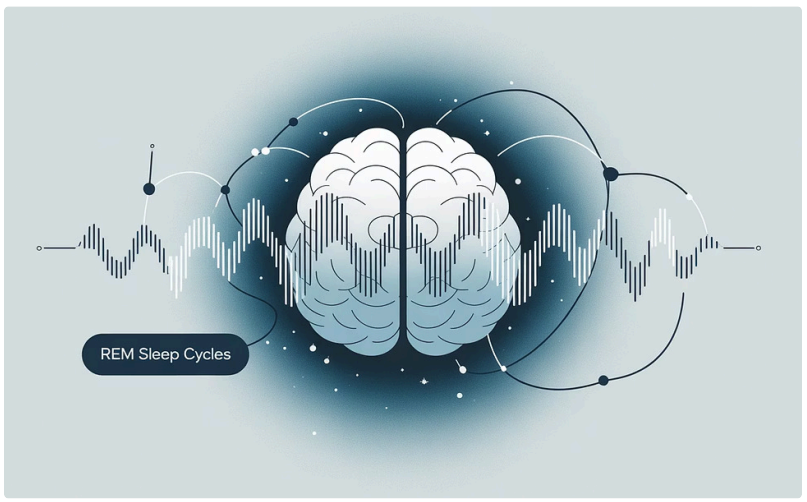
Infradian Rhythms

Duration: Longer than 24 hours

Examples:

- Menstrual cycle (approximately 28 days)
- Seasonal affective disorder (SAD)
- Hibernation in animals
- Seasonal breeding patterns

Infradian rhythms often align with longer-term environmental changes such as seasons or lunar cycles. They regulate processes that require longer periods to complete and often involve complex hormonal interactions.



Ultradian Rhythms

Duration: Shorter than 24 hours

Examples:

- REM sleep cycles (90-120 minutes)
- Basic rest-activity cycle (BRAC, 90-120 minutes)
- Hunger cycles
- Attention span fluctuations

Ultradian rhythms regulate processes that occur multiple times within a day. They often reflect the body's need to alternate between periods of activity and rest to maintain optimal functioning and prevent exhaustion.

Understanding biological rhythms is crucial for optimising performance, managing shift work, treating sleep disorders, and addressing jet lag. Disruption of these rhythms can have significant negative effects on physical and mental health, including increased risk of cardiovascular disease, metabolic disorders, and mood disturbances.

Examination Questions:

1. Compare and contrast circadian, infradian, and ultradian rhythms, giving examples of each. (9 marks)

2. Explain why biological rhythms are important for survival and optimal functioning. (6 marks)

3. Discuss the potential consequences of disrupting biological rhythms. (8 marks)

Endogenous Pacemakers and Exogenous Zeitgebers

Endogenous Pacemakers

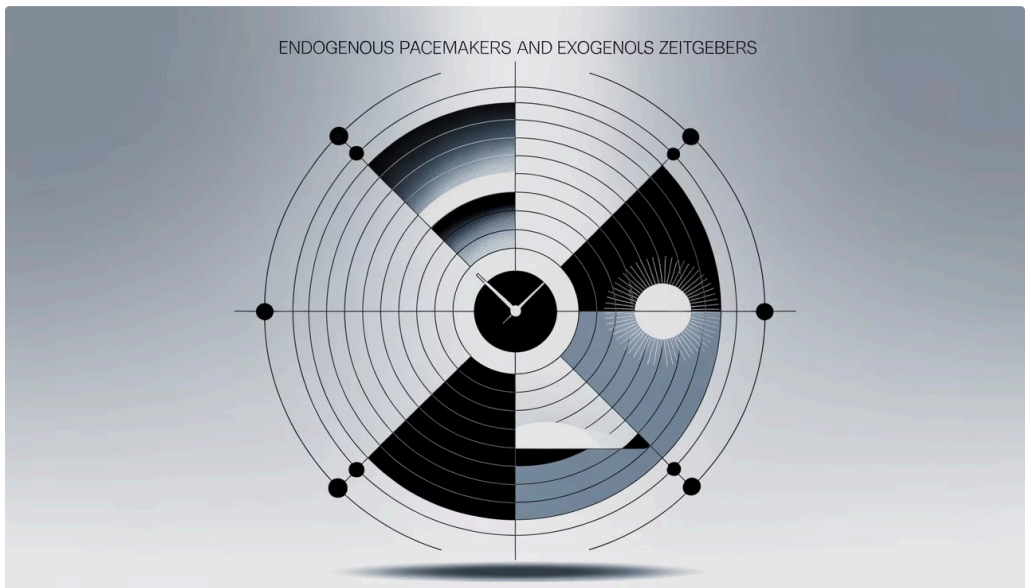
Endogenous pacemakers are internal biological mechanisms that regulate our biological rhythms. They function even in the absence of external cues.

Key endogenous pacemakers:

- **Suprachiasmatic Nucleus (SCN):** Located in the hypothalamus, the SCN is the master circadian pacemaker. It contains about 20,000 neurons that generate rhythmic activity with a period of approximately 24 hours.
- **Pineal Gland:** Produces melatonin, a hormone that regulates sleep-wake cycles. Melatonin secretion increases in darkness and decreases in light.
- **Peripheral Clocks:** Many tissues and organs contain their own circadian clocks, which are synchronised by the SCN.

Evidence for endogenous pacemakers:

- Free-running experiments show that circadian rhythms persist in constant conditions but may drift slightly (typically to a 25-hour cycle).
- Lesion studies show that damage to the SCN disrupts circadian rhythms.
- Transplant studies show that SCN transplants can restore rhythms in animals with SCN lesions.



Exogenous Zeitgebers

Zeitgebers (German for "time-givers") are external cues that entrain or synchronise biological rhythms to the environment.

Key zeitgebers:

- **Light:** The most powerful zeitgeber for circadian rhythms. Light information is transmitted from the retina to the SCN via the retinohypothalamic tract.
- **Temperature:** Changes in environmental temperature can entrain some biological rhythms.
- **Social Cues:** Meal times, work schedules, and social interactions can act as zeitgebers.
- **Exercise:** Regular physical activity can help entrain circadian rhythms.

The Sleep/Wake Cycle:

The sleep/wake cycle is regulated by the interaction between:

- Circadian process (controlled by the SCN)
- Homeostatic sleep drive (pressure to sleep that builds during wakefulness)
- External zeitgebers (primarily light)

Examination Questions:

1. Explain the role of endogenous pacemakers in regulating circadian rhythms. (8 marks)

2. Discuss the relative importance of endogenous pacemakers and exogenous zeitgebers in controlling the sleep/wake cycle. (10 marks)

3. Describe research that has investigated the role of the suprachiasmatic nucleus in controlling biological rhythms. (6 marks)