Biopsychology – Unit 2.

The Specification:

- The **divisions of the nervous system**: central and peripheral (somatic and autonomic).

- The **structure and function of sensory, relay and motor neurons**. The process of synaptic transmission, including reference to neurotransmitters, excitation and inhibition.

- The **function of the endocrine system**: glands and hormones.

- The **fight or flight response** including the role of adrenaline.

- **Localisation of function in the brain and hemispheric lateralisation**: motor, somatosensory, visual, auditory and language centres; Broca’s and Wernicke’s areas, split brain research. **Plasticity** and functional recovery of the brain after trauma.

- **Ways of studying the brain**: scanning techniques, including functional magnetic resonance imaging (fMRI); electroencephalogram (EEGs) and event-related potentials (ERPs); post-mortem examinations.

- **Biological rhythms**: circadian, infradian and ultradian and the difference between these rhythms. The effect of *endogenous pacemakers* and *exogenous zeitgebers* on the sleep/wake cycle.
Part A The Central Nervous System (CNS)

The Brain:
- The Central Nervous System consists of the **brain** and the **spinal cord**. The brain’s outer layer, the Cerebral Cortex, is highly developed in humans than in any other animal. It is what we see when we picture a human brain, the gray matter with a multitude of folds making up the outer layer of the brain. It is involved in a variety of higher cognitive (conscious thought), emotional, sensory (5 senses), and motor (movement) functions.
- The brain is divided into two symmetrical hemispheres: **left** (language, the ‘rational’ half of the brain, associated with analytical thinking and logical abilities) and **right** (involved with musical and artistic abilities). These are further divided up into **four** distinct lobes, which you will learn more about later. Under the cerebral cortex is the area of the brain which is more primitive and are concerned with vital functioning and instinctive behaviour.

The Spinal Cord:
- The spinal cord is a white bundle of nerves, which runs from your brain along a canal in your backbone. It’s roughly 40cm long and about as wide as your thumb for most of its length. Like the brain, your spinal cord is part of your central nervous system. Its main function is to pass messages to and from the brain. It is also involved in reflex actions, such as the startle response, i.e. pulling your hand away from a hot plate.
Part B The Peripheral Nervous System (PNS)

The PNS consists of nerves outside the brain and spinal cord. It is divided into two major systems, the **Somatic Nervous System** (SNS) and the **Autonomic Nervous System** (ANS).

**The Somatic Nervous System (SNS)** is part of the PNS that is concerned with the interaction of the outside world. It controls the voluntary movement of skeletal muscles (i.e. the biceps; moving an arm, typing on a keyboard). It also consists of the nerves that carry messages to the eyes, ears, skeletal muscles and the skin to give the CNS experience of its environment.

**The Autonomic Nervous System (ANS)** is the part of the PNS that controls involuntary movement from non-skeletal muscles, for example, the ‘smooth muscles’ that control the intestines, digestion, bladder, pupil size and the cardiac muscle (the heart).

Are there any other differences between the SNS and ANS?

- SNS functions include posture and movement; ANS functions include secretion and control of metabolism (converting food into energy).
- SNS – in vertebrates - includes excitatory neurotransmitters. ANS – in vertebrates has both excitatory & inhibitory neurotransmitters (we’ll consider these types of neurotransmitters later when we look at synaptic transmission).

The ANS is split into two further systems: The Sympathetic and the Parasympathetic nervous systems.

**The Sympathetic Nervous System** is activated in situations requiring arousal and energy. When we feel threatened or under stress, the sympathetic branch of the ANS is activated which starts the instinctive reaction of ‘fight or flight’, aiding survival (we will review in more detail later). It produces increased heart and respiratory (breathing) rate, increasing blood flow to the muscles and pupil dilation (bigger pupils).
The Parasympathetic Nervous System is activated soon after the threat of danger has passed. This has the opposite effect of the Sympathetic Nervous System and allows for the body to return to homeostasis (balance). Here the person’s heart and respiratory rate decrease to normal levels and blood flow decreases. The pupils return to normal size. This system is vital for the individual to conserve energy and not to become exhausted.

Just to summarise...

- The Nervous System consists of the Central Nervous System – the brain and spinal cord.
- The brain has a left and right hemisphere. Left associated with language; right associated with music/artistic abilities.
- The spinal cord is a bundle of nerves running along the brain along the backbone. It passes messages to and from the brain.
- The Nervous System also consists of the Peripheral Nervous System – the Somatic and Autonomic Nervous System which are quite distinct in function.
- The SNS controls voluntary skeletal muscles.
- The ANS controls involuntary movement from non-skeletal muscles.
- The ANS is further divided into the sympathetic and parasympathetic systems.
- The sympathetic system activates when the body requires arousal/energy, i.e. under threat. This is the fight/flight response.
- The parasympathetic system kicks in soon after the threat has passed and it aims to restore the body back to homeostasis.
The structure and function of sensory, relay and motor neurons

What are neurons?
Neurons are nerve cells in the brain, spinal cord, PNS etc. and there are approximately 100 billion in the nervous system. Neurons receive information and transmit it to other neurons. This ‘communication’ is done electrically and chemically.

Neurons are microscopic in size and can be one of three types: sensory, motor and relay. They typically consist of a cell body, dendrites and an axon but each type of neuron has a unique structure related to its function within the nervous system. The cell body consists of a number of short branching extensions called dendrites and one long extension called an axon. They vary in size from four micrometres (0.004 mm) to 100 micrometres (0.1 mm) in diameter. Their length varies from a few millimetres up to one metre.

How do they work?
Electrochemical messages or nerve impulses are conducted into the cell body by the Dendrites, whilst the axon conducts these impulses away from the cell body. Some neurons have myelinated axons. Myelin is a fatty insulative substance surrounding the axon cable. Its function is to help speed up the rate at which the nerve impulses are passed along the axon. When an impulse reaches the end of the axon it is passed onto another neuron, gland or organ via the axon terminals – short extensions found at the end of the axon. Neurotransmitters are the chemicals (some you may know, serotonin, dopamine etc.) that pass from one neuron to another to pass the signal being transmitted.

Now, we will explore in more depth how neurons communicate with each other - synaptic transmission.

Exam hint: You have considered the biological approach in your Approaches unit. It’s worth mentioning again the difference between genotype and phenotype because you could be asked a question on them. The genotype is a person’s unique genetic make-up that is coded in their chromosomes and fixed. However, the phenotype is the expression of a person’s genetic make-up (genotype) that can be influenced by the environment.
The process of Synaptic transmission

The following diagram explains the process of synaptic transmission.

**Electrical impulses** are passed through the *axon* of a neuron to the *synaptic terminal* (1). The electrical impulse *cannot* go through the gap between neurons, the *synaptic gap/cleft*.

Instead the electrical impulse causes calcium to be released (2) and trigger *vesicles* (little sacs) that contain *neurotransmitters* to be released (3). The released neurotransmitters cross the synapse (gap) (4).

They then *bind* to the *receptors* on the *post-synaptic neuron* (5)

This triggers a *signal* in the post-synaptic neuron (6). Neurotransmitters can have an *excitatory* effect on the receiving neuron (making them *more* likely to fire) or an *inhibitory* effect (making them less likely to fire).

**Excitation and Inhibition**

As mentioned in the last point, neurotransmitters have either an excitatory or inhibitory effect on the post-synaptic neuron. For example, the neurotransmitter *GABA* causes an inhibition in the receiving neuron, resulting in the neuron becoming more negatively charged and less likely to fire. In contrast, *acetylcholine* has an excitatory effect on the neighbouring neuron by increasing its positive charge, therefore making it more likely to fire an impulse. A good analogy is to think of excitation as an accelerator on a car, and inhibition as the brake.

So, don’t forget excitatory and inhibitory influences are summed, if the *net* effect on the post synaptic neuron is inhibitory, the neuron will be less likely to ‘fire’ and if the *net* effect is excitatory, the neuron will be more likely to fire.

Note : (Ca²⁺ = calcium)
**Sensory, motor and relay neurons**

**Sensory neurons**, located in the peripheral nervous system (PNS) respond to stimulation in sensory receptors. They send signals to the spinal cord and brain about this sensory experience. There are sensory neurons for all senses (vision, hearing, smell, taste and touch). Most sensory neurons have long dendrites and short axons. Sensory neurons carry signals **away** from the organ to the brain and spinal cord (**afferent**).

**Motor neurons** are cells in the PNS that send messages **from** the brain and the spinal cord to the muscles and glands (**efferent**). These usually have long axons and short dendrites.

**Relay Neurons** (interneurons) form connections between other neurons. They can send signals to other relay neurons, or form links between sensory and motor neurons. All neurons in the CNS are relay neurons, and there are over 100 billion relay neurons.
Let’s review neurons in a little more depth…

**Sensory neurons** are also known as **afferent** neurons, meaning moving towards a central organ or point, that is they move impulses towards the **CNS**. This type of neuron receives information or stimuli from sensory **receptors** found in various locations in the body, for example the eyes, ears, tongue, skin. This information enters sensory neurons through the **dendrites** and passes it to the cell body – the control centre of the cell. From here it is sent through the axon, until it reaches the end of the neuron (axon terminals). Electrical impulses flow in one direction only through a neuron. So just like a series of electrical power lines that pass electricity through the suburbs of a city, so too do electrical impulses flow through the body along thousands of tiny neurons.

In sensory neurons, the cell body and dendrites are located outside the spinal cord in the torso, arms and legs. The dendrites (also known as dendrons) are usually long and the axons short.

**Motor neurons** are also known as **efferent** neurons meaning ‘moving away from a central organ or point’, that is they move impulses away from the CNS. This type of neuron takes information or responses from the brain to muscles or organs, which are referred to as effectors. The information enters a motor neuron through the dendrites, which then passes it into the cell body. From here it is sent down through the axon until it reaches the end of the neuron (axon terminals). If a motor neuron connects with a muscle, the axon terminals are called **motor end plates**. In a motor neuron, the dendrites are usually short and the axons are typically long. Information about a response required has been formulated in the brain and sent through motor neurons in the form of a series of electrical impulses, similar to the impulses sent along sensory fibres.

**Relay (interneuron)** are smaller neurons found only within the brain and spinal cord, and are responsible for linking sensory and motor neurons. They have short dendrites and axons.

**Myelin sheath**

Many neurons outside the CNS are **myelinated**. Myelin is rich in lipid (fat) and creates an electrically insulative layer around the axon that helps to increase the speed at which impulses travel. Specialised **Schwann cells** produce a tightly wrapped **myelin sheath** around the axon of a neuron. The outer-most membrane that covers the myelin is called the neurilemma. Small gaps between the myelin on the axon are called **nodes of Ranvier**. These help the electrical impulse ‘jump’ from section to section to increase the speed of the electrical impulse.

**Axon terminals and the synapse**

Axon terminals are found at the end of an axon. This structure allows electrical impulses to be passed from one neuron to the next without the neurons physically touching. The gap between two neurons is called a **synapse**. The axon terminals are short extensions that terminate in tiny knobs in the pre-synaptic neuron that contain chemicals called **neurotransmitters**. When an electrical impulse arrives at the end of the axon, it causes neurotransmitter chemicals to be released from tiny storage **vesicles**. These move across the synaptic gap between the axon and the dendrite of the closest post-synaptic neuron.

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Notes
The Endocrine System

It’s important that you can outline the function of the endocrine system including the different glands and hormones in the body. Therefore, you need to understand what hormones are released by the various glands in the body and what effects they have on the body.

The endocrine system is a network of glands across the body that secrete chemical messengers called hormones.

<table>
<thead>
<tr>
<th>Gland</th>
<th>Hormones</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothalamus</td>
<td></td>
<td>This is connected to the pituitary gland and it stimulates and controls the release of hormones from the pituitary gland.</td>
</tr>
<tr>
<td>Pituitary gland</td>
<td>Oxytocin Thyroid Stimulation Hormone (TSH) ACTH</td>
<td>The ‘Master gland’ as it controls all other glands, for example, TSH signals action in the thyroid, ACTH signals action in the adrenal glands.</td>
</tr>
<tr>
<td>Thyroid gland</td>
<td>Thyroxine</td>
<td>Primarily involved with the regulation of metabolism, such as the conversion of food into energy for the muscles.</td>
</tr>
<tr>
<td>Parathyroid gland</td>
<td>Parathormone</td>
<td>PTH essentially acts to increase the concentration of calcium in the blood from kidneys and bone.</td>
</tr>
<tr>
<td>Pancreas</td>
<td>Insulin</td>
<td>Promotes the absorption of glucose from the blood into fat, liver and skeletal muscle cells.</td>
</tr>
<tr>
<td>Adrenal glands</td>
<td>Adrenaline &amp; Noradrenaline</td>
<td>Responsible for reacting to threat via the fight or flight response.</td>
</tr>
<tr>
<td>Ovaries (female)</td>
<td>Oestrogen and progesterone</td>
<td>Responsible for the development and regulation of the female reproductive system and secondary sex characteristics.</td>
</tr>
<tr>
<td>Testes (male)</td>
<td>Testosterone</td>
<td>A key role in the development of male reproductive system such as the testes and prostate, as well as promoting secondary sexual characteristics such as increased muscle and bone mass, and the growth of body hair.</td>
</tr>
<tr>
<td>Pineal gland</td>
<td>Melatonin</td>
<td>Regulates the Sleep-wake cycle.</td>
</tr>
</tbody>
</table>
Just to summarise...

- Neurons are nerve cells in the brain, spinal cord, PNS etc. They receive information and transmit it to other neurons.
- Neurons communicate via neurotransmitters that bind onto receptors on the post synaptic neuron (synaptic transmission).
- Neurotransmitters can have an excitatory or inhibitory effect on post synaptic neurons.
- There are sensory, motor and relay neurons.
- Neurons outside the CNS are covered in myelin a fatty layer that helps increase the speed at which impulses travel.
- The endocrine system is a network of glands that secrete chemical messengers called hormones.
- Hormones have various effects on the body.
How does the ANS react to threat? – Fight or flight and the role of adrenaline

Don’t forget the parasympathetic response: After a few minutes, the parasympathetic branch of the ANS is activated, and the body returns to normal by establishing homeostasis. Heart rate and respiratory rates decrease, adrenaline secretion slows down, the feeling of butterflies subside and sweating stops.
Pause... Personal Notes so far. Use this page for anything you feel you need to review again. Make a list of areas you're unsure about. (Nervous system, Structure and Function of Neurons, Endocrine system, Fight/Flight response).

My List

What I need to do to review those topics (flash cards, mind maps, quizlet, go to a subject extension etc)

Give yourself a realistic deadline to meet for you to review your list and feel a sense of accomplishment!
The human brain is one of the most complex and fascinating biological systems. Discovering how the brain functions is an on-going scientific journey, however there is sufficient evidence suggesting certain parts of the brain perform particular activities. This topic will consider localisation, hemispheres and the cerebral cortex, the four lobes, language centers and finally evaluation.

**Localisation of function theory**

Localisation suggests that different functions of the brain are localised in specific areas and are responsible for different behaviours, processes or activities. You need to know the localisation of the following areas:

- **Motor area** - A region in the frontal lobe involved in regulating movement
- **Somatosensory area** - An area of the parietal lobe that processes sensory information (e.g. touch)
- **Visual area** - A part of the occipital lobe that receives and processes visual information
- **Auditory area** – Located in the temporal lobe and concerned with analysis of speech.
- **Language centres**
  - **Broca’s area** – An area of the frontal lobe in the left hemisphere (in most people) responsible for **speech production**
  - **Wernicke’s area**- An area of the temporal lobe (encircling the auditory cortex) in the left hemisphere (in most people) responsible for **language comprehension**

**Hemispheres of the Brain and the Cerebral Cortex**

The Brain is divided into **two symmetrical halves** called left and right hemispheres. Some of our physical and psychological functions are controlled or dominated by a particular hemisphere. The outer layer of both hemispheres is called the Cerebral Cortex.

The Cerebral cortex sits like a tea cosy covering all the inner parts of the brain. It is 3mm thick and appears grey due to the location of cell bodies (grey matter).
The Motor, Somatosensory, visual and auditory centres

The Cortex is subdivided into four lobes. The lobes are named after the bones beneath which they lie; frontal lobe, parietal lobe, occipital lobe and temporal lobe.

<table>
<thead>
<tr>
<th>Area</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor area</td>
<td>Situated at the back of the <strong>frontal lobe</strong> in both hemispheres which controls voluntary <strong>movement</strong> in the opposite side of the body. Damage may result in a loss of control over fine movements.</td>
</tr>
<tr>
<td>Somatosensory</td>
<td>Situated at the front of the <strong>parietal lobes</strong>. This is where <strong>sensory information</strong> from the skin is presented (e.g. heat) The amount of somatosensory area devoted to a particular body part denotes its sensitivity. For example receptors in our face and hands occupy over half of the somatosensory area.</td>
</tr>
<tr>
<td>Visual</td>
<td>In the <strong>Occipital lobe</strong> at the back of the brain is the visual area (or cortex). The eye sends information from the right visual field to the left visual cortex and from the left visual field to the right visual cortex. This means that damage to the left hemisphere for example can produce blindness in the right eye.</td>
</tr>
<tr>
<td>Auditory</td>
<td>The <strong>Temporal lobes</strong> house the auditory area which has <strong>speech based information</strong>. Damage here may produce partial hearing loss. Damage specifically to Wernicke’s area may affect an individual’s ability to comprehend language.</td>
</tr>
</tbody>
</table>
Language centers of the brain

In most individuals the Broca and Wernicke area is located in the left hemisphere, and that is where most language processing is situated.

**Broca’s area** - The work of Broca identified the area responsible for speech production. Damage to this area can cause Broca’s Aphasia which is characterised by speech which is slow and lacking in fluency. Not all words are affected equally for example nouns and verbs seem relatively unaffected in patients with damage to Broca’s area but other classes of words such as conjunctions cannot be spoken.

![Paul Broca, (French neurologist)](image)

**Wernicke’s area** - Carl Wernicke worked at a hospital in Germany and found patients who had damage in an area close to the auditory cortex in the left temporal lobe had specific language impairments including the inability to comprehend language and a struggle to locate the word they need.

![Carl Wernicke (German neurologist)](image)

Notes
Localisation of the brain

Evaluation

• Arguments for localisation:

Brain scan evidence of Localisation

Petersen et al (1988) used brain scans to demonstrate how Wenicke’s area was active during a listening task and Broca’s area was active during a reading task. These findings support a theory of localisation as the findings evidence specific areas of the brain having specific and different functions.

Neurosurgical evidence

Surgically removing or destroying areas of the brain to control behaviour was developed in the 1950s. Controversially neurosurgery is still used today to treat extreme cases of psychological disorders.

Dougherty et al (2002) reported on 44 OCD patients who had undergone a cingulotomy which is a procedure that cuts the cingulate gyrus. Findings showed a third of patients significantly improved and a further 14% showed partial improvement. The success of these procedures strongly supports that the symptoms and behaviours of mental disorders are localised.

Case study evidence

The Case of Clive Wearing- An individual with brain damage as a result of a viral infection had damage to his semantic long term memory however little damage to his procedural memory. This suggests localisation because if the function was spread throughout the entire brain there would not be specific deficits in this way. However, a case study only provides evidence, not proof.

• Arguments against localisation:

Challenging theory and research

Lashley (1950) the work of Karl Lashley suggests higher cognitive process such as learning are not localised but distributed holistically

Lashley removed between 10-50% of areas of the cortex in rats. The rats were learning a maze. No particular area was shown to be more important in terms of the rats’ ability to complete the maze. This suggests the process of learning required every part of the cortex. This seems to suggest learning is too complex to be localised, supporting a more holistic and multifunctional theory in regards to the function of the brain.
Criticisms of Lashley’s study however relate to the fact that the research was conducted on animals. This means we should be cautious in drawing conclusions related to human learning as we know the human brain is much more complex.

**Plasticity**

The notion of cognitive mapping or **plasticity is a compelling argument against localisation.**

Evidence shows that when the brain has become damaged through illness or accident and a particular function has been compromised or lost, the rest of the brain appears to be able to **reorganise itself** to recover the function. An example of this is in stroke victims many of whom seem to able to recover abilities that were seemingly lost as a result of illness (E.g. speech)

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**Just to summarise…**

- Localisation is the notion that certain areas of the brain are responsible for certain functions.
- Motor area - back of frontal lobe in both hemispheres; controls voluntary movement
- Somatosensory – at the front of the parietal lobe
- Visual – The occipital lobe (at the back of the brain)
- Auditory – located in the temporal lobe
- Broca’s area is in the frontal lobe. This area is responsible for speech production. Wernicke’s area is in the temporal lobe and responsible for language comprehension.
- Broca and Wernicke’s areas are located in the left hemisphere
- Evidence for localisation; brain scans, neurological evidence and Clive Wearing
- Evidence challenging localisation; Lashley’s rat study and plasticity.

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Notes
Plasticity and Functional Recovery of the Brain after Trauma

What is Brain Plasticity?

This refers to the fact that the brain can change and develop as a result of our experience and learning, and also that it can recover after trauma. The brain changes throughout the lifespan. During infancy, the brain experiences a rapid growth in the number of synaptic connections there are to other neurons, peaking at around 15,000 at age 2-3 years. This is around twice as many as there are in the adult brain. As we age, connections that we don’t use are deleted and connections that we use a lot are strengthened. This process is known as synaptic pruning. Even though the majority of changes in neural connections happen during childhood, adult brains still change and develop, on a smaller scale, as a result of learning and experience.

Research into Brain Plasticity

Maguire et al (2000) studied the brains of London taxi drivers and found that there was a significantly greater volume of grey matter in the posterior hippocampus than in a matched control group. This part of the brain is associated with spatial and navigational skills in humans and other animals. Part of a London taxi driver’s training involves taking a test known as ‘the knowledge’, which assesses their ability to recall the names and locations of the streets in the city. The results of the study suggest that the learning the drivers undertake as part of their training alters the structure of their brains. It was also noted that there was a positive correlation between how great the volume of grey matter was and how long they had been in the job. (The longer the participant had been driving the taxi, the larger his hippocampus). This suggests evidence (correlational) for structural differences in the brain due to extensive experience of spatial navigation.

Kuhn et al (2013) found a significant increase in grey matter in various regions of the brain after participants played video games (Super Mario 64) over a period of 2 months for 30 minutes per day. (Comparison to a control group). This shows evidence for brain plasticity and shows how experience (playing games) can result in structural changes in the brain.

Draganski et al (2006) imaged the brains of medical students three months before and after their final exams. Learning induced changes were seen to have occurred in the posterior hippocampus and parietal cortex, presumably as a result of the exam.

Mechelli et al (2004) found a larger parietal cortex in the brains of bilingual people, compared to non-bilingual people.

Notes

...such a fascinating study, but Maguire’s research is correlational so we cannot conclude causality, i.e. the longer they worked as taxi drivers CAUSED them to develop a larger posterior hippocampus.
Functional Recovery of the Brain after Trauma

The brain is often able to recover from trauma that is caused by physical injury or illness (e.g. stroke). This is another example of neural plasticity. Unaffected areas of the brain are often able to adapt and compensate for the areas that have been lost or damaged. **Healthy brain areas may take over the functions of the areas that have been affected.** Neuroscientists suggest that this process can occur quickly after the trauma, but then slow down after several weeks or months. The person may then require rehabilitative therapy to assist their recovery.

How Does Brain Recovery Work?

The brain is able to **reorganise** and rewire itself by forming new synaptic connections close to the area of damage. Secondary neural pathways that would not usually be used to carry out certain functions are activated to enable functioning to continue, often in the same way as before. Support for this comes from structural changes that are known to take place in the brain. Examples are:

- **Axonal sprouting:** The growth of new nerve endings which connect with other undamaged nerve cells to form new neuronal pathways
- **Reformation of blood vessels**
- **Recruitment of homologous (similar) areas** on the other side of the brain to take over specific tasks

These new connections are activated and compensate for nearby damage areas of the brain, therefore recovering any damage occurring in specific regions.

Research:

Laura Danelli et al (2013) investigated EB, a 17yr old Italian boy who had his entire left brain hemisphere removed at 2yrs old. (Due to non-cancerous tumour). By 5ys, his language fluency improved due to intensive rehabilitation and by 17, using various brain scans, although there were minor problems with his grammar, in his everyday life, EB’s language appeared virtually normal. Suggesting language abilities can still function even after severe trauma, such as the removal of the left hemisphere.
# Evaluation of Plasticity and Functional Recovery of the Brain following Trauma

## Practical application

Our increased understanding in this area has contributed to the field of **neurorehabilitation**. In other words, it has helped in the treatment of those who have suffered brain trauma. The fact that we know that spontaneous brain recovery slows down after a few weeks, means that we are aware of when it may be necessary to start physical therapy to maintain improvements in functioning. Also, electrical stimulation of certain parts of the brain following particular damage following injury or strokes. This suggests the brain has the ability to fix itself to a certain extent, but some intervention is likely to be necessary if full recovery is to be achieved.

## Negative plasticity

The brain’s ability to rewire itself does **not** always have positive consequences. Some adaptations may be maladaptive (unhelpful). Prolonged drug use, for example, has been shown to result in poorer cognitive functioning as well as an increased risk of dementia in later life. Also, 60-80% of amputees are known to develop **phantom limb syndrome**. This is the continued experience of sensation in the missing limb. These sensations are usually unpleasant and painful and are thought to arise from cortical reorganisation in the **somatosensory cortex** that results from the limb loss.

This shows that there can be a negative consequence of the brain rewiring itself, although there are treatments that aim to help individuals that have seen positive results.

## Individual differences:

### Age & Gender

Functional plasticity tends to **reduce** with age, and this therefore affects the speed of recovery. Marquez de la Plata et al (2008) found that, following brain trauma, older patients (40+ years old) regained less function in treatment than younger patients and they were also more likely to decline in terms of function for the first five years following the trauma.

However, Bezzola et al (2012) found that 40 hours of golf training produced changes in the neural representation of movement in participants aged between 40 and 60. Using fMRI they found that motor cortex activity was reduced for the novice golfers compared to a control group. Suggesting more efficient neural representation after training. This supports the view that neural plasticity does continue throughout the lifespan. There is also evidence to suggest that women recover **better** from brain injury because their function is not as lateralised. (concentrated in one hemisphere)

## Individual differences:

### Education

Evidence suggests that the person’s level of educational attainment will influence how well the brain recovers after trauma. Schneider (2014) found that the more time brain injured patients had spent in education, (known as their **cognitive reserve**) the greater their chances of a disability-free recovery.

This suggests that the cognitive reserve could be an important factor in brain recovery after trauma.
Biopsychology: Split-brain research

Lateralisation

The ability to produce and understand language, for most people, is controlled by the left hemisphere. This suggests that for the majority of us, language is subject to hemispheric lateralisation. In other words, the specialised areas associated with language are found in one of the hemispheres rather than both.

In the late 1960’s, Roger Sperry and his colleagues began to conduct a number of experiments investigating this, this collection of research became known as ‘split-brain research’.

Sperry’s studies involved a unique group of individuals, all of whom had undergone the same surgical procedure – an operation called a commissurotomy – in which the corpus callosum and other tissues which connect the two hemispheres were cut down the middle. This was done as a treatment for people who had frequent and severe epileptic seizures, because separating the two hemispheres would help to control seizures.

This meant for the split brain patients the main communication line between the two hemispheres was removed. This allowed Sperry and his colleagues to see the extent to which the two hemispheres were specialised for certain functions and whether the hemispheres performed tasks independently of one another.

Sperry’s procedure

Sperry devised a way of being able to test hemispheric lateralisation using visual and tactile tasks. This involved using a piece of equipment called a ‘T-scope’ (see below) which allowed each hemisphere to be tested in isolation of the other.

The general procedure involved the participant being asked to focus on the ‘fixation point’ and then an image or word was projected very quickly (1/10th of a second) to one or both visual fields. For example, the word ‘key’ could be projected so that it only is processed by the participant’s right visual field (processed by the left hemisphere) and then the same, or different, image could be projected to the left visual field (processed by the right hemisphere).

To test for non-verbal processing, this equipment also enabled the participants to be able to pick up or match objects that were out of the participant’s sight.

In a ‘normal’ brain, the corpus callosum would immediately share information between both hemispheres giving a complete picture of the visual world. However, presenting the image to one hemisphere of a split-brain patient meant that information could not be conveyed from that hemisphere to the other.
Sperry’s findings

Sperry and his colleagues have conducted a large number of studies on split brain patients. Here are some of the key findings from his original study.

1. When a picture/word was projected to the right visual field (information processed in left hemisphere), the patient could easily describe what had been shown. However when the picture/word was projected to the left visual field (information processed in right hemisphere), the patient could not describe what had been shown and typically reported that there was nothing there. This supports hemispheric lateralisation showing that language is processed in the left hemisphere as the patients could only describe what they had seen when it was projected to the right visual field.

2. Although the patients could not describe what had been shown to their left visual field, they were able to use their left hand to point to a matching object or picture. This shows that the right hemisphere has processed the information but obviously cannot verbalise what was shown.

3. If two words/pictures were projected simultaneously, one on either side of the visual field (e.g. ‘a dollar sign’ on the left and ‘a question mark’ on the right), the patient would say that they saw a question mark but when asked to draw (with their left hand) what they saw, they would draw a dollar sign. The patients were not aware that they had drawn a different object or picture to the one they said they had seen. This suggests the two hemispheres were working separately from each other. It also suggests that drawing ability is dominant in the right hemisphere.

4. An object placed in the patients right hand (the patient could not see it just feel it) it could be easily described or named in speech or writing, whereas, if the same objects were placed in the left hand, the patient could only make wild guesses. However, when this object is taken from them and placed in a grab-bag along with other objects, the patient is able to search for and retrieve the object with their left hand. This also supports hemispheric lateralisation as it shows the left hemisphere is dominant for speech and writing. It also shows again that the right hemisphere is able to comprehend what the object is but just cannot identify it verbally.
Evaluation of Split Brain Research

Evaluation of Methodology:

Split brain research is experimental and involves the use of specialised equipment that can objectively measure the lateralisation of function in each hemisphere. The use of this equipment allows for the image or word to be projected extremely quickly (1/10th of a second) to one or both visual fields. This meant that the split-brain patients would not have time to move their eyes across the image and so the visual information would only be processed by one visual field (and one hemisphere) at a time, therefore increasing the internal validity of the research.

The standardised procedures used in the research, for example giving the same tasks to each participant and using standardised equipment (the T-scope) have helped to enable the research to be checked for reliability. The same procedure has been used on a number of split-brain patients and the results on the left hemisphere being dominate for language has been found to be consistent.

The control group used by Sperry were people with no history of epileptic seizures therefore they could be seen as an inappropriate group to use as a comparison. As the split brain patients suffered from epilepsy, it could be argued that it may have caused unique changes in the brain which could have influenced the results, so a more appropriate control group would have been people who had a history of epilepsy but had not had the split-brain procedure.

Small sample sizes are used in split brain research meaning it is difficult for the results on hemispheric lateralisation to be generalised to the wider population. However, as commissurotomy is a rare procedure, there is a limited amount of ‘split brain’ patients available for investigation therefore small sample sizes are unavoidable.

The data gathered from the split brain research came from the patients being testing under artificial conditions. In real life a severed corpus callosum can be compensated for by the unrestricted use of two eyes therefore the research findings cannot be generalised to how split brain patients function in everyday tasks.

Usefulness and Theoretical value:

- Split brain research has been very useful for investigating and demonstrating lateralisation of function. This has led to a significant improvement in our understanding of the role of each hemisphere and brain processes associated with each hemisphere.

- Sperry’s work prompted a theoretical and philosophical debate about the degree of communication between the two hemispheres in everyday functioning and the nature of consciousness. Some theorists have suggested that the 2 hemispheres are so functionally different that they represent a form of ‘duality’ in the brain – that in effect we are all ‘two minds’ in contrast, other researchers have argued that, far from working in isolation, the two hemispheres form a highly integrated system and are both involved in most everyday tasks.

- Modern neuroscientists suggest that the differences in function may be overstated and that the actual distinction between the each hemisphere is less clear and more complex. In a ‘normal’ brain the two hemispheres are in constant communication when performing everyday tasks, and many of the behaviours typically associated with one hemisphere can be effectively performed by the other when the situation requires it.
Just to summarise...

- Plasticity refers to the brain changing and developing as a result of experiences, learning and trauma.
- Maguire’s work on taxi drivers provides insight into plasticity with structural changes to the brain due to experiences of navigating through London streets.
- Functional recovery is an example of plasticity. It is when healthy areas take over functions of damaged areas.
- Functional recovery happens due to a reorganisation of synaptic connections close to damaged areas.
- Structural changes can occur due to axonal sprouting, reformation of blood vessels and homologous areas taking over.
- Lateralisation is the idea that the two halves of the brain are functionally different, i.e. like language being lateralised in the left hemisphere.
- Research by Sperry suggests language is lateralised in the left hemisphere.
Ways of investigating the brain

Advances in science and technology have brought with them even more sophisticated and precise methods of studying the brain. Ways of studying the brain include: functional magnetic resonance imaging (fMRI), electroencephalogram (EEG) and event related potentials (ERPs), and post-mortem examinations.

Functional magnetic resonance imaging (fMRI)

fMRI works by detecting the changes in blood oxygenation and flow that occur as a result of neural (brain) activity in specific parts of the brain.

When a brain area is more active it consumes more oxygen and to meet this increased demand blood flow is directed to the active area (known as the haemodynamic response).

fMRI produces 3-dimensional images (activation maps) showing which parts of the brain are involved in particular mental processes and this has important implications for our understanding of localisation of function.

This brain scan shows which areas of the brain are more active (shaded areas) during encoding, maintenance and recognition (memory processes). As you can see different areas of the brain are lit up for different tasks.

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>• Unlike other scanning techniques, fMRI does not rely on the use of radiation. If administered correctly it is virtually risk-free, non-invasive and straightforward to use. Therefore, it can be used to measure activity in the brain without causing harm.</td>
<td>• fMRI is expensive compared to other neuroimaging techniques and can only capture an image if the person stays perfectly still.</td>
</tr>
<tr>
<td>• It produces images that have very high spatial resolution, showing detail by the millimetre, and therefore providing a clear picture of how brain activity is localised.</td>
<td>• It has poor temporal resolution (doesn’t show changes over time accurately). So in the scan picture above the highlighted areas appear 4/5 seconds after the brain activity occurred. This means findings could be misinterpreted.</td>
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<td>• fMRI can only measure blood flow in the brain, it cannot tell us the exact activity of individual neurons and so it can be difficult to tell what kind of brain activity is being represented on the screen.</td>
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**Electroencephalogram (EEG)**

EEGs measure electrical activity within the brain via electrodes that are fixed to an individual's scalp using a skull cap.

The scan recording represents the brainwave patterns that are generated from the action of millions of neurons, providing an overall account of brain activity.

The main 4 types of EEG waves are alpha, beta, theta and delta.

Scientists can also measure brain activity through amplitude and frequency. Amplitude is the intensity or size of activity, frequency is the speed or quantity of activity.

In the diagram above, the delta wave has the largest amplitude. The beta wave has the highest frequency (14-30 Hz).

EEG is often used by clinicians as a diagnostic tool as unusual arrhythmic patterns of activity (i.e. no particular rhythm) may indicate neurological abnormalities such as epilepsy, tumours or disorders of sleep.

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<tr>
<td>• EEG is valuable at helping diagnose conditions such as epilepsy and schizophrenia because the difference in brain activity can be detected on the screen i.e. schizophrenic patients may display 'unusual' EEG wave patterns. This is useful for clinical diagnosis.</td>
<td>• EEG represents brainwave patterns and as such it cannot detect activity in deeper brain regions. Therefore, if there were issues to a patient's hippocampus, an EEG wouldn’t necessarily pick up this information. Suggesting the limitation of this technique.</td>
</tr>
<tr>
<td>• It has contributed to our understanding of the sleep stages and sleep problems. Strengthening the usefulness of EEG.</td>
<td>• EEG is not useful in pinpointing the exact source of neural activity (the activity of many thousands of neurons) and therefore it's hard to work out which area of the brain the waves originate from, highlighting a further limitation of this technique.</td>
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<tr>
<td>• It has extremely high temporal resolution (unlike fMRI) it records brain activity in real time. Therefore, researchers can monitor responses to tasks.</td>
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In the diagram above, the delta wave has the largest amplitude. The beta wave has the highest frequency (14-30 Hz).

EEG is often used by clinicians as a diagnostic tool as unusual arrhythmic patterns of activity (i.e. no particular rhythm) may indicate neurological abnormalities such as epilepsy, tumours or disorders of sleep.
Event-related potentials (ERPs)

ERPs use similar equipment to EEG (electrodes attached to the scalp) however, a stimulus is presented to a participant i.e. picture or sound, and the researcher looks for activity related to the stimulus and investigate how an EEG wave pattern changes in response to the stimulus. This change is an ERP. (Types of brainwaves triggered by particular events).

The stimulus is presented hundreds of times and an average response is graphed. This is a statistical averaging technique, and it reduces any extraneous brain activity which makes the specific response to the stimulus stand out.

Research has revealed many different forms of ERP and how, for example, they are linked to cognitive processes such as attention and perception.

For example, in the graph on the left it shows the types of brain waves triggered by an auditory (sound) stimulus.

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</table>
| - The limitations of EEGs being too general are partly addressed by ERPs- they are much more specific to the measurement of neural processes.  
- They provide a continuous measure of processing in response to a stimulus. Therefore, this provides quantitative experimental data.  
- Researchers have also been able to identify ERP’s of mental health issues like phobias. It has been found that people with phobias have ERP’s of a greater amplitude (intensity of activity) in response to images of the objects they feared compared to non-phobic individuals. This allows researchers more of an understanding of complex mental processes. | - There is a lack of standardisation in ERP methodology between different research studies, which makes it difficult to confirm findings.  
- It may not always be possible to completely eliminate background noise and extraneous material needed to establish pure data in ERP studies, therefore validity may be questionable. |
Post-mortem examinations

This is a technique involving the analysis of a person’s brain following their death.

In psychological research, individuals whose brains are subject to a post-mortem are likely to be those who have a rare disorder and have experienced unusual deficits in mental processes or behaviour during their lifetime.

Areas of damage within the brain are examined after death as a means of establishing the likely cause of the affliction the person suffered. This may also involve comparison with a typical brain in order to determine the extent of the difference between them.

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<tr>
<td>- Post-mortem evidence was vital in providing a foundation for early understanding of key processes in the brain e.g. Broca’s and Wernicke’s areas were identified using post-mortem because neuroimaging did not exist at this time.</td>
<td>- Causation is an issue within these investigations. Observed damage in the brain may not be linked to the deficits under review but to some other unrelated trauma or decay. (For example drugs and age may affect brain tissue). Therefore, there are issues with cause and effect being established.</td>
</tr>
<tr>
<td>- Post-mortem studies improve medical knowledge and help generate hypotheses for further study. E.g. Zhou analysed the brains of female-male transsexuals and found an area of the brain associated with gender to be larger in these individuals- more similar to that of a male.</td>
<td>- They raise ethical issues of consent from the patient BEFORE death. – A patient may have significant brain abnormality when alive and are therefore too ill to give consent for their brains to be investigated upon their death. This poses an ethical concern as a post-mortem may still be carried out.</td>
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This demonstrates the beneficial nature of post-mortems in our understanding of gender development.

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Just to summarise...

- fMRI scans show brain activity
- EEG’s show electrical activity
- ERP’s show electrical activity in the brain in response to a stimulus
- Post-mortem examinations show the structure of the brain.
- Spatial resolution refers to the smallest feature/measurement that a scanner can detect.
- Temporal resolution is how quickly the scanner can detect changes in brain activity.
Biological rhythms: circadian, infradian and ultradian and the difference between these rhythms.

Introduction:

Biological rhythms are cyclical changes in the way biological systems (humans, animals, plants) behave. Rhythms can be classified according to how long they last.

- **Circadian Rhythms** – have cycles that generally occur once every 24 hours, such as the sleep-wake cycle, another example is body temperature.
- **Infradian Rhythms** – have cycles that occur longer than 24 hours and can be weekly, monthly or annually.
- **Ultradian Rhythms** - last fewer than 24 hours and can be found in the pattern of human sleep.

The timing of biological rhythms is regulated by factors both inside and outside our bodies. Factors inside our body are called **Endogenous pacemakers**; those outside the body are **exogenous zeitgebers**.

- **Circadian Rhythms:**

The most obvious circadian rhythm in humans is the **sleep-wake cycle**. (Circa = ‘about’ and diem = ‘a day’, so a cycle that lasts a day). It is a 24 hour rhythmic cycle where there are differing levels of consciousness. People sleep for a certain time every 24 hours, and conduct other activities during wakefulness. The fact that we feel drowsy when it’s night time and alert during the day shows the effect of daylight (exogenous zeitgeber) in our sleep/wake cycle. However, what would happen if the biological clock was ‘left to its own devices’ without the influence of light (called free running)? Would we still fall asleep and awake at regular times?

Research: Siffre’s cave Study

In 1962 Michel Siffre (pronounced ‘Seef’) spent two months living in complete isolation in a cave to study the effects on his own circadian rhythm. He was deprived of natural light, a clock, a calendar and sound, but had access to adequate food and drink. He slept and ate only when his body ‘told him to’. Therefore, the only influence was his internal body clock (endogenous pacemaker). Siffre re-surfaced in mid-September 1962 believing it to be mid-August! He believed the date to be a month earlier than it was. His lack of external cues made him feel a day was actually ‘longer’ than it was and fewer days had passed in total.

A decade later he performed a similar feat for six months in a cave in Texas.

In each case, his ‘free running’ circadian rhythm settled to around **25 hours**. Just beyond the usual 24 hours.
Aschoff and Wever (1976) asked a group of participants to spend **four** weeks in a WWII bunker...

...The participants were shielded from natural light (no windows), temperature changes or other environmental cues. They had access to artificial light and could switch it on/off. Similar to Siffre, they displayed a circadian rhythm of approximately **25 hours**. (One participant extended to 29 hours).

These studies suggest the ‘natural’ sleep/wake cycle may be slightly longer than 24 hours but we use natural light to **entrain** (adjust) our pacemakers associated with the 24 hour clock.

Furthermore, circadian rhythms are **not** easily overridden by external cues...

Simon Folkard et al (1985) studied a group of 12 participants who agreed to live in a dark cave for 3 weeks, isolating them from natural light. The researchers manipulated the clock. Participants would retire when the clock read 11.45pm and awoke when it read 7.45am. Over the course of the study, the researchers speeded up the clock (unbeknown to participants) so what they believed was a normal 24 hour day was in fact only lasting 22 hours.

Interestingly, only one of the participants could adjust comfortably to new regime! This seems to suggest the existence of a strong free running circadian rhythm that cannot be easily overridden by changes in the external environment.

**Evaluation to consider...**

<table>
<thead>
<tr>
<th>Small sample sizes and generalisation</th>
<th>As fascinating as the research is in this area, it tends to involve small groups of participants and in the case of Siffre, one individual. The people involved may not be representative. This therefore limits the degree to which meaningful generalisations can be made and applied to the wider population.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confounding variables</td>
<td>Although the participants in Aschoff and Wever’s study were deprived of natural light, they still had access to artificial light. Siffre would turn on a lamp every time he woke up which remained on until he went to bed. It was assumed that artificial light would have no effect on his free running circadian rhythm however other research Czeisler 1999, suggests the opposite, that artificial light can have an influence. This means the use of artificial light could have been a confounding variable and affected the validity of the results.</td>
</tr>
<tr>
<td>Individual differences</td>
<td>Linked with generalisation is that individual cycles can <strong>vary</strong>, some people have a natural preference for going to bed early and rising early (known as ‘larks’) whereas others prefer the opposite (‘owls’). There are also <strong>age</strong> differences in sleep/wake patterns. Thus, individuals seem to have innate differences in their cycle length and onset and these individual differences can further complicate generalisation.</td>
</tr>
<tr>
<td>Practical applications to shift work</td>
<td>Research has provided a better understanding of the consequences of disrupted circadian rhythms i.e. <strong>shift work</strong>. Night workers can experience reduced concentration around 6am, making mistakes and accidents more likely. Poor health has been linked with night shifts. This highlights economic implications and how changes in shift work patterns could help workers stay healthy and manage productivity.</td>
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</table>
Endogenous pacemakers and exogenous zeitgebers on the sleep wake cycle:

Sleep is not a random human function. It is influenced by particular factors both inside and outside us. Don’t be alarmed by the words endogenous pacemakers and exogenous pacemakers. In a nutshell, endogenous pacemakers refer to an internal body clock that sets many of our bodily rhythms, including sleep. The internal body clock that has an effect on when we sleep and when we are awake is the suprachiasmatic nucleus (SCN). Exogenous zeitgebers are external cues that have an influence on when we’re sleep or awake, such as light.

So how does endogenous pacemakers and exogenous zeitgebers influence our circadian rhythm (sleep/wake cycle)? Let’s go inside the body first.

The main endogenous pacemaker (internal) is the suprachiasmatic nucleus (SCN) or biological clock. It’s a bundle of nerves located in the hypothalamus of the brain.

- The SCN is located above the optic area (i.e. Optic nerve & optic chiasm)
- Therefore, it can receive information about light directly. The SCN passes the information about day length/light to the pineal gland.
- Based on this information, the pineal gland will release melatonin (a chemical that makes us feel sleepy).
- During the night, the pineal gland increases melatonin production. With more daylight, less melatonin. The SCN is therefore to a degree regulated by light from our outside world.
- However, even in the absence of any light (trapped in a cave). The SCN generates a rhythm related to its production of protein. When it reaches a certain level of protein it passes a message to the pineal gland and melatonin will still be released or inhibited.
- So although daylight influences the SCN it’s not absolutely essential. (Think of a person who is blind, they still have a sleep/wake cycle regardless of light input).
Research supporting the SCN: Morgan’s hamster study

Morgan (1995) removed and transplanted the SCNs from hamsters and shows support the importance of the SCN as an endogenous pacemaker. Hamsters were bred so that they had a circadian rhythm of 20 hours rather than 24. The SCN cells from these abnormal hamsters were transplanted onto the brains of normal hamsters. These normal hamsters began to adopt the same abnormal circadian rhythm as their 20 hour donor.

Furthermore, when hamsters with nocturnal patterns of activity (usual) had their SCNs replaced with SCNs from mutated hamsters which slept through the night and were active during the day (unusual), the hamsters followed the new daytime activities of the donor’s patterns. Further evidence from lesioning (cutting) the SCN in rats showed a complete disruption to the animals sleep/wake cycle.

So…? This suggests the transplanted SCN had imposed its pattern onto the hamsters and shows the significance of the SCN and how endogenous pacemakers are important for biological rhythms.

Let’s now turn to exogenous zeitgebers, or external cues.

The most influential exogenous zeitgeber is light, (zeitgeber is German for ‘time giver’) and it’s an important factor in our environment that ‘resets’ our biological clocks, this is called entrainment.

Light enters the eye through the retina and this information is passed onto the SCN. (Another example of zeitgebers would be social cues such as meal times).

The main point is that although most of the processes are internally driven, it can be governed by the exogenous zeitgeber of light.

Notes
Research supporting exogenous zeitgebers: Campbell and Murphy (1998)

An innovative study by Campbell & Murphy showed that light may be detected by skin receptor sites on the body, even when the same information is not received by the eyes. 15 participants were woken up at various times and a light pad was shone on the back of their knees. The researchers found a change in their sleep/wake cycle of up to 3 hours in some cases.

So…? This suggests that light is a powerful exogenous zeitgeber that doesn’t need to rely on the eyes to exert influence on the brain.

Evaluation to consider…

<table>
<thead>
<tr>
<th>Ethics in animal studies</th>
<th>Generalising findings from animal studies to humans is questionable.</th>
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<tbody>
<tr>
<td>Methodological issues in research</td>
<td>The findings from the Campbell and Murphy study have yet to be replicated. Critics have suggested that participants may have been exposed to a limited amount of light to their eyes which would be a major confounding variable and affect the validity of the results.</td>
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</tbody>
</table>

Exam hint: These three areas, circadian rhythms, endogenous pacemakers and exogenous zeitgebers all interact to control biological rhythms so aim to consider these concepts together rather than as separate components.

Just to summarise…

- Circadian rhythms are once in a day (24 hours)
- Siffre and Aschoff & Wever’s circadian studies showed a 25hr cycle with participants
- The SCN is the main endogenous pacemaker (biological clock). It passes information to the pineal gland. This gland releases melatonin
- Research by Morgan (hamsters) suggests SCN controls sleep/wake cycle
- Light is the main exogenous zeitgeber
- Research by Campbell & Murphy (knees) suggests light is so powerful, it doesn’t need to enter the eyes to influence circadian rhythms.
• **Infradian Rhythms: The Menstrual Cycle**

Infradian rhythms have cycles that occur **longer than 24 hours**. The best example is the female **menstrual cycle** because it occurs monthly. The cycle begins from the **first day of a woman’s period**, when the womb lining is shed, to the **day before her next period**. The ‘average’ cycle takes about 28 days to complete, however it varies with every woman and can be anywhere between 21 days (short cycle) and 35 days (long cycle). Every woman’s cycle is different.

**Hormones:**

Being a biological rhythm the menstrual cycle is governed by changes in hormones. One of the most important hormones is **oestrogen** and this is at its highest around half way through the cycle during ovulation. At this point an egg is released from the ovary. After ovulation, another hormone called **progesterone** also increases in preparation for the possible development of an embryo and this ‘preparation’ is the womb lining starting to thicken with blood, getting the womb ready for pregnancy.

If pregnancy doesn’t occur, the egg is absorbed back into the body, the lining of the womb sheds, and this is the menstrual flow. Below is a calendar showing an example of ‘Keri’s cycle’. (Let’s assume she has an average 28 day cycle).

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<th>2017</th>
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1. Keri starts her period 10th August. This is the **first** day of her cycle. Her menstrual flow lasts 5 days (14th). Her levels of oestrogen are increasing.

2. Around 14 days (23rd) after Keri starts her period, she begins to ovulate.

3. Keri has a 28 day cycle which means she is likely to start her period 6th September. Her cycle ends the day before (5th).

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**Exam hint:** Although it does appear the menstrual cycle is governed by internal factors (endogenous pacemakers) such as hormonal changes, research suggests they can be heavily influenced by exogenous zeitgebers.
Research supporting the infradian rhythms: menstrual cycle

Reinberg (1967) conducted a study where one female participant spent three months in a cave with only light from a small lamp. Reinberg noted that her menstrual cycle shortened from the usual 28 days to 25.7 days. This suggests that the lack of light (an exogenous zeitgeber) affected the woman’s menstrual cycle, and therefore demonstrates the effect of external factors on infradian rhythms. (This research relates to the exam hint).

A further study that also links to the exam hint...

McClintock and Stern (1998)

**Aim:** to show that the menstrual cycle is influenced by pheromonal secretions from other women.  
**Sample:** 29 female university students, not taking birth control pills.  
**Design:** A Longitudinal experiment with independent measures.  
**Method:** Samples of pheromones were gathered from 9 of the women at different stages of their menstrual cycle, via a cotton pad placed under their armpit. The pads were worn for at least 8 hours to ensure pheromones were picked up. The pads were treated with alcohol and frozen (to eliminate any bacteria). This was the control group.  
The odour from these pads were inhaled by the other 20 women (the experimental group) by being rubbed on their upper lip. On day 1, pads from the start of the cycle were applied to the 20 women, on day 2 they were given pads from the second day of the cycle, and so on.  
**Result:** when the experimental group inhaled secretions from women who were about to ovulate, their menstrual cycles became shorter. When they inhaled secretions from women who had just ovulated, their menstrual cycles became longer. The experimental groups’ menstrual cycles were affected by the secretions from the control group. On 68% of occasions the recipients of the sweat donation had experienced changes to their cycle which brought them closer to their ‘odour donor’. (Synchronised)  
**Conclusion:** This possibly explains why when a group of women live in close proximity their menstrual cycles tend to synchronise and provides support for the role of exogenous zeitgebers (pheromones) in infradian rhythms.

‘To synchronise or not to synchronise’

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**Notes**

Note: Pheromones are chemicals released (i.e. through sweat) that may trigger a response from a member of the same species (mammals/bees).
McClintock’s research has criticisms that suggest there are numerous factors other than pheromones that could change a woman’s cycle, such as stress, diet, exercise etc., that may act as confounding variables. Furthermore, research involves small samples of women and relies on women self-reporting the onset of their own cycle. Therefore, these ‘other factors’ both methodological and individual differences, make the influence of pheromones on infradian rhythms questionable.

Recent replication of research between women’s cycles in close proximity has failed to find evidence of menstrual synchrony suggesting reduced reliability.

The knowledge gained about pheromones is mainly from animal studies, in animal sex selection. In contrast, evidence for definite effects of pheromones in human behaviour is still questionable and again poses doubt on the validity of pheromones affecting the menstrual cycle.

Evolutionary psychologists suggest a possible reason for women’s menstrual cycles synchronising is that it provides an evolutionary advantage for groups of women – in other words the synchronisation of pregnancies means that childcare can be shared among multiple mothers who have children at the same time due to a couple of reasons firstly, women lactating at the same time (having breast milk) and secondly, through the release of oxytocin – mothers are able to bond to babies.

Therefore, these factors mean that ultimately synchronisation of women’s menstrual cycles will enhance survival.

Just to summarise...

- The menstrual cycle is an example of an Infradian Rhythm because it occurs longer than 24 hours (once per month)
- The average cycle lasts 28 days, but it can be between 21 to 35 days
- The hormone estrogen is at its highest during ovulation. After ovulation progesterone increases in preparation of the womb for pregnancy.
- The cycle is primarily an endogenous pacemaker, but it can be influenced by exogenous zeitgebers.
- Research had suggested that light can influence the cycle and also the pheromones of other women may lead to ‘synchronisation’ (women on their periods at the same time).
• Ultradian Rhythms: The cycles of sleep

These occur less than 24 hours and a good example are the stages of sleep. A typical night’s sleep takes you from stage 1 to 4 then back to 2 and finally into REM. Sleep is the perfect example of an ultradian rhythm, that is, one that repeats itself over a period of less than 24 hours. One cycle of sleep typically lasts about 90 minutes and during a typical night’s sleep we will repeat this cycle four or five times, although the cycles do differ through the night. Here, we will first consider the stages of sleep, then how these stages form a cycle (pattern) during the night while we’re asleep.

Note: It might be a good idea to remind yourself of the brainwave patterns we considered when we looked at EEGs. Alpha, beta, theta and delta waves. They will come up again here with ultradian rhythms.

Sleep stages:

- Stages 1 and 2 are ‘light sleep’ stages: Brain patterns become slower starting with alpha waves, progressing to theta waves.
- Stages 3 and 4 are ‘deep sleep’ associated mainly with delta waves.
- Stage 5 (REM sleep). The body is ‘paralysed’ to prevent acting out our dreams. The eyes rapidly move from side to side (Rapid eye movement - REM). The brain activity resembles a person who is awake.
- Stages 1-4 are NREM stages (Non REM)
- Stage 5 is REM stage
- On average the entire cycle repeats every 90 minutes and a person may have 4 or 5 full cycles per night.
Sleep cycle:

How do the stages of sleep create a cycle of sleep?

Looking at the table above on the y axis we have the stages of sleep, on the x axis are the hours of sleep.

As we fall asleep we enter stage 1 sleep which is high frequency and low amplitude sleep. As we progress through stages 1-4 sleep becomes deeper. Stage 4 sleep is characterised by delta waves and is the deepest sleep stage, it’s difficult to wake up at this point! Heart rate and blood pressure fall and muscles are very relaxed. We are in stage 4 for about 30 minutes. We’ve been asleep for about an hour all together. Then we start to ascend back through these stages in reverse order, i.e. back to stage 3, and then stage 2, but instead of going back to level 1, after just over an hour, we enter REM sleep. (REM is characterised by rapid eye movement, the body is paralysed and dreaming occurs). This is one cycle completed.

Each sleep cycle lasts around 90 minutes, and a good night of sleep will feature 4-5 cycles with episodes of REM sleep.

As the table illustrates we spend most of the first half of the night in deep sleep (NREM) and most of the second half in REM sleep.

Of course, do remember the above describes a ‘typical’ night’s sleep and there are significant individual differences between people (in fact this is one of the methodological issues with studying sleep cycles because of unique differences). Sleep cycles also differ with age, a 17 year old will have a different cycle to a 70 year old.

Exam hint: When discussing the ultradian rhythms and the sleep cycle, you must explicitly mention that the cycle occurs more than once every 24 hours.
Research evidence for the distinct stages of sleep and the role of REM sleep

Dement and Kleitman (1957)

**Aim:** The aim of this laboratory experiment was to investigate the relationship between eye movements and dreaming.

**Method:** The nine participants were seven adult males and two adult females. The participants were studied under controlled laboratory conditions. Participants had to report to the laboratory at bedtime where they were connected to an EEG. The EEG took measurements throughout their time asleep all night. P’s were asked not to drink caffeine.

**Results:** The results show that REM sleep is predominantly, though not exclusively, associated with dreaming, and Non-REM sleep is associated with periods of non-dreaming sleep. P’s were able to recall dreams when awakened during REM periods. If they were awakened in other stages they were less likely to report dreaming.

The REM periods occurred at regular intervals during the night, though each participant had their own pattern: the mean period between each REM phase for the whole group was 92 minutes, with individual norms varying between 70 minutes and 104 minutes.

**Conclusions:** Three things… first, from these findings (which are reliable as there has been much replication) it can be said the stages of sleep follow a pattern throughout the night second, dreams mostly occur in REM and finally, participants did on average go into REM every 90 or so but there were still individual differences.

Dement (1960) compared participants who had been deprived of REM sleep with a control group who had been deprived of the same amount of NREM sleep. He found that the REM deprived group were more irritable, more aggressive and unable to concentrate on various tasks. Borbely (1986) found that REM deprived individuals made 31 attempts to re-enter REM on the first night of deprivation (called REM re-bound), 51 attempts on the second night and over 60 attempts on the third… Dement and Borbely’s research suggests that REM is a distinct and significant stage of the ultradian rhythm and also important for our psychological well-being.

In 1964 Randy Gardner remained awake for 264 hours. While he experienced numerous problems such as blurred vision and disorganised speech, he coped incredibly well despite his significant sleep deprivation.

After his experience, he slept for just 15 hours and over several nights recovered only 25% of his lost sleep. He recovered about 70% of stage 4 sleep, 50% of his REM sleep and very little of the other stages. These results suggest the wide degree of flexibility in terms of the different stages within the sleep cycle and the variable nature of this ultradian rhythm.
### Evaluation to consider...

<table>
<thead>
<tr>
<th>Individual differences</th>
<th>A significant problem when studying sleep cycles is the differences observed in people. This can be seen in Dement and Kleitman’s research. <strong>Tucker</strong> et al (2007) also found differences in participants in terms of the <strong>duration</strong> of each stage, particularly stages 3 and 4 (NREM). These research suggest there may be innate individual differences in ultradian rhythms which means it’s worth focusing on these differences during investigations into sleep cycles.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lack of ecological validity</strong></td>
<td>Sleep cycles are usually investigated with a high degree of control in sleep laboratories. Participants will wear caps with electrodes to monitor EEG patterns and asked to sleep and then be woken up at various points during their cycle. This is both invasive for the participant as well as being very artificial and may lead them to sleep in a way that doesn’t represent their ordinary sleep cycle. This lack of ecological validity could lead to false conclusions being applied to our understanding of sleep cycles.</td>
</tr>
<tr>
<td><strong>Flexible</strong></td>
<td>Randy Gardner’s experience of remaining awake for 264 hours and subsequently recovering 70% of stage 4 and 50% of his REM sleep and little of the other stages. This suggests the degree of flexibility in terms of the different stages may not be as ‘fixed’ as psychologists believed. However, we should consider that Gardner’s results could be unique to him, for example an older individual may have very different results in the sleep they recovered. This means generalisation of such specific cases could be difficult to the wider population.</td>
</tr>
</tbody>
</table>
| **Just to summarise...** | - The cycle of sleep is an ultradian rhythm as it occurs less than 24 hours.
  - One cycle lasts about 90 minutes and this is repeated 4-5 times during the night depending on how many hours sleep a person has.
  - Stages 1-2 is light sleep; Stages 3-4 deep sleep and these are Non-REM sleep (NREM). Stage 5 or REM sleep is where dreaming usually occurs and brain activity is similar to a person who is awake.
  - One cycle lasts about 90 minutes. There are about 4-5 cycles per night.
  - Research suggests dreaming usually occurs during REM stage and it’s important for psychological well-being. |

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**Notes**
Sample exam questions

- **The divisions of the nervous system: central and peripheral (somatic and autonomic)**

Which **one** of the following responses results from the action of the sympathetic division of the autonomic nervous system? Shade **one** box only.

A. Decreased pupil size
B. Increased digestion
C. Increased heart rate
D. Increased salivation

(Total 1 mark)

- **The structure and function of sensory, relay and motor neurons. The process of synaptic transmission, including reference to neurotransmitters, excitation and inhibition.**

Briefly outline how excitation and inhibition are involved in synaptic transmission.

(Total 4 marks)

- **The function of the endocrine system: glands and hormones**

Briefly explain **one** function of the endocrine system (2 marks)

- **The fight or flight response including the role of adrenaline**

You are a passenger in a car that has suddenly slammed on its brakes to avoid hitting a dog. Your breathing quickens, your mouth is dry and you have a feeling of ‘butterflies’ in your stomach. But after a few minutes these physical changes start to disappear. Using your knowledge of the body’s response to stress, explain why you are likely to have experienced:

(a) the changes that occurred in the first 30 seconds; (2 marks)
(b) The changes that occurred after a few minutes. (2 marks)

- **Localisation of function in the brain and hemispheric lateralisation: motor, somatosensory, visual, auditory and language centers; Broca’s and Wernicke’s areas, split brain research. Plasticity and functional recovery of the brain after trauma.**

Split brain patients show unusual behaviour when tested in experiments. Briefly explain how unusual behaviour in split brain patients could be tested in an experiment. (2 marks)
• Ways of studying the brain: scanning techniques, including functional magnetic resonance imaging (fMRI); electroencephalogram (EEG’s) and event-related potentials (ERPs); post-mortem examinations.

The electroencephalogram (EEG) and event-related potentials (ERPs) both involve recording the electrical activity of the brain.

Outline one difference between the EEG and ERPs. (2 marks)

• Biological rhythms: circadian, infradian and ultradian and the difference between these rhythms. The effect of endogenous pacemakers and exogenous zeitgebers on the sleep/wake cycle

Outline one example of a circadian rhythm (4 marks)

• Genotype/phenotype

Rita and Holly are identical twins who were separated at birth. When they finally met each other at the age of 35, they were surprised at how different their personalities were. Rita is much more social and out-going than Holly.

Use your knowledge of genotype and phenotype to explain this difference in their personalities (4 marks)

• Questions linked to research methods

A psychologist wanted to test the effects of biological rhythms on the ability to solve maths problems. She used random sampling to form two groups each of 20 students.

She tested one group on one set of maths problems at 3 am in the morning. The other group was tested on another set of maths problems at 3 pm in the afternoon. She found that performance of the group tested at 3 pm was significantly better than the group tested at 3 am.

When submitted for peer review the paper was rejected because of serious design problems.

Explain one problem with the design of this study and suggest ways of dealing with this problem. (4 marks)

• Application 16 mark essay

Robert suffered a stroke at the age of 55. After the stroke he was paralysed down his right side, though he could move his left arm and leg easily. Robert could clearly understand what was said to him, but was unable to produce any speech.

Discuss how knowledge of hemispheric lateralisation and language centres in the brain has helped our understanding of cases such as Robert's. Refer to Robert’s case in your answer. (Total 16 marks)
Essay planning (A describe and evaluate question)

Describe and evaluate evidence of plasticity and functional recovery after trauma in the brain

(16 marks)

**A01**: 6 marks, **A02**: 10 marks

- **AO1** Definition of brain plasticity
- Maguire as correlational evidence…link back i.e. ‘the larger hippocampus in London Taxi drivers suggests the experience of driving a taxi led to brain plasticity in the hippocampus’
- Description of functional recovery…link back ‘the new connections in the brain are activated allowing recovery of nearby regions in the brain.’
  (roughly 120/150 words)
- **AO3** research support – Kuhn for example…
  
  P – There is research support for the idea of brain plasticity
  E- Kuhn found a significant increase in grey matter in various regions of the brain
  E- This occurred after participants played video games for 30 minutes over a two month period
  L – This matters because Kuhn provides evidence for brain plasticity showing how experience and lead to structural changes in the brain.

- **AO3** further support – Maguire
  P- There is further evidence to support the idea of brain plasticity
  E- Maguire found the posterior hippocampus of London Taxi drivers’ brains was positively correlated with their time as a taxi driver and this was different in comparison to controls.
  E - (Issue & debate) point – However, some psychologists suggest that research investigating brain plasticity is limited. Maguire’s research is biologically reductionist and only examines a single biological factor (size of hippocampus) in relation to spatial memory. This approach is limited because it fails to consider all the different biological/cognitive processes involved in spatial navigation which may limit understanding.
  L- Therefore, while Maguire’s research shows that the brain can change in response to frequent exposure to a particular task, some psychologists argue that a more holistic approach may be deemed more appropriate.

- **AO3**
  P- A final strength of research examining plasticity and functional recovery is the practical application of neurorehabilitation
  E – This uses motor (physical) therapy and electrical stimulation of brain areas following significant accident, injury or strokes.
  E – The brain has the ability to fix itself to a certain to a certain extent.
  L- This matters because it shows the positive application of research in this area to help improve the cognitive functions of people suffering injuries.
Essay Planning (A discuss question)

Discuss the effects of endogenous pacemakers and exogenous zeitgebers on the sleep-wake cycle (16 marks)

AO1: Describe how the sleep-wake cycle is controlled endogenously below.

AO3: Fully complete the P.E.E.L points below

P- Evidence to support the role of endogenous pacemakers comes from Morgan (1995)
E- They found …….
E- Also,

L-This shows the importance of endogenous pacemakers because…………

AO3: Fill in the next P.E.E L statement

P- A further piece of evidence that supports the role of endogenous pacemakers is Siffre.
E-

E-

L- This shows us the sleep-wake cycle is controlled by the SCN because despite there being no exogenous zeitgebers e.g. light or clocks, Siffre still woke and slept.
**AO1:** Describe how light effects the working of the sleep-wake cycle (e.g. mention stopping melatonin) (16 mark)

**AO3:** Select one study from the pack and use it to show the importance of an exogenous zeitgebers on the sleep-wake cycle.

Continue...
The endocrine system: Fight or flight – Exam question

Below is an exam question with an answer. Many students make the mistake of not ‘fully’ addressing a question. This one has two parts, an outline and to make reference to something.

Outline the key processes involved with the fight or flight response, make reference to the role of adrenaline in your answer (6 marks)

Core knowledge 1: up for the fight (or flight)

A person will change from their normal resting state (the parasympathetic state) to the physiologically aroused sympathetic state when faced with a perceived threat. This causes the pituitary gland to release adrenocorticotropic hormone (ACTH). This has the effect on the cells of the adrenal gland causing them to release adrenaline. This triggers physiological changes in the body which creates the physiological arousal necessary for the fight or flight response.

Core knowledge 2: what biological changes occur due to increased adrenaline?

The physiological changes initiated by the secretion of adrenaline include increased heart rate, increased breathing rate, dilated pupils, inhibits digestion and inhibits saliva production.

Q) Feeling anxious? This often leads to the sensation of butterflies in the stomach, can you guess using a physiological reason why these may occur?

The physiological changes in the stomach cause this. Blood is diverted away from the stomach to the vital organs, and the stomach muscles tighten. This adds to the feeling of ‘butterflies’ and people can feel quite ‘sick’ and occasionally experience nausea.

Core knowledge 3: - calming down again

Once the threat has passed, the parasympathetic nervous system is activated to calm the person down and return them to a resting state. Adrenaline is no longer secreted from the adrenal glands. Heart and breathing rates return to normal, and the person establishes homeostasis. The parasympathetic nervous system works in opposition to the sympathetic nervous system and act like a brake so we do not use up all our vital resources by staying in a constant state of heightened physiological arousal.
9/12 mark design question

9/12 mark design a study questions can be tricky to answer, the more you practice doing them the better you will become at answering them effectively rather than writing obscure points showing a lack of understanding. As they are 9 or 12 marks they can really make the difference in your overall grade.

One example is below...

Imagine you have been asked to design a study to investigate whether there is a relationship between the number of hours students spend sleeping and how successful they are at completing a series of anagrams. You decide you will time the participants as they do the anagram task.

Discuss the following aspects of this investigation:

- Write an aim and a fully operationalised hypothesis
- Explain the procedure you would use to carry out the investigation
- How would you ensure that the experience of your participants is ethical?

(9 marks)