Psychology Units 1 & 2

Chapter 5 — Role of the brain in mental processes and behaviour

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Chapter 5 Role of the brain in mental processes and behaviour — 5A Approaches to understanding the role of the brain

Theory

For thousands of years people have asked where our thoughts, feelings and behaviour come from. The story of how humans have answered this question is one of steady **progression** — from crude, philosophical and even **pseudoscientific** ideas, through **invasive experiments** on damaged brains, to modern techniques that let us watch the **living, working brain** without harming it. Each approach was a genuine step forward for its time, and each was **limited** by the tools and ideas available. This subtopic follows that progression; the detailed jobs of particular brain regions belong to the next subtopic.

The brain-versus-heart debate. The earliest question was simply *which organ* is responsible for thought and emotion. The **cardiocentric hypothesis** (the "heart" hypothesis) held that the **heart** is the seat of thought, feeling and the mind. This was an ancient and widely held view — the ancient Egyptians carefully preserved the heart but discarded the brain during mummification, and the philosopher Aristotle argued that the heart was the centre of intelligence while the brain merely cooled the blood. The rival **cephalocentric hypothesis** (the "brain" hypothesis) held that the **brain** is the seat of the mind. Thinkers such as Hippocrates argued that our thoughts, emotions and sensations arise from the brain, and later observations of how head injuries changed people's abilities gradually built the case. Over time the evidence favoured the **brain** hypothesis, which we now accept — but for centuries this was a real and unresolved debate.

The mind–body problem. Once the brain was accepted as central, a deeper, more philosophical question remained: what is the relationship between the **mind** (our thoughts, consciousness and experience) and the **physical body and brain**? Two broad positions developed. **Dualism** proposes that the mind and the body are **two separate things** — the mind is non-physical and distinct from the physical brain (a view associated with the philosopher René Descartes). **Monism** proposes that there is really only **one kind of thing**: the mind is a **product of the physical brain**, so mental processes arise from, and are explained by, the activity of the brain. Modern psychology and neuroscience take a broadly **monist** view — this is what makes it sensible to study the mind by studying the brain — but note this was reached by argument, not yet by experiment.

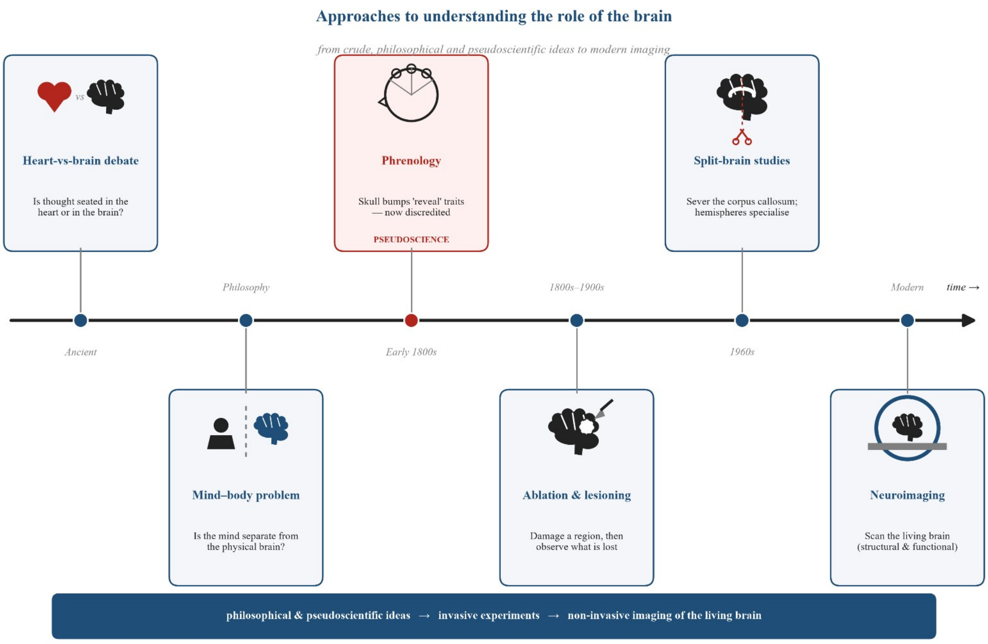
Phrenology. In the early 1800s, phrenology proposed that the brain is made up of separate regions, each responsible for a specific trait or ability, and that a well-used faculty would grow larger and push out a **bump** on the overlying skull. A phrenologist claimed to read a person's personality, character and talents by feeling the **bumps and contours of their skull**. Phrenology is now completely **discredited**: it is a classic example of a **pseudoscience** — something that is *presented* as scientific but is **not based on sound scientific evidence or method**. It fails as science because its core assumptions were false (the shape of the skull does not reflect the brain beneath it, and the brain does not mould the skull into bumps), and because its claims were "supported" only by **anecdote and by confirming what practitioners already believed**, rather than by rigorous, controlled, **reproducible** testing — and they did not hold up when properly tested. Yet phrenology matters historically: it was an early attempt at the **localisation of function** — the idea that specific parts of the brain are linked to specific functions. That general idea, in a very different and evidence-based form, later proved partly correct, even though phrenology's own method was invalid.

Early experimental methods: ablation, lesioning and stimulation. As science matured, researchers moved from armchair theorising to experimenting on the brain itself. **Ablation** is the **surgical removal or destruction** of an area of brain tissue (originally in animals), and **lesioning** is the deliberate **damaging or destroying** of brain tissue. The logic is the same for both: remove or damage a specific region, then observe what the animal can **no longer do** — if damage to a region reliably removes a particular ability, that region is probably **involved in** that ability. Researchers reasoned in the same way about **humans with brain damage** from accident, stroke or illness, studying such patients as natural "experiments". A complementary method was **electrical stimulation of the brain** — applying a small electrical current to a region and observing the response it produced (such as a movement) — which mapped function from the other direction. Together these methods produced the **first real evidence** linking brain regions to functions. Their **limitations**, however, are serious: they are highly **invasive** and raise major **ethical** concerns (especially destroying healthy tissue in animals); the damage is often **imprecise** and may affect neighbouring tissue or connections, so it is hard to be sure exactly which region caused the change; findings from **animals may not generalise** to humans; and human brain-damage cases are **rare, uncontrolled and differ** from person to person.

Split-brain studies. In the mid-twentieth century, some people with severe, otherwise untreatable **epilepsy** had their **corpus callosum** — the thick band of nerve fibres connecting the brain's two hemispheres — surgically **cut** to stop seizures spreading from one side to the other. Studying these **split-brain** patients allowed researchers to investigate what each hemisphere could do **on its own**, and revealed that the two hemispheres are **specialised** for somewhat different functions (**hemispheric specialisation**) — a real advance over simply knowing "the brain does it". The **limitations** are that such patients are **very few**, they already had **atypical** brains (severe epilepsy), and the surgery obviously cannot be performed experimentally on healthy people — so it is hard to **generalise** the findings to everyone.

Modern neuroimaging. The biggest advance of all is the ability to study the **living, working brain non-invasively** — without surgery or damage. Neuroimaging techniques fall into two families. **Structural** imaging shows the brain's **physical structure** — what it looks like. A **CT** (computerised tomography) scan uses X-rays to build a picture of the brain's structure, and an **MRI** (magnetic resonance imaging) scan uses magnetic fields to produce a highly detailed structural image; these are ideal for detecting injury, bleeding or tumours. **Functional** imaging shows the brain's **activity** — what it is *doing*, and where, while a person performs a task. An **fMRI** (functional MRI) tracks changes in blood oxygenation to show which regions become active over time, and a **PET** (positron emission tomography) scan uses a **radioactive tracer** to reveal metabolic activity (such as glucose use) across the brain. The key distinction to keep straight is **structure versus function**: structural imaging (CT, MRI) is like a **still photograph of the anatomy**, whereas functional imaging (fMRI, PET) is like a **moving picture of what the brain is doing**. The great advantage over every earlier method is that we can now study an **intact, healthy, living brain at work** without damaging it.

The overall progression. Each approach was a step forward, limited by the science of its time. Philosophical debate (heart-versus-brain; the mind–body problem) could **argue** but not **test**; phrenology *looked* scientific but used an **invalid, pseudoscientific** method; ablation, lesioning and stimulation gave the first real **evidence** but were **invasive, crude and often confined to damaged or animal brains**; split-brain studies revealed **specialisation** but only from **rare, atypical** patients; and modern **neuroimaging** finally lets us study the **normal, living, working brain non-invasively**. The clear trend is towards methods that are **more scientific, more precise, less invasive**, and able to study the healthy working brain.



How to analyse a question. When a question describes an approach, (1) **identify which approach** it is from its features (heart-versus-brain, mind–body problem, phrenology, ablation/lesioning, split-brain, or neuroimaging); (2) place it in the **historical progression** (crude/philosophical → pseudoscientific → invasive experiment → non-invasive imaging); and (3) be ready to state **what it revealed or contributed** and **one limitation**. For neuroimaging questions specifically, decide whether the aim needs the brain's **structure** (a still image → **CT** or **MRI**) or its **activity/function** (a working image → **fMRI** or **PET**).

Worked examples

Example 1 — scaffolded

Arrange these six approaches in the order they emerged, earliest first, and note in a phrase what each contributed: neuroimaging; the heart-versus-brain debate; ablation and lesioning; the mind–body problem; split-brain studies; phrenology.

Working	Comment
1. **Heart-versus-brain debate** (ancient) — the first question: is the mind seated in the *heart* (cardiocentric) or the *brain* (cephalocentric)?	Start with the most ancient, pre-scientific question.
2. **Mind–body problem** (philosophy) — is the mind *separate* from the physical brain (dualism) or does it *arise from* it (monism)?	A philosophical debate — argued, not yet experimental.
3. **Phrenology** (early 1800s) — an early but *pseudoscientific* attempt to localise functions by reading bumps on the skull.	Looks scientific but uses an invalid method; comes before real experiments.
4. **Ablation and lesioning** (1800s–1900s) — the first *experimental* evidence: damage a region, observe the deficit, infer its function.	The move from theorising to experimenting on the brain.
5. **Split-brain studies** (1960s) — cutting the corpus callosum revealed *hemispheric specialisation*.	Mid-twentieth century; still relies on damaged, atypical brains.
6. **Neuroimaging** (modern) — *non-invasive* techniques image the living, working brain.	The only method that studies the intact, healthy, working brain.

Example 2 — scaffolded

A neurologist has two aims: (i) check whether a patient who has had a fall has any physical damage or bleeding in the brain; and (ii) find out which regions of a healthy volunteer's brain become active while they read. For each aim, state whether a **structural** or a **functional** technique is required, name a suitable technique, and justify the choice.

Working	Comment
Aim (i) needs to see the brain's **physical structure** (damage or bleeding) → a **structural** technique.	Damage / anatomy = structure → structural imaging.
A **CT** scan (X-rays) or an **MRI** (magnetic fields) gives a still image of the brain's anatomy, revealing injury or bleeding.	Name a real structural technique and what it uses.
Aim (ii) needs to see the brain's **activity** while a task is performed → a **functional** technique.	"Which regions become active" = function/activity → functional imaging.
An **fMRI** (blood-oxygen changes) or a **PET** scan (radioactive tracer) shows *where* activity occurs while the volunteer reads.	Function = what the brain is *doing*, not just its shape.

Example 3 — unscaffolded

Explain why phrenology is classified as a pseudoscience rather than a science.

Phrenology claimed to reveal a person's personality and abilities by feeling the **bumps on their skull**, on the assumption that a well-used mental faculty enlarges and pushes out the overlying skull. It is classified as a **pseudoscience** because, although it was *presented* as scientific, it was **not based on sound scientific evidence or method**. Its central assumptions were **false** — the shape of the skull does not reflect the brain beneath it, and the brain does not mould the skull into bumps. Its claims were supported only by **anecdote** and by **confirming what practitioners already believed**, rather than by **controlled, reproducible testing**, and they **failed** when properly investigated. A genuine science makes claims that can be **tested and disproven by evidence**, and that hold up when others repeat the work; phrenology met none of these standards. ∴ because it wore the *appearance* of science without its **evidence, testing or reproducibility**, phrenology is a pseudoscience — though it is historically important as an early attempt to localise brain function.

Example 4 — unscaffolded

In an early experiment, a researcher surgically removes a small region from a pigeon's brain. Afterwards the pigeon can no longer coordinate its balance when landing. The researcher concludes that this region is responsible for balance. Explain the reasoning behind this ablation study, and give one limitation of drawing such a conclusion.

The study uses **ablation** — the surgical **removal** of brain tissue. The reasoning is that if removing a specific region reliably causes the **loss** of a particular ability (here, balance), then that region must normally be **involved in** that ability; by comparing what the animal could do before and after, the researcher **infers the region's function** from the deficit that appears. A **limitation** is that ablation is **crude and imprecise**: the surgery may also damage **neighbouring tissue or connections**, so the lost ability might depend on more than the targeted region, and the deficit does not prove that region alone is "responsible". (It is also **invasive**, raises **ethical** concerns, and findings in a pigeon may not **generalise** to humans.) ∴ ablation can provide real evidence linking a region to a function, but a single lesion cannot, on its own, prove that one region is solely responsible.

Practice questions

Scaffolded

Q1. Define each of the following: (a) the cardiocentric hypothesis; (b) phrenology; (c) ablation.

Q2. The mind–body problem asks how the mind relates to the physical brain. (a) Explain what is meant by dualism. (b) Explain what is meant by monism. (c) State which view underlies modern neuroscience, and why.

Q3. Consider the brain-versus-heart debate. (a) Name the two competing hypotheses. (b) State which hypothesis is accepted today. (c) Give one reason this debate was historically important.

Q4. Consider split-brain studies. (a) Name the brain structure that is cut. (b) State the medical reason the surgery was originally performed. (c) State what studying split-brain patients revealed about the hemispheres.

Q5. Neuroimaging techniques are described as either structural or functional. (a) State what structural imaging shows. (b) State what functional imaging shows. (c) Classify each of CT, MRI, fMRI and PET as structural or functional.

Q6. Ablation and lesioning were early experimental methods. (a) Explain how damaging a brain region lets a researcher infer that region's function. (b) State one strength of these methods (what they were able to reveal). (c) State one limitation of these methods.

Unscaffolded

Q7. Distinguish between structural and functional neuroimaging. *(2 marks)*

Q8. Each of the following describes a different approach to understanding the role of the brain. (i) A researcher surgically destroys a small area of a monkey's cortex and records the ability that is lost. (ii) A scanner tracks changes in blood oxygenation while a volunteer solves a puzzle. (iii) A practitioner runs their fingers over a client's skull and declares them "naturally cautious". (iv) A philosopher argues that the mind is non-physical and therefore separate from the body. Name the approach each description refers to, place the four in the order in which they emerged (earliest first), and state the overall trend that order shows. *(3 marks)*

Q9. As well as ablation and lesioning, early researchers used electrical stimulation of the brain, and they studied people who had suffered brain damage through accident, stroke or illness. Explain how each of these two approaches allowed a brain region to be linked to a function, and state one limitation of relying on human brain-damage cases. *(3 marks)*

Q10. For each of the following, name the approach that produced the finding or idea: (a) the two hemispheres are specialised for somewhat different functions; (b) damaging a specific brain region removes a specific ability; (c) the heart, not the brain, is the seat of thought and emotion; (d) a detailed still image showing a tumour in a living patient's brain. *(4 marks)*

Q11. Explain how the method of lesioning allows a researcher to infer the function of a brain region, and identify one limitation of relying on this method. *(3 marks)*

Q12. Distinguish between dualism and monism. *(2 marks)*

Q13. A student writes: “Phrenology was a valid scientific method because it correctly showed that different parts of the brain have different functions.” Identify and correct the error in this statement. *(2 marks)*

Q14. *Research scenario.* A researcher surgically destroys a small area of a rat’s brain. Afterwards the rat can no longer learn its way through a maze it had previously mastered. The researcher concludes that the destroyed area is “the maze-learning centre” of the brain. (a) Explain the reasoning the researcher has used to reach this conclusion. (b) Identify two problems with this study or its conclusion. (c) Suggest one modern technique that could be used to study brain activity during maze learning without damaging the brain. *(5 marks)*

Q15. *Research scenario.* A psychologist plans two investigations: (i) measuring whether the overall brain structure of a group of adults differs after a stroke; and (ii) identifying which regions become active while healthy participants listen to music. (a) For investigation (i), state whether a structural or functional technique is needed and name a suitable technique. (b) For investigation (ii), state whether a structural or functional technique is needed and name a suitable technique. (c) Justify your choice for investigation (ii). *(4 marks)*

Q16. Explain why modern neuroimaging is regarded as a major advance over ablation, lesioning and split-brain studies. *(3 marks)*

Q17. Explain one strength and one limitation of using split-brain patients to draw conclusions about how the brain works. *(3 marks)*

Q18. The ancient Egyptians preserved the heart during mummification but removed and discarded the brain. (a) Name the hypothesis about the role of the brain that this practice reflects. (b) Explain what this hypothesis claimed. (c) Name the competing hypothesis that is accepted today. *(3 marks)*

Q19. *Extended response.* “The ways humans have tried to understand the role of the brain have changed dramatically over time.” Outline the progression of approaches from earliest to most recent, referring to at least **four** approaches, and explain how each advanced understanding and/or was limited. Conclude by stating what modern neuroimaging can do that the earlier methods could not. *(6 marks)*

Answers

Q1. (a) The view that the heart is the seat of thought, emotion and the mind. (b) The discredited, pseudoscientific idea that bumps on the skull reveal a person's personality and abilities. (c) The surgical removal or destruction of an area of brain tissue. **Q2.** (a) The mind and body/brain are two separate things; the mind is non-physical and distinct from the physical brain. (b) There is only one kind of thing; the mind arises from and is a product of the physical brain. (c) Monism, because it treats mental processes as arising from brain activity, which is why the mind can be studied by studying the brain. **Q3.** (a) The cardiocentric (heart) hypothesis and the cephalocentric (brain) hypothesis. (b) The cephalocentric / brain hypothesis. (c) It was the first attempt to identify which organ is responsible for thought and behaviour; accepting the brain made a science of the brain possible. **Q4.** (a) The corpus callosum. (b) To stop severe epileptic seizures spreading between the hemispheres. (c) That the two hemispheres are specialised for somewhat different functions (hemispheric specialisation). **Q5.** (a) The brain's physical structure/anatomy (what it looks like). (b) The brain's activity/function (what it is doing, and where). (c) CT = structural; MRI = structural; fMRI = functional; PET = functional. **Q6.** (a) By removing or damaging a region and observing what the animal can no longer do; if an ability is lost, that region is likely involved in it. (b) They produced the first real evidence linking specific regions to functions. (c) They are invasive/unethical, imprecise (may damage nearby tissue), and animal findings may not generalise to humans (any one). **Q7.** Structural imaging (CT, MRI) shows the brain's physical structure/anatomy; functional imaging (fMRI, PET) shows the brain's activity — which regions are working during a task. **Q8.** (i) ablation/lesioning; (ii) functional neuroimaging (fMRI); (iii) phrenology; (iv) the mind–body problem. Order: (iv) → (iii) → (i) → (ii). The trend is from philosophical argument, through a pseudoscientific method and then invasive experiment, to non-invasive imaging of the living brain — methods becoming more scientific, more precise and less invasive. **Q9.** Electrical stimulation: apply a small current to a region and observe the response it produces (such as a movement), which links that region to that function. Human brain-damage cases: compare what the person can no longer do with what they could do before, and infer that the damaged region was involved in the lost ability. Limitation: such cases are rare, uncontrolled and differ from person to person, so they are hard to compare or to generalise from. **Q10.** (a) Split-brain studies. (b) Ablation/lesioning. (c) The cardiocentric (heart) hypothesis / brain-versus-heart debate. (d) Structural neuroimaging (CT or MRI). **Q11.** Damage a region, then observe the ability that is lost; the lost ability is inferred to depend on that region. Limitation: the damage may be imprecise and affect nearby tissue, so the deficit may not be due to that region alone (also invasive/unethical; poor generalisation). **Q12.** Dualism holds that the mind and the physical brain are two separate things; monism holds that the mind arises from and is a product of the one physical brain. **Q13.** Error: calling phrenology a valid scientific method. Correction: the idea of localisation of function was partly right, but phrenology's method (reading skull bumps) was invalid and pseudoscientific, so it was not valid science. **Q14.** (a) The lost ability (maze learning) after the area was destroyed is taken to mean that area is responsible for maze learning. (b) e.g. the lesion may have damaged nearby tissue/connections, so the area is not necessarily solely responsible; it is invasive/unethical; results in a rat may not generalise to humans; "a centre" oversimplifies (any two). (c) A functional technique such as fMRI or PET. **Q15.** (a) Structural; CT or MRI. (b) Functional; fMRI or PET. (c) Because the aim is to see which regions are *active* during a task, which requires imaging the brain's function, not just its structure. **Q16.** Because it is non-invasive and lets us study the intact, healthy, living, working brain, whereas the earlier methods were invasive and relied on damaged or atypical (or animal) brains. **Q17.** Strength: they allowed each hemisphere to be studied separately, revealing hemispheric specialisation. Limitation: they are few and had atypical (epileptic) brains, so findings are hard to generalise. **Q18.** (a) The cardiocentric (heart) hypothesis. (b) That the heart is the seat of thought, emotion and the mind. (c) The cephalocentric (brain) hypothesis. **Q19.** Model response given in the solutions.

Fully-worked solutions

Q1. (a) The **cardiocentric hypothesis** is the view that the **heart** is the **seat of thought, emotion and the mind**. (b) **Phrenology** is the now-discredited, **pseudoscientific** idea that the **bumps and contours of a person's skull** reveal their personality, character and abilities. (c) **Ablation** is the **surgical removal or destruction** of an area of brain tissue, used to infer that region's function from the deficit that follows.

Q2. (a) **Dualism** is the view that the **mind and the body/brain are two separate things** — the mind is **non-physical** and distinct from the physical brain. (b) **Monism** is the view that there is really only **one kind of thing**: the **mind arises from, and is a product of, the physical brain**, so mental processes are explained by brain activity. (c) Modern neuroscience is broadly **monist**, because it treats the mind as arising from the workings of the brain — which is exactly what makes it sensible to study the mind by **studying the brain**.

Q3. (a) The two competing hypotheses are the **cardiocentric (heart) hypothesis** and the **cephalocentric (brain) hypothesis**. (b) The **cephalocentric / brain hypothesis** is accepted today. (c) The debate was historically important because it was the **first attempt to identify which organ is responsible** for thought, emotion and behaviour; once the **brain** was accepted as the seat of the mind, it became possible to develop a **science of the brain** and to ask *how* the brain produces behaviour.

Q4. (a) The structure that is cut is the **corpus callosum**, the band of nerve fibres connecting the two hemispheres. (b) The surgery was originally performed to **stop severe epileptic seizures spreading** from one hemisphere to the other in patients whose epilepsy could not otherwise be controlled. (c) Studying split-brain patients revealed that the two hemispheres are **specialised for somewhat different functions** — that is, **hemispheric specialisation**.

Q5. (a) **Structural** imaging shows the brain's **physical structure/anatomy** — essentially what the brain looks like. (b) **Functional** imaging shows the brain's **activity or function** — which regions are working, and where, while a person performs a task. (c) **CT = structural**, **MRI = structural**, **fMRI = functional**, **PET = functional**.

Q6. (a) A researcher **removes or damages** a specific region and then **observes what the animal can no longer do**; if a particular ability is **lost** after the damage, the researcher infers that the region was **normally involved in** that ability. (b) A strength is that these methods produced the **first real, experimental evidence** linking specific brain regions to specific functions, moving beyond mere speculation. (c) A limitation is that they are **invasive and raise ethical concerns**, and the damage is often **imprecise** (it may affect neighbouring tissue), while **animal findings may not generalise** to humans (any one).

Q7. Structural neuroimaging (such as **CT** and **MRI**) produces images of the brain's **physical structure/anatomy** — a still picture of what the brain looks like — and is used to detect injury or abnormalities. **Functional** neuroimaging (such as **fMRI** and **PET**) shows the brain's **activity**: which regions become **active** while a person performs a task. The contrast is **structure** (what the brain *looks like*) versus **function** (what the brain is *doing*).

Q8. Identifying each from its features: (i) destroying tissue and recording the deficit is **ablation and lesioning**; (ii) tracking blood oxygenation during a task is **functional neuroimaging** (an **fMRI**); (iii) reading character from skull contours is **phrenology**; (iv) arguing that the mind is non-physical and separate from the body is **dualism**, from the **mind–body problem**. In order of emergence: **(iv) mind–body problem** (philosophy) → **(iii) phrenology** (early 1800s) → **(i) ablation and lesioning** (1800s–1900s) → **(ii) neuroimaging** (modern). The trend the order shows is a move from **philosophical argument** that could not be tested, through a **pseudoscientific** method, to **invasive experiment** on damaged or animal brains, and finally to **non-invasive imaging** of the intact living brain — approaches becoming steadily **more scientific, more precise and less invasive**.

Q9. Electrical stimulation works in the opposite direction to ablation: a small **electrical current** is applied to a specific region and the **response it produces** is observed — stimulating one strip of cortex, for instance, makes a particular part of the body move. Because the region is **activated rather than destroyed**, the function it serves can be **mapped directly**. Studying **people with brain damage** from accident, stroke or illness instead uses the logic of a **natural experiment**: the damage was not created by the researcher, but comparing what the person **can no longer do** with what they could do **before** allows the researcher to **infer that the damaged region was involved in** the lost ability. A **limitation** of relying on human brain-damage cases is that they are **rare, uncontrolled and differ from person to person** — the site and extent of the damage are not chosen, matched or repeatable — so it is difficult to compare one patient with another or to generalise from them.

Q10. (a) **Split-brain studies** revealed hemispheric specialisation. (b) **Ablation/lesioning** showed that damaging a specific region removes a specific ability. (c) The **cardiocentric (heart) hypothesis**, from the **brain-versus-heart debate**, held that the heart was the seat of thought and emotion. (d) A detailed still image of a tumour in a living patient comes from **structural neuroimaging** (a **CT** or **MRI** scan).

Q11. In **lesioning**, a researcher deliberately **damages a specific region** of the brain and then **observes which ability is lost**. Because the ability was present before the damage and absent after it, the researcher **infers that the damaged region was involved in that ability**. A **limitation** is that the damage is often **imprecise** and may affect **neighbouring tissue or connections**, so the lost ability may not depend on the targeted region alone — meaning a single lesion cannot prove that one region is **solely responsible** (the method is also invasive and generalises poorly from animals to humans).

Q12. Dualism holds that the **mind and the physical brain are two separate things**, with the mind being **non-physical** and distinct from the body. **Monism** holds that there is only **one kind of thing**, so the **mind arises from and is a product of the physical brain**. The contrast is whether the mind is **separate from** the brain (dualism) or **produced by** it (monism).

Q13. The **error** is describing phrenology as a **valid scientific method**. The **correction** is that, while the broad idea of the **localisation of function** (different parts of the brain having different functions) later proved partly correct, **phrenology's own method — reading bumps on the skull — was invalid and pseudoscientific**, resting on false assumptions and unsupported by controlled evidence. So phrenology was **not** valid science, even though it hinted at a real idea.

Q14. (a) The researcher has reasoned that, because the rat **could learn the maze before** the area was destroyed but **could not afterwards**, the destroyed area must be **responsible for maze learning** — the logic of an **ablation** study, inferring a region's function from the deficit that appears after damage. (b) Two problems are: the lesion may have **damaged nearby tissue or connections**, so the area is **not necessarily solely responsible** for maze learning; calling it a single "**maze-learning centre**" **oversimplifies**, since a complex ability such as learning almost certainly involves several regions working together; the procedure is **invasive and raises ethical concerns**; and results obtained in a **rat may not generalise to humans** (any two). (c) A modern **functional** technique such as **fMRI** or **PET** could show which regions are active during maze learning **without damaging the brain**.

Q15. (a) Investigation (i) examines **brain structure** after a stroke, so it needs a **structural** technique such as a **CT** or **MRI** scan. (b) Investigation (ii) examines **which regions become active** while listening to music, so it needs a **functional** technique such as **fMRI** or **PET**. (c) Investigation (ii) requires a functional technique because its aim is to see **where activity occurs while a task is performed** — this is a question about the brain's **function**, which structural imaging (a still picture of anatomy) **cannot** show; functional imaging tracks **activity over time**, so it can identify the regions that switch on while participants listen to music.

Q16. Modern neuroimaging is a major advance because it is **non-invasive** — it requires **no surgery and causes no damage** — so it allows researchers to study the **intact, healthy, living and working brain**. The earlier methods were far more limited: **ablation and lesioning** were **invasive**, unethical and often confined to **animal or already-damaged** brains, and **split-brain studies** relied on a **few atypical patients**. Neuroimaging removes these constraints, letting us observe the **normal brain in action** in ordinary, healthy people, which makes findings more valid and easier to generalise.

Q17. A **strength** of split-brain studies is that severing the corpus callosum let researchers test **each hemisphere separately**, which revealed **hemispheric specialisation** — something that could not be seen in an intact brain. A **limitation** is that split-brain patients are **very few** and already had **atypical brains** (severe epilepsy), and the surgery cannot be performed on healthy people for research, so it is difficult to **generalise** the findings to the wider population.

Q18. (a) The practice reflects the **cardiocentric (heart) hypothesis**. (b) This hypothesis claimed that the **heart** is the **seat of thought, emotion and the mind** — which is why the heart was preserved as the important organ while the brain, thought to be unimportant, was discarded. (c) The competing view accepted today is the **cephalocentric (brain) hypothesis**, that the **brain** is the seat of the mind.

Q19. *Model response (6 marks).* Human understanding of the brain's role has progressed from **crude, philosophical ideas** to **modern, non-invasive imaging**. The earliest question, in the **brain-versus- heart debate**, was simply *which organ* houses the mind: the **cardiocentric hypothesis** placed it in the **heart**, while the **cephalocentric hypothesis** correctly placed it in the **brain** — but this could only be **argued**, not tested. **Phrenology** (early 1800s) was an early attempt to **localise function** by reading **bumps on the skull**; it *looked* scientific but was a **pseudoscience**, resting on **false assumptions** and **anecdote** rather than controlled evidence, so it advanced the *idea* of localisation while its **method was invalid**. **Ablation and lesioning** then provided the first real **experimental evidence**: by **damaging a region and observing the deficit**, researchers could **infer its function** — though these methods were **invasive, imprecise and often limited to animals or damaged brains**. **Split-brain studies** (1960s), which cut the **corpus callosum**, revealed **hemispheric specialisation**, but drew on **very few, atypical patients**, so generalising was difficult. Finally, **modern neuroimaging — structural** (CT, MRI) and **functional** (fMRI, PET) — allows us to study the **living, healthy, working brain non-invasively**, which is exactly what earlier methods **could not** do: rather than relying on argument, pseudoscience, or damage to animal and atypical brains, we can now watch the **normal brain's structure and activity** directly and safely. *(Full marks require: at least four approaches placed in correct historical order; a contribution and/or limitation for each; and a clear final point that modern neuroimaging studies the intact, living, working brain non-invasively, unlike the earlier methods.)*

Chapter 5 Role of the brain in mental processes and behaviour — 5B The hindbrain, midbrain and forebrain (including the cerebral cortex)

Theory

The brain is not one uniform lump of tissue but a set of **specialised regions** that work together, each with its own jobs. A useful way to organise them is by **position and complexity**. The brain divides into three broad regions — the **hindbrain**, the **midbrain** and the **forebrain** — which run roughly from the **base** (where the spinal cord enters) **upward and outward**, and from the most **basic, life-sustaining** functions to the most **complex, higher-order** mental processes. The hindbrain and midbrain keep the body alive and set our general level of **arousal**; the forebrain, and especially its outer **cerebral cortex**, carries out the sophisticated thinking, perceiving and deciding that we usually mean by "the mind". This subtopic describes each region, the main structures inside it, and what each one does. (How researchers *discovered* these roles belongs to the previous subtopic; how the brain *recovers* after damage belongs to the next chapter.)

The hindbrain. The hindbrain sits at the **base** of the brain, where the brain joins the spinal cord. It looks after **basic survival functions** and the **coordination of movement**. It contains three key structures: the cerebellum, the medulla and the pons.

- The **cerebellum** ("little brain") is the wrinkled structure tucked under the **rear** of the brain. It **coordinates fine, voluntary movement** and maintains **balance and posture**, and it stores the procedural "**muscle memory**" of well-practised motor skills (such as riding a bike or a tennis serve) so that they become **smooth and automatic**. Importantly, the cerebellum does not *initiate* movement — that is the job of the motor cortex — it **coordinates and fine-tunes** it. Damage to the cerebellum therefore leaves movement **clumsy, jerky and poorly coordinated**, with a loss of balance.
- The **medulla** (medulla oblongata) is at the **very base**, continuous with the spinal cord. It regulates the **vital, automatic (autonomic) functions** that keep us alive without our conscious control — **heart rate, breathing, blood pressure**, and reflexes such as **swallowing**, coughing and sneezing. Because these functions are essential to life, damage to the medulla is often **fatal**.
- The **pons** is a rounded bulge just **above the medulla**. It acts as a **bridge**, relaying signals between the spinal cord and hindbrain and the higher regions of the brain, and between the two halves of the cerebellum. It is also involved in regulating **sleep, arousal and breathing**.

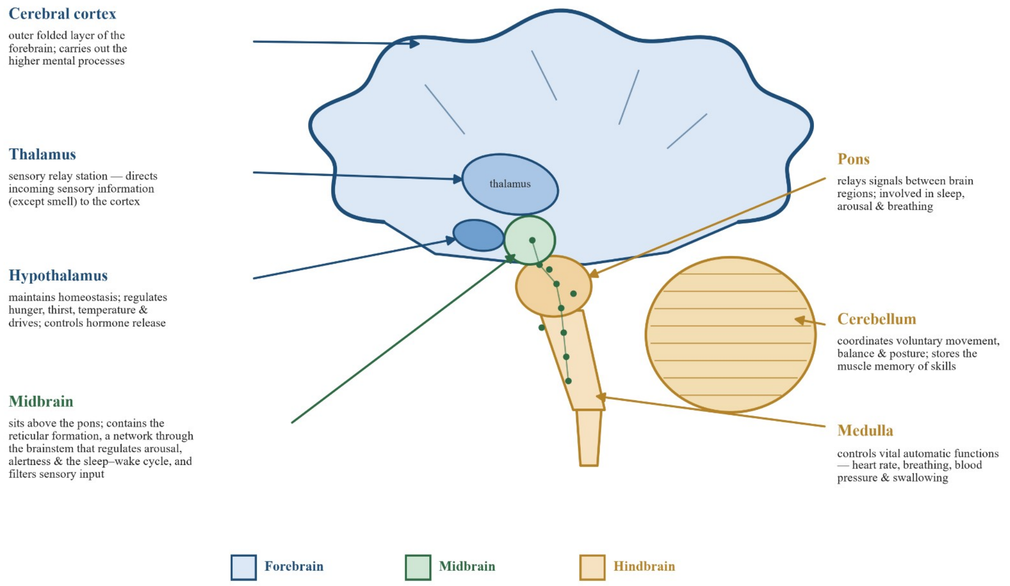
The midbrain. The midbrain is a small region **above the pons** that forms part of the **brainstem**. It helps connect the hindbrain and forebrain and relays signals between them. For our purposes its most important structure is the **reticular formation**.

- The **reticular formation** is a diffuse **network of neurons** that runs through the core of the brainstem. It regulates **physiological arousal and alertness** and the transition between sleep and wakefulness — the **sleep–wake cycle**. It also **filters incoming sensory information**: it screens out unimportant, repetitive stimuli and lets important stimuli through to the higher brain. This filtering (sometimes called the **reticular activating system**) is why you can sleep through familiar traffic noise yet wake instantly to an unfamiliar sound or to your own name. Damage to the reticular formation disrupts **arousal, consciousness and the sleep–wake cycle**.

The forebrain. The forebrain is the **largest and most complex** region, sitting at the **top and front** of the brain. It is responsible for our most sophisticated mental processes — **thinking, perceiving, planning, learning, language and decision-making** — and for the **regulation of emotions**: the **frontal lobe** of the cortex controls how strongly an emotion is expressed and acted on, while the **hypothalamus** produces the bodily changes that go with it. Its key structures are the cerebral cortex, the thalamus and the hypothalamus.

- The **cerebral cortex** is the thin, heavily **folded (wrinkled) outer layer** of the forebrain. The ridges and grooves of the folds greatly **increase its surface area**, so that far more cortex can fit inside the skull. The cortex carries out the **higher-order mental processes** — perception, reasoning, language, planning and voluntary action — and it receives, processes and responds to information from the whole body. It is divided into two hemispheres and, on each side, into **four lobes** (described below).

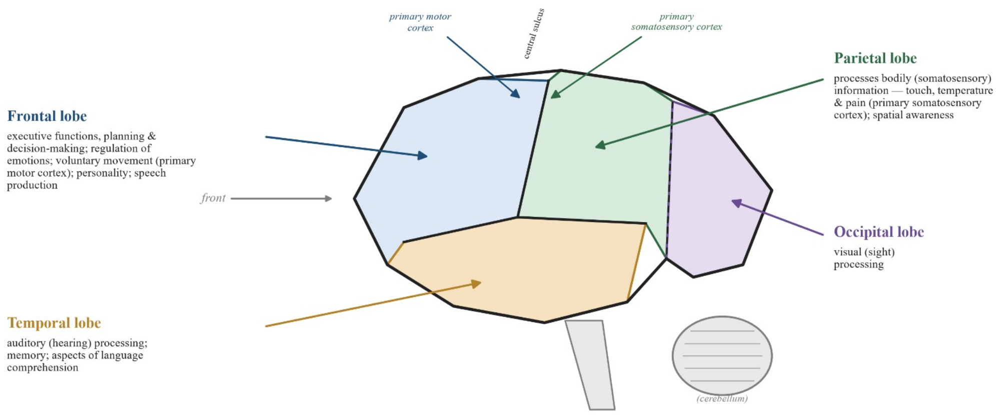
- The **thalamus** is a small structure deep in the **centre** of the forebrain. It acts as the brain's **sensory relay station**: almost all incoming sensory information — sight, sound, touch and taste — first passes **through the thalamus**, which then directs it on to the appropriate area of the cerebral cortex for processing. The one exception is **smell**, which reaches the cortex directly without passing through the thalamus.
- The **hypothalamus** is a small structure **below the thalamus**. It maintains the body's internal balance — **homeostasis** — by regulating basic drives and functions such as **hunger, thirst, body temperature** and sleep, and by **controlling the release of hormones** (through its links to the pituitary gland). Through those same controls it produces the **bodily side of an emotional response** — the racing heart, faster breathing and rush of arousal that come with fear or anger — which the frontal lobe then **regulates**. In short, it keeps the internal environment **stable** and drives behaviour that meets the body's needs.



The cerebral cortex and its four lobes. Each hemisphere of the cerebral cortex is divided into four **lobes**, each with somewhat specialised functions.

- The **frontal lobe** (at the **front**) is the largest lobe. It carries out higher-order "**executive functions**" — reasoning, **planning, decision-making**, controlling impulses — and is involved in aspects of **personality**, in the **regulation of emotions** (keeping an emotional impulse in check and expressing feelings in a way that suits the situation) and in the **production of speech**. At its rear strip lies the **primary motor cortex**, which initiates and controls **voluntary movement** of the body's muscles.
- The **parietal lobe** (at the **top, behind the frontal lobe**) processes **bodily (somatosensory) sensation**. Its front strip, the **primary somatosensory cortex**, receives and processes sensory information from the skin and body — **touch, pressure, temperature and pain**. The parietal lobe is also involved in **spatial awareness** (knowing where the body and objects are in space).
- The **temporal lobe** (at the **side**, near the temples and ears) processes **auditory** information (hearing). It is also involved in **memory** and in aspects of **language comprehension** (understanding what is said).
- The **occipital lobe** (at the **back**) processes **visual** information (sight).

Two of these areas sit either side of the **central sulcus**, the deep groove that separates the frontal and parietal lobes: the **primary motor cortex** (rear of the frontal lobe) sends **movement out**, while the **primary somatosensory cortex** (front of the parietal lobe) brings **body sensation in**.



How to analyse a question. (1) **Identify the region or structure** from its described role or location (base of the brain → hindbrain; brainstem network for arousal → midbrain/reticular formation; large upper region for complex thought → forebrain). (2) For a **damage** question, reason from the structure's **normal job** to the deficit that would follow — the deficit is the **loss of that job** (e.g. cerebellum damage → poor coordination and balance). (3) For a **locate-a-function** question, match the function to the correct lobe — **movement/planning/decision-making/controlling emotion → frontal; body sensation → parietal; hearing/memory/understanding speech → temporal; vision → occipital** — or to the correct deep structure — **relay → thalamus; homeostasis/drives/the bodily side of emotion → hypothalamus; arousal → reticular formation; coordination/balance → cerebellum; vital functions → medulla**. Keep the two cortices straight: the **motor** cortex (frontal) sends movement **out**; the **somatosensory** cortex (parietal) brings sensation **in**.

Worked examples

Example 1 — scaffolded

Sort each of the following seven structures into its brain region (hindbrain, midbrain or forebrain) and state its main role: cerebellum; thalamus; medulla; hypothalamus; reticular formation; pons; cerebral cortex.

Working	Comment
Cerebellum → hindbrain. Coordinates voluntary movement, balance and posture; stores the muscle memory of skills.	The wrinkled structure under the back of the brain; think *coordination*, not initiation.
Medulla → hindbrain. Controls vital automatic functions — heart rate, breathing, blood pressure, swallowing.	At the base, joining the spinal cord; the body's "life-support".
Pons → hindbrain. Relays signals between regions; involved in sleep, arousal and breathing.	A "bridge" just above the medulla.
Reticular formation → midbrain. Regulates arousal, alertness and the sleep–wake cycle; filters sensory input.	A network running through the brainstem; think *arousal and filtering*.
Cerebral cortex → forebrain. The folded outer layer that carries out higher mental processes.	The "thinking" surface; divides into four lobes.
Thalamus → forebrain. Sensory relay station — directs incoming sensory information (except smell) to the cortex.	Central "switchboard"; remember the smell exception.
Hypothalamus → forebrain. Maintains homeostasis; regulates hunger, thirst, temperature and drives; controls hormone release.	Small but powerful; keeps the internal environment stable.

Example 2 — scaffolded

Two patients are assessed after separate brain injuries. Patient 1 has damage to the **cerebellum**; Patient 2 has damage to the **medulla**. For each, predict the main consequence and justify it from the structure's normal role.

Working	Comment
Patient 1 (cerebellum). Normal role = coordinating voluntary movement, balance and posture. Predicted consequence: movements become **jerky, clumsy and poorly coordinated**, with a **loss of balance**, and well-learned skills are no longer smooth.	Start from the structure's job; the deficit is the **loss of that job**. Don't just name the region — link to the effect.
Patient 2 (medulla). Normal role = controlling vital automatic functions (heart rate, breathing, blood pressure). Predicted consequence: these functions become **unstable or fail** — a **life-threatening** outcome.	The medulla is life-support, so its damage is far more serious than damage to a "thinking" region.

Example 3 — unscaffolded

While watching a film, Priya **sees** the images on the screen, **hears** the dialogue, and **remembers** that she has seen the lead actor before. Name the lobe of the cerebral cortex chiefly responsible for each of these three functions and state the role of each.

Seeing the images is the work of the **occipital lobe**, which processes **visual** information. **Hearing** the dialogue is the work of the **temporal lobe**, which processes **auditory** information. **Remembering** having seen the actor also draws on the **temporal lobe**, which is involved in **memory**. ∴ vision is handled by the **occipital lobe**, while both hearing and memory are handled by the **temporal lobe**.

Example 4 — unscaffolded

After an illness, a patient can no longer regulate his **body temperature** (sweating and shivering at the wrong times), constantly feels **hungry and thirsty**, and his **sleep** is disturbed — yet his movement, vision and reasoning are all normal. Identify the forebrain structure most likely affected, and justify your answer.

The affected structure is almost certainly the **hypothalamus**. The hypothalamus maintains **homeostasis** by regulating exactly the functions that have gone wrong here — **body temperature, hunger, thirst** and sleep. The fact that the patient's **movement** (cerebellum and motor cortex), **vision** (occipital lobe) and **reasoning** (frontal lobe) are all **intact** shows the damage is **localised** and has not affected those regions — only the small structure responsible for the internal drives and homeostasis is impaired. ∴ the pattern of deficits points specifically to the **hypothalamus**.

Practice questions

Scaffolded

Q1. State which brain region — hindbrain, midbrain or forebrain — each of the following belongs to: (a) the medulla; (b) the cerebral cortex; (c) the reticular formation.

Q2. The hindbrain contains three key structures. (a) State the role of the cerebellum. (b) State the role of the medulla. (c) State the role of the pons.

Q3. The forebrain contains the cerebral cortex, the thalamus and the hypothalamus. (a) Describe the role of the thalamus. (b) Describe the role of the hypothalamus. (c) State the one type of sensory information that does NOT pass through the thalamus on its way to the cortex.

Q4. The cerebral cortex is divided into four lobes. (a) Name the lobe mainly responsible for processing vision. (b) Name the lobe mainly responsible for processing hearing. (c) Name the lobe that contains the primary motor cortex.

Q5. The midbrain contains the reticular formation. (a) State the main role of the reticular formation. (b) Name the sleep-related process that it regulates. (c) Explain how the reticular formation allows a sleeping person to keep sleeping through familiar noise yet wake to an important, unfamiliar sound.

Q6. Damage to a brain structure removes or impairs the function that structure normally performs. For each of the following, predict the main consequence: (a) damage to the cerebellum; (b) damage to the occipital lobe; (c) damage to the primary motor cortex of the frontal lobe.

Unscaffolded

Q7. Distinguish between the roles of the primary motor cortex and the primary somatosensory cortex. *(2 marks)*

Q8. For each of the following roles, name the structure responsible: (a) directs incoming sensory information (except smell) to the cortex; (b) maintains homeostasis and controls hormone release; (c) coordinates voluntary movement and balance; (d) controls heart rate and breathing. *(4 marks)*

Q9. Explain why damage to the medulla is far more likely to be life-threatening than damage to the occipital lobe. *(3 marks)*

Q10. For each of the following everyday abilities, name the lobe of the cerebral cortex chiefly responsible and state **one other** function carried out by that same lobe: (a) understanding what a friend is saying to you; (b) feeling that the bath water is too hot; (c) holding back an angry outburst and answering calmly instead. *(6 marks)*

Q11. A tennis coach notes that a beginner's serve is "jerky and uncoordinated" at first but becomes "smooth and automatic" after months of practice. Name the hindbrain structure most responsible for this improvement and explain its role. *(3 marks)*

Q12. Explain the role of the reticular formation in arousal and the sleep–wake cycle, and describe how it filters sensory information. *(4 marks)*

Q13. After a stroke deep in the forebrain, a patient's **vision, hearing and sense of touch** are all badly disrupted, even though her eyes, ears and skin receptors are healthy and the four lobes of her cerebral cortex are undamaged. Her sense of **smell** is unaffected. Name the structure most likely damaged and justify your answer. *(2 marks)*

Q14. *Research scenario.* A 38-year-old man, R.K., suffered a localised brain injury in a workplace accident. Since then his family report that he acts **impulsively**, is quick to anger and cannot **keep his emotional reactions in check**, cannot **plan ahead** or make sound **decisions**, and his **personality** has changed noticeably; however, his vision, hearing, memory and movement are all normal. (a) Identify the lobe most likely damaged. *(1 mark)* (b) Justify your answer, referring both to R.K.'s difficulties AND to the functions that remain intact. *(3 marks)* (c) State one everyday function you would expect to remain unaffected, and name the lobe responsible for it. *(2 marks)*

Q15. *Research scenario.* Four patients were each assessed after damage to a different part of the brain. Their main reported difficulties are shown below.

Patient	Main reported difficulty
W	Cannot see, although the eyes and the pathways from them are healthy.
X	Loss of balance, with jerky and poorly coordinated movements.
Y	Reduced touch and temperature sensation on one side of the body; poor spatial awareness.
Z	Heart rate and breathing have become irregular and unstable.

For each patient, identify the region or lobe most likely to be damaged. *(4 marks)*

Q16. Explain the difference between the roles of the thalamus and the hypothalamus. *(2 marks)*

Q17. A student writes: "The cerebellum is where we decide to move, and the primary motor cortex just keeps the body balanced." Identify and correct the two errors in this statement. *(2 marks)*

Q18. Explain why the cerebral cortex is folded, and state why this folding matters for its function. *(2 marks)*

Q19. Consider a person learning to drive a car. (a) Name the lobe or structure that plans the route and makes decisions. (b) Name the structure that coordinates the smooth pedal-and-steering movements. (c) Name the lobe that processes the sight of the road ahead. (d) Predict what would happen to their driving if the cerebellum were damaged. *(4 marks)*

Q20. *Extended response.* "The brain's three regions each make an essential and distinct contribution." Describe the hindbrain, midbrain and forebrain, naming at least one key structure and its role in each, and explain how their contributions differ in complexity. Then predict one consequence of damage to a named structure in each region. *(7 marks)*

Answers

Q1. (a) Hindbrain. (b) Forebrain. (c) Midbrain. **Q2.** (a) Coordinates voluntary movement, balance and posture, and stores the muscle memory of skills. (b) Controls vital automatic functions — heart rate, breathing, blood pressure and swallowing. (c) Relays signals between brain regions; involved in sleep, arousal and breathing. **Q3.** (a) The sensory relay station — it directs incoming sensory information (except smell) to the appropriate area of the cortex. (b) Maintains homeostasis; regulates hunger, thirst, body temperature and other drives, and controls hormone release. (c) Smell (olfaction). **Q4.** (a) Occipital lobe. (b) Temporal lobe. (c) Frontal lobe. **Q5.** (a) It regulates arousal and alertness and filters incoming sensory information. (b) The sleep–wake cycle. (c) It filters sensory input, screening out familiar/repetitive stimuli while letting important or unfamiliar stimuli through to wake the higher brain. **Q6.** (a) Jerky, clumsy, poorly coordinated movement and loss of balance. (b) Impaired or lost vision despite healthy eyes. (c) Impaired or lost voluntary movement (e.g. paralysis or weakness of the muscles controlled by that area). **Q7.** The primary motor cortex (frontal lobe) initiates and controls voluntary movement (output); the primary somatosensory cortex (parietal lobe) receives and processes bodily sensation — touch, temperature and pain (input). **Q8.** (a) Thalamus. (b) Hypothalamus. (c) Cerebellum. (d) Medulla. **Q9.** The medulla controls vital automatic functions (heart rate, breathing, blood pressure) that are essential to life, so its damage can be fatal; the occipital lobe controls vision, the loss of which is disabling but not itself life-threatening. **Q10.** (a) Temporal lobe — also processes hearing (or is involved in memory). (b) Parietal lobe — also spatial awareness. (c) Frontal lobe — also planning and decision-making (or speech production, personality, voluntary movement via the primary motor cortex). **Q11.** The cerebellum — it coordinates voluntary movement and stores the muscle memory of skills, so the serve becomes smooth and automatic with practice. **Q12.** It regulates arousal/alertness and the sleep–wake cycle, and filters sensory information by screening out unimportant, repetitive stimuli while letting important stimuli through to the higher brain. **Q13.** The thalamus — as the sensory relay station it directs sight, sound and touch on to the cortex, so damage to it disrupts those senses even when the receptors and the lobes are healthy; smell is spared because it reaches the cortex without passing through the thalamus. **Q14.** (a) Frontal lobe. (b) Its executive functions (planning, decision-making, impulse control), its regulation of emotion and its role in personality are impaired, while intact vision (occipital), hearing/memory (temporal) and movement show the damage is localised to the frontal lobe. (c) e.g. vision — occipital lobe (or hearing — temporal lobe). **Q15.** W = occipital lobe; X = cerebellum; Y = parietal lobe; Z = medulla. **Q16.** The thalamus relays incoming sensory information (except smell) to the cortex; the hypothalamus maintains homeostasis, regulates drives (hunger, thirst, temperature) and controls hormone release. **Q17.** Error 1: the primary motor cortex (not the cerebellum) initiates/decides voluntary movement. Error 2: the cerebellum (not the motor cortex) coordinates balance. The student has swapped the two roles. **Q18.** The folds increase the cortex's surface area so that much more cortex fits inside the skull, giving greater capacity for higher-order processing. **Q19.** (a) Frontal lobe. (b) Cerebellum. (c) Occipital lobe. (d) Movements would become jerky and poorly coordinated with poor balance, so smooth steering and pedal control would be lost. **Q20.** Model response given in the solutions.

Fully-worked solutions

Q1. (a) The **medulla** is part of the **hindbrain**. (b) The **cerebral cortex** is part of the **forebrain**. (c) The **reticular formation** is part of the **midbrain**.

Q2. (a) The **cerebellum coordinates fine, voluntary movement** and maintains **balance and posture**, and it stores the **muscle memory** of well-practised skills so they become smooth and automatic. (b) The **medulla** controls **vital, automatic (autonomic) functions — heart rate, breathing, blood pressure** and reflexes such as **swallowing** — which keep the body alive without conscious effort. (c) The **pons** acts as a **bridge**, **relaying signals** between brain regions, and is involved in **sleep, arousal and breathing**.

Q3. (a) The **thalamus** is the brain's **sensory relay station**: almost all incoming sensory information passes through it first, and it **directs each type on to the appropriate area of the cerebral cortex** for processing. (b) The **hypothalamus** maintains **homeostasis** — the body's internal balance — by regulating drives and functions such as **hunger, thirst and body temperature**, and by **controlling the release of hormones**. (c) **Smell (olfaction)** is the exception: it reaches the cortex **directly**, without passing through the thalamus.

Q4. (a) The **occipital lobe** processes vision. (b) The **temporal lobe** processes hearing. (c) The **frontal lobe** contains the **primary motor cortex**.

Q5. (a) The **reticular formation** regulates **arousal and alertness** and helps control the transition between sleep and wakefulness; it also **filters incoming sensory information**. (b) It regulates the **sleep–wake cycle**. (c) It **filters sensory input** reaching the higher brain: familiar, repetitive stimuli (such as ordinary traffic noise) are **screened out** so they do not disturb sleep, whereas an **important or unfamiliar** stimulus is **allowed through**, increasing arousal and waking the person. This is why a sleeper can ignore constant background noise yet wake to their own name.

Q6. (a) Damage to the **cerebellum** would leave movement **jerky, clumsy and poorly coordinated**, with a **loss of balance and posture** (the loss of the coordination it normally provides). (b) Damage to the **occipital lobe** would cause **impaired or lost vision**, even though the eyes themselves are healthy, because the occipital lobe is where visual information is processed. (c) Damage to the **primary motor cortex** would cause **impaired or lost voluntary movement** — weakness or paralysis of the muscles that area normally controls.

Q7. The **primary motor cortex**, at the rear of the **frontal lobe**, **initiates and controls voluntary movement** — it is an **output** area that sends commands to the body's muscles. The **primary somatosensory cortex**, at the front of the **parietal lobe**, **receives and processes bodily sensation** such as **touch, pressure, temperature and pain** — it is an **input** area. In short: the motor cortex sends movement **out**, the somatosensory cortex brings sensation **in**.

Q8. (a) The **thalamus** directs incoming sensory information (except smell) to the cortex. (b) The **hypothalamus** maintains homeostasis and controls hormone release. (c) The **cerebellum** coordinates voluntary movement and balance. (d) The **medulla** controls heart rate and breathing.

Q9. The **medulla** regulates the body's **vital automatic functions** — **heart rate, breathing and blood pressure** — which are **essential to staying alive**; if the medulla is damaged, these functions can **fail**, so the damage is often **fatal**. The **occipital lobe**, by contrast, processes **vision**; damage to it causes a **serious but survivable** loss of sight. Because one region controls **life-support functions** and the other controls a **single sense**, damage to the medulla is far more likely to be life-threatening.

Q10. (a) Understanding what is said to you is **language comprehension**, which belongs to the **temporal lobe**; that lobe also processes **auditory (hearing) information** and is involved in **memory**. (b) Feeling that the water is too hot is **bodily (somatosensory) sensation** — temperature — which is received by the **primary somatosensory cortex** at the front of the **parietal lobe**; the parietal lobe is also responsible for **spatial awareness**. (c) Holding an angry impulse in check is the **regulation of emotion**, one of the executive jobs of the **frontal lobe**; the frontal lobe also carries out **planning and decision-making** (and contains the primary motor cortex, which initiates voluntary movement).

Q11. The structure is the **cerebellum**. The cerebellum **coordinates voluntary movement, balance and posture**, and it **stores the "muscle memory"** of well-practised motor skills. When the beginner first serves, the movement is **not yet coordinated** and looks jerky; with **repeated practice**, the cerebellum builds and refines the motor pattern, so the serve becomes **smooth, automatic and well-coordinated**. The improvement therefore reflects the cerebellum's role in coordinating and automating learned movement.

Q12. The **reticular formation** is a network of neurons running through the brainstem that regulates the body's overall level of **arousal and alertness** and controls the **sleep–wake cycle** — helping to shift the brain between sleeping and waking states. It also acts as a **filter** on the stream of incoming sensory information: it **screens out** unimportant, familiar or repetitive stimuli so they do not reach conscious awareness, while **letting important or novel stimuli through** to the higher brain. This filtering keeps us from being overwhelmed by irrelevant input and allows a genuinely significant stimulus (such as one's name) to raise arousal and capture attention.

Q13. The structure most likely damaged is the **thalamus**. Almost all incoming sensory information must pass **through the thalamus**, which then **directs each type on to the appropriate area of the cerebral cortex**; because the receptors (eyes, ears, skin) and the cortical lobes are both **healthy**, the fault must lie in the **relay between them**. The intact sense of **smell** confirms this: smell is the one sense that reaches the cortex **directly, without passing through the thalamus**, so it is exactly the sense that thalamic damage would spare.

Q14. (a) The **frontal lobe**. (b) R.K.'s difficulties — acting **impulsively**, being unable to **keep his emotional reactions in check**, being unable to **plan** or **make decisions**, and a change in **personality** — are exactly the **executive functions**, the **regulation of emotion** and the personality aspects that the **frontal lobe** governs, so damage there would produce this pattern. At the same time, his **vision** (occipital lobe), **hearing and memory** (temporal lobe) and **movement** remain **normal**, showing that those regions are **undamaged** and that the injury is **localised to the frontal lobe** (specifically its executive areas, sparing the primary motor cortex, since movement is intact). (c) For example,

vision would remain unaffected — it is the responsibility of the **occipital lobe** (equally acceptable: hearing or memory, the **temporal lobe**).

Q15. Reasoning from each deficit to the region that normally performs the lost function: Patient **W** cannot see despite healthy eyes → the **occipital lobe** (visual processing). Patient **X** has poor balance and jerky, uncoordinated movement → the **cerebellum** (coordination and balance). Patient **Y** has reduced touch and temperature sensation and poor spatial awareness → the **parietal lobe** (somatosensory processing and spatial awareness). Patient **Z** has an unstable heart rate and breathing → the **medulla** (vital automatic functions).

Q16. The two structures have very different jobs despite their similar names. The **thalamus** is a **sensory relay station**: it **receives incoming sensory information** (all senses except smell) and **directs it on to the correct area of the cerebral cortex**. The **hypothalamus** maintains **homeostasis** — it **regulates internal drives** such as hunger, thirst and body temperature and **controls the release of hormones**. So the thalamus **routes sensory information to the cortex**, whereas the hypothalamus **regulates the body's internal state and drives**.

Q17. Error 1: the claim that the **cerebellum** is "where we decide to move". Deciding on and **initiating voluntary movement** is the role of the **primary motor cortex** (in the frontal lobe), not the cerebellum. **Error 2:** the claim that the primary motor cortex "keeps the body balanced". **Balance and coordination** are the role of the **cerebellum**, not the motor cortex. The student has **swapped the two roles**: the motor cortex **initiates** movement, and the cerebellum **coordinates and balances** it.

Q18. The cerebral cortex is **folded** (with ridges and grooves) so that its **surface area is greatly increased**, allowing **much more cortex to fit inside the limited space of the skull**. This matters because the cortex is where the brain's **higher-order processing** happens, so a larger cortical surface provides **greater capacity** for complex mental processes such as perception, reasoning and language.

Q19. (a) The **frontal lobe** plans the route and makes decisions (executive functions). (b) The **cerebellum** coordinates the smooth pedal-and-steering movements and keeps them balanced and controlled. (c) The **occipital lobe** processes the sight of the road ahead. (d) If the **cerebellum** were damaged, the driver's movements would become **jerky, clumsy and poorly coordinated**, with **impaired balance and control**, so they could no longer steer smoothly or operate the pedals in a coordinated way — making safe driving very difficult.

Q20. *Model response (7 marks).* The brain's three regions contribute in an ascending order of **complexity**, from basic survival to sophisticated thought. The **hindbrain**, at the base of the brain, looks after **basic survival and movement**: its **medulla** controls **vital automatic functions** such as heart rate and breathing, and its **cerebellum** coordinates **voluntary movement, balance and posture**. The **midbrain**, just above it, contains the **reticular formation**, a network that regulates **arousal, alertness and the sleep–wake cycle** and **filters incoming sensory information** — it sets the brain's general state of wakefulness. The **forebrain** is the **largest and most complex** region and carries out our **highest mental processes**: its **cerebral cortex** performs higher-order thinking, perception and voluntary action; its **thalamus** relays sensory information to the cortex; and its **hypothalamus** maintains **homeostasis**. The contributions clearly differ in complexity — the hindbrain keeps the body **alive**, the midbrain sets the level of **arousal and attention**, and the forebrain performs the **complex, conscious mental processes** that we think of as the mind. Predicting the effect of damage in each: damage to the **medulla** (hindbrain) would disrupt heart rate and breathing and could be **fatal**; damage to the **reticular formation** (midbrain) would disturb **arousal and the sleep–wake cycle**; and damage to the **frontal lobe** of the cortex (forebrain) would impair **planning, decision-making, the regulation of emotion and personality**. *(Full marks (7) require: a named key structure and its role in each of the three regions — 3 marks; a clear statement of how their contributions differ in complexity — 1 mark; and a predicted consequence of damage to a named structure in each region — 3 marks.)*