

Brain Matters: Brain Anatomy

Lesson Overview

Students share what they already know about brain structure and function, and then, guided by descriptions of brain regions explore the *G2C Online 3-D Brain* to learn more about the anatomy and physiology of the brain.

Description of Activity

In Part 1 of *Brain Matters: Brain Anatomy*, students read a passage about how scientists have learned about brain structure and function, and then write what they already know about the brain. They share out, and then visit the *G2C Brain* to learn more about brain structure and function. Clues guide students to key information about brain structure and function. Finally, they recognize any preconceptions that they held that were not correct and make corrections.

In Part 2 of *Brain Matters: Brain Diagram*, students fill in the names of structures and functions on an unlabeled brain map. They check accuracy by comparing their work with other students.

Parts 1 and 2 can be completed independently of each other.

Goals and Objectives

Students will be able to:

- identify the functions of structures of the brain
- associate the brain structures with their functions
- describe how scientists have been able to associate structure and function of brain regions
- locate various structures of the brain using the 3-D model

Assumptions of Prior Knowledge

Students should be familiar with basic information about structure and function of the nervous system and with the basic image of the brain.

Common Misconceptions

Students often think:

- The brain is composed of only three parts: the cerebrum, the cerebellum, and the medulla.
- Each of the brain parts performs a discrete function.

- The brain is composed of afferent (sensory) neurons, efferent (motor) neurons, and interneurons (associative neurons).
- More intelligent people have larger brains than less intelligent people.
- People only use 10% of their brains.

Implementing the Lesson

Time allotment:

Part 1: 1 x 50-minute class

Part 2: 1 x 50-minute class

Before class

Become familiar with *Genes to Cognition Online*. If necessary, reserve computers for the lesson.

Photocopy student worksheets:

Part 1: *Brain Matters: Brain Anatomy*

Part 2: *Brain Matters: Brain Diagram*

During class

Use student worksheet, Part 1: *Brain Matters: Brain Anatomy*, to introduce brain anatomy and physiology. Ask students, “How do you think scientists learned that parts of the brain are associated with specific functions before they had the technology developed in the last 50 years?” Following a brief discussion, have students read the introduction, and then write what they already know about the brain. You may choose to go over responses with the class, or not.

You may want to demonstrate how to navigate the *3-D Brain* area of *G2C Online*. Start with the text area on the left. Show students the drop-down text menu of parts of the brain, and what is included for the whole brain and each brain region: overview, case study, associated functions, associated cognitive disorders, associated with damage, research reviews, links, and *BrainInfo*. Show students that brain structures are highlighted on the *G2C Brain* as each structure is studied, and that the parts are labeled when “View Labels” is clicked. Demonstrate how to rotate the *G2C Brain* revealing the mid-sagittal section, as well as the anterior (front), superior (top), posterior (back), and inferior (bottom) surfaces.

Tell students to complete the worksheet, finding the brain structures associated with the “clues.”

Near the end of the session, go over answers, and check that students delete/cross out any of their preconceptions that are not correct.

Use Part 2: *Brain Matters: Brain Diagram* to enable students to label brain regions with names of structures and their functions, and answer related questions. Have pairs of students check their accuracy by comparing their work with other students.

Recommendations for evaluation:

Collect student handouts and assess the responses.

Quiz students:

- by choosing segments of the “case study” sections of the *G2C Brain* text for various brain parts, and asking students what part is associated with each description.
- by choosing parts of the brain for students to label with names of the parts and/or functions of the parts on a blank outline diagram of the brain.

Suggestions for extended learning

Have groups of students create a “brain game” that involves making a game board, playing pieces, and question cards. After students have finished making their games, have them exchange games and play each other’s games.

View teaching modules from *The Mind* (videostreamed at www.learner.org), including Chapter 10, “Life Without Memory: The Case of Clive Wearing” and Chapter 11 “Clive Wearing, Part 2: Living Without Memory”. We also recommend *The Brain* (also videostreamed at www.learner.org) series, especially Chapter 18 “Living With Amnesia: The Hippocampus and Memory” and Chapter 25 “Frontal Lobes and Behavior: The Story of Phineas Gage.” Have students describe how viewing any of these modules helps them understand brain function better.

Have students explore the *Neuroimaging* area of *G2C Online* and other websites. Ask them to differentiate among the various types of imaging, and explain how their use has increased our knowledge of brain anatomy and physiology. Include any or all of the following:

- CAT
- EEG
- fMRI
- MEG
- MRI
- PET
- SPECT
- SQUID

Glossary

Amygdala: The amygdala is a complex brain structure that is particularly involved in processing emotions and fear-learning.

Anterior: In mammals, anterior or ventral refers to the front or belly surface. In the human brain, it is toward the front or prefrontal surface.

Aphasia: Aphasia is difficulty speaking or comprehending language and is associated with brain damage. The two most common aphasias are Broca's and Wernicke's.

Basal ganglia: The basal ganglia comprise a group of structures that regulate the initiation of movements, balance, eye movements, and posture. They are strongly connected to other motor areas in the brain and link the thalamus with the motor cortex. The basal ganglia are also involved in cognitive and emotional behaviors and play an important role in reward and reinforcement, addictive behaviors and habit formation.

Brain: The brain is the major part of the central nervous system and is contained in the cranium. It consists of the forebrain, midbrain, and hindbrain, which are further divided into a large number of substructures.

Brainstem: The brainstem consists of a group of structures that lie deep within the brain, including the pons, medulla oblongata, and midbrain. It plays an important role in maintaining homeostasis by controlling autonomic functions such as breathing, heart rate, and blood pressure. While the brainstem can organize motor movements such as reflexes, it coordinates with the motor cortex and associated areas to contribute to fine movements of limbs and the face.

Broca's area: Broca's area is a functionally defined structure in the left frontal lobe of about 97% of humans (including a large majority of left-handers). Broca's area is involved mainly in the production of spoken and written language and also in language processing and comprehension.

Caudate nucleus: The caudate nucleus is a nucleus in the basal ganglia that plays a role in learning and memory and movement.

Cingulate gyrus: The cingulate gyrus is an important part of the limbic system that helps regulate emotions and pain. It is thought to directly drive the body's conscious response to unpleasant experiences. In addition, it is involved in fear and the prediction (and avoidance) of negative consequences.

Computed axial tomography (CAT): Computed axial tomography (CAT, formerly computed tomography (CT)) is a neuroimaging technique that uses x-ray to produce 3-D images of the brain.

Dentate gyrus: The hippocampal formation has three regions, which are highly interconnected: the dentate gyrus, CA3, and CA1. It is one of the very few regions in the brain where adult neurogenesis (development of new neurons) has been confirmed. The dentate gyrus may play an important role in translating complex neural codes from cortical areas into simpler code that can be used by the hippocampus to form new memories.

Diencephalon: The diencephalon is the part of the brain that includes the thalamus, hypothalamus, and epithalamus. These structures are heavily involved in regulating the autonomic nervous system.

EEG: Electroencephalography (EEG) is a neuroimaging procedure that uses electrodes placed on the scalp to record electrical signals, an electroencephalogram, from the brain.

Entorhinal cortex: The entorhinal cortex is a brain region that plays a major role in memory formation. Two major connections from the entorhinal area (lateral and medial) provide the main input to the hippocampus and are important to pre-processing memorable information. The lateral input stream is thought to convey spatial information to the hippocampus, while the medial input stream conveys nonspatial information.

Fissure: A fissure is a groove in the brain's surface.

fMRI: Functional magnetic resonance imaging (fMRI) is a neuroimaging technique that takes snapshots of the brain to produce 3-D images of brain activity. Unlike standard MRI procedure, fMRI allows researchers to examine specific structures as they respond to various stimuli.

Forebrain: The forebrain (prosencephalon) is the anterior or frontal part of the brain. It is divided into the telencephalon (cerebrum, hippocampus and olfactory lobes) and the diencephalon (thalamus, hypothalamus, and epithalamus).

Frontal lobe: The frontal lobes are part of the cerebral cortex and are the largest of the brain's structures. They are the main site of so-called 'higher' cognitive functions. The frontal lobes contain a number of important substructures, including the prefrontal cortex, orbitofrontal cortex, motor and premotor cortices, and Broca's area. These substructures are involved in attention and thought, voluntary movement, decision-making, and language.

Gyrus: A gyrus (plural gyri) is a ridge on the surface of the brain.

Hemisphere: The brain is divided into the right and left hemispheres, which are its two halves either side of the midline.

Hindbrain: The hindbrain, or rhombencephalon, is the posterior part of the brain that gives rise to the cerebellum and brainstem.

Hippocampus: The hippocampus is the structure in the brain most closely aligned to memory formation. It is important as an early storage place for long-term memory, and it is involved in the transition of long-term memory to even more enduring permanent memory. The hippocampus also plays an important role in spatial navigation.

Hypothalamus: The hypothalamus is a brain region that regulates a wide range of behavioral and physiological activities. It controls many autonomic functions such as hunger, thirst, body temperature, and sexual activity. To do this, the hypothalamus integrates information from many different parts of the brain and is responsive to a variety of stimuli including light (it regulates circadian rhythms), odors (e.g. pheromones), stress, and arousal (hypothalamic neurons release oxytocin directly into the bloodstream).

Inferior: In mammals, inferior refers to the bottom or lower region or surface.

Lateral: In mammals, lateral refers to the region furthest from the long axis. In the human

brain, it is toward the side or temporal surface.

Limbic system: The limbic system is a group of brain structures including the amygdala, hippocampus, and hypothalamus that are involved in processing and regulating emotions, memory, sexual arousal, and response to stress.

Magnetic Resonance Imaging (MRI): Magnetic Resonance Imaging (MRI) is an imaging technique that takes snapshots of the brain to produce 3-D images of the brain. Unlike functional MRI (fMRI), MRI does NOT allow researchers to dynamically examine structures in response to stimulation.

Medial: In mammals, medial refers to the region closest to the long axis. In the human brain, the medial surface is exposed when a plane cuts through the corpus callosum connecting the left and right cerebral hemispheres.

Medulla oblongata: The medulla oblongata is a part of the brainstem that controls autonomic functions including blood pressure, respiration, and swallowing.

MEG: Magnetoencephalography (MEG) is a neuroimaging technique that takes dynamic 3-D images of the brain, magnetoencephalograms. MEG records the magnetic signals from the brain that result from underlying neural activity.

Mesencephalon: The mesencephalon is the middle portion of the brain (the midbrain) and is part of the brainstem. It is involved in movement, perception, and reward-processing.

Metencephalon: The metencephalon is the part of the hindbrain (rhombencephalon) that gives rise to the pons and cerebellum. It is involved in regulated movement and respiration.

Midbrain: The midbrain is the middle portion of the brain (the mesencephalon) and is part of the brainstem. It is involved in movement, perception, and reward-processing.

Midsagittal section: In a midsagittal section the plane passes through the midline, dividing the the organism in half. In the case of the brain, the midsagittal section divides the left and right hemispheres of the brain. The midsagittal section is the most frequently depicted view

MRI: Magnetic Resonance Imaging (MRI) is an imaging technique that takes snapshots of the brain to produce 3-D images of the brain. Unlike functional MRI (fMRI), MRI does NOT allow researchers to dynamically examine structures in response to stimulation.

Myelencephalon: The myelencephalon is part of the hindbrain (rhombencephalon) and contains the medulla oblongata.

Neocortex: The neocortex is the outside surface of the cerebral cortex. Made up of 6 layers (Layers I through VI), the neocortex consists of pyramidal neurons (mostly excitatory) and interneurons (mostly inhibitory).

Occipital lobe: The occipital lobes are the primary visual area of the brain. They receive projections from the retina (via the thalamus), where different groups of neurons separately encode different visual information such as color, orientation, and motion.

Olfactory bulb: The olfactory bulb is a region in the brain that sits above the nasal passage. It transmits smell information to the brain and is one of the few regions known to undergo adult

neurogenesis.

Parahippocampal gyrus: The parahippocampal gyrus is a brain structure that surrounds the hippocampus. It is important to memory formation and retrieval and plays a particularly important role in both spatial memory and episodic (declarative) memory. The parahippocampal gyrus is also involved in face recognition.

Parietal lobes: The parietal lobes are regions in the brain that play an important role in integrating information from different senses to build a coherent picture of the world. They integrate information from the ventral visual pathways (which process what things are) and dorsal visual pathways (which process where things are). This allows us to coordinate our movements in response to the objects in our environment. They contain a number of distinct reference maps of the body, near space, and distant space, which are constantly updated as we move and interact with the world. The parietal cortex processes attentional awareness of the environment, is involved in manipulating objects, and representing numbers.

Perirhinal cortex: The perirhinal cortex is a part of the brain that plays an important role in object recognition and in storing information (memories) about objects. It is highly connected to other brain structures, including the amygdala, basal ganglia, and frontal cortex. These extensive connections allow the perirhinal cortex to specialize in associating objects with sensory information and potential consequences (e.g. reward).

PET: Positron emission tomography (PET) is an imaging technique that can take dynamic 3-D images of the brain as it responds to particular stimuli. PET works by detecting the path of a radioactive tracer isotope, which has been injected into the blood.

Pituitary gland: The pituitary gland is a small bulb at the base of the brain that releases hormones such as corticotropins (ACTH) and endorphins. It is part of the endocrine system.

Pons: The pons is the region in the brain most closely associated with breathing and with circuits that generate respiratory rhythms. It forms a bridge between the cerebrum and cerebellum and is involved in motor control, posture, and balance. It is also involved in sensory analysis and is the site at which auditory information enters the brain.

Posterior: In mammals, posterior refers to the dorsal or back surface. In the human brain, it is toward the occipital surface.

Prefrontal cortex: The prefrontal cortex is a region in the brain associated with 'higher' brain functions. It is a critical part of the executive system, which refers to planning, reasoning, and judgment. It is also involved in personality and emotion by contributing to the assessment and control of appropriate social behaviors.

Premotor cortex: The premotor cortex is a narrow region of the brain between the prefrontal and motor cortices. It is involved in preparing and executing limb movements and uses information from other cortical regions to select appropriate movements. The premotor cortex is also important for learning (imitation) and social cognition (empathy) – mirror neurons in the premotor cortex area of the macaque brain fire when the animal observes an action in others.

Primary motor cortex: The primary motor cortex (also known as M1) is critical to initiating motor movements. Areas of the motor cortex correspond precisely to specific body parts.

Primary sensory cortex: The primary sensory cortex (also known as postcentral gyrus or

somatosensory cortex) is a region in the brain that receives tactile information from the body. Sensory information is carried to the brain by neural pathways to the spinal cord, brainstem, and thalamus, which project to the primary sensory cortex (which in turns has numerous connections with other brain areas). It integrates sensory information (e.g. touch, pressure, temperature, and pain, spatial attention), producing a 'homunculus map', similar to that of the primary motor cortex. Sensory information about the feet, for example, map to the medial primary sensory cortex .

Prosencephalon: The prosencephalon (forebrain) is the anterior or frontal part of the brain. It is divided into the telencephalon (cerebrum, hippocampus and olfactory lobes) and the diencephalon (thalamus, hypothalamus, and epithalamus).

Putamen: The putamen is a region in the brain that is part of the basal ganglia. It is associated with learning and regulating movement.

Reticular formation: The reticular formation is a part of the brainstem that stretches between the spinal cord and thalamus. It consists of a complex group of brain cells and fibers that participate in arousal, pain modulation, respiration, and sleep.

Rhombencephalon: The rhombencephalon, or hindbrain, is the posterior part of the brain that gives rise to the cerebellum and brainstem.

Somatosensory cortex: The somatosensory cortex (postcentral gyrus) is a region in the brain that receives tactile information from the body. Sensory information is carried to the brain by neural pathways to the spinal cord, brainstem, and thalamus, which project to the somatosensory cortex (which in turns has numerous connections with other brain areas). It integrates sensory information (e.g. touch, pressure, temperature, and pain, spatial attention), producing a 'homunculus map', similar to that of the primary motor cortex. Sensory information about the feet, for example, map to the medial somatosensory cortex.

SPECT: Single-photon emission computerized tomography (SPECT) is an imaging technique that can produce 3-D images of the brain by tracing the route of a radioactive tracer in the blood.

SQUID: Superconducting quantum interfering device (SQUID) are used in imaging to detect and translate the tiny magnetic fields into a signal that can be recorded with computers. They are then able to be further processed into pictures of brain activity.

Sulci: Sulci is the plural of sulcus, a groove or depression in the brain.

Superior: In mammals, superior refers to the upper or top region or surface.

Superior colliculus: The superior colliculus is a structure in the midbrain most commonly associated with eye movements.

Superior temporal gyrus: The superior temporal gyrus is a part of the brain's temporal lobe. It contains the primary auditory cortex, which is responsible for processing sounds.

Telencephalon: The telencephalon is the most rostral part of the brain that gives rise to the cerebrum, hippocampus and olfactory lobes.

Temporal lobe: The temporal lobe is a region of the brain containing a large number of

substructures, whose functions include perception, face recognition, object recognition, memory acquisition, understanding language, and emotional reactions.

Thalamus: The thalamus is a region in the brain heavily involved in relaying information between the cortex and brain stem and within different cortical structures. Because of this role in corticocortical interactions, the thalamus contributes to many processes in the brain including perception, attention, timing, and movement. It plays a central role in alertness and awareness.

Ventral stream: The ventral stream links the visual cortex with the temporal lobe and is involved in determining what objects are. It differs from the dorsal stream, which determines where objects are located.

Ventricles: The cerebral ventricles are interconnected fluid-filled spaces that are extensions of the spinal cord. They have no unique function but provide cushioning against brain damage and are useful landmarks for determining the location of other brain structures.

Wernicke's area: Wernicke's area is a functionally defined brain structure that is involved in language comprehension. In about 97% of humans (including a large majority of left-handers) major language functions are contained in the left hemisphere of the brain and for most people, Wernicke's area is lateralized to the left side.

Resources

Videos/DVDs

Discovering Psychology (2001), produced by WGBH Boston with the American Psychological Association. Can be purchased or videostreamed at www.learner.org

The Brain: Teaching Modules (1997), produced by Colorado State University. Can be purchased or videostreamed at www.learner.org

The Mind: Teaching Modules (1999), produced by Colorado State University. Can be purchased or videostreamed at www.learner.org

The Secret Life of the Brain (2002), produced by PBS WNET/Thirteen. Can be purchased or videostreamed at www.pbs.org

Book(s)

Restak, R. (2001). *The Secret Life of the Brain*. Washington, DC: The Dana Press and the Joseph Henry Press.

Wang, S., Aamodt, S. (2008). *Welcome to Your Brain: Why You Lose Your Car Keys but Never Forget How to Drive and Other Puzzles of Everyday Life*. New York: Bloomsbury, USA.

American Psychology Association National Standards for High School Psychology

Standard Area IA: Introduction and Research Methods

Content Standard IA-3: Research strategies used by psychologists to explore behavior and mental processes

Standard Area IIA: Biological Bases of Behavior

Content Standard IIA-3: Hierarchical organization of the structure and function of the brain

Students are able to (performance standards):

IIA-3.1 Identify the structure and function of the major regions of the brain.

IIA-3.2 Recognize that specific functions are centered in specific lobes of the cerebral cortex.

IIA-3.3 Describe lateralization of brain functions

Content Standard IIA-4: Technologies and clinical methods for studying the brain

Students are able to (performance standards):

IIA-4.1 Explain how research and technology have provided methods to analyze brain behavior and disease.

Standard Area VA: Psychological Disorders

Content Standard VA-1: Characteristics and origins of abnormal behavior

1.1: Distinguish the common characteristics of abnormal behavior.

1.2: Cite examples of abnormal behavior.

1.4: Describe major explanations for the origins of abnormality.

Content Standard VA-2: Methods used in exploring abnormal behavior

2.1: Identify the purpose of different research methods.

2.2: Characterize the advantages and limitations of different research methods for studying abnormal behavior.

National Science Education Standards

Content Standard A: Science as Inquiry

- Identify questions and concepts that guide scientific investigations
- Formulate and revise scientific explanations and models using logic and evidence
- Recognize and analyze alternative explanations and models

Content Standard C: Life Science

The Behavior of Organisms

- Multicellular animals have nervous systems that generate behavior. In sense organs, specialized cells detect light, sound, and specific chemicals and enable animals to monitor what is going on in the world around them. Behavioral biology has implications for humans, as it provides links to psychology, sociology, and anthropology.

Content Standard G: History and Nature of Science

Nature of scientific knowledge

- Scientific explanations must meet certain criteria. First and foremost, they must be consistent with experimental and observational evidence about nature, and must make accurate predictions, when appropriate, about systems being studied.
- Because all scientific ideas depend on experimental and observational confirmation, all scientific knowledge is, in principle, subject to change as new evidence becomes available.

Historical Perspectives

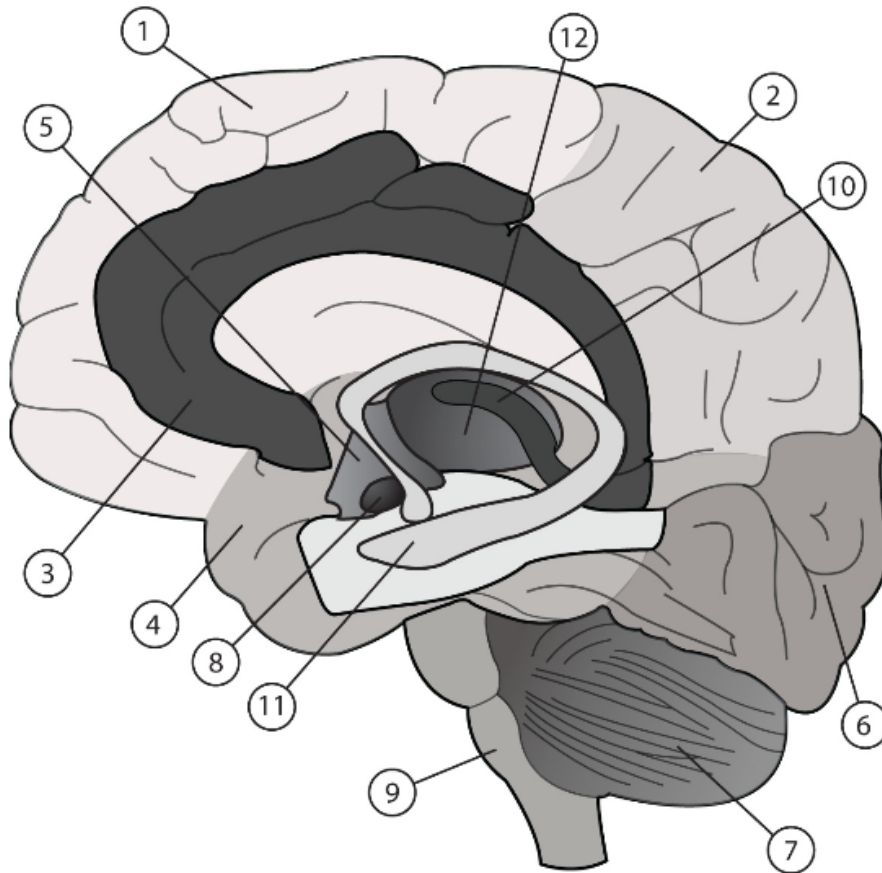
- Usually, changes in science occur as small modifications in extant knowledge. The daily work of science and engineering results in incremental advances in our understanding of the world and our ability to meet human needs and aspirations. Much can be learned about the internal workings of science and the nature of science from study of individual scientists, their daily work, and their efforts to advance scientific knowledge in their area of study.

Answer Key

Part 1: *Brain Matters: Brain Anatomy*

Depending on the pieces of information a student gathers, answers will vary. The G2C Online information found in the document under “Test Items” represents some possible answers.

Part 2: *Brain Matters: Brain Matters: Brain Diagram*



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|--------------------|-------------------|-----------------|
| 1. Frontal Lobe | 6. Occipital Lobe | 11. Hippocampus |
| 2. Parietal Lobe | 7. Cerebellum | 12. Thalamus |
| 3. Cingulate Gyrus | 8. Amygdala | |
| 4. Temporal Lobe | 9. Brainstem | |
| 5. Hypothalamus | 10. Epithalamus | |