The human brain is the central organ of the nervous system and is composed of billions of neurons and supportive glial cells. The brain consists of the cerebrum, cerebellum, and brainstem, which are connected by various tracts and the corpus callosum. The cerebrum is the largest part of the brain and is divided into the hemispheres, connected by the corpus callosum. The thalamus, hypothalamus, and basal ganglia are located in the brainstem. The brain receives and processes sensory information and is responsible for cognitive processes such as language, memory, and reasoning. The brainstem is connected to the spinal cord and controls voluntary motor functions. The cerebellum is involved in motor control and coordination. The brain is contained within the skull bones and is protected by the meninges, cerebrospinal fluid, and the blood-brain barrier. Human brain - Wikipedia https://en.wikipedia.org/wiki/Human_brain
of other cells. Brain activity is made possible by the interconnections of neurons and their release of neurotransmitters in response to nerve impulses. Neurons connect to form neural pathways, neural circuits, and elaborate network systems. The whole circuitry is driven by the process of neurotransmission.

The brain is protected by the skull, suspended in cerebrospinal fluid, and isolated from the bloodstream by the blood–brain barrier. However, the brain is still susceptible to damage, disease, and infection. Damage can be caused by trauma, or a loss of blood supply known as a stroke. The brain is susceptible to degenerative disorders, such as Parkinson's disease, dementia including Alzheimer's disease, and multiple sclerosis. Psychiatric conditions, including schizophrenia and clinical depression, are thought to be associated with brain dysfunctions. The brain can also be the site of tumours, both benign and malignant; these mostly originate from other sites in the body.

The study of the anatomy of the brain is neuroanatomy, while the study of its function is neuroscience. A number of techniques are used to study the brain. Specimens from other animals, which may be examined microscopically, have traditionally provided much information. Medical imaging technologies such as functional neuroimaging, and electroencephalography (EEG) recordings are important in studying the brain. The medical history of people with brain injury has provided insight into the function of each part of the brain. Brain research has evolved over time, with philosophical, experimental, and theoretical phases. The next phase has been predicted to be one of simulating brain activity.[1]

In culture, the philosophy of mind has for centuries attempted to address the question of the nature of consciousness and the mind-body problem. The pseudoscience of phrenology attempted to localise personality attributes to regions of the cortex in the 19th century. In science fiction, brain transplants are imagined in tales such as the 1942 Donovan's Brain.

### Contents

<table>
<thead>
<tr>
<th>Structure</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross anatomy</td>
<td></td>
</tr>
<tr>
<td>Microanatomy</td>
<td></td>
</tr>
<tr>
<td>Cerebrospinal fluid</td>
<td></td>
</tr>
</tbody>
</table>

### Large-scale brain networks

**References**


The human brain has many properties that are common to all vertebrate brains. Many of its features are common to all mammalian brains, most notably a six-layered cerebral cortex and a set of associated structures, including the hippocampus and amygdala. The cortex is proportionally larger in humans than in many other mammals, and a highly developed visual system. As a primate brain, the human brain has a much larger cerebral cortex, in proportion to body size, than most mammals, and a highly developed visual system. As a hominid brain, the human brain is substantially enlarged even in comparison to the brain of a typical monkey. The sequence of human evolution from Australopithecus (four million years ago) to Homo sapiens (modern humans) was marked by a steady increase in brain size. As brain size increased, this altered the size and shape of the skull, from about 600 cm$^3$ in Homo habilis to an average of about 1520 cm$^3$ in Homo neanderthalensis.

Differences in DNA, gene expression, and gene–environment interactions help explain the differences between the function of the human brain and other primates. Cerebral atrophy, cortical spreading depression, and other phenomena help explain the differences between the function of the human brain and other primates.

Enrichedloom
Cortical spreading depression
Enchanted loom
Comparative anatomy
**Structure**

**Gross anatomy**

The adult human brain weighs on average about 1.2–1.4 kg (2.6–3.1 lb) which is about 2% of the total body weight,[4][5] with a volume of around 1260 cm³ in men and 1130 cm³ in women.[6] There is substantial individual variation,[4] with the standard reference range for men being 1,180–1,620 g (2.60–3.57 lb)[7] and for women 1,090–1,400 g (2.37–3.09 lb).[8]

Neurological differences between the sexes have not been shown to correlate in any simple way with IQ or other measures of cognitive performance.[9]

The cerebrum, consisting of the cerebral hemispheres, forms the largest part of the brain and overlies the other brain structures.[10] The outer region of the hemispheres, the cerebral cortex, is grey matter, consisting of cortical layers of neurons. Each hemisphere is divided into four main lobes – the frontal lobe, parietal lobe, temporal lobe, and occipital lobe.[11] Three other lobes are included by some sources which are a central lobe, a limbic lobe, and an insular lobe.[12] The central lobe comprises the precentral gyrus and the postcentral gyrus and is included since it forms a distinct functional role.[12][13]

The brainstem, resembling a stalk, attaches to and leaves the cerebrum at the start of the midbrain area. The brainstem includes the midbrain, the pons, and the medulla oblongata. Behind the brainstem is the cerebellum (Latin: little brain).[10]

The cerebrum, brainstem, cerebellum, and spinal cord are covered by three membranes called meninges. The membranes are the tough dura mater; the middle arachnoid mater and the more delicate inner pia mater. Between the arachnoid mater and the pia mater is the subarachnoid space and subarachnoid cisterns, which contain the cerebrospinal fluid.[14] The outermost membrane of the cerebral cortex is the basement membrane of the pia mater called the glia limitans and is an important part of the blood–brain barrier.[15]

The living brain is very soft, having a gel-like consistency similar to soft tofu.[16] The cortical layers of neurons constitute much of the cerebral grey matter, while the deeper subcortical regions of myelinated axons, make up the white matter.[17] The white matter of the brain makes up about half of the total brain volume.[18]

**Modern period**

Studies of the brain became more sophisticated with the use of the microscope and the development of a silver staining method by Camillo Golgi during the 1880s. This was able to show the intricate structures of single neurons.[20] This was used by Santiago Ramón y Cajal and led to the formation of the neuron doctrine, the then revolutionary hypothesis that the neuron is the functional unit of the brain. He used microscopy to uncover many cell types, and proposed functions for the cells he saw.[21] For this, Golgi and Cajal are considered the founders of twentieth century neuroscience, both sharing the Nobel prize in 1906 for their studies and discoveries in this field.[22]

Charles Sherrington published his influential 1906 work *The Integrative Action of the Nervous System* examining the function of reflexes, evolutionary development of the nervous system, functional specialisation of the brain, and layout and cellular function of the central nervous system.[23] John Farquhar Fulton, founded the *Journal of Neurophysiology* and published the first comprehensive textbook on the physiology of the nervous system during 1938.[24] Neuroscience during the twentieth century began to be recognised as a distinct unified academic discipline, with David Riech, Francis O. Schmitt, and Stephen Kuffler playing critical roles in establishing the field.[25] Riech originated the integration of basic anatomical and physiological research with clinical psychiatry at the Walter Reed Army Institute of Research, starting in the 1950s.[26] During the same period, Schmitt established the Neuroscience Research Program, an inter-university and international organisation, bringing together biology, medicine, psychological and behavioural sciences. The word neuroscience itself arises from this program.[27]

Paul Broca associated regions of the brain with specific functions, in particular language in Broca’s area, following work on brain-damaged patients.[28] John Hughlings Jackson described the function of the motor cortex by watching the progression of epileptic seizures through the body. Carl Wernicke described a region associated with language comprehension and production. Korbinian Brodmann divided regions of the brain based on the appearance of cells.[24] By 1950, Sherrington, Papez, and MacLean had identified many of the brainstem and limbic system functions.[29][30][31] The capacity of the brain to re-organise...
The human brain is divided into two main hemispheres, the right and the left, which are connected by the corpus callosum. Each hemisphere is divided into several lobes: frontal, parietal, temporal, and occipital. The frontal lobe is involved in movement and decision-making, the parietal lobe in sensory processing, the temporal lobe in hearing and language, and the occipital lobe in vision.

The surface of the brain is covered by the cerebral cortex, which is divided into smaller areas or gyri by deep grooves called sulci. Each gyral area has a specific function, such as motor control or sensory processing. The cerebral cortex is also connected to other parts of the brain through white matter tracts, such as the corpus callosum.

The brain is composed of gray matter, which contains the neuronal cell bodies, and white matter, which contains the neuronal axons. The gray matter is responsible for processing information, while the white matter is responsible for transmitting it to other areas of the brain.

The brain is also connected to the spinal cord and peripheral nerves, allowing it to control voluntary and involuntary movements and sensations.

The brain is protected by the skull and meninges, and blood supply is ensured by the circle of Willis. The brain is also connected to the pituitary gland, which regulates hormonal functions.

The study of the brain, known as neurology, has a long history, with early works by Hippocrates, Galen, and Erasistratus. In the 16th and 17th centuries, works by Andreas Vesalius, Archangelo Piccolomini, and Mondino de Luzzi provided important insights into brain anatomy. In the 19th century, works by René Descartes and Johannes Peter Müller laid the foundations for modern neuroscience.

In the 20th century, advances in technology have allowed for a deeper understanding of brain function, with the use of MRI and fMRI to visualize brain activity andEEG and MEG to measure it. This has led to a better understanding of the brain's role in various cognitive processes, such as memory, language, and perception.
directly in front of the somatosensory area. The primary sensory areas receive signals from the sensory nerves and tracts by way of relay nuclei in the thalamus. Primary sensory areas include the visual cortex of the occipital lobe, the auditory cortex in parts of the temporal lobe and insular cortex, and the somatosensory cortex in the parietal lobe. The remaining parts of the cortex are called the association areas. These areas receive input from the sensory areas and lower parts of the brain and are involved in the complex cognitive processes of perception, thought, and decision-making.[27] The main functions of the frontal lobe are to control attention, abstract thinking, behaviour, problem solving tasks, and physical reactions and personality.[28][29] The occipital lobe is the smallest lobe; its main functions are visual reception, visual-spatial processing, movement, and colour recognition.[28][29] There is a smaller occipital lobule in the lobe known as the cuneus. The temporal lobe controls auditory and visual memories, language, and some hearing and speech.[28]

The cerebrum contains the ventricles where the cerebrospinal fluid is produced and circulated. Below the corpus callosum is the septum pellucidum, a membrane that separates the lateral ventricles. Beneath the lateral ventricles is the thalamus and to the front and below this is the hypothalamus. The hypothalamus leads on to the pituitary gland. At the back of the thalamus is the brainstem.[30]

The basal ganglia, also called basal nuclei, are a set of structures deep within the hemispheres involved in behaviour and movement regulation.[31] The largest component is the striatum, others are the globus pallidus, the substantia nigra and the subthalamic nucleus.[32] Part of the dorsal striatum, the putamen, and the globus pallidus, lie separated from the lateral ventricles and thalamus by the internal capsule, whereas the caudate nucleus stretches around and abuts the lateral ventricles on their outer sides.[32] At the deepest part of the lateral sulcus between the insular cortex and the striatum is a thin neuronal sheet called the claustrum.[33]

Below and in front of the striatum are a number of basal forebrain structures. These include the nucleus accumbens, nucleus basalis, diagonal band of Broca, substantia innominata, and the medial septal nucleus. These structures are important in producing the neurotransmitter, acetylcholine, which is then distributed widely throughout the brain. The basal forebrain, in particular the nucleus basalis, is considered to be the major cholinergic output of the central nervous system to the striatum and neocortex.[34]

Cerebellum

The cerebellum is divided into an anterior lobe, a posterior lobe, and the flocculonodular lobe.[35] The anterior and posterior lobes are connected in the middle by the vermis.[36] Compared to the cerebral cortex, the cerebellum has a much thinner outer cortex that is narrowly fenestrated in numerous curved transverse fissures.[36] Viewed from underneath between the two lobes is the third lobe the flocculonodular lobe.[37] The cerebellum rests at the back of the cranial cavity, lying beneath the occipital lobes, and is separated from these by the cerebellar tentorium, a sheet of fibre.[38]

It is connected to the midbrain of the brainstem by the superior cerebellar peduncles, to the pons by the middle cerebellar peduncles, and to the medulla by the inferior cerebellar peduncles.[36] The cerebellum consists of an inner medulla of white matter and an outer cortex of richly folded grey matter.[38] The

In popular culture

Research has disproved some common misconceptions about the brain. These include both ancient and modern myths. It is not true that neurons are not replaced after the age of two; nor that only ten per cent of the brain is used.[21] Popular culture has also oversimplified the lateralisation of the brain, suggesting that functions are completely specific to one side of the brain or the other. Akio Mori coined the term ‘game brain’ for the unreliable supported theory that spending long periods playing video games harmed the brain’s pre-frontal region, and impaired the expression of emotion and creativity.[218]

Historically, the brain featured in popular culture through phrenology, a pseudoscience that assigned personality attributes to different regions of the cortex. The cortex remains important in popular culture as covered in books and satire.[219][220] The brain features in science fiction, with themes such as brain transplants and cyborgs (beings with features like partly artificial brains).[221] The 1942 science fiction book (adapted three times for the cinema) Donovan’s Brain tells the tale of an isolated brain kept alive in vitro, gradually taking over the personality of the book’s protagonist.[222]

History

Early history

The Edwin Smith Papyrus, an ancient Egyptian medical treatise written in the 17th century BC, contains the earliest recorded reference to the brain. The hieroglyph for brain, occurring eight times in this papyrus, describes the symptoms, diagnosis, and prognosis of two traumatic injuries to the head. The papyrus mentions the external surface of the brain, the effects of injury (including seizures and aphasia), the meninges, and cerebrospinal fluid.[223][224]

In the fifth century BC, Alcmaeon of Croton in Magna Grecia, first considered the brain to be the seat of the mind.[224] Also in the fifth century BC in Athens, the unknown author of On the Sacred Disease, a medical treatise which is part of the Hippocratic Corpus and traditionally attributed to Hippocrates, believed the brain to be the seat of intelligence. Aristotle, in his biology initially believed the heart to be the seat of intelligence, and saw the brain as a cooling mechanism for the blood. He reasoned that humans are more rational than the beasts because, among other reasons, they have a larger brain to cool their hot-bloodedness.[225] Aristotle did describe the meninges and distinguished between the cerebrum and cerebellum.[226]

Herophilus of Chalcedon in the fourth and third centuries BC distinguished the cerebrum and the
Some 400 genes are shown to be up-regulated in the neocortex in primate brains, with many involved in synaptic function. The neocortex is the area of the brain responsible for higher cognitive functions such as language, thought, and memory. These genes may be involved in the development and maintenance of these cognitive abilities. Additionally, some of these genes are expressed in the amygdala, which is involved in emotional processing and memory. This suggests a potential link between changes in gene expression and cognitive functions.
Cerebrospinal fluid

Cerebrospinal fluid is a clear, colourless transcellular fluid that circulates around the brain in the subarachnoid space, in the venricular system, and in the central canal of the spinal cord. It also fills some gaps in the subarachnoid space, known as subarachnoid cisterns. The four ventricles, two lateral, a third, and a fourth ventricle, all contain choroid plexus that produces cerebrospinal fluid. The third ventricle lies in the midline and is connected to the lateral ventricles. A single duct, the cerebral aqueduct between the pons and the cerebellum, connects the third ventricle to the fourth ventricle. Three separate openings, the middle and two lateral apertures, drain the cerebrospinal fluid from the fourth ventricle to the cisterna magna one of the major cisterns. From here, cerebrospinal fluid circulates around the brain and spinal cord in the subarachnoid space, between the arachnoid mater and pia mater. At any one time, there is about 150mL of cerebrospinal fluid – most within the subarachnoid space. It is constantly being regenerated and absorbed, and is replaced about once every 5–6 hours.

A lymphatic system has been described as the lymphatic drainage system of the brain. The brain-wide lymphatic pathway includes drainage routes from the cerebrospinal fluid, and from the meningeal lymphatic vessels that are associated with the dural sinuses, and run alongside the cerebral blood vessels. The pathway drains interstitial fluid from the tissue of the brain.

Blood supply

The internal carotid arteries supply oxygenated blood to the front of the brain and the vertebral arteries supply blood to the back of the brain. These two circulations join together in the circle of Willis, a ring of connected arteries that lies in the interpeduncular cistern between the midbrain and pons.

The internal carotid arteries are branches of the common carotid arteries. They enter the cranium through the carotid canal, travel through the cavernous sinus and enter the subarachnoid space. They then enter the circle of Willis, with two branches, the anterior cerebral arteries emerging. These branches travel forward and then upward along the longitudinal fissure, and supply the front and midline parts of the brain. One or more small anterior communicating arteries join the two anterior cerebral arteries shortly after they emerge as branches. The internal carotid arteries continue forward as the middle cerebral arteries. They travel sideways along the sphenoid bone of the eye socket, then upwards through the insula cortex, where final branches arise. The middle cerebral arteries send branches along their length.

The vertebral arteries emerge as branches of the left and right subclavian arteries. They travel upward (including high blood pressure, atrial fibrillation, and smoking). Further investigation is needed in younger patients. An ECG and biotelemetry may be conducted to identify atrial fibrillation; an ultrasound can investigate narrowing of the carotid arteries; an echocardiogram can be used to look for clots within the heart, diseases of the heart valves or the presence of a patent foramen ovale. Blood tests are routinely done as part of the workup including diabetes tests and a lipid profile.

Some treatments for stroke are time-critical. These include clot dissolution or surgical removal of a clot for ischaemic strokes, and decompression for haemorrhagic strokes. As stroke is time critical, hospitals and even pre-hospital care of stroke involves expedited investigations – usually a CT scan to investigate for a haemorrhagic stroke and a CT or MR angiogram to evaluate arteries that supply the brain. MRI scans, not as widely available, may be able to demonstrate the affected area of the brain more accurately, particularly with ischaemic stroke.

Having experienced a stroke, a person may be admitted to a stroke unit, and treatments may be directed as preventing future strokes, including ongoing anticoagulation (such as aspirin or clopidogrel), antihypertensives, and lipid-lowering drugs. A multidisciplinary team including speech pathologists, physiotherapists, occupational therapists, and psychologists plays a large role in supporting a person affected by a stroke and their rehabilitation. A history of stroke increases the risk of developing dementia by around 70%, and recent stroke increases the risk by around 12%.

Brain death

Brain death refers to an irreversible total loss of brain function. This is characterised by coma, loss of reflexes, and apnoea; however, the declaration of brain death varies geographically and is not always accepted. In some countries there is also a defined syndrome of brainstem death. Declaration of brain death can have profound implications as the declaration, under the principle of medical futility, will be associated with the withdrawal of life support and as those with brain death often have organs suitable for organ donation. The process is often made more difficult by poor communication with patients’ families.

When brain death is suspected, reversible differential diagnoses such as, electrolyte, neurological and drug-related cognitive suppression need to be excluded. Testing for reflexes can be of help in the decision, as can the absence of response and breathing. Clinical observations, including a total lack of responsiveness, a known diagnosis, and neural imaging evidence, may all play a role in the decision to pronounce brain death.

Society and culture

Neuroanthropology is the study of the relationship between culture and the brain. It explores how the brain gives rise to culture, and how culture influences brain development. Cultural differences and their relation to brain development and structure are researched in different fields.

The mind

neurons, NRGN and REEP2 are also expressed. GAD1 – essential for the biosynthesis of the neurotransmitter GABA – is expressed in interneurons. Proteins expressed in glial cells are astrocyte markers GFAP, and S100B. Myelin basic protein, and the transcription factor, OLIG2 are expressed in oligodendrocytes.


8 of 50 4/8/20, 8:29 AM 4/8/20, 8:29 AM


The blood-brain barrier

**Definition:** The blood-brain barrier (BBB) is a specialized barrier that helps protect the brain and spinal cord from potentially harmful substances in the bloodstream.

**Function:** The BBB is a complex network of cells and molecules that regulates the exchange of substances between the brain and the bloodstream. It is made up of specialized cells called endothelial cells, which form a barrier between the brain's blood vessels and the surrounding tissues. These cells are tightly packed together, which helps prevent the passage of certain substances into the brain.

**Role:** The BBB is crucial for maintaining the health and function of the brain. It helps protect the brain from harmful substances, toxins, and infections by preventing them from entering the brain's sensitive tissues. It also helps regulate the exchange of nutrients and oxygen between the brain and the bloodstream, ensuring that the brain has the necessary resources to function properly.

**Examples:** The BBB is present in most parts of the brain, but it is particularly important in the brain's blood vessels, where it helps prevent the entry of harmful substances into the brain.

---

**Stroke**

**Definition:** Stroke is a medical emergency that occurs when blood flow is interrupted to part of the brain, leading to cell death and brain function loss.

**Types:** There are several types of strokes, including ischemic strokes (caused by blood flow interruption) and hemorrhagic strokes (caused by blood vessel rupture).

**Symptoms:** The symptoms of stroke can vary depending on the location and severity of the damage. Common symptoms include sudden numbness or weakness in the face, arm, or leg, confusion, difficulty speaking, double vision, and vision loss.

**Treatment:** The treatment for stroke depends on the type and severity of the symptoms. Immediate medical attention is crucial, as quick treatment can help reduce the risk of brain damage and improve outcomes.

---

**Epilepsy**

**Definition:** Epilepsy is a neurological disorder characterized by recurring seizures caused by abnormal electrical activity in the brain.

**Types:** There are several types of epilepsy, including generalized epilepsies and focal epilepsies.

**Symptoms:** The symptoms of epilepsy can vary depending on the type of seizure. Common symptoms include sudden loss of consciousness, convulsions, and altered awareness.

**Treatment:** The treatment for epilepsy depends on the type and severity of the seizures. Common treatment options include medication, surgery, and other interventions.

---

**Congenital disorders**

**Definition:** Congenital disorders are medical conditions that are present at birth and can affect various parts of the body, including the brain.

**Types:** There are many types of congenital disorders, including genetic disorders, structural abnormalities, and functional abnormalities.

**Symptoms:** The symptoms of congenital disorders can vary widely depending on the type and severity of the condition.

**Treatment:** The treatment for congenital disorders depends on the type and severity of the symptoms. Common treatment options include medication, surgery, and other interventions.
Neural crest and neural crest cells
Primary and secondary vesicle stages of development in the early embryo to the fifth week of development. This process is necessary for the development of the brain and the central nervous system. Some neural crest cells migrate through the cranial neural crest to form the head, while others remain closer to the body axis where they contribute to the formation of cartilage and bone. The neural crest cells give rise to the parasympathetic nervous system, the adrenal medulla, and certain types of glial cells in the brain.

Development

At the beginning of the third week of development, the embryonic ectoderm forms a thickened strip called the neural plate. By the fourth week of development, the neural plate has widened to give a broad cephalic end, a less broad middle part and a narrow caudal end. These swellings are known as the primary brain vesicles and represent the beginnings of the forebrain, midbrain and hindbrain.[69]

Neural crest cells (derived from the ectoderm) populate the lateral edges of the plate at the neural folds. In the fourth week—during the neurulation stage—the neural folds close to form the neural tube, bringing together the neural crest cells at the neural crest.[70] The neural crest runs the length of the tube with cranial neural crest cells at the cephalic end and caudal neural crest cells at the tail. Cells detach from the crest and migrate in a cranio-caudal (head to tail) wave inside the tube.[70] Cells at the cephalic end give rise to the brain, and cells at the caudal end give rise to the spinal cord.[71]

The tube flexes as it grows, forming the crescent-shaped cerebral hemispheres at the head. The cerebral hemispheres first appear on day 32.[72] Early in the fourth week the cephalic part bends sharply forward in a cephalic flexure.[70] This flexed part becomes the forebrain (prosencephalon); the adjoining curving part becomes the midbrain (mesencephalon) and the part caudal to the flexure becomes the hindbrain (rhombencephalon). These areas are formed as swellings known as the three primary brain vesicles. In the fifth week of development five secondary brain vesicles have formed.[73]

The forebrain separates into two vesicles – an anterior telencephalon and a posterior diencephalon. The telencephalon gives rise to the cerebral cortex, basal ganglia, and related structures. The diencephalon gives rise to the thalamus and hypothalamus. The hindbrain also splits into two areas – the metencephalon and the myelencephalon. The metencephalon gives rise to the cerebellum and pons. The myelencephalon gives rise to the medulla oblongata.[74] Also during the fifth week, the brain divides into repeating segments called rhombomeres.[69][75] In the hindbrain these are known as rhombomeres.[76]

A characteristic of the brain is the cortical folding known as gyrification. For just over five months of prenatal development the cortex is smooth. By the gestational age of 24 weeks, the wrinkled morphology of the brain is clearly visible. The brain grows to about 16% of its adult weight by the sixth month of development. The brain mass increases at the rate of 1% per day during the last trimester of pregnancy and the early postnatal period. This rate of growth is significantly higher than the normal growth rate for any other organ in the body.

Injury

Injury to the brain can manifest in many ways. Traumatic brain injury, for example received in contact sport, after a fall, or a traffic or work accident, can be associated with both immediate and longer-term problems. Immediate problems may include bleeding within the brain, this may compress the brain tissue or damage its blood supply. Bruising to the brain may occur. Bruising may cause widespread damage to the nerve tracts that can lead to a condition of diffuse axonal injury.[77] A fractured skull, injury to a particular area, deafness, and concussion are also possible immediate developments. In addition to the site of injury, the opposite side of the brain may be affected, termed a contrecoup injury. Longer-term issues that may develop include posttraumatic stress disorder, and hydrocephalus. Chronic traumatic encephalopathypath can develop following multiple head injuries.[78]

Disease

Neurodegenerative diseases result in progressive damage to different parts of the brain’s function, and worsen with age. Common examples include dementia such as Alzheimer’s disease, alcoholic dementia or vascular dementia; Parkinson’s disease; and other rarer infectious, genetic, or metabolic causes such as Huntington’s disease, motor neuron diseases, HIV dementia, syphilis-related dementia and Wilson’s disease. Neurodegenerative diseases can affect different parts of the brain, and can affect movement, memory, and cognition.[79]

The brain, although protected by the blood–brain barrier, can be affected by infections including viruses, bacteria and fungi. Infection may be of the meninges (meningitis), the brain matter (encephalitis), or within the brain matter (such as a cerebral abscess).[76] Rare prion diseases including Creutzfeldt–Jakob disease and its variant, and kuru may also affect the brain.[75]

Tumours

Brain tumours can be either benign or cancerous. Most malignant tumours arise from another part of the body, most commonly from the lung, breast and skin.[76] Cancers of brain tissue can also occur, and originate from any tissue in and around the brain. Meningioma, cancer of the meninges around the brain, is more common than cancers of brain tissue.[76] Cancers within the brain may cause symptoms related to their size or position, with symptoms including headache and nausea, or the gradual development of focal symptoms such as gradual difficulty seeing, swallowing, talking, or as a change of mood.[76] Cancers are in general investigated through the use of CT scans and MRI scans. A variety of other tests including blood tests and lumbar puncture may be used to investigate for the cause of the cancer and evaluate the type and stage of the cancer.[76] The corticosteroid dexamethasone is often given to decrease the swelling of brain tissue around a tumour. Surgery may be considered, however given the complex nature of many tumours or based on tumour stage or type, radiotherapy or chemotherapy may be considered more suitable.[76]

Mental disorders

Mental disorders, such as depression, schizophrenia, bipolar disorder, posttraumatic stress disorder, attention deficit hyperactivity disorder, obsessive-compulsive disorder, Tourette syndrome, and addiction,
Other related studies have also shown evidence of synaptic alterations and their loss, in the motor cortex, which may contribute to the disease progression. These changes have been noted in the motor cortex, and are seen as a factor causing the drive to alcohol dependence, and also to other substance abuses. The motor cortex is involved in motor control, emotion, and language. It contains the motor neurons that originate in the spinal cord and project through the corticospinal tract to the body and control the action of muscles.

As of 2017, just under 20,000 protein-coding genes are seen to be expressed in the brain, and about 2000 transcription factors are expressed in the interior of forebrain. Bioinformatics and studies in genomics have enabled objective insights into mental disorders, leading to faster diagnosis, more accurate prognosis, and better monitoring.

Advances in neuroimaging techniques show changes in brain activity that relate to the function of specific brain areas. Imaging methods rely on the detection of a pre-existing signal, such as electrical activity, which generates patterns of activity in the brain. Functional near-infrared spectroscopy (fNIRS) is a non-invasive technique that measures changes in blood flow and oxygenation in the brain. The data that has been provided on neuroimaging has allowed us to better understand the brain and its functions.

Functional neuroimaging techniques show changes in brain activity that relate to the function of specific brain areas. These methods rely on the detection of a pre-existing signal, such as electrical activity, which generates patterns of activity in the brain. Functional magnetic resonance imaging (fMRI) is a commonly used technique that allows researchers to study brain function in real-time. It uses magnetic fields and radio waves to create images of the brain and its activity. The data that has been provided on neuroimaging has allowed us to better understand the brain and its functions.

The frontal lobe is involved in reasoning, motor control, emotion, and language. It contains the motor neurons that originate in the spinal cord and project through the corticospinal tract to the body and control the action of muscles. The frontal lobe is also responsible for higher-level cognitive functioning; and changes in gene expression alter the levels of proteins in various neural pathways and this has been shown in some disorders, notably schizophrenia.

Different biological approaches using imaging have given more insight for example into the disorders of the brain. Any electrical current generates a magnetic field; and turns it into a much deeper ridge known as the groove. As the hemisphere has to curve over in a forward direction to fit into the restricted space. This covers the fossa and a much deeper ridge known as the groove. Any electrical current generates a magnetic field; and turns it into a much deeper ridge known as the groove. This covers the fossa and a much deeper ridge known as the groove. Any electrical current generates a magnetic field; and turns it into a much deeper ridge known as the groove. This covers the fossa and a much deeper ridge known as the groove. Any electrical current generates a magnetic field; and turns it into a much deeper ridge known as the groove. This covers the fossa and a much deeper ridge known as the groove.

The data that has been provided on neuroimaging has allowed us to better understand the brain and its functions. Functional neuroimaging techniques show changes in brain activity that relate to the function of specific brain areas. Imaging methods rely on the detection of a pre-existing signal, such as electrical activity, which generates patterns of activity in the brain. Functional near-infrared spectroscopy (fNIRS) is a non-invasive technique that measures changes in blood flow and oxygenation in the brain. The data that has been provided on neuroimaging has allowed us to better understand the brain and its functions.

The data that has been provided on neuroimaging has allowed us to better understand the brain and its functions. Functional neuroimaging techniques show changes in brain activity that relate to the function of specific brain areas. Imaging methods rely on the detection of a pre-existing signal, such as electrical activity, which generates patterns of activity in the brain. Functional near-infrared spectroscopy (fNIRS) is a non-invasive technique that measures changes in blood flow and oxygenation in the brain. The data that has been provided on neuroimaging has allowed us to better understand the brain and its functions.
Gross movement—such as locomotion and the movement of arms and legs—is generated in the motor cortex, divided into three parts: the primary motor cortex, found in the prefrontal gyrus and has sections dedicated to the movement of different body parts. These movements are regulated by two other areas, lying anterior to the primary motor cortex: the premotor area and the supplementary motor area.[65] The hands and mouth have a much larger area dedicated to them than other body parts, allowing finer movement; this has been visualised in a motor homunculus.[65] Impulses generated from the motor cortex travel along the corticospinal tract along the front of the medulla and cross over (decussate) at the medullary pyramids. These then travel down the spinal cord, with most connecting to interneurons, in turn connecting to lower motor neurons within the grey matter that then transmit the impulse to move to muscles themselves.[84] The cerebellum and basal ganglia, play a role in fine, complex and coordinated muscle movements.[86] Connections between the cortex and the basal ganglia control muscle tone, posture and movement initiation, and are referred to as the extrapyramidal system.[87]

Sensory

The sensory nervous system is involved with the reception and processing of sensory information. This information is received through the cranial nerves, through tracts in the spinal cord, and directly at centres of the brain exposed to the blood.[88] The brain also receives and interprets information from the special senses of vision, smell, hearing, and taste. Mixed motor and sensory signals are also integrated.[86]

From the skin, the brain receives information about fine touch, pressure, pain, vibration and temperature. From the joints, the brain receives information about joint position.[89] The sensory cortex is found just near the motor cortex, and, like the motor cortex, has areas related to sensation from different body parts. Sensation collected by a sensory receptor on the skin is changed to a nerve signal, that is passed up a series of neurons through tracts in the spinal cord. The dorsal column-medial lemniscus pathway contains information about fine touch, vibration and position of joints. The pathway fibers travel up the back part of the spinal cord to the back part of the medulla, where they connect with second-order neurons that immediately send fibers across the midline. These fibers then travel upwards into the ventrobasal complex in the thalamus where they connect with third-order neurons which send fibers up to the sensory cortex.[89] The spinothalamic tract carries information about pain, temperature, and gross touch. The pathway fibers travel up the spinal cord and connect with second-order neurons in the reticular formation of the brainstem for pain and temperature, and also terminate at the ventrobasal complex of the thalami for gross touch.[89]

Vision is generated by light that hits the retina of the eye. Photoreceptors in the retina transduce the sensory stimulus of light into an electrical nerve signal that is sent to the visual cortex in the occipital lobe. Visual signals leave the retinas through the optic nerves. Optic nerve fibers from the retinas’ nasal halves cross to the opposite sides joining the fibers from the temporal halves of the opposite retinas to form the
glucose for energy, and deprivation of glucose, as can happen in hypoglycemia, can result in loss of consciousness.[141] The energy consumption of the brain does not vary greatly over time, but active regions of the cortex consume somewhat more energy than inactive regions: this fact forms the basis for the functional brain imaging methods PET and fMRI[142] These functional imaging techniques provide a three-dimensional image of metabolic activity.[143]

The function of sleep is not fully understood; however, there is evidence that sleep enhances the clearance of metabolic waste products, some of which are potentially neurotoxic, from the brain and may also permit repair.[56][144][145] Evidence suggests that the increased clearance of metabolic waste during sleep occurs via increased functioning of the glymphatic system.[56] Sleep may also have an effect on cognitive function by weakening unnecessary connections.[146]

Research

The brain is not fully understood, and research is ongoing.[147] Neuroscientists, along with researchers from allied disciplines, study how the human brain works. The boundaries between the specialties of neuroscience, neurology and other disciplines such as psychiatry have faded as they are all influenced by basic research in neuroscience.

Neuroscience research has expanded considerably in recent decades. The “Decade of the Brain”, an initiative of the United States Government in the 1990s, is considered to have marked much of this increase in research,[148] and was followed in 2013 by the BRAIN Initiative.[149] The Human Connectome Project was a five-year study launched in 2009 to analyse the anatomical and functional connections of parts of the brain, and has provided much data.[147]

Methods

Information about the structure and function of the human brain comes from a variety of experimental methods, including animals and humans. Information about brain trauma and stroke has provided information about the function of parts of the brain and the effects of brain damage. Neuroimaging is used to visualize the brain and record brain activity. Electrophysiology is used to measure, record and monitor the electrical activity of the cortex. Measurements may be of local field potentials of cortical areas, or of the activity of a single neuron. An electroencephalogram can record the electrical activity of the cortex using electrodes placed non-invasively on the scalp.[150][151]

Invasive measures include electrocorticography, which uses electrodes placed directly on the exposed surface of the brain. This method is used in cortical stimulation mapping, used in the study of the relationship between cortical areas and their systemic function.[152] By using much smaller microelectrodes, single-unit recordings can be made from a single neuron that give a high spatial resolution and high temporal resolution. This has enabled the linking of brain activity to behaviour, and the creation of neuronal maps.[153]

The development of cerebral organoids has opened ways for studying the growth of the brain, and of the cortex, and for understanding disease development, offering further implications for therapeutic applications.[154][155]
Metabolism

Regulation

Neurotransmission

Physiology

Learning how the brain works is a daunting task. We are beginning to understand that the brain is a complex network of neurons that communicate with each other through electrical and chemical signals. Neurons are the basic building blocks of the nervous system and are responsible for processing and transmitting information. The brain is made up of numerous different structures, each with its own specialized function. Some of these structures include the cerebral cortex, the cerebellum, and the brainstem. The cerebral cortex is responsible for higher cognitive functions such as language, memory, and decision-making. The cerebellum is involved in movement coordination and motor control. The brainstem is responsible for controlling basic life functions such as breathing and heart rate. Understanding how these different parts of the brain work together is crucial to understanding how the brain functions as a whole.
The hypothalamus in the diencephalon, is involved in regulating many functions of the body. Functions include neuroendocrine regulation, regulation of the circadian rhythm, control of the autonomic nervous system, and the regulation of fluid, and food intake. The circadian rhythm is controlled by two main cell groups in the hypothalamus. The anterior hypothalamus includes the suprachiasmatic nucleus and the ventrolateral preoptic nucleus which through gene expression cycles, generates a roughly 24 hour circadian clock. In the circadian day an ultradian rhythm takes control of the sleeping pattern. Sleep is an essential requirement for the body and brain and allows the closing down and resting of the body’s systems. There are also findings that suggest that the daily build-up of toxins in the brain are removed during sleep.\cite{99} Whilst awake the brain consumes a fifth of the body’s total energy needs. Sleep necessarily reduces this use and gives time for the restoration of energy-giving ATP. The effects of sleep deprivation show the absolute need for sleep.\cite{100}

The lateral hypothalamus contains orexigenic neurons that control appetite and arousal through their projections to the ascending reticular activating system.\cite{101,102} The hypothalamus controls the pituitary gland through the release of peptides such as oxytocin, and vasopressin, as well as dopamine into the median eminence. Through the autonomic projections, the hypothalamus is involved in regulating functions such as blood pressure, heart rate, breathing, sweating, and other homeostatic mechanisms.\cite{103} The hypothalamus also plays a role in thermal regulation, and when stimulated by the immune system, is capable of generating a fever. The hypothalamus is influenced by the kidneys: when blood pressure falls, the renin released by the kidneys stimulates a need to drink. The hypothalamus also regulates food intake through autonomic signals, and hormone release by the digestive system.\cite{104}

**Language**

While language functions were traditionally thought to be localized to Wernicke’s area and Broca’s area,\cite{105} it is now mostly accepted that a wider network of cortical regions contributes to language functions.\cite{106,107,108}

The study on how language is represented, processed, and acquired by the brain is called neurolinguistics, which is a large multidisciplinary field drawing from cognitive neuroscience, cognitive linguistics, and psycholinguistics.\cite{109}

**Lateralisation**

The cerebrum has a contralateral organisation with each hemisphere of the brain interacting primarily with one half of the body: the left side of the brain interacts with the right side of the body, and vice versa. The developmental cause for this is uncertain.\cite{110} Motor connections from the brain to the spinal cord, and sensory connections from the spinal cord to the brain, both cross sides in the brainstem. Visual input follows a more complex rule: the optic nerves from the two eyes come together at a point called the optic chiasm, and half of the fibres from each nerve split off to join the other.\cite{111} The result is that connections from the left half of the retina, in both eyes, go to the left side of the brain, whereas connections from the right half of the retina go to the right side of the brain.\cite{112} Because each half of the retina receives light coming from the opposite half of the visual field, the functional consequence is that visual input from the left side of the world goes to the right side of the brain, and vice versa.\cite{110} Thus, the right side of the brain receives somatosensory input from the left side of the body, and visual input from the left side of the visual field.\cite{113,114}

Emotion

Emotions are generally defined as two-step multicomponent processes involving elicitation, followed by psychological feelings, appraisal, expression, autonomic responses, and action tendencies.\cite{115} Attempts to localize basic emotions to certain brain regions have been controversial; some research found no evidence for specific locations corresponding to emotions, but instead found circuitry involved in general emotional processes.\cite{116,117,118,119} The left and right sides of the brain appear symmetrical, but they function asymmetrically.\cite{115} For example, the counterpart of the left-hemisphere motor area controlling the right hand is the right-hemisphere area controlling the left hand. There are, however, several important exceptions, involving language and spatial cognition. The left frontal lobe is dominant for language. If a key language area in the left hemisphere is damaged, it can leave the victim unable to speak or understand,\cite{115} whereas equivalent damage to the right hemisphere would cause only minor impairment to language skills.

A substantial part of current understanding of the interactions between the two hemispheres has come from the study of “split-brain patients”—people who underwent surgical transection of the corpus callosum in an attempt to reduce the severity of epileptic seizures.\cite{116} These patients do not show unusual behaviour that is immediately obvious, but in some cases can behave almost like two different people in the same body, with the right hand taking an action and then the left hand undoing it.\cite{116,117} These patients, when briefly shown a picture on the right side of the point of visual fixation, are able to describe it verbally, but when the picture is shown on the left, are unable to describe it, but may be able to give an indication with the left hand of the nature of the object shown.\cite{117,118}

Cognition

The brain is responsible for cognition,\cite{120,121} which functions through numerous processes and executive functions.\cite{122,123,124} Executive functioning include the ability to filter information and tune out irrelevant stimuli with attentional control and cognitive inhibition, the ability to process and manipulate information held in working memory, the ability to think about multiple concepts simultaneously and switch tasks with cognitive flexibility, the ability to inhibit impulses and prepotent responses with inhibitory control, and the ability to determine the relevance of information or appropriateness of an action.\cite{120,125} Higher order executive functions require the simultaneous use of multiple basic executive functions, and include planning and fluid intelligence (i.e., reasoning and problem solving).\cite{125}

The prefrontal cortex plays a significant role in mediating executive functions.\cite{123,125,126} Planning