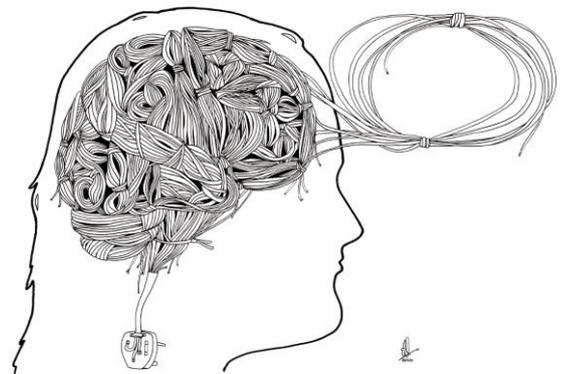
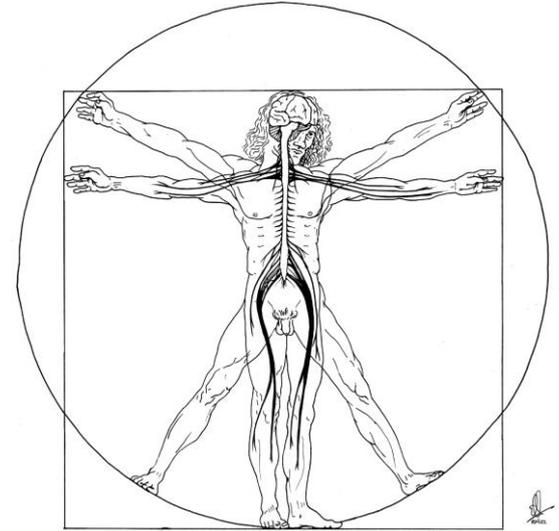




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## **Nervous system and Wired**

The nervous system comprises two major anatomical subdivisions, the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS includes the brain and the spinal cord. The PNS consists of sensory neurons (nerves that transmit sensory information such as sight, sound touch etc.) which carry signals from all over the body to the CNS for processing, and motor neurons which carry signals from the muscles to the CNS to control movement. Within the brain itself there are a vast number of connections. Brain cells called neurons connect through axons, which are like long electrical wires. In our nervous system, collections of wires make different connections to make a very complex electrical circuit. Each connection serves a purpose, some of which we will explore here.





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## **Brain Puzzle**

Here the brain is depicted as a jigsaw puzzle consisting of six main areas (a-f), each of which can be further subdivided into multiple smaller 'pieces'. The role of each area is outlined. Of these six areas, four lobes (frontal, parietal, occipital and temporal) belong to a larger area referred to as the Forebrain, or more specifically the cerebral cortex. The other two areas (the cerebellum and brainstem) make up the Hindbrain, which connects the brain to the spinal cord. The parietal lobe, which is responsible for the perception of touch, is where the primary somatosensory cortex is located (referred to later in the *homunculus* section). The brain here is shown in its entirety from a side (or sagittal) view. When looking at the brain in a transverse plane (cut in half to reveal the inside portion) sub-cortical structures become visible such as the thalamus and limbic system (hypothalamus, basal ganglia, amygdala and *hippocampus*). The pituitary gland is a protrusion from the bottom of the hypothalamus at the base of the brain (referred to later in the *hormones* picture). These sub-cortical areas are responsible for many of the involuntary processes in the body, such as controlling breathing, the sleep-wake cycle, hunger, temperature regulation, hunger & thirst.





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## **Brain Map and Left brain/Right brain**

We have seen what the brain looks like from the side and now here is a view of the brain from above. This *brain map* represents some of the functions of the different areas of the brain. The courthouse is in the front of the brain (frontal lobe) which is responsible for complex thought and judgement. The frontal lobe is depicted as being under construction as it is not fully developed until a person's twenties. The barracks is in the frontal lobe (pre-frontal gyrus) which is responsible for the conscious control of movement. The library is located in the temporal lobe and represents this region's role in memory. The university is located where the parietal lobe would be, and represents this area's role in language. The observatory is located in the occipital lobe (where vision is perceived). Furthermore, brain functionality can be crudely divided into left and right hemispheres. It is thought that the right side of the brain is responsible for creative traits such as musicality and artistic talent whereas the left hemisphere is more heavily involved in logical tasks such as in mathematics and language.



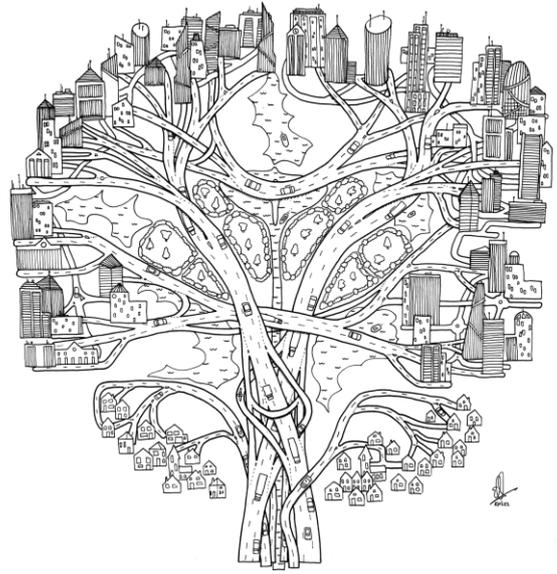


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## **Information highway**

It was briefly mentioned above in the *nervous system* section that messages from the body travel to the brain via sensory and motor neurons. In turn, the brain transmits messages to the rest of the body via bundles of nerve cells which extend from the brain itself (via the *cranial nerves*) and spinal cord (via 31 pairs of spinal nerves).





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## Cranial nerves

The *cranial nerves* relay information between the brain and the head and neck. There are 12 pairs of cranial nerves and these are numbered (in Roman numerals) according to the order in which they emerge from the brain, from top to bottom. These are responsible for (I) smell, (II) vision, (III, IV, VI) eye movement, (V) chewing and facial sensation, (VII) facial expression, (VIII) hearing and balance, (IX) taste (and salivation), (X) swallowing, (XI) shoulder elevation (and head-turning) and finally (XII) tongue movement. In addition to swallowing, cranial nerve X (the *Vagus nerve* – for “vague” or “wandering”) which extends all the way from the brain as far as the large bowel is also responsible for carrying signals which control your heart rate and how your gut handles food, as well as many other functions.

In comparison, signals from the brain reach the spinal nerves via the spinal cord. There are a number of large bundles of nerve cells which travel in groups called *tracts*. The inside of the cerebral cortex is made up of thousands upon thousands of these cells, called the ‘white matter’. Importantly, a lot of these tracts swap sides in the brainstem before they reach the spinal cord – this is why the left side of your brain controls the right side of your body, and vice versa. So if you are right handed, your dominant lobe is your left side. This is important for two reasons – firstly, problems that affect one side of the brain will manifest as symptoms on the opposite side of the body, and secondly, because these tracts are densely packed with nerve cells, even a small stroke (a bleed in the brain) can have devastating effects depending on where in the brain it occurs.

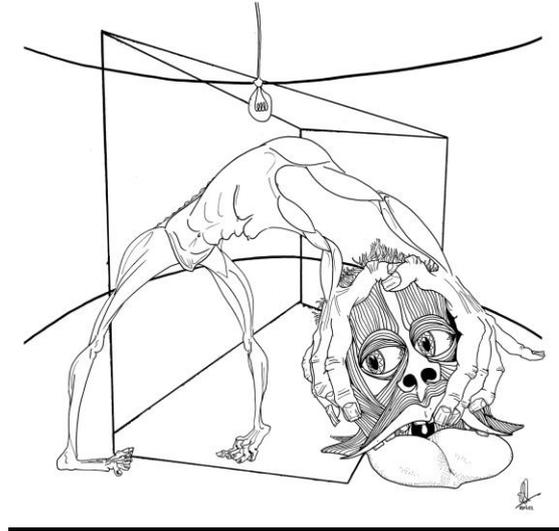




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## Homunculus

The primary somatosensory cortex (PSC) is located in the parietal lobe of the brain (see the *brain puzzle* picture). This area controls our ability to perceive the sensation of touch. The Homunculus is a visual representation of the location of each body part on the PSC, and in this sense is a neurological map of the body. The Homunculus also depicts the sensitivity of each body part to touch by their size relative to one another and thus the homunculus is distorted in shape from the normal human body. For example, this is why the tongue, lips and hands are huge in proportion to the toes or knees. *Note; sensitivity of a body part is controlled by the total area of the PSC designated to it.*



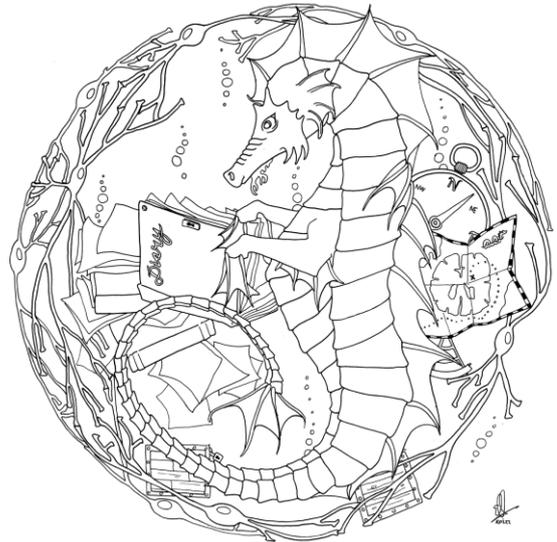


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## Hippocampus

The hippocampus is located beneath the cerebral cortex, and is part of the limbic system. It consists of two closely related crescent-like regions; the dentate gyrus (DG) and Ammon's horn, which give it the seahorse-like shape. The hippocampus is critical for memory, and specifically the processing of new memories (which is why the seahorse is reading its diary in the picture). Its importance in the conversion of short to long term memory was first realised when removal of two thirds of the hippocampus caused short-term memory loss in a patient with epilepsy, known as H.M. In other words, H.M.'s long-term memories remained intact, but he could not remember anything new (such as what he had for breakfast or people he just met). The hippocampus also plays an important role in spatial navigation, or our sense of direction (this is why there is a compass and map to the right of the seahorse). The formation of spatial maps is a form of what is known as 'working memory'.



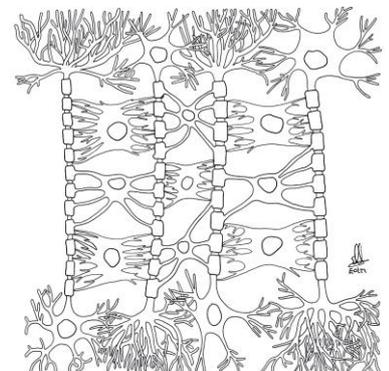
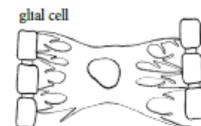
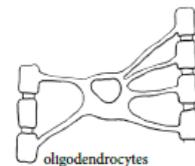
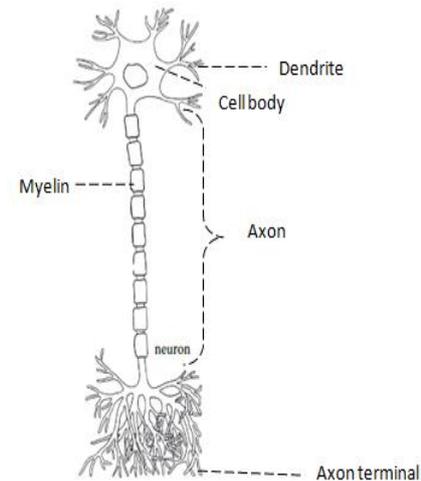
## Brain cells

A *neuron* (or nerve cell) consists of dendrites, a cell body, an axon and axon terminals. Neurons function by producing electrical signals, which are transmitted along the axon and cause the release of chemicals from the axon terminal (called neurotransmitters). The function of a Neuron depends on its location and the chemicals it releases. They have different receptors on their surface (see *Synapse*) which allow them to respond to these chemicals and trigger the relevant action.

*Glial cell* is the umbrella term for all non-neuronal cells in the nervous system – i.e. the cells that are not directly involved in transmitting nerve signals. Glial cells are approximately three times more common than neurons in the brain and function in supporting and modifying neuronal activity.

The three types of glial cell are;

1. *Oligodendrocytes* – these produce a substance called myelin (which is made up of 'lipids'; fats). When myelin is wrapped around the axon of a neuron it helps in the transmission of electricity, by insulating the cell. *Note: Degree of myelination is what distinguishes Grey matter from White matter.*
2. Microglia (not shown) – these are the brain's defence cells. They are known as *scavenger* cells -they remove cellular debris which results from injury or normal cell turnover. They also release chemicals called *cytokines* which can modulate inflammation and cell death or survival.
3. Astrocytes (not shown) – these function in maintaining an appropriate chemical environment for neuronal signalling.

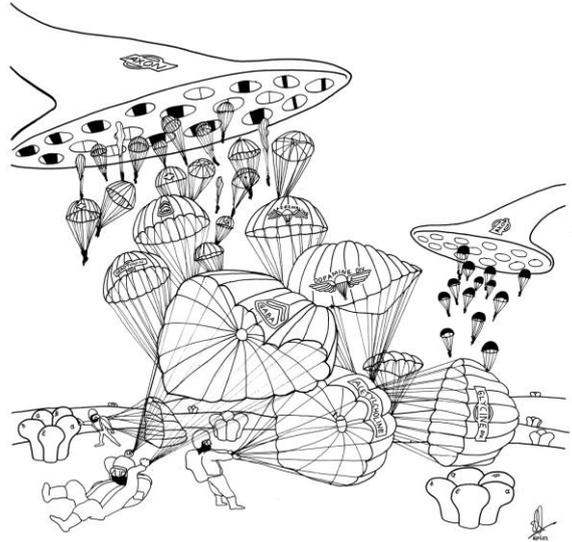




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## Synapse

The *synapse* is where a neuron transmits a signal to another neuron. It is located at the axonal terminal (see *brain cell* section). Neurons communicate with one another by releasing chemicals which travel across the synapse to receptors on a neuron in the vicinity. This is required for all brain activity. These chemicals are called *neurotransmitters* and are pictured as 'little parachutists' in the synapse picture. You can see the receptors too – one of the little parachutists is touching it and so communicating across the synapse. When enough of these receptors are activated, it either stimulates or inhibits a signal in the receiving neuron.



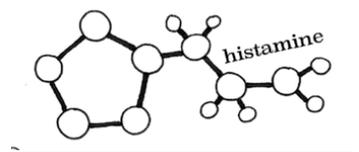
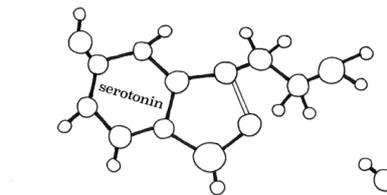
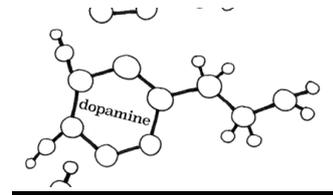
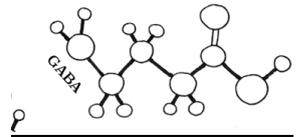
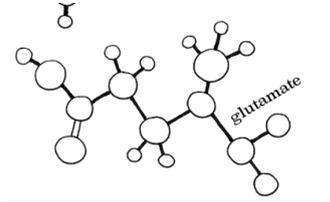
## Neurotransmitters

Neurotransmitters are the chemicals responsible for mediating all activity in the brain and nervous system. Some neurotransmitters are excitatory and others are inhibitory i.e. some enhance the activity of the Neuron they reach while others dampen its activity. The main excitatory neurotransmitter is *glutamate* and the main inhibitory is *gamma-aminobutyric acid (GABA)*. Other examples of neurotransmitters include *dopamine*, *serotonin*, *acetylcholine*, *noradrenaline* and *histamine*.

*Dopamine* functions in our reward system: our brain rewards us with positive feelings when we do something that is good for us, for example eat or exercise. The problem is that certain substances, many illegal drugs for example, can trick the reward system into releasing dopamine and therefore give us the rewarding feeling but in response to a stimulus that may be harmful. This is the basis of addiction. Furthermore, in certain disorders of the brain, the reward system may not be working properly. For example in schizophrenia there is a lot of evidence for disruption to dopamine levels in areas of the brain involved in reward and motivation (prefrontal cortex and striatum).

*Serotonin* is often thought of as the “happy” neurotransmitter. It functions in mood regulation and is thought to contribute to the feeling of well-being. Some illegal drugs also increase levels of serotonin in the brain, leading to feeling of elation. Furthermore, there is evidence for decreased levels of serotonin in the synapse of people suffering from depression.

*Histamine* functions in the sleep-wake regulation, specifically it increased wakefulness and prevents sleep. Histamine however also functions outside of the brain, and can contribute to the symptoms of allergies and hay-fever. This is why hay-fever or allergy tablets, which block histamine functioning, called “anti-histamines”, can also cause drowsiness as a side-effect.





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## **Biomarker Sea**

In medicine, a *biomarker* is defined as a biological indicator of illness. Of importance in particular to psychiatry, these biomarkers are objective diagnostic tools. Biomarkers for brain disorders can be found in brain tissue (from a post-mortem), or in cerebrospinal fluid (the fluid that surrounds the brain and spinal cord). However the most clinically useful biomarkers are in the blood (it's much easier to obtain). In the *biomarker sea* red and white blood cells (which look like little rafts), and buoys (to represent biomarkers) are visible bathed in plasma.



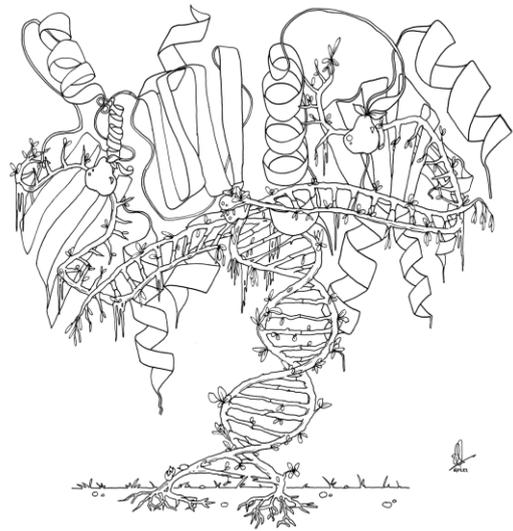


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## Translation Tree

The translation tree represents how we inherit certain traits from our parents (the seed). The trunk of the tree is a double-helix of DNA (deoxyribonucleic acid). DNA is packaged and organised into structures called chromosomes. Human cells have 23 pairs of chromosomes: 1 pair of sex chromosomes which determine a person's sex along with sex-linked genetic traits (the X and Y chromosomes) and 22 pairs of autosomes containing all other hereditary information. The genetic code is *translated* into a trait in two steps: First the conversion of DNA to *messenger RNA (mRNA)* is known as transcription, and secondly the mRNA is translated (as in converted from one language or code into another) into a specific amino acid chain. This second stage is called *translation*. The resulting amino acids are used to make our proteins –the building blocks of our bodies. In this image the double helix of DNA splits in two at the top, and two strands of mRNA can be seen at either side resulting from transcription. There is a pear on the strand of mRNA, which represents the ribosome –where mRNA is being translated in a protein. The protein is depicted as many loops and coils (i.e. the leaves of the tree).





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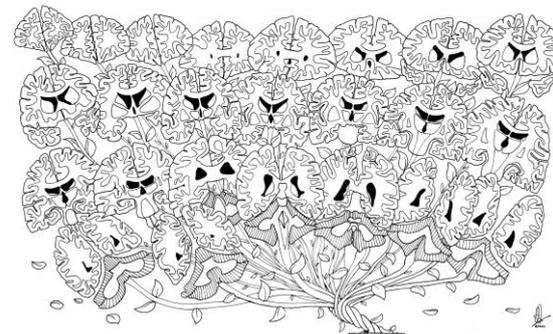
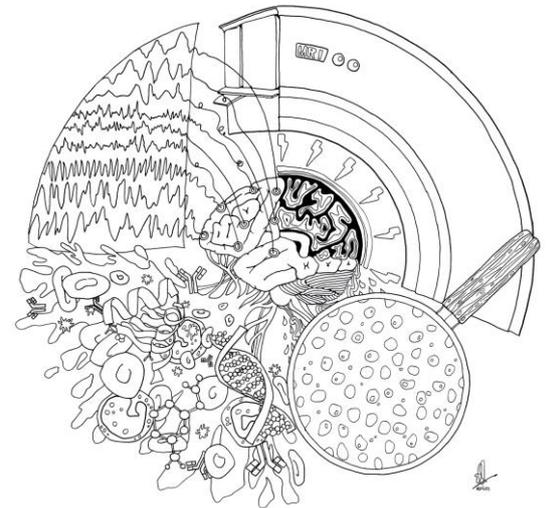
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## Investigating the brain and Inside the brain

This drawing shows a small portion of the variety of methods available to us to investigate the brain and nervous system. CT (computed tomography) scans, MRI (magnetic resonance imaging) and EEG (electroencephalogram) share the ability to safely probe the living brain. CT scans achieve this by using a narrow X-ray beam and a row of detectors, on opposite sides of the head, which rotate around in order to collect radio-density information of a thin slice of the brain, from every orientation. Radio-density, in this case, refers to the inability of X-rays to pass through the brain. CT scans are most suitable for detecting haemorrhages or tumours.

MRI scanners (seen in the upper right section of the *Investigating the brain* picture) manipulate magnetic fields and radio waves to construct detailed spatial images of the brain, at any location and orientation. MRI scans are often used to detect diseases caused by de-myelination (loss of myelin) such as multiple sclerosis.

Finally, EEGs measure the electrical properties of brain by placement of electrodes on the scalp (electrodes shown attached to brain in the centre). The properties of neural oscillations or 'brain waves' (shown in the upper left corner) can become abnormal in neurological diseases such as epilepsy. The magnifying glass in the lower right corner represents the use of biological techniques in order to study the molecular components of the fluid surrounding the brain; to obtain information about brain health. We can look for biomarkers in this fluid, or in the blood, to help diagnose diseases in the brain.



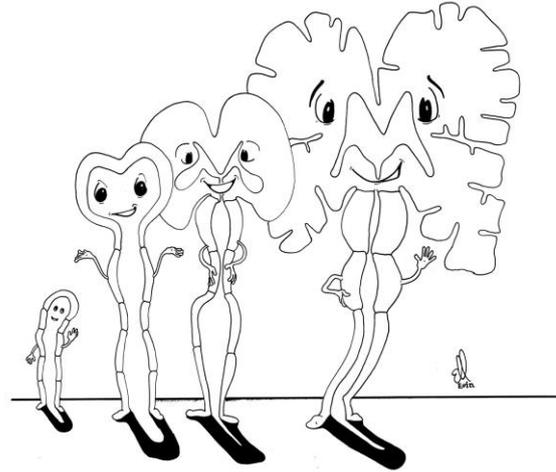


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## **Brain growing up**

This process is referred to as neurodevelopment. The central nervous system is derived from a portion of the outermost tissue layer of the embryo (the neural ectoderm). A series of divisions then take place resulting in a neural tube (which is the source of the majority of neurons and glial cells) filled with cerebrospinal fluid. The neural tube bends and expands to form primary regions of the brain: the forebrain, midbrain and hindbrain. In humans the forebrain develops more than in other animals, accounting for our greater cognitive abilities. These regions enlarge and further divide to become the 'mature' brain areas. Newly generated neurons migrate to different parts of the developing brain and organise themselves into different brain structures. Once the neurons have reached their positions, they extend axons and dendrites (see *brain cell* section). This process of development does not stop once we are born, but continues into our early twenties, and in some cases beyond this. Our brain is however more 'plastic' or malleable when we are young, which explains why children can absorb knowledge at a greater pace than adults, for example it is much easier for a child to learn a new language.





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## Hormones

Hormones, like neurotransmitters, are signalling molecules. However, there are a number of distinctions in terms of how and where they transmit signals. Hormones are involved in processes such as metabolism, growth and development (e.g. in puberty), reproduction (e.g. ovulation, menstruation and the production of sperm) and in mood regulation. The glands that produce and secrete hormones make up the endocrine system. One of the most important glands is the pituitary gland, located on the undersurface of the brain. The pituitary coordinates the activity of other glands such as the adrenal glands (which secrete many hormones including cortisol and adrenaline which are both important in the 'stress response'), the thyroid gland (which secretes hormones including thyroxine which is important for growth and metabolism), and the reproductive glands (the ovaries or testes which secrete hormones like oestrogen and testosterone). We depict the pituitary here as a master puppeteer which controls the body through the release of hormones, which in turn regulate other glands and organs (such as the brain – see *Emotions*).





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## Emotions

The culmination of the processes discussed here is *emotions*. The frontal and temporal lobes are highly involved in emotional response and personality. Furthermore, the limbic system is often referred to as the 'emotional brain' because it is here, specifically in a structure called the amygdala, where our basic emotions are processed. Fear, joy, anger, disgust are examples. Our genetics can also affect our emotional responses to things by affecting our hormones and neurotransmitters. Similarly, the exposure to stress in many forms (influenza, appendicitis, parental divorce, bullying at school) can cause imbalances in these systems.

