a squishy wonder

brain structure and function

Written by Sue Younger, MA(Hons), MCW (Hons), DipTchg, DipProfEth, Trustee

It's soft, and sort of spongy. It's much more squishy than we think, because we often see images of brains that have been preserved. Unpreserved, the brain is fragile and soft. Because it is so delicate, we have a bony cage, our skull, to protect it, and it also floats in fluid. The average adult brain weighs only about 1.4kg.[1] Researchers claim it is the most complex structure on earth.

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The brain is responsible for so much. It's involved when we breathe and when we digest our food. It helps us to move and to keep our balance. It creates our emotions, our behaviour, allows us to love, and to laugh. It promotes our survival. It is responsible for dreams, and it monitors our body to see whether we need a drink. And much much more. The brain is part of the central nervous system and works with the nerves throughout the body and our five senses, sending messages back and forth constantly. Through it we 'read' and respond to the world

We know a lot more about brains than we used to. But there is still a lot that is a mystery. It's worth remembering that there is much we do not yet understand about the complex way in which brain regions communicate with, and influence, each other, the rest of the body, and us as people.[2]

1. Dekaban & Sadowsky, 1978
2. Center on the Developing Child at Harvard University, 2016

Let's start with the tiny cells, that make up all the parts of the brain.

What is a cell?

A cell is a tiny chamber, bound by a membrane,which is a sort of 'skin' that can let some things in and keep others out. It can only be seen under a microscope. In the centre of each cell is the nucleus, which contains DNA unique to each person, and which instructs the cell to do its specific job.

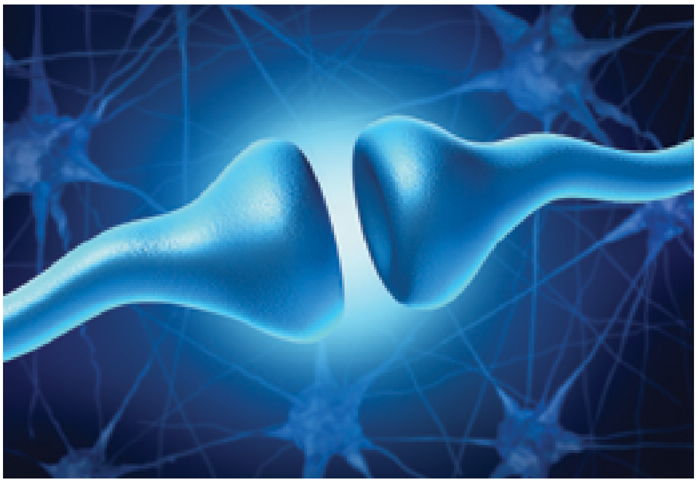
There are hundreds of different types of human cells. They join together to make up organs and limbs, nerves and muscles, blood and much more. Every living thing is made up of cells.

Brain cells

A human brain is made up of billions and billions of tiny brain cells.
There are two main types:

1. Neurons are nerve cells, that send and receive messages
2. Glia (the Greek word for glue) are various types of 'caretaker' cells that support, protect, and strengthen the neurons.[3]

Neurons and Glial cells work together to make the brain do what it does. We are only just beginning to understand the way this works.



Neurons

Neurons can look different in different areas of the brain, but they generally have each of these:

1. a CELL BODY which contains both DNA and tiny structures which are responsible for all sorts of busy work within the cell, such as producing its energy, making neurotransmitters and more.
2. an AXON –- a kind of tube structure, a branch along which messages are sent. This can be long or short.
3. many DENDRITES, tiny little twigs and branches that RECEIVE messages from other cells.

It is estimated that there are a massive 86 billion neurons in the brain[4], but they are not evenly spread throughout, i.e. some areas are much more dense in neurons than others. Glial cells are there in roughly the same number, it is thought. These number are unimaginably large.

Synapses – A Contactless Message Delivery Service

But these billions of cells are no good on their own. They need to communicate with each other. And to do that, they need some super high-tech equipment.

> The brain is a set of integrated circuits that function as a whole.

The neurons set up SYNAPSES, or 'connections', in the little gaps between neurons. Most commonly, the end of an axon and the dendrite of another neuron organise themselves so that the cell can convert the 'electrical' messages that come hurtling along the axon into 'chemical' messages.[5] They use cool chemicals called neurotransmitters. There are about one hundred identified neurotransmitters in the brain (glutamine, serotonin, dopamine and noradrenaline are some you may have heard of). A little sac on the end of the axon releases the chemicals into the gap and then the dendrite is all set up to receive them, re-converting the messages to 'electrical' signals. In most cases, the two neurons never actually touch. It's a kind of contactless delivery. The glial cells often then come along and clean up, re-cycling the neurotransmitters.

But the synapse doesn't always send the message. Sometimes the job is to STOP the message going further, i.e. to BLOCK the message from that part of the brain. To allow this 'send or block' function to work, when the neurotransmitters reach the surface of the next neuron they work like a lock and key with receptors on the next neuron. They can either trigger an impulse travelling down the next neuron, or inhibit it. Synapses, because of the lock and key system, can work like people with lollipop signs on a crossing. STOP or GO, they can say. But this over-simplifies it – neural networks are exquisitely precise, working with impenetrable complexity.

Strengthening Connections – Myelination

Myelin is a fatty covering that is wrapped around the axon, allowing the messages to move faster and more efficiently. In many areas, those connections that are used the most often become the most protected by myelin. A type of glial cell is responsible for myelinating the brain connections. Myelin looks white when you cut open the brain, so areas with lots of myelination are called 'white matter'. Less myelinated areas and the neuronal cell bodies are called 'gray matter.

Neural Networks

Each one of these little messages and synapses carries only a small part of the information, and a tiny bit of the picture. Neurons are also interconnected to form networks that work together for the exchange and processing of information. The brain is a set of integrated circuits that function as a whole. Many of the pathways along which messages travel are used again and again and, through myelination, they become very fast indeed.

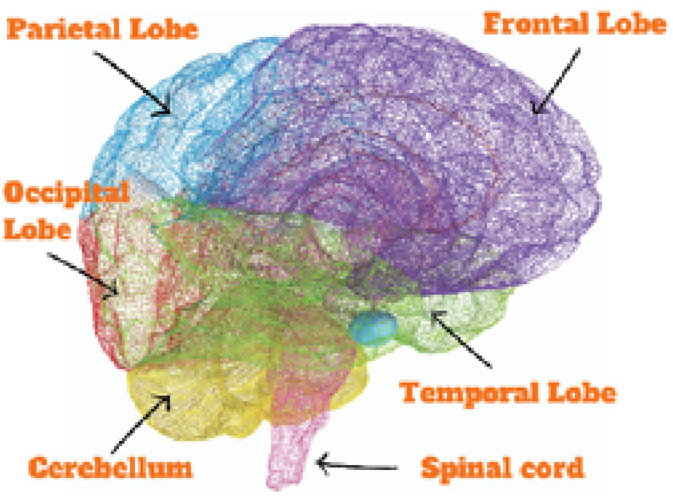
Some of the networks involve back and forth communication with the rest of the body. Others – those for thinking, calculating, and dreaming, for example - happen entirely within the brain.

3. Henstridge et al., 2019
4. Azevedo et al., 2009
5. Webb et al., 2001

Brain Structure

Brains are multi-layered.We can analyse them in many ways: left and right hemispheres, outer layers and inner layers, brain regions (such as the cortex) and specific structures (such as the medulla, amygdala etc.). All of these layers and structures work together, even though they can be highly specialised in some ways.

It's a bit like trying to understand a city. Sometimes we just divide it up into North, South, East and West. We often map it from above. Or we can look at it suburb by suburb. It can be seen as a set of railway stations joined by tracks, a road network, or a series of waterways. Every person in that city is doing their own thing, but we can also divide all the people into families, or into communities by where they live, which sports teams they support and much much more. Each will give us part of the picture.



And all of these things run into each other, and overlap and interact. No one of them gives us a "true" picture of that city, but it all helps us understand, describe and find our way around the city.

In the same way, although different regions of the brain can have separate jobs, they are all extensively interconnected, and the brain functions as a whole. For the purposes of understanding the crucial learning and brain development in the first years of life, it is useful to understand a little about the following regions of the brain.

An Outline of Four Regions.

1. **The Brainstem.** *Survival, Consciousness, Brain and Body Communication*

Where the spinal cord meets the brain is the first area of the brain to develop. The brainstem helps to control the survival functions of the body (e.g. breathing, digestion, circulation) and has an important role in maintaining consciousness. All messages between the brain and the body must travel through the brainstem.

2. **The Cerebellum.** *Movement, Motor Memory, Co-ordination*

The cerebellum (the bulge at the bottom of the brain, behind the top of the brain stem) is mostly involved in motor coordination, posture and balance. It takes input from other areas of the brain to regulate and fine-tune movement. Its other prominent role is in the memory of motor activity that has been learned - e.g. speech, riding a bike, playing a musical instrument, touch typing. The cerebellum represents only 10% of the total brain

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volume, however it has more than 80% of the brain's neurons. This may because movement is so complex. It is said that cats have a relatively larger cerebellum which, in conjunction with their intricate inner ear and balance system, is why they can always land on their feet if they fall from a height.

3. **The Limbic System.** *Survival, Emotions, Reactions, Threat, Memory, Appetites*

Deep within the brain lies a set of structures which we sometimes group together as the Limbic System. They are above the brainstem, but hidden under the outer layers of the cerebral cortex.

The Limbic System is crucial in our behavioural and emotional responses. It is important for our survival: for feeding ourselves, in raising our young and, importantly, in the fight or flight responses that help us react to threat. Some of the structures in the limbic system:
The relay station for many of the constant messages the brain receives from the eyes, ears, skin and internal organs is the ***Thalamus***. All of these messages go through this region for processing, on their way to other parts of the brain. It is also yet another brain region that plays a function in motor control.

The ***Hypothalamus*** is only about the size of a pea, but is involved in releasing many of the hormones needed for body functions. The hypothalamus monitors and controls daily sleep/wake cycles, appetite, thirst and similar functions. and also plays a role in emotions. In addition, the hypothalamus is crucial in survival functions, the things that we do without thinking, such as heartbeat, breathing, and blood pressure. As if that is not enough it also plays a large part in motor functions and movement.

The tiny almond-shaped ***Amygdala*** is far more important than its size would suggest. It plays a large role in producing our emotions, especially fear. The amygdala attaches an emotional significance to our memories, and helps in storing and classifying 'emotionally charged 'memories, in other words, those memories that come with strong feelings.[6] It is essential in our social behaviour. The amygdala has been found to trigger physical responses to strong emotion, such as sweaty palms, freezing, fast heart rate, fast breathing and the release of stress hormones.

The primary role of the curvy sea-horse shaped ***Hippocampus*** is in memory. Crucially, it processes and stores new and temporary memories, prior to long term storage. It also plays a role in storing and retrieving long-term memories.

4. **The Cortex** *Thinking, Calculating, Perceiving, Language, Logic*

The wrinkly pinkish outer layers of the larger part of the brain are called the cerebral cortex. It is dense in neurons that

6. Braun, 2011

are not myelinated; it is largely grey matter. Humans have the largest cortex of any animal. The cortex is divided into four lobes; frontal, temporal, parietal and occipital lobes, each with different functions.

The cortex is responsible for things like logical thinking, decision making, perceiving, understanding language and producing language. It is heavily involved in interpreting what we experience through our senses.

Half a Brain? Those Two Hemispheres

From above, the brain is also divided into two very similar, inter-connected hemispheres. They do have somewhat differing functions, but almost all talk of 'right brain' and 'left brain' we hear in the community is an inaccurate over-simplification. The corpus callosum, found in the middle of the brain, connects the two hemispheres of the cortex. It consists of approximately 200 million myelinated fibres. The function of this area is to integrate the activities of the left and right hemispheres, in itself, a remarkably complex business.[7]

The regions described above are just some examples of the way we understand brain structure and function: there are many more.

Conclusion

Brains are amazing, but complicated. Learning about them can be frustrating and confusing, but is also very rewarding. There are real 'a-ha' moments when they help us understand ourselves and others. But nothing is ever simple.

Since they make us who we are, and we are all so much the same, and yet so different, they are endlessly fascinating.

In the context of child development, just a little understanding of brains and the way they 'connect up' in the early years is very useful indeed.

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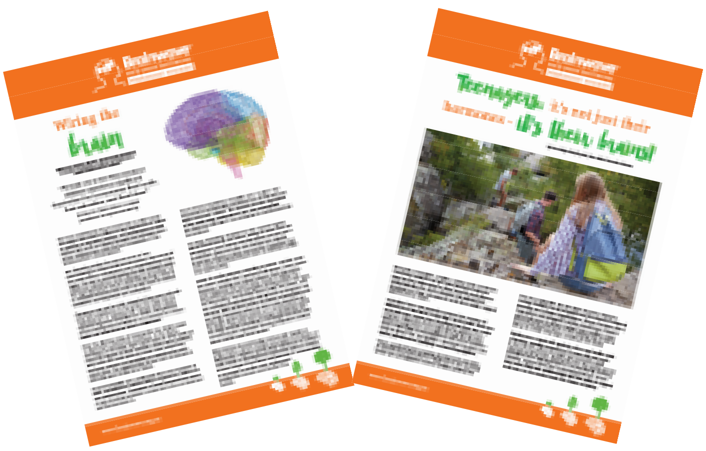

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7. Lenroot & Giedd, 2006,