Anatomy, Physiology & Brain Networks: The Basics

(This article is complementary material to Tutorial 1)

Anatomy and physiology is about what bits of your brain are called and where they are and a bit about what they do. There are diagrams in the galleries that also might be of interest when you're studying brain anatomy.

Directions and positions for Samurai Warriors (Not for the squeamish)

We hear a lot of scientific names for brain bits such as 'anterior cingulate gyrus', and 'Saggittal section'…What do terms like 'anterior/dorsal/saggittal/ispilateral' mean?

These are directional labels for the orientation and position of parts of the body and brain in 3D space. Imagine you are holding a Samurai sword...

- Anterior –If your opponent has an Anterior Flush it means they have a redness towards

the front of the head or the body (opposite to posterior).

- Caudal –in gutting a fish, this means towards the tail end. In humans only (because we stand upright and most animals don't), the term 'caudal' means 'towards the back of the brain AND/OR bottom of the spinal cord' . You can use the same term for damage to an opponent of either kind.
- Contralateral –on opposite sides of the brain or body, for example if you slice off your opponent's right ear, the ear that is contralateral to the wound is his left ear.
- Coronal –a 'coronal section' of the brain [for example viewed in MRI] is a slice from left to right on a vertical plane. If you stood at the side of an opponent with a samurai sword and struck straight down, you'd do a coronal section.
- Dorsal –in humans only [see 'caudal', above], the 'dorsal' direction changes depending on what part of the body we are viewing. In the brain it means 'towards the top', but in the body it means 'towards the spinal cord', which of course is at the back! Human posture has caused a great deal of trouble both for mammalian classification and close-quarters combat.
- Horizontal –a 'horizontal section' of the brain is a slice from left to right through a horizontal plane. If an opponent was standing upright facing any direction and you swiped horizontally with a samurai sword, you'd do a horizontal section
- Inferior –towards the bottom
- Ipsilateral –on the same side of the body or brain, for example the elbow that is ipsilateral to your right hand is your right elbow
- Lateral –a plane from left to right
- Medial –a vertical plane from front to back through the middle. If you stood facing an opponent with your samurai sword and struck straight down in the middle, you'd get a medial section.
- Posterior –towards the back of the head or the body. If your opponent gets a 'posterior flush' he is either a redneck or is shitting himself.
- Rostral –in humans only [see 'caudal', above], the term 'rostral' means 'towards the front of the brain'. In the body, it means 'towards the top of the spinal cord'.
- Saggittal –a 'saggittal section' of the brain is a vertical slice from front to back, just like a medial section except not necessarily in the middle. If your opponent stepped a bit sideways as you attempted a medial swipe, you'd end up doing a saggittal section.
- Superior –towards the top
- Ventral –in humans only [see 'caudal', above,] 'ventral' in the brain means 'towards the bottom' but in the body, it means 'towards the front'.

Your Nervous System

Your brain is to be found inside your head, in-between the ears :)

Together with your spinal cord it makes up the Central Nervous System [CNS]. Obviously you have nerves all over your body as well, and they're part of the Peripheral Nervous system [PNS].

The branch of the PNS that takes care of your innards and how they behave is called the Autonomic Nervous System [ANS], and the branch that gives you your ability to move your muscles and feel things with your skin is called the Somatic Nervous System [SNS].

In neurohacking, we'll learn that each can be influenced by the other to our benefit.

The PNS

The PNS, and various areas in your brain, form the interface between your body 'in here' and your environment 'out there', and is sometimes called your 'sensory/motor system'. This is how your actions can be linked to your needs and the environment via locomotion and sensation, pressure, pain, and skin temperature. Some of the longest nerves in the body are in the PNS because it's quite a long way from your brain to your foot, for example.

The ANS

The ANS, and a part of the bottom of your brain called the Hypothalamus form the interface between your brain and your body. This is how your actions can be linked to your mood and behavior, because the Hypothalamus uses hormones to get the body and brain to do things.

It's permanent job is to maintain a stable environment inside the body; not too hot, nor too cold, blood pressure just right, digestion adjusted so that you get the most energy available out of what you've eaten, lungs taking in just the right amount of air, kidneys busy filtering out wastes, and so on. Adjusting all these body systems constantly into a balanced healthy state is called 'homeostasis'. So the ANS is like a 'bus' transferring information about the state of internal organs to the brain, and information about the state of the brain to the internal organs.

This is essential because we evolved in a world where we were quite likely to die without the ability. Our biology has to cope with a lot of variety and adapt adequately to sudden changes in what is going on around us. The ANS and PNS have to work in synchrony for a beneficial result.

Blood-Brain Barrier

Your body is the interface between the external environment and the brain, with only the blood/brain barrier as a firewall between body and brain. This firewall can be a pain in the ass to hack around, from a chemical point of view, because it protects the brain from infection or poisoning and you cannot turn it off. It needs to be considered when learning about drugs and chemicals, but that's another tutorial.

Neurons

Neurons are nerve cells; what nerves and networks are made up of. Although the neurons in the brain are indeed mixed together like a bundle of spaghetti, they do have their main parts [called their 'cell bodies'] in certain areas. Most of the "grey matter" in your brain is nerve cell bodies, the "white matter" is made of their long tails, or "axons". Neurons also have bushy protuberances called "dendrites".

An interesting thing about neurons is that they're not purely electrical conductors but are [mostly] electro-chemical, like batteries. They behave like an EMP [ElectroMagnetic Pulse] weapon in that they build up a charge, and only fire if the charge is sufficient. After firing they have to recharge before they can fire again, but fortunately for us this happens very, very fast [speeds of up to 120 metres per second!] A neuron 'firing' makes it release chemicals that transmit the 'message' to the next neuron along, and they do not actually touch; the chemicals 'bridge a gap', and that gap is called a synapse.

The Cell body is the 'command centre' of the neuron. Axons make up the long fibres that we normally think of as 'nerves', and they spread out all over the body. In the brain, axons form the

'white matter'. Axons are output lines.

Dendrites are input lines, and they look like leafless trees.

It's important to notice here that information flow has a definite direction, and not get confused by the fact that axons send information both from and to the brain! Axons can be an output line from anywhere, but when they get to their destination, they pass their information over to dendrites or the cell body. Dendrites are receivers of input and Axons are transmitters of output…now you've got it. A cell 'firing' is called an action potential.

Synapses

Synapses are the teeny gaps between neurons that the chemicals cross to deliver the signal, and they are very important in neurohacking. So don't forget about them okay?

Synapses have three parts. They are:

- The Presynaptic Terminal –the signal sender
- The Postsynaptic Terminal –the signal receiver
- The Synaptic Cleft –the gap in-between.

There's more information about synapses in the "Drugs & Chemicals" Section introductory tutorial.

Neurotransmitters

Neurotransmitters are chemicals that the brain uses for communication. They are normally stored in little bubbles called vesicles, on the presynaptic terminal. When an action potential reaches the presynaptic terminal, the neurotransmitter is released by exocytosis and crosses the tiny gap. Due to its specific chemical function, it activates receptors on the postsynaptic membrane. A sequence of very specific events then leads to a change in the electrical properties of the neuron on the receiving end by making it more or less likely to produce an action potential. The postsynaptic neuron integrates the information transferred through all of its synapses and determines whether or not an action potential is generated.

There's lots more information about neurotransmitters and what they do in the NH tutorials.

Brain Networks

Most of our neurons communicate like this. Size of and density of connections in neural nets is dependent on how much those nets are used. The type of use determines their architecture and the differences between us. The pattern of connections or synapses each neuron makes with other neurons is unique and determines the path taken by future signals as they travel inside neuronal networks. Small changes in the patterns of connectivity can occur, for example by increasing or decreasing the number of synapses or even changing the shape of a synapse. These differences in the arrangement of synapses distinctly influence the flow of information and the way it is processed by the nervous system. These small changes in connectivity, known as synaptic plasticity, play an important role in the mechanisms underlying memory, learning, and intelligence.

Anatomy began long before we knew very much about the brain. Physically the brain looks like any other organ; it's a lump of tissues. So originally it was divided into the three bits that are first apparent in an embryo; the 'forebrain', the 'midbrain' and the 'hindbrain'. Now, we know that inside the brain there are networks of nerves tangled together like a load of spaghetti and there's no way you could take out a section of tissue without getting a sample of bits of axons originating from all over the brain.

It makes more sense for neurohackers to work with the brain as a series of neural networks, rather than by anatomical division, because we can work on sets of networks that correspond to brain functions, such as memory or emotion. The main networks controlling the functions required for intelligence are only a few in number, which makes our work much easier, and they also correspond to the areas called 'matrices' in Matrix theory, which is handy.

There are six main networks we work on in neurohacking. They are complex and really need a tutorial in their own right to explain adequately so there's loads more information about what they do in the main NH Tutorials section of the files and graphic guides to networks too.

We often refer to "network hubs" of the brain as areas where the networks have their 'centres', even though we know that their axons spread out throughout the brain; (just as we can relate to microchips as 'hubs' in a circuit between all the wires, even though the circuit itself is a whole mess with wires leading everywhere.)

The brain has many different anatomical regions that are marked by textural or color differences or that are separated by fluid-filled areas, but these are not the same things as networks. Throughout the twentieth century, researchers made slow but steady progress in understanding how different networks of the brain are involved in the control of activities such as movement, hearing, speech, and emotions. They have also learned that it is not specific anatomical areas that carry out these functions alone. Instead, it is now known that different areas in the brain have to work together as networks to accomplish all the complex activities that are part of human thought and consciousness. So the brain really functions more like an orchestra than a computer.

The Cortex and Its 'Lobes'

The outside part of the brain is called the Cortex.

The brain can be divided into sections called lobes that correspond to cortical function. [Remember that this doesn't work inside the brain; only on the outside.]

The lobes are:

- Frontal [at the front; you have two of these]
- Parietal [behind the frontal lobes. –If you put your hands on top of your head behind your ears, your fingers will be over the Parietal lobe].
- Occipital [at the back]
- Temporal [at the sides. You have two of these].

The Inside

The inside of the brain contains several structures, some holes, and a couple of glands.

The holes are called Ventricles and they are the source of the fluid that your brain sits in [Cerebrospinal fluid].

The glands are the Pineal, the Pituitary, and the Hypothalamus, and they handle a great deal of the brain's 'domestic' tasks such as sleeping/waking, feeding, respiration and heartbeat. They are not normally primary targets in neurohacking because the side effects of interfering with them directly can too easily disrupt bodily functions, but they can be useful targets if bodily functions are already disrupted!

We'll now look at each brain structure in turn, starting caudally at the neck and moving rostrally [towards the front of the brain]. The functions of these parts is discussed further in the tutorials. We've placed them in their network categories so you can get a better idea of which networks are associated with what parts.

Networks 1 & 2
The Brainstem

The Brainstem is an extension of the spinal cord into the brain from below. The brainstem and the cerebellum together form most of networks 1 and 2. These networks are involved in sensorymotor processing and transfer, including such things as timing, taste, hearing and balance, sleep and the regulation of breathing, and the muscular movements for speech and muscles of the face, head and neck.

The Cerebellum

There is an extra bit of brain underneath the Occipital lobe. It looks like a small cauliflower and it's called the Cerebellum. The cerebellum is concerned with coordinating body movements.

The Hypothalamus

Below the thalamus, this structure is concerned with homeostasis and is in control of the ANS and various glands. Intimately connected with it is the Pituitary gland that releases many hormones directly into the bloodstream under the control of the hypothalamus.

Some neurons in the hypothalamus are responsive to changes in blood glucose levels [which is associated with the need to eat]. Others respond to changes in blood pressure, salt loss [associated with the need to drink]. The hypothalamus also produces many responses that are associated with the expression of emotions.

Network 3
The Thalamus

Pretty much right in the very middle of the rear half of the brain, the thalamus is part of network 3. It is in charge of information logistics –what data gets sent where and why and when. It does a fair bit of processing on incoming information in order to achieve this, and one of its main tasks is 'weighting' data [i.e., deciding on how important data is and what departments it is

relevant to]. It has different sections for dealing with different kinds of sensory input [e.g., auditory, visual].

The Basal Ganglia

These are various structures surrounding the Thalamus. Among them are the Substantia Nigra and the Striatum, important areas in neurohacking because they are a part of the 'desire' network and important in motivation, in the fine-tuning of movement, and in forming procedural memories of motor skills.

The Amygdala

The amygdalae are in the lower part of the brain, beside one end of the hippocampus. They are concerned with 'weighting' input and output and also memory, depending upon its emotional significance. The Amygdala ("Amy") is one of the most important areas in neurohacking. You have two of it, one on the left and one on the right. The one on the right assesses dangers. The one on the left assesses benefits. This is not the Amy's only function by any means, but it is an important one.

The Hippocampus

Another vitally important bit for hackers, the hippocampus [fondly known as 'the hippo'] is roughly banana shaped and curls around the brain in-between the Corpus Callosum and network 3 structures. It is responsible for much of memory processing, imagination, learning and spatial awareness.

The hippo contains special kinds of cell called 'Mirror Neurons', which give us our ability to learn from example and also to empathise with the state of others by creating a lower-intensity replica of their emotions inside our own minds. This is an incredible ability and one that hardly anyone

ever develops to the full. When they do, they get accused of being telepathic.

There are two branches of the hippocampus; one on the left and one on the right.

Temporal Lobes & Parietal Lobe

Parts of the temporal lobes, medial temporal cortex and parietal lobe are included in network 3. They are home to several functions that give us some rather remarkable abilities, from a neurohacking point of view, including what are sometimes called 'spiritual experiences'.

Association Areas

The Association area at the juncture of the temporal, occipital and parietal lobes integrates sensory input with information stored in memory and with emotional 'weighting'.

Network 4
The Right Hemisphere

Creative thought , procedures and the phonological aspects of language, including the analogical meanings of words processing almost always occurs in the right hemisphere [although see 'handedness' below]. Our ability to bring order out of chaos and our skills of social interaction rely a lot on thgis area. Long term procedural memory association, fine-tuned dexterity and tool use are also reliant on N4, as is your sense of humor, your appreciation of music and the part of your language comprehension that 'gets' jokes. :)

The right hemisphere includes the right frontal lobe and right section of the PFC [PreFrontal Cortex].

Network 5
The Left Hemisphere

Intellectual reductionist thought, analysis and the technical aspects of language [such as syntax] processing almost always occur in the brain's left hemisphere, although the brain can have a 'handedness' like hands do, and in a minority of individuals, these aspects of language are processed on the right. [we now know that speech is processed bilaterally]. The two most famous language processing areas, Broca's area and Wernicke's area, are found here and on the left temporal lobe. Your ability to assess your resources and position are network 5 skills, and much of your self-esteem and self awareness are fine-tuned here.

The left hemisphere includes the left frontal lobe and left section of the PFC [PreFrontal Cortex].

Network 6
The ACG [Anterior Cingulate Gyrus] / Cingulate Cortex

Lives in-between the Pre-Frontal Cortex and the Corpus Callosum. It's the 'command and control' region of the brain and is involved in attention, decisions, judgment, prediction, planning and strategy, especially in new or unknown experiences. It too contains mirror neurons.

Frontal Association Area

Association areas are in various places around the brain. The frontal Association area integrates ideas with actions and performs cognitive processes associated with them [such as the integration of sensory information with that stored in the memory.]

PFC [PreFrontal Cortex]

Parts of this are also included in network 6.

Brain Wiring

There are main 'busses' connecting various parts of the brain, called 'commissures'.

Main Commissures

- N4-N5 corpus callosum
- N1-N2 middle cerebellar peduncle
- N3-N4-N5 anterior commissure
- N3 to everything Thalamus [Habenular commissure & hippocampal commissure, fornix, Posterior commissure]

If any of these are slimmer than the others, they won't perform so well. Too much cognitive work too soon (which almost all of us get) overdevelops some connections and starves others. One of the main ones it starves is the anterior commissure. If this is too small, emotion won't 'connect' to cognition.

There is more information about all the brain networks and exercises for them in the main Neurohacking Tutorials.

Biological Psychology

You probably wouldn't go hacking a computer if you didn't know anything about them, and it's

scary the risks people take in doing things to their brains without really appreciating the consequences. Whatever reason you are here for, it's always good to know a bit about the brain's software as well as hardware, and to get to know the relationships between the brain, mind, consciousness and behavior.

The study of these links is called Biological Psychology and is a field in its own right. There are tutorials in the files to get you going and also links to sites where interesting research or further information can be found. You're probably best working through a few tutorials and then exploring the areas you personally find interesting.

Holistic Systems

Most recently researchers determined that hormones of the endocrine system work together with the immune and nervous systems (including the brain) to defend the body and mind. For example, both hormones and neurotransmitters (chemicals with which the brain communicates) can initiate actions in the brain and immune system in response to injury or infection. A healthy neurochemical response acts as an immune system regulator. It can dampen down the immune system so it doesn't go overboard, and stimulate it when we need extra defense.

Immune molecules, known as cytokines, can initiate brain actions. For example, some cytokines help the body recuperate by sending messages to the brain that set off a series of sickness responses, such as fever. The high body temperature of a fever creates an unfavorable environment for toxins and infections. The immune molecules also can trigger feelings of sluggishness, sleepiness and loss of appetite; behaviors that can keep sick people out of harm's way until they feel better.

Researchers found that cytokines can activate certain nerves for quick brain activation or set off actions from posts in the blood (some cytokines are produced directly in the brain).

The increasing number of links that researchers are discovering between the immune, nervous and endocrine systems has led them to discover how excess stress (anxiety) or too little stress (apathy) can abnormally alter the immune defenses. Defects in this system can also possibly lead to autoimmune disorders, in which the immune system attacks the body.

Resources For Further Study

http://www.med.harvard.edu/AANLIB/home.html

The Whole Brain Atlas

http://isc.temple.edu/neuroanatomy/lab/imaging/index.htm

Diagnostic imaging atlas

http://www.hhmi.org/senses/

Sight, hearing and olfaction (smell)

http://www.freebookcentre.net/medical_text_books_journals/anatomy_books_online_texts_download.html

Free ebooks

http://www.biopsychology.com/news/index.php?descType=always&id=2&type=chapter&page=0

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