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ACADEMY FOR DOG TRAINERS

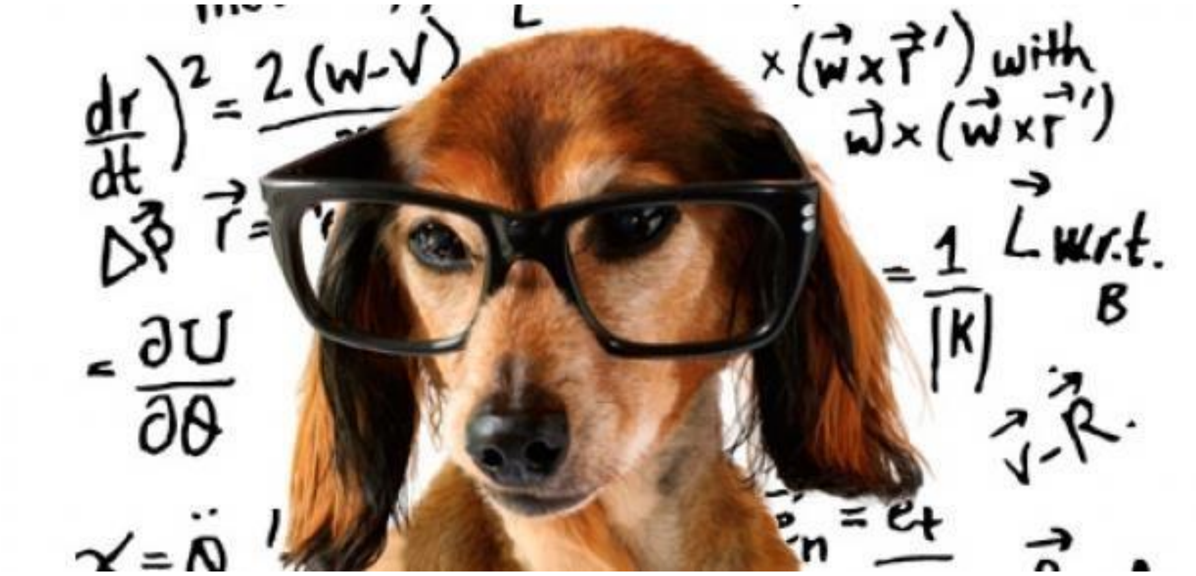
Professional Dog Training Instructor Neuroscience

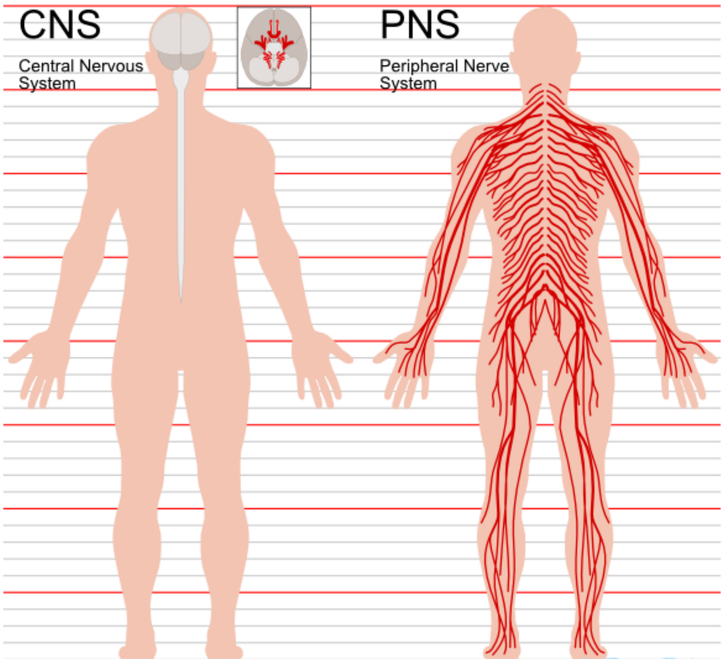
Introduction

This course has been designed to give you a superior education in relation to becoming a professional dog trainer. To truly understand behaviour you must understand how it is influenced at a neurological level so that you will in turn be able to fully understand how dogs can be a victim to their neurochemistry – that their decisions are not based solely on their personality but instead on a response to their nervous system, and this will help take the mystery out of dog behaviour for both you and your clients.

Goals of This Module

We will take a deeper look at how behaviours are triggered, what happens at a cellular level, and how this lesson can help you become a better dog trainer through understanding the internal activities of the body.



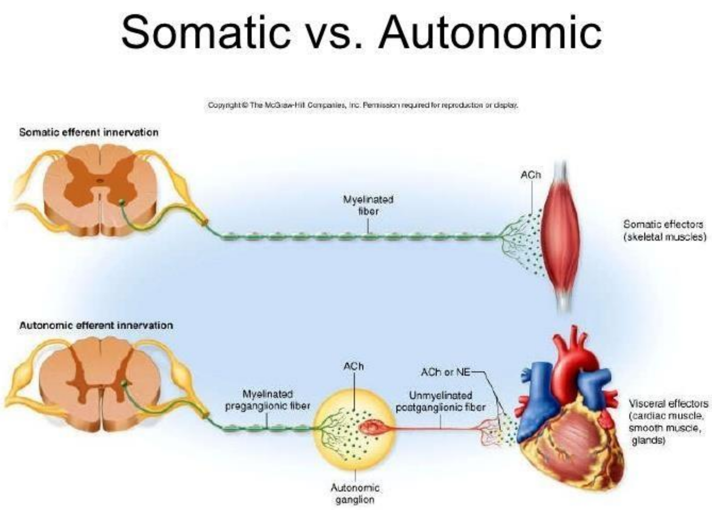


Central Nervous System

As you may remember, the central nervous system relates to the brain, brain stem and spinal cord, the main motorway of the body, where cars (messages) drive up to the head office (brain) from other towns (spinal cord gaps).

Peripheral Nervous System

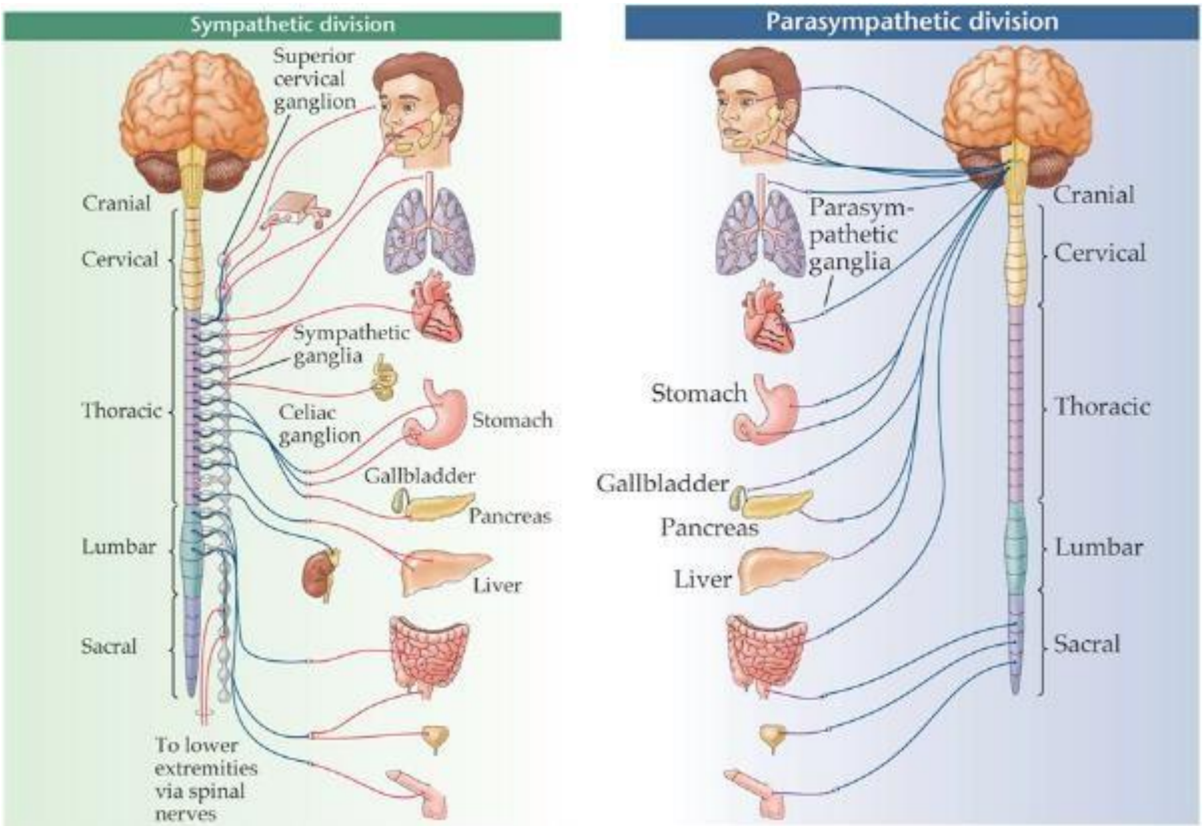
The peripheral nervous system are the national and regional roads, leading to the motorway to head office. The peripheral nervous systems have **somatic nervous systems** – this is the spy's that get the gossip from the regional offices and brings it to the bosses in head office, so the somatic nervous system brings in the information (I touched something yucky, I feel cold, I smell I tasted something sweet) to the brain. Then, after head office hear the gossip from the regional office, the **autonomic nervous system** is the security men that the bosses send out to 'get the job done', so the autonomic nervous system controls the muscles and tells the body how to respond to the information that has been brought in by the somatic nervous system.



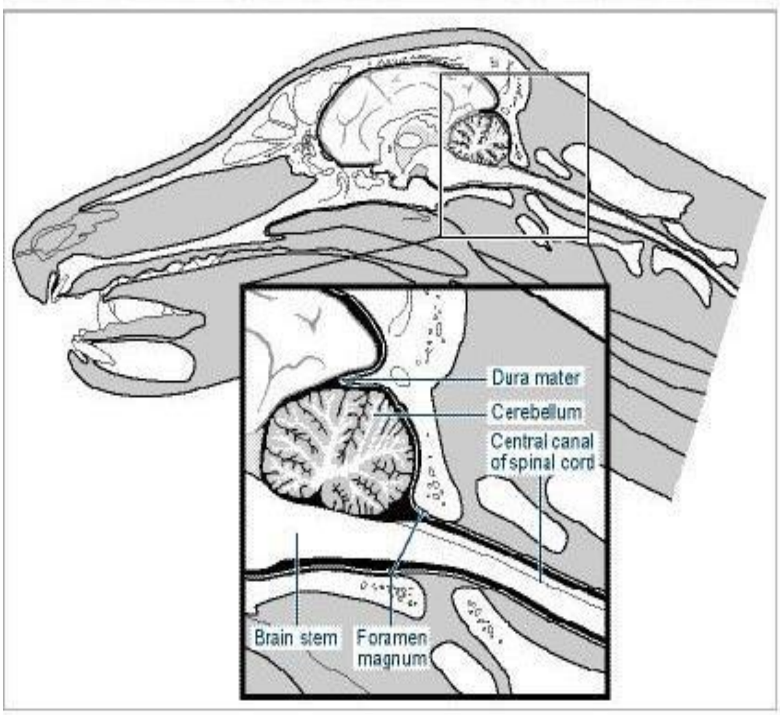
It doesn't end there. You may recall the autonomic nervous system then splits into two parts. When the body is calm the autonomic nervous system focuses on 'rest and digest', or 'housekeeping', and is said to be in a **parasympathetic nervous system** dominant state. Cell repair is occurring, digestion is occurring, and the autonomic nervous system focuses its attention on basic organ functioning.

When the body decides that it needs to become alert, the **sympathetic nervous system** becomes dominant – preparing the body for action. Pupil dilation occurs, increased heart rate, blood flow decreases to organs and increases to muscles and so on.

Dogs in a sympathetic nervous system dominant state a lot more than they should, can have serious side effects, such as compromised cell repair, compromised immune system, and increased risk of disease and infection.



The Dogs Brain



Cerebellum

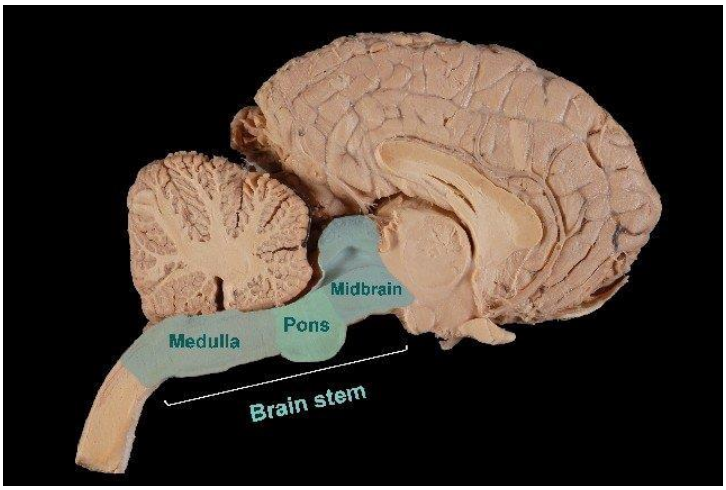
Coordinates muscular activity and movement. It smooths out movement and makes it more accurate. So, when a dog does an 'air snap' the cerebellum ensures it doesn't make contact.

The cerebellum receives information on the **motor plan** from the cerebrum about which muscles need to be contracted, how long for, and how strongly.

It then receives **position information** in sensory neurons to inform the cerebellum what it is standing on, what movement has occurred, and can see if the motor plan sent down by the cerebellum is being carried out correctly. If the dog's nails are overgrown this can send confusing information to the cerebellum. The cerebellum then sends **feedback** back to the cerebrum that created the motor plan. This can then adjust the motor plan.

Brain Stem

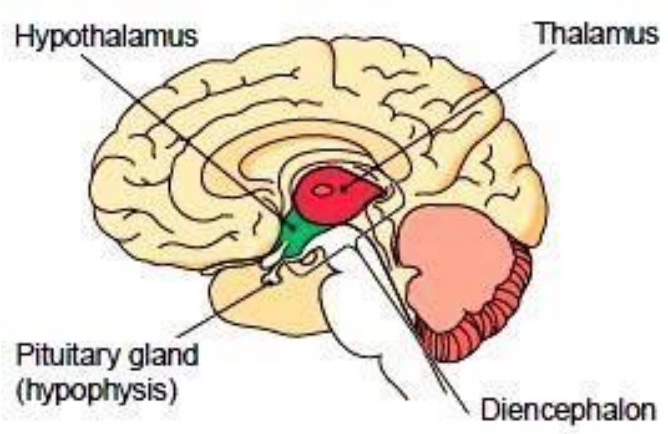
Relays information between the body and higher regions of the brain. Three components to the brain stem, the **midbrain**, the **pons** and the **medulla oblongata**. The brain stem regulates basic functions of an involuntary nature, such as regulating heartbeat, controlling the lungs, sleet, appetite, pain sensitivity, awareness and so on.



These are the troopers of the body – the civil servants that get the roads fixed, ensure that streetlights work, street bins are emptied, clear away broken glass on road sides and so on – keep the country (the body!) ticking over without anyone giving them a moments bit of notice.

The midbrain region carries out the higher-level functions. When you respond to a stimulus very quickly – such as turning when you hear your name called, or looking when a spider crosses the wall out of the corner of your eye, the midbrain takes in that information from the somatic nervous system, processes the sensory information, and sends out reflexive motor signals so that you respond without actually having to think. The midbrain ensures your rapid responses keep you informed, safe, and ready to react instantly, preserving survival. The information is then also passed on to the cerebral cortex – head office – to ensure the information is filed away or in case head office thinks further action is needed.

The midbrain is basically the undercover FBI – stepping in when a threat is imminent and keeping head office in the loop when necessary.



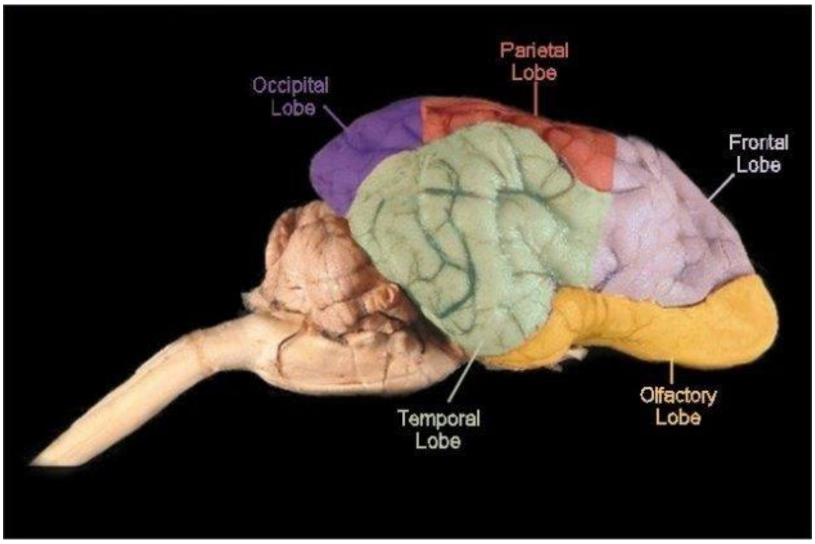
The **Diencephalon**

In this central part of the brain, you will find the **hypothalamus**, **thalamus**, **epithalamus** and the **mammillary bodies**. This keeps the body in a homeostasis state, controls alertness and is also responsible for controlling the reproductive activity of the body.

The **limbic system** is also found in the diencephalon region of the brain, and this is the centre of all things emotional. We look back at the Jaak Panksepp emotional states, and when the dog is in a heightened emotional state, whether it is fear, pain, panic, lust, seeking, rage or care, the limbic system is highly active during this period. It is a very instinctive part of the brain.

In the limbic system you will also find the **hippocampus** which stores short term memory, and the **amygdala** which controls social and sexual behaviour, and also stores memories formed through one trial learning.

The **Cerebrum**



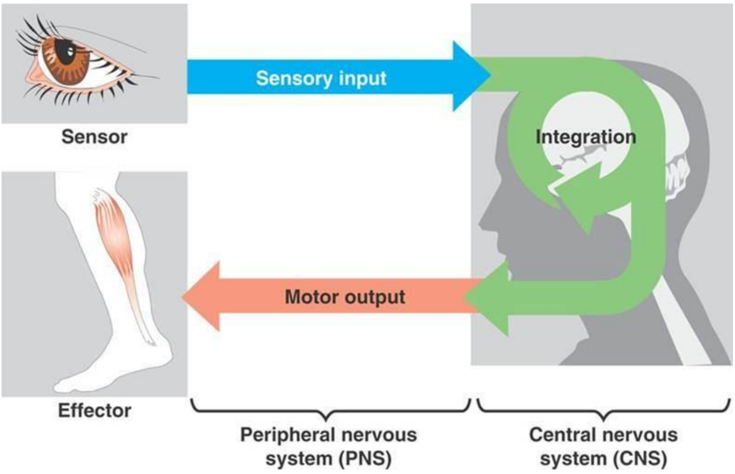
This is the largest region of the brain, performs the highest functions. The wrinkled outer layer, or 'grey matter' as you would have heard it called is the part of the cerebrum called the **cerebral cortex,** and also the **white matter** found beneath the grey matter.

The cerebrum controls voluntary movement, thinking, learning, regulating and recognizing emotions, and personality. It is folded and creased to allow for more neurons to allow for more activity.

The cerebrum has different **lobes**, the **frontal lobe** is in charge of muscle movement, motor skills and cognitive functions. The **occipital lobe** is responsible for processing visual sensory information, the **parietal lobe** processes touch, pain and pressure, and the **temporal lobe** processes auditory information, and will process verbal cues.

Neurons

Some of you might remember all about cells from your school days. Neurons are cells specific to the nervous system, and they are vitally important cells that are the be all and end all of the universe. They control your organs, your physiological and psychological activity, even the endocrine system is nothing compared to the nervous system. The neurons are the citizens of the body, from the security men to head office, to drivers of gossip, they do everything, sending messages up and down the motorway and all other roads in the road map of the body.

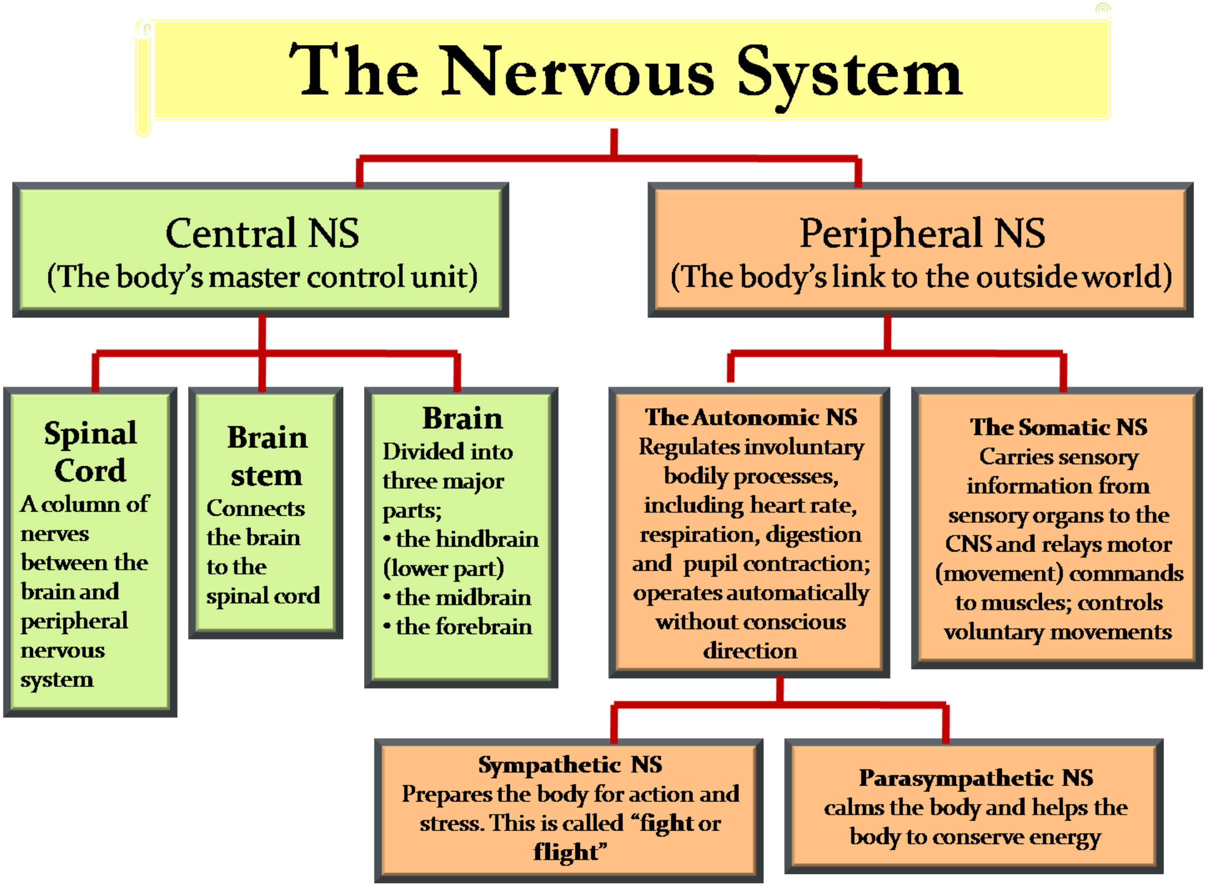


All of dog's thoughts, actions and emotions can be broken down to the very fundamentals that are the function of the nervous system, sensory input, integration and motor output.

The dog smells food, which is the **sensory input**, the **integration** is when the central nervous system processes the information of the presence of the food and processes the dog's decision about what should be done with the newly acquired information. The **motor output** is when the brain sends instructions which forms the response that occurs when your nervous system activates certain parts of the body. This could be moving the direction of the head and eyes to look at the food source, activating leg muscles to get up and move toward the food, activating the salivary glands to produce saliva, and so on.

Recapping once more, there are several levels to this. The CNS is the main control centre, it took the information of the sensory input to the brain and will take the motor output message toward the correct part of the body. The PNS is the external nerve pathways, that take the sensory information to the CNS, and then take the motor output information from the CNS to the extremities. (internal and external, fingers and organs).

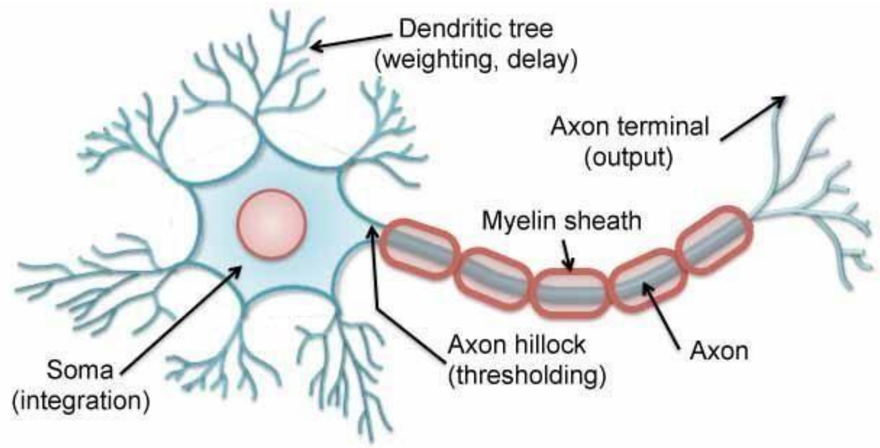
The sensory division of the PNS is also called the afferent division, it picks up sensory information. The motor division, or efferent division sends the muscles and glands. It includes the somatic nervous system which is also the voluntary nervous system that controls the skeleton and the autonomic nervous system which controls involuntary responses, heartbeat, digestion etc., and, once again, has the two divisions, the sympathetic division which gets the body ready for action while the parasympathetic division relaxes the body.



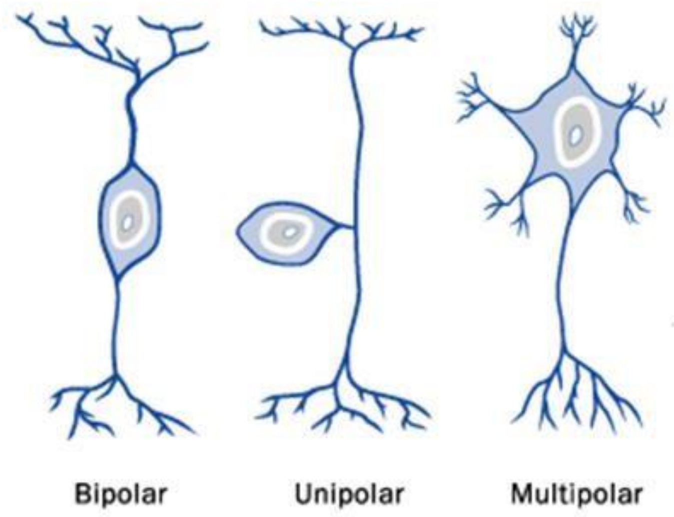
Nervous Cells

Neurons are the cells involved in the nervous system that respond to stimuli and transmit signals. They are some of the longest-lived cells in your body.

The soma is the cell body, and this is where typical cell material is found, such as the nucleus, mitochondria, ribosomes, cytoplasm and so on.



The dendrites are the listeners – they take in the information and messages without interrupting, just listening. They send the information to the cell body which is then passed through to the axon. The axon is the gossip, the talker, the one that passes on the information.



There are a couple of different types of neurons, multipolar, bipolar (retina of the eye) and unipolar (found in sensory receptors).

The type of cell shows their function – what way is the impulse travelling through the neuron?

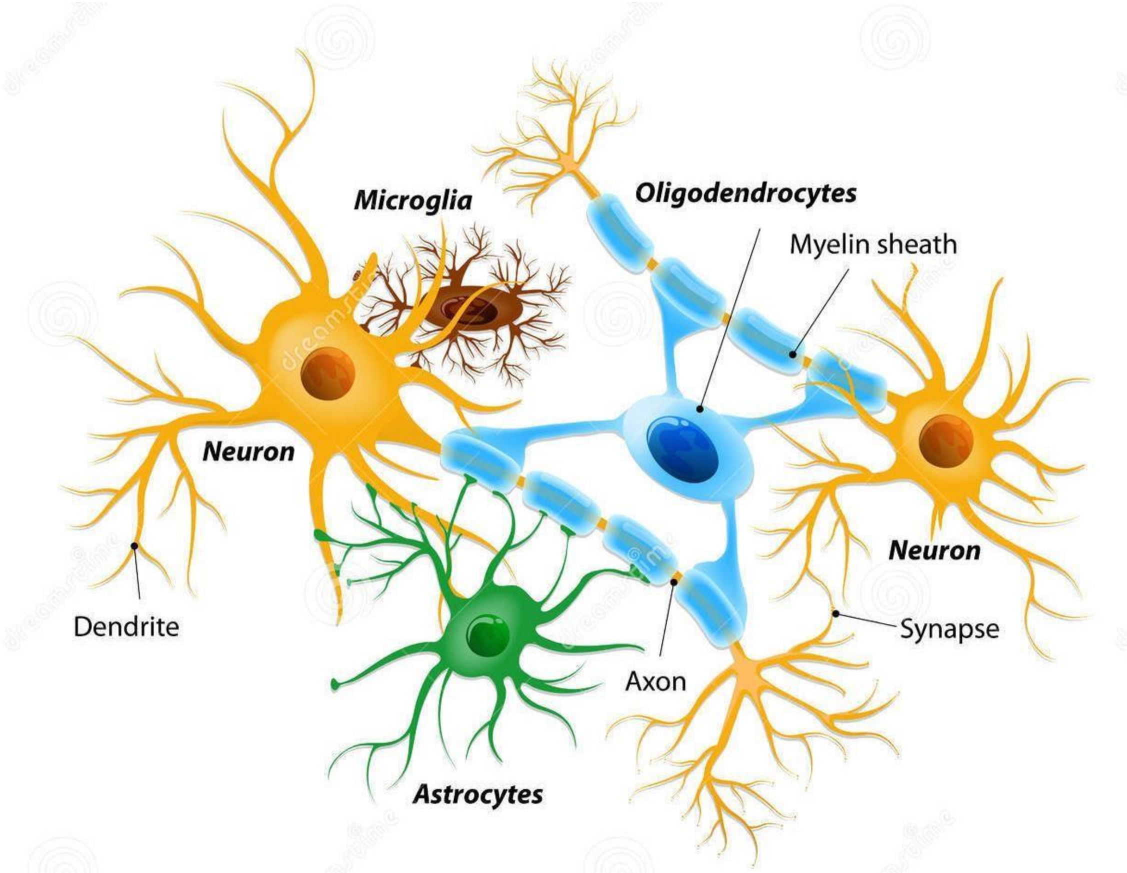
Sensory neurons (afferent neurons) take information from the sensory receptors and brings it to the CNS. The majority of sensory neurons are unipolar – they are trying to get the gossip they just heard straight to head office. Picture the road runner found out where the coyote lives so is running to the boss to tell him, he only needs one path to travel on as he speeds up to head office.

Some are bipolar, the sensory neurons for smell, sight, taste, hearing and vestibular functions are bipolar neurons.

Interneurons are association neurons that can be found in the CNS. The function of the interneurons is to pass messages between sensory and motor neurons. They are multipolar.

Motor neurons are then sending the messages back to the muscles, so have to usually spread the message out. Picture the army being sent out to carry out a security missions, they are likely to have multiple sources of intelligence to listen to and interact with to ensure all army personnel are working as a unit, so communication between lots of cells is important.

Glial Cells



Glial cells then surround the neurons, they serve many functions and make up about half the mass of the brain, glial cells outnumber neurons approximately 10:1, and play a massive role in protecting and amplifying the neurons.

Glial Cells in the Central Nervous System

Astrocytes

The astrocyte is the most abundant of all glial cells. They anchor neurons to blood vessels, and exchange material between neurons and the blood vessels.

Microglial Cells

Smaller cells, the microglial cells are the security system. They are the main immune defence against foreign bodies in the CNS.

Ependymal Cells

Line cavities in the brain and spinal cord. Cerebral fluid is created and secreted by these cells to fill up any gaps to ensure that cells are supported.

Oligodendrocytes

Wrap around neurons, insulating them with material known as the myelin sheath. This allows messages to speed along the cells and keeps cells healthier.

Glial Cells in the Peripheral Nervous System

Satellite Cells

Surround and support neurons in the PNS.

Schwann Cells

Wrap around axons and provide myelin sheath in the PNS.

How Are Decisions to Act Made?

Neurons are electrically charged, and the messages that are sent along neural paths are electrical impulses. The electrical impulse is only activated if the cell is stimulated enough into action. Once it is stimulated enough, it will activate, and the electrical current will pass through the cell in a pulsating manner. The more important the message, the more repetitions of impulses will be fired.

This is known as the **Action Potential**.

This is all going to sound extremely technical, but it's important, as this will show you why dogs react, or don't react, in different situations, and what we mean when we say a dog is sub-threshold or over threshold, or sensitised and habituated.

Resting Neuron

Neurons are chemically charged; they are basically little batteries that can push electrical impulses along neural pathways.

However, when the battery is not switched on, it’s not doing anything. So, when a neuron isn’t in an action potential state, it is a resting neuron.

When it is a resting neuron, it has particles on the inside and outside of the cell membrane. A charged particle is known as an ion. The particles on either side are sodium ions (Na+) on the outside and potassium ions (K+) on the inside when in a resting state, known as **resting potential**.

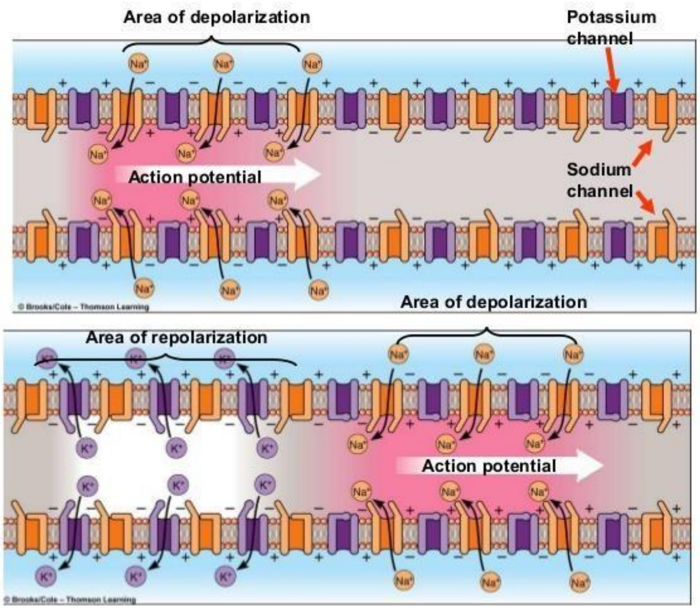
All along the cell membranes there are lipid molecules fats), and they prevent things entering or leaving the cell, as they are packed closely together. However, all over the cell membrane you can find proteins, and the proteins stick out both sides of the cell membrane, so they let things in and out – specifically they are ion channels that let particles in and out.

If you picture the cell membrane as a cue for the buffet, with lots of overweight people (lipid cells) packed closely together an hour before the buffet opens. However, intermittently through the cue there are tiny little rope barriers (ion channels) to let the cleaning staff out (potassium ions) and the cooking staff in (sodium ions).

Cells want balance, so if there is too much of one particle on the outside or inside of the membrane, it works on regaining balance. At the buffet – health and safety states that only x number of employees are allowed inside the buffet area at any one time in case of fire, so the cooking staff and cleaning staff have to balance to ensure not too many people are on duty at the same time. The ion channels (rope barriers) have gates that open and close, letting sodium and potassium particles in and out, and will depend on whether the particle is positively or negatively charged. This is like the rope barriers only opening or closing depending on what type of staff it is, and if they are on duty or off duty.

The Action Potential

When information is taken into the cell it begins at the dendrites. The membrane near the dendrites begins to open sodium gates, letting sodium ions in by the dendrites, making the cell less negative. If enough sodium is let in it reaches a certain level, this is known as the **threshold**, and once the threshold is reached more sodium gates open and even more positively charged sodium ions enter the cell. This is what is called the **action potential**, the cell has been stimulated enough to have an action potential response, which means the information will be passed on to the next cell.

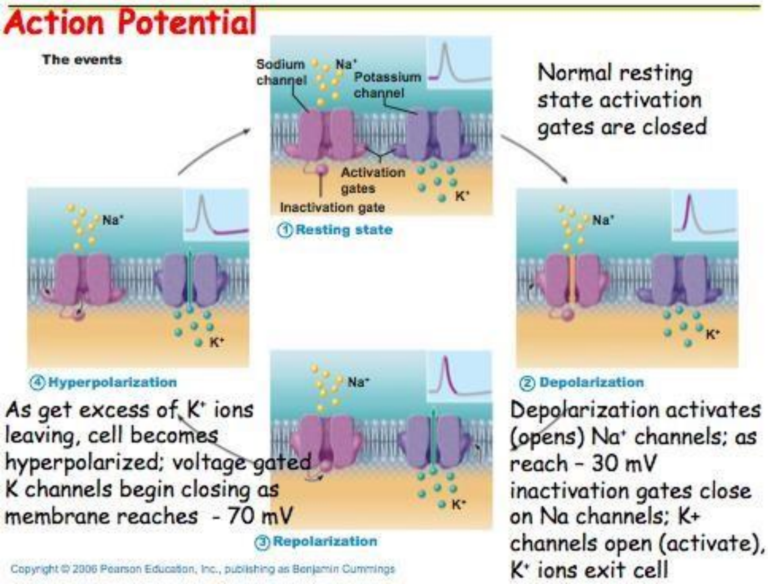


In our buffet situation, at the very back of the cue a member of the cooking staff arrives and comes through the rope barriers (gate). Then another member of cooking staff arrives. Then another. The manager sees that enough staff have started to arrive that the kitchen can open, and sends a text out saying, 'all systems go, everyone get to work now!', and all
of the other little rope barriers open up as cooking staff come into the buffet.

The cell becomes positively charged on the inside, and negatively charged on the outside because so many sodium and potassium particles are inside in the cell. This makes the cell unhappy so the sodium gates close and potassium gates open, potassium rushes out of the cell, making it negative once more on the inside and positive on the outside.

At the buffet, this is where the place becomes too stuffy and loud with all of the cooking staff and cleaning staff inside at the same time, so the cleaning staff go out through their rope barriers.

The cooking staff are inside while the action potential is active. The cell then wants to return to resting potential, so once the action potential is finished (the meals are served at rush hour) the cell wants to return to resting.



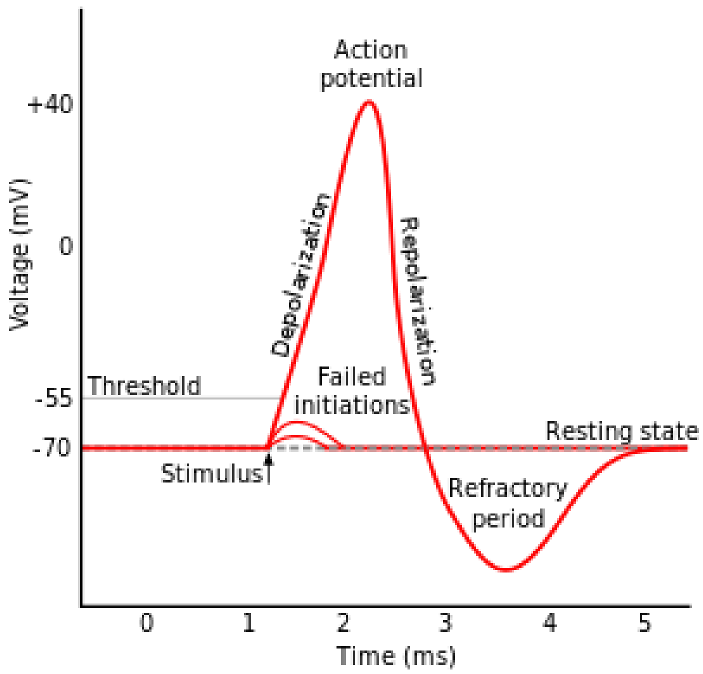
The cell wants the sodium back out and the potassium back in, so there are sodium potassium pumps that push the ions back to where they should be.

NOW, in just one neuron this actually happens in sections all the way down the cell – so this can be thought of as loads of buffet. restaurants next door to one another, all doing the same thing one after another, and the cell is the 'main street' on which all of the buffet restaurants can be found.

Myelin sheath that is formed with glial cells can wrap around the axons, so that once the cell has gone over threshold and an action potential occurs, the transmission is quicker. The myelin sheath allows the triggering of segments to happen faster, and for the electrical impulse to travel faster by skipping sections.

In our buffet example, the myelin sheath is scaffolding netting that covers up a lot of closed restaurants, so instead of 12 buffets on the street having to open and shut one after another to allow the message to get to the next street, 9 of the restaurants are closed, so only 3 need to open and close before the next street is told 'all systems go'.

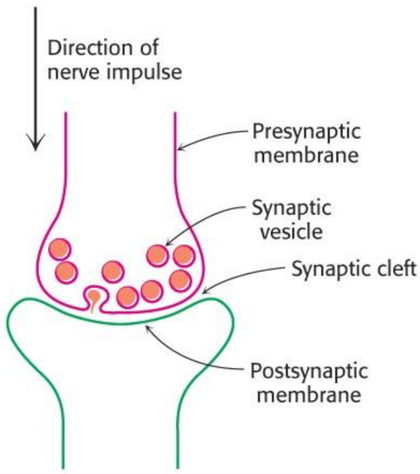
Back to our electrical current. Electricity works in voltage. Action potentials work with voltage. The voltage of an electrical impulse needs to be high enough to go over threshold and trigger the cell into an action potential. The resting potential of the cell is -70mV, for the cell to reach threshold the voltage of the impulse needs to be over 55mV to send the cell into action potential state. Failed initiations are when a dog will see a stimulus but will be habituated to it – the clock ticks, the sensory information comes in but is sub threshold so doesn't require an action potential. Or, the TV is turned on, initially the stimulus is enough to trigger the firing of the cells to instruct the dog to lift their head, orientate their eyes and ears toward the TV, gather further information. Then the cerebrum decides it is unimportant, the sensory information continues to come in, but the threshold is not reached, and action potentials stop impulsing.



Serious responses are caused by lots of action potential impulses, so the message for going crazy at the doorbell is loads of rapid firing action potentials and the message for 'pay attention' if the dog thinks they may have heard footsteps 300ft away would be a lesser frequency of action potentials.

To actually transfer the message to the next neuron, at the base of the axon, the action potential tells the 'gossip' part of the cell to pass on the message to the next neuron. To do this, at the ending of the axon another ion, calcium (Ca++) enters the axon ending, causing little vessels to leave the axon and enter the space between the two neurons, to be picked up by the dendrite of the next neuron. This is the gossip message being passed from the speaker to the next listener….

The Synapse

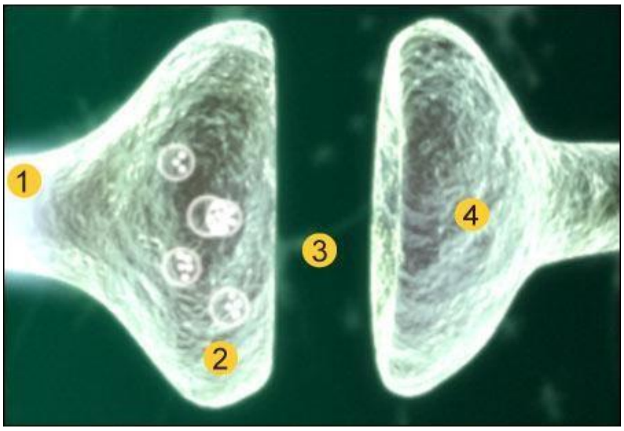


The synapse is the meeting point between two neurons. The synapse is vitally important as the neuron works in pathways, so the neurons need to be able to join to send the message all the way from the sensory organ to the brain, or from the brain to the extremities.

The presynaptic neuron is the cell sending the message, and the postsynaptic neuron is the cell receiving the message. The pre-synaptic neuron sends the message from its axon (usually) to the dendrites of the next post-synaptic neuron. The pre-synaptic terminal, or axon terminal has pre-synaptic vesicle sacs with thousands of molecules of a neurotransmitter. It sends these vesicles to the postsynaptic neuron, usually to the dendrites, or occasionally directly to the cell body, to an area known as the receptor region.

The presynaptic and postsynaptic neurons don't actually touch; the synaptic cleft is a tiny space between the neurons where the neurotransmitter vesicles float across to the next cell.

So, the action potential reaches the axon base, and gets to the pre-synaptic terminal. Here, we find voltage-gated calcium ion channels. Similar to the channels we found along the membrane to allow sodium and potassium in and out, this channel opens when the action potential hits the terminal. Calcium is released into the cytoplasm, the fluid inside in the cell, and the presence of this calcium then causes the synaptic vesicles to reach the membrane and open up, releasing the neurotransmitters inside in the vesicles out into the synaptic cleft.



The neurotransmitters then travel across to receptor sites on the postsynaptic neuron.

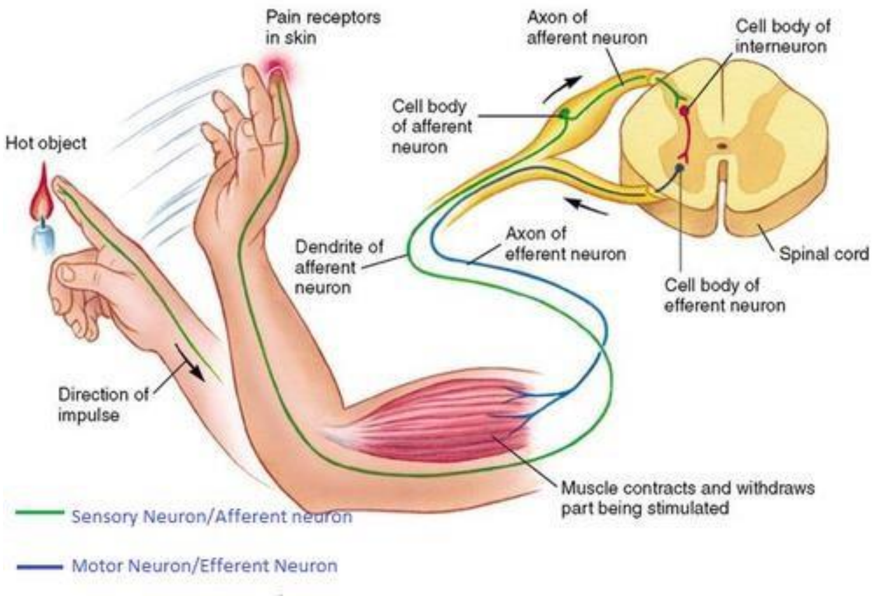
The neurotransmitter then binds to a receptor, which can either cause the cell to wake up or rest, to get excited or inhibited.

If the neurotransmitter that was released was an excitatory neurotransmitter, then it will make an action potential more likely whereas if the neurotransmitter was an inhibitory neurotransmitter, it causes the next cell to become hyperpolarised – even less likely to have an action potential then if it was in a resting potential state.

Once they have travelled over to the post-synaptic neuron and given their message, they will either return to the pre-synaptic neuron to get recycled, degrade, or are sent away from the synapse through diffusion.

We have over 100 different types of neurotransmitters in our body, for different functions. There are so many synapses at the end of each neuron, and each can have different neurotransmitters, so what message the cell actually passes on to the next depends on the function of the action potential.

Reflex Arc



When a stimulus is perceived, the receptors that took in the information usually transmits that signal to the brain.

This activates an action potential which sends the information along a neural pathway to get to the spinal cord. In a reflex arc situation, where the body decides that an immediate response to preserve life, the action potential reaches.

multipolar interneurons in the spinal cord of the CNS, and that interneuron will then tell the motor neurons to respond – usually a blink, or jerk away, or catch a ball, or a dog turning and biting a hand that grabbed it unexpectedly, or the ankle of a foot that just stood on its tail. The reflex arc is innate or learned, but don't need 'thinking'. The information will also continue up the spinal cord to the brain, so that the brain can process what happened, but the response has already been carried out.

How do Neurons create Learning?

External events cause a dog to gain information. Once the information is stored it becomes learning.

Learning is all about creating and strengthening pathways through neurons for impulses of electricity. Learning is basically about forming pathways that one stimulus, or multiple stimuli mean to respond with a known response.

In basic dog training, the sensory input of the verbal cue 'sit' initially means nothing, so there are no strong neural pathways in the brain that create a link between the sensory input and the motor output. The learning has to occur at the integration. Initially the integration section of the pathway is weird, wild and wonderful. Thing spilling a class of water on a flat surface, the water goes everywhere, this is similar to what happens when the sensory input reaches the brain for the first time. Any outcome could happen. When the integration section of the neural pathway makes connections that determines a motor response that works, and is reinforced, it is likely to be repeated. The more times it is repeated the fatter, healthier and faster that neural pathway will become, and the better the action potentials of this neural pathway.

Each neuron has thousands of dendrite synapses, and these grow as more learning occurs. So, an action potential enters a neuron that the word 'sit' has entered the integration of the brain. The path that that action potential follows could be any of a gazillion pathways. This is where learning occurs, the action potential pathway that had a successful outcome will be more likely to fire. The dendrite synapses that are not reinforced will become weaker and weaker with each message sent through the neural pathway. This is synaptic pruning.

In doing so, the neurons must make a sensory memory, which either decays and dissipates, or results in encoding to create working, or short term, memory. At this stage, the dog has determined which neural pathway to follow, due to some action potentials becoming sub threshold and becoming resting potentials, and the neural pathway that created the desired outcome was reinforced, causing it to become an action potential that is electrically charged over the -55mV, and becoming a 'busy' action potential there and then.

Further encoding occurs again, and when this knowledge is retrieved again in the future, long term potentiation occurs, and it results in long-term memory storage. Learning that is long term learning is known as brain plasticity, and this is why you can remember your childhood friends name, or why dogs remember where the food bowl is kept in their summer home. Learning results in changes in the shape of the brain, which can be moulded then stays there, like moulded plastic.

Short term memory and long-term memory is stored in different parts of their brain.

Learning and memory in the brain causes connections between neurons in the brain – though it doesn't rewire 'new' neurons. Dogs have the ability to learn so much with the neurons that are already in their brains. However, once they have learned many connections new learning can latch on to existing knowledge and prior learning. For example, a dog that has learned how to listen for cues, follow lures, manoeuvre its body in to positions and so on, then learning the difference between a spin and a roll over is minimal as the neural connections have already been made.

The more myelin sheath on the neurons, and the healthier that myelin sheath, the quicker learning and thinking occurs.

Synapse strength increases, through long term potentiation, when synapses are strengthened, and the ion channels become better skilled.

LTP is a long-lasting enhancement in signal transmission between two neurons after repeated stimulation.

During the early phase of LTP calcium attaches to proteins which embed themselves in the postsynaptic neuron membrane. This lasts for a few hours.

During the late phase of LTP a prolonged influx of calcium causes an increase in transcription factors ultimately resulting in gene expression and new proteins to be synthesised. They embed themselves into the postsynaptic membrane at the synapse.

In addition, there is an increase in the creation of proteins called growth factors which grow more synapses, the base of plasticity, which is how the brain grows and changes.

Sleep and Learning

The brain functions in an awake mode, where it is constantly processing sensory information, and a sleeping mode where learning and memory can be 'figured out' without distraction of external stimuli. Dogs need to rest after a training session so that the neural connections that have been made can fine tune and learning can be stored.

Stress and Learning

When stressed the dogs body releases adrenaline and cortisol, both making learning difficult. It's important to keep dogs calm, and in a safe environment when initial training is occurring so the neural pathway can form.

Water and Learning

The brain needs hydration to form new pathways, meaning dogs usually become thirstier during training and need constant supply of water while being trained to maximise learning.

Food and Learning

Dogs on poor diet will be unable to concentrate, making learning difficult.

Discomfort and Learning

If too hot or cold, hungry or tired, the brain will not be able to focus on learning which can again make learning more difficult for the dog.