The Context of Modern Neuroscience

NEUR30003 Principles of Neuroscience

The Nervous System

'Cogito ergo sum' is a proposition by Descartes that translates into English as 'I think, therefore I am'.

Ancient Egyptians believed that the mind is a product of the flow of fluids around the body, that the centre of the mind is the heart, and that the brain has a minor role in the function of the body.

Hippocrates, in Ancient Greece, recognised that the brain is involved in consciousness and behaviour.

Aristotle, in Ancient Greece, disagreed with Hippocrates and instead believed that the centre of the mind is the heart because the heart moves, simple animals do not appear to have a brain, warmth emanates from the heart, and that all known civilisations believed that the centre of the mind is the heart.

Galan, in Ancient Rome, believed that the mind is a product of the flow of fluids around the body, where intellect is a product of the brain, animalistic and instinctive functions are a product of the liver, and strong passions are a product of the heart.

Descartes, in France, believed that the brain functions by the flow of fluids through tubes.

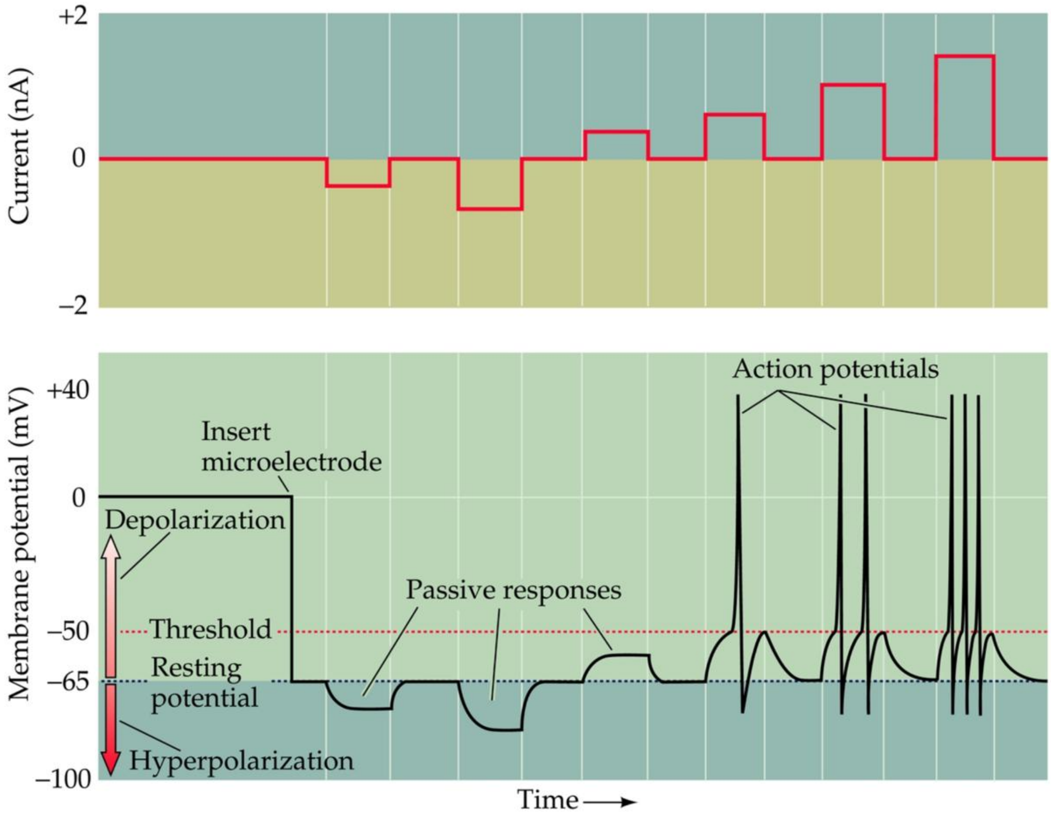
Broca, in France, assigned regions of the brain with specific functions by post-mortem study of the brain of patients that had had a behavioural deficit.

Charcot, in France, became known as the founder of neurology.

The Cellular Basis of Neural Function

Galvani postulated that nerves transmit electrical signals.

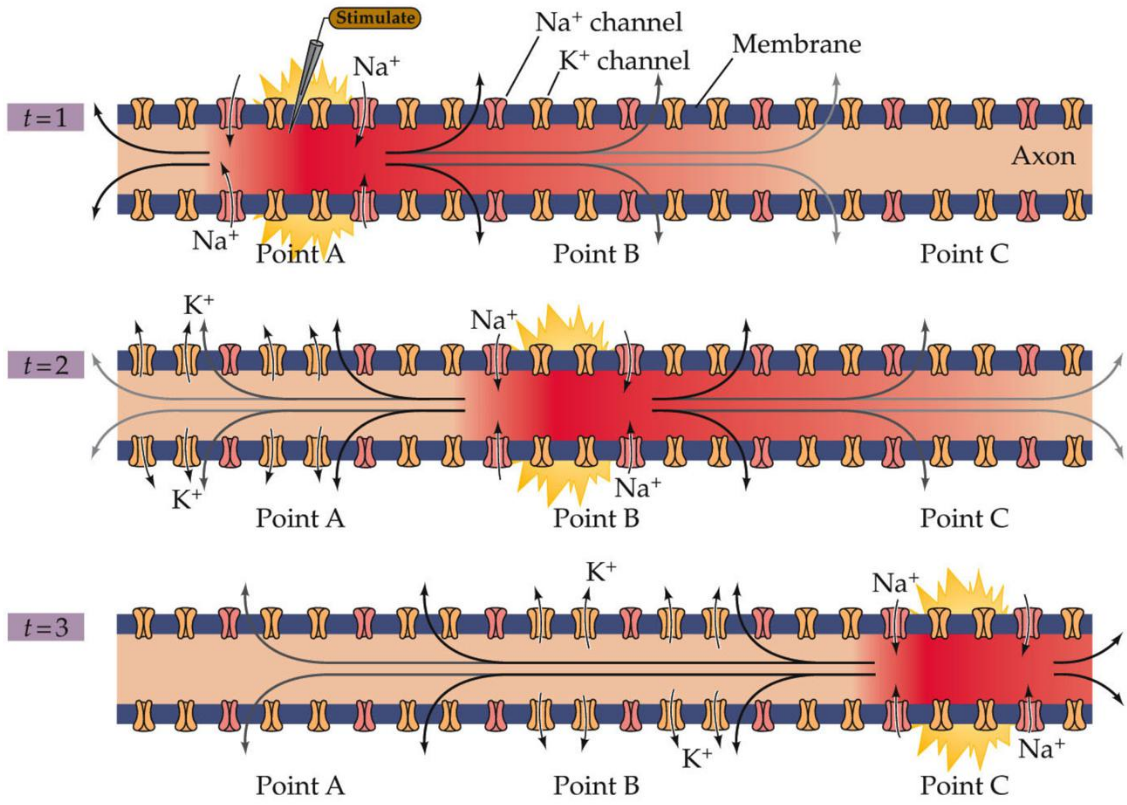
Aldini, Galvani's nephew, found that facial muscles could be contracted by electrically stimulating the brain.



The membrane potential of a neuron during electrical stimulation.

The membrane potential of a neuron is produced by ion transporters, which selectively move ions against their concentration gradient, and ion channels, which selectively allow ions to diffuse down their concentration gradient.

The resting membrane potential of a neuron is primarily a product of the electrochemical gradient established by the diffusion of potassium ions through potassium channels.



Action potentials are produced by voltage-gated potassium channels and voltage-gated sodium channels.

Myelination increases the speed of conduction of an action potential along an axon by enabling saltatory conduction, which involves the jumping of action potential from a node of Ranvier to an adjacent node of Ranvier.

When cell theory became broadly accepted, it initially was thought by most to not apply to the nervous system, which was believed to be a reticular network.

Silver staining of neural tissue by Golgi and Ramón y Cajal supported the neuron doctrine, which states that the nervous system consists of discrete cells.

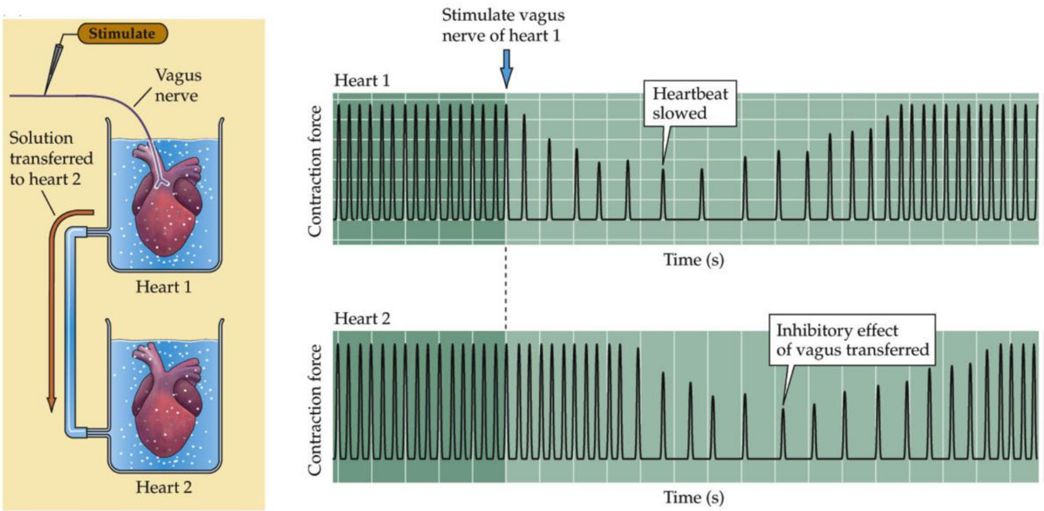
Neural Communication and Plasticity

Ramón y Cajal found evidence of dynamic morphology of growing neurons.

Even before the neuron doctrine was broadly accepted, Sherrington proposed that there must exist a junction between discrete cells of the nervous system, which he called a synapse, because the speed of reflex responses is much slower than the speed of nerve conduction.

The hypothesis that communication between neurons involved sparks was not supported by the study of the autonomic nervous system, which found that many organs are innervated by two nerves that in many cases produced opposing effects when stimulated.

Oliver proposed that synaptic transmission is chemical.



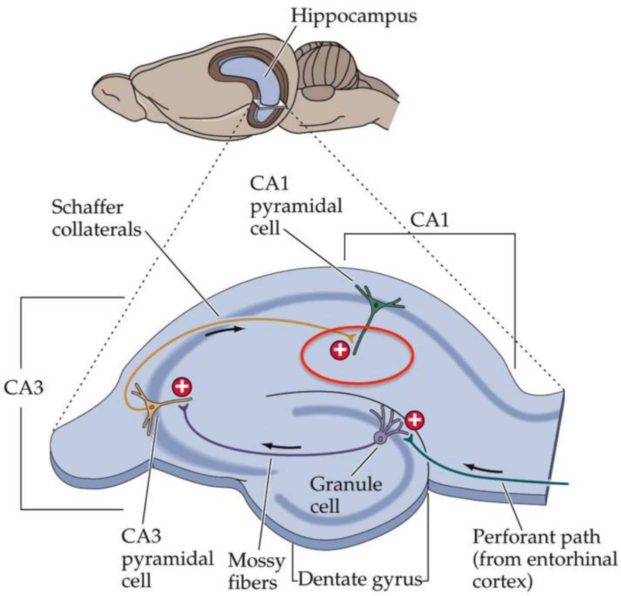
An experiment by Loewi that supports the hypothesis that synaptic transmission is chemical.

Electrical synaptic transmission, which occurs at some synapses, is excitable, passive, fast, and typically bi-directional.

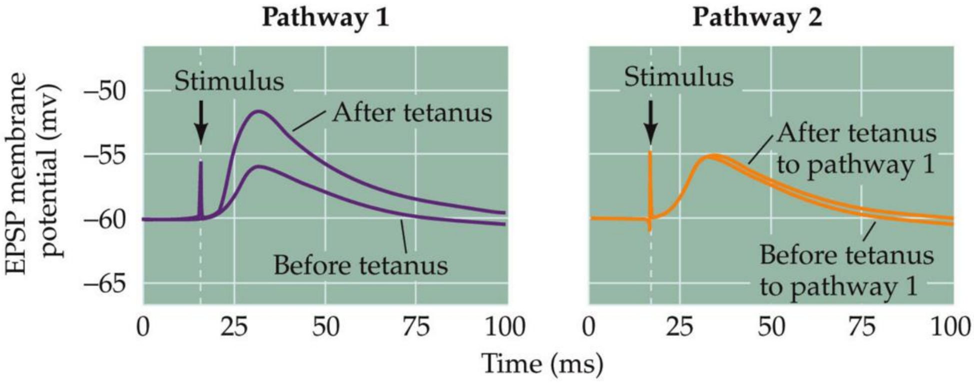
Neurotransmitters are typically small molecules.

Short-term changes in synaptic efficacy can be caused by changes in the amount of neurotransmitter released by the pre-synaptic neuron.

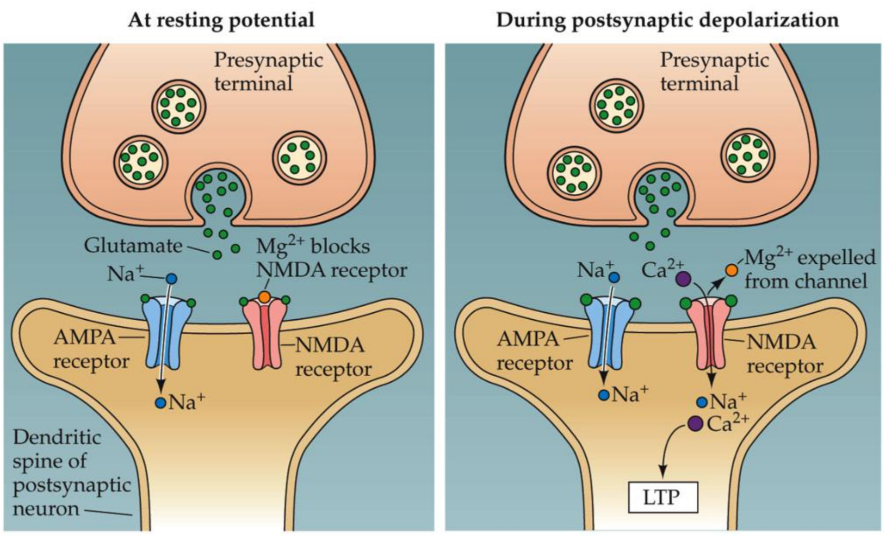
Long-term changes in synaptic efficacy can be caused by signalling pathways and changes in gene expression.



A CA3 pyramidal cell, a CA1 pyramidal cell, and Schaffer collaterals of the hippocampus of a rodent.



The long-term potentiation of Schaffer colatteral-CA1 synapses, which is restricted to the pathway that was tetanically stimulated.



NMDA receptors initiate long-term potentiation during postsynaptic depolarisation.

The maintenance of long-term potentiation requires protein synthesis.

Measurement of Neural Structure and Function

Neurological Exams

Neurological exams include specific tests that localise the site of nervous system dysfunction.

The twelve cranial nerves each have functions that can be tested in a neurological exam.

Microscopy

Abbe discovered that the resolution of light microscopes is limited to the wavelength of visible light.

Super-resolution microscopy increase the resolution of light microscopes with the use of fluorescent dye molecules that can be individually detected.

Microscopy has high spatial resolution.

Patch Clamp Electrodes

Patch clamp electrodes can measure the current through a single ion channel, have high spatial resolution, and have high temporal resolution.

Electroencephalography and Magnetoencephalography

Electroencephalography and magnetoencephalography are used to measure the electrical activity of the brain, have low spatial resolution, and have high temporal resolution.

When awake and when in REM sleep, the brain produces a low amplitude and high frequency electroencephalogram.

When in non-REM sleep, the brain produces a high amplitude and low frequency electroencephalogram.

Computed Tomography

Computed tomography involves the processing of multiple X-ray images, and has moderate spatial resolution.

Positron Emission Tomography

Positron emission tomography can detect metabolic activity by detecting pairs of gamma rays produced by the electron-positron annihilation of electrons of the body and positrons from a positron-emitting glucose tracer, has low spatial resolution, and has low temporal resolution.

Magnetic Resonance Imaging

Magnetic resonance imaging detects the density of water and fat of objects in a magnetic field by emitting and detecting radio waves, and has moderate spatial resolution.

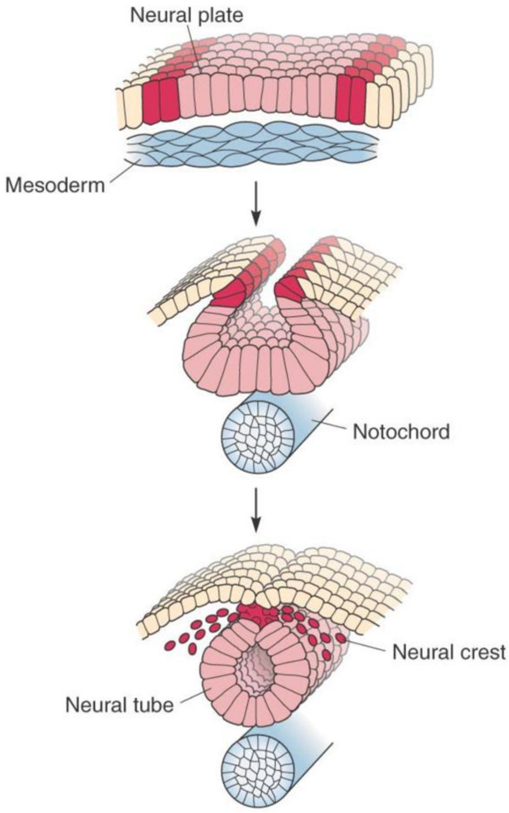
Functional magnetic resonance imaging detects changes in blood flow, has moderate spatial resolution, and has moderate temporal resolution.

Development of the Nervous System

The development of the nervous system involves neural induction, neurulation, the morphogenesis and patterning of the neural tube, neurogenesis, gliogenesis, neuronal migration, dendritic arborisation, axonal formation and pathfinding, synaptogenesis, synaptic refinement, and myelination.

Neural Induction, Neurulation, and the Morphogenesis and Patterning of the Neural Tube

A region of the embryonic ectoderm is induced to form the neural plate by signalling that blocks signalling that establishes epidermal fate.



The neural plate undergoes neurulation to form a neural tube and neural crest cells.

Spinal bifida is caused by a failure of neural tube formation.

Neural crest cells form the ganglia of the peripheral nervous system, the ganglia of the enteric nervous system, melanocytes, Schwann cells, and bone cells of the face.

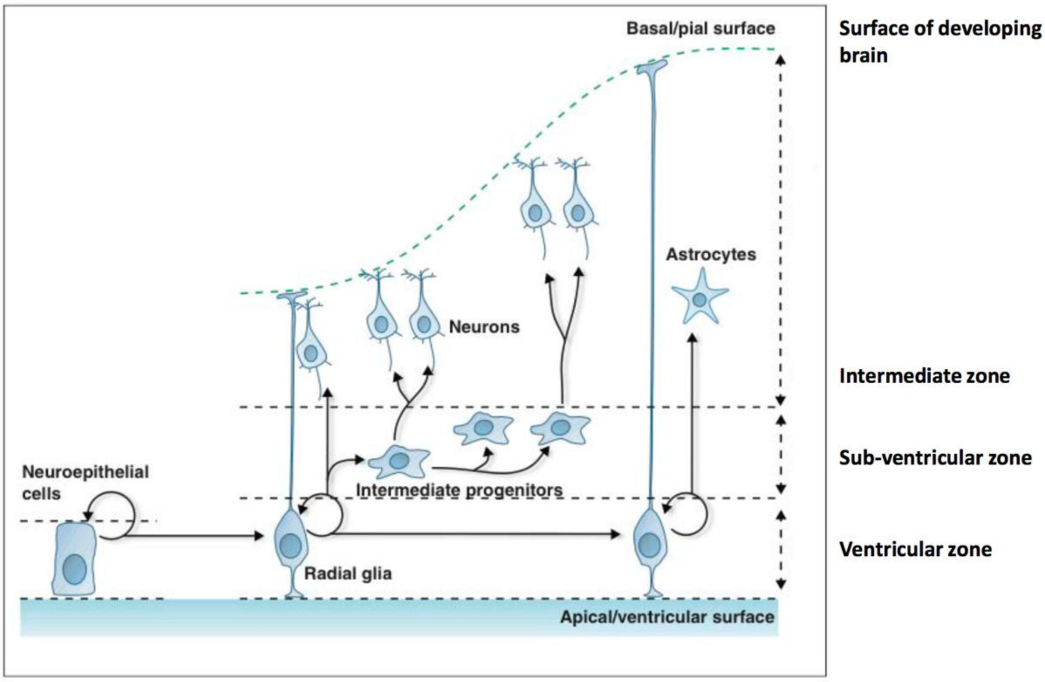
The rostral end of the neural tube forms three vesicles, which form the forebrain, the midbrain, and the hindbrain.

The caudal end of the neural tube forms the spinal cord.

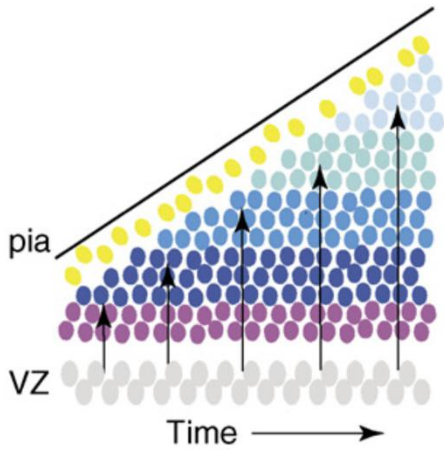
Two of the three rostral vesicles of the neural tube split to form two vesicles.

Dorsal-ventral patterning of the neural tube involves gradients of morphogens that are secreted by the overlying ectoderm and the underlying notochord.

Neurogenesis, Neural Migration, and Gliogenesis



Neurogenesis involves symmetric divisions of neuroepithelial cells, asymmetric divisions of radial glia, and symmetric divisions of radial glia.



The cerebral cortex forms inside-out.

Cortical projection neurons, which are excitatory, are born in the ventricular zone, and then migrate along processes of radial glia to the pial surface of the developing cerebral cortex.

Cortical interneurons, which are inhibitory, are born lateral to cortical projection neurons, and then migrate tangentially into the developing cerebral cortex.

Gliogenesis follows neurogenesis.

Dendritic Arborisation, Axonal Formation and Pathfinding, Synaptogenesis, Synaptic Refinement, and Myelination

Dendritic arborisation is controlled by genetic factors and environmental factors.

The growth cone of a growing axon is guided by attractive and repulsive environmental signals, including soluble factors and membrane-bound factors.

Actin filaments regulate the shape and the growth of the growth cone of a neuron.

Microtubules provide structural support to growing axons.

Synaptic refinement involves competition between, and the elimination of, synapses.

Myelination predominantly occurs following birth.