Basic Function and Structure of the Nervous System
A Simple Nerve Circuit – the Reflex Arc.

The simplest type of nerve circuit regulates a reflex (or autonomic response) and is called a reflex arc.

The simplest reflex arc require only two kinds of nerve cells:

1) **Sensory neuron**: conveys signals from a sensory receptor to a motor receptor

   **Motor neuron**: sends signals to an effector cell, a muscle or a gland cell that carries out the response.
Your brain and nervous system

How does it work?
Your nervous system is divided into the central nervous system (CNS) which is the brain and spinal cord and the peripheral nervous system (PNS) which connects everything to the brain and spinal cord.
your brain

interprets the information it gets through your senses in order to monitor and regulate your body as well as being responsible for thinking, learning, memory and emotion

Different parts of your brain have different functions...
different regions have different functions

Cerebral cortex
Functions include: planning; reasoning; language; recognising sounds and images; memory.

Corpus callosum
connects the brain’s right and left hemispheres

Brain stem
regulates heart rate, breathing, sleep cycles and emotions

Cerebellum
important for coordination, precision and timing of movement
the cells of the nervous system are called **neurones**

- **nucleus**
- **cell body**
- **dendrites**
- **axon**
- **myelin sheath**
- **nerve endings**

structure of a neurone
There are different types of neurone.

1. **Sensory Neurone**: Sends signals from your sense organs.
2. **Motor Neurone**: Sends signals to your muscles to tell them to move.
3. **Relay Neurone**: Connects neurones to other neurones.

- **Dendrites** connect the neurone to other neurones.
- **Cell body** contains the nucleus.
- **Axon** sends electrical signals.
- **Myelin sheath** speeds up the signal transmission.
- **Nerve endings** connect to other neurones or muscles.
neurones communicate with each other using a mixture of electrical & chemical signals

But what happens when the signal reaches the end of the axon?
signals cross between neurones at the synapse.

The signal is transmitted to another neurone across a junction called a synapse by chemicals called neurotransmitters.

Smarter UK
The signal is transmitted to another neurone across a junction called a synapse by chemicals called neurotransmitters.

1. Electrical impulse triggers vesicles to move to the synapse membrane.
2. Vesicles fuse with the membrane and release neurotransmitter into the synaptic cleft.
3. Neurotransmitter diffuses across the cleft and binds to receptors on the other side.
4. Once enough receptors have neurotransmitters bound to them, the signal is transmitted...
The point where your muscles and nervous system meet is called the **neuromuscular junction (NMJ)**.

Signals sent from your central nervous system to the NMJ tell muscles to move.

The synapses at the NMJ use a neurotransmitter called **acetylcholine**.
Your brain changes and adapts

What happens as our brains mature?
your brain changes and adapts all the time and all through your life

your brain learns and forms memories by strengthening synapses that are used a lot and weakening those that are used less often
What happens with Huntington's?

Symptoms typically appear between the ages of 30 and 50, but may appear earlier or later. HD is characterized by progressive physical, cognitive and psychological deterioration.

Since the genetic problem causes nerve cell loss in the brain, specifically the basal ganglia, symptoms of HD may develop gradually, and will affect an individual’s ability to move, think and process thoughts and feelings. The progression of HD is frequently divided into stages, and each stage marks a loss in ability, or a change in situation. As HD progresses, additional neurons are damaged in the brain, leading to further physical, cognitive and psychological decline.
The following slide shows the brain of a victim of Huntington's disease in top image and the normal image of a brain in bottom image.
The human brain, showing the impact of HD on brain structure in the basal ganglia region of a person with HD (top) and a normal brain (bottom).

http://kobiljak.msu.edu
ALS

As motor neurons degenerate, they can no longer send impulses to the muscle fibers that normally result in muscle movement. Early symptoms of ALS often include increasing muscle weakness, especially involving the arms and legs, speech, swallowing or breathing. When muscles no longer receive the messages from the motor neurons that they require to function, the muscles begin to atrophy (become smaller). Limbs begin to look "thinner" as muscle tissue atrophies
As your brain matures, it prunes synapses to make it more efficient. During adolescence your brain has a major tidy-up and gets rid of lots of connections it isn’t using. This is a critical and delicate process. It is thought that conditions such as schizophrenia could be the result of it going wrong. Some evidence suggests that using drugs can disrupt this process.
Master control and communication system

Has three overlapping functions

**Sensory** - receptors monitor changes (stimuli) and gathers information inside and outside the body

**Integrative** - processes and interprets sensory input, makes decisions

**Motor** - dictates a response by activating effector organs
Central nervous system (CNS)
  - Brain and spinal cord
  - Integration and command center

Peripheral nervous system (PNS)
  - Outside the CNS
  - Carries messages to and from the spinal cord and brain
  - Consists of paired nerves extending from brain and spinal cord
  - Peripheral nerves link all regions of the body to the CNS
  - Ganglia are clusters of neuronal cell bodies
Cells are densely packed and intertwined

Two main cell types

**Neurons** – transmit electrical signals

**Support cells** *(neuroglial cells in CNS)*

Nonexcitable

Surround and wrap neuron
The human body contains billions of neurons
Basic structural unit of the nervous system
Specialized cells conduct electrical impulses along the plasma membrane
Nerve impulses are called *action potentials*

Other special characteristics

**Longevity** – can live and function for a lifetime

**Do not divide** – fetal neurons lose their ability to undergo mitosis; neural stem cells are an exception

**High metabolic rate** – require abundant oxygen
Nucleus and Perikaryon (around nucleus)  
Size of cell body varies from 5–140µm  
Contains usual organelles plus other structures  

**Chromatophilic bodies** (Nissl bodies), seen because they stain darkly, actually clusters of rough ER and free ribosomes, renew membranes of the cell  
**Neurofibrils** – bundles of intermediate filaments, form a network between chromatophilic bodies  

Most neuronal cell bodies are located within the CNS in cluster called nuclei, protected by bones of the skull and vertebral column  
**Ganglia** – clusters of cell bodies outside CNS, lie along nerves in the PNS
**Neuron Processes - Dendrites**

Extensively branching from the cell body
Transmit electrical signals toward the cell body
Function as receptive sites for receiving signals from other neurons
Neuron Processes - Axons

Neuron has only one Impulse generator and conductor
Transmits impulses away from the cell body
No protein synthesis in axon
Neuron Processes

Neurofilaments, actin microfilaments, and microtubules
Provide strength along length of axon
Aid in the axonal transport of substances to and from the cell body
Branches along length are infrequent - axon collaterals
Multiple branches at end of axon

**Terminal branches** (telodendria)
End in knobs called **axon terminals**
(also called end bulbs or boutons)
Neuroglia in the CNS

Neuroglia

Glial cells have branching processes and a central cell body
Outnumber neurons 10 to 1
Make up half the mass of the brain
Can divide throughout life
Astrocytes are the most abundant glial cell type
Sense when neurons release glutamate
Extract blood sugar from capillaries for energy
Take up and release ions in order to control environment around neurons
Involved in synapse formation in developing neural tissue
Produce molecules necessary for neuronal growth
Neuroglia in the CNS

**Microglia** – smallest and least abundant glial cell

**Phagocytes** – the macrophages of the CNS

Engulf invading microorganisms and dead
Neuroglia in the CNS

**Ependymal cells**
- Line the central cavity of the spinal cord and brain
- Bear cilia – help circulate the cerebrospinal fluid

**Oligodendrocytes** – have few branches, wrap their cell processes around axons in CNS, produce myelin sheaths
Neuroglia in the PNS

**Satellite cells** – surround neuron cell bodies within ganglia

**Schwann cells** (neurolemmocytes) – surround axons in the PNS

Form myelin sheath around axons of the PNS
Structural Classes of Neurons

Unipolar
Dendrite, axon continuous
Afferent neurons

Multipolar
Many dendrites, one axon
Most common class of neuron

Bipolar
One dendrite, one axon
Possess one short, single process
Very rare
Found in some special sensory organs
Neurons Classified by Structure

(a) Multipolar neuron
- Association neuron (interneuron)
- Motor neuron
- Muscle
- Impulse
- Cell body
- Dendrites
- Axon

(b) Bipolar neuron
- Eye
- Impulse
- Bipolar neuron of retina of eye
- Dendrites
- Cell body

(c) Unipolar neuron
- Sensory neuron
- Skin
- Impulse
- Cell body
- Peripheral process
- Receptive endings
- Short single process
- Central process
- Axon
Functional Classification of Neurons

Sensory (afferent) neurons
Transmit impulses toward the CNS
Virtually all are **unipolar** neurons
Cell bodies in ganglia outside the CNS
Short, single process **divides into**
The **central process** — runs centrally into the CNS
The **peripheral process** — extends peripherally to the receptors
Functional Classification of Neurons

Motor (efferent) neurons
- Carry impulses away from the CNS to effector organs
- Most motor neurons are multipolar
- Cell bodies are within the CNS
- Form junctions with effector cells

Interneurons (association neurons) – most are multipolar
- Lie between motor and sensory neurons
- Confined to the CNS
Myelin Sheaths

Segmented structures composed of the lipoprotein **myelin**
Surround thicker axons
Form an insulating layer
Prevent leakage of electrical current
Increase the speed of impulse conduction

**Nodes of Ranvier** – *gaps along axon*
Thick axons are **myelinated**
Thin axons are **unmyelinated**, conduct impulses more slowly
Myelin Sheaths in the PNS

Formed by **Schwann cells** *(neurolemmacytes)*
Develop during fetal period and in the first year of postnatal life
**Schwann cells** wrap in concentric layers around the axon, cover the axon in a tightly packed coil of membranes
**Neurilemma** - material external to myelin layers
Myelin Sheaths in the PNS

(a) Formation of myelin

(b) Schwann cell on myelinated axon

Cell body

Axon

Schwann cell cytoplasm

Schwann cell plasma membrane

Schwann cell nucleus

Myelin sheath

Neurilemma

Schwann cell cytoplasm

Area of polarity reversal (node of Ranvier)

Myelin sheath

Distal axon
Oligodendrocytes form the myelin sheaths in the CNS
Have multiple processes
Coil around several different axons
Nerve impulse
- Generated at the initial segment of the axon
- Conducted along the axon
- Releases neurotransmitters at axon terminals
  - **Neurotransmitters** – excite or inhibit neurons
- Neuron receives and sends signals
Site at which neurons communicate
Signals pass across synapse in one direction
**Presynaptic neuron** - conducts signal toward a synapse
**Postsynaptic neuron** - transmits electrical activity away from a synapse
Nerve impulses reach the axon terminal of the presynaptic neuron and open Ca2+ channels. Neurotransmitter is released into the synaptic cleft via exocytosis. Neurotransmitter crosses the synaptic cleft and binds to receptors on the postsynaptic neuron. Postsynaptic membrane permeability changes due to opening of ion channels, causing an excitatory or inhibitory effect.