

Introduction to Neurobiology

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1 About this course

Objective of the course is to learn how the nervous system produces behaviour, how we use our brains in our day to day lives, and how neuroscience can help explain the problems afflicting people today. There'll be focus on functional human neuroanatomy, and neuronal communication, to help understand how we perceive the world, do body movements, and interact with others.

2 Resources

- **Coursera: Understanding the Brain: The Neurobiology of Everyday Life** taught by professor of Neurobiology Peggy Mason, at the University of Chicago (<https://www.coursera.org/learn/neurobiology>)

3 Introduction

- **The Diving Bell and the Butterfly:** Jean-Dominique Bauby, locked-in syndrome.

4 The Nervous System

4.1 The Four Functions

The locked-in syndrome tells of the four basic functions of the brain/central nervous system.

1. **Voluntary Movement:** Every thing we do that is driven by the brain, both deliberate actions, such jumping, speaking, raising your hand, etc, and not so deliberate actions like wincing in reaction to stepping on a lego piece.
2. **Perception:** Perception is distinct from sensation; its what we consciously appreciate about sensation. Its what we're capable of being aware of such as vision, hearing, smell, taste, balance, position, lung pressure, etc.
3. **Homeostasis:** Used to keep body within its physiological limits. For example, making sure the body has enough oxygen, the right blood pressure, right body temperature. Also, homeostasis accounts for life cycle events like a mother giving birth, and the conditions needed for the child to be healthy. Altogether, a process of maintaining healthy internal conditions.
4. **Abstract functions:** Higher functions of the central nervous system like thinking, language, motivation, feeling emotion, etc. Also, plays a huge role in how we interact with other humans.

4.2 Central Anatomy

Mapping of the four functions to regions of the brain.

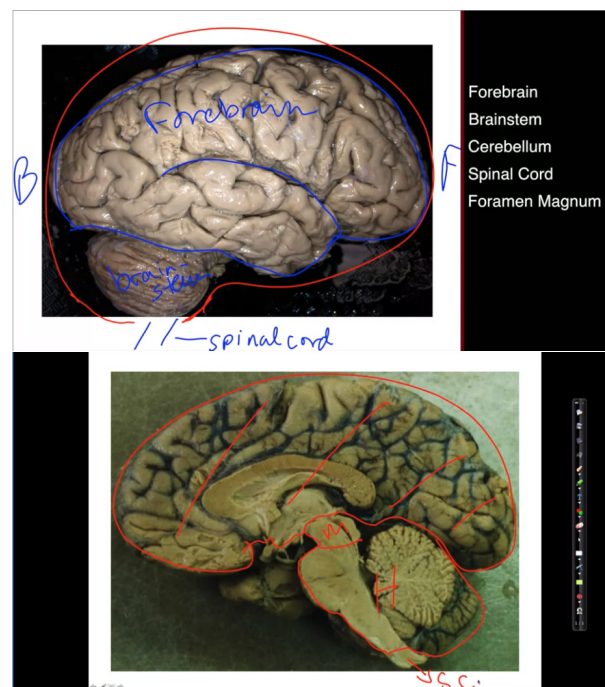
1. Motor neurons which exist in the brain stem, or the spinal cord are responsible for **voluntary movement**. There are less than 100,000 motor neurons, out of about 200 billion in the entire nervous system. Motor neurons in the brain system are responsible of movement of the mouth, face, hence speech, facial expressions, swallowing, etc. Motor

neurons in the spinal cord are responsible for bodily movements like movement of the arms, legs, etc.

2. **Perception** is entirely in the **Forebrain**; more specifically, it depends entirely on the **Cerebral Cortex**. Perception is one of the higher brain functions; if the information carried by neurons does not make it to the Cerebral Cortex, then there's no perception; there's no conscious appreciation/awareness of sensation.
3. **Homeostasis** depends on the **Forebrain, brain stem, and spinal cord**. The forebrain's contribution to homeostasis is hormonal. The brain stem has a varied contribution; it's responsible for the automatic changes we're not able to control, the autonomic (involuntary) functions of our nervous system. The spinal cord's contribution is similar to that of the brain stem.

The brain stem, and spinal cord serve as pathways for information, both incoming, and outgoing.

4. **Abstract functions** are entirely in the forebrain, and function independent of the brain stem, and spinal cord. The forebrain is the "seat of consciousness"; all perception, and abstract cognitive functions like memory, depend on the forebrain; more specifically, the cerebral cortex.



5 Neurons; the “stars” of the nervous system”

5.1 Parts of the Neuron

There are four parts to neurons.

1. Cell body, also known as the **Soma**. Place that keeps the cell going, makes all the materials needed for the entire neuron
2. **Dendrites**; they branch out of the cell body, creating a **tree like structure called the dendritic arbour/tree**. They’re responsible for gathering information for the neuron. Information goes into the dendrites. Dendrites may be perceived as the ears of the neuron.
3. Information processed locally from dendrites, sent out through one **axon** which is more globally distributed compared to the dendrites. Axon can travel a metre; and ultimately carry information to a **synaptic terminal**.
4. **Synaptic terminals** are the point of information transfer between cells; information is carried to the terminal via axons. There’s a small space between the synaptic terminal, and the receiving cell/dendrite; that space is where the event of information transfer occurs, which we know as a **synapse**.

5.2 Neuronal Uniqueness

A wide variety of ways the anatomy of neurons can make them different from each other. Neurons also differ in the sense of what the neurons are connected to, what neurons are talking to; the inputs and outputs. In addition to the **anatomy**, other differences include:

- **Excitability**: how talkative is the neuron. How much work is needed to get neuron to fire action potentials. How likely or unlikely is it to fire action potentials.
- **Neurotransmitters**: What chemical/substance does the neuron use to communicate. For instance, some neurons use serotonin. How does the neuron “speak”. Difference in communication speed. Affirmative vs negative.

5.3 Glial cells

Neurons don't exist on their own, they require the support of Glial Cells. There's a one-to-one mapping of neurons to glia. There's different types of Glial Cells:

1. **Astrocytes:** behave as sanitation workers of the brain. They collect the refuse of neurons, such as excess ions, and neurotransmitters. They also allow neurons to get to where they have to go during development. Synapses are enveloped in the processes of Astrocytes, which helps with maintaining them. Comprised about 20 percent of glial cells
2. **Oligodendrocytes (Central nervous sys.), and Schwann cells (Peripheral nervous sys.):** Create myelin in their respective areas of the nervous system. Combined, these comprise about 75 percent of glial cells.
3. **Microglia:** comprise about 5 percent of glia. Immune cells from the blood lineage that have invaded into the central nervous system, and are idle as long as the human body is healthy. However they react to areas of damage, and sometimes even contribute to the damage. Implicated in several diseases like chronic pain, and neurodegenerative disorders like Alzheimer's.

5.4 Myelin

Myelin is a **fatty wrap that goes around some axons**. The difference between a myelinated axon, and an unmyelinated axon/naked axon.

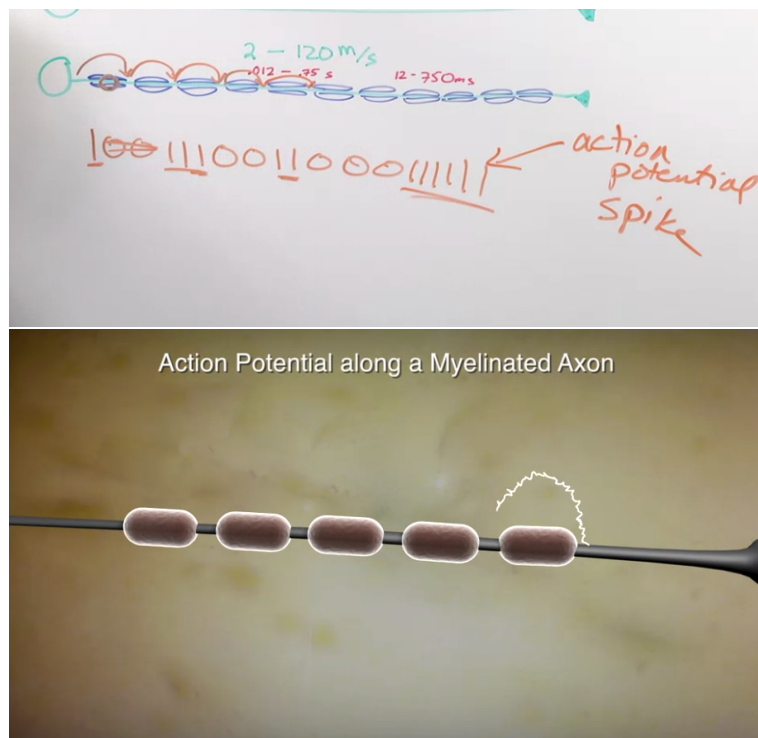
- **Unmyelinated** axons can only transfer information at a slow rate; about **0.2 - 1.0 m/s**
- **Myelinated** axons have myelin applied and carry information orders of magnitude faster than naked axons. the speed at which these axons carry information increases to **2 - 120 m/s**. A speed imperceptible to us humans.

Myelinated axons are significant especially in cases where we need information fast such as information about our balance, which we need the fastest. Neurons that support a posture against gravity, use myelinated axons.

The information that gets transferred through myelinated axons can be perceived as binary digits (**011001110111...**). What's important about this sequence of binary digits is less about whether it's a 1 or 0, but more of the

pattern of 1's that appear in the sequence. That is the neural code; the **1s represent action potentials or spikes**. The **timing** of the spikes is what carries information.

The spikes that traverse through the myelinated axon travel so fast because they jump between the gaps of the myelin wraps, thus not having to traverse through the wraps, and hence the entire physical distance of the axon; effectively shortening the distance, and time required for the action potential to travel.



However, consider if along the myelinated axon, there becomes less, and less myelin wraps. Our initial action potential, if starting as a string of bits say **00110011101011011101**, may come out on the other end due to the decrease in myelin wraps as a completely incoherent message inconsistent with the initial one, say: **000001001000100000100**. This is caused by what are known as **demyelinating diseases** which degrade the information transfer.

5.5 Demyelinating Diseases

Recall that Glial Cells that create Myelin are either in central nervous system, or Peripheral nervous system. Thus people who get demyelinating diseases either get it in the CNS, or PNS, but not both.

So the problem is either in the interaction between the **Oligodendrocytes** and the axon, in which case we get a **Central Demyelinating Disease**, which the most common by far is **Multiple Sclerosis**.

Or, there's a problem in the Schwann cells, and its interaction between with the axons. In which case, we get something like **Charcot-Marie-Tooth** which are a diverse group of hereditary demyelinating neuropathies.

Neural code is disrupted any where there is demyelination. Demyelination would mostly affect motor axons which travel information the fastest. **Symptoms someone gets from Multiple Sclerosis would depend on which axon group is affected.**

6 Central Nervous System vs. Peripheral Nervous System

Barrier between CNS, and PNS are made of three membranes; the meninges. There are **three meningeal layers that go from very weak, very tender (the pia) to very tough (the dura)**

6.1 Meninges

- Three meningeal layers
- **Pia** (very weak, most tender, and the inner most membrane; closer to the brain and spinal cord), **Arachnoid** (mid membrane, with spider-like structure). The **Dura** (outer most membrane, and the toughest)
- **Dura**, is the toughest sack, and what prevents concussions from happening all the time. It "floats" the brain in fluid and prevents it from banging about, and getting bruised.
- Neurons of these three membranes are entirely contained in the Central Nervous System
- The only neurons that leave the CNS are those that serve a motor function; these neurons **go out the meninges and into the periphery (PNS)**

- **Motor, and Autonomic neurons** that carry information from the CNS through the meninges, into the PNS
- **Sensory neurons** that carry information from the PNS, through the meninges to the CNS
- Neurons are either sensorial, or peripheral, based on where the cell body is, not where its axons, or dendrites are.
- Peripheral Neurons include **sensory, and autonomic** neurons, located in the autonomic ganglia
- These autonomic ganglia neurons, **share vulnerabilities with each other, but none with the neurons in the CNS**. A consequence of this is diseases like Congenital Insensitivity to Pain; where people who suffer a genetic mutation that prevent a group of sensory neurons from developing, like those that respond to injury (they don't feel pain).

6.2 Peripheral Diseases

Diseases that affect that affect nervous system, affect either CNS, or PNS. Meninges perform as a very effective barrier, that protects the CNS, from the diseases that the PNS is often more vulnerable to than CNS. As a result, two regions (PNS, and CNS), have different capacities for repair; PNS is better capable of repairing damage, as compared to the CNS.

Peripheral Nervous System is vulnerable to large molecules like **botulinum toxin**, viruses like **Polio, Herpes Zoster**.

- **Botulinum Toxin**: comes from spoiled food, primarily affects peripheral nervous system. Doesn't get past meninges.
- **Polio**: unlike the botulinum toxin, **gets past the meninges**. Gets through to the meninges, by **entering between the synapse between the motor neuron and the voluntary muscle**, travelling through the the meninges by riding along the axon of a motor neuron. Once it gets through the meningeal layer, it **kills the motor neuron on that side**. As a result, there'll be an inability to control that muscle, or conduct voluntary movement to that neuron's corresponding motor actions.
- **Herpes Zoster**: produces what's commonly known as shingles. Blossoms, and makes copies of itself, inside cells in the sensory territory, causing a virus in that area, producing a rash on the skin.

6.3 Brain Tumors

To understand the origins of brain tumors, we must know the basics of cancer. Cancer tumors are cells that divide uncontrollably without limitations; they become immortal. Not only do they divide limitlessly, but also, the spread from one region of the body, to another, becoming bigger and bigger, and starting new tumors elsewhere. Hence, one source of brain tumors: **Metastasis**; tumors that start elsewhere like the lung, or colon, and spread to the brain.

Metastasis is a massive problem for brain. Brain tumors that expand uncontrollably, are constrained within the fixed, unexpanding, bony container that is the cranium. As a result, the limitless growth of tumors in the brain only increase pressure on the brain, which is problematic.

Besides metastasis, what are other sources of tumors in the brain? Neurons, fortunately do not divide; they are what's called **Post-mitotic** cells. Neurons don't divide, don't regenerate, have not any descendants; once they're born, they live, then die. Hence, this leaves the development of brain tumors to other to other cells in the brain; primarily, **Glial Cells**.

Glial Cells don't have the limitations of division that neurons do, thus can divide uncontrollably, creating **Glials, or Gliomas** (the tumors of glial cells); the most common brain tumor.

Meningiomas; another type of brain tumor. These are caused by uncontrolled division of meningeal cells.

Glandular cells (gland cells) are another major source of tumors in the brain. Namely, from the **Pineal Gland**, responsible for producing **melatonin** which helps us sleep, and also responsible for the daily rhythm of waking and sleeping. **Pituitary Adenomas** caused by uncontrolled division of the other glandular cells in our brain, the **Pituitary gland cells**. They're fairly common, and account for about 10-25 percent of inter-cranial tumors.

6.4 The Brain and the Spinal Cord

The two main components of the Central Nervous System: the Brain, and the Spinal Cord.

The **Foramen Magnum** is the point of connection between the spinal cord and the brain. It's an opening at the bottom of the skull, where the spinal cord, and brain connects.