Faculty of Medicine 2012

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Physiology

Sheet

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Physiology

Second lecture with Dr. Eman Al Khateeb

The brain performs various functions; it performs sophisticated functions and very simple functions.

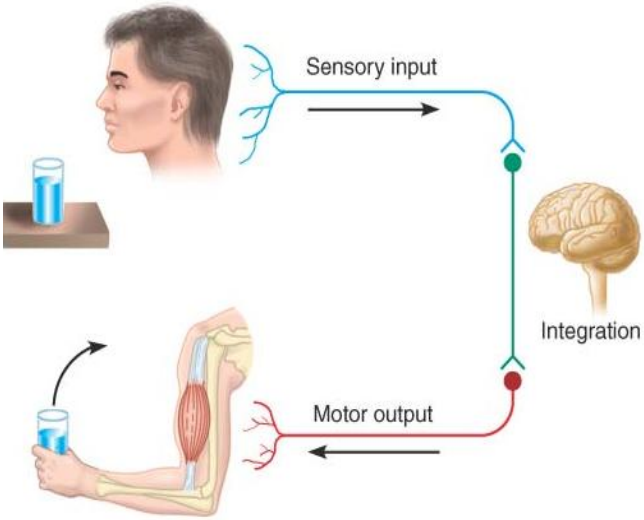
Sophisticated functions	Simple Functions
The higher intellectual functions: solving a problem, inventing something, any function that needs a lot of integration, etc.	Moving a muscle or a group of muscles.

In any of these functions, we need both of these activities.

From this image we can deduce that:

There is a **sensory input** to the brain, usually it is a **sensation**: hearing, seeing, tasting, smelling, touching, pressure, vibrations, feelings, etc.)

The brain will **respond** by giving an order (a response) usually in the form of a **motor activity** to contract or relax a muscle.



For today's lecture we are talking about the **bilingual ability** of the brain. A function as simple as holding a pen in between your fingers takes a lot of electrical signals from the sensory receptors that are present on your fingers that will be transferred to the **contralateral** side of your brain.

Meaning: Your right hand is controlled by → your left brain!
Why?
Because there is **decussation** or **crossing** of the fibers.

The majority of us are right-handed people → our left brain is more advanced and more sophisticated as a result of that.

Arrhythmia: a condition in which the heart beats with an irregular or abnormal rhythm.

In the previous picture, the brain will think about the action required (drinking water) and many cells and areas will be recruited to work and carry out the action. When the brain decides that he should hold the glass and drink the water, then it will send the appropriate signals.

Although the mechanism seems simple, it is not. The brain has to regulate every length and every tension in each muscle participating in the action, and has to send thousands of electrical signals to the small muscles of the hand and muscles of the arm.

Therefore, we need a signal that can propagate; that can move and transfer information from peripheral areas to the brain. Also, we need another signal that can summate or subtract to tell us what is the exact thing that has to be done.

This is why we need two different languages of the brain.

Action potential → the electrical signal that the brain uses to **propagate** and transfer information **faithfully** and **unchanged** with the **same amplitude** and with **no external source of energy**.

- **Review of the action potential:**

Major contributing factor to the resting membrane potential, that determines the excitable issue, is the capability of the membrane to be permeable100 times more to the Potassium ion (K^+) than Sodium ion (Na^+).

Resting membrane potential ranges from -70mV to -45mV depending on the diameter of the nerve fiber of the neuron.

A nerve can be stimulated by an:

1- Electrical stimulus.
2- Mechanical stimulus (stretching).
3- Chemical stimulus.
4- Thermal stimulus.

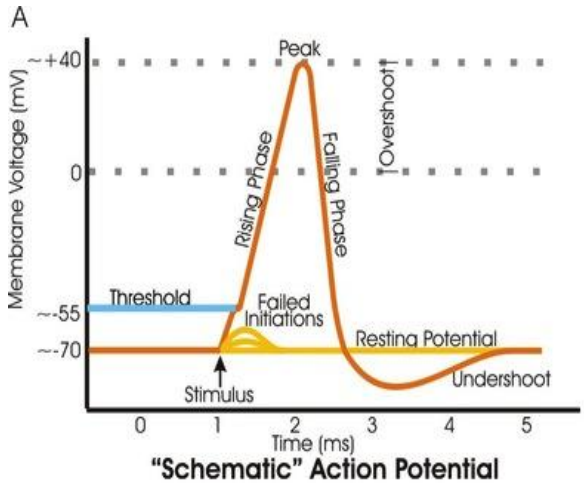
Adequate stimulus: a stimulus that is capable of opening enough amounts of sodium channels that will change the membrane potential with at least 10mV – 15mV increase. At this moment, the positive feedback mechanism will start.

At the threshold level: the voltage-gated sodium channels are all open or the majority of them are → there will be a huge influx of sodium ions to the inside of the nerve fiber → change of membrane potential toward a positive value.

Contralateral: Taking place or originating in a corresponding part on an opposite side.
Decussation: used in biological contexts to describe a crossing.

Remember:
Depolarization → Sodium influx.
Repolarization → Potassium efflux.

The reason why sodium channels and potassium channels open at a different time is because they have different sensitivities to the voltage.



"Schematic" Action Potential

- **Importance of Action Potential:**

Firstly, we'll give a brief introduction (the first couple of points might not be important but I have to write everything that has been said in the lecture):

- 18 scientists have received a Nobel Prize for their studies on Action Potential.
- To receive a Nobel Prize your discovery should have two criteria: It's a new discovery, and it's applicable and helps patients. If it doesn't have a clinical application, you won't receive a Nobel Prize.
- The reason why Action Potential discovery received a Nobel Prize is because it is new, and has improved the quality of life of hundreds of patients.
- If we don't know the normal, then we are unable to diagnose the abnormality. Action potential discovery has helped us in the diagnosis of so many disorders; if I have a patient that has suffered from a radial, ulnar, or a median nerve injury, then part of my job as a neurologist or a neurophysiologist is to carry out a test called EEG (Electroencephalography) for brain trauma, or ENG (Electroneurography) for nerves, or EMG (Electromyography) for skeletal muscles. So if I don't know the normal action potential for each of them, how can I diagnose the abnormality?

- So Action Potential benefits are:
  1- Helped us in diagnosing many disorders; partial or complete injuries to peripheral nerves or areas in the brain.
  2- Helped in the follow-up of the patient (prognosis).
  3- Drugs that have saved thousands of lives. **Lidocaine**; a drug, is a common local anesthetic and antiarrhythmic.

Arrhythmia: a condition in which the heart beats with an irregular or abnormal rhythm.

More explanation on point number 3:

Normal heart rate 65-75beats/min.
If the heart rate became 200beats/min → this is failing heart and if I don't treat it immediately, the patient will die within minutes → direct Lidocaine injection into the heart (aiming toward slowing the Action Potential that is created in the SA node).

How does this injection work?
Lidocaine blocks the voltage-gated Sodium channels.
Thus, the SA node will slow down its autorhythmic generation of action potential.
From 200beats/min → 75beats/min

This is life saving! And this is the reason why those scientists received Nobel Prizes.

Diagnosis	Prognosis
The identification of the nature of an illness or other problem by examination of the symptoms	The likely course or outcome of a disease or ailment

- **Affect of the diameter of the nerve on the resting membrane potential:**

If you have a very narrow nerve fiber, the internal resistance will be very high. As the internal resistance increases, impedance to the sodium ion and other ions will be stronger, so there will be a difficulty in disturbing the membrane potential; a difficulty in propagation.

Thus, the narrow nerve fiber will have a lower resting membrane potential in the negative area (eg. -70mV), and the larger nerve fiber will have a higher resting membrane potential in the negative area (eg. -40mV).

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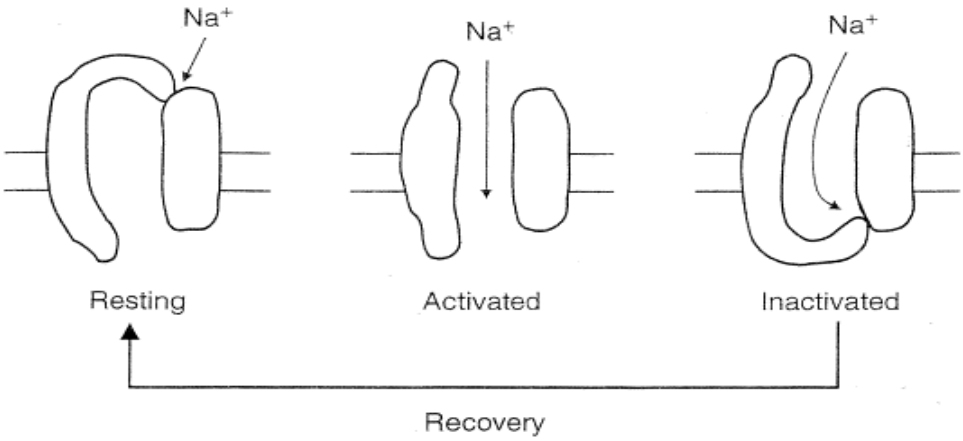
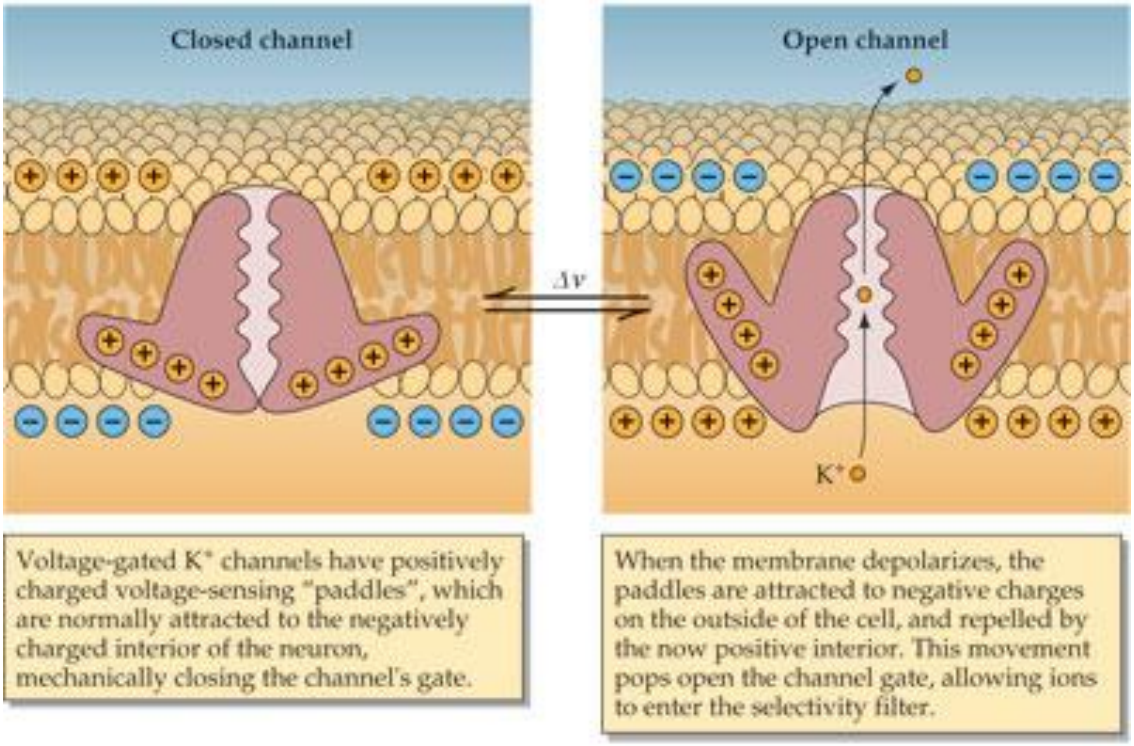
- **Voltage-gated channels:** these channels are sensitive to the voltage of the membrane.

1- **Sodium channels:** they have an **<u>inactivation gate</u>** on the **<u>intracellular</u>** side, and an **<u>activation gate</u>** on the **<u>extracellular</u>** side.
2- **Potassium channels:** they only have **<u>one</u>** gate that activates and inactivates.

Each of these gates open or close at a certain voltage and time during the action potential. This is what explains the duration of the action potential.





Arrhythmia: a condition in which the heart beats with an irregular or abnormal rhythm.

- We already know that after the action potential, the ionic composition will be disturbed within the nerve fiber. The **Sodium-Potassium pump** restores the original normal ionic composition.

- The more ionic disturbance there is within the neural tissue, the more active the sodium-potassium pump becomes. If the Sodium concentration inside the nerve fiber becomes double the normal concentration, the sodium-potassium pumps will work 8 times harder than normal.

- The sodium-potassium pump is an active pump; it needs ATP to work. Thus, we need Glucose to replenish the ATP is uses. It uses about 70% of the energy required by the brain (brain needs 20% energy → 15% of this is used by the pump).

- The action potential propagates; if you step on a nail, you will feel pain and immediately lift your foot. This feeling of pain was transported to the brain by the action potential and its propagation.

- The scientists have found that the action potential is transported (propagated) along the nerve fiber with the same amplitude; faithfully and unchanged. This means that the same intensity of pain will be conveyed to the brain. If this process was decremental, then we will feel it mildly, and perhaps we will not feel anything. **It is ALL OR NONE!**

- Every action potential that is generated along the nerve fiber does not need energy. You only need a stimulus to initiate the first action potential. This is why we call the action potential **REGENERATIVE**.

Always remember that:
Input to the brain → Sensation.
Output from the brain → Motor.

Are all of the sensations conveyed to the brain at the same speed?
Of course, not. Some sensations are conveyed at 0.5m/s, others are conveyed at 120m/s.

Which sensation is conveyed the fastest to the brain?
Balance & Equilibrium! It is conveyed at 120m/s.

- Patients who suffer from disequilibrium are usually miserable.
- The information that is conveyed very fast to the brain is that information which is related to the length and tension of the muscles, and deals with the position of your body, or parts of your body, in space.
- Pain is usually conveyed at a slow or moderate speed. The most important thing is for it to be persistent.

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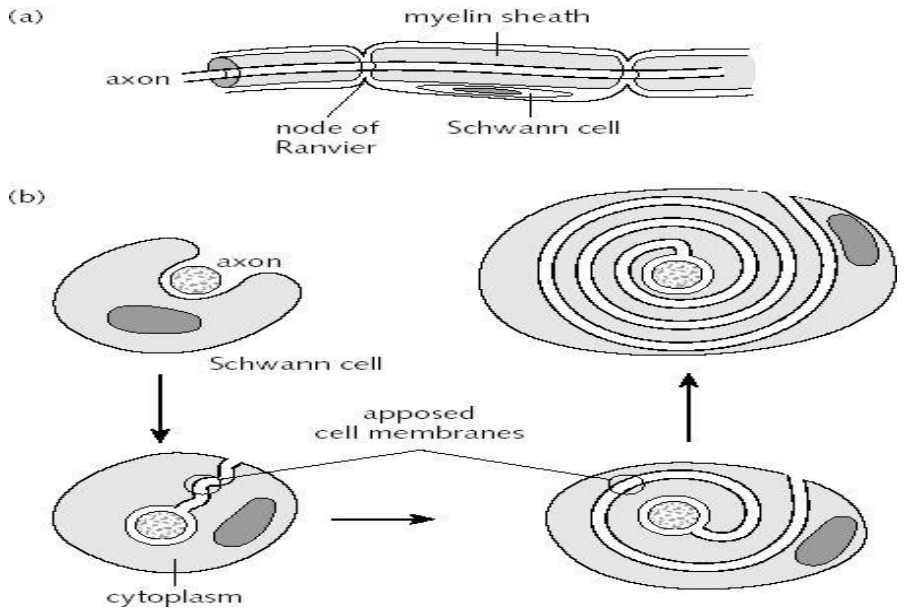
- **Nerve Fibers:**

- In order to convey information to the brain rapidly along the nerve fiber, we need it to be large in diameter and myelinated.
- In the human body, we cannot afford having large nerve fibers, so we compensated for this by myelination of nerve fibers.
- We have myelinated and unmyelinated nerve fibers.
- In the CNS we have cells called **Oligodendrocytes**, and at the peripherals (anything outside CNS) we have **Schwann cells**. Both of these cells are responsible for Myelination.
- The only difference between them is that the Oligodendrocytes myelinate multiple axons, while the Schwann cells are specific and myelinate only one axon each.

What is the difference between the myelinated and unmyelinated nerve fibers?

Type/Category	Myelinated	Unmyelinated
Wrapping of Schwann or Oligodendrocytes	Wrapping around the axon many times (about 10-15 times).	Multiple fibers covered by a single incomplete thin myelin sheath
Characteristics	High conduction velocity	Slow conduction velocity
More Correct Name	Heavily Myelinated Nerve Fiber	Partially Myelinated Nerve Fiber



Arrhythmia: a condition in which the heart beats with an irregular or abnormal rhythm.

- Please note how the Oligodendrocyte stretches out and myelinates multiple axons.
- Please note how in heavily myelinated fibers the Schwann cells wraps around one axon.
- Please note how in unmyelinated fibers the Schwann cells wraps around many axons packing them together.

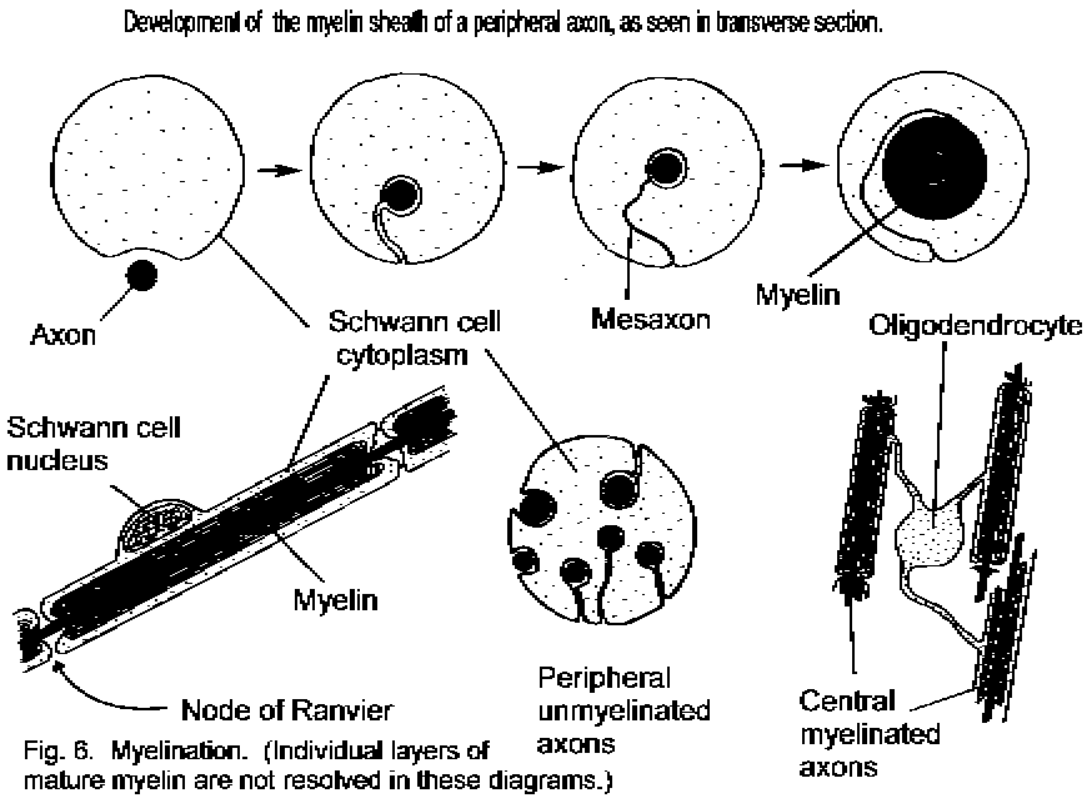


Fig. 6. Myelination. (Individual layers of mature myelin are not resolved in these diagrams.)

Best of luck!

"Ordinary people think merely of spending time. Great people think of using it."

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