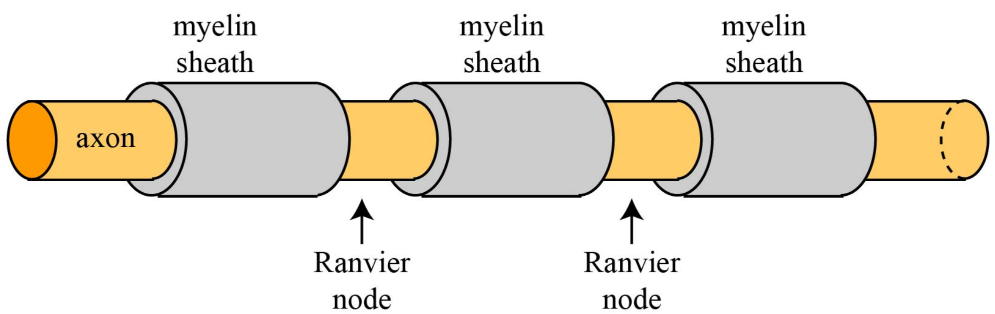
A.3.5. Saltatory Propagation

Introduction: 'Saltatory' propagation is a special type of propagation for the action potential. It only occurs along the 'very' long axons of nerve cells. The purpose of this type of propagation is to increase the **speed** of propagation.

A. Structural and physiological components required:

1. A cell membrane, along an axon, with Na^+ and K^+ ion channels located in this membrane.	2. A **myelin sheath** wrapped around the axon. This sheath is interrupted by **nodes of Ranvier**. The myelin sheath is like an insulator that isolates the axon membrane from the extracellular fluid.

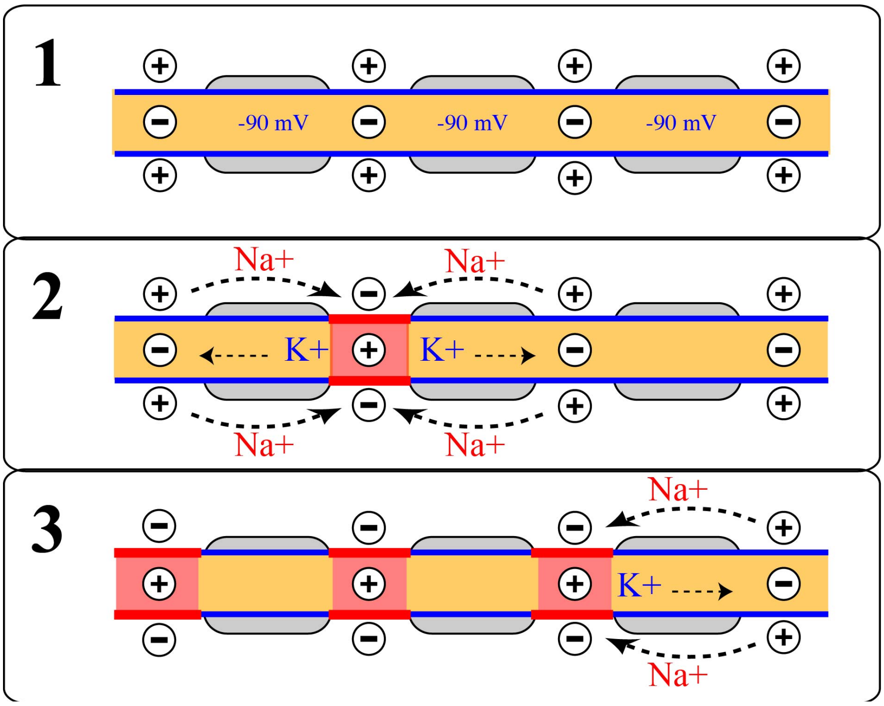


3. The nodes of Ranvier are the locations where the cellular membrane of the axon is in contact with the extracellular fluid.	4. The Na^+ and K^+ ion channels are only located at those Nodes of Ranvier (spoken as 'ranveer')

B. Saltatory Propagation; how does it work?

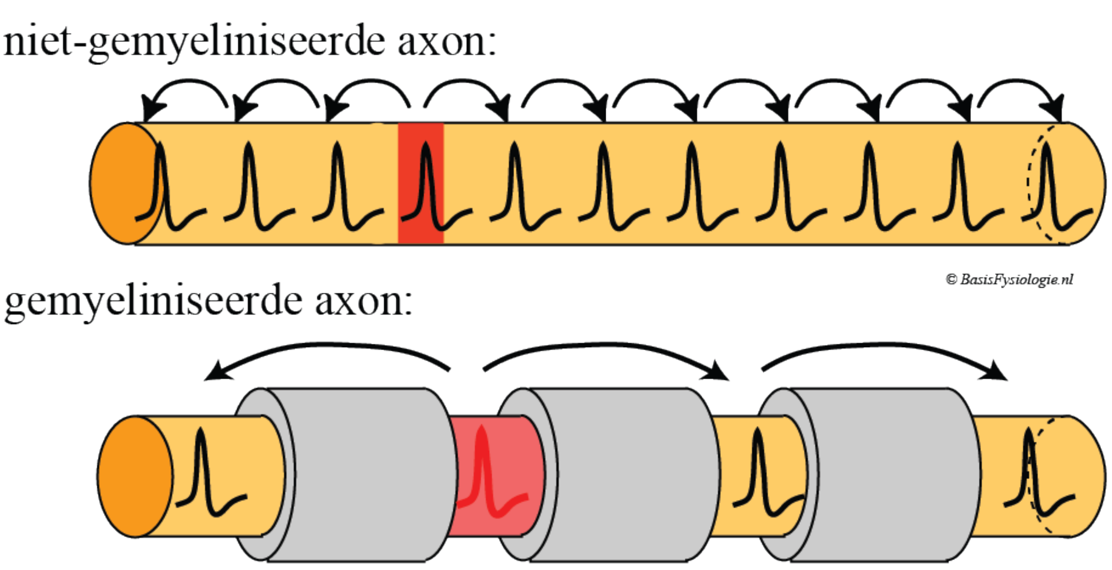
1. The potential distribution in a myelinated axon is the same as in a 'naked' axon. Inside is negative and outside is positive (see panel below).	2. In panel 2, an action potential has been initiated (by whatever mechanism) in one node of Ranvier panel (red color)
3. This means that at that location, the inside of the cell is then positive and the outside is negative. This occurs at the height of the action potential, during the overshoot.	4. Similar to normal electrical propagation, the neighborhood, left and right of this activated membrane, are still at rest and displays a resting potential: i.e. inside negative and outside positive.

5. In contrast to normal electrical propagation however, the next available channels are located further away, **at the next node**. The myelin sheath between these two nodes works as an **insulator** to the **extracellular** current flow.	6. In spite of the larger distance (0.5 – 2 mm max), there is still sufficient flow of ions (K^+ inside and Na^+ outside) between the **active** site and the two (left and right) **resting** sites (panel 2).



7. These current fluxes or current circuits (as these are also called) will influence the resting potential of the resting membrane in the left and the right node.	8. So, the flux of positive K^+ ions inside the membrane will decrease the negative resting potential while the removal of positive Na^+ ions outside the membrane will decrease the positive potential.
9. Hence the difference between the inside and outside becomes less, inducing a local depolarization, just like during a normal propagation.	**10.** When the depolarization of the resting membrane in the neighboring nodes reaches threshold, a new action potential is generated at these nodes.
11. This is essentially the same process as with normal propagation; the only difference is that saltatory propagation 'skips' a piece of the membrane.	**12.** Then, this new action potential will influence the next patch of resting membrane in the next node of Ranvier and the whole story starts all over again (panel 3).

C. In Summary: small steps vs. LARGE steps!

1. A local action potential, by influencing the flow of ions in its neighborhood, will effectively induce a new action potential in the next node of Ranvier. The action potential propagates therefore in **lager** steps from one node of membrane to the next and so on.	2. Because it makes bigger steps, the propagation will go **faster** (think of running with big steps in contrast to running with many small steps).
	

D. Some important Notes:

1. The big difference between normal propagation and saltatory propagation is **speed**. In normal propagation, the action potential is making small steps and that takes time. In saltatory propagation, these small steps are avoided by the myelin isolation that **forces** the action potential to make bigger steps.	2. Normal propagation along a non-myelinated axon is typically in the range of 0.5-1 m/sec. In myelinated axon, this ranges from 15 to 150 m/sec (i.e. 30-150x faster!)
3. Saltatory propagation is much faster than normal propagation because most of the distance is covered by **current** flow of ions, which is very fast. In normal propagation,	4. The term ‘saltatory’ means ‘jumping’ (**salto** = a leap), as in ‘*Salto Mortale*’ (= a deadly or daring jump!)

this flow is each time interrupted by having to induce a new action potential, which has to reach threshold, and then to depolarize and reach the overshoot, before the next current flow starts etc.	5. As with normal propagation, saltatory propagation can occur in any direction. Normally however, the propagation occurs from the soma to the pre-synaptic terminals.

E. Nice to know:

1. In primitive animals, such as the squid, there are also nerve cells and axons but these axons are not myelinated.	2. You only see myelinated axons in more advanced animals such as vertebrates (although some invertebrates, like the shrimp, do have myelin-like structures).
3. The theory is that during evolution, the nervous system became more complicated and needed faster propagation to control the body.	4. Therefore, myeline structures were developed to force the action potential to propagate faster.
5. There are several diseases, such as multiple sclerosis, in which the myelin cells are destroyed.	6. Although a lot of research is going on in this area of demyelination, a treatment is not yet available.