Why does an action potential propagate?

Local circuit theory

Axon behaves like passive electric cable to transmit depolarization.

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Active zone
Peak of action potential here at instant of time

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Local current flow will tend to depolarize axon on either side of action potential, thus triggering action potential there.

Why does action potential travel only one way?

Because axon behind action potential is refractory (Na+ channels are still inactivated)

Thus, only region ahead of action potential can be stimulated.
Nervous system designed so nerves normally excited only at one end – thus action potential always go in one direction: **orthodromic**.

**But:** can artificially stimulate to get 'backward' action potential: **antidromic**.
Figure 3.12 (Part I) Action Potential Conduction

1. Na+ channels open while K+ channels remain open.
2. Upstream Na+ channels inactivate.
3. Local depolarization causes neighboring Na+ channels to open.
4. Point A activates Na+ channels.
Figure 3.12 (Part 2) Action Potential Conduction

-55 Resting Potential
Threshold

-65 Resting Potential
Threshold

-85 Resting Potential
Threshold

Point C
Point B
Point A

0 mV

Time (ms)
0 1 2 3

The process is repeated.
Q. What determines speed of propagation of action potential?

A. How fast the next region of the axon can be depolarized to threshold for it to generate an action potential.

Local current from active zone must flow through axoplasmic resistance ($R_A$) to charge up capacitance ($C_m$) of next region of membrane.

This will be faster if:

- $R_A$ is smaller
- $C_m$ is smaller
Two ways to make an axon transmit action potentials faster

1. Make it fatter. (like the squid axon)

- Axoplasmic resistance $R$ varies with cross-sectional area of axon.
- Capacitance $C$ varies with circumference of axon.

Thus, $R_A$ will vary as $\frac{1}{r^2}$.

$C_M$ will vary as $r$.

Net effect is that as $r$ increases, $R_A \times C_M$ decreases, so that conduction velocity increases.
(2) Wrap myelin around axon.

myelin sheath laid down by Schwann (glial) cell

myelin sheath increases effective thickness of axon membrane many-fold. Thus capacitance is greatly reduced, speeding action potential.

Very efficient - as overall diameter of nerve increased only slightly.

Saltatory conduction

If all axon were wrapped in myelin, no space left for Na⁺ channels. Solution is to leave gaps of exposed axon

Action potential 'jumps' rapidly from node to node.
Figure 3.13 (Part 1) Saltatory Action Potential Conduction along a Myelinated Axon
Figure 3.13 (Part 2) Saltatory Action Potential Conduction along a Myelinated Axon