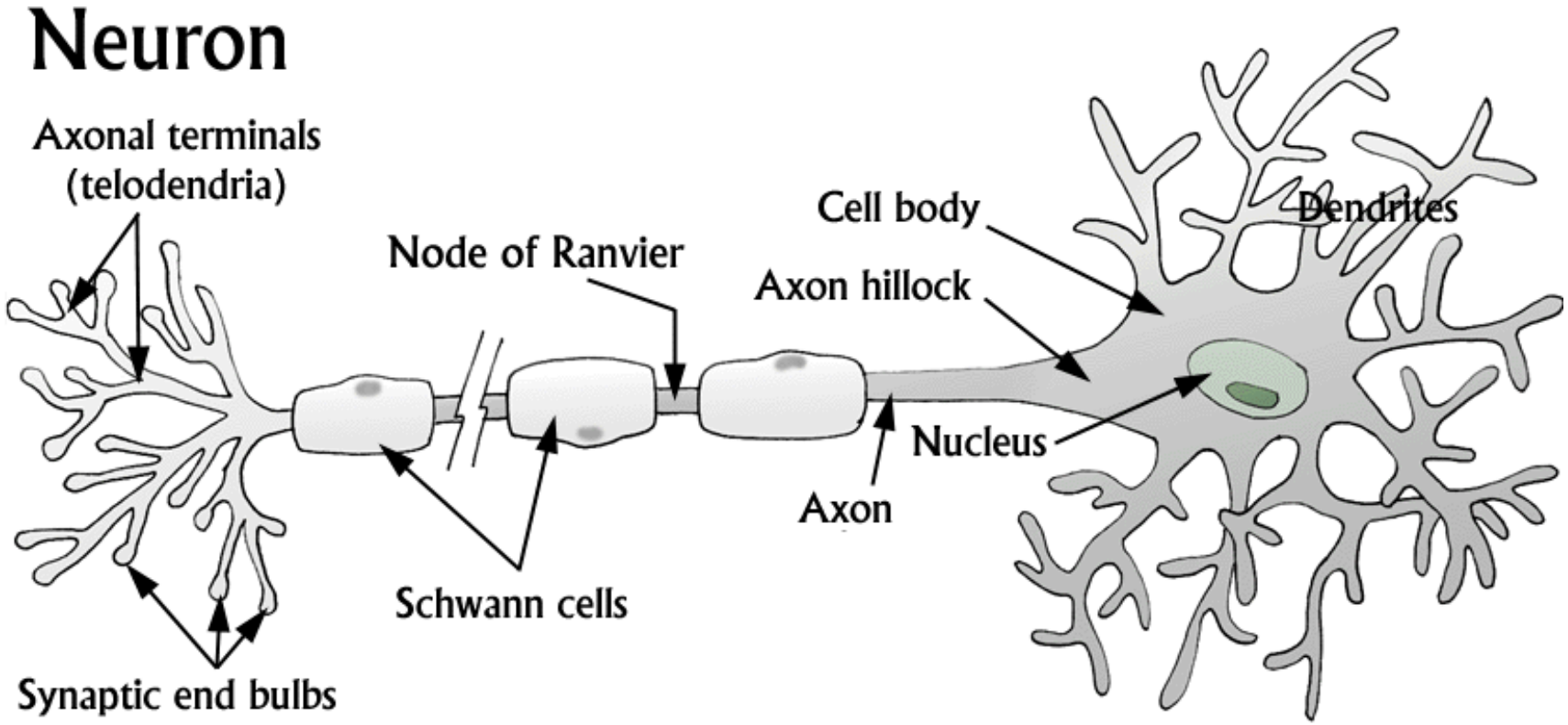
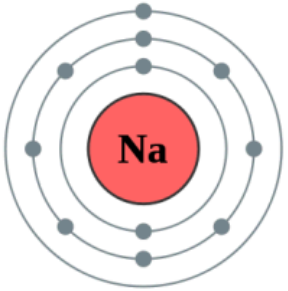
Electrical properties of neurons

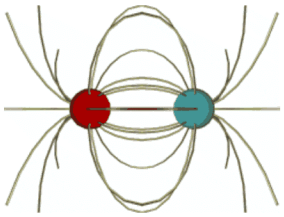


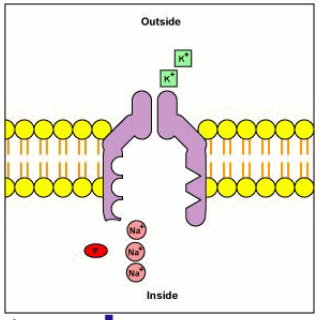
Neurons carry information electrically

What is electricity?

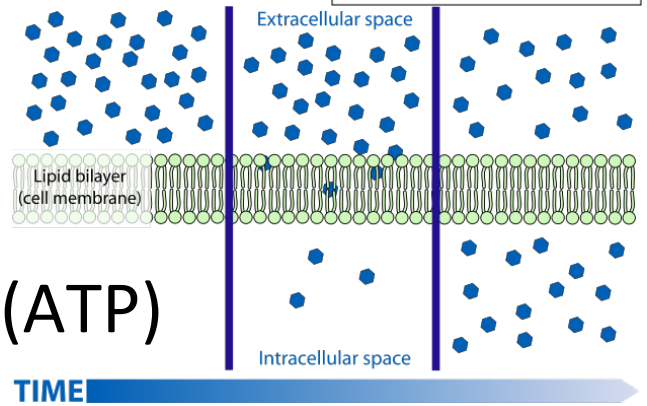


- A moving stream of charged particles…
  - Electrons in copper wires
  - **IONS** (Na+, K+, Cl-, Ca++) in biological "wires"

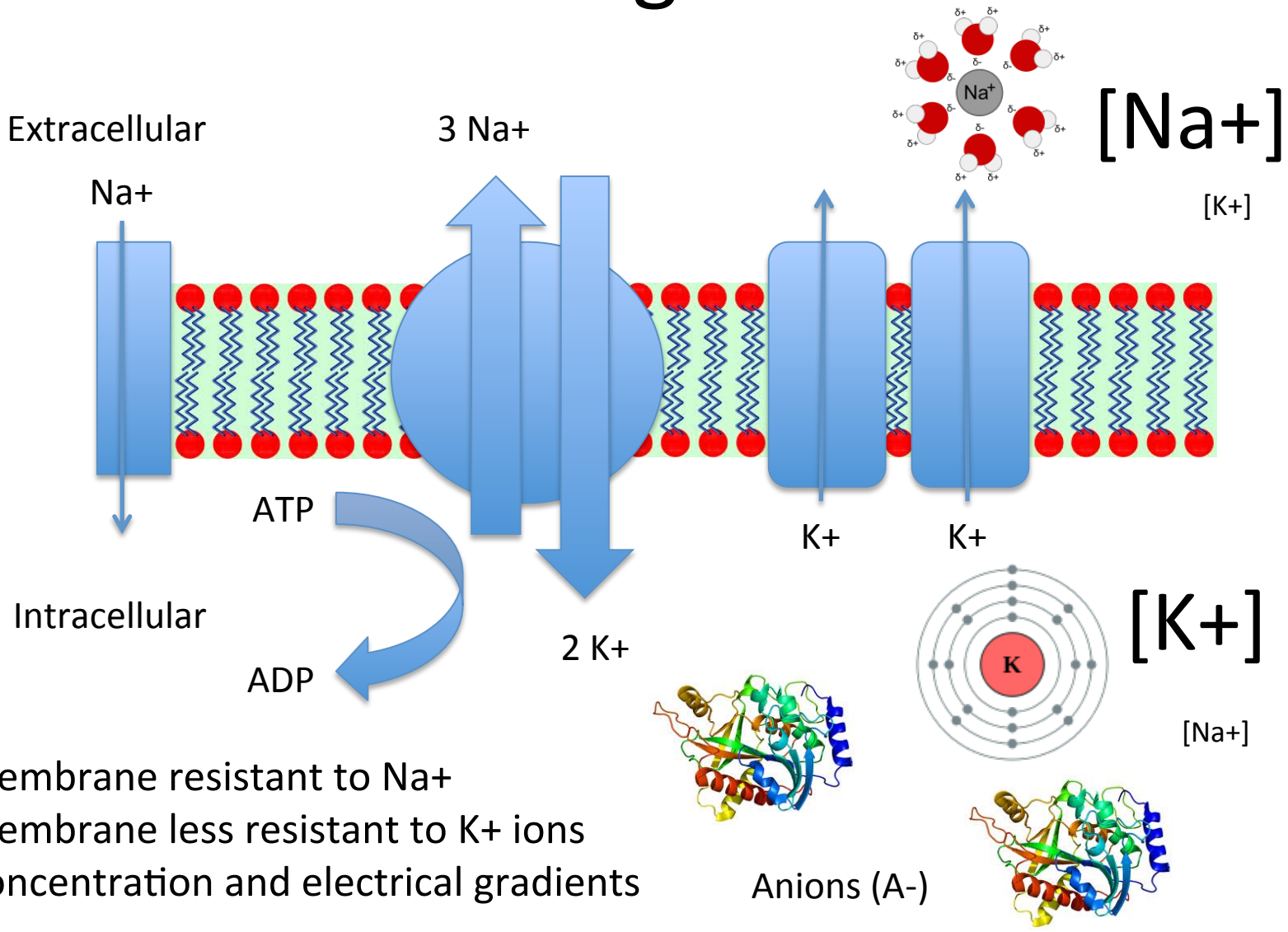




- WHY WOULD IONS MOVE..?
  - Electrical force
  - Concentration gradient force
  - Biological protein "machines" (ATP)



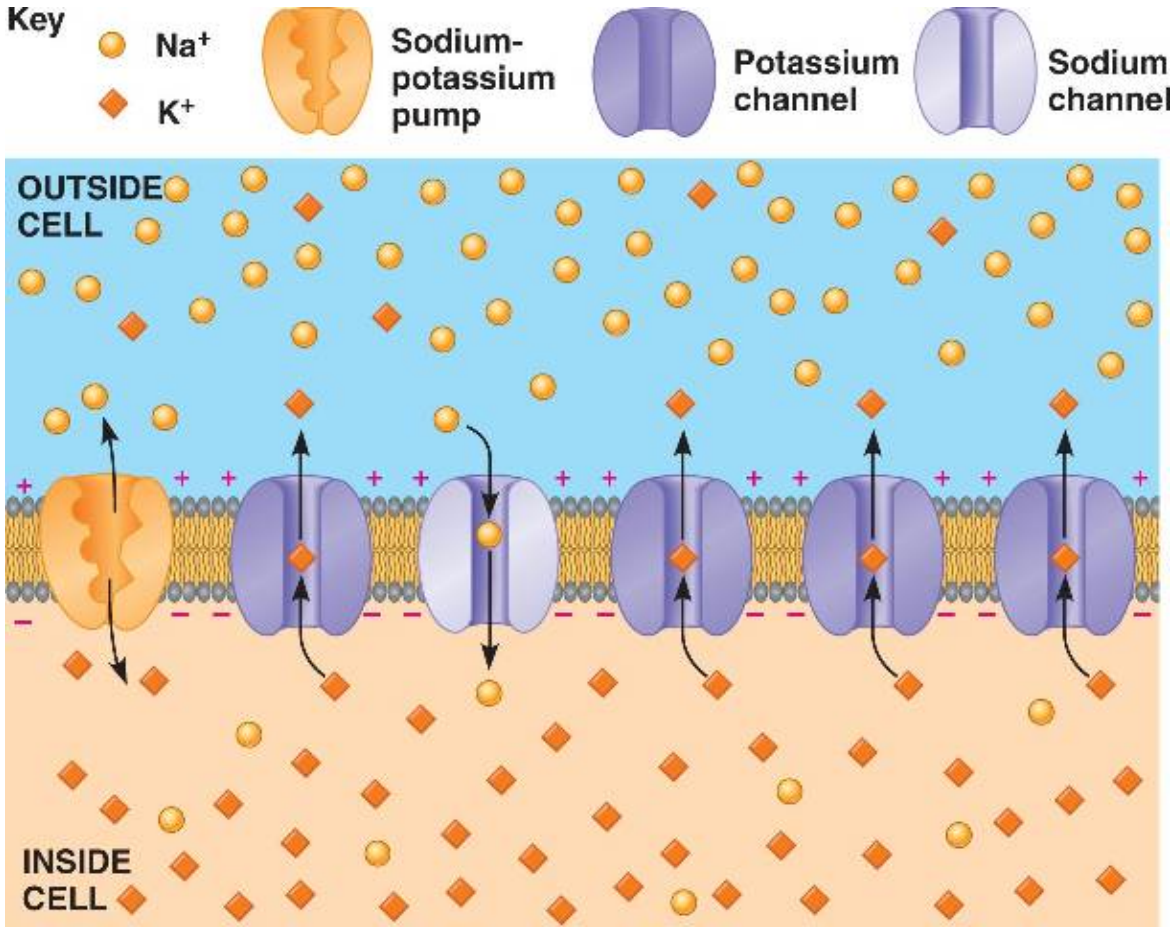
The Resting Potential



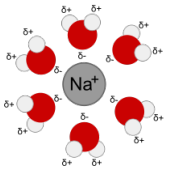
Membrane resistant to Na+
Membrane less resistant to K+ ions
Concentration and electrical gradients

Charge difference @ “rest”

- 65 – 70mV MORE NEGATIVE inside neuron vs. outside…
- High resistance to Na+ ions
- Small currents only; no “action” potential



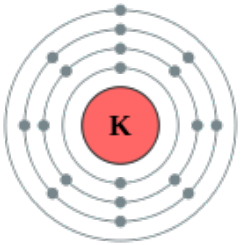
Polarization: @ rest, -65mV



[Na+]

[K+]

-65mV MORE negative



[K+]

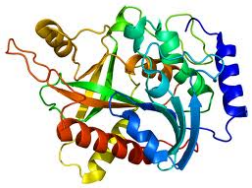
[Na+]

Less difference in charge:

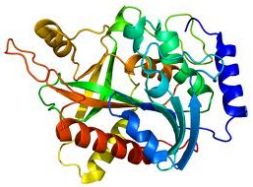
DEPOLARIZATION

More difference in charge:

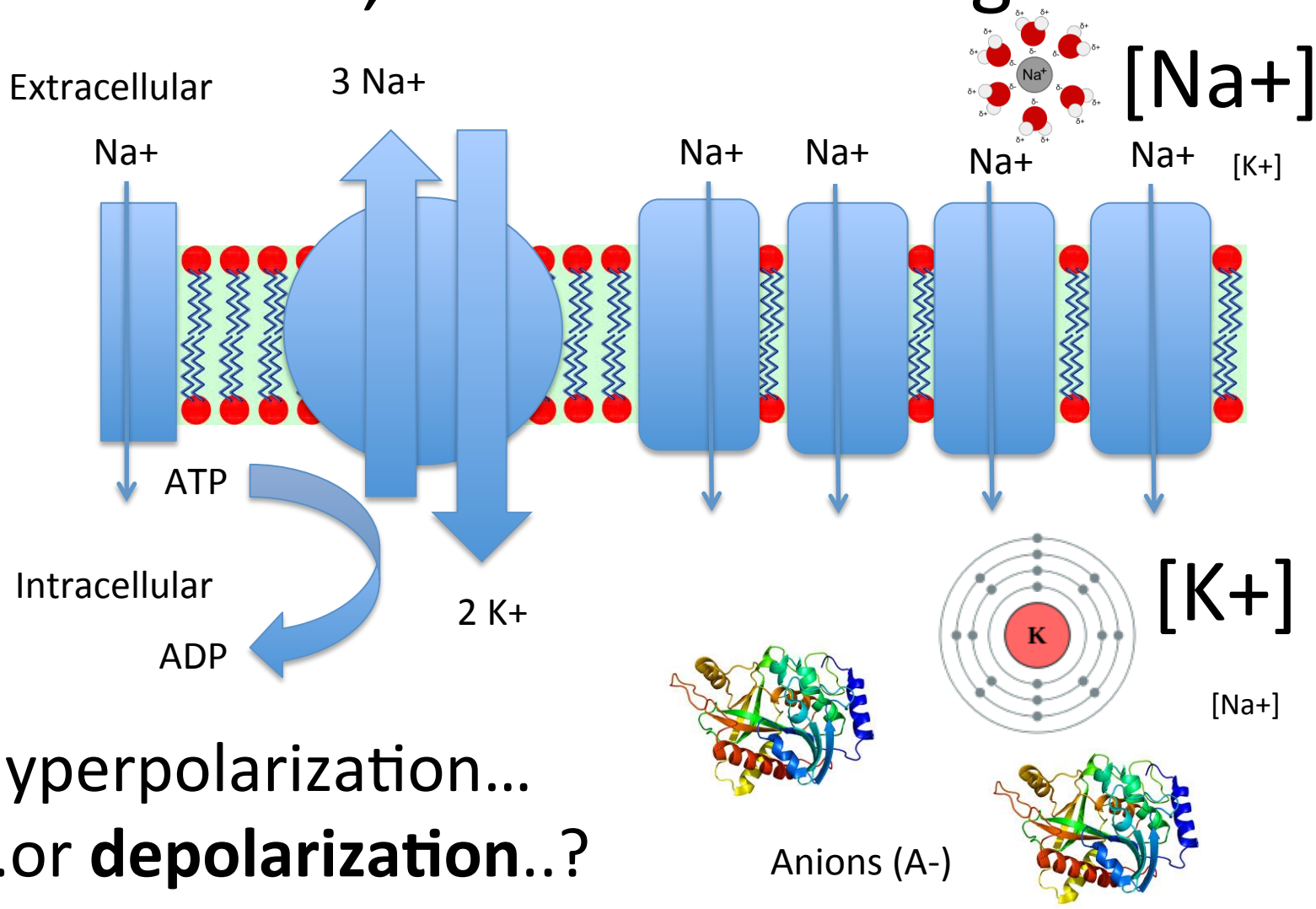
HYPERPOLARIZATION



Anions (A-)



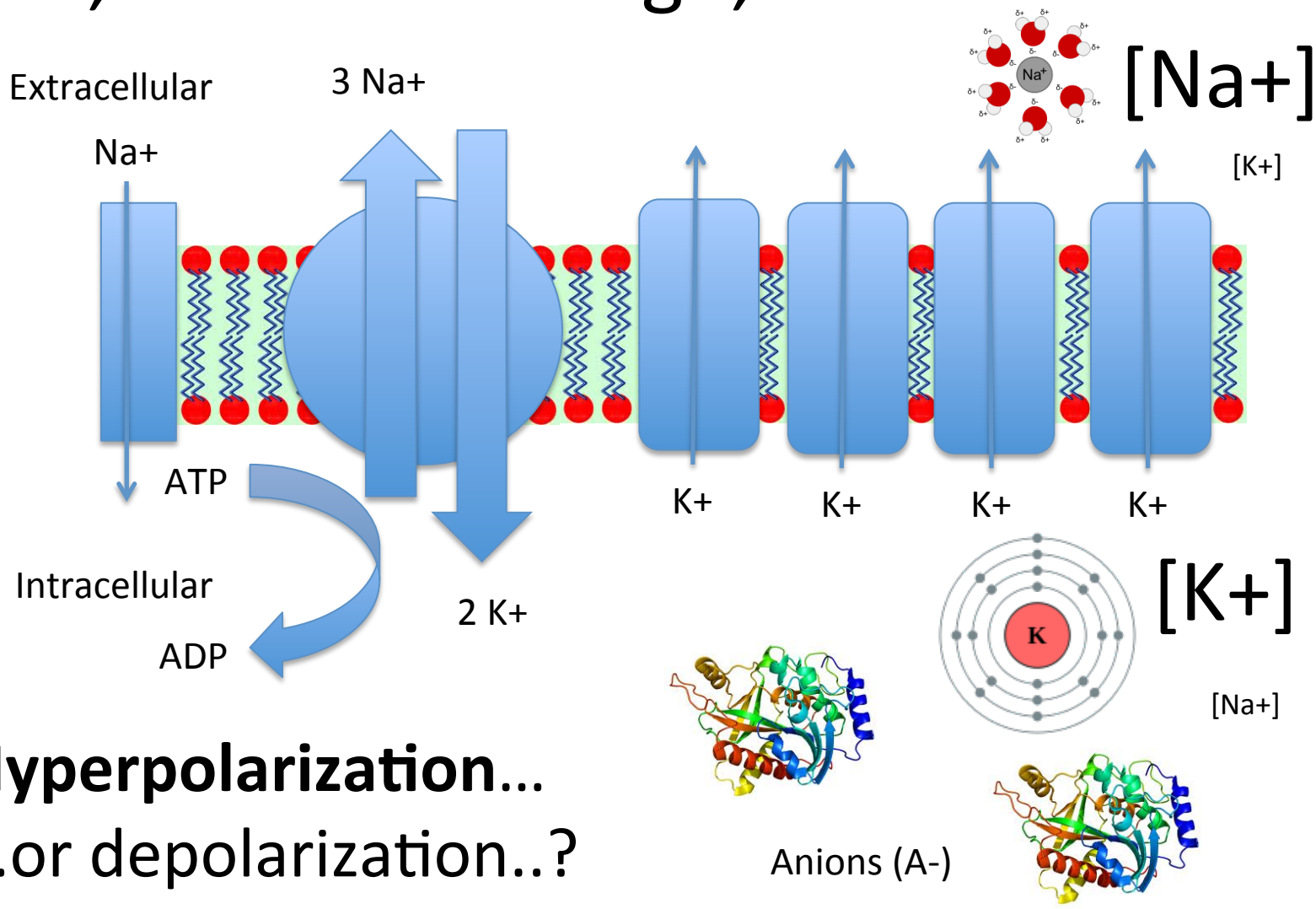
So if you open more Na+ channels at rest, where will Na+ go?



Hyperpolarization…

…or **depolarization**..?

So if you open more K+ channels at rest, where will K+ go, and until when?

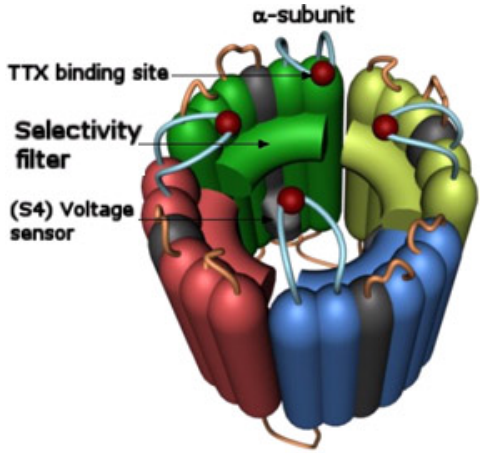


Hyperpolarization…

…or depolarization..?

The Action Potential

- How electrical messages travel within neurons
- *A rapid change in potential difference across the neuron membrane caused by the movement of ions*



THINK: *How do ions move across the membrane?*

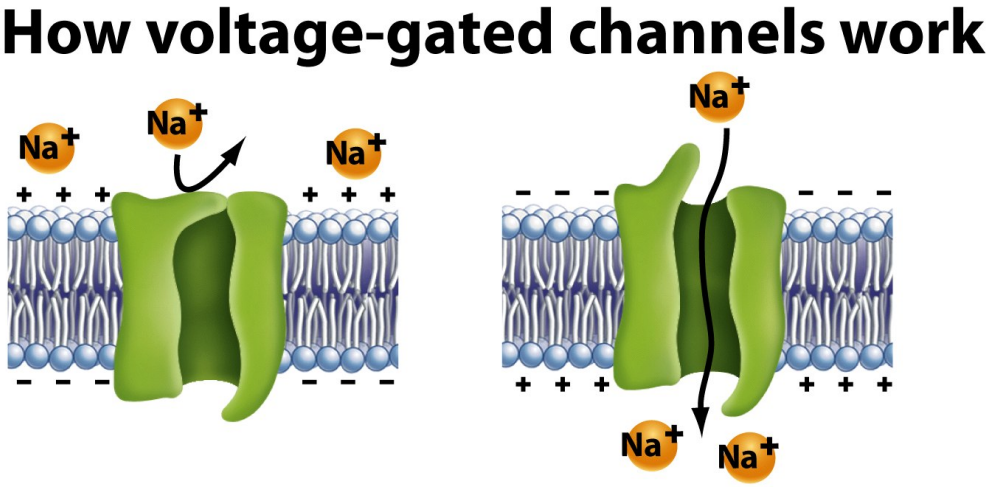
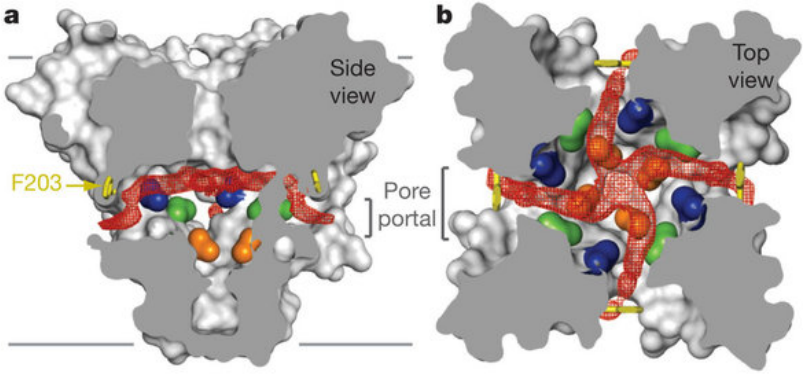


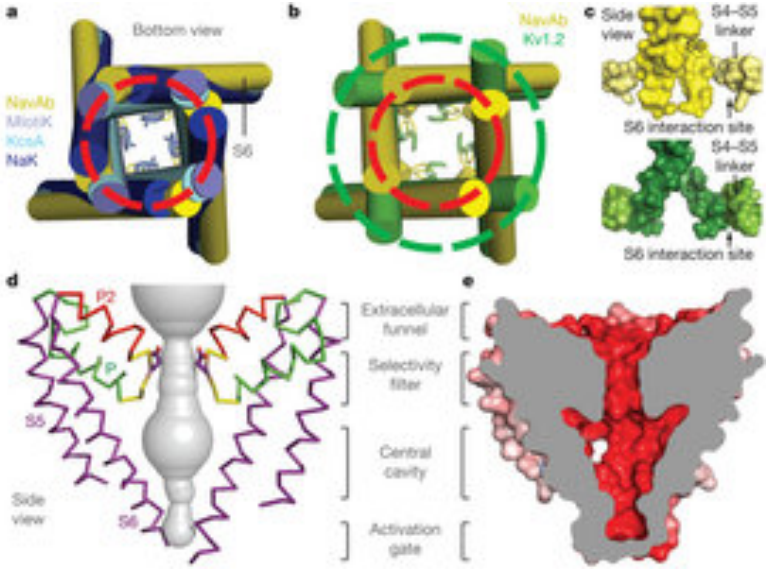
Figure 45-8c Biological Science, 2/e

Voltage gated Na+ channel

- Closed at the resting potential (-65mV)
- Opens at the threshold potential (-55mV)
- Sodium ions rush in, furthering depolarization
- Voltage gated sodium channel closes (after 1ms)
- Won't re-open until repolarization (to -65mV)

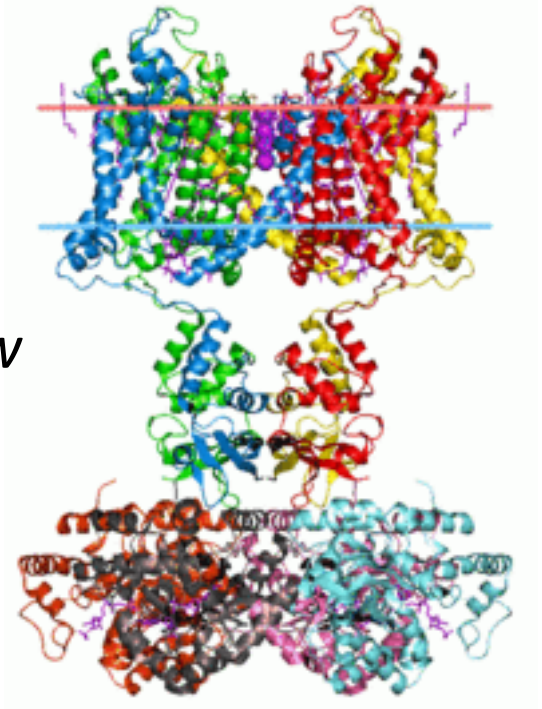


The crystal structure of a voltage-gated sodium channel, Payandah et al (2011)



Voltage gated K+ channel

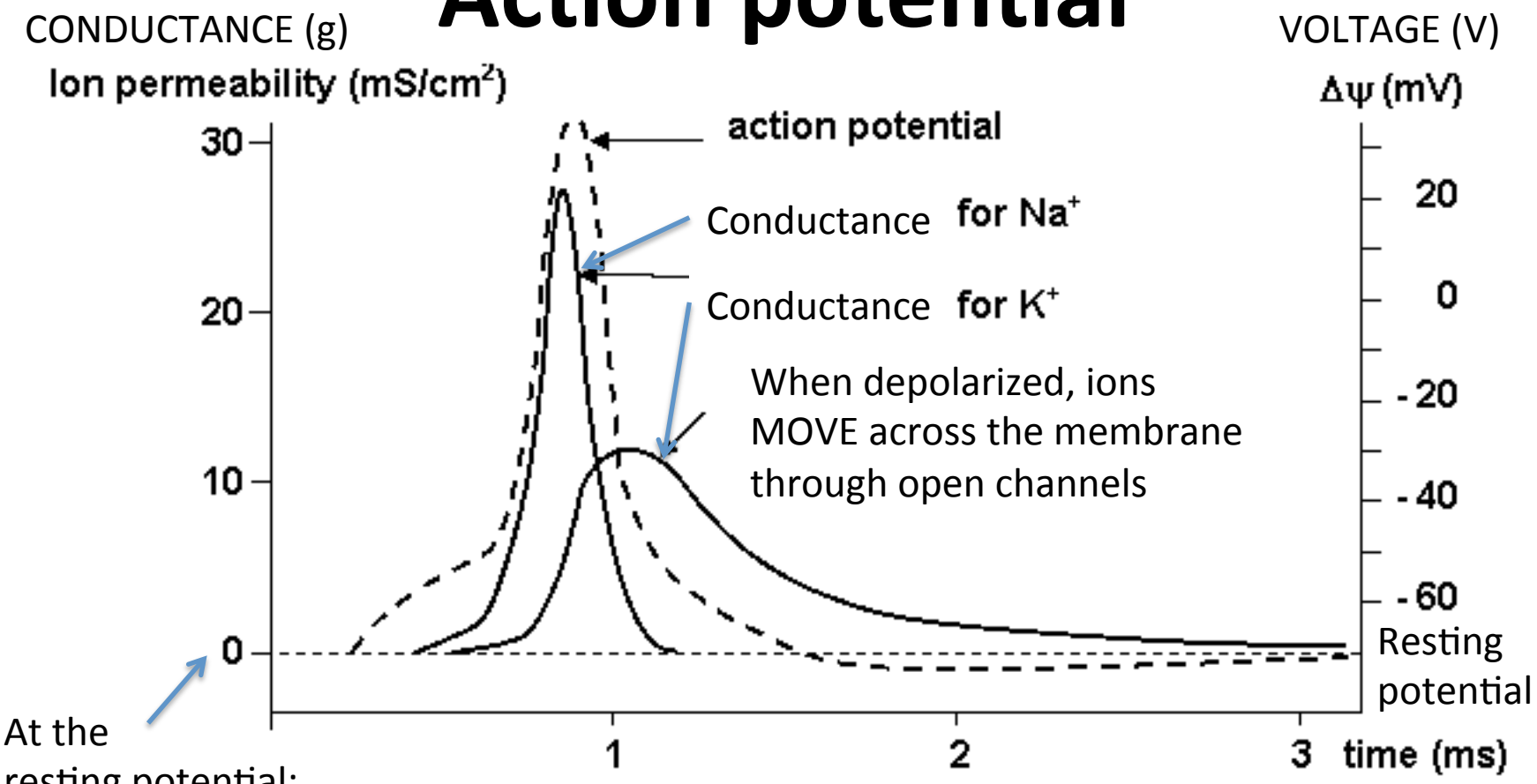
- Another voltage gated channel
- Opens at similar threshold (-55mV)
- Remains open longer…
- *Which way will K+ ions go?*



CONSIDER: *How will the rate of ion flow change as these rapid voltage changes occur..?* Forces at work include:

1. Concentration gradient
2. Electrical force…

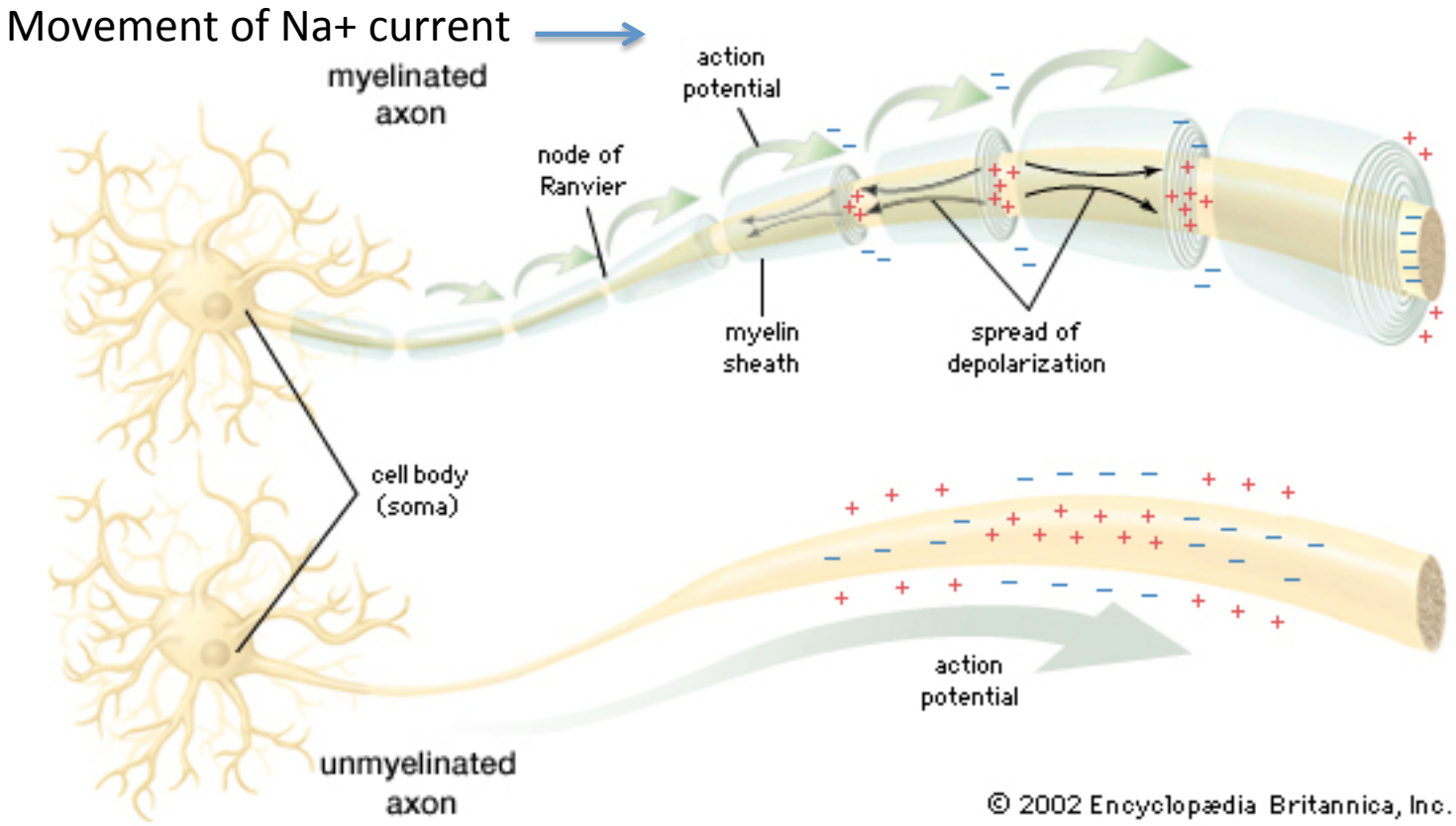
Action potential



At the resting potential: No open voltage-gated Na+ or K+ channels, so no conductance

Voltage changes across the membrane are caused by ions moving across that membrane - through ion channels

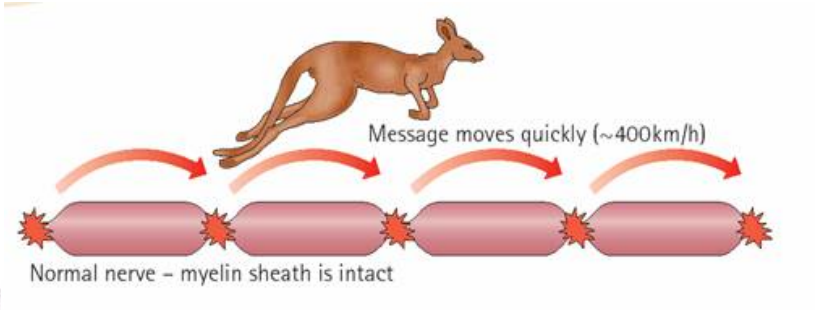
Propagation of the action potential

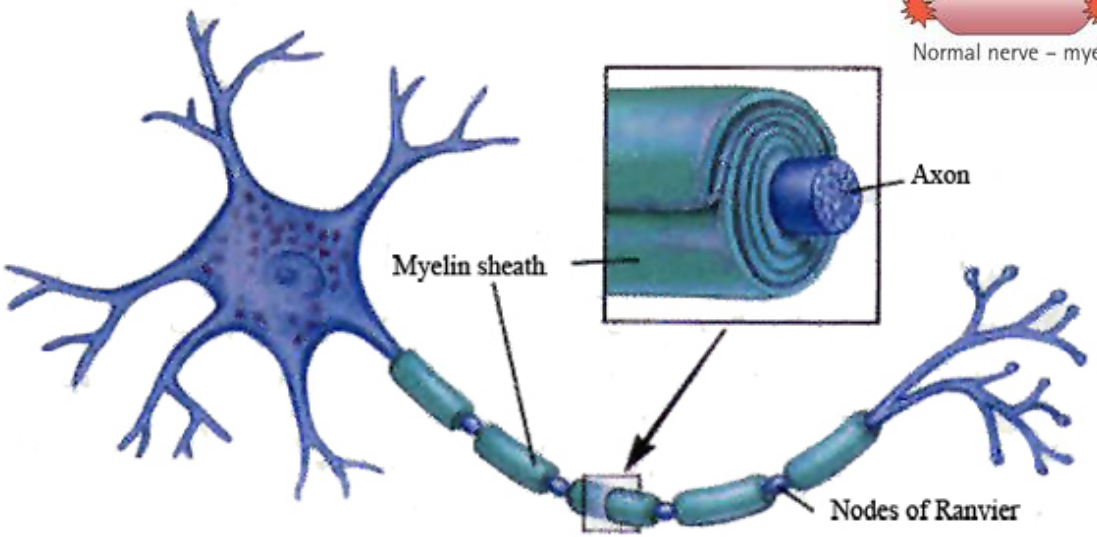


- If the axon hillock is depolarized to threshold…
- Try drawing what happens next ☺

What does myelin do?

Speeds up electrical signals

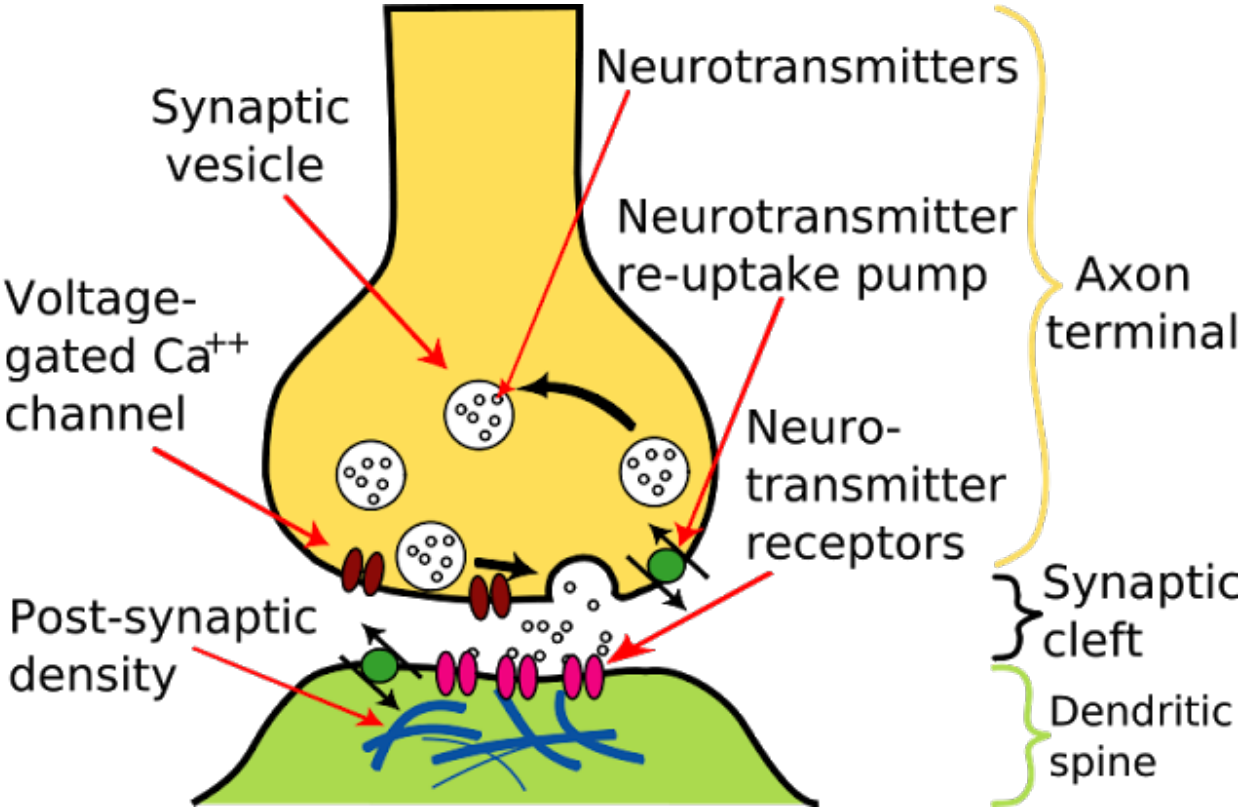




- **Saltatory conduction** (from 2m/sec to 120m/sec)
- **Multiple sclerosis**, an autoimmune disorder

The Synapse

Where the “language” changes; energy is converted; a switch from electrical current to the release of chemicals



Neurotransmitters

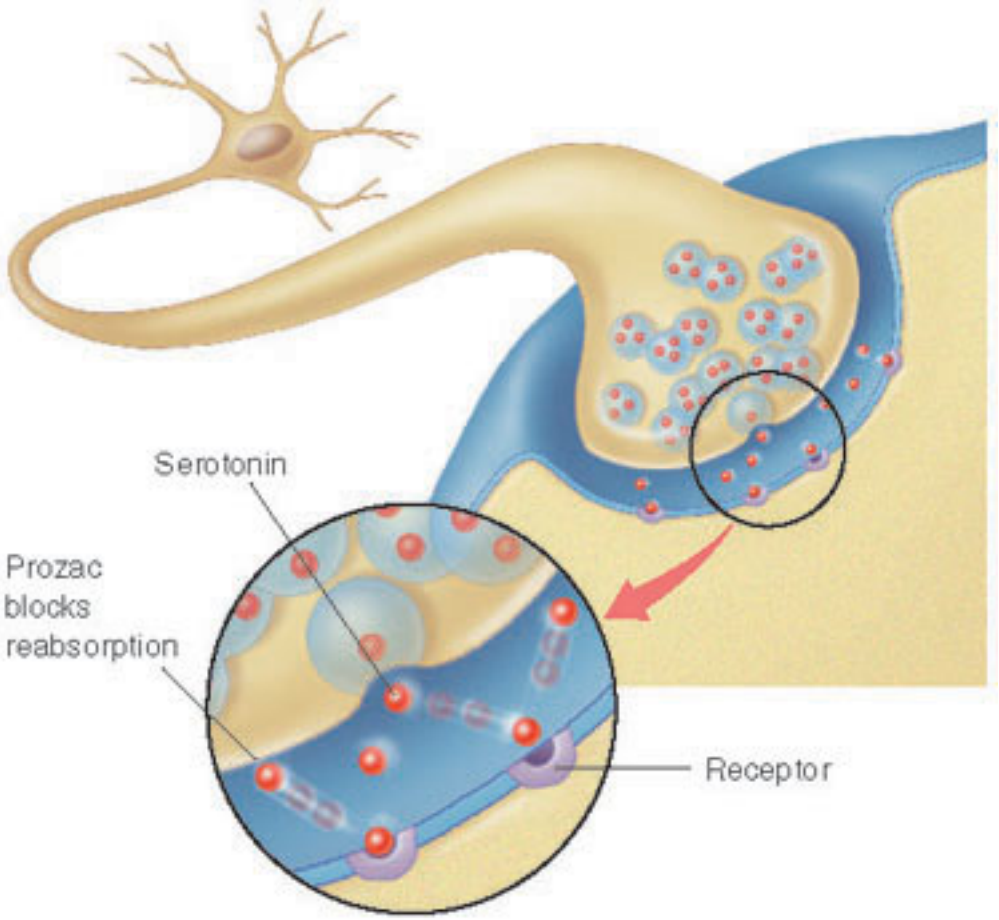
Act on **RECEPTORS**.

Neurotransmitter binds to the receptor, and the receptor plus neurotransmitter changes shape…

That sudden change in shape/ structure changes function…

Excitation? Action potential

Inhibition? NO AP…



Excitation vs. Inhibition

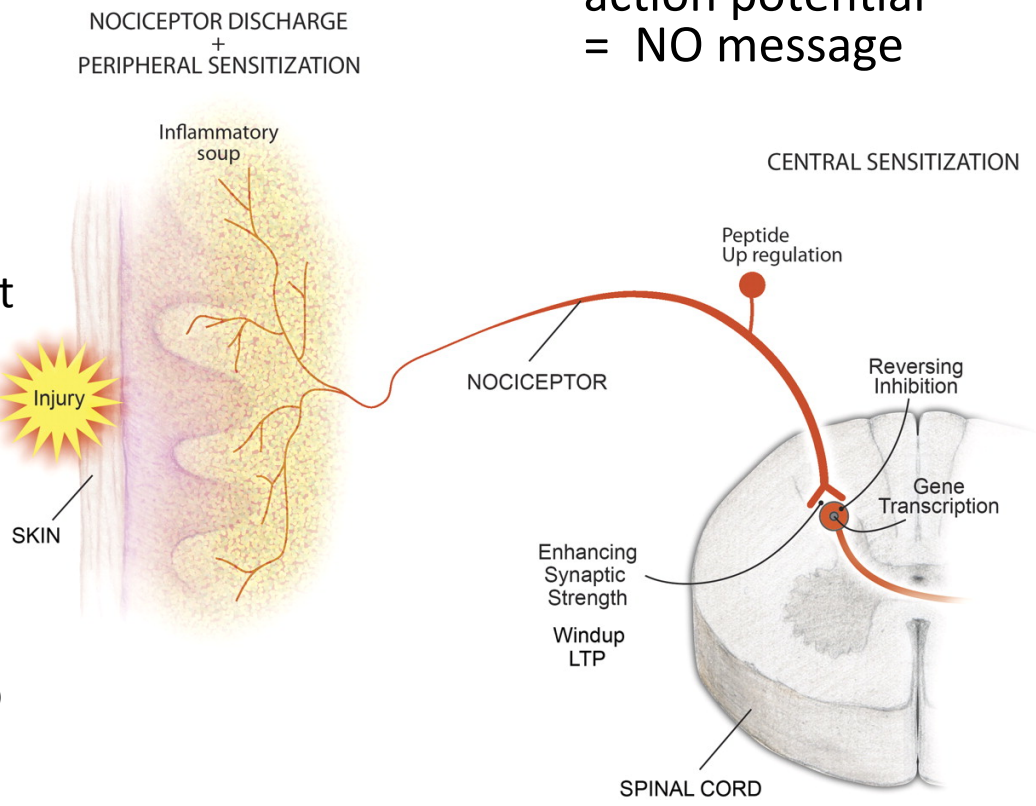
THINK PAIN…

What is detected?
Tissue damage: proteins spill out of broken cells

What does the detection?
Specialized sensory neurons, called **nociceptors**. They have receptors in their membrane that bind released proteins…

WHY do nociceptors respond(send out an action potential)?
Receptors plus released proteins change shape. Open channels to Na+ ions; nociceptor depolarizes to threshold for AP…

- **Excitation**: Action potential = message!
- **Inhibition**: NO action potential = NO message



Where does information go?

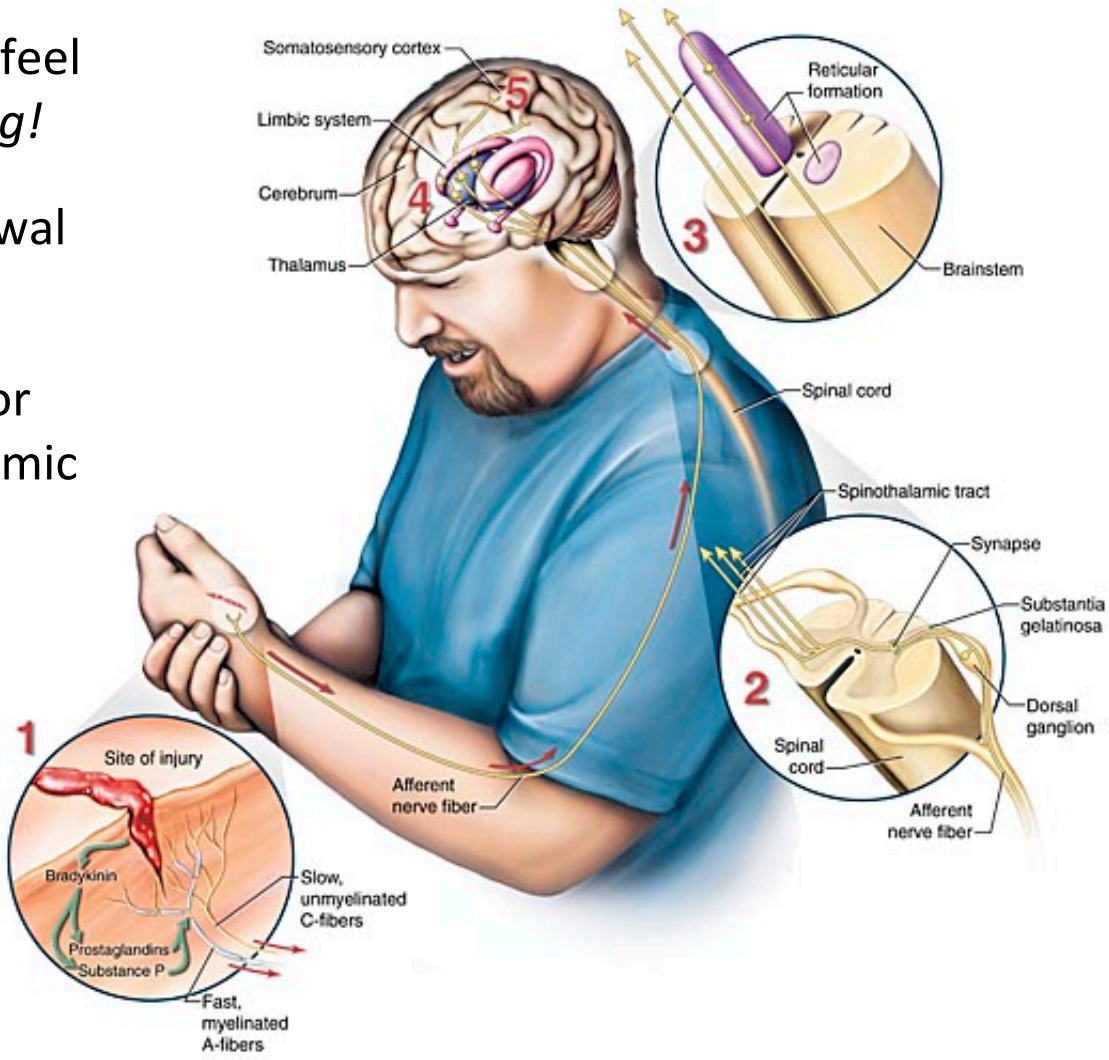
Nociceptor detects the damage…but you don't yet feel the pain. *But lots happening!*

Spinal cord: reflex withdrawal

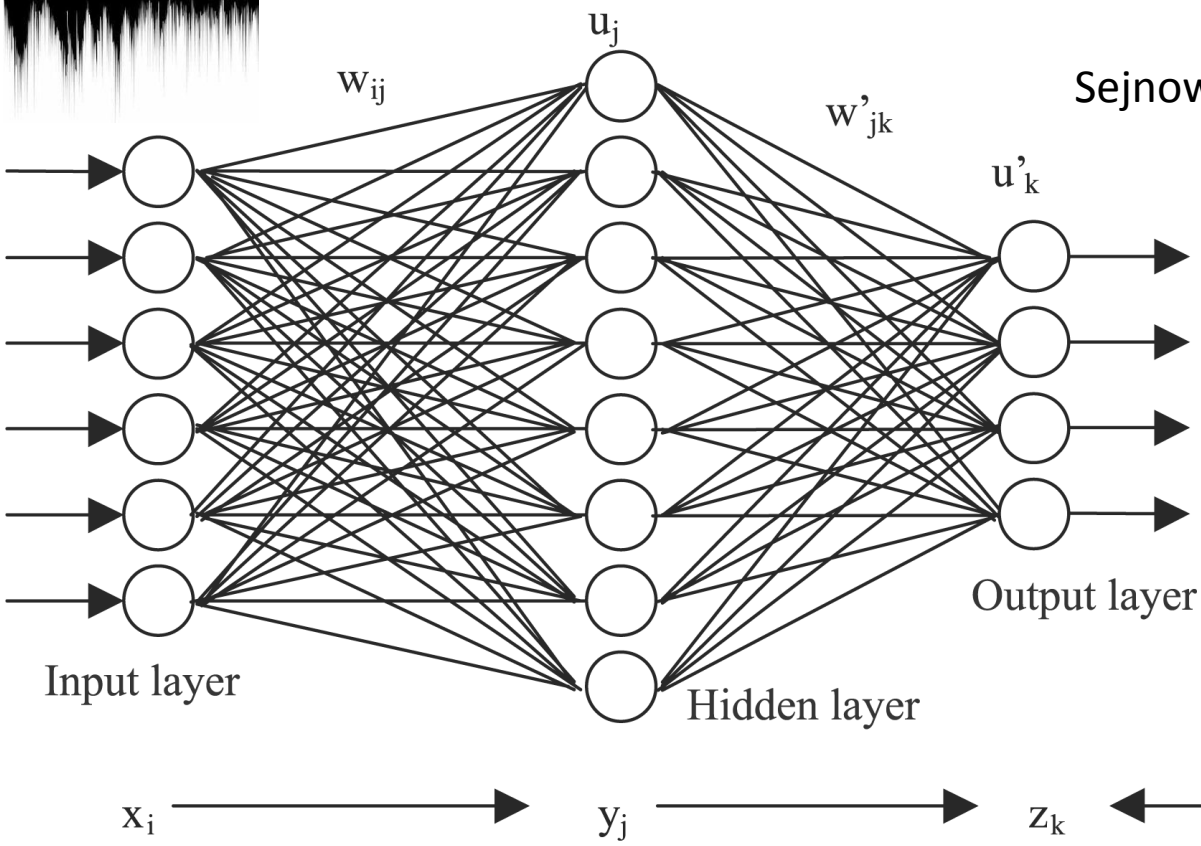
Brainstem: reticular formation (arousal); superior colliculi (orienting); autonomic nervous system(increased heart rate, etc.)

Cortex: Feeling (ouch!!), decision making, memory, higher level conscious appreciation.

PERCEPTION..?



Neural networks



Sejnowski & Gorman, 1987)

Sonar echoes…

Mine?

Or rock..?

Sensory neurons CNS/interneurons Motor neurons