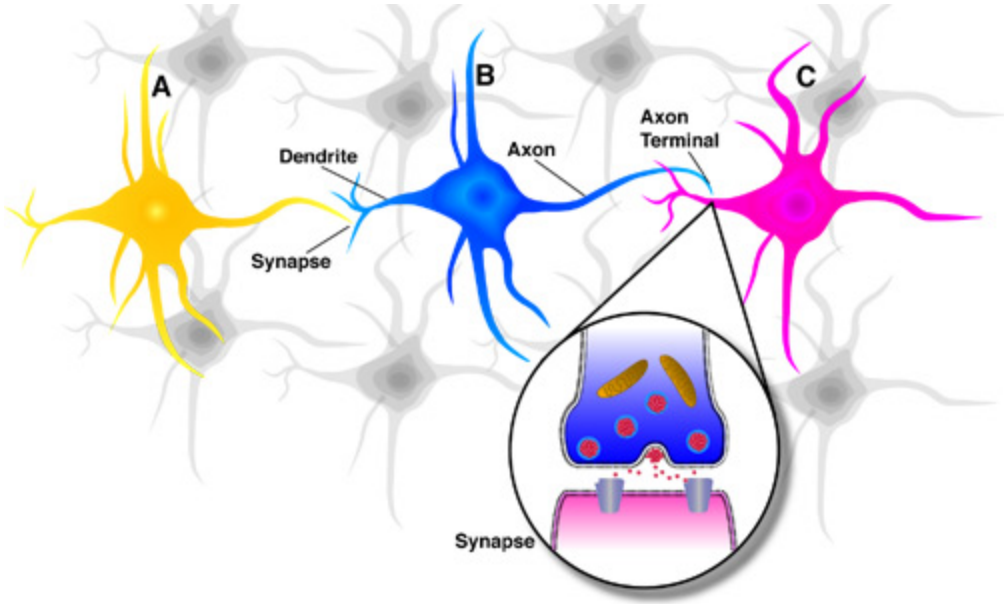
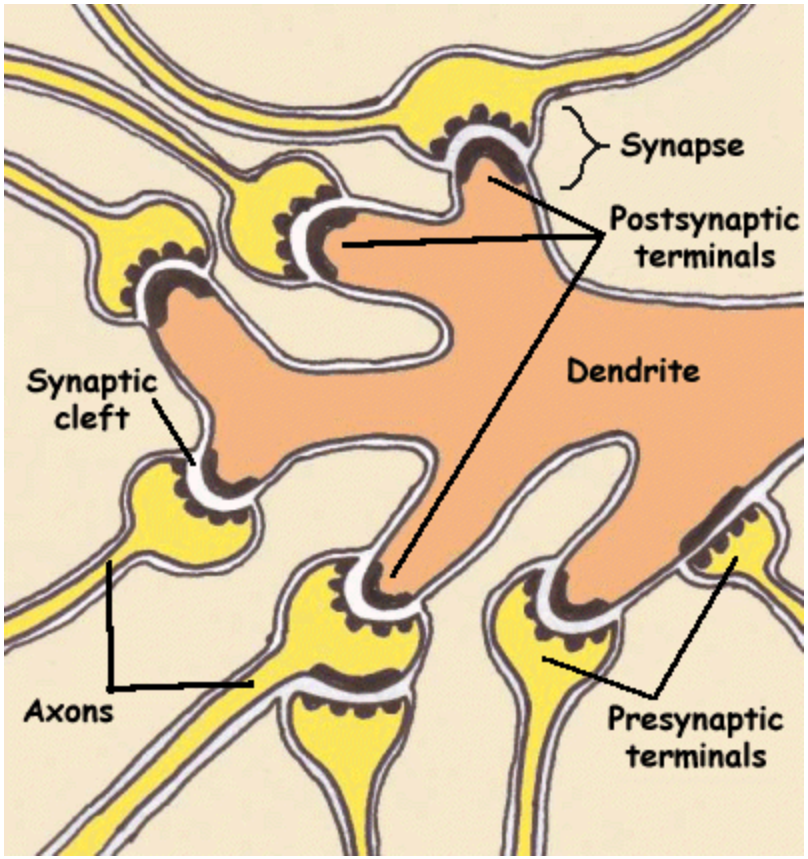
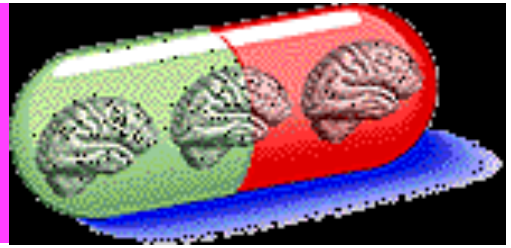
How does information within our nervous system travel?

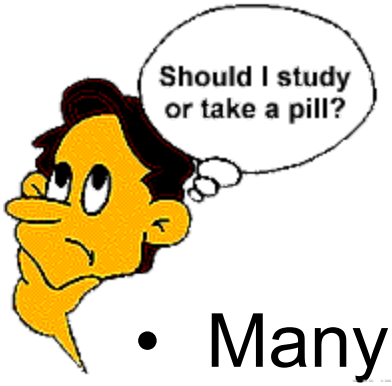




Smart Drugs

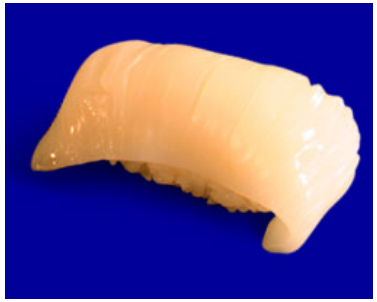


- Wouldn’t it be nice if you could take a pill and not study for exams?
- There are drugs called **“cognitive enhancers”** or “smart drugs”
  - Originally intended to treat Alzheimer's or Parkinson's disease
- These improve memory, learning, attention, concentration, problem solving, reasoning, social skills, decision making and planning.



Would you buy a smart drug?

- Many companies make "smart" drinks, smart power bars and diet supplements containing certain "smart" chemicals
- **Ginkgo Biloba** is believed to increase blood flow in the brain = smartness!
- **Question:** Should it be illegal to pop a smart pill before a test? Would this be like taking a stimulant before a swim race? Would this be cheating?



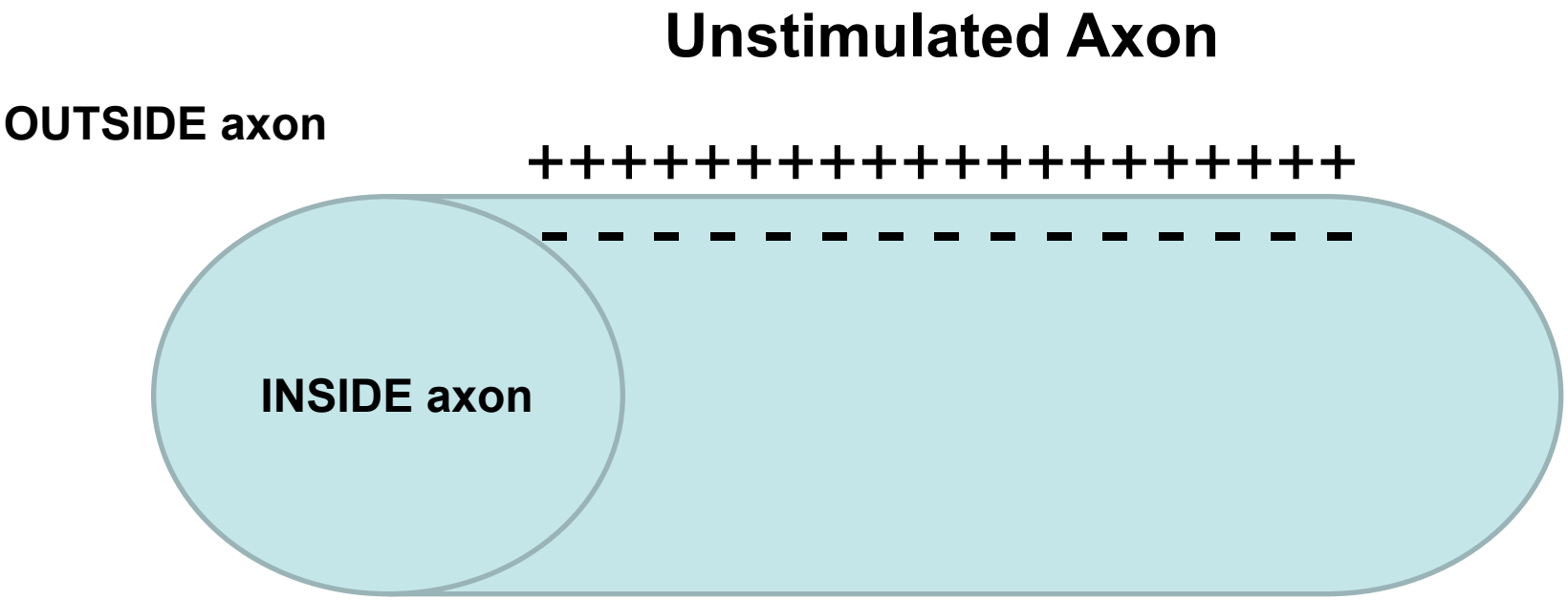
Electrochemical properties of neurons

- How do we know what a nerve impulse is and how is it created?
- K.S. Cole and J.J Curtis studied the **giant squid axon**
  - They placed electrodes inside the nerve of the squid

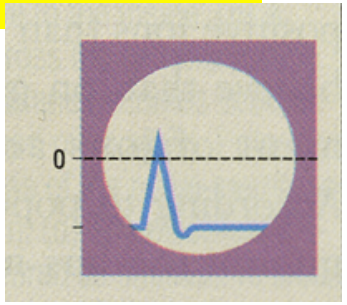
Resting membrane potential = **-70mV**

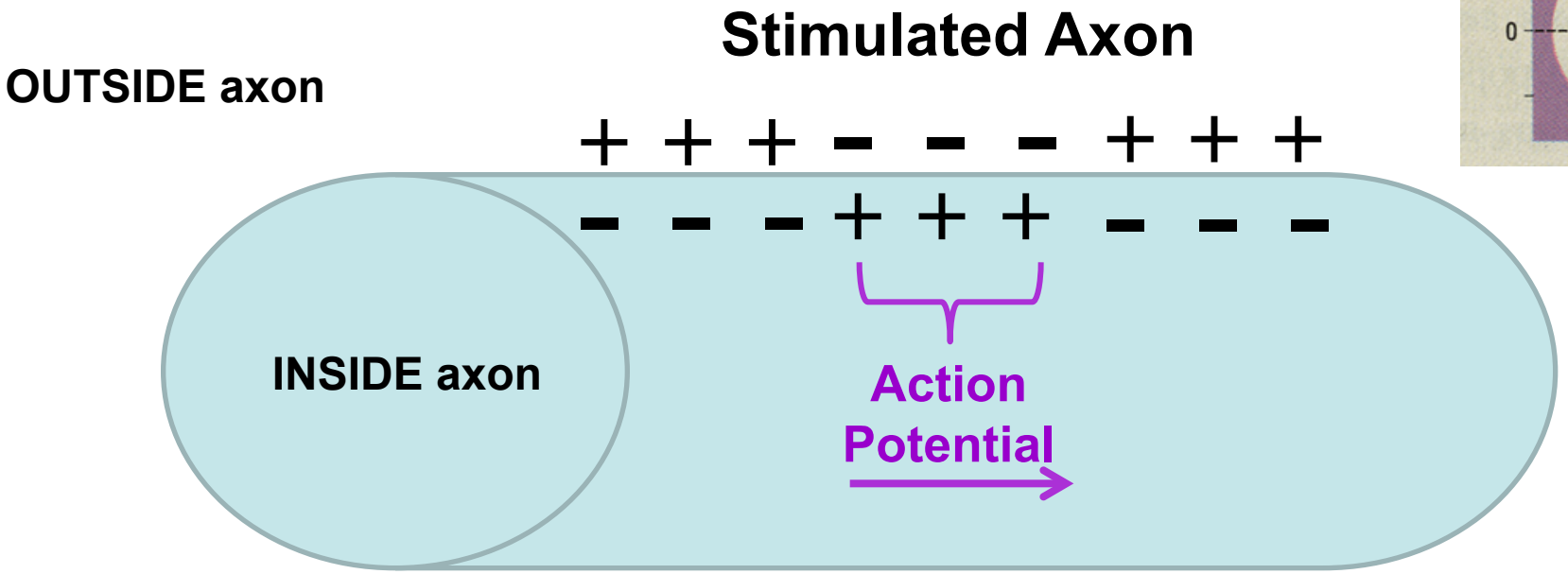
This is when the neuron is not active

An unstimulated axon is negative on the inside in respect to the outside



Action potential = **+40mV**
This is when the axon **becomes excited.**
Every time the axon is stimulated, there is a change in charge across the membrane.





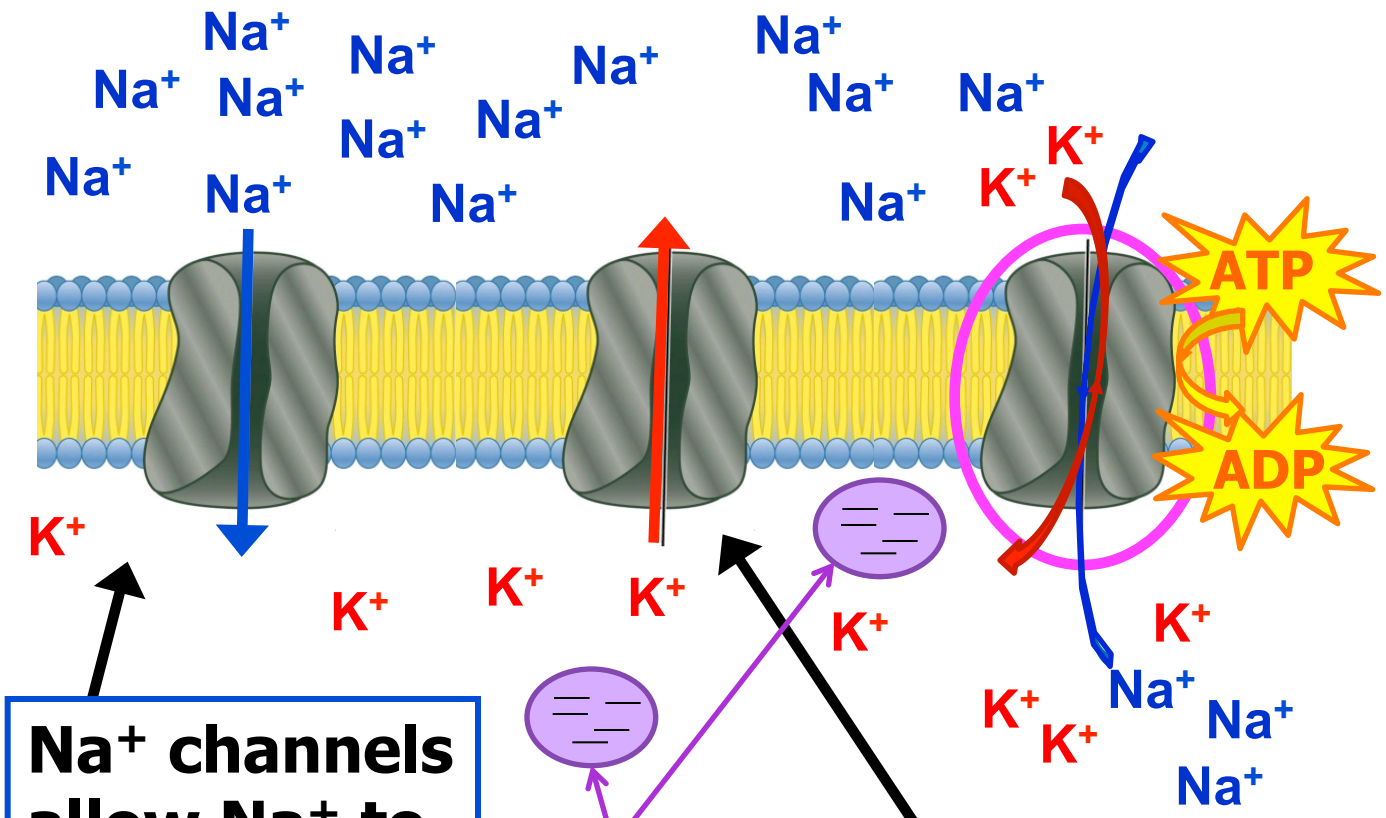
CLICK ME:
Action Potential

Resting neuron – What creates the charge difference?

- The charge difference is due to positive ions
- There are more sodium ions (Na^+) outside than potassium ions (K^+) inside the neuron = separation of charge = polarization

Axon Membrane

OUT



Na^+/K^+ pump moves $3Na^+$ out for every $2K^+$ in. Requires ATP

Na^+ channels allow Na^+ to diffuse in

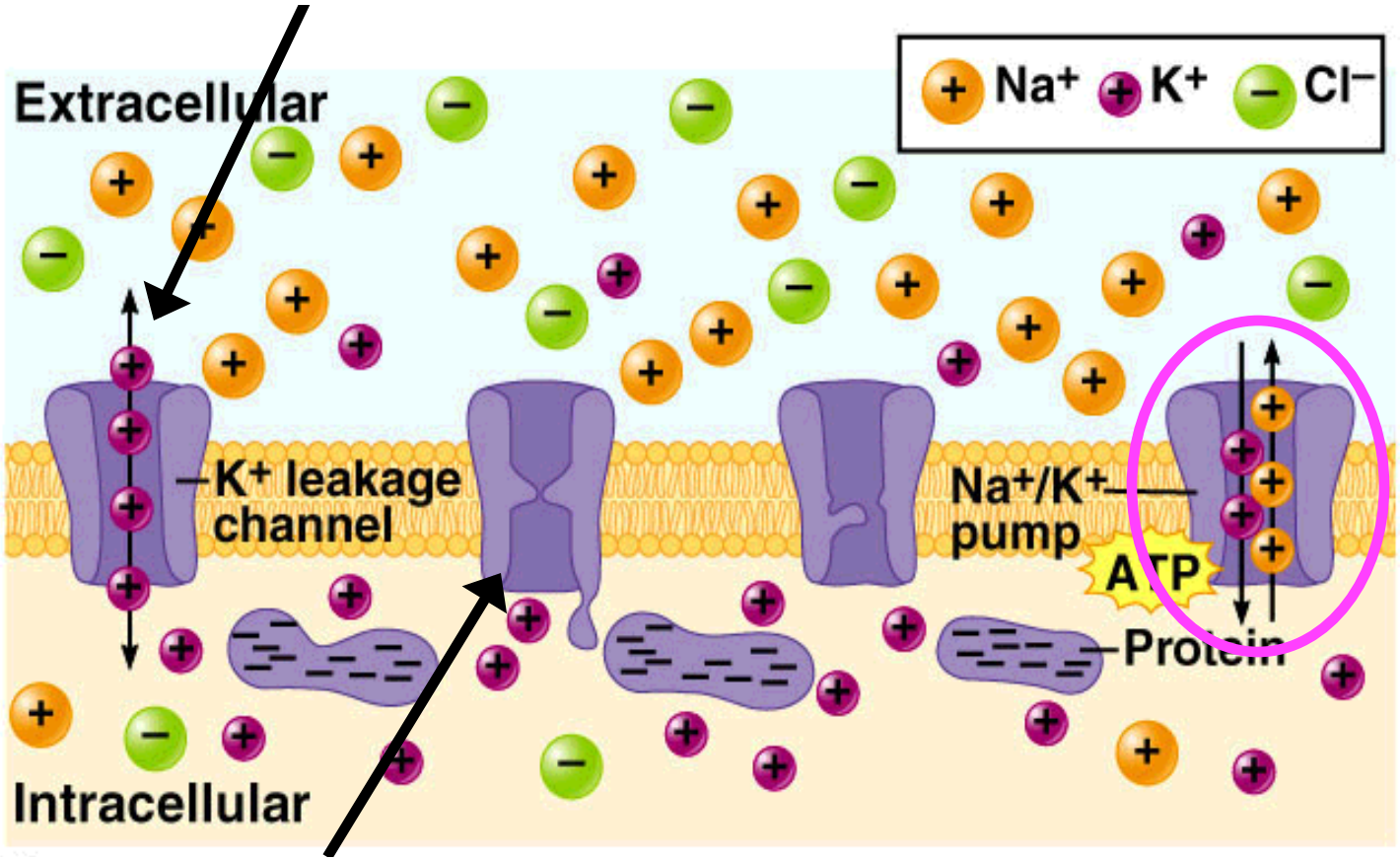
Negatively charged proteins

K^+ channel allows K^+ to diffuse out (and in)

IN

Resting neuron

K+ channel allows K+ to diffuse out



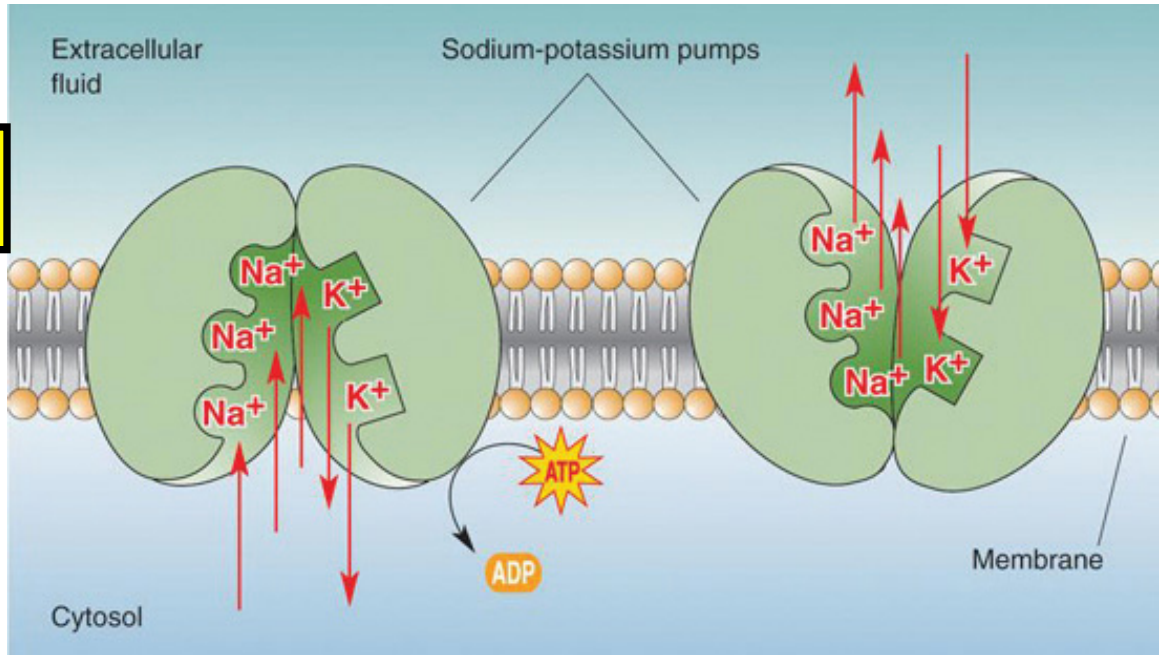
Na+ channels allow Na+ to diffuse in

Sodium – Potassium Pump

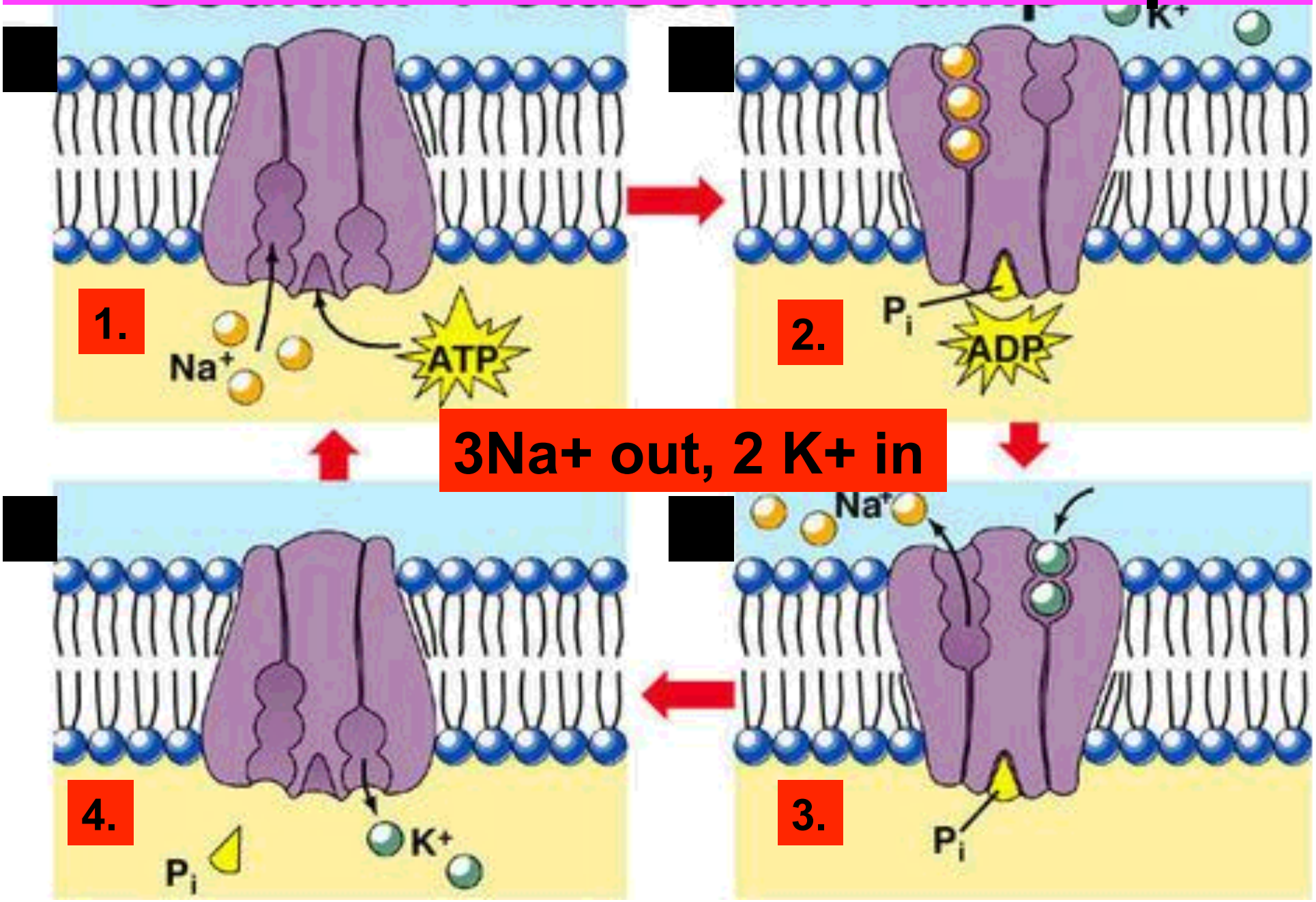
- The sodium – potassium pump actively takes 3 Na^+ out and brings 2 K^+ in by using ATP
- This means that there are more positive charges found on the outside than the inside

3 Na^+ out: 2 K^+ in

CLICK ME: Sodium Potassium Pump



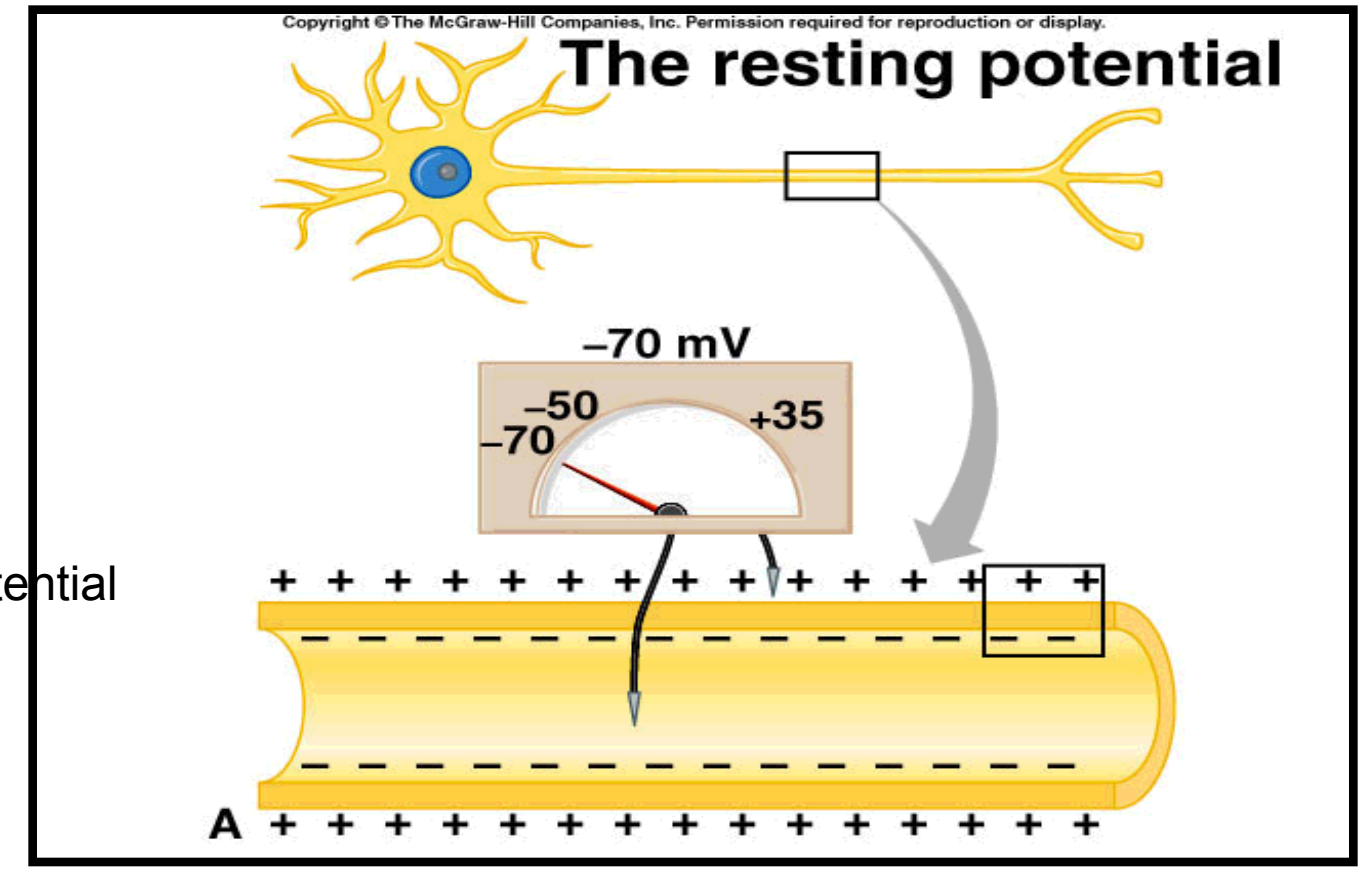
Sodium – Potassium Pump



What does this mean?

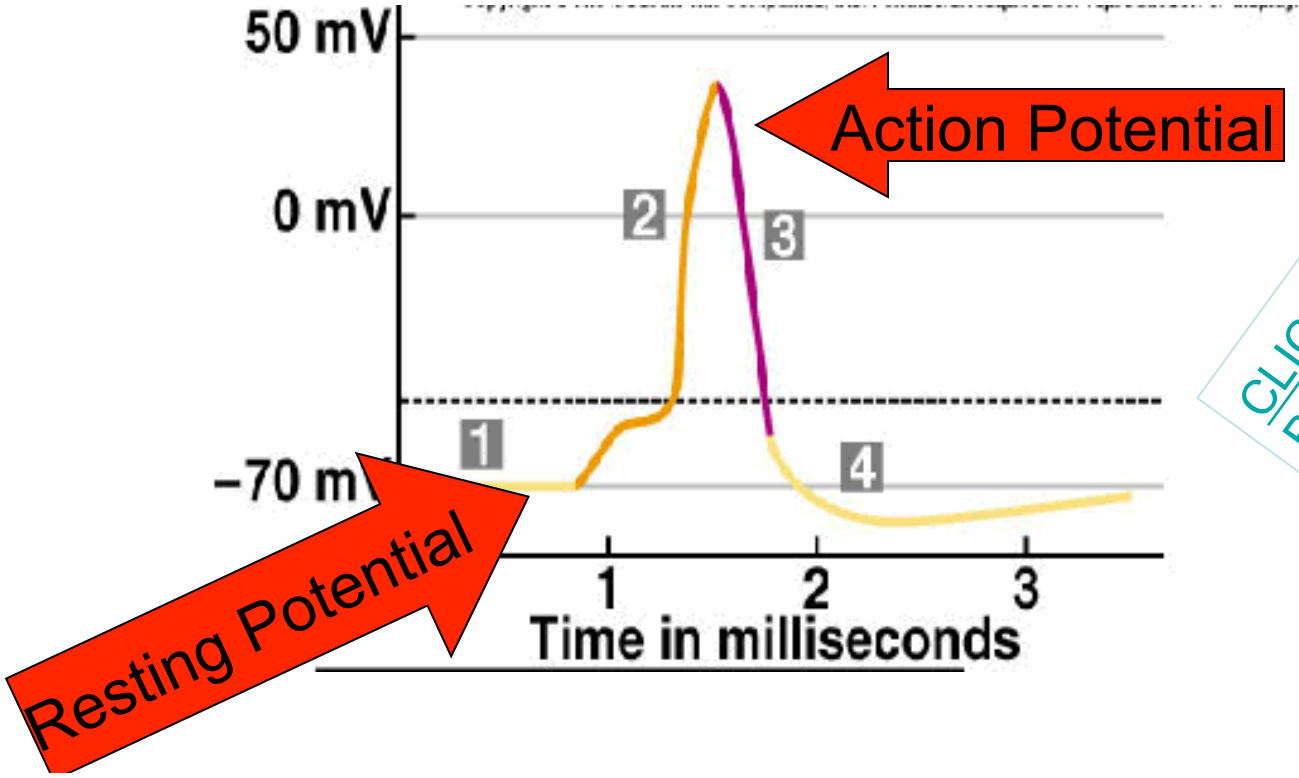
Result: **Voltage = - 70 mV, inside the axon**

Action Potential

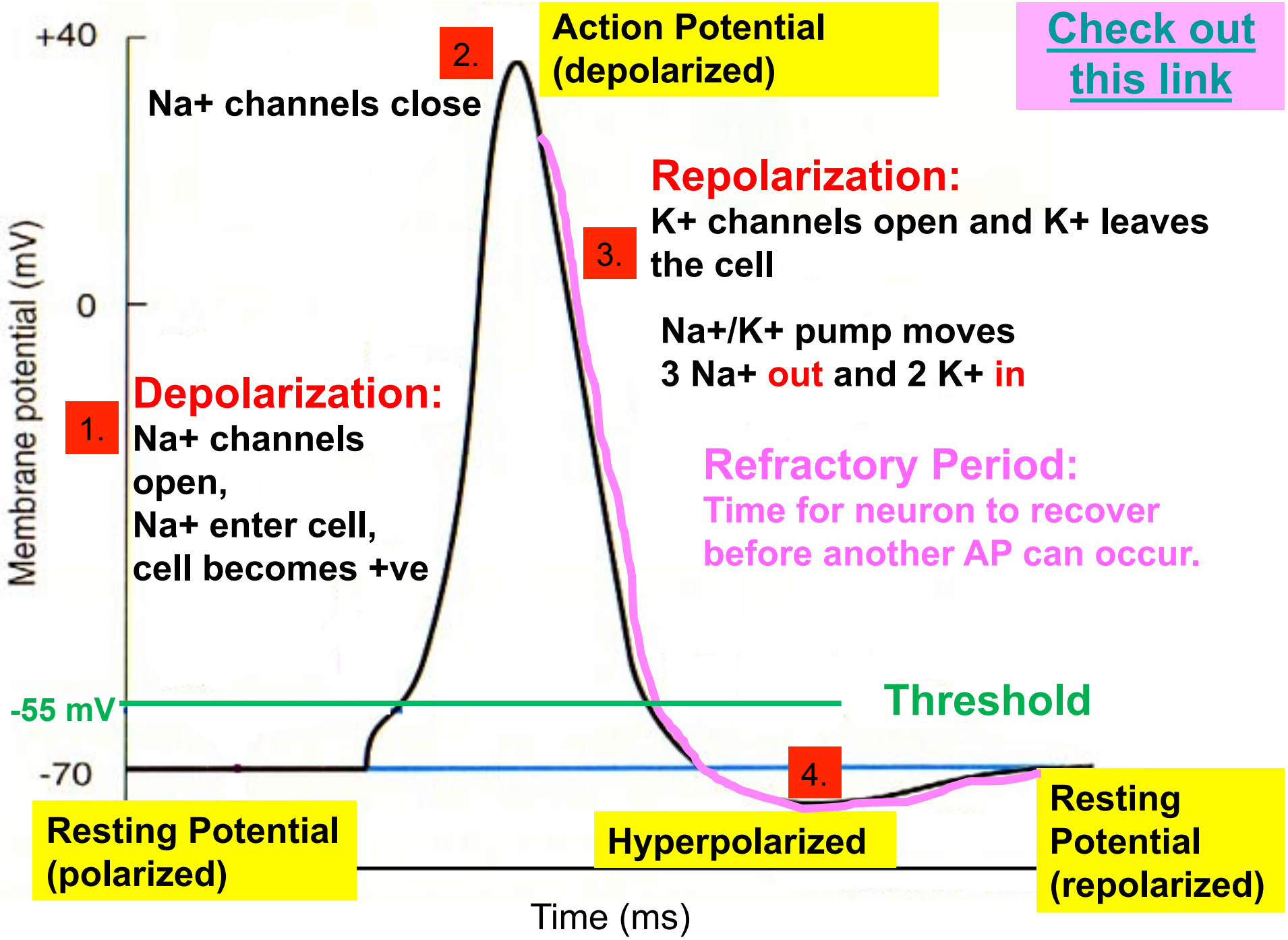


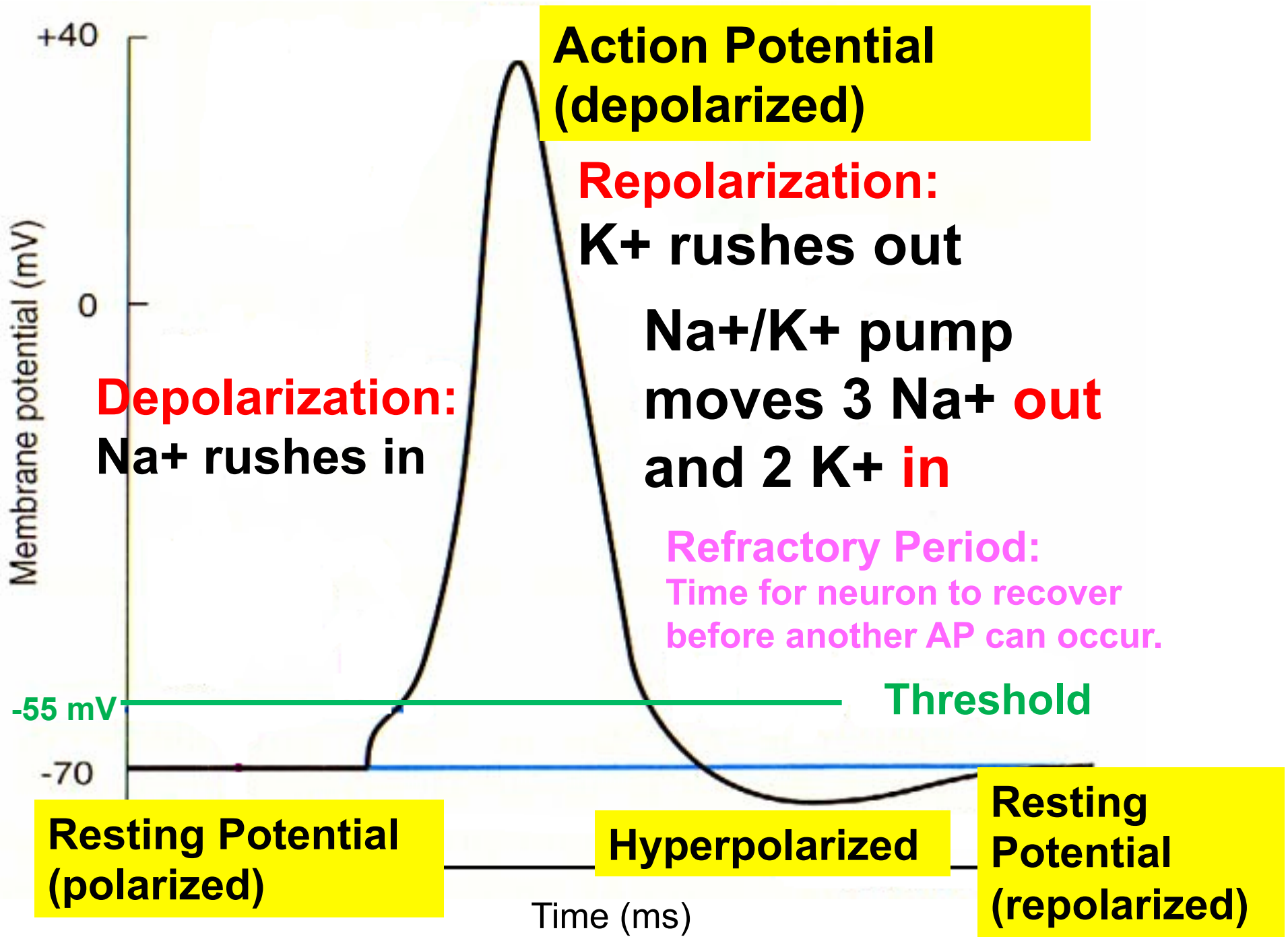
Action Potential

- When a neuron is excited an **action potential** is generated
- Na^+/K^+ pump is turned off

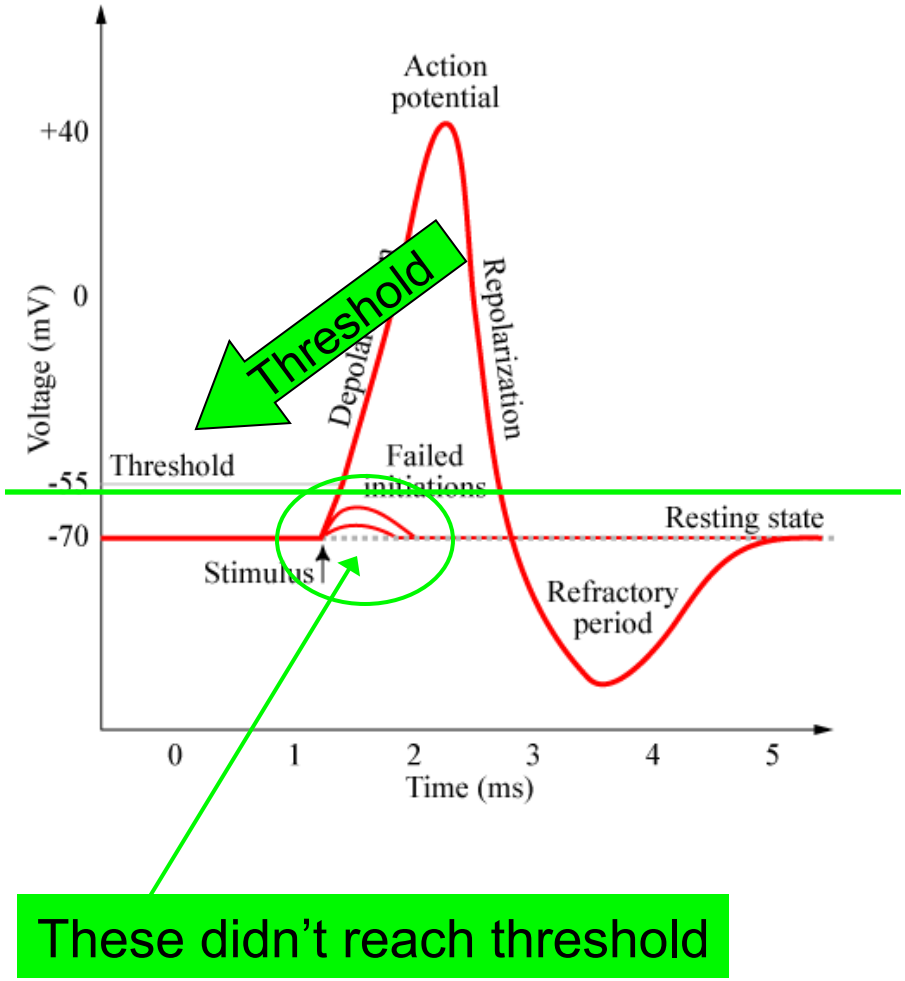


CLICK ME: Roach Beatbox


+40
0
-55 mV
-70
Membrane potential (mV)
Time (ms)
2.
Action Potential (depolarized)
Na+ channels close
Check out this link
Repolarization:
K+ channels open and K+ leaves the cell
3.
Na+/K+ pump moves
3 Na+ out and 2 K+ in
Refractory Period:
Time for neuron to recover before another AP can occur.
Depolarization:
1.
Na+ channels open,
Na+ enter cell,
cell becomes +ve
Threshold
4.
Resting Potential (polarized)
Hyperpolarized
Resting Potential (repolarized)


Action Potential (depolarized)
Repolarization:
K+ rushes out
Na+/K+ pump moves 3 Na+ out and 2 K+ in
Depolarization:
Na+ rushes in
Refractory Period:
Time for neuron to recover before another AP can occur.
Threshold
-55 mV
Resting Potential (polarized)
Hyperpolarized
Resting Potential (repolarized)
+40
0
-70
Membrane potential (mV)
Time (ms)

Threshold level and the All-or-None Response



- **Threshold level** is the min. level of stimulus required to produce a response:

  - 55mV

- **All-or-none response:** neurons either reach threshold and fire or they don't
  - Intensity and speed of nerve transmission remain the same

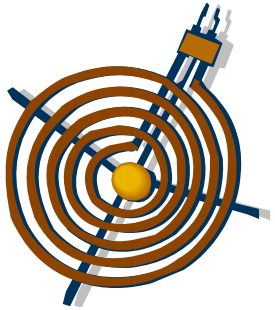
Action Potential

IMPORTANT!!
It is important to understand that when a neuron is stimulated, DEPOLARIZATION OCCURS EVERY TIME, however, if there is not enough stimulus and the threshold is not achieved (-55mV), no action potential occurs.

TRY ME: Nerve impulse transmission molecular animation

CLICK ME: Action Potential crash course

Hot or Really Hot?



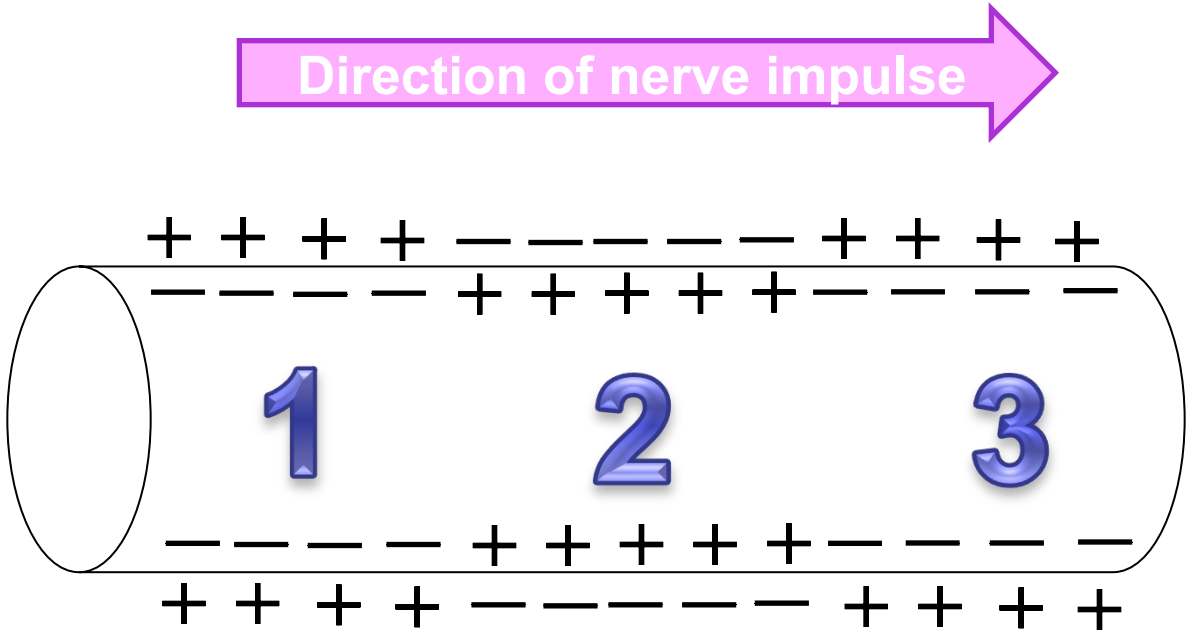
- How does our brain differentiate between hot and really hot if all AP's have the same intensity and speed?

  The number of neurons that are excited.

  Hot = fewer neurons

  Really Hot = many neurons

Nerve impulses form from many AP's

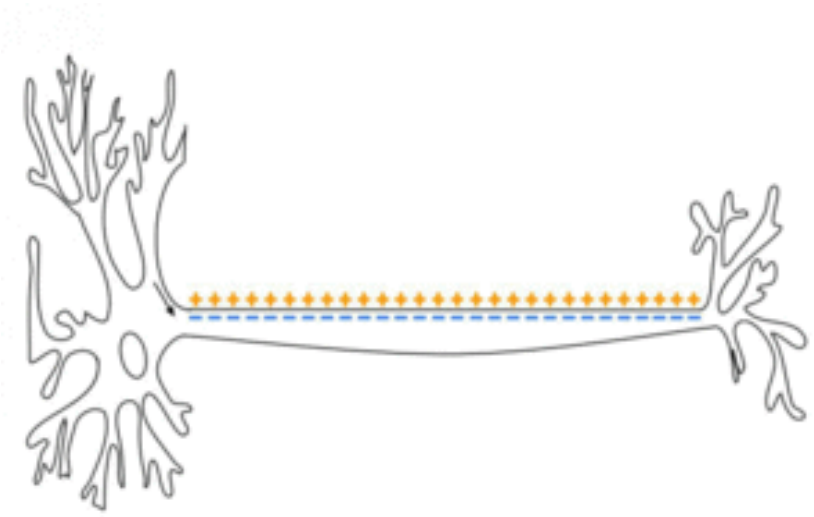


1 Repolarized

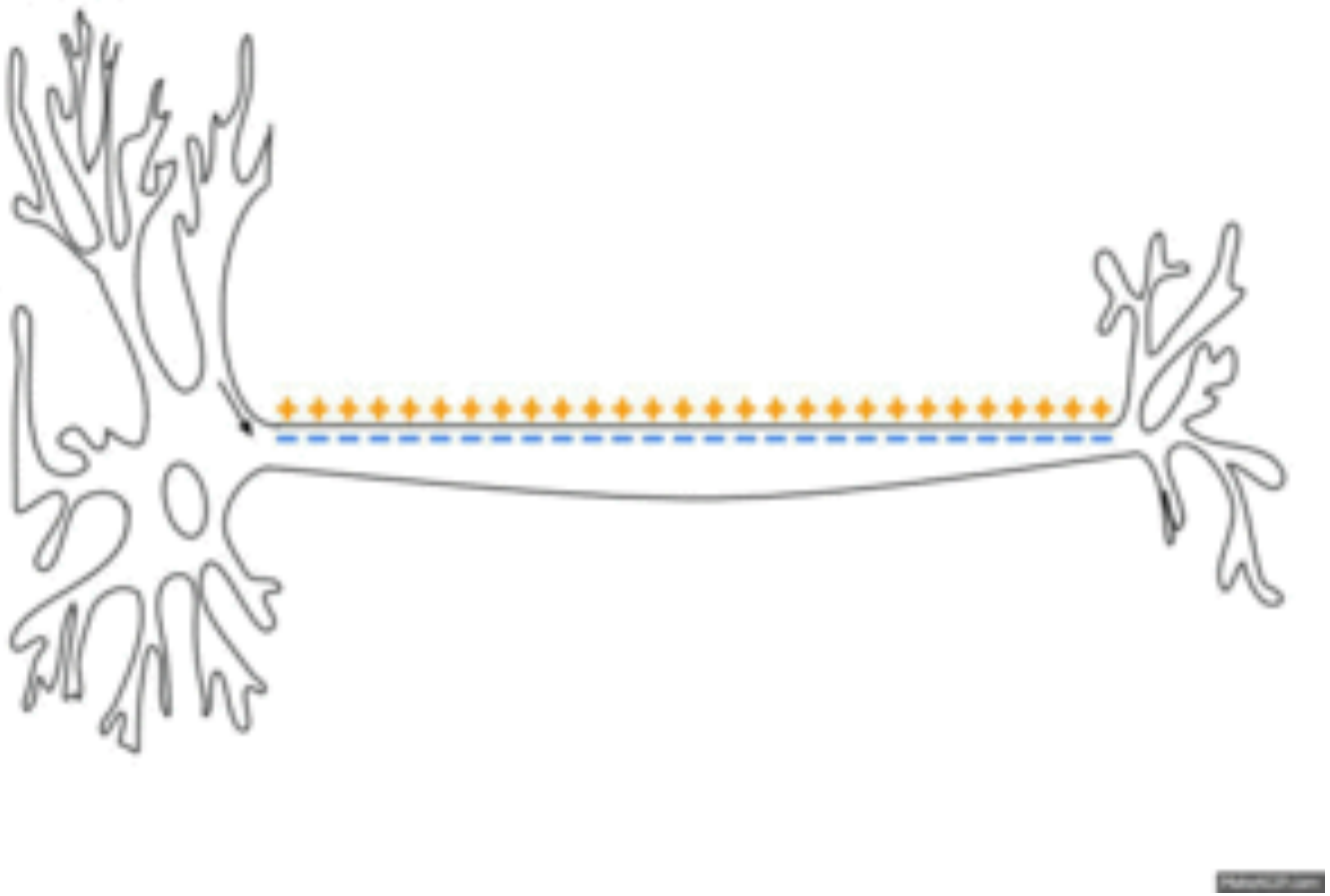
2 Depolarized

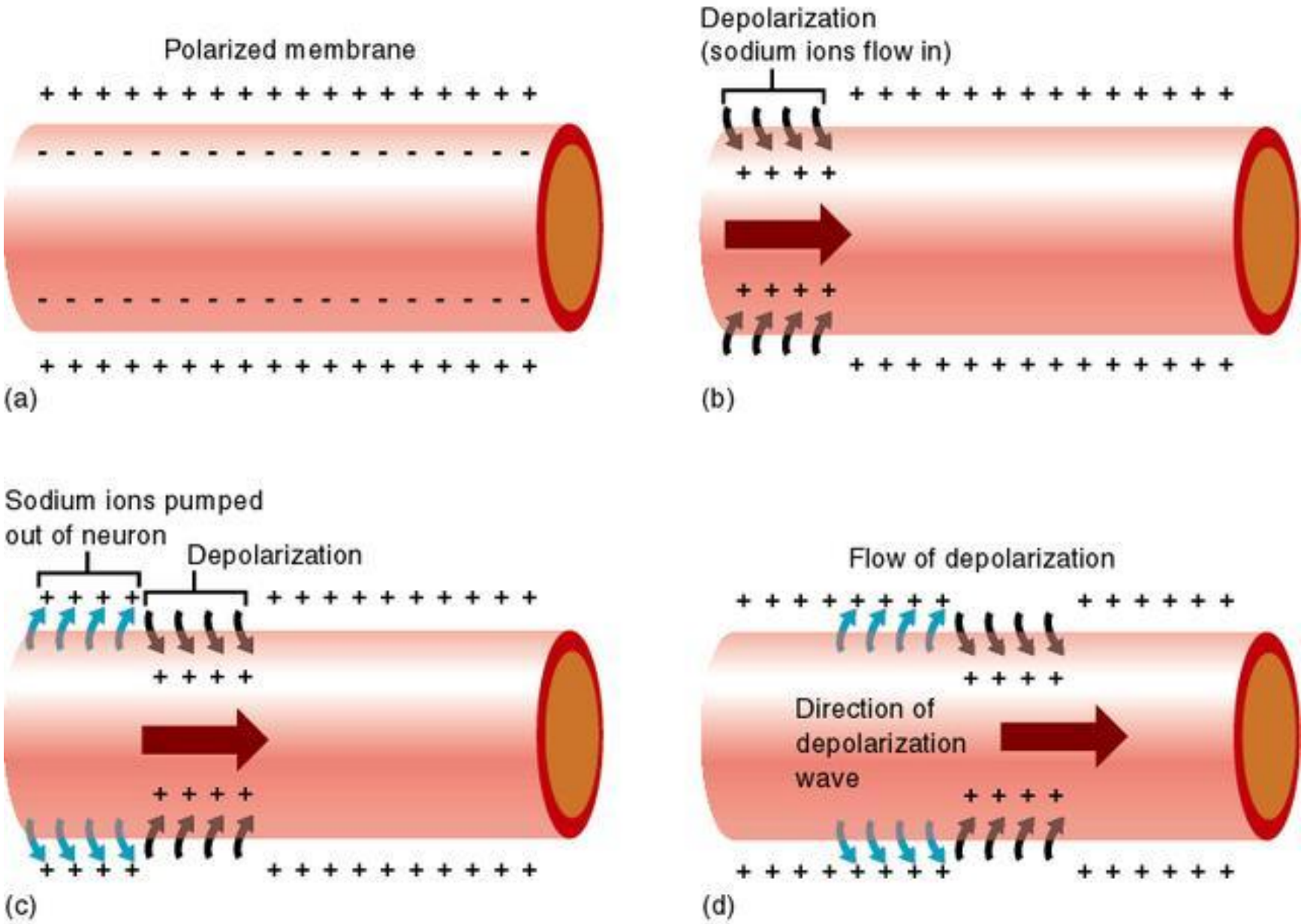
3 Polarized

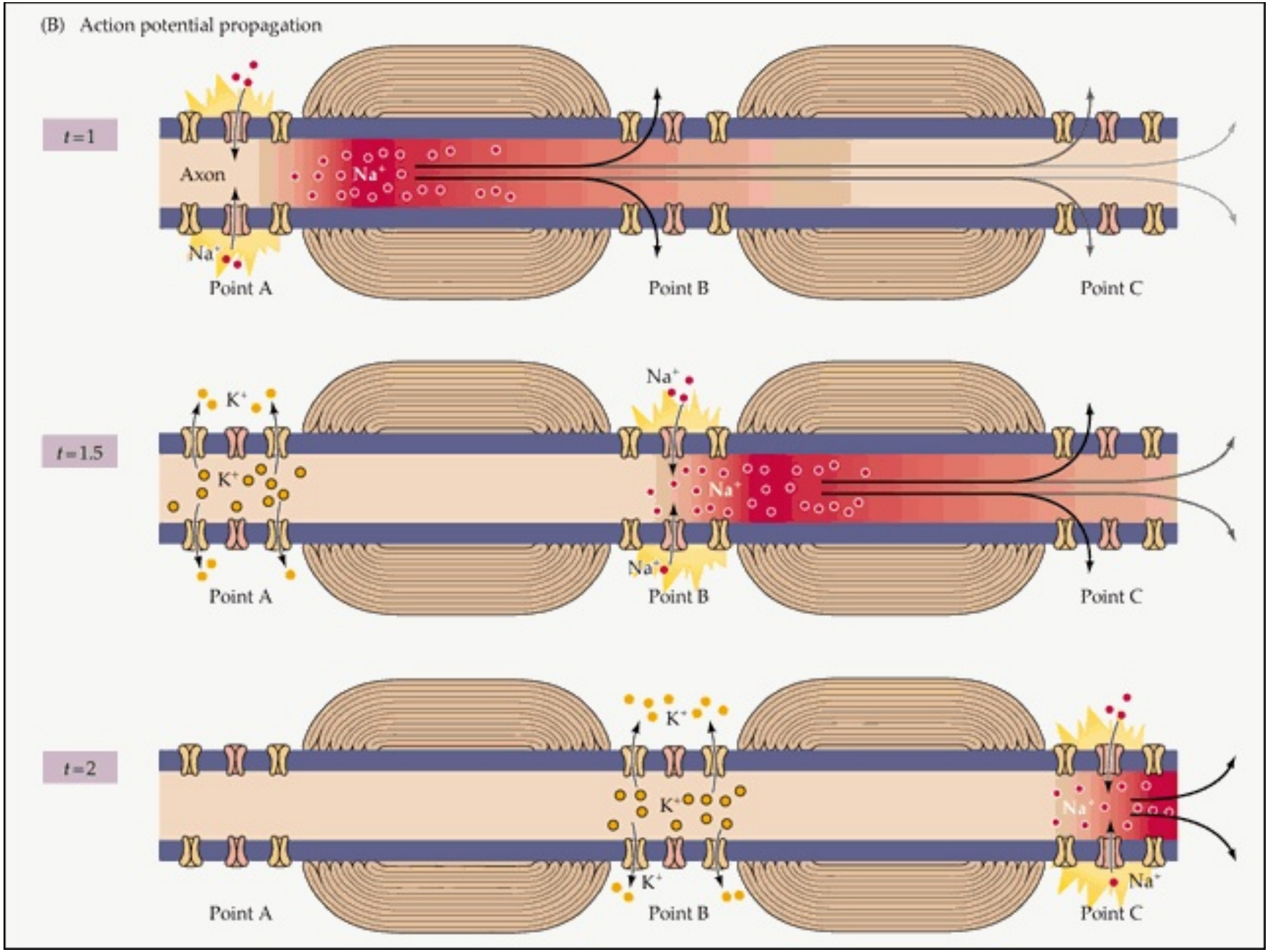
Neural impulse animation:
-with quiz



Nerve impulses form from many AP's

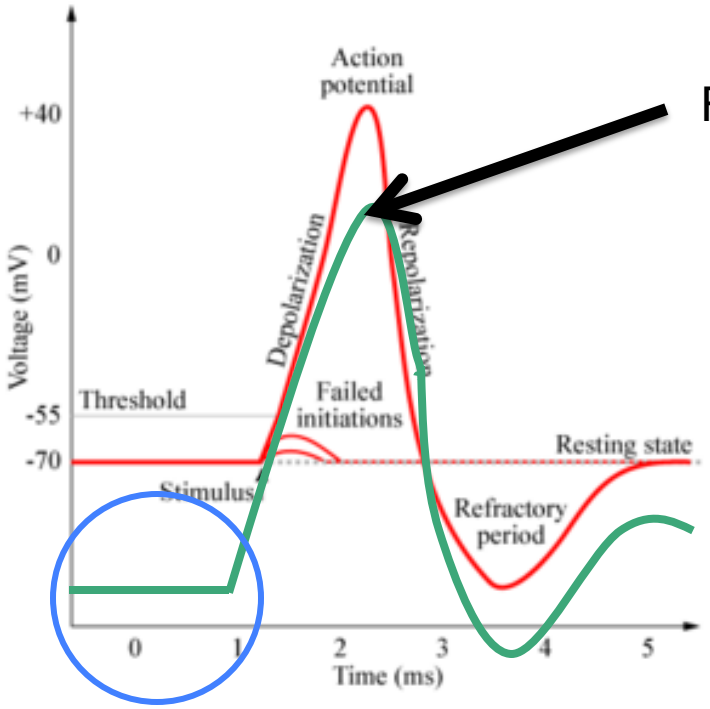



Polarized membrane
(a)
Depolarization
(sodium ions flow in)
(b)
Sodium ions pumped
out of neuron
Depolarization
(c)
Flow of depolarization
Direction of
depolarization
wave
(d)


(B) Action potential propagation
t=1
Axon
Na+
Na+
Point A
Point B
Point C
t=1.5
K+
K+
Na+
Na+
Na+
Point A
Point B
Point C
t=2
K+
K+
K+
Na+
Na+
Point A
Point B
Point C

Inhibitory Drugs?

- Inhibitory drugs will **lower resting potential** making it harder to generate an AP
- Alcohol affects acetylcholine in the brain



FIX THIS: make +40mV

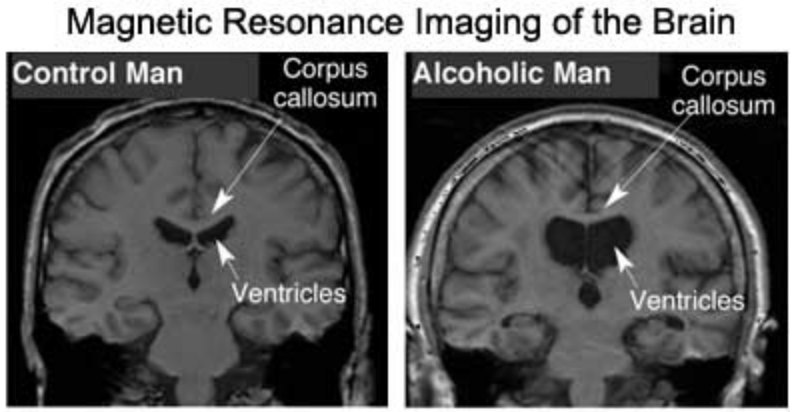
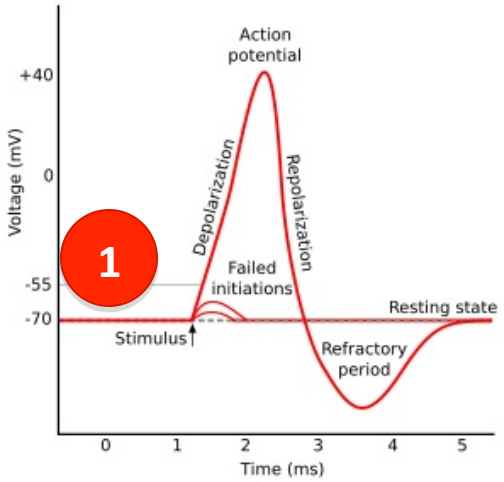
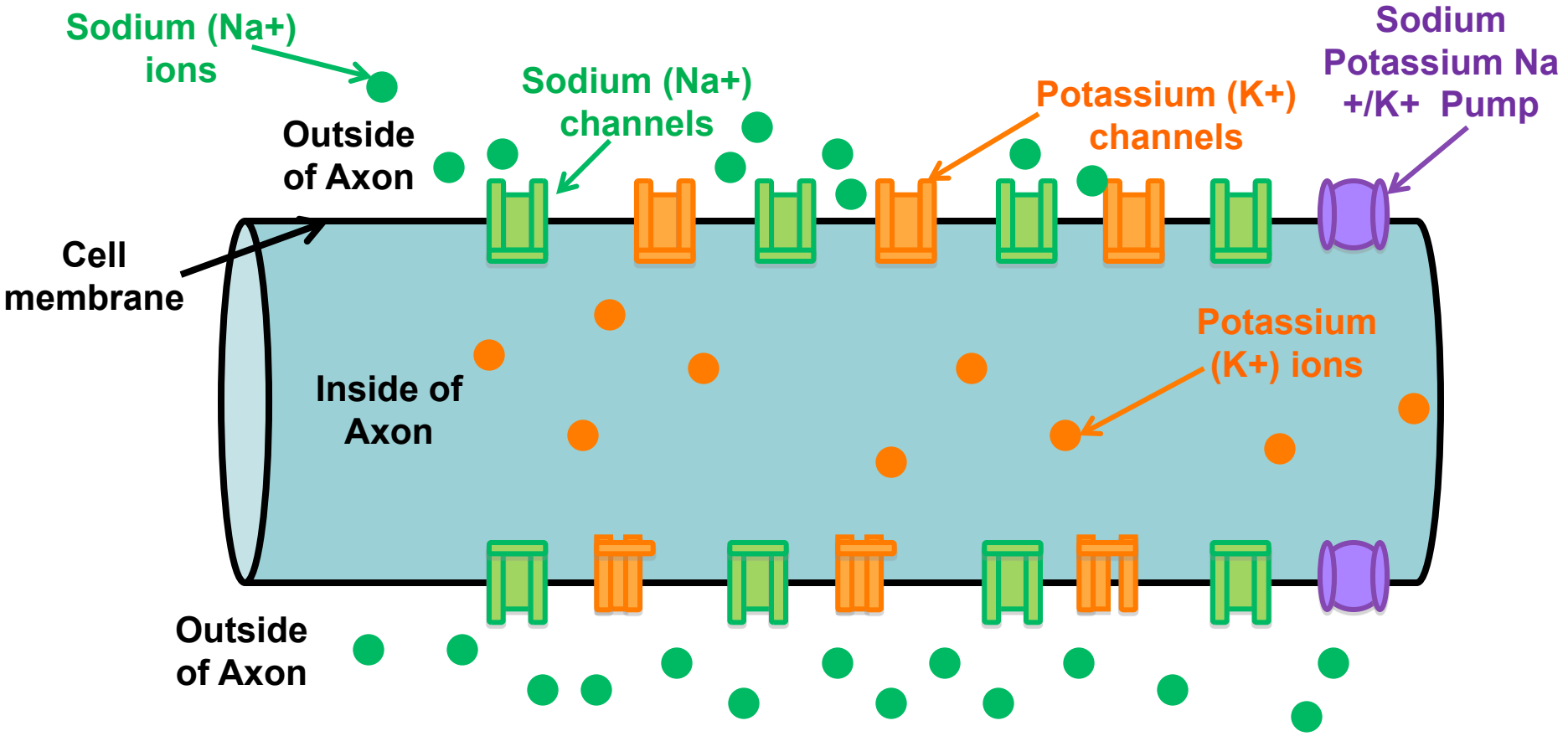


Image courtesy of the National Institute on Drug Abuse

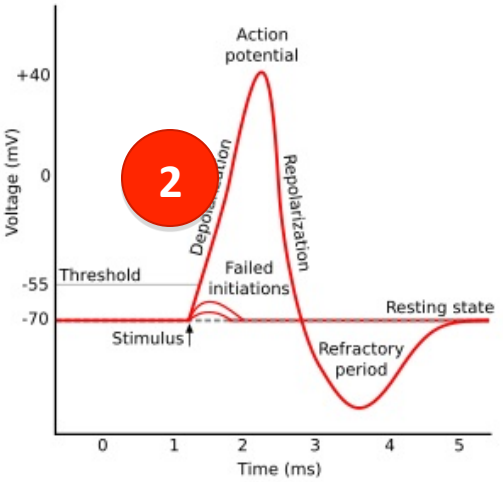
Generating an Action Potential



1. **Resting State (Polarized)**
   - Voltage activated Na+ and K+ channels are closed
   - More Na+ outside relative to K+ inside

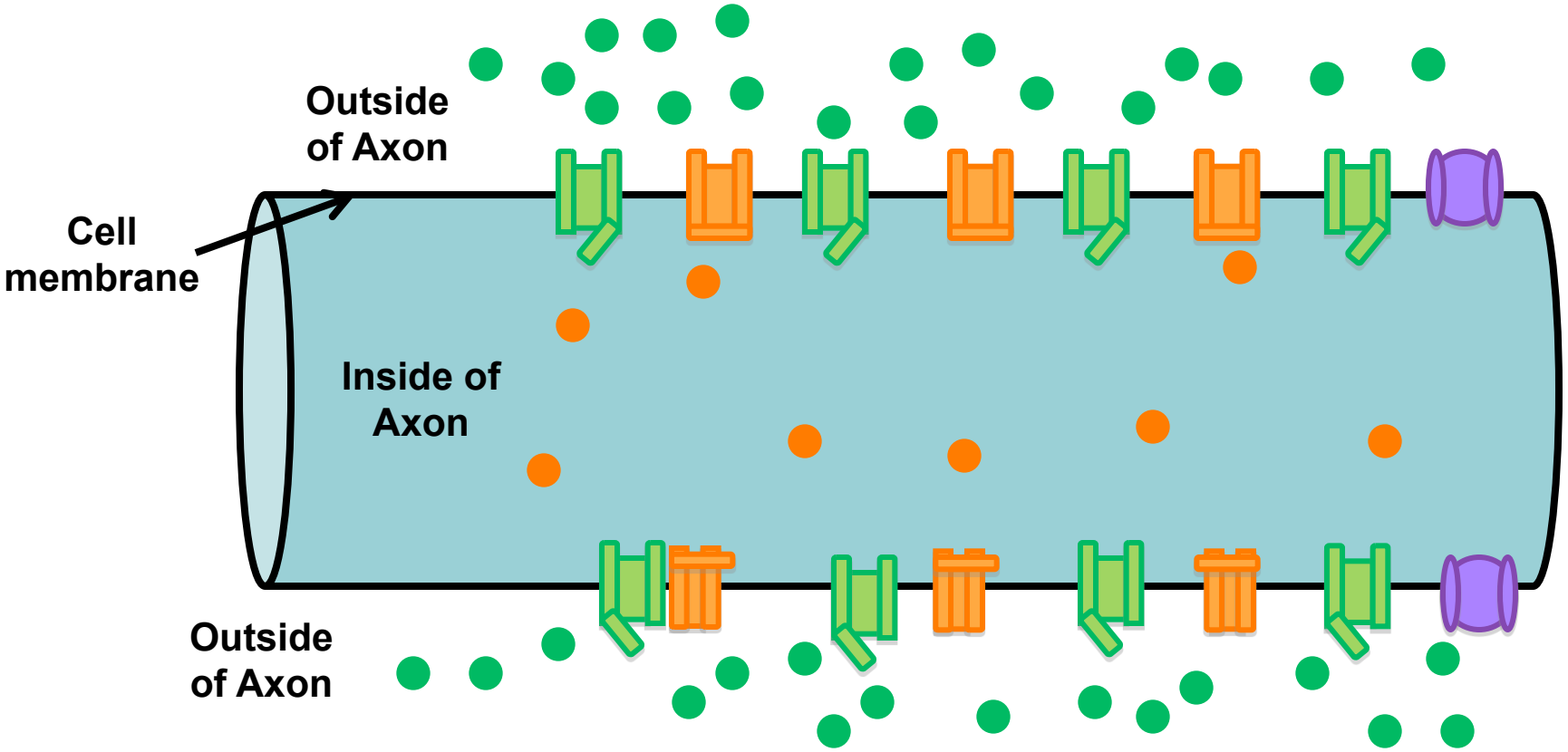


Generating an Action Potential

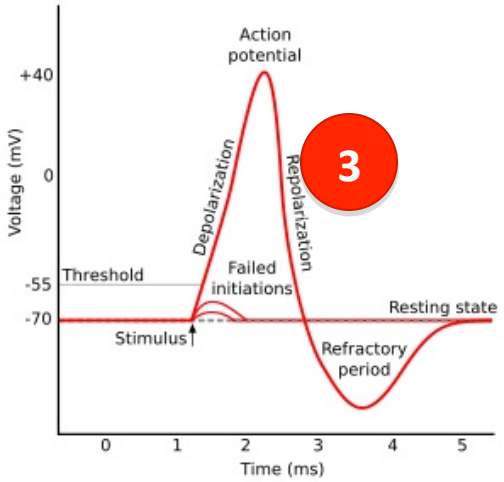


2. Depolarization

- Na+ channels open and sodium **rushes** into neuron
- Inside becomes positive relative to outside

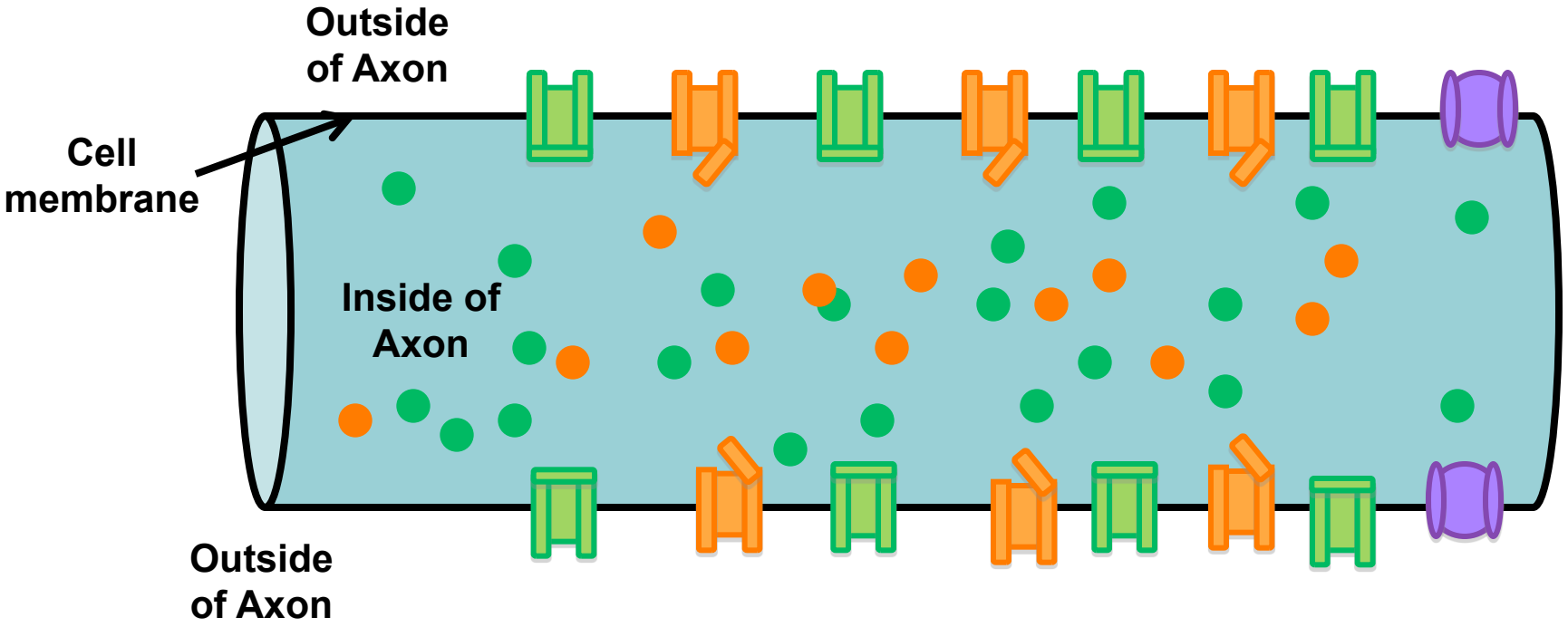


Generating an Action Potential

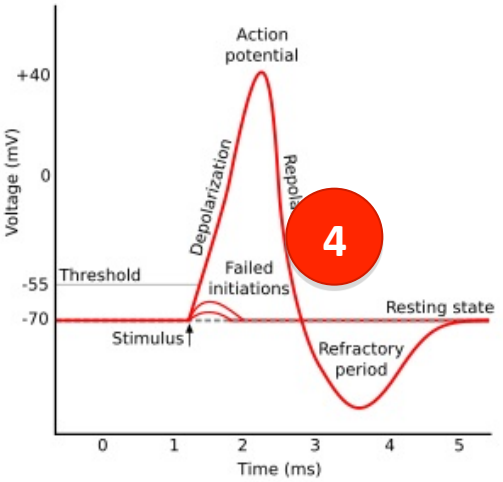


3. Repolarization

- Na+ channels close and K+ channels open; K+ ions move out of cell
- Negative charge is restored to inside of the cell

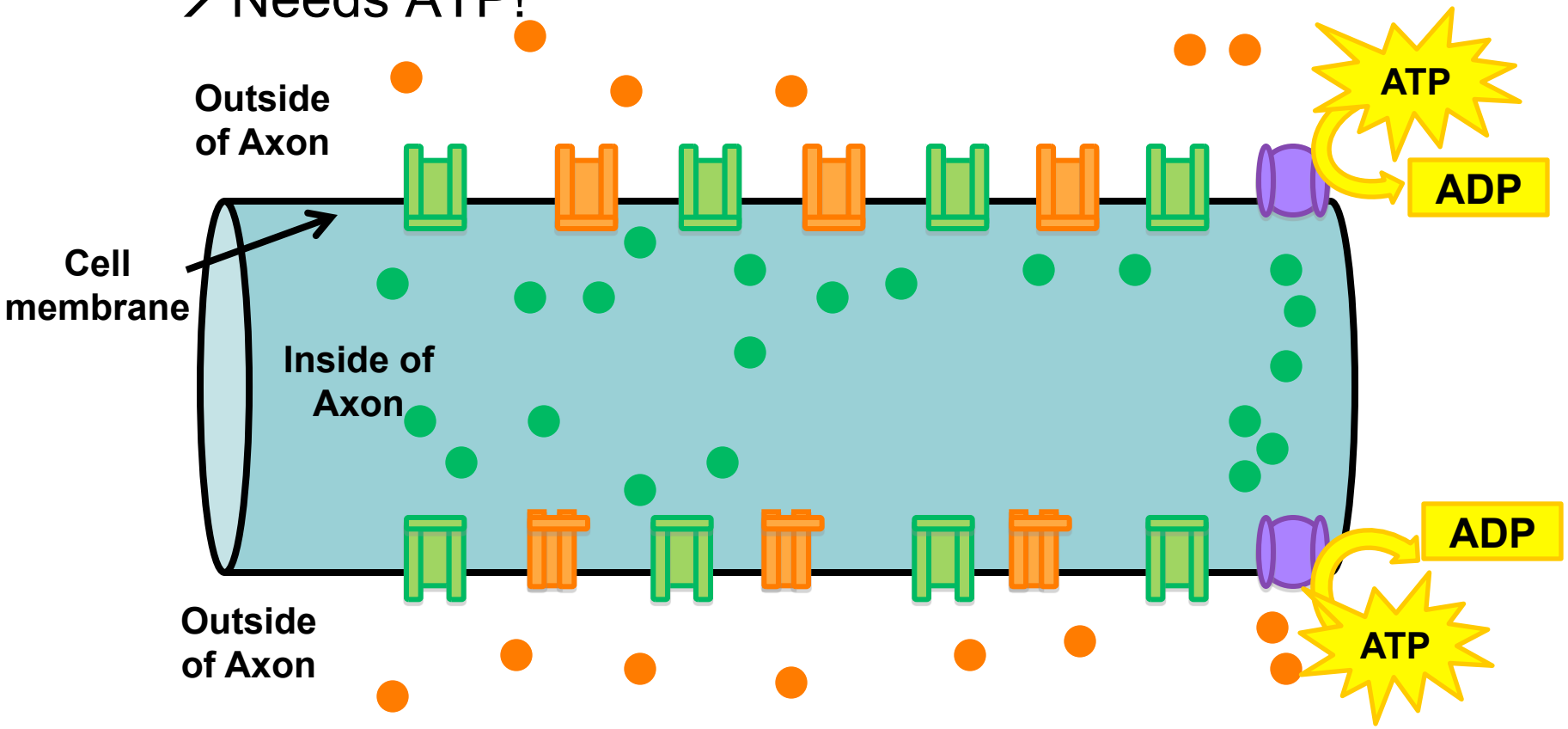


Generating an Action Potential



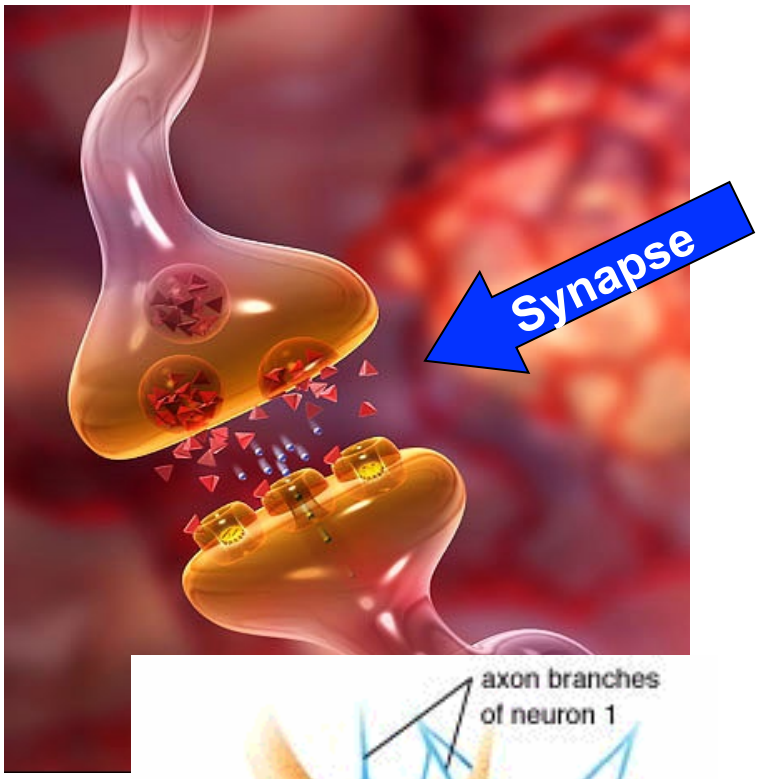
4. Return to Resting State

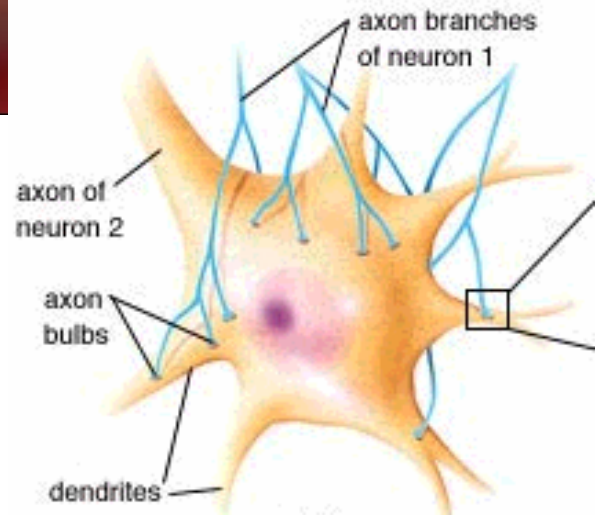
- Na+ and K+ channels close
- Na+/K+ pump restores original concentrations of sodium and potassium (Actively transports 3Na+ out and 2K+ in)
  → Needs ATP!



Synaptic Activities

How does info get from one neuron to another?





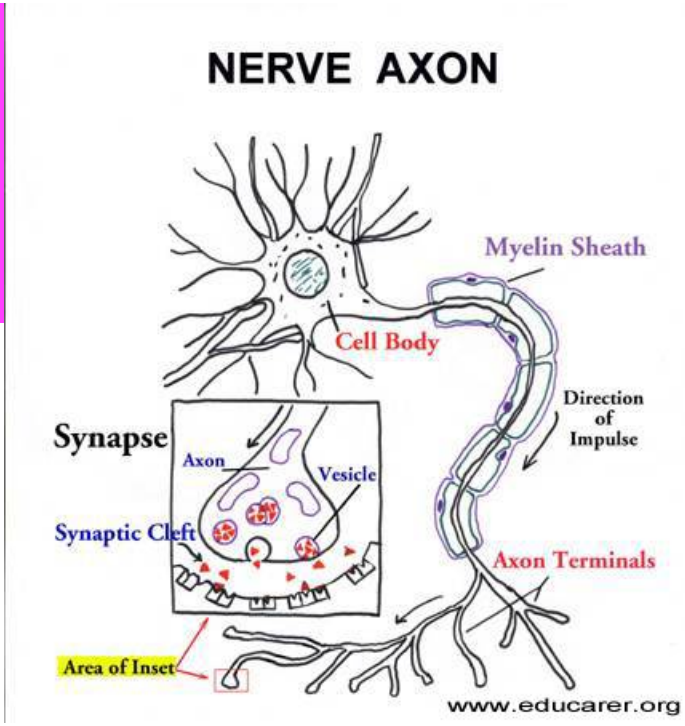
- Neurons don't actually touch
- Info needs to jump from one neuron to the next across the **synapse or synaptic cleft**
- **Synapse:** space between neurons ~ 20nm
- Transmission across a synapse is slow
- There are many synapses

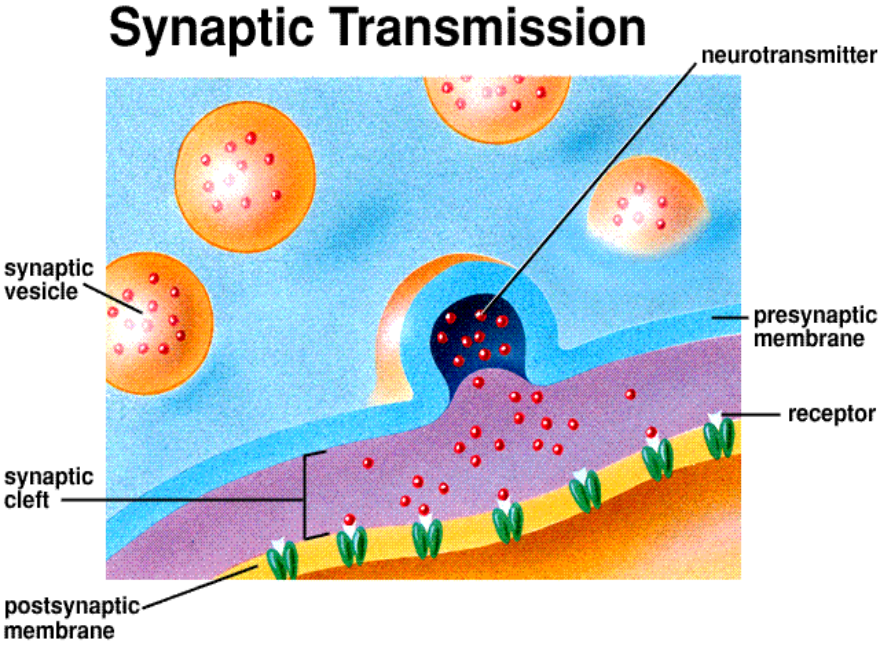
CLICK ME: SynapseAnimation

CLICK ME: Synaptic Transmission

Pre- and Postsynaptic neurons

- An impulse moves from the **presynaptic** to the **postsynaptic** neuron.
- The nerve endings of the presynaptic neuron are filled with **synaptic vesicles** which contain **neurotransmitters.**

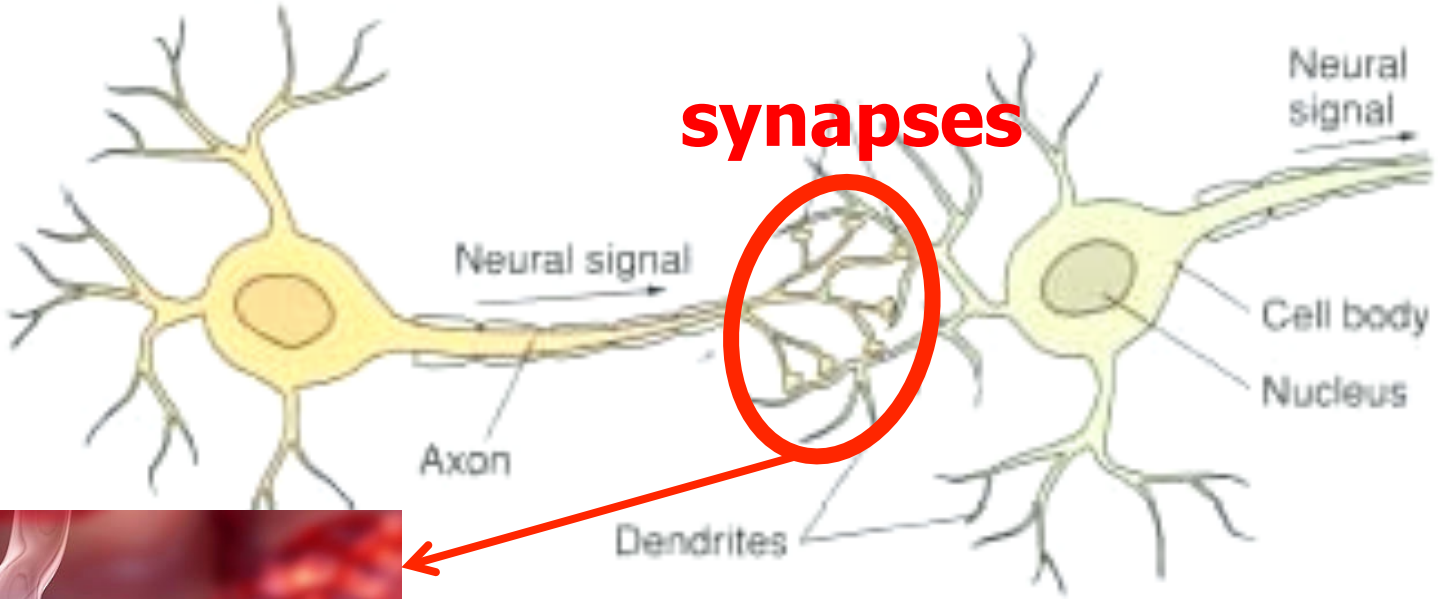


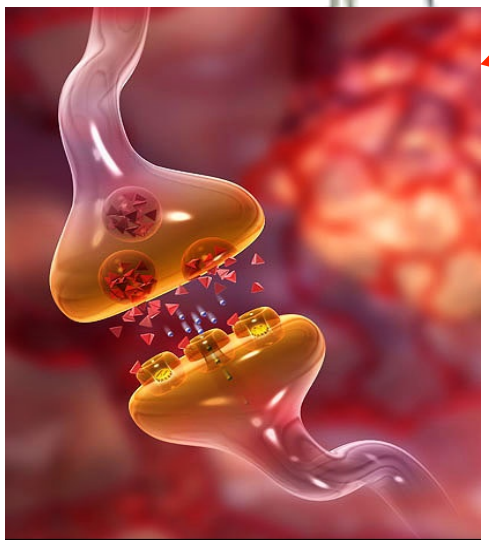


Pre and Post-synaptic Neurons

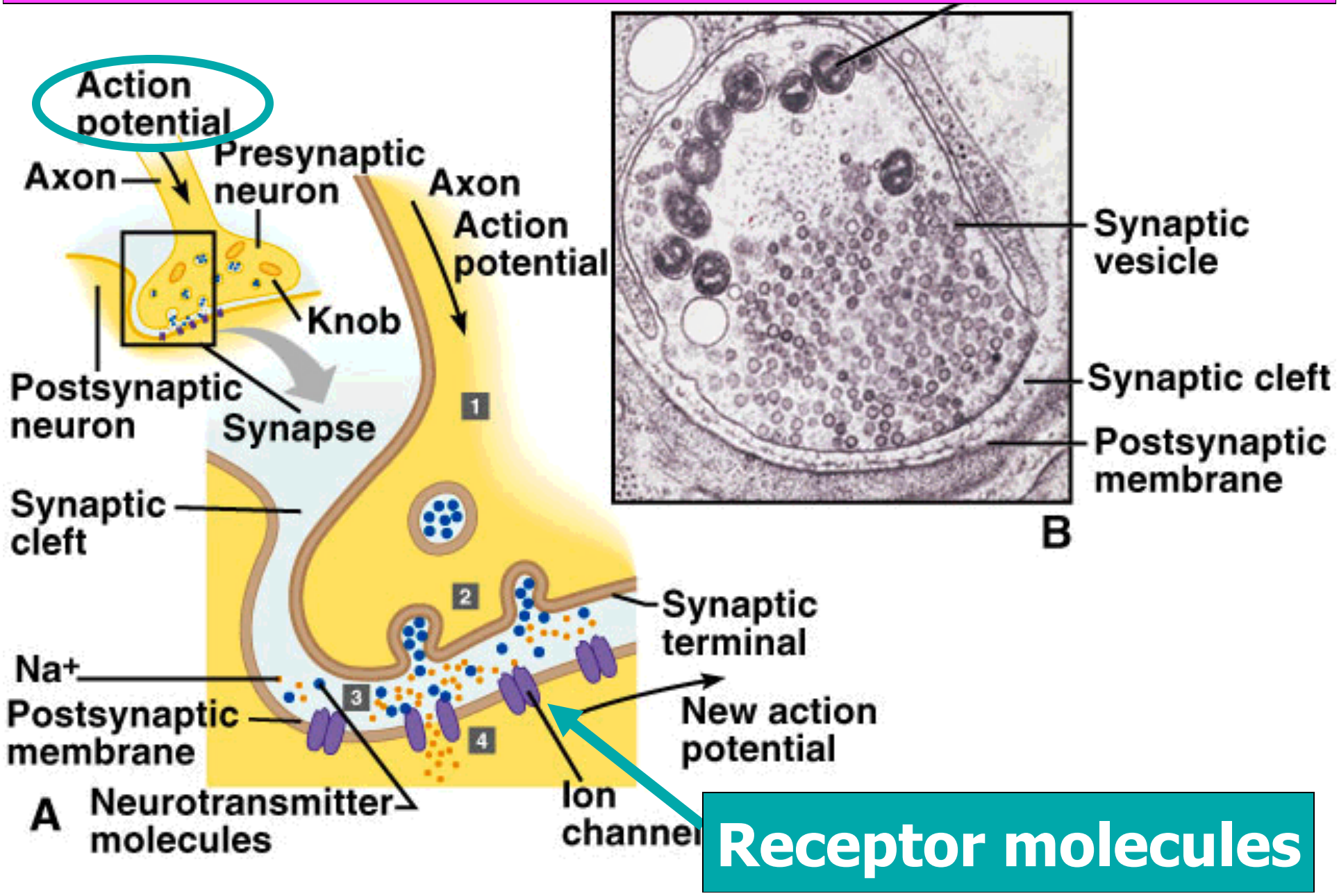
Pre-synaptic Neuron

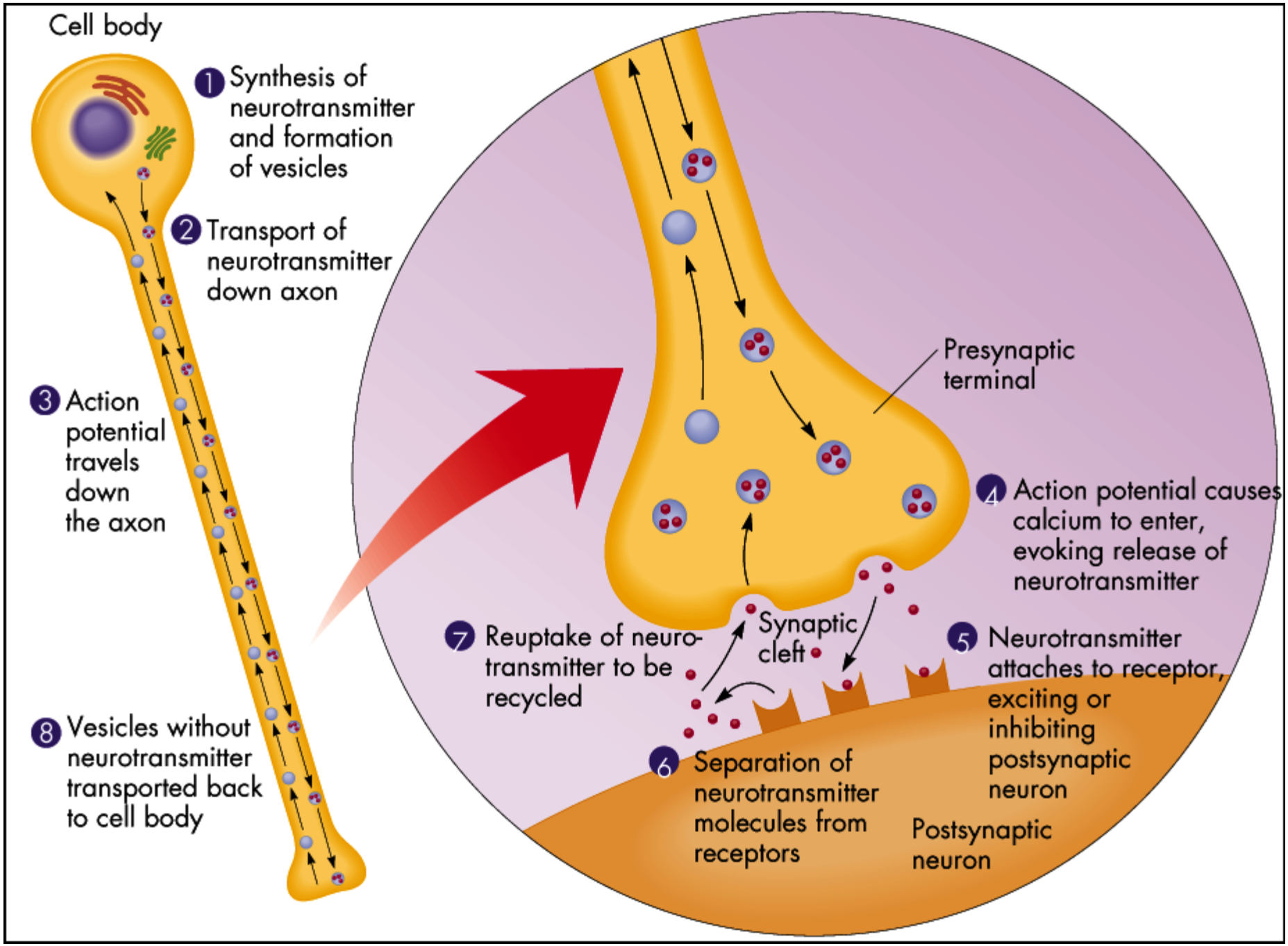
Post-synaptic Neuron





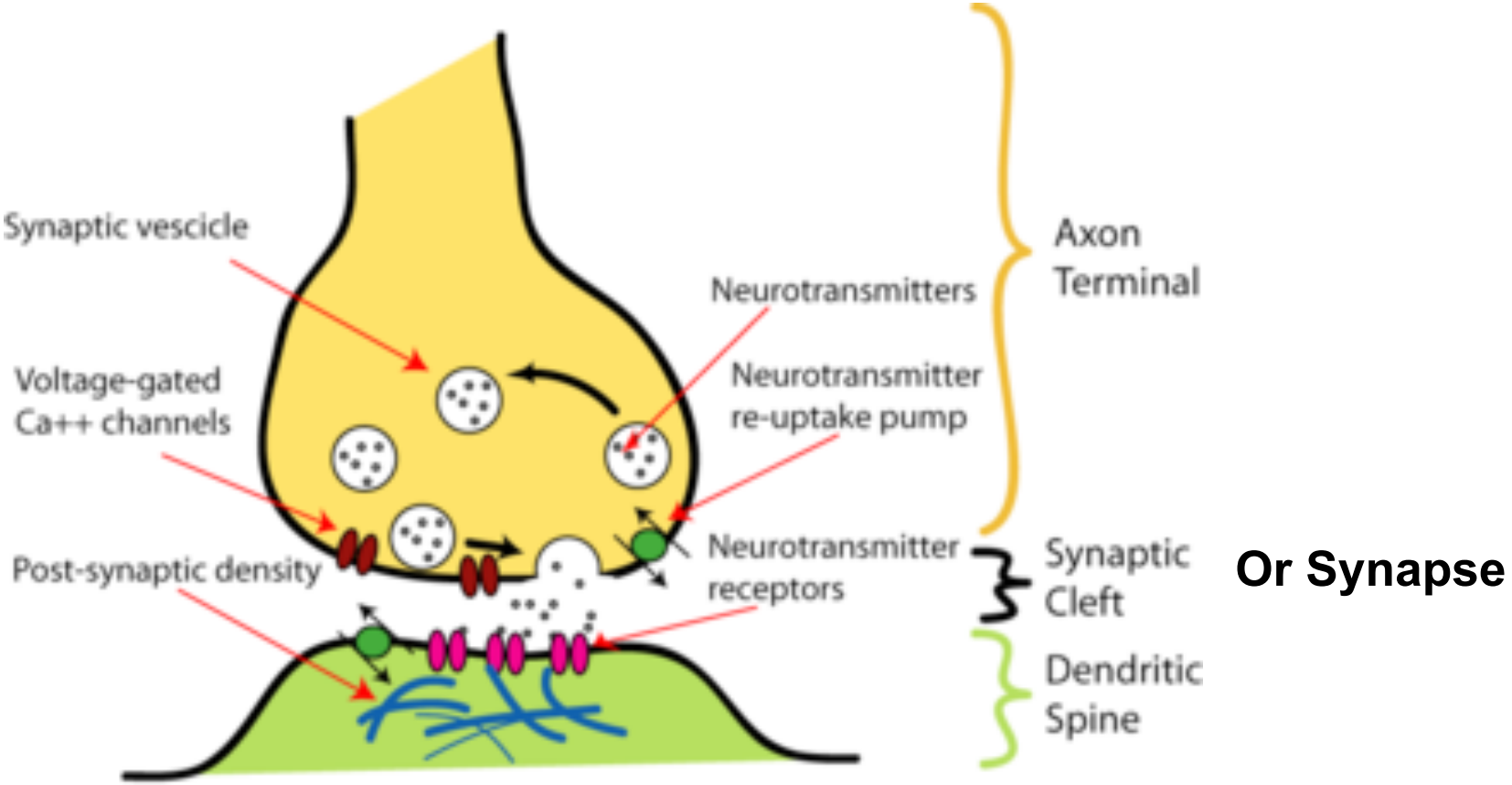
Synaptic Activities




Cell body
1 Synthesis of neurotransmitter and formation of vesicles
2 Transport of neurotransmitter down axon
3 Action potential travels down the axon
8 Vesicles without neurotransmitter transported back to cell body
Presynaptic terminal
4 Action potential causes calcium to enter, evoking release of neurotransmitter
Synaptic cleft
7 Reuptake of neuro-transmitter to be recycled
5 Neurotransmitter attaches to receptor, exciting or inhibiting postsynaptic neuron
6 Separation of neurotransmitter molecules from receptors
Postsynaptic neuron

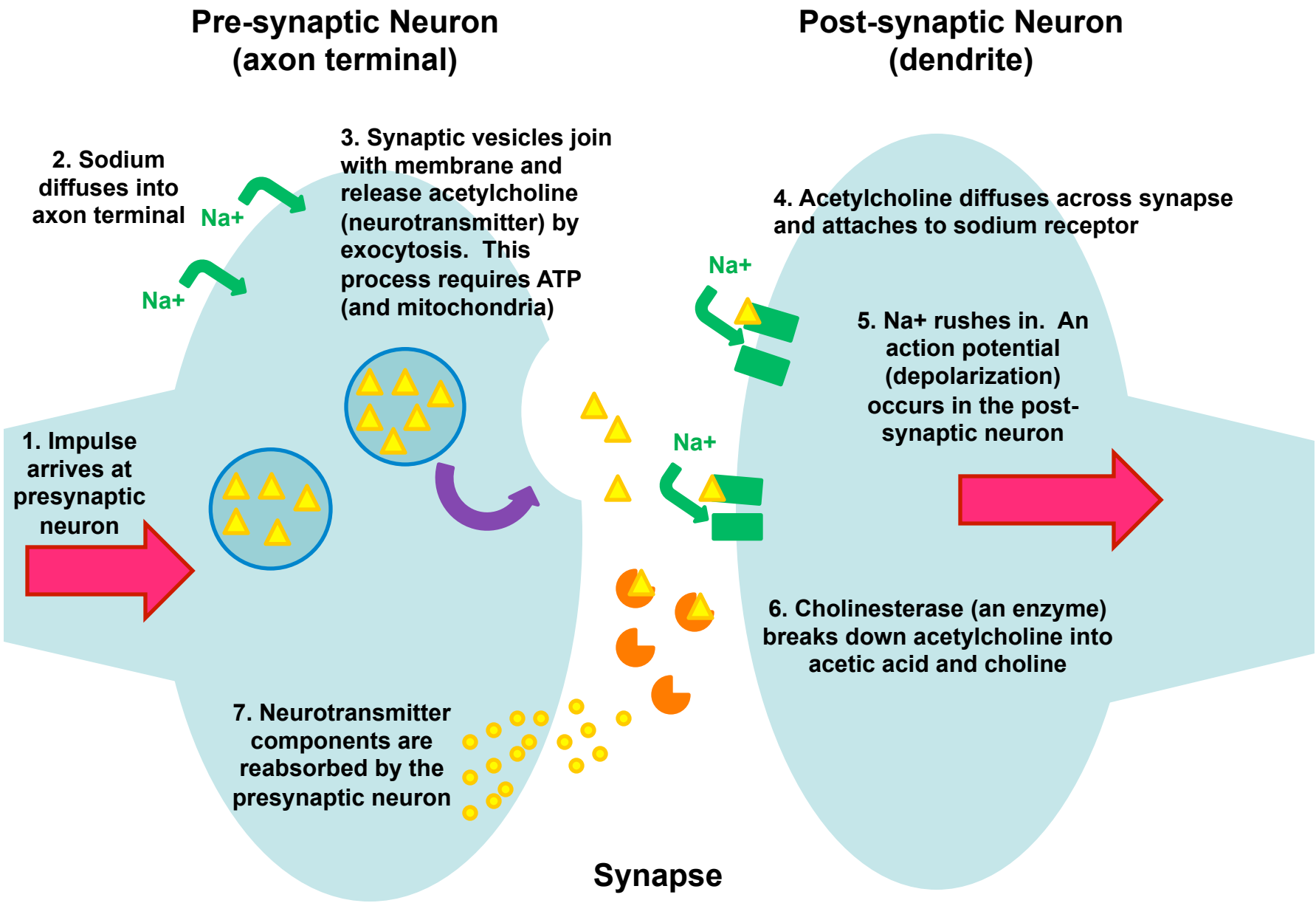
Synaptic activities

We will draw the events which occur at the synapse using **acetylcholine** **(a neurotransmitter**)



Or Synapse

Synaptic Activity



Synaptic Activities

1. The nerve impulse arrives at the **presynaptic** membrane.
2. **Na^+** and Ca^{2+} ions rush into the presynaptic membrane.
3. Synaptic vesicles merge with the membrane and release acetylcholine (neurotransmitter) into the synaptic cleft by **exocytosis. (requires ATP)**
4. Acetylcholine diffuses across the synapse and attaches to **receptors** on the postsynaptic membrane.
5. Na+ channels open, Na+ enters the cell and causes **depolarization** in the postsynaptic neuron = action potential.

Synaptic Activities

6. **Cholinesterase (enzyme)** from the **postsynaptic neuron** breaks down acetylcholine into **acetic acid and choline. This stops the postsynaptic neuron from being stimulated.**
7. **Neurotransmitter** components are reabsorbed by the **presynaptic neuron**.

Synapses: Crash Course

Non-narrated video of ion movement:
http://www.youtube.com/watch?v=90cj4NX87Yk&feature=related
Mcgraw Hill video
Transmission across Synapse: with quiz

Did you know?

Insecticides block the action of cholinesterase
-The hearts of insects are completely under nervous control, so the heart will contract and never relax, finally causing death!

Review

Put the steps in order:

1.Na+ channels open, Na+ enters the cell and causes depolarization in the postsynaptic neuron = action potential.

2.Synaptic vesicles merge with the membrane and release acetylcholine (neurotransmitter) into the synaptic cleft by exocytosis. (requires ATP)

3.Cholinesterase (enzyme) from the postsynaptic neuron breaks down acetylcholine into acetic acid and choline. This stops the postsynaptic neuron from being stimulated.

4.Na^+ and Ca^{2+} ions rush into the presynaptic membrane.

Answer: 4213

MORE Review

Put the steps in order:

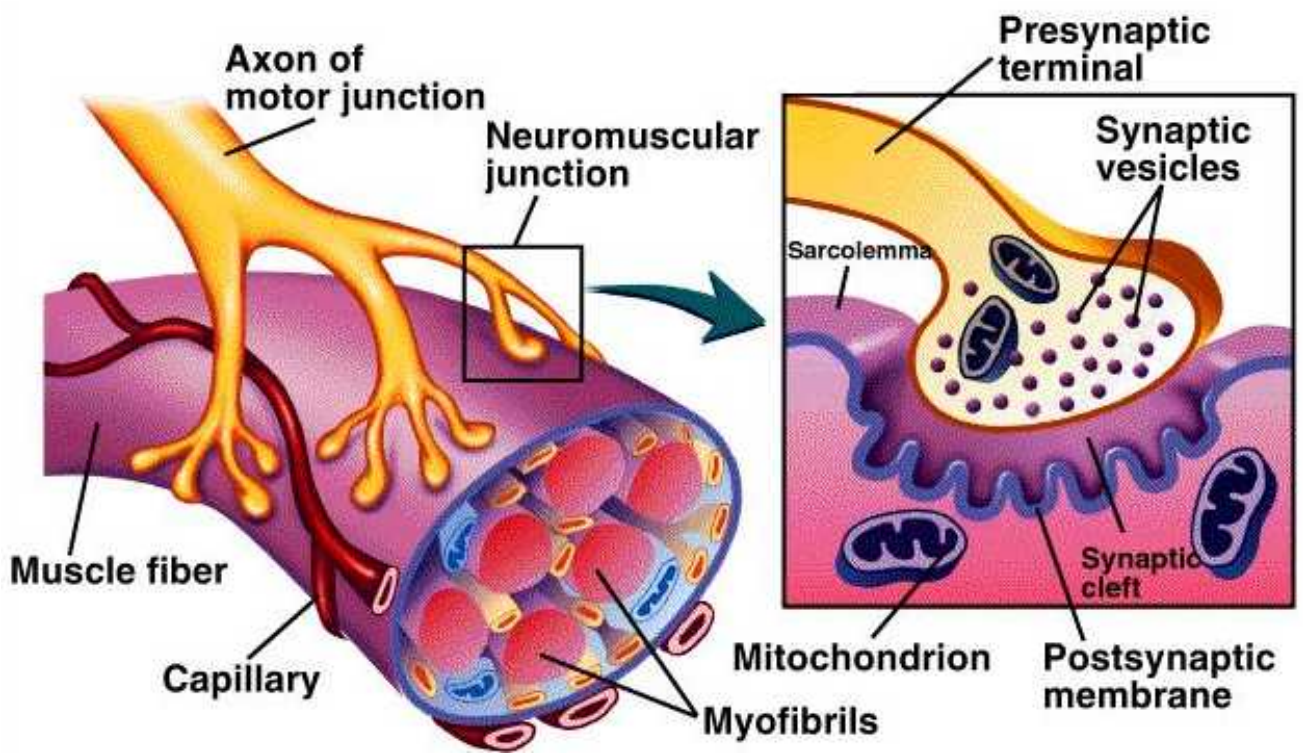
1. Neurotransmitter components are reabsorbed by the presynaptic neuron.
2. The nerve impulse arrives at the presynaptic membrane.
3. Acetylcholine diffuses across the synapse and attaches to receptors on the postsynaptic membrane.
4. Acetylcholine enters synapse

Answer: **2431**

Neuromuscular Junctions

Neuromuscular junction is the synapse of a motor neuron with a muscle fibre

- causes the muscle to contract



Types of Synapses

Excitatory

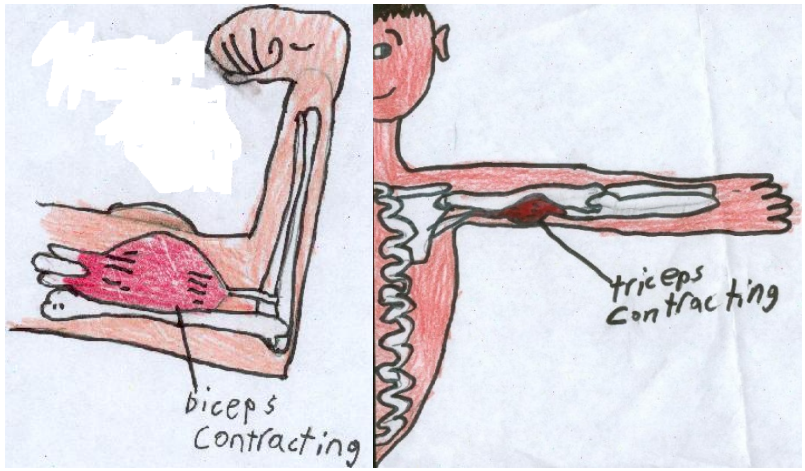
- Causes **depolarization** of the post synaptic neuron = action potential
- **Na+ channels on post synaptic neuron open (= Na^+ in)**

Inhibitory

- Causes **hyperpolarization** of the post synaptic neuron (axon becomes more negative)
- This **inhibits depolarization**
- **K^+ channels on the post synaptic neuron open (= K^+ out)**

Why do we need inhibitory synapses?

- To **prioritize sensory info**
  - What is more important? Remembering that you are wearing clothes or listening to me talk?
- To **coordinate movement** (biceps and triceps)



- Pain killers inhibit transmission along sensory neurons (e.g. Tylenol)

Think about it…

In pairs or partners, determine what would happen to **nerve transmission in the post-synaptic neuron** in the following cases:

a) A drug is taken that **inhibits** the activity of cholinesterase

The post-synaptic neuron would be continuously stimulated.

b) A student drinks alcohol, which opens **potassium** channels in the post-synaptic neuron

Hyperpolarization of the post-synaptic membrane.

c) A drug (ex: amphetamine) is taken which **blocks the reuptake** of neurotransmitter

The post-synaptic neuron would stay depolarized.

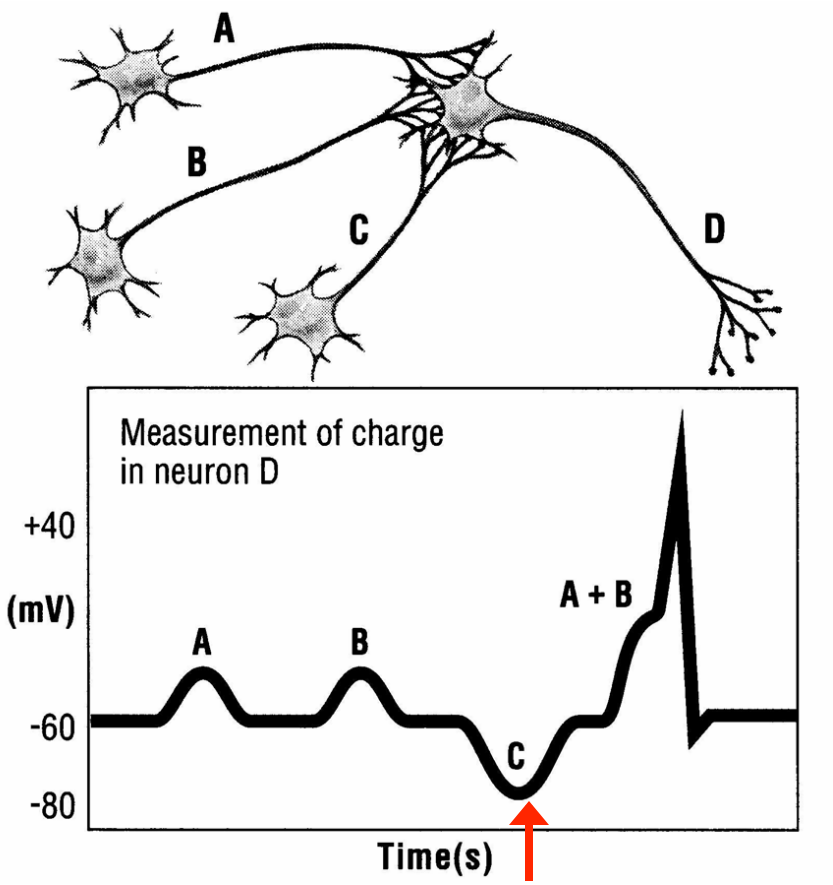
d) A drug is taken which prevents vesicles from releasing neurotransmitter

The post-synaptic neuron would NOT be stimulated. (stay polarized)

e) A drug is taken which activates the same receptors as the neurotransmitter (opens more **sodium** channels in the post-synaptic neuron)

The post-synaptic neuron would be depolarized.

Summation



Two or more neurons release neurotransmitters at the same time to cause an action potential

- **Neurons A and B** must **work together** to cause an action potential in neuron D
- Alone, they **cannot reach threshold**

Neuron C is inhibitory

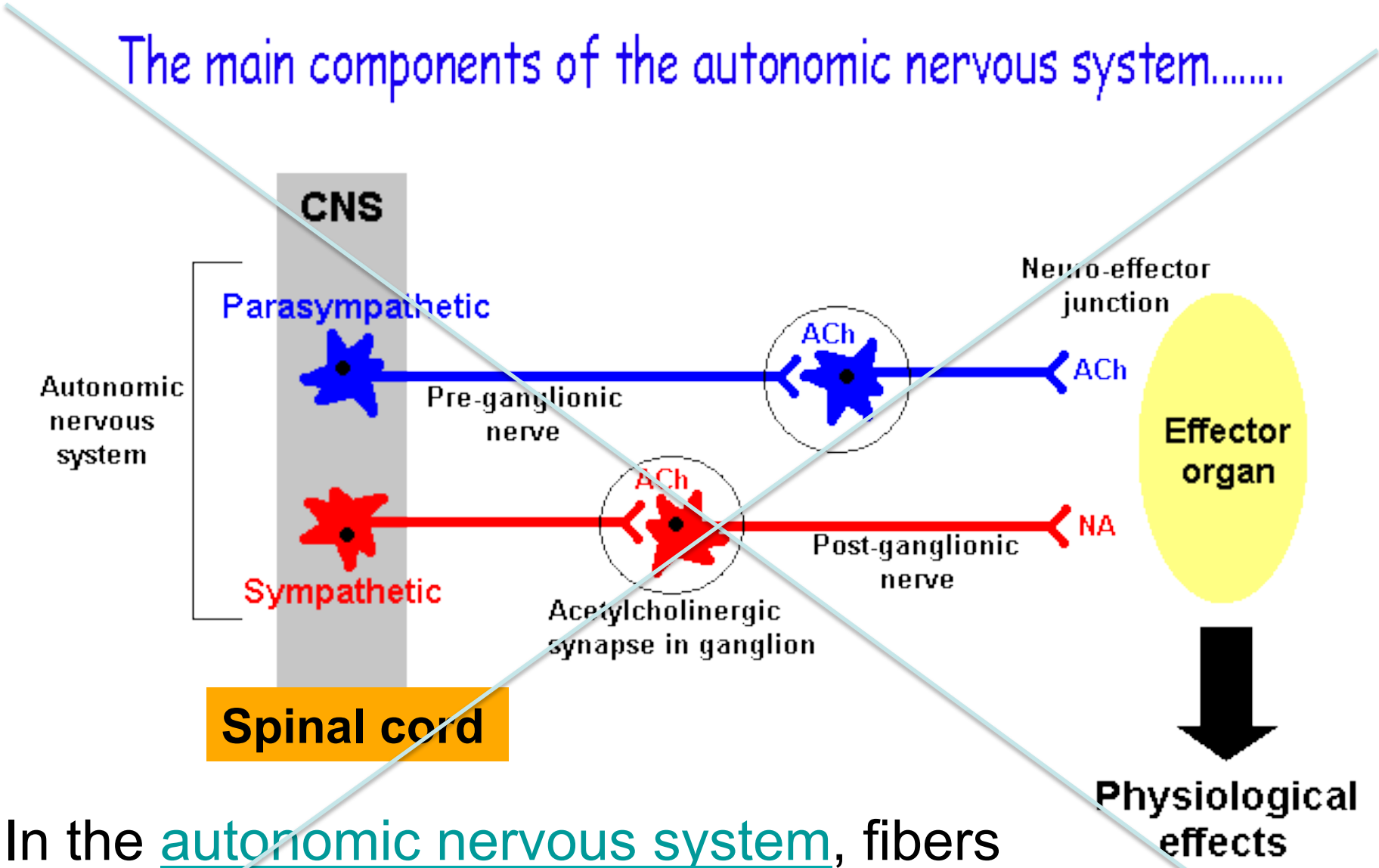
Summary of nervous system: bozeman

http://www.youtube.com/watch?v=UabDiuTtU0M&safety_mode=true

Parasympathetic and Sympathetic Nervous System

- Both utilize **two neurons** and **one ganglion** for each impulse.

Ganglion: Collection of neuron **cell bodies** outside the CNS



In the autonomic nervous system, fibers from the ganglion to the effector organ are called **postganglionic fibers or nerves**.

Autonomic Motor Pathways

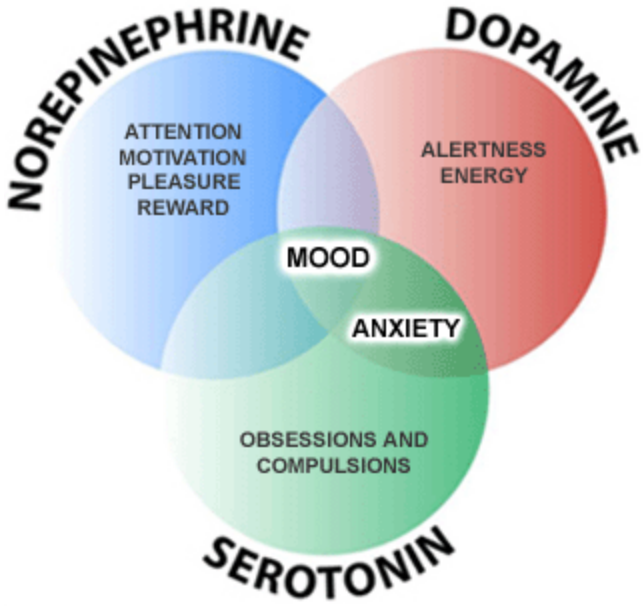
	Sympathetic	Parasympathetic
Type of control	**Involuntary**	**Involuntary**
Function	**Fight or flight**	**Rest and digest**
Neurotransmitters	**Norepinephrine**	**Acetylcholine**

Nerve transmission in a myelinated neuron and neurotransmitters. Narrated by David Suzuki.

http://www.youtube.com/watch?v=haNoq8UbSyc&safety_mode=true

Neurotransmitters, drugs and you!

- There are several NT important to nervous system functioning, such as
  - Serotonin
  - Acetylcholine
  - Norepinephrine
  - Dopamine and
  - GABA (gamma aminobutyric acid)
  - endorphins
- Drugs contain chemicals that
  - ↑ or ↓ NT production
  - mimic the NT or
  - Block receptor sites

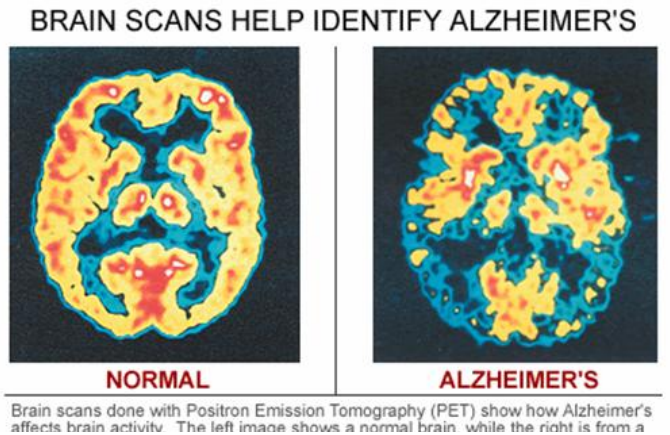


The Effects of Drugs and disease on synaptic transmission. Animations

http://outreach.mcb.harvard.edu/animations/synapse.swf

Acetylcholine

- Usually **excitatory**, but can be inhibitory
- Important in **thinking and memory**
- Low levels of acetylcholine is a symptom of **Alzheimer's disease**
  - Memory loss and decreased mental capabilities



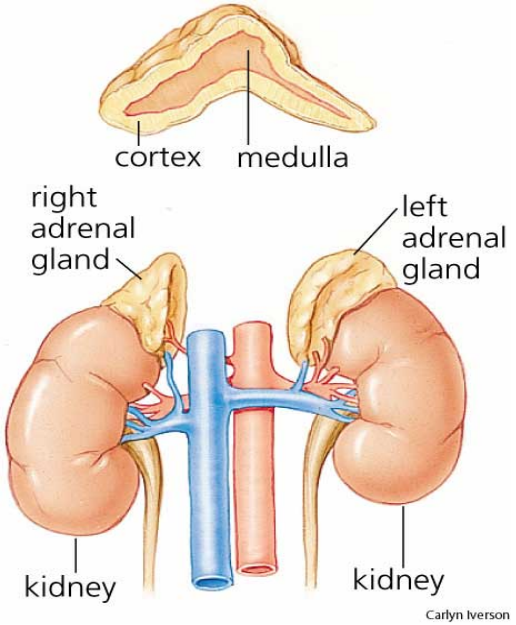
Hallucinogens

- Blocks acetylcholine receptors on the postsynaptic neuron
- **Scopolamine** – found in Gravol, to treat motion sickness

Ex. *Atropa belladonna*

- In ancient Rome and Egypt, it was squirted into the eyes of women to make their pupils dilate, which was considered attractive

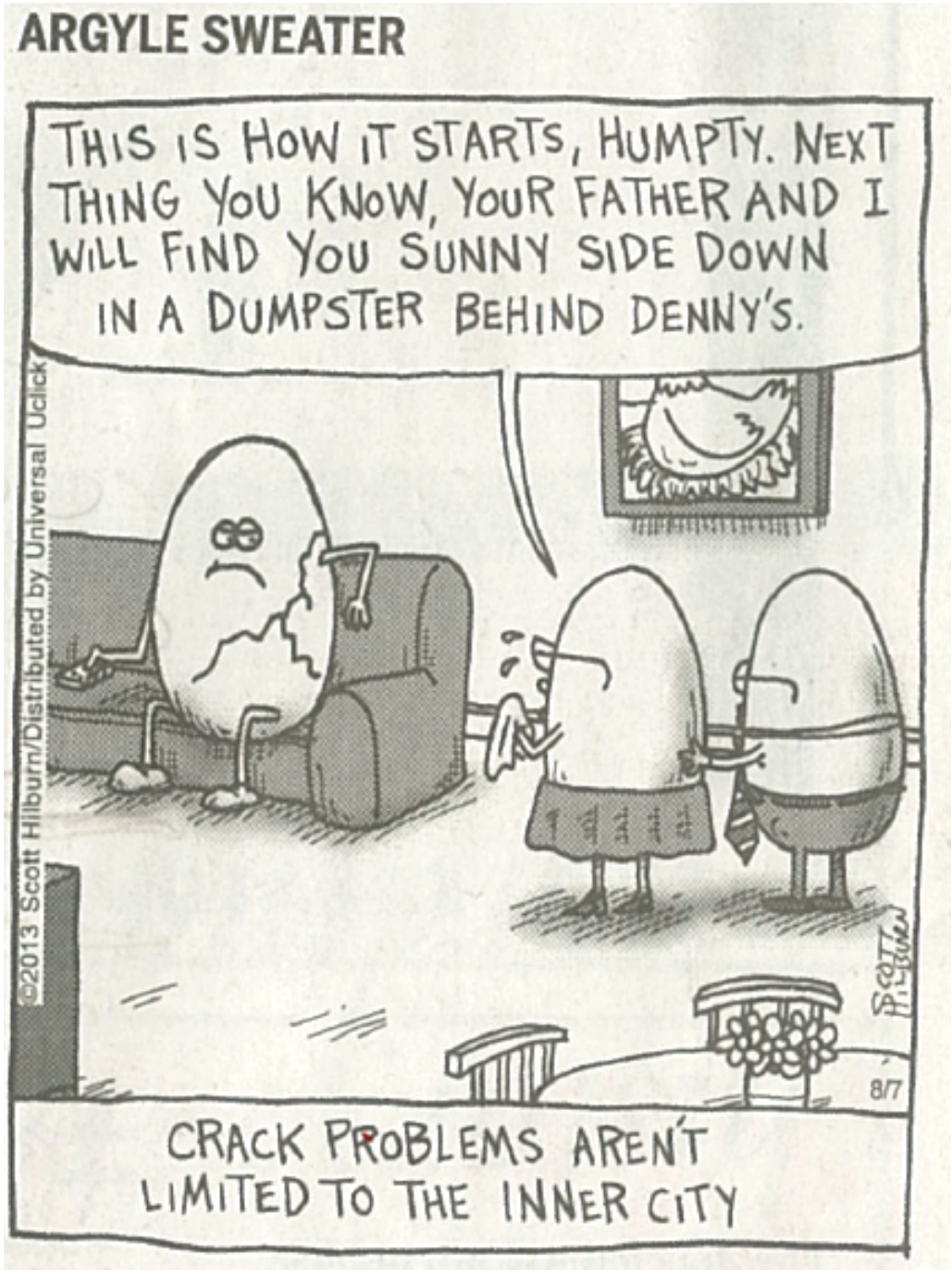
Norepinephrine



- Produced in the **adrenal gland**
- Can be excitatory or inhibitory
- Involved in **fight-or-flight response (sympathetic nervous system)**
- Creates feelings of euphoria
  - Low amounts related to depression
- **Cocaine** blocks the reuptake of **norepinephrine,** also **dopamine** and **serotonin**

- Do you know where **coca cola** got its name?
  - Up to 1904, coke contained small amounts of cocaine
  - Today, coke still contains coca leaf extracts – but these leaves are de-cocainized

ARGYLE SWEATER

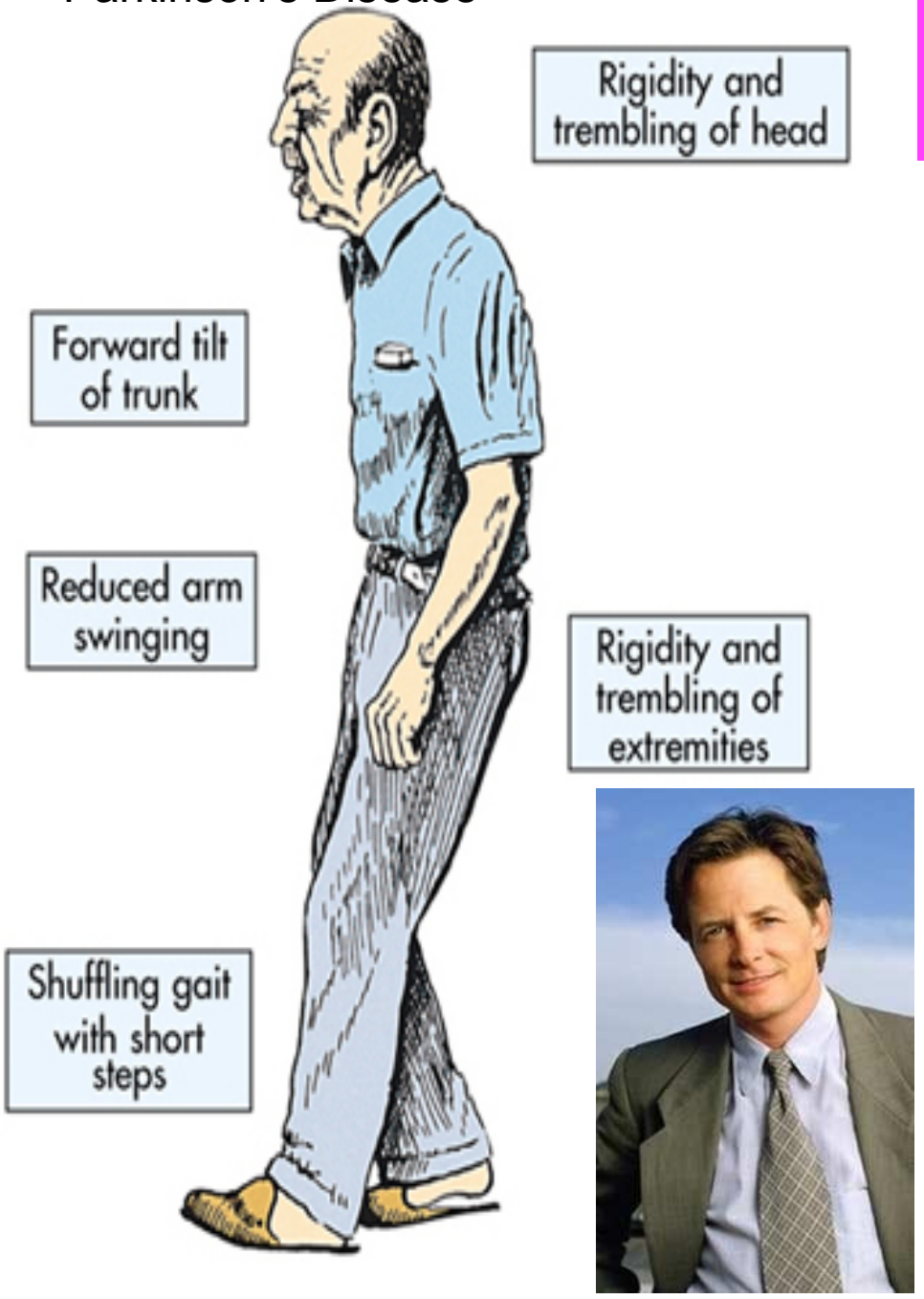


Methamphetamine (Crystal meth)

- Psychostimulant drug
- Causes the increased release of **norepinephrine**
- stimulates the heart and respiration, constricts blood vessels and induces sleeplessness
- Originally used to treat ADHD and obesity
- disturbs sleep patterns, loss of REM dreaming sleep, hyperactivity, nausea, delusions of power, increased aggressiveness and irritability

www.methmadness.com/methbodyphotos.html

Parkinson's Disease

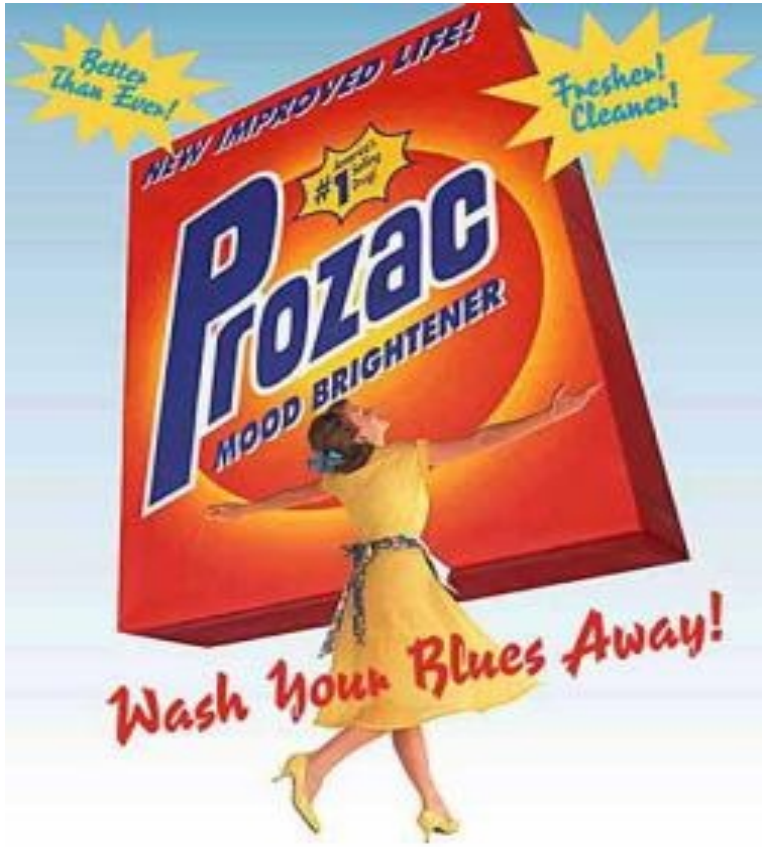


Dopamine

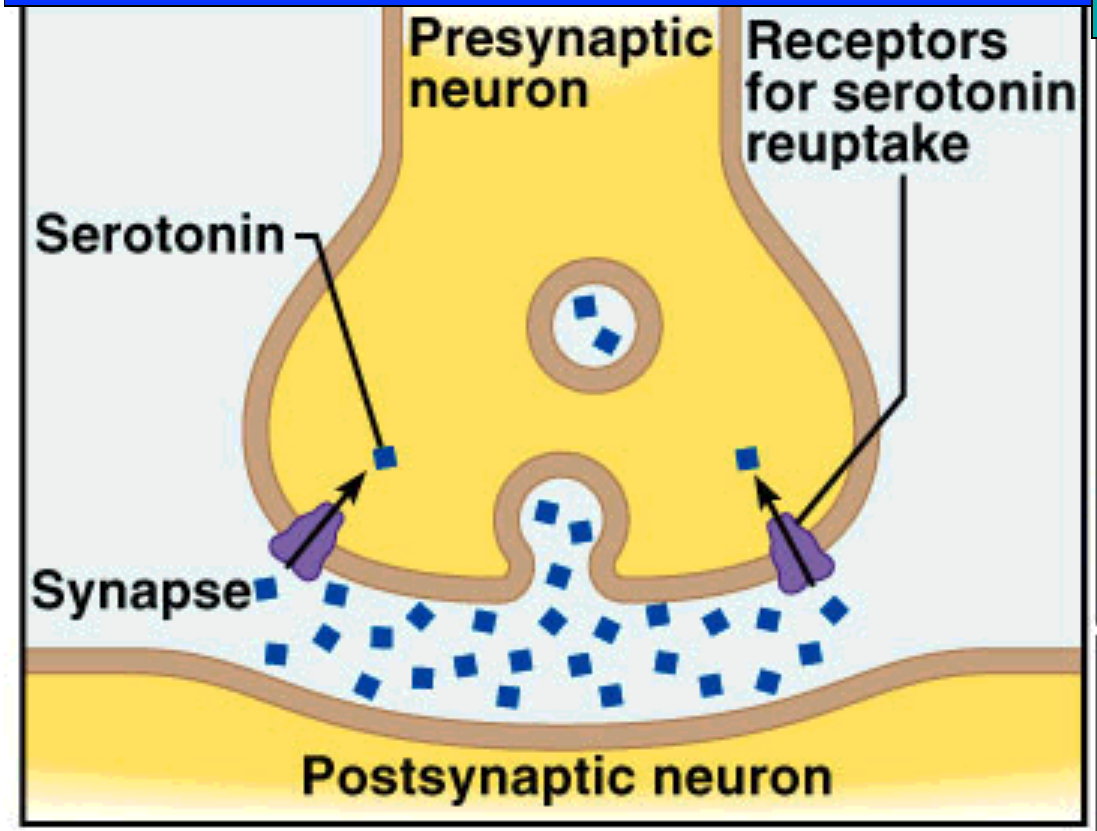
- Excitatory or inhibitory
- **commonly associated with the *pleasure system* of the brain,**
  - **feelings of enjoyment and reinforcement to motivate**
- **Dopamine is released by naturally rewarding experiences such as**
  - **Food**
  - **Sex**
- Involved in muscle activity
- Low levels are involved in **Parkinson's disease**
  - Involuntary muscle contractions and tremors
- Michael J. Fox

Serotonin

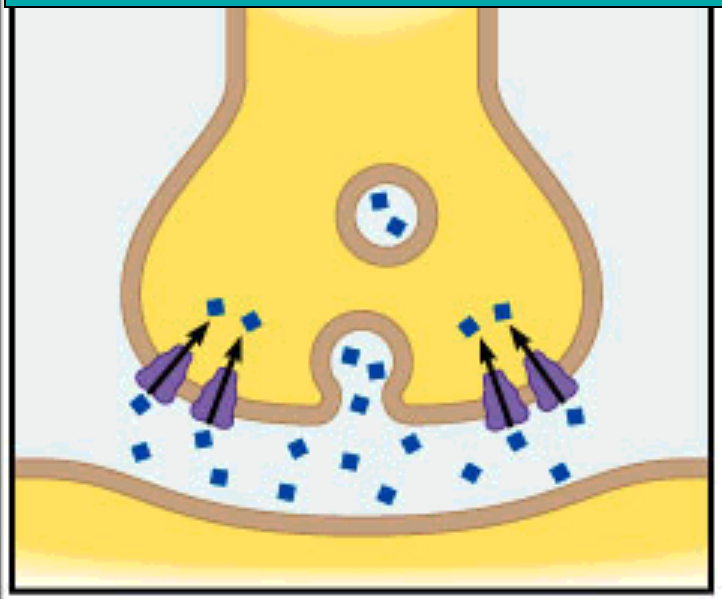
- Generally inhibitory
- High levels causes sleepiness
- Low levels are associated with **depression**
  - Serotonin is reabsorbed too quickly by the pre SN
- Drug like **Prozac (Zoloft)** prevent the reuptake of serotonin or stimulate serotonin receptors
- These are called **SSRI's (Selective Serotonin Reuptake Inhibitors)**

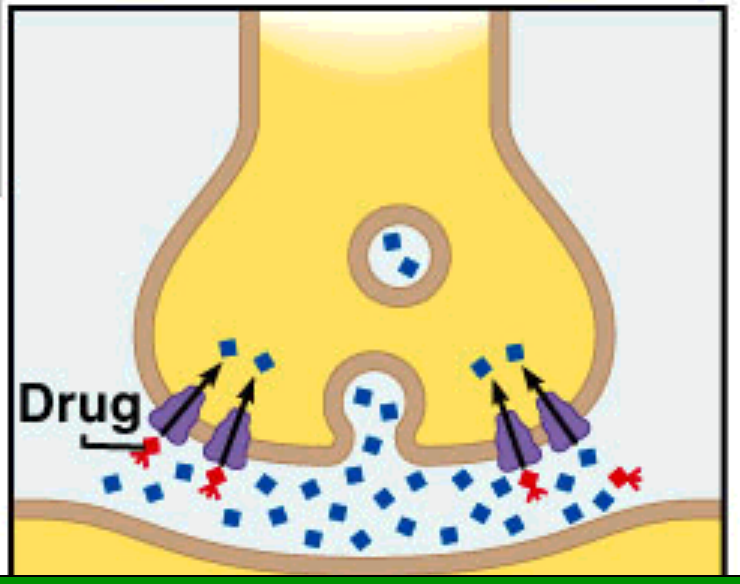


Non-depressed individuals



Depressed individuals



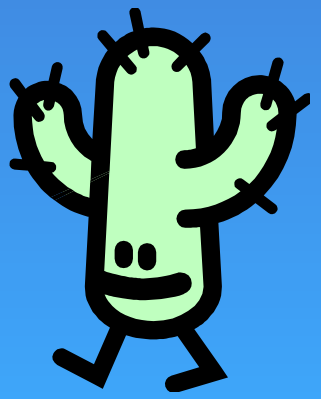


Anatomy of an anti-depressant

Depressed individuals treated with SSRI

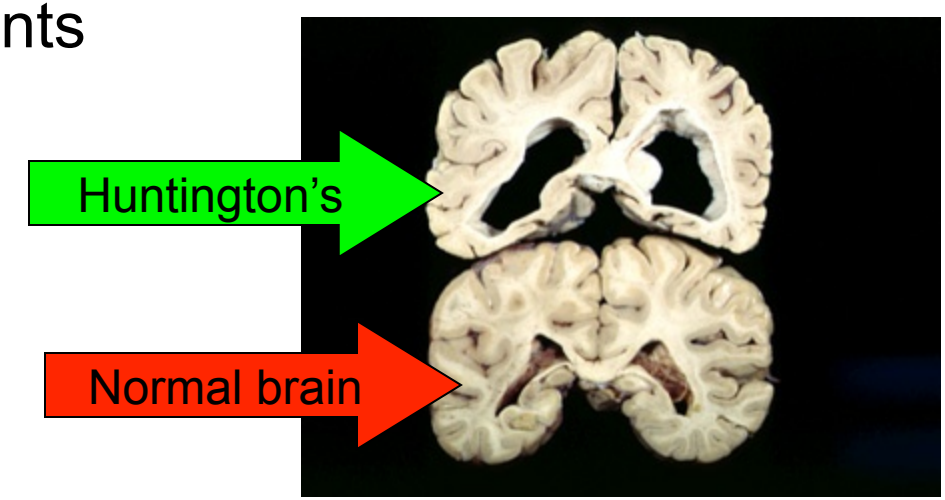
Serotonin, LSD and mescaline

- Serotonin is **blocked** by LSD and mescaline
- **LSD** (Lysergic acid diethylamide) is grown from fungus
- **Mescaline** comes from a cactus plant
  - Mescaline buttons are eaten to produce color hallucinations



GABA

- **Gamma aminobutyric acid**
- Inhibitory transmitter (Reduces neurons excitability)
- Controls complex movements
- Low levels linked to **Huntington's disease**
    - Involuntary movements



Rohypnol

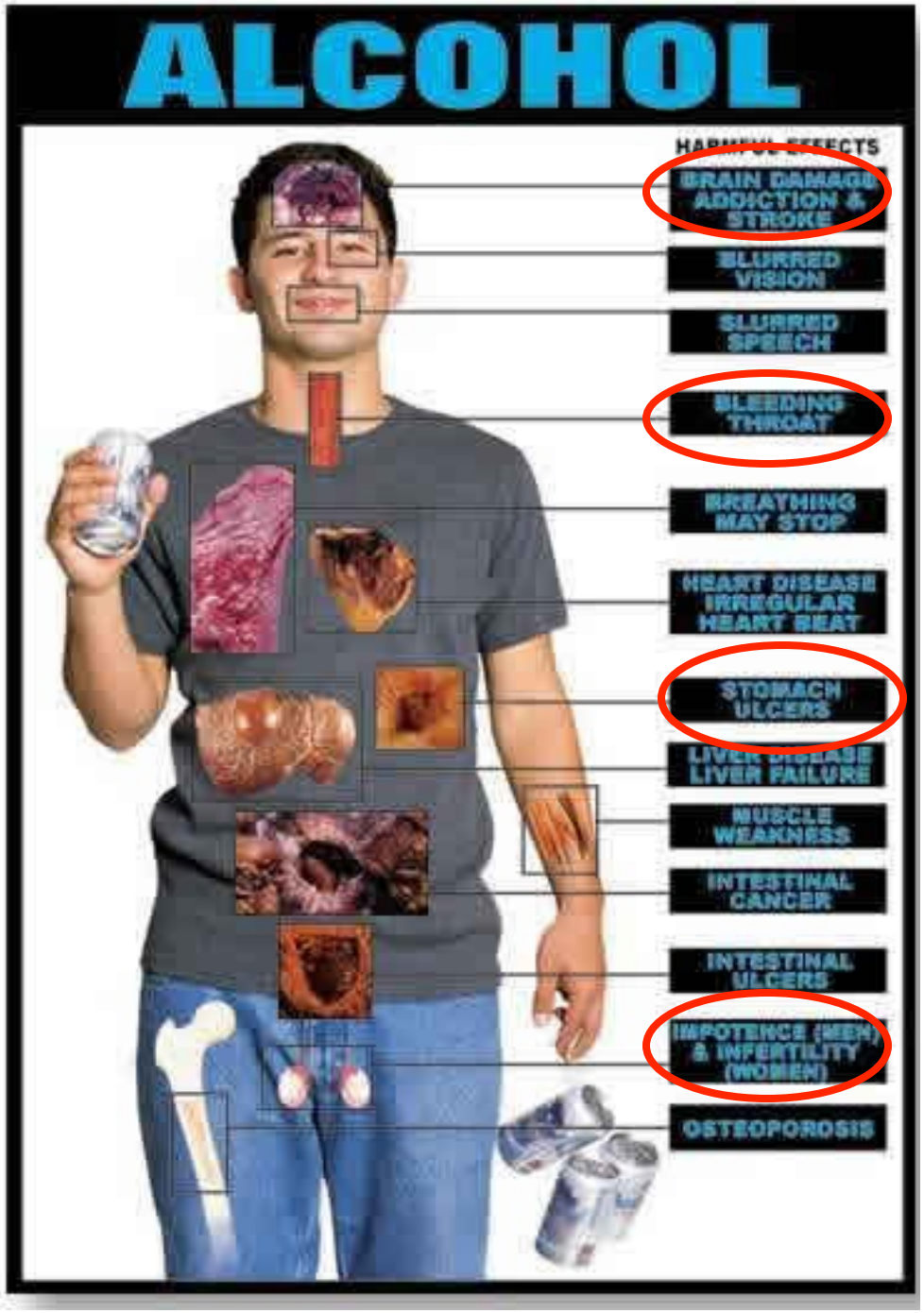
- You might know it as **“roofies”**
- Depresses the CNS
- Increases the binding ability of **GABA** to its receptor

(makes GABA do more)

- **Date rape drug**

Alcohol

- **"Water of life"**
- Alcohol abuse: ↑ GABA production
- Thus increasing inhibition
- Results in memory loss, mood swings, slower breathing
- **Reduces brain size**
- The fall of the Roman Empire has been blamed on **alcohol**



Alcohol


DILBERT
OUR OFFICERS CAME UP WITH A NEW COMPANY SLOGAN AFTER TWO WEEKS AT A RETREAT.
THE NEW SLOGAN IS "SHTOP SPITTING AHN ME WHEN YOU TALK!"
WE BELIEVE ALCOHOL WAS INVOLVED.
Dilbert.com DilbertCartoonist@gmail.com
6-26-14 © 2014 Scott Adams, Inc. /Dist. by Universal Uclick

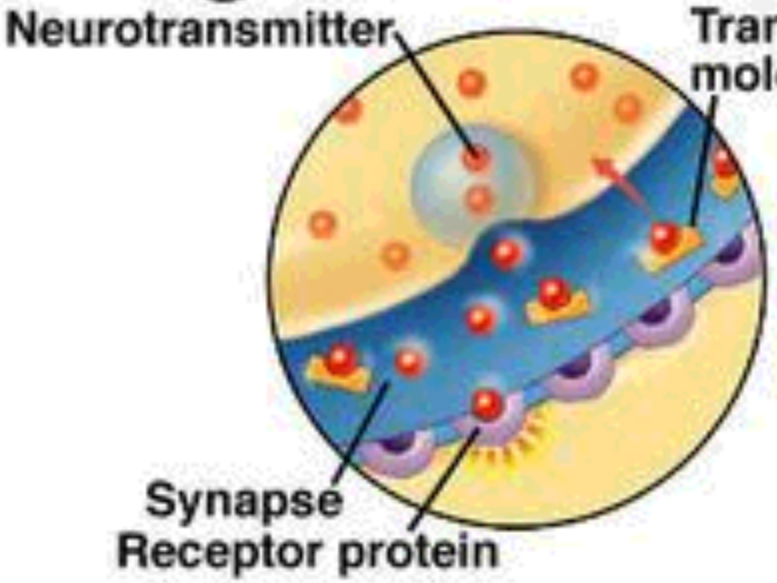
Endorphins

- Generally inhibitory
- They are produced by the pituitary gland and the hypothalamus during **strenuous exercise**, excitement, pain, death and orgasm and they resemble the opiates in their abilities to produce analgesia and a sense of **well-being**.
- Endorphins work as "**natural pain relievers**", whose effects may be enhanced by other medications.
- Effects mimicked by **morphine, heroin** and **methadone**
- Besides pain killing effects, prolonged morphine use can also lead to constipation!

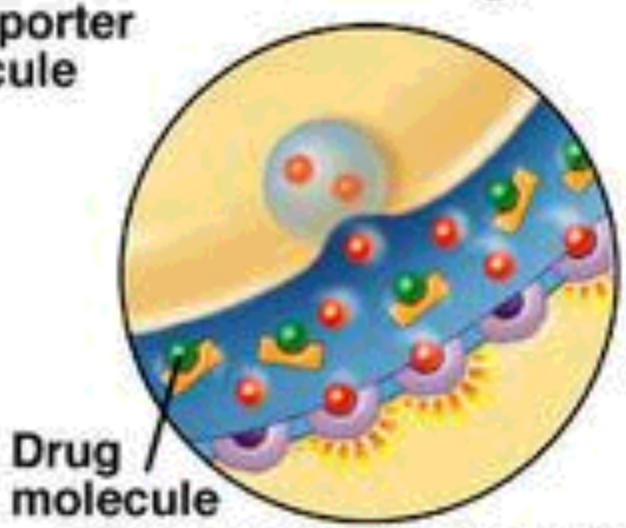
What causes addictions?

- **A drug that causes increased** production of **dopamine** creates feelings of reward
- This activates reinforcement systems, that are naturally activated by reinforcers such as food, water, sex, etc.
- **This reduces receptor numbers** on the post synaptic neuron
  - thus need more drugs to produce the same effect
  - The individual develops **tolerance**

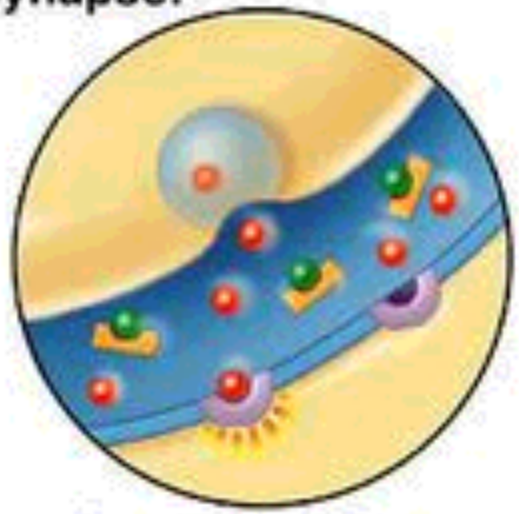
Drug Addiction and the Synapse



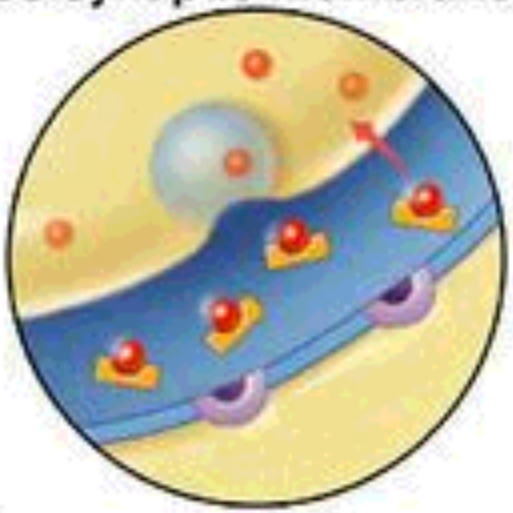
Neurotransmitter is reabsorbed at a normal synapse.



Drug molecules prevent reabsorption and cause overstimulation of postsynaptic membrane.



The number of receptors decreases.



The synapse is less sensitive when the drug is removed.

- Check out The “ Mouse Party” game to learn more about how drugs interact in your brain

Mouse Party URL

http://learn.genetics.utah.edu/content/addiction/mouse/