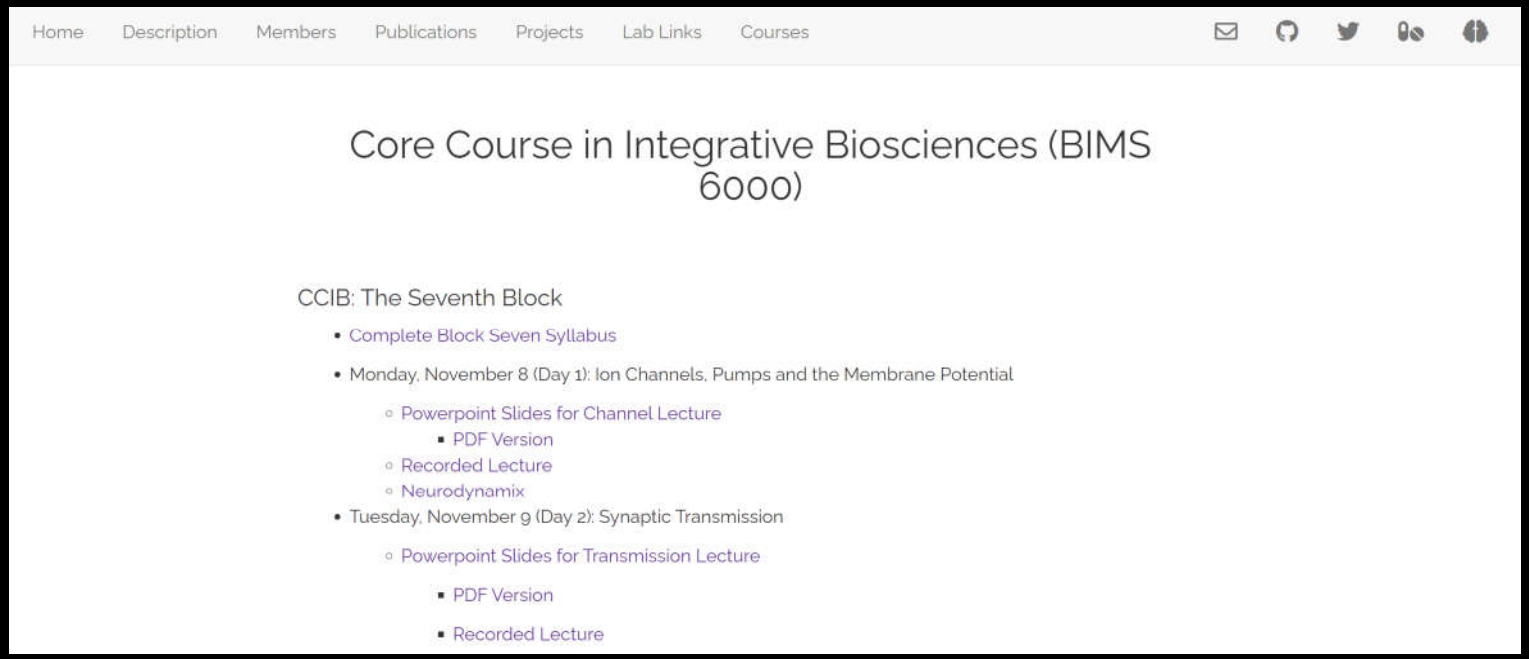
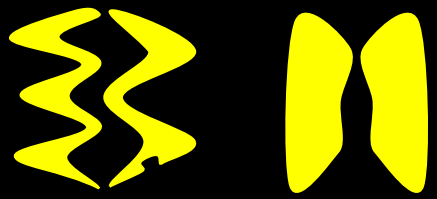
CCIB
The Seventh Block



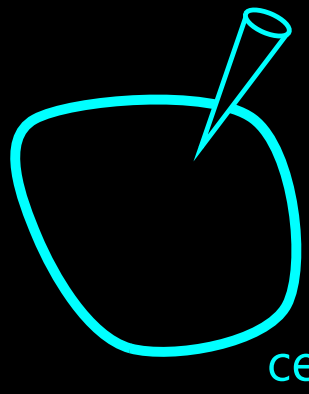
http://beenhakkerlab.org/

Ion Channels & Cellular Electrophysiology

Mark Beenhakker
markbeen@virginia.edu



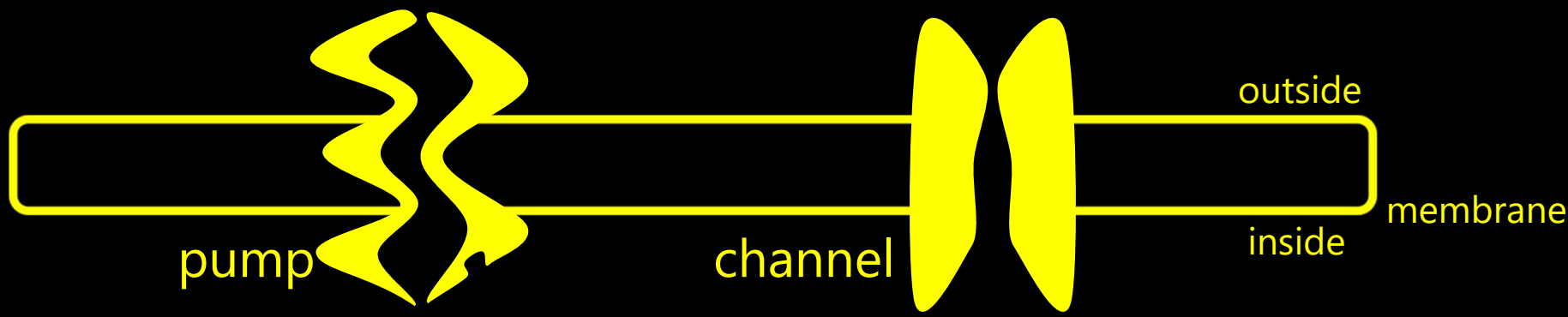
pumps &
channels



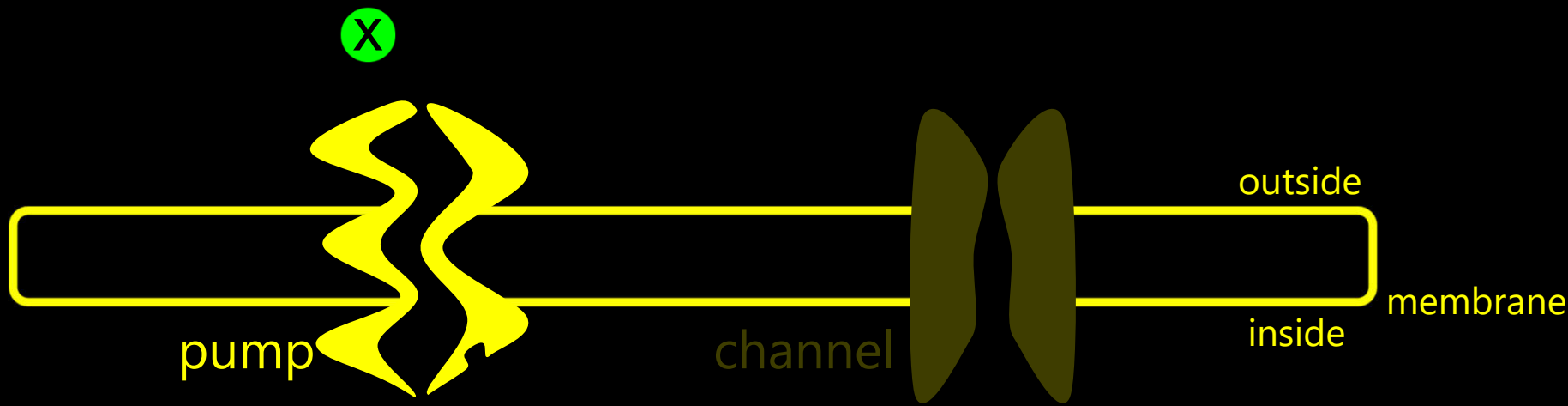
membrane
voltage

electrical
signals

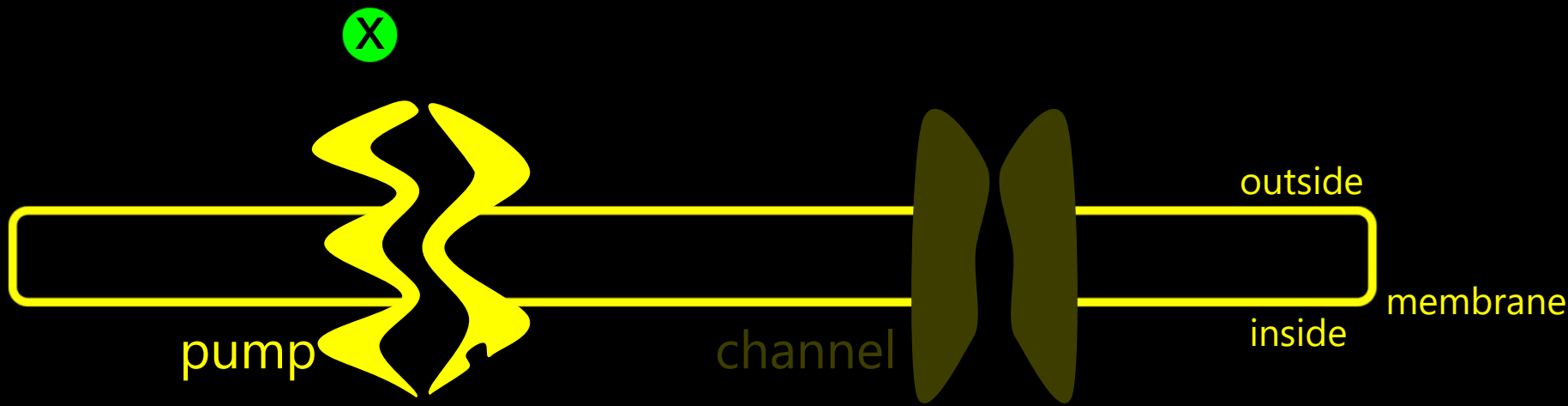
Pumps & Channels



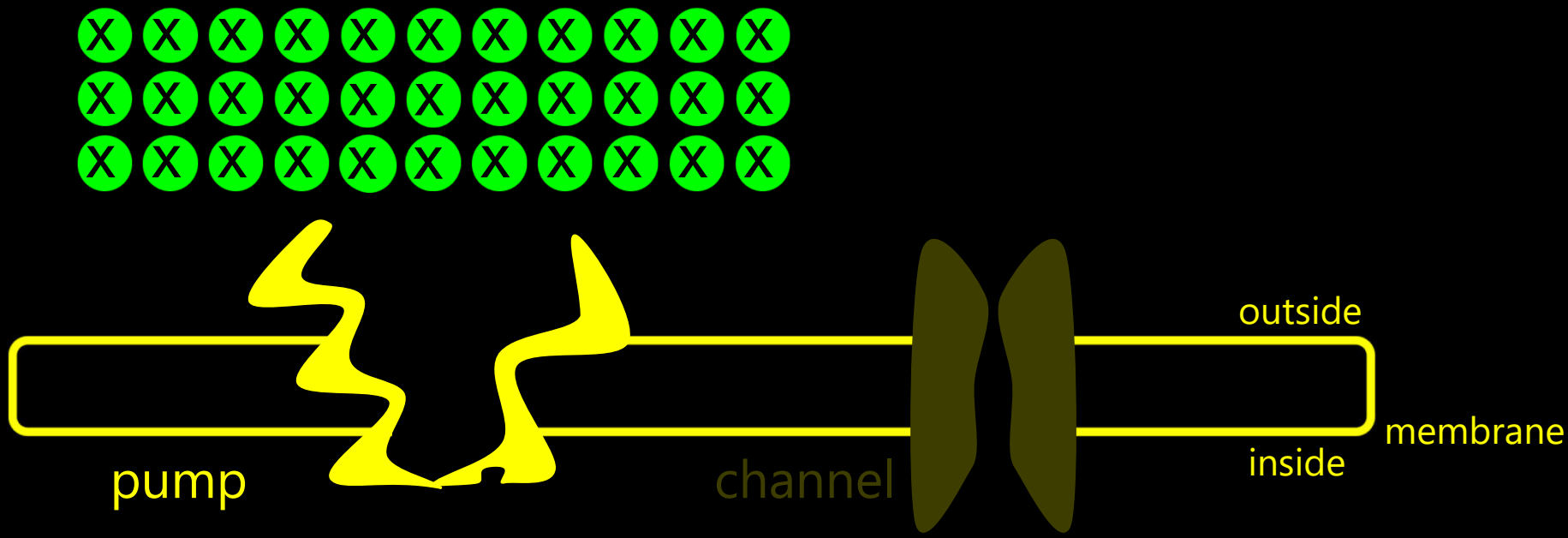
Pumps & Channels



Pumps & Channels

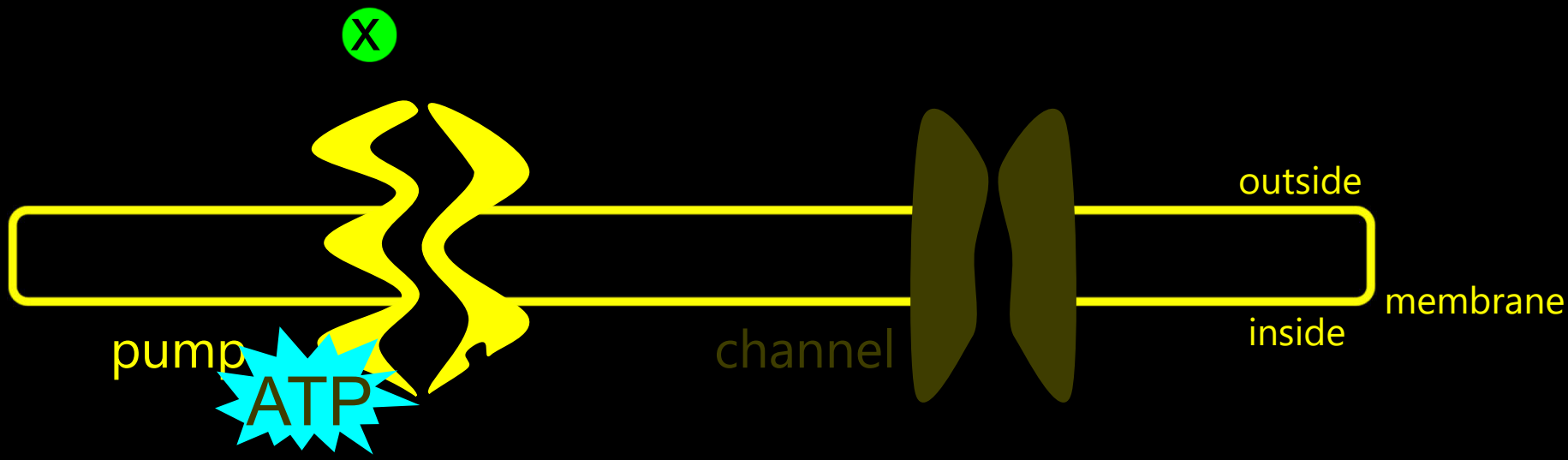


Pumps & Channels



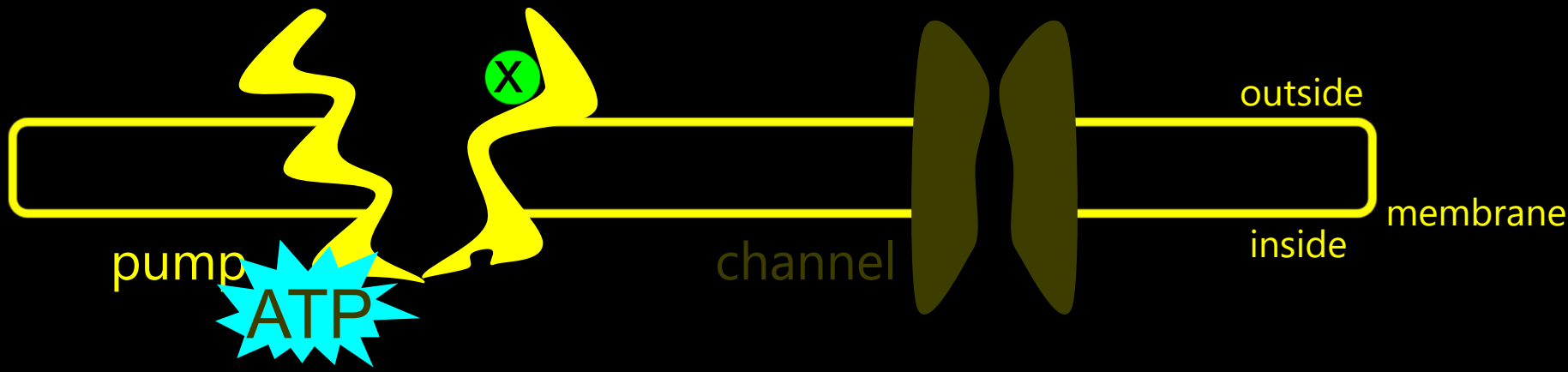
passive transport

Pumps & Channels



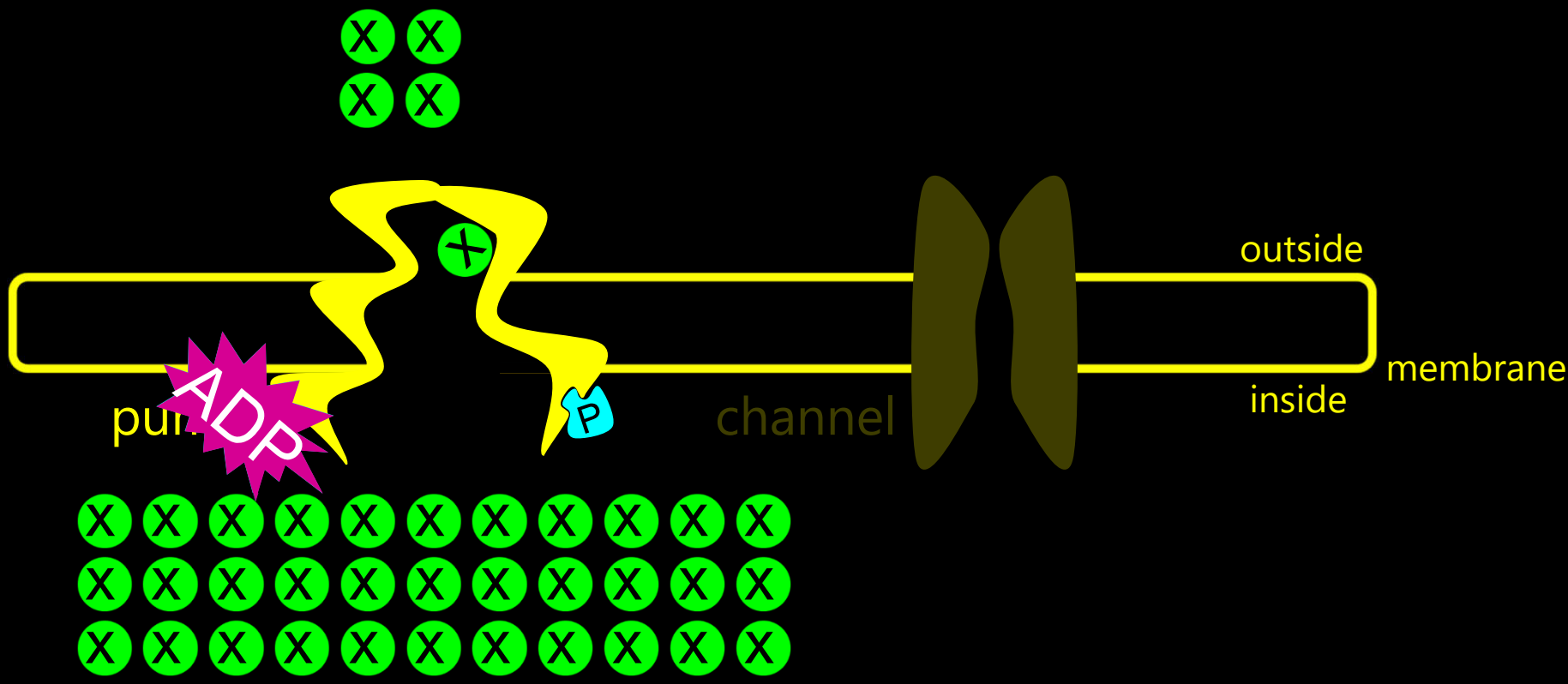
active transport

Pumps & Channels



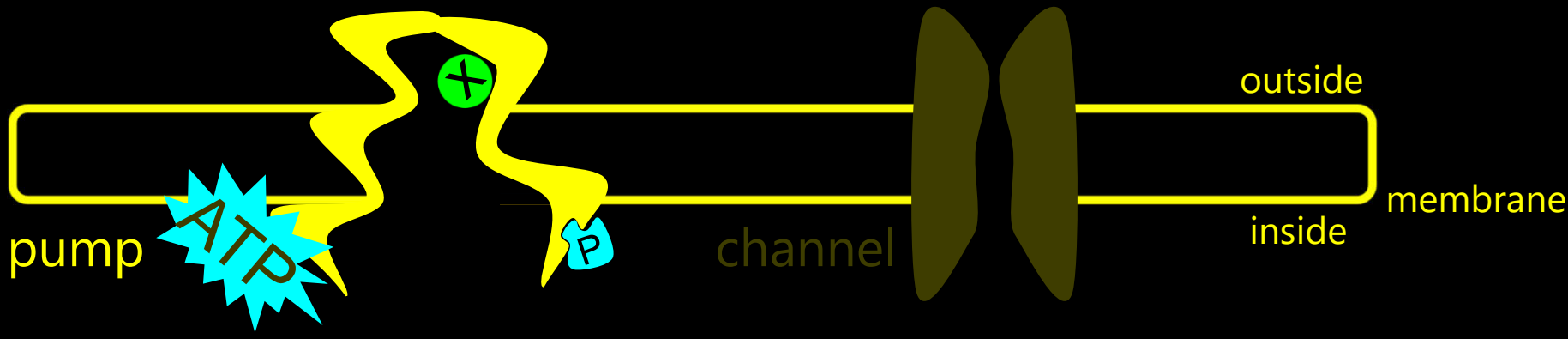
active transport

Pumps & Channels



active transport

Pumps & Channels

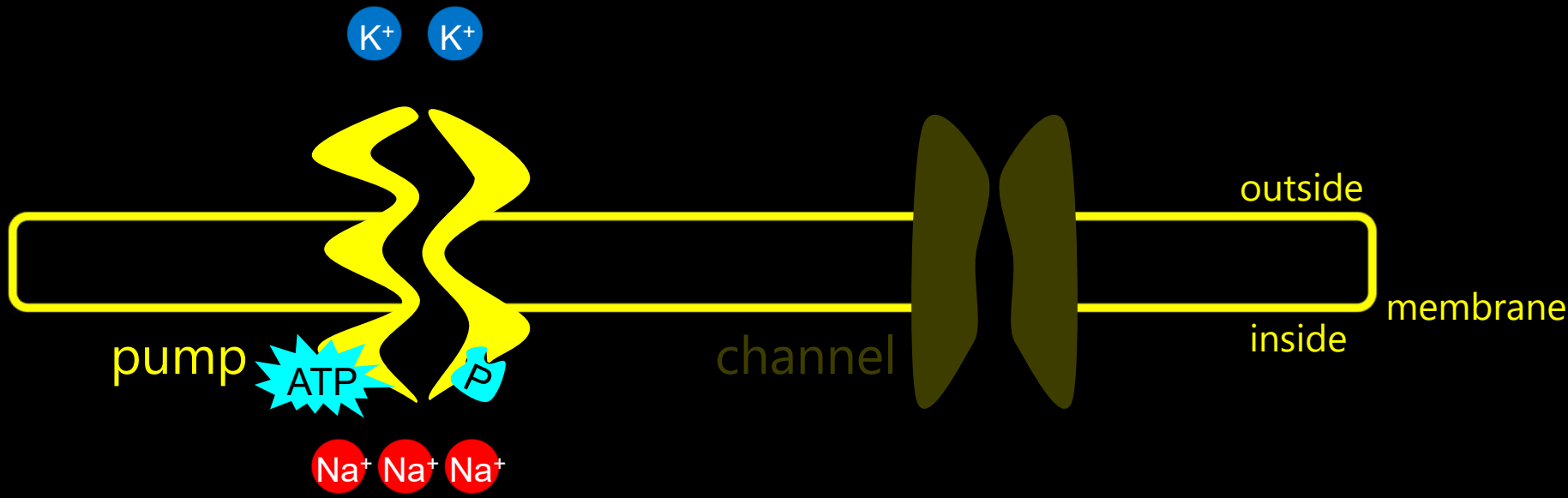


ATP-Driven Pumps

- P-type pumps
- ABC transporters
- V-type pumps

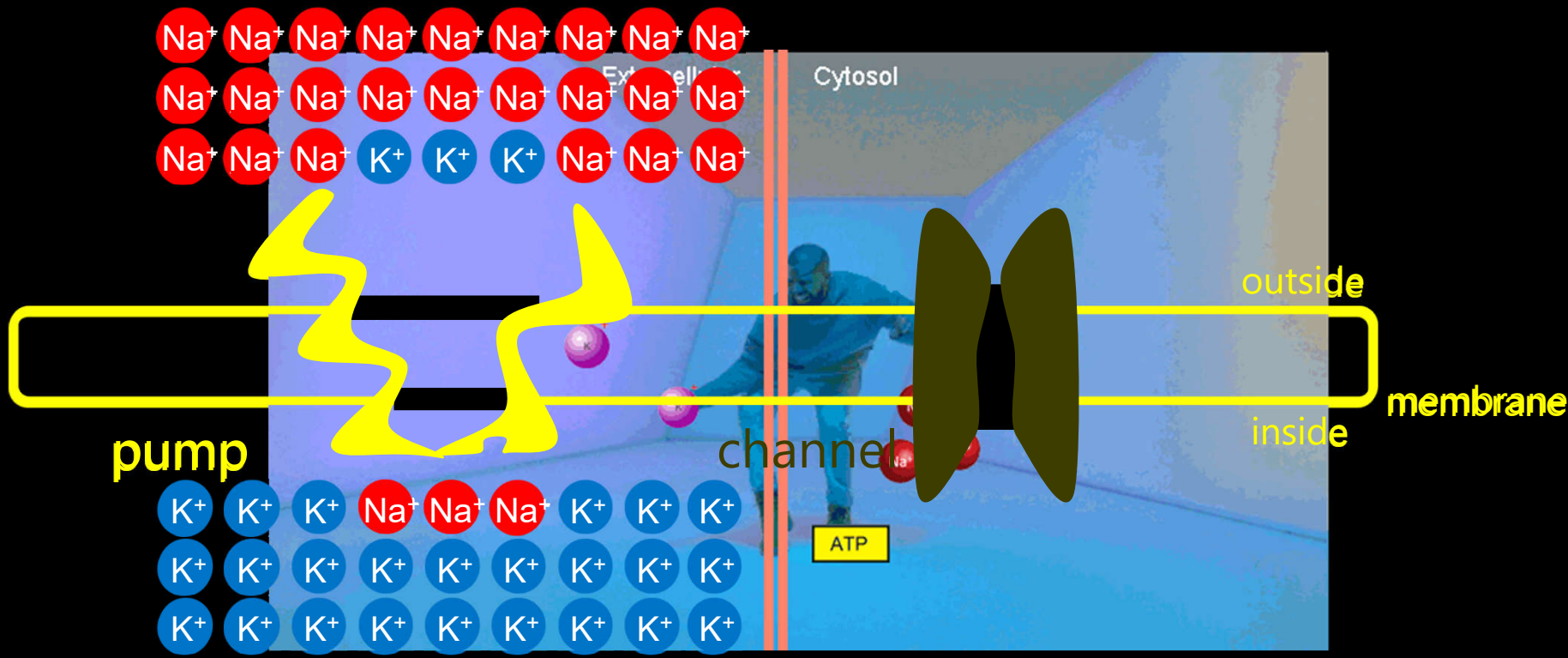
Na^+-K^+ Pump

Pumps & Channels



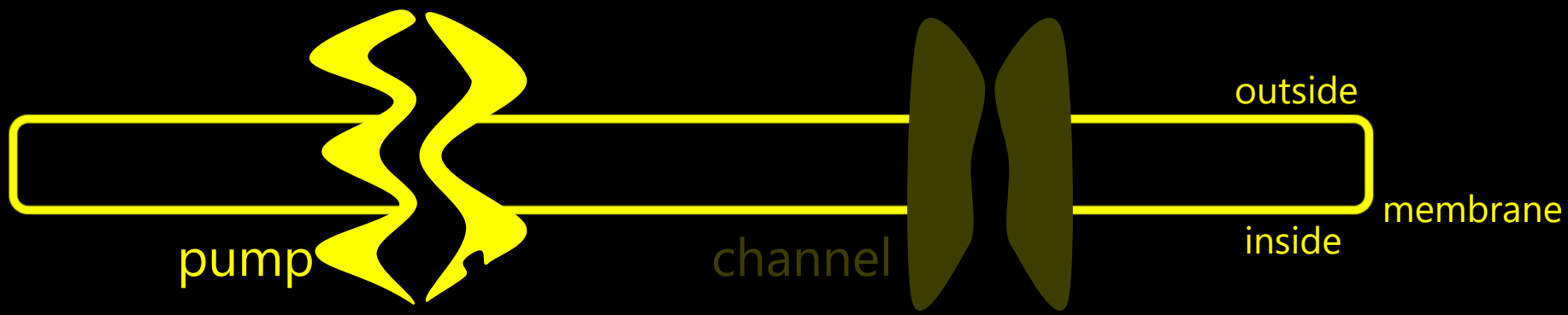
Na^+-K^+ Pump

Pumps & Channels

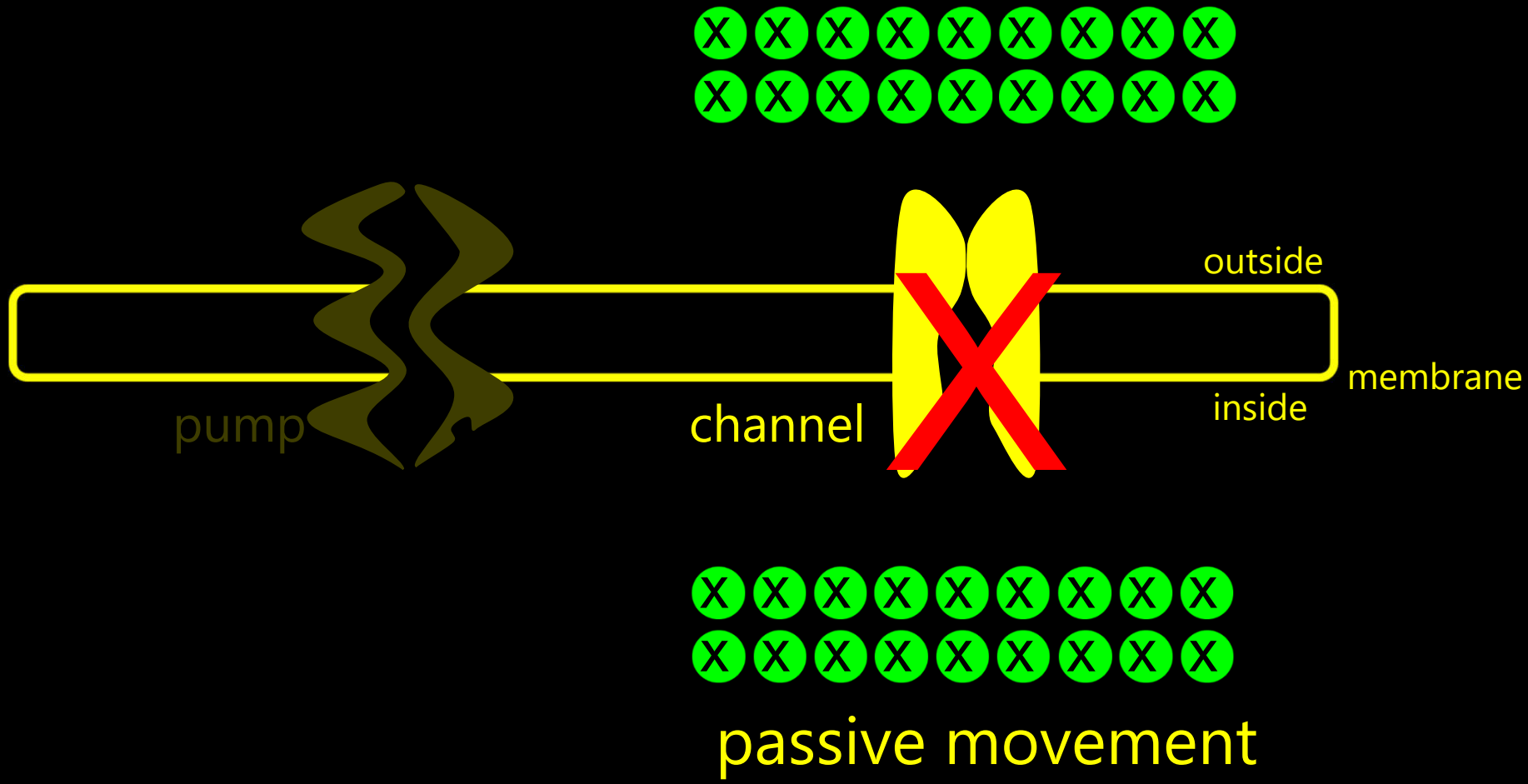


Na^+-K^+ Pump

Pumps & Channels

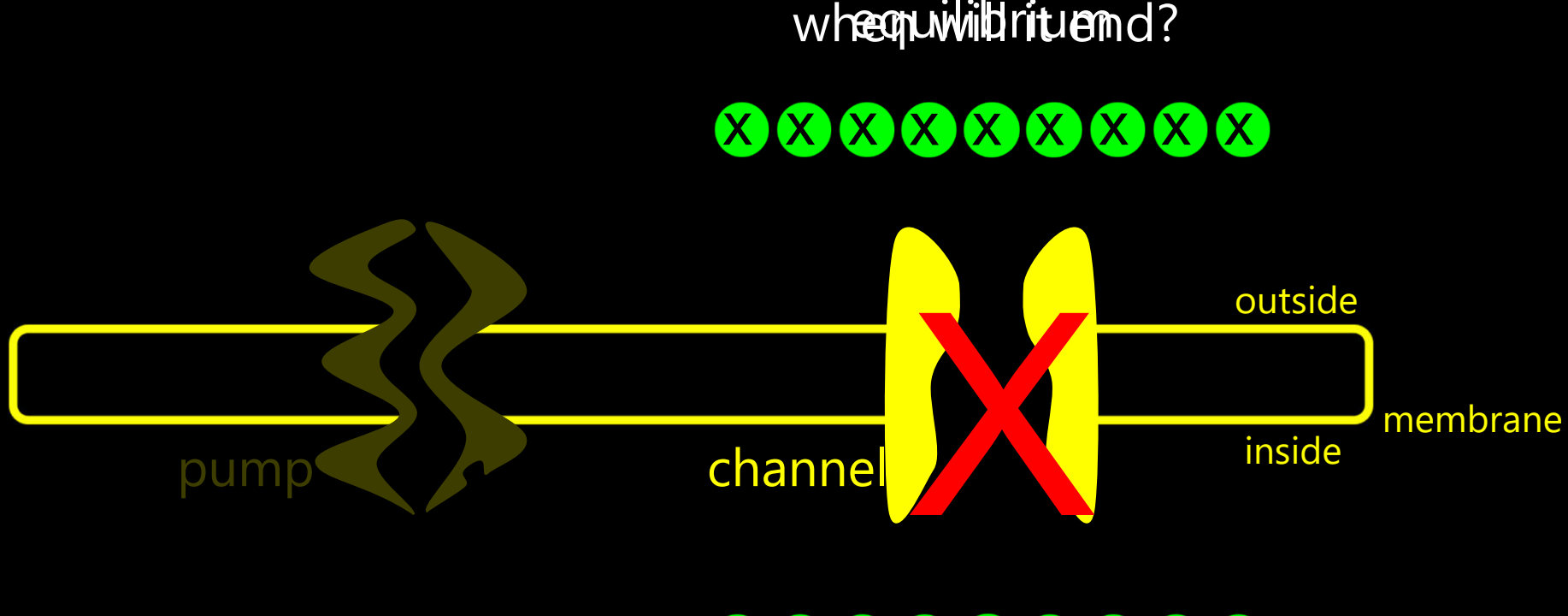


Pumps & Channels



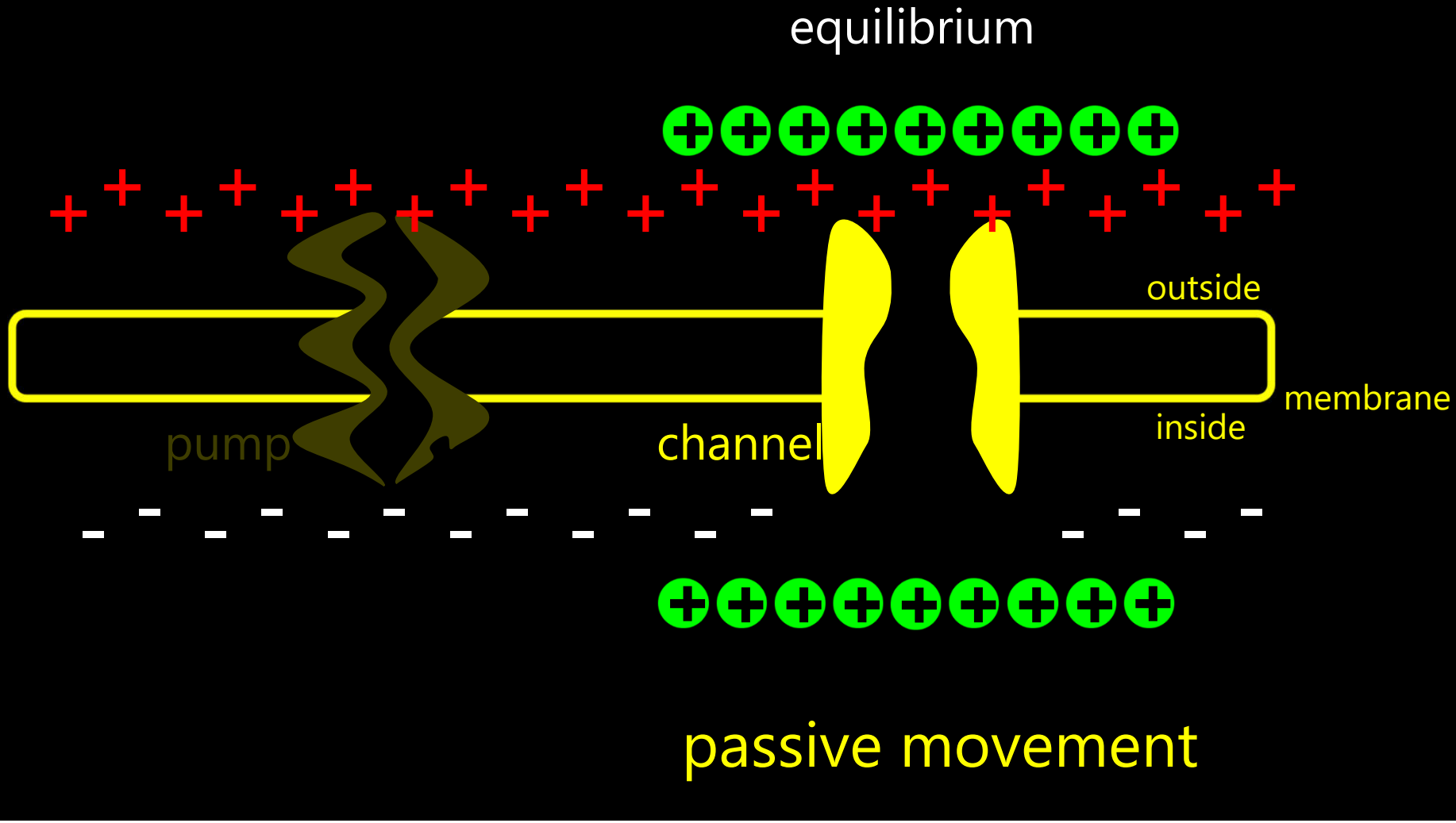
Pumps & Channels

when will it end?



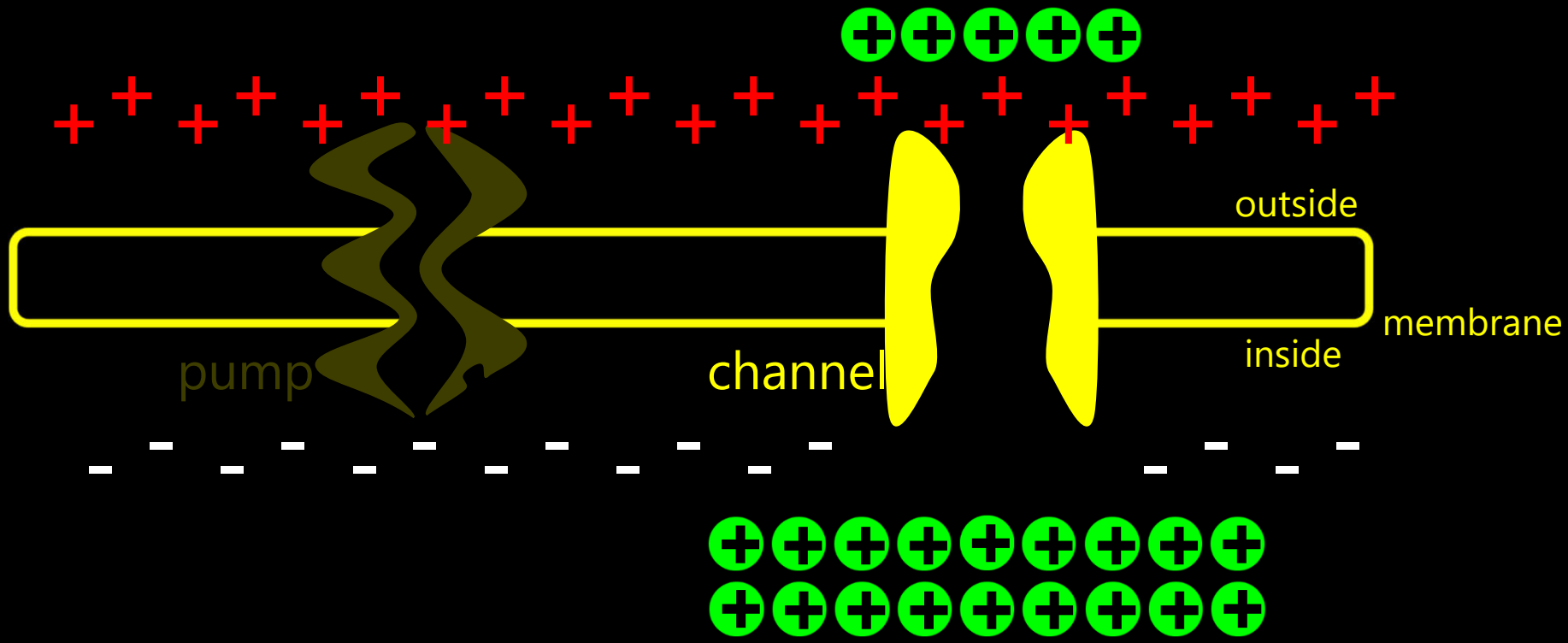
passive movement

Pumps & Channels



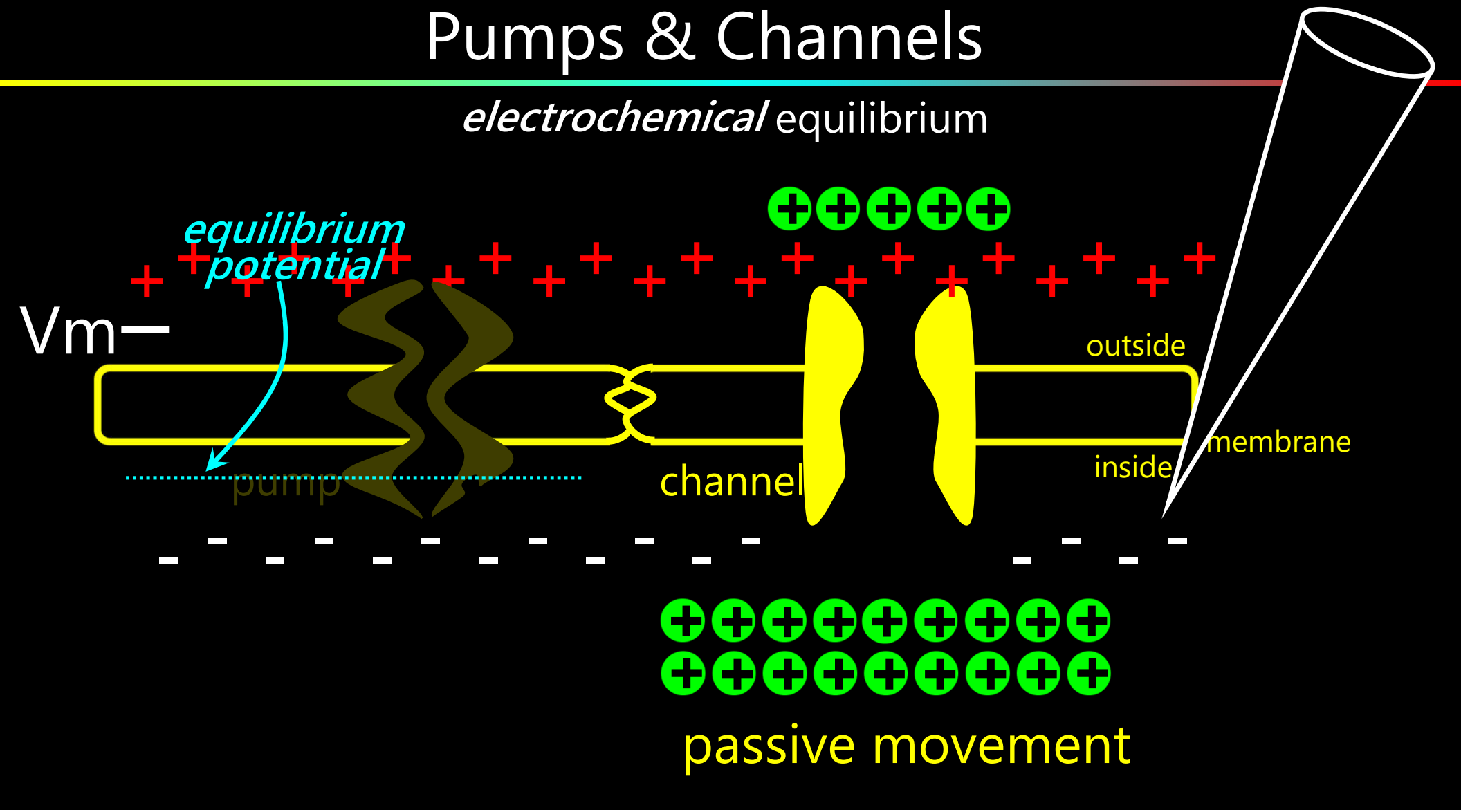
Pumps & Channels

electrochemical equilibrium



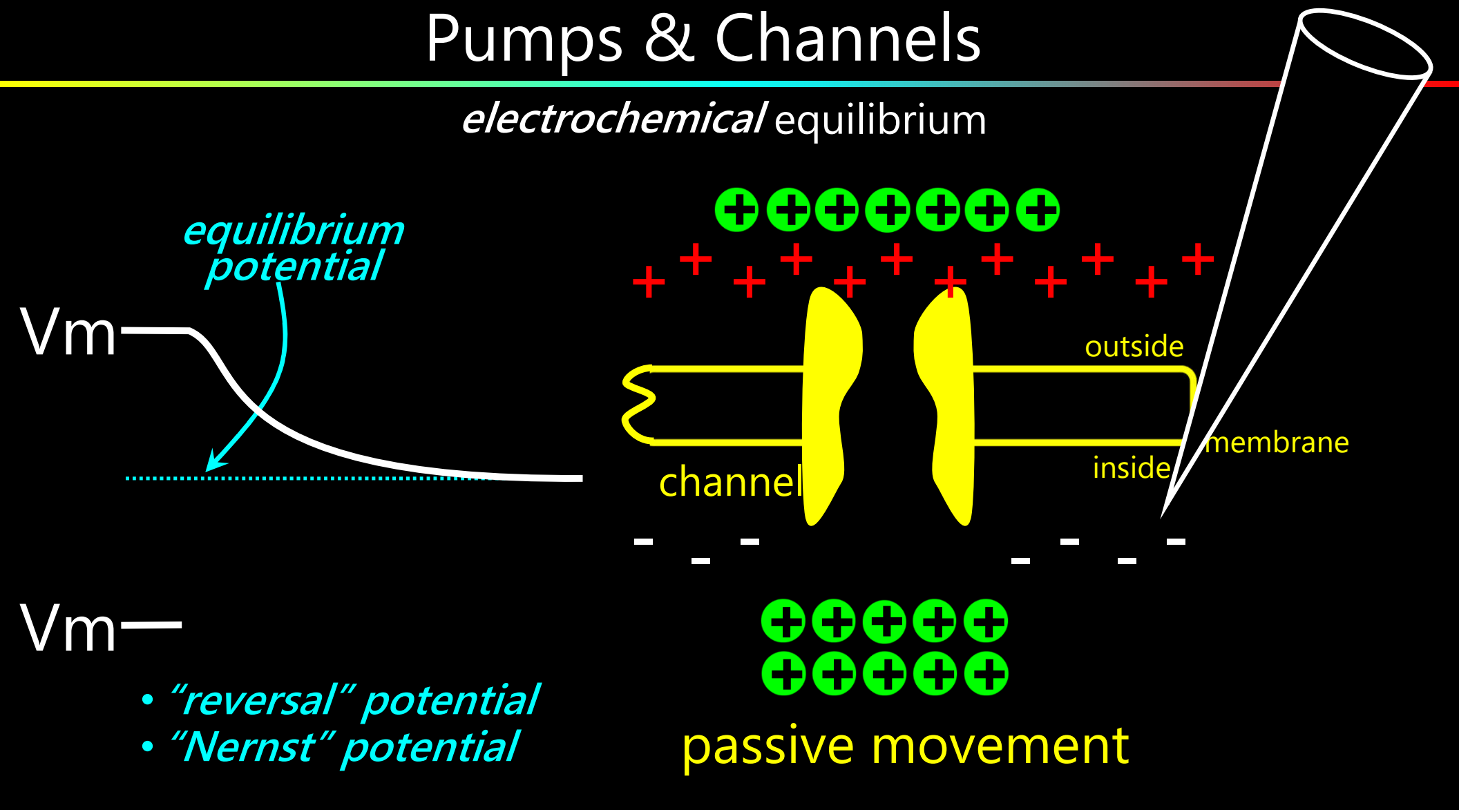
Pumps & Channels

electrochemical equilibrium



Pumps & Channels

electrochemical equilibrium



- *"reversal" potential*
- *"Nernst" potential*

Pumps & Channels

electrochemical equilibrium

equilibrium potential

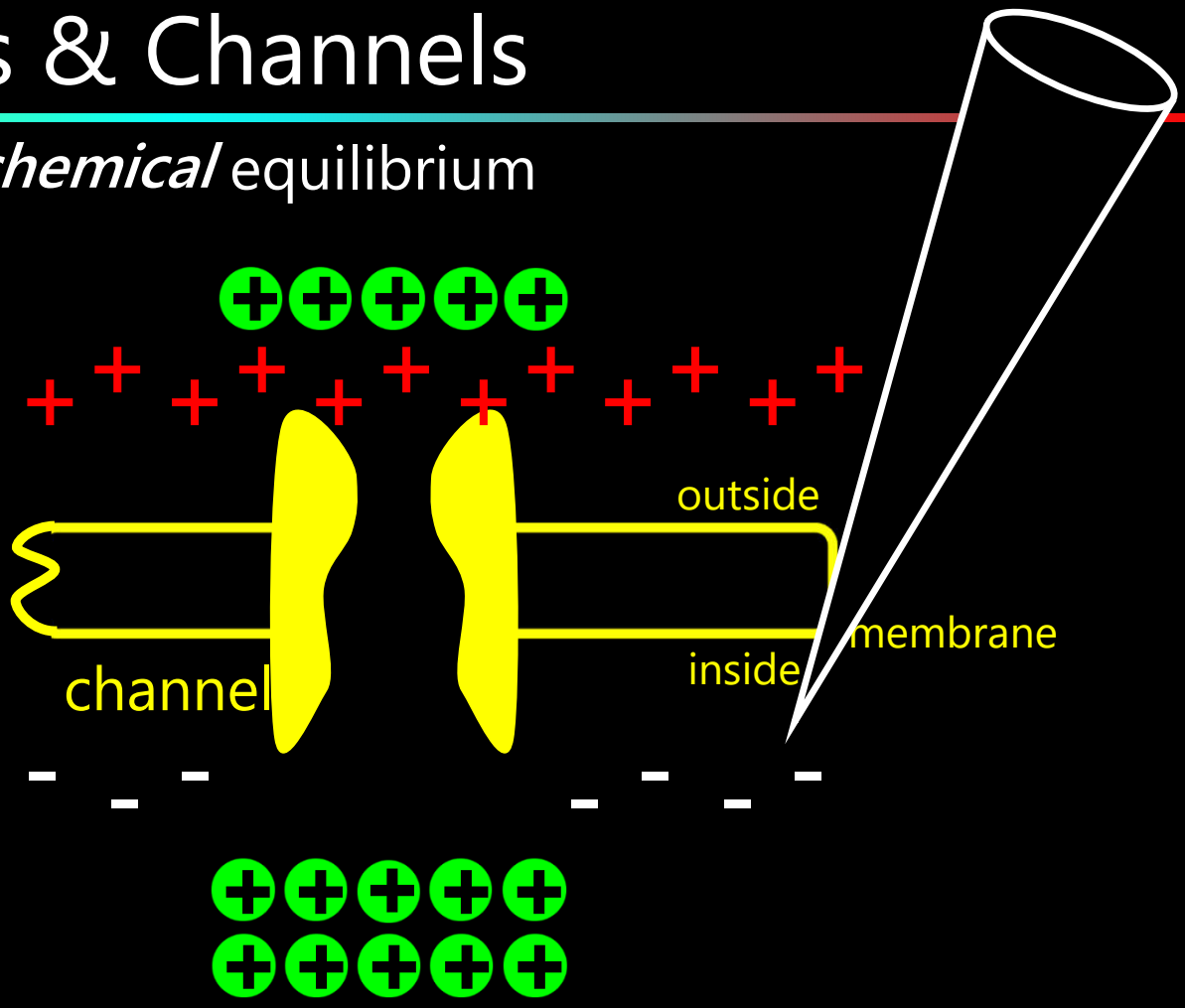
Nernst Equation

$$V_{equilibrium} = \frac{RT}{zF} \ln \frac{[X]_o}{[X]_i}$$

- R = gas constant
- T = temperature
- Z = valence of the ion
- F = Faraday's constant

V_m

- *"reversal" potential*
- *"Nernst" potential*



passive movement

Pumps & Channels

electrochemical equilibrium

Nernst Equation

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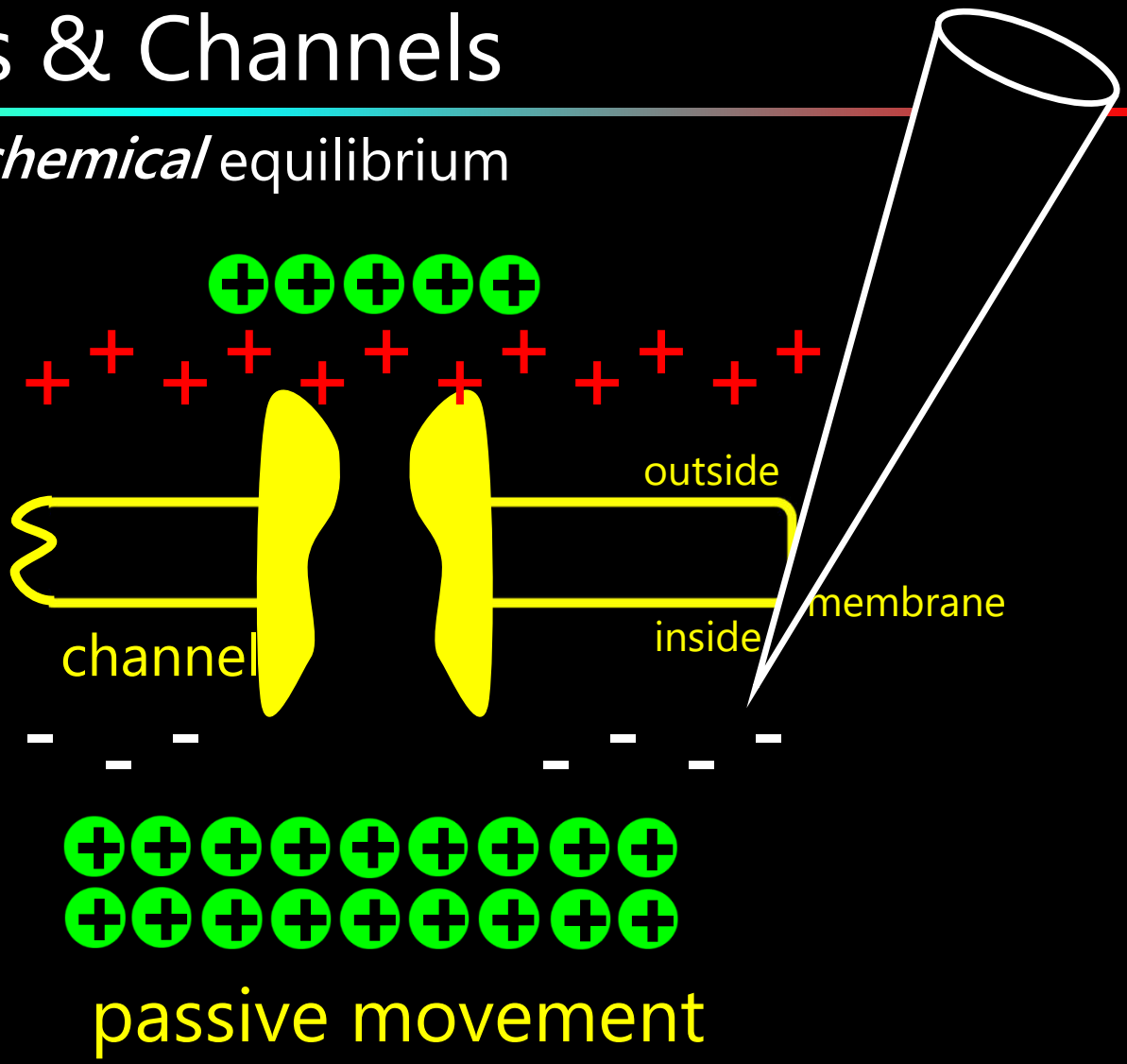

Pumps & Channels

electrochemical equilibrium

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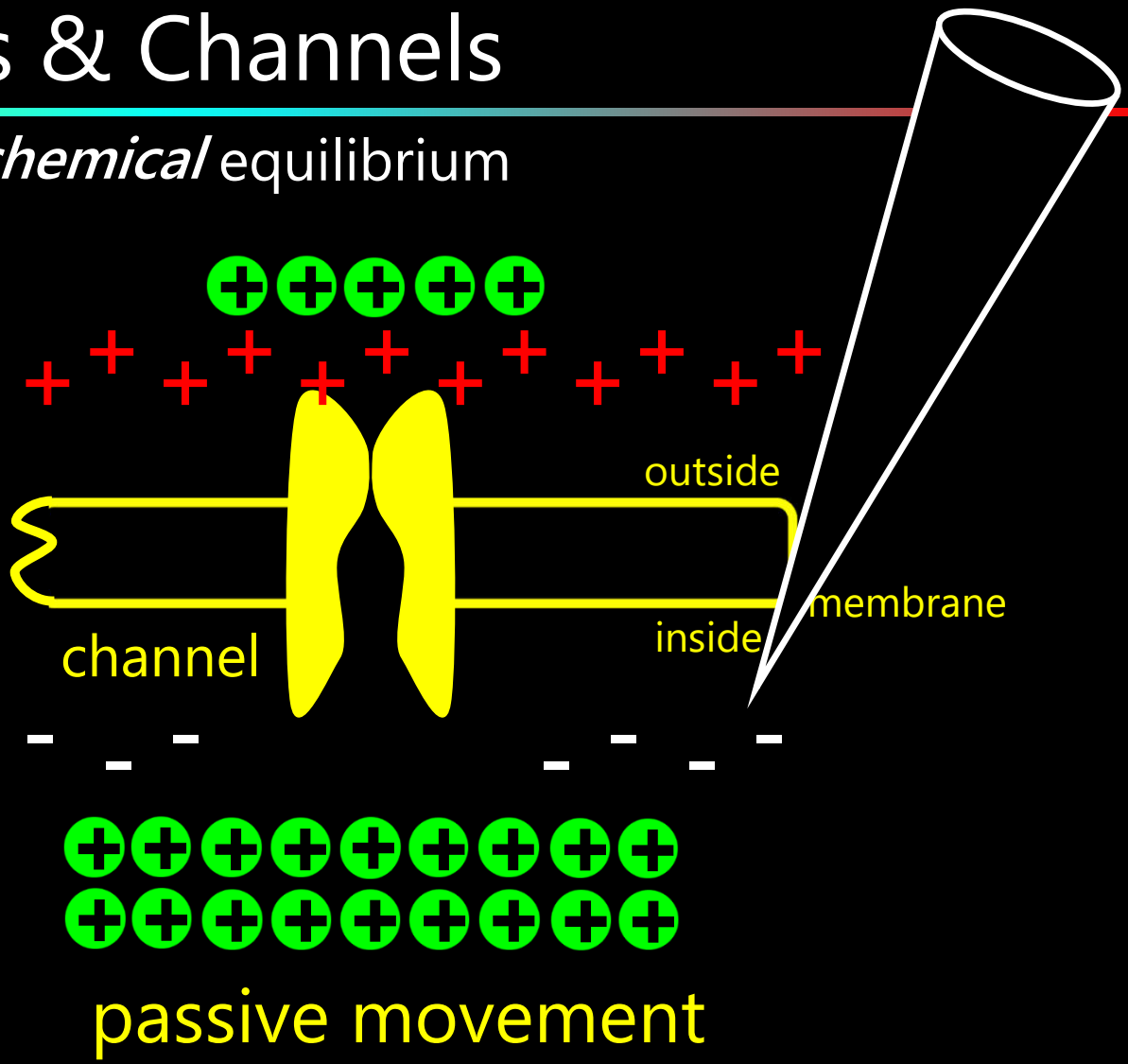
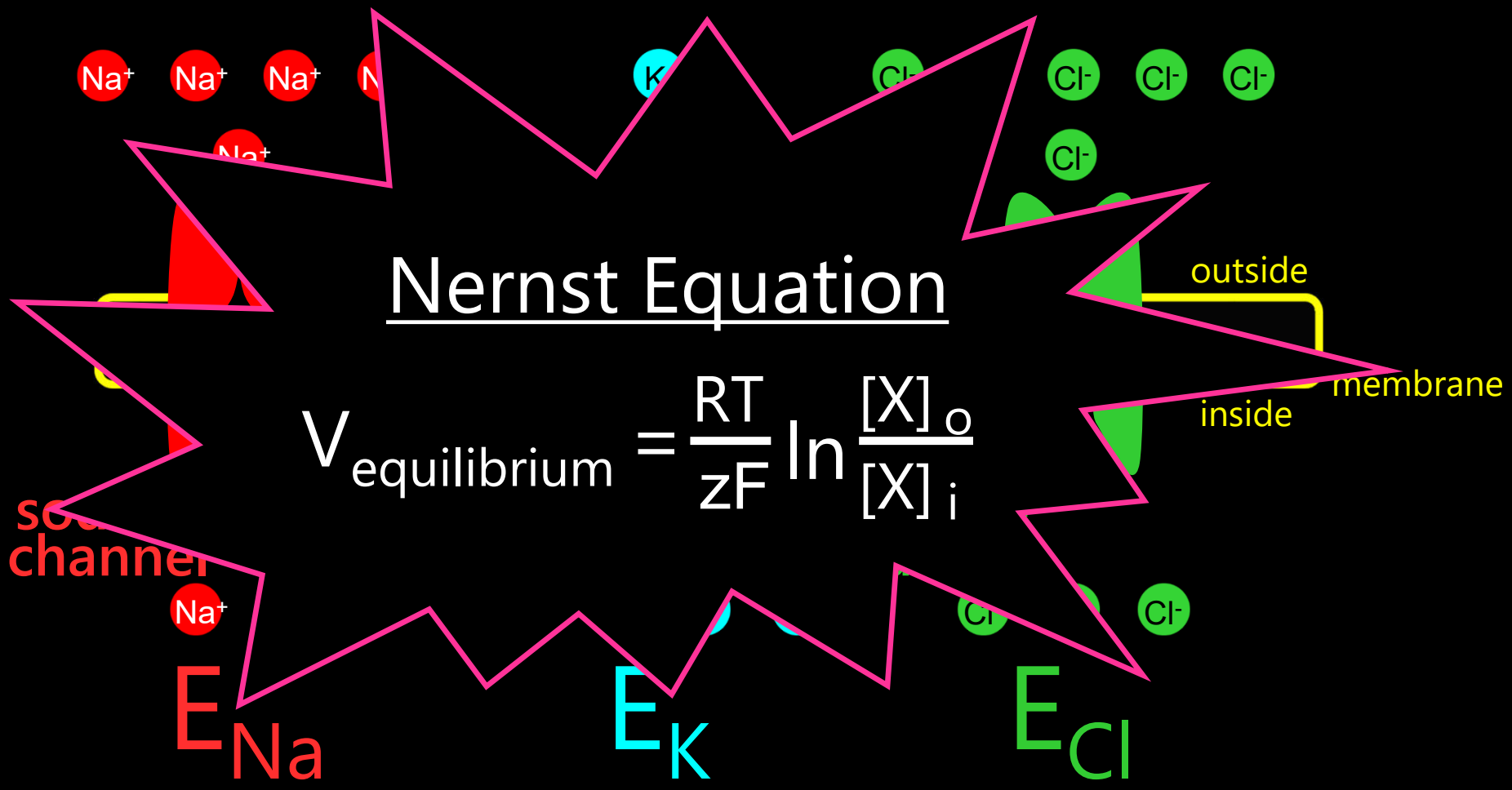


Pumps & Channels

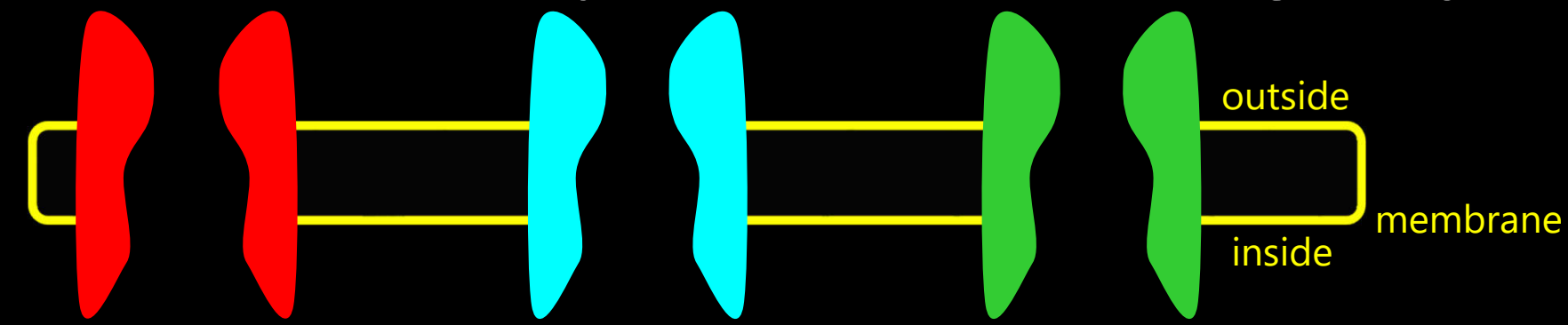
Pumps & Channels



Pumps & Channels

$$V_m = \frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$$

$$V_m = \frac{RT}{zF} \ln \frac{[X]_o}{[X]_i}$$



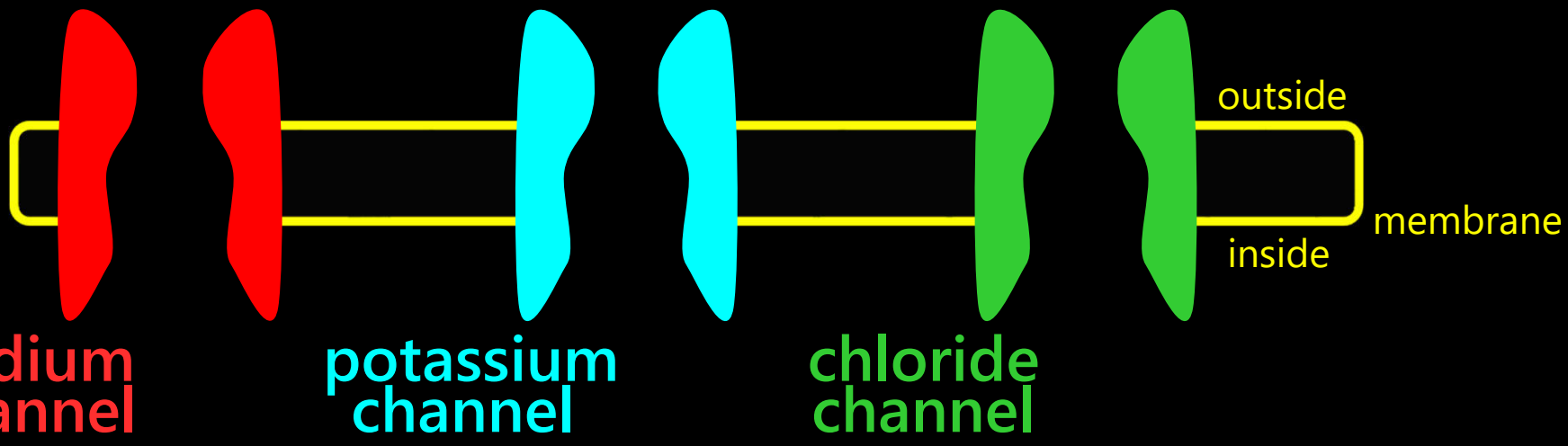
sodium channel — E_{Na}

potassium channel — E_K

chloride channel — E_{Cl}

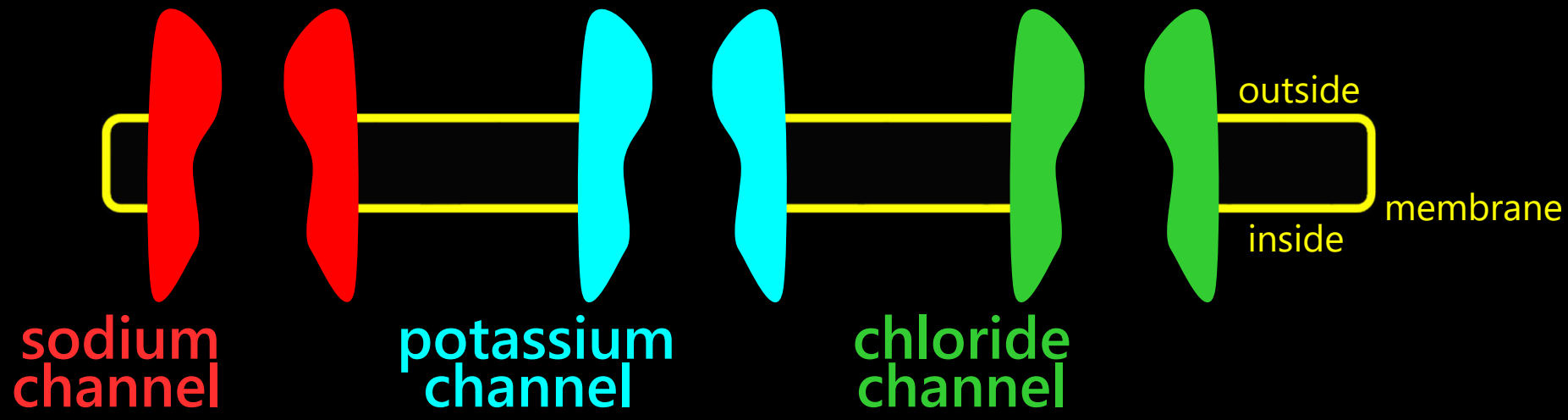
Pumps & Channels

$$V_m = \frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$$



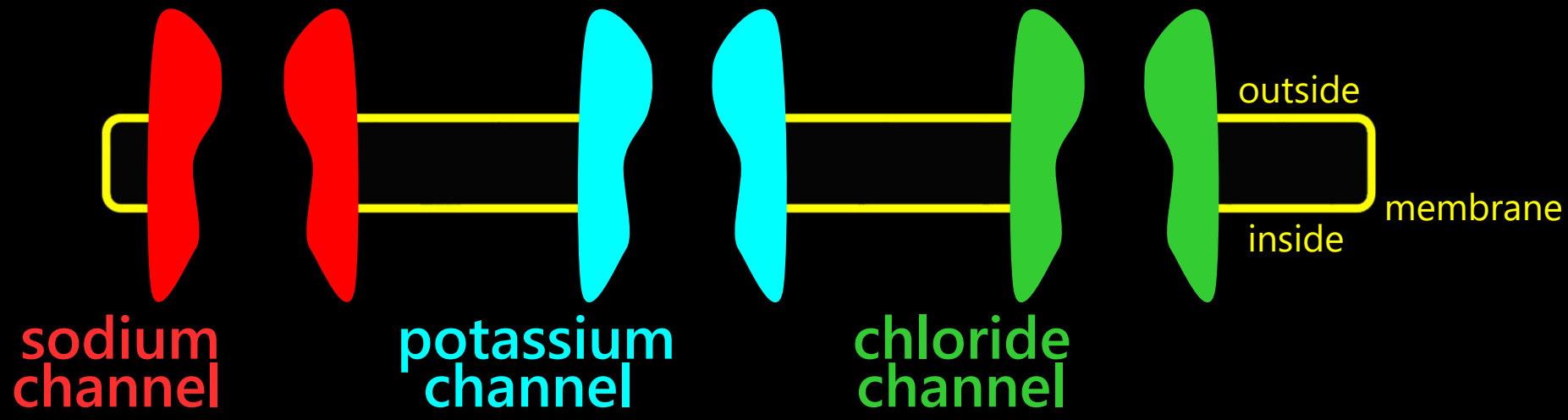
Pumps & Channels

per·me·a·bil·i·ty: *the state or quality of a material or membrane that causes it to allow liquid or gases to pass through it.*



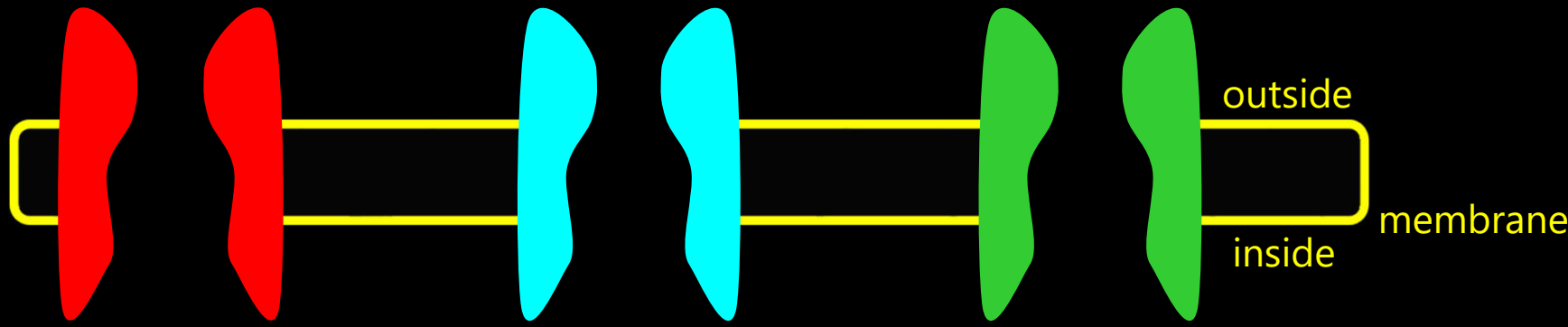
Pumps & Channels

per·me·a·bil·i·ty: *the ability of an ion to pass through the membrane.*



Pumps & Channels

$$V_m = \frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$$



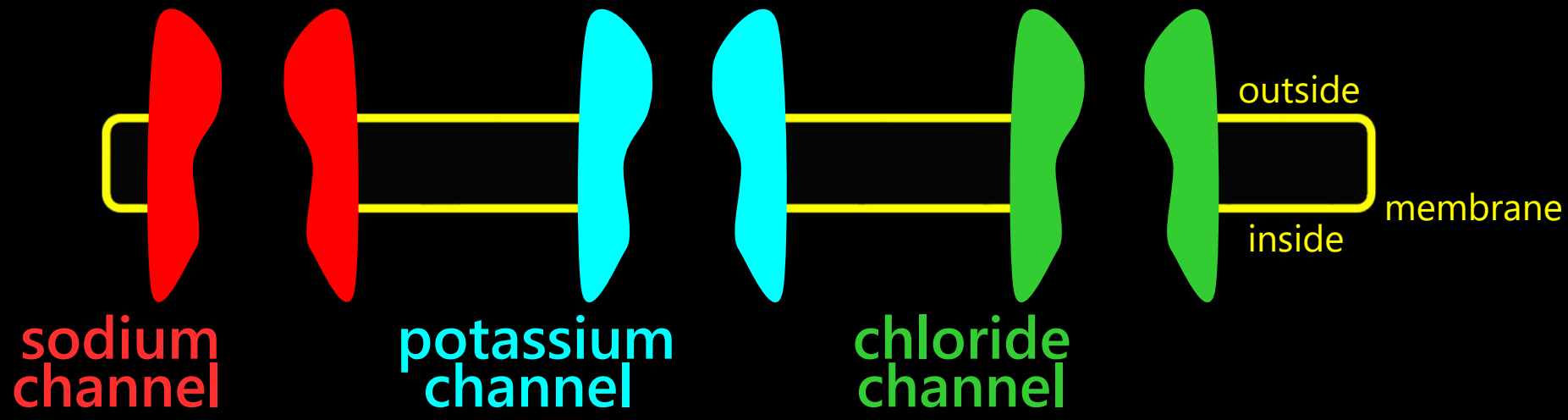
sodium channel

potassium channel

chloride channel

Pumps & Channels

what opens a channel?



Pumps & Channels

what opens a channel?

Pumps & Channels

what *gates* a channel?

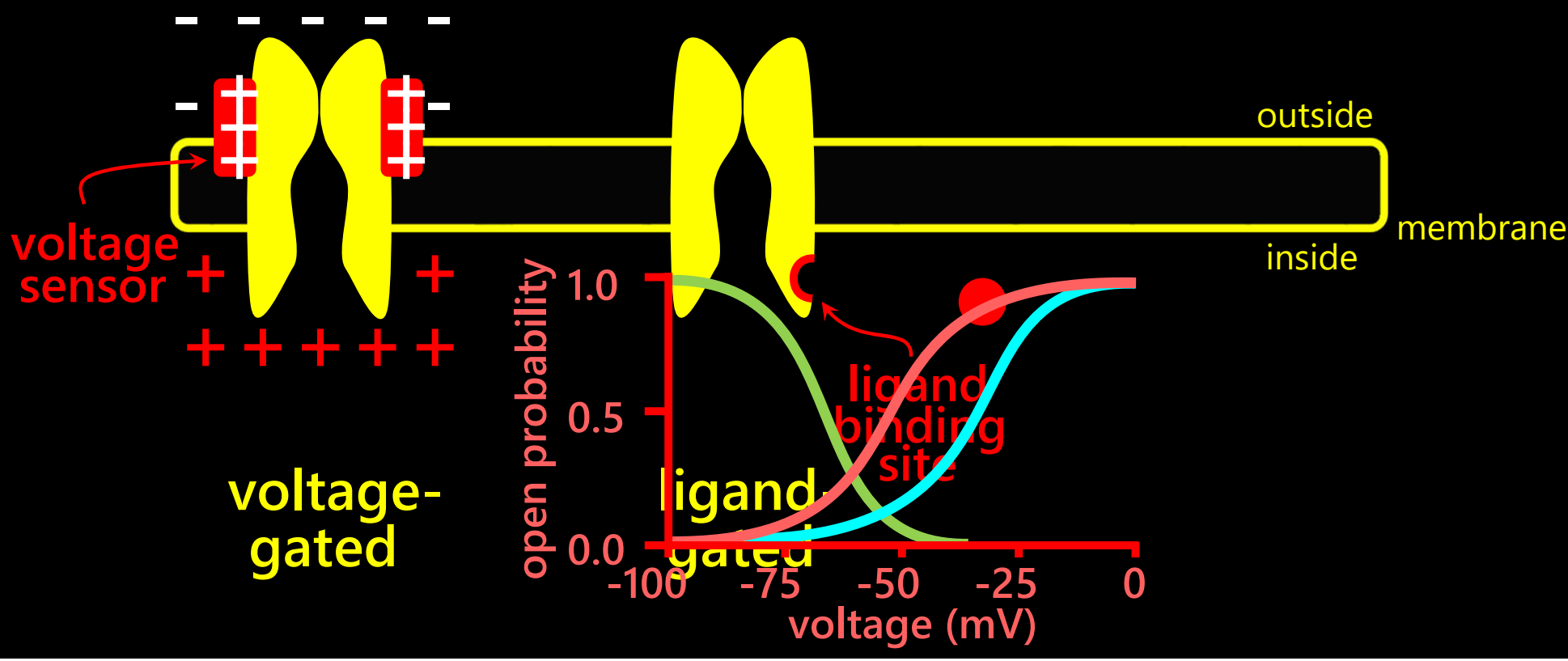
Pumps & Channels

what *gates* a channel?

voltage-gated

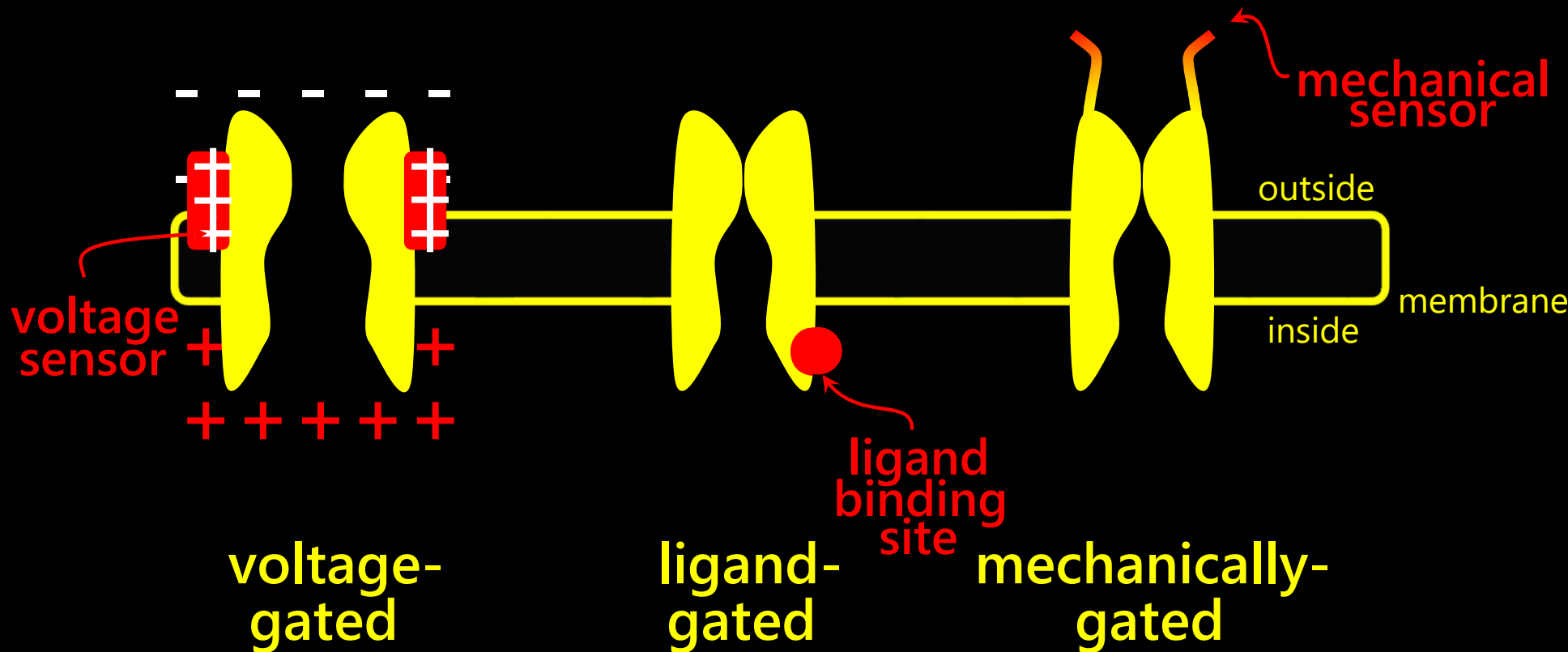
Pumps & Channels

what *gates* a channel?



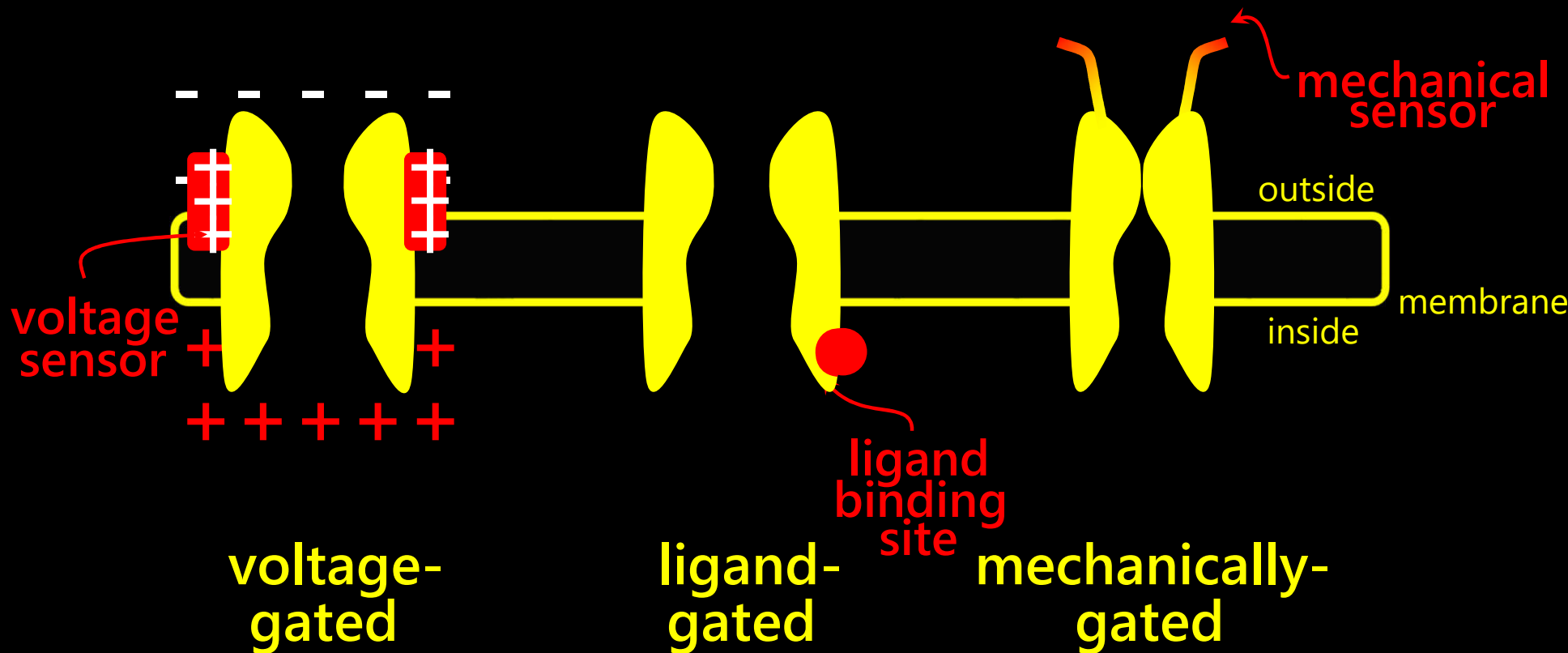
Pumps & Channels

what *gates* a channel?



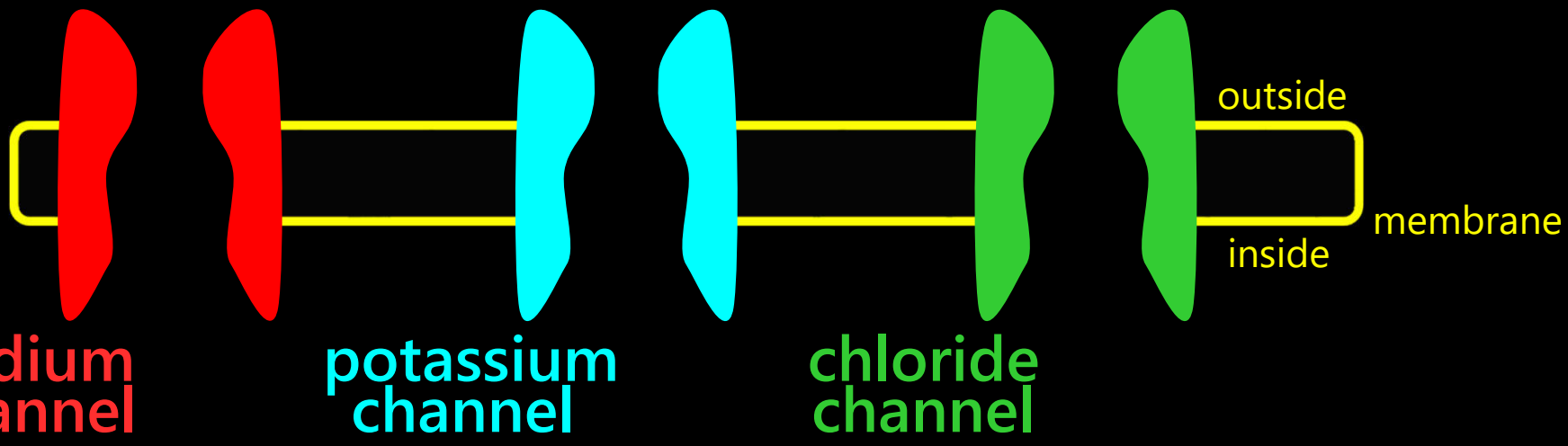
Pumps & Channels

what *gates* a channel?



Pumps & Channels

$$V_m = \frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$$



Ion Channels & Cellular Electrophysiology

Pumps

ATP-Driven Pumps

Na-K Pump

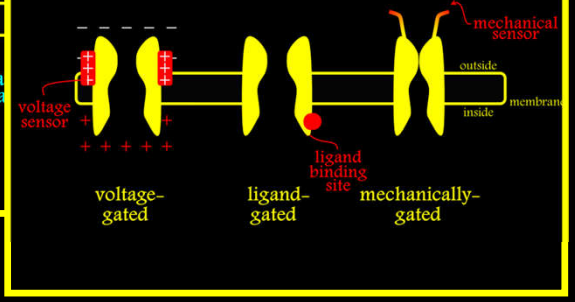
Na-K Gradients

Channels

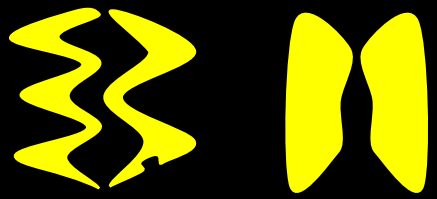
Equilibrium Potential

Ion-Selective Channels

Channel Gating



Ion Channels & Cellular Electrophysiology



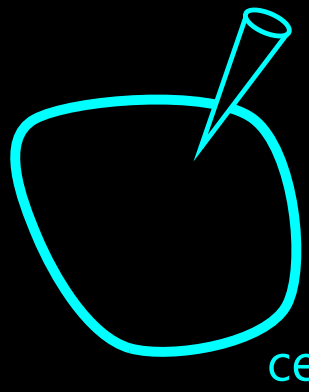
pumps &
channels

membrane
voltage

electrical
signals

Ion Channels & Cellular Electrophysiology

pumps &
channels



membrane
voltage

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Ion Channels & Cellular Electrophysiology

Pumps

ATP-Driven Pumps

Na-K Pump

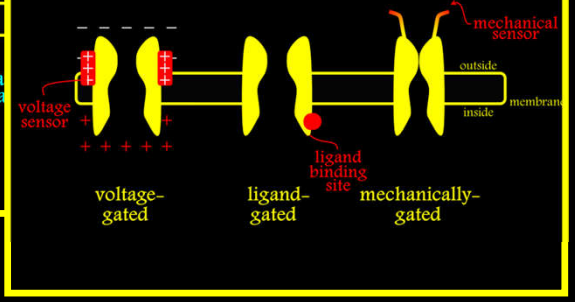
Na-K Gradients

Channels

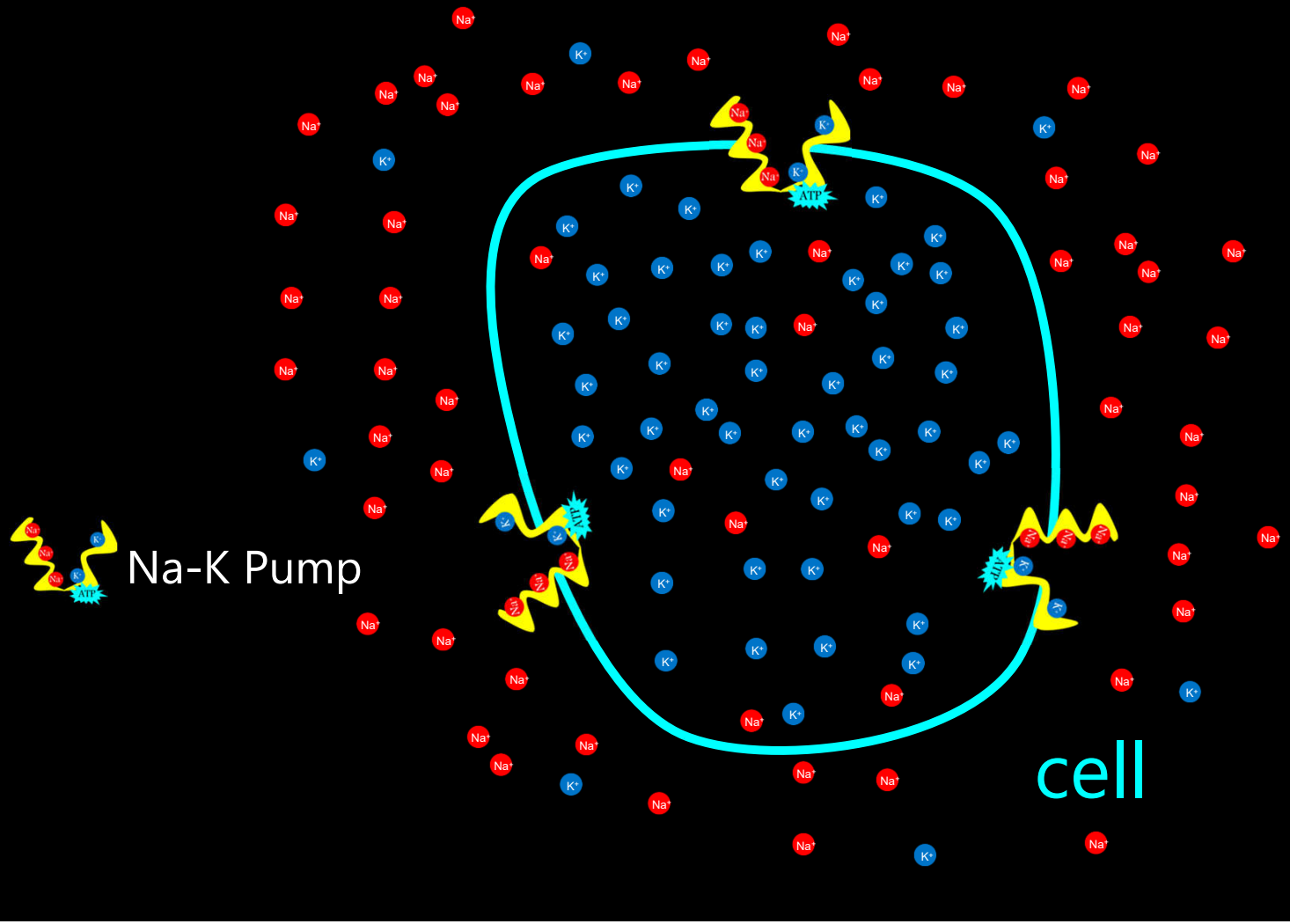
Equilibrium Potential

Ion-Selective Channels

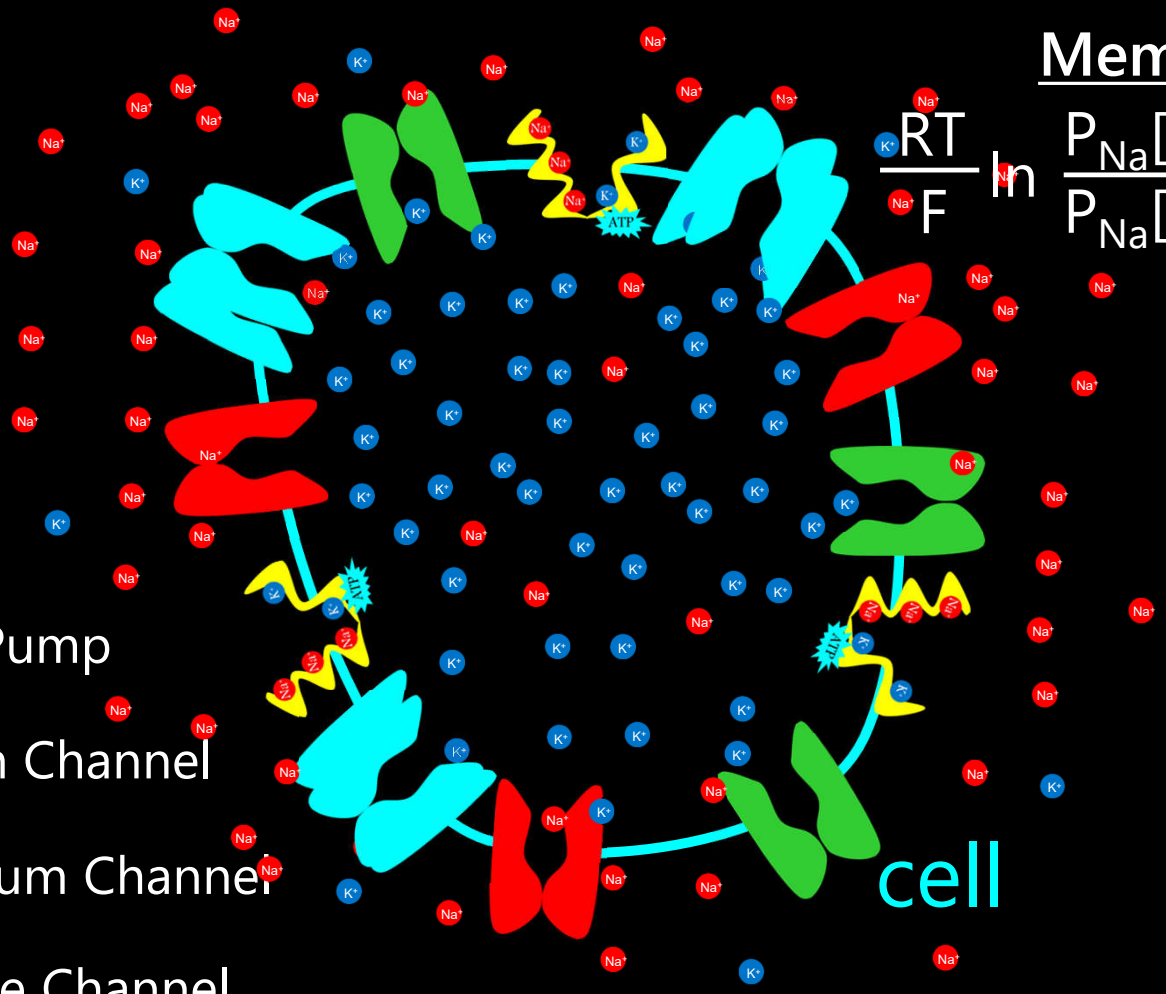
Channel Gating



Ion Channels & Cellular Electrophysiology



Ion Channels & Cellular Electrophysiology



Na-K Pump

Sodium Channel

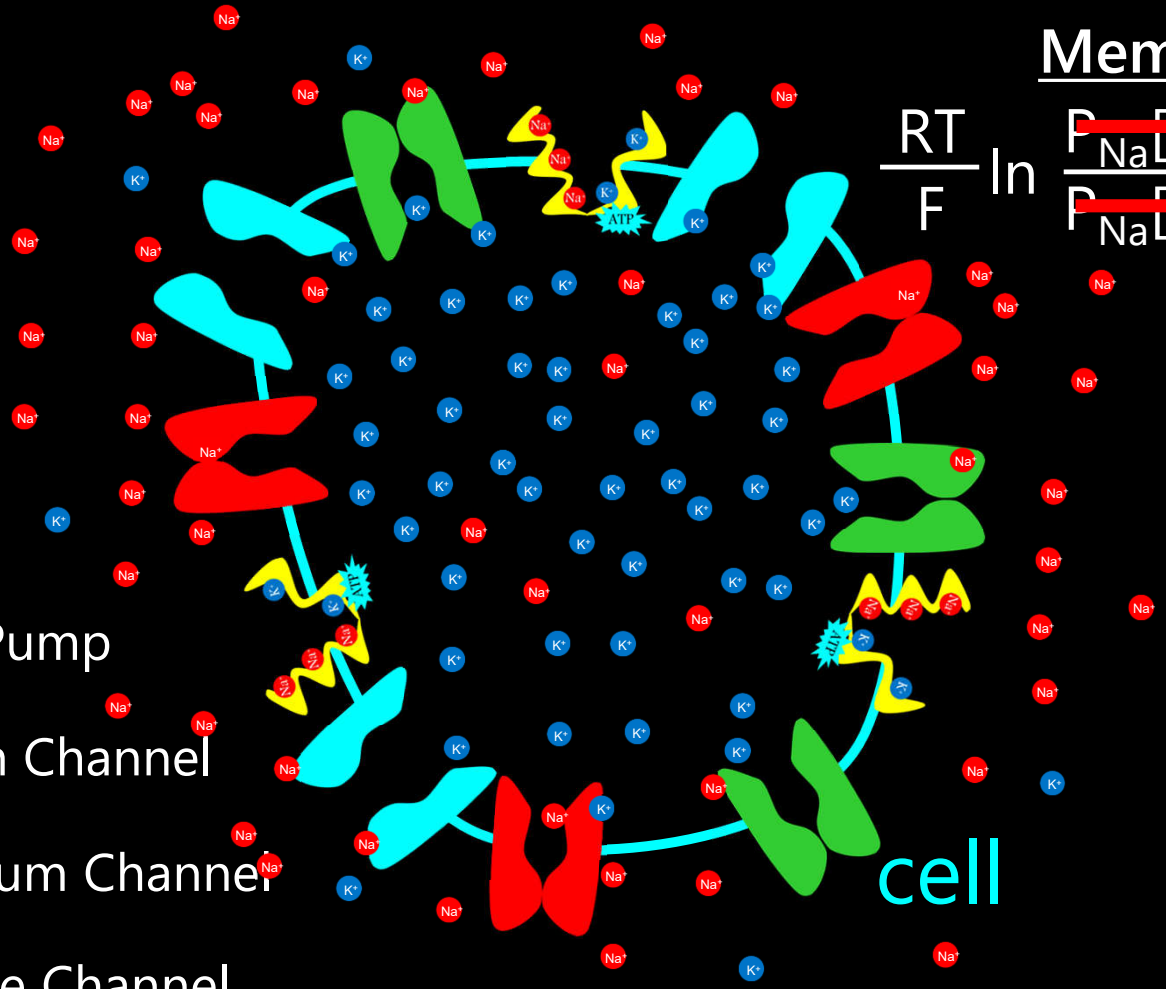
Potassium Channel

Chloride Channel

Membrane Potential

$$\frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]i + P_{Cl}[Cl]_o}$$

Ion Channels & Cellular Electrophysiology



Na-K Pump

Sodium Channel

Potassium Channel

Chloride Channel

Membrane Potential

$$\frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]i + P_{Cl}[Cl]_o}$$

Nernst Equation

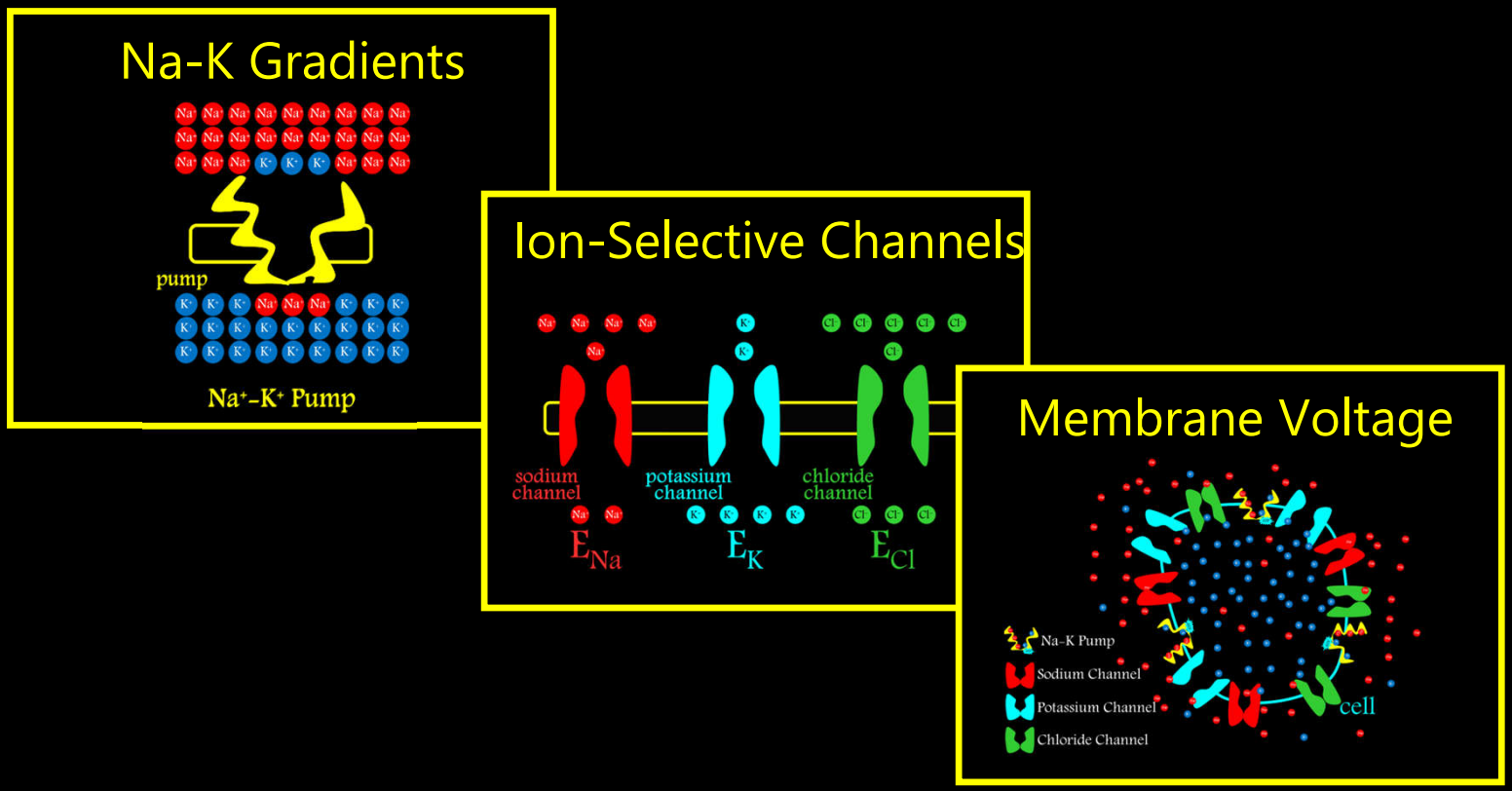
$$E_K = \frac{RT}{zF} \ln \frac{P_K[K]_o}{P_K[K]i}$$

$$E_K = -90mV$$

$E_{Na} = +50mV$

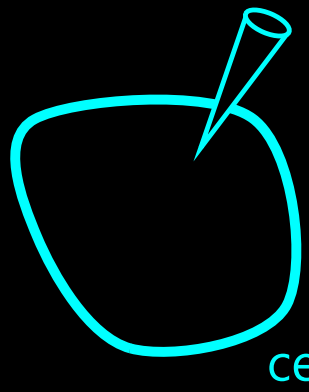
$E_{Cl} = -70mV$

Ion Channels & Cellular Electrophysiology



Ion Channels & Cellular Electrophysiology

pumps &
channels



membrane
voltage

electrical
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Ion Channels & Cellular Electrophysiology

pumps &
channels

membrane
voltage

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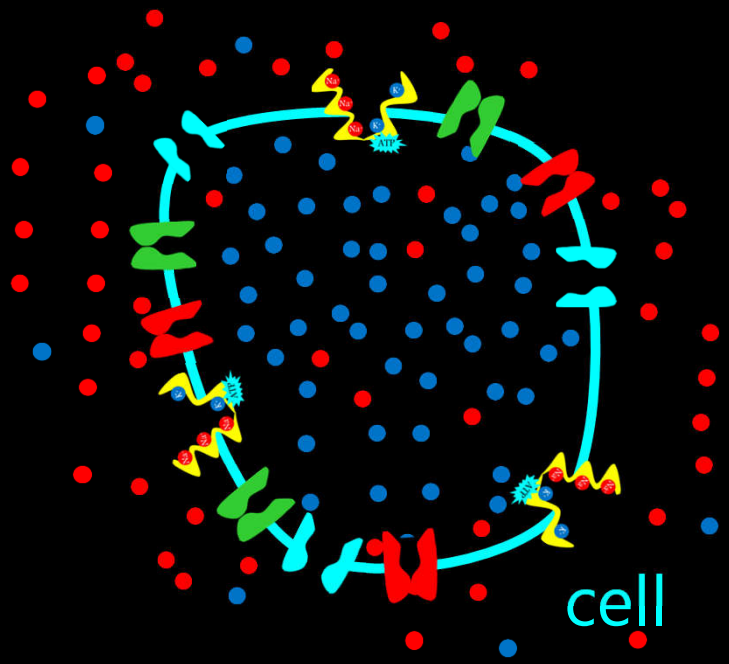
Ion Channels & Cellular Electrophysiology



Na-K Pump

Sodium Channel

Potassium Channel

Chloride Channel

Membrane Potential

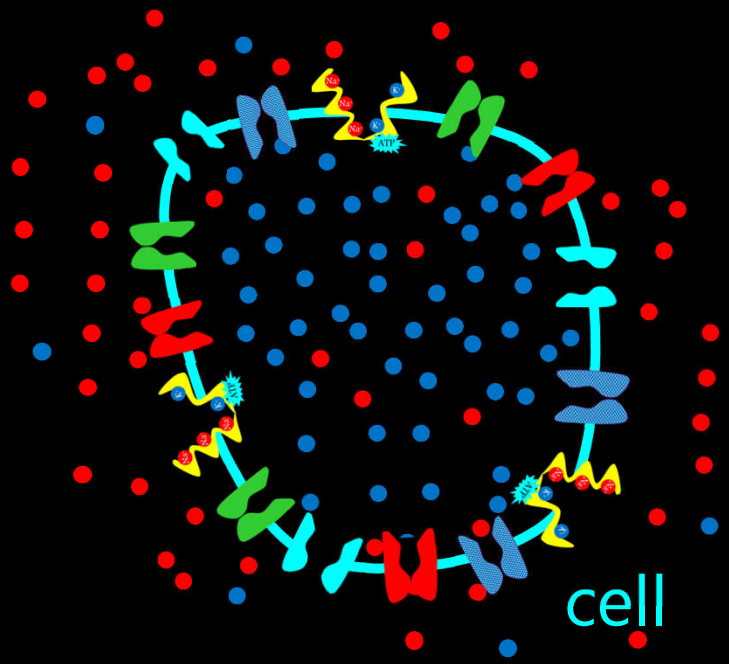
$$\frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$$

E_{Na} = +50mV

E_K = -90mV

E_{Cl} = -70mV

Ion Channels & Cellular Electrophysiology



Na-K Pump

Sodium Channel

Potassium Channel (leak)

Delayed Rectifier Potassium Channel

Chloride Channel

Membrane Potential

$$\frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$$

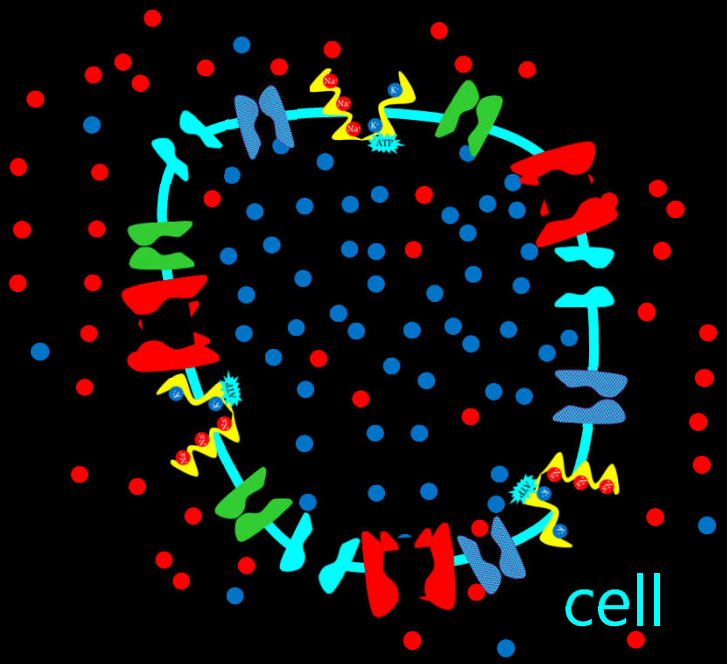
E_{Na} = +50mV

E_K = -90mV

E_{Cl} = -70mV

Vm—

Ion Channels & Cellular Electrophysiology



Na-K Pump

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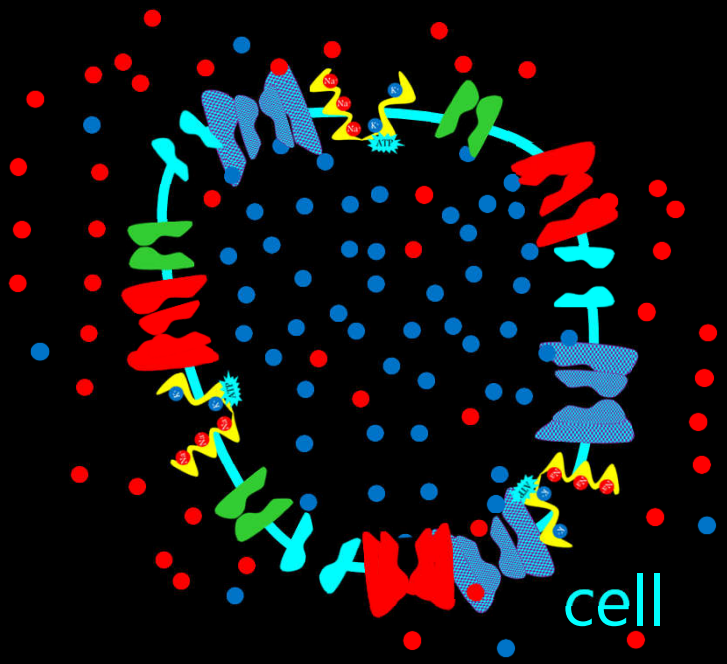
E_{Na} = +50mV

E_K = -90mV

E_{Cl} = -70mV

Vm—

Ion Channels & Cellular Electrophysiology



Na-K Pump

Sodium Channel

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Delayed Rectifier Potassium Channel

Chloride Channel

Membrane Potential

$$\frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$$

E_{Na} = +50mV

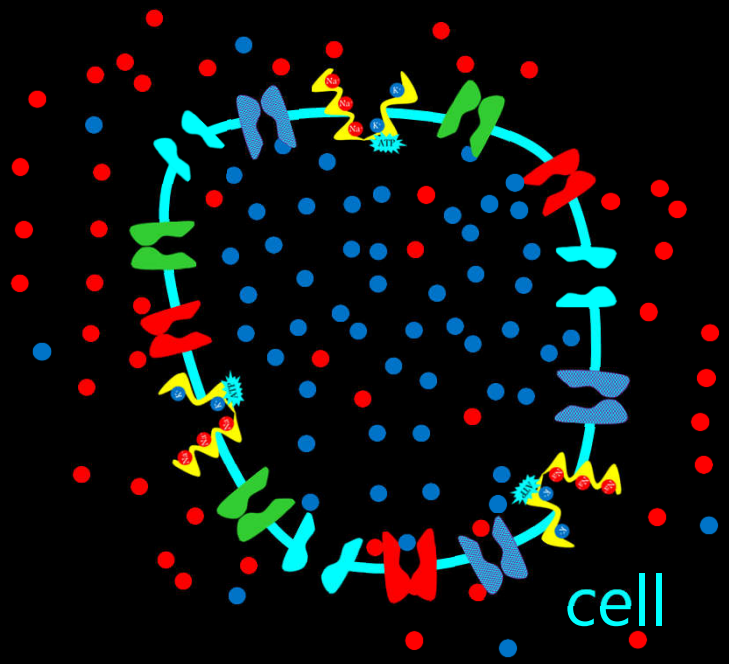
E_K = -90mV

E_{Cl} = -70mV

Vm—

action potential

Ion Channels & Cellular Electrophysiology



Na-K Pump

Sodium Channel

Potassium Channel (leak)

Delayed Rectifier Potassium Channel

Chloride Channel

Membrane Potential

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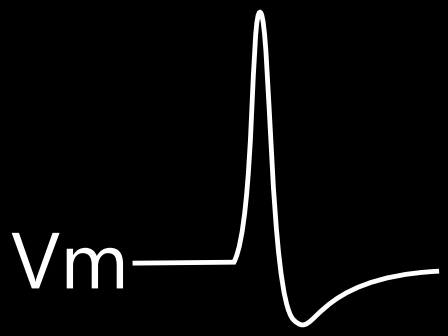

action potential

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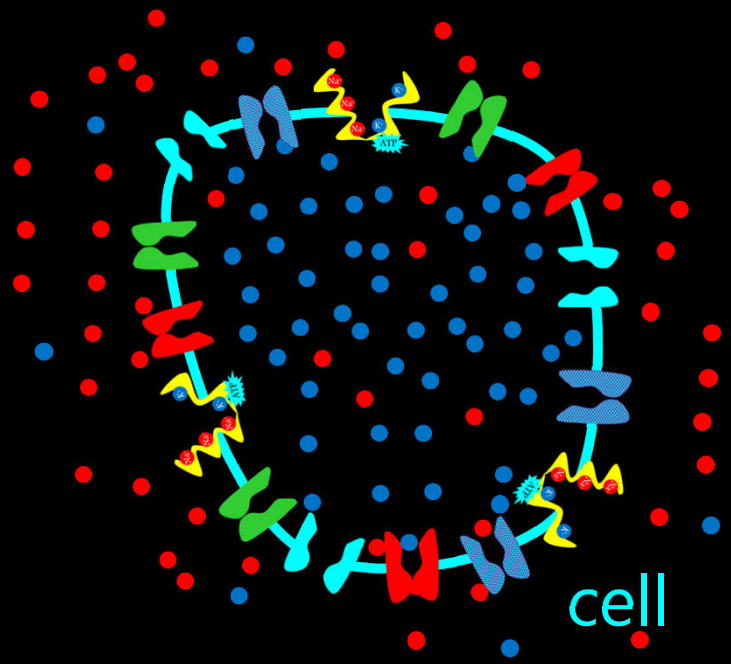

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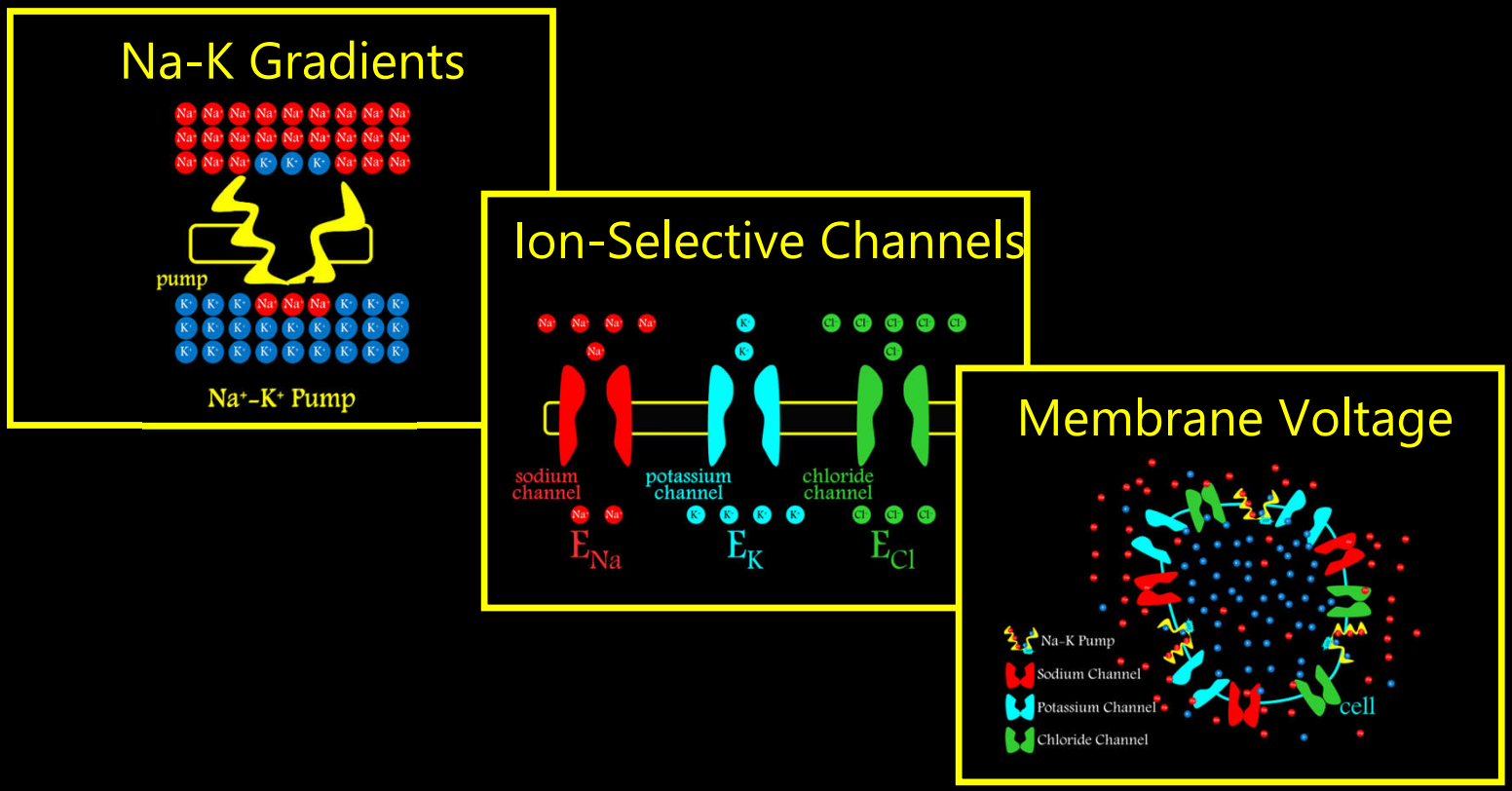
Ion Channels & Cellular Electrophysiology



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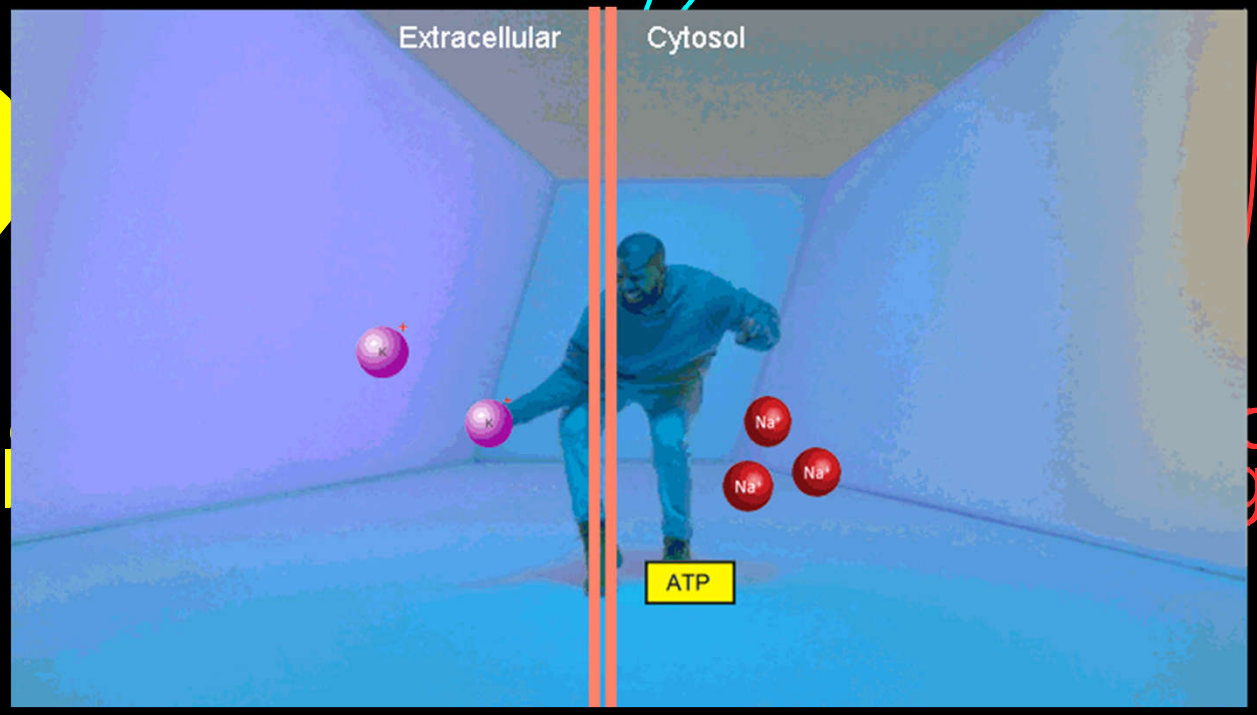

action potential

pumps
channel

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