CCIB
The Fourth Block

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Core Course in Integrative Biosciences (BIMS 6000)

CCIB: Electrical and Chemical Signals in Cellular Physiology

- By day:
  - **Thursday, September 17 (1st Beenhakker Lecture):** Ion Channels, Pumps and the Membrane Potential
    - Powerpoint Slides for Channel Lecture (or as a PDF)
    - Recorded Lecture
  - **Friday, September 18 (2nd Beenhakker Lecture):** Synaptic Transmission
    - Powerpoint Slides for Transmission Lecture (or as a PDF)
    - Recorded Lecture
  - **Friday, September 18 (3rd Beenhakker Lecture):** Neural Circuits
    - Powerpoint Slides for Circuit Lecture (or as a PDF)
    - Recorded Lecture
- A peaceful afternoon of neurophysiology simulations. **Follow me here.**

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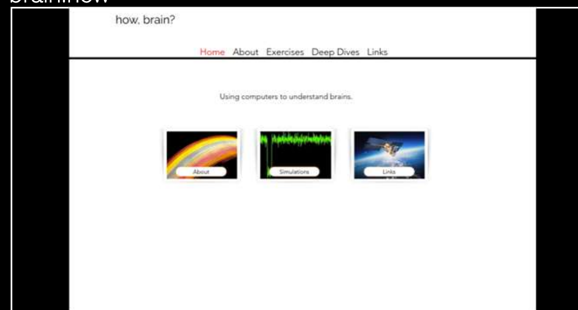
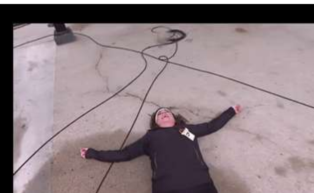

how, brain?

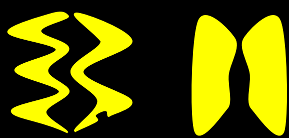
Home About Exercises Deep Dives Links

Using computers to understand brains.

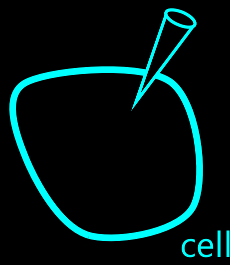


Ion Channels & Cellular Electrophysiology

Mark Beenhakker
markbeen@virginia.edu



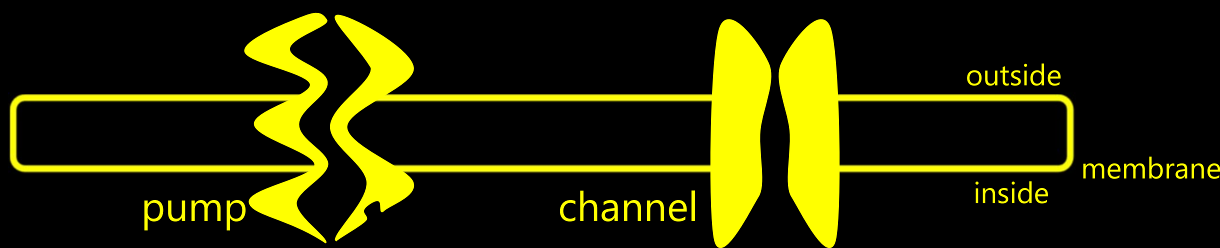
pumps &
channels



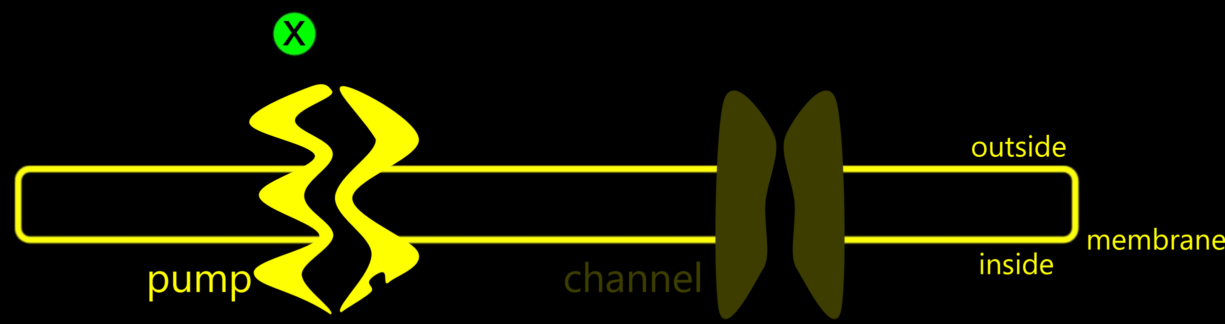
membrane
voltage

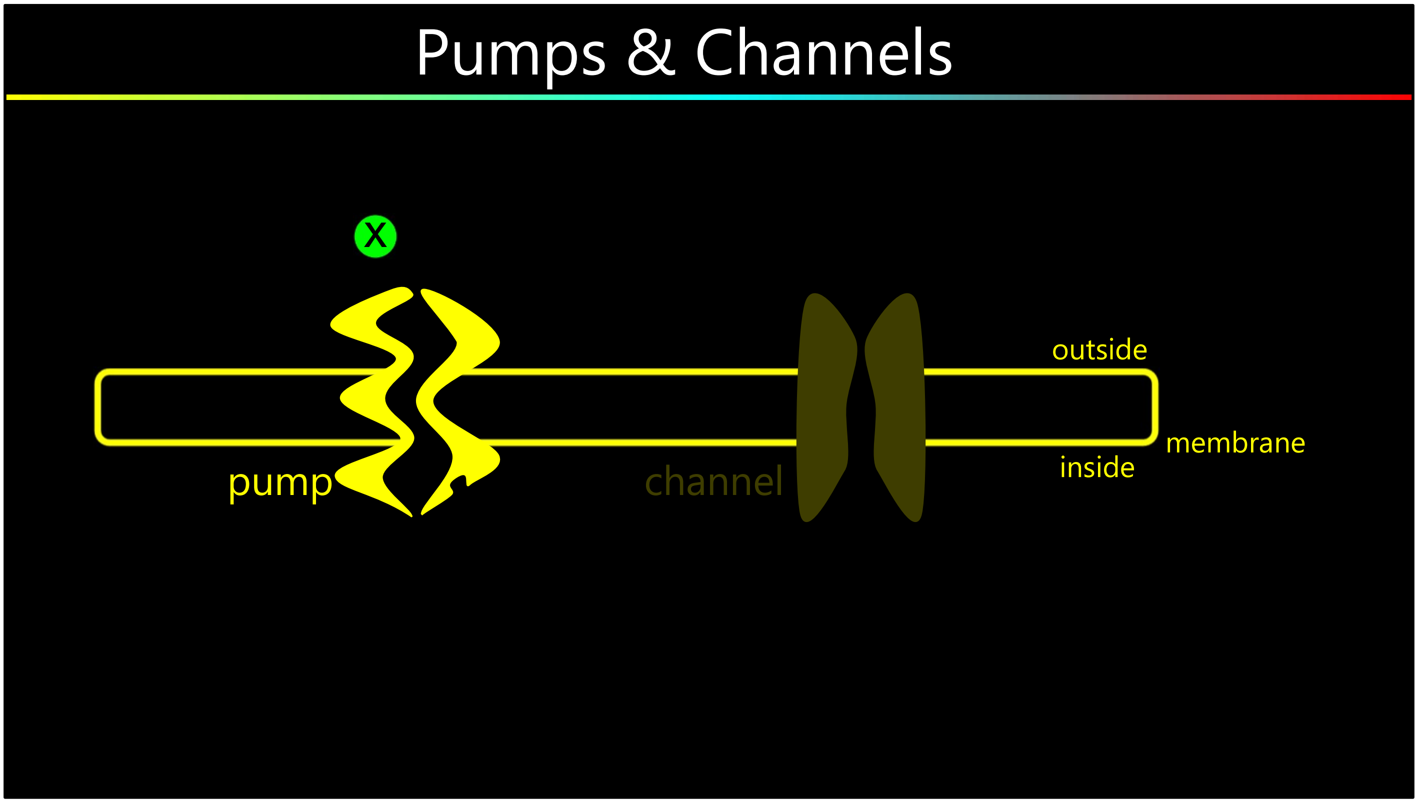
electrical
signals

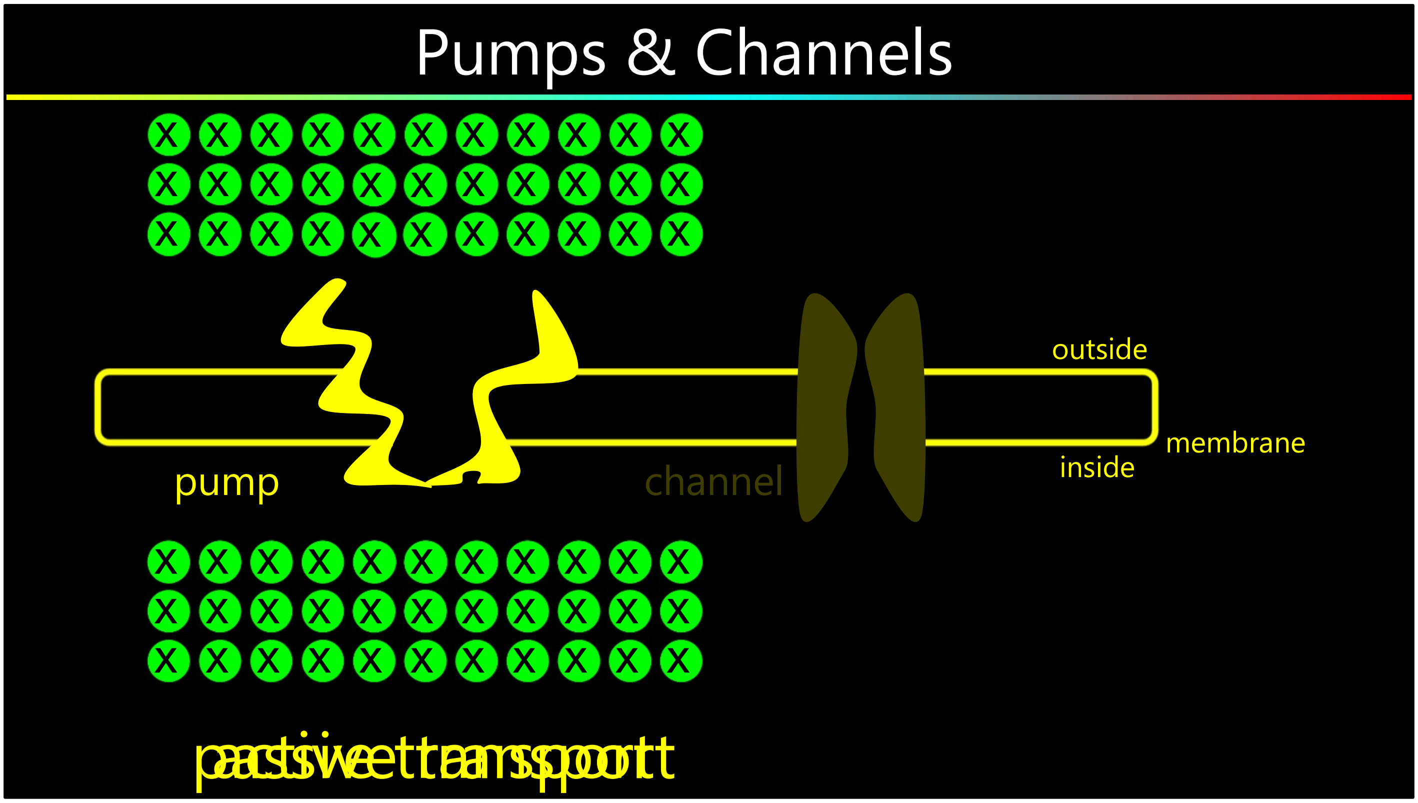
Pumps & Channels

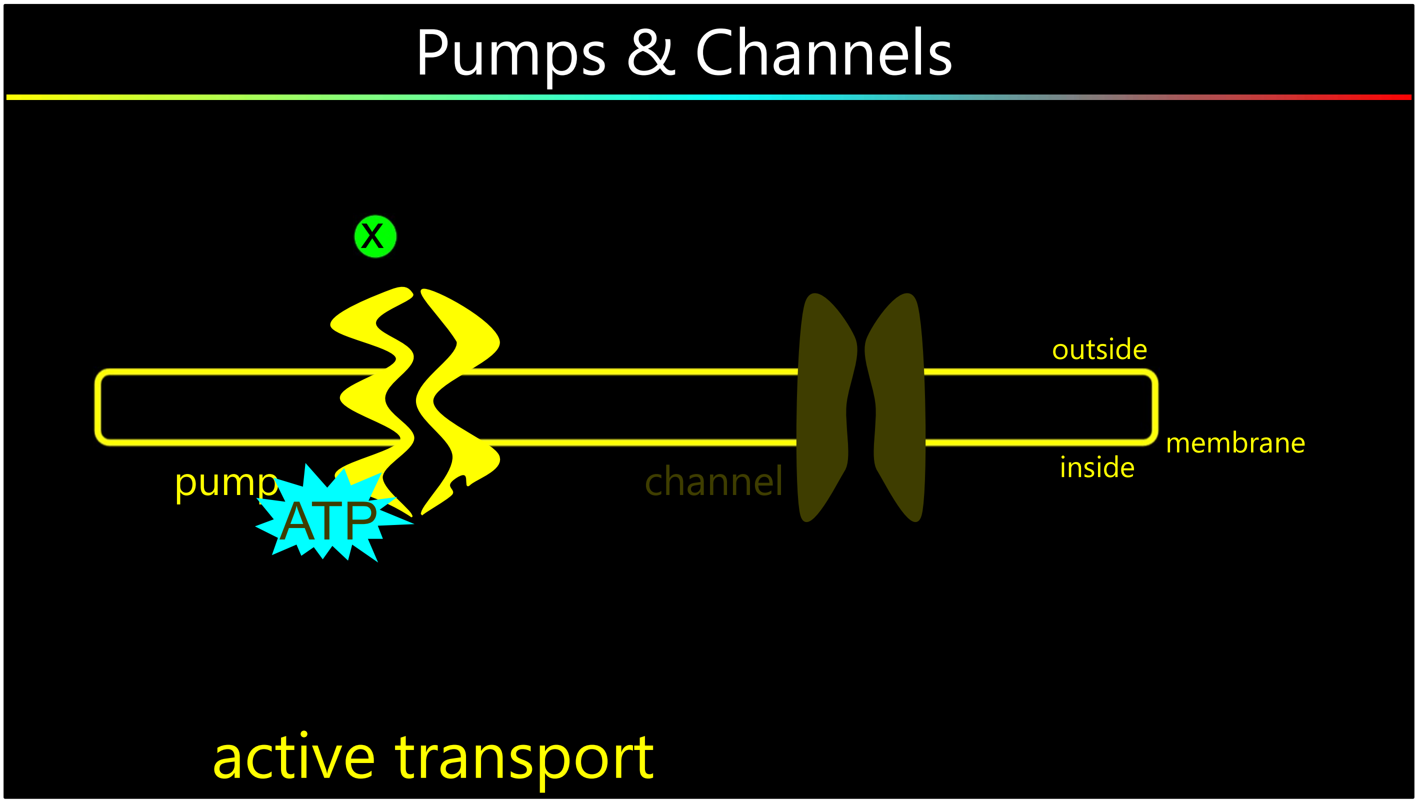


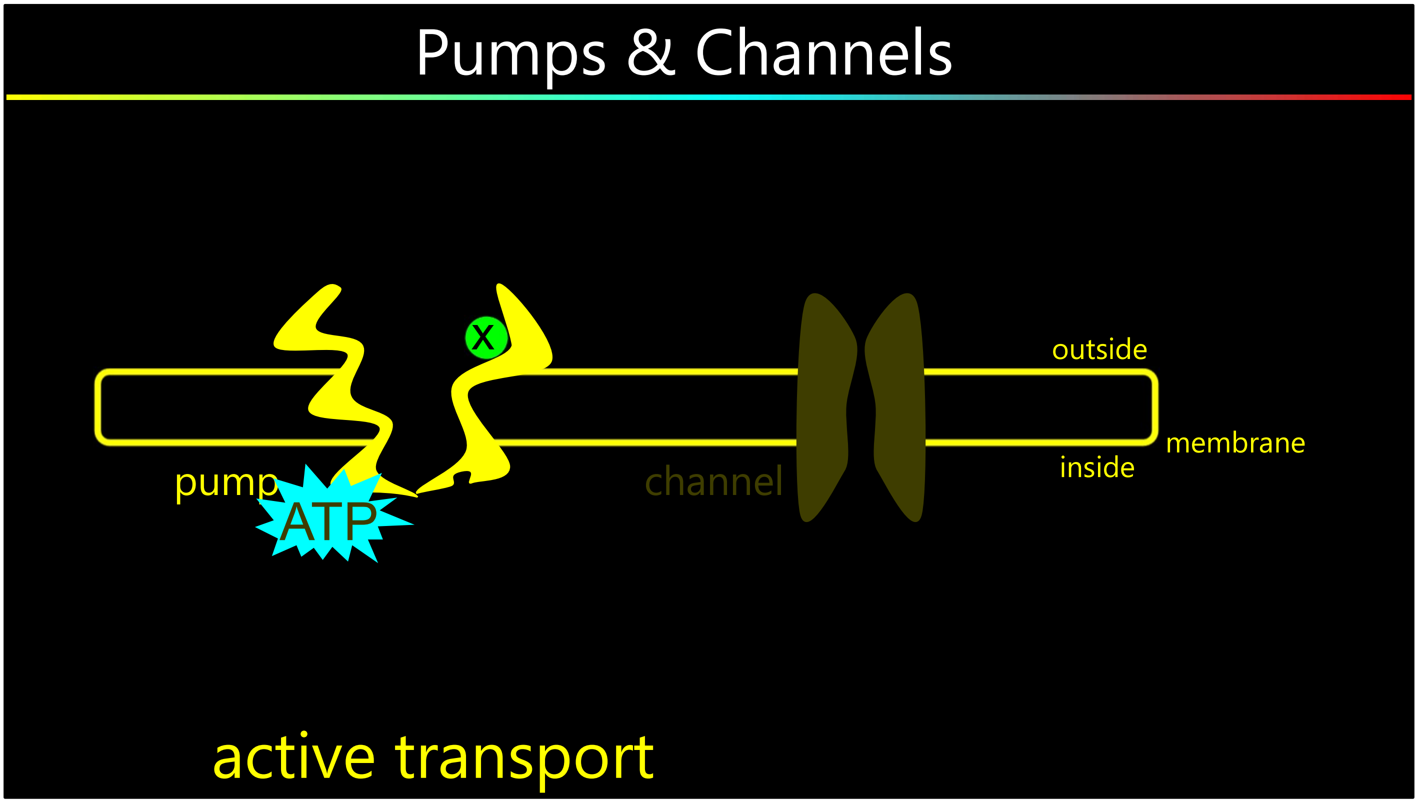
Pumps & Channels



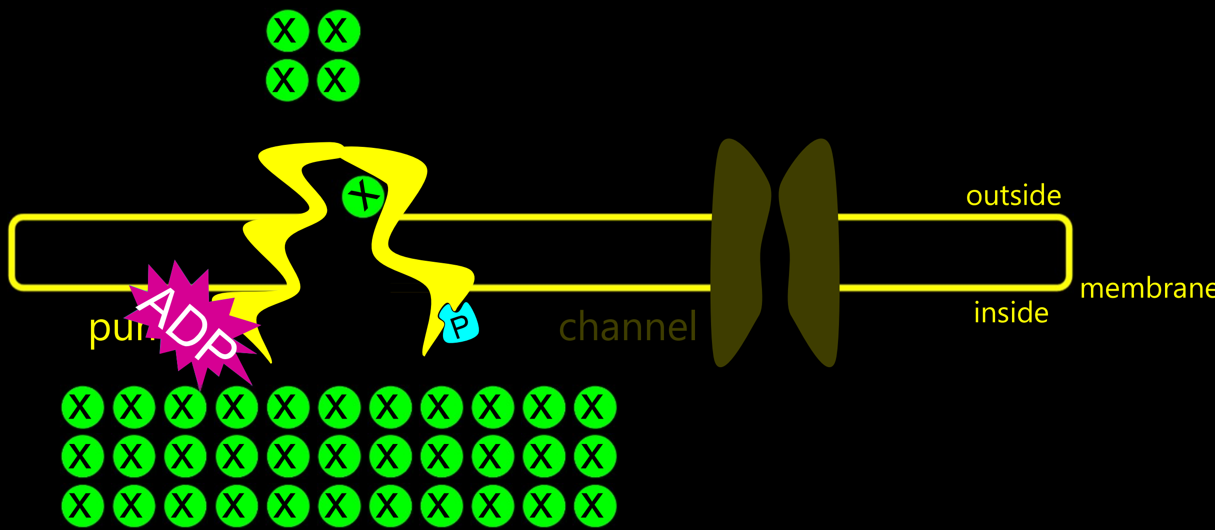

Pumps & Channels
X
outside
membrane
inside
pump
channel


Pumps & Channels
outside
membrane
inside
pump
channel
passive transport
active transport


Pumps & Channels
X
outside
membrane
inside
pump
ATP
channel
active transport

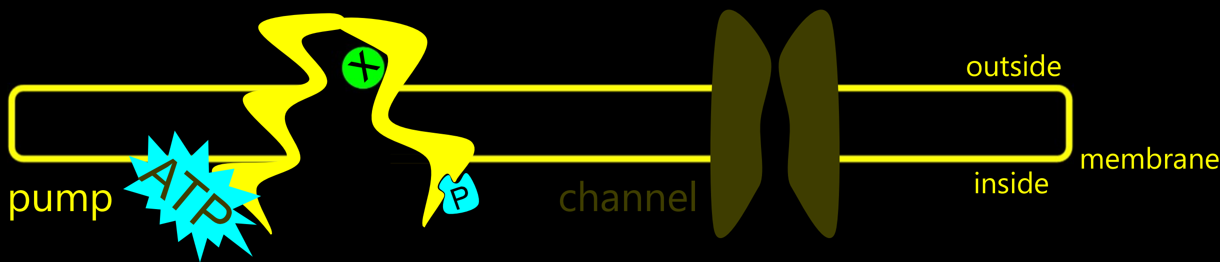

Pumps & Channels
outside
X
membrane
pump
ATP
channel
inside
active transport

Pumps & Channels



active transport

Pumps & Channels

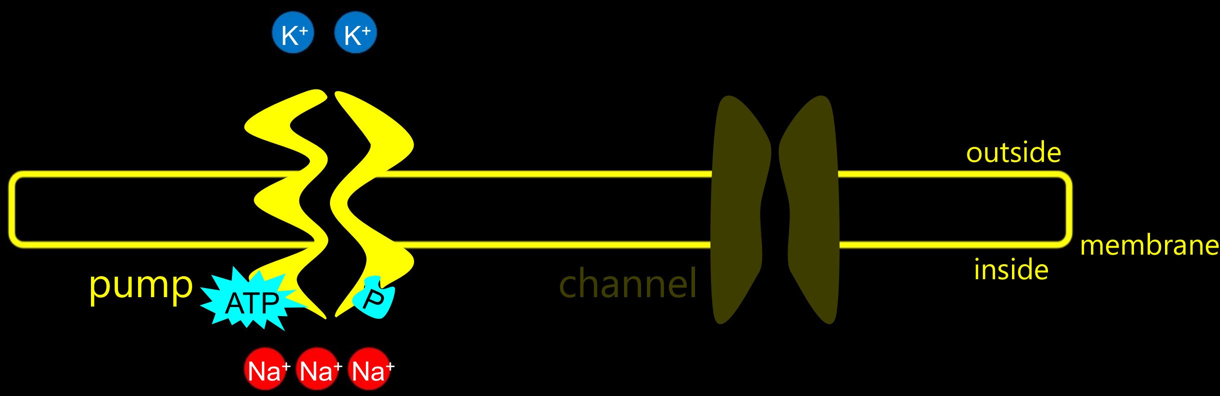


ATP-Driven Pumps

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

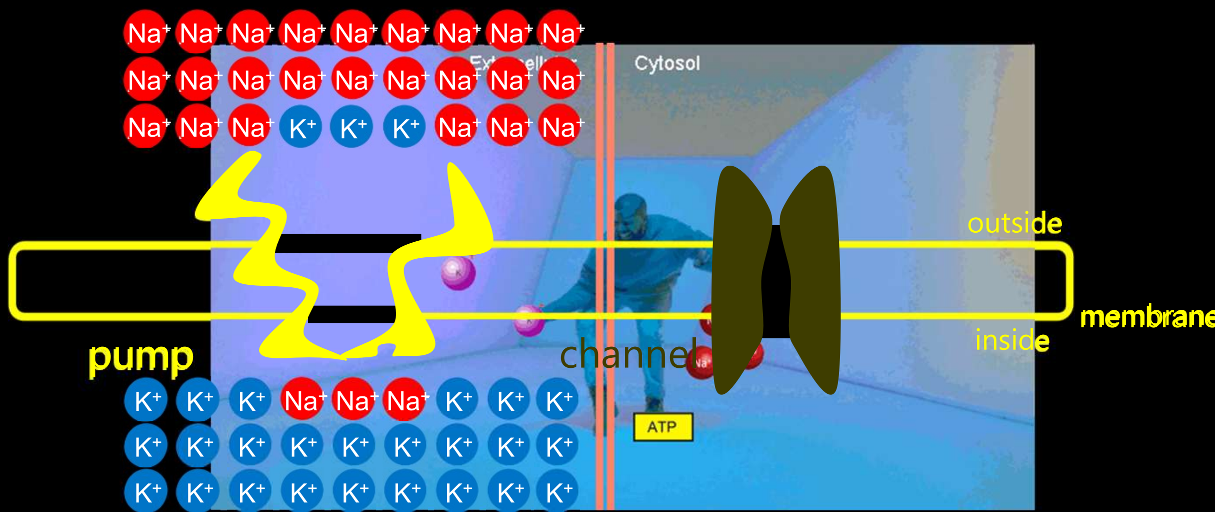
Na^+-K^+ Pump

Pumps & Channels



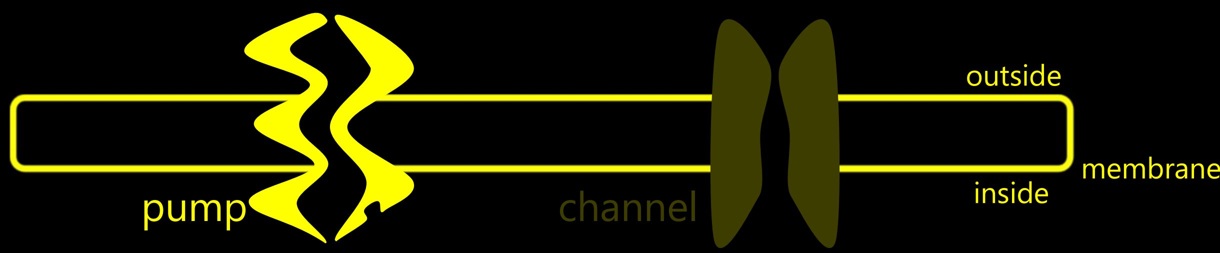
Na$^+$-K$^+$ Pump

Pumps & Channels

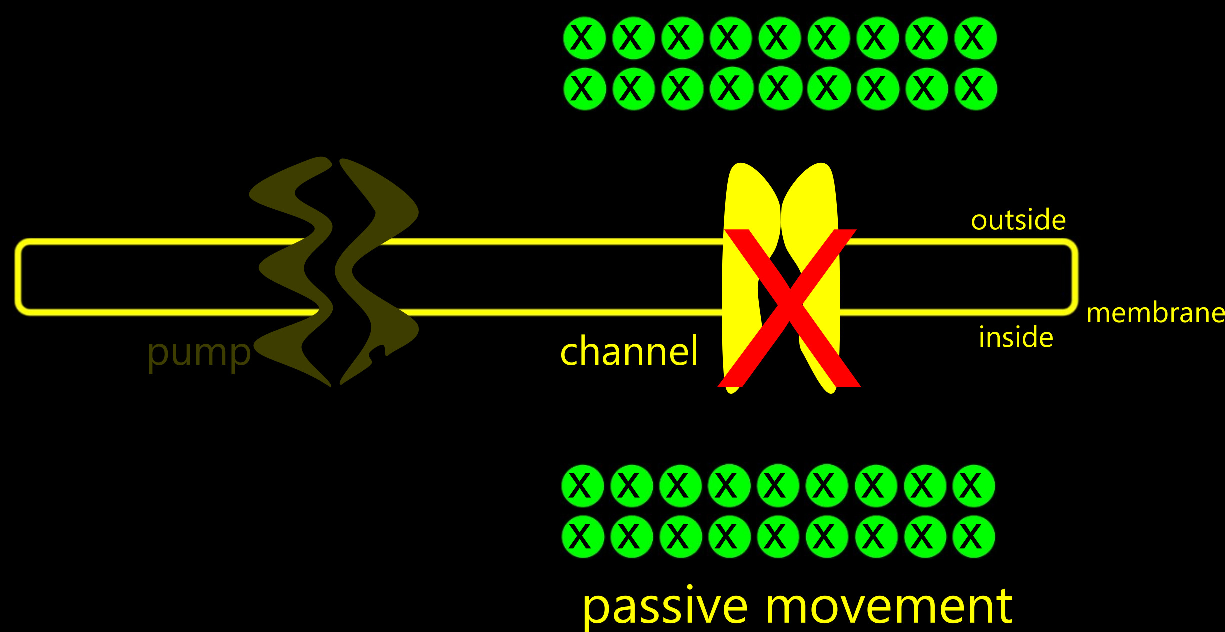


Na^{+}-K^{+} Pump

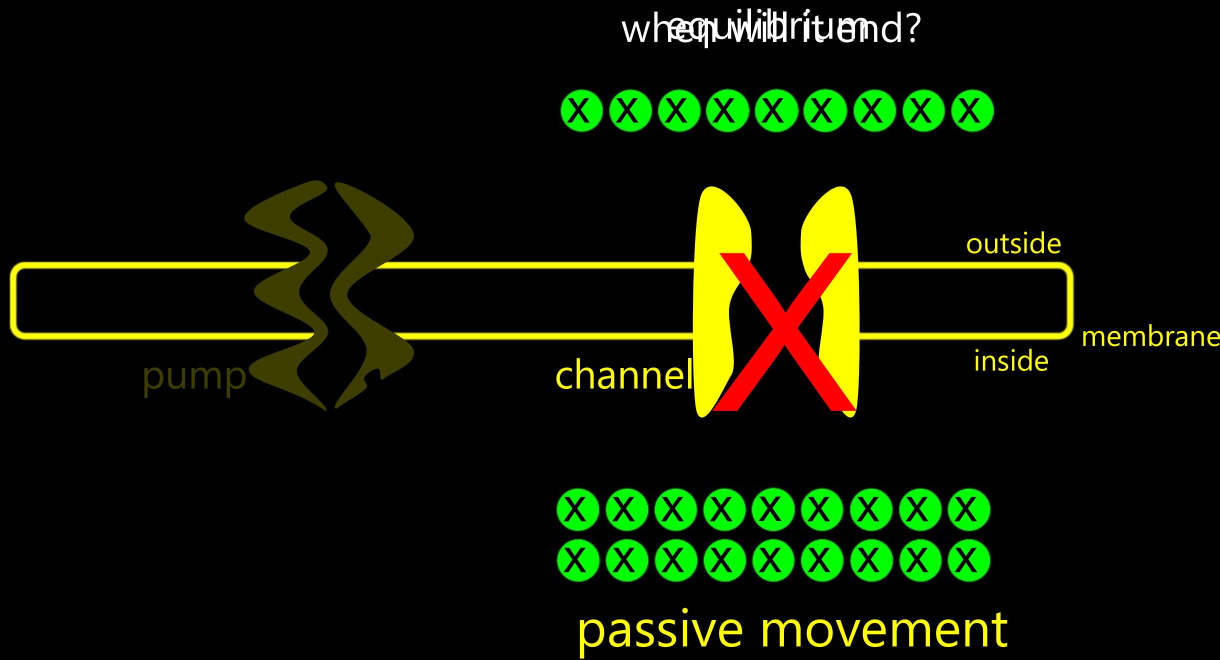
Pumps & Channels

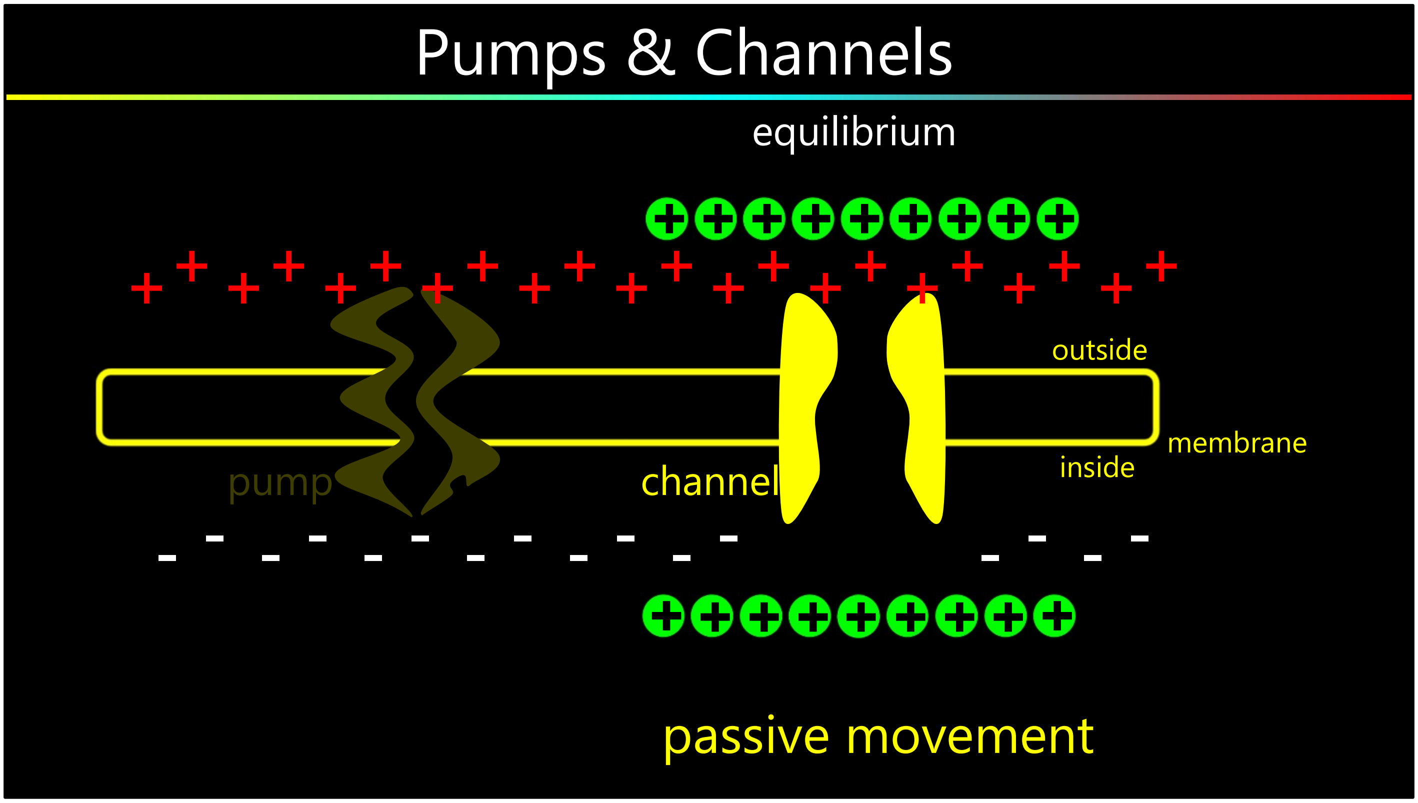


Pumps & Channels



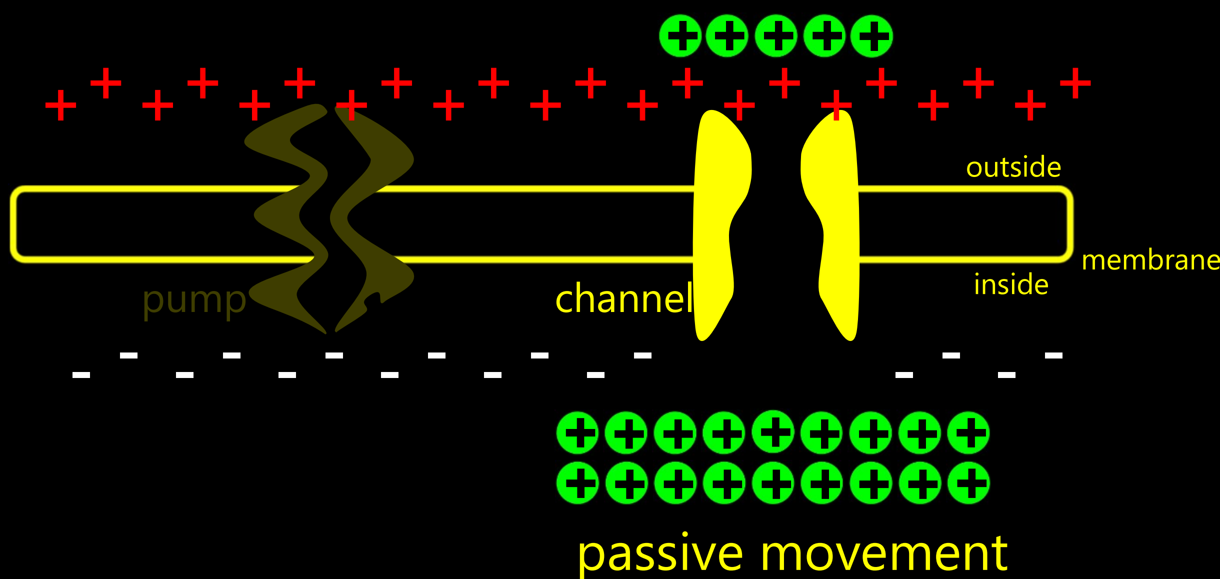
Pumps & Channels

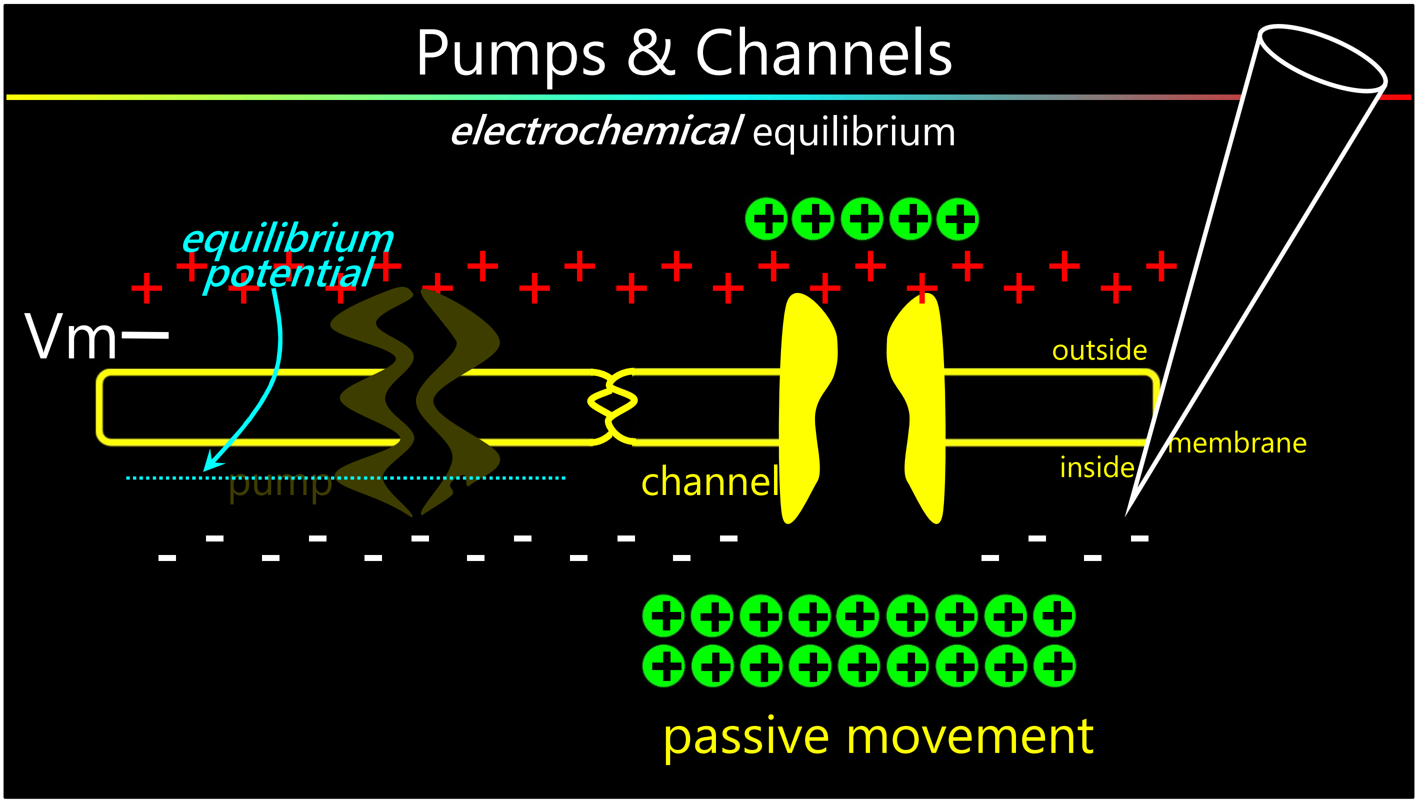



Pumps & Channels
equilibrium
outside
membrane
inside
pump
channel
passive movement

Pumps & Channels

electrochemical equilibrium

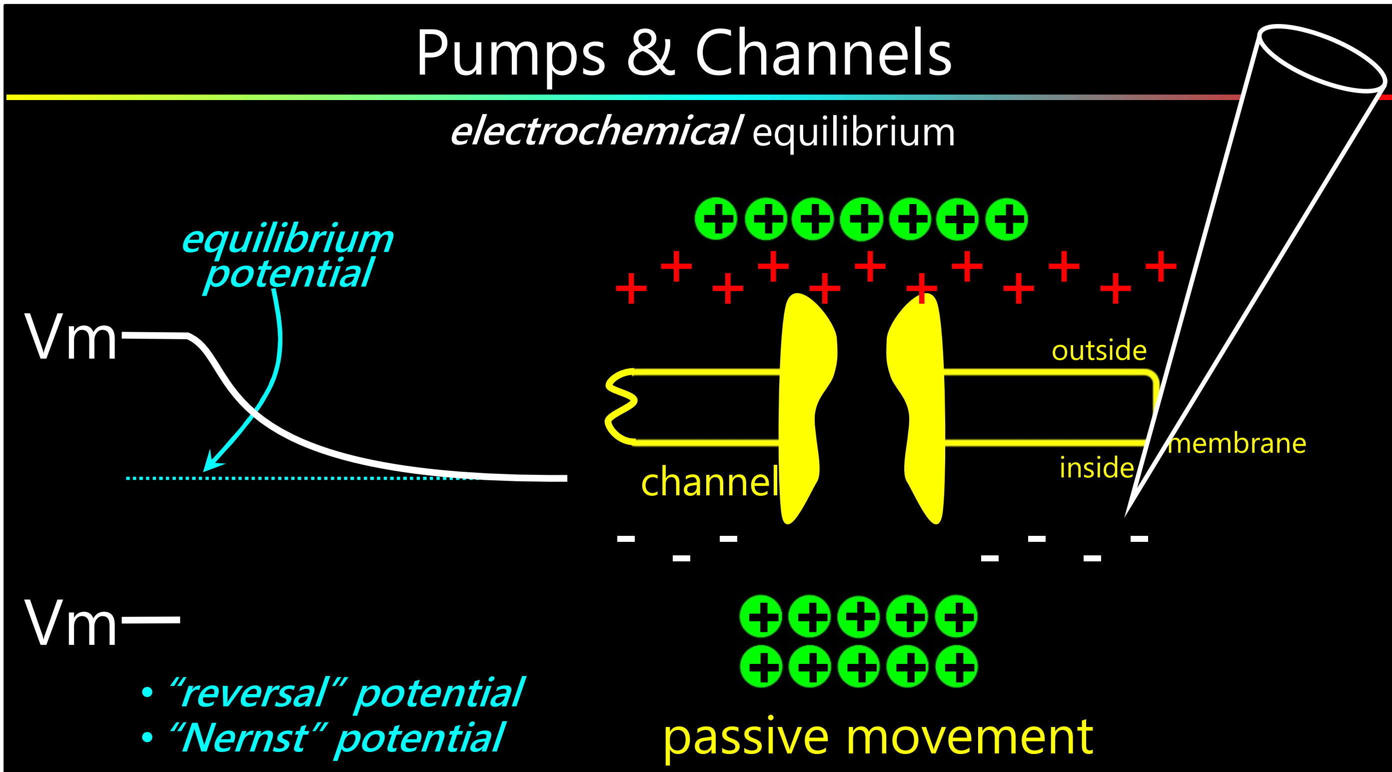




Pumps & Channels
electrochemical equilibrium
equilibrium potential
Vm
pump
channel
outside
membrane
inside
passive movement

Pumps & Channels

electrochemical equilibrium



Pumps & Channels

electrochemical equilibrium

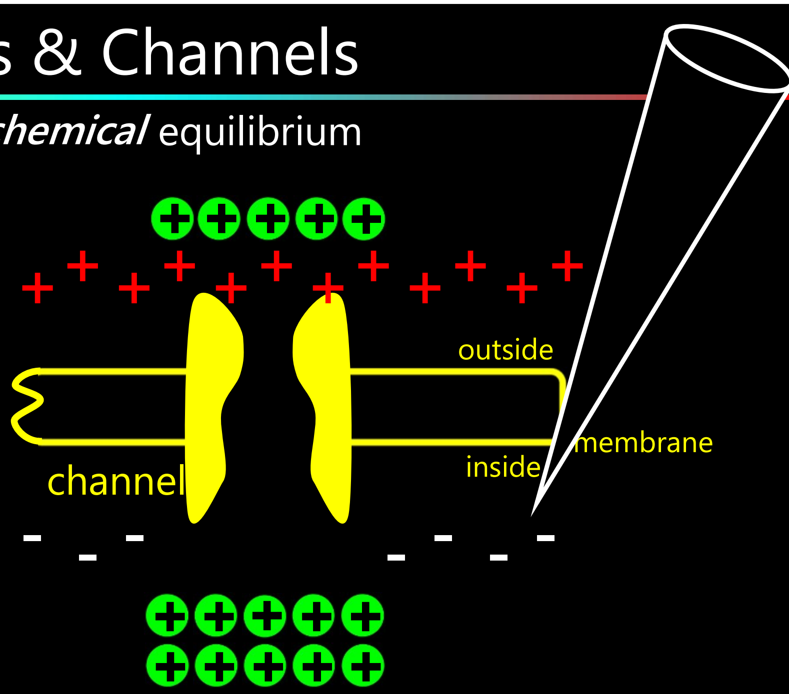
Nernst Equation

equilibrium potential

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

Vm

- R = gas constant
- T = temperature
- Z = valence of the ion
- F = Faraday's constant
  - *"reversal" potential*
  - *"Nernst" potential*



passive movement

Pumps & Channels

electrochemical equilibrium

Nernst Equation

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

- R = gas constant
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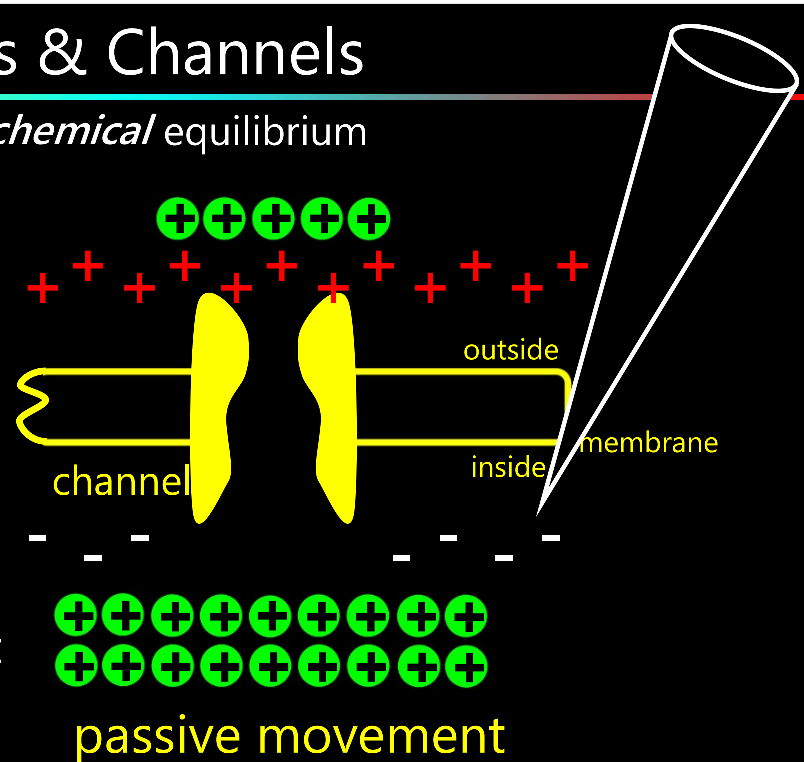

Pumps & Channels

electrochemical equilibrium

Nernst Equation

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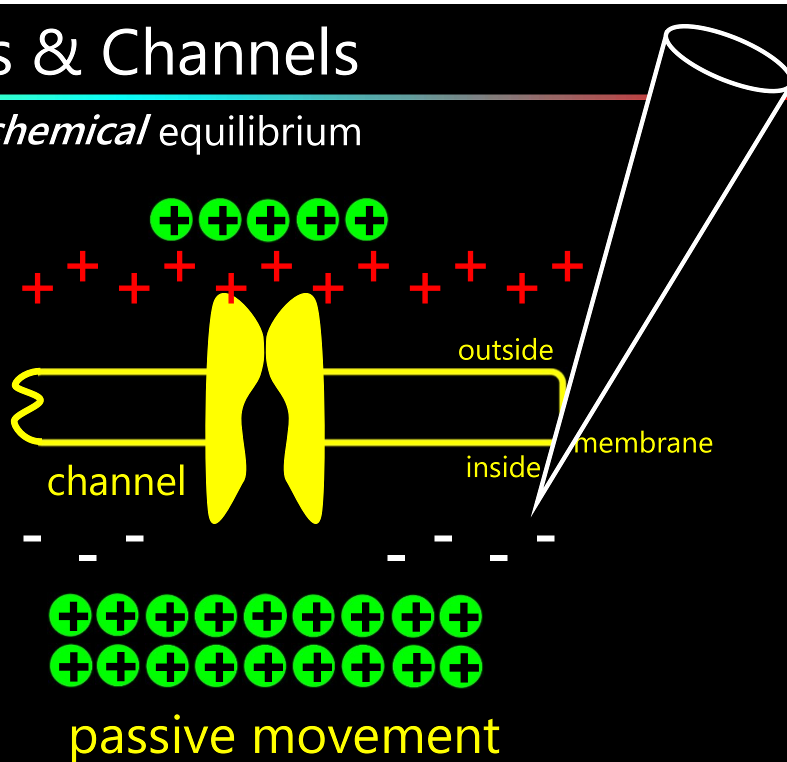

Pumps & Channels

electrochemical equilibrium

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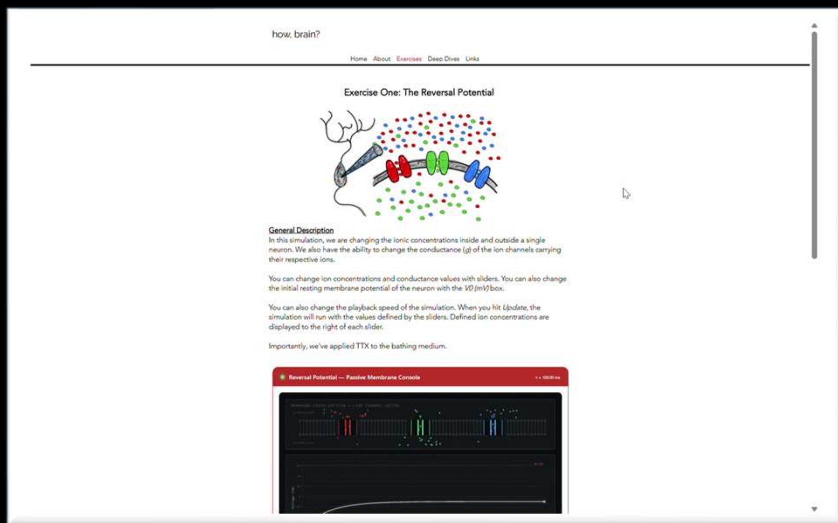
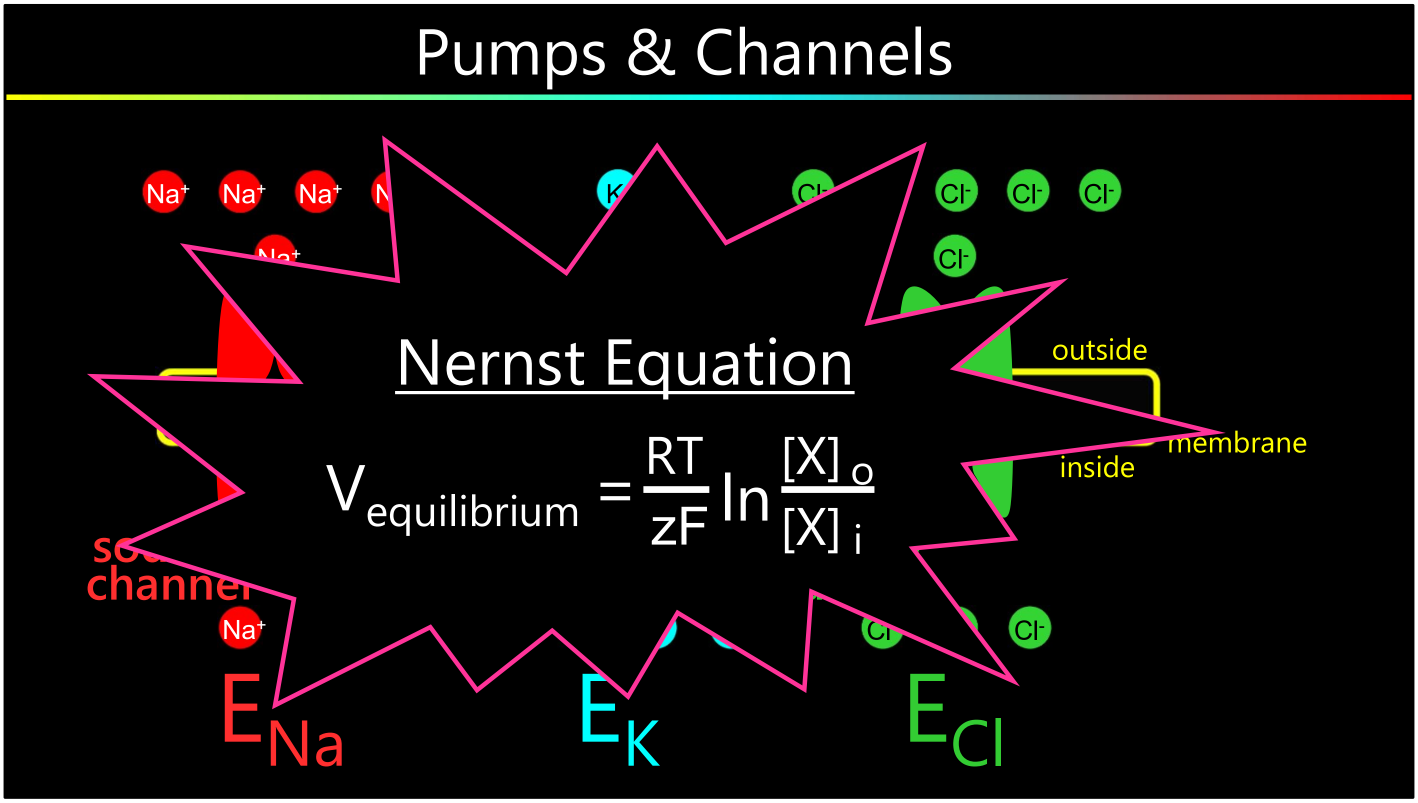
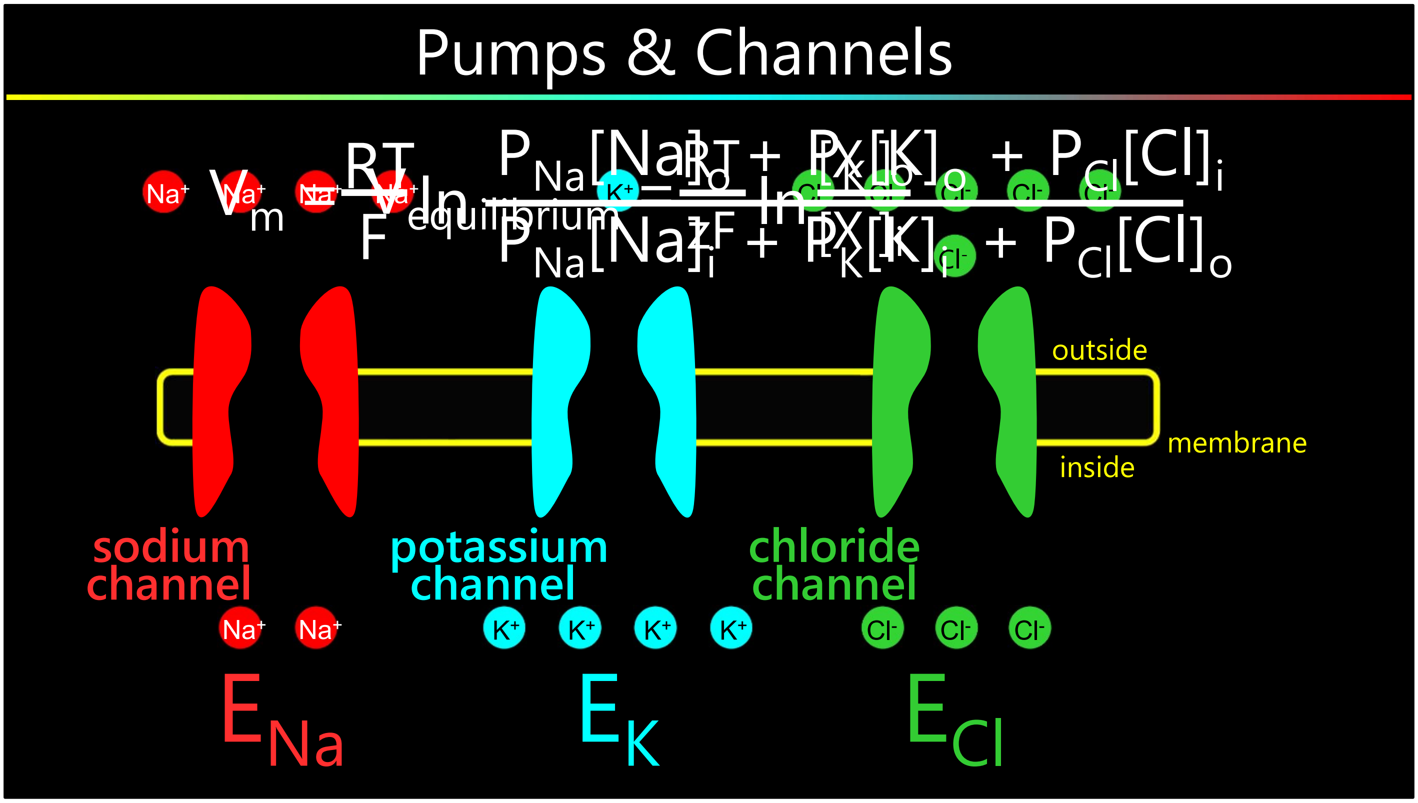


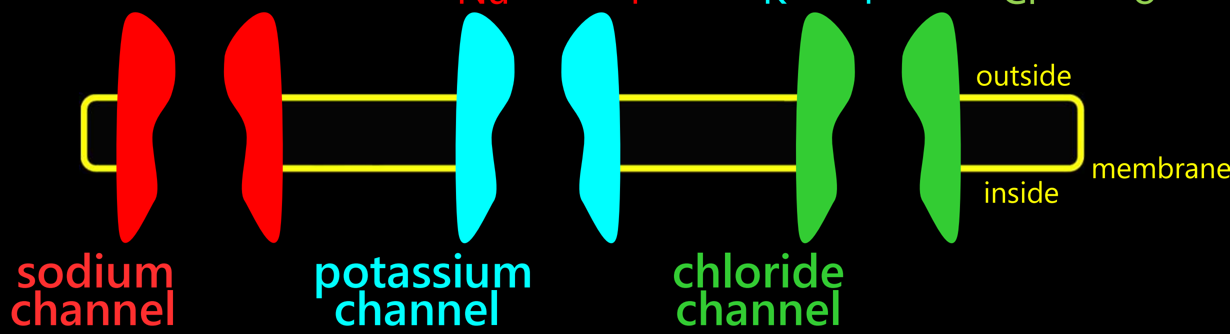
Pumps & Channels


Pumps & Channels
Na+
Na+
Na+
Cl-
Cl-
Cl-
Cl-
outside
membrane
inside
channel
Na+
Cl-
Nernst Equation
$V_{equilibrium} = \frac{RT}{zF} \ln \frac{[X]_o}{[X]_i}$
E_{Na}
E_K
E_{Cl}


Pumps & Channels
$V_m = \frac{RT}{F} \ln \frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$
$V_{equilibrium} = \frac{RT}{zF} \ln \frac{[X]_o}{[X]_i}$
outside
membrane
inside
sodium channel
potassium channel
chloride channel
Na^+
K^+
Cl^-
E_{Na}
E_K
E_{Cl}

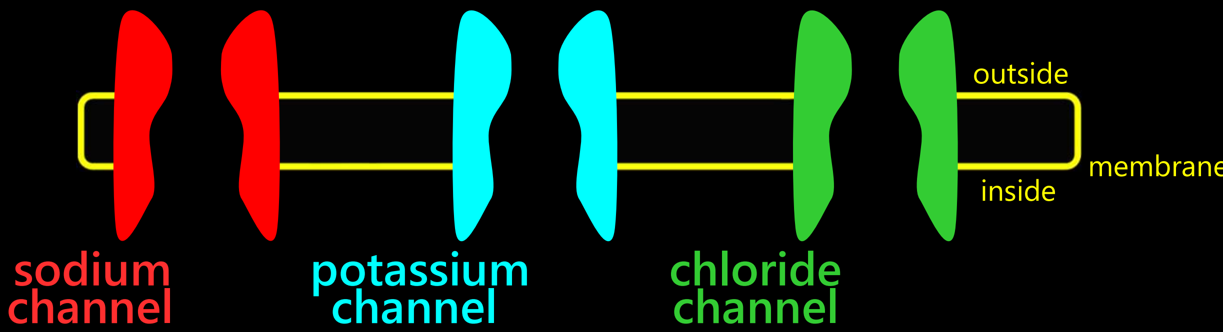
Pumps & Channels

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



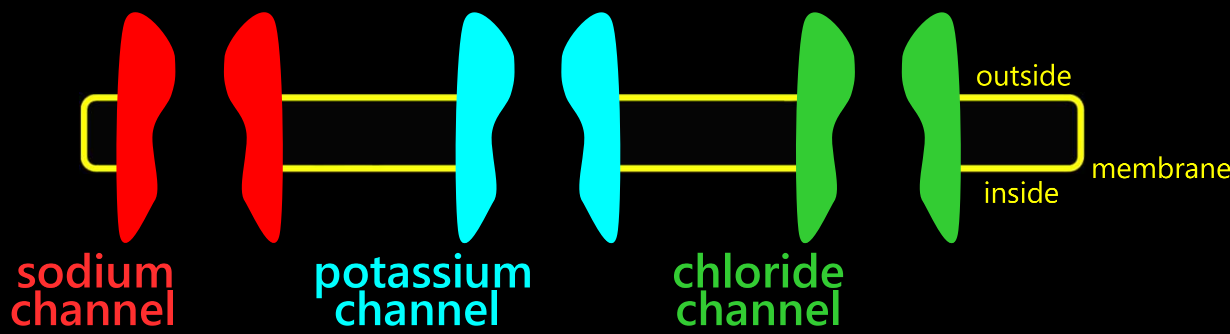
Pumps & Channels

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.*



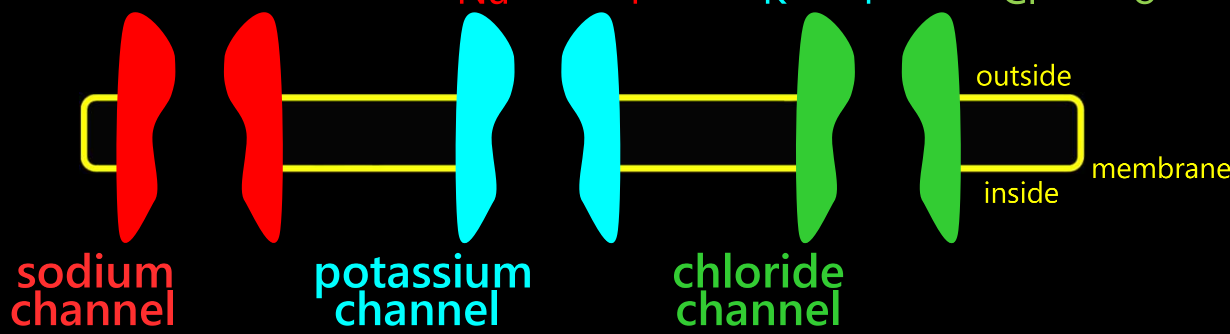
Pumps & Channels

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



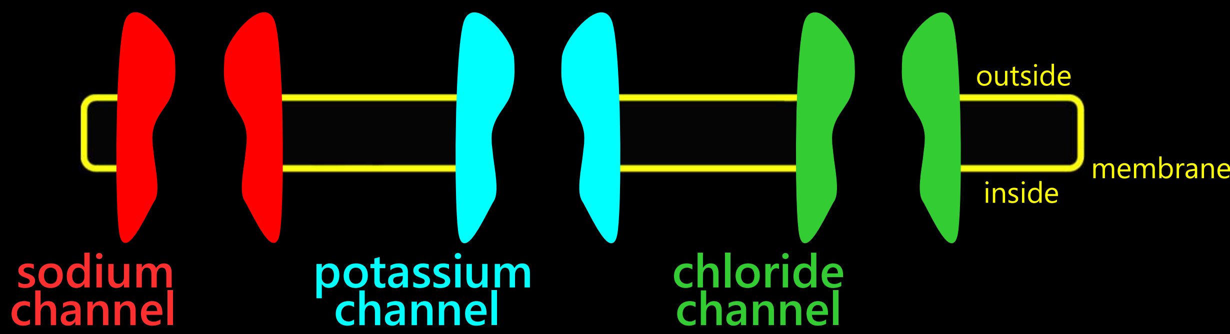
Pumps & Channels

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



Pumps & Channels

what opens a channel?



Pumps & Channels

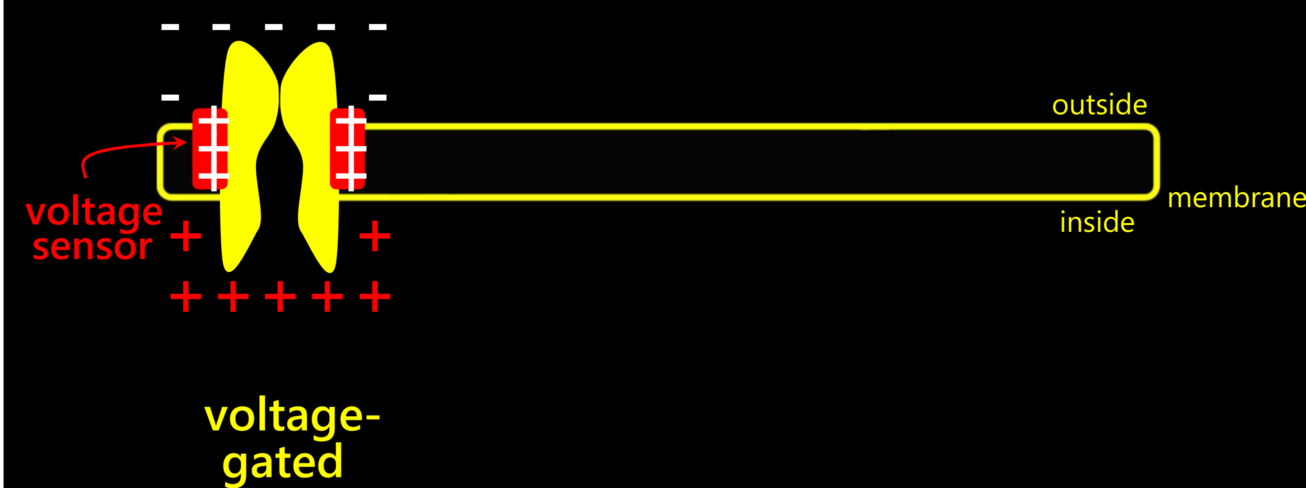
what opens a channel?

Pumps & Channels

what *gates* a channel?

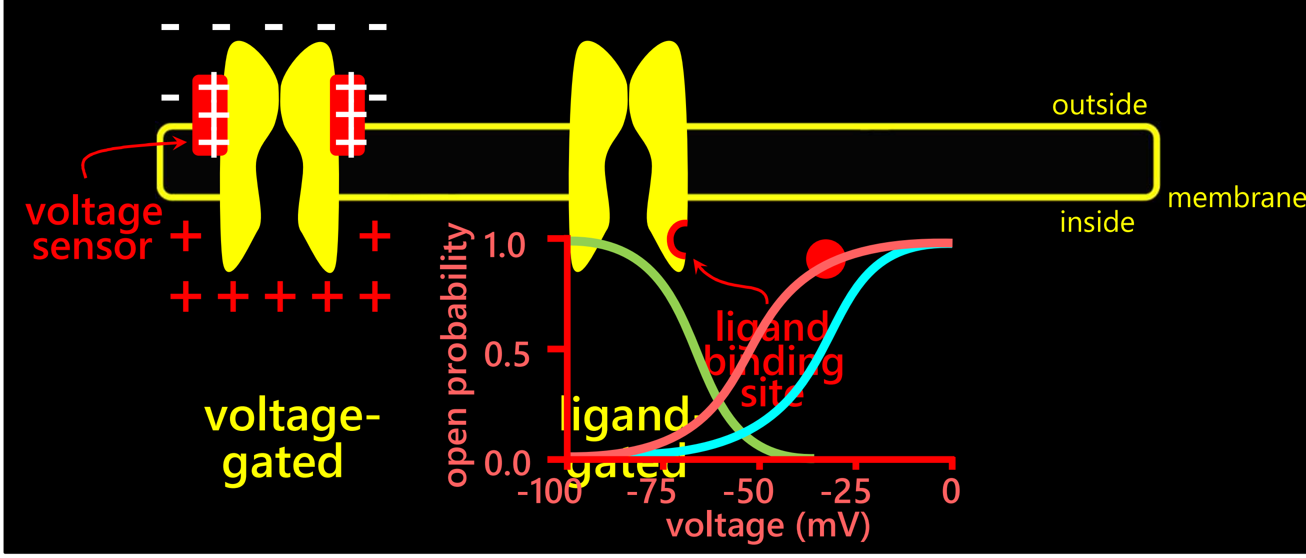
Pumps & Channels

what *gates* a channel?



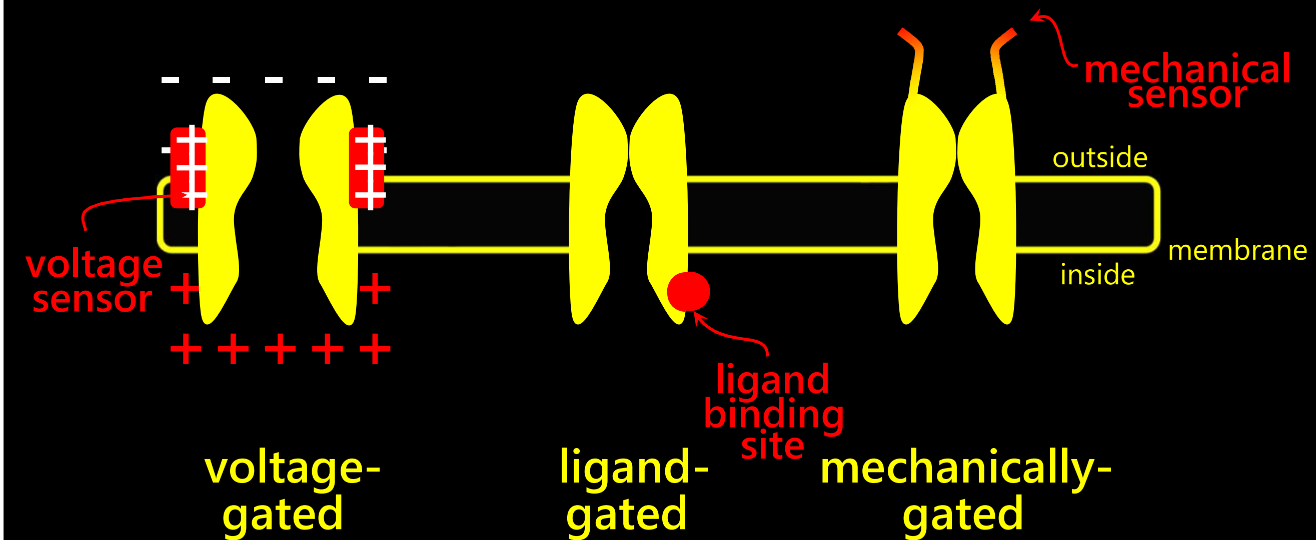
Pumps & Channels

what *gates* a channel?



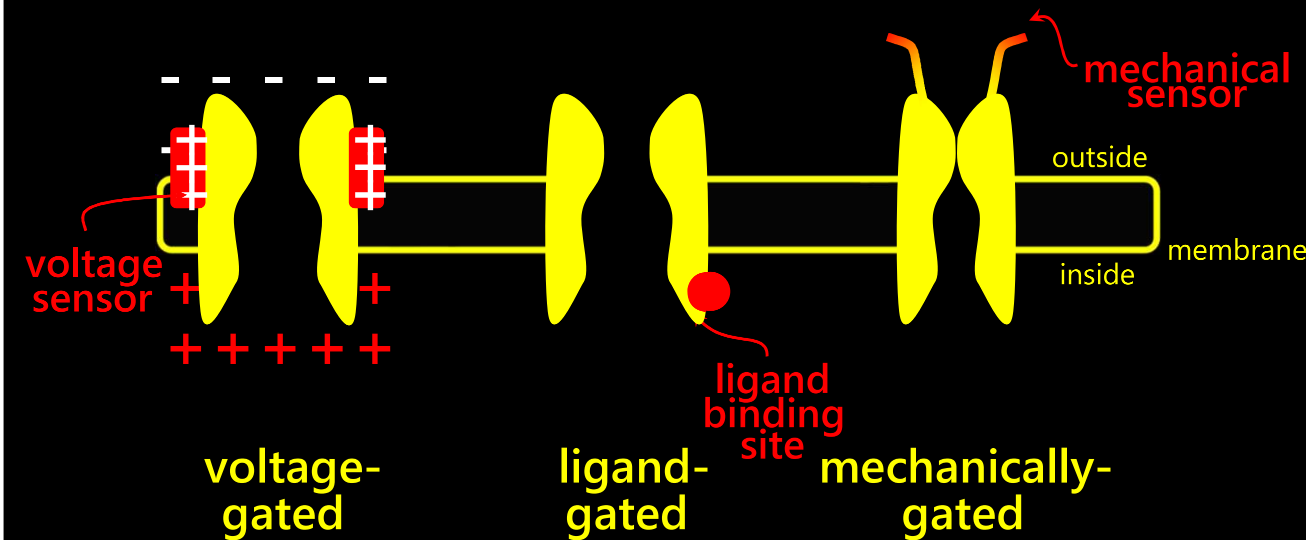
Pumps & Channels

what *gates* a channel?



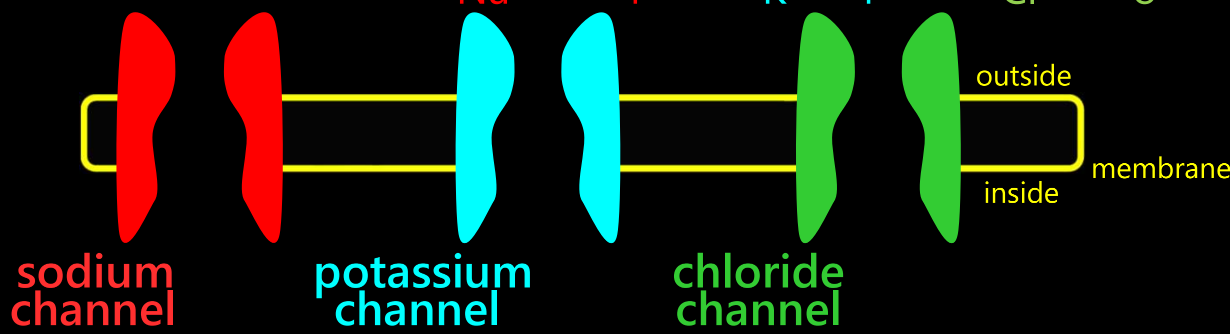
Pumps & Channels

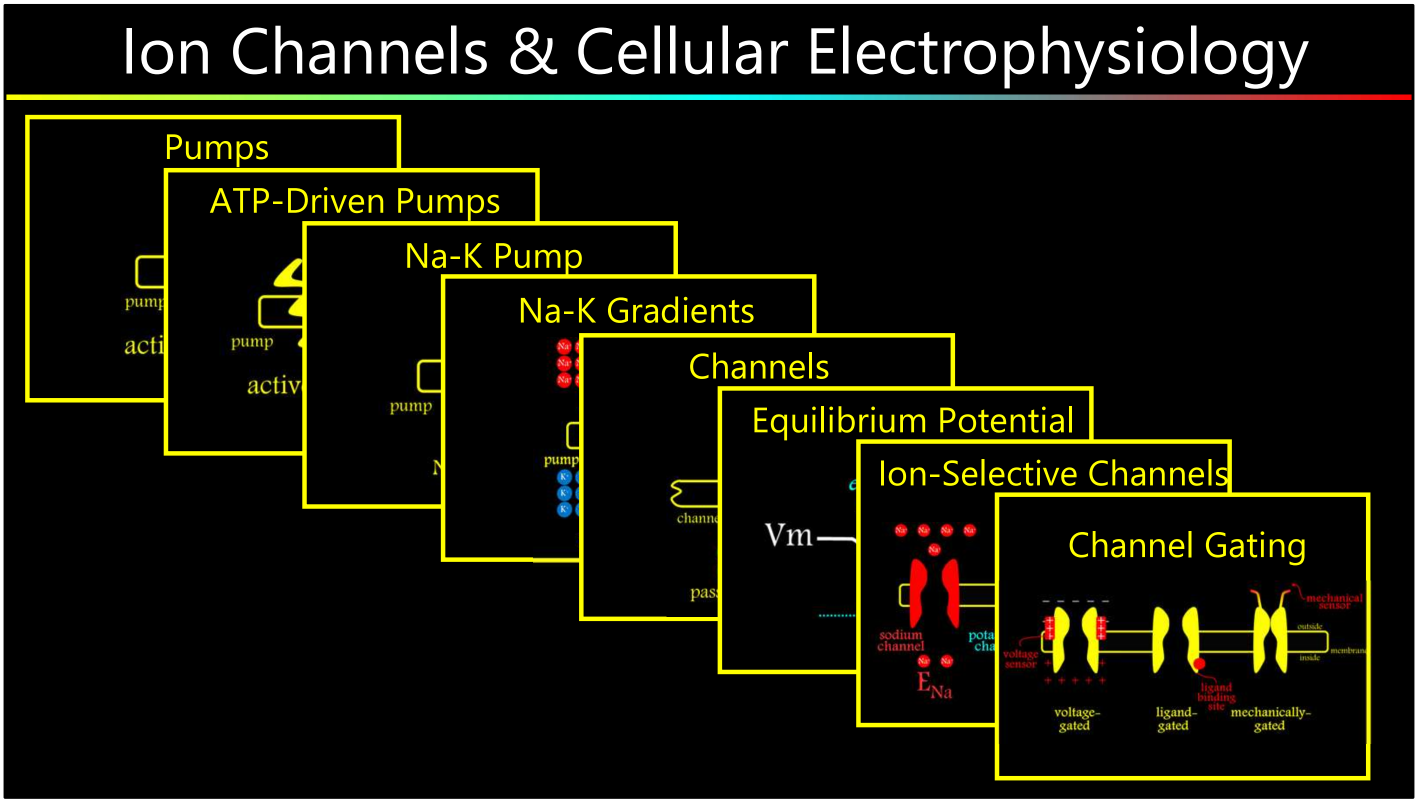
what *gates* a channel?

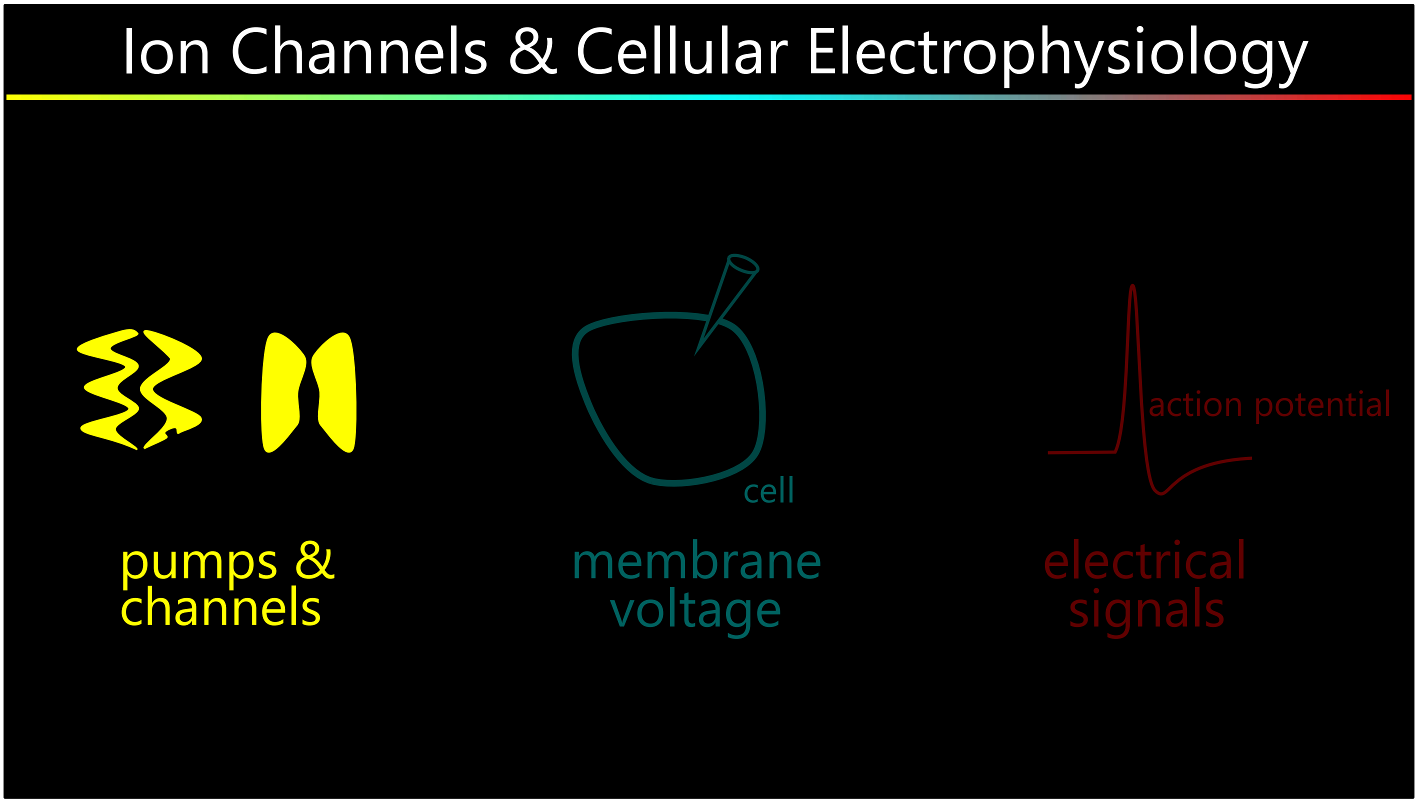


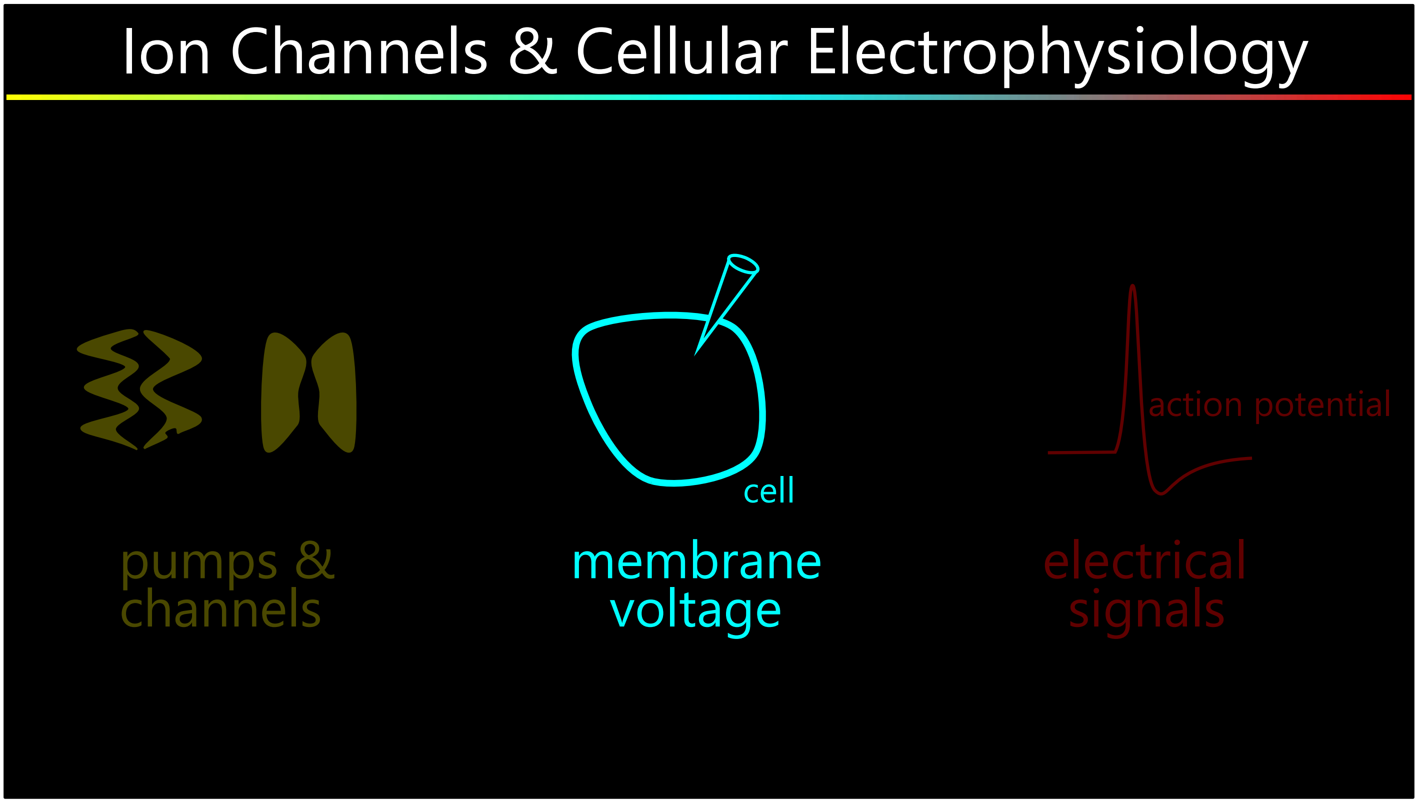
Pumps & Channels

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

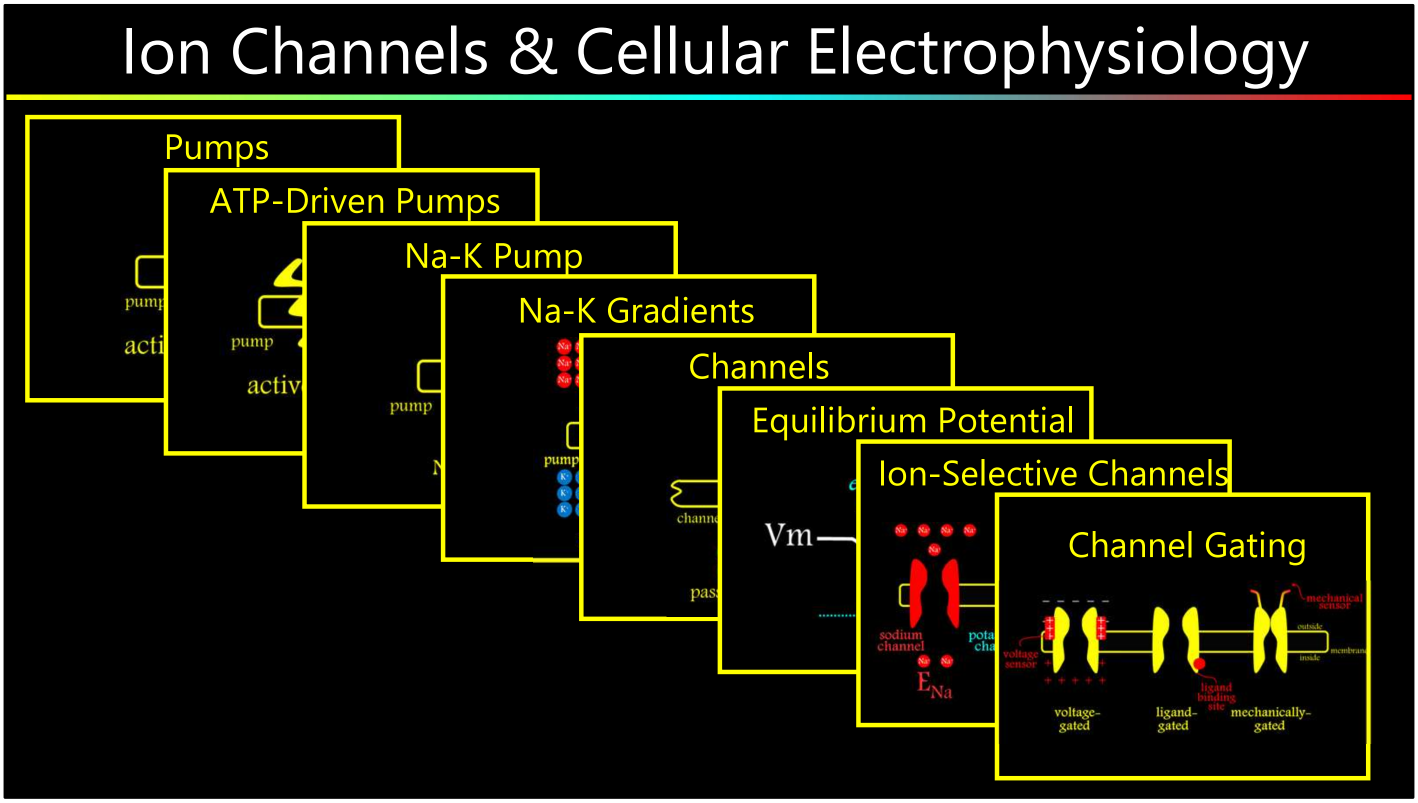



Ion Channels & Cellular Electrophysiology
Pumps
ATP-Driven Pumps
Na-K Pump
Na-K Gradients
Channels
Equilibrium Potential
Ion-Selective Channels
Channel Gating
Vm
sodium channel
voltage-gated
ligand-gated
mechanically-gated


Ion Channels & Cellular Electrophysiology
pumps &
channels
cell
membrane
voltage
action potential
electrical
signals



Ion Channels & Cellular Electrophysiology
cell
action potential
pumps & channels
membrane voltage
electrical signals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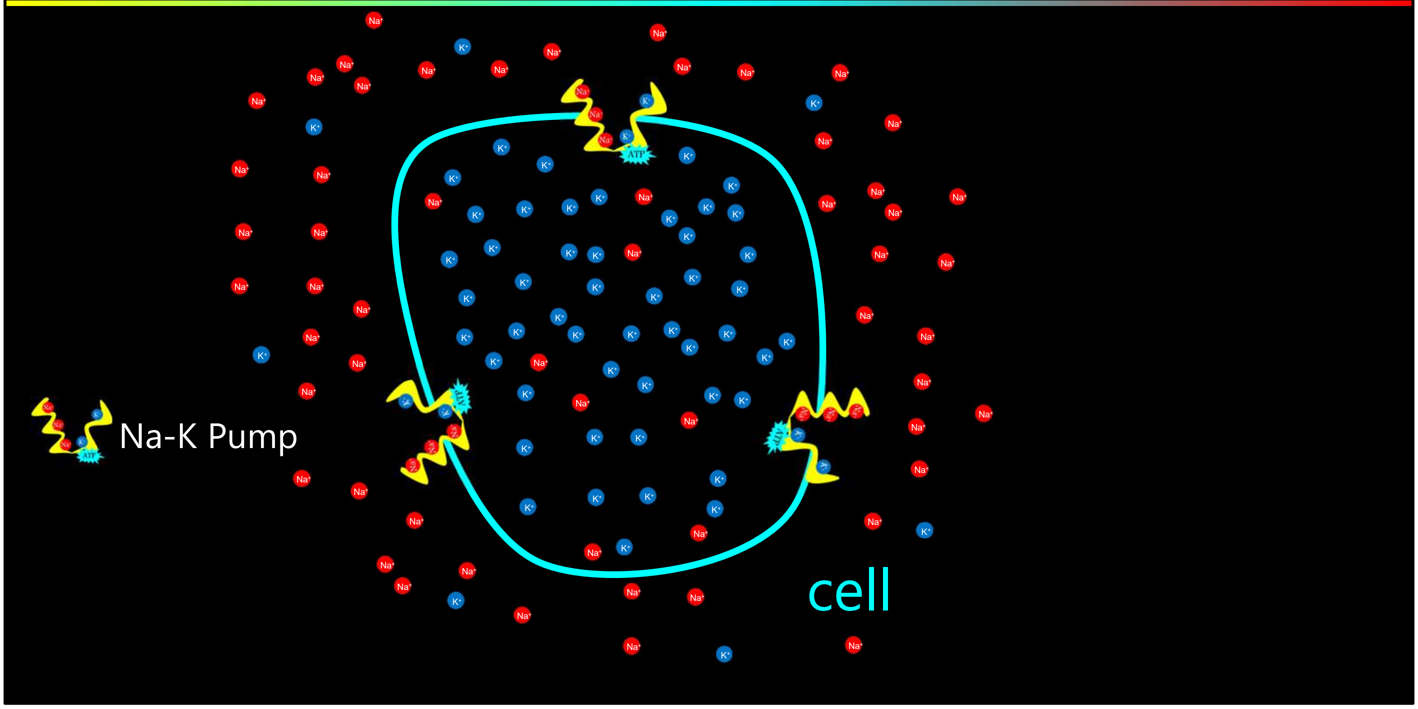
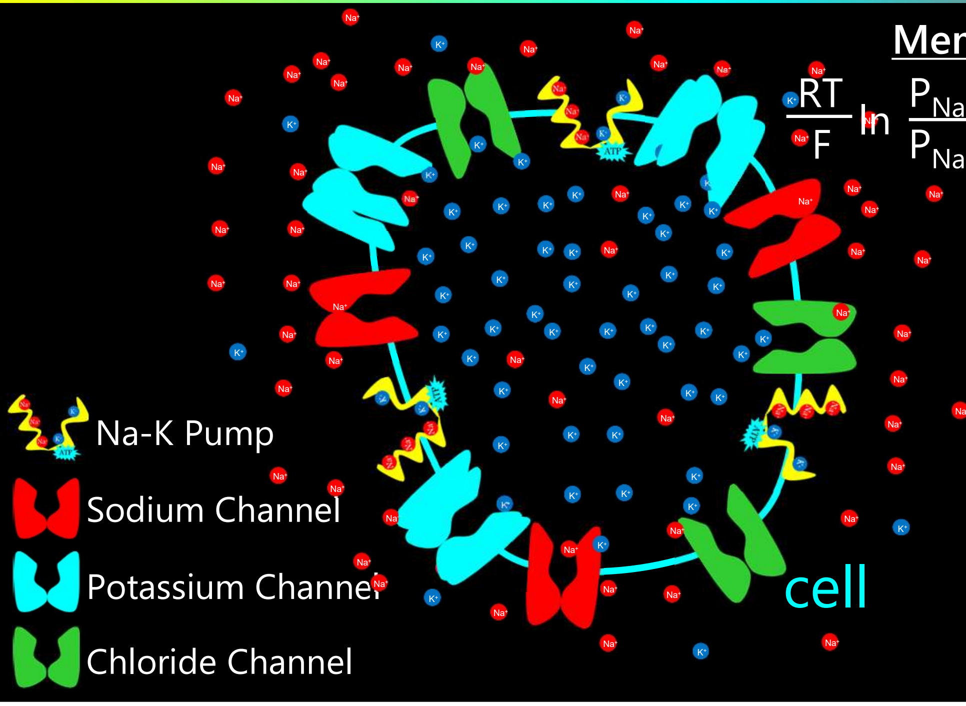
Ion Channels & Cellular Electrophysiology



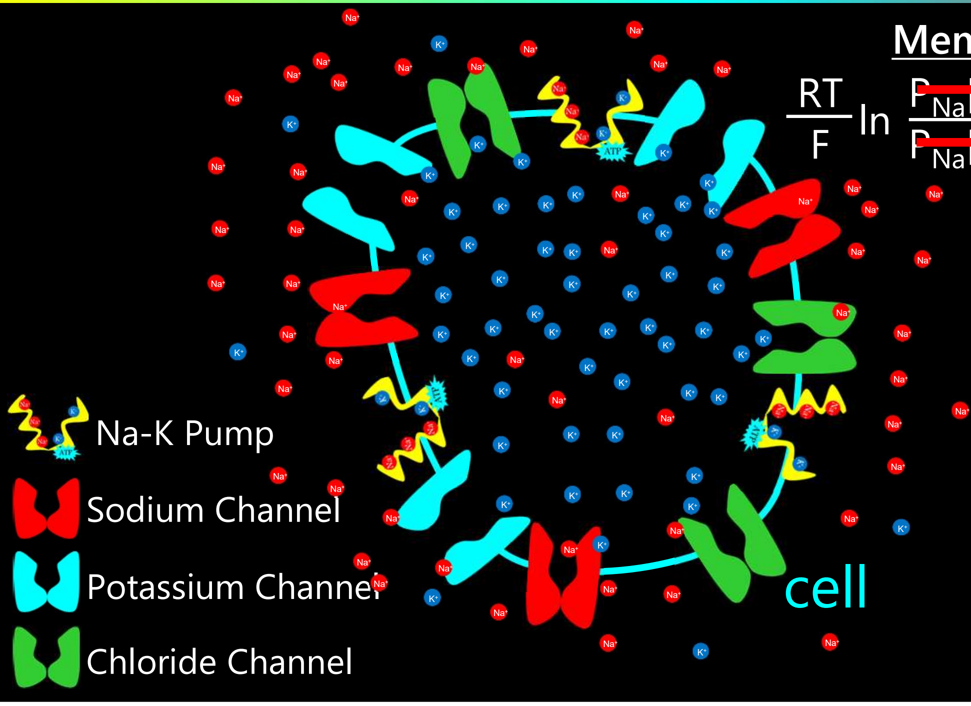
Ion Channels & Cellular Electrophysiology

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



Membrane Potential

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

Nernst Equation

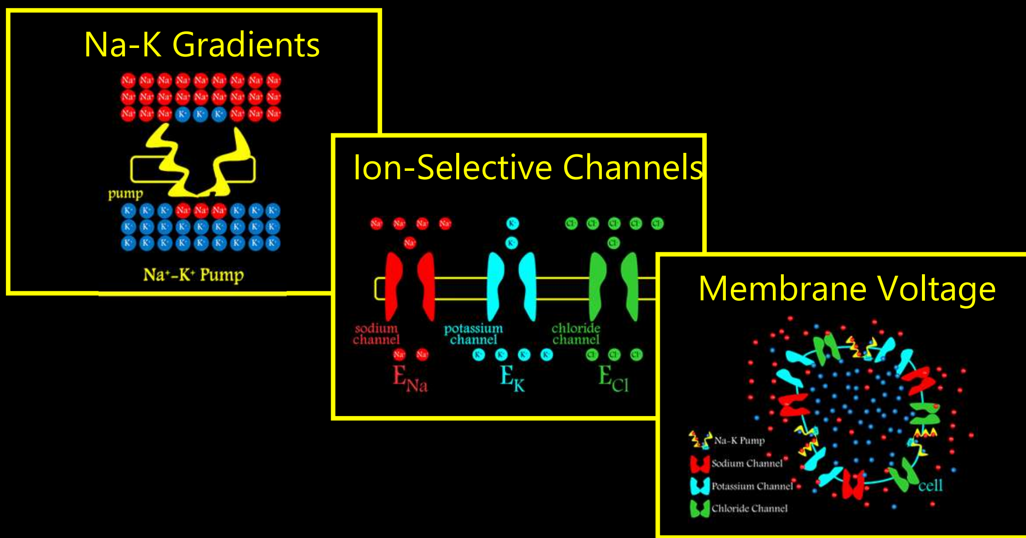
$$E_K = \frac{RT}{zF}\ln\frac{P_K[K]_o}{P_K[K]i}$$

$E_K = -90mV$

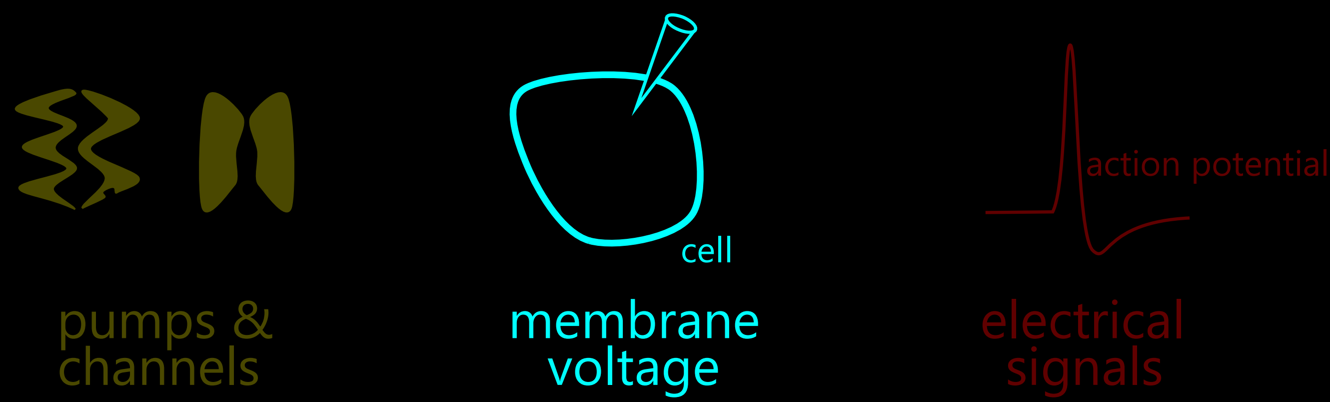
$E_{Na} = +50mV$

$E_{Cl} = -70mV$

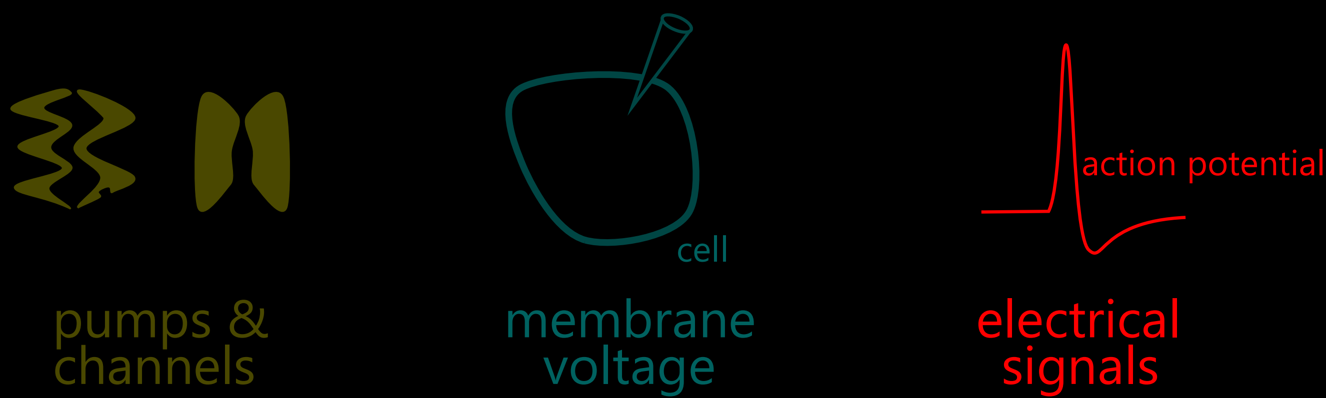
Ion Channels & Cellular Electrophysiology



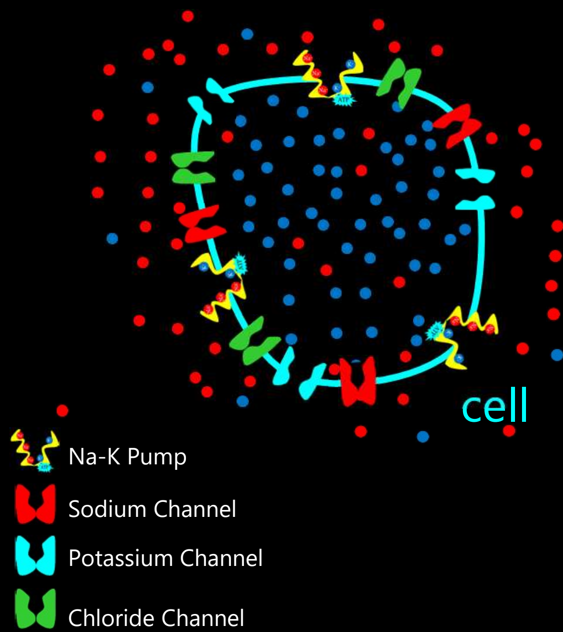
Ion Channels & Cellular Electrophysiology



Ion Channels & Cellular Electrophysiology



Ion Channels & Cellular Electrophysiology



Membrane Potential

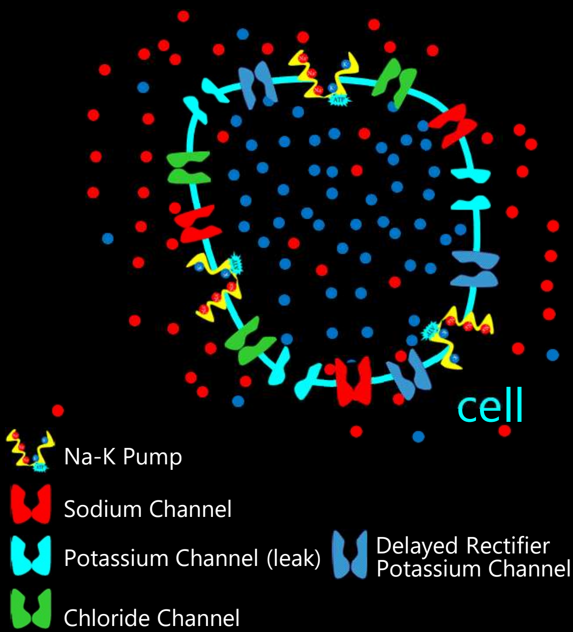
$$\frac{RT}{F}\ln\frac{P_{Na}[Na]_o + P_K[K]_o + P_{Cl}[Cl]_i}{P_{Na}[Na]_i + P_K[K]_i + P_{Cl}[Cl]_o}$$

$E_{Na} = +50mV$

$E_K = -90mV$

$E_{Cl} = -70mV$

Ion Channels & Cellular Electrophysiology



Membrane Potential

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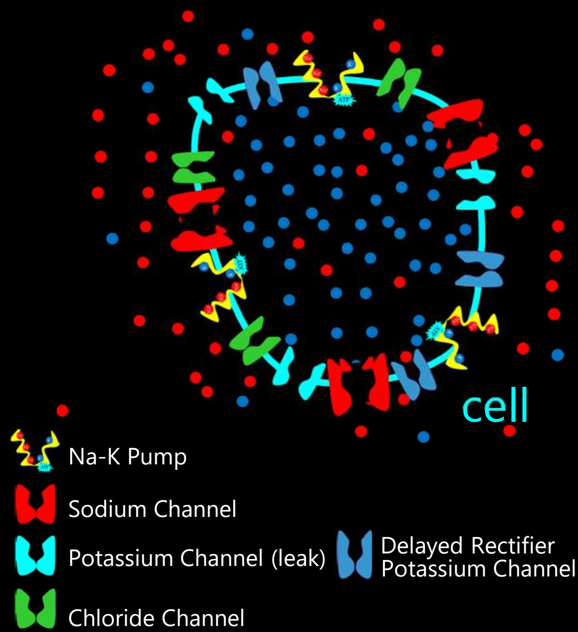
$E_{Na} = +50mV$

$E_K = -90mV$

$E_{Cl} = -70mV$

Vm—

Ion Channels & Cellular Electrophysiology



Membrane Potential

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

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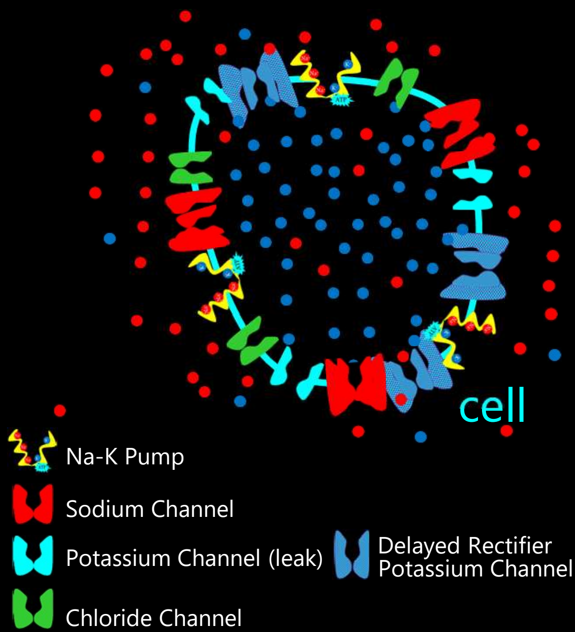
Vm—

Ion Channels & Cellular Electrophysiology



Membrane Potential

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

$E_{Na} = +50mV$

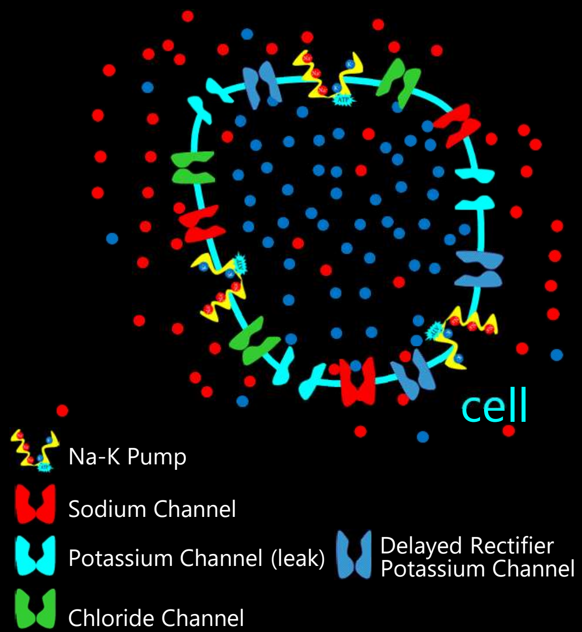
$E_K = -90mV$

$E_{Cl} = -70mV$

Vm—

action potential

Ion Channels & Cellular Electrophysiology



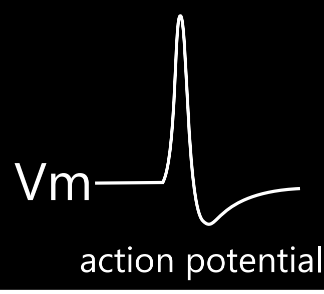
Membrane Potential

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

$E_{Na} = +50mV$

$E_K = -90mV$

$E_{Cl} = -70mV$



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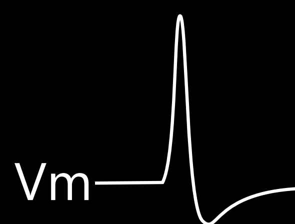

action potential

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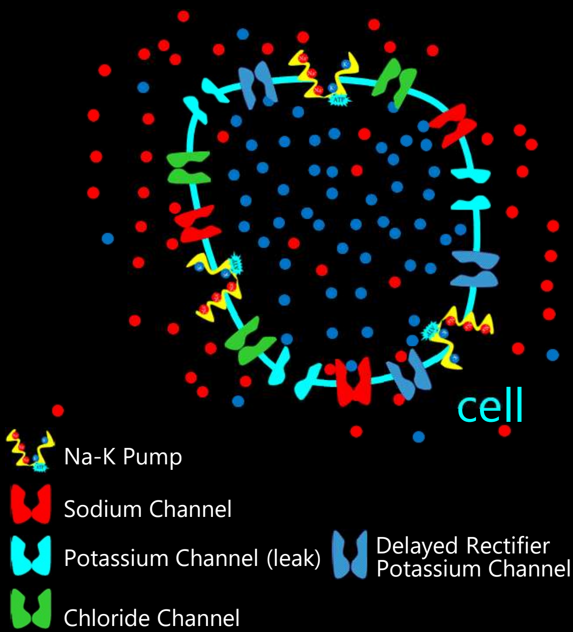

Membrane Potential

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

$E_{Na} = +50mV$

$E_K = -90mV$

$E_{Cl} = -70mV$

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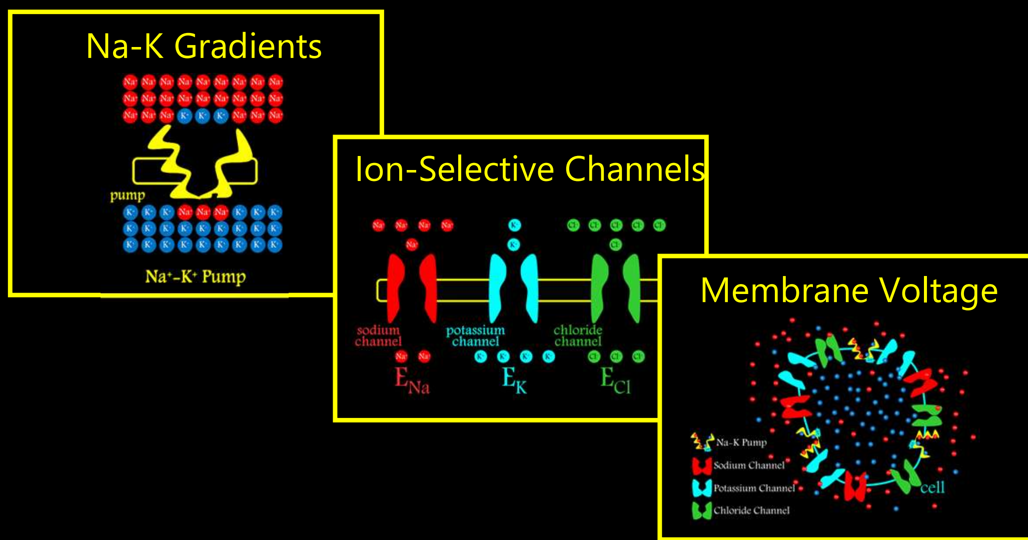

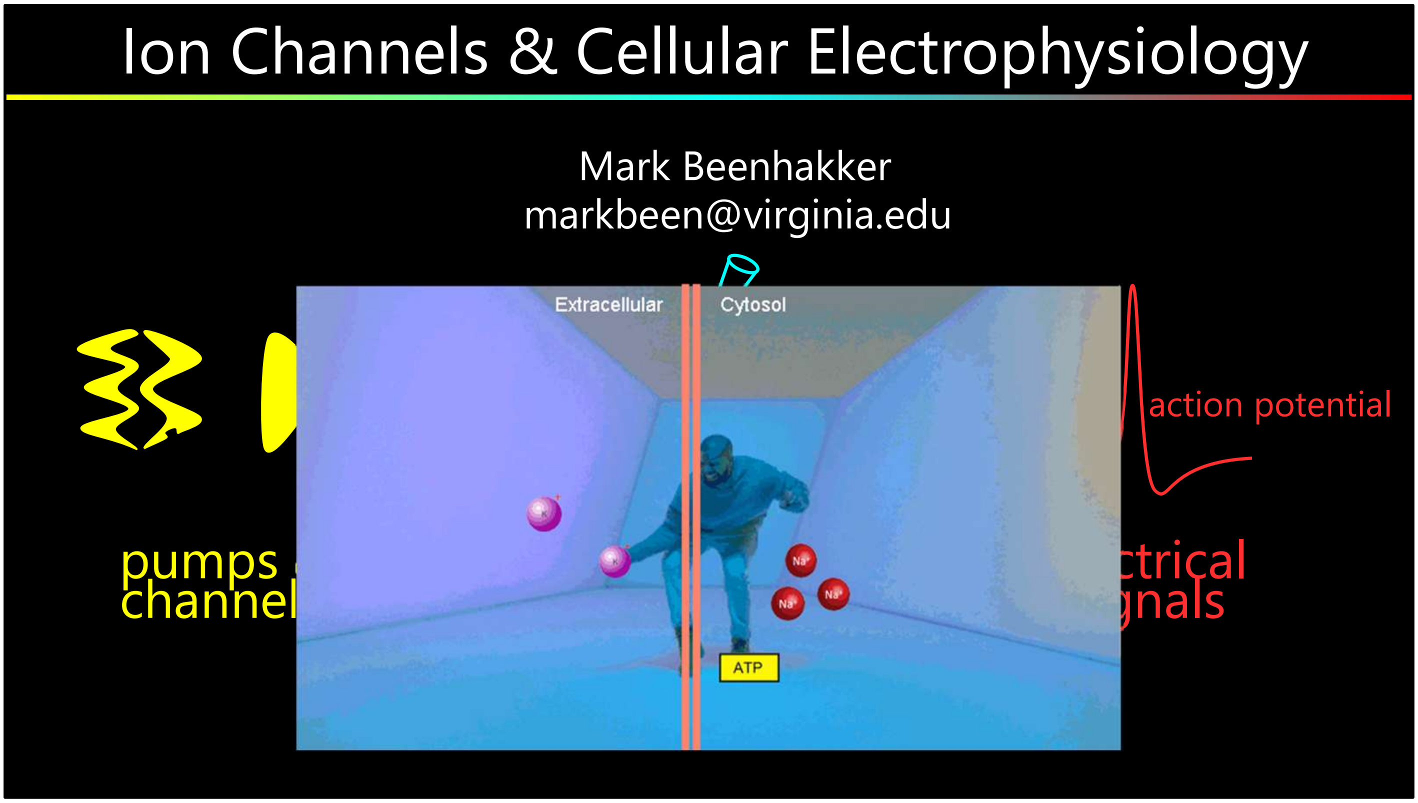
Ion Channels & Cellular Electrophysiology
Mark Beenhakker
markbeen@virginia.edu
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Cytosol
ATP
action potential
pumps
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