Neurons have:

A “Receiving End”
* dendrites

A “Decision Center”
* soma, axon hillock

A “Sending End”
* axon, axon terminals
Structure of a Neuron

- **Dendrites** - input
- **Axon hillock** - start of the axon
- **Axon** - output
- **Soma** - cell body
- **Axon Terminals** - release of neurotransmitters
- **Myelin Sheath** - glia
- **Synapse** - junction between neuron & its target

*Motor neuron*
INPUT and PROCESSING
Transmitter-gated receptors
EPSP / IPSP summation

TRANSMISSION and NT RELEASE
Voltage-gated channels
All or nothing principle
Synaptic events to release neurotransmitters
Components of neuron cell membranes

- **Na⁺** selective protein channel (**Na⁺ IN**)
- **K⁺** selective protein channel (**K⁺ OUT**)
- **Cl⁻** selective protein channel (**Cl⁻ IN**)
- **Na⁺ - K⁺** pump – requires ATP energy  (**ATP is made from glucose & oxygen**)
Summary of forces - neuron at rest

Forces:

- **Concentration Gradient**
  - $\text{Na}^+$
  - $\text{K}^+$

- **Electrical Gradient**
  - $\text{Na}^+$
  - $\text{K}^+$

The voltage difference across the membrane is about -70 mV.
Transmitter-gated channels can create positive synaptic potentials called EPSPs.

As $\text{Na}^+$ ions enter the cell, the electrical potential becomes more positive.

At rest:
- Transmitter-gated channel
- Closed channel
- $\text{Na}^+$
- $\text{K}^+$
- $-70 \text{ mV}$

Activated:
- Open channel
- $\text{Na}^+$
- $\text{K}^+$
- $-65 \text{ mV}$

EPSP = Excitatory Post-Synaptic Potential

NOTE: The channel is only open for a brief period.
Transmitter-gated channels can create **negative** synaptic potentials called IPSP.

Negative potentials can occur if specific neurotransmitters bind to the $K^+$ **specific channels** causing them to open.

IPSP = Inhibitory Post-Synaptic Potential

**NOTE:** The channel is only open for a brief period.
Temporal & Spatial Summation

- Must always be close in time (window of activation)
- Increased summation = the closer in space & time.

*Can occur through multiple inputs or a single neuron*
Voltage-gated channels begin at axon hillock

Voltage-gated channel

Na⁺ channel (closed)

At Threshold

Na⁺ channel (open)

Polarized membrane (normal state)

Depolarized membrane

Closed until membrane threshold is reached
Visualizing ionic transport during the action potential.

1. Rising Phase: $\text{Na}^+$ Entry

2. Falling Phase: $\text{K}^+$ Exit

3. The $\text{Na}^+$/K$^+$ pump restores ion concentrations
Visualizing ionic transport during the action potential.

1. Rising Phase: **Na\(^+\) Entry**

2. Falling Phase: **K\(^+\) Exit**

3. The **Na\(^+\)/K\(^+\)** pump restores ion concentrations
Visualizing ionic transport during the action potential.

1. Rising Phase: **Na⁺** Entry
2. Falling Phase: **K⁺** Exit
3. The **Na⁺/K⁺** pump restores ion concentrations
As the axon becomes more positive during the *rising phase* of the action potential the **voltage** spreads out causing other voltage-gated channels to open. Thus, the **voltage propagates the action potential** down the axon.

This also creates a lot of work for the Na+/K+ pump, which uses ATP energy! - Not very efficient for long neurons.
Pumps working
Action Potentials in **Myelinated** Neurons

The nodal “jumping” of the action potential is called **saltatory conduction**.
NT Release in the synaptic cleft

• Action potential causes **influx** of **Ca**\(^{++}\) which facilitates the **fusing of** vesicles with the cell membrane releasing the neurotransmitter into the **synaptic cleft** - this entire process is called **exocytosis**
Postsynaptic receptors (2 types)

- Transmitter-gated Ion Channels or **Ionotropic Channels**

**Important Ionotropic Channels:**

- $\text{Na}^+$ channel ($\text{Na}^+$ into neuron - *EPSP*)
- $\text{K}^+$ channel ($\text{K}^+$ out of neuron - *IPSP*)
- $\text{Cl}^-$ channel ($\text{Cl}^-$ into neuron - *IPSP*)
Postsynaptic receptors (2 types)

**Metabotropic Receptor** - binding of the transmitter causes reaction inside cell producing a signal or "second messenger"
Roles of second messengers

- Activated g-protein can open an ionotropic channel – producing synaptic potentials
- Usually longer activation of the channel than neurotransmitter-gated activation
- *Can also result in keeping ionotropic channels closed even in the presence of the ionotropic channel’s activating neurotransmitter!*
Various 2\textsuperscript{nd} Messenger Actions

duration of action

seconds

ion channels

minutes to hours

neurotransmitter

seconds

minutes to hours

"permanent"

changes in excitability

changes in cellular processes

transcription factors

changes in gene expression

nucleus

kinases