Neural Resonance: a property of neurons that enables them to generate spontaneous membrane-voltage oscillations or preferentially respond to inputs delivered at a specific frequency.

The resonant frequency (preferred frequency) is determined by the physiological properties of the neuron, including:

- The size of the neuron
- The membrane potential
- The types of receptors/ion channels
- The number of receptors/ion channels
If neurons preferentially respond to inputs that are delivered within a specific frequency range, does this limit or enhance their ability to appropriately react to inputs from a wide range of sources?
Models of neurons as electrical circuits to understand resonance

Membranes as **capacitors**:  

Two conductors (the fluid inside and outside the neuron) are separated by an **insulator** (the membrane), allowing an electric potential difference to exist across the cell membrane.  

This is often represented as a circuit with a **capacitor**.  

Neurons often have a **negative resting membrane potential** around -70mV.
Models of neurons as electrical circuits to understand resonance

Passive channels as **resistors**:

Channels in the membrane have limited permeability to select ions, allowing some ions to passively **flow across the membrane**. This is often represented as a circuit with a **resistor** and **capacitor**, or an RC circuit.
Models of neurons as electrical circuits to understand resonance

Channels that oppose changes in membrane voltage as **inductors**:

Certain voltage-gated ion channels can **oppose changes** in the membrane potential when open. This is often represented as a circuit with a resistor, capacitor, and inductor, or an **RLC circuit**.

Examples are:

1) Depolarization-activated K+ channels which allow K+ to flow out of the neuron

2) Hyperpolarization-activated HCN channels which allow cations to flow into the neuron.
Models of neurons as electrical circuits to understand resonance

What happens when an alternating current is applied to the circuit?

In the brain, this is the equivalent of receiving *rhythmic inputs* from other neurons.
Models of neurons as electrical circuits to understand resonance

Fast input:

The membrane (capacitor) slows down the voltage response to any given current.

Responses to fast inputs are suppressed.
Models of neurons as electrical circuits to understand resonance

Slow input:

Active channels (inductors) counteract slow changes in membrane voltage.

Responses to slow and fast inputs are suppressed.
Models of neurons as electrical circuits to understand resonance

Neurons are *tuned* to preferentially respond to a specific frequency range:

Input impedance = determines how much a neuron depolarizes in response to an alternating current

Adapted from Hutcheon and Yarom, *Trends in Neuroscience*, 2000
Models of neurons as electrical circuits to understand resonance

Neurons can be *tuned* to preferentially respond to a specific frequency range:

![Circuit diagram for a simple crystal radio](bioweb.biology.utah.edu/goldenberg/)
If neurons preferentially respond to inputs that are delivered within a specific frequency range, does this limit or enhance their ability to appropriately react to inputs from a wide range of sources?