Queensland Brain Institute

How do neurons work?

The key difference between neurons and glia is that neurons are 'excitable'. This means that they produce electrical events called action potentials (/brain-basics/brain/brain-physiology/action-potentials-and-synapses), which are also known as nerve impulses, or spikes. Nerve impulses are the basic currency of the brain. They allow neurons to communicate with each other, computations to be performed, and information to be processed.

When a neuron spikes it releases a neurotransmitter (/brain/brain-physiology/what-are-neurotransmitters), a chemical that travels a tiny distance across a synapse (/brain-basics/brain/brain-physiology/action-potentials-and-synapses) before reaching other neurons (Fig 1). Any time a neuron spikes, neurotransmitters are released from hundreds of its synapses, resulting in communication with hundreds of other neurons.

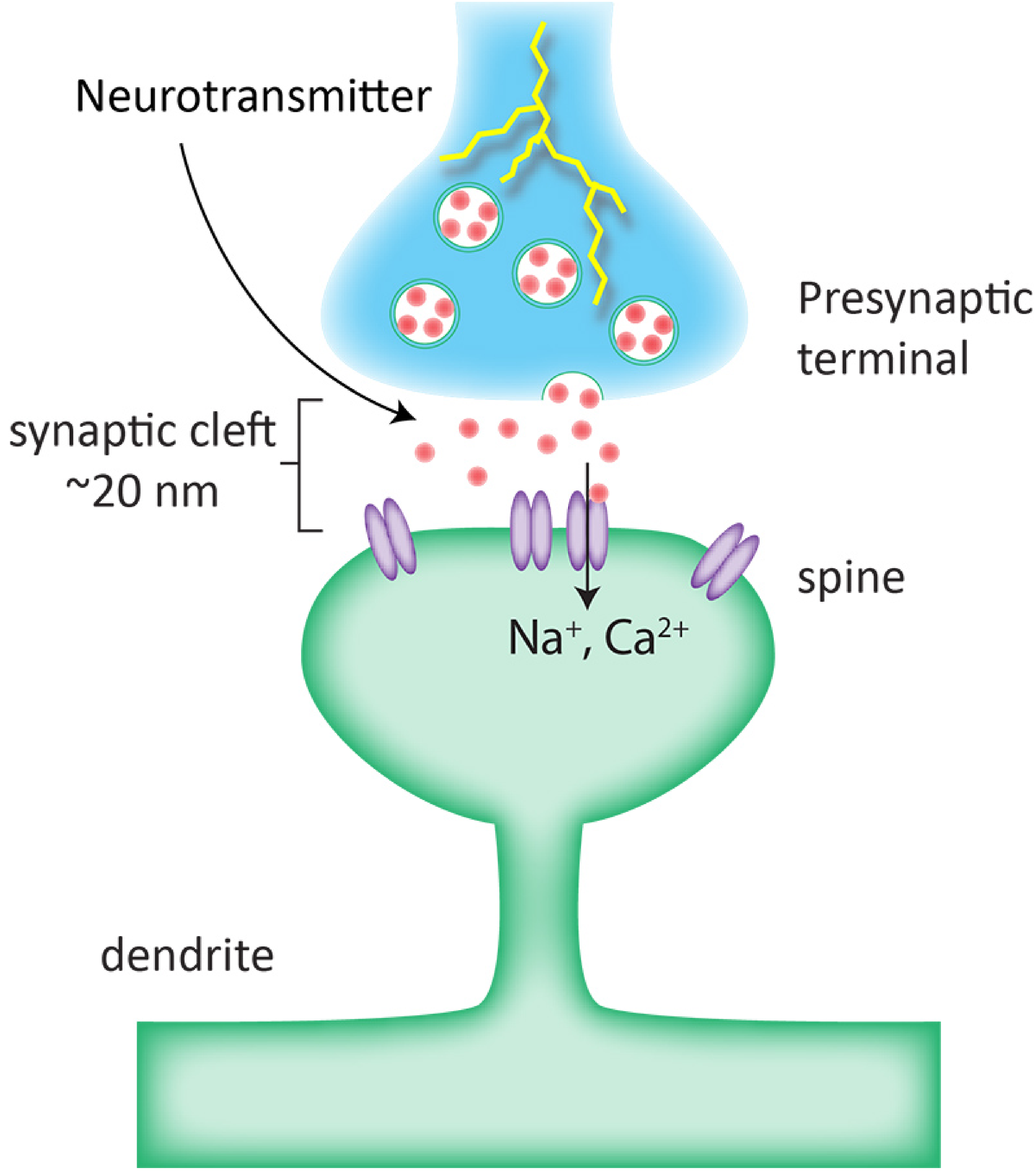

Figure 1: *Synapses are tiny gaps between neurons, across which the neurons talk to each other. An action potential here (yellow lightning) causes neurotransmitter to be released. The neurotransmitter travels across the gap to activate receptors on the receiving neuron. (Image: Alan Woodruff / QBI)*

Neurons communicate through synapses

What do these neurons hear as they listen to other neurons talking? That depends on the language being spoken—or the identity of the neurotransmitter (/brain/brain-physiology/what-are-neurotransmitters) that is released. Although some research has revealed exceptions (http://www.neuwritewest.org/blog/2015/2/7/neurotransmitters-not-simply-one-per-neuron), the vast majority of neurons are currently thought to be monolingual—they can only release one type of neurotransmitter.

Most of these (~80%) release the *excitatory* transmitter glutamate, which promotes spiking in target neurons, whereas other neurons release GABA, an *inhibitory* neurotransmitter that functions to prevent spiking. Other neurotransmitters include:

- Dopamine (the loss of which leads to Parkinson's Disease)
- Serotonin
- Acetylcholine
- Glycine

Action potentials and synapses: in depth (/brain-basics/brain/brain-physiology/action-potentials-and-synapses)

More excitation than inhibition

Neuronal communication is exquisitely regulated as a balance between excitatory and inhibitory influences (Fig 2). A given neuron receives hundreds of inputs, almost exclusively on its dendrites and cell body. These inputs add and subtract in a constantly evolving pattern, depending on what the brain is thinking. This is a process called **synaptic integration**, which determines whether a neuron becomes active.

In order to become active, the total input must reach a threshold at which excitation outweighs inhibition enough. Only at this point will the receiving neuron spike, adding its voice to the conversation by releasing its own neurotransmitter.

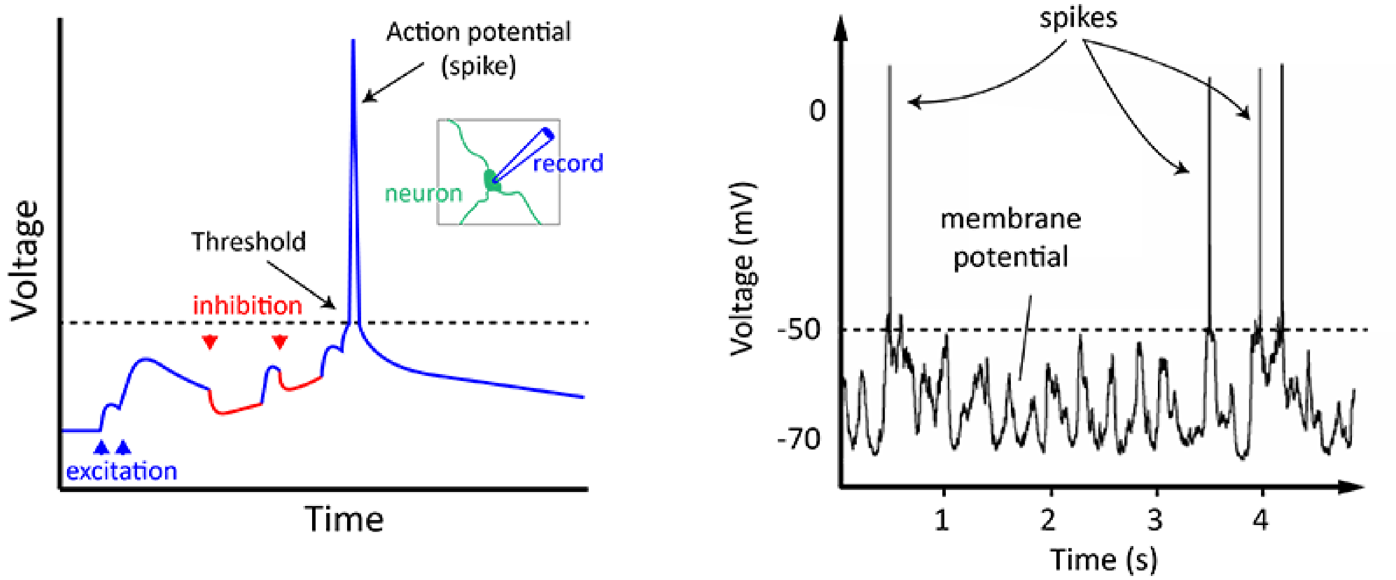

Figure 2: *A neuron spikes when a combination of all the excitation and inhibition it receives makes it reach threshold. On the right is an example from an actual neuron in the mouse's cortex. (Image: Alan Woodruff / QBI)*

Neurons are diverse

Neurons aren't all the same; for starters, they release different neurotransmitters. Moreover, several different subclasses of neurons can use the *same* transmitter. These different subclasses seem to be suited to different tasks in the brain, although we don't fully know yet what those tasks are. One major goal of contemporary neuroscience is to understand the extent of this diversity (http://news.berkeley.edu/2014/09/30/nih-awards-uc-berkeley-7-2-million-to-advance-brain-initiative/).

How many different types of neuron are there (and how can we define a "type" of neuron)? What do they all do? Are particular types more important than others in various diseases, and can we target them for therapies?

The ongoing genetic revolution has made these questions more addressable than ever before, yet we still have a long way to go. Once you appreciate this diversity and combine it with the fact that there are 86 billion neurons (plus at least as many glia!) you can begin to understand why we still have much more to discover about how brains work.

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