

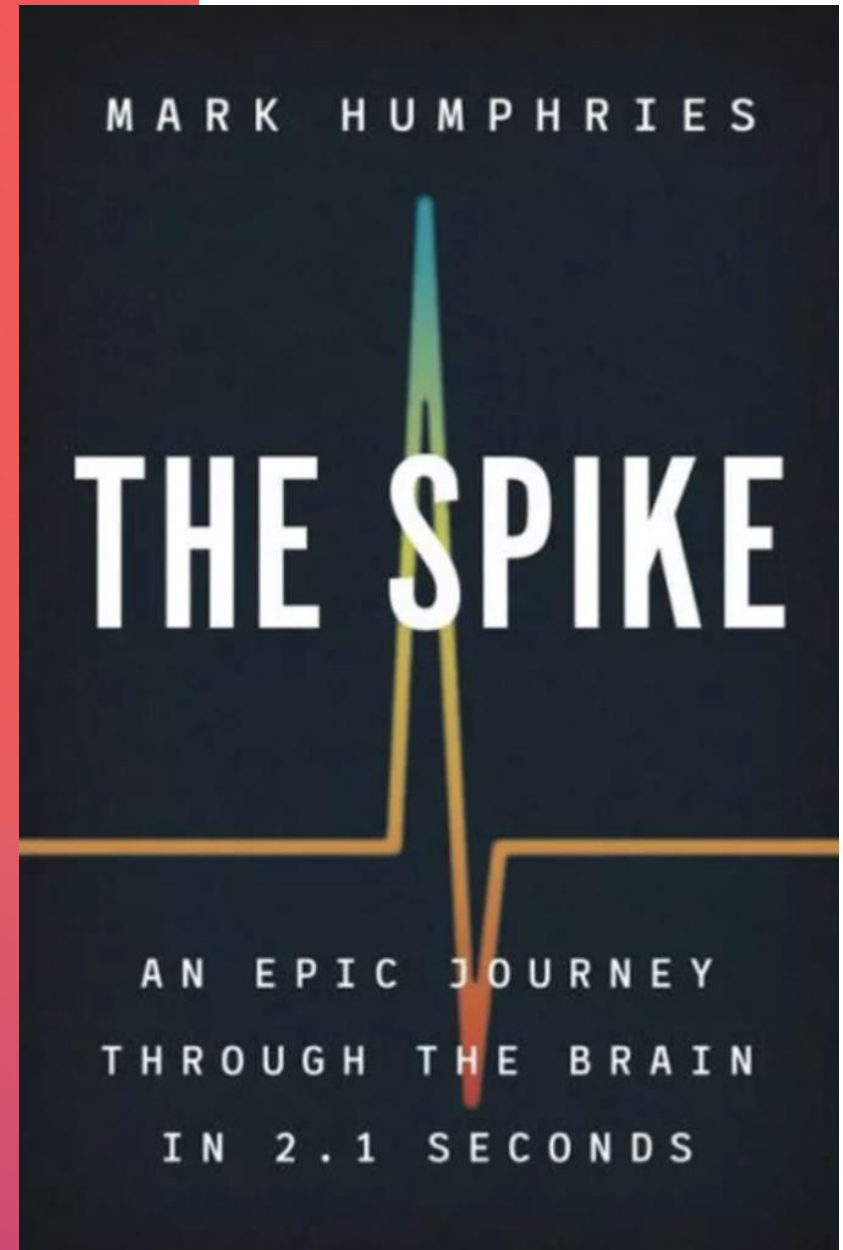
# SUMMARY OF BOOK

## THE SPIKE

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# LAYOUT

- Quick Background
- What is Spike?
- How are spikes generated?
- Spike Failure
- Dark Neurons
- How spike encodes information?
- Experiments and methods in Neuroscience
- Role of spikes in Decision Making
- MYTHS
- Open Questions for research in Human Brain
- End Note

# QUICK BACKGROUND

- In the adult human brain – each nerve cells has about 86 billion neurons
- Each neuron on average connects to ~7500 other neurons
- Neurons communicate with each other by sending electric spikes
- Brain areas share same type of neurons but do different things with the spike sent between them.

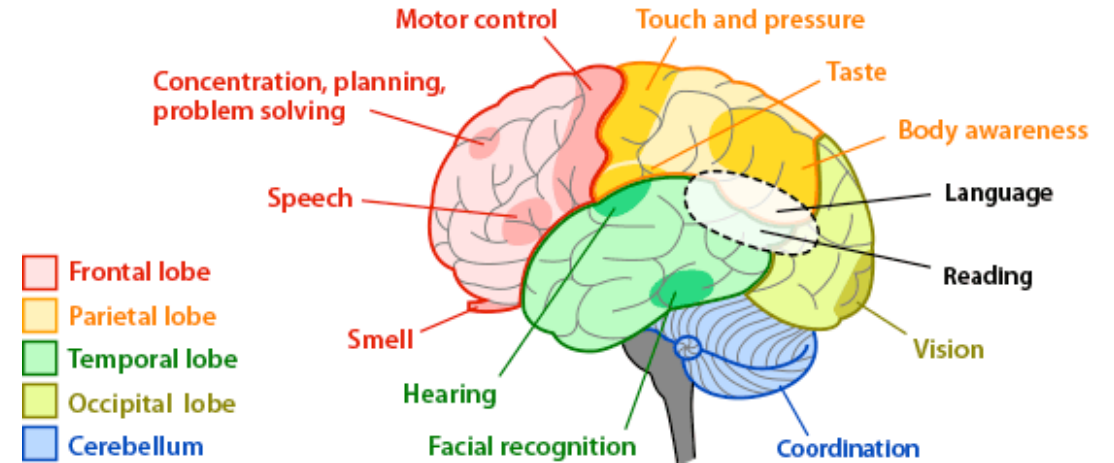


Image Source: <https://askabiologist.asu.edu/brain-regions>

# WHAT IS SPIKE?



Electrical charges are responsible for all brain activity.



There are charged particles, like sodium and potassium, both inside and outside the cell generating these electrical potentials.



Neuron's membrane potential quickly rises values and then drops back to around -65 mV.

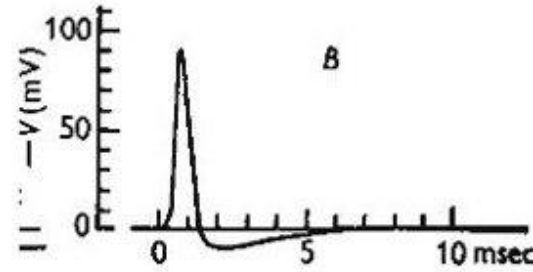


Spikes are changes in the potential difference across the membrane over the time course or signals generated by neurons to communicate with one another.



Some primitive animals and early layers of our visual system don't use spikes.

# HOW ARE SPIKES GENERATED?



This shows neuron action potential - it goes rapidly up in voltage and then back down making a "spike" shape.

Figure from Hodgkin and Huxley, *A quantitative description of membrane current and its application to conduction and excitation in nerve*, The Physiological Society, volume 117, 1952; Wiley-Blackwell Publishing.

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One incoming spike at a neuron is often not enough to generate an action potential.

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It requires hundreds of excess spikes (above the threshold) arriving together to change the spiking behavior of the neuron.

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Our brain's activity never ceases (except when we die), so **the neurons inside the brain are kept "at the edge of firing"** with activations from the incoming thousands of connections from other neurons.

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**For the same input, sometimes they'd fire, sometimes they won't.**

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There are two types of neurons: excitatory and inhibitory

# SPIKE FAILURE

A neuron's spike can have different levels of impact for each of the thousands of neurons it connects to.

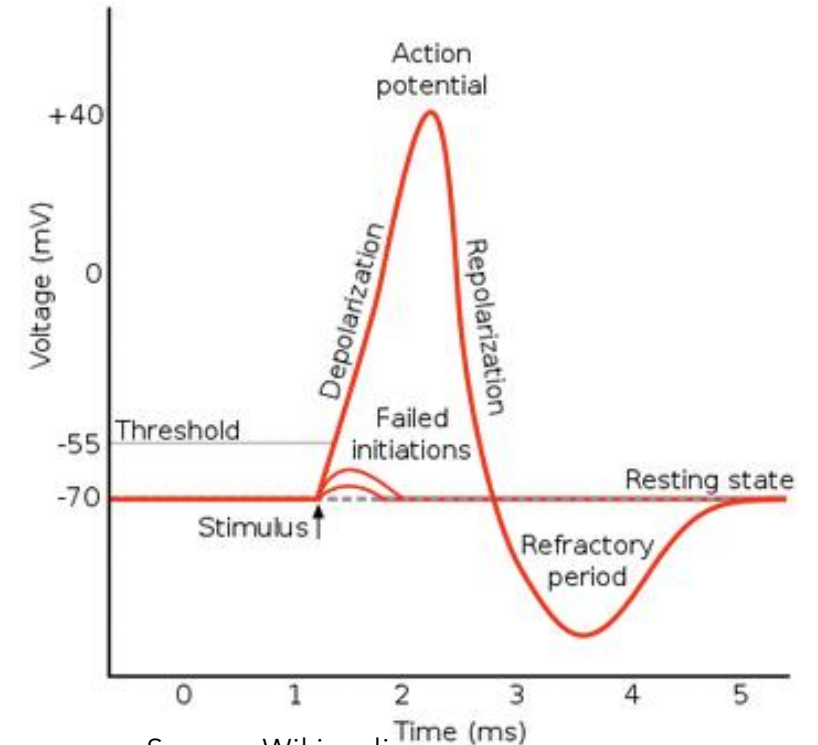
## The failure to produce a spike gives a neuron several advantages

- It helps in dynamically adjusting the "reliability" of input from a neuron (thus spiking only when an incoming neuron is firing at a high rate by requiring successive spikes for action potential to happen);
- Random failures help "overfitting" in the network and hence help in generalization

On average neurons fire at 1 Hz frequency, most neurons don't spike at all.

This implies two things:

- most spikes in the brain are produced by a small percentage of neurons that spike at  $>10\text{Hz}$ ;
- most neurons are "**dark neurons**" - they don't spike at all.



Source : Wikipedia

# DARK NEURONS

- Electrodes into a brain to measure activity and biased towards measuring active neurons.
- Dark neurons make up most of cortex, and do nothing most of the time
- These neurons fires rarely but they vastly outnumber the active neurons
- Do sparse firing ( similar to the concept of spiking neural network in Artificial Intelligence)
- How will we ever detect neurons that don't spike?
  - Only recently modern methods have revealed that most neurons are silent most of the time: neuron imaging
- May be used when brain needs new circuits like learning new information.

## HOW SPIKE ENCODES INFORMATION?

**Spike rate coding** : More spikes to certain info and no spike for other

- For example, a neuron in the visual cortex might increase its firing upon seeing left to right moving figures while decreasing it for the right to left.

**Spike time coding**: a neuron encodes information in the time delay between two successive spikes.

- For example, Sensory system -> if someone falls but feels pain later .

**Brain uses both types of codings** in different neural circuits for different functions.

- For example, neurons near the sensory organs rely more on timing while the cortex neurons that do computation rely more on spike rates.



# EXPERIMENTS AND METHODS IN NEUROSCIENCE

- What Experiments?
  - Work done on animal model
  - Human models still not possible
- What methods?
  - Statistical Methods
  - Bayesian Methods
  - Animal models is using Machine Learning for analyzing and predicting the outcomes
  - Researchers can predict the decision making in the task like left or right movements in rats (EEG/chemicals)



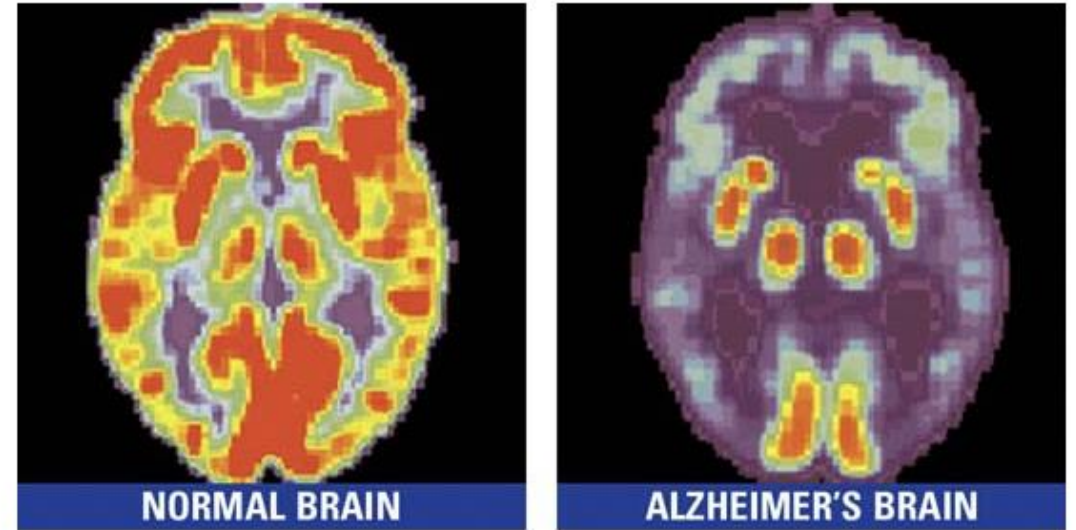
# ROLE OF SPIKES IN DECISION MAKING

**Population Encoding:** The collective encoding of a population of neurons that may encode the representation of the task.

- Quickly decision made -> More spike generated
- Neurons fire before the stimulus task
- Allows learning through feedback loops
  - E.g. Circuit does not fail if one neuron doesn't fire.

# MYTH : 10% OF BRAIN USED

- If the 10% myth is instead supposed to mean that humans only use 10% of their brain in a given moment, it is still false
  - If 90% of the brain were not used, then 90% of the brain tumors would cause no problem
- The brain is not a collection of independent machines that are turned on or off depending on whether you are reading or singing.
- Healthy humans use all of their brain. There is no part of the brain that goes unused. Certain tasks work certain parts of the brain more, but they all play important roles



PET scans show the disease's devastation through the disappearance of the bright reds and yellows that indicated intense brain activity.

Image Source: <https://www.brainandlife.org/reports/advanced-imaging-can-now-detect-changes-that-foreshadow-alzheimers-years>

# OPEN QUESTIONS FOR RESEARCH IN HUMAN BRAIN

- How neurons separates info b/w language, math, music etc. / How is information encoded by neurons?
- Why do we sleep and dream?
- EEG/fMRI/MRI tells us group level neurons activity, but single level neuron is far away.
- Human consciousness still unexplained.

# END NOTE

- Spiking neural network and other neural networks in Artificial Intelligence all inspired by brain networks.
- Computer vision inspired by mammalian visual system.
- As neuroscientists uncover more secrets about the brain (increasingly aided by the use of computers), engineers can take more inspiration from the working of the brain to further improve the architecture and performance of computers.

**THANK YOU**

ANY QUESTIONS ?

