COMS30017
Computational Neuroscience

Week 1 / Video 4 / Neuronal computation and communication

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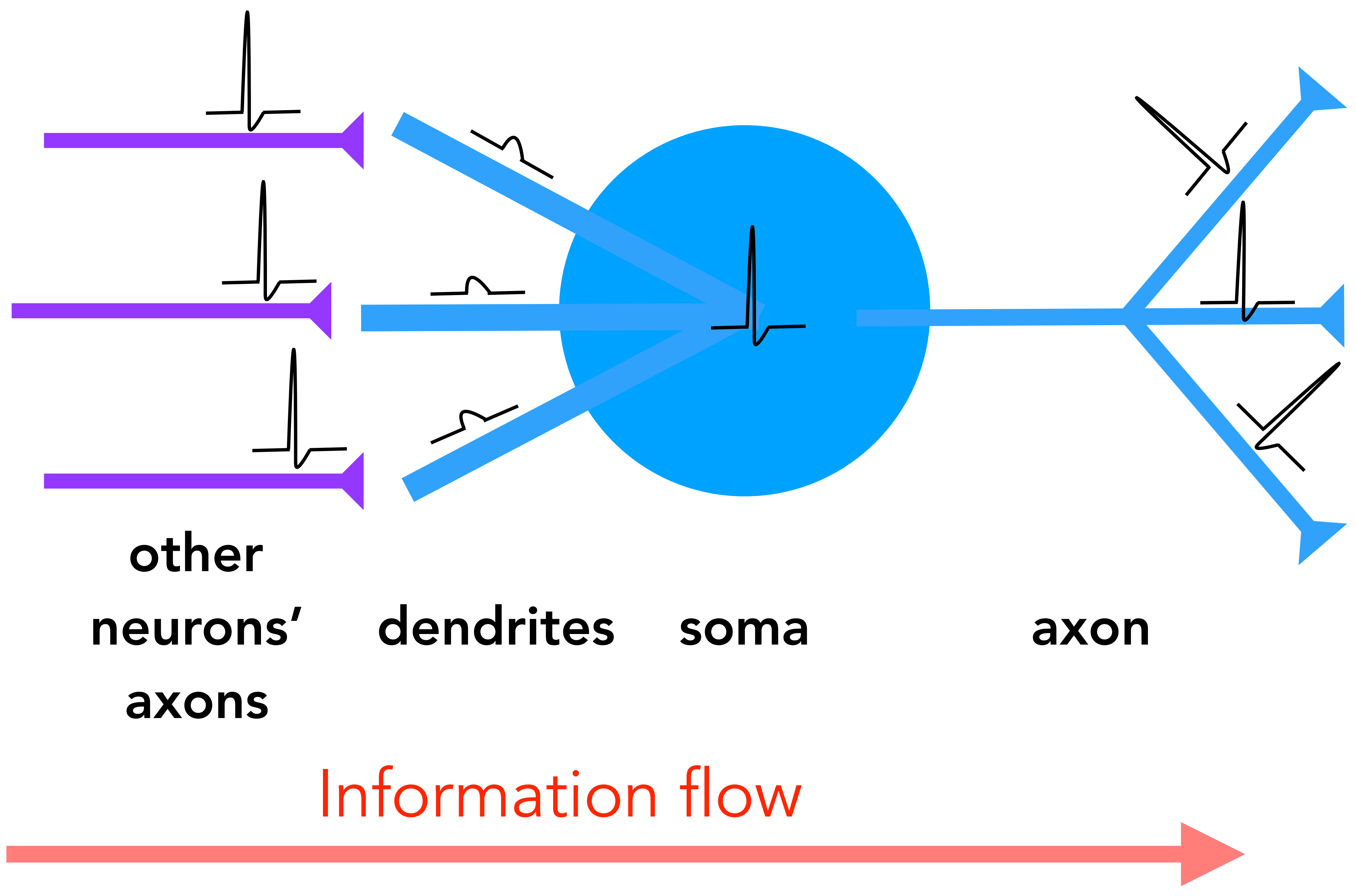
Intended learning outcomes

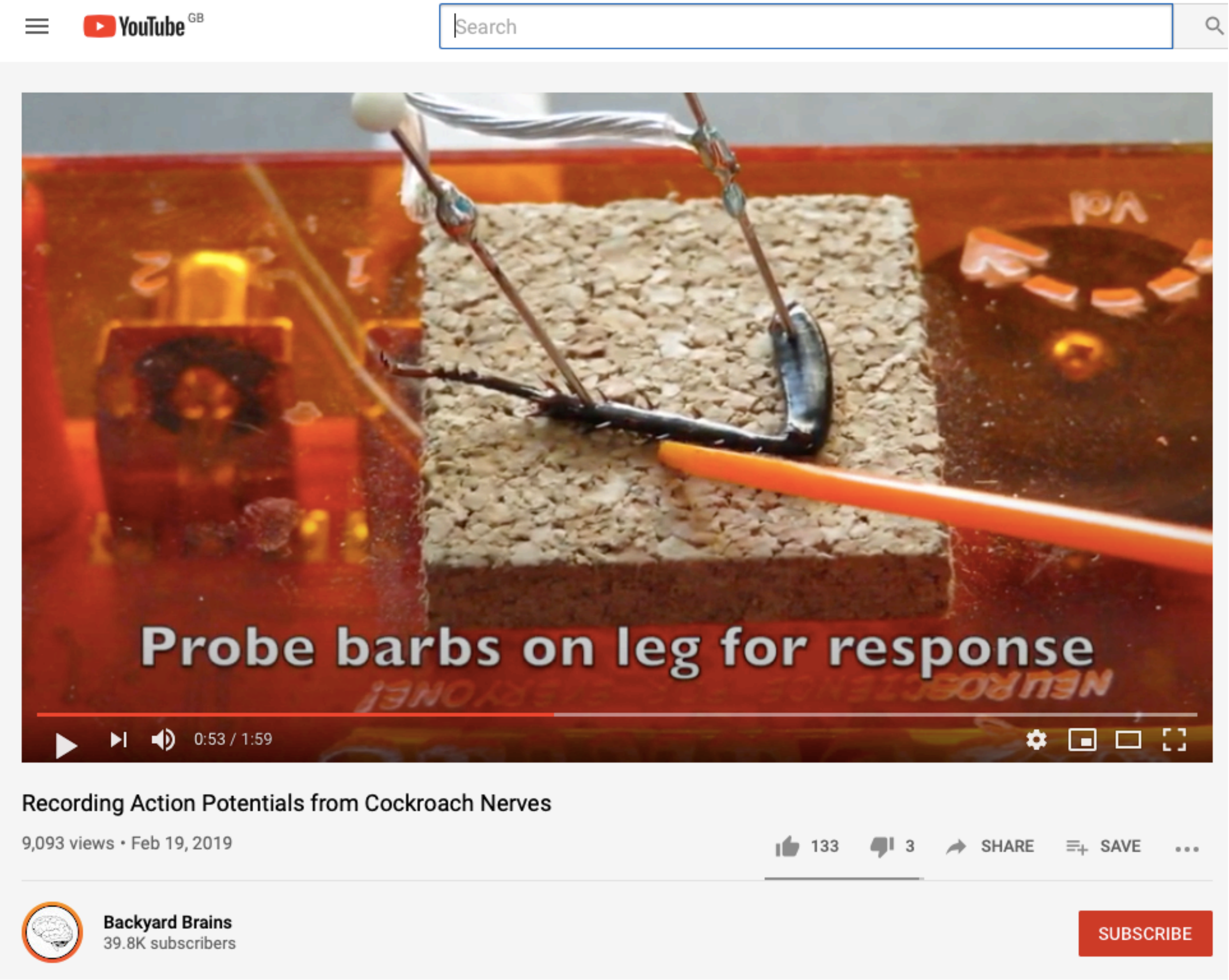
- Gain a basic understanding of the input-output function of a neuron.
- Understand the difference between a post-synaptic potential and an action potential.
- Distinguish between feedforward and recurrent neural networks.

Information flow in single neurons

- Input from other neurons arrives at the synapses.
- Each synapse triggers a small post-synaptic potential (PSP) in a dendrite, roughly 1mV in amplitude and 10ms duration.
- The somatic voltage sums all these PSPs (both excitatory and inhibitory).
- If the soma's voltage reaches a threshold (around 20 mV above rest), the neuron emits an action potential or "spike". The spike itself is around 100mV in amplitude and 1-2 ms in duration.
- Copies of this spike travel down the axon to target neurons.
- Each spike is stereotypical, information is encoded only in their timing and frequency.



Backyard brains video of cockroach nerve spikes



https://youtu.be/zkE7wA1F6aU?t=53 **Sound on!**

Where is the computation?

- Roughly speaking, the fundamental computation that neurons do is weighted sum of their inputs, followed by a threshold:

$$y = \Theta\left(\sum_i x_i w_i\right)$$

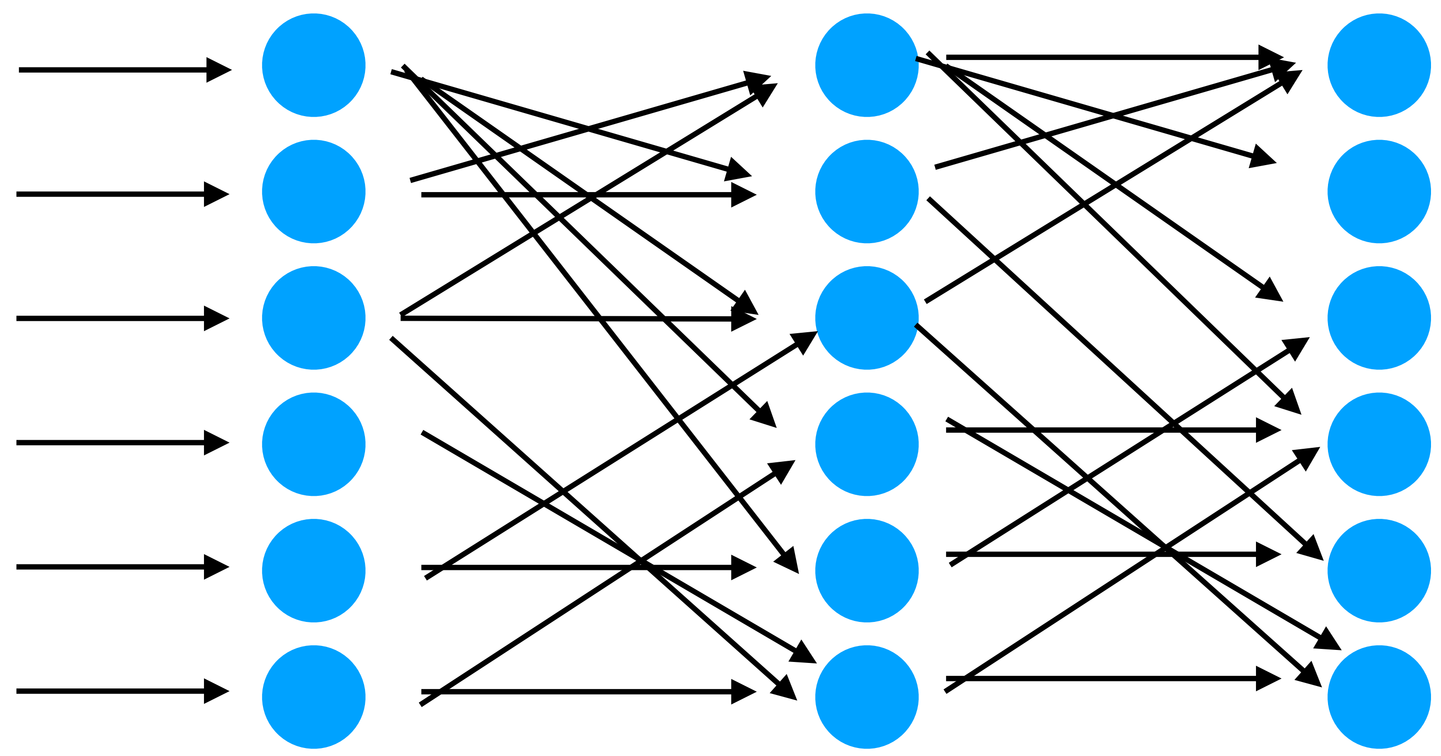
output threshold inputs synaptic weights

- However please remember that this model — although common — is a gross simplification of reality! The input-output function is also affected by:
  - other nonlinearities (at the synapses and dendrites)
  - dynamics (the recent past affects the current output)
  - noise (unavoidable randomness and stochasticity).

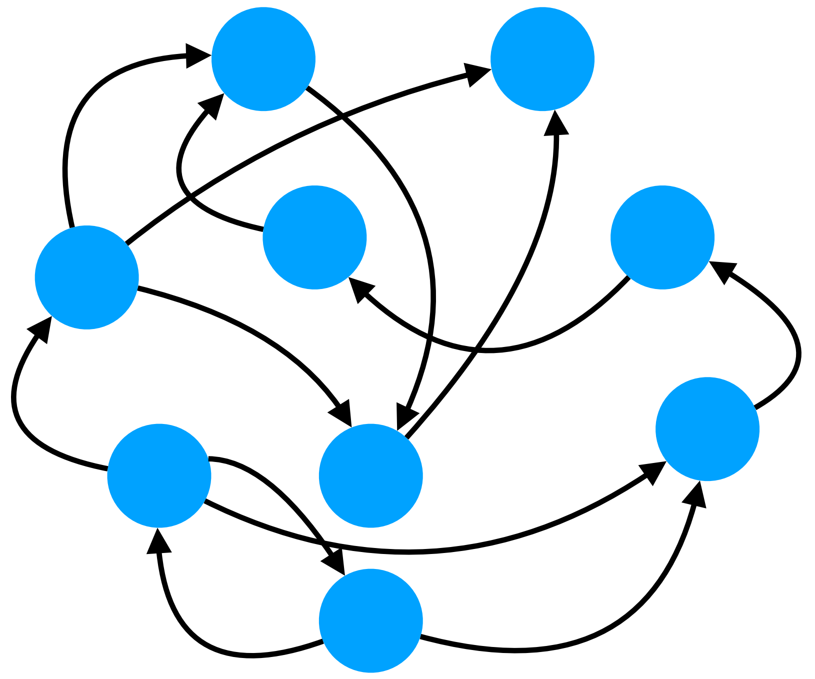
Networks of neurons

- The real computational power of the brain comes from hooking together lots of neurons.
- There are two common architectures for neural networks models:
  - Feedforward (no loops, neurons can be organised in sequential layers).
  - Recurrent (contains feedback loops).
- Feedforward networks are much easy to study and understand but are rarely accurate models for a brain circuit. Often used as a starting point for modelling.
- Recurrent networks are computationally more powerful, but harder to reason about and control. The real brain is very recurrent.

Feedforward network



Recurrent network



Test yourself questions

- Which is bigger, the post-synaptic potential or the action potential?
- What is the key nonlinearity in the neuron’s input-output function?

Summary

- Information flow within a single neuron is (mainly) unidirectional: from synapse → dendrite → soma → axon.
- A single neuron take input signals from many other neurons, does a weighted sum, thresholds, and sends this one output signal to all its target neurons.
- Neural networks come in two basic flavours: feedforward and recurrent.