Summary Presentation of

Cortical Computing with Memrisitve Nanodevices

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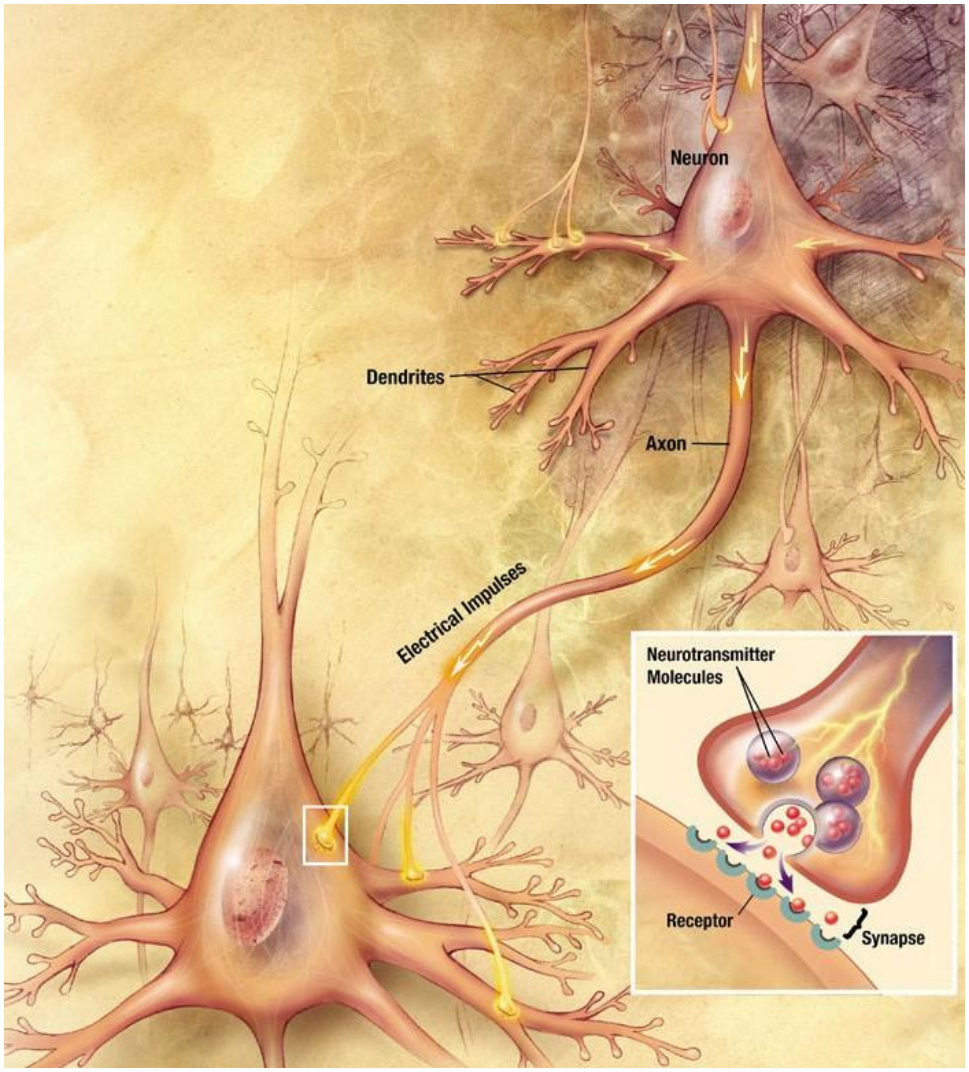
Overview of Topics

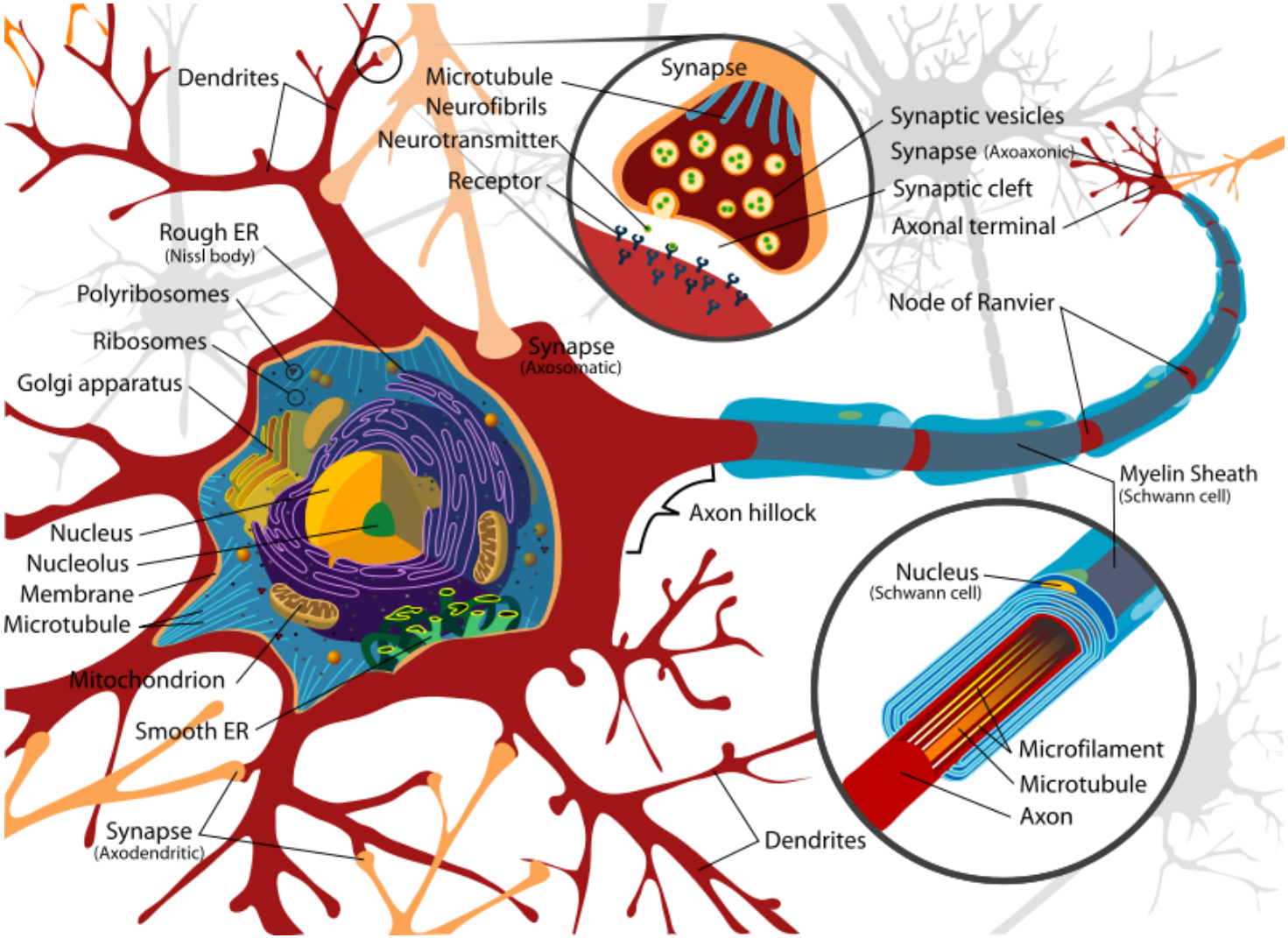
- Quick refresher on real neurons
- Reminder of artificial neural networks
- Memristors
- Memristor-based neural circuits
- “Cortical Computing”

Neurons are nervous system cells



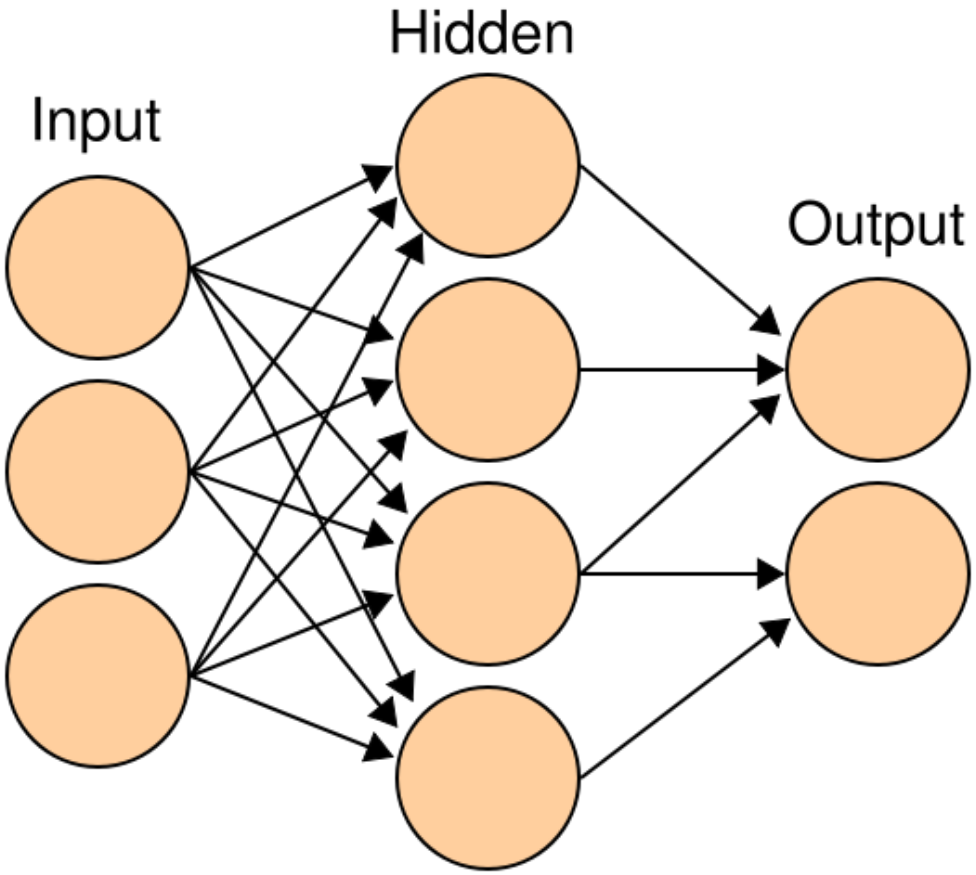
- Neuron body receives signals from other neurons
- **Synapse** is connection point between neurons
- Synapse can be electrical or chemical
- **"All-or-none" principle**

More detailed makeup of a neuron



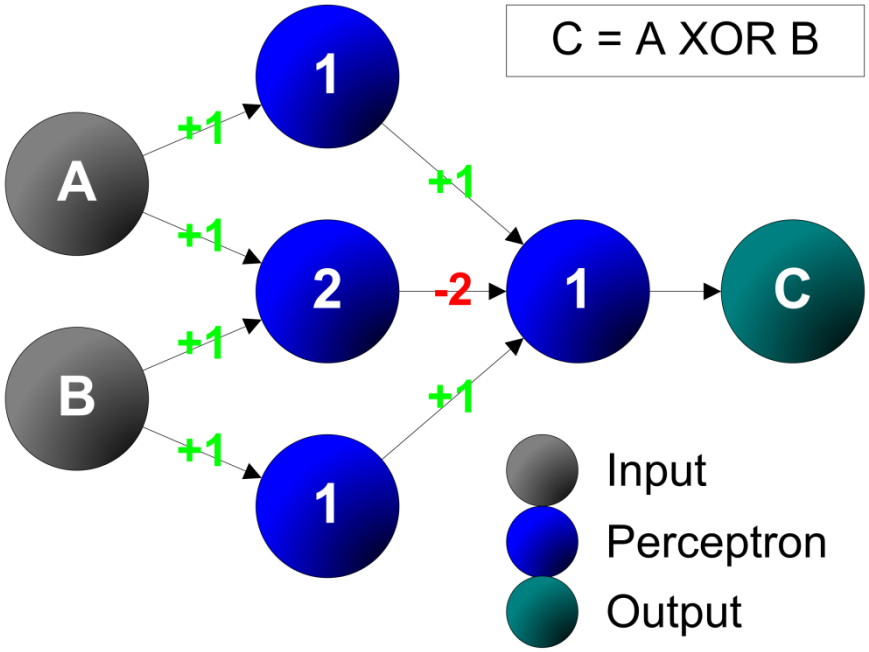
Artificial Neural Networks

- Computational model that simulates real neurons
- Inputs send signals through hidden layer
- Hidden layer weighs inputs and gives outputs based on those inputs
- This yields actions akin to neurons



Artificial Neural Net Example

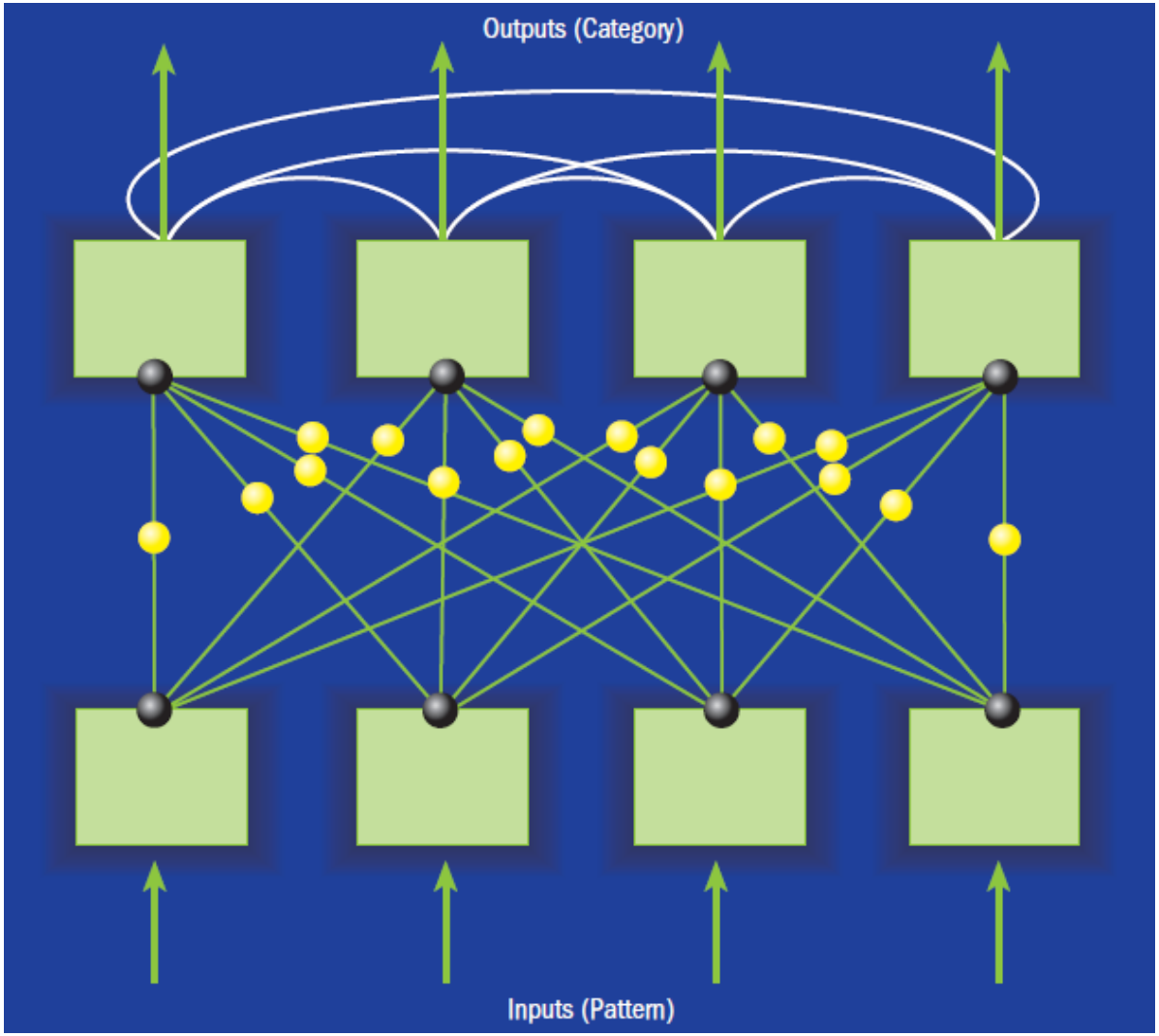
- Artificial Neural Networks can be used to do full-fledged computations
- This perceptron example requires designer to know a truth table.



- Would like to have a circuit that trains itself based on examples

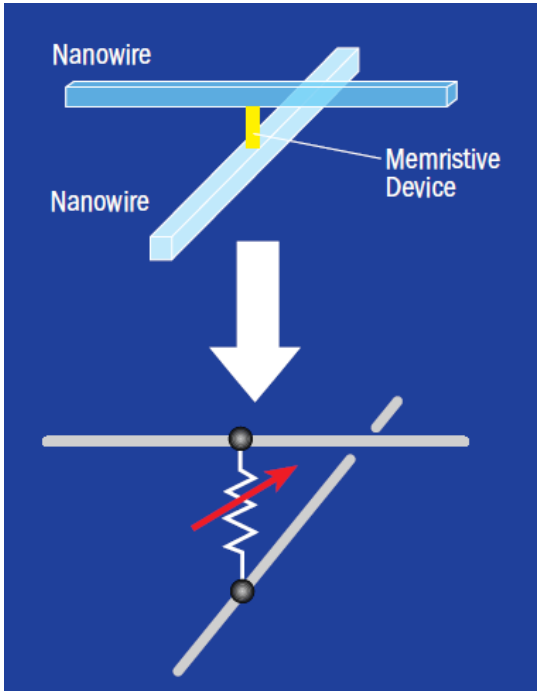
Pattern Recognition ANN

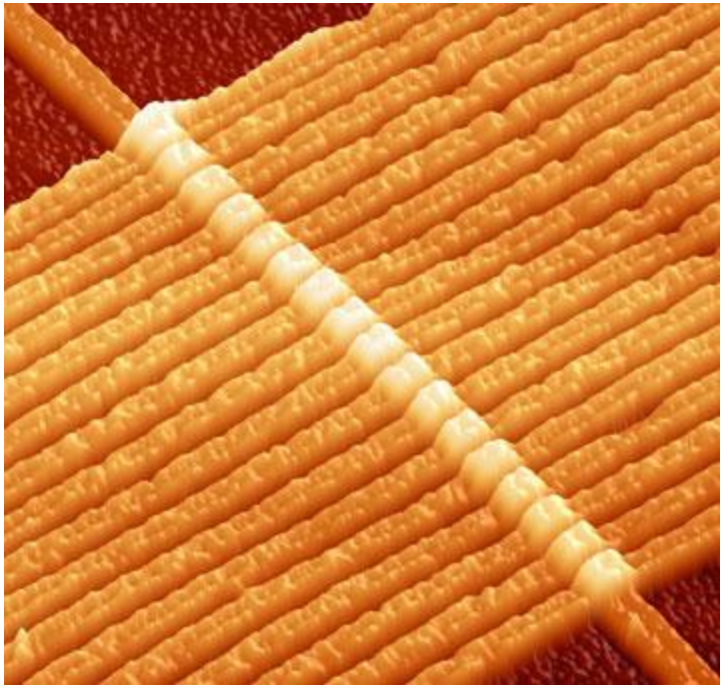
- "Neurons"
- "Synapses"
- Pattern
- Excitatory inputs
- Inhibitory inputs
- Categorization



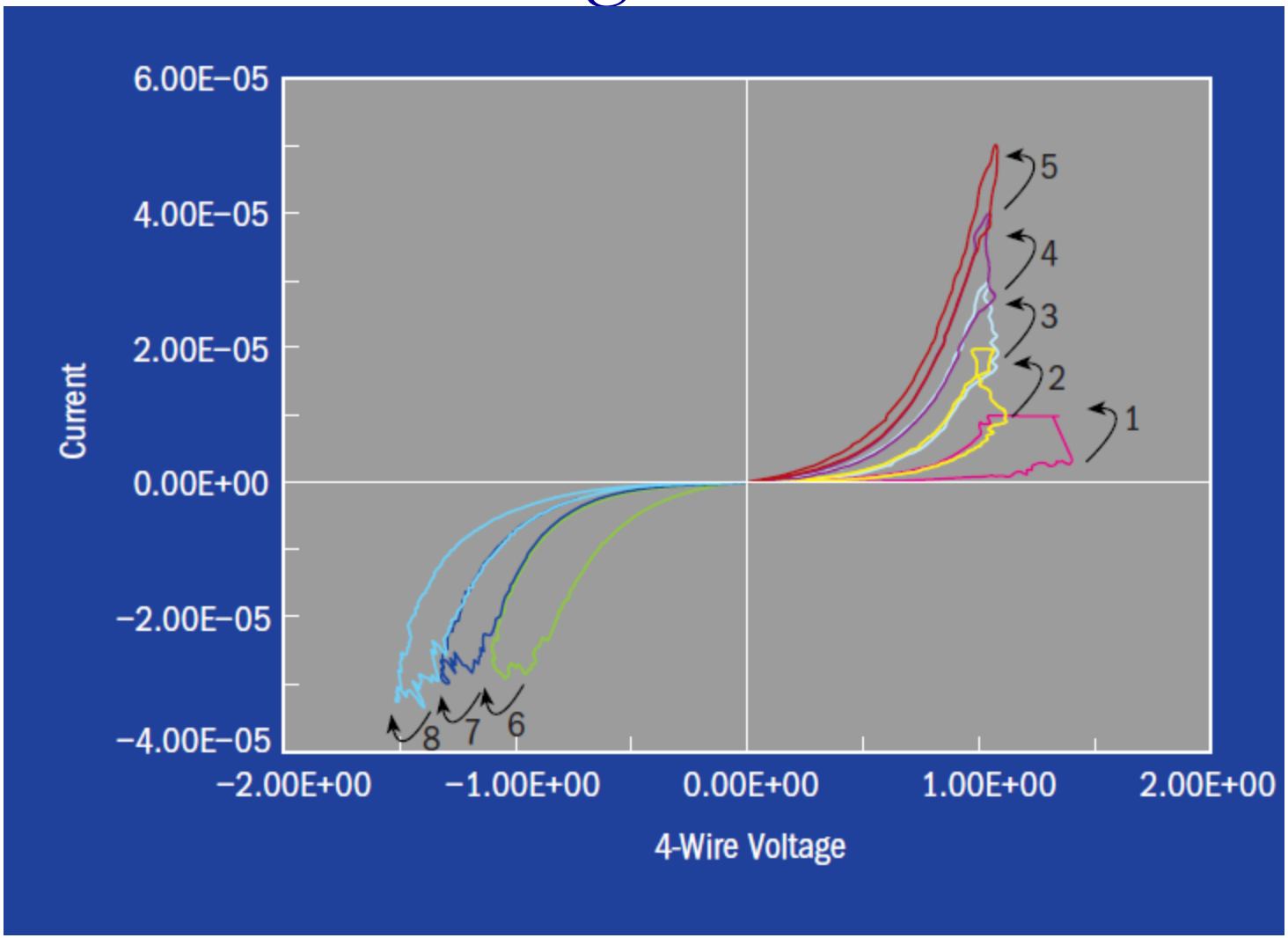
Memristors

- Passive two-terminal devices
- Basically: Variable resistance as a function of voltage previously applied





Memristor Learning Behavior



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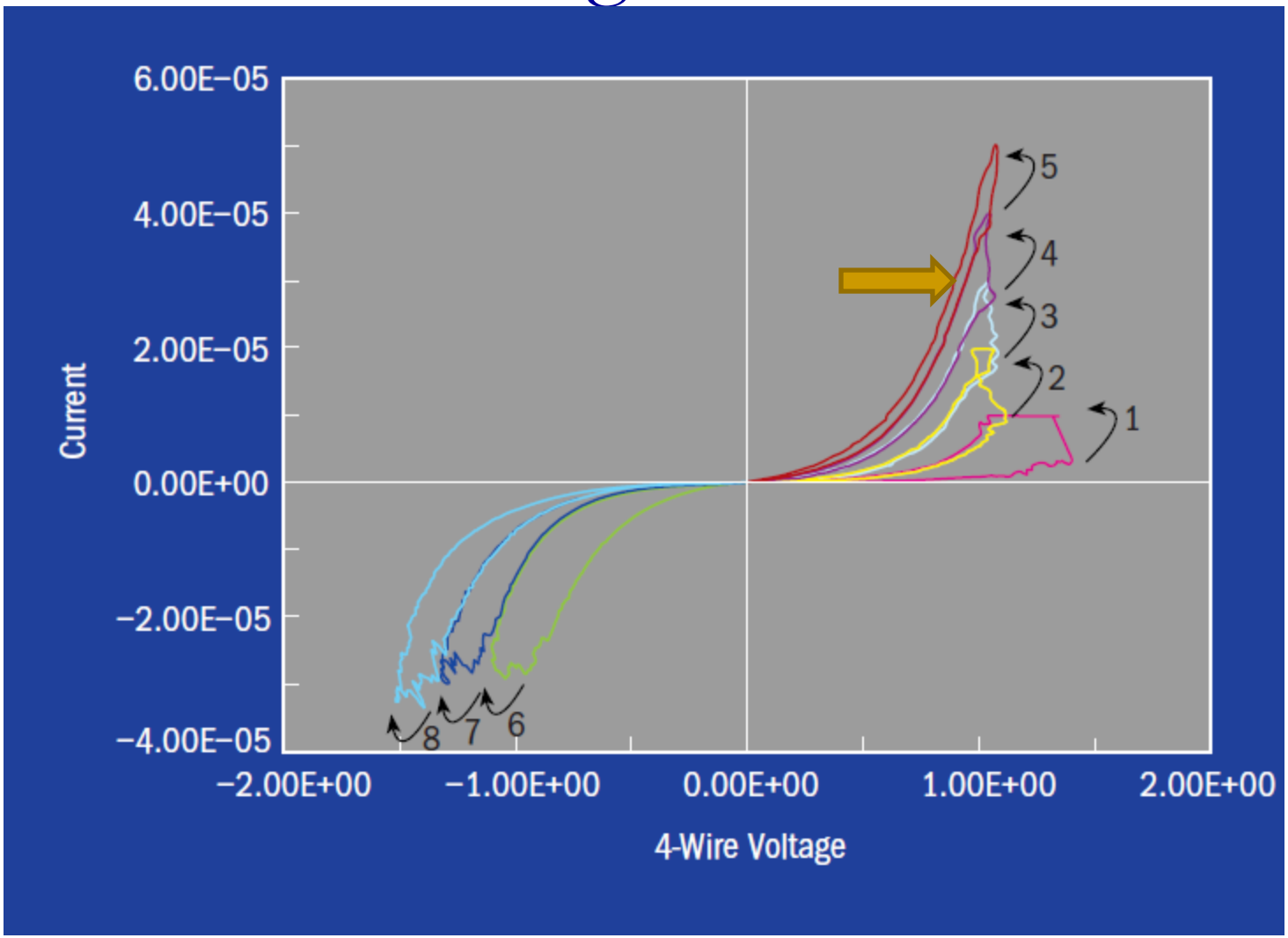

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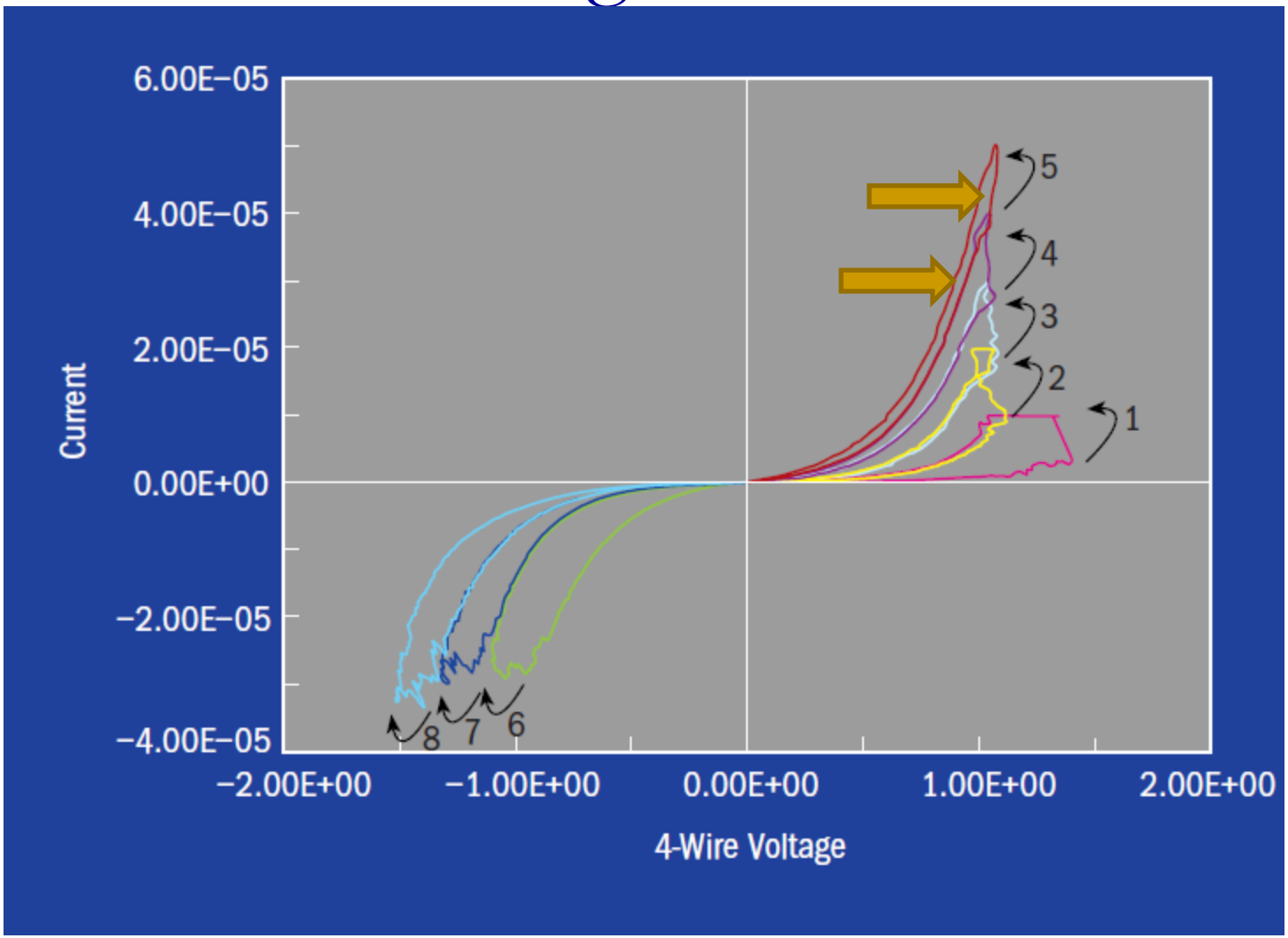


Utilizing Memristors for ANN Synapses

- ANNs can use memristors as artificial synapses
- Resistance changes signal strength between input & output neurons
- Memristors allow learning to take place utilizing only two terminals

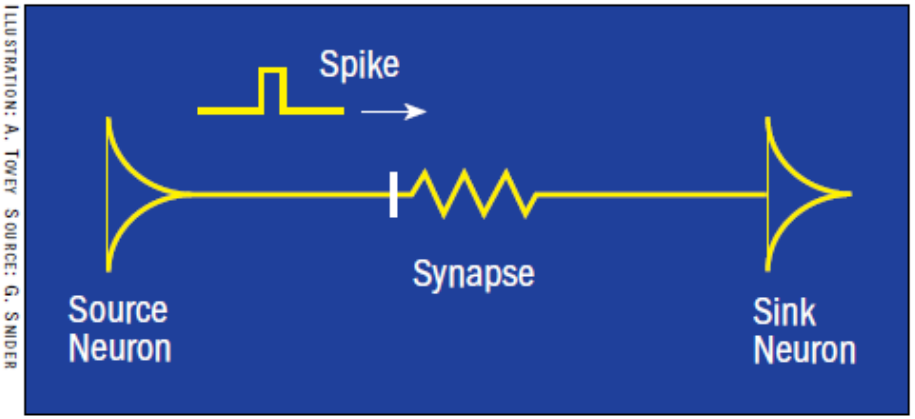


Figure 3. *A source neuron sending a signal, a "spike," through a synapse to a destination neuron.*

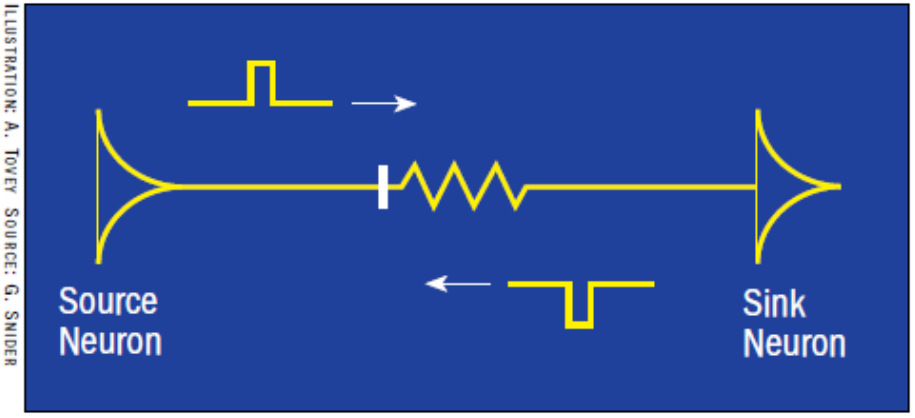
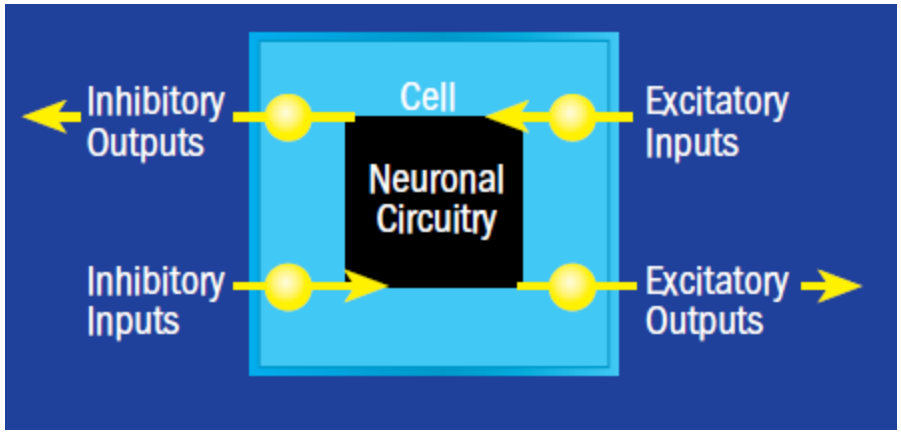
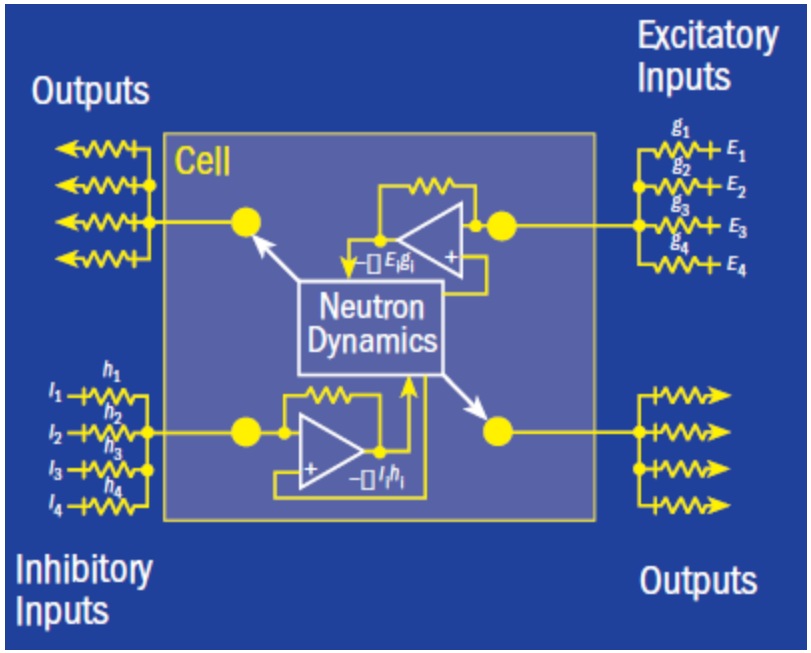


Figure 4. *Correlational learning in memristive*

Artificial neurons as a circuit

- Two inputs (inhibitory/excitatory)
- Two outputs (inhibitory/excitatory)
- Some calculation core





- Example of this as a computational neuron with memristors

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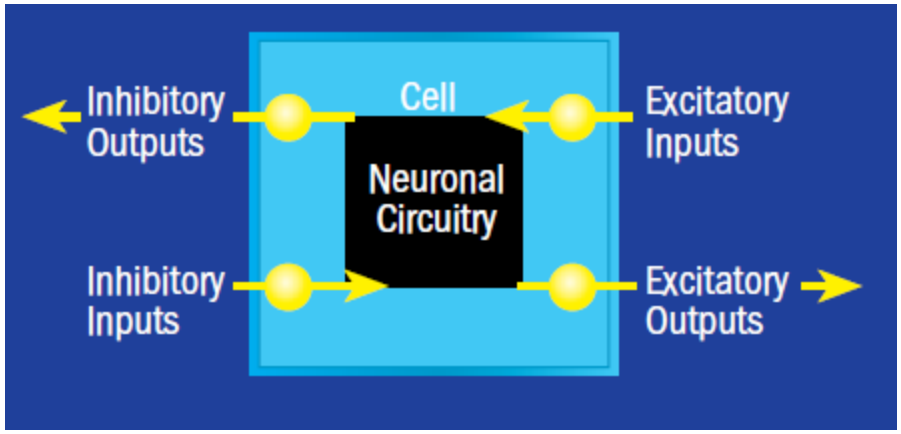

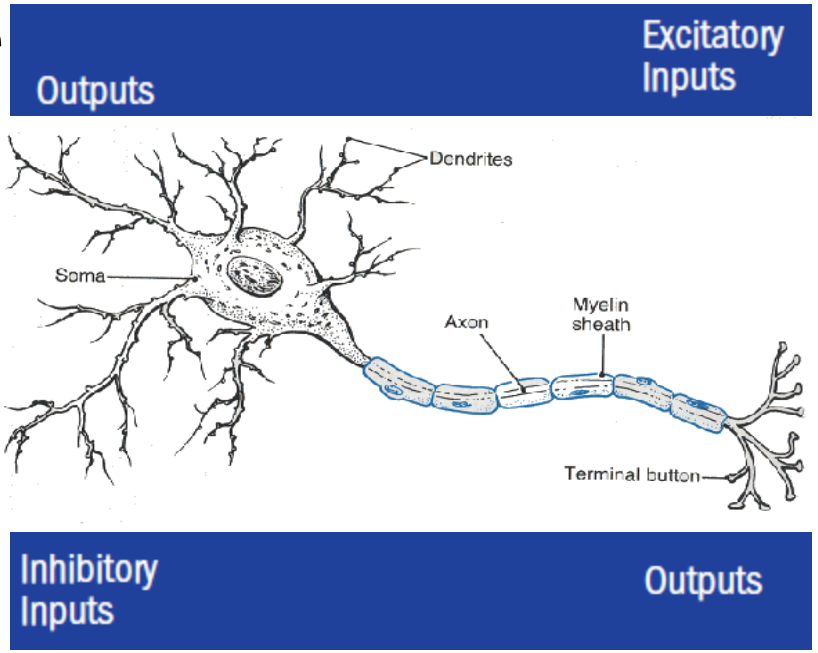

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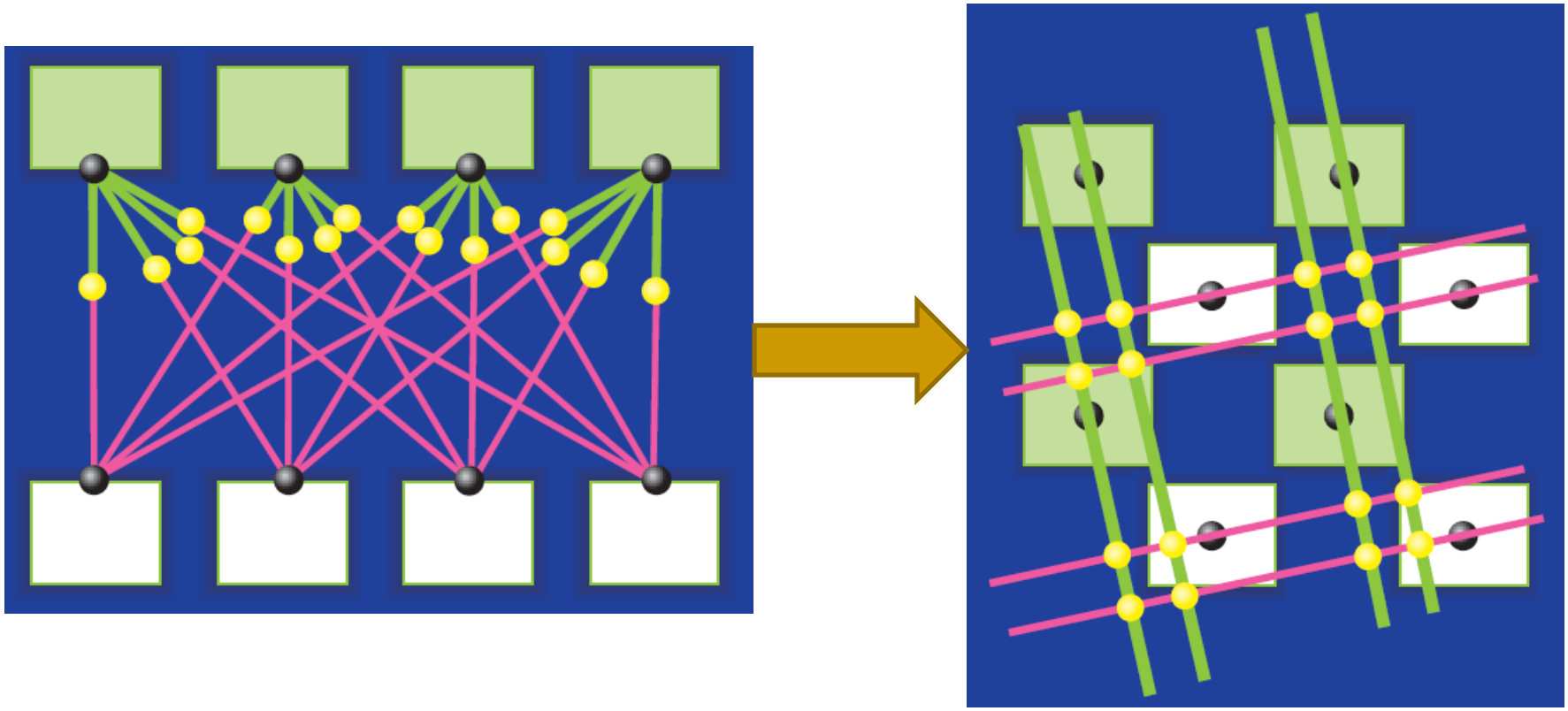
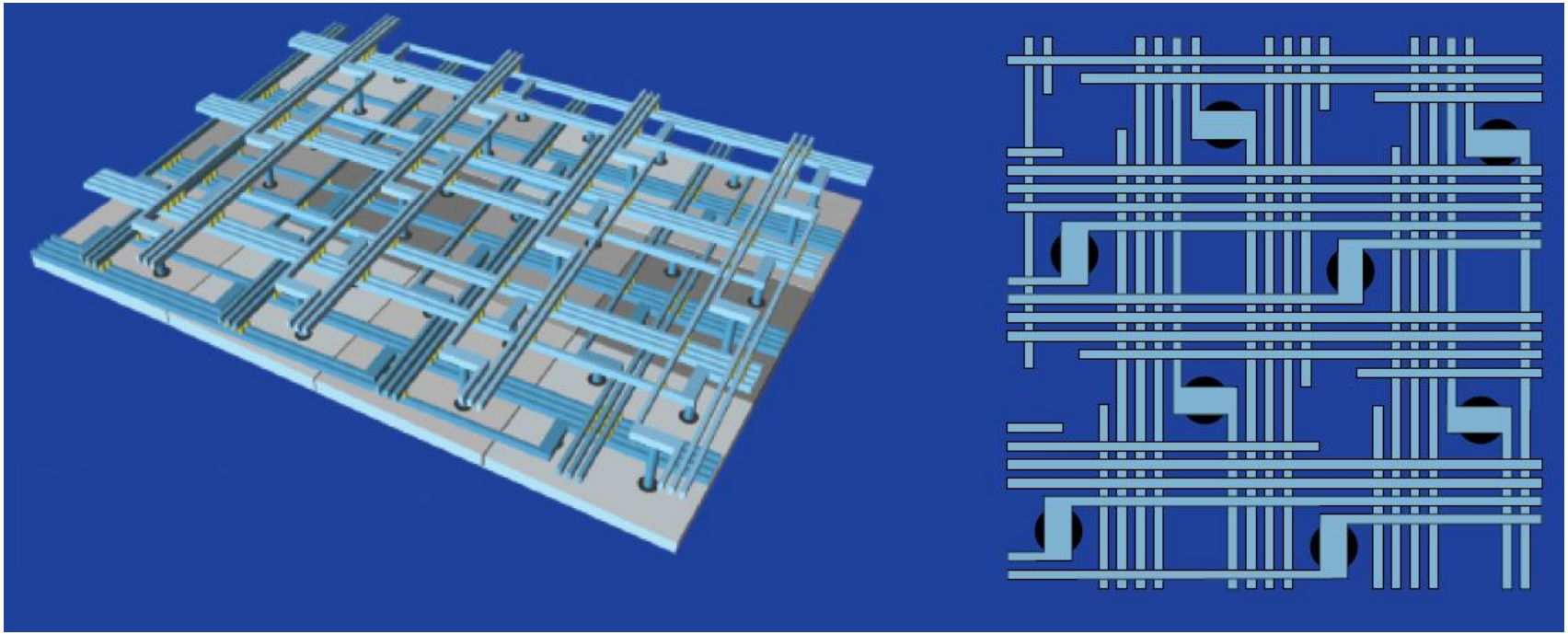
Building circuit on silicon

- Lay out circuit to use multiple metal layers
- Each neuron circuit fabbed in regular CMOS

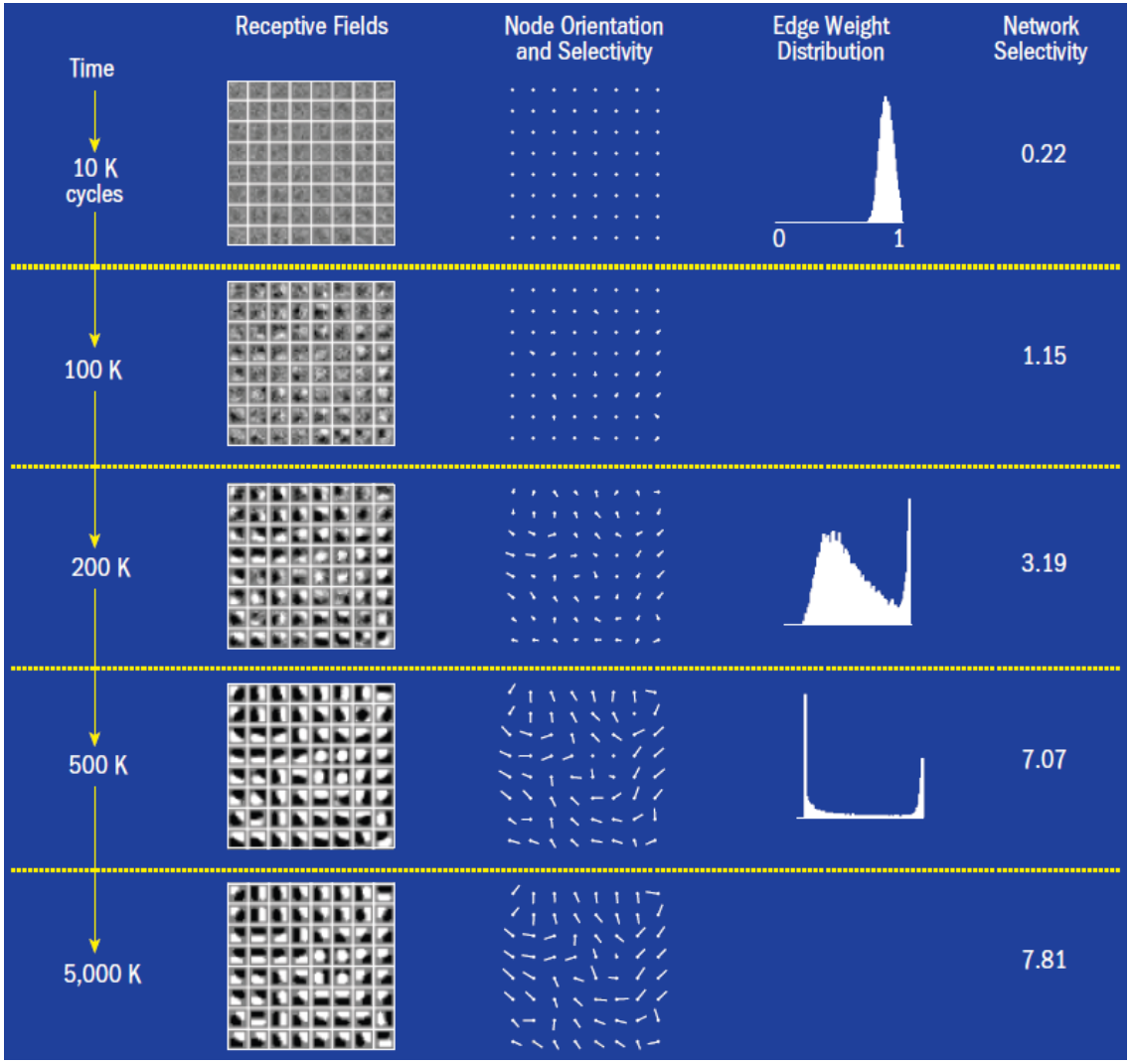


Layout of an entire neural network

- Build entire cortex structure using Neurons (boxes/circuits), axons & dendrites (wires), and synapses (memristors/wire crossings).



Neural circuitry doing pattern recognition



Cortical Computing

- *"People confuse these kinds of networks with neural networks," … But neural networks - the previous best hope for creating an artificial brain - are software working on standard computing hardware. "What we're aiming for is actually a change in architecture,"*
  -- from “Memristor minds: The future of artificial intelligence”