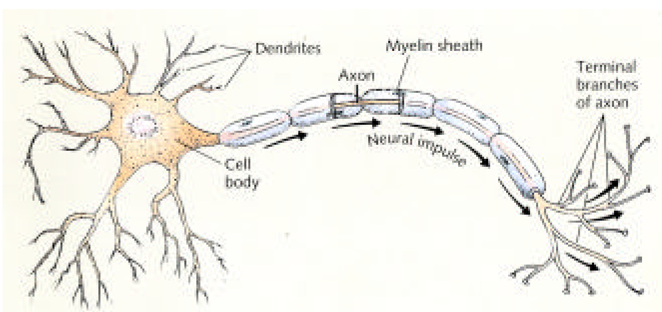
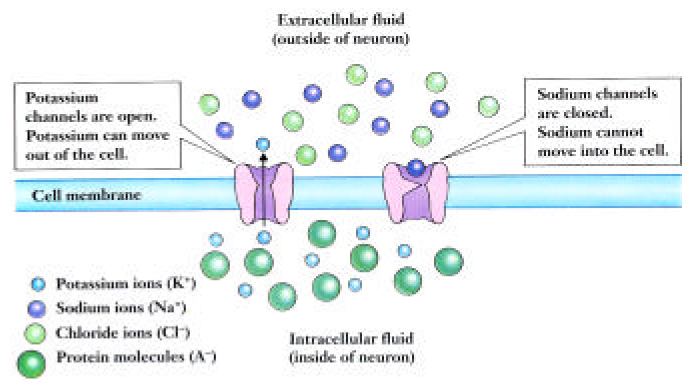
Neurons and Neural Computation

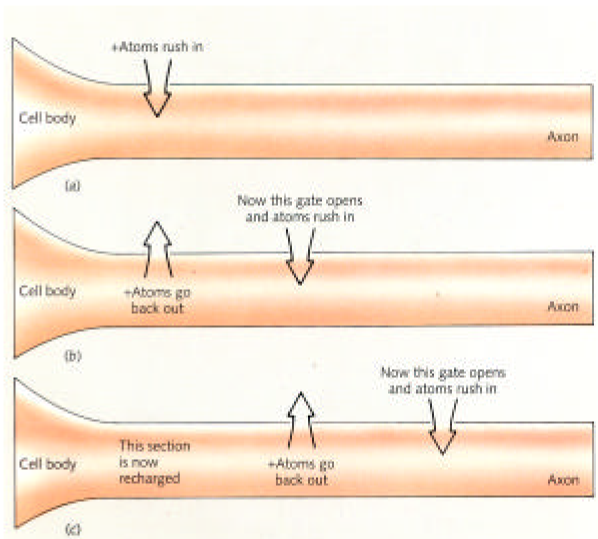
Neurons and Neural Computation

- I. Importance of Neural Computation
  - – Neuroscience: What brain tissue does.
  - – Computational theory of mind: Implementing elementary information processes.

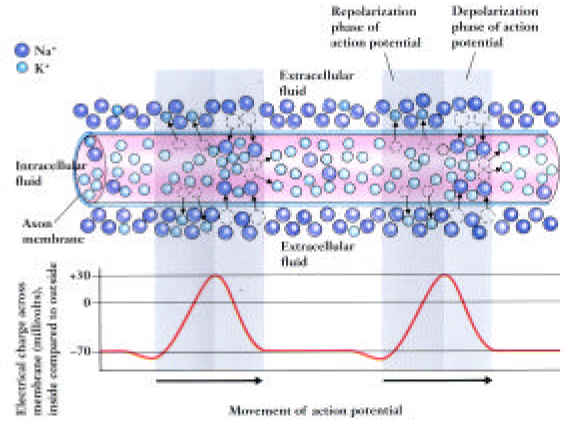


The Resting Potential

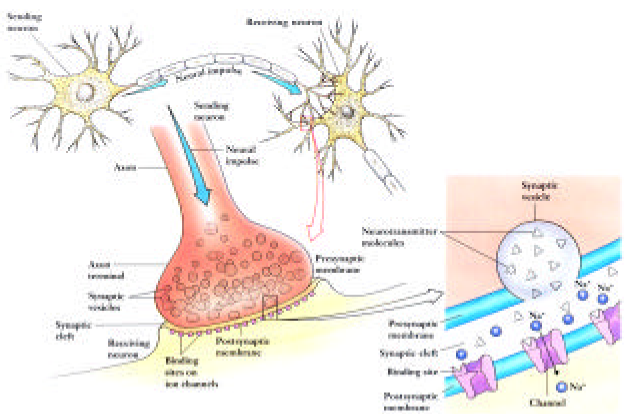




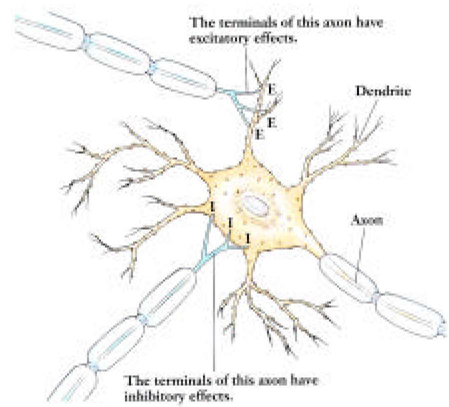
The Action Potential



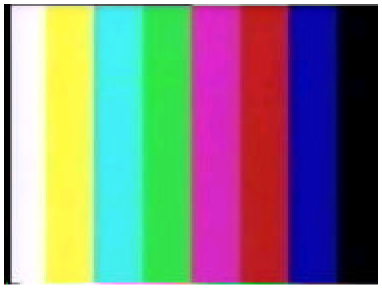
Synaptic Transmission



Excitatory and Inhibitory Synapses



Feature Detectors

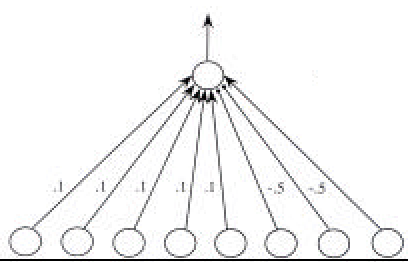


Neural Computation

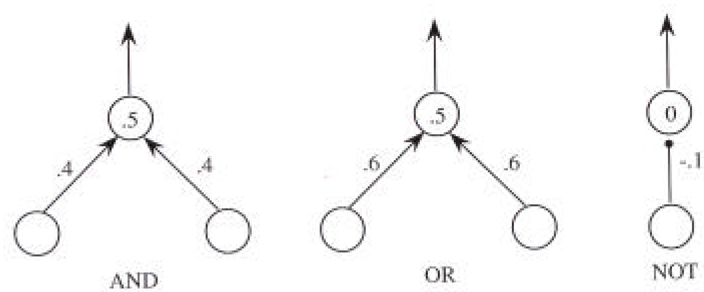
- Computing logical functions with neurons.
  Kosher =
  {[Chews its cud] AND [Has cloven hooves]}
  OR
  {[Has fins] AND [Has scales]}

Neural Computation

- Multiply each input signal by the "weight" (strength) of the synapse.
- Sum the weighted signals.
- If they exceed the cell's threshold, fire.

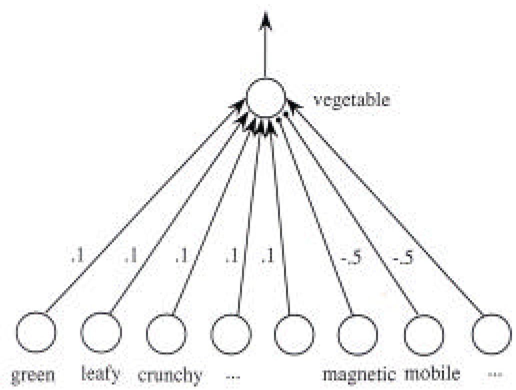


Building Logic Gates out of Neurons



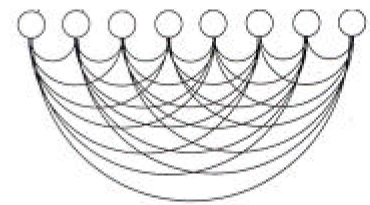
Neural Computation, continued

Aggregating statistical evidence with neurons.

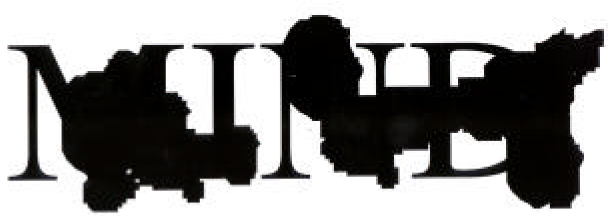


Local vs. Distributed Representations

- Local representation: “grandmother cell,” “yellow Volkswagen detector”
- Distributed representation; “auto-associator”:



Pattern completion by auto-associators:



Learning in Neural Networks

- **Neural Computation:**
  - Multiply each input signal by the "weight" (strength) of the synapse.
  - Sum the weighted signals.
  - If they exceed the cell's threshold, fire.
- **Neural Learning:**
  - Change the weights of synapses.
  - Change the thresholds of cells.

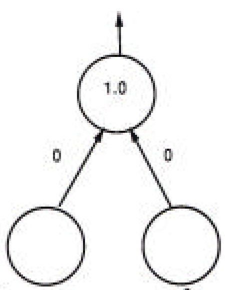
Learning in Neural Networks, continued

- Real but simple example of learning in a neural network: Aplysia (sea snail). See textbook.
- More complex but still hypothetical form of neural learning:

Perceptron Learning Procedure

- Compare current output to correct output (from "teacher").
- If too low, increase weights for active inputs, and decrease threshold.
- If too high, decrease weights for active inputs, and increase threshold.

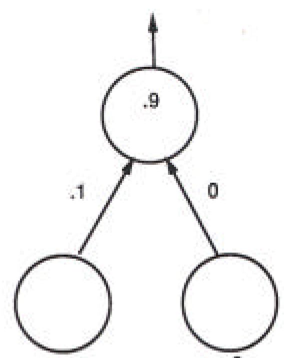
How a two-layer network can learn "OR" with the perceptron learning procedure.



Input: 1 0

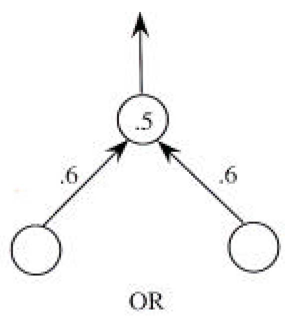
Correct Output: 1
Actual Output: (1 X 0) + (0 X 0) = 0. 0 < 1.0. Therefore 0.

Too small.
Increase first weight by .1.
Leave second weight alone.
Decrease threshold by .1.



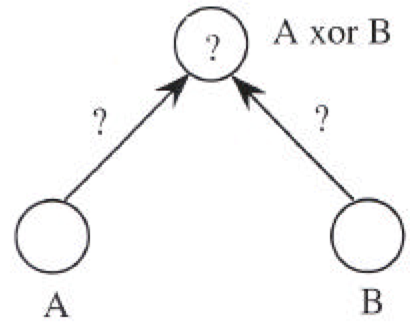
Input: 1 0
Correct Output: 1
Actual Output: (1 X .1) + (0 X 0) = .1. .1 < .9 Therefore 0.

Too small.
Increase first weight by .1.
Leave second weight alone.
Decrease threshold by .1.

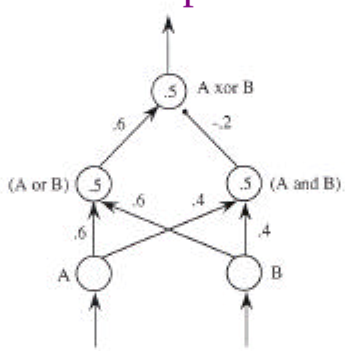


Neural Computation, continued

Why a two-layer network cannot compute "XOR."



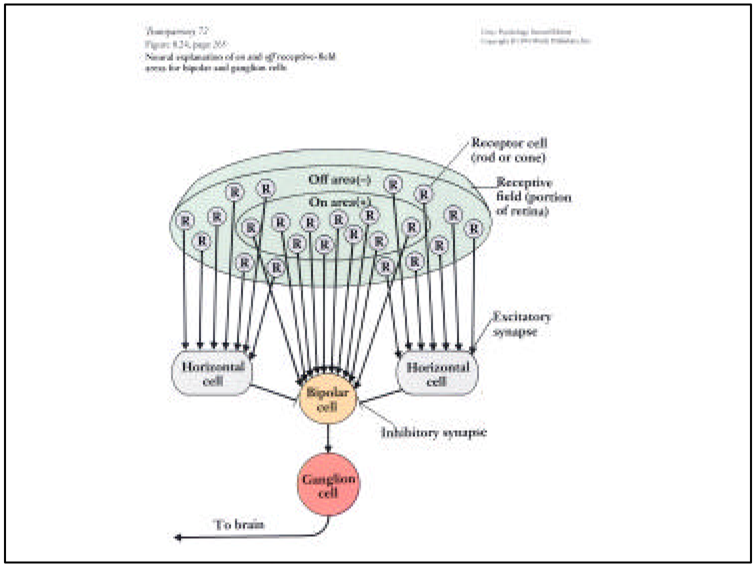
A 3-layer network that *can* compute XOR:

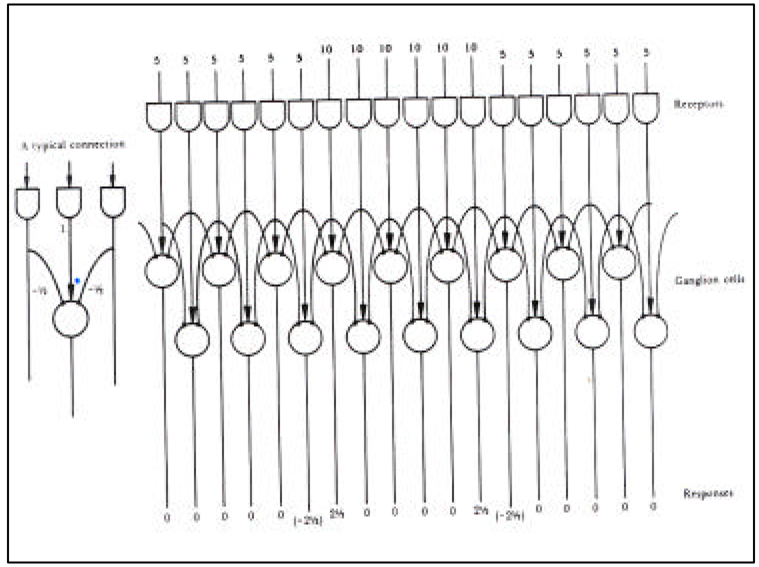


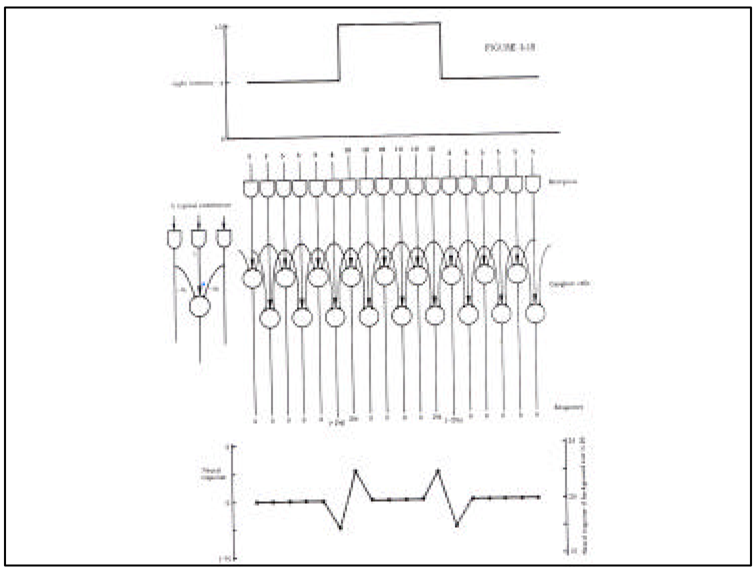
But: A three-layer network needs a fancier learning procedure: "Error back-propagation."

Relating Neural Networks to Psychology

- Lateral inhibition: Turn on your own output; turn down your neighbor's output.



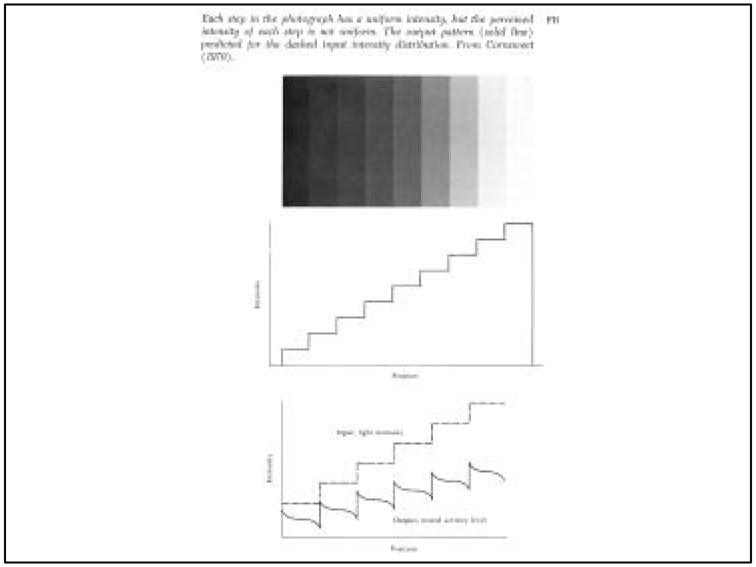


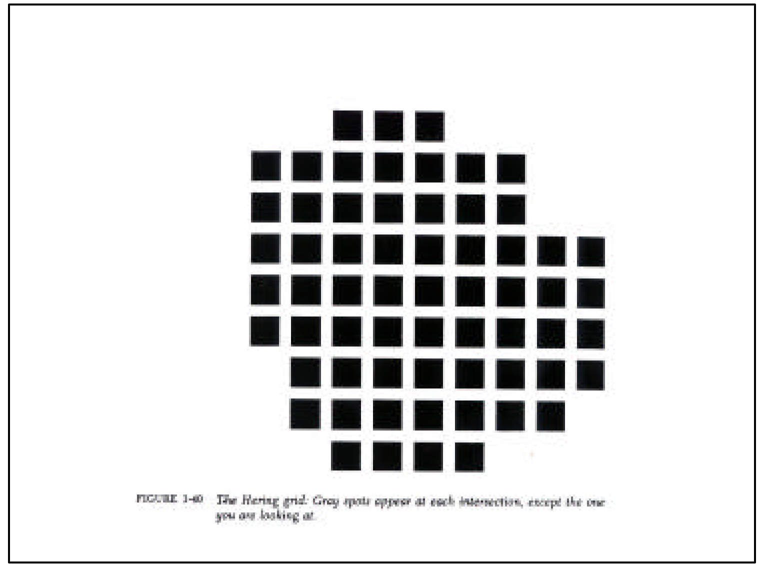


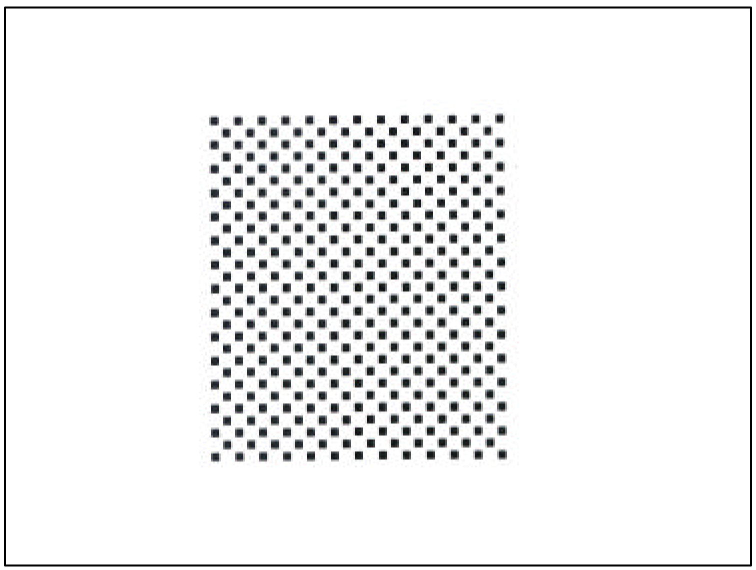
Lateral inhibition as an explanation for:

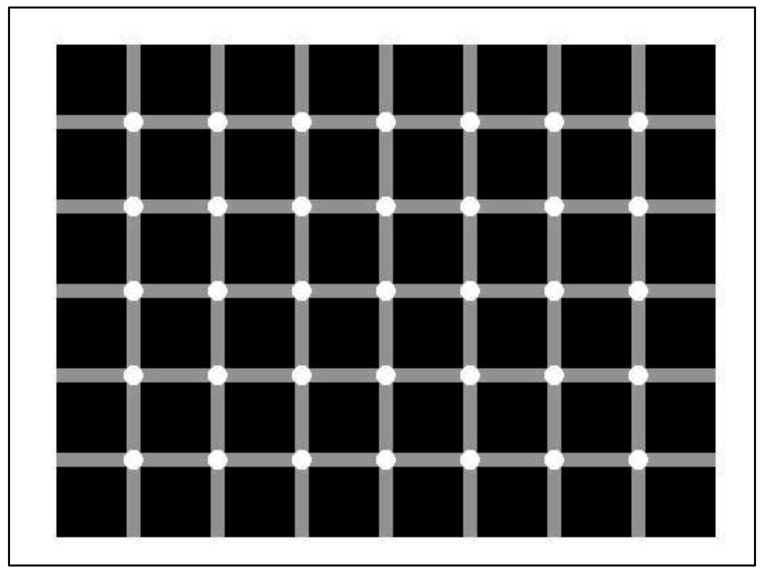
- Mach bands
- The Hering grid
- Simultaneous contrast

Week 4, Lecture 2: Neural Computation









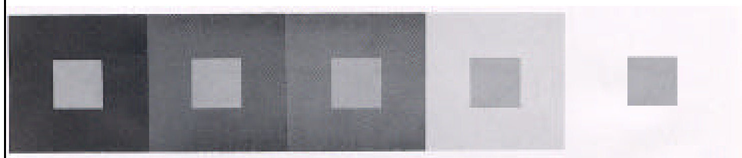
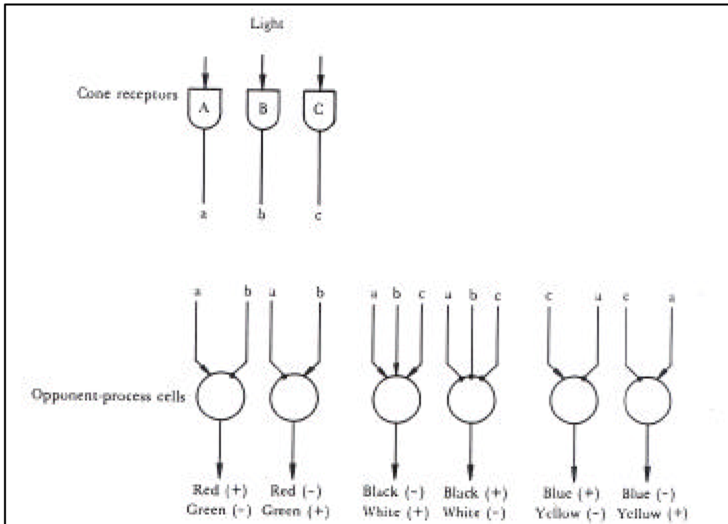


FIGURE 1-41 *Simultaneous contrast: The small squares all have the same intensities. From Cornsweet (1970).*

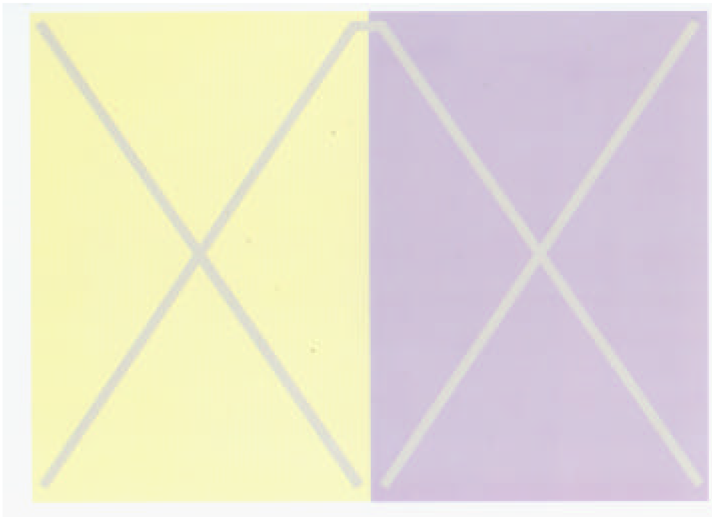
Relating Neural Networks to Psychology, continued

- **Opponent process circuits:**
  - Two inputs to one cell, from opposite kinds of stimuli (red/green, dark/light, move up/down, etc.
  - A signal for one perceptual quality excites an output; a signal for the complementary quality inhibits the output.
  - The level of activity of the output (excited or inhibited relative to resting level) determines the perceived quality.



Lateral Inhibition + Opponent-Process =

- Simultaneous *color* contrast (similar to simultaneous lightness contrast, but with color, not lightness, affected by neighboring patch)



- **Habituation:** Neurons that fire a lot over a long period of time "get tired."
- Opponent-process circuitry plus habituation:
  - Show stimulus A for a long time → A cells habituate
  - Show neutral stimulus → A cells habituated (below resting rate), B cells fresh (at resting rate)
  - B > A, so perceive neutral stimulus as B
- Explains:
  - Color aftereffects
  - Motion aftereffects