So far...

- **Units**: ions, conductance, membrane potential, firing.
- **Networks**: transformations, amplifications, attractors, basic building blocks of cognition.

How do networks ever come to do interesting things?

- **Learning**

Learning

- Describe an “ideal” learning system. (If you could design one, what features would it have?)
- Describe the human learning system. (How do our models need to learn to capture how we learn?)

Learning

- Tuning detectors locally to achieve global results.

- Two main types:
  - Learning internal **model** of environment (Ch 4)
  - Learning to solve a **task** (produce output from input) (Ch 5)
  - Doing both at the same time (Ch 6)

Model learning

Pick up on correlations in the world.

(whether for pixels in visual images, emotions and people, behaviors, etc.)

Simulation.
Biology suggests associative or Hebbian learning: LTP and LTD. (“Units that fire together wire together!”)

Synaptic efficacy (weights) change when neurons are excited:

- Going up: Long Term Potentiation (LTP)
- Going down: Long Term Depression (LTD).

NMDA = Associativity: Both Pre & Post Active

1. Mg+ unblocks NMDA channels as postsynaptic $V_m$ increases
2. Glutamate released with spike binds to and opens NMDA channels
3. Ca$^{++}$ enters through NMDA channels

Biology: NMDA-mediated LTP/D

Strong activity ($\text{Ca}^{++}$) = LTP, weak = LTD

Hebbian Learning Picks up on Correlations

Simple Hebb rule: $\Delta w_{ij} = \epsilon a_i a_j$

Linear Activation: $a_j = \sum_i a_i w_{ij}$

Weights get stronger for the two units that are correlated, don’t get stronger for uncorrelated unit!
Problems

Simple Hebb rule: $\Delta w_{ij} = \epsilon a_i a_j$

Weights will grow infinitely large.

Normalize by subtracting off weight.

$$\Delta w_{ij} = \epsilon a_j(a_i - w_{ij})$$ (1)

Biological Correspondence

$$\Delta w_{ij} = \epsilon a_j(a_i - w_{ij})$$

When both $a_j$ and $a_i$ large: Lots of Ca++ $\rightarrow$ LTP
When $a_j$ large but $a_i$ small: Some Ca++ $\rightarrow$ LTD
When $a_j$ small: Mg+ blocking NMDA channels $\rightarrow$ nothing.
Simulations.

Model learning

Pick up on correlations in the world.

(whether for pixels in visual images, emotions and people, behaviors, etc.)

Based on Hebbian (LTP/LTD) mechanisms.