Computational Cognitive Neuroscience

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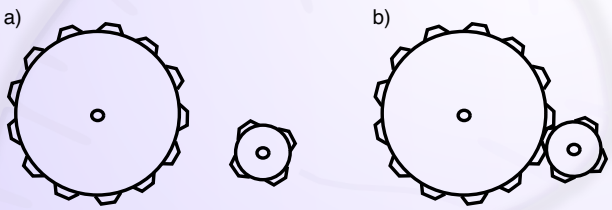
How Would You Build It?

- If you want to understand how something works, take it apart, then *try to put it back together.*
- We're going to take the brain apart, an put it back together again.
- How would you do it??

Emergence and Learning

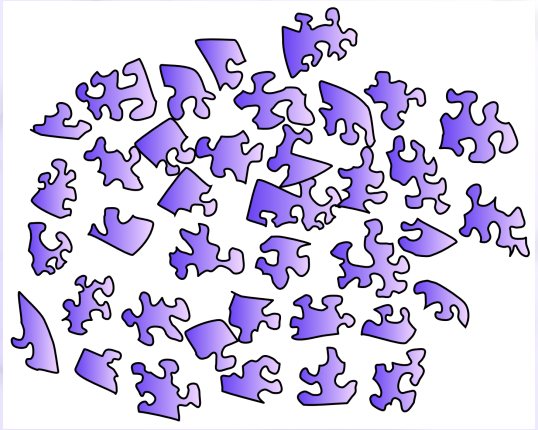
- With 10,000,000,000 neurons, you can't build it by hand..
- It basically has to build itself (development & learning)
- Complexity must emerge from simplicity (not that many genes control brain development..)

Emergence

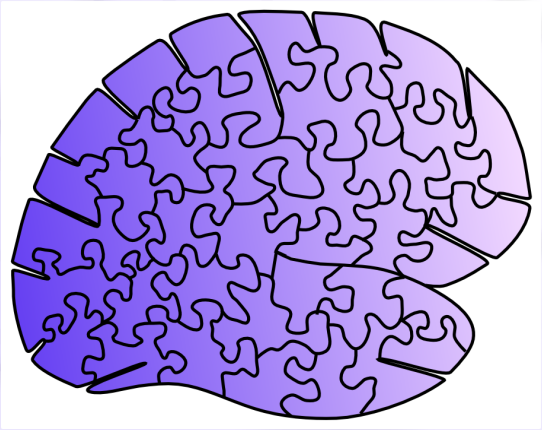


(Now Imagine 10,000,000,000 gears, each interacting with 10,000 others..

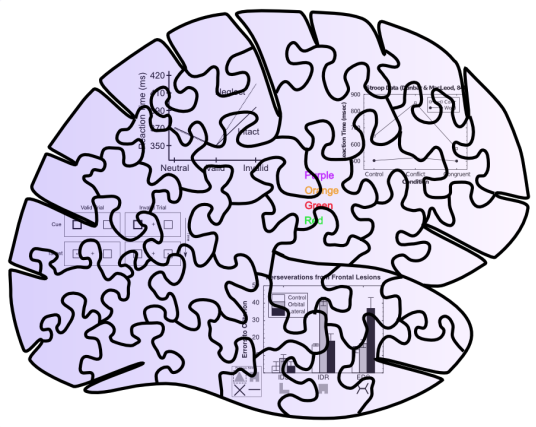
The Problem



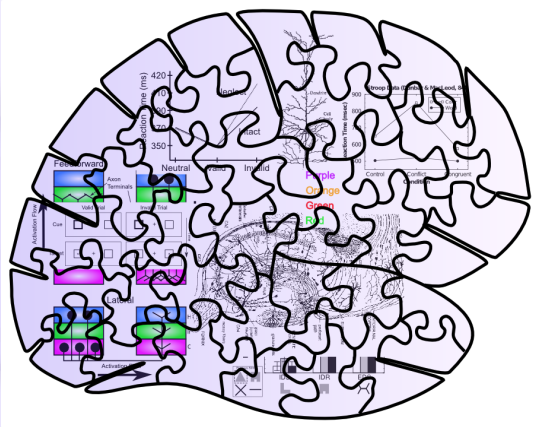
The Problem



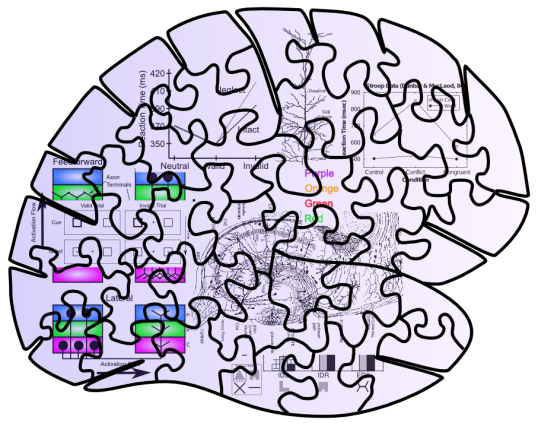
Behavioral Constraints



Neuro + Behavioral Constraints

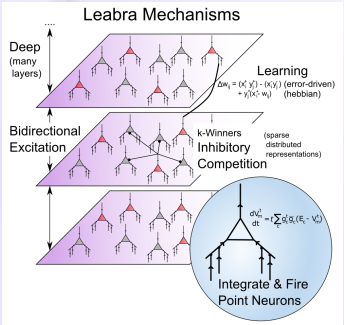


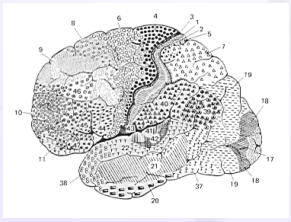
Messy Puzzles are Easier to Solve!!



Course Overview

- From Neurons to Networks to the Brain/Mind..





Cognitive Phenomena

- **Visual encoding:** A network views natural scenes (mountains, trees, etc.), and develops brain-like ways of encoding them using principles of learning.
- **Spatial attention:** Taking advantage of interactions between two different streams of visual processing, a model focuses its attention in different locations in space, and simulates normal and brain-damaged people.
- **Episodic memory:** Replicating the structure of the hippocampus, a model forms new episodic memories and solves human memory tasks.
- **Working memory:** A neural network with specialized biological mechanisms simulates our working memory capacities (e.g., the ability to mentally juggle a bunch of numbers while trying to multiply multidigit values).

Cognitive Phenomena

- **Word reading:** A network learns to read and pronounce nearly 3,000 English words, and generalizes to novel nonwords (e.g., “mave” or “nust”) just like people do. Damaging a reading model simulates various forms of dyslexia.
- **Semantic representation:** A network “reads” every paragraph in a textbook, acquiring a surprisingly good semantic understanding by noting which words tend to be used together or in similar contexts.
- **Task directed behavior:** A network simulates the “executive” part of the brain, the prefrontal cortex, which keeps us focused on performing the task at hand and protects us from distraction.