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Computational Cognitive Neuroscience

Psych 4175/5175

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1. Syllabus, student info cards, introductions.

2. What this course is all about.

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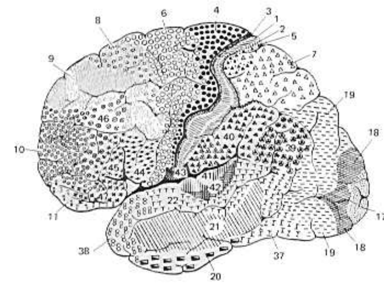
The Most Interesting Thing in the Universe..



It is also the most complex. Computer models can help.

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Physical Reductionism

Reductionism: explaining in terms of underlying mechanisms.

What mechanisms for cognition? CPU & RAM? Logic? Lisp? Productions?

Physical Reductionism: mechanism is the *brain*.

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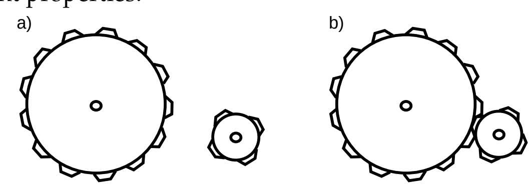
Reconstructionism

Putting the reduced pieces back together.

Critical when there are billions of such pieces (neurons).

Computer simulations are essential.

Emergent properties:



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Complexity and Levels of Analysis

The brain is very complex: billions of neurons, 5,000 x billion synapses, changing every nanosecond.

Need to abstract away from this complexity!

Is there some simpler, higher level for describing what the brain does during cognition?

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In a Computer Program..

You can have three levels of abstraction (Marr):

Computational: what is overall goal?

Algorithmic: what strategy?

Implementational: how to physically encode?

Can we focus only on 1st two levels?

Only if you assume a particular implementation!

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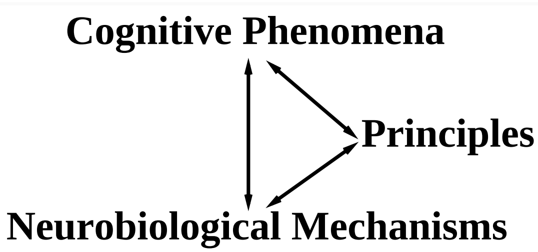
Our Levels



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Neurobiological Mechanisms and Principles

Neurons: serve as *detectors*, signal with *activity*.

Networks: link, coordinate, amplify, and select patterns of activity over neurons.

Learning: organizes networks to perform *tasks* & develop good *models* of environment.

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Psychological 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).

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Psychological 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.

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Advantages of Simulation Method

- Models help us understand phenomena:
  - Provides novel insights.
  - Effects of brain damage/drugs.
  - Can explain *why* things are (function).
- Models deal with complexity, span levels.
- Models are explicit:
  - Deconstruct psychological constructs.
  - Makes novel predictions.
  - Forces accountability in simulating data.
  - Completeness in all problem aspects.
- Enables complete control & understanding.
- Forces consistency & unity in framework.

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Potential Traps/Problems

- Models are too simple (need multiple levels).
- Models are too complex (need a theory).
  - Which properties are relevant?
- Models can do anything:
  - Too many degrees of freedom (use same params).
  - Indeterminacy problem (many tasks).
- Models are reductionistic (reconstruct!).
- Modeling lacks cumulative research.