# 9.13 The Human Brain

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**TAs:** Heather Kosakowski, Anya Ivanova, Dana Boebinger

Outline for Today

I. A Story

themes of the course echoed in the story

II. Studying the Human Brain

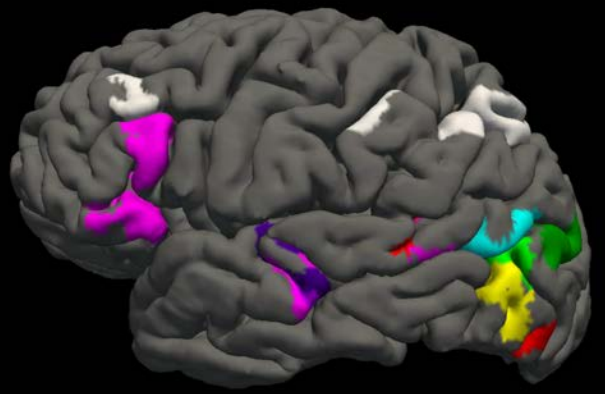
Why

How

What

III. A few details about the course

course content, goals, assignments,



# Themes of this Course (echoed in the Story)

- The brain is not just amorphous mush,
  - it has structure,
  - with *different parts that do different things*
  - Bob didn'gt just get overall dumber.
  - Good news for science: divide and conquer
- Some parts of the brain do *extremely* specific things
  - (not all parts, but some)
- The organization of the brain reveals the architecture of the mind
  - parts of brain ≅ fundamental components of mind
  - the point: not *where*, but *what* (precise functional characterization)
- How do brains change
  - over development
  - from learning and experience
  - after injury
- Which methods can answer which questions?
  - sooooo many methods! each with both strengths and limitations

Outline for Lecture 1

I. A Story

II. Exploring the Human Brain

- Why
- How
- What

III. Details about the course

- course content, goals, assignments, etc.

# *Why* Should we Study the Human Brain in the first place?

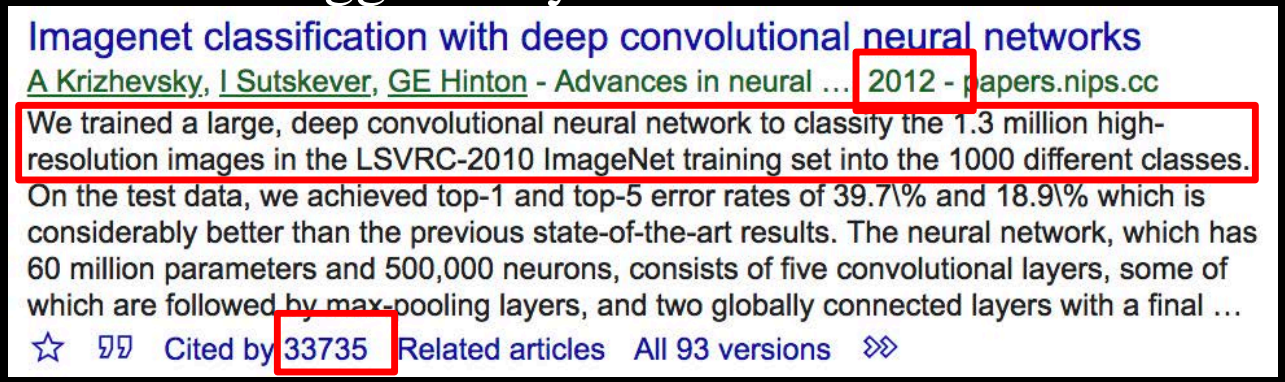
- To know thyself.
  - your mind/brain is who you are; understand yourself!
  - many other fine organs, but the brain is special
    - you would die without a heart,
      - but your brain is your *identity*.
    - that's why heart transplants not brain transplants
    - that's why decade of the brain not pancreas or kidney or liver.

# *Why* Should we Study the Human Brain in the first place?

- To know thyself.
  your mind/brain is who you are; understand yourself!

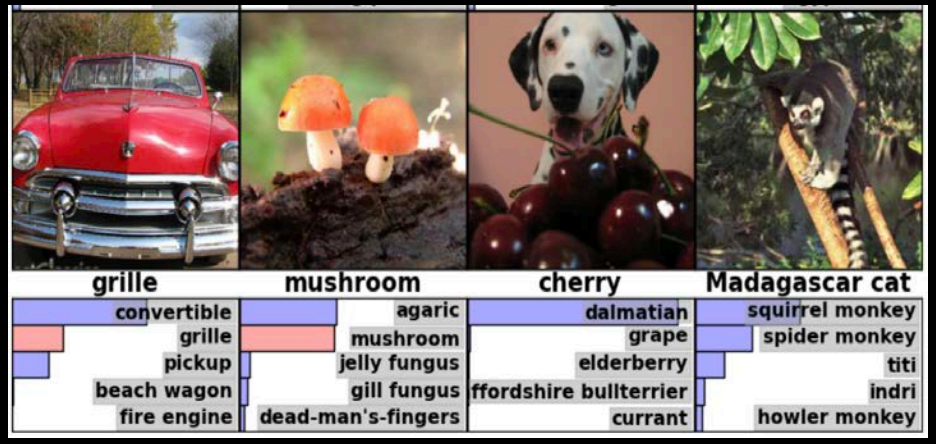
- To understand the origins and limitations of human knowledge (empirical epistemology)
  (how) does the structure of our brain shape the structure of our thought?

- To advance AI.
  For example visual object recognition.
  Machines lagged very far behind humans until….




MUCH more accurate than anything before. Approaching humans.

# *Why* Should we Study the Human Brain in the first place?


Amazing, and transformative for CS and cog sci and neuroscience.

These networks can be taken as computationally precise models of obj rec.

But do they really perform as well as humans?

What if tested on images not in ImageNet?

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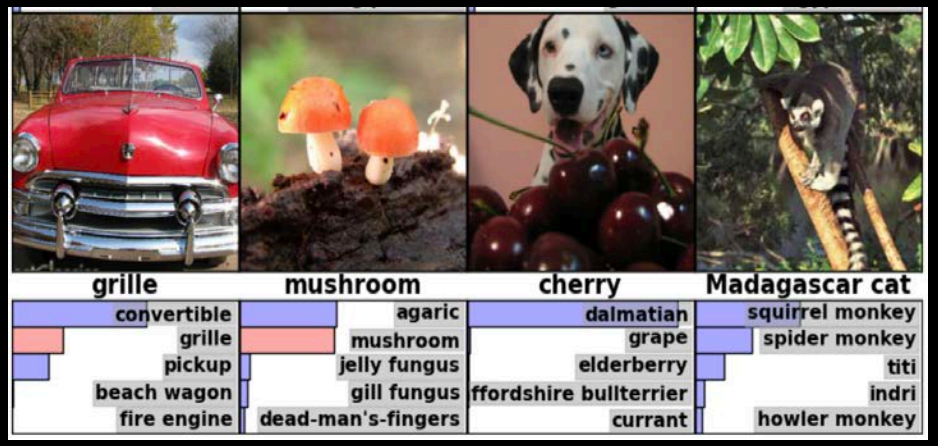


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But do they really perform like humans?

What if tested on images not in ImageNet?

Katz & Barbu:

More variable locs/orientations than Imagenet.

Human performance is still good, but...

Accuracy of ResNet-200 drops from 71% correct (ImageNet) to 25% correct (Katz/Barbu imgs).

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- To advance AI.

  Deep nets are awesome and transformative.
  But still do not perform like humans on object recognition.
  What about harder problems, like understanding an image?
  "image captioning"...

Official White House photo by Pete Souza. Image is in the public domain.

Big idea (Tenenbaum):
Both humans & deep nets are good at *pattern recognition*.
What humans, but not machines, are good at:
*building models to understand the world*.
e.g. What do some people here know but the guy on the scale doesn't?
Why is Obama smiling?
Why is this funny?

# *Why* Should we Study the Human Brain in the first place?

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  your mind/brain is who you are; understand yourself!

- To understand the origins and limitations of human knowledge
(empirical epistemology)
(how) does the structure of our brain shape the structure of our thought?

- To advance AI.
  AI has much to learn from the brain.

  & the fourth reason...

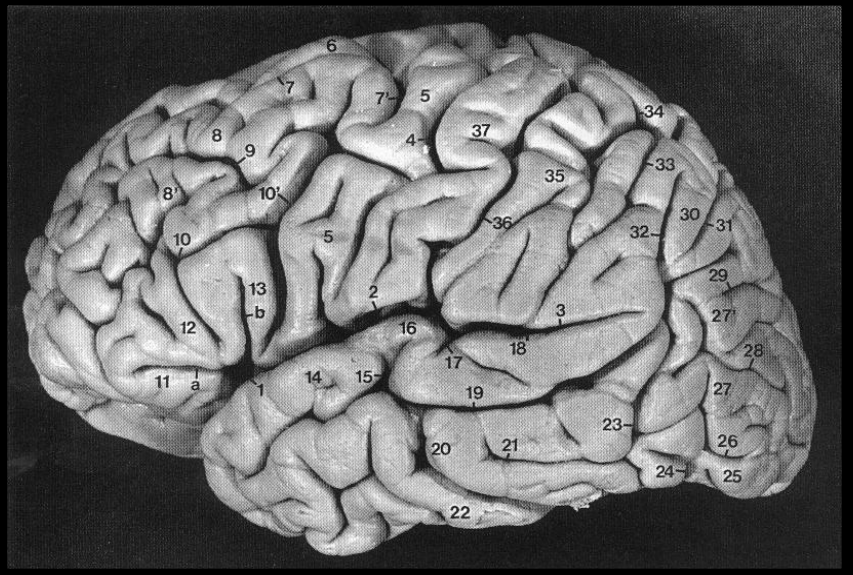
More generally, no current AI system can…..
navigate new situations,
infer what others believe,
use language to communicate,
write poetry and music to express how they feel, or
create math to
build bridges, devices, and life-saving medicines*.

- Because it is the greatest intellectual quest of all time.



*DiCarlo, *Wired*, Feb 2018

# *How* can we study the human brain?




Question:
How does this thing work?

Can Approach @ Multiple levels:
molecules and their interactions
properties of individual neurons
circuits of interacting neurons
brain regions
networks of brain regions

The somewhat different question we ask in this course:
*How does the brain give rise to the mind?*

To answer this question, we need to start with the mind.
And the various mental functions it includes, like...

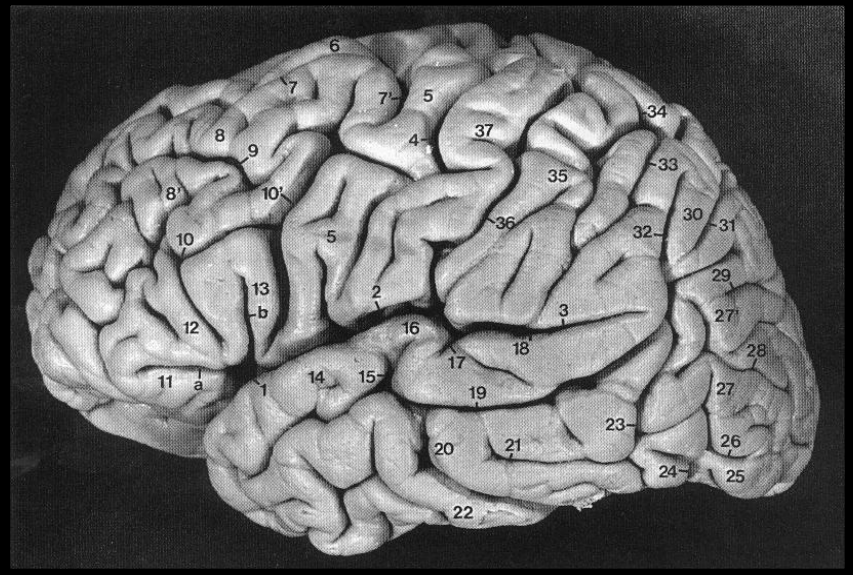
Perception:
vision
hearing
Cognition
language
thinking about
people
things
...

# *How* can we study the human brain?

For each mental function we will:

1. Understand how it works in minds
   what is computed and how?

2. Look at its brain basis:
   specialized brain machinery?
   what information is represented?
   when?
   how?

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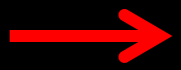


Lots of Methods

Psychophysics
RT & accuracy
Illusions

2. Look at its brain basis:
   specialized brain machinery?
   what information is represented?
   when?
   how?

How do we answer these questions?

An important point about this course...

***Student 50458*** **-**
***This class was not sold in the correct way. It should not be called the Human Brain, because it was basically just Cog Sci, not a brain class. I expected to learn very different material.***

Dear Student 50458-
Sorry I didn't make that clear.
The fundamental reason the brain is cool is that *it gives rise to the mind*.
Studying the biological properties of the brain without considering the mental functions it implements would be like studying the physical properties of a book without considering the meaning of its text.

# *How* can we study the human brain?

For each mental function we will:

1. Understand how it works in minds
   what is computed and how?
   = lots of cognitive science!
2. Look at its brain basis:
   specialized brain machinery?
   what information is represented?
   when?
   how?

How do we answer these questions?

Lots of Methods

→ Psychophysics
  RT & accuracy
  Illusions

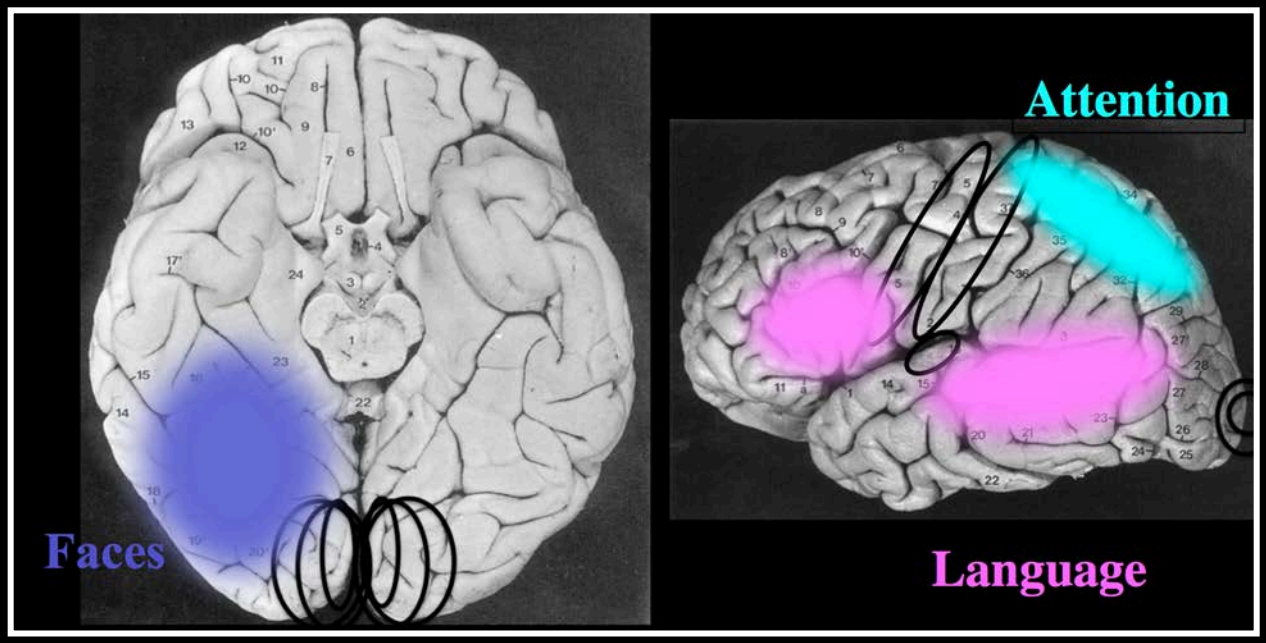
→ Neuropsychology Patients
  fMRI
  Neurophysiology
    animals
    humans (ECoG)
  EEG (scalp electrodes) ERPs
  Magnetoencephalography (MEG)
  Diffusion tractography

Which mental functions will we consider in this course?

The ones for which this research enterprise has made progress.

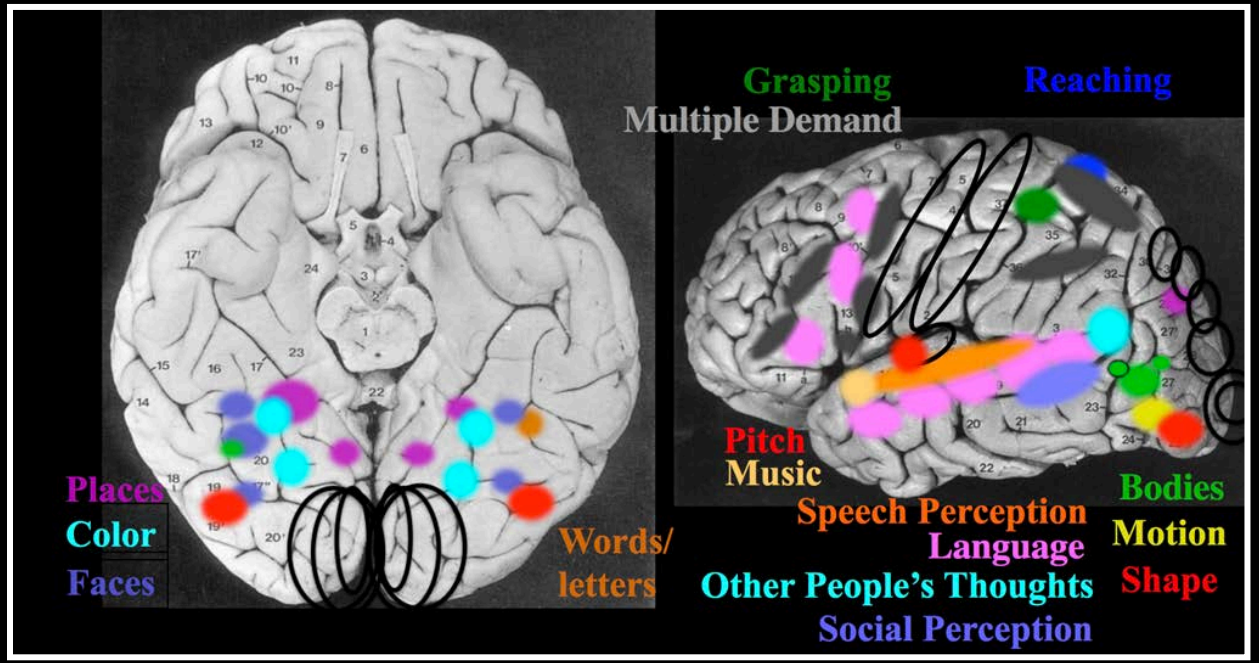
All of this is quite recent...

# What we knew about the Functional Organization of the Human Brain circa 1990




## What we Know Now

- We now know the ~function of dozens of brain regions.
- This is new and important.
- And has made possible a great deal of progress.



# *What* we will study about the human brain?

This course focuses on mental functions whose brain bases are best understood:

visual perception of color, shape, and motion
visual recognition of faces, places, bodies, and words
perceiving scenes and navigation
representing numerical quantity
perceiving speech and music
understanding language
understanding other minds

Note: lots on perception
high-level vision
high-level audition
That is a lot of the brain
And where much progress has been made.

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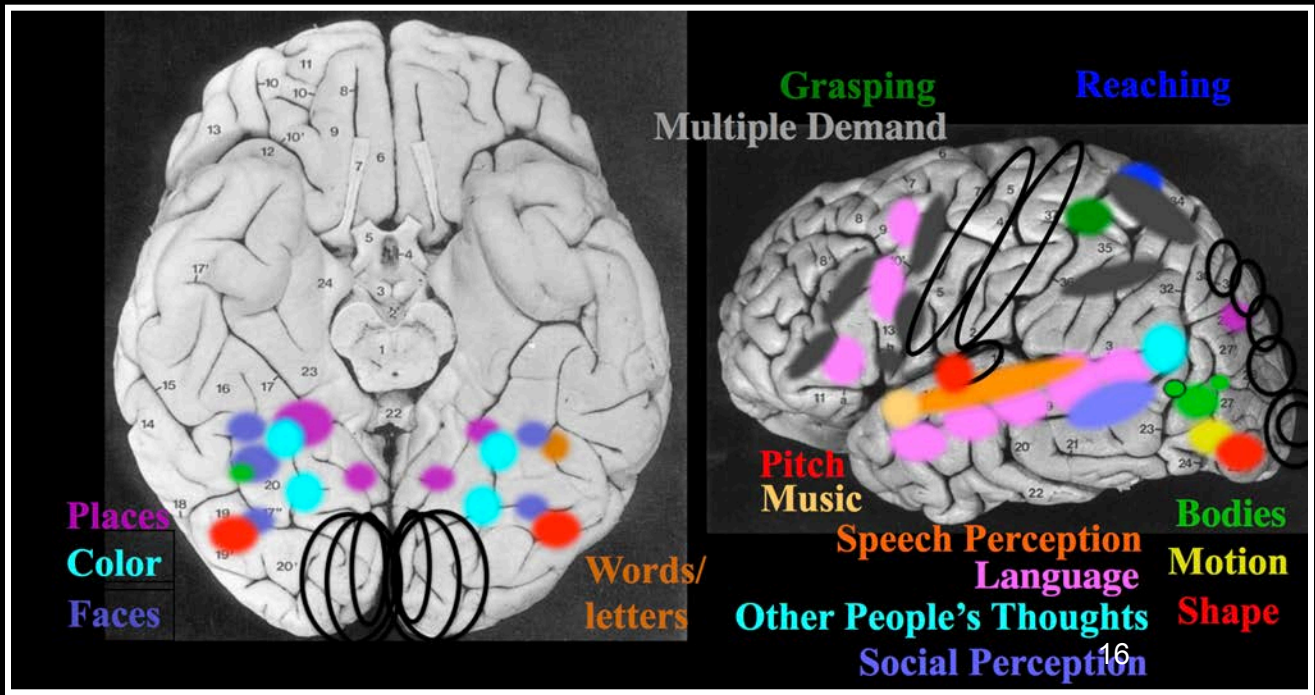
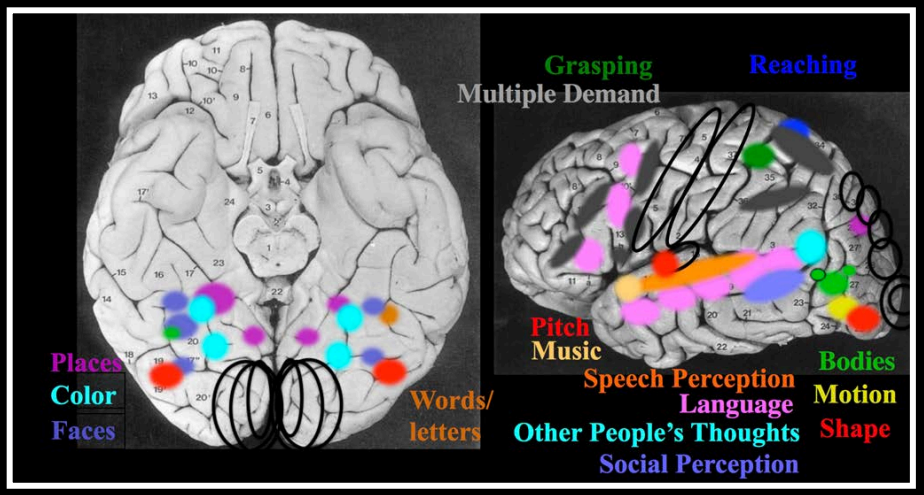


# *What* we will study about the human brain?

This course focuses on mental functions whose brain bases are best understood:

- visual perception of color, shape, and motion
- visual rec of faces, places, bodies, and words
- perceiving scenes and navigation
- representing numerical quantity
- perceiving speech and music
- understanding language
- understanding other minds




For each of these aspects of perception/cognition we will ask:

A. To what extent is this process implemented in its own specialized brain hardware?
B. Do multiple brain regions contribute to this process?
C. What does each one do?
D. How does this region/system develop?
E. Does this region/system have homologues in other species, or is it uniquely human?

and also...

# *What* we will study about the human brain?

Other Cool Questions we Will Consider Along the Way

- What (if anything) is "special" about the human brain?
- Where does knowledge come from?
  How much genetic, how much experience?
- How plastic are our minds and brains?
  can we change the structure of our minds/brains?
  by training?
  after brain damage?
- Can we think without language?
- Can we perceive/understand/think/decide without awareness?

# What will we *not* Cover in this Course

Lots of Important Topics that could have been included are mostly not:

- Motor control
- Subcortical function, basal ganglia, habits, etc.
- Decision-making
- Circuit-level mechanistic explanations of cognition
  - rarely do we have access to this info in humans
  - even in animals actual cases are rare where
    - we can see how the circuit implements the computation

Lots of Important Topics will Get Short shrift:

memory/hippocampus (9.00 and 9.01)
reinforcement learning/reward systems (9.00 and 9.01)
attention (9.00 and 9.01)

# A Comment about Overlap with 9.00 and 9.01

If you have not taken 9.01 or 9.00,

I will try to post alternate sources for you to get the background e.g. the review of retina to cortex.

For the most of you who have taken both 9.01 or 9.00:

These courses are broad surveys of mind and brain, so some overlap with this course is inevitable.

(If I taught only things that hade never been mentioned, even briefly, in 9.00 or 9.01, this course would cover only weird side topics!)

So expect to hear about some things you have heard of before.

HOWEVER, I have tried to minimize overlap, except for brief reminders before we go deeper.

Also, the goals if this course are different.

Not to memorize a lot of facts, but to *understand*...

# Goals of the Course

- To appreciate the big questions in the field,
  what is at stake theoretically in each.

- To understand the methods in human cog neuro
  and what you can and cannot learn from each
  what methods you would use to answer each kind of question

- To gain some actual knowledge of some aspects of cognition and the brain regions that carry them out (e.g. face rec., navigation, language)

- To learn to understand and critically evaluate current papers in the field.

- To take you to the cutting edge of the field, and invite you to participate.

# Why no Textbook?

This is a fast-moving field.
Any textbook is out of date.
We'll be mostly reading stuff that is vey hot off the press.
Plus a major goal is to teach you to read current articles in the field.

# Grading/Requirements

- **Midterm 25% in class March 20**
- **Final 25% (cumulative but weighted to the second half of course)**
- **Reading/writing assignments:**

**25% (10 papers to read & write brief responses to, 2.5 points each).**

First written response is due Feb 12 6pm,

But other readings assigned before then (e.g. one assigned today).

All these assignments are due 6pm the night before the class they are listed under.

- **Quizzes 10% (~8 of these)**

**will be simple and short and will cover lecture material (including the lecture in which the quiz is given) *and readings*.**

**first quiz is at end of class Feb 20, using Google Forms**

**bring computer or phone to class (tell us if this is a problem)**

- **One longer written assignment 15%: You will read some background papers and design your own experiment within a specific topic area. Approx 3-5 pages.**

# Sequence of Topics

1. Feb 6 INTRO.
2. Feb 11  NEUROANATOMY
3. Feb 13  Master Class: HUMAN BRAIN DISSECTION (by Ann Graybiel)
4. Feb 19T  Cog Neuro Methods I
5. Feb 20 Cog Neuro Methods II
6. Feb 25 EXPERIMENTAL DESIGN
7. Feb 27.  Controversies about the organization of Visual Cortex
8. March 4  Navigation I
9. March 6  Navigation II
10. March 11 Development,  Nature & Nurture I
11. March 13 Development,  Nature & Nurture II
12. March 18 The Blind Brain
13. March 20 MIDTERM
14. April 1 Number
15. April 3 ~ Neuroeconomics

Note: The above mental abilities are largely shared with animals, the stuff below is largely not.

16. April 8 Speech
17. April 10 Music
18. April 17 Brain-machine Interface (Guest lecture: Michael Cohen)
19. April 22  Language I
20. April 24 Language II
21. April 29 Theory of Mind
22. May 1 Brain Networks
23. May 6. In-class Discussion of Design of proposed experiments
24. May 8 Deep Nets and what they can tell us about minds & brains (Dobs)
25. May 13 Attention and awareness
26. May 15 Lecture Topic TBA

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Spring 2019

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