

# 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

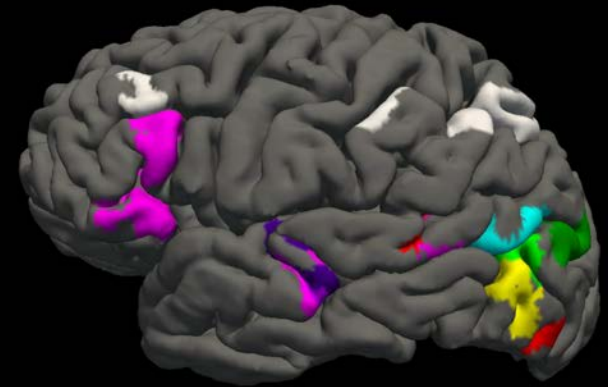
Why

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't 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  $\equiv$  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<sub>2</sub>

## 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.

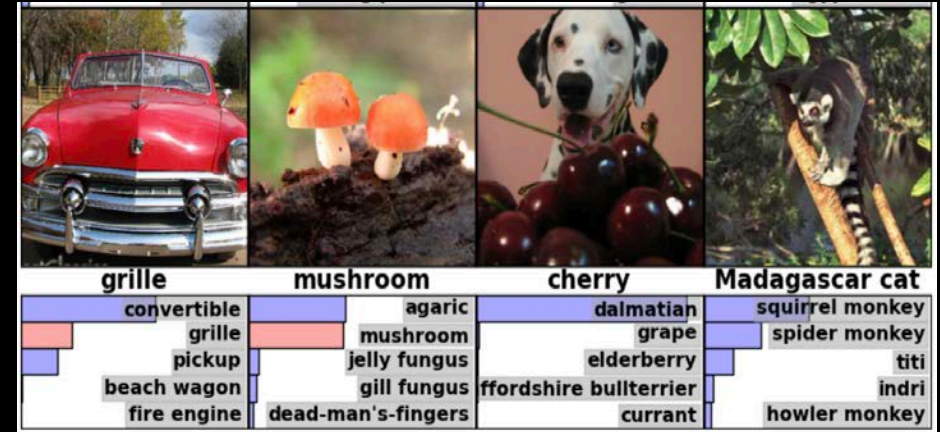
# Why Should we Study the Human Brain in the first place?

- 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....

Imagenet classification with deep convolutional neural networks  
A Krizhevsky, I Sutskever, GE Hinton - Advances in neural ... 2012 - papers.nips.cc  
We trained a large, deep convolutional neural network to classify the 1.3 million high-resolution images in the LSVRC-2010 ImageNet training set into the 1000 different classes. On the test data, we achieved top-1 and top-5 error rates of 39.7% and 18.9% which is considerably better than the previous state-of-the-art results. The neural network, which has 60 million parameters and 500,000 neurons, consists of five convolutional layers, some of which are followed by max-pooling layers, and two globally connected layers with a final ...  
☆ 77 Cited by 33735 Related articles All 93 versions >>

MUCH more accurate than anything before. Approaching humans. 5

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

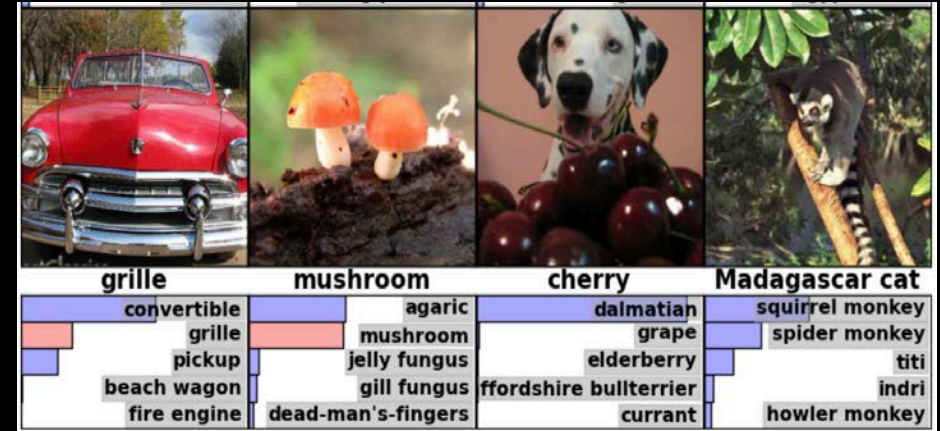


Amazing, and transformative for CS and cog sci and neuroscience.  
 These networks can be taken as computationally precise models of obj rec.  
 But do they really perform as well as humans?  
 What if tested on images not in ImageNet?

MUCH more  
 accurate than  
 anything before.  
 Approaching  
 humans.<sup>6</sup>



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 These networks can be taken as computationally precise models of obj rec.  
 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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(empirical epistemology)  
(how) does the structure of our brain shape the structure of our thought?
- 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?

- 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.

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.

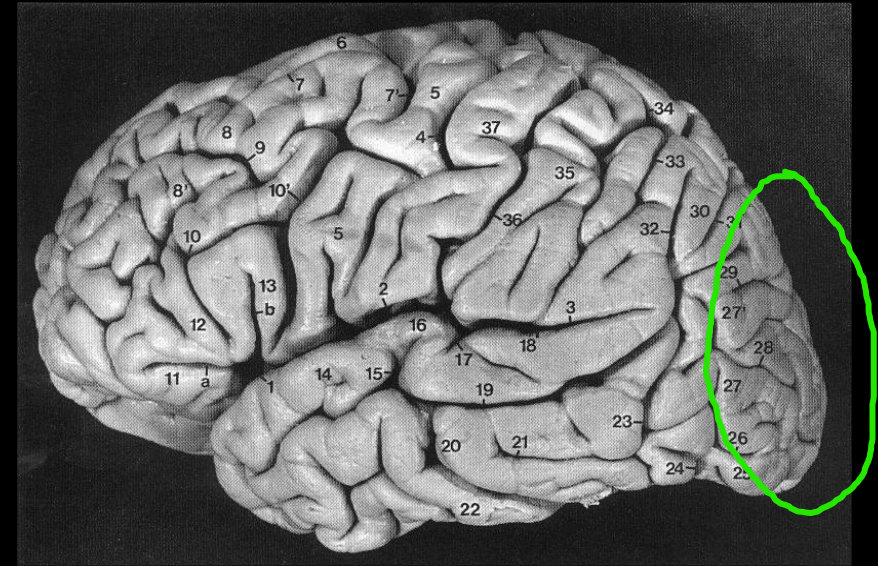
# How can we study the human brain?

## 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...

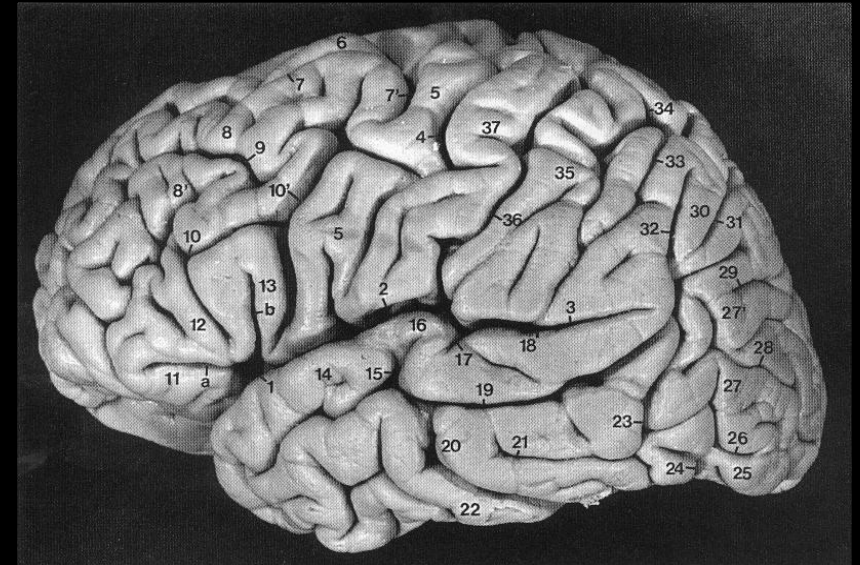
## Perception:

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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when?  
how?

How do we answer these questions?

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.

Lots of Methods



Psychophysics  
RT & accuracy  
Illusions

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.*

# *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?

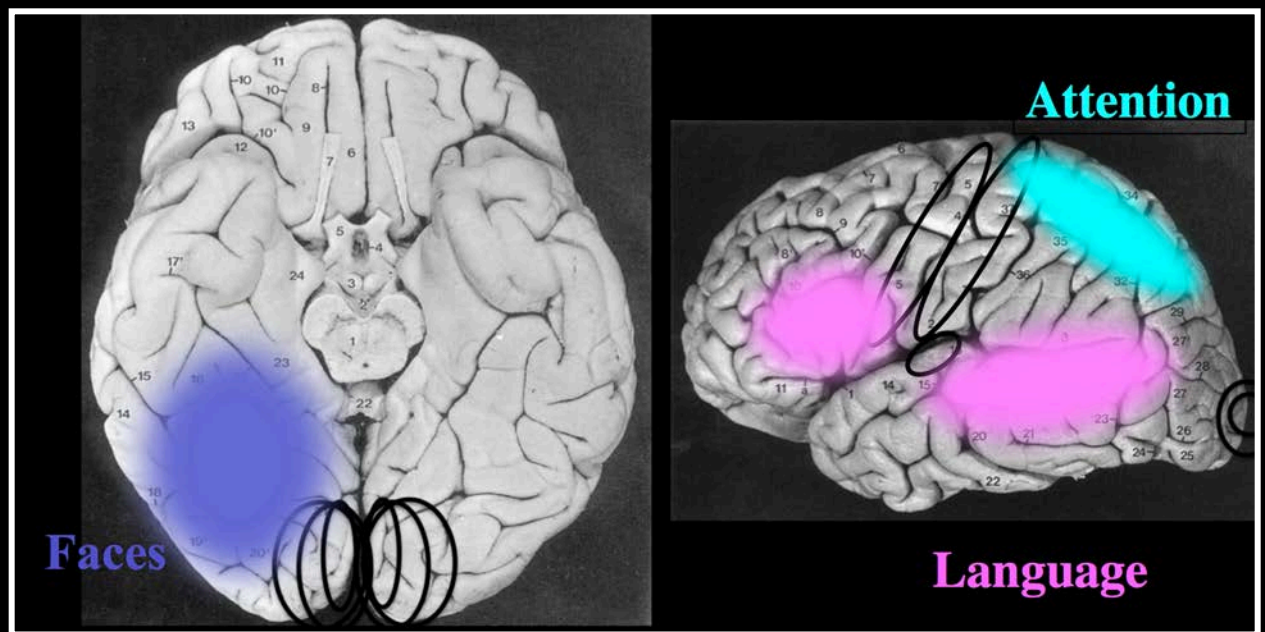
The ones for which this research enterprise has made progress.

All of this is quite recent...



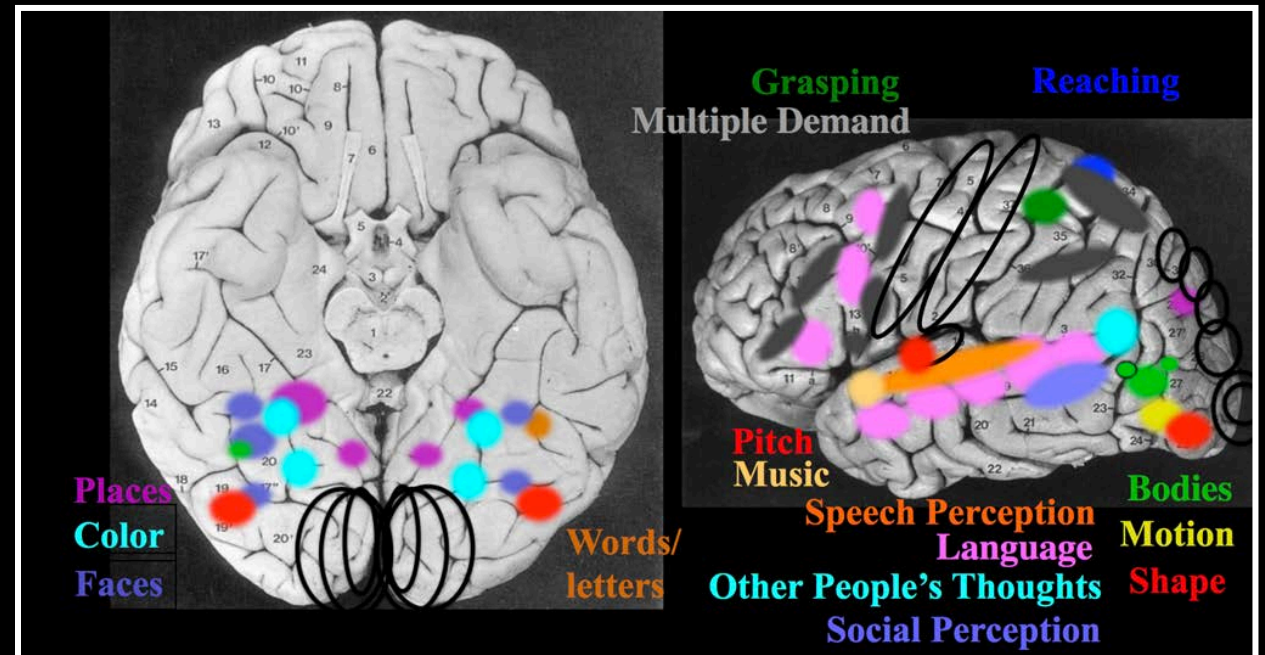
# What we knew about the Functional Organization of the Human Brain circa 1990

damN.



## 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?

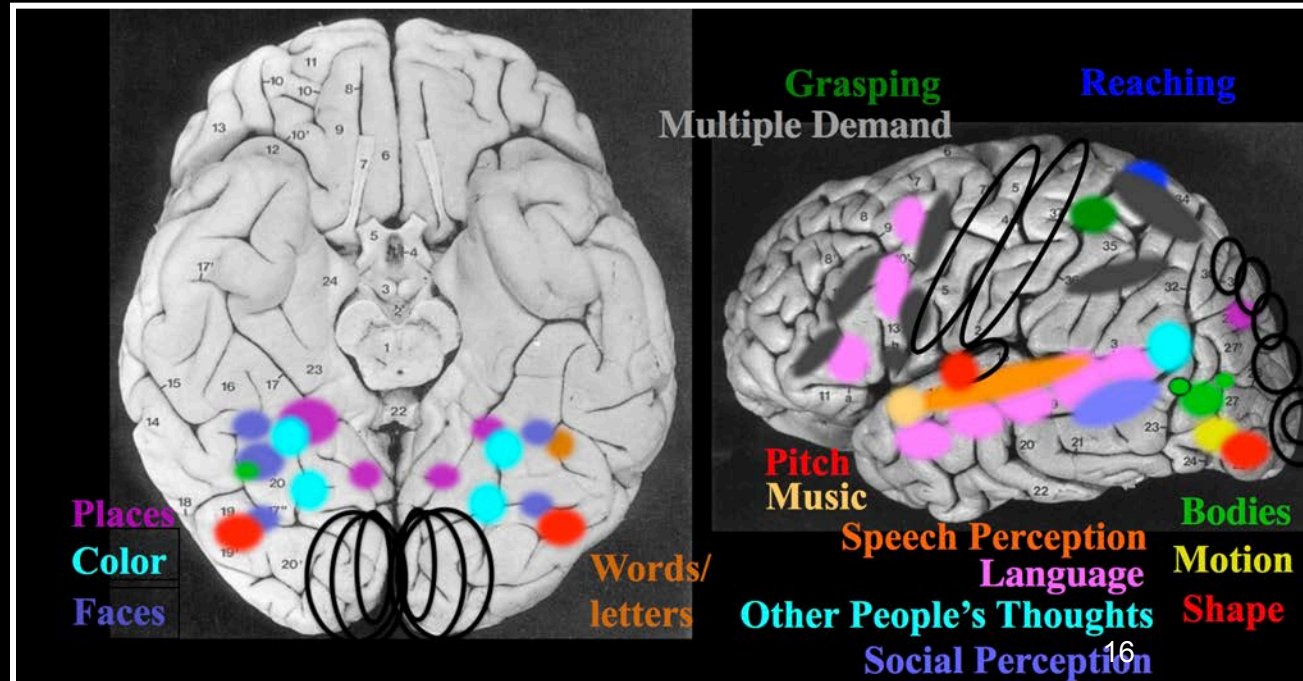
This course focuses on mental functions whose brain bases are best understood:

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.

## What we Know Now

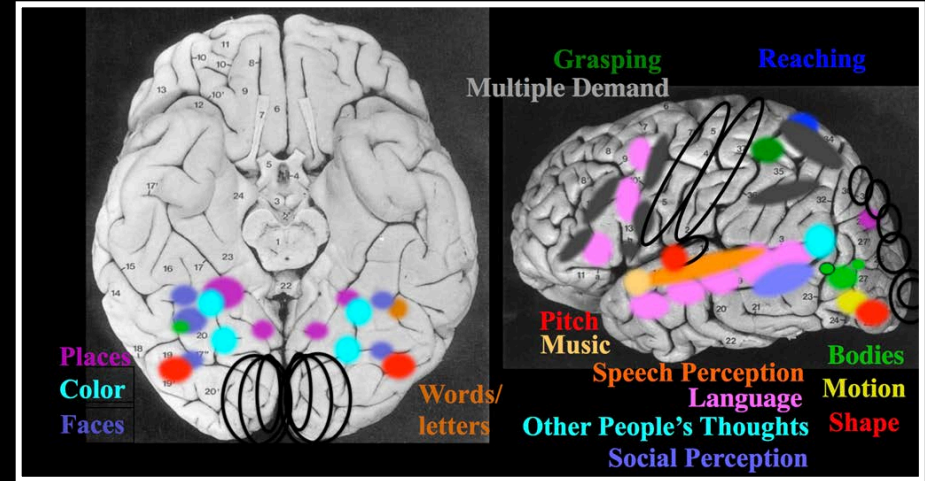
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For each of these aspects of perception/cognition we will ask:

- 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 had 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 of 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? *They suck!*

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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