9.13 The Human Brain
Lecture 2

Outline for Today

I. Motion Demo: What do we need visual motion information for?

II. Basic Neuroanatomy Refresher (prep for dissection Wednesday)

III. Cortex.
criteria for a visual area
case study: visual motion area MT(V5)

(Why) Do We Need to be Able to See Motion? ?

1. How do we use visual motion information?

2. Might this ability be important enough that our brains would allocate special machinery to seeing motion?

3. If you had to write an algorithm to take video input and figure out if an object is moving or in what direction, what would that code look like?

The Marr reading assigned for today points out that:
we cannot understand perception without thinking about
what each perceptual inference is necessary for ecologically,
the computational challenges involved in making that inference.
More on that next week.

Some Bare Basics about the Brain

* = jeff bezos' net worth
*no you don't have to remember this

- human brain contains ~ 100 billion (10^{11}) neurons*

  ~~ thousand of synapses per neuron

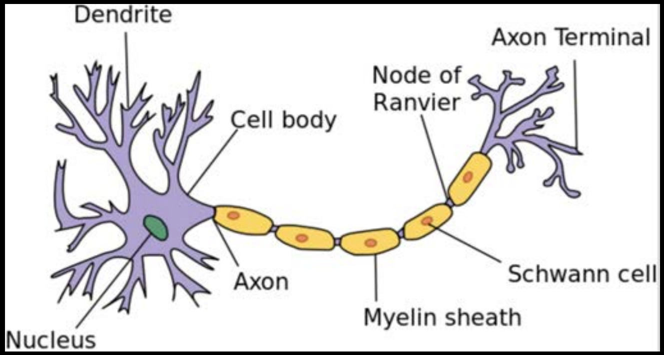
- human brain runs on 20 watts

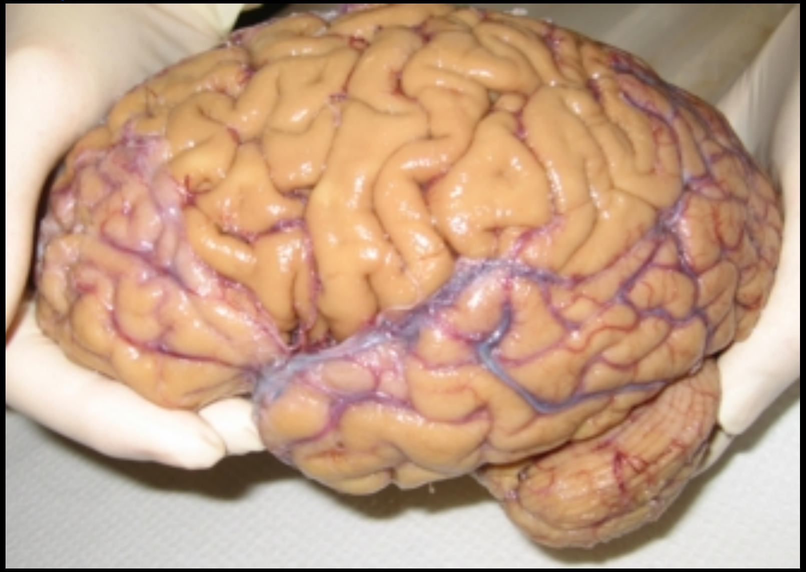
  vs: IBM's Watson: 20,000 watts

- primary focus of this course: the cortex

  folded outer surface
  approx. area of a large pizza

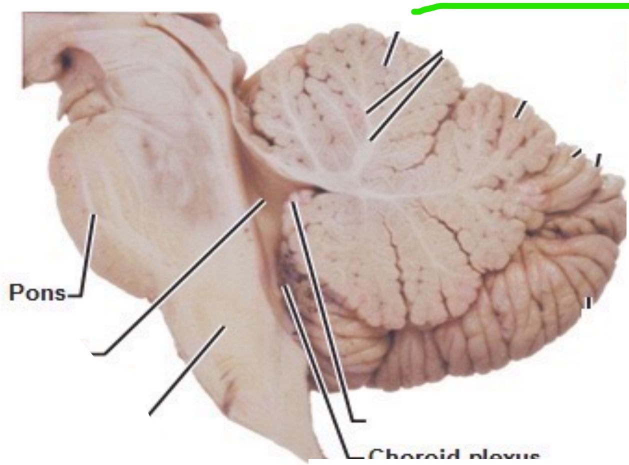
- But there are lots of other important bits



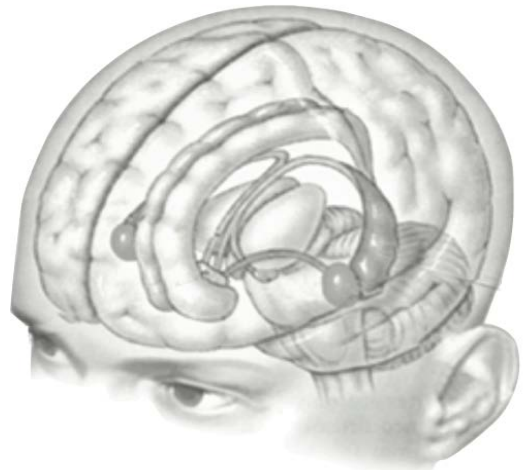


Four Major Components of the Brain

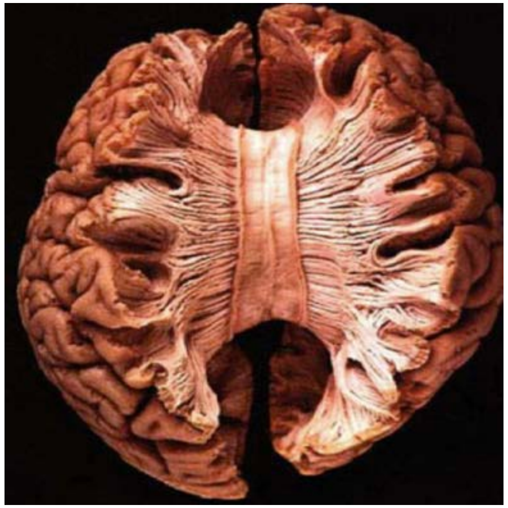
1. Brain stem & cerebellum



2. Limbic system (subcortical regions)



3. White Matter



This course will focus mostly on the cortex. But the other parts are easier to see in a dissection, so we will briefly review them here.

4. Cerebral cortex (outer sheet)

slide adapted from Michael Cohen

Who Cares about White Matter?

we will discuss in more detail on May 1, but just to foreshadow….

I. White matter makes up 45% of the human brain.

2. We cannot understand cortex w/out knowing the connections between regions.

3. The specific connections of each region may serve as a "fingerprint" of that region across species, enabling us to discover interspecies homologies.

4. The specific connections of each region may play a causal in its development.

5. Disruptions of white matter may be key to clinical disorders

6. Structural connections provide a major constraint in circuit design and likely too in brain design.

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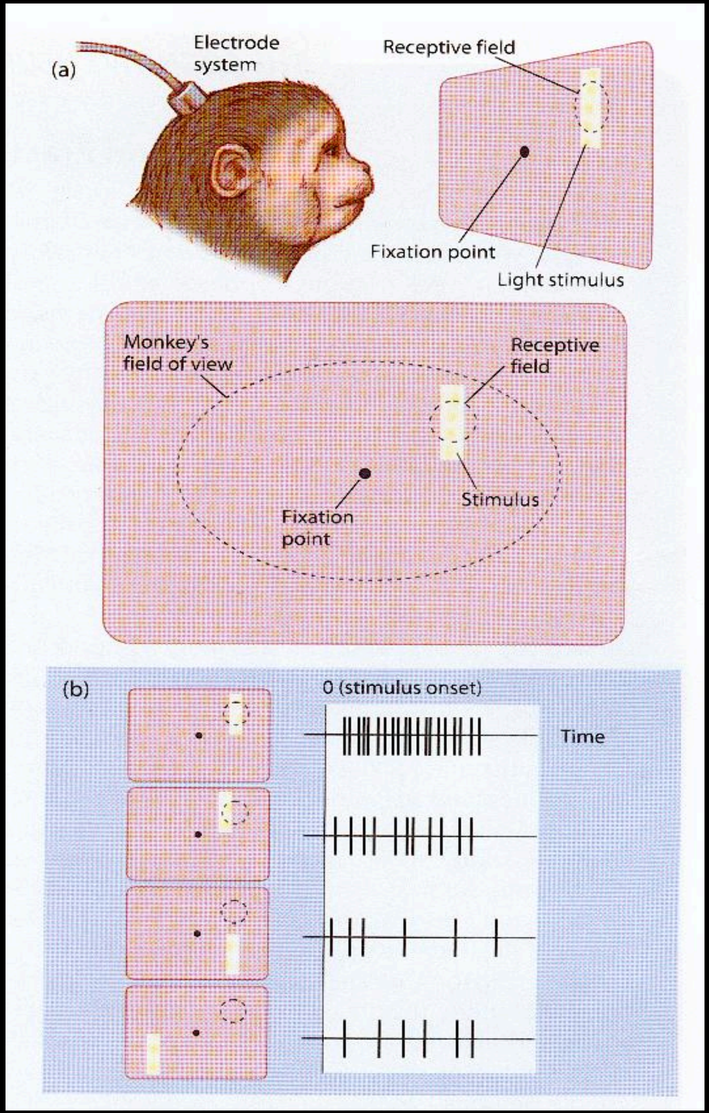
let's start with the easy parts, which you have already seen...

Refresher: What is a Receptive Field? !



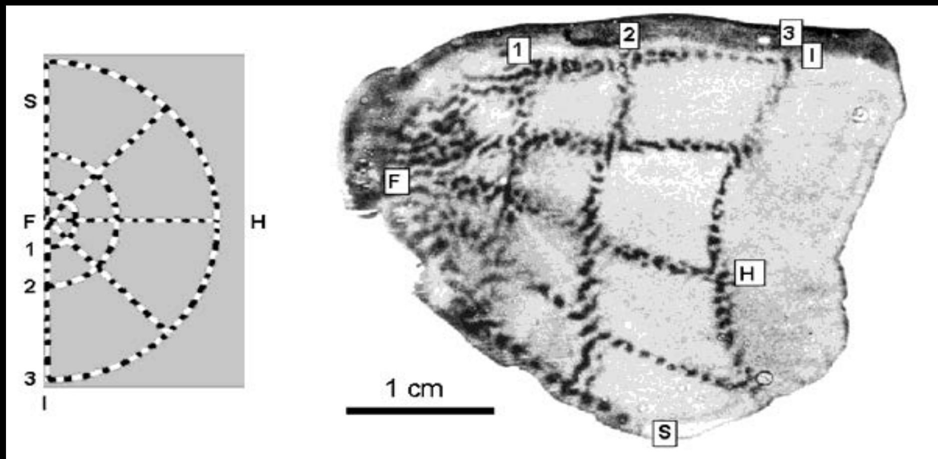
- Place an electrode next to a cell in monkey visual cortex
- Train the monkey to stare at a fixation spot w/out moving its eyes
- Stimulate various regions of visual space
- A cell will respond to stimulation in one part of space more than any others
- The region of visual space that drives a particular cell forms its receptive field (RF)

- Different cells have different RFs
- Some cells' responses are tuned not only to the location of the stimulus but also other properties (shape, color, direction of motion)

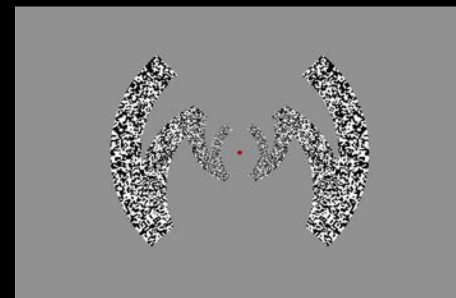
- Nearby cells in the cortex have nearby receptive fields, producing *retinotopic maps* in visual cortex…..

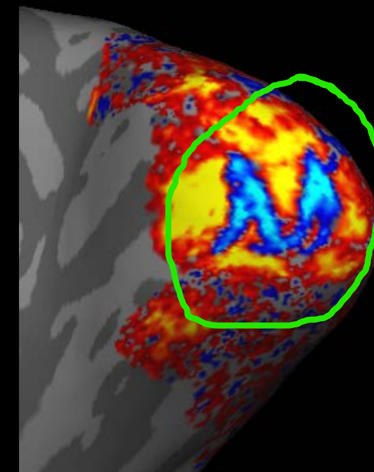
Sources: Gazzaniga, Ivry & Mangun, 2002
Jody Culham

Retinotopic Maps



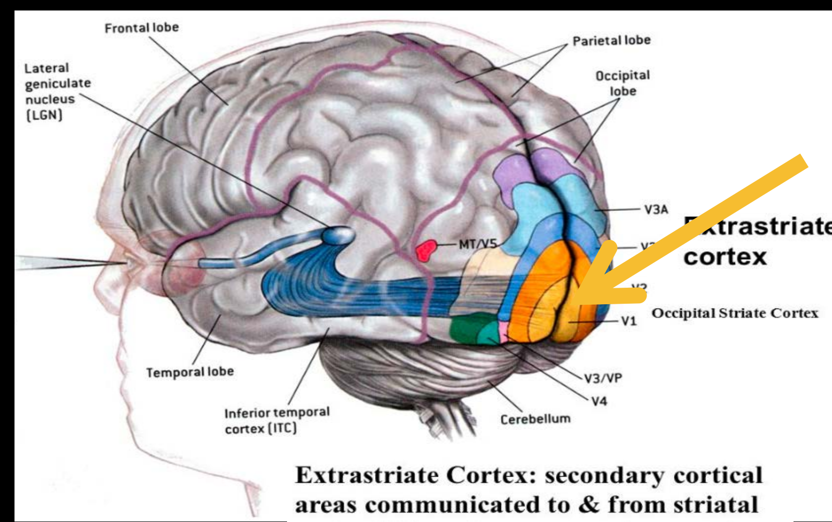
Retinotopy in Macaque V1
Tootell et al., 1982
deoxyglucose method





Retinotopy in Human V1
Polimeni et al (2009) fMRI at 7T

- Retinotopy: Adjacent parts of the visual scene are mapped to adjacent parts of the cortex
- Terminology: V1 = primary visual cortex = striate cortex



What exactly is a cortical area?

Criteria: A region of cortex distinct from its neighbors in

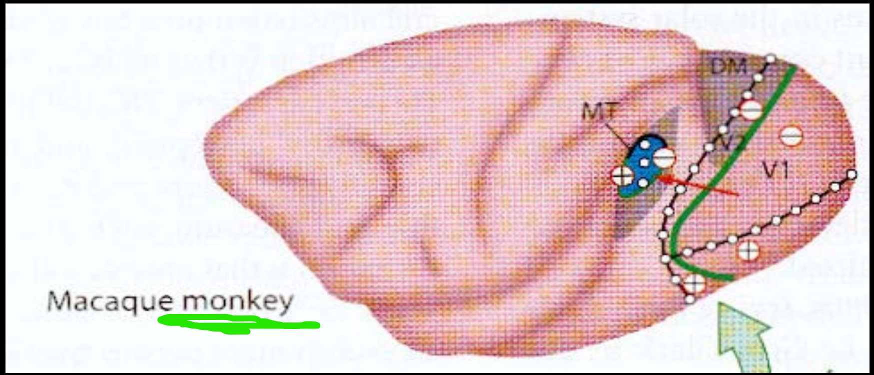
- Function
- Connectivity to other areas
- Distinctive layer structure/cell types ("cytoarchitecture")
  - » (sometimes)

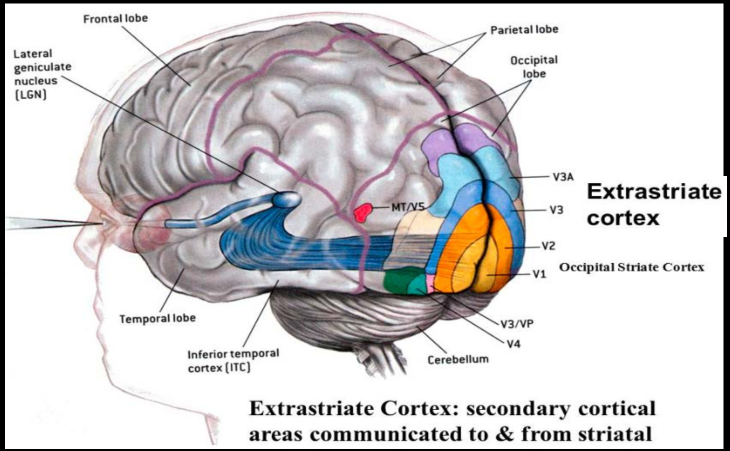
Let's look at a classic example: Visual Motion area MT

Meets all the criteria for a visual area.

How do we know this?

lots of ways…

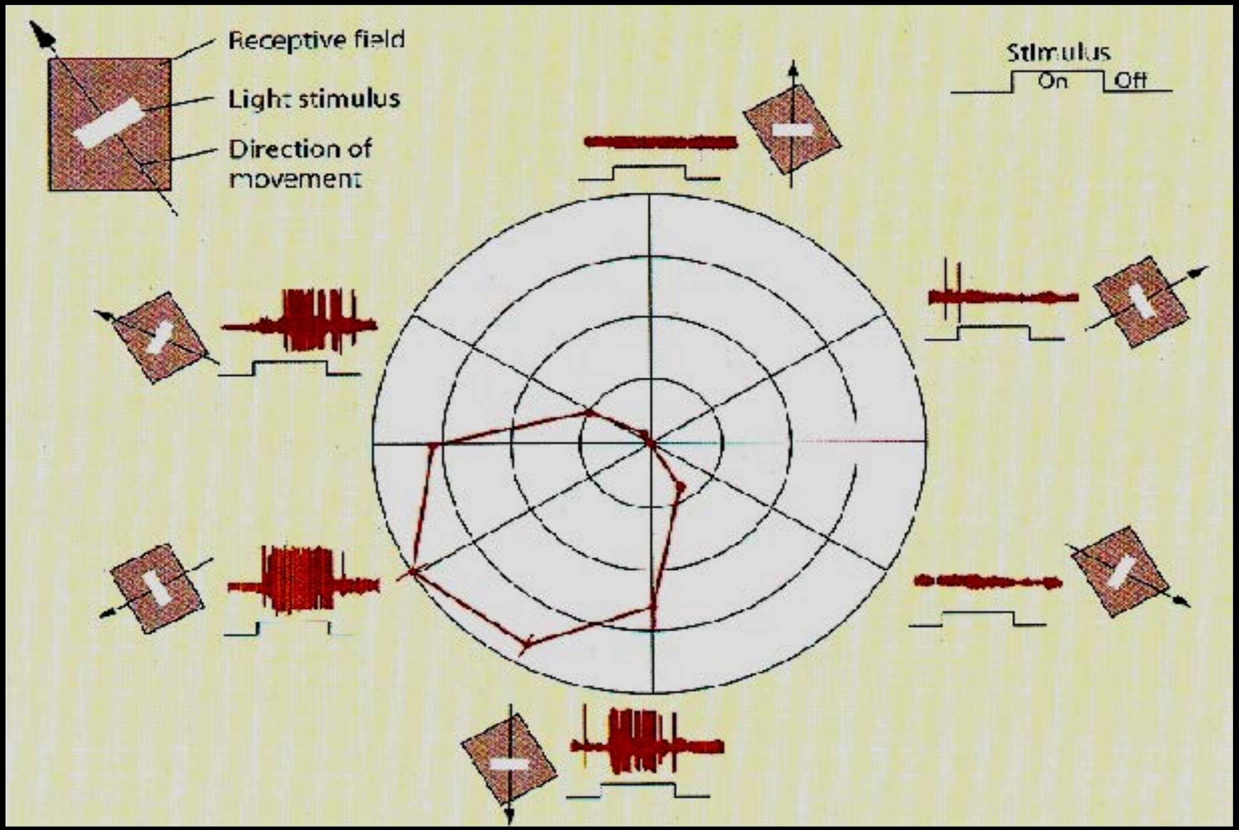


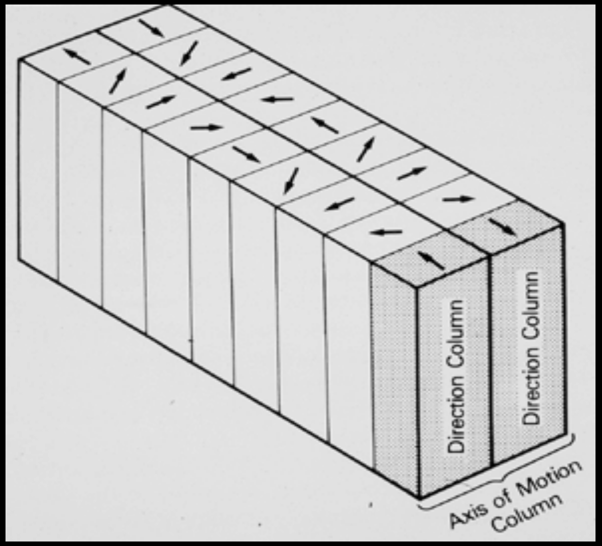


MT: Function

Single unit recording

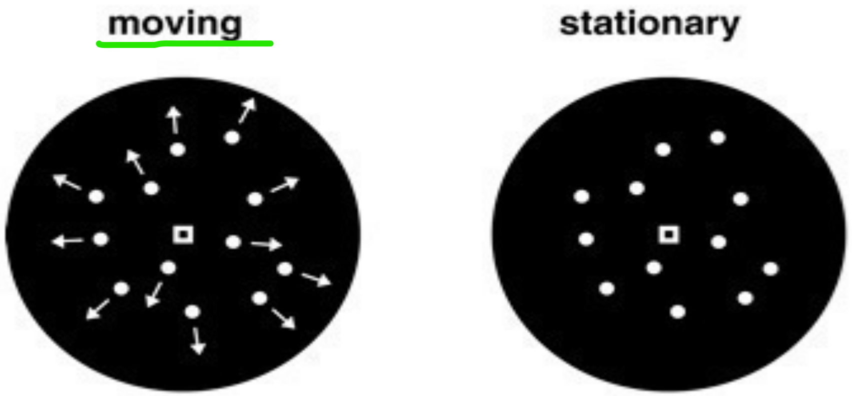
- Single neurons in MT are tuned to the direction of motion
- Nearby neurons within MT have similar directional selectivity (sound familiar?)

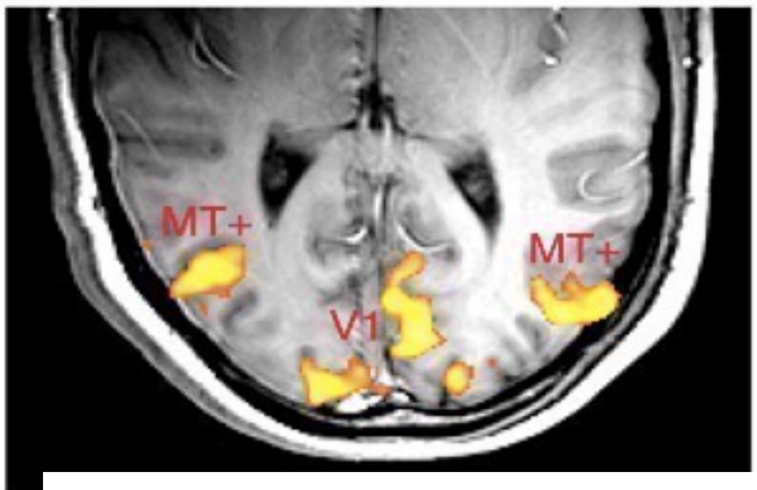


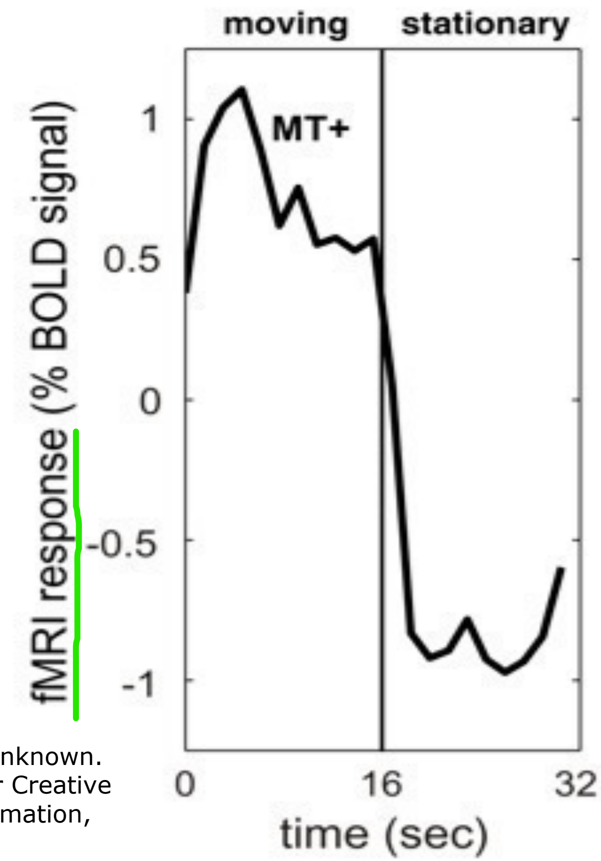


What about humans?
Can we record from single neurons in humans?

Visual motion area MT





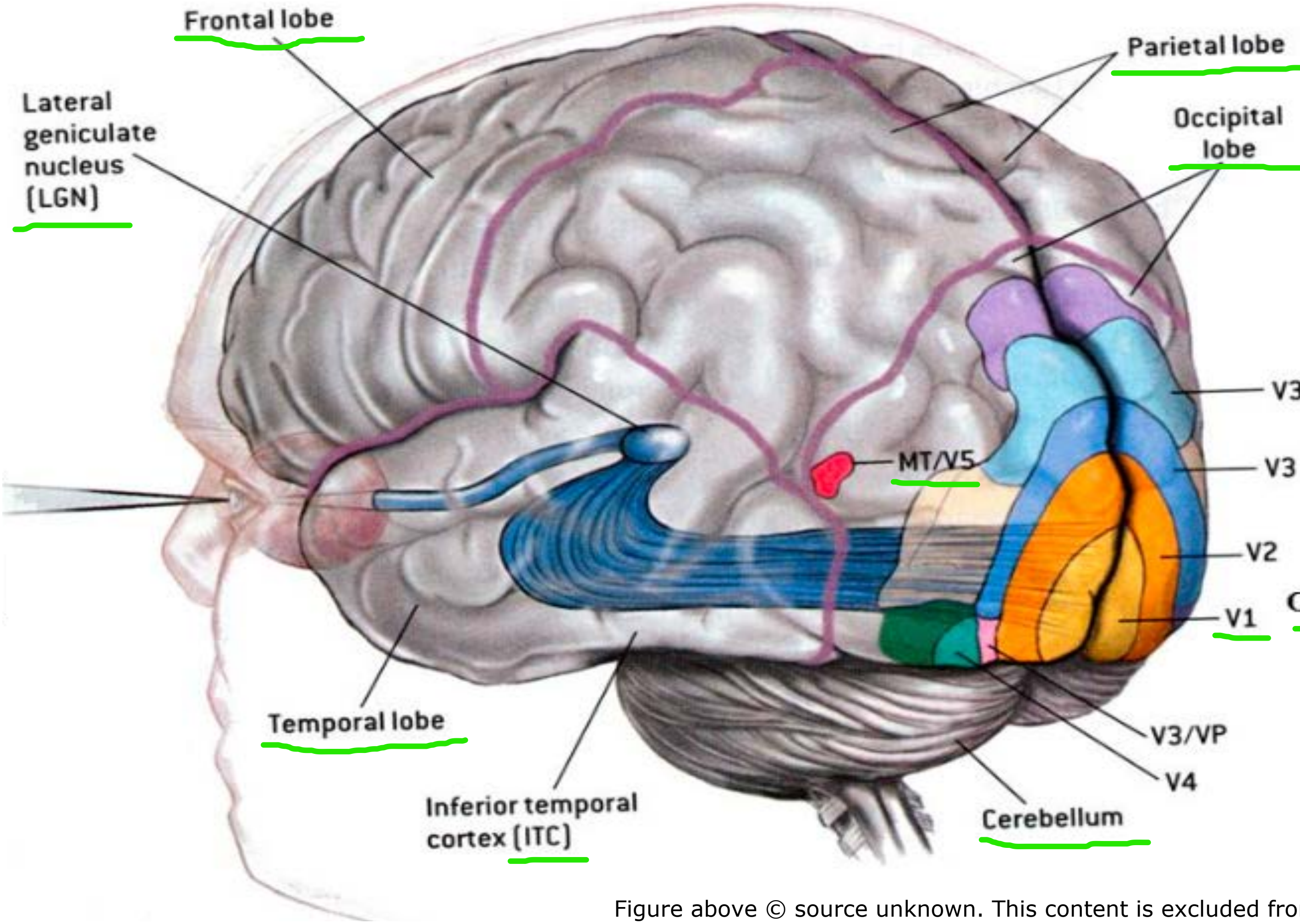


Does this tell us that MT represents the *direction* of motion, or just the *presence* of motion?

tion?

Visual motion area MT

How might you use the motion aftereffect to test for direction selectivity in M



Cool, BUT:

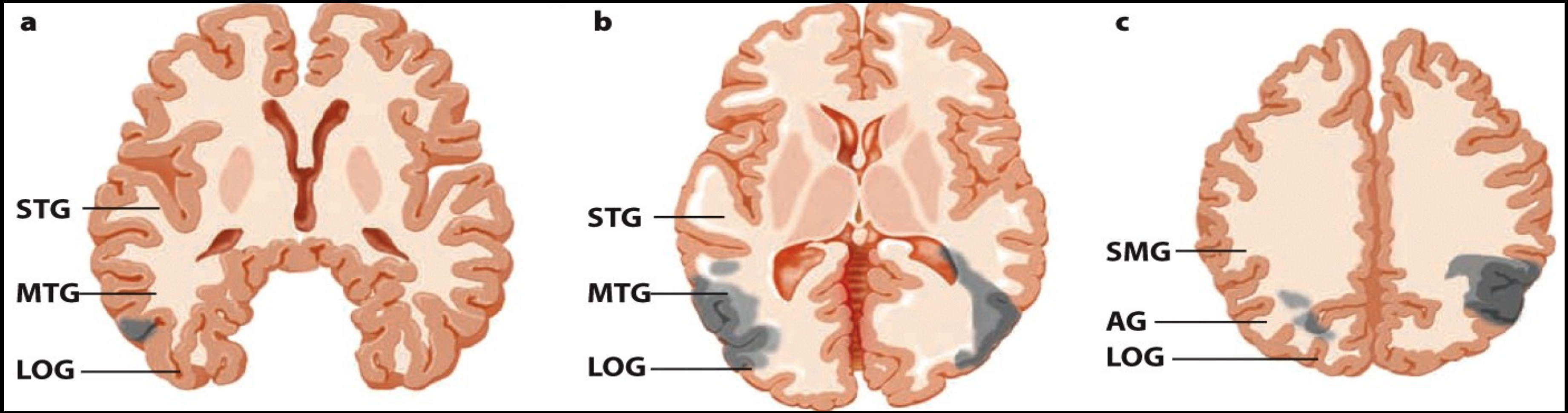
Does this tell us that MT is *necessary* for motion perception?

More MT Function

- Microstimulation
  - stimulation affects the perception of motion
- Lesions
  - lesions to MT lead to deficits in perceiving motion

A patient with bilateral lesions to MT can no longer perceive motion (Zihl et al., 1983)

"Akinetopsia"



What exactly is a cortical area?
Example: Visual Motion Area MT

Criteria: A region of cortex distinct from its neighbors in

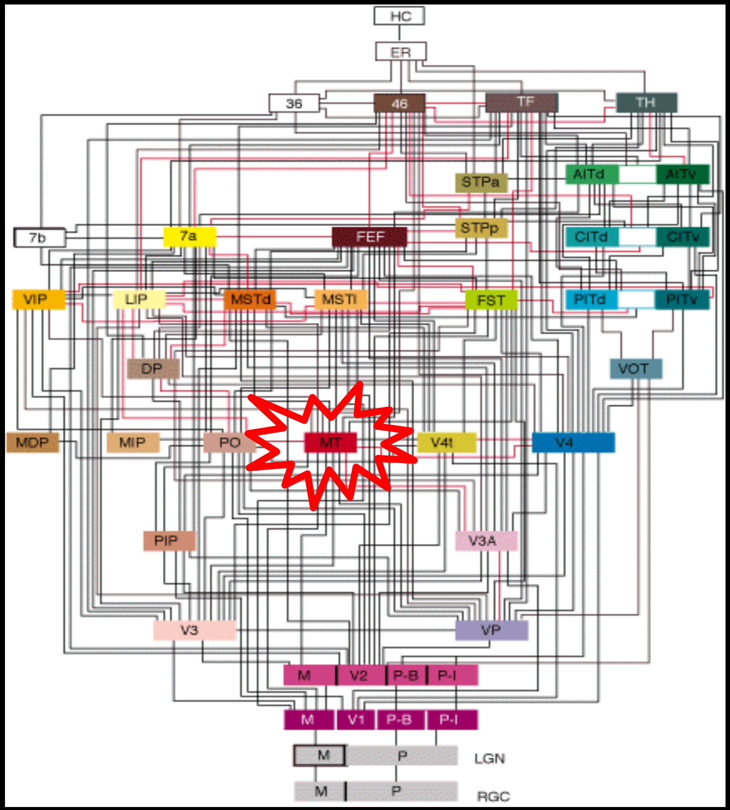
- Function, e.g. selectivity/processing a specific dimension, e.g.
    - MT selectively engaged in processing motion
        - – single neurons in monkeys
        - – fMRI in humans
        - – psychophysics (aftereffects)
        - – microstimulation in monkeys
        - – lesions in humans
- Specific Connectivity
    - – To other areas

      a distinct "connectivity fingerprint"

      a signature of that region
- What about physical/cellular diffs?

  = "cytoarchitecture"

  an old idea….



Brodmann Areas

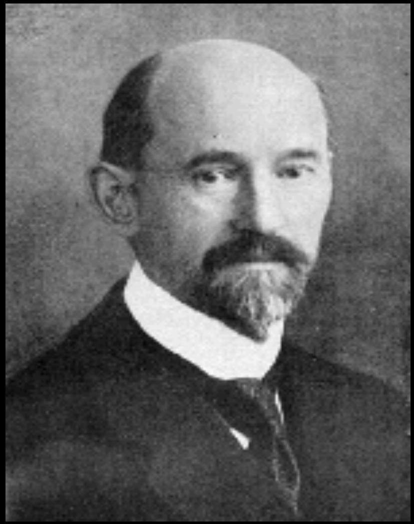
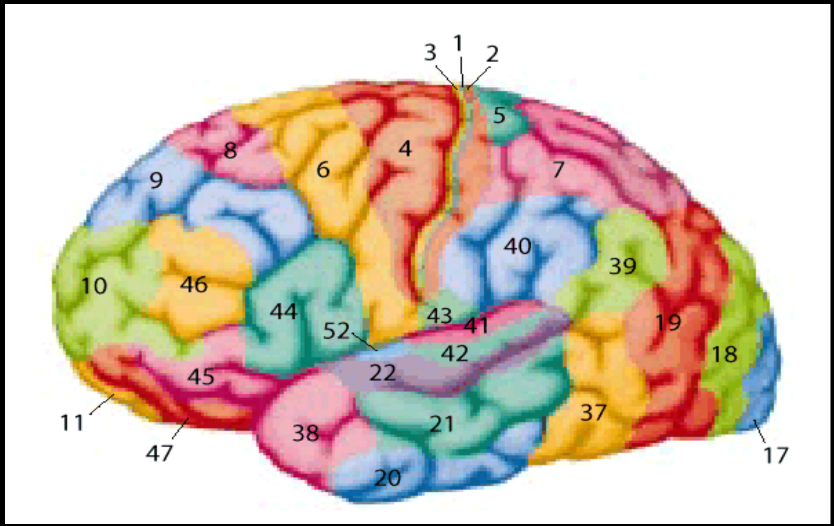


Photo of K. Brodmann is in the public domain. Source: Wikimedia Commons.

- Korbinian Brodmann (1868 –1918)

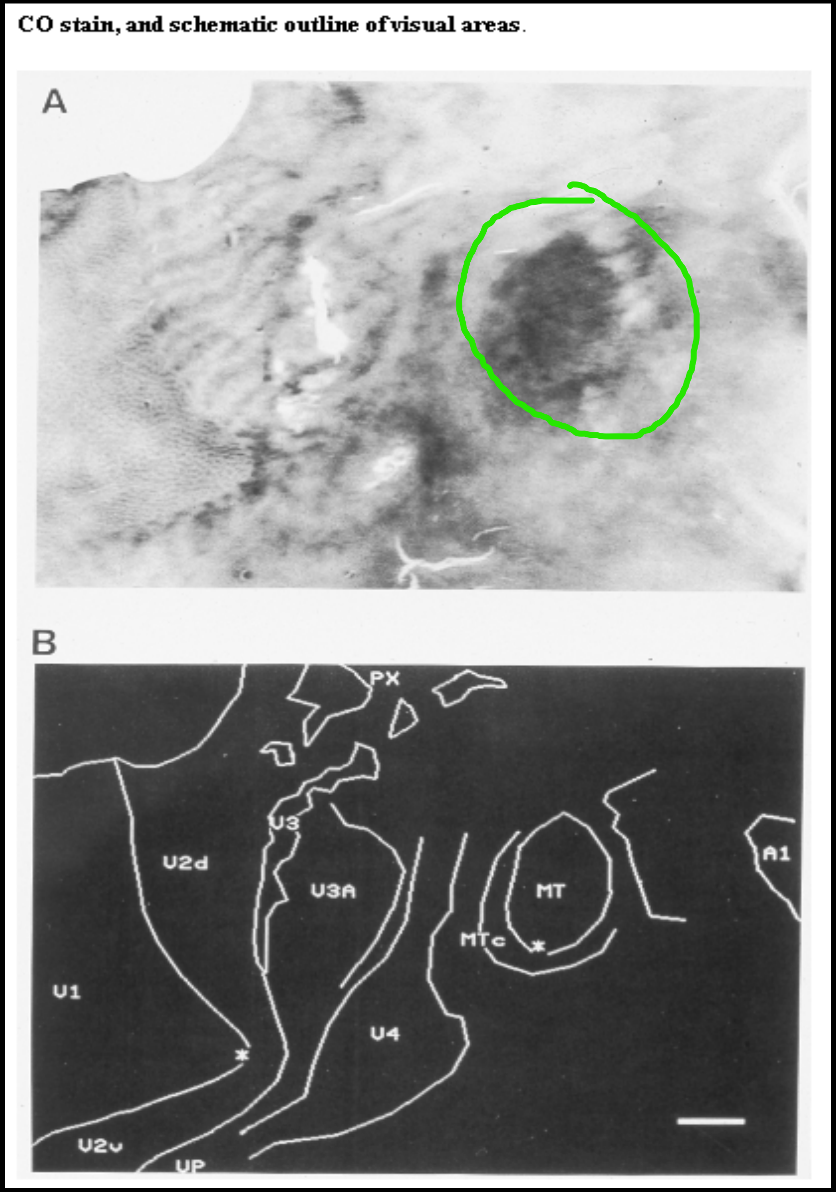
  Identified 52 distinct "areas' based on cytoarchitecture
  Thought of them as like "organs"

> "*The specific histological differentiation of the cortical areas proves irrefutably their specific functional differentiation--for it rests as we have seen on the division of labor.*"



Very clear for primary cortical regions (visual, auditory, ss, motor).
Less clear for most others, except...

MT is also distinctive in Cytoarchitecture

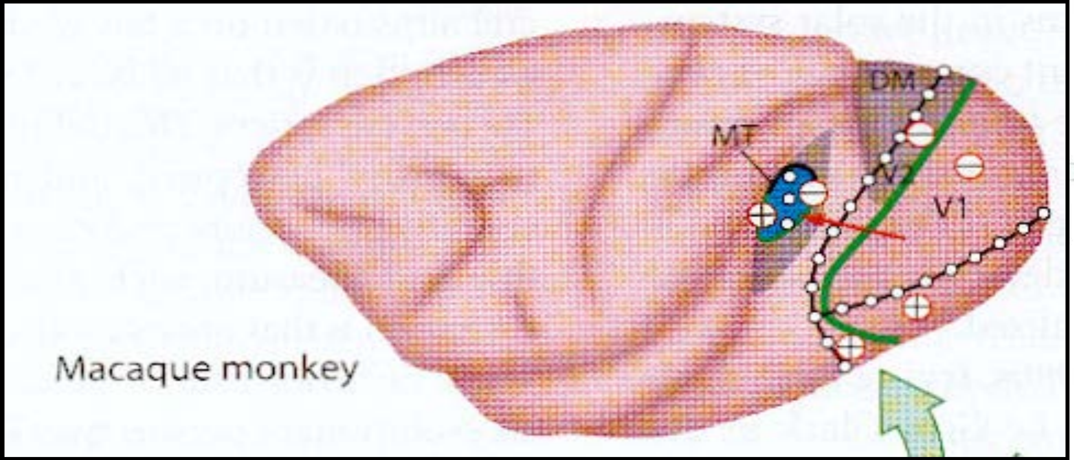


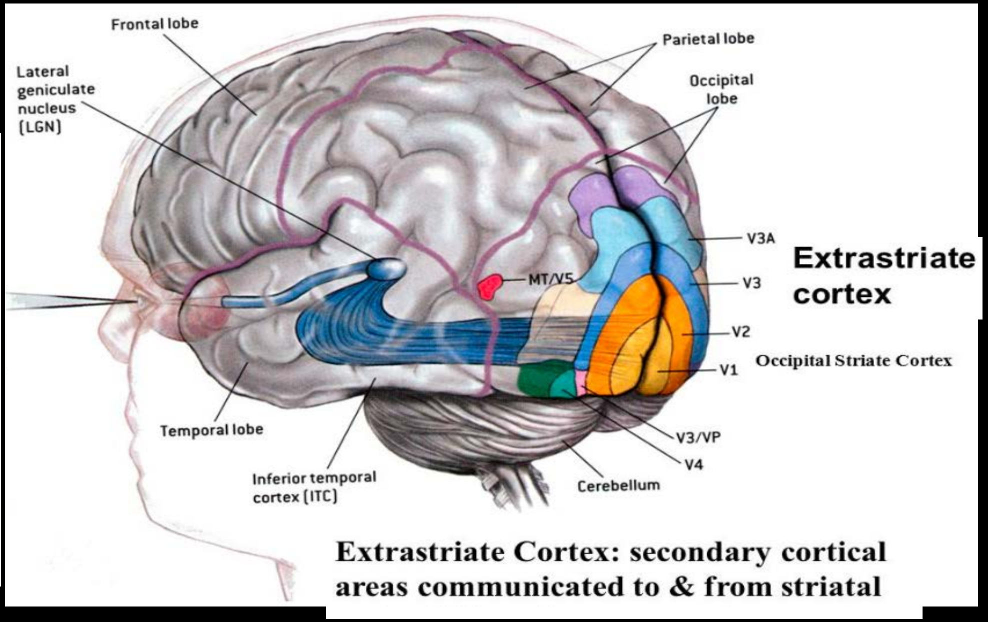
- MT is stained with cytochrome oxidase (which indicates high metabolic activity)

Summary on Cortical Area MT

MT fulfills all the criteria for a cortical area:

- Distinctive function: motion processing
  - lots of lines of evidence (remember these)
- Distinctive connectivity (best data from monkeys)
- Distinctive cytoarchitecture (best data from monkeys)





Concepts you Should be Comfortable with from this Lecture

- cerebellum, thalamus, amygdala, hippocampus, grey vs white matter
- retina, LGN, primary visual cortex
- retinotopy, receptive fields, cortical maps, cytoarchitcture
- what is a "map" in cortex?
- Criteria for a cortical area
- What does MT do and what methods have told us that?
- What is akinetopsia?

*4F

Questions?

Please do not arrive late for next class.