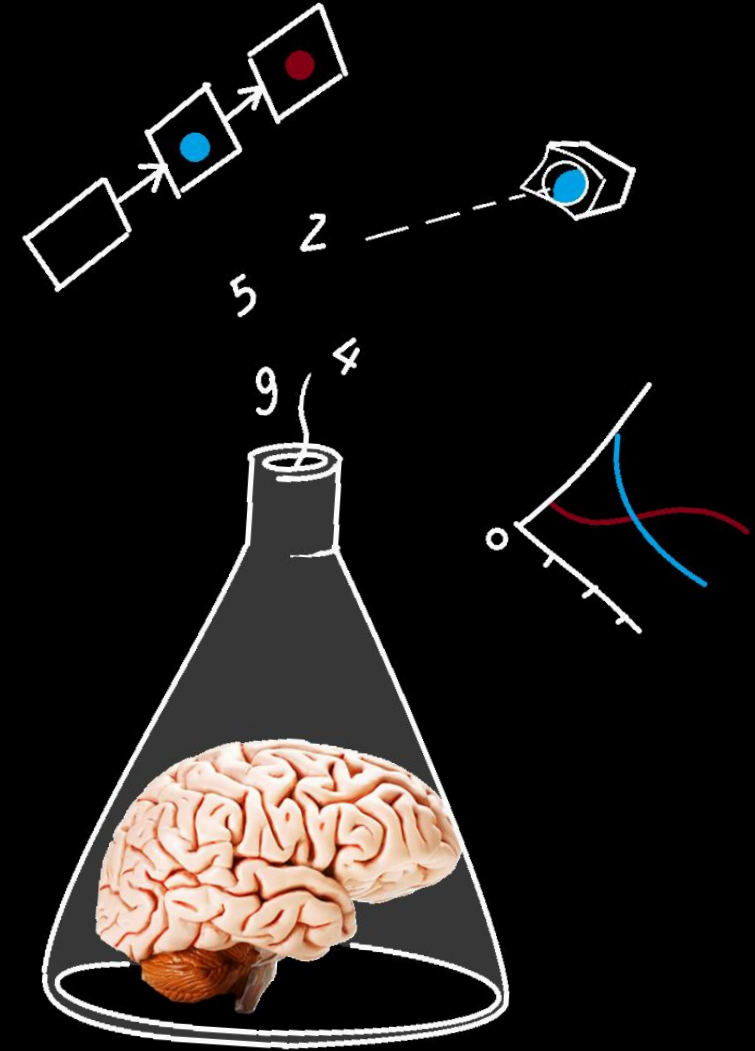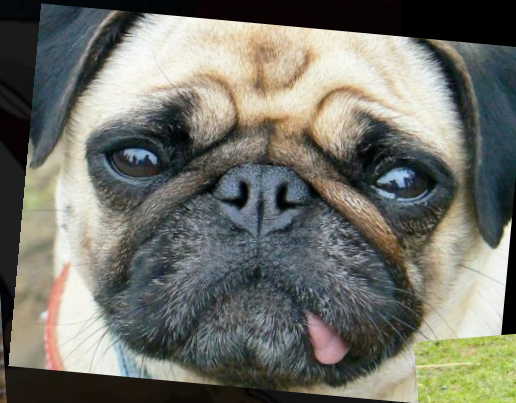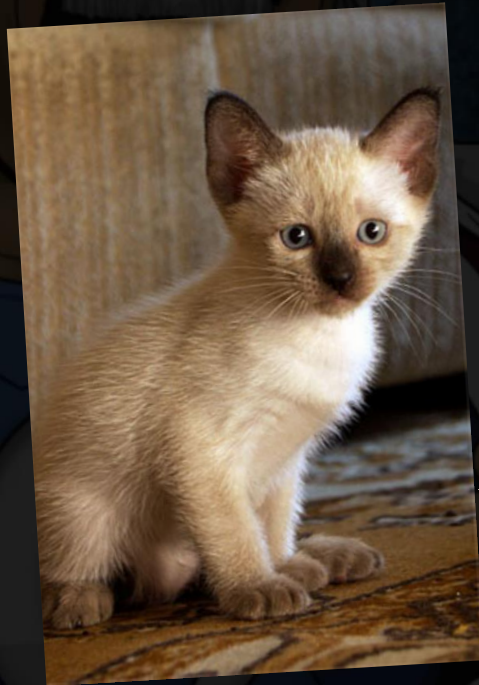# Perception & Attention

Sept 14th

Joshua Snell   J.J.Snell@VU.nl
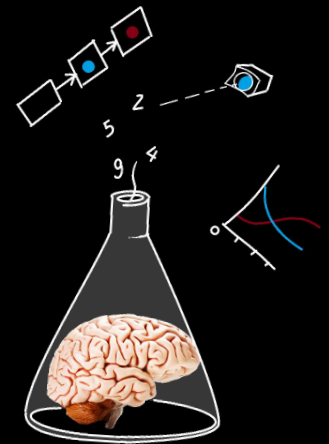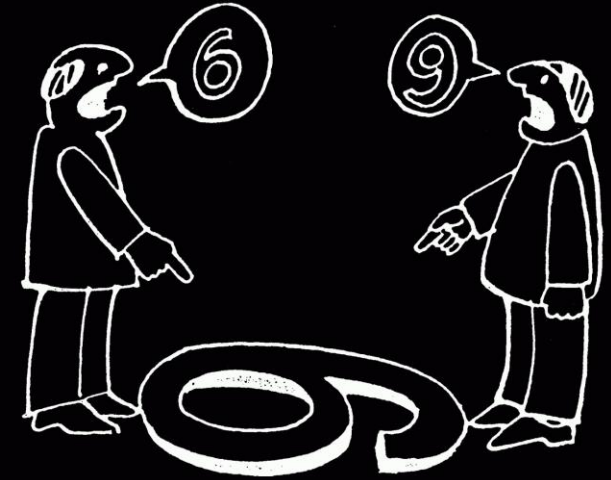
Cats, Dogs & Capybara's   -   shortcomings?

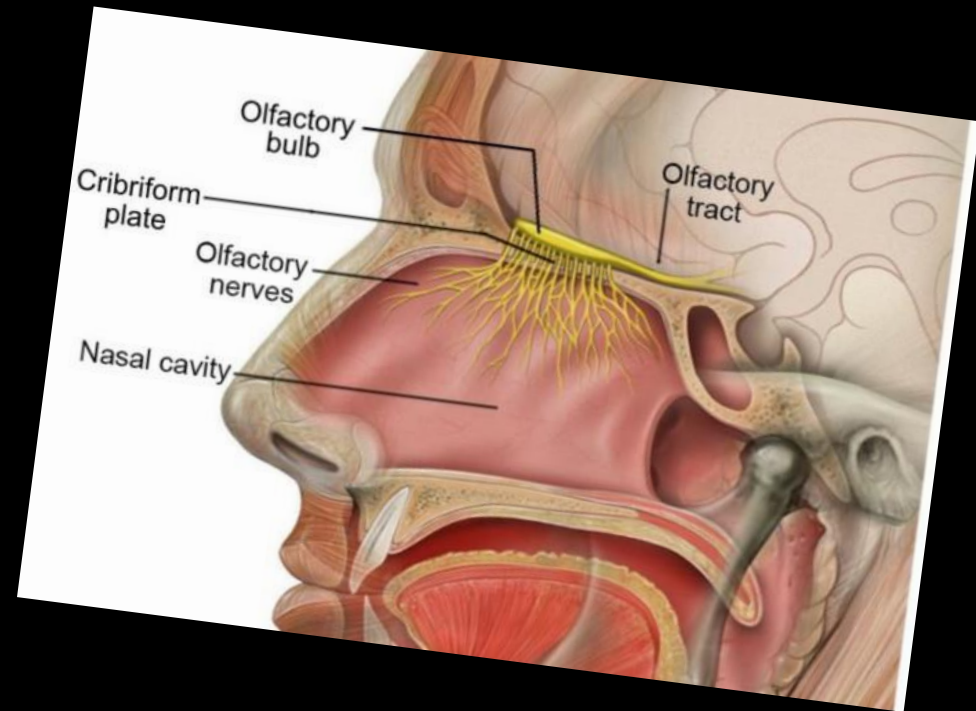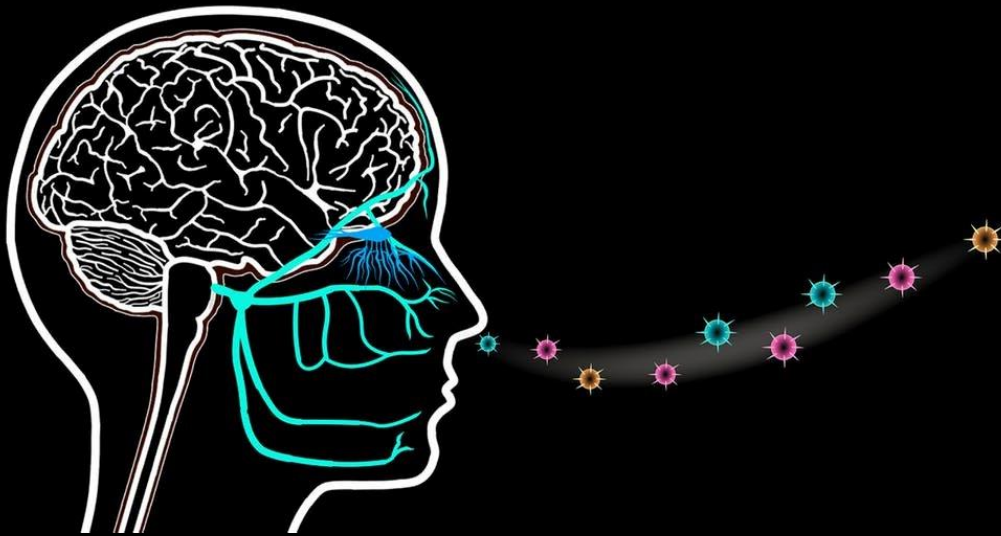Multisensory Integration

Perception

We will cover:
- What is perception, and what is sensation?
- The core challenge: resolving ambiguity
- Bottom-up versus top-down processes
- Bottom-up: *Gestalt* principles
- Top-down: *Experience*
- Neurophysiology

What is perception?

Sensation: The registration of a physical stimulus by receptive neurons

Olfactory bulb

Cribriform plate

Olfactory nerves

Nasal cavity

Olfactory tract

Example: activation of olfactory bulb

What is perception?

Sensation: A physical, factual thing, not susceptible to interpretation etc.

Olfactory bulb

Cribriform plate

Olfactory nerves
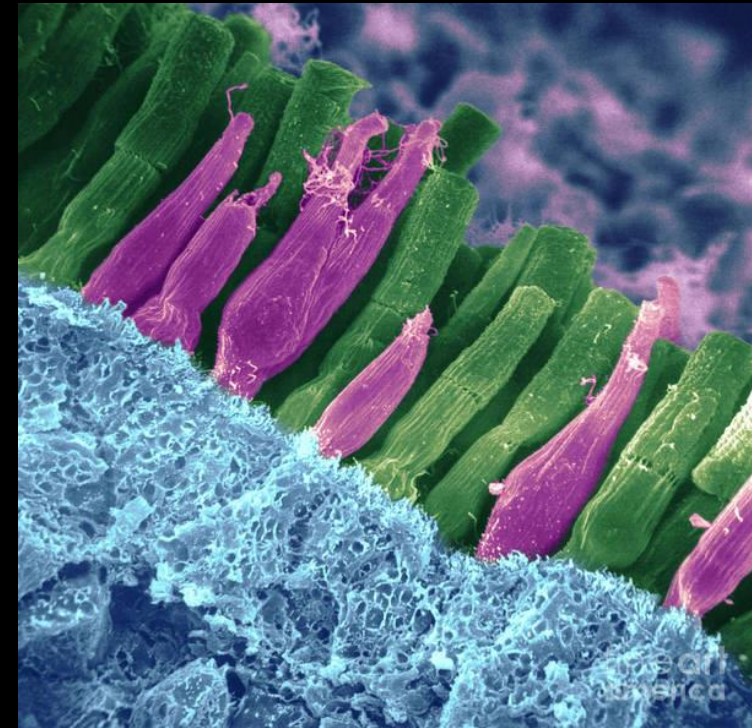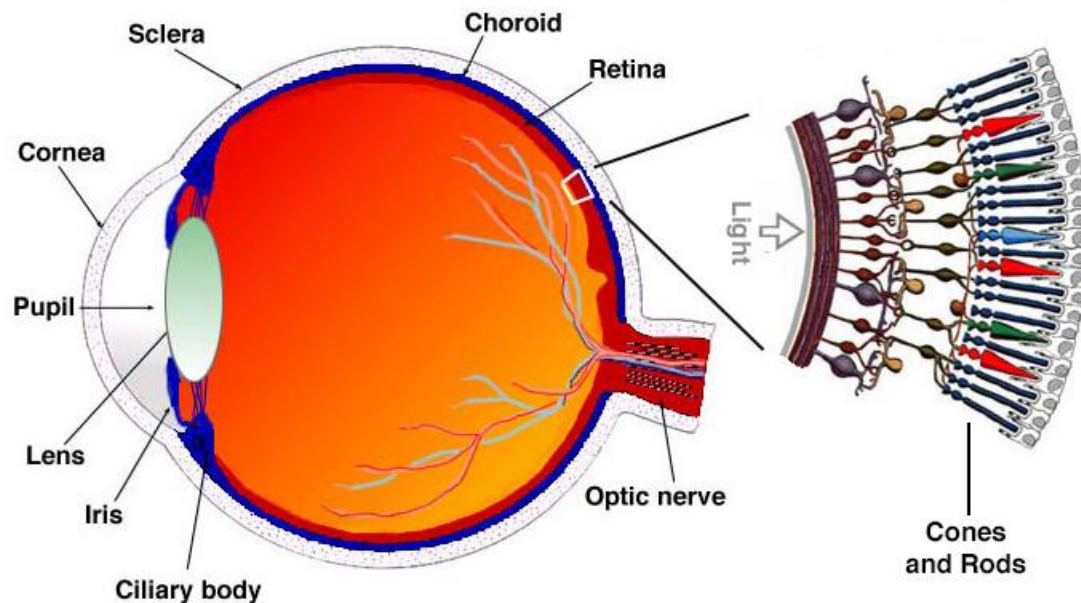
Nasal cavity

Olfactory tract
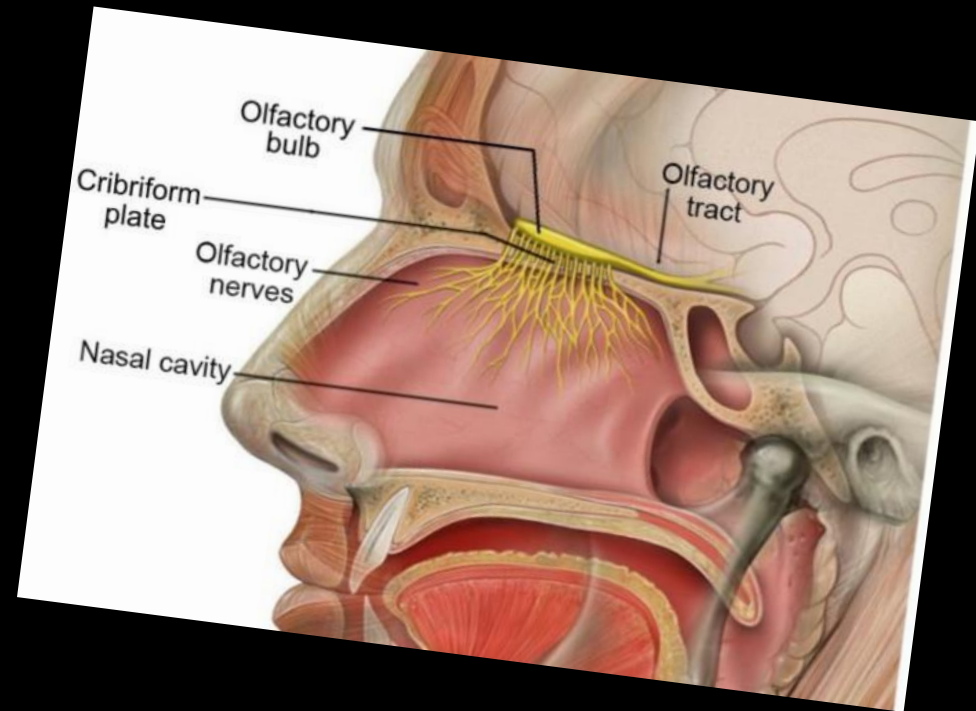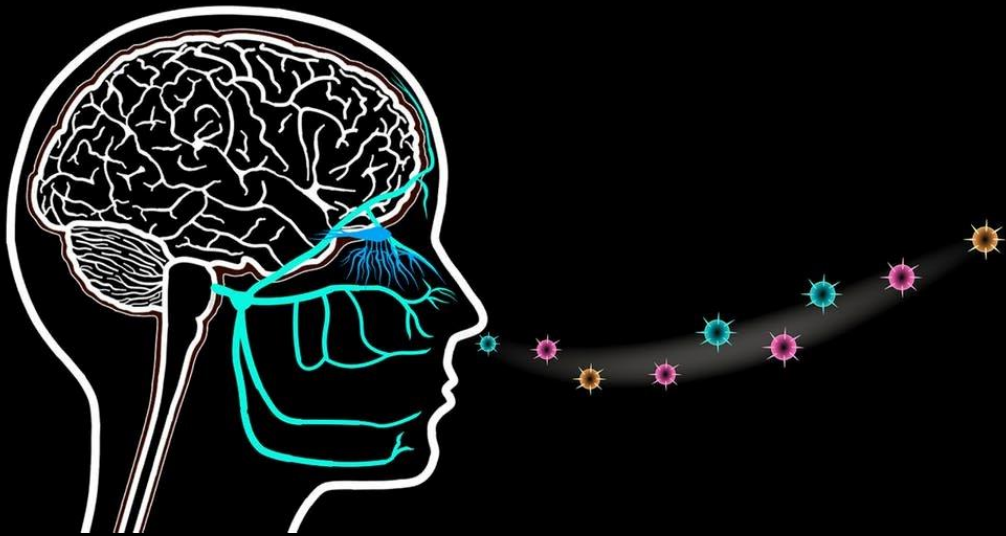
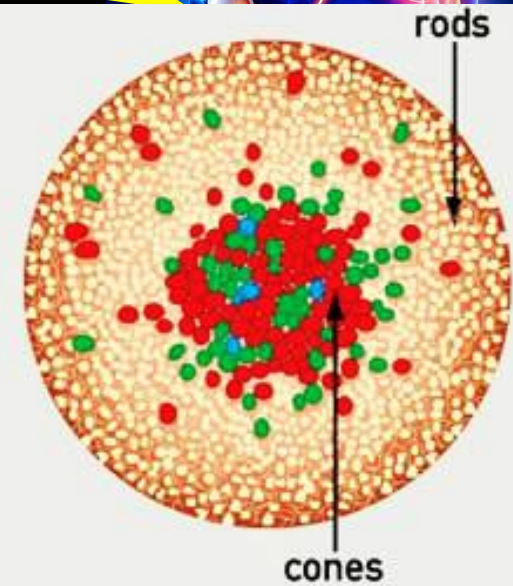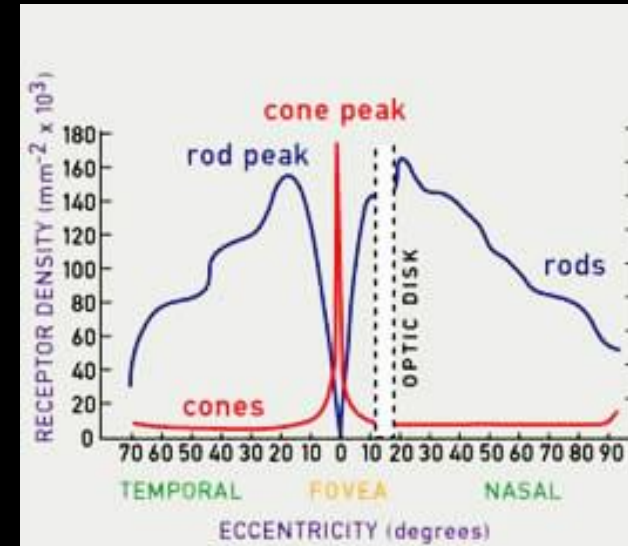Example: activation of olfactory bulb

What is perception?

Sensation: A physical, factual thing, not susceptible to interpretation etc.

Example: activation of visual cortex
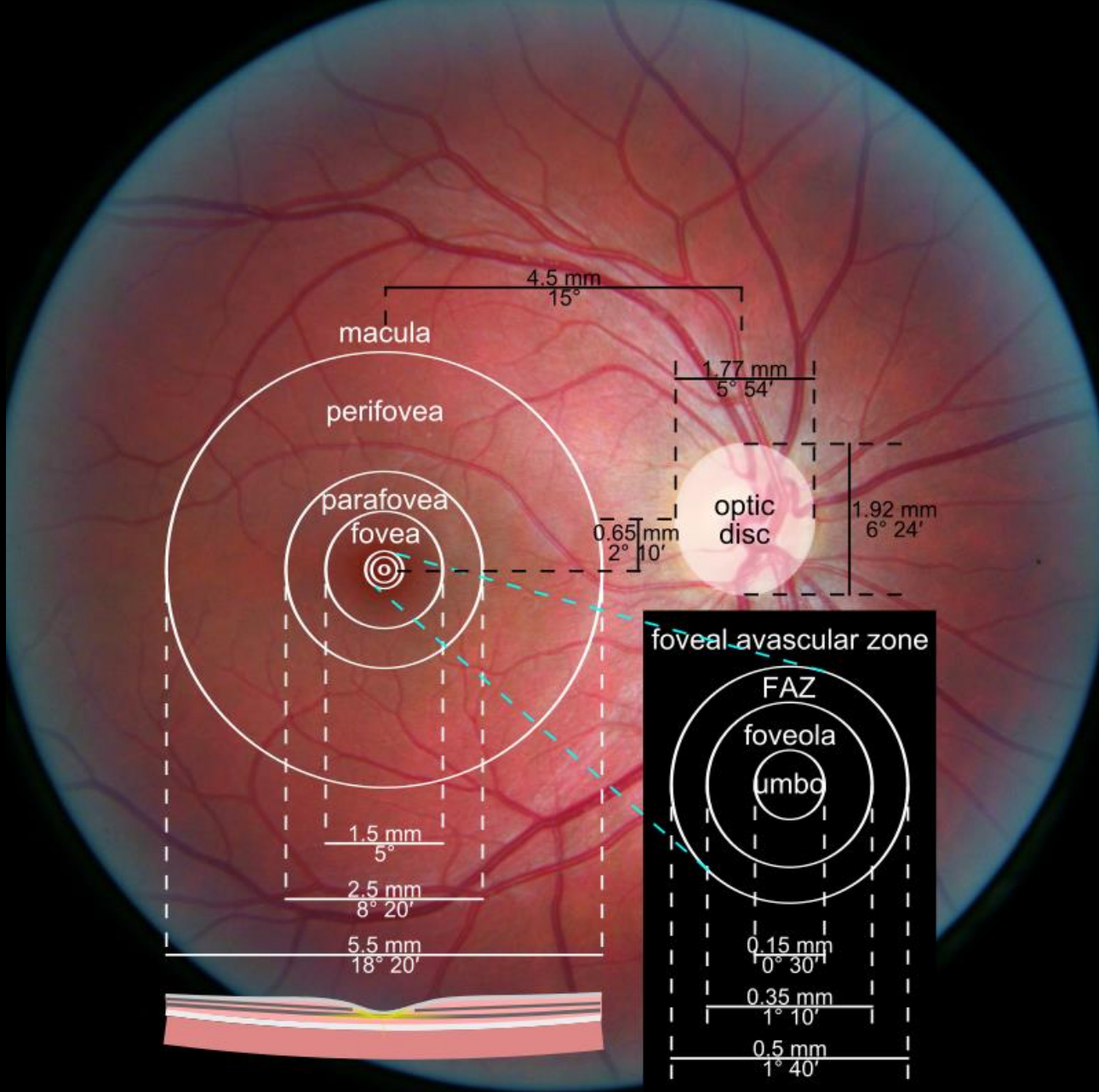
Fovea (1°): many cones, sharp vision (high *acuity)*, color vision, lower sensitivity
Parafovea (6-8°): mix of cones and rods
Perifovea (>8°): mostly rods, low acuity, no color vision, more sensitivity

What is perception?

Perception: the process of *interpreting* sensations

"Stink"
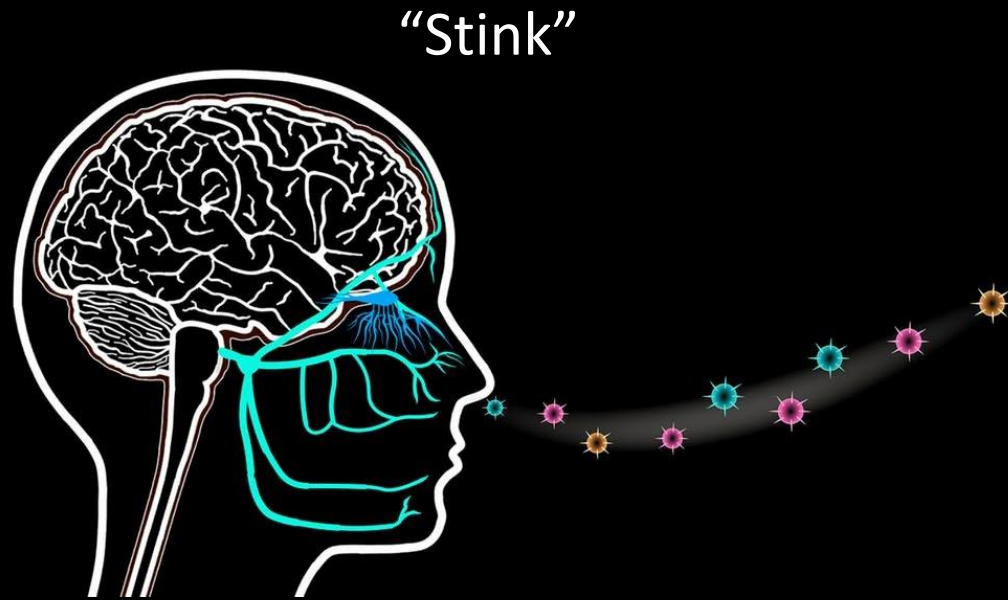
Example: Smelling
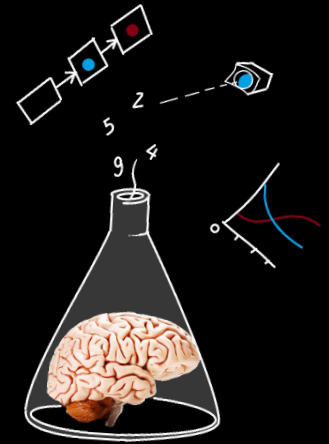
What is perception?

The goal:
Interpreting, recognizing, understanding ('<u>what</u> is it?')
Interacting with the world ('<u>How</u> to respond?')
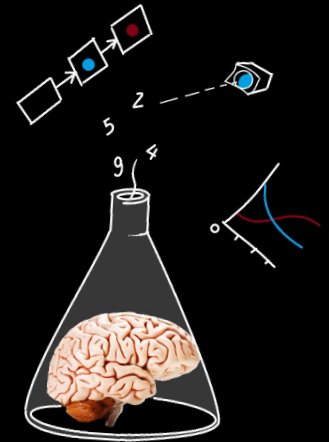
A thin line between sensation and perception...

Pupillary light response is not just triggered by incoming light... but also by *thinking* about bright objects!
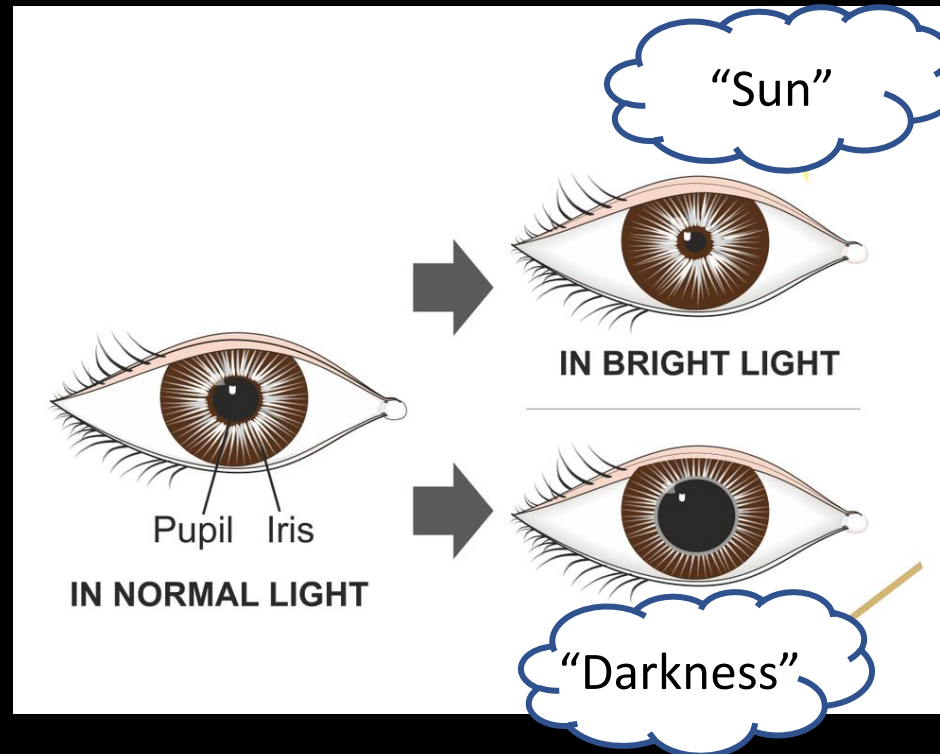
A thin line between sensation and perception...

Pupillary light response is not just triggered by incoming light... but also by *thinking* about bright objects!

Sebastiaan Mathôt

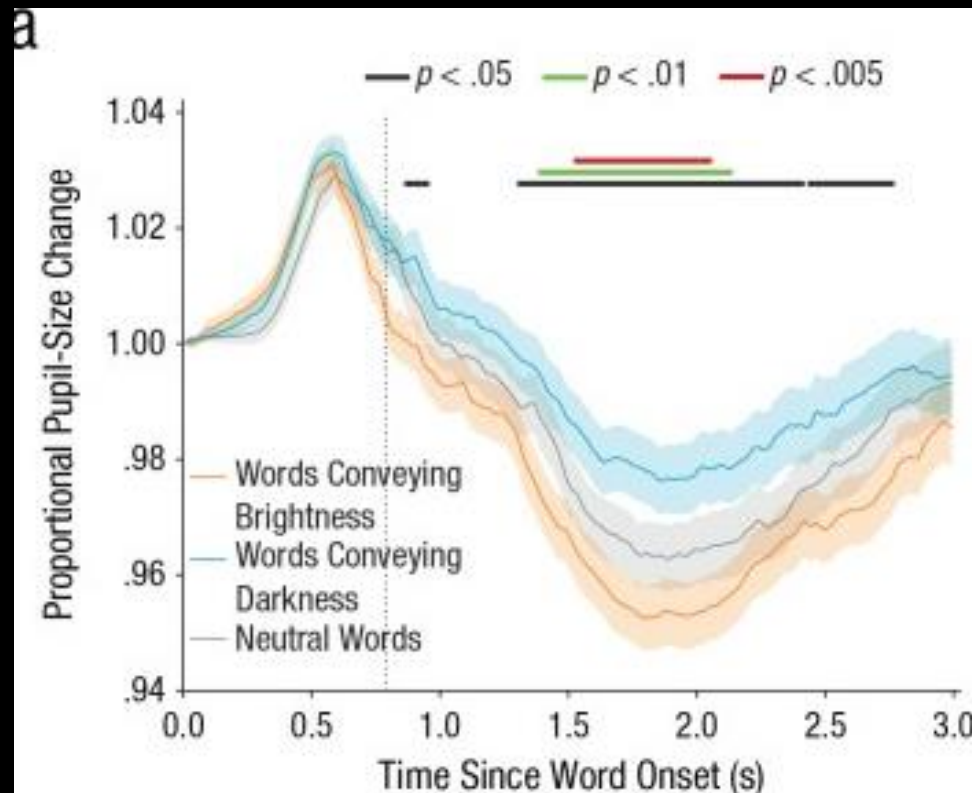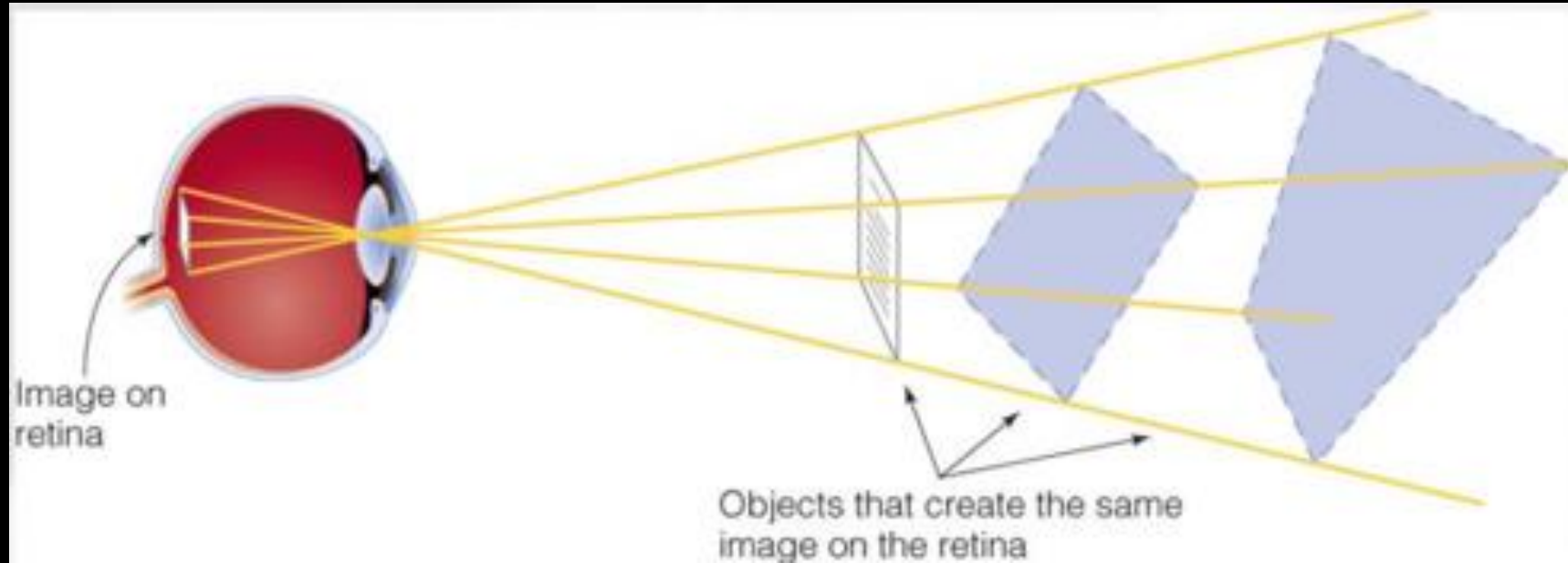# The core challenge in perception:
to resolve ambiguity

Image on retina

Objects that create the same image on the retina

The inverse projection problem
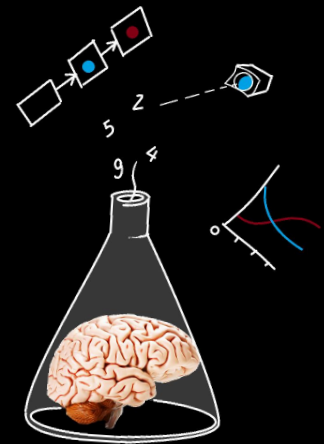→ From sensory processing alone we cannot say anything conclusive about the world!

The core challenge in perception:
to resolve ambiguity

The inverse projection problem
→ From sensory processing alone we cannot say anything conclusive about the world!

The core challenge in perception:
to resolve ambiguity

An auditory example...

Green needle   Brainstorm

Bottom-up versus top-down processing

bottom-up: Sensory organs provide activation
of 'low' cortical regions, cascades to 'higher' regions

Crucial concept!

Bottom-up versus top-down processing

bottom-up: Sensory organs provide activation
  of 'low' cortical regions, cascades to 'higher' regions

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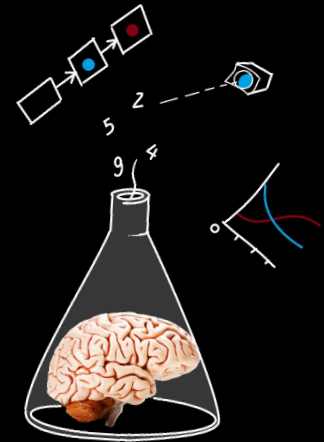
Crucial concept!
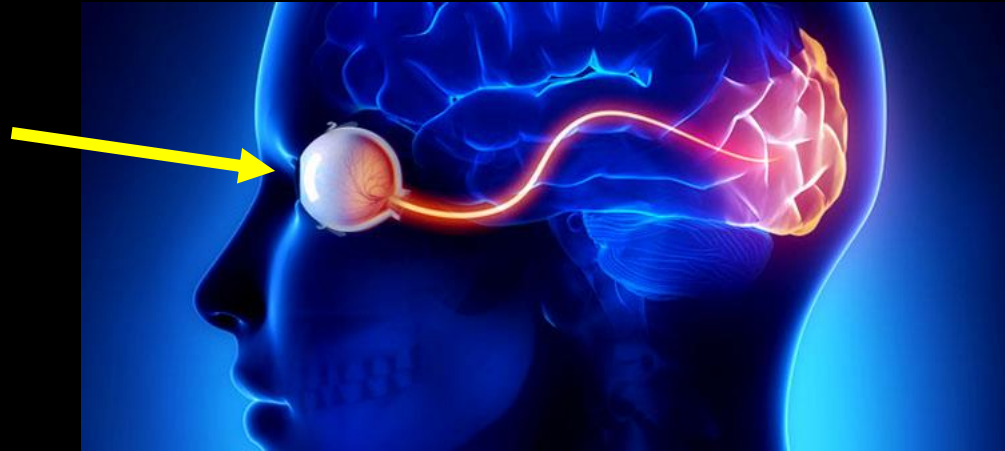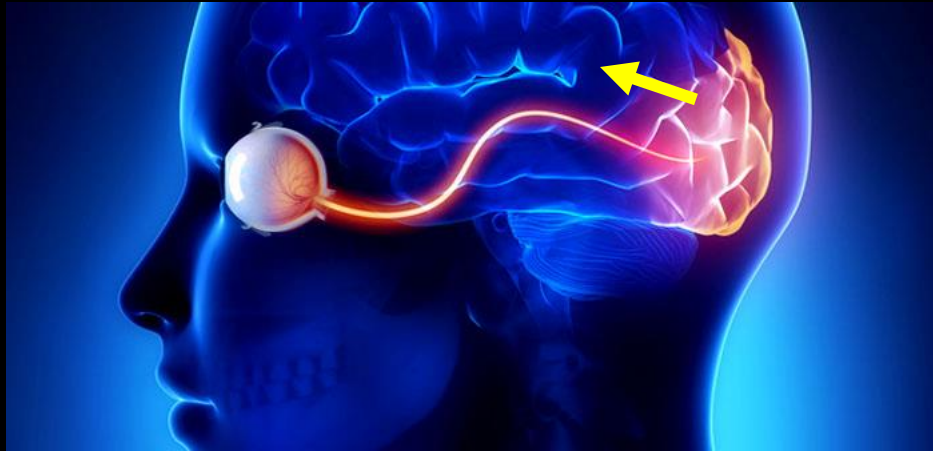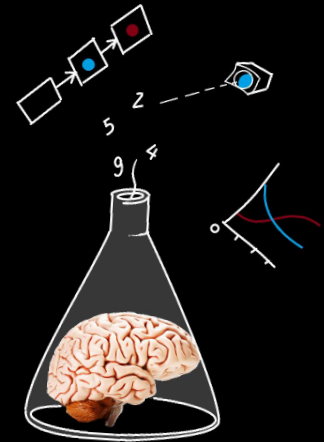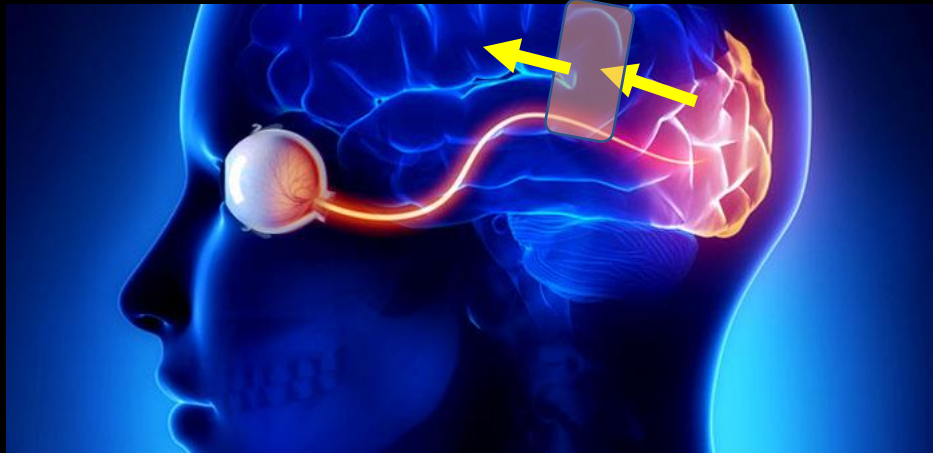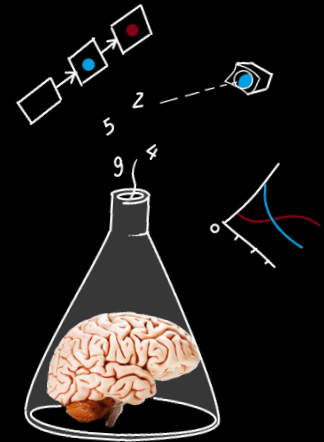
Bottom-up versus top-down processing

bottom-up: Sensory organs provide activation of 'low' cortical regions, cascades to 'higher' regions
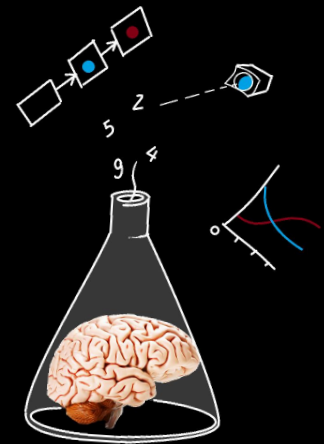
Crucial concept!

Bottom-up versus top-down processing

Top-down: 'higher' regions influence activation of
  'lower' regions

Crucial concept!
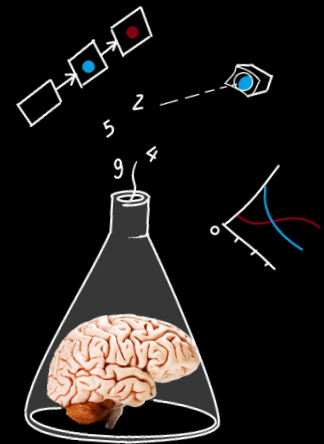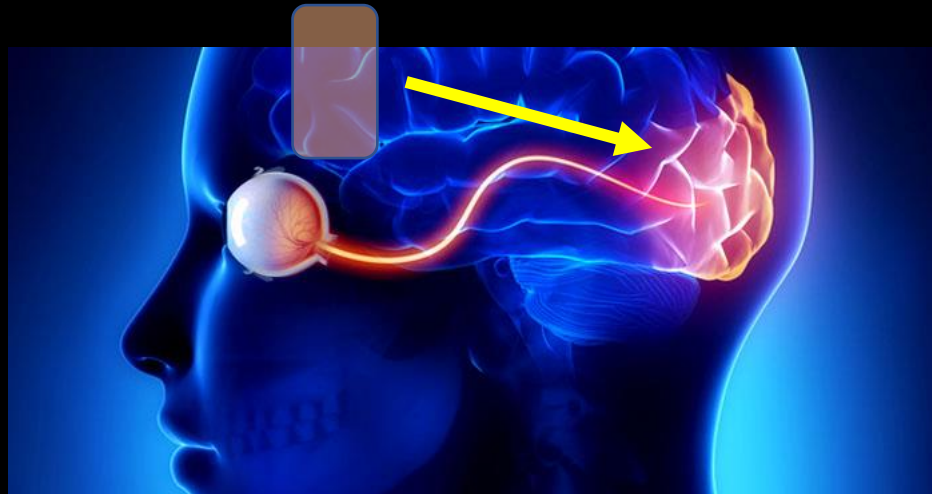
Bottom-up versus top-down processing

sensation = bottom-up
perception = mixture of both
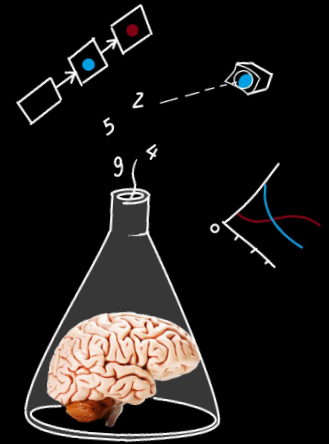
Bottom-up processing: perceptual organization

Let's see why bottom-up processing might be not just sensation...

Grouping of local features
into global structures seems
to proceed automatically

Bottom-up processing

Gestalt principles: A set of assumptions about things that happen in an automatic, bottom-up fashion

...a mere product of the system's architecture

continuity

closure

similarity

proximity

symmetry

common fate

and one that relies on motion →

Bottom-up processing

Gestalt principles: A set of assumptions about things
that happen in an automatic, bottom-up fashion

similarity, proximity, symmetry, closure, continuity, common fate
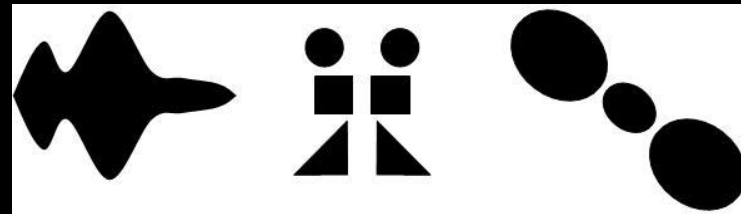
Bottom-up processing

Gestalt principles: A set of assumptions about things that happen in an automatic, bottom-up fashion

...a mere product of the system's architecture

But are all these 'effects' really the result of bottom-up processes?

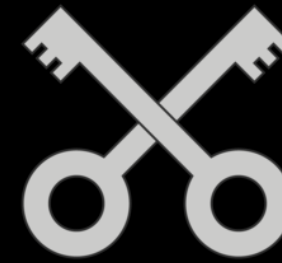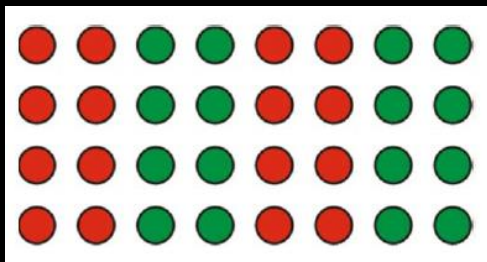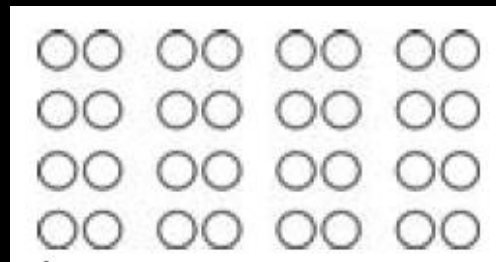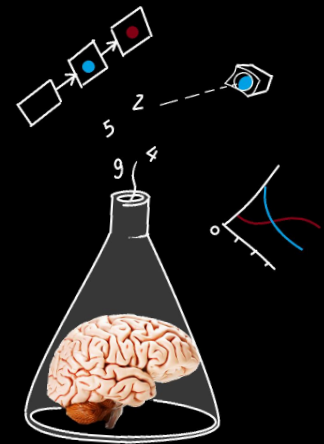*Probably not.* Our life experiences bolster the expectation that
- Similar-looking things belong together
- Objects are most often symmetrical
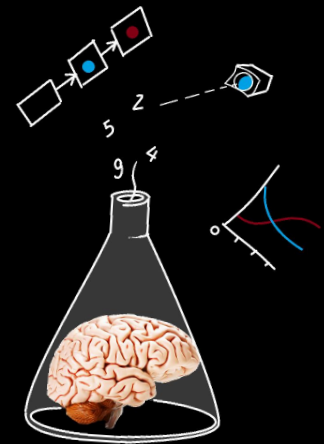
Top-down processing

This is how we typically conceptualize processing in the brain.
– *various levels of processing*
– *interactions among levels*

"Sun"

semantics / memories
e.g. furriness, animalness, your cat Mr. Mittens

words
e.g. detector for *dog*, detector for *cat*, etc.

letters
e.g. detector for 'A', detector for 'B', etc.

Features
e.g. horizontal line detectors curve detectors, etc.

Visual input
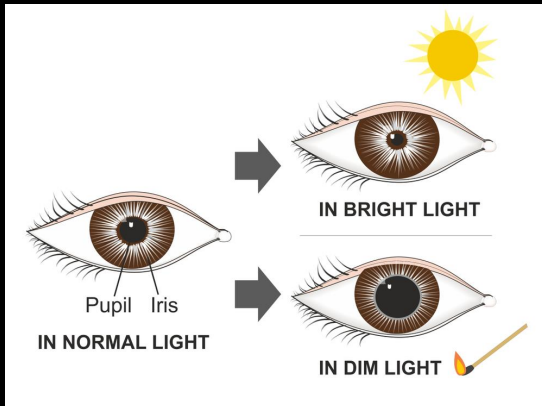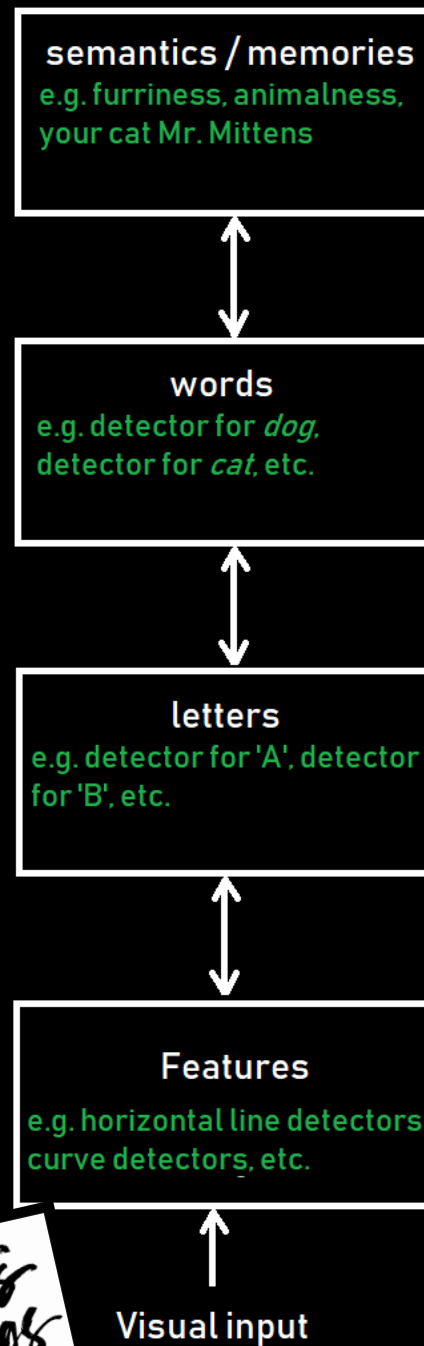
green needle vs. brainstorm

Top-down processing

James McKeen Cattell, 1886

The *word-superiority effect*: a letter is recognized faster if if it is in a word than if it is in a non-sensical string

PL<u>U</u>MP   PM<u>U</u>LP

semantics / memories
e.g. furriness, animalness,
your cat Mr. Mittens

words
e.g. detector for *dog*,
detector for *cat*, etc.

letters
e.g. detector for 'A', detector
for 'B', etc.

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e.g. horizontal line detectors
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Visual input
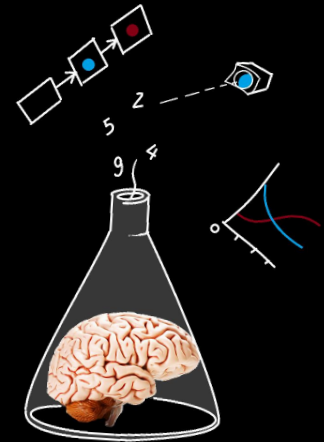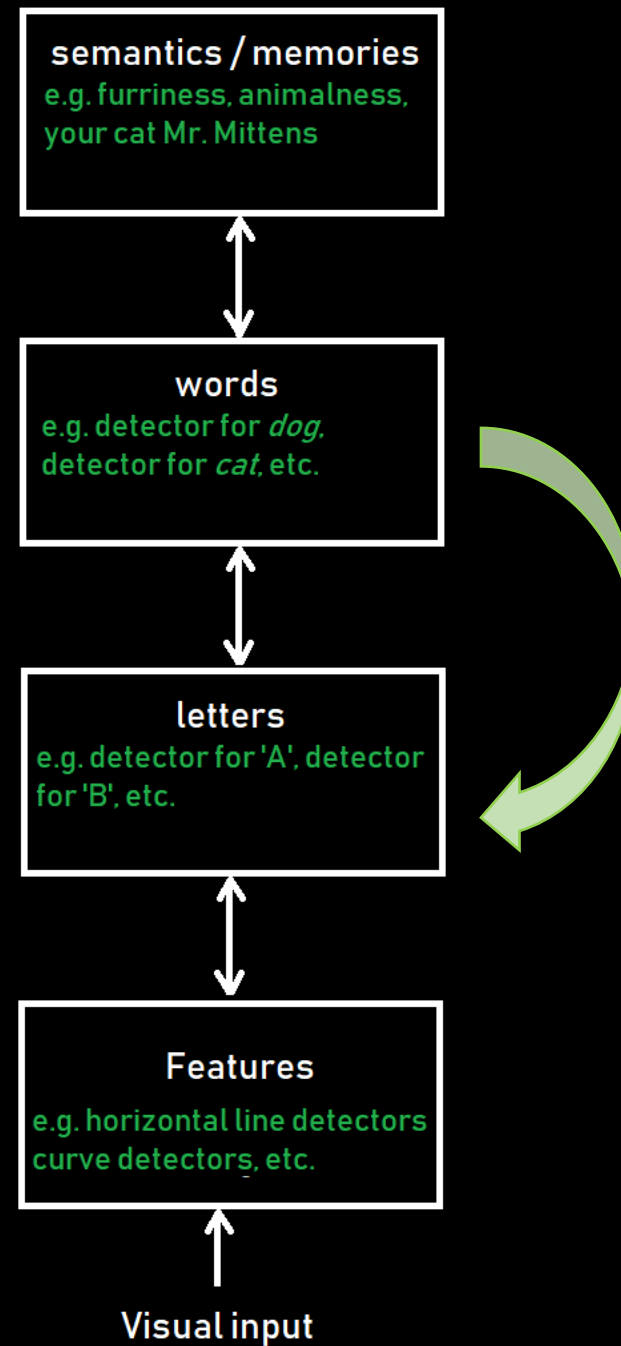
Another way to frame the interaction between top-down & bottom-up

Predictive coding

A grand unifying theory of the mind?
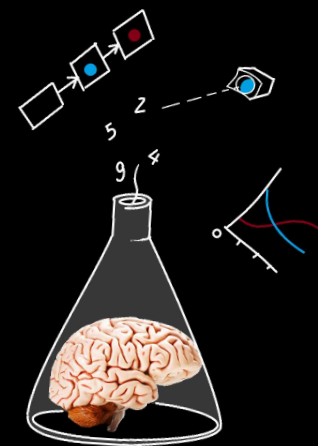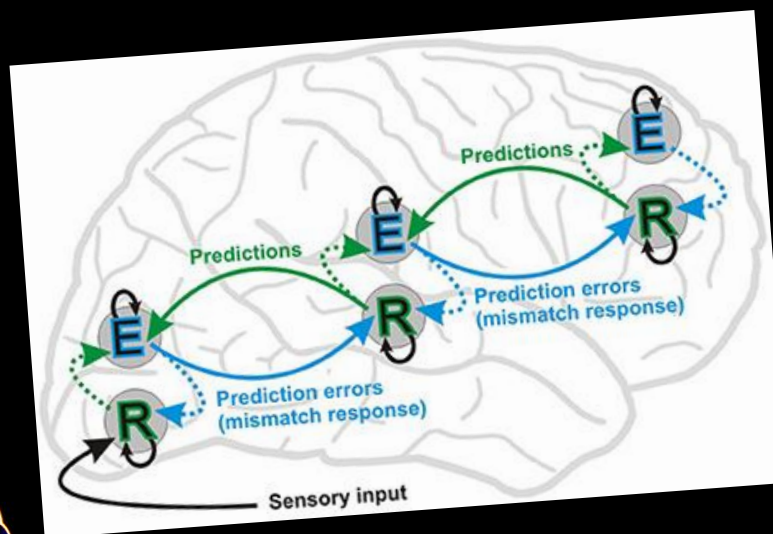
Neurophysiology: perception in the brain
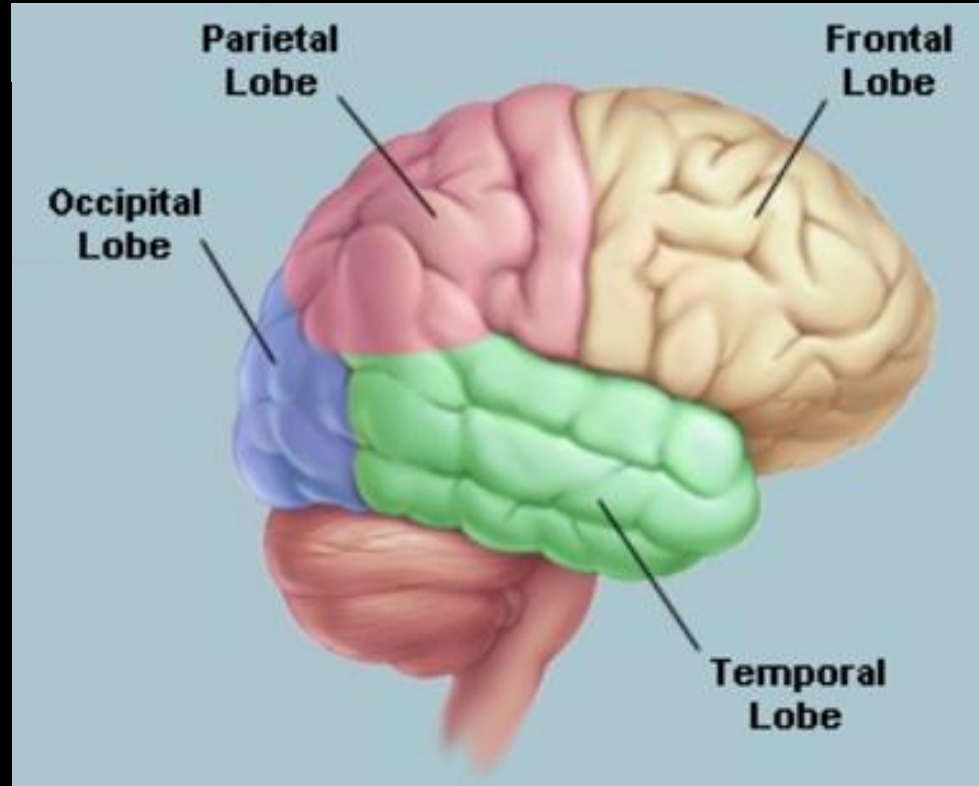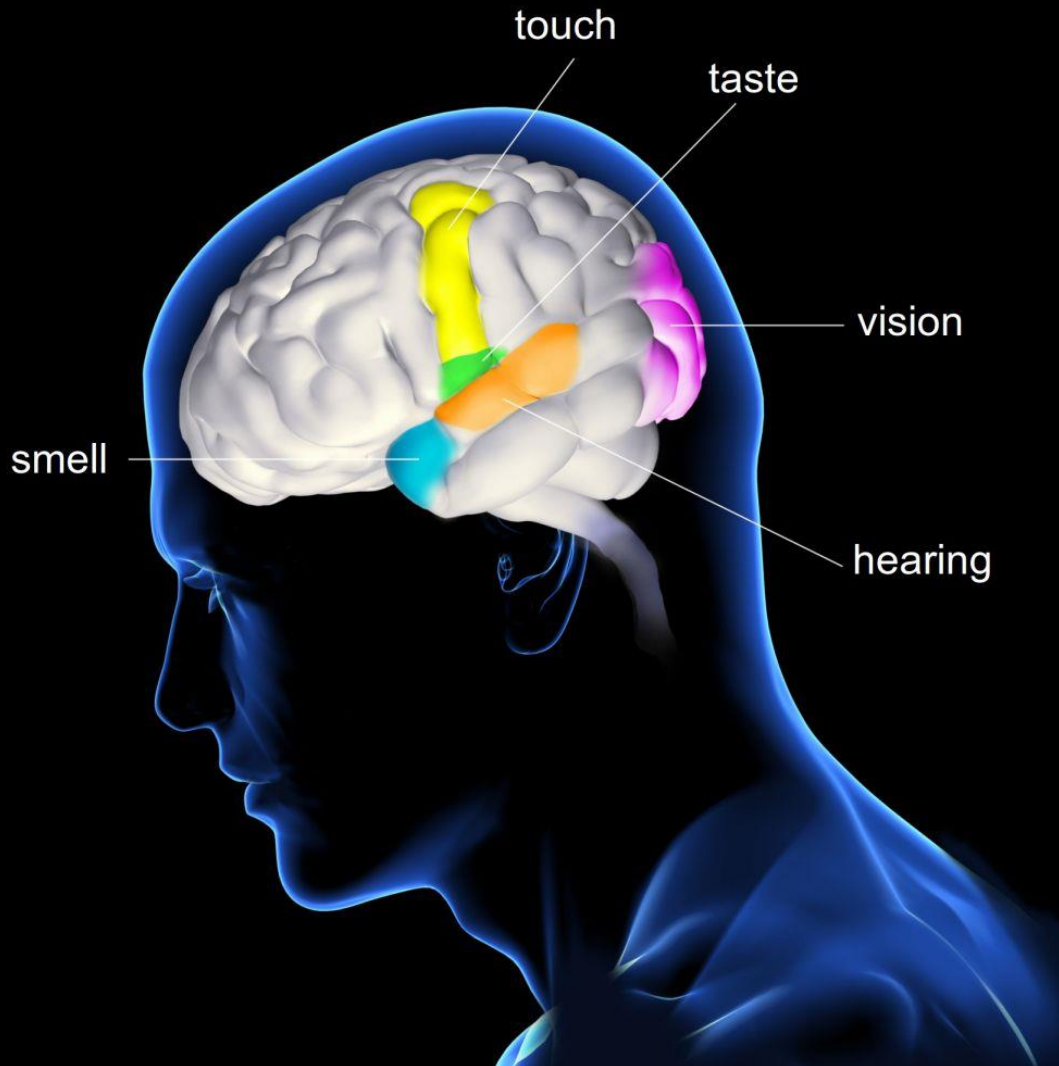
BUT: it's never about isolated brain area's

Neurophysiology: *Dorsal* and *Ventral* pathways

'Dorsal' = backside: 'Where' pathway
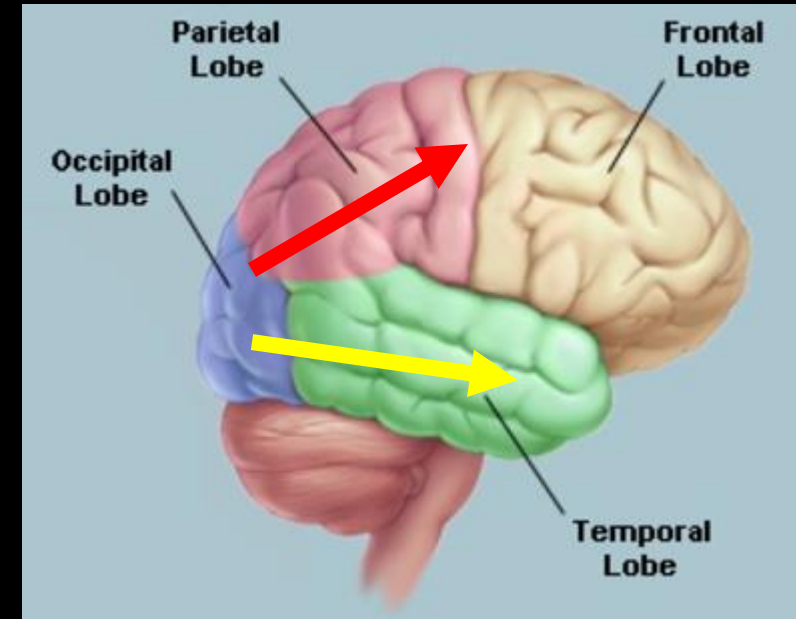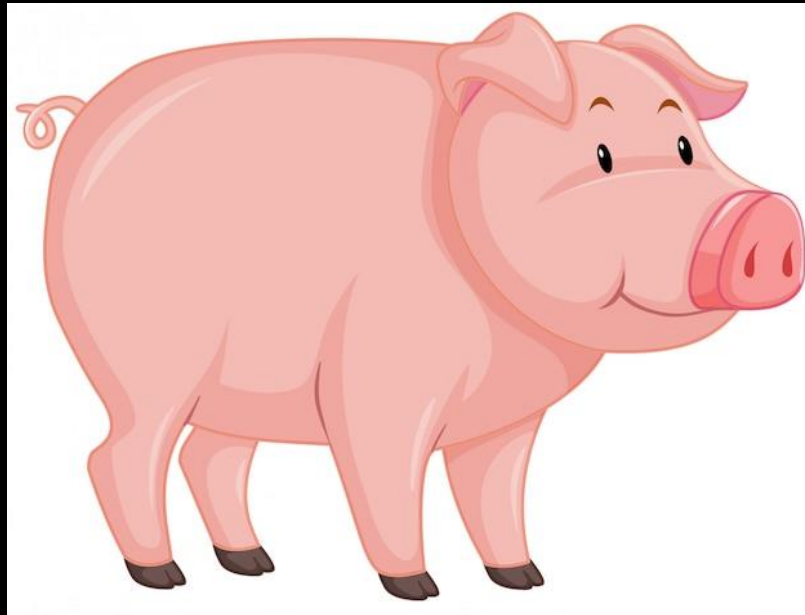
'Ventral' = belly: 'What' pathway

Plasticity in the brain: the brain is flexible

Where do 'detectors' come from?
Our experiences shape dedicated clusters of neurons

The sad-cat story
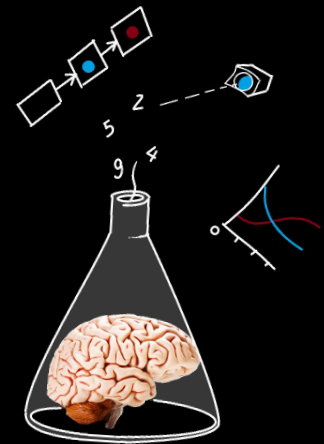
Recap

Sensation vs. perception: a thin line
Perception is about interpreting and interacting
with the world

Bottom-up & top-down processes

In vision: from back of brain to front → from lower to higher
levels of cognition

Neuronal plasticity

Attention

- What is attention?
- Various types of attention:

  Spatial vs. feature-based attention
  Top-down vs. bottom-up attention
  Endogenous vs. exogenous attention
  Overt vs. covert attention

- Early or late selection?
- Is attention the key to everything? → *Feature Integration theory*
- Attentional disorders
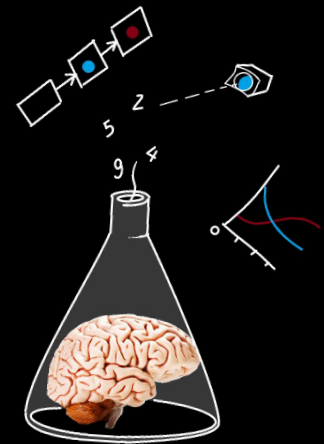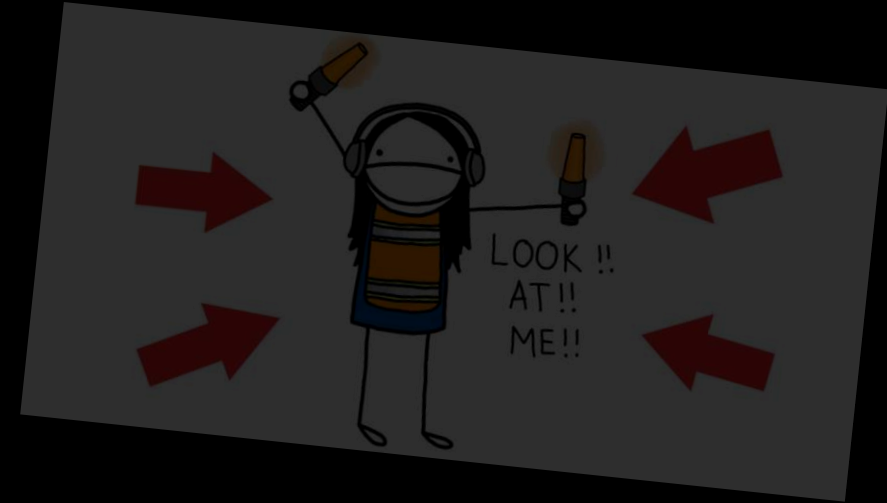
What is attention?

Many psychologists have provided definitions... Here is one:

Attention is the mind's capacity to enhance and suppress sensory input and internal representations

Also applies to things that we keep in memory
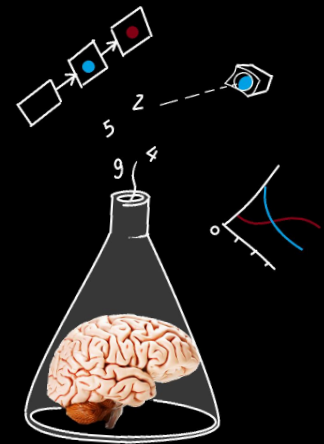
Why do we need attention?

Tap with your hands on your knees:

left left right right left left right right etc.

super easy!
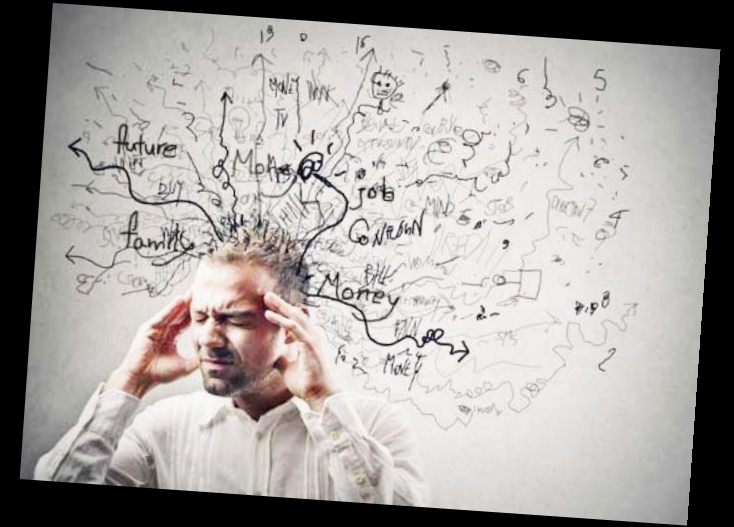
Now simultaneously count backwards from 100 in steps of 3
100, 97, 94, 91, 88 etc.

How's the tapping going now?
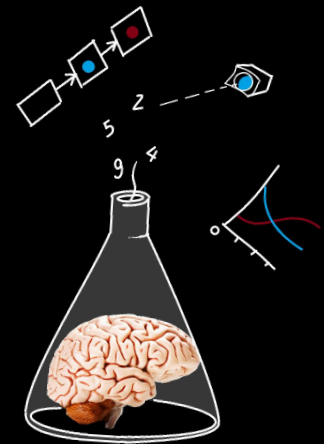
Why do we need attention?

Our brain cannot do an infinite number of computations at once

both consciously and subconsciously

Computations must be run to completion at the expense of other computations

both consciously and subconsciously
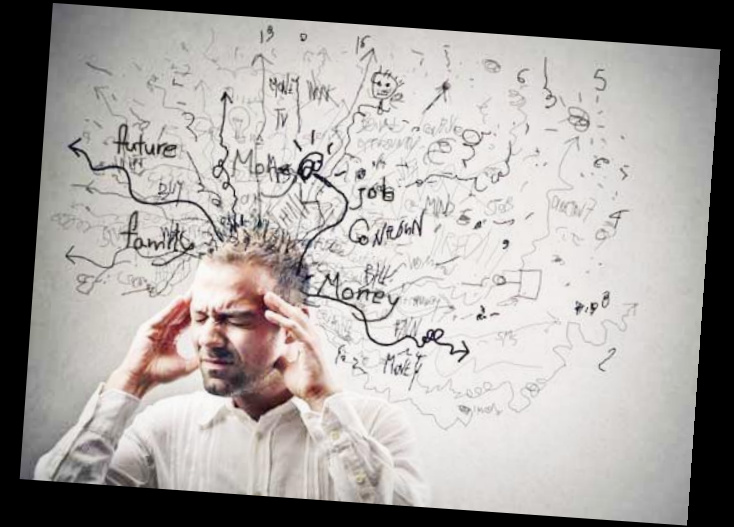
Let's discuss various types of attention...

Within the realm of vision: Overt & Covert attention

Overt is Obvious to others; the eyes and head move
Covert is Concealed to others; the eyes and head do not move

In the lab we often track overt attention

How might we track *covert* attention?
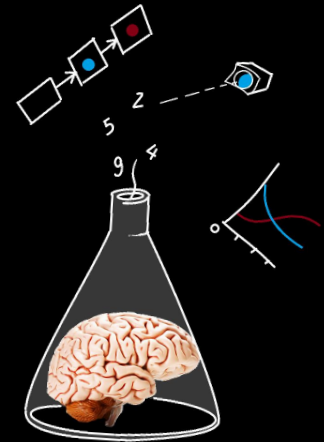
Let's discuss various types of attention…

Within the realm of vision: Overt & Covert attention

Mathôt et al.: The pupil responds to the brightness of *covertly* attended locations
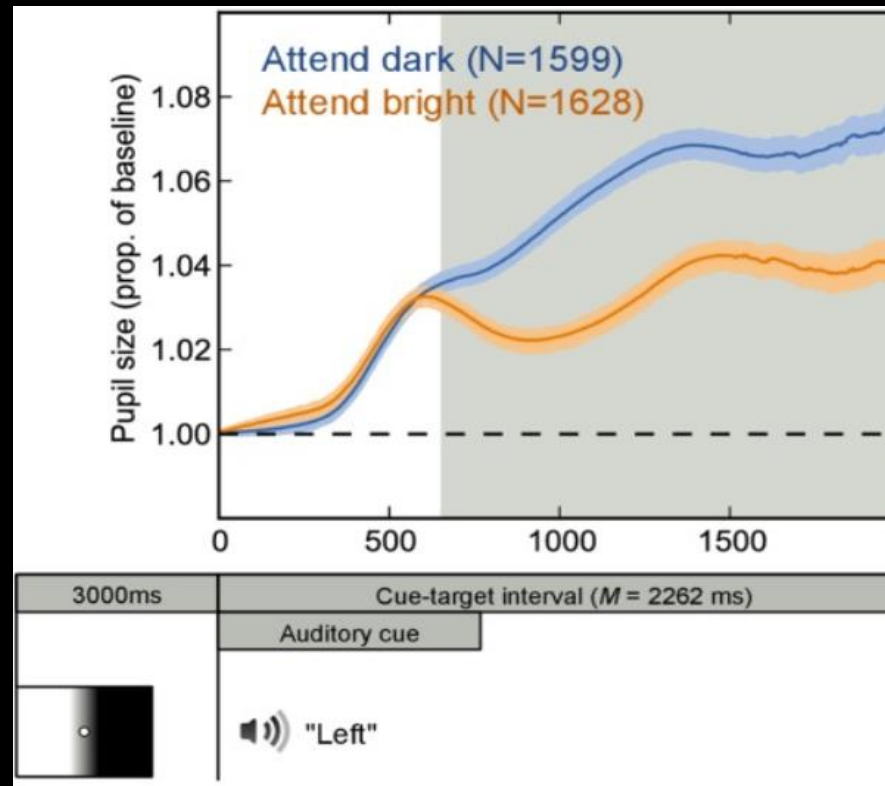
Let's discuss various types of attention...

Within the realm of vision: Spatial vs. Feature-based attention

Attentional orienting in vision is often spatial ...but you can choose to be more 'sensitive' to apples; we focus in terms of both *where* and *what*
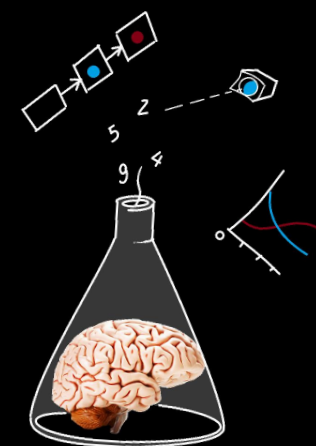
Let's discuss various types of attention...

Endogenous vs. **Exogenous** attention

internally driven (by ourselves) vs. externally driven (by the world)
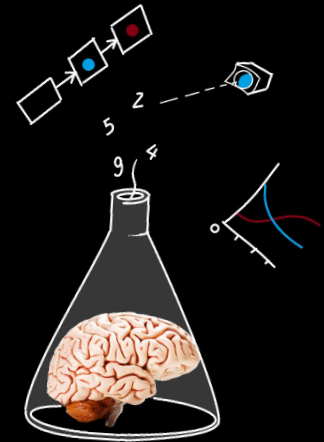
Endogenous or exogenous?

Attention research in the 1950's

Participants heard two messages simultaneously
and had to focus on one...
...and could not report what had
been said in the other stream
endogenous

But when hearing one's own name,
attention is *captured*.
exogenous

Endogenous or exogenous?

Attention research in the 1950's

Participants heard two messages simul[taneously]
and had to focus on one...
...and could not report what had
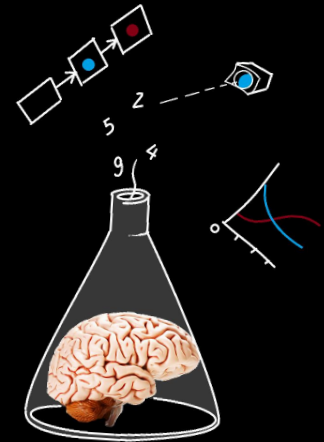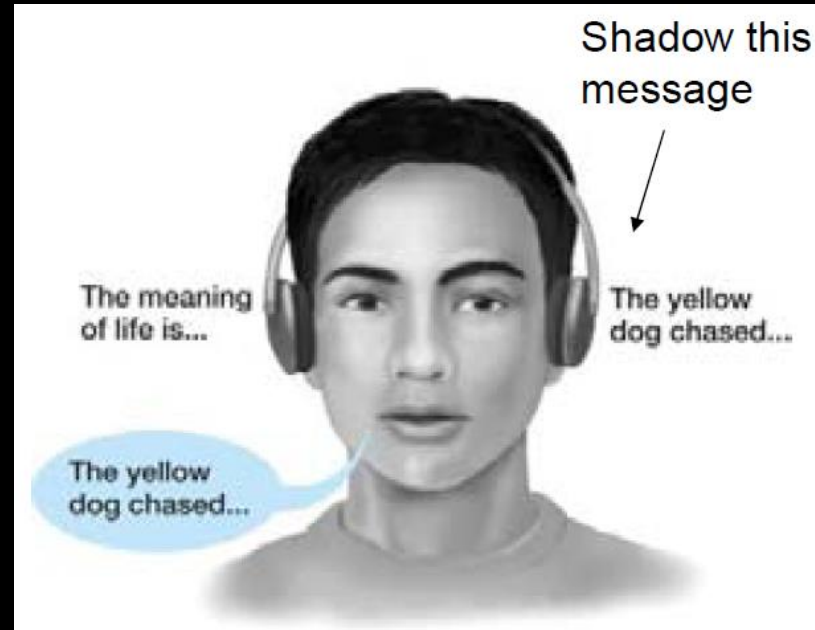been said in the other stream
endogenous

But when hearing one's own name,
attention is *captured*.
exogenous → *'cocktail party effect'*

The singleton paradigm

Respond to the line orientation in the red circle
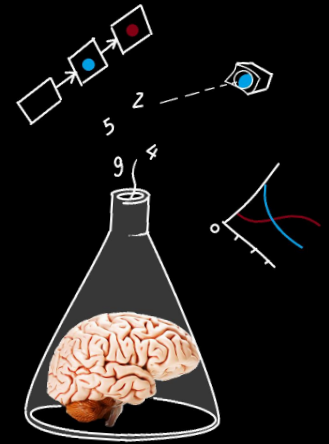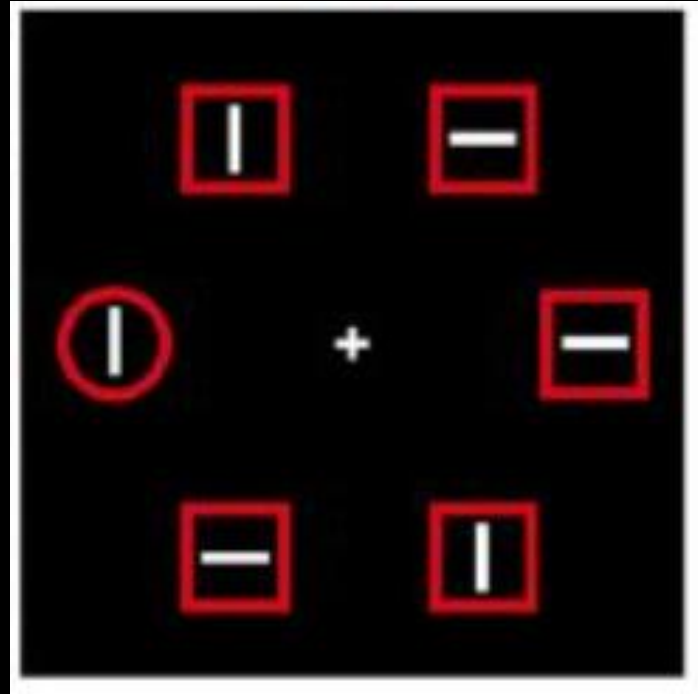
The singleton paradigm

Respond to the line orientation in the red circle

So how does all this work, cognitively?
Let's look at neurons...

Neurons have thresholds for when to fire

The more a neuron is excited (the more input it receives via its dendrites), the more frequently it will fire action potentials

So how does all this work, ~~c~~
Let's look at neurons...

visual field

retina

fovea

Cortical retinotopic Map

Left

Right

Primary
visual
cortex

Calcarine
fissure
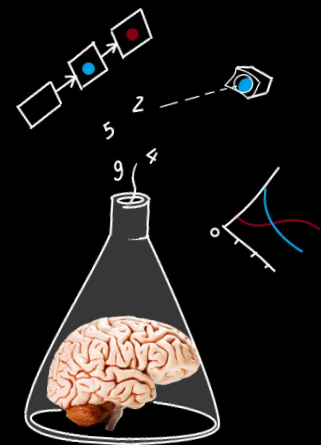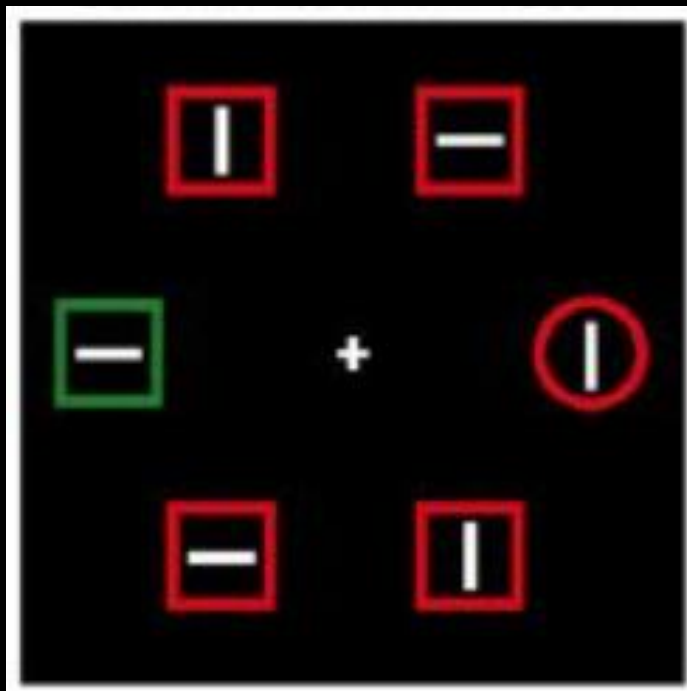
Calcarine
fissure

Cortical
magnification

Neurons have
thresholds for when to fire

The more a neuron is excited (the more input it receives via its
dendrites), the more frequently it will fire action potentials

So how does all this work, [...]
Let's look at neurons...

Topographic organization of the visual cortex

Cortical retinotopic Map

fovea

Cortical magnification

Neurons have thresholds for when to fire

The more a neuron is excited (the more input it receives via its dendrites), the more frequently it will fire action potentials
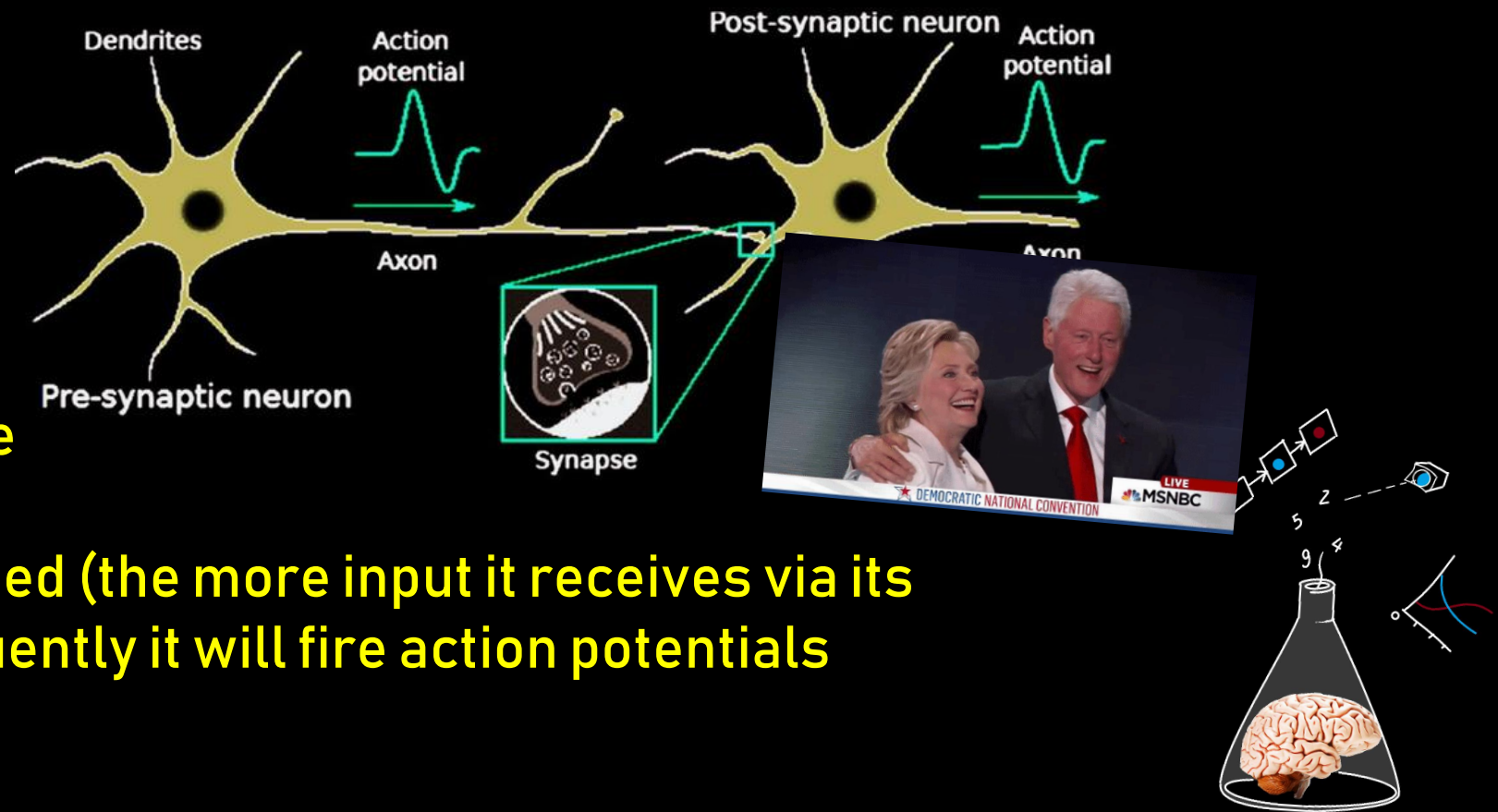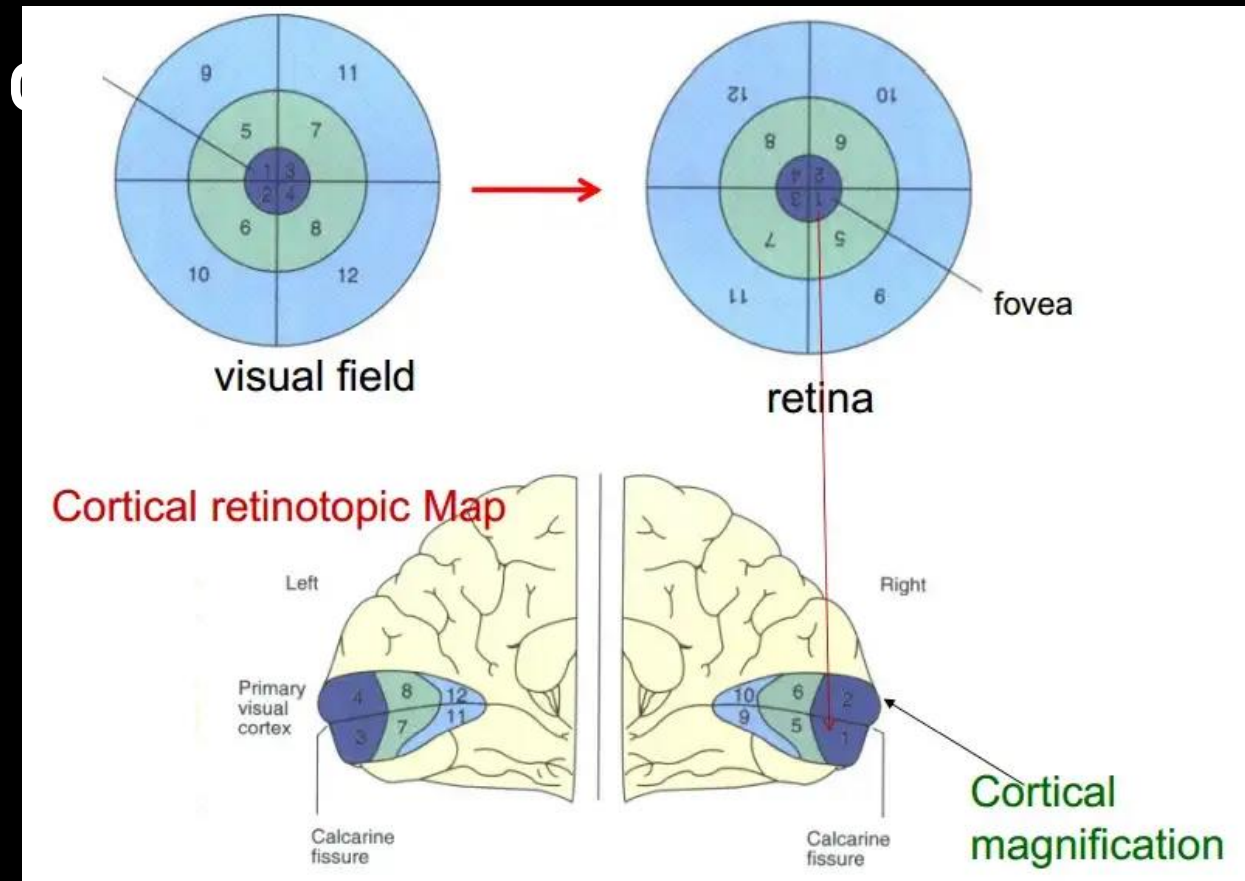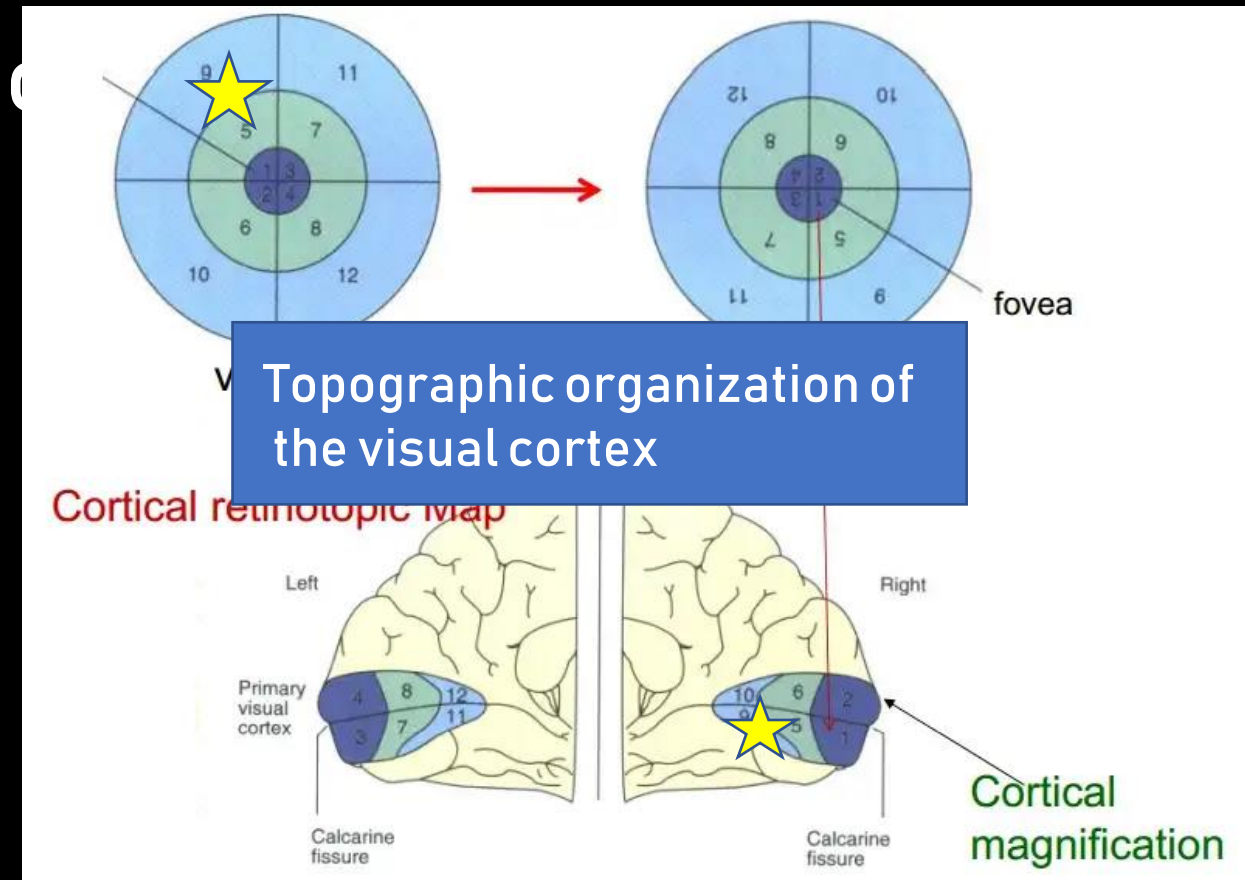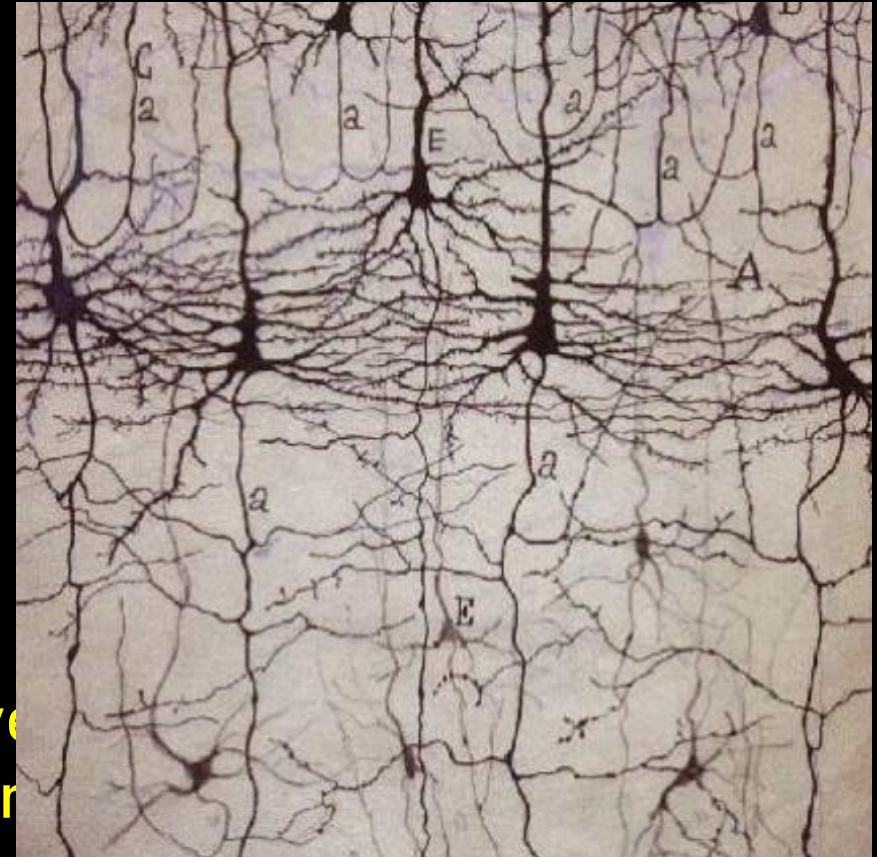
So how does all this work, cognitively?
Let's look at neurons...

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Neurons coding for Hillary's upper visual field may have suppressed neurons
coding for Hillary's lower visual field when 'the thing' happened.

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Rec...
me...
in L...

Neu...
thro...

The...receive
den...on poten...

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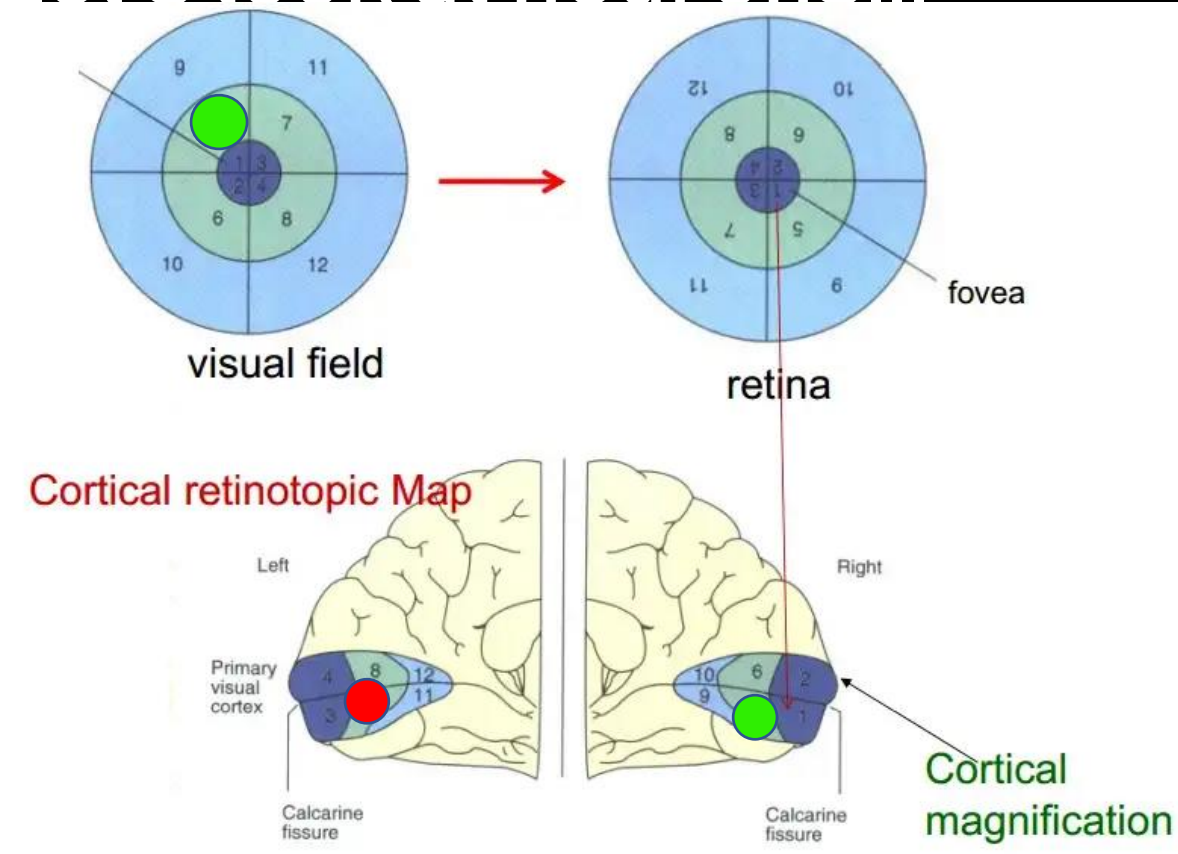coding for Hillary's lower visual field when 'the thing' happened.

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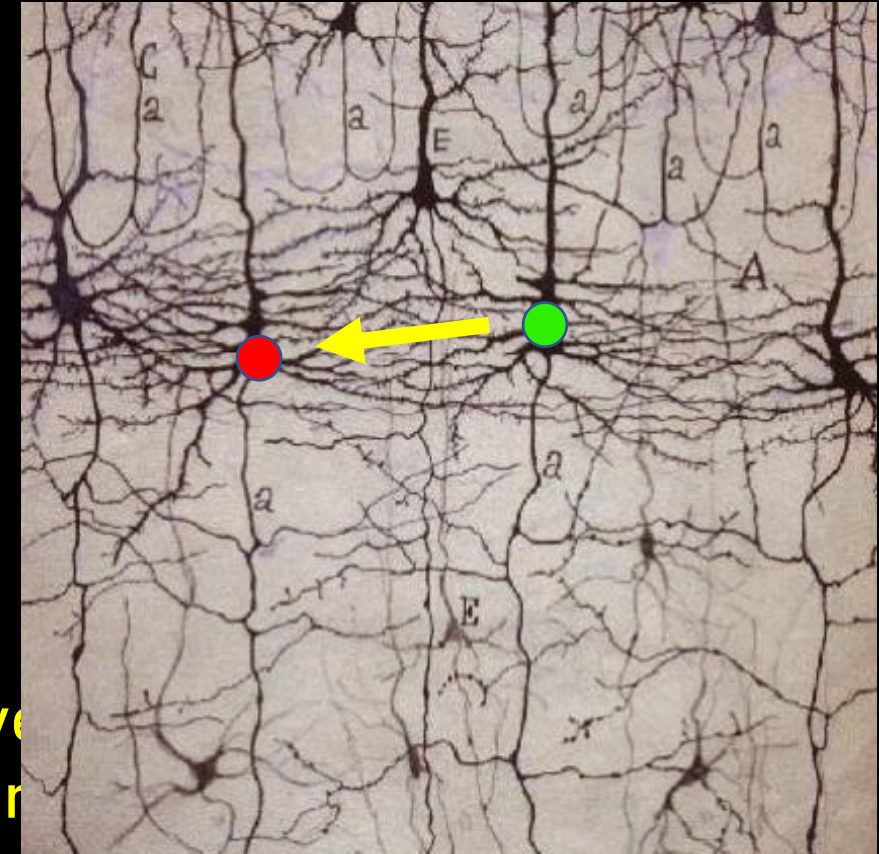## Let's look at neurons...

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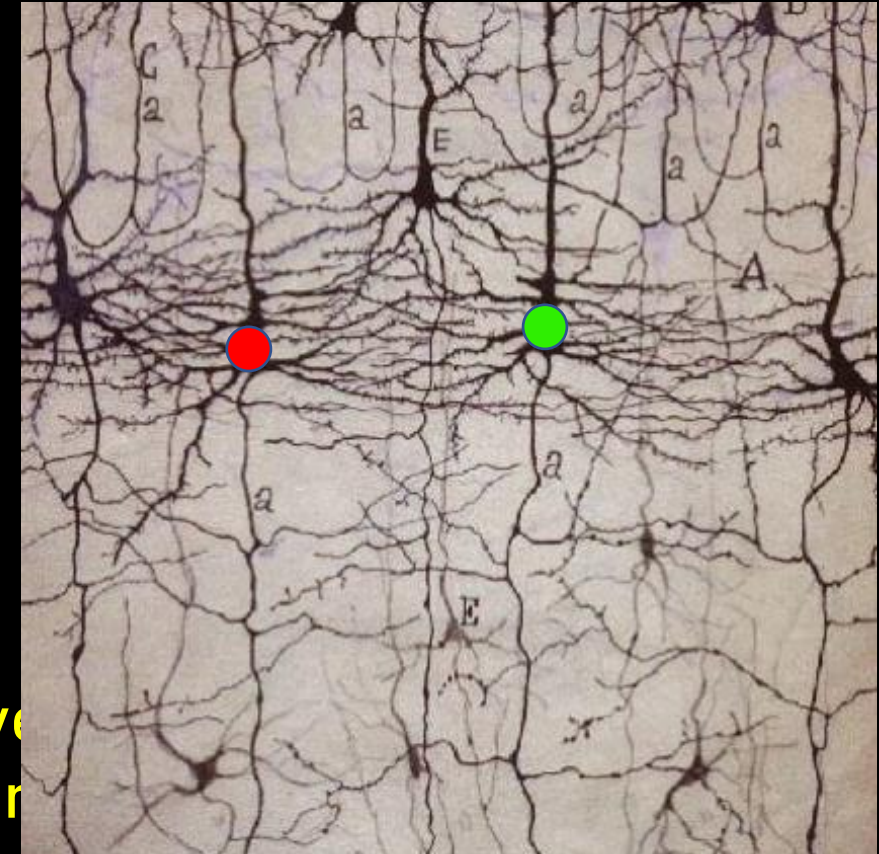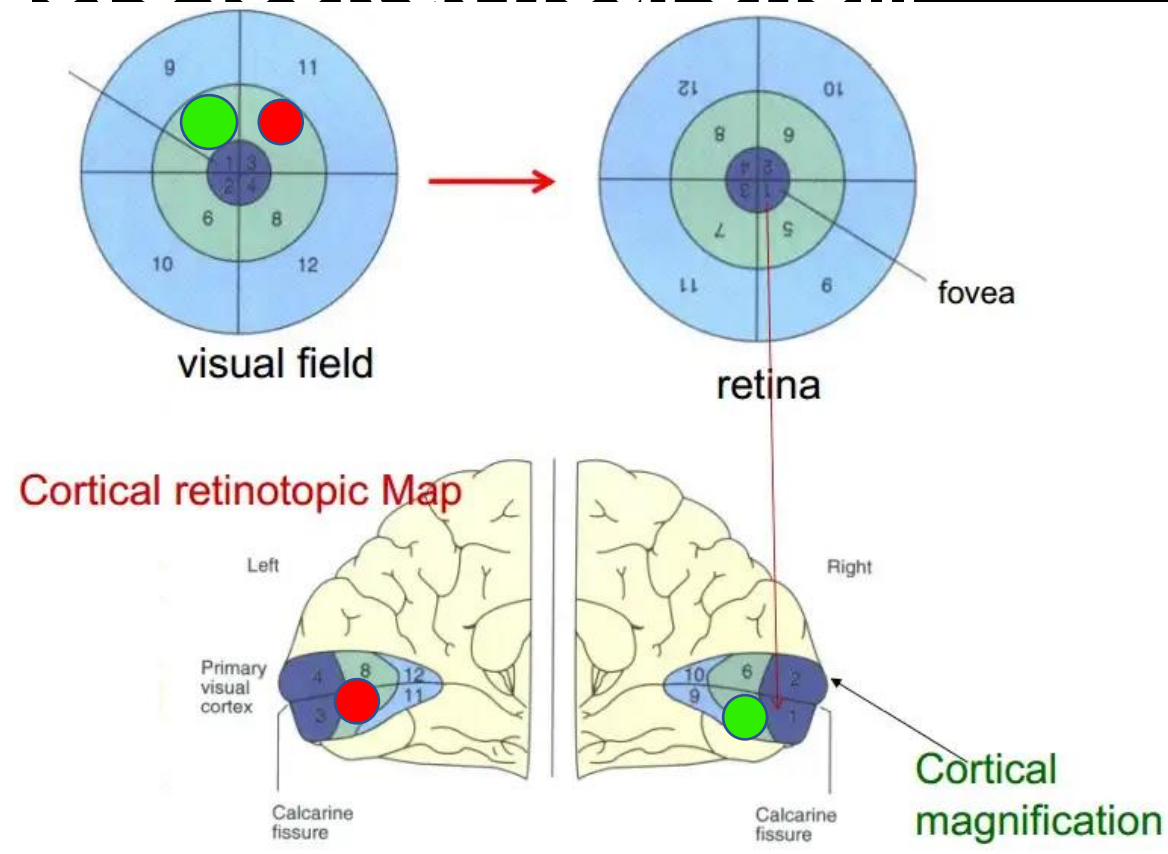coding for Hillary's lower visual field when 'the thing' happened.
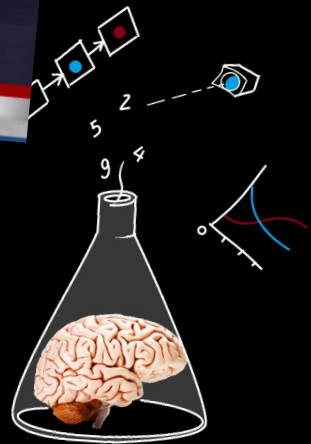
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Signals sent by the upper-visual-field neurons will have entered conscious awareness (frontal brain regions) faster
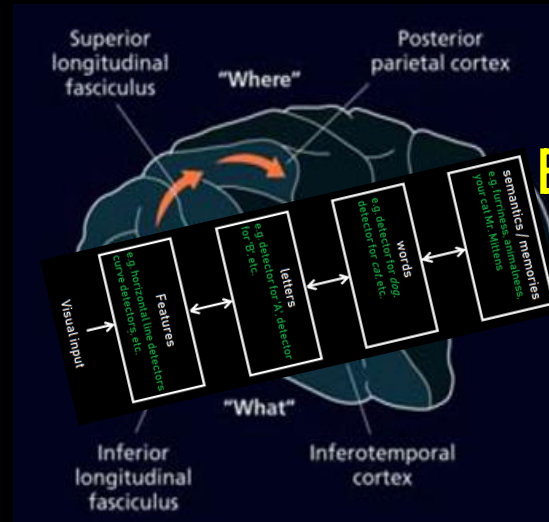
So how does all this work, cognitively?

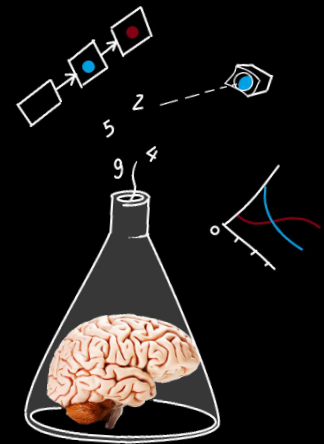Exogenous attention: strong sensory input tips the balance

(in terms of the 'neuron battle' described on previous slide)

Endogenous attention: higher-order neurons suppress or excite neurons at the level of perception
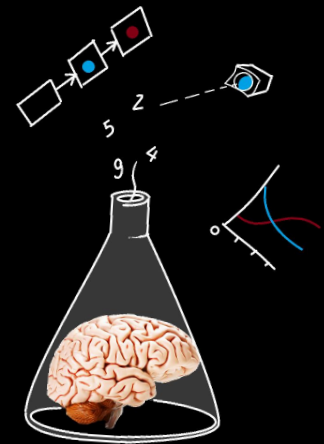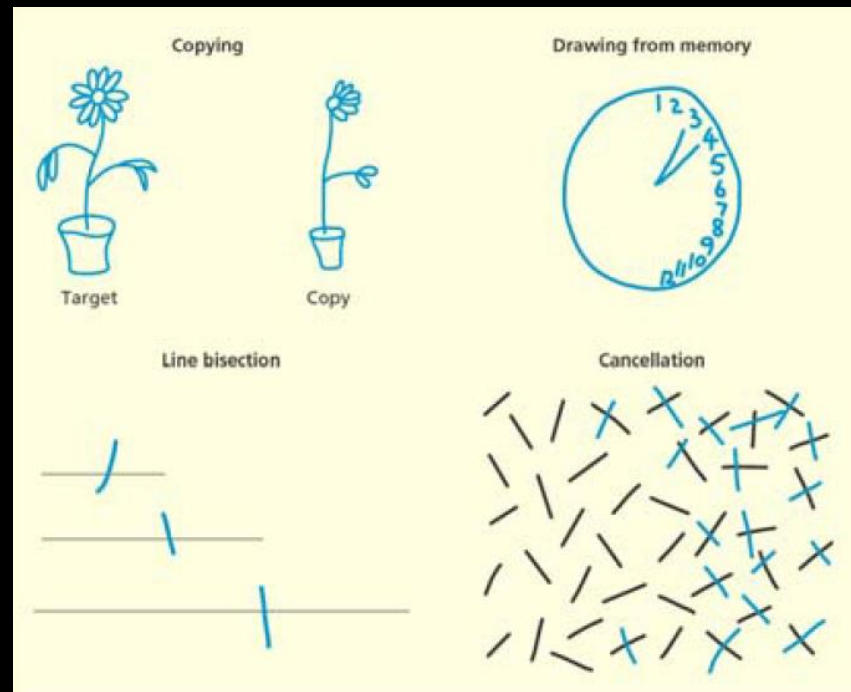
Recall story about bottom-up & top-down interactions

Biasing of low-level detectors by higher levels is a form of endogenous attention!
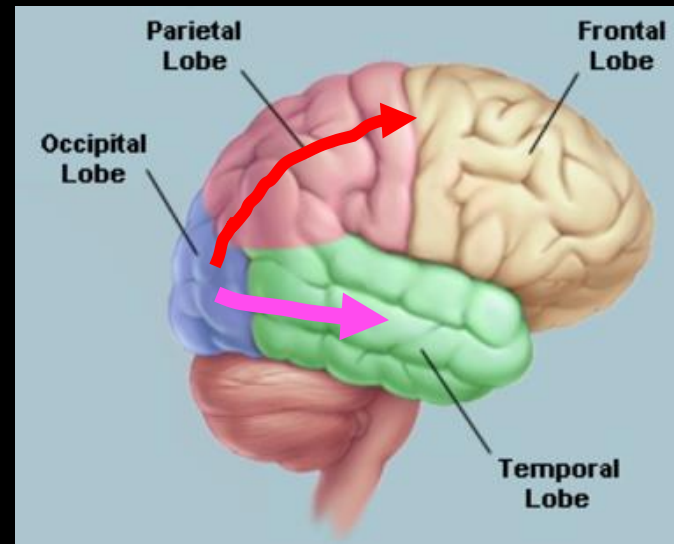
Attentional disorders

(Hemispatial) neglect

In all these tasks, one side (hemifield) is ignored, even though the patient *can* see things in that hemifield when attention is forcefully directed to it

Attentional disorders
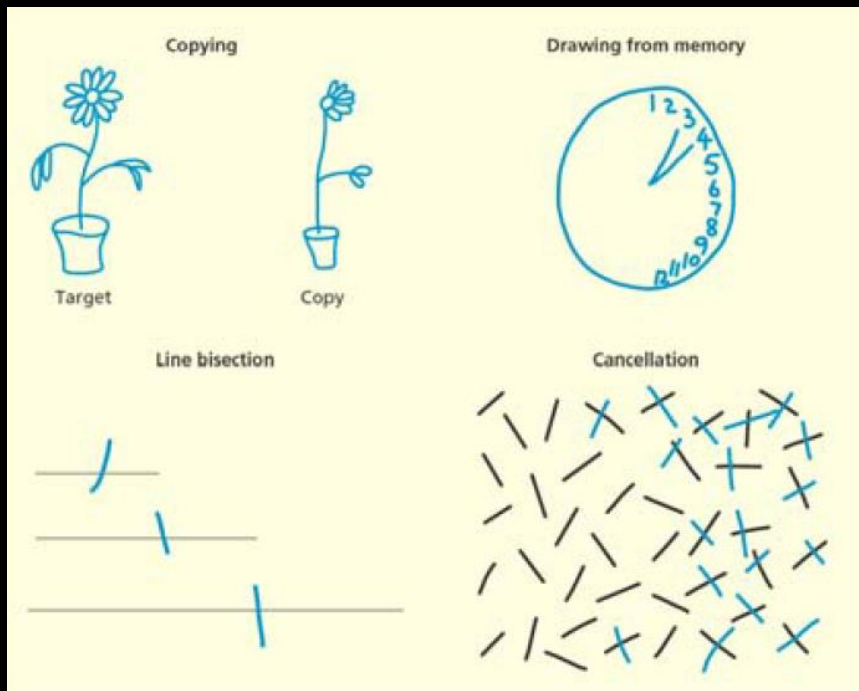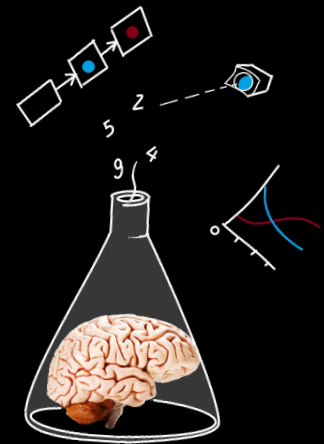
(Hemispatial) neglect   *Where is the lesion?*

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"where"

"what"

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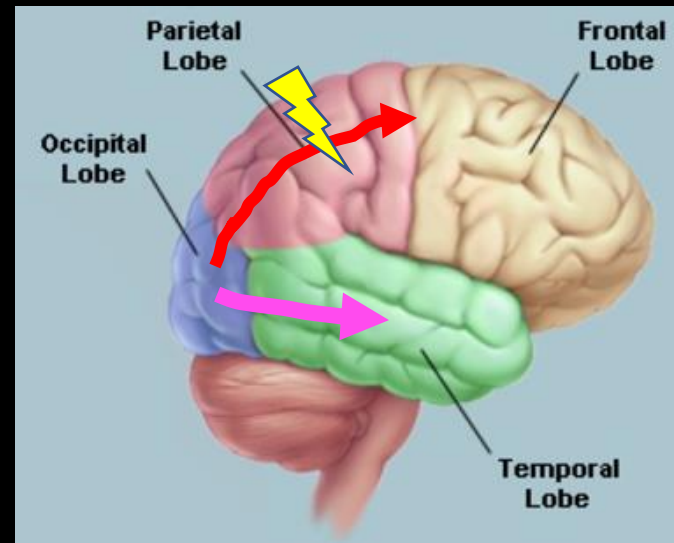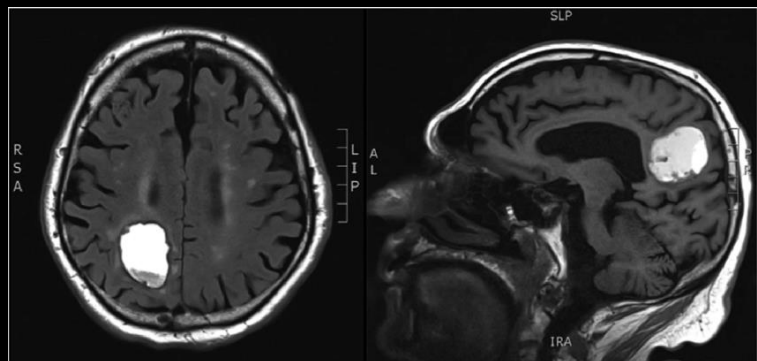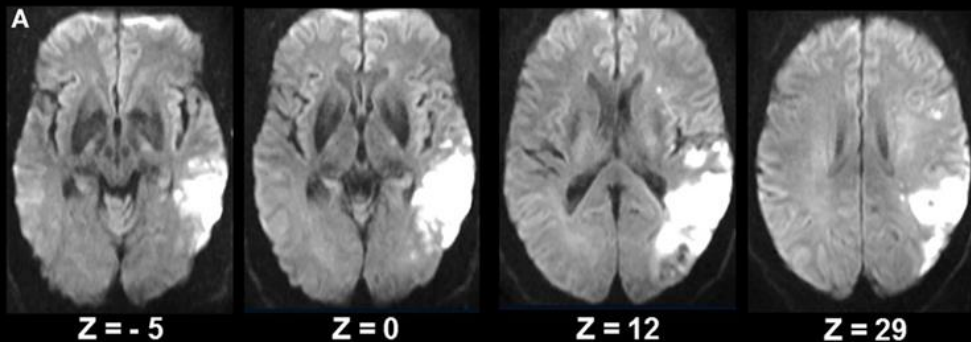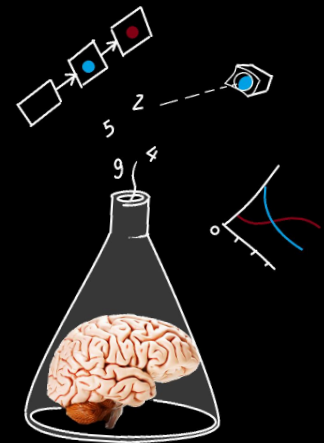

"where"

"what"

Recap

Attention:
- is the mind's capacity to enhance and suppress sensory input and internal representations
- exists because the brain can only do so many computations at once

Various types of attention: spatial vs. feature-based attention, endogenous vs. exogenous attention, overt vs. covert attention

Remember the neural dynamics explanation

Hemispatial neglect