Overview of Lecture: Sensory, Perceptual Mechanisms
Read: Text ch 49 & 50.

Bullet Points:
• the CNS - Brains
• cortical maps & fMRI
• sensation & perception
• limbic system
• selective attention
• “cortical control”
• placebo effect
• emotions & decisions
• vision - illusions
• split-brains: consciousness - Mind the Gap
• lateralization
• Theory of Other Minds
• empathy - Yawn!
The Brain evolved & develops as an elaboration of the dorsal hollow neural tube, & the basic organization is apparent in fish.

<table>
<thead>
<tr>
<th>Embryonic brain regions</th>
<th>Brain structures present in adult</th>
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<tbody>
<tr>
<td>Forebrain</td>
<td>Cerebrum (cerebral hemispheres; includes cerebral cortex, white matter, basal nuclei)</td>
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<td></td>
<td>Diencephalon (thalamus, hypothalamus, epithalamus)</td>
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<td>Midbrain (part of brainstem)</td>
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<tr>
<td>Midbrain</td>
<td>Pons (part of brainstem), cerebellum</td>
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<tr>
<td>Hindbrain</td>
<td>Medulla oblongata (part of brainstem)</td>
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<tr>
<td></td>
<td>Cerebral hemisphere</td>
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<td>Diencephalon: Hypothalamus</td>
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<td></td>
<td>Thalamus</td>
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<td>Pineal gland (part of epithalamus)</td>
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<td>Brainstem: Midbrain</td>
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<td>Pons</td>
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A human brain consists of ~100 billion neurons each connected to as many as 10,000 other neurons. The brain of a three-year-old child has about $10^{15}$ synapses (1 quadrillion). This number declines with age, stabilizing by adulthood at ~$10^{14}$ synapses.
These mappings are variable across people, and ‘plastic’ within people (some reorganization after injury).

Pre-surgical Mapping. **Left** - pre-surgical craniotomy mapping several motor and sensory regions. Note regions A, J and K are mappings during right finger movement and sensory input. **Right** - surface rendered brain from a pre-surgical fMRI scan during right finger movement. The clusters observed in the fMRI (A, J and K) during the finger paradigm are in excellent agreement with the craniotomy method.

Motor and sensory body surfaces w/ ‘association areas’ nearby.
... a new technique called **functional magnetic resonance imaging, fMRI:** provides high resolution, noninvasive reports of neural activity detected by a blood oxygen level dependent signal ...

... maps of human brain function.
Sensations & perceptions
begin with the detection of a stimulus by sensory receptors... specialized neurons or epithelial cells
Sensations are action potentials that reach the brain via sensory neurons.

Perceptions - such as colors, smells, sounds, and tastes - are constructions formed in the brain and do not exist outside it. {color?}
The perception depends on where action potentials go, not what triggers them. {consider cochlear implants}

In vertebrates, sensory signals the gateway to the cerebral cortex.

This gateway is influenced by instructions coming back from the cortex. {there is active ‘top down’ control of sensory input}
The information is then sent on to the many parts of the brain that contribute to forming our perceptions.

Our memories and expectations can strongly influence our perceptions, ...we perceive what we expect to hear or see ...
{perception involves selective attention & active interpretation → illusions}
Maps of pixels in which individual subject rCBF \{\textit{regional cortical blood flow}\} was significantly correlated with individual-subject episodic-memory enhancement …

The \textbf{amygdala} activity related to enhanced memory for pleasant and aversive stimuli

Hamann et al. 1999 Nature Neurosci 2, 289-293.

\textbf{Pleasant or aversive events}

Using positron emission tomography, we show that bilateral amygdala activity during memory encoding is correlated with enhanced episodic recognition memory …

The \textbf{amygdala} seems to modulate the strength of memory for events

The \textbf{hippocampus, amygdala}, some inner portions of the cortex’s lobes and sections of the \textbf{thalamus} and \textbf{hypothalamus}, form a ring around the brainstem called ... - interacts with neocortex & generates \textit{emotions}.

\textbf{Limbic regions} \{\textit{emotions}\} are central in determining the importance of the sensory input to the organism.
Homer-ing In on Memories
The neural correlates of remembering can only be studied with complete confidence in humans, because the subjects can verbally report their internal experience. Brain surgery in which therapeutic electrodes are implanted in the brain of patients with intractable epilepsy provides an opportunity for doing such studies. Gelbard-Sagiv et al. (p. 93, see 5 September news story by Miller) report that neurons in and near the hippocampus of these patients

Later, when these same episodes were brought to mind by free recollection, demonstrating that, at least in the hippocampus, recall of a stimulus is accompanied by activation of
Neural correlates of conscious self-regulation of emotion.  

... brain activation was measured \{fMRI\} in normal male subjects while they either responded in a normal manner to erotic film excerpts \{?\} or voluntarily attempted to inhibit the sexual arousal ...

... the sexual arousal experienced in response to the erotic film excerpts, was associated with activation in limbic and paralimbic structures, such as the right amygdala \{A\}, right anterior temporal pole \{B\}, and hypothalamus \{C\}.

... the attempted inhibition of the sexual arousal ... was associated with activation of the right superior frontal gyrus \{A - cortex\} and right anterior cingulate gyrus \{B - cortex\}.

is normally implemented by

- humans have the capacity to influence the electrochemical dynamics of their brains, by voluntarily changing the nature of the mind processes unfolding in the psychological space.
In the late nineteen-sixties, Carolyn Weisz, a four-year-old with long brown hair, was invited into a “game room” at the Bing Nursery School, on the campus of Stanford University. … A researcher then made Carolyn an offer: she could either eat one marshmallow right away or, if she was willing to wait while he stepped out for a few minutes, she could have two marshmallows when he returned. He said that if she rang a bell on the desk while he was away he would come running back, and she could eat one marshmallow but would forfeit the second. Then he left the room.

... 

{decades later} ... low delayers, the children who rang the bell quickly, seemed more likely to have behavioral problems, both in school and at home. They struggled in stressful situations, often had trouble paying attention, and found it difficult to maintain friendships. The child who could wait fifteen minutes had an S.A.T. score that was, on average, than that of the kid who could wait only thirty seconds.
**Placebo** and opioid analgesia - Imaging a shared neuronal network.

Petrovic Pet al. SCIENCE 295 (5560): 1737-1740 MAR 1 2002

We compared the analgesic effects of a placebo treatment (PPL) and a rapidly acting opioid (POP) ... in a standard pain-stimulus paradigm.

Higher cortical systems rACC may exert direct control over the analgesic opioid systems of the thalamus & brainstem not only during opioid analgesia (POP) but also during placebo analgesia (PPL).

Covariation between rACC and the brainstem

Red: correlated changes in blood flow

- rACC (rostral Anterior Cingulate Cortex)

The larger the anticipated benefit from a drug or a procedure, the greater is the actual health improvement observed ([de Craen et al., 2000](#) and [Moseley et al., 2002](#)).
Revealed: **how the mind processes placebo effect**
Expecting a big reward helps the reward to come true.

Neuroscientists have found that **people who experience a strong dose of pleasure at the thought of an upcoming reward {$$$}**
{measured by activity of limbic dopamine cells during reward anticipation }

The research shows how **the placebo effect ...**

of positive experiences, and which is also implicated in gambling and drug addiction.
{people who anticipate greater pleasure from a win or a “high” are more vulnerable to addiction and show a greater placebo effect – less pain when injected}

Greater activity in this brain region, called **the nucleus accumbens**, {“reward center” in forebrain} is linked to a stronger placebo effect ...
Let's look at the basic nuts & bolts picture of a **sensory system - vision**

1. Rays of light (blue) reflected off of an image \{3D\} are focused through the lens onto the back of the eye, forming an upside-down image \{2D\} on the retina.

2. ... we can think of the image as a \{2D\} pixellate map of activated and nonactivated photocells on the retina.

3. **{After much processing in retina by horizontal, amacrine & bipolar cells}** A nerve from each \{ganglion cell\} connects to a particular location in the visual cortex of the brain.  **{via lateral geniculate nucleus of thalamus}\**

4. **The brain ... reconstructs** the pixellate map.

5. then **interprets** \{or misinterprets\} the \{2D\} map as an \{3D\} image \{made up of "sensible" objects\}.
Amacrine & Horizontal cells: lateral inhibition enhances edges & contrast

In the human retina, rods absent from the fovea. You cannot see a dim star at night by looking at it directly; you can see it at an angle by focusing the starlight onto the periphery & rods. You achieve your sharpest daylight vision by looking straight at the object of interest because cones are most dense at the fovea, (about 150,000 per mm²).

We allocate visual attention by sequentially fixing the fovea (saccades); mind constructs a high resolution color perception.
Edge enhancement from lateral inhibition by amacrine & horizontal cells in retina creates **Mach bands** - emphasize edges, which are important and informative.
When the 3D world is projected onto the 2D retina, the image is ‘underdetermined:’ different hypothetical ‘real 3D worlds’ could have created the same 2D image.

From phylogeny and ontogeny,

**about how the real world works,**

things like: every mark is in only one place at a time
a dot on one retina corresponds to only one dot on the other,
matter is smooth and cohesive, etc  (“folk physics”)

We are constantly testing alternative hypotheses against sensory data in “the mind’s eye.”

{above looking down or below looking up?}

Necker cube


"Whilst part of what we perceive comes through our senses from the object before us, another part (and it may be the larger part) always comes out of our own mind."

William James

The account of perception that’s starting to emerge is what we might call the **brain’s best guess** theory of perception ...

The mind integrates *information* from a variety of sensory channels, past experiences, and hard-wired processes, and produces ... meaning.

(from an article in the New Yorker... by Atul Gawande).
Kanizsa's triangle
The body-surface to cortical-surface mapping crosses over, and back, unless ...

By using a tachistoscope, which displays visual stimuli for very brief intervals of time on each half of the screen in front of the patient, information presented on the left is exclusively perceived by the right hemisphere, and vice versa. If we ask the patient to identify what is seen, the right hand (controlled by the left hemisphere) will point toward a chicken...

... whereas the left hand (operated by the right hemisphere) will choose a shovel (needed to remove snow in the scene).

Figure 1. Lateralized presentation of information in a split-brain patient

Gazzaniga’s ‘left-brain interpreter’ (from Massimo Pigliucci) if asked to explain ... the left hemisphere acted as an interpreter ... and fabricated a just-so story to fit all the available data! {is consciousness just a post hoc interpretation – story? more later}
During an infant’s or child’s brain development, typically …

The **right** hemisphere becomes stronger at spatial relations, music …

{ ‘holostic hemisphere’}

The **left** becomes most adept at fine visual & auditory details …

{ ‘reductionist hemisphere’}

**Neurology: Self-recognition and the right hemisphere.** JULIAN PAUL KEENAN et al.

Here we show that in humans the right hemisphere of the brain seems to be preferentially involved

**Figure 1** Five patients were presented with a picture showing a morph of a face that was composed of their own face and a famous face during the time when either the right or the left hemisphere of their brain was anaesthetized.

Following anaesthesia of the left hemisphere (LH), patients selected the 'self' face as having been shown to them (5/5);

after anaesthesia of the right hemisphere (RH), patients selected the famous face as the one they had viewed (4/5).

**Left gaze bias in humans, rhesus monkeys and domestic dogs.**

Reductionist efforts are getting us to the **neural correlates of brain function**, but we still haven’t found ‘the **mind**.’

http://www.sci-con.org/reviews/20031101.html

The split-brain phenomenon gave rise to a host of conflicting propositions about **the neuroanatomical localization of the self**. **Where is the self in the split brain?**

- In the left hemisphere?
- In the right hemisphere?
- In both?

With fMRI we can now distinguish what specific areas of the brain are active when people think, feel, imagine, perceive, and so on. Researchers are starting to apply this technology to find the self in the brain.

**Mirror self-recognition (MSR) and Theory-of-Mind (TOM)** seem to be associated with **right hemispheric activity** ...

{but not exclusively, and interpreting and explaining verbally is localized on left}
The Blind Decision-Maker
What is the relation between intention, choice, and introspection?

Johansson et al. (p. 116) used a card trick in a simple decision task to identify a dissociation between awareness of the initial choice and the outcome when this has been surreptitiously altered. Participants were given a choice to make in the attractiveness of two female faces shown on two cards, and then asked to justify their choice as they examined the card with the alternative they had allegedly chosen. In some trials, the experimenters covertly switched the cards.

In the majority of such trials, of the card they were handed, although it was not the one they had selected.

when asked to describe the reasons behind their choices.

{post hoc rationalization this why one more attractive}

Our consciousness may be primarily the continuous story we tell ourselves, from moment to moment, about what we did and why we did it. It is a thin,
By looking at brain activity while making a decision, researchers could predict what choice people would make before they were even aware of having made a decision. The work calls into question the ‘consciousness’ of our decisions and may even challenge ideas about how ‘free’ we are to make a choice at a particular point in time.

Unconscious determinants of free decisions in the human brain

... a freely paced motor-decision task while their brain activity was measured w/ fMRI ...
{press right or left button & report letter on screen} when their motor decision was consciously made.

Two specific regions in the frontal and parietal cortex
the subject had not yet consciously made.
{the self report on timing of the ‘conscious decision’ is closer to the execution of the motor act than to the neural pattern that predicts the act}
Baron-Cohen et al.'s (1996) **false belief test** is presented to a subject as a simple story.
1. There are two puppets, Sally and Anne. Sally has a marble, which she keeps in a basket.
2. Then Sally leaves the room, and while she is away
3. Anne takes the marble out of the basket and hides it in the box.
4. Sally comes back into the room.
   The child subject is then asked the question: "Where will Sally look for her marble?"

---

because they know that Sally doesn't know it has been moved from the basket, and they can distinguish Sally's (false) belief from their own (true) belief.

**Younger children, and autistic children,**

The false belief test, therefore, explores the change that happens as common-sense psychology develops. *{a Theory of Other Minds - TOM}*
The extreme male brain theory of autism

‘Empathising’ is the drive to identify another person’s emotions and thoughts & to respond appropriately.
… allows you to predict a person’s behaviour.
I review evidence that on average,

‘Systemising’ is the drive to analyse a system, to derive the underlying rules that govern the behaviour of a system.
… allows you to predict the behaviour of a system.
I review evidence that, on average,

… autism can be considered as
{this is highly controversial, of course!}

… males tend to have a longer ring finger than their second finger,
{associated w/ higher levels of testosterone in uterus}
people with autism show this trait in a magnified form

2nd to 4th digit ratios, fetal testosterone and estradiol.
Contagious yawning:
the role of self-awareness and mental state attribution

We hypothesized that contagious yawning
is part of a more general phenomenon known as mental state attribution
(i.e. the ability to inferentially model the mental states of others).

... we compared susceptibility to contagiously yawn
{response to video clips of neutral, laughing or yawning people}
with performance on a self-face recognition task {left-right hand response time},
several theory of mind stories, {about false beliefs & social faux pas}
and on a measure of schizotypal personality traits. {the SPQ test}

Consistent with the hypothesis, susceptibility to contagiously yawn
was positively related to performance on self-face recognition
& faux pas stories,
and negatively related to schizotypal personality traits.

\[
\begin{align*}
\text{If autistic people are poor at mental state attribution (TOM)} \\
\text{what does this imply about contagious yawning?}
\end{align*}
\]

... yawning faces triggered more than twice as many yawns in non-autistic children
than in their autistic counterparts ...