Cognitive Neuroscience is the attempt of our nervous system to understand itself.

This section of the course will provide an introduction to current knowledge about the neuronal processes involved in sensation and perception.
How can we go about studying the neuronal processes involved in sensation and perception?

Experimental variables
Strategies, approaches

quantified sensory input

sensory coding

neuronal activity
decoding, decision making

percept, behavior

psychophysics
Today, the minimum knowledge of cortical organization to begin to approach sensory systems.

- Neocortex has evolved... largely to accommodate the processing of sensory channels
- Functions are localized - the oldest chapter in Neuroscience
- Within sensory regions, processing is not *disorganized*, but is arrayed in “maps”

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- Maps constrain how we perceive the world
- But maps are the start of the inquiry, not the end

... but the golden triangle will come much later.
Cerebral cortical evolution:

*cerebral cortex / whole brain increases*
Hypothalamus

responsible for metabolic processes, neurohormones, body temperature, hunger, thirst, fatigue, sleep...

(brain images rescaled to similar size for illustration)
The diagram illustrates the comparison of convolution patterns across different species:

- Opossum
- Anteater
- Cat
- Human
- Dog
- Pig

The arrow indicates the trend in number of convolutions, showing a pattern from the Opossum to the Pig, with species like Anteater, Cat, and Dog in between.
unconvoluted
“lissencephalic”

subcortical tissue
cortex

convoluted
“gyrencephalic”

subcortical tissue
cortex
gyrus
sulcus
To expand volume, why not just increase thickness?

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**REPORT**

Cortical folding scales universally with surface area and thickness, not number of neurons

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**ABSTRACT**

Larger brains tend to have more folded cortices, but what makes the cortex fold has remained unknown. We show that the degree of cortical folding scales uniformly across lissencephalic and gyrencephalic species, across individuals, and within individual cortices as a function of the product of cortical surface area and the square root of cortical thickness. This relation is derived from the minimization of the effective free energy associated with cortical shape according to a simple physical model, based on known mechanisms of axonal elongation. This model also explains the scaling of the folding index of crumpled paper balls. We discuss the implications of this finding for the evolutionary and developmental origin of folding, including the newfound continuum between lissencephaly and gyrencephaly, and for pathologies such as human lissencephaly.
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Localization of function by lesion
(neuropsychology)
1861
Broca’s patient, “Tan”

Broca’s area

Localized region for language production

Destruction of area produces behavioral deficit
In humans, luck (usually bad luck) determines lesion site

Controlled, limited lesions in animals

David Ferrier
Ferrier (1870)

Munk (1880)
Munk (1880)

First to distinguish sensation from perception.

Temporal lobe lesion leads to visual agnosia: loss of visual knowledge = loss of visual perception
Munk (1880)

First to distinguish sensation from perception.

Temporal lobe lesion leads to visual agnosia: loss of visual knowledge = loss of visual perception
Tatsuji Inouye, 1905
Fig. 2. Inouye's schema for the projection of the visual fields on the striate cortex.

Inouye's schema for the projection of the visual fields on the striate cortex.

Flächen treue Darstellung der linken Hauptsehsphäre.

Fig. 2. Inouye's schema for the projection of the visual fields on the striate cortex.
human visual cortex retinal map by modern methods
Localization of function by electrical recording and stimulation (neurophysiology and neurosurgery)
the method of targeted and restricted electrical stimulation...

Hitzig

Fritsch
electrode conducts signal to cortical tissue

electrical stimulus

current generator
...led to the detection of areas with specific motor functions

- movement of back leg
- movement of front leg
- movement of snout (face)
Today’s methods
Wilder Penfield
physiological exploration of the human cerebral cortex
(c. 1930-1970)

“evoked potentials”
a probe of the activity of neuronal populations

electrode on the cortical surface conducts evoked potentials to the amplifier
Hands, 9:40
Singing - 2:25, 2:40, 5:20, 8:10
the motor and the sensory maps in the human
experimental basic research proceeds in parallel

neurophysiology laboratory, 1930s
Clinton Woolsey
University of Wisconsin
What is the **receptive field** for this cortical site?

Woolsey’s evoked potential mapping:
the skin area projecting to a single cortical site
bat auditory cortex
• expansion of the most valuable sensory modality
• expansion of the most valuable receptors within a given representation
microelectrode conducts signal from individual neurons, or neuron clusters
End lesson 1 / start lesson 2
barrel cortex is one of the most robust examples of mammalian columnar organization

Waite & Tracey (1995)
Does the map really mean anything?
Experimental variables
Strategies, approaches

- quantified sensory input
  - Sensory coding
  - neuronal activity
    - Decoding, decision making
  - Psychophysics
    - percept, behavior
10x10 electrode matrix
100-channel amplifier
digital signal processor
Pentium workstation
ISA board
stimulus generator
experiment status
audio monitor
stimulus site C1
multi-unit PSTHs
0-40ms, 5ms bins

firing rate on each channel
(spikes per trial)
with interpolation

1.0 spikes
40 ms
cortical territory of single whiskers
territory in which learned sensory information is stored . . .
new whisker: common cortical territory
Subjects learned to use one fingertip to discriminate between two grades of sandpaper
Transfer from “trained” finger to others

<table>
<thead>
<tr>
<th>Percent correct</th>
<th>Same hand</th>
<th>Opposite hand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>O</td>
</tr>
<tr>
<td>+1 +2</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
</tbody>
</table>

Note: * indicates significant difference from baseline performance.
So the representation of a signal – either from a whisker or from a fingertip – passes through a bottleneck in the SI map, and some critical form of learning takes place in this restricted territory.
the law of functional localization

cerebral cortex is composed of many anatomically identifiable regions,
each of which carries out some special, unique function.

cognitive processes arise from the coordination between functionally
specialized processing areas
Geography is the beginning, not the end
Geography is the beginning, not the end

“Area x is involved with task y” does not fully tell us brain function.

What is the message carried by the neurons of area x during task y?

How does that signal, and the transformation carried out by those neurons, contribute to behavior?
Great challenges in Sensory Neuroscience

- How do sensory receptors really work?
- Coding of real, natural stimuli in spike trains
- Sensory-motor integration and decision making
- Transformation from coding of physical signals to representation of meaningful objects.
- Learning, memory, recall