Applied Neuroscience

Columbia Science Honors Program
Fall 2016

Emotions and Language

Emotion and Language

Objective: Cognition and Computation

Agenda:

1. Emotions
   - *Science of Inside Out*
   - *Neurobiology*
2. Language
   - *Neurobiology*
   - *Google Translate*
3. Social Robots
   - *Android Erica*
   - *Pepper*
4. Demo: Brain Bank

Emotions

Inside Out - Sparknotes version

- Movie follows a young girl Riley
  - Timeline: from the day she's born till she is 12 years old
- Movie centers around five main emotions in her brain
  - Joy, Sadness, Disgust, Fear and Anger
- Each of these emotions was its own animated character that could take advantage of Riley via a control board
  - When Riley was a baby, the control board was a single button, and depending on which emotion touched it, that was the emotion she felt
  - As she grew older, the control board became more complex with dozens of buttons, nobs, switches, dials and sockets (to screw in idea lightbulbs)

Inside Out - Sparknotes version

- These emotions and the control board reside in “Headquarters”, a fancy bubble room that floated above a dark pit surrounded by a never ending number of bookshelves to hold long-term memories.
- Radiating away from headquarters, connected by glass tubes, are Islands of Core Values that floated above the pit.
    - Each of the islands were powered by Core Memories from Headquarters
    - These Core Memories were so powerful that they shaped Riley’s personality
    - Some examples include her first goal in hockey, where she slipped on ice and accidentally hit the puck into the goal post past her father – this memory connected to memories of Honesty and Family

Inside Out - Sparknotes version

Portrayal of memories:

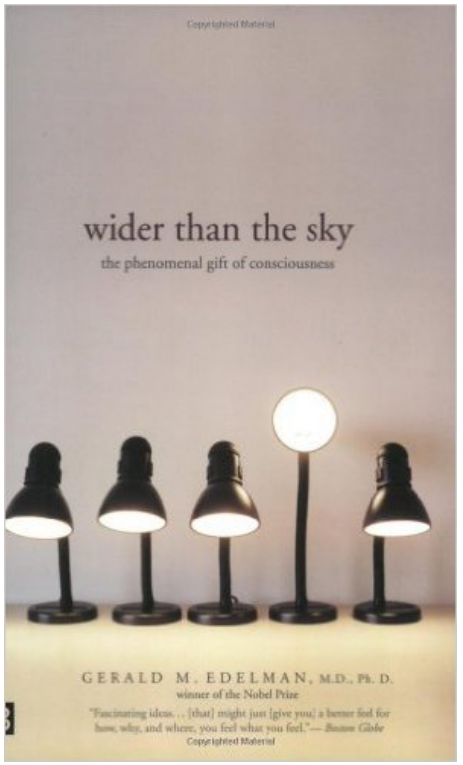
- Memories were spheres tinted with a different color, depending on their emotional context
  - Yellow spheres = Joy, blue spheres = Sadness, etc.
- Any of the five Emotions or other workers in the brain could pick up a memory sphere and replay it
- Memories of events of the day come into headquarters as they happen and are stored there for a short time (**Short-Term Memory)**
- Each night, before Riley went to bed, memories were sent out of Headquarters to the long term storage bookshelves (**Long-Term Memory)**
- Little workers monitor the long term memory shelves and decommission faded memories (grey spheres that are eventually sent to a huge central pit to turn to dust)

The scientific minds behind Inside Out (from Columbia!)

COLUMBIA | ZUCKERMAN INSTITUTE
Mortimer B. Zuckerman Mind Brain Behavior Institute

Riley of Inside Out

Inside Out: Metaphor of Neuroscience



Central Command

Control panel is operated by different emotions.

Do we have a central command?

We do not have a “seat of consciousness.”

Rather, consciousness is highly distributed. We do have the limbic system that regulates emotions.

Headquarters of Inside Out: Hippocampus

Each time Riley experiences an event, a memory sphere of that event rolls into Headquarters. These memories can move into long-term storage.

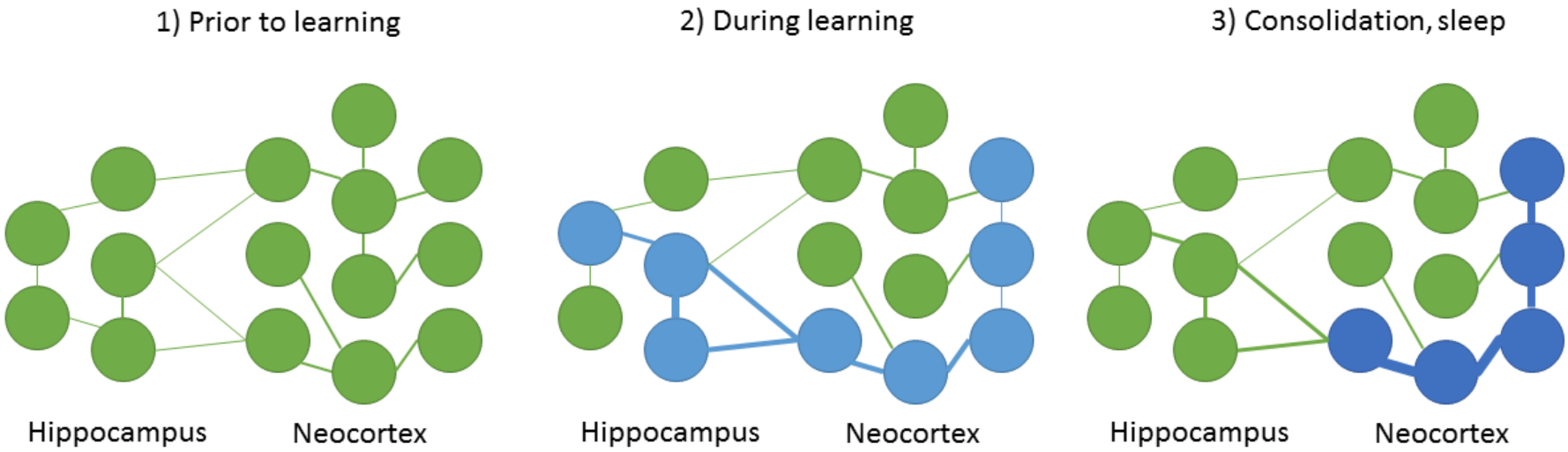
Hippocampus:
component of limbic system that is vital for the formation of episodic memories

Episodic Memories:
memory of autobiographical events (memories that consist of a what, when, and where)

Without a hippocampus, people can no longer form new episodic memories. Which patient is an example of this?

Patient HM: He had his entire hippocampus removed due to seizures.

Consolidation of Memories



Once the hippocampus has formed an episodic memory, where do these memories then go?

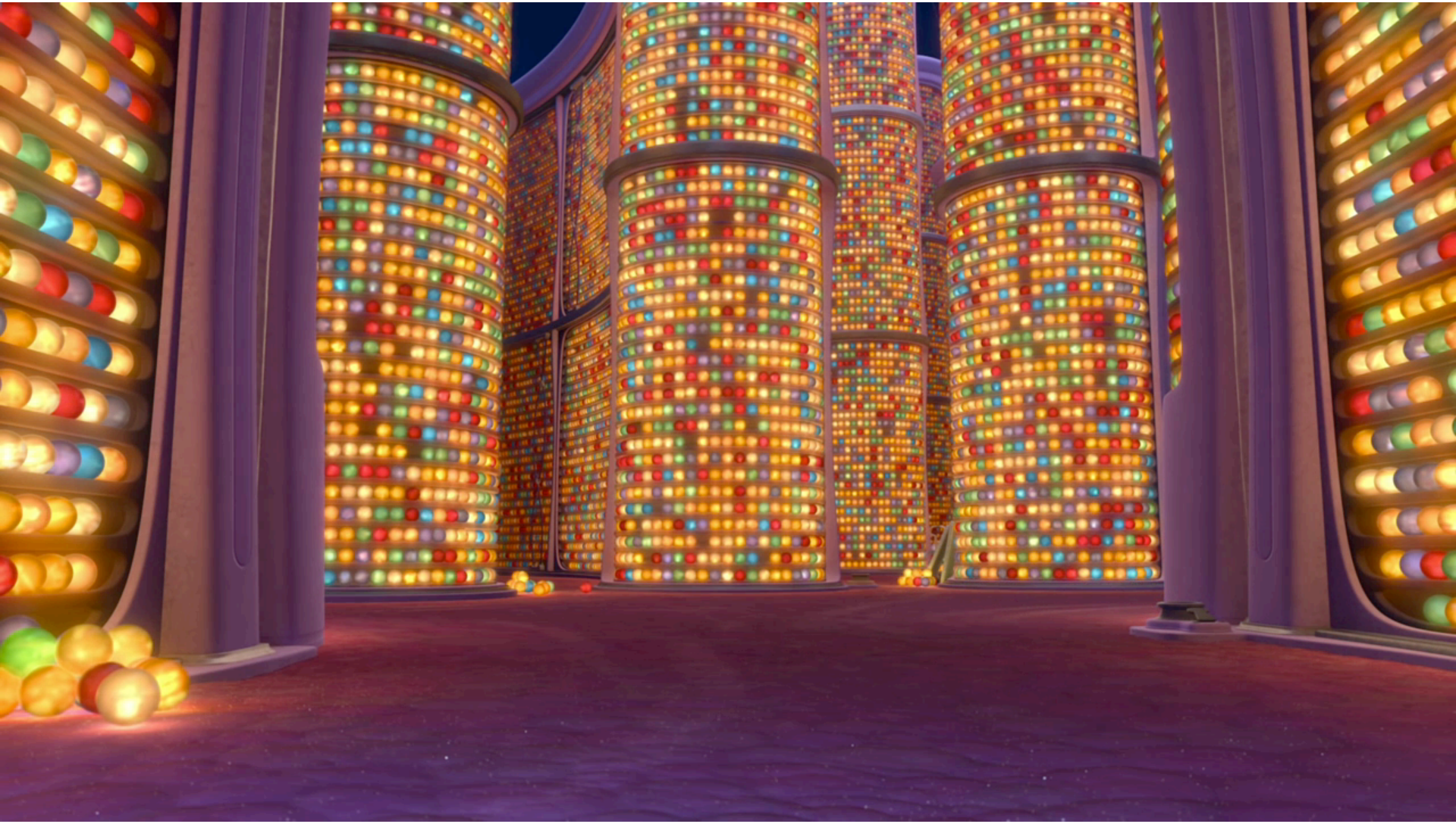
Cerebral Cortex

Consolidation:

Process of maintaining a memory for long-term storage

Sleep is believed to play an important role in consolidation of memories from the hippocampus to the cortex.

Inside Out: Long-Term Memory



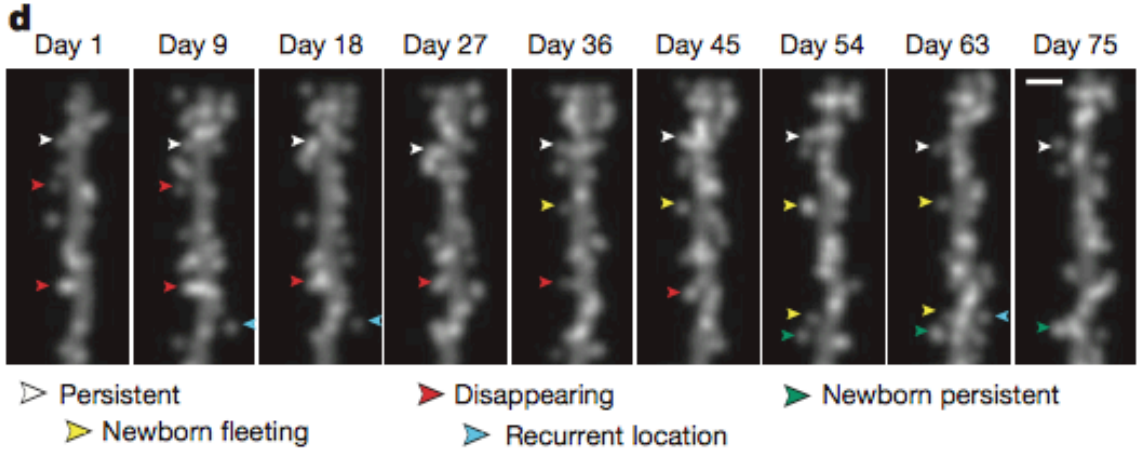
Neurobiology of Long-Term Memory

Is there evidence for the process of memories leaving the hippocampus to the cortex in vivo?

Yes: the laboratory of Mark Schnitzer at Stanford found that hippocampal synapses persist for time intervals that match the known duration of hippocampal dependent-memory.

Background:

- Mammalian hippocampus transiently retains information for about 3-4 weeks in adult mice and longer in humans
- Neural synapses are the elemental sites of information storage

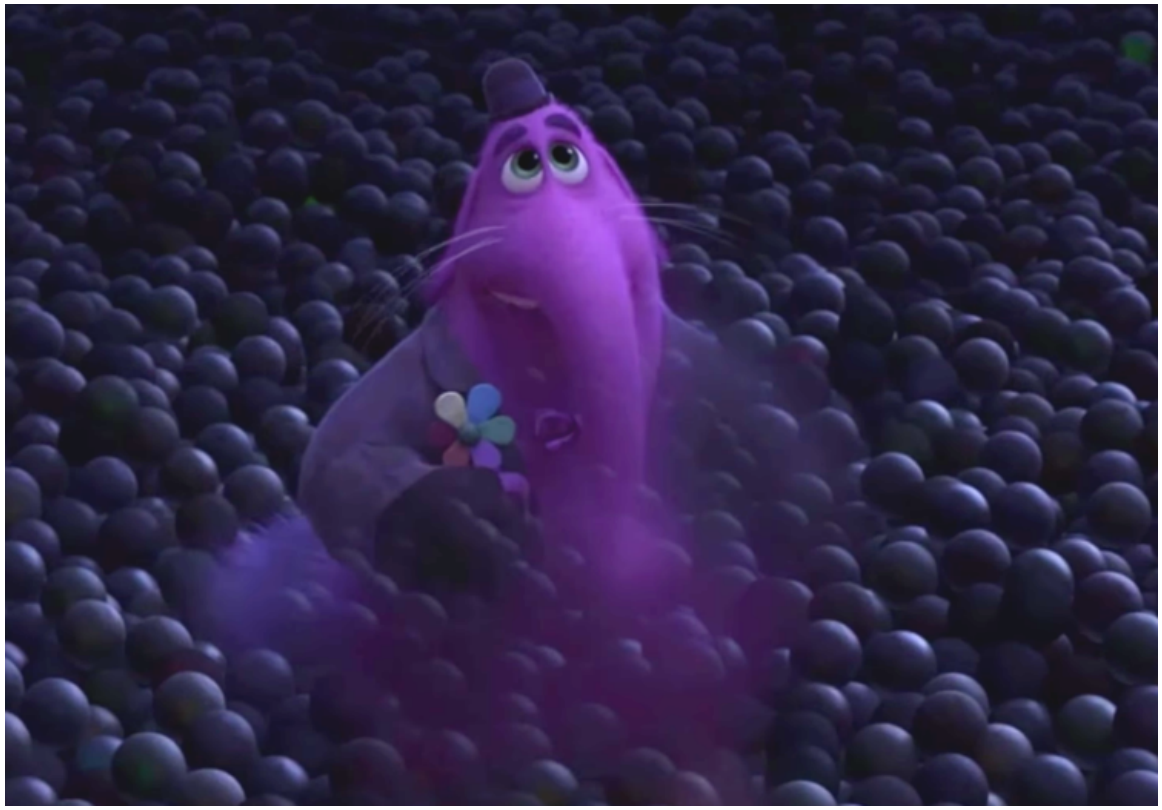


Time-lapse two-photon microendoscopy of hippocampal area of live mice was done to monitor dendritic spines of pyramidal neurons

Results:

Dendritic spine dynamics in the hippocampus was distinct from that of the cortex. In this study, spines had a mean lifetime of 1-2 weeks. This implies 100% turnover about 2-3 times.

Inside Out: Forgotten Memories



Inside Out depicts the degradation of a long-term memory as its loss of color and glow. Some memories turn to a puff of dust. In neuroscience, there are many theories as to how we forgot memories.

Cue-Dependent Forgetting: failure to recall memories without a cue

Rather than the memory being gone, this theory implies that it was simply hard to access.

Trace Decay Theory: memory trace decays and is lost permanently

Where are memories physically stores?

Dendritic Spines: spines can degrade and their connections can be lost. This is important in selectivity of memories.

Physical Traces of Memory

Inside Out depicts memories as luminous spheres. In neuroscience, an episodic memory is represented by a neuronal ensemble.

Engram: theoretical representation of how memories are stored (physical or chemical changes in response to external stimuli)

Inside Out: Emotions

Emotions: internal states expressed by behaviors

- Triggered by specific stimuli (extrinsic or intrinsic to environment)
- Functional and adaptive role

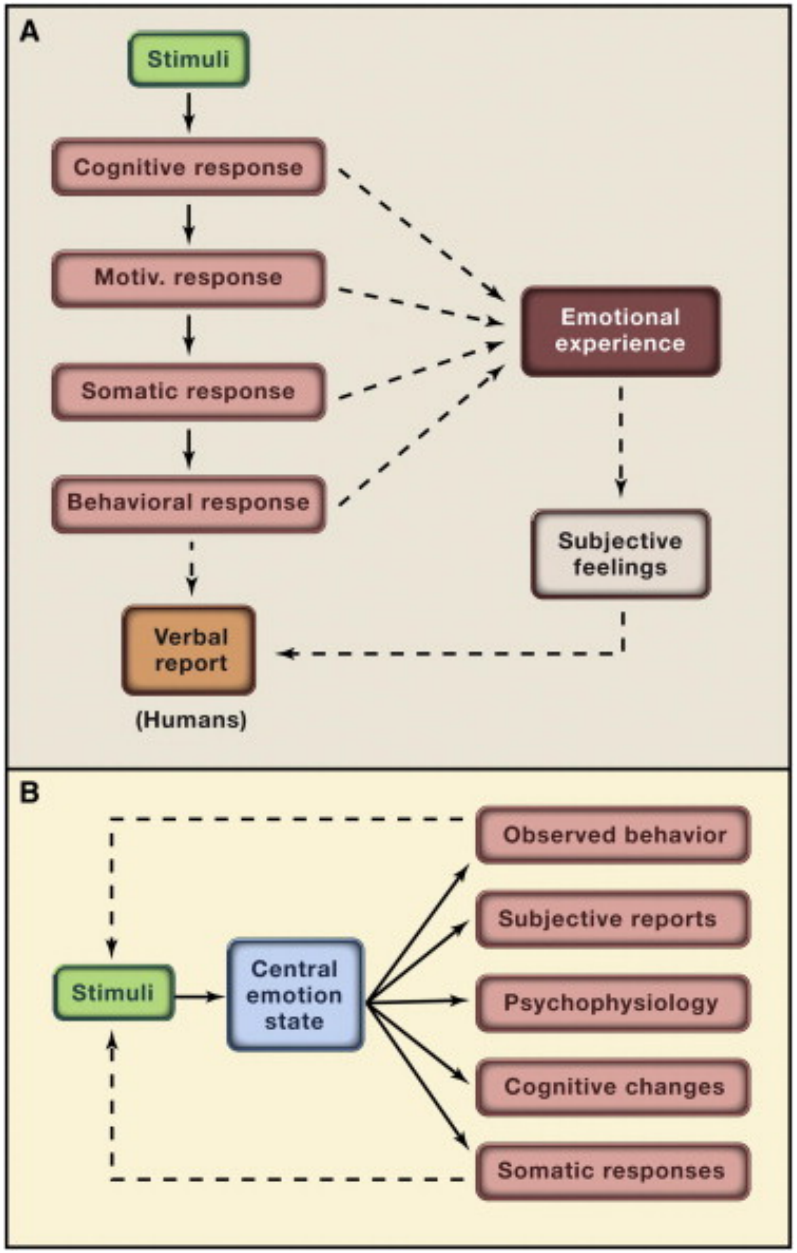
Are emotions a cause or consequence of their associated behaviors?

Charles Darwin argues for consequence.

William James argues for cause.

"I feel *afraid* because I run from the bear; I do not run because I feel afraid."

Emotions: Central, Causative States



A. Traditional View

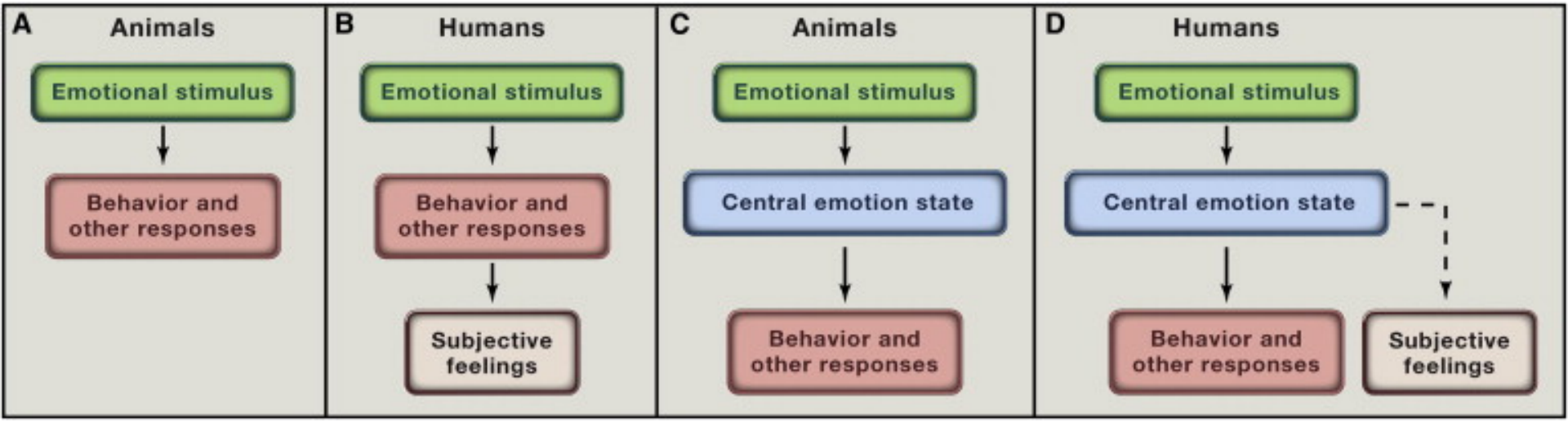
Emotions are distinguished by multiple components that need to be coordinated and often synchronized.

B. Updated View

Emotions result in multiple components that need to be coordinated and often synchronized.

A central emotion state results in multiple parallel responses.

The Relationship between Emotions and Feelings



A, B. Traditional View

Emotional stimuli evoke behaviors and other responses. In humans, the subjective feelings of emotions is assumed to arise from our conscious awareness of behavioral and somatic responses to stimuli.

Is there a seat of consciousness in animals?

C, D. Updated View

Responses to emotional stimuli are mediated by central emotion states. In humans, those central states produce feelings in parallel with behavior and other responses.

Test Your Understanding: Emotions

During emotional states, epinephrine and norepinephrine are released because of activation of which of the following?

A. Cortex
B. Thalamus
C. Amygdala
D. Sympathetic Nervous System

What is the part of the limbic system involved in regulating emotion?

A. Cortex
B. Hypothalamus
C. Amygdala
D. Adrenal Gland

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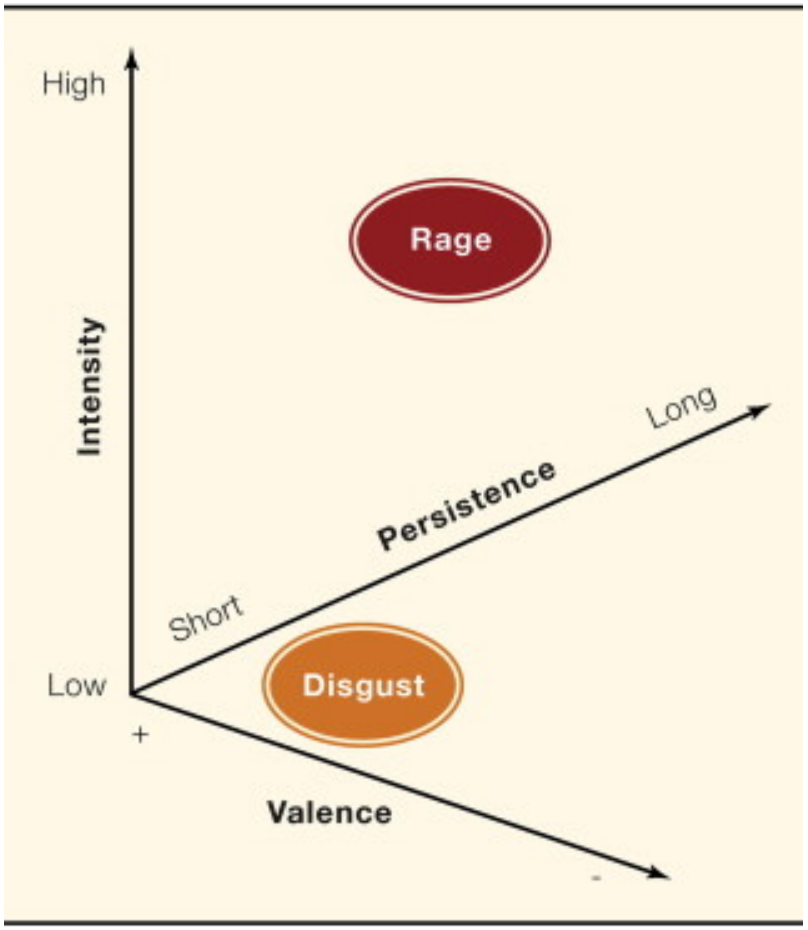
Central Emotion States



Features of Central Emotion States:
Scalability: gradations of intensity
Example: Defensive Behavior

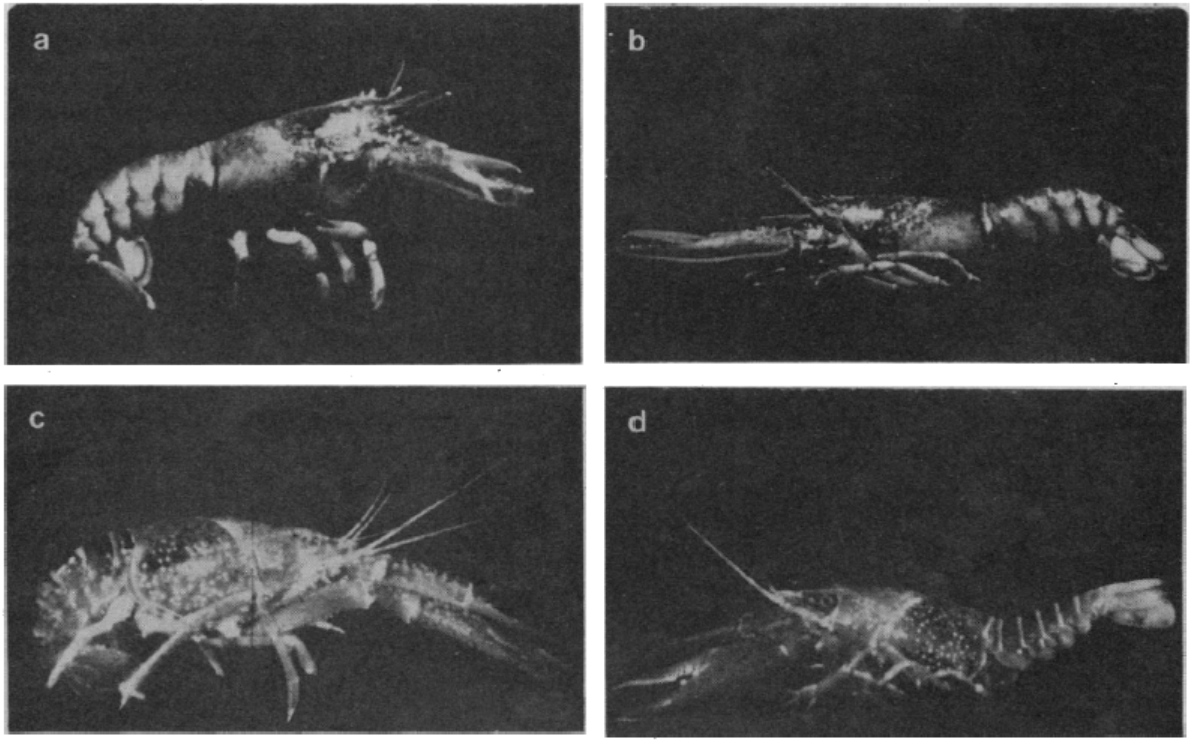
- freezing (avoid detection) to flight (avoids capture)
- In octopi, switch from *crypsis* (camouflage) to ink jetting and propulsion

Central Emotion States

Features of Central Emotion States:
Valence: emotions come in opposites
Example: withdrawal v. approach to an object

measured by locomotor activity

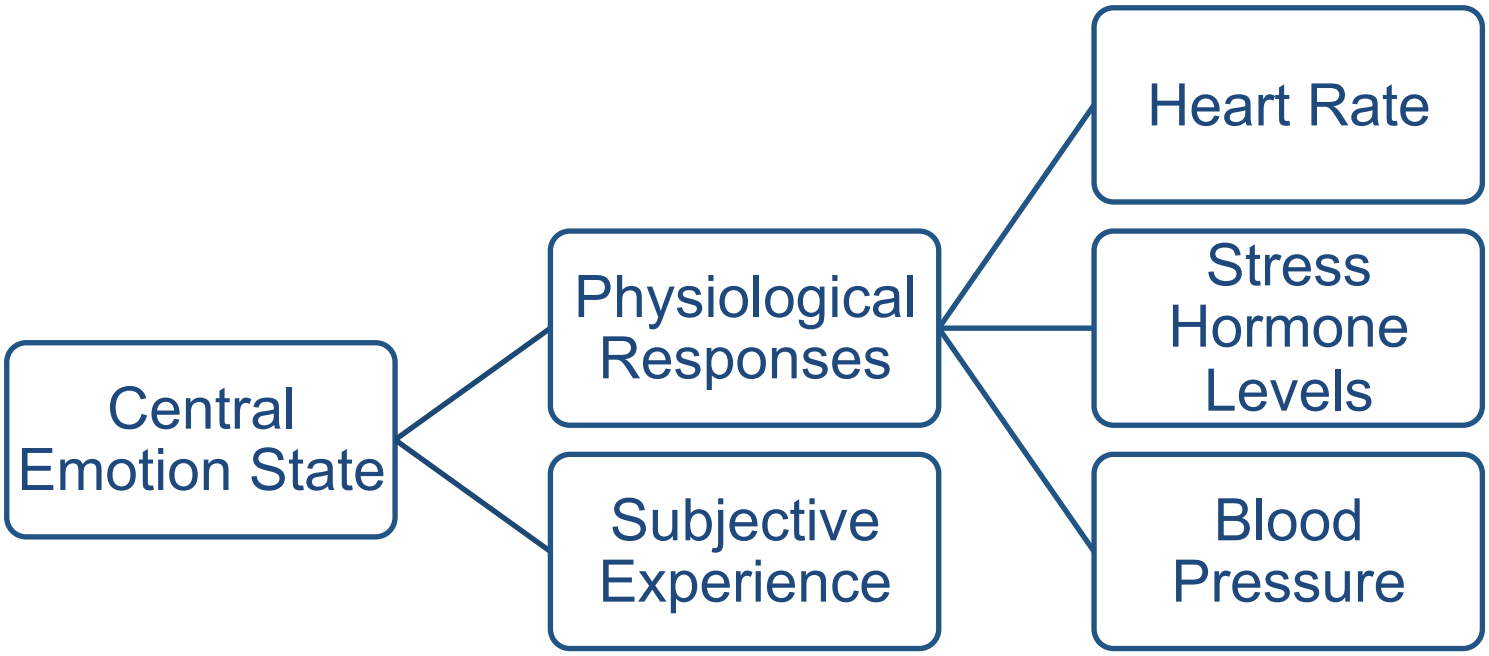
Valence can be the result of chemicals, namely *serotonin* and *octopamine*.



Octopamine injection produces sustained extension of the limbs and abdomen; serotonin injection produces sustained flexion.
A, B. *Lobster*
C, D. *Crayfish*
(Livingstone, 1980)

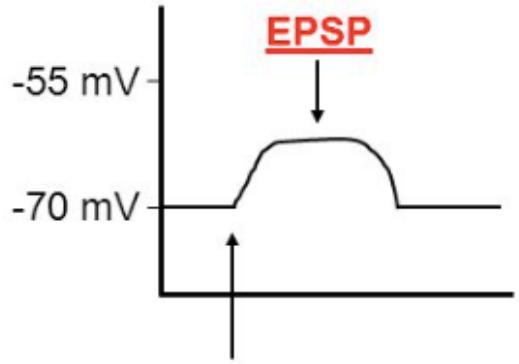
Central Emotion States

Features of Central Emotion States:
Persistence: distinguishes emotional behaviors from simple stimulus reflexes
Emotional behaviors outlast the stimuli that elicit them.



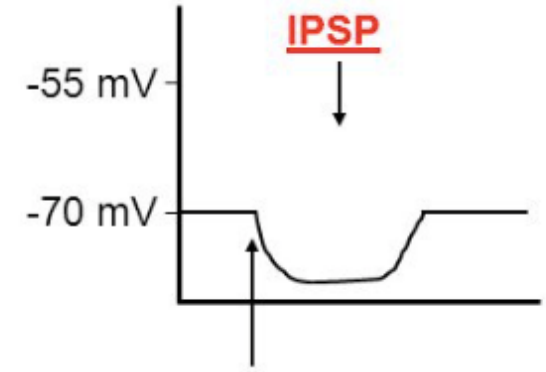
Interoception: term that represents the brain's detection of the body's internal state

Neural Integration



Nt binds and opens channels allowing Na^+ or Ca^{2+} influx

Depolarization = EPSP → ? AP



Nt binds and opens channels allowing Cl^- or K^+ efflux

Hyperpolarization = IPSP ≠ AP

Neural Integration:
Process of summing (integrating) signals
There are two types of signals that represent post-synaptic responses:

1. **Excitatory Post-Synaptic Potential:**
   - bring neuron closer to firing
   - graded depolarization
2. **Inhibitory Post-Synaptic Potential:**
   - move neuron farther away from its firing level
   - graded hyperpolarization

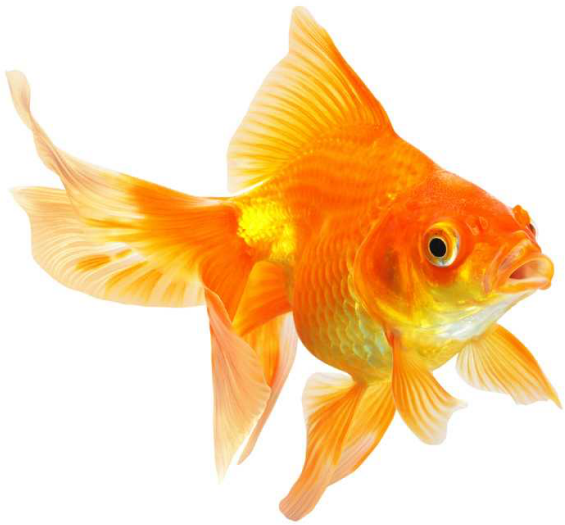
Integration occurs on two levels:

1. **Single-Cell** (Neuronal) Level
2. **Circuit** (Neuronal Ensemble) Level

Brain Calculus: Neural Integration and Persistent Activity

How does the brain keep track of external and internal behaviors?

Hypothesis: Sustained synaptic excitation generated by reverbatory interactions among neuronal ensembles (Hebbian Learning)



Experiment by Laboratory of David Tank:

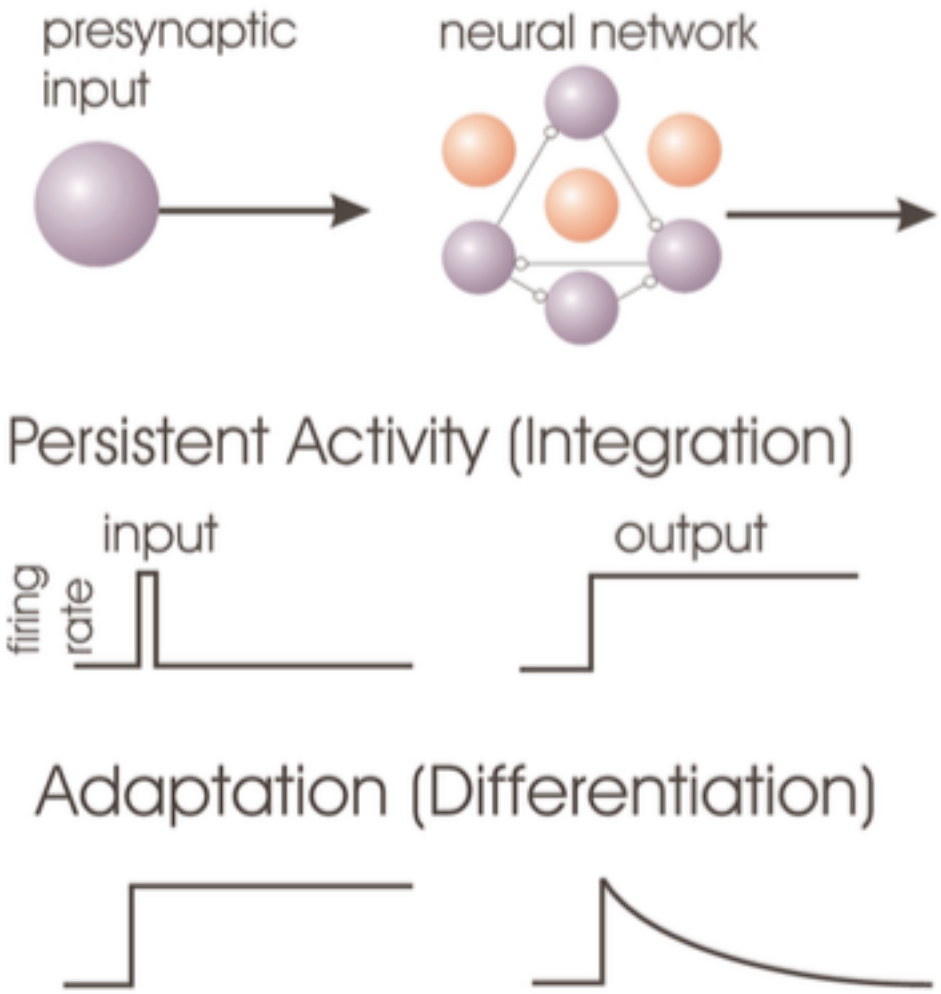
Why test the visual system?

Our eyes scan the world by rapid movements known as **saccades.** Each saccade is separated by a **fixation point.** A fixation point requires continuous contraction of eye muscles, ***which is an example of persistent activity that uses working memory.***

Why goldfish?

Goldfish continuously scan the visual world through a series of horizontal saccades.

Brain Calculus: Neural Integration and Persistent Activity



Each fixation point is maintained by persistent activity of neurons in the goldfish brainstem known as **Area I.**

How do we know so?

If Area I is inhibited, the goldfish loses the ability to fixate and instead gazes after each movement.

How is persistent activity generated?

Re-entrant excitation and transient activity through adaptation. Adaptation is the activation of hyperpolarizing currents or synaptic depression.

What is language?

1. Communication through words or symbols for words
2. Words are an association between sound and meaning
3. By 6 y.o., children understand about 13000 words
4. By 18 y.o., high schoolers understand about 60000 words.

Is language learned or innate?

Question of development being learned or innate was brought up by neuroscientists Skinner and Chomsky in the 1950s.

Both men had different views and theories on the same study of how humans manage to obtain grammar.

Chomsky's Theory	Skinner's Theory
Innate biological ability that all humans possess – every child has a "language acquisition device"	Learning process involving the shaping of grammar into a correct form by the re-enforcement of other stimulus.
Innate learning mechanisms enables a child to figure out how language works	Approaches child as a blank slate that is filled up with knowledge gained through experience.

Development of language

Evidence supporting innate development of language:

1. All cultures learn language
2. Children that live together in a social environment but deprived of any developed language will make their own

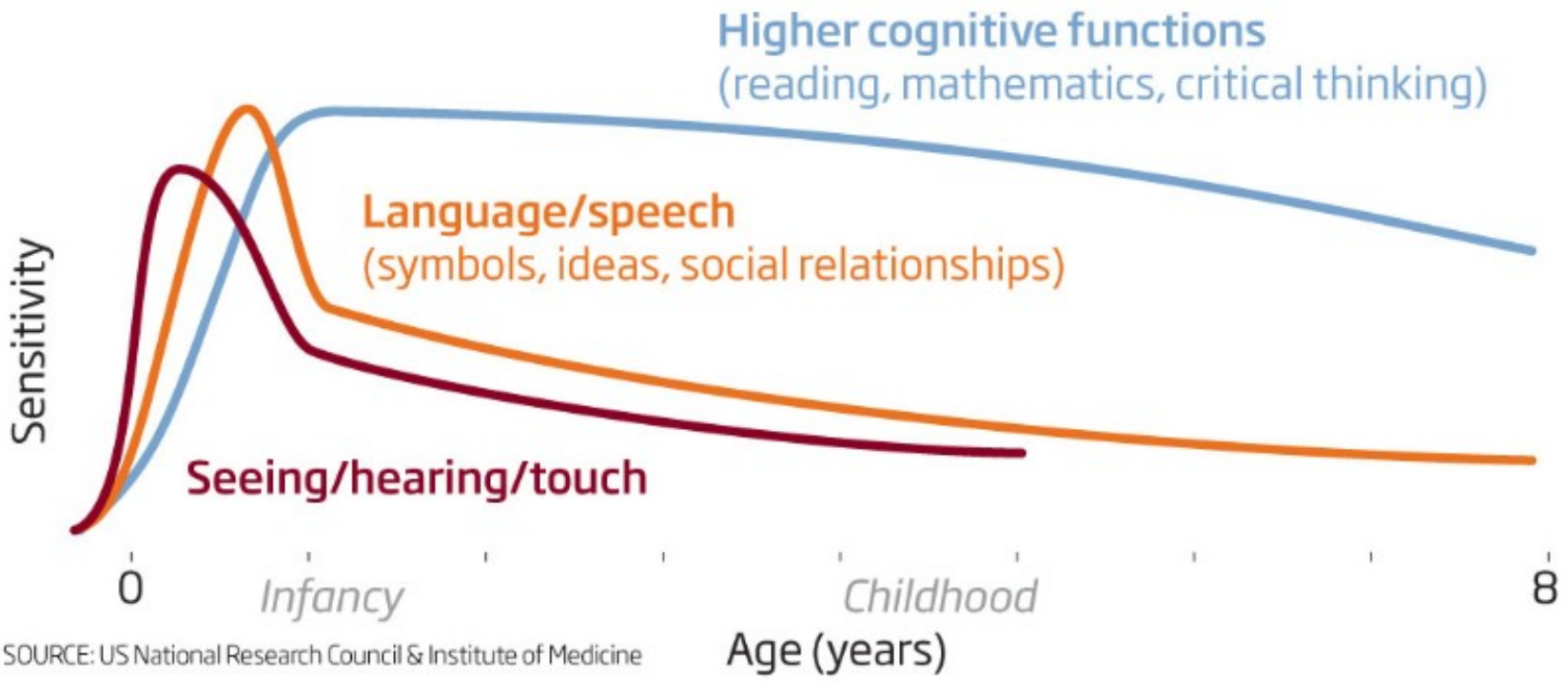
Evidence supporting learned development of language:

1. Young children deprived of language (i.e. parents are deaf or depraved) acquire language fully if learning takes place before puberty. If after puberty, they aren't able to learn language.
2. Young children acquire several languages perfectly – this is much more difficult in adults (with telltale signs of accents and grammatical errors).

From the nurture standpoint, there is a critical period for language acquisition. From a neurological standpoint, the developing brain is plastic with regard to language for several years.

Critical period:

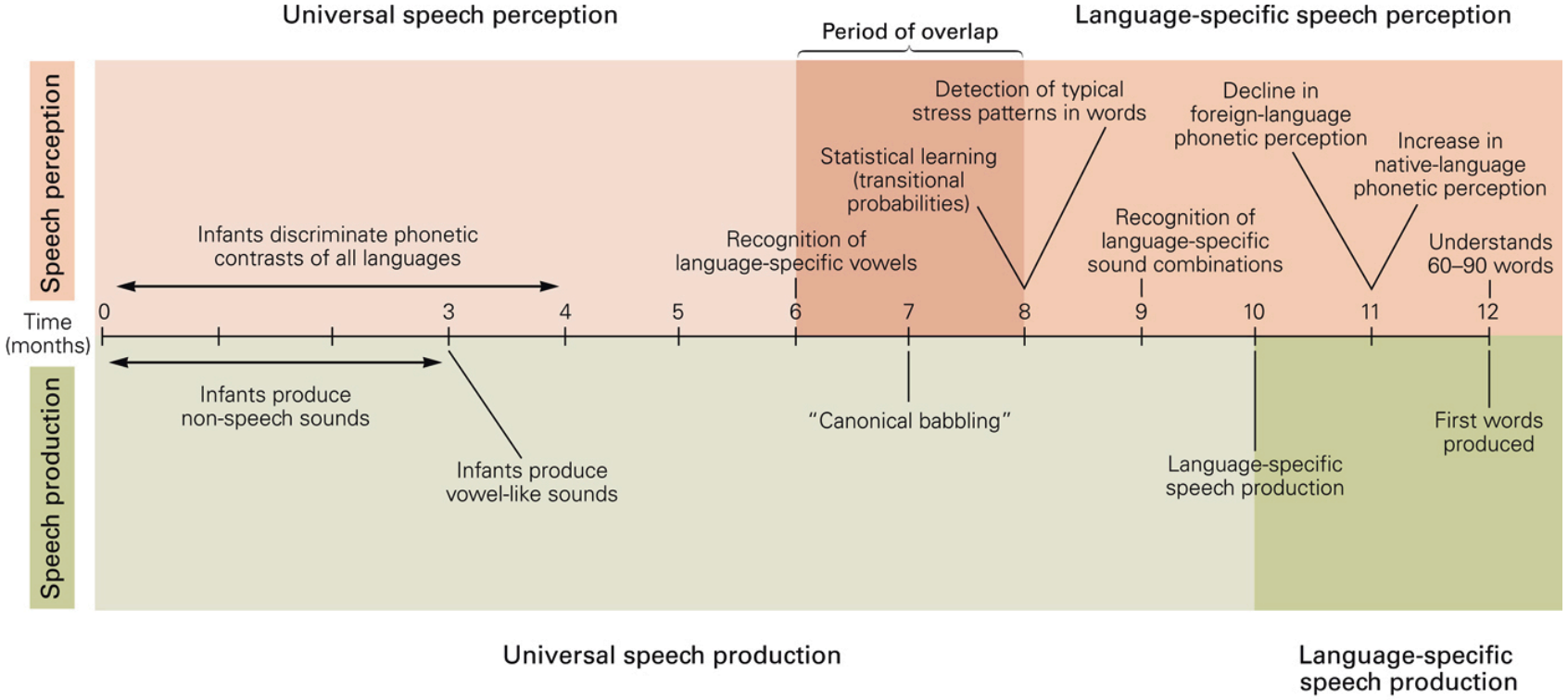
1. Precritical period: The initial formation of neuronal circuits that is independent of experience
2. **Critical period: A distinct onset of robust plasticity in response to an experience. This means the initially formed circuit can be modified by experience.**
3. Closure of the critical period: At the end of the critical period, the same experience no longer elicits the same degree of plasticity.



Development of language

Language is believed to be developed in five phases:

1-4 months	Cooing	Vowel sounds
5-10 months	Babbling	Strings of consonant-vowel syllables
10-15 months	First words	Consistent object labels
18-24 months	Two word utterances	Meaningful pairs of words
>25 months	Meaningful speech	Meaningful strings of words



Test Your Understanding: Language development

Chomsky and Skinner were two important figures in the debate over the development of language. Chomsky believed that language acquisition was innate while Skinner believed that it was learned.

A. True
B. False

The initial formation of neural circuits that is independent of experience is called:

A. Postcritical period
B. Precritical period
C. Critical period
D. Antecritical period

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Language disorders

Aphasia is a language disorder.

Language is lateralized to the left hemisphere in about 96% of the population. This percentage is somewhat less for left-handed people than right-handed people.

What would happen if language were represented in both hemispheres, and a person had brain damage?

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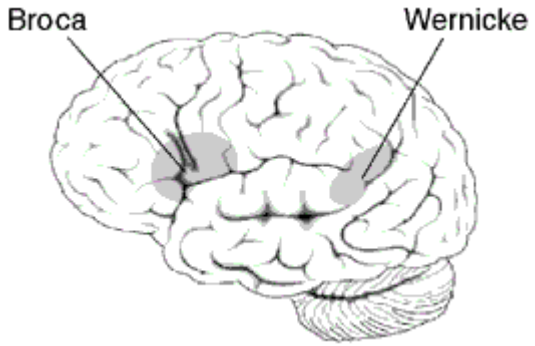
What would happen if language were represented in both hemispheres, and a person had brain damage?

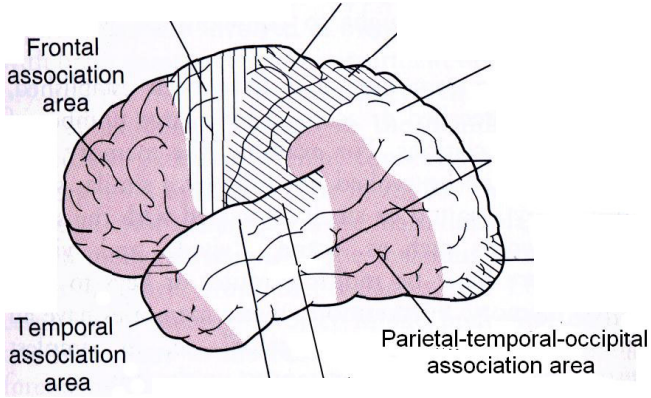
Brain damage would be less likely to reveal aphasia because the other undamaged hemisphere would likely take over language function.

Modern framework of language



Implementation system: Broca's and Wernicke's areas analyze incoming speech in terms of phonemes and other grammar

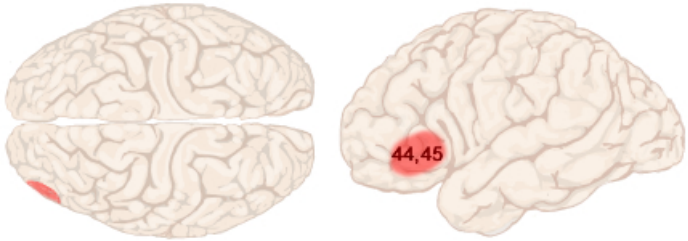
Mediational system: Areas of the temporal, parietal and frontal association cortices that surround the implementation system make up the mediational system. This system allows for communication between the implementation and conceptual systems.



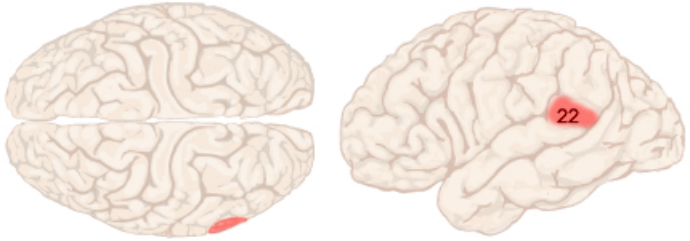
Conceptual system: Areas distributed throughout the association cortices are important in learning, memory and conceptual knowledge.

Different types of Aphasia

Broca Aphasia (non-fluent aphasia)**:**
Speech output is severely reduced and limited mainly to short utterances of <4 words. They can understand speech well and are able to read, but are limited in writing.



Wernicke Aphasia (fluent aphasia)**:**
The ability to grasp the meaning of spoken words is impaired, while the ease of producing connected speech is not affected. Speech is not normal. Reading and writing is severely impaired.



Conduction Aphasia:
Speech production and comprehension are less affected than Broca or Wernicke aphasias. Sentences are not repeated accurately and they have trouble naming pictures and objects.

Global Aphasia:
All disabilities of Broca, Wernicke and Conduction Aphasias.

What does this actually look like?

Type of Aphasia	Auditory comprehension Stimulus: **"What kind of trouble are you having?"**	Capacity for repetition Stimulus: **"Please repeat this sentence: the stray animal was timid."**
Broca	*"Well, um… see… I um… not sure."*	*"Timid."*
Wernicke	*"I'm having some trouble."*	*"Um… eh…"*
Conduction	*"I can't seem to, my sentences, the words having trouble saying."*	*"The dog was… what was that last word?"* **("Let me repeat it: The stray animal was timid.")** *"The dog was… um…"*
Global	*(no words, only gestures)*	*(no response)*

Test Your Understanding: Aphasia

Language is lateralized to the right side of the brain in 96% of the population.

A. True
B. False

Reading and writing is severely impaired in this type of aphasia:

A. Broca's
B. Wernicke's
C. Global
D. Conduction

Which of these types of aphasia are there severe deficits in sentence repetition?

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Which of these types of aphasia are there severe deficits in sentence repetition? (choose all that apply)

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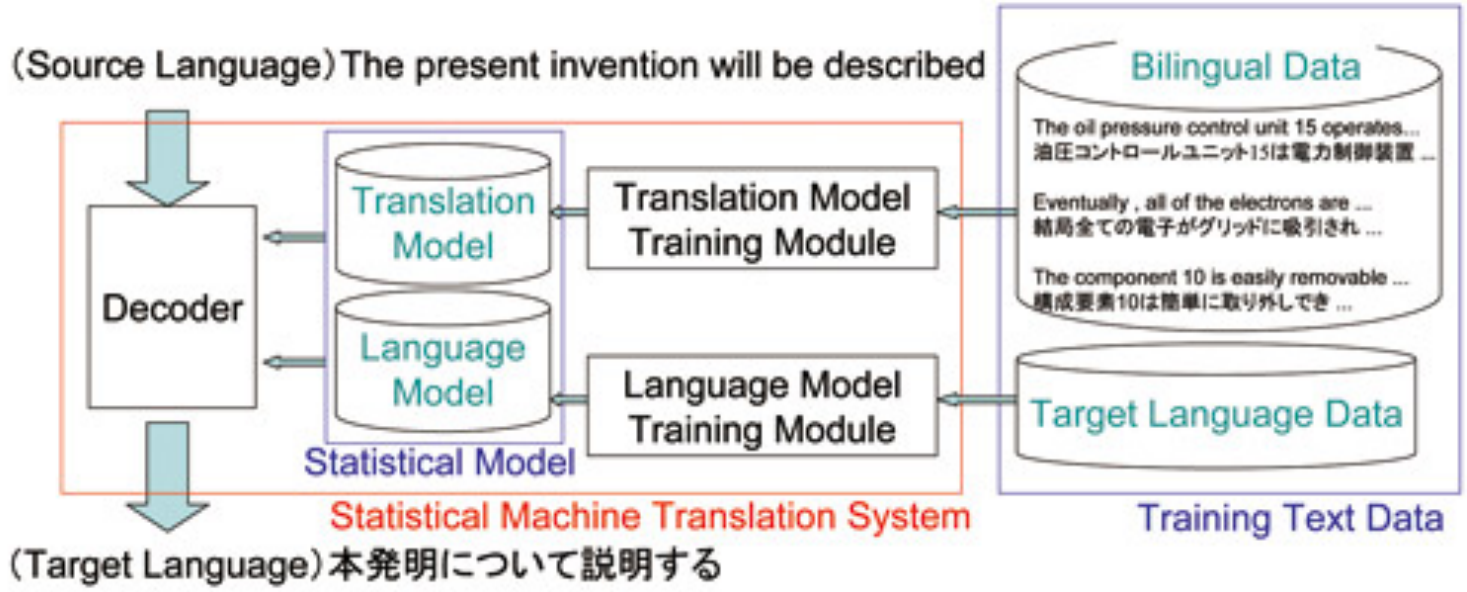
Google Translate

How does Google Translate work?

Statistical machine translation:

1. Starts with a very large data set of good translations (a corpus of texts) that have already been translated into many languages.
   - Google makes use of UN documents that are translated in all six official UN languages
2. It then uses these texts to automatically infer a statistical model of translation.
3. This new model is then applied to new texts to make a new guess for a reasonable translation.

Google Translate



1. The model consists of translation and language models
   i. The translation model represents probable world translations and is trained by bilingual data.
   ii. The language model encodes the sentence fluency and is trained by the target language data.
2. The decoder searches for the most likely target word sequence from a large amount of hypotheses using these two models.

Google Translate

<u>Difficulties Google Translate has to deal with:</u>

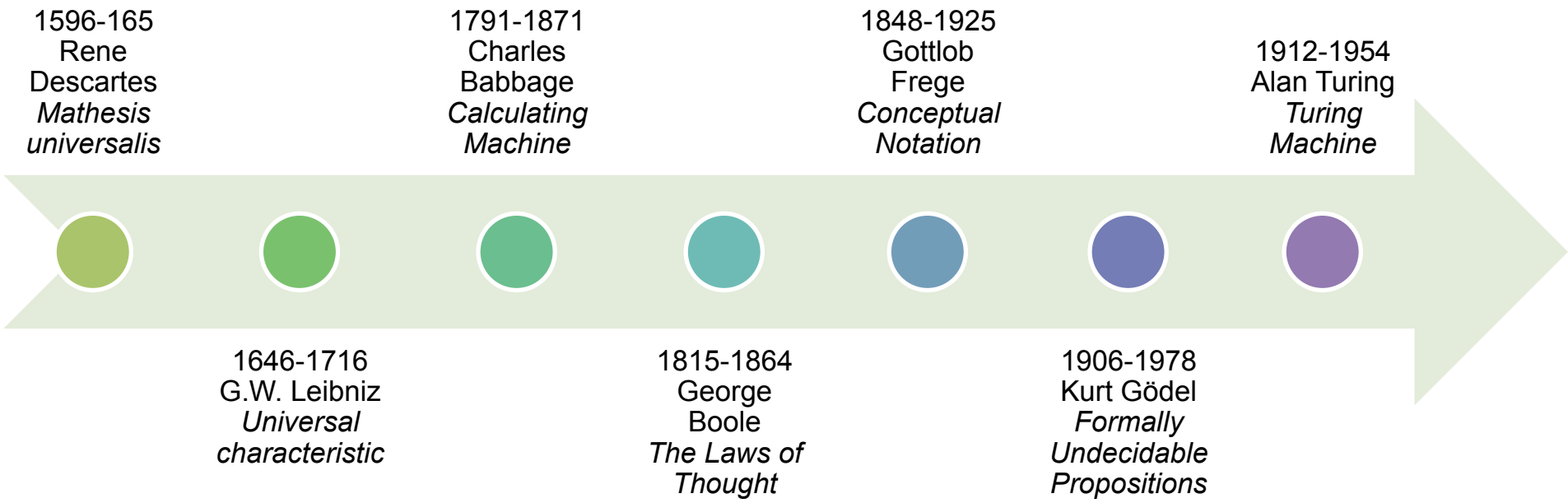
Finding linguistic data large enough to create legit statistical analyses is not easy.

1. Since more documents are available in English than any other language, Google almost always uses English as an intermediary step when translating between two languages that aren't English.
   - Russian → Spanish = Russian → English → Spanish (2 iterations)
   - Catalan → Japanese = Catalan → Spanish → English → Japanese (3 iterations)
2. Multiple iterations are slow and complex grammar is often lost in the process.

Google Translate summary

Philosophical Questions on Computers

1. What is *intelligence?* What is *thought?*
2. Are these functions that a machine can have?
3. If machines can display thought or intelligence, does this imply that human cognition is a type of computational ability?
4. If human cognition is a computation, does this imply that the human mind is a machine?



Social Robots

There are four classes of social robots:

1. **Socially Evocative**
   human-like
2. **Social Interface**
   natural interface by human-like social cues and communication modalities
3. **Socially Receptive**
   learning from interaction
4. **Sociable**
   pro-actively engaging with humans in order to satisfy internal social aims

Using Computers to Change What We Think and Do

Current robotics research focuses on building “human social” characteristics such as:
emotion, dialogue, relationship, natural communication, personality, and learning

Cue	**Example**
Physical	Face, eyes, body, movement
Psychological	Preferences, humor, personality, feelings, empathy
Language	Interactive language use, spoken language, language recognition
Social Dynamics	Taking turns, cooperation, praise for good work, answering questions, reciprocity
Social Roles	Doctor, teammate, opponent, teacher, pet, guide

Human-Computer Interactions

Test Your Understanding: Artificial Intelligence

What is the name for information sent from robot sensors to robot controllers?

A. Temperature
B. Pressure
C. Feedback
D. Signal
E. Output

Which of the basic parts of a robot unit would include the computer circuitry that could be programmed to determine what the robot would do?

A. Sensor
B. Controller
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Android Robots

Android:
A robot designed to look and act like a human, with flesh-like resemblance

Artificial intelligence is used to train robots to think and respond the way a human would.
On left: ***Android Erica*** *was developed by Japanese robotocist Hiroshi Ishiguro in 2015*

"My research question is to know what a human is. I use humanlike robots as test beds for my hypotheses" – hypotheses about human nature, intelligence, and behavior (Ishiguro of Osaka University)

Android Erica

Applications of Android Robots

1. Robot as a ***persuasive machine*** to ***change*** the behavior, feelings, or attitudes of humans

2. Robot as an ***avatar,*** *which is a* ***representation of*** *or* ***representation for*** *the human*

Robots with social skills can:

- develop interactions themselves
- support a wide range of users
- can be a part of an individual's life

Hiroshi Ishiguro built an android robot of his four year old daughter for her birthday
Example of Uncanny Valley

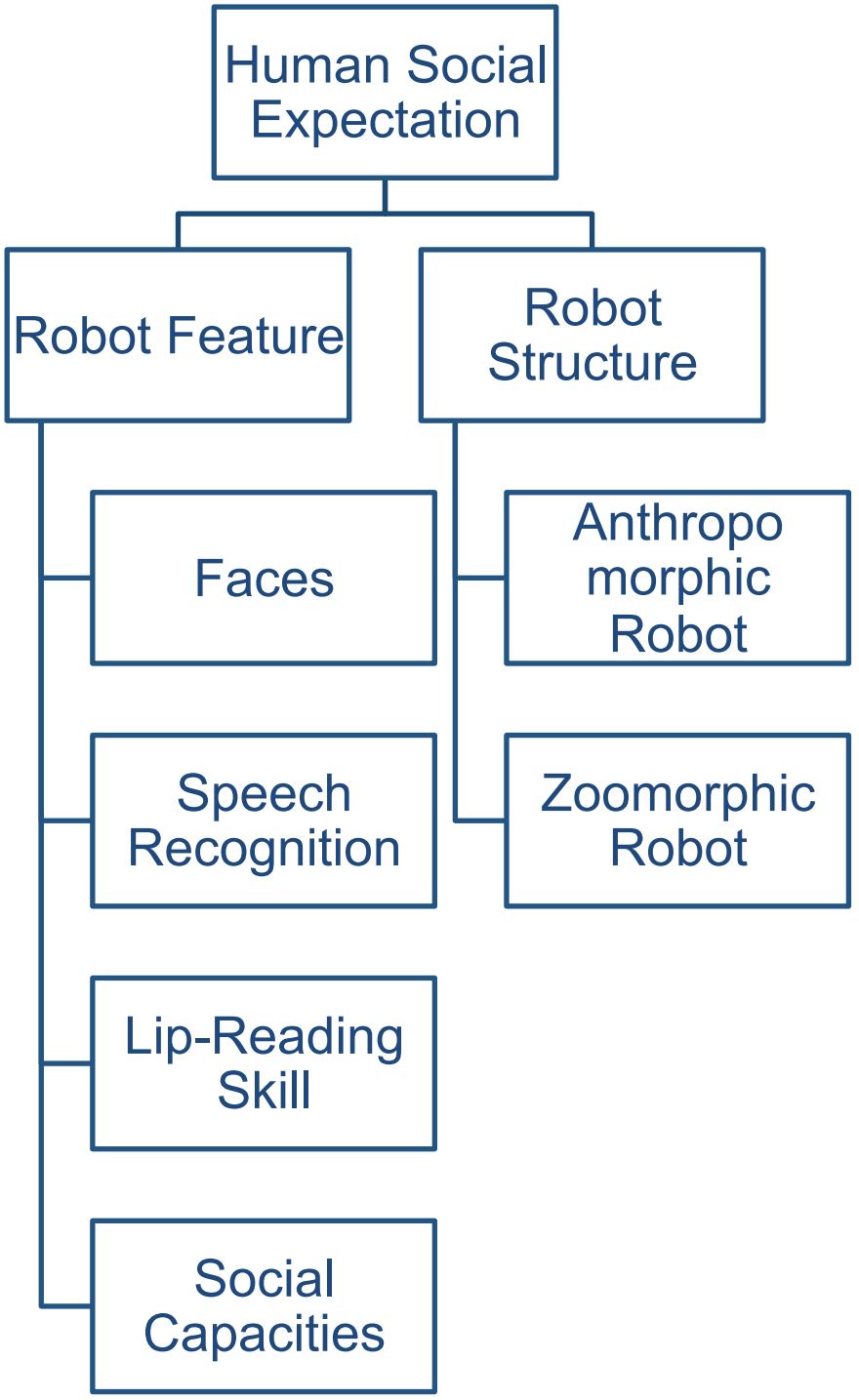
Justification of Android Robots:
A machine with human-like form may have more human-like interactions with people

Social Robot Design

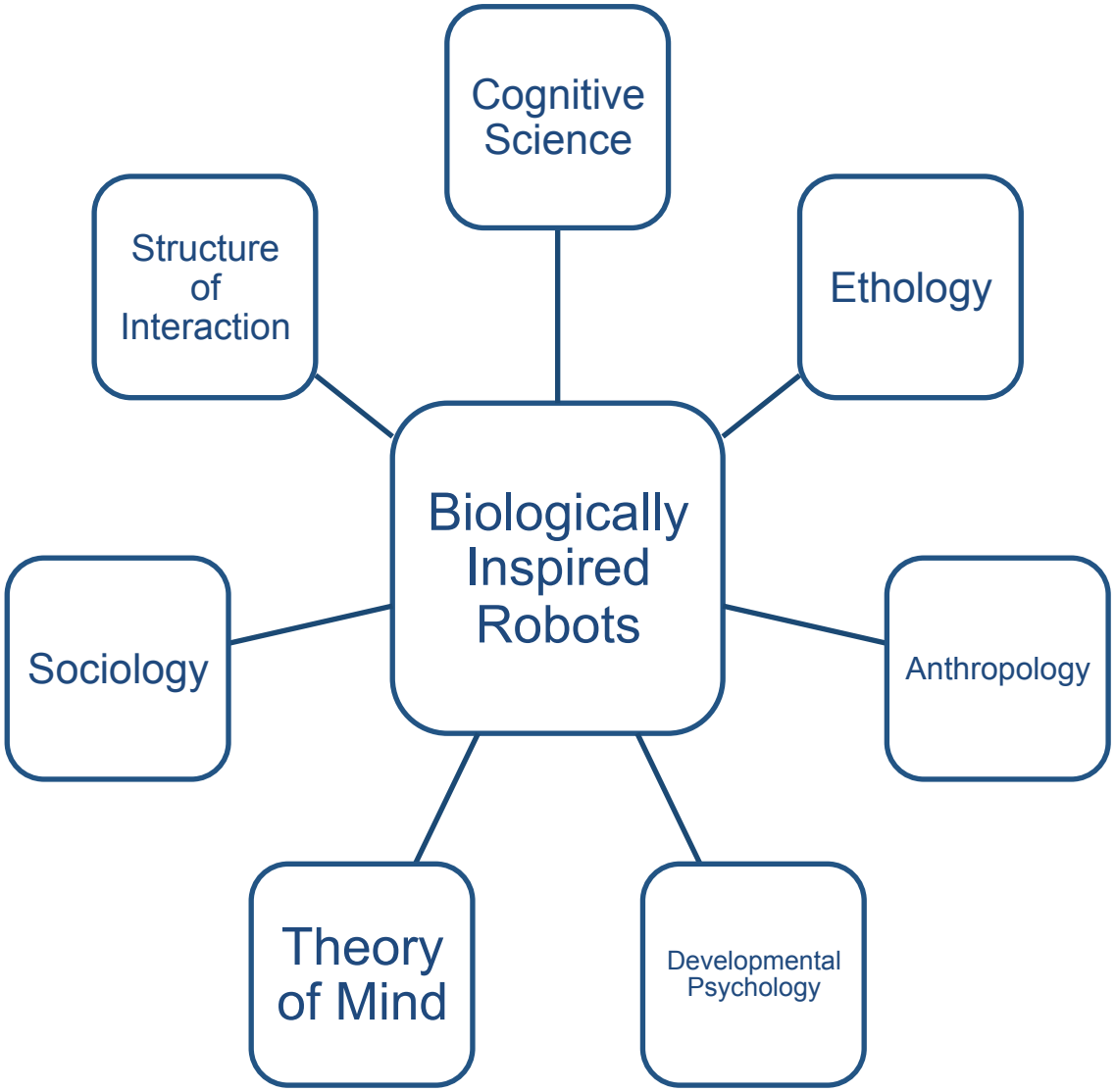
Human social expectations include: enjoyment, empowerment, and competency

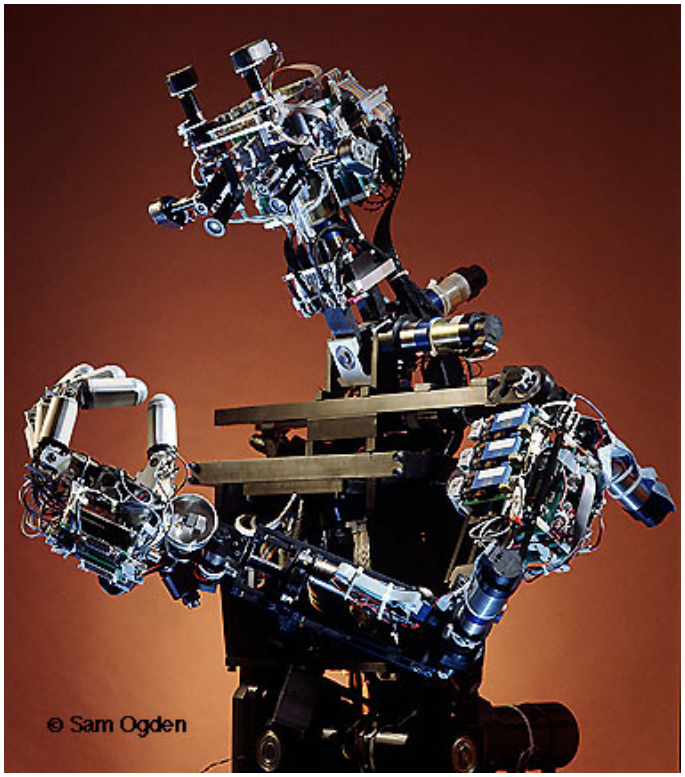
How are socially interactive robots built?

1. Biologically-inspired robot
   Social Intelligence and Socially Interactive
2. Functionally-designed robot
   Socially Interactive and Functionally Structured



Biologically Inspired Robots





Cog (MIT):
Project at Humanoid Robotics Group
Idea: Human-level intelligence requires interacting with humans

Functionally Designed Robots

1. Constrained operational and performance objectives
   i.e. a restaurant robot can do greetings, serving, and cleaning
2. Certain effects and experiences with the user
   i.e. greetings: joy
   serving: happiness
   mistake: sadness

DyRos (Dynamic Robot System) Humanoid Robot:
DyRos was 3-D printed in full. It was a collaborative effort of two South Korean institutes: Digital Human Research Center and Dynamic Robot Systems Lab. The top half is in progress.

Functionally Designed Robots

Motivations for Functional Design:

1. Physical Limitation
   - short-term interaction
   - limited quality of interaction
   - limited embodiment and capability of a robot
   - constraint by the environment
2. Effects of Functional Design
   - affordances (action possibilities) and usability can be improved even with the limited social expression
     i.e. recorded or scripted speech
   - artificial designs can provide compelling interactions for entertainment
     i.e. video games and electronic toys

Principles of Traditional Robot Design

Traditional Robots:

1. Cognition: planning and decision-making
2. Environment sensing and navigation
3. Actuation: mobility and manipulation
4. Interface: inputs and display
5. System Dynamics: control architecture and electro-mechanics

Factors that affect impact and acceptance of a robot design:

1. Morphology
   - physical form influences desirability, expressiveness and accessibility of a robot
2. Anthropomorphic
   - Superior peer interactions
   - Balance of visual illusion and interactive functionality
3. Zoomorphic
   - Entertainment robots as toys
   - Expectations are lower

Principles of Social Robot Design

Social Robots:

1. **Human oriented perception**
   - detecting and organizing gestures
   - monitoring and classifying activity
   - discerning intent
   - measuring feedback from human peers
2. **Natural Human-Robot Interaction**
   - believable behavior
   - following social norms
3. **Readable Social Cues**
   - useful for expression and easy interaction
   - gestures and voice recognition
4. **Real-Time Performance**
   - operate at human interaction rates

- If meant to do tasks for a human, robot should look closer to a product.
- If meant for peer interaction, robot should look closer to a human.
- A considerable amount of robot qualities should be maintained as to prevent excess confidence in the robot's abilities
- A specific amount of familiarity should exist

Test Your Understanding: Robot Design

Which of the following terms is **not** one of the five basic parts of a robot?

A. Peripheral tools
B. Effectors
C. Controller
D. Drive
E. Sensor

The number of moveable joints in the base, the arm, and the end of the effectors of the robot determines:

A. Payload Capacity
B. Operational Limits
C. Flexibility
D. Degrees of Freedom
E. Cost

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Artificial Emotion in Robots

Why is emotion important?
People tend to treat computers as they treat **other people.**

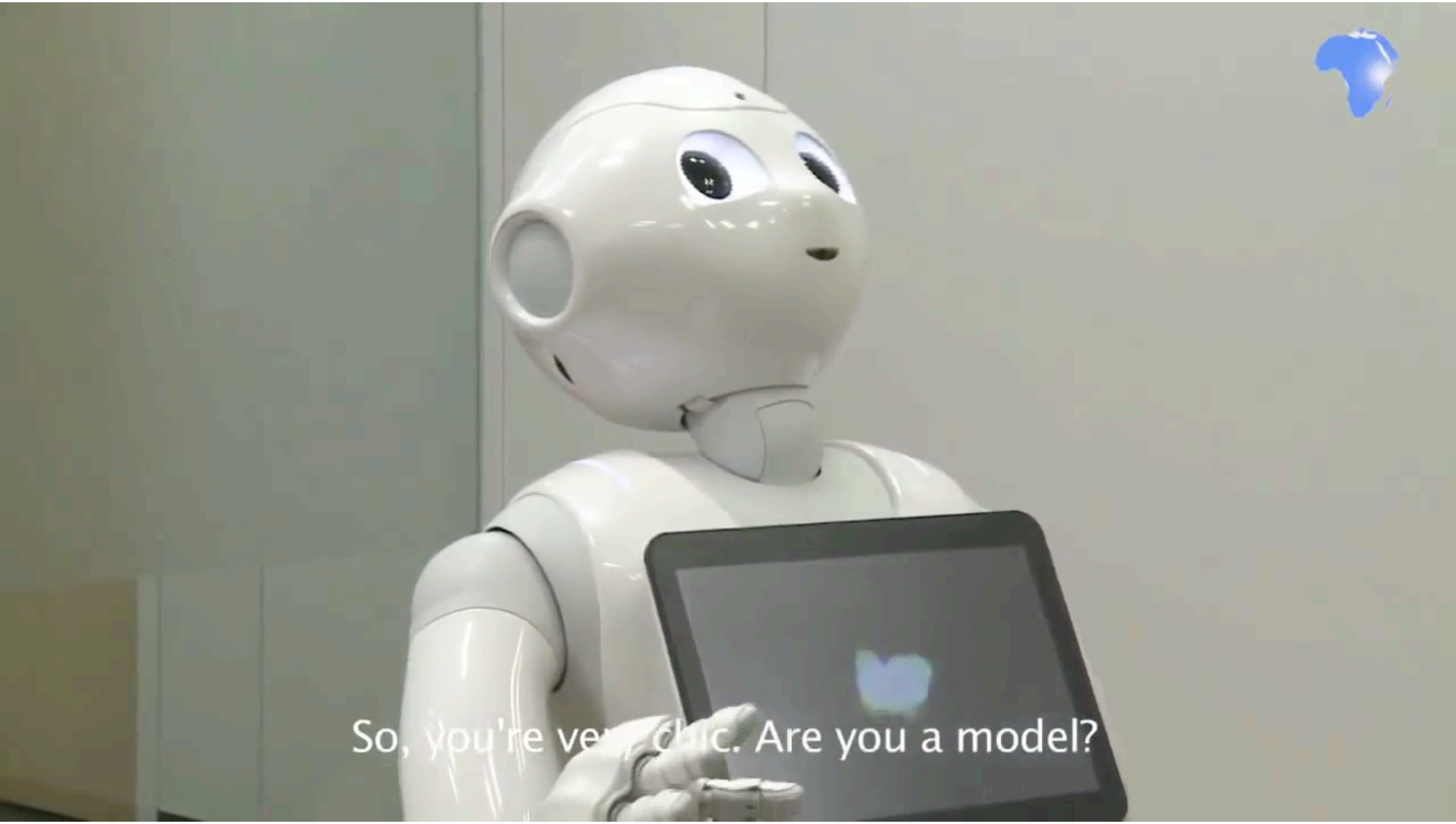
Artificial emotion used in social robots

- Emotion aids human-robot interactions
- Provides feedback to user
- Acts as a control mechanism

How do robots display emotion?

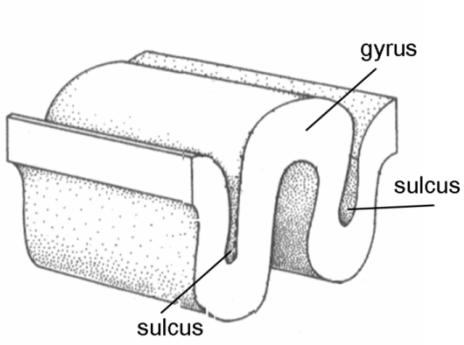
- Design-of-frameworks vary in size

Pepper: First Robot with Artificial Emotion

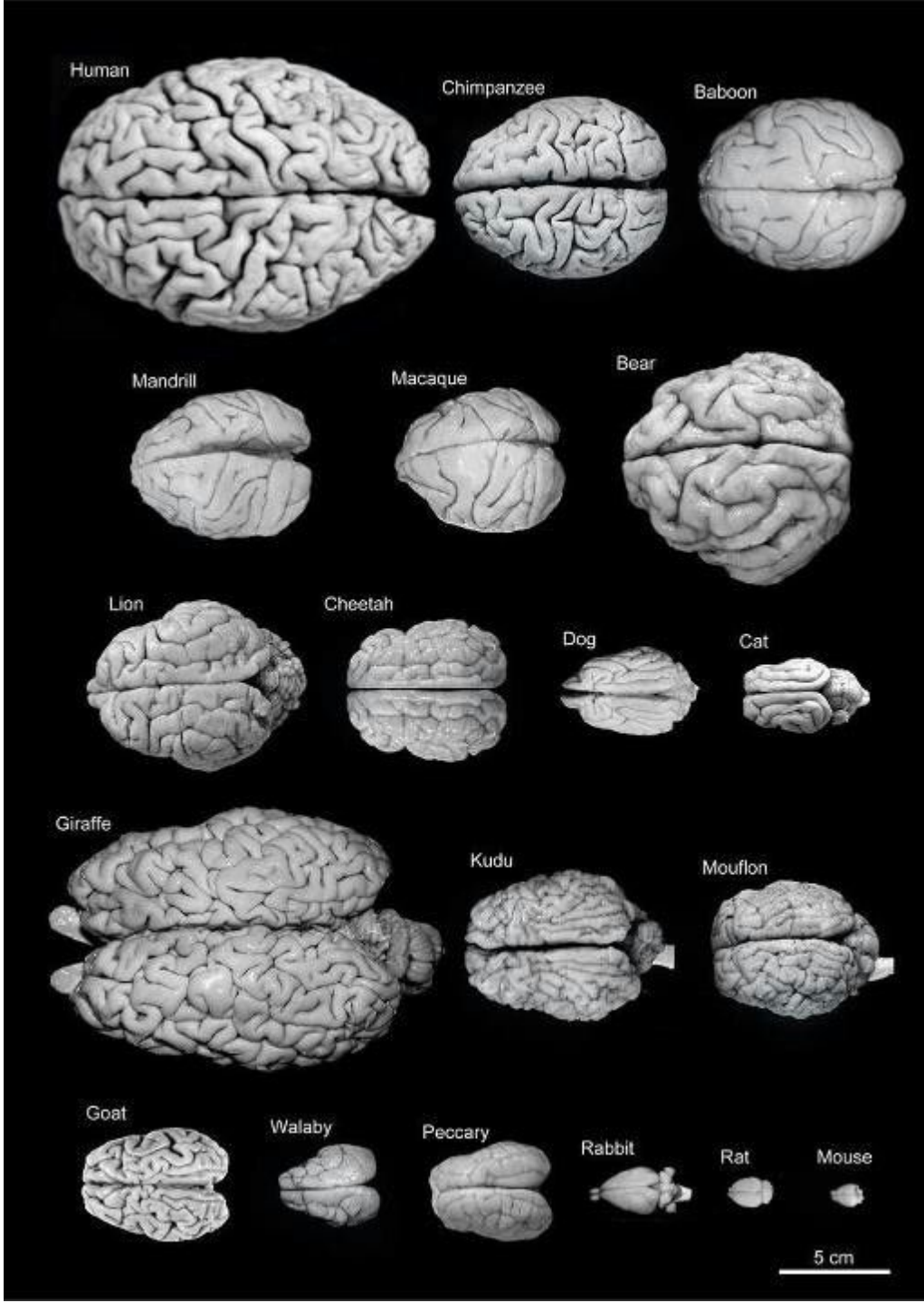


Demo: Brain Bank

1) Wear gloves
2) Don't remove brains from vials
3) Be gentle!



The folds allow for greater surface area =
better organization of complex behaviors



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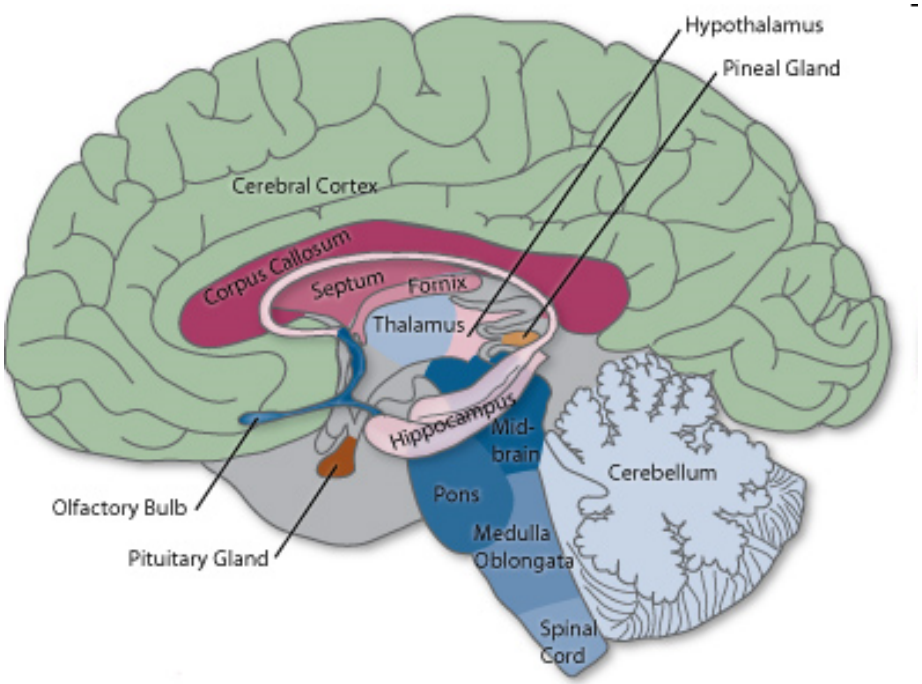
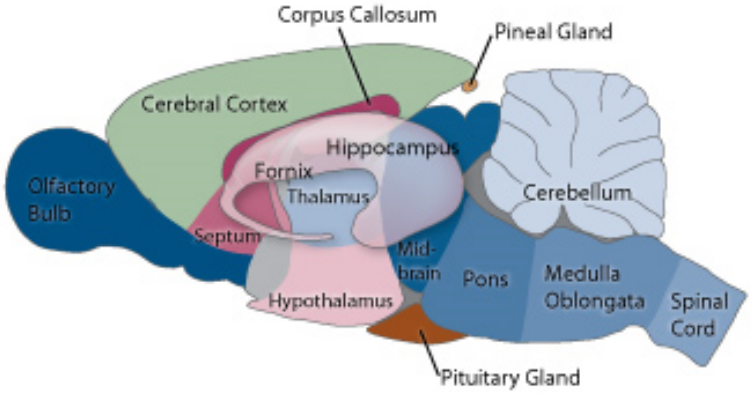
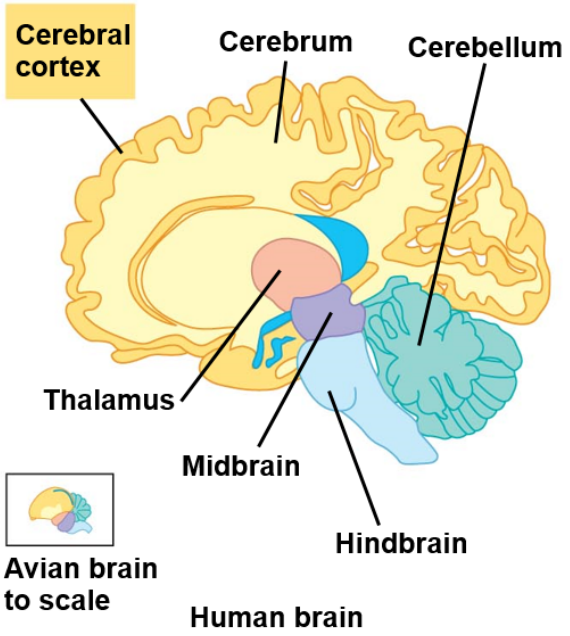
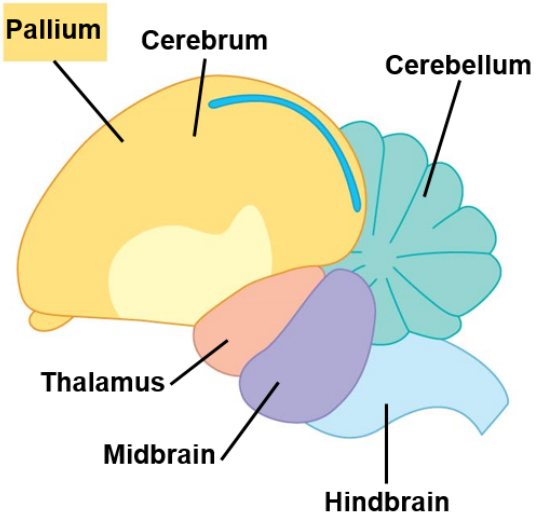




Human vs. Rat brain

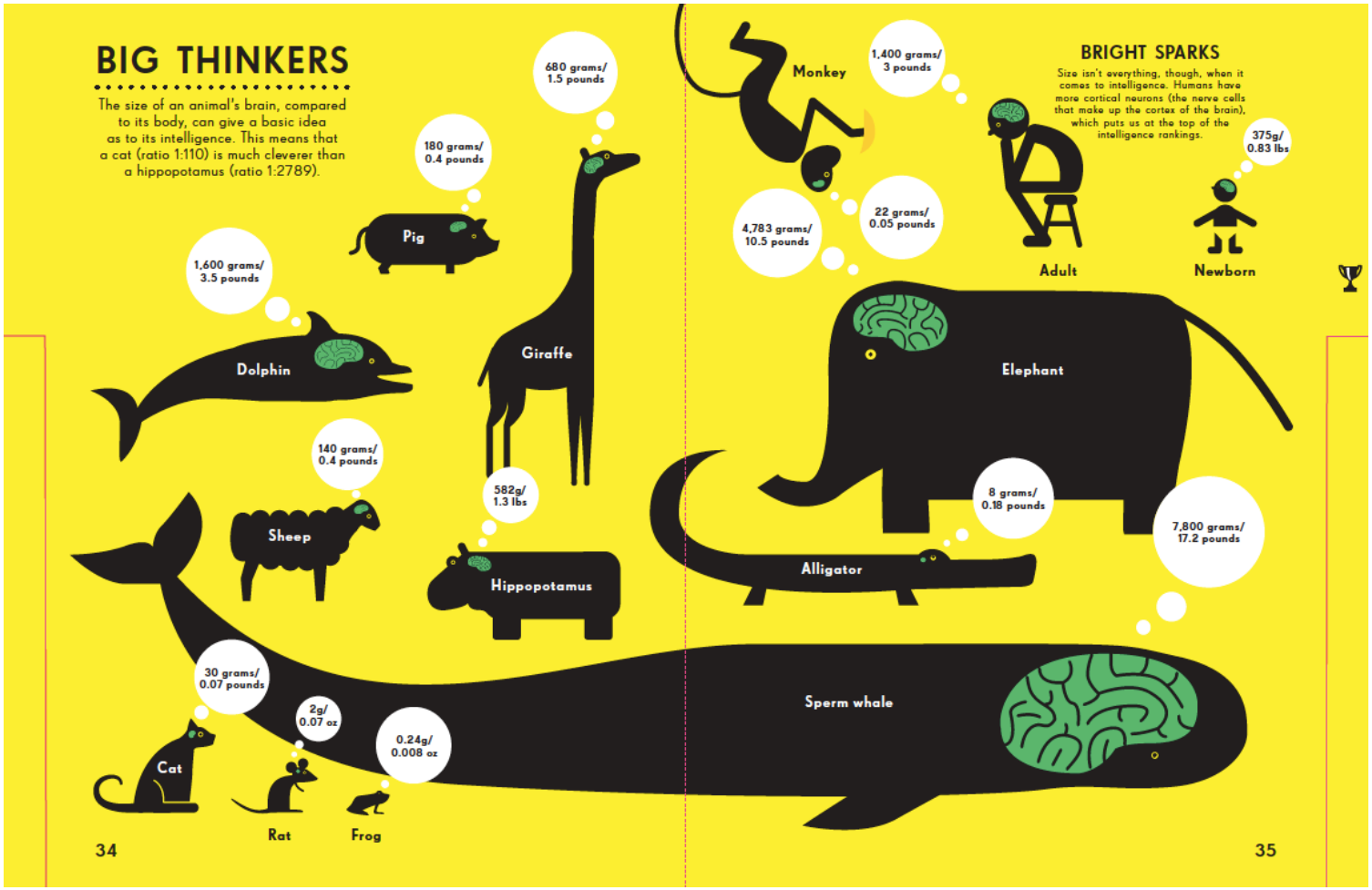




Human vs. Bird brain

Comparing brains in different animals

1. Greater surface area of cerebral cortex allows for more social and complex behaviors, like emotion and language.
2. Different animals have larger areas of their brain dedicated to different regions (take note of size of olfactory bulbs)
3. Proportion of brain region usually dictates importance of that function



Next Time

Guest Lecture by Professor Aurel Lazar of the Department of Electrical Engineering

Title: The Fruit Fly Brain Observatory