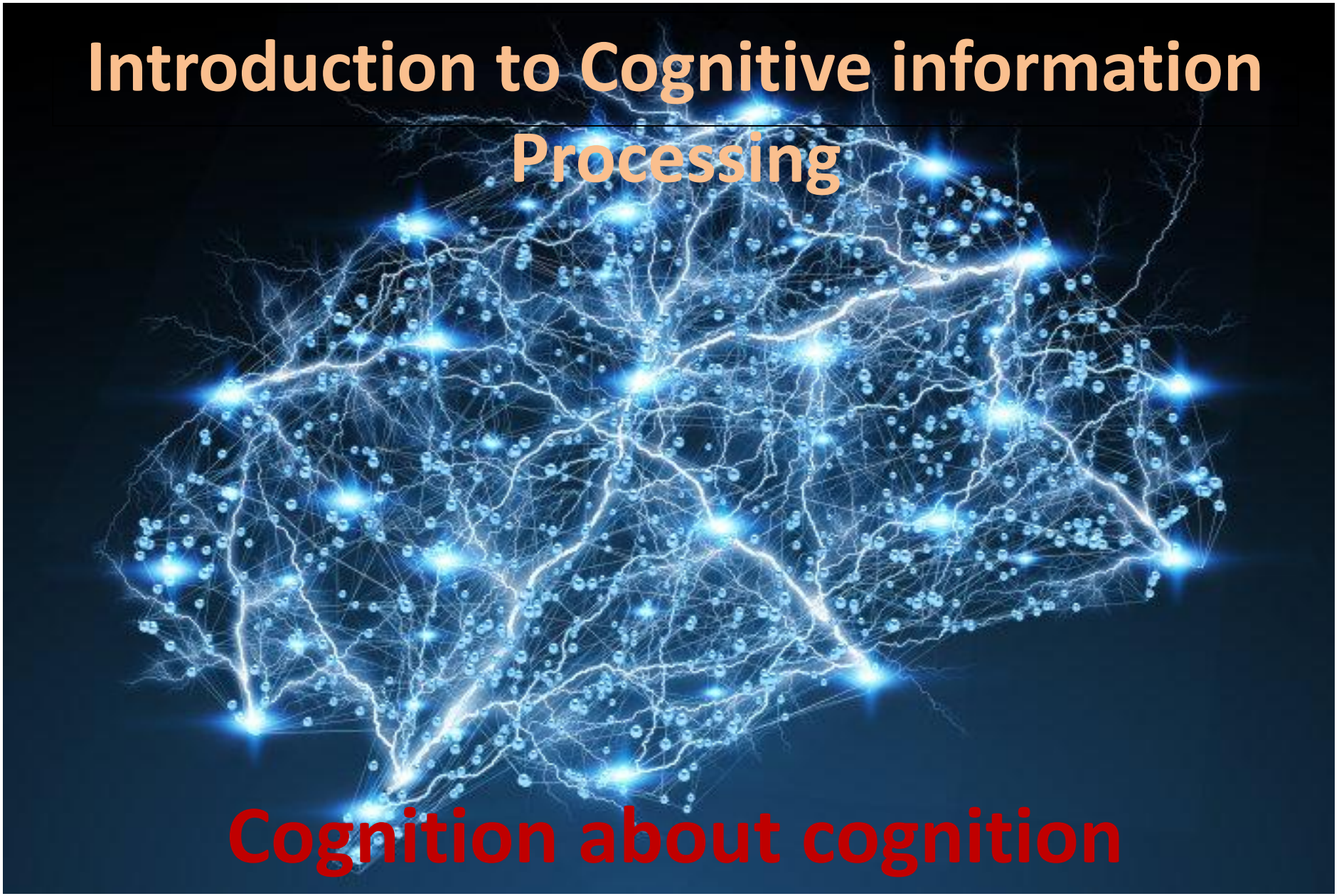
Introduction to Cognitive information Processing



Cognition about cognition

Lecture 1

Points to ponder…

- **Why do we think the way we think?**
- **Why do we believe the things we believe?**
- **What is "knowledge," and**
- **how secure (how complete, how accurate) is our knowledge of the world around us?**
- **How is knowledge acquired?**
- **How is knowledge retained so that it's available when needed?**
- **How is knowledge used—whether as a basis for making decisions or as a means of solving problems?**

- **How can I help myself to remember more of the material that I'm studying in my classes?**
- **Is there some better way to solve the problems I encounter?**
- **Why is it that my roommate can study with music on, but I can't?**

What is Cognition?

The ability to process information through:

- **Perception (stimuli that we receive through our different senses)**
- **Knowledge acquired through experience &**
- **Personal characteristics**

that allow us to integrate all of this information to evaluate and interpret our world

Cognition is the ability to assimilate information from different sources (perception, experience, beliefs, etc.) and convert them into knowledge

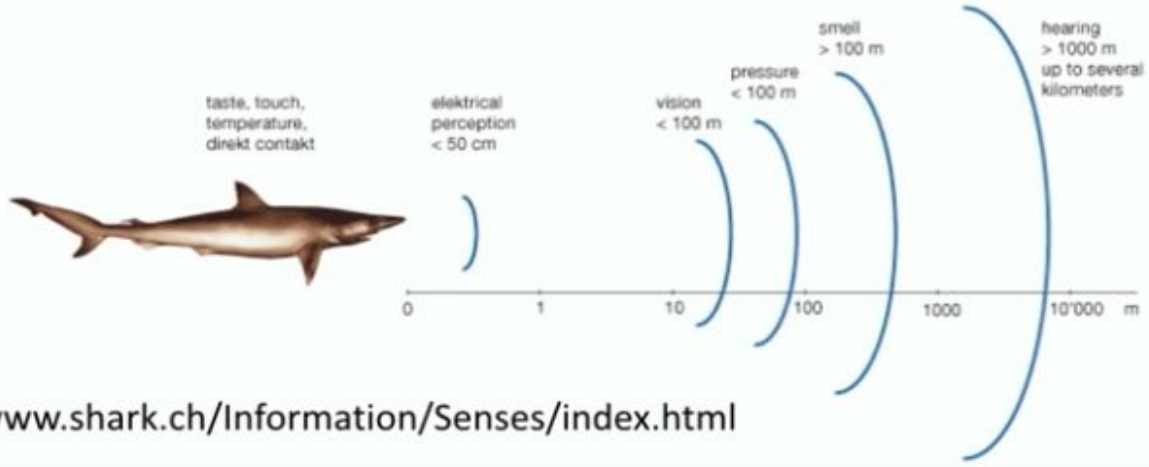
- **Perception**
- **Attention**
- **Imagery**
- **Learning and conditioning**
- **Memory**
  - ✔ **Episodic**
  - ✔ **Semantic**
  - ✔ **Procedural**
- **Language**
- **Problem-solving**
- **Reasoning & DM**

Studying cognition entails inferring mental organization from observing behavior

Behaviour reflects sensory, motor, and motivational as well as cognitive mechanisms

Do we see the world as it really is?

- A shark:
  - hears its prey at >1 km or more
  - smells its prey at >100m
  - 'feels' its prey up to 100m away
  - perceives electrical activity of its prey 50 cm away
  - tastes prey before ingesting it, using taste receptors on the surface of the face
  - only ever sees a blurry image at near range

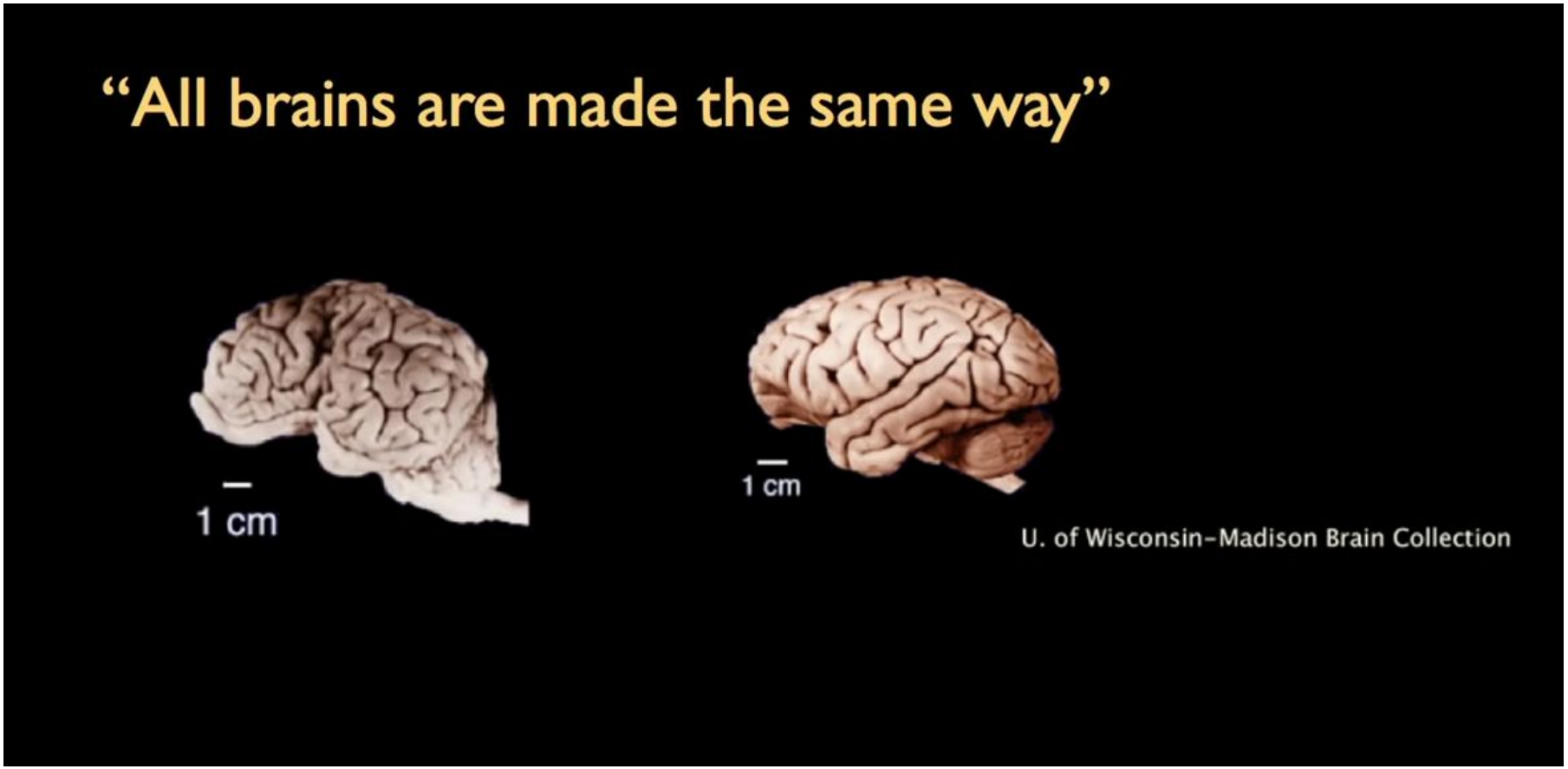


http://www.shark.ch/Information/Senses/index.html

Each species has its own sets of sensors and neural systems to perceive the world

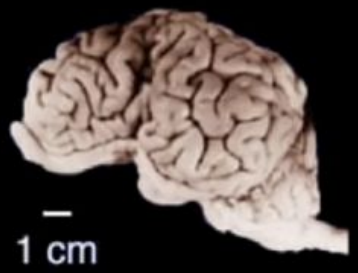
Evolution of Cognition

Earlier scientists believed…



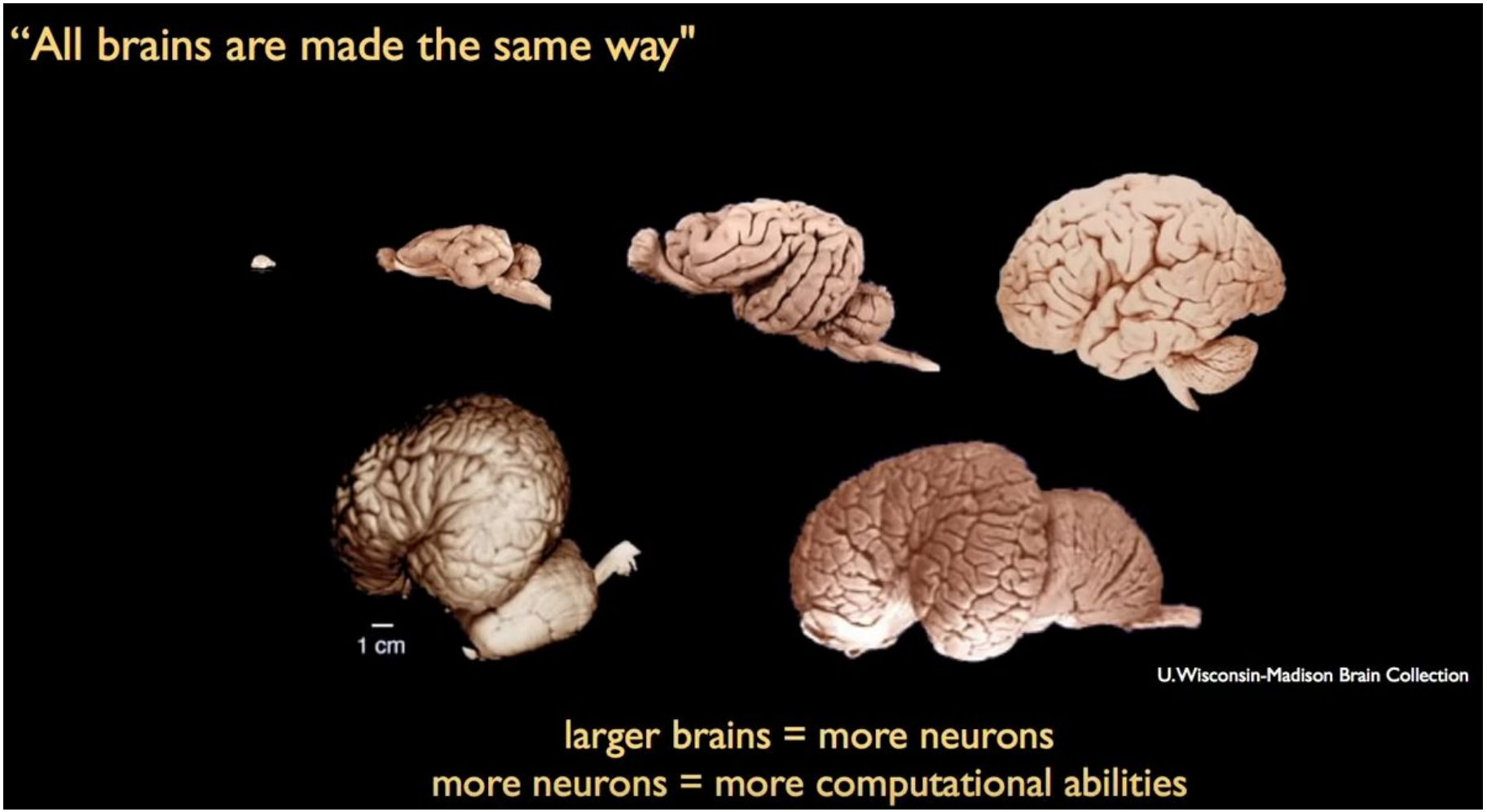
…that is the number of neurons would be proportional to the size of the brain – brains of the same size would have similar number of neurons

Same type – same level of Processing?



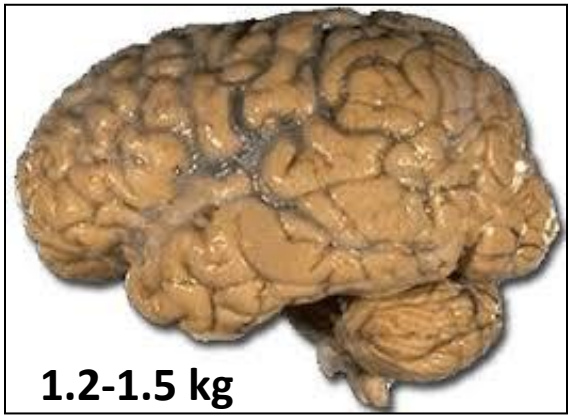
U. of Wisconsin-Madison Brain Collection

Bigger brain – better cognitive processing?



Is the largest brain then the most cognitively efficient brain?

Different bodies different brains

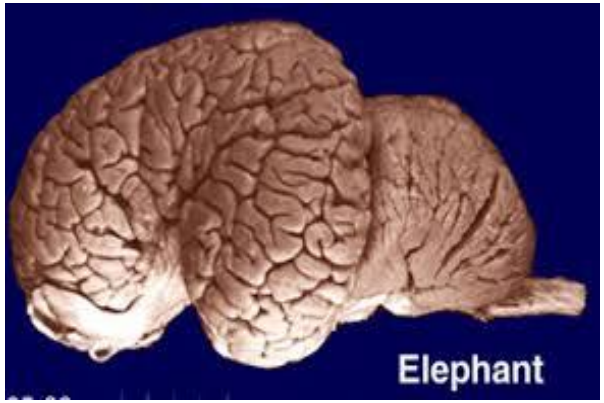


1.2-1.5 kg

Human brain – 2% of body weight

- Small vertebrates on average have small brains &
- Large animals large brains

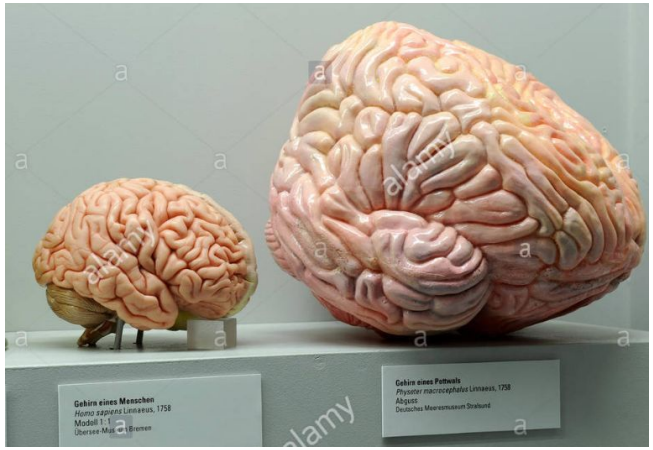
brain size is determined roughly by body size



4-5 kg

In shrews - brains comprise 10% or more of body volume, while in the largest mammal (and extant animal), the blue whale, the brain occupies less than 0.01% of the body

However -
Brain size relative to body size tends to decrease with an increase in body size, resulting in the fact that small animals have relatively large and large animals relatively small brains



Sperm Whale - 9 kg

Brain size and cognition

There is no clear correlation between absolute or relative brain size and intelligence

Examples

- **Whales or elephants not smarter than humans**
- **Chimpanzees more intelligent than horses**
- **Shrews should be the smartest mammal (highest relative brain size)**

Then what determines effective Cognitive Information Processing?

Is it the number of neurons in the Brain?

Do the number of neurons determine effective cognitive processing?

- **Why do some monkeys with about one billion cortical neurons in many respects appear to be as intelligent as great apes with five to eight times more cortical neurons?**
- **Why elephants and cetaceans (whales and dolphins) with numbers of cortical neurons equal to or even higher than those found in great apes exhibit only modest degrees of intelligence?**

RESEARCH FINDINGS:

- **the number of neurons in the entire brain or in the pallium or cortex**
- **the degree of connectivity**
- **axonal conduction velocity**

- are relevant for 'information processing capacity (IPC)' of the brain

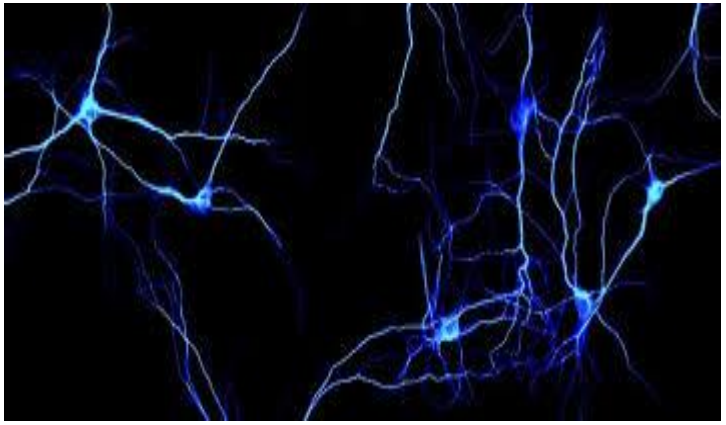
IPC is coincident with the notion of 'general intelligence' as largely defined by the efficiency of working memory and, accordingly, mental manipulation abilities

What is so special about the human brain?

What makes them different from the others?

Human brain is special

- The human brain has the largest number of cortical neurons (about 15-16 billion)
- Despite the fact that the human brain and cortex are much smaller in size than those of cetaceans and elephants (with 10–12 billion or even fewer cortical neurons)
- Humans use more energy to keep the brain working
- 25% of body energy (500 kcal/day)



Neurons

Differences in the speed of intra-cortical information processing

+

Higher Neuron Packing Density

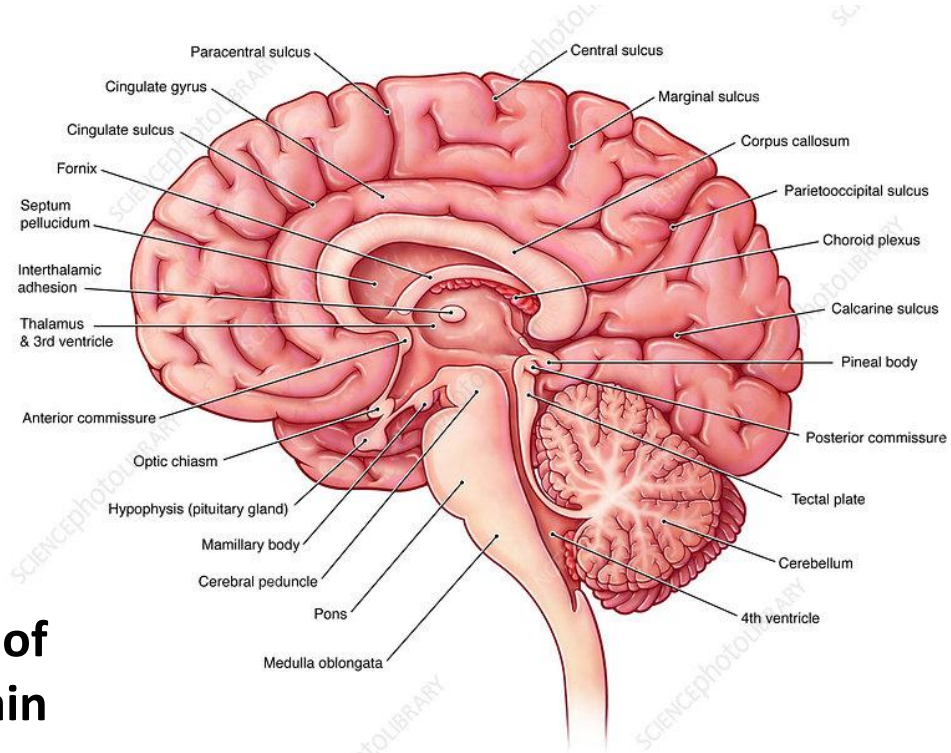
→

Cortical information processing is much faster in humans than that in the large brained elephants and cetaceans

A combination of very many cortical neurons and a relatively high IPC that appears to make our brains very smart

Cerebral Cortex is the 'seat' of intelligence and mind in mammals
During their evolution, there was a dramatic increase in cortical surface area with increasing brain size, while the thickness of the cortex increases only slightly

THE HUMAN BRAIN



Sagittal section of the human brain

Cognitive Information Processing

Can Human Cognitive Processing be replicated computationally?

A few thoughts….

- **Can the performance of the human brain, with respect to cognitive processes, be augmented with artificial systems?**
  - ✔ **(current examples, other areas to be explored)**
- **Is there an upper threshold of performance enhancement? Is that a mathematical function of the human ability for cognitive processing?**
- **When is there a cognitive breakdown or delay in transmission of information? Can it be reduced by systemic aids?**
- **Is there any function of the human brain (in terms of CP) that cannot be replicated?**

Blending with CCIP

- **Information and its Storage and Retrieval :**
  - What is knowledge to human brain?
  - How do humans acquire knowledge? What are the processes used?
  - How information is recorded (registered), stored and assimilated in the human brain - different from a computer
  - How is STM, LTM, Procedural memory represented? (say it in brief)
  - Why is there a loss of information? – can it be altered with computational aids? (advantages and disadvantages)

- **Loss of information: In different cognitive processes:**
  - **Memory** – Forgetting; compensation (confabulation, eye witness testimony) , eidetic imagery
  - **Perception** – Illusions; compensation (perceptual constancy - despite loss of information)
  - **Attention** – Filtering information, channel capacity; Compensation (Dual tasking, attenuation, skill development and automacity)
    - errors in signal detection (hits, misses, correct rejection, false alarms) measurements
  - **Pattern recognition:** AOI in object perception – optimal features; Compensation (Gestalt, template matching)
  - **Language** –Tip-of-tongue phenomena, delay in thought processing (relationship between thought and language), salient features to comprehend meaning; Compensation (mixed language, use of emojis)
  - Relationship of language and memory, Language and thought

Blending with CCIP

- **Sampling:**
  - sampling frames / sampling space in relation to identifying events. EEG and Event Related Potential (ERPs) and event markers during experiments with a bio-markers (demonstration). High speed camera – for micro-expressions in emotion, Area of Interest in Eye tracking, Event markers in fMRI

- **Sensing and Sense-Processing**:
  - How are the senses represented in the brain?
  - How is the message stored and meaning derived (perception from sensation)
  - How is time represented in relation to space?
  - What is space-time in the brain? Relativity of time in respect to this – (influence of other scientific developments in the study of cognition)
  - Circadian rhythm and affect on cognitive processes (2017 Nobel in Meds for Circadian rhythm and human biological clock)

- **Assimilation**: Discuss metacognition
- **Feature Extraction**: Mention in Pattern recognition, measurements

- **Thresholds:** In respect to each cognitive process
- **Explain algorithms through Brain's approximation in**:
  - Problem solving & Decision making
  - Errors due to approximation in the social context stereotyping (very brief)

Discuss the computational aids that are used currently to understand and evaluate human cognition – (the Human Brain Project)

Michio Kaku on the Evolution of Intelligence

https://www.youtube.com/watch?v=bu7VulZUUdE