



Cognitive AI*

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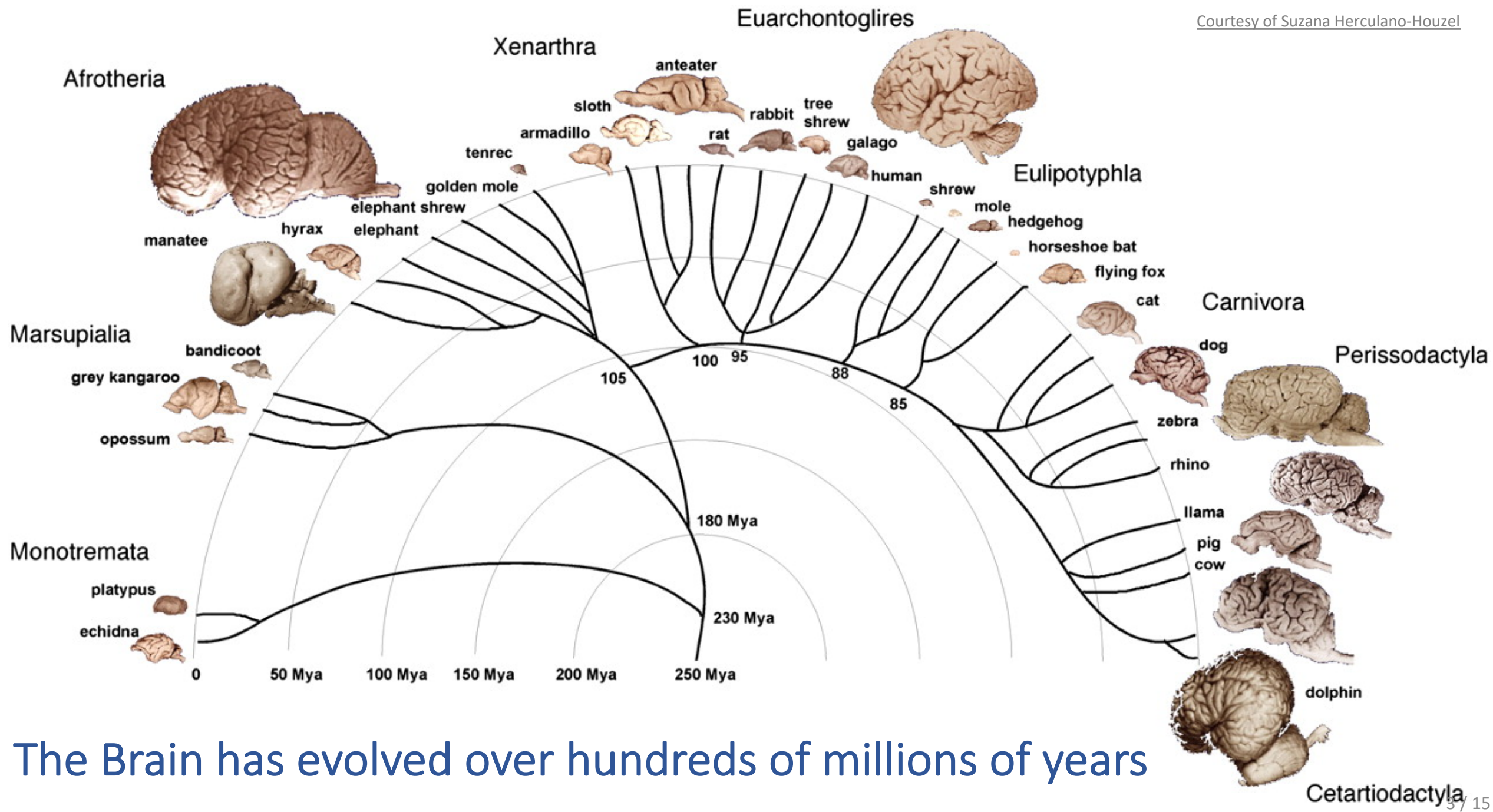
10 January 2020

Based upon the Cognitive Sciences
(the scientific study of human mind and behaviour)

* see: <https://www.w3.org/Data/demos/chunks/chunks.html>

Cognitive AI

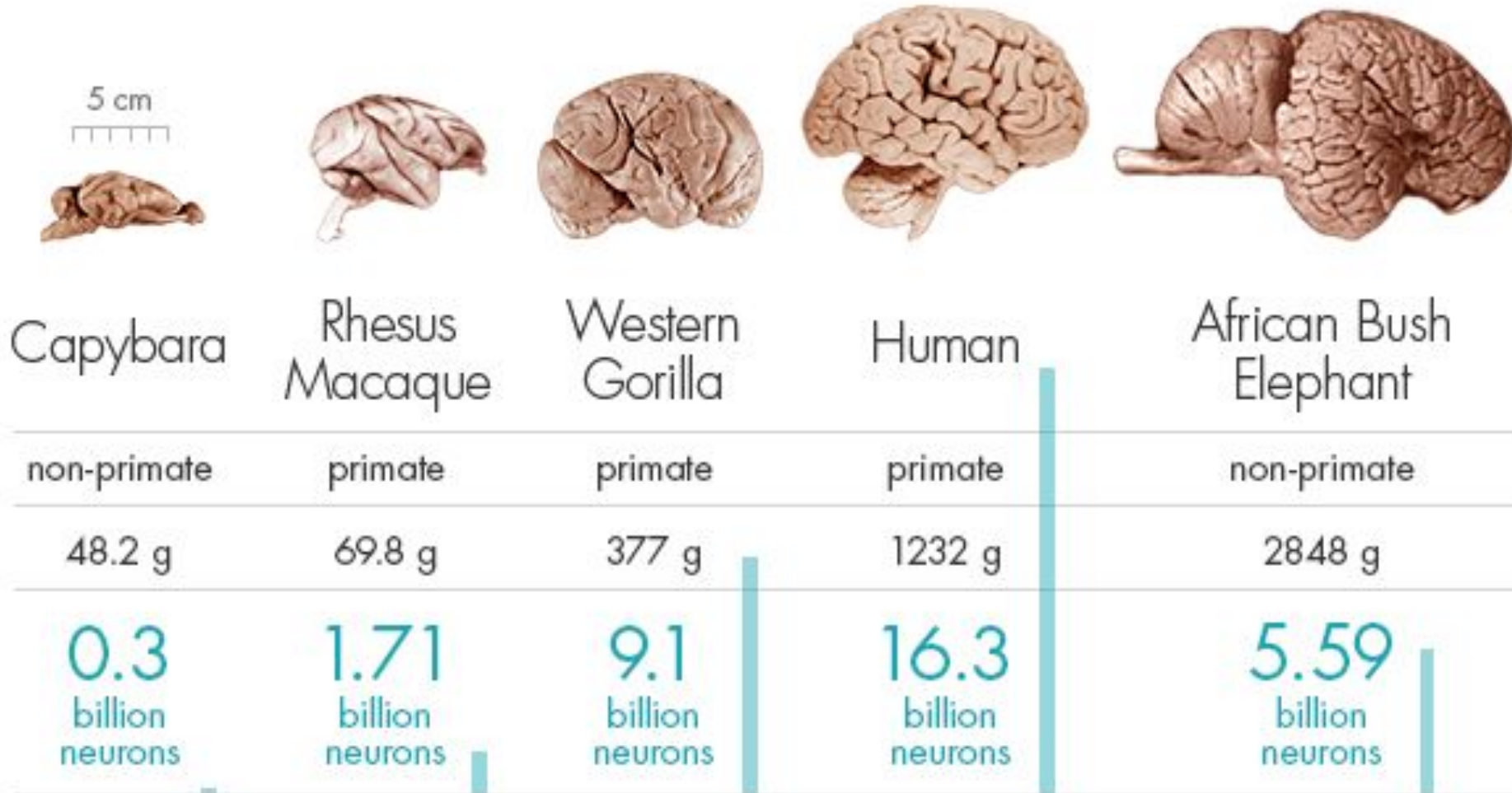
- In short, Artificial Intelligence inspired by advances in the cognitive sciences
- In other words, we would do well to borrow from nature when it comes to building AI systems
- This talk looks at how the brain is composed from many specialised modules
- We can mimic these at a functional level using conventional computer technology without having to implement cognitive agents in terms of artificial neurons
- There are many potential applications of cognitive agents for human-machine collaboration
- We first need to define and evolve the modules through a suite of demonstrators
- We will then work on a suite of exemplary application use cases
- You can help by contributing to the W3C Cognitive AI Community Group

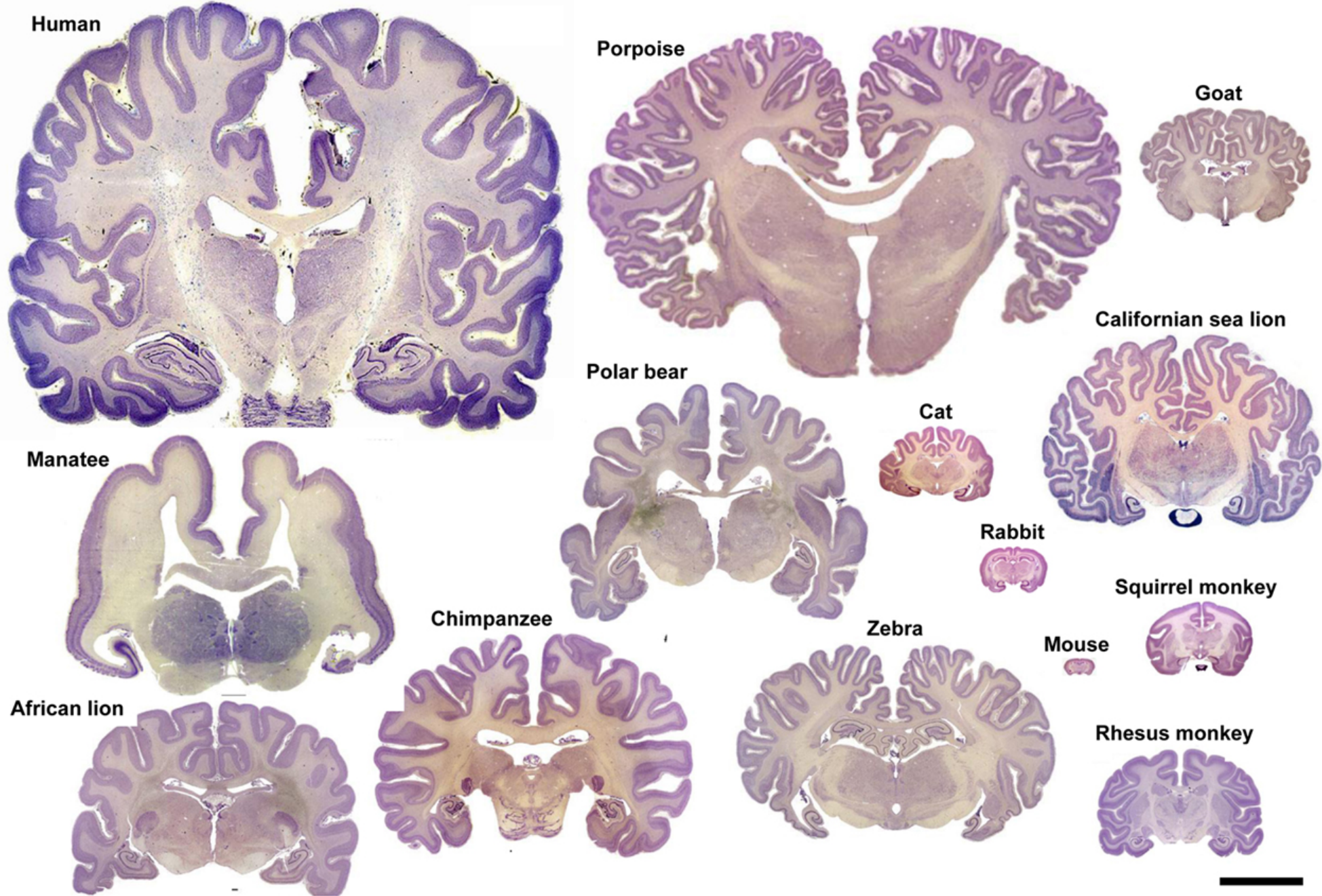


The Brain has evolved over hundreds of millions of years

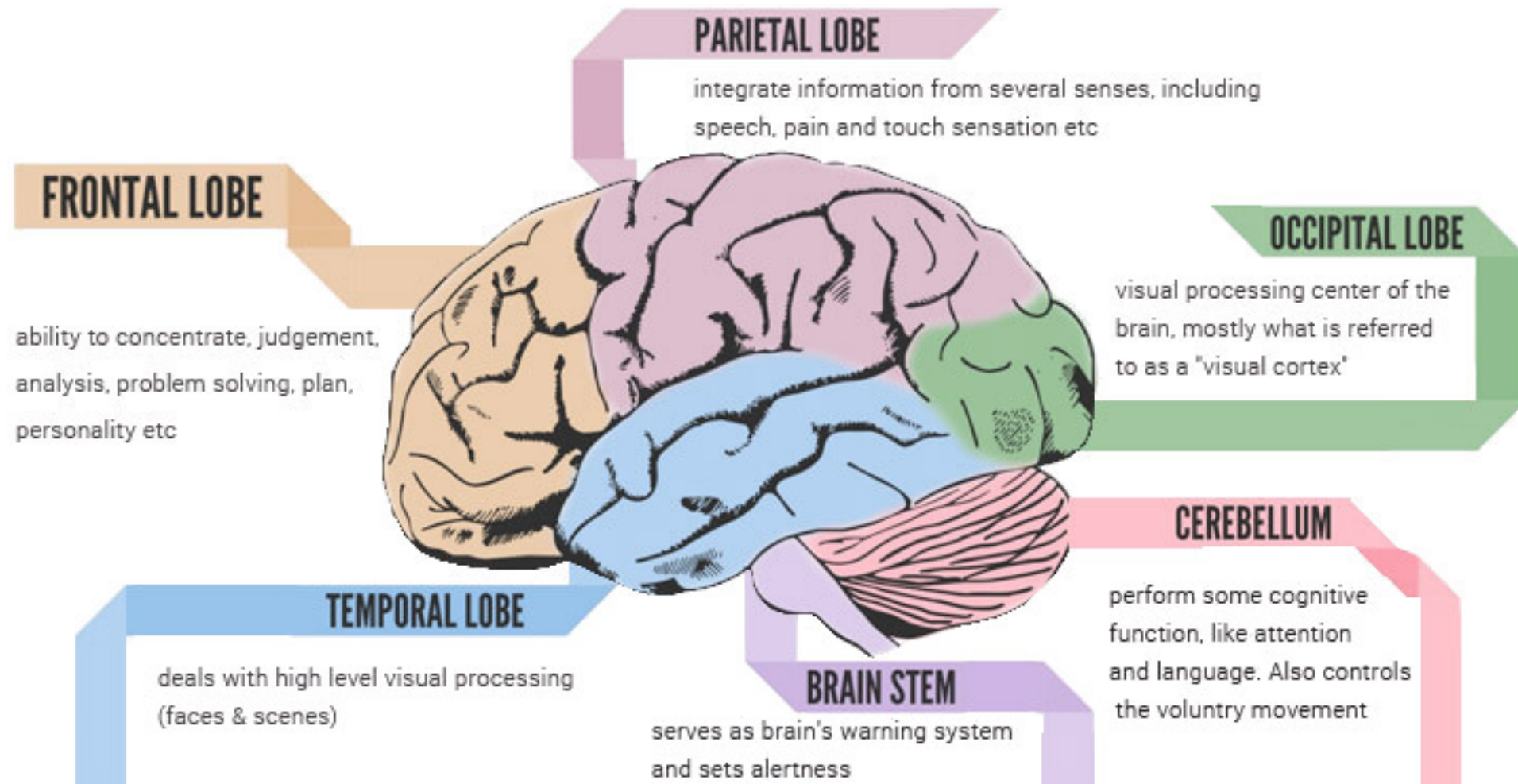
BRAIN SIZE AND NEURON COUNT

Cerebral cortex mass and neuron count for various mammals.



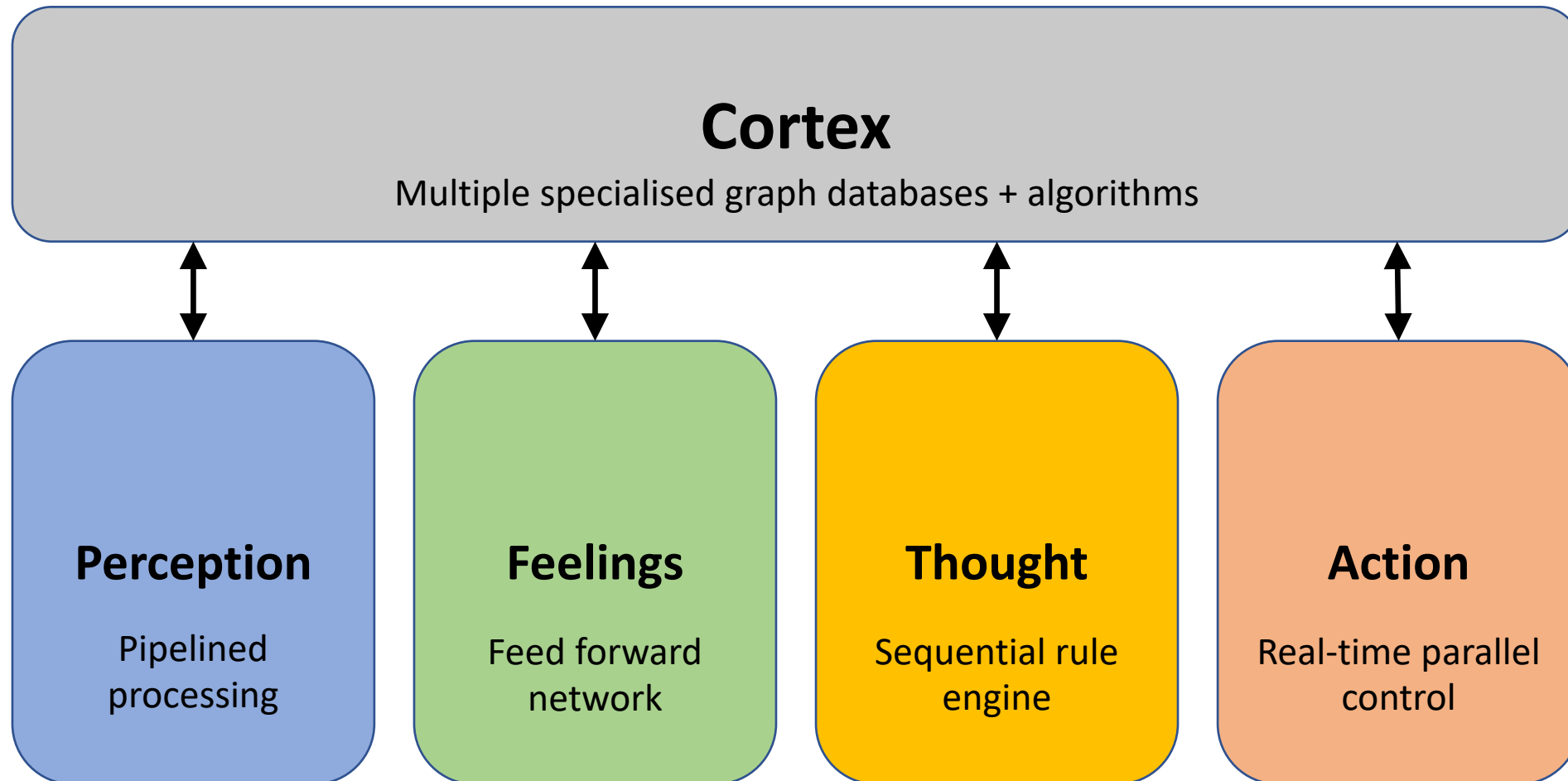


Brain function – many specialized areas



Cognitive Architecture

multiple cognitive circuits





Modelling the Cortex with Cognitive Databases

- The human cortex is functionally equivalent to a set of specialised cognitive databases and associated algorithms
- A cognitive database holds chunks: collections of properties that include references to other chunks
- Chunks are associated with statistical information reflecting prior knowledge and past experience
- Cognitive databases have the potential to store vast amounts of information similar to the human cortex
- Cognitive databases can be local or remote, and shared with multiple cognitive agents, subject to access control policies
- Memory retrieval fits Web architecture
 - Remote invocation of graph algorithms in request/response pattern rather like HTTP
 - Analogous to Web search engines where results are computed based upon what is likely to be most relevant to the user – impractical and inappropriate to try to return complete set of matches
- Cognitive databases support a variety of algorithms that are executed local to the data
 - Scalable to handling Big Data
- The algorithms depend on the intended function of the database, e.g.
 - Basic storage and recall
 - Specialised algorithms for natural language, spatial and temporal reasoning
 - Algorithms for data analytics

Sensory Perception

- Our senses
 - Smell, taste, touch, pain, heat, sound, vision, ...
 - Perception creates short lived representations in the cortex
 - The cortex can likewise direct sensory processing as needed
- Touch and pain are mapped to a homuncular model of our bodies
- Proprioception – sense of self-movement and body position
 - Limbs, joints, muscle load
 - Vestibular system (inner ear)
- Sound is fleeting
 - Processing word by word
 - Emotional cues

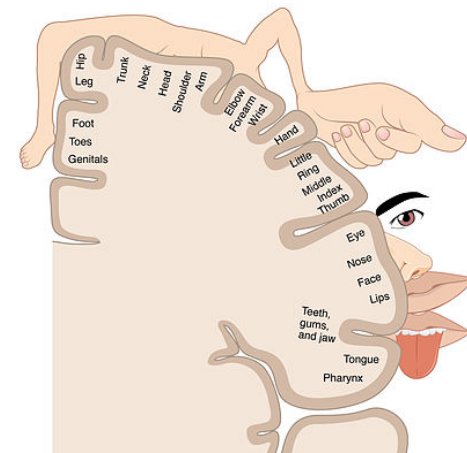
- Vision is much more complex
 - Two eyes for stereo depth perception
 - Each eye: high resolution narrow angle + low resolution wide angle
 - Saccades as eyes swivel to scan areas of interest
 - Good at recognizing many different kinds of things, including their structures & behaviours
 - Context determines what is interesting and relevant
 - Alerts signal relevant things in field of view
 - Focus directs attention to specific things
 - Reinforcement learning from experience



Visual system



Hearing



Cortical homunculus

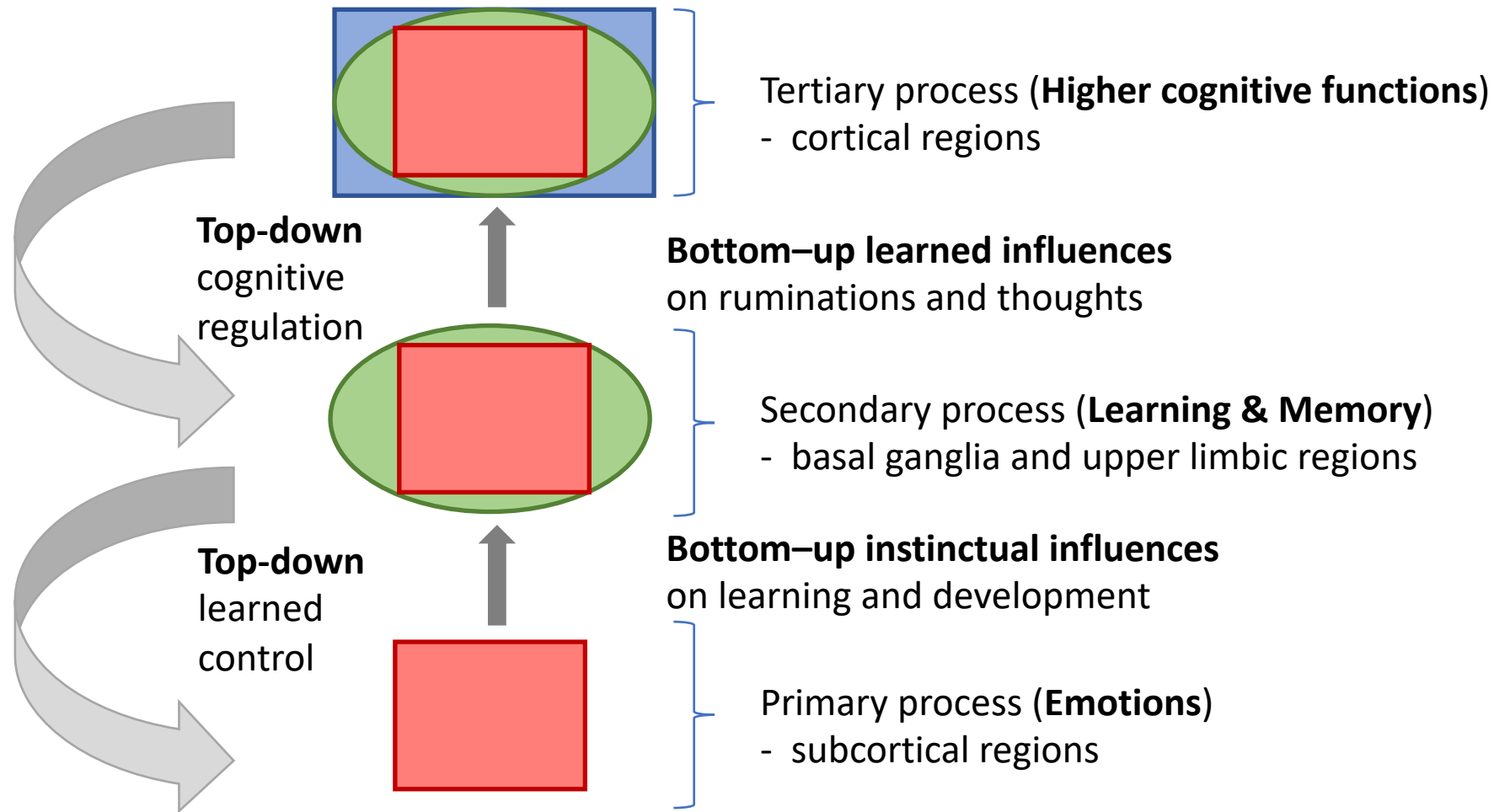
Implementation as pipelined neural networks

Feelings and Emotions



- Cortico-Limbic system
- Important from an evolutionary perspective
 - Pain: withdrawal from physical harm
 - Fear of predators, interest in prey, courtship, mating, care of eggs/offspring
 - Many species including humans live in social groups
 - Rich range of emotions related to survival benefits from being able to construct workable models of ourselves and other people
 - Emotions influence our thoughts and vice versa
 - Involved in assessment of anticipated reward/penalty for behaviours
 - Refined through experience
- Fast and instinctive vs slow and deliberate
 - Our ability to gauge the feelings of others from fleeting non-verbal cues
 - Our ability to likewise communicate our feelings to others
 - Rapid instinctive appraisal and response, avoiding the delay incurred with conscious thought, but subject to errors of judgement due to lack of thought
- Functional implementation as a feed-forward classification network

Emotions and Cognition



Nested hierarchies of circular emotional control and cognitive regulation for “bottom-up” influences and “top-down” regulations

Conscious Thought

- Cortico basal-ganglia circuit
 - The centre of conscious thought
- Symbolic (graphs) + sub-symbolic (statistics)
 - Chunk based symbolic representation of concepts and relationships
 - Statistical weights reflecting prior knowledge and past experience
- Rule engine connected to many parts of the cortex
 - Connections via buffers that hold single chunks
 - Rules represent reasoning & procedural knowledge
 - Learned from experience (hierarchical reinforcement learning)
- Sequential application of rules to cognitive buffers
 - Approximately every 50 mS
- Parallel processes for graph algorithms
 - Recall of memories
 - Selection of rules
- Autobiographical and episodic memories
- Reasoning at multiple levels of abstraction



Chunks: a collection of properties that include references to other chunks

Modules: specialised graph databases and algorithms, accessed via buffers that hold a single chunk

Rules: conditions ranging over module chunk buffers, and actions that either update the buffers or invoke graph algorithms

Action



[Courtesy of Freepik](#)

- Cortico cerebellar circuit
- Handles actions devolved to it by conscious thought
- Real-time control with parallel processing
- Cerebellum acts as flight controller managing activation of myriad sets of muscles in coordination with perceptual input from the cortex
- Offloads processing from cortico basal-ganglia circuit thereby enabling higher level thought whilst actions are underway
- Performance degrades when conscious thought diverts visual attention, starving cerebellum of visual feedback
- Learning through experience, starting with conscious thought
- Implemented as suite of real-time state machines
- Examples: talking, walking and playing the piano

W3C Cognitive AI Community Group

- Focus on demonstrating the potential of Cognitive AI
- Collaboration on defining use cases, requirements and datasets for use in demonstrators
- Work on open source implementations and scaling experiments
- Work on identifying and analysing application areas, e.g.
 - Helping non-programmers to work with data (worth \$21B by 2022 according to Forester)
 - Cognitive agents in support of customer services (worth \$5.6B by 2023)
 - Smart chatbots for personal healthcare
 - Assistants for detecting and responding to cyberattacks
 - Teaching assistants for self-paced online learning
 - Autonomous vehicles
 - Smart manufacturing
- Outreach to explain the huge opportunities for Cognitive AI
- Participation is open to all, free of charge
- See: <https://www.w3.org/community/cogai/>



Cognitive AI

giving computing a human touch