How Minds Work

Brains, Ontologies & Virtual Machines

Stan Franklin

Computer Science Division &

Institute for Intelligent Systems

The University of Memphis

Question: How do minds work?
What would an answer be like?

That depends on the level
of granularity.

Granularity in Science

Field	Subfield	Example Entities
Neuroscience	Neuroanatomy	Hippocampus, amygdale, neocortex
Neuroscience	Neural tissue	Neuropil, cortex, layer, cluster
Neuroscience	Neurons	Cell body, dendrites, axon, membrane
Biology	Cell biology	Membrane, nucleus, mitochondria, organelle
Chemistry	Organic chemistry	Alcohol, acid, amine, phosphate, amino acid
Chemistry		Elements, molecules
Physics	Nuclear physics	Atoms, protons, electrons, neutrons
Physics	Sub-atomic physics	Quarks, bosons, hadrons, leptrons

Levels of Granularity

Each level has its own

- Entities
- Relations
- Processes
- Theories

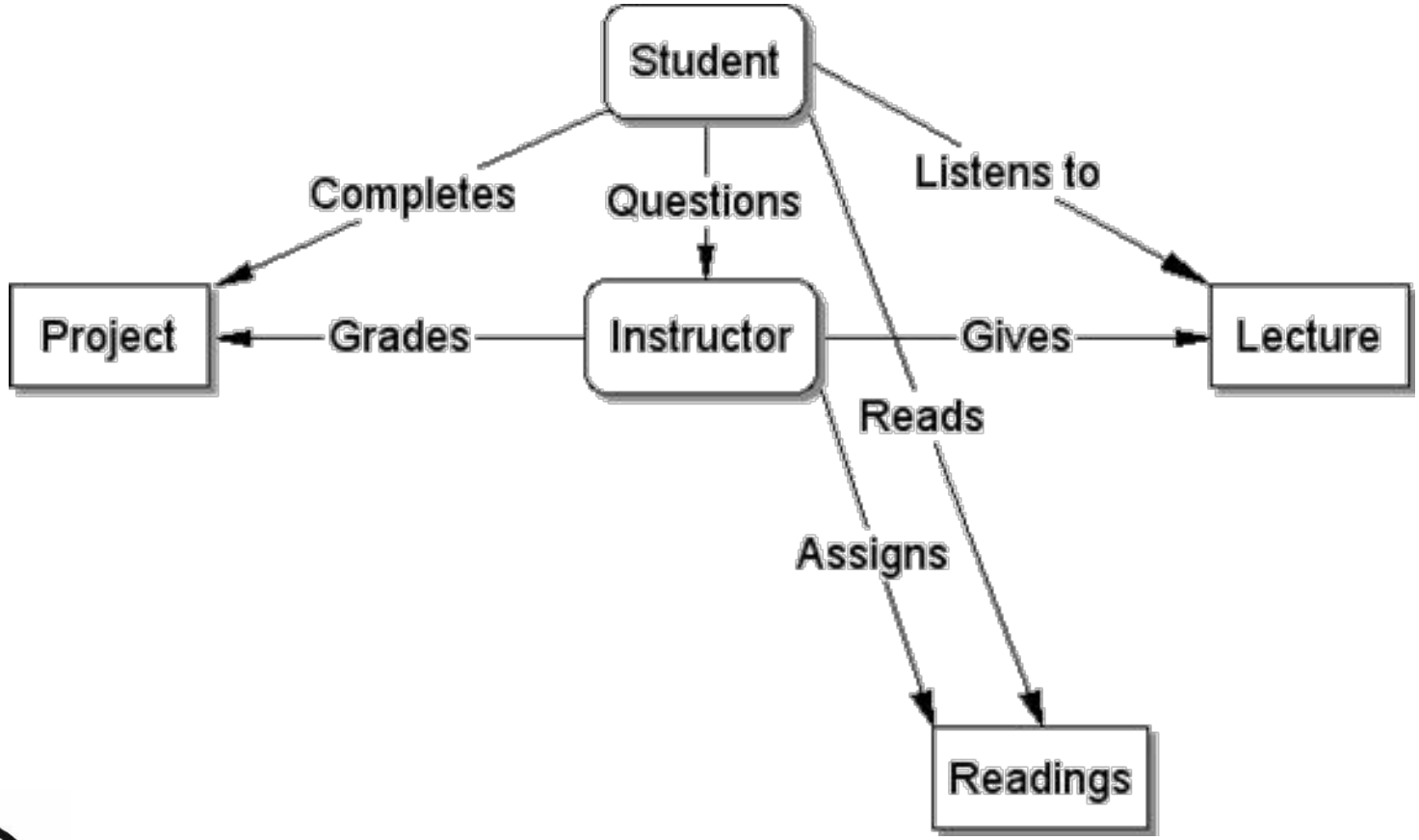
Each level

- Supports the level above it
- Needs its own theories to explain it
- Theories are in terms of its own ontology

Ontology?

- Philosophy—the study of the nature and relations of being
- Computer Science—a specification of the objects in a system and their relations
- How Minds Work—a particular collection of entities, relations, processes

A Simple Ontology



Types of Machines

- Matter manipulating machines — *diggers, drills, cranes, cookers, …*
- Energy manipulating machines — *drill, cookers, transformers, steam engines, …*
- Information manipulating machines — *thermostats, controllers, most organisms, operating systems, compilers, organizations, governments, …*

Computational Virtual Machines

Type	Virtual Machine Examples
Application program	Microsoft Word, Internet Explorer, computer games, IDA
Developmental environment	JDK, JRE, Java Gnome, IntelliJ IDEA, etc.
Operating system	Berkeley Unix, Windows XP, Mac OS X, Red Hat Linux
Microcode	Specific to each machine
Hardware	Mainframe, PDP-11, IBM-PC, Mac Powerbook, Dell, etc.

Virtual Machines

- Can be implemented on
  - Physical machines
  - Other virtual machines
- Composed of abstract entities — *words, sentences, numbers, bit-patterns, trees, procedures, rules, etc.*
- Have causal powers
- Obey internal laws, but not physical laws

Things vs Agents

- Things (*molecules, rocks, planets, etc*.) react to physical forces acting on them
- Autonomous agents (*animals, mobile robots, software agent, etc*.) initiate (goal constrained) actions
- Autonomous agents have control structures, that is, minds

Mind and Information

- Minds are control systems
- Control systems must *produce, process* and *use* information
- What's out there? (*perception*)
- What do I do about it? (*action selection*)
- How do I do it? (*procedural control*)

Minds as Virtual Machines

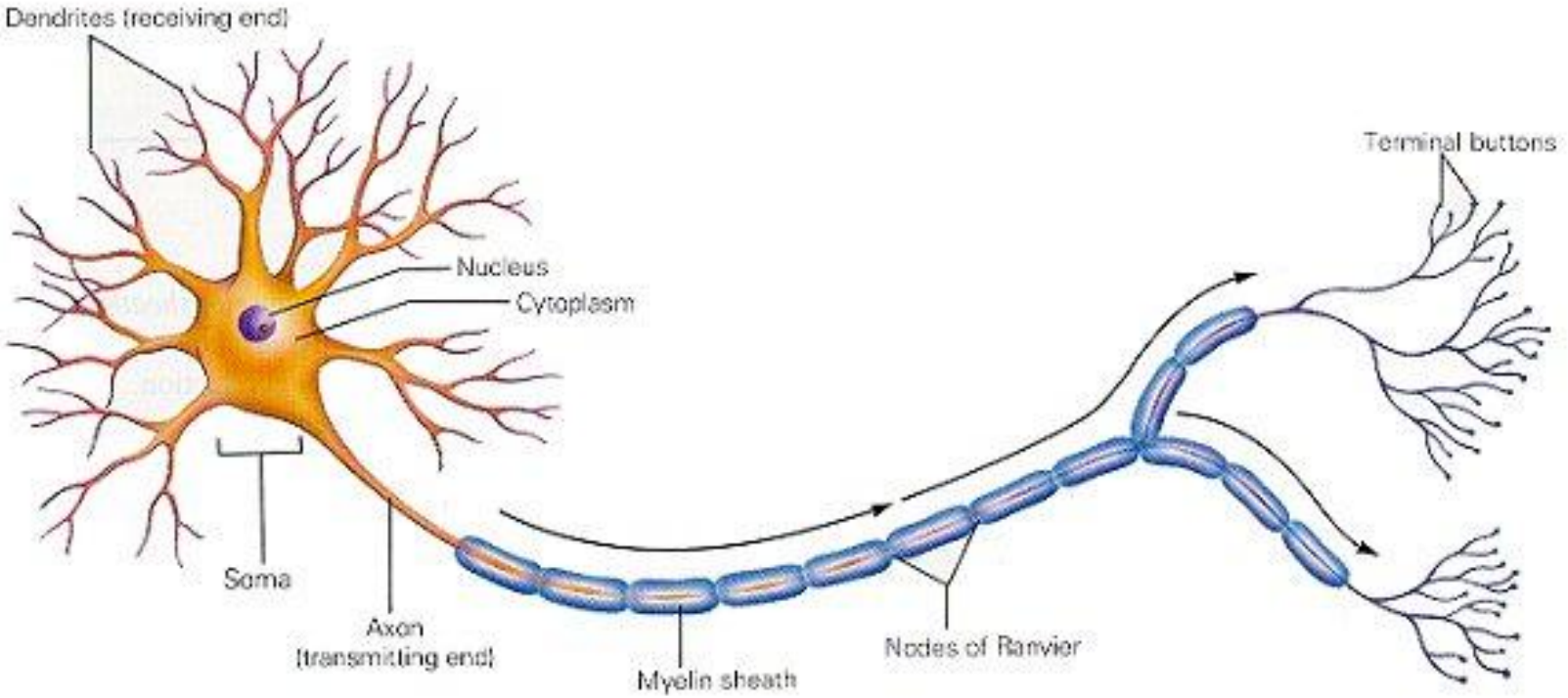
- Not every mind is a virtual machine — *a thermostat's is purely causal*
- The mind of any mobile robot or software agent is a virtual machine implemented on another virtual machine
- The minds of humans or animals are virtual machines implemented on brains

Virtual Machine on a Brain

- Entities include *qualia, objects, categories, feelings, intentions, internal images, internal speech, etc.*
- Relations include *cause, before, on top of, isa, is not, can drink from, etc.*
- Processes include *perception, memory, action selection, learning, etc.*
- Note the partial ontology just created

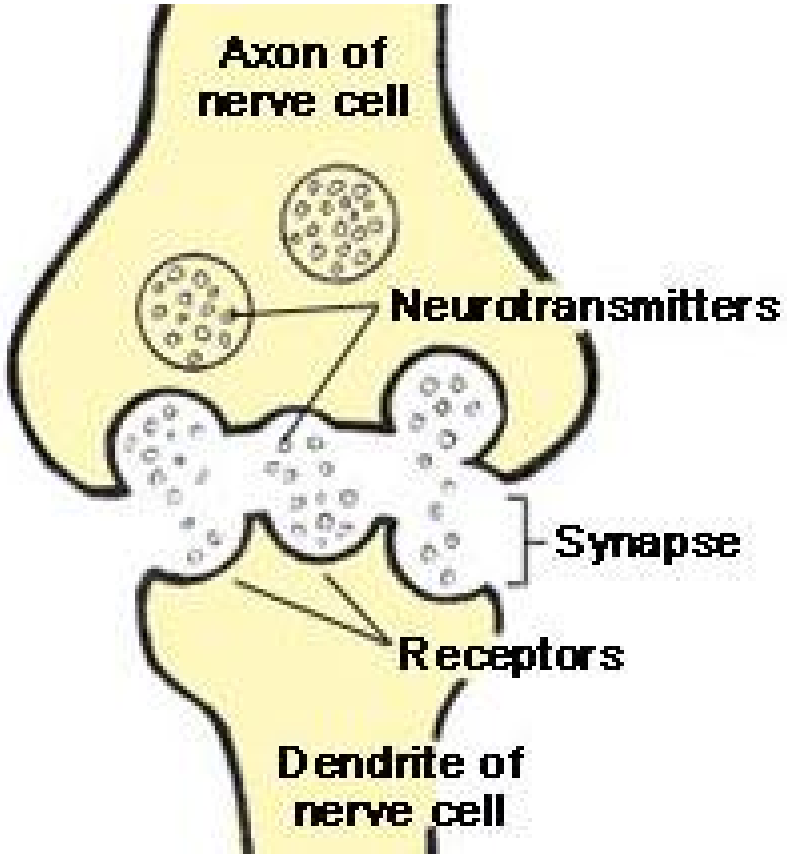
The Major Structures of the Neuron

The neuron receives nerve impulses through its dendrites. It then sends the nerve impulses through its axon to the terminal buttons where neurotransmitters are released to stimulate other neurons.



Synapses

- Pulse - chemical - wave
- Excitatory or inhibitory
- Neurotransmitter reuptake
- Signal vs modulator
- Learning via strengthening
- Decay with disuse



Neurons in Action

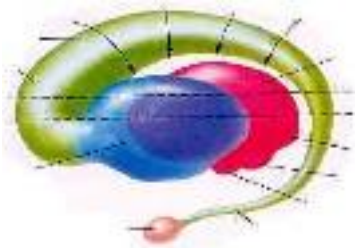
- Neurotransmitters cross synaptic clefs changing the voltage of the neuron
- Internal voltage exceeds threshold
- Triggers pulse down the axon
- Releases neurotransmitter at each synaptic clef

About Neurons

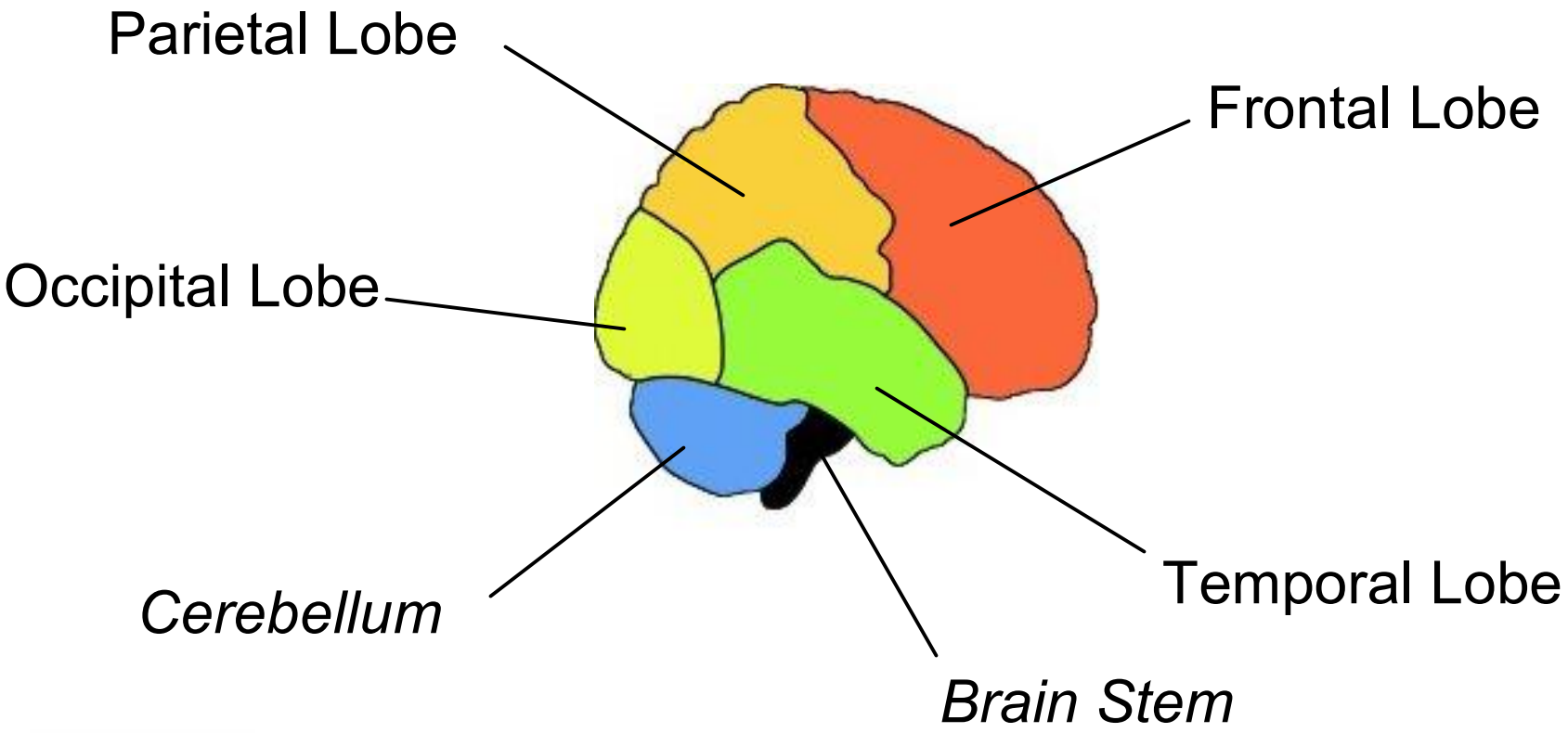
- Little used neurons tend to die
- Learning by
  - Strengthening synapses
  - Adding new synapses
  - adding new neurons
- Interneurons vs projection neurons

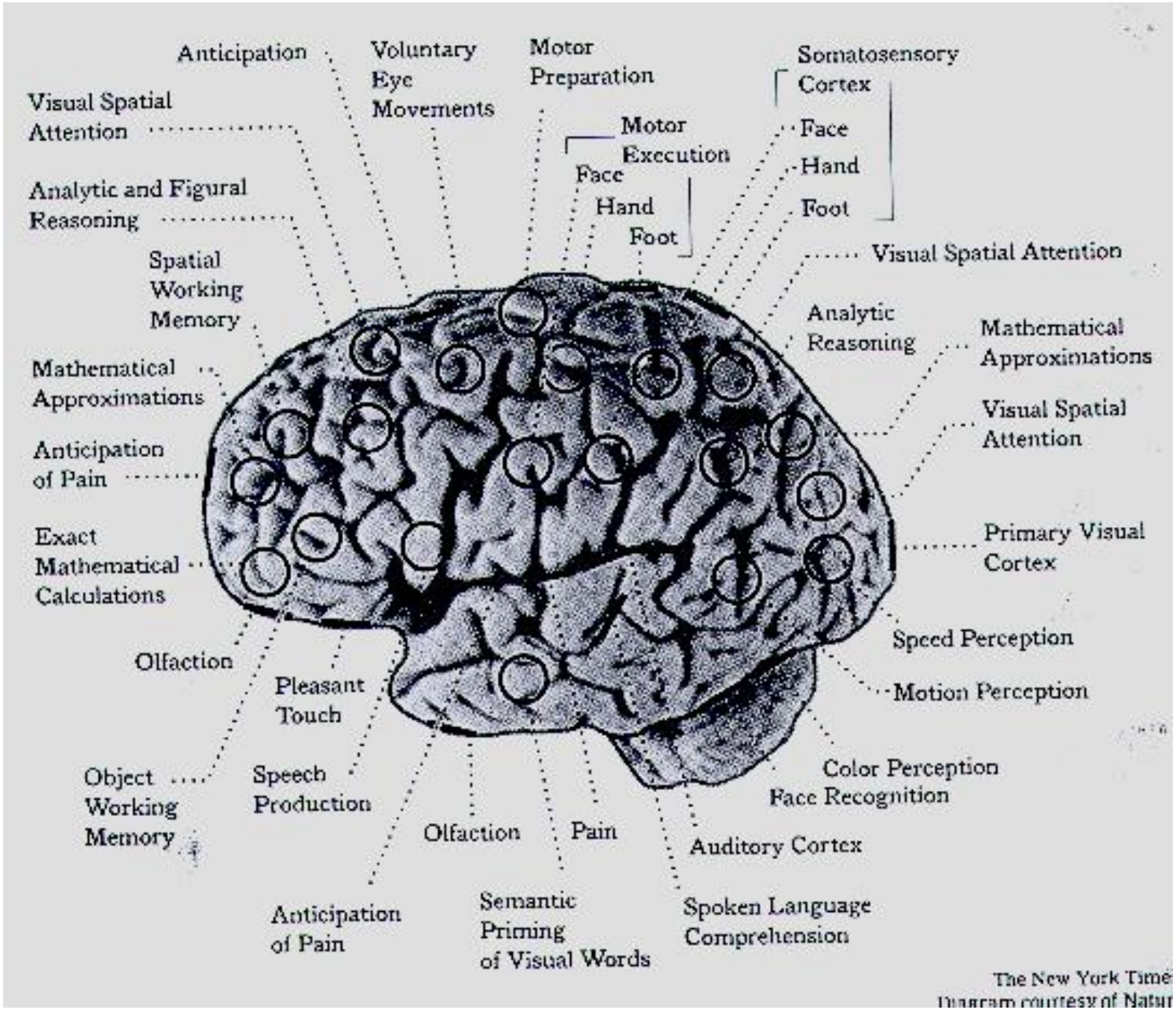
The Triune Brain

- Reptilian brain
  snakes, lizards – hunger, temperature control
- Limbic system
  cats, rats – mood, memory
- Neocortex
  primates – social, planning

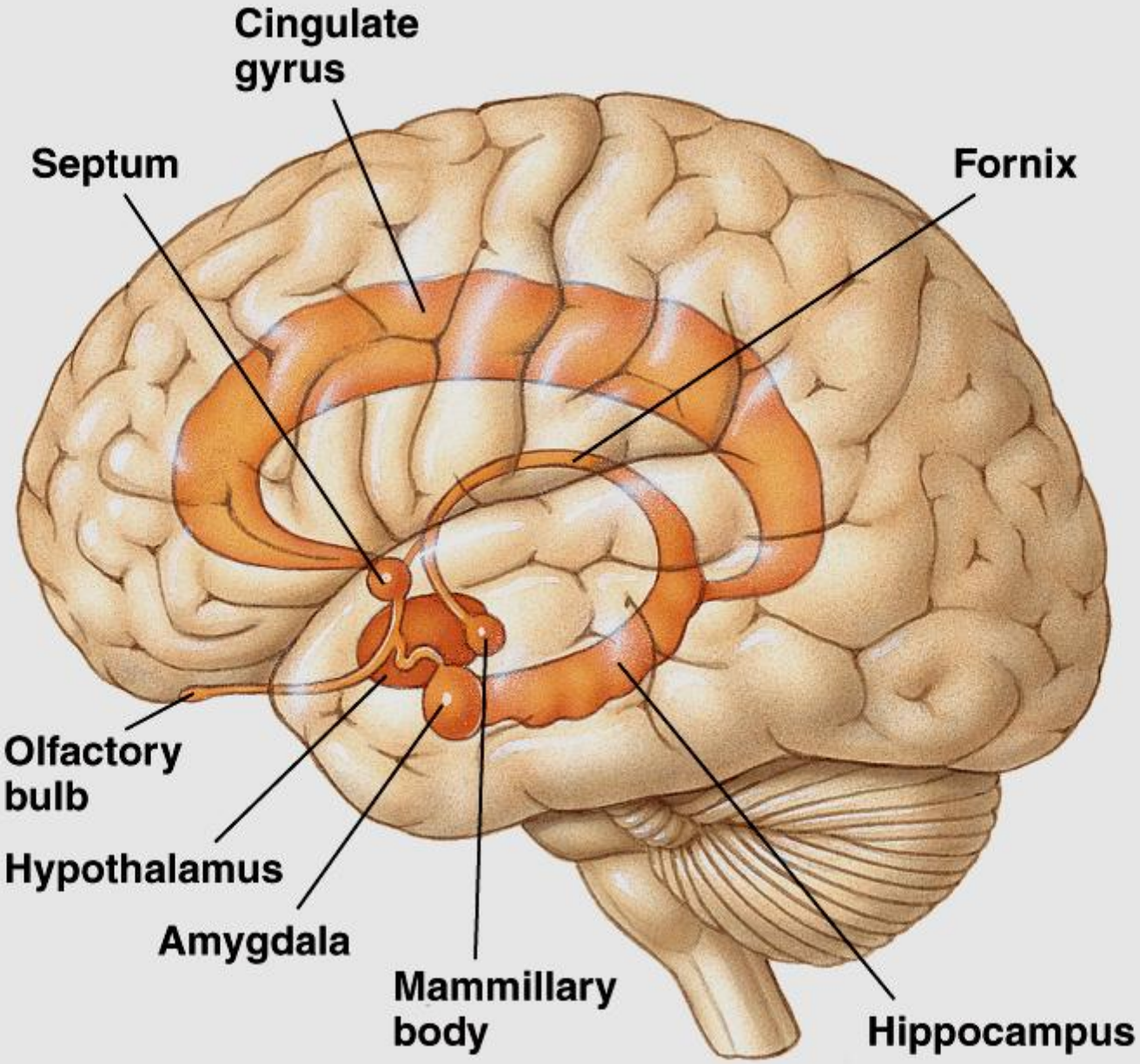


Lobes of the Human Neo-cortex




Anticipation
Voluntary Eye Movements
Motor Preparation
Somatosensory Cortex
Face
Hand
Foot
Visual Spatial Attention
Motor Execution
Face
Hand
Foot
Analytic and Figural Reasoning
Spatial Working Memory
Visual Spatial Attention
Analytic Reasoning
Mathematical Approximations
Mathematical Approximations
Visual Spatial Attention
Anticipation of Pain
Exact Mathematical Calculations
Primary Visual Cortex
Speed Perception
Olfaction
Pleasant Touch
Motion Perception
Object Working Memory
Speech Production
Color Perception
Face Recognition
Olfaction
Pain
Auditory Cortex
Anticipation of Pain
Semantic Priming of Visual Words
Spoken Language Comprehension
The New York Time
Diagram courtesy of Natur

► Location of Major Limbic System Structures



A Cognitive “Theory of Everything”

- Sensation
- Perception
- Feeling & Emotion
- Working memory
- Episodic memory
- Consciousness
- Learning
- Deliberation
- Volition
- Automization
- Action Selection
- Problem solving
- Self
- Metacognition

Assigned Readings

Sloman, A., and R. Chrisley. 2003. Virtual Machines and Consciousness. *Journal of Consciousness Studies* 10:133-172.

Your "3-Brains-in-One" Brain http://www.psycheducation.org/emotion/triune%20brain.htm (take the tour)

Email and Web Addresses

- Stan Franklin
  - franklin@memphis.edu
  - www.cs.memphis.edu/~franklin
- “Conscious” Software Research Group
  - www. csrg.memphis.edu/