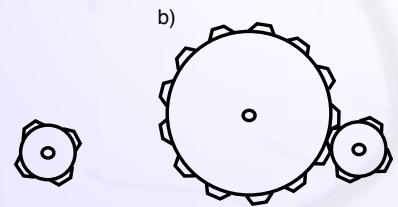
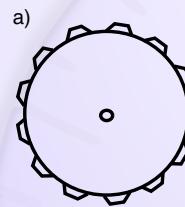


Neuroscience

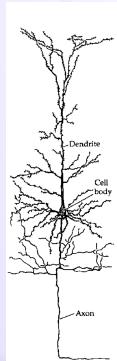
Randall C. O'Reilly

Emergence
The soul in the machine..



(Now Imagine 10,000,000,000 gears, each interacting with 10,000 others..)

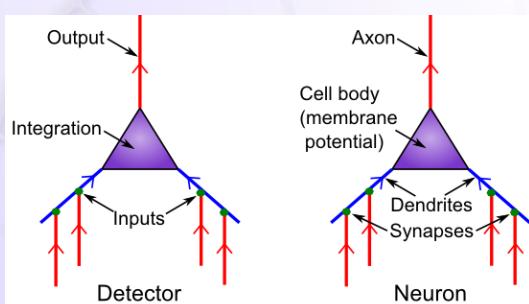
The Basic Unit of Cognition!?



Neurons are *Detectors*

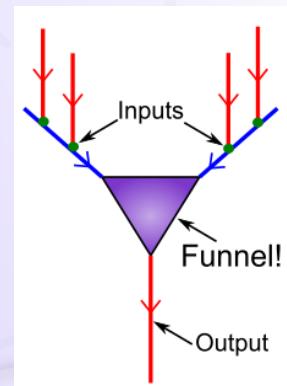


Detector Model



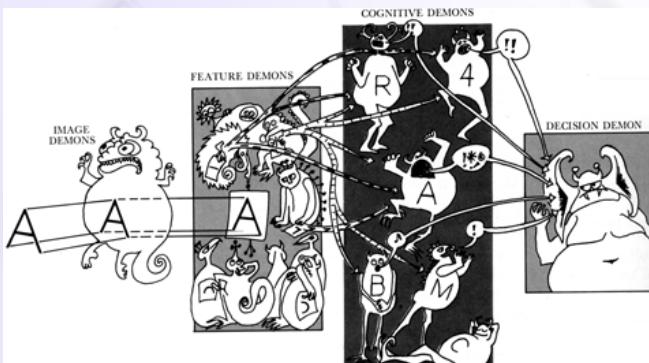
Is it really all just detection?

Neurons Compress 10,000 → 1



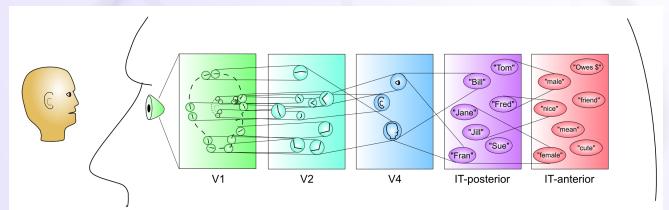
Pandemonium!

(Oliver Selfridge)



Hierarchy of Detectors

(Compression: abstract, simplify)

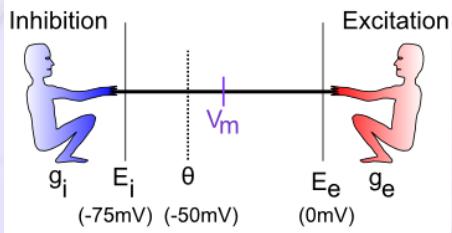


Inferior Temporal (IT) cortex has high-level abstractions that are *relevant* to your life!

It takes a village of neurons to build up these abstractions.

8

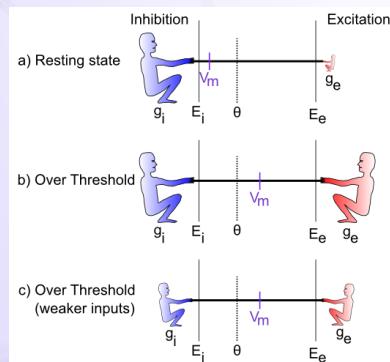
The Tug-of-War



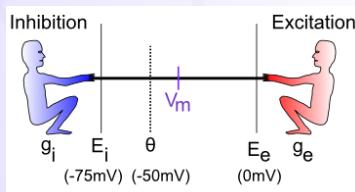
How strongly each guy pulls: $I = g(E - V_m) = \text{current}$
 $g = \text{how many input channels are open}$
 $E = \text{driving potential (pull down for inhibition, up for excitation)}$
 $V_m = \text{the "flag" -- reflects net balance between two sides}$

The Tug-of-War

(Contrast: Excitation *relative* to Inhibition)



Equations (just for fun)!

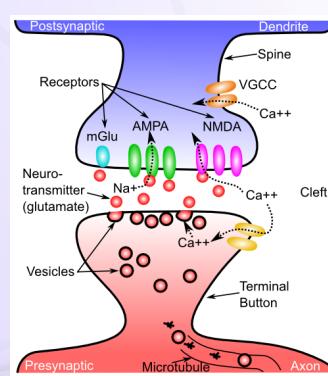


$$I_{net} = I_e + I_i + I_l = g_e(E_e - V_m) + g_i(E_i - V_m) + g_l(E_l - V_m)$$

$$V_m(t) = V_m(t-1) + dt_{vm} I_{net}$$

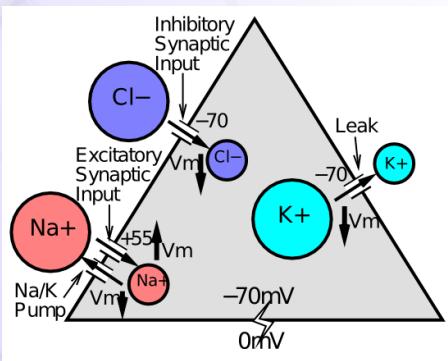
$$V_m(t) = V_m(t-1) + dt_{vm} [g_e(E_e - V_m) + g_i(E_i - V_m) + g_l(E_l - V_m)]$$

The Synapse

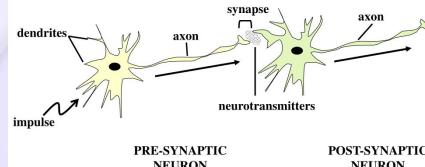


12

The Full Story..



Neuron Summary

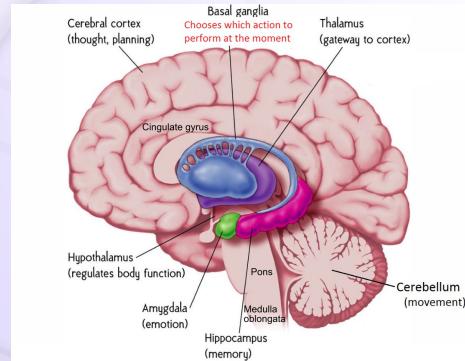


- Neurons integrate electrical signals (**depolarization**) received via **synapses** on their **dendrites**, from **axons** of other neurons
- When membrane potential exceeds **threshold, action potential** (spike) is sent down axon, triggering release of **neurotransmitter** in synapse, which opens **ion channels** on receiving (**postsynaptic**) neuron (goto start)
- **GABA** = inhibitory, Cl⁻, **Glutamate** = excitatory, Na⁺
- In Neocortex, a neuron either releases GABA or Glu, *not both!*

Neurotransmitter Terms

- **Agonist:** acts like a given neurotransmitter
- **Antagonist:** blocks receptors for given NT
- **Reuptake:** takes NT back out of synapse
- **Neuromodulator:** a broadly-released neurotransmitter that has widespread modulatory effects on the brain

Gross Anatomy



16

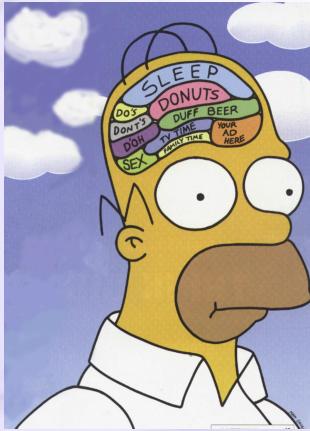
We are Corticocentric..

- **Cerebral Cortex** (Neocortex) is where most of the good stuff happens: cognition, intelligence, knowledge, memory, *consciousness*, ...
- **Hippocampus** (archicortex), **Amygdala**, **Basal Ganglia**, **Thalamus** all interact extensively with neocortex, form tightly integrated subsystems (Limbic system is not super useful construct).
- Lots of more specialized brain areas in subcortex, but seriously, who cares.. ☺

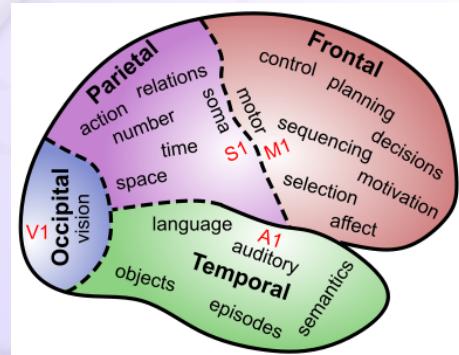
Summary of Brain Area Functions

- **Neocortex:** perception, thought, action.. Everything!
- **Thalamus:** sensory relay, arousal, attention..
- **Basal ganglia:** decision making, control, dopamine
- **Amygdala:** emotion
- **Hippocampus:** episodic memory
- **Cerebellum / pons:** error-driven motor learning
- **Hypothalamus:** core body functions (eating etc), stress, hormones
- **Medulla oblongata:** more core functions (breathing)

Functional Specialization

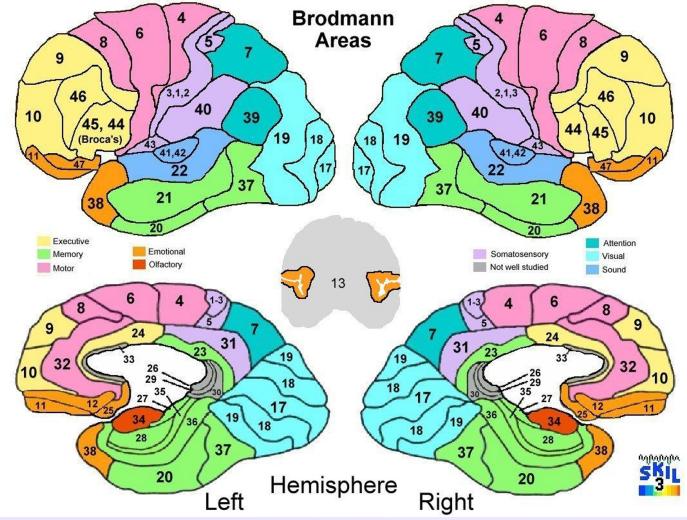
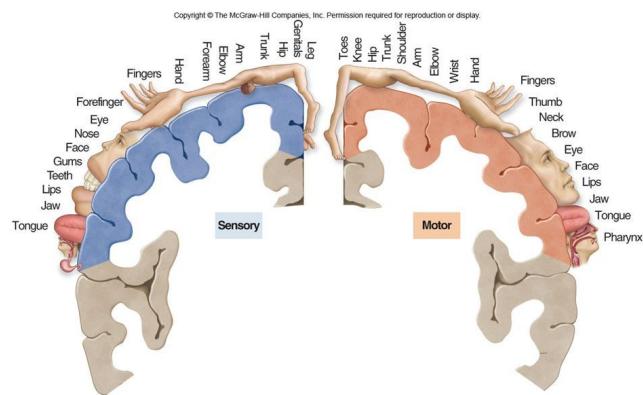


Lobular Functions: Follow the trail..

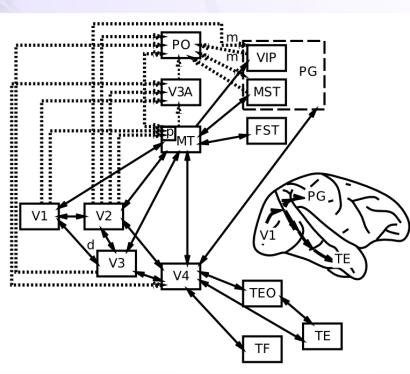


20

Sensory/Motor Homunculus

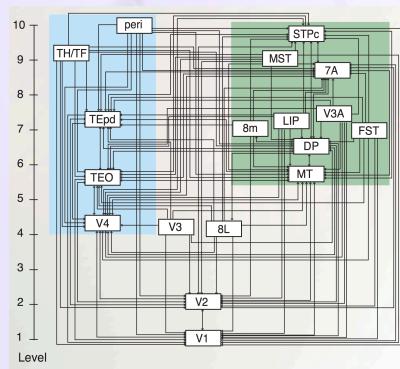


Visual Hierarchy: What vs Where



23

“Van Essen” Hierarchy



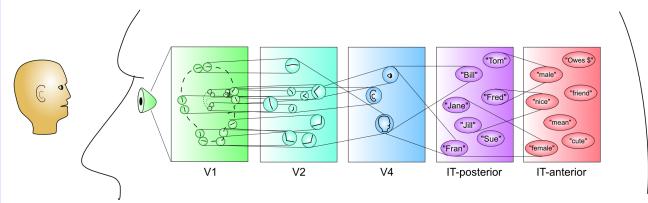
TE.. = Temporal
LIP, DP.. = Parietal
8L = Frontal Eye Field

To hippocampus:
TH/F = Parahippo
peri = Perirhinal

Markov et al., 2014

24

Hierarchy of Detectors (CCC = Compression: abstract, simplify)



Inferior Temporal (IT) cortex has high-level abstractions that are *relevant* to your life!

It takes a village of neurons to build up these abstractions.

25

Cortical Organization Summary

- **Occipital Lobe:** vision
- **Temporal Lobe:** object & face recognition, audition, speech, language, semantics
- **Parietal Lobe:** space, number, action, somatosensory
- **Frontal Lobe:** (motor) **Control** (executive), emotion, motivation
- **Left / right:** not too popular in science now..

Rest of Brain

- **Hippocampus** (archicortex – old cortex): episodic memories (events, facts, this lecture..)
- **Amygdala:** emotions (reward, fear, etc): major controller of dopamine
- **Basal Ganglia:** motor / cognitive initiation based on what has worked in the past (dopamine)
- **Thalamus:** mini-me to cortex, interacts with BG
- **Cerebellum:** tunes up fine motor control

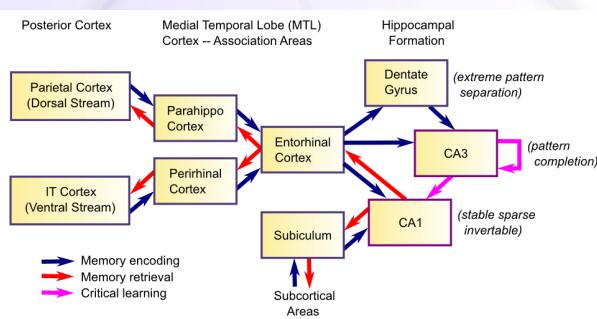
Learning Rules Across the Brain

Area	Learning Signal		
	Reward	Error	Self Org
Primitive Basal Ganglia	+++	--	--
Cerebellum	--	+++	--
Advanced Hippocampus	+	+	+++
Neocortex	++	+++	++

Legend:
+ = has to some extent ... +++ = defining characteristic – definitely has
- = not likely to have ... -- = definitely does not have

28

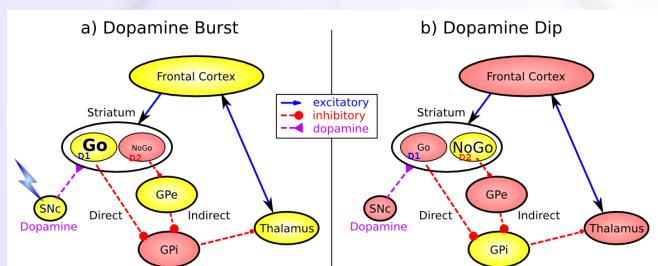
Memory and the Hippocampus



Memory is based on highly Compressed (CCC) summary of cortex – we don't remember actual details very well!

29

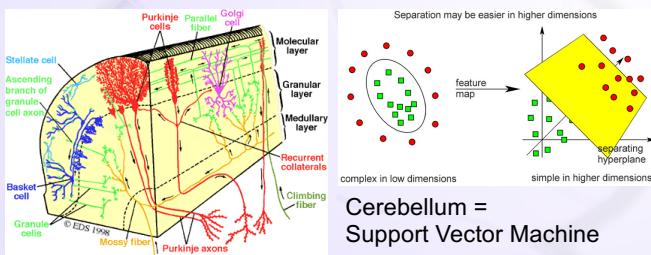
Basal Ganglia: Motor Initiation



Dopamine shapes selection of most rewarding (least punishing) action plan

30

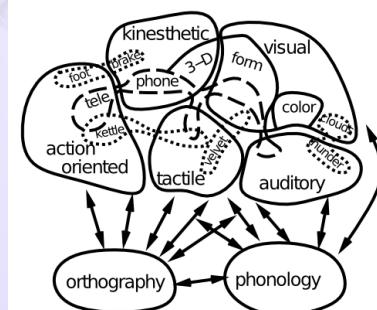
Cerebellar Error-driven Learning



- Granule cells = high-dimensional encoding (separation)
- Purkinje/Olive = delta-rule error-driven learning
- Classic ideas from Marr (1969) & Albus (1971)

31

Language = Whole Brain!



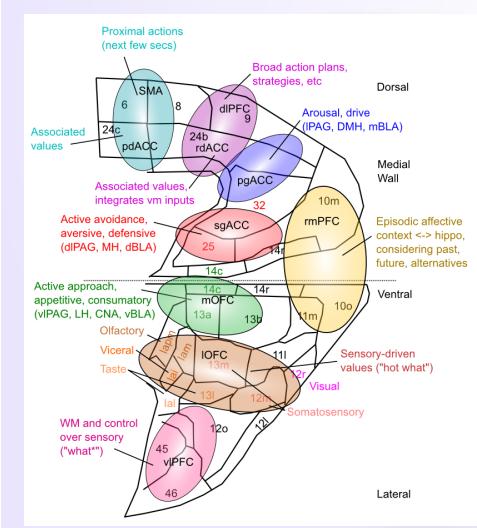
Language and higher-level cognition builds on already-learned sensory / motor pathways

32

Frontal Executive: Top-Down Biasing CCC = Control!



PFC active maintenance provides top-down biasing of posterior-cortical processing



Medial Frontal Map of Values

This is your emotional life

34

Brain imaging

