Networks of Neurons

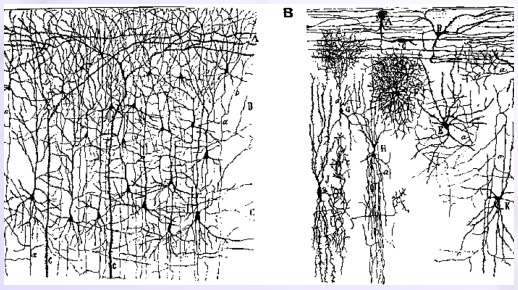
Computational Cognitive Neuroscience

Randall O'Reilly

Networks

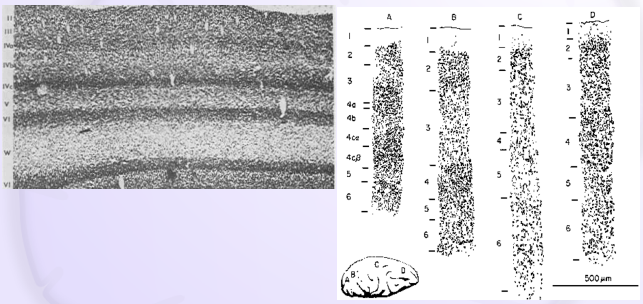
- Biology of Neocortex ("cortex")
- Categorization and Distributed Reps
- Bidirectional Excitation and Attractors
- Inhibitory Competition and Activity Regulation

Neurons: Excitatory and Inhibitory

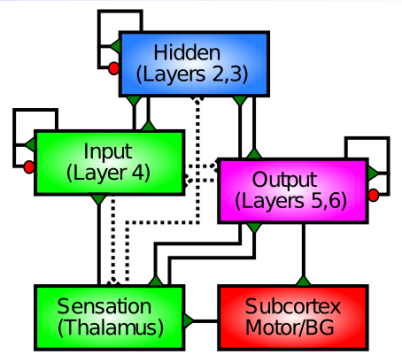


Excitatory = main info processing, long-range connections
Inhibitory = local, activity regulation and competition

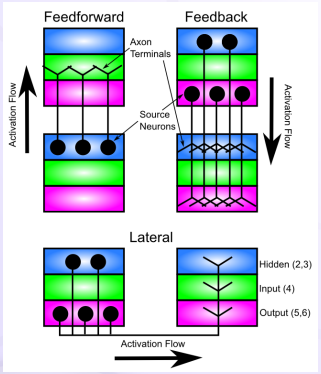
The 6 Layer Cake..



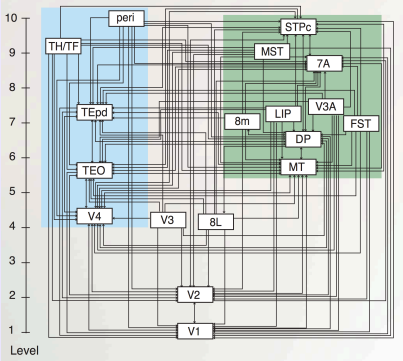
Is Actually Only 3..



Patterns of Connectivity



“Van Essen” Hierarchy



TE.. = Temporal

LIP, DP.. = Parietal

8L = Frontal Eye Field

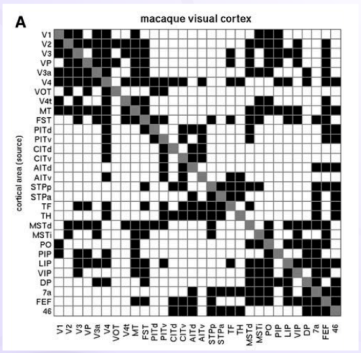
To hippocampus:

TH/F = Parahippo

peri = Perirhinal

Markov et al., 2014

Bidirectional Symmetry



Biology => Function

- Feedforward excitation => categorization
- Feedback excitation => attractor dynamics
- Lateral inhibition => competition, regulation

Detectors naturally perform *categorization*

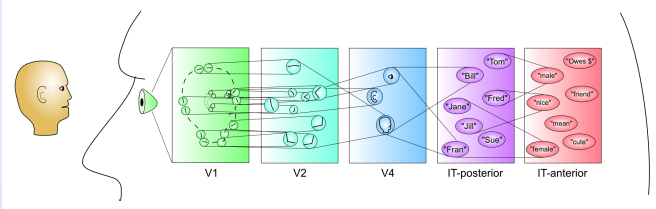
Categorizing things properly is at least 80% of the solution to any problem:

- Object recognition
- Spoken word recognition
- Idiom recognition
- Relationship recognition
- Person recognition
- Action recognition
- ….

We Think in Categories

(much easier than disconnected pixels..)

Hierarchy of Categories



The Chair Category

Getting the right ones is key..

- Two men are dead in a cabin in the woods. What happened??

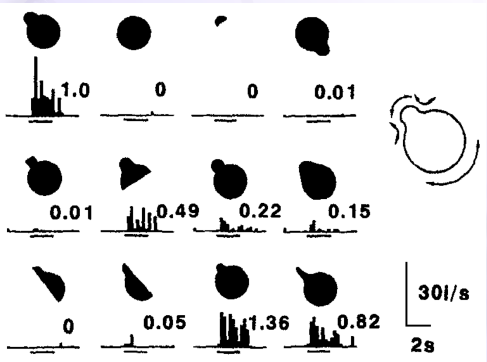
Categories are Interesting!

- What makes a mental categorization accurate? Is there something “real” about a “chair?”
- Stereotypes are mental categories..
- Can you encode multiple categories at the same time??

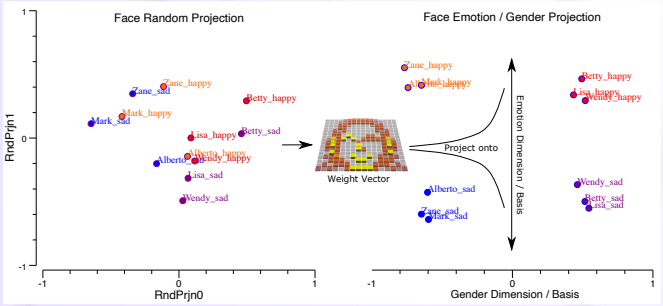
Distributed Representations

- Let a 1,000 categories bloom.. You’ve got the room in your head (billions of neurons)
- Each neuron can respond to multiple things (graded similarity)
- And each thing activates many neurons (who knows what is going to be relevant this time?)

Graded Responses



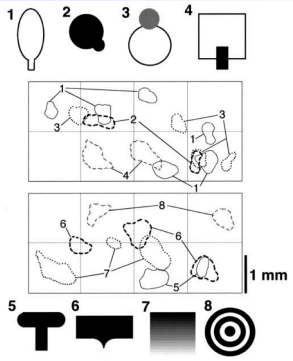
Detection = Dimension



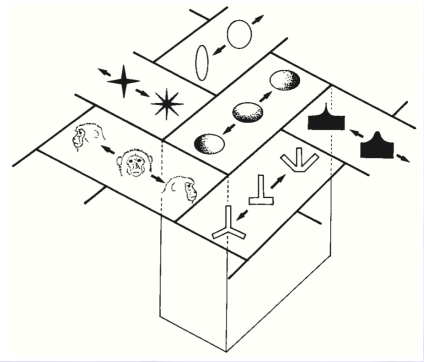
Detection = extracting relevant dimension from input: emotion detector, gender detector

face_categ example from Chapter 3

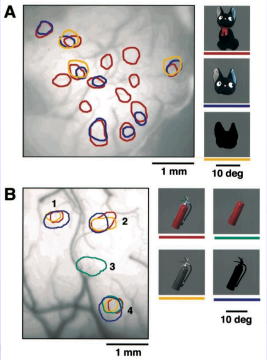
Distributed Patterns



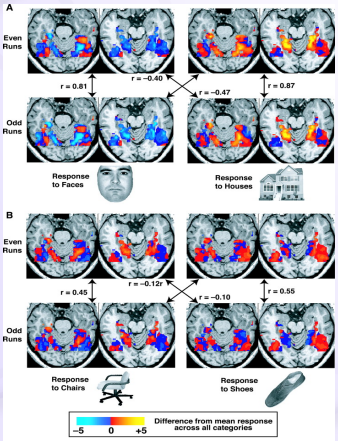
Topographic Organization



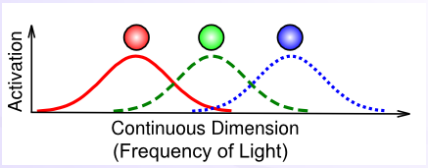
Distributed Parts



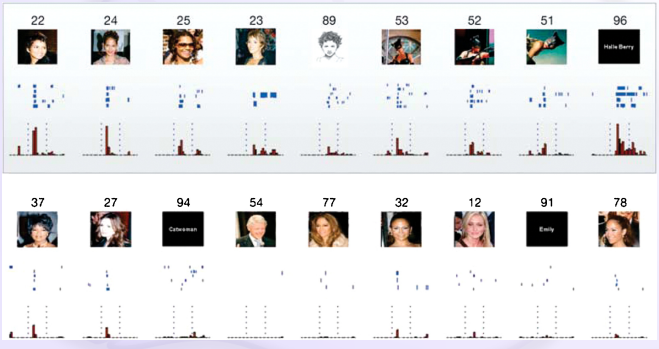
Not Just Monkeys



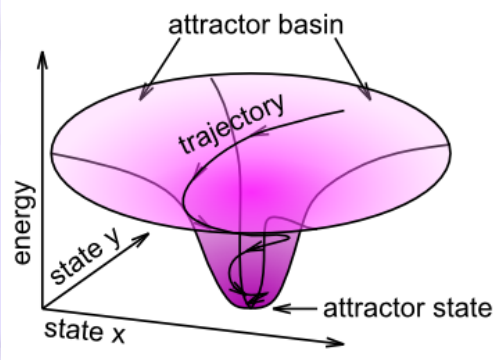
Coarse Coding Efficiency



Localist Representations?

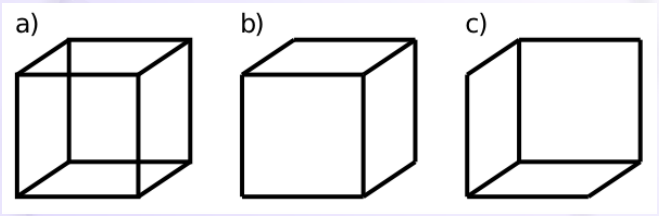


Bidirectional Excitatory Dynamics

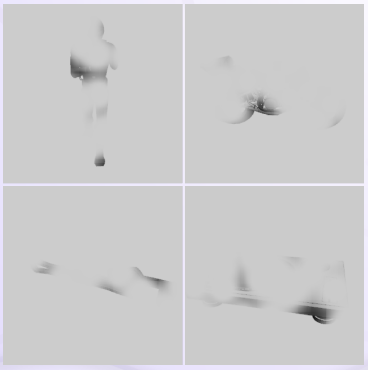


Top-down Ambiguity Resolution

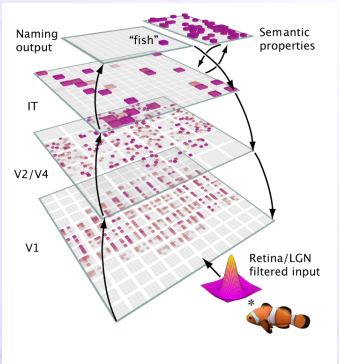
Behold, the cube!



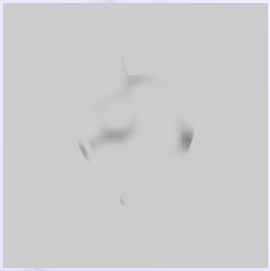
What Are These?

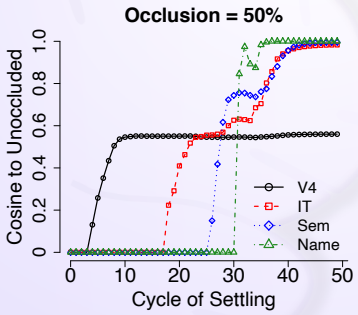


A Big Network Model..



Bidirectional Dynamics





You say *Energy*, I say *Harmony*!

Potato, potato; tomato, tomato… two different ways of saying the same thing:

$$E = -\frac{1}{2}\sum_j \sum_i x_i w_{ij} y_j$$

$$H = \frac{1}{2}\sum_j \sum_i x_i w_{ij} y_j$$

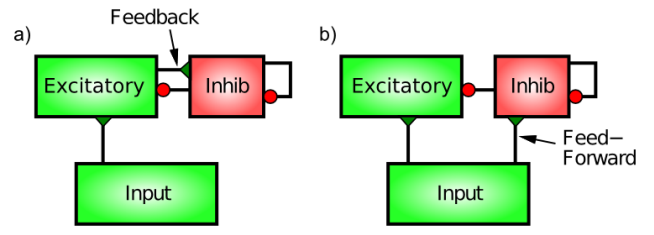
Key is that either shows that Ge (dot prod) improves overall state:

$$\frac{\partial H}{\partial y_j} = \sum_i x_i w_{ij}$$

Inhibition

- Competition: selection pressure, survival of the "fittest", picking the best detector for the job..
- Interacts with learning: "rich get richer" (but also narrower – no hogging the inputs please!)
- "Sparse distributed representations"
- (and also essential for controlling activity, like an air conditioner)

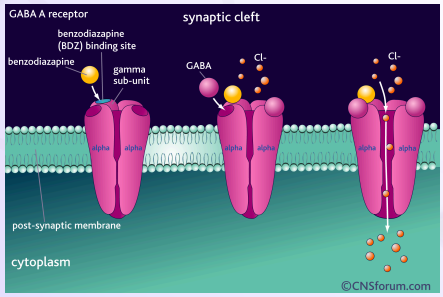
Feedforward and Feedback Inhib



- Feedback "**reacts**" (AC comes on after it gets hot enough)
- Feedforward "**anticipates**" (e.g., if AC measured outdoor temp, or weather forecast)

Benzo, Valium, Xanax, etc

Agonists for GABA inhibitory channels



Muscimol widely used in neuro studies to turn off brain areas
Midazolam used in anesthesia
Bicuculline = GABA *antagonist* removes inhibition (not safe in whole brains!)

kWTA Approximation