Intelligent Control and Cognitive Systems

Perception and Memory in Cognitive Systems

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About the Course(work)

- Course was designed as MSc level.
- One of its deliverables is engaging you with research (both reading & writing.)
  - Informed public, citizen science.
  - Exam a concession to final-year dissertations.
- …so, a bit about research (& coursework.)

Time Management and Degree Outcomes

- Most of you are writing dissertations.
- 100 hours/course / 10 weeks/course ⇒ (10 hours/week
- - 3 hours/week lectures) * 3 week/ coursework ⇒ 21 hours/coursework.

6 hours in lab; robots longest.

~5 writing up ⇒ 16 hours to hack and read!

Doing Research

- First you need to get your hands dirty.
  - Learn about the problem domain.
  - Check to see whether you have an approach that might work.
- Publishable projects are normally preceded by pilot projects.

What's Worth Doing?

- By third week, you should run with something you have.
- Normally – look at literature for controversies you might take a side on. Test which side is right.
  - Google Scholar – who cited a paper you're interested in, and why?

Writing Up Research

- Any paper can have only one point.
  - Point is in the Intro & Conclusion. Results prove the conclusion; Approach & Discussion explain the Results.
- Pick a point / claim you think will be most promising to talk about, then examine it in detail..

Which Point?

- What surprised you? What did you need to learn to get your robot working?
- Is there something your robot does better than the others? Could you teach others to do it?
- Look for “tricks” / lessons learned; think about the Brooks contribution.

Intelligent Control
and Cognitive Systems

brings you...

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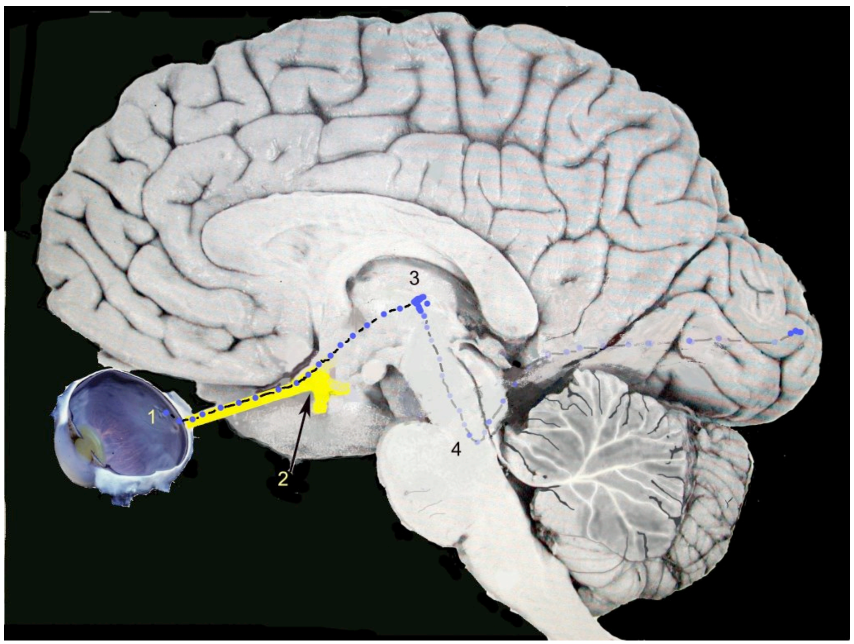
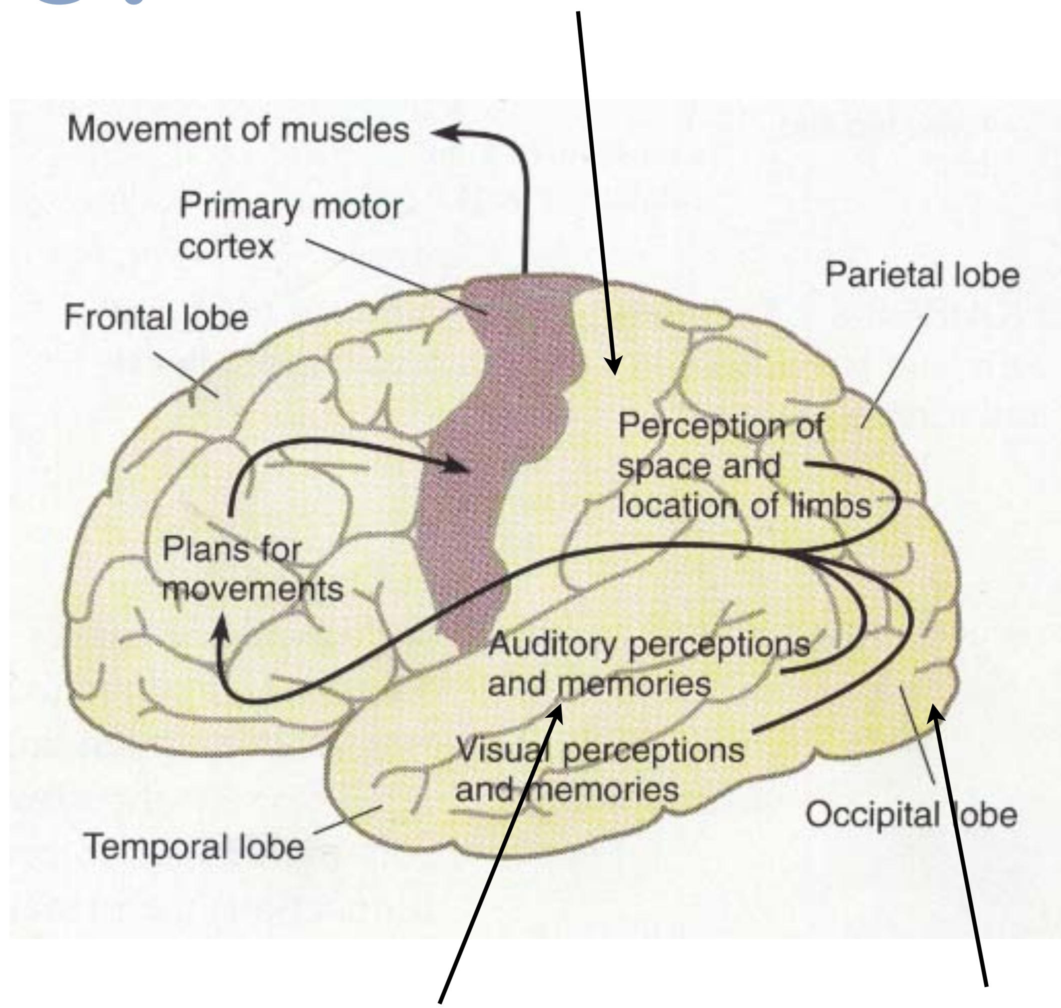
Sensing vs Perception

- First weeks: Sensing – what information comes in.
- This week: Perception – what you think is going on.
  - Perception includes expectations.
  - Necessary for disambiguating noisy and impoverished sensory information.

What Would Nature Do?

Touch input

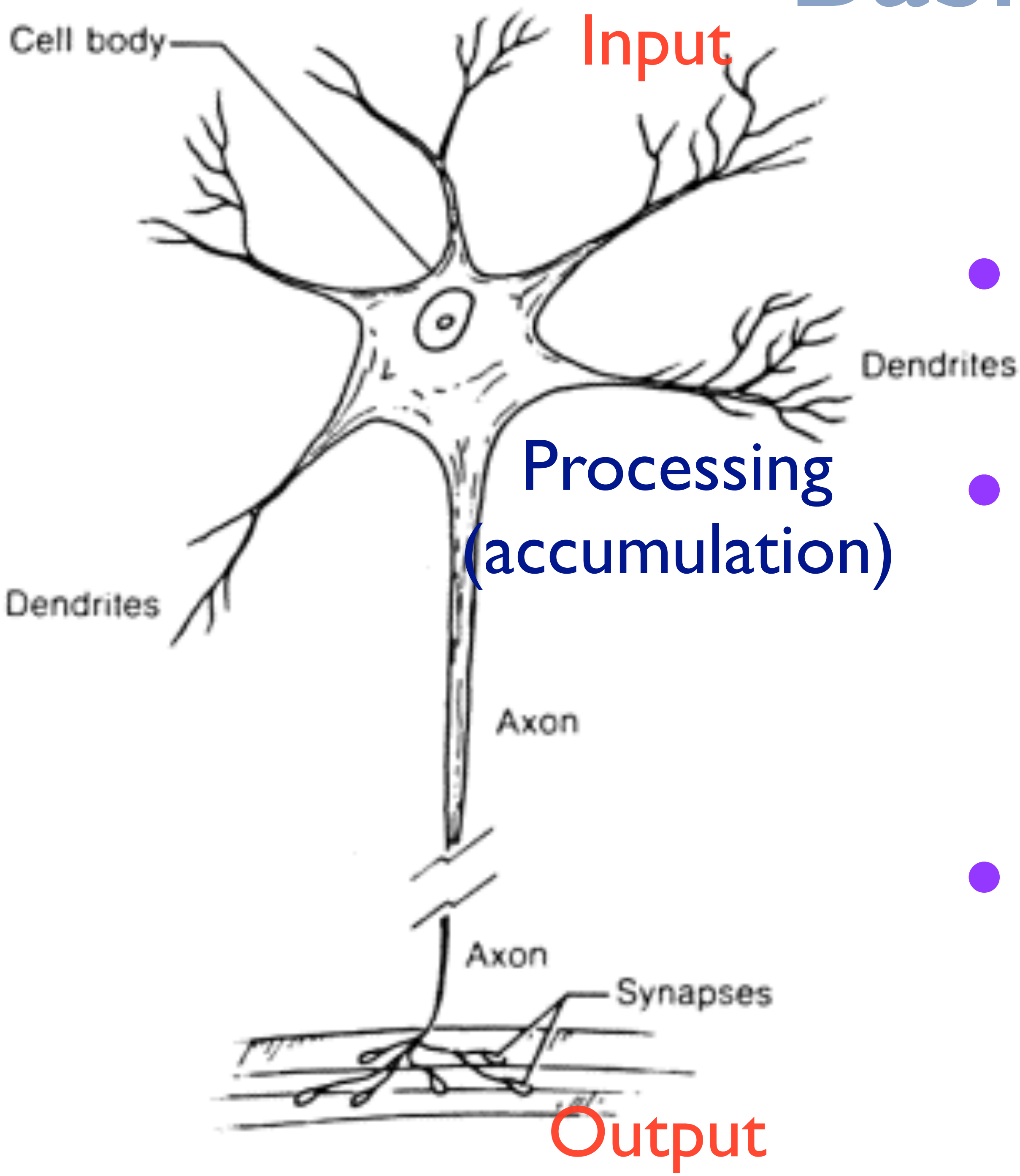




Ear input

Eye input

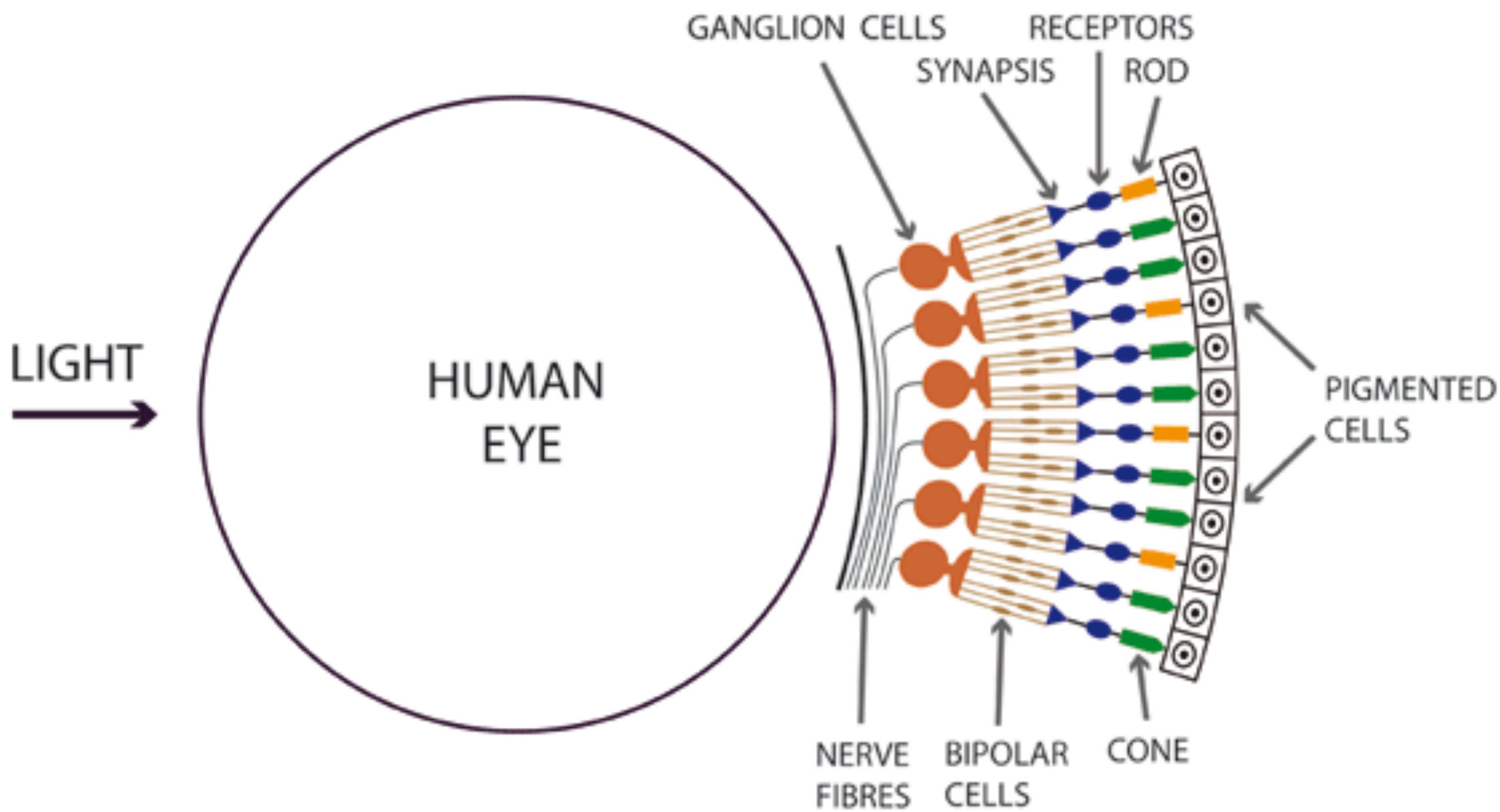
Basic Natural CPU



- Actually whole thing computes & senses.
- Signal takes time to propagate, one cell may get two messages from same axon.
- Many different types & configurations of nerve cells.

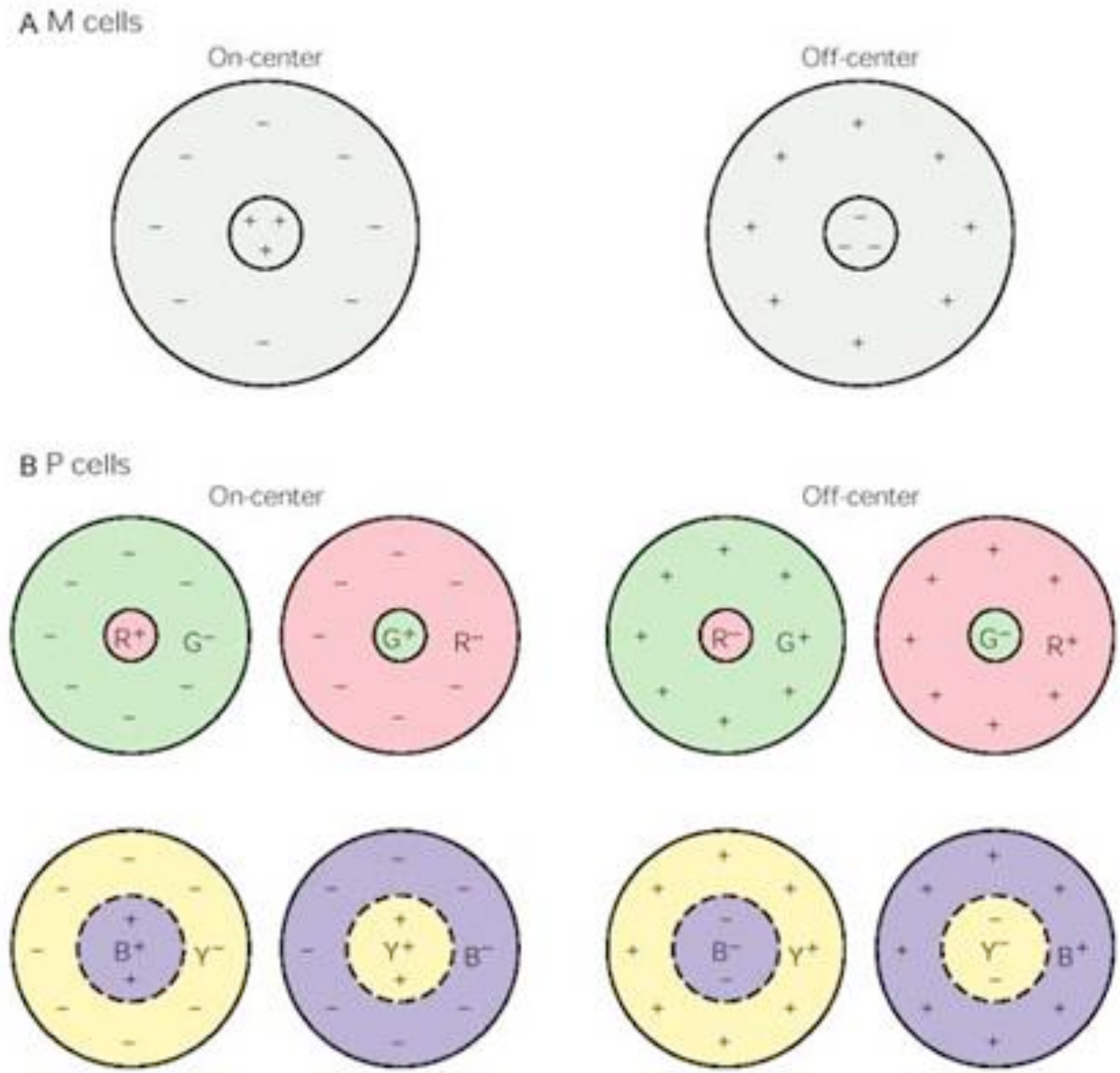
How Eyes Work

Basic Cross section of the Eye - Showing the Rods and Cones



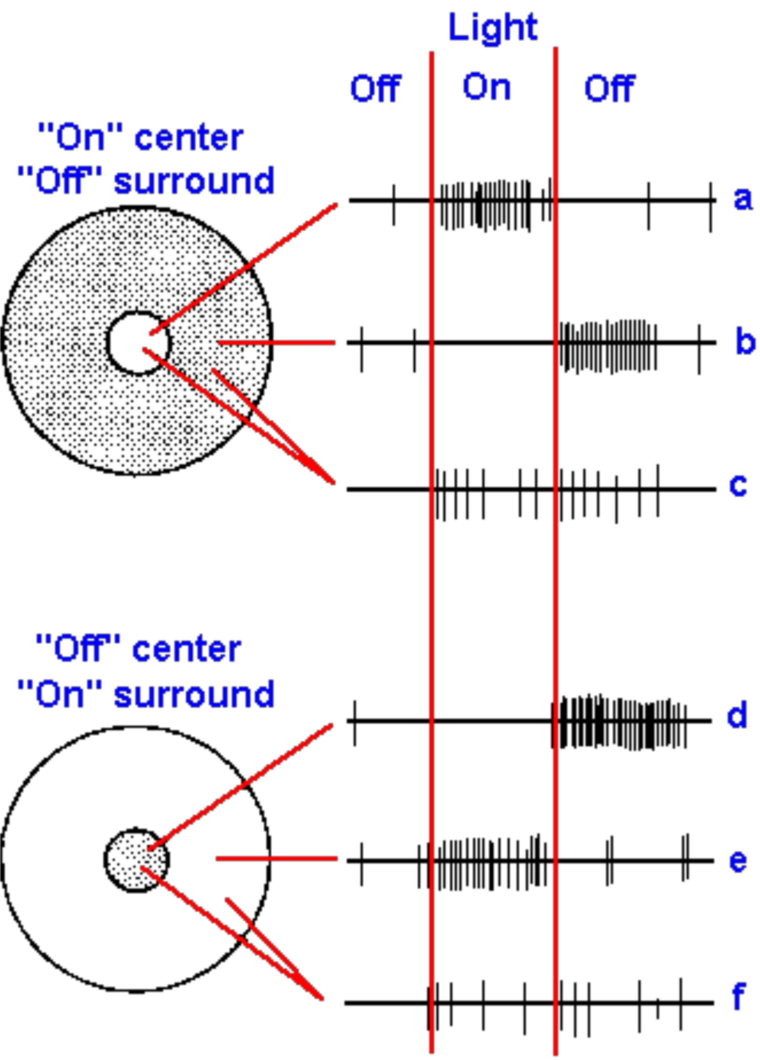
How (Vertebrate) Eyes Work

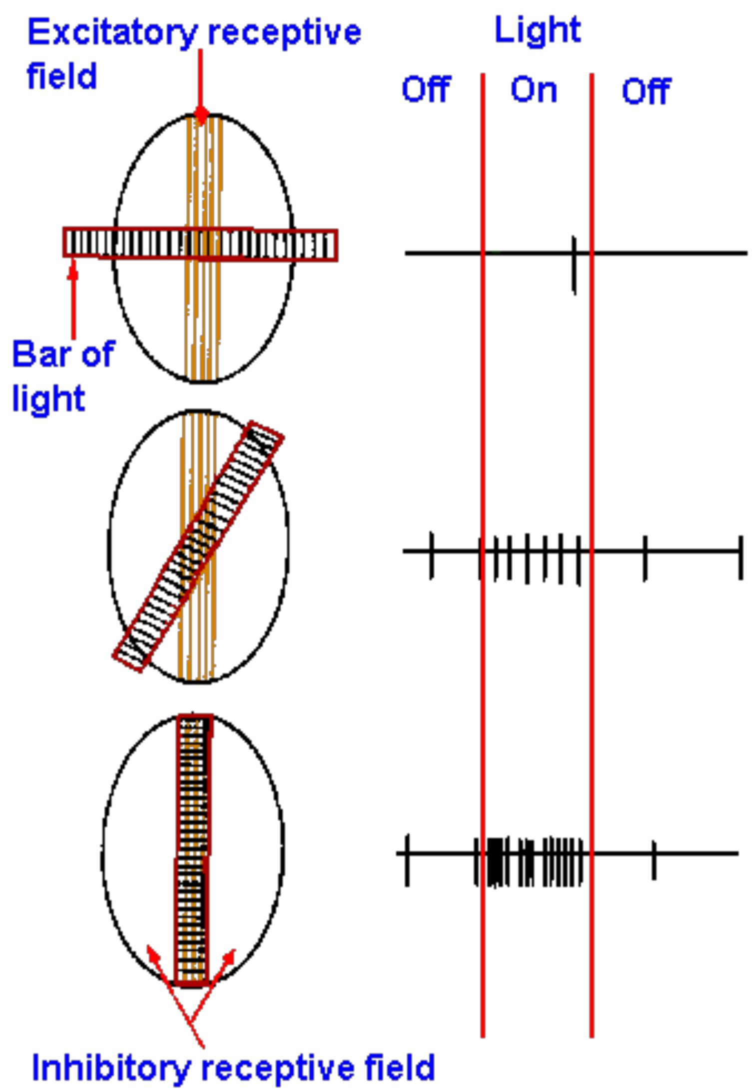
- Lens focuses world on back of eye.
- Rods & cones (receptors) respond to light falling on them.
- Bipolar cells combine information, detect edges & gradients.
- Ganglian cells aggregate bipolar cells.

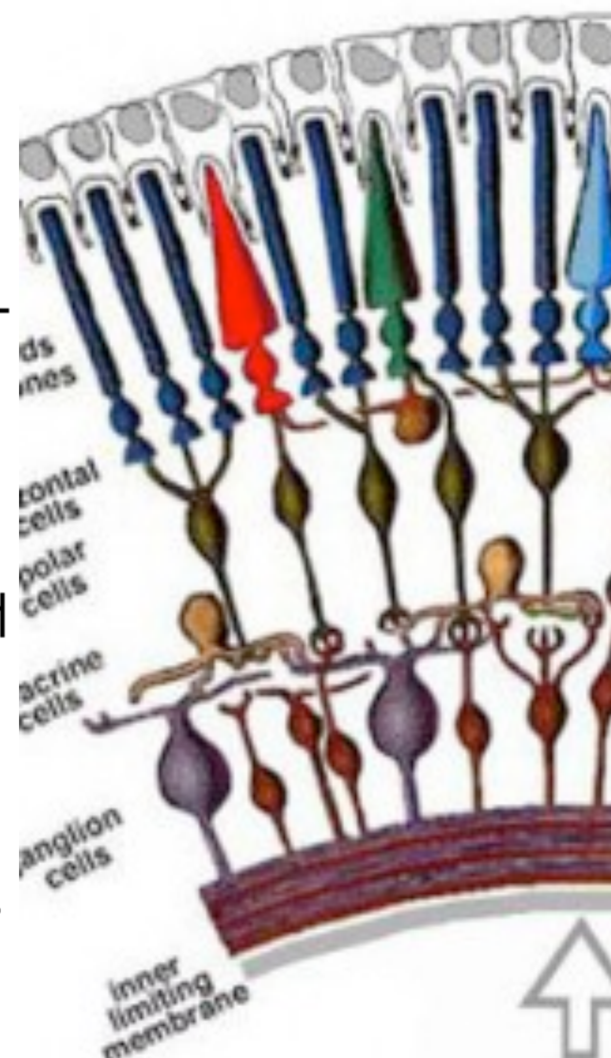


Ganglian cells detect changes in colour, brightness.
Send this information to the back of the brain.

Excitation, Inhibition & Feature Detection



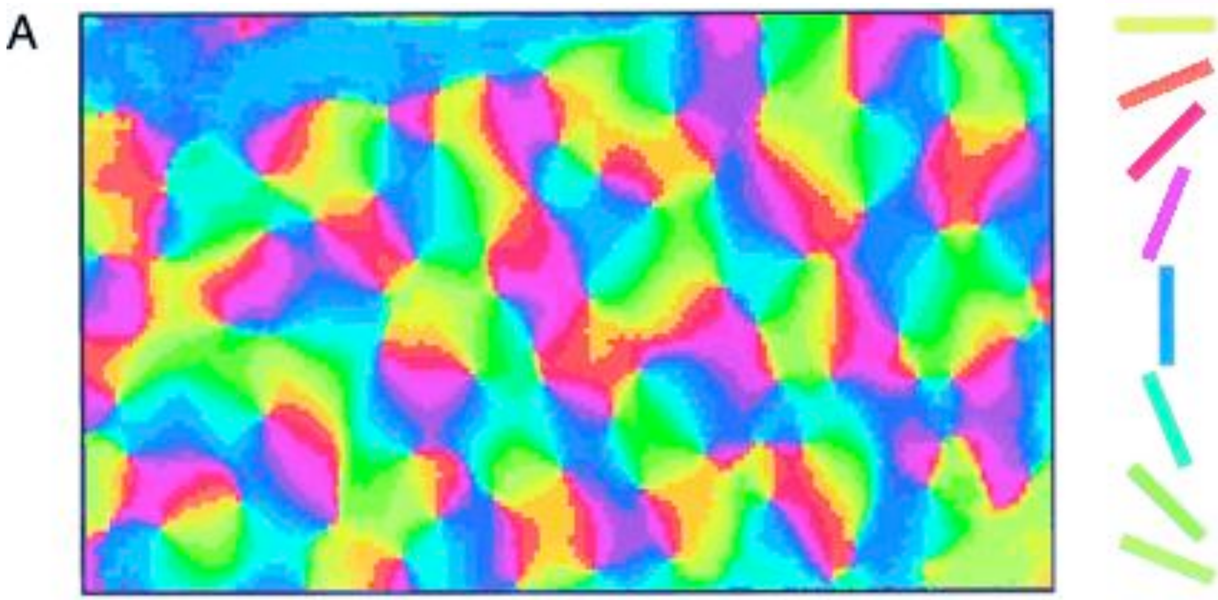


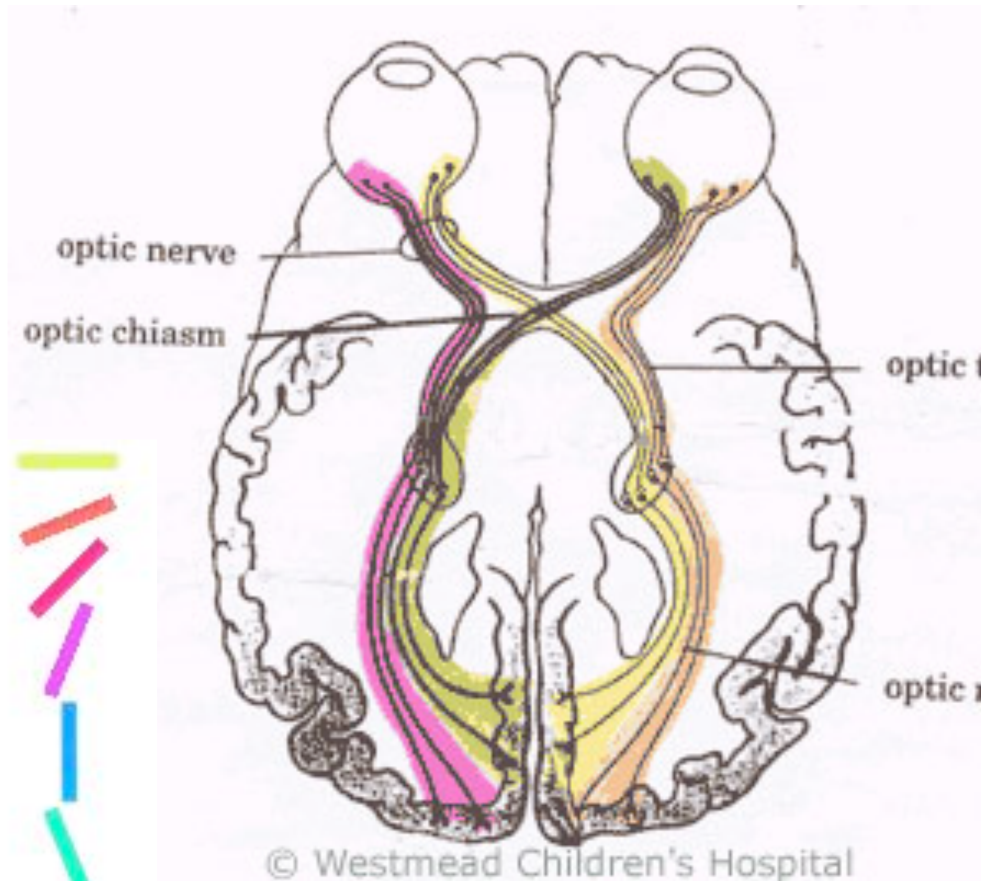


c.f. Mann link

Information Projected and Accumulated

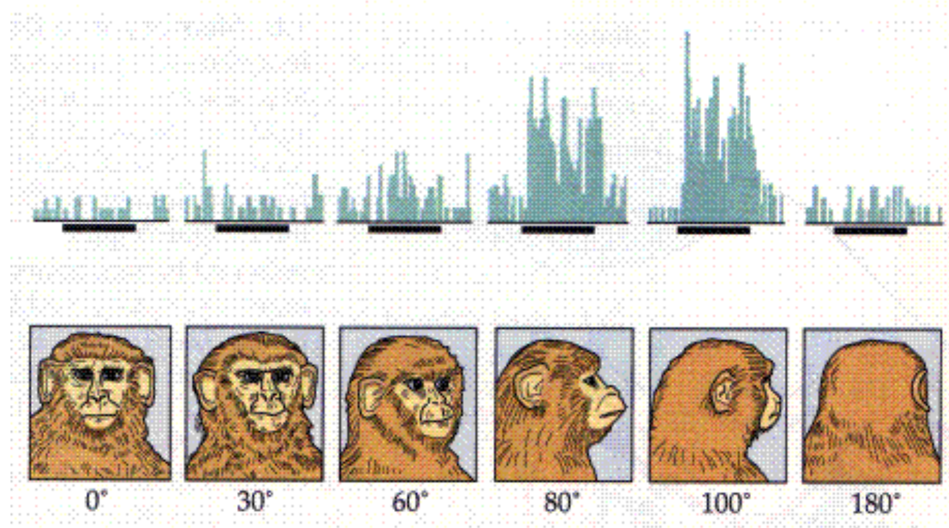
Visual cortex has retinotopic maps responding to different edges, motions.





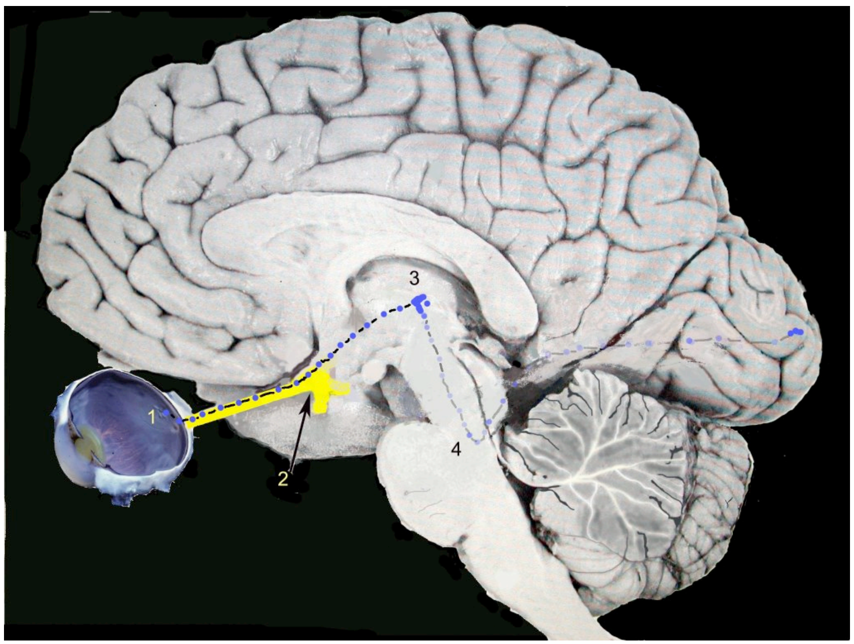
Associative Cortices

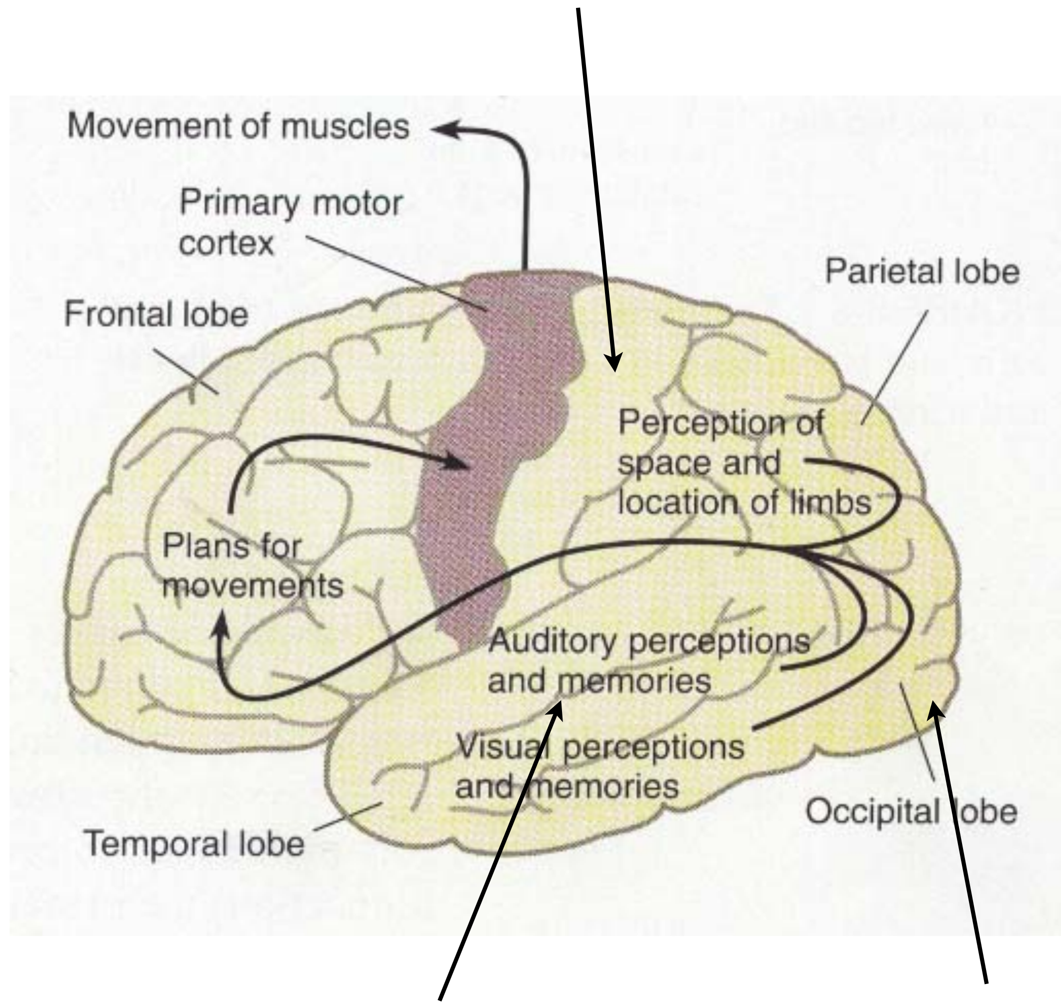
- Features aggregated into objects.
- Still in maps, e.g. for pose.
- Different systems for what versus where.



Output of a pose sensitive cell.

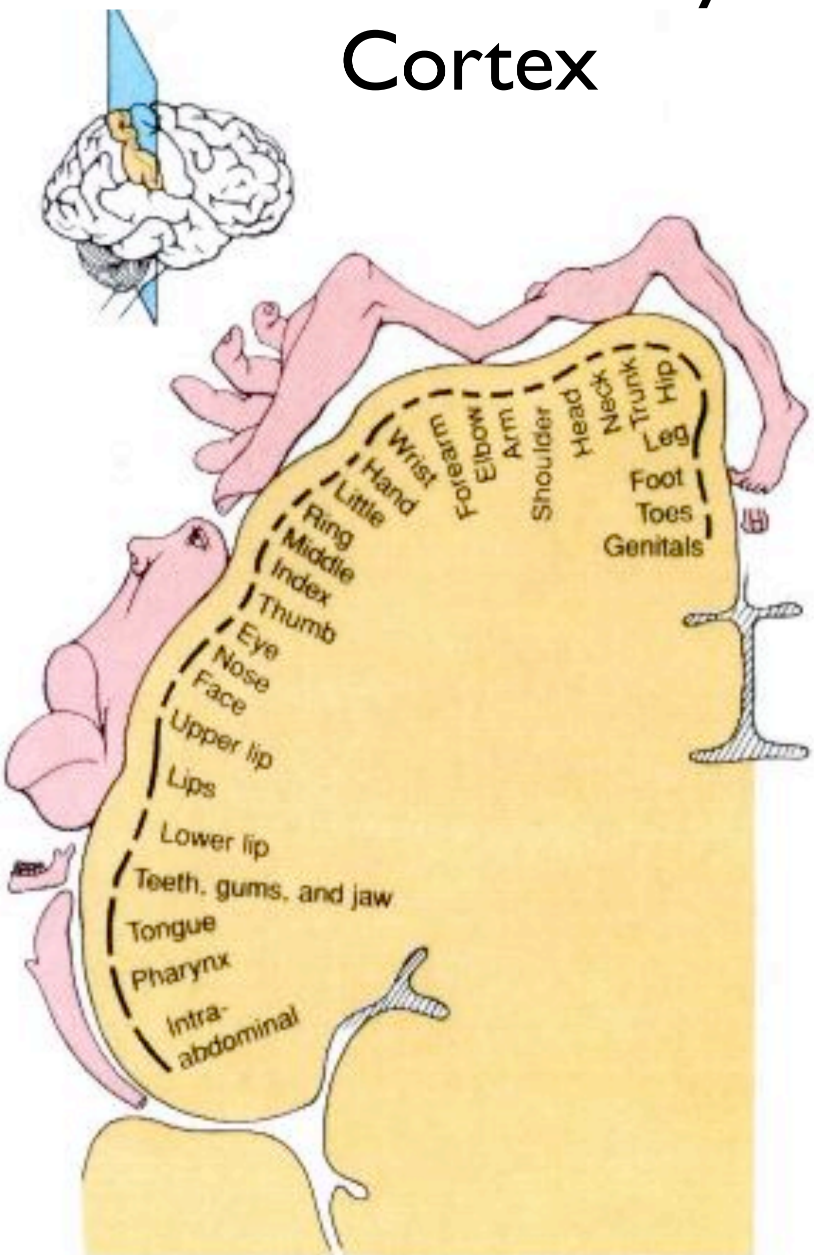
Back to Perception



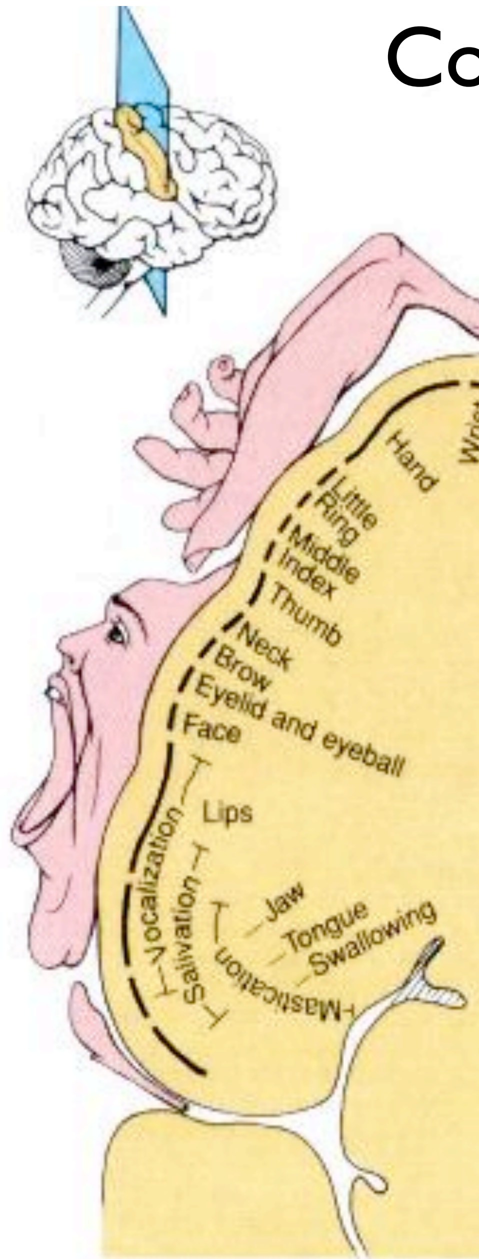


Somatasensory Cortex

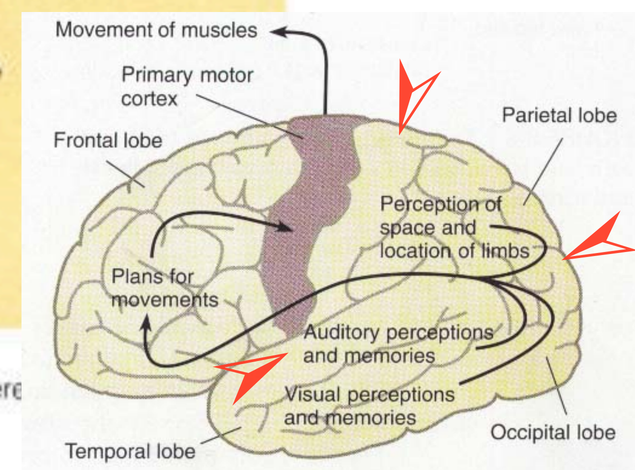
Motor Cortex



(a) Somatosensory cortex in right cerebral hemisphere

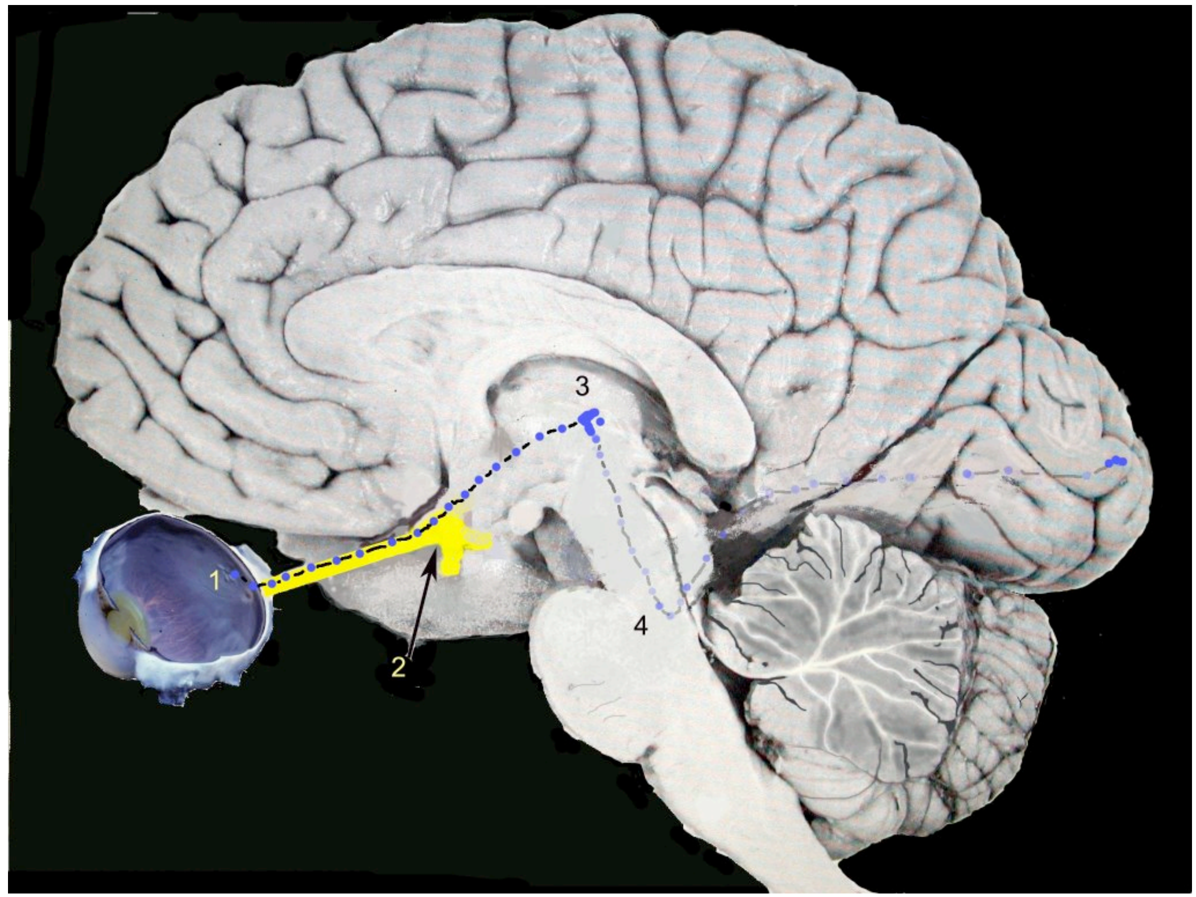


(b) Motor cortex in right cere



Brain Expectations

Up until the Thalamus → Retina connection, there are as many axons going towards the eye as away from it.



Perception Requires Knowledge

- Sensing alone is impossible to discriminate.
- A whole lot of what the brain does is look for regularities (co-occurrences), then represent them.
    - Nerve connections positively reinforced when both sides fire in sequence.

The Brain's Job

Pattern Recognition

- Changing actions / developing skills,
- Discovering concepts / categories for contexts to apply actions,
- Optimising representations.

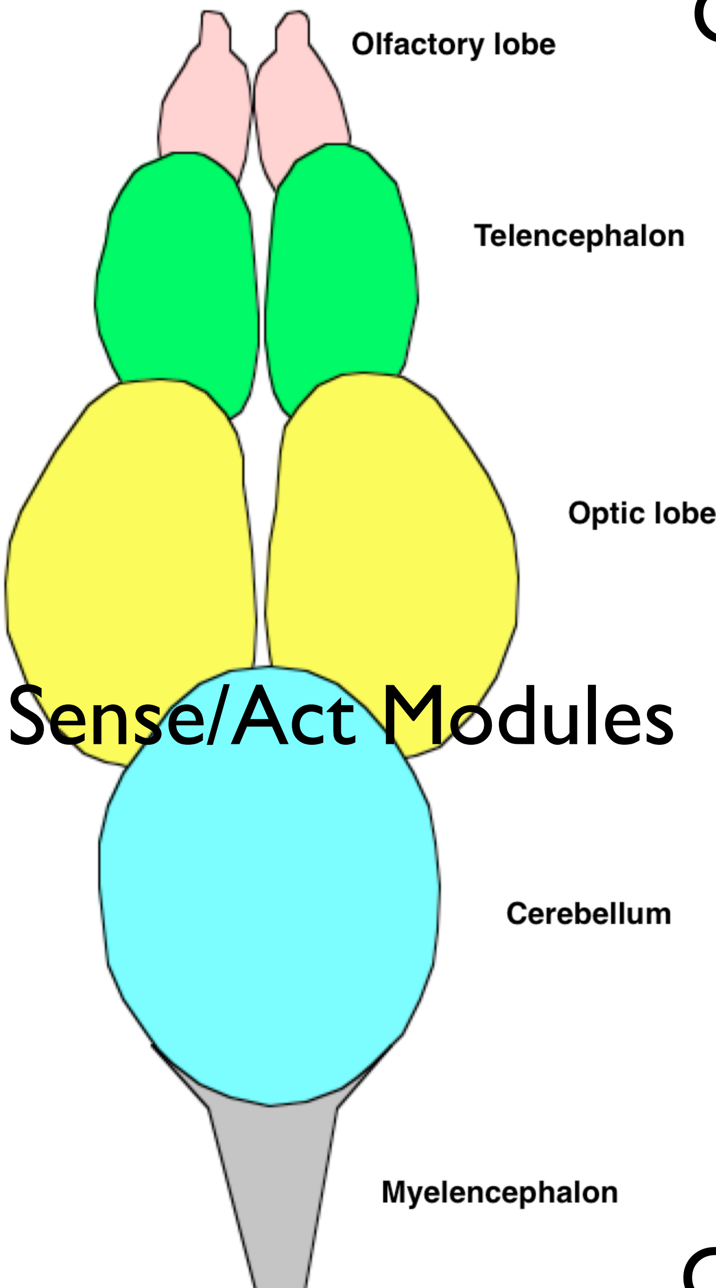
Cognitive Architecture:
Modularity

Archetypical Real-Time AI Architecture

- Perception / action modules (bottom layer)
- Reactive (dynamic) plans to arbitrate between them.
- (Maybe) planner or at least goal arbitration at the top.

e.g. 3T, PRS, Soar

Vertebrate (Fish) Brain as 3-Layer Architecture

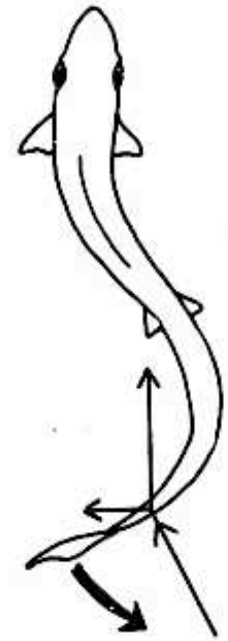


Goal Acquisition (smell)

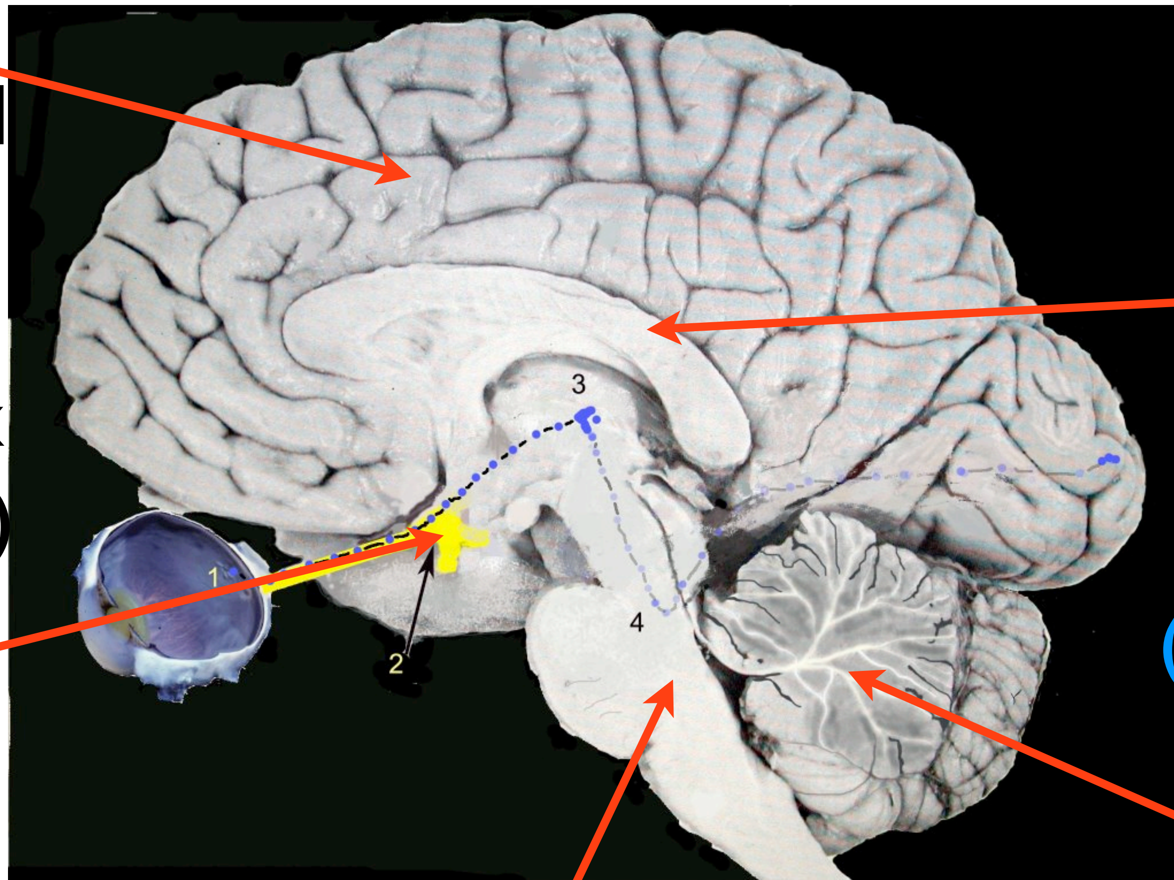
Behaviour Patterns

Sense/Act Modules

Output (spinal cord)



The Obvious Brain Modules are Functional



Long-term storage and category learning (neocortex / cerebrum)

episodic memory construction & use / RAM (hippocampus)

routing (thalamus)

smoothing (cerebellum)

autonomic (midbrain)

Modules in Cognitive Systems

- Many AI cognitive architectures separate episodic or working memory from long term memory.
  - Few have the process emphasis of brain e.g. smoothing, category learning, autonomic systems. Exceptions: Ymir (Thórisson 1996).
- Brooks' sensing→action modules are almost ubiquitous in AI.

Non-Modular AI

- Some researchers try to solve all AI with a single learning function.
- Can get amazing skills together this way.
- Complete systems (e.g. driverless cars) need more structure.

Atkeson, Schaal & students
1997-2014

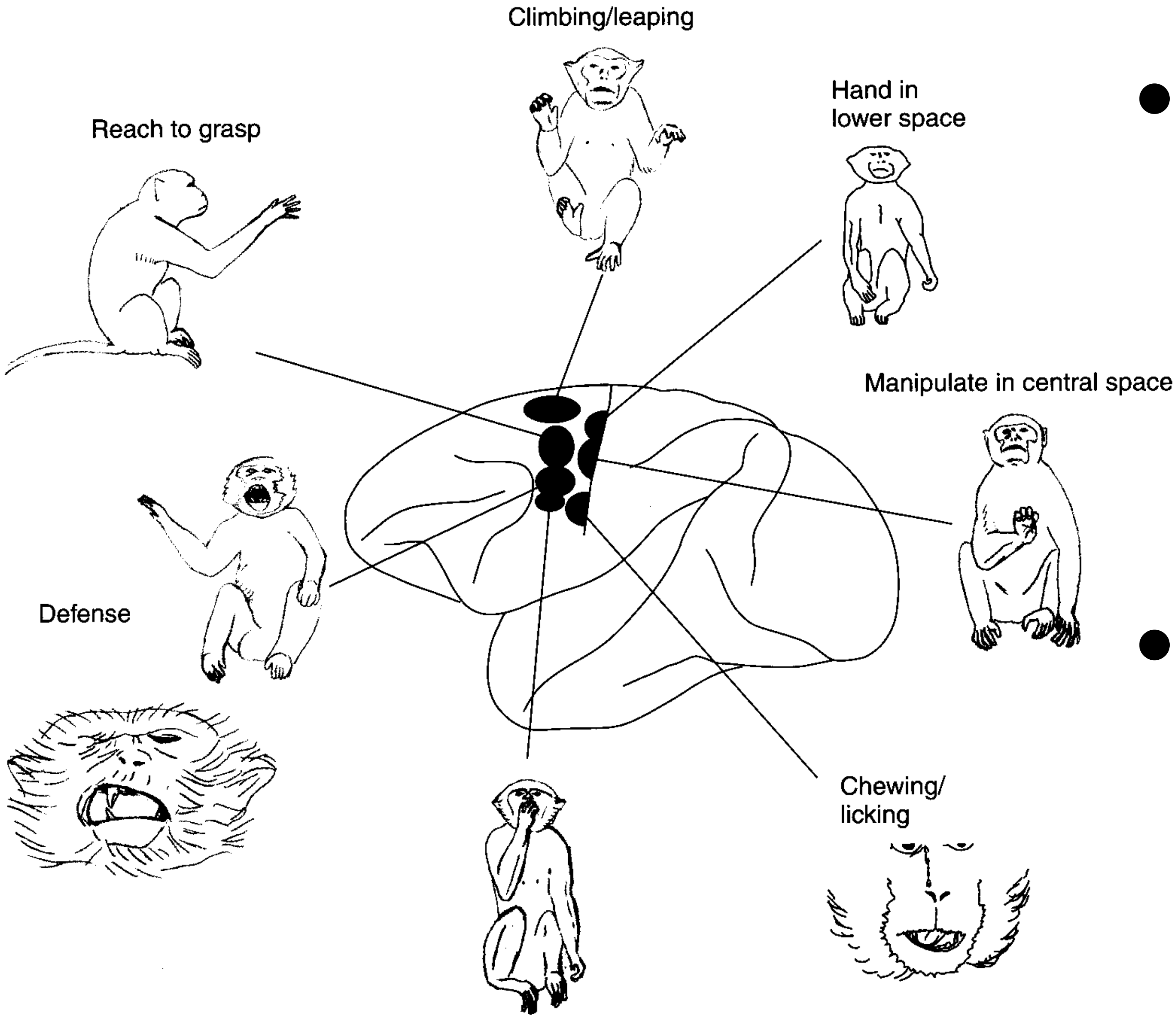
Modularity in Cognitive Science

- Fodor (1983) describes two kinds of modules:
  - Vertical (sensing or motor skills)
  - Horizontal (cross-task skills like language, reasoning.)
- Brooks' (1986) are sort of super vertical (sense and act; cf. Minsky's agents, Society of Mind 1985).

Perception in Nature

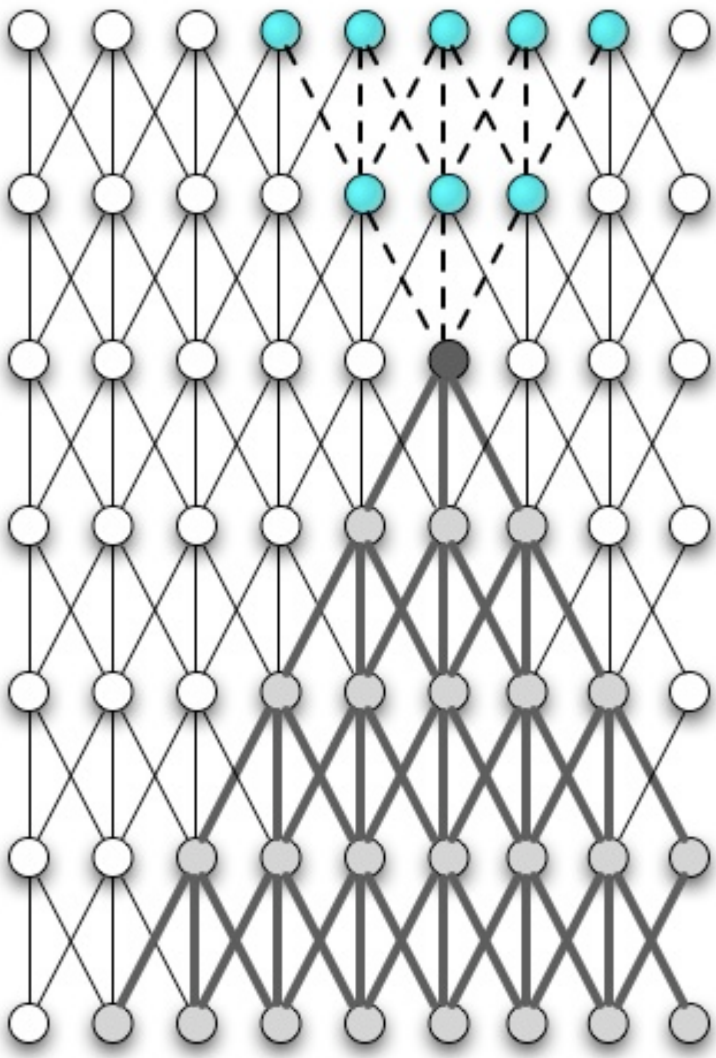
- Perception can be seen as both horizontally and vertically divided.
  - Horizontal: specialist mapping regions.
  - Vertical: Cone of perceptual processing leading to single "decision" cell coordinating descending cone of motor activation.

Vertical Modules

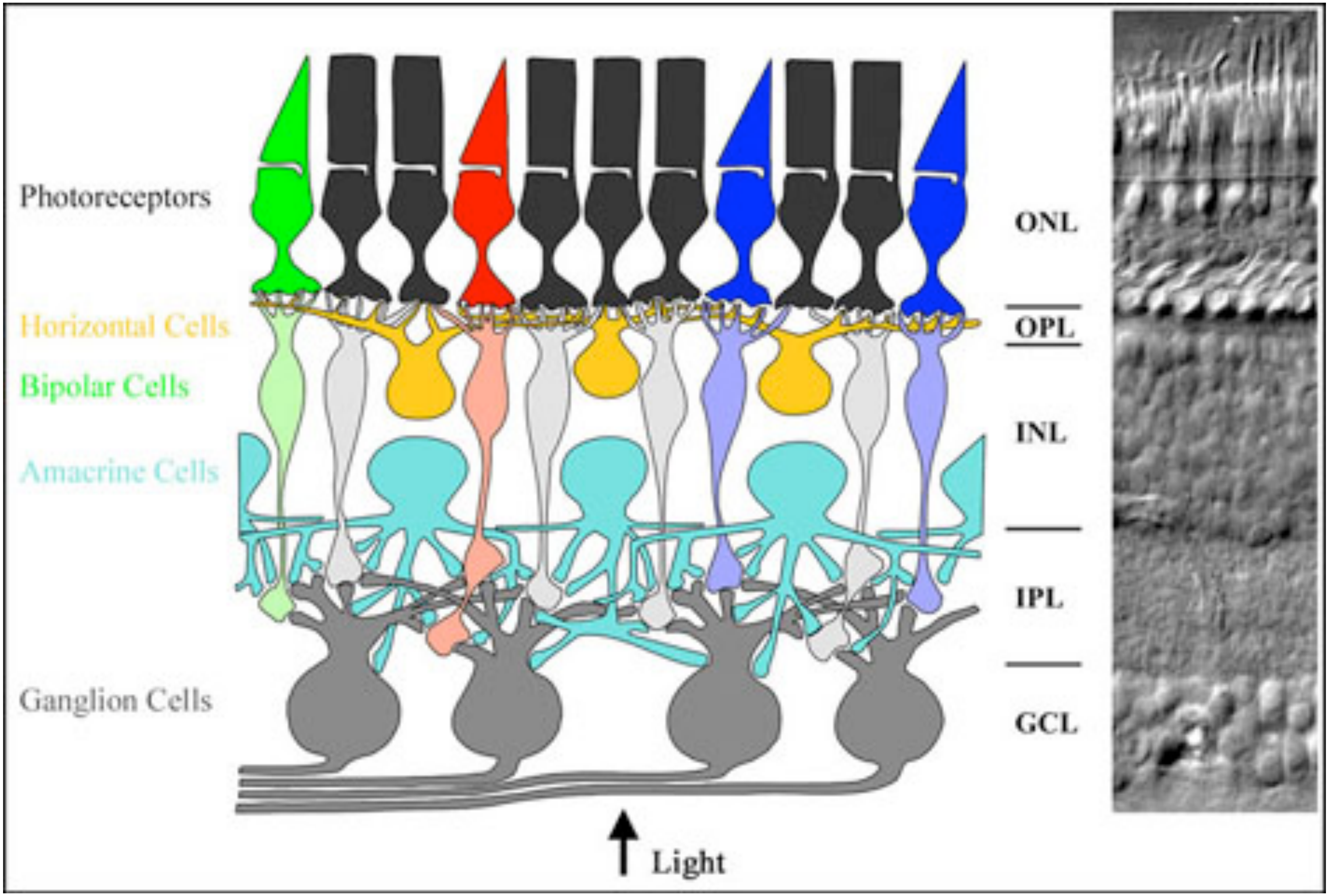


- Distributed across sensory-motor & pre-motor cortex – names are dated (Graziano 2010)
- Species-typical behaviour (again mapped); multi-modal stimuli.

Cone or Column?



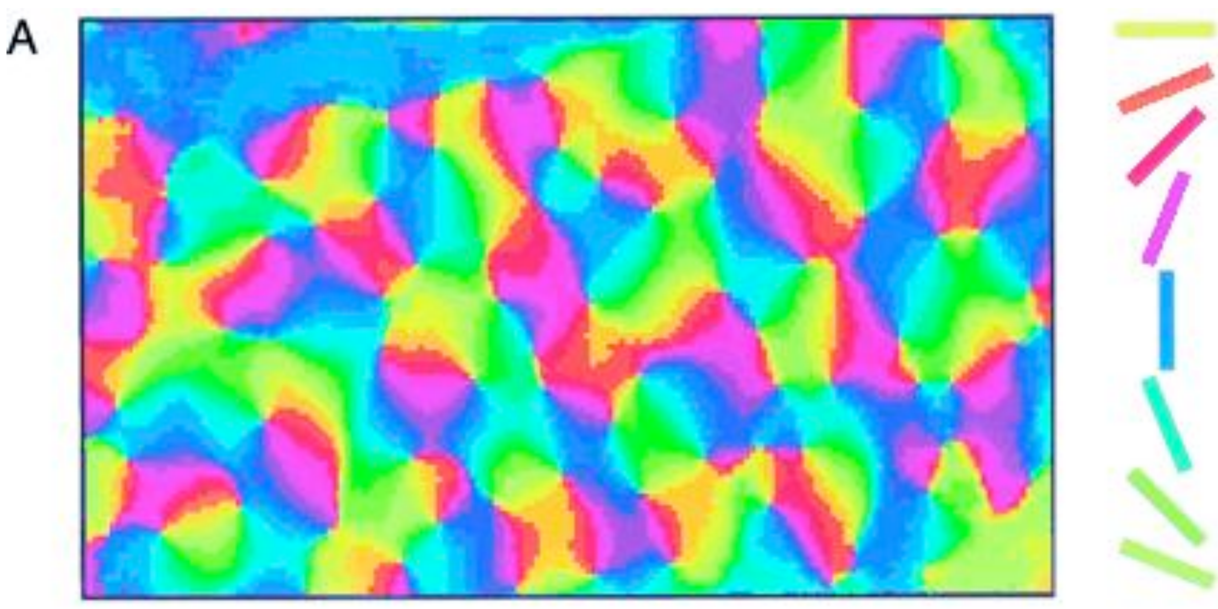
- Individual neurons must be agnostic, can’t know whether they are the winner while processing.
- Winning candidates shift continuously with stimuli, posture.
- Local competitors inhibit each other (winner-take-all).

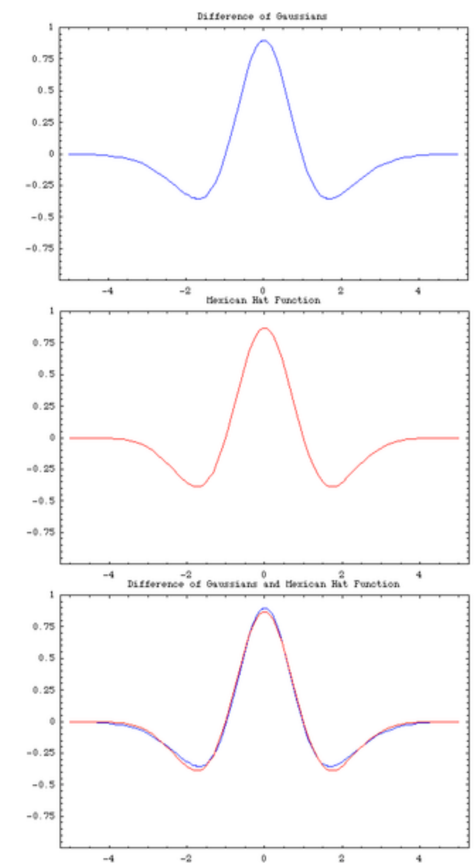


Retina again: Bipolar and Ganglian cells not only gather receptor information but locally inhibit.

Models of Cortical Maps Built with Localised Excitation and Inhibition

Mexican hat function + Winner take all
c.f. Willshaw, Hinton.



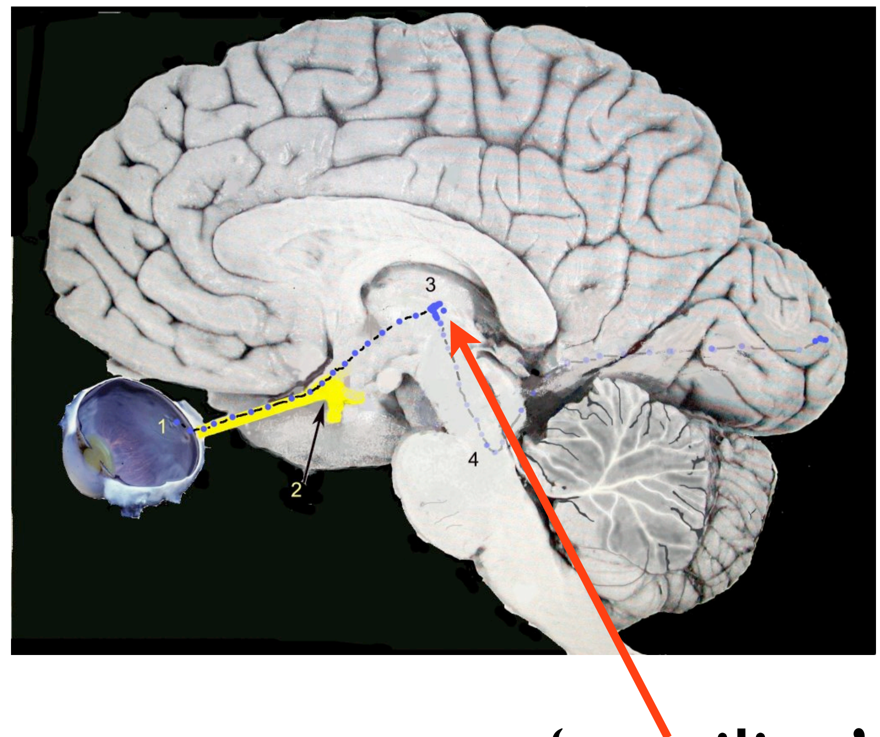


References

- Mann's Book (linked, on line).
- Carlson, *Physiology of Behaviour* (many editions in many years, great text book.)
- Tom Mitchell, *Machine Learning*, 1997.
  - Both in Library!

Q: Why put the visual cortex in the rear?

- More time-critical processing happens in midbrain.
- V1 also processes Braille.
- Light travels faster than sound: facilitates coincidence detection.



'reptilian' vision