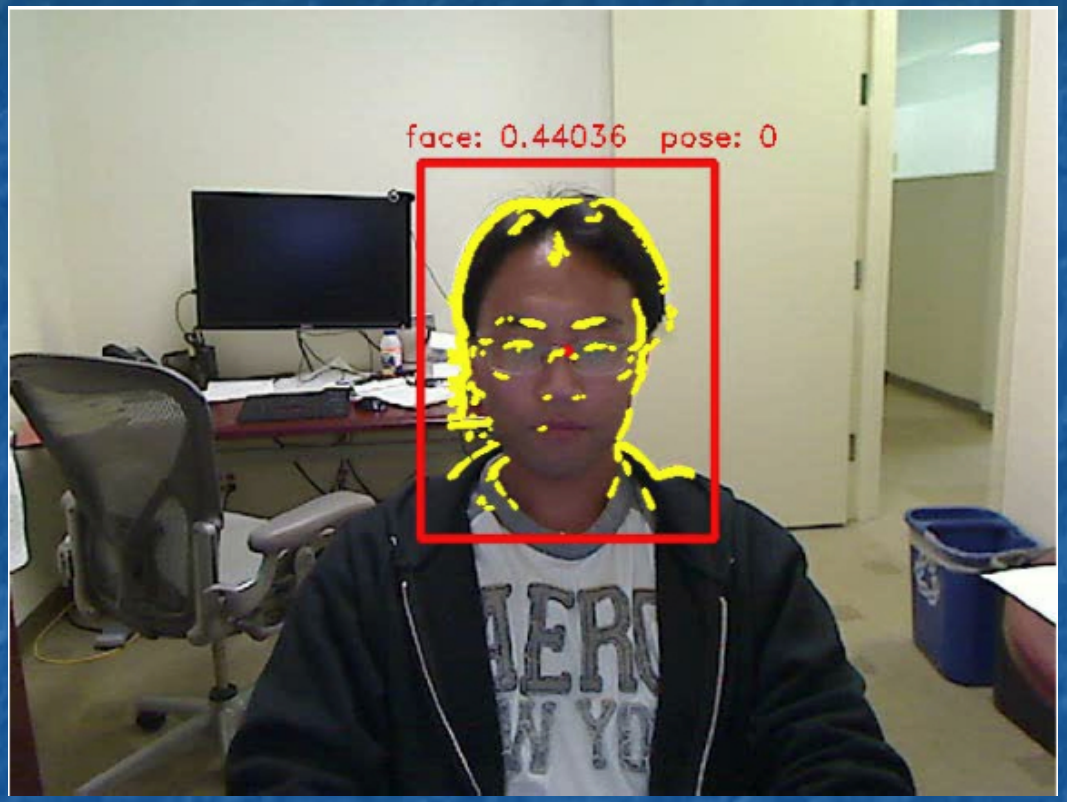
INF1-CG 2016
Lecture 20

Vision: the beginnings

Richard Shillcock

Today's goals



To begin looking at vision and to identify some computational issues.

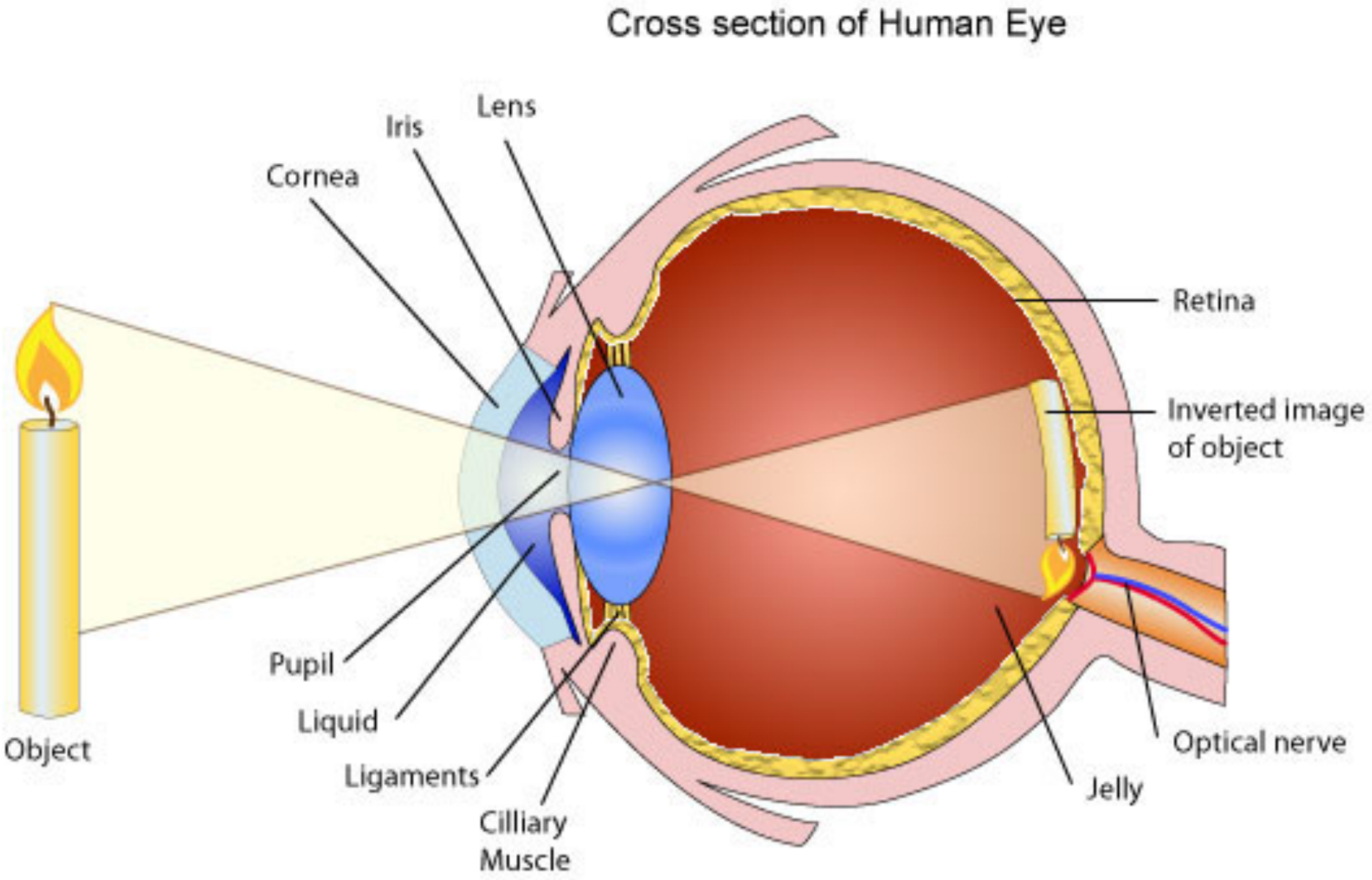
Today's readings

Land, M. F., & Hayhoe, M. (2001). In what ways do eye movements contribute to everyday activities? *Vision Research, 41* (25), 3559-3565.

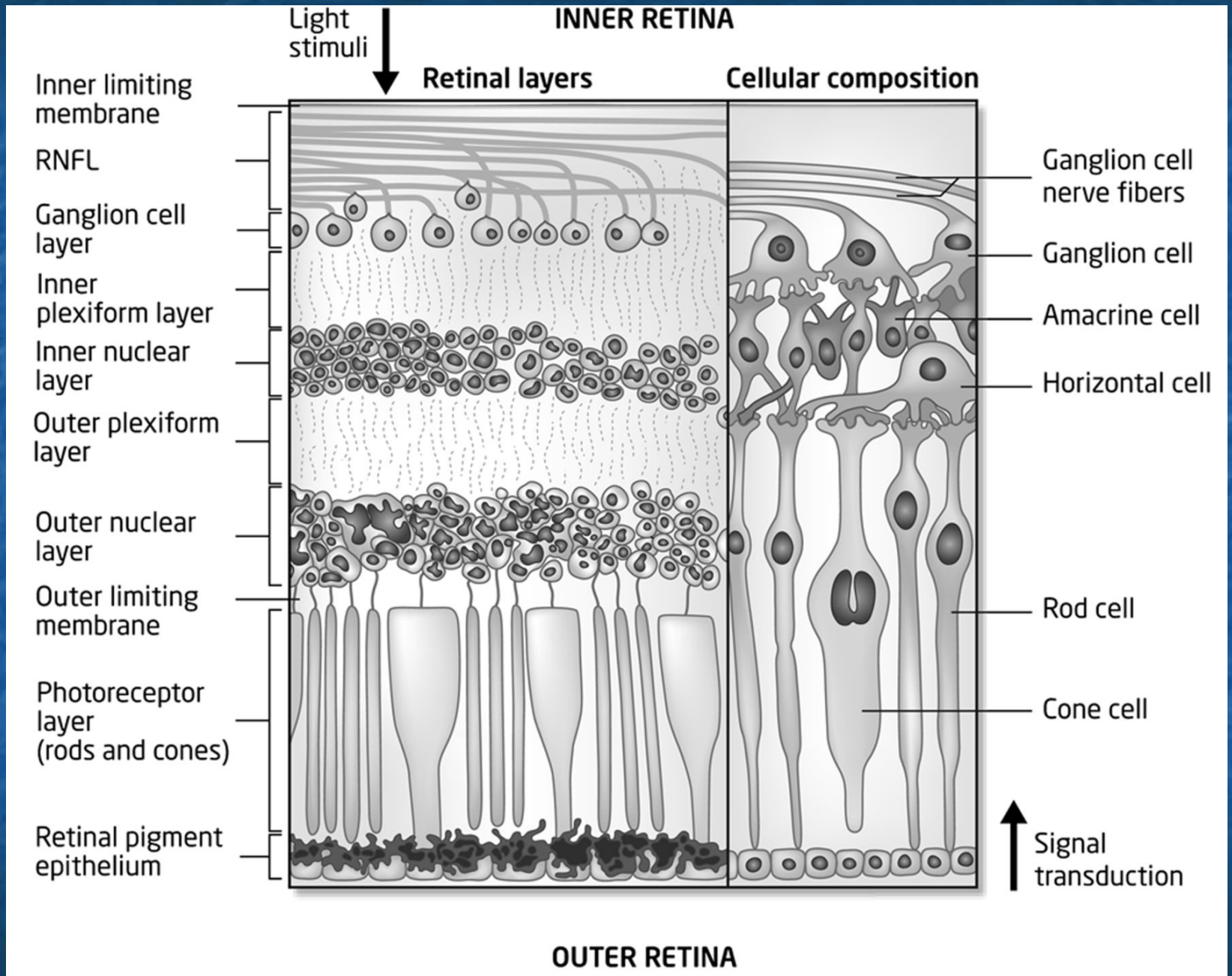
http://www.scholarpedia.org/article/Neuron

Amir, O., Biederman, I., Wang, Z., & Xu, X. (2013). Ha Ha! Versus Aha! A Direct Comparison of Humor to Nonhumorous Insight for Determining the Neural Correlates of Mirth. *Cerebral Cortex first published online December 8, 2013 doi:10.1093/cercor/bht343*

Fixating the world

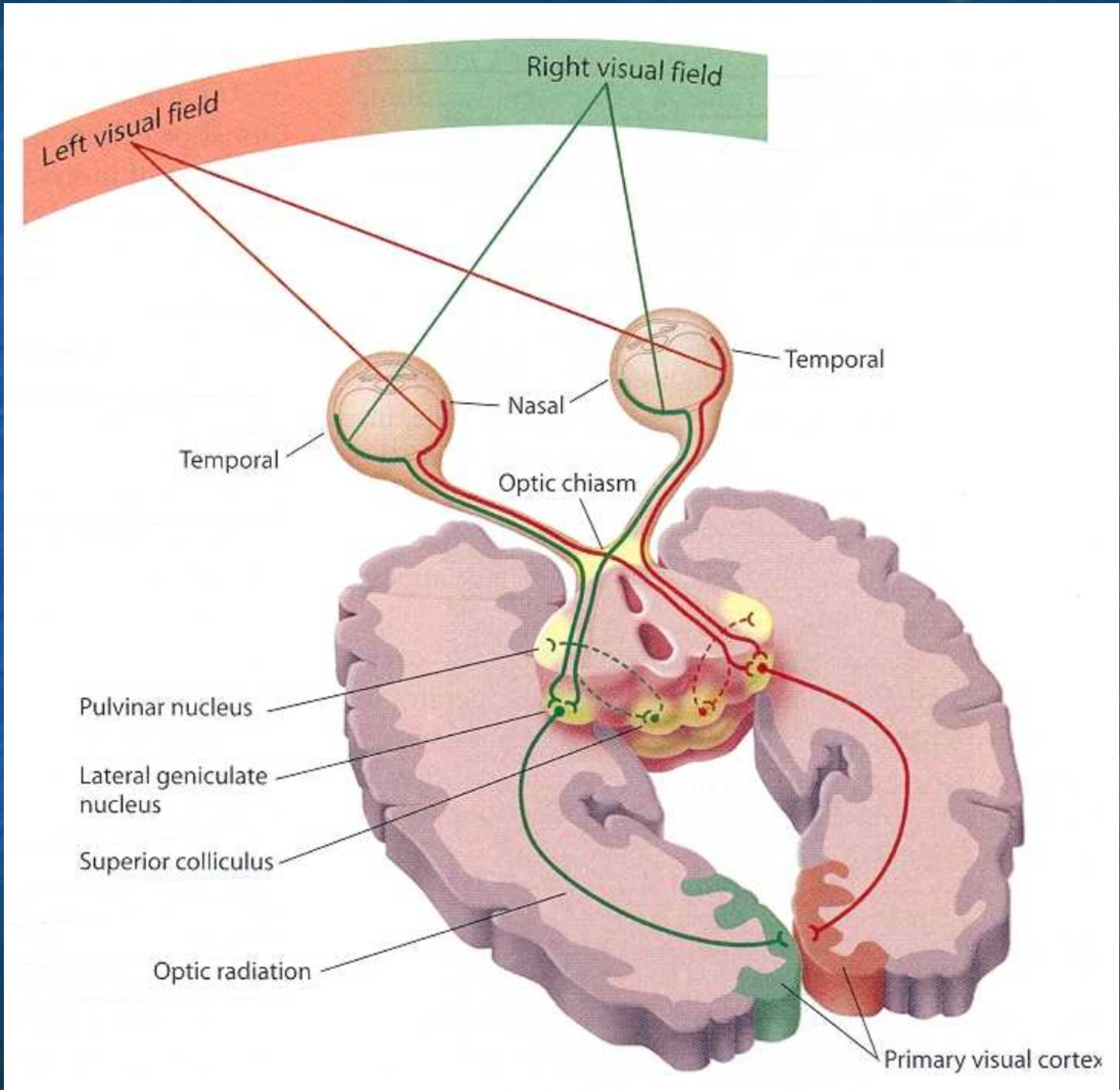


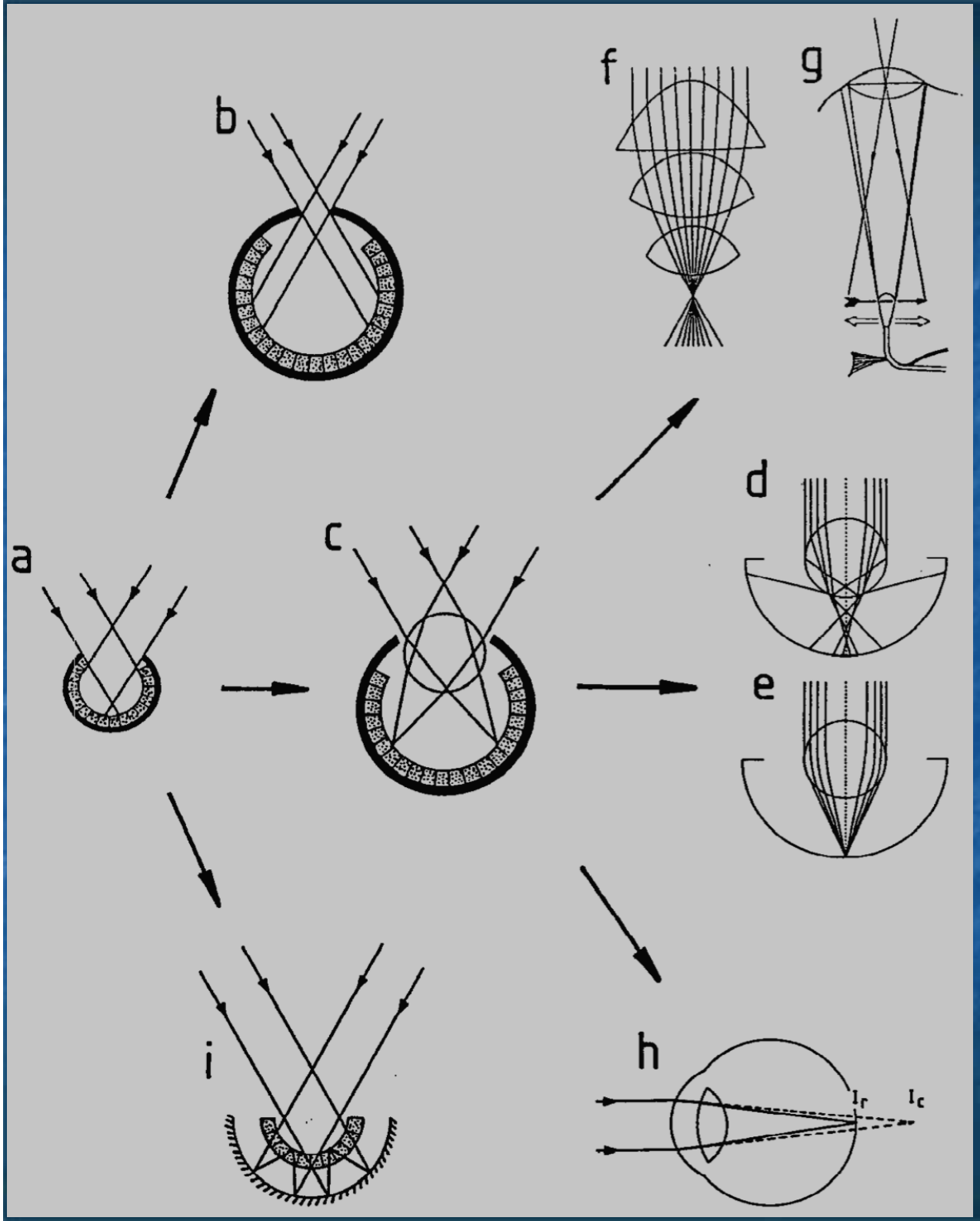
The structure of the retina



RNFL: retinal nerve fiber layer.

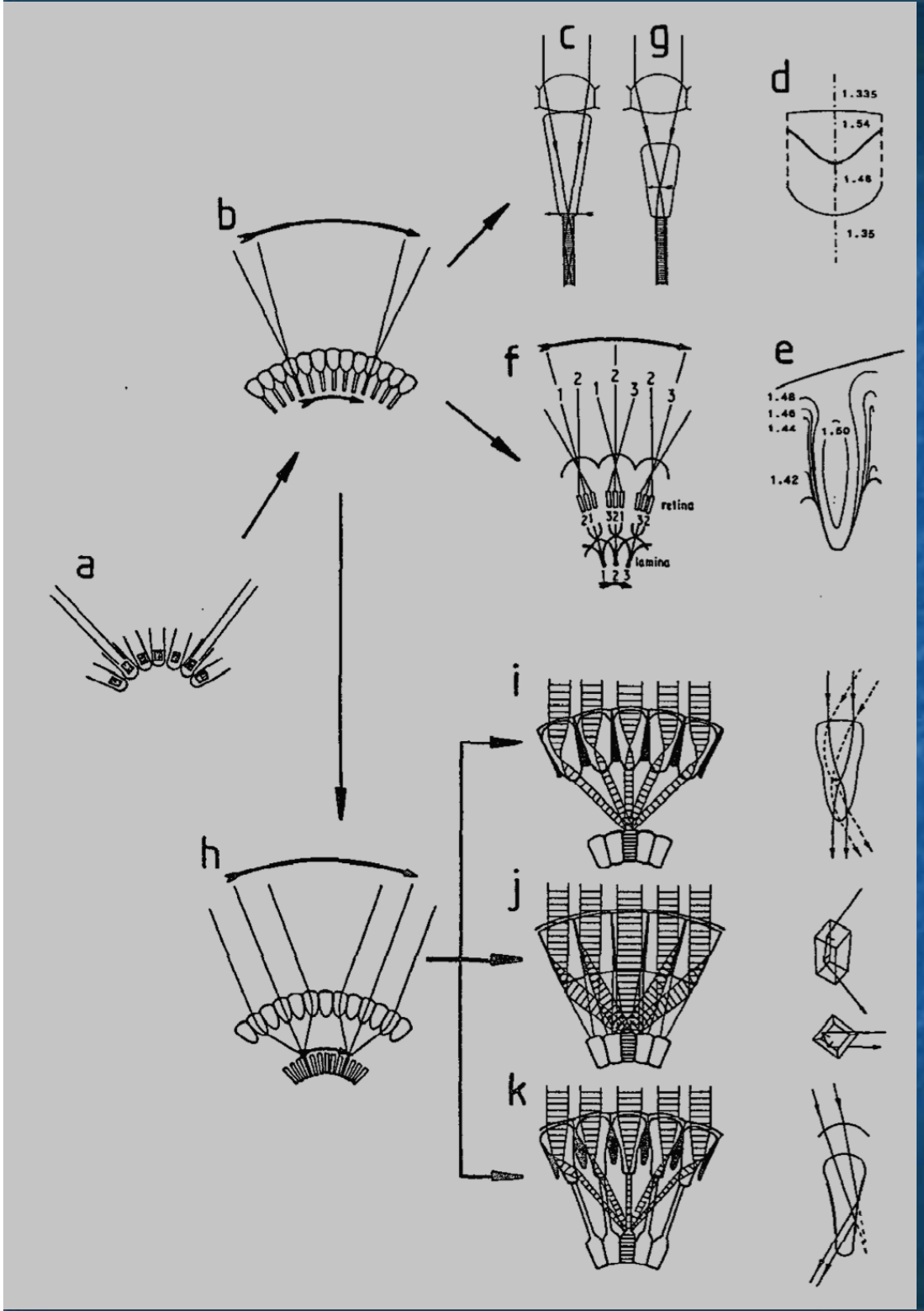
The visual pathways





Other solutions

Evolution has discovered single chamber eyes multiple times (Land & Fernald, 1992).

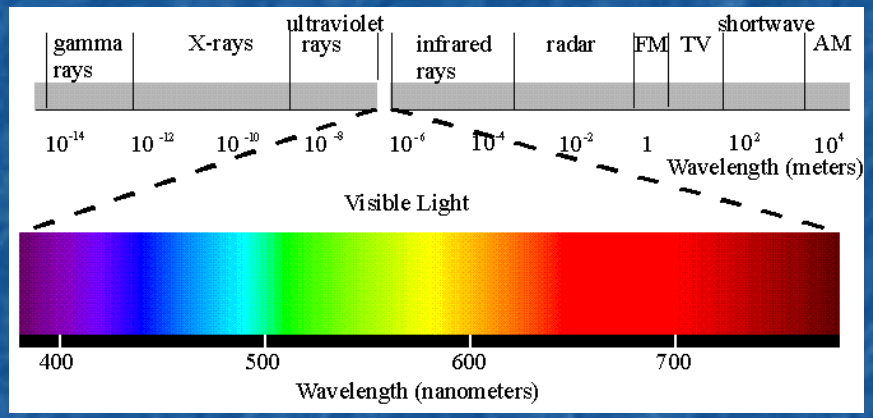


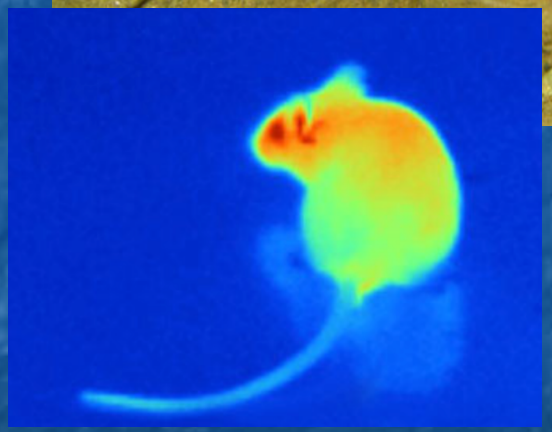
Other solutions

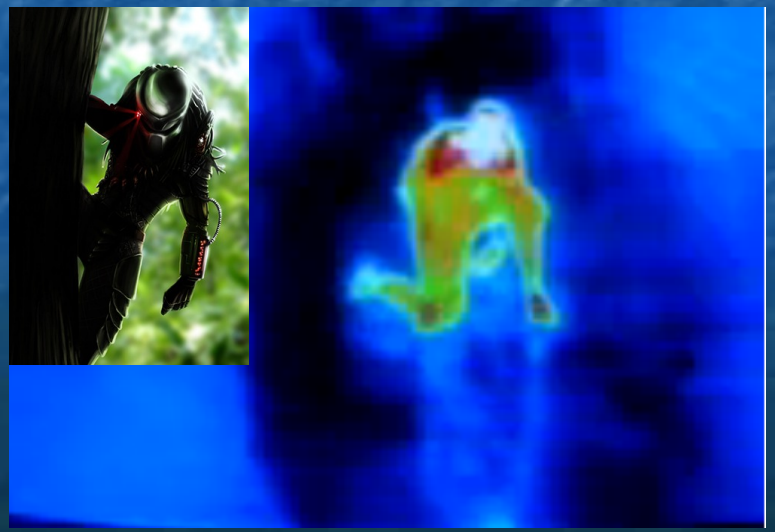
The same is true for compound eyes (Land & Fernald, 1992).

"Vision as sampling"

Human vision "samples" only a small part of the electromagnetic spectrum. We will see other instances of "vision as sampling".







Visual development

Retinal waves: waves of activity spontaneously emerge travelling over the retina in an activity-dependent refinement of connectivity (see Wong, 1999)

"Starting small"

In human visual development, there are early limitations on breadth and depth of vision.

Reducing the initial scale and complexity of the problem may assist development.

See Jeff Elman's (1993) modelling of starting small in learning language (but there is a *caveat* …).

Development: the juvenile period

Marr's (1982) levels of description

We need *metaphors*, *simplifications* and *abstractions* to be able to understand the brain.

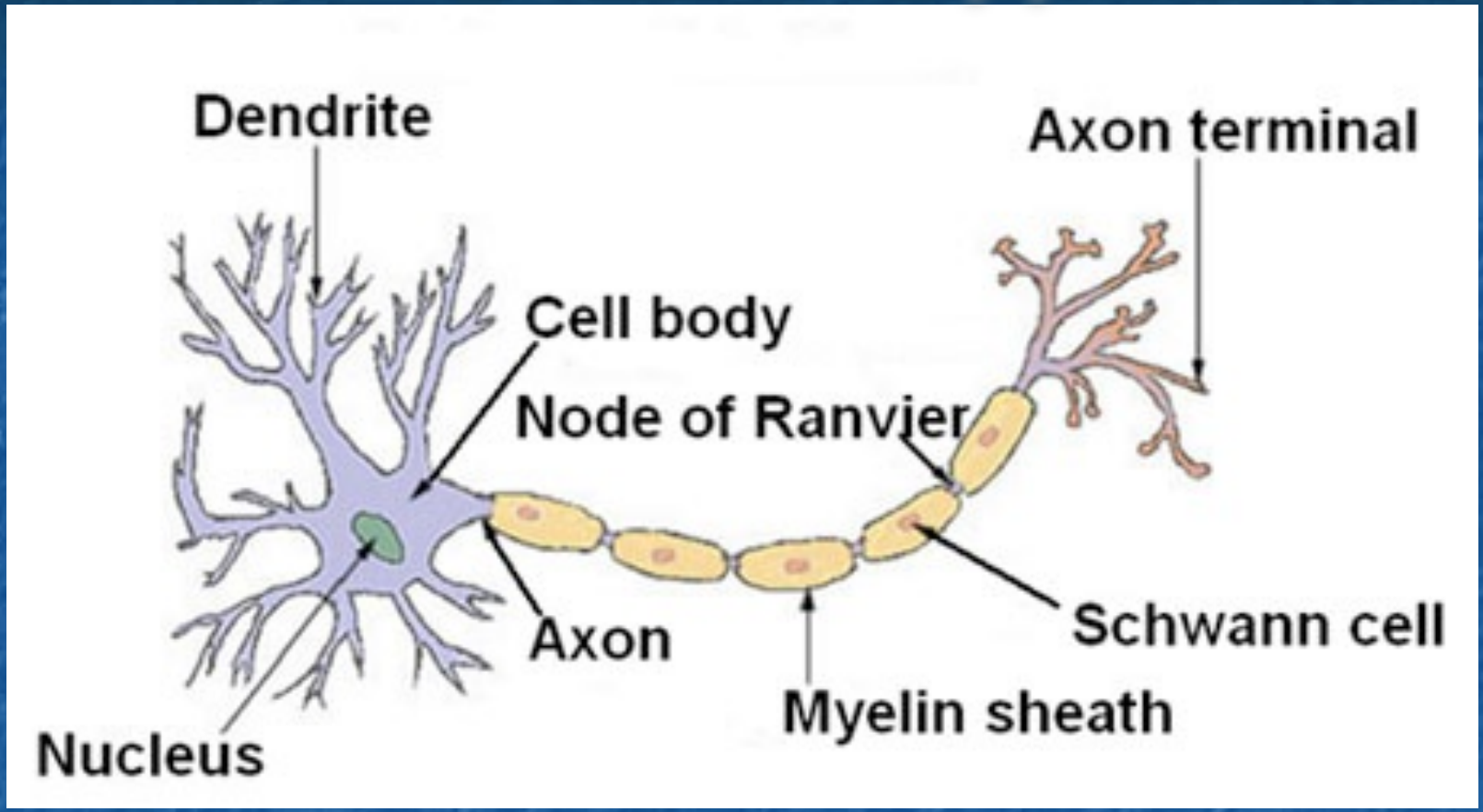
Computational level: what is computed, and why (e.g. rules of arithmetic – 2 x 5, 5 + 9, …)

Algorithmic level: the procedures and representations used (*cf.* abacus, "carry one", *etc.*)

Implementational level: the physical substrate – silicon, neurons, …

Hippocampal neurons

Structure of a typical neuron

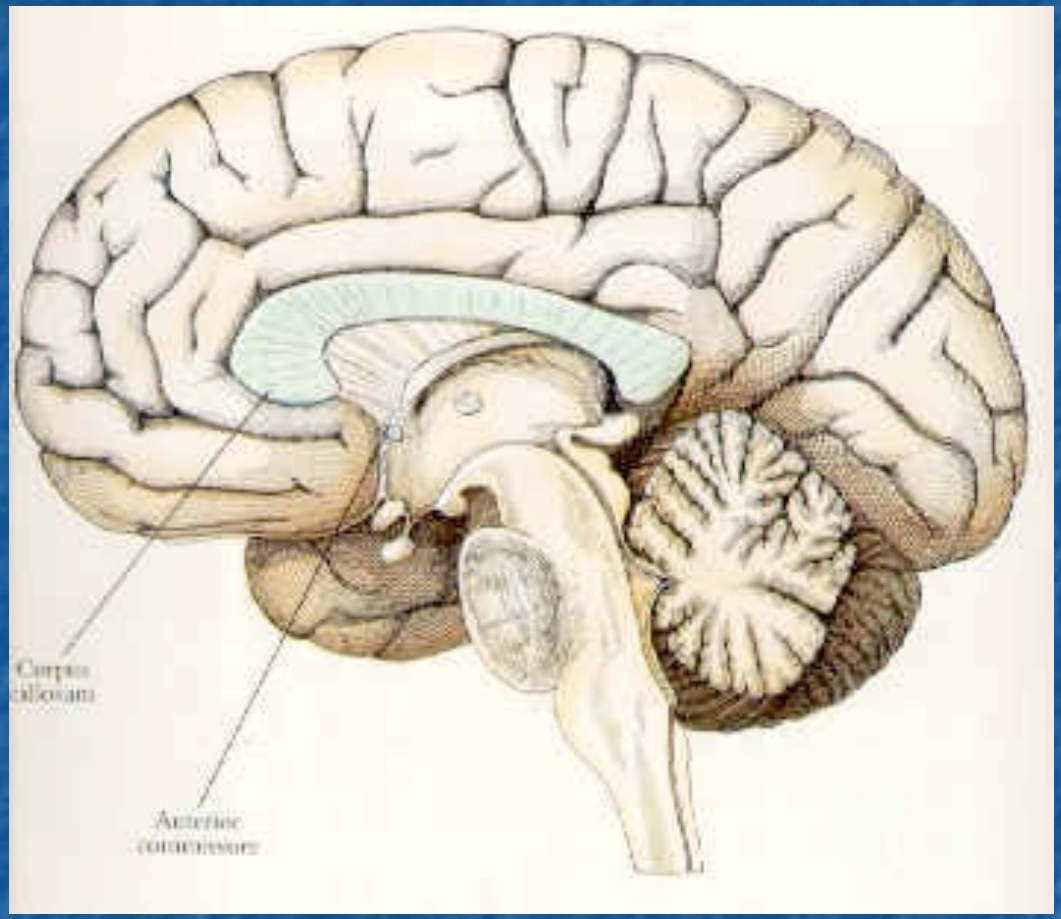


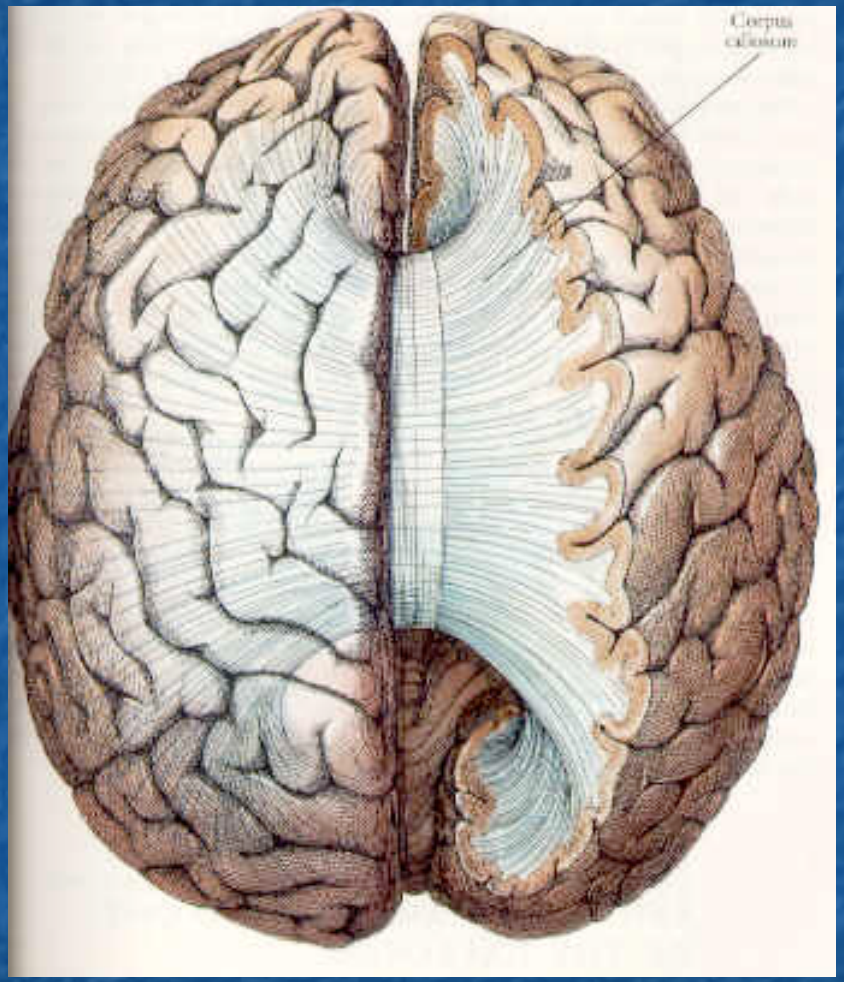
Some neural statistics.

Evolutionary continuity and conservation.

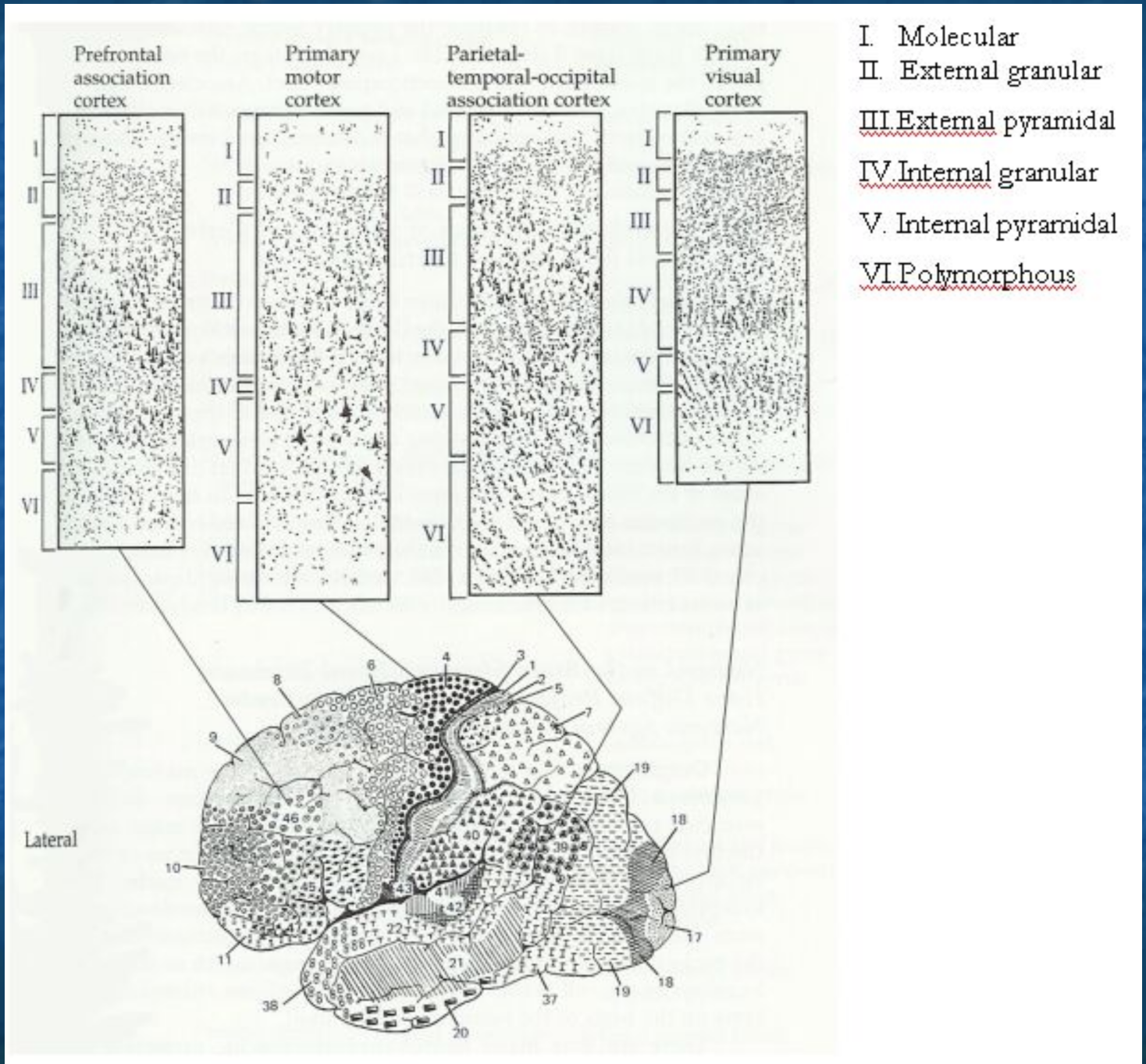
Exuberant connectivity, pruning and growth spurts.

A very quick tour of the brain



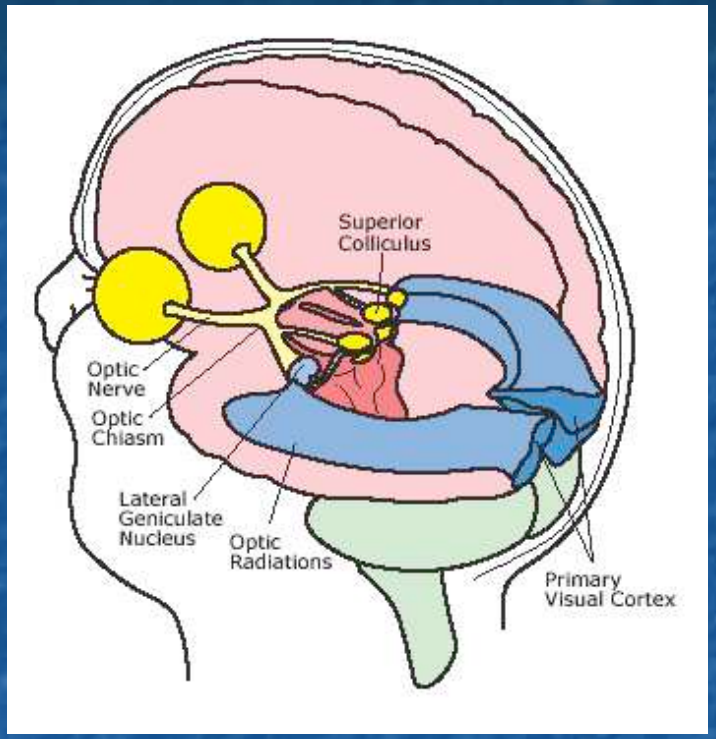


A very quick tour of the brain

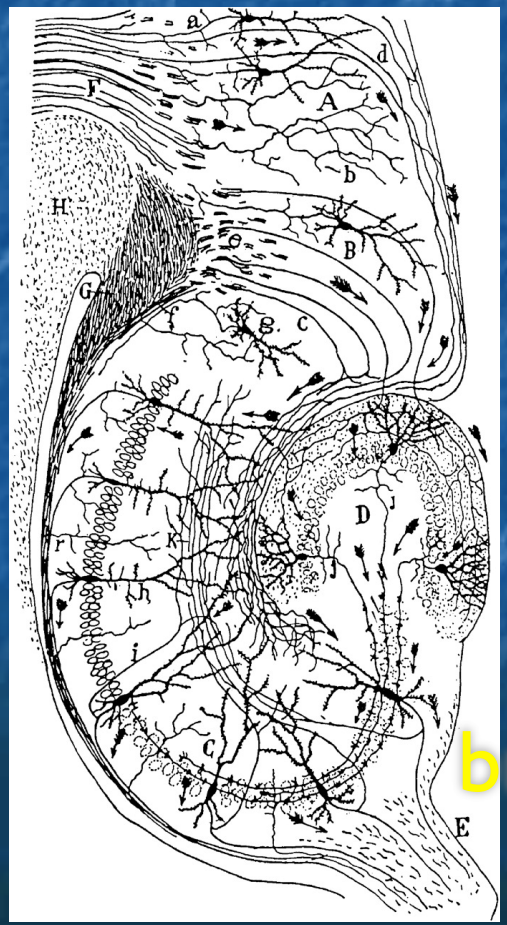


Aspects of analysis

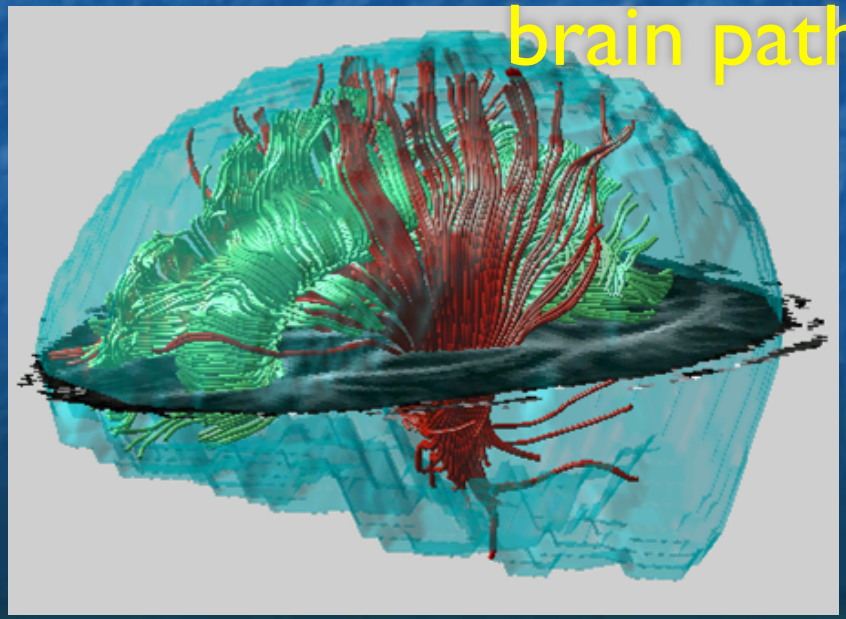
behaviour



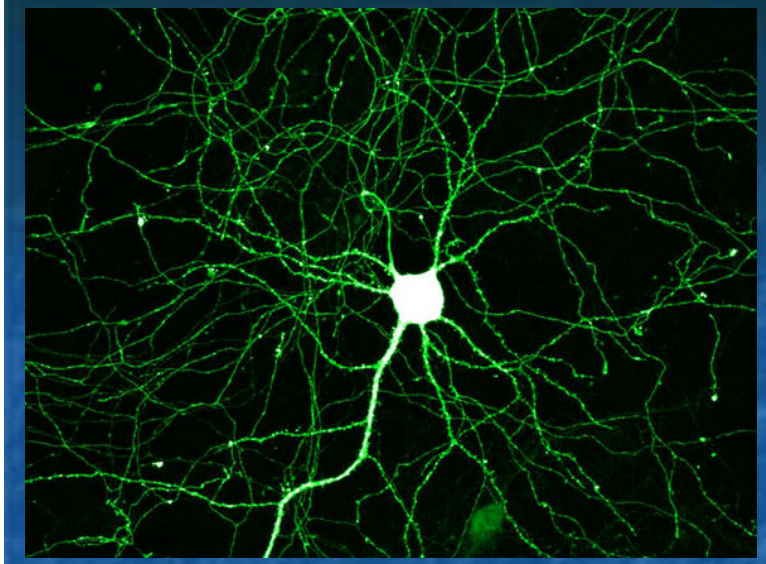
brain pathways



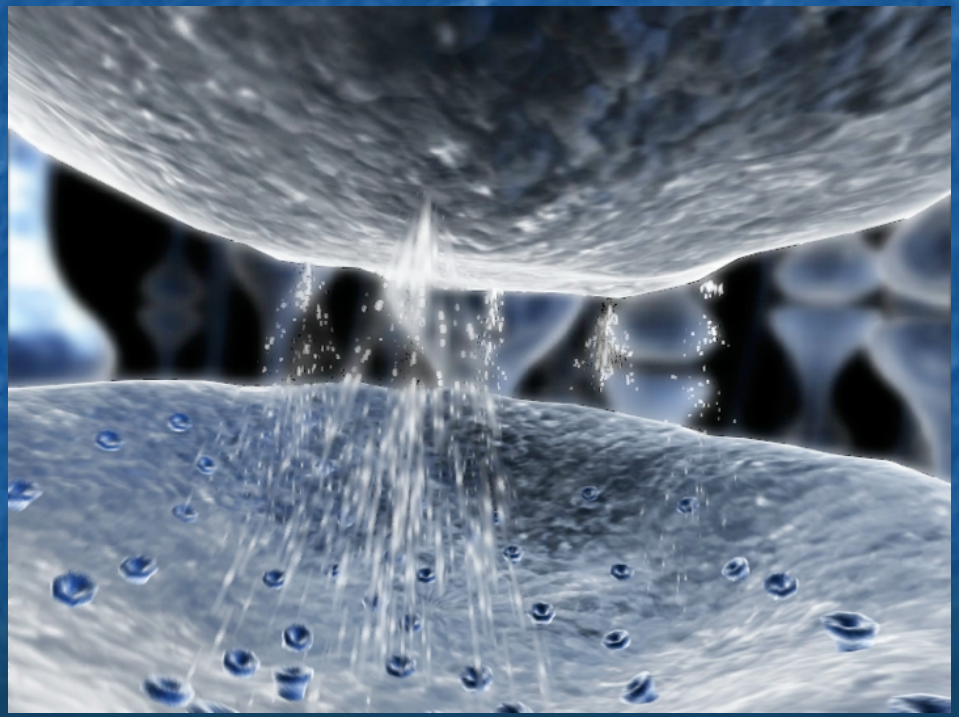
brain circuits



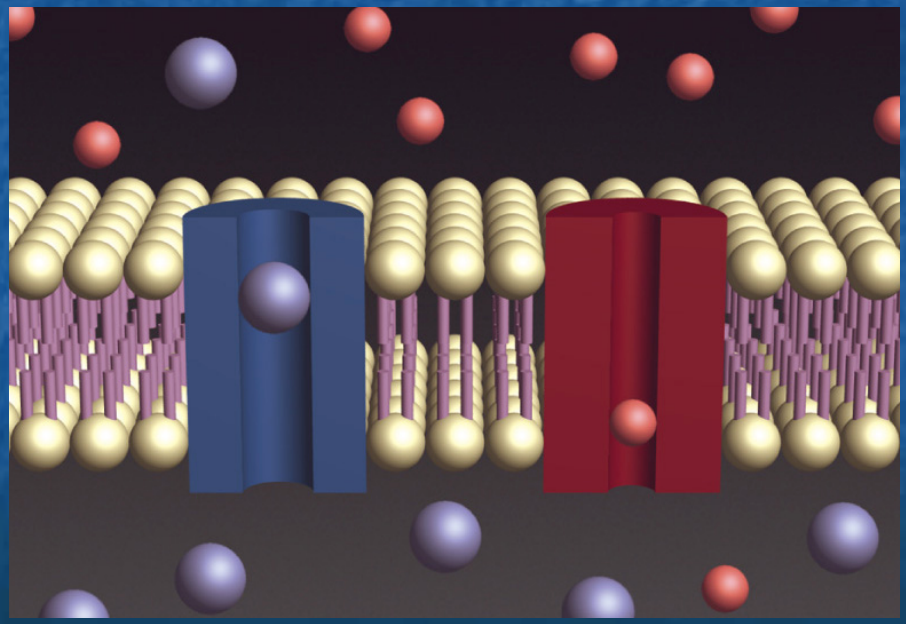
Aspects of analysis



neurons

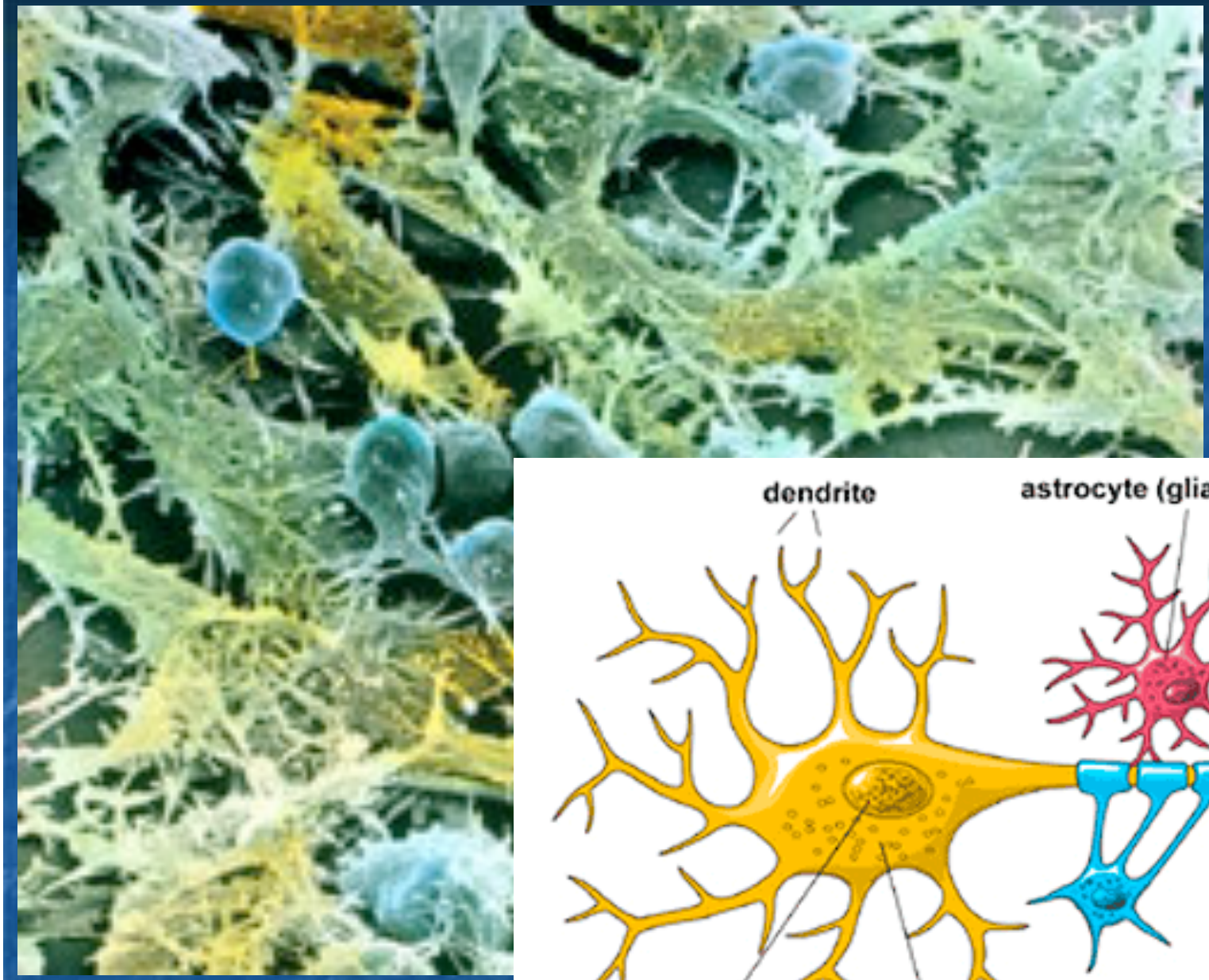


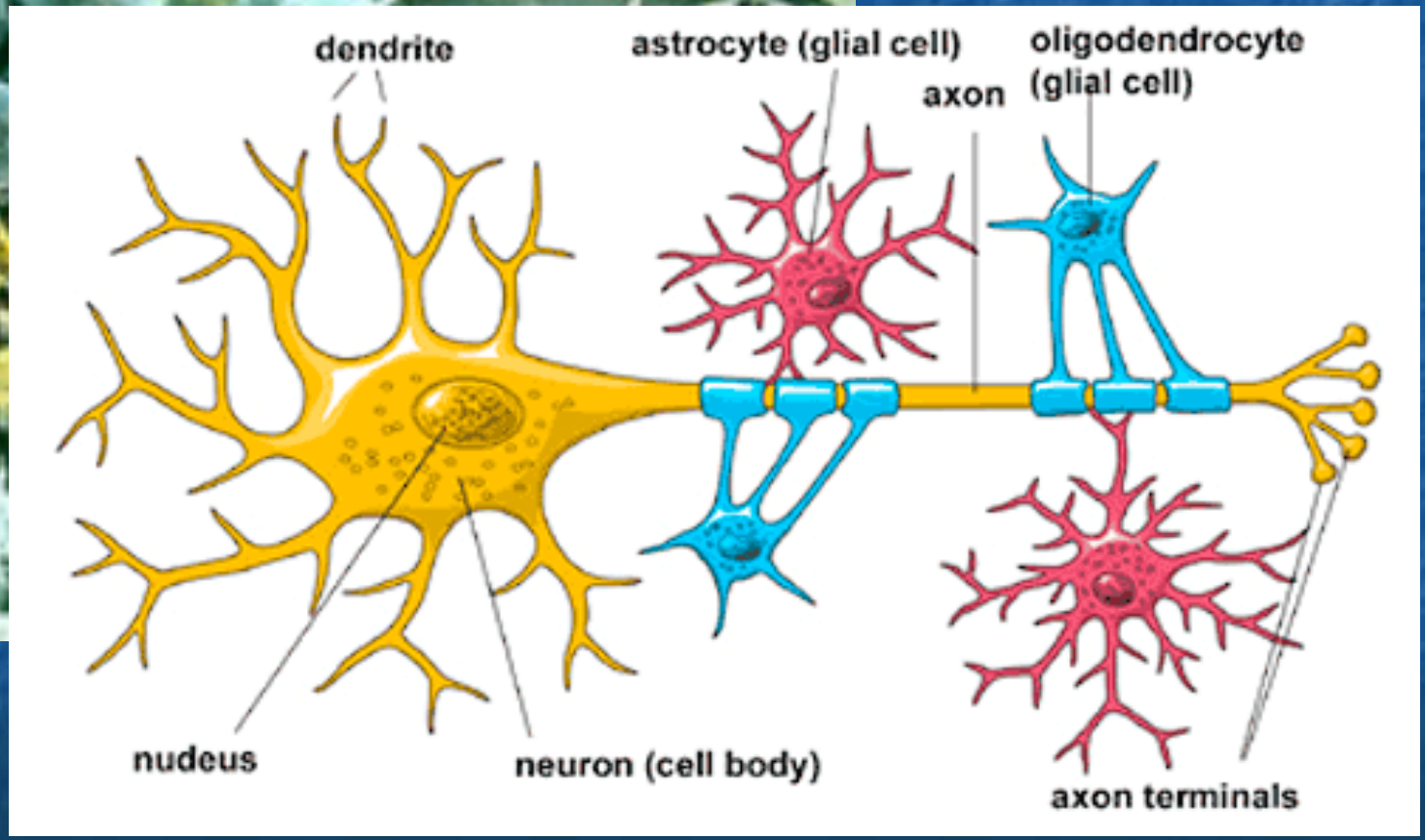
synapses



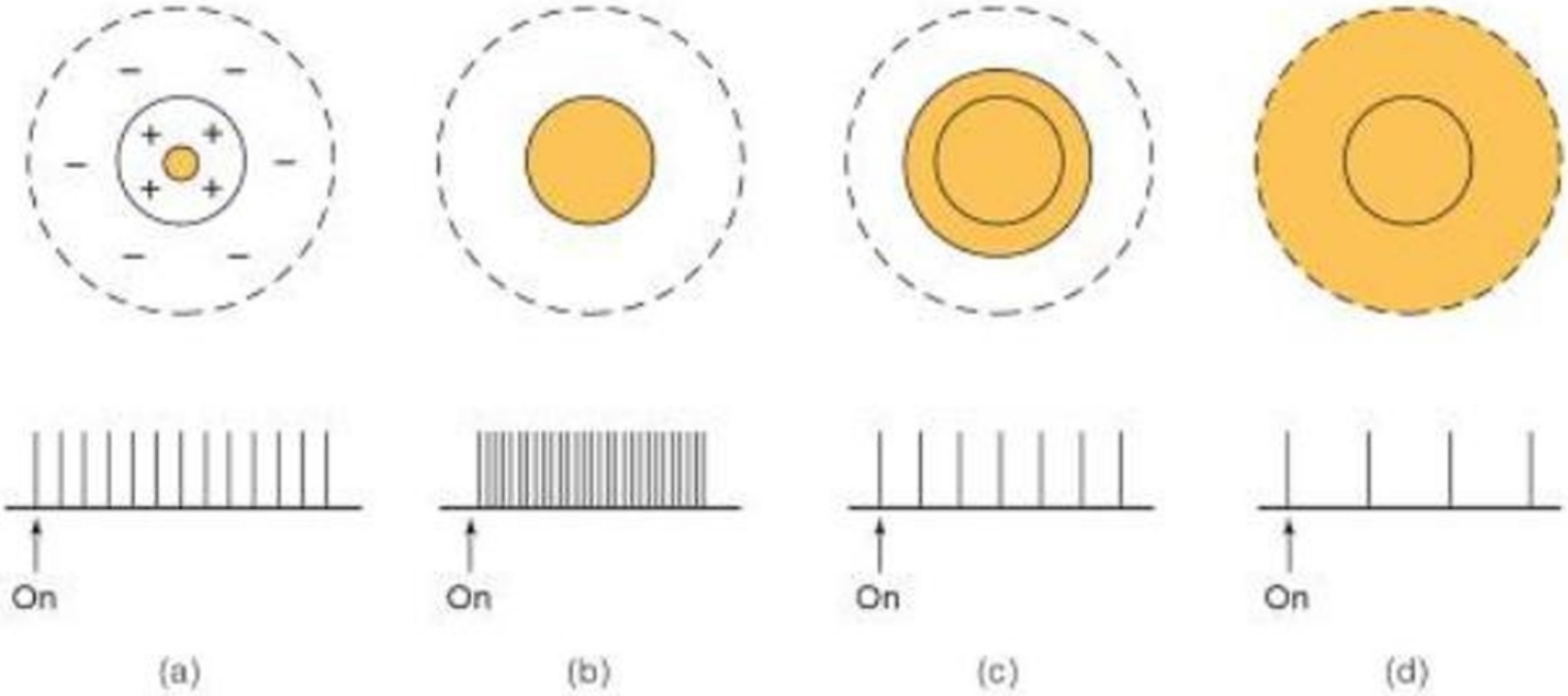
subcellular, molecular

Glial cells




dendrite
astrocyte (glial cell)
axon
oligodendrocyte
(glial cell)
nucleus
neuron (cell body)
axon terminals

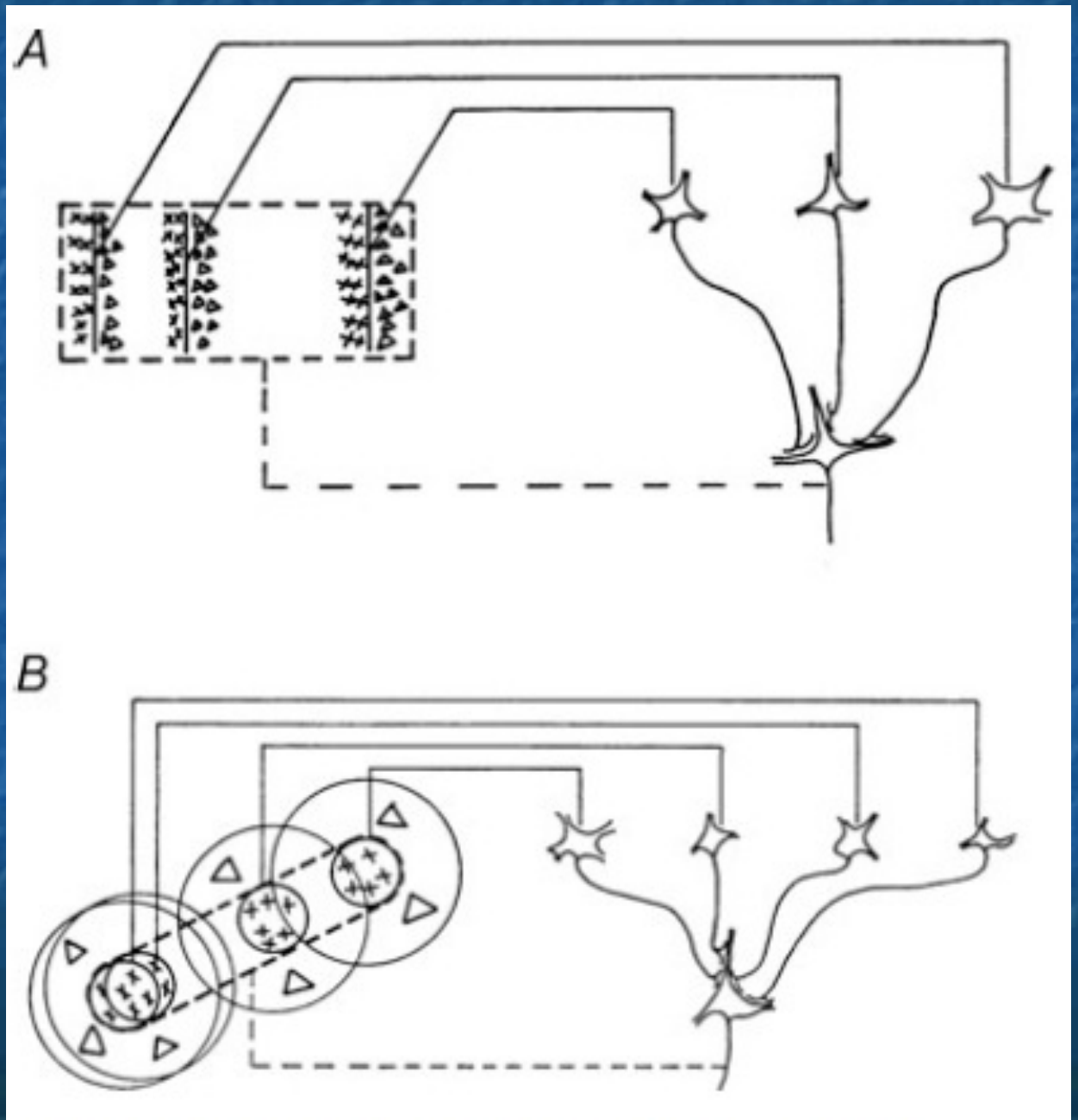
Centre-surround cells



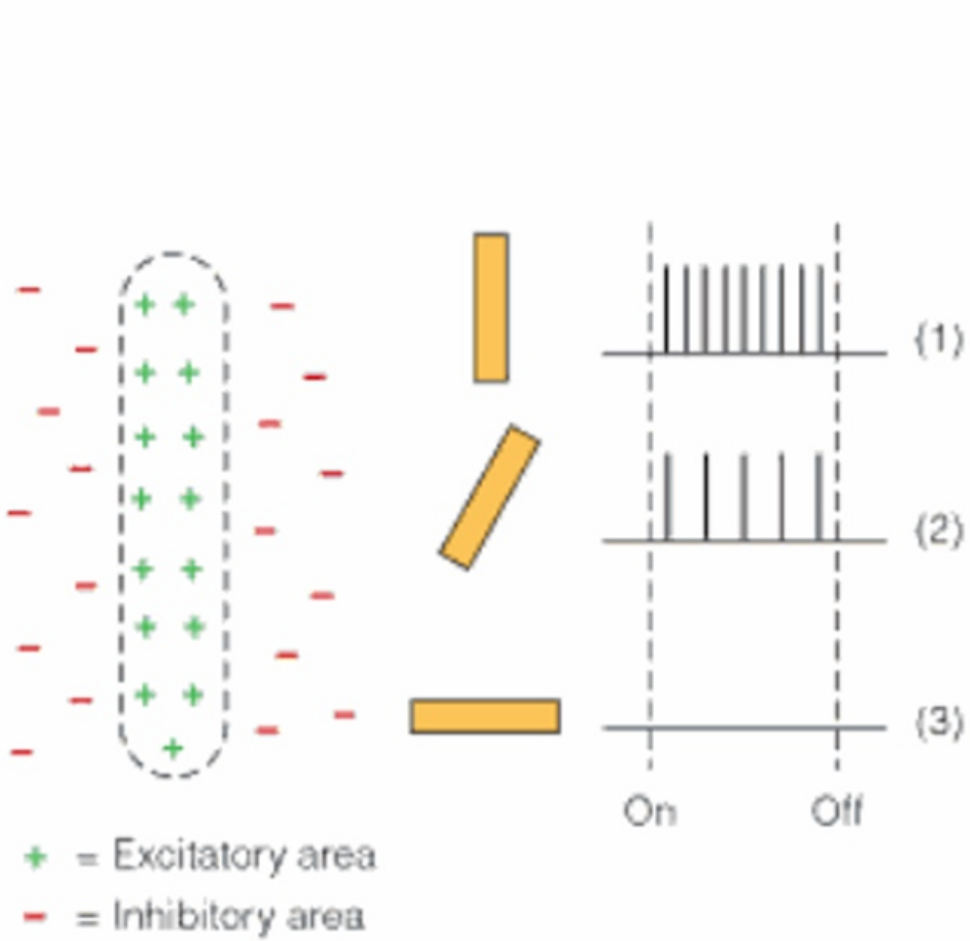
The emergence of receptive fields.

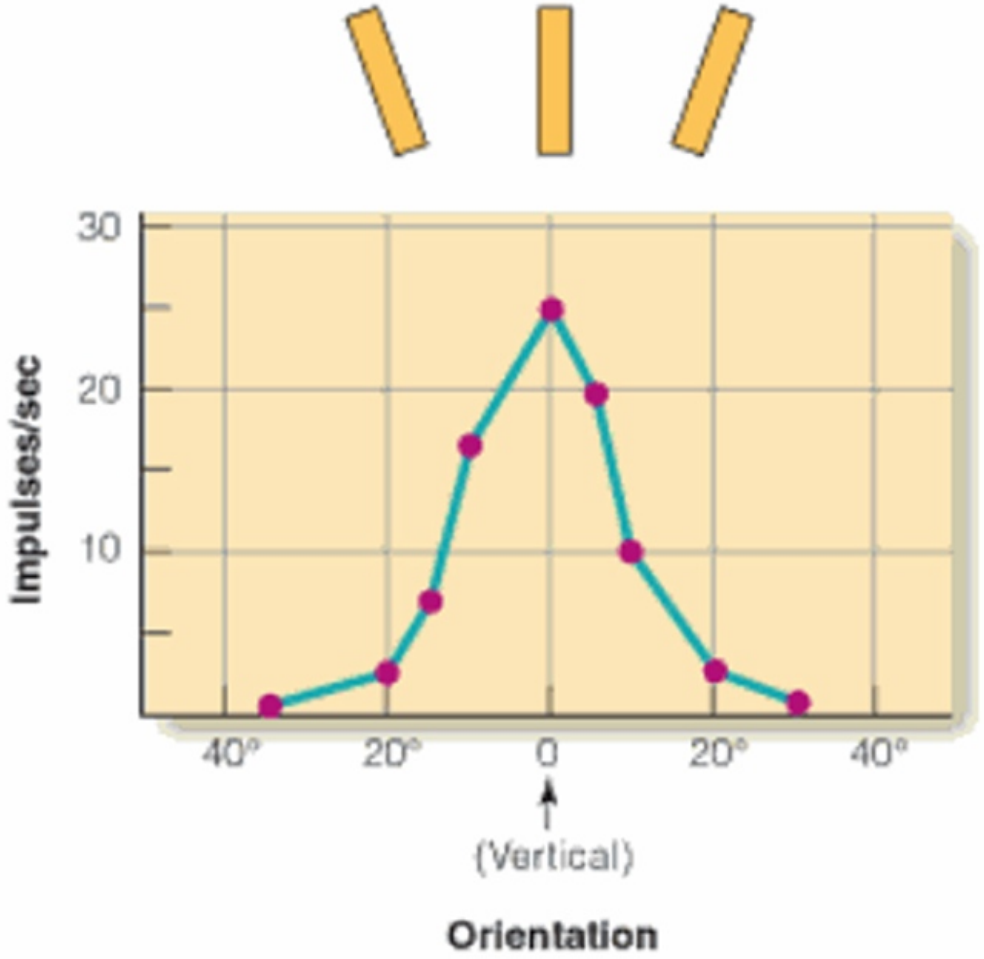
Complex cells from simple cells

Hubel & Wiesel (1962)



Tuning curve for an orientation detector



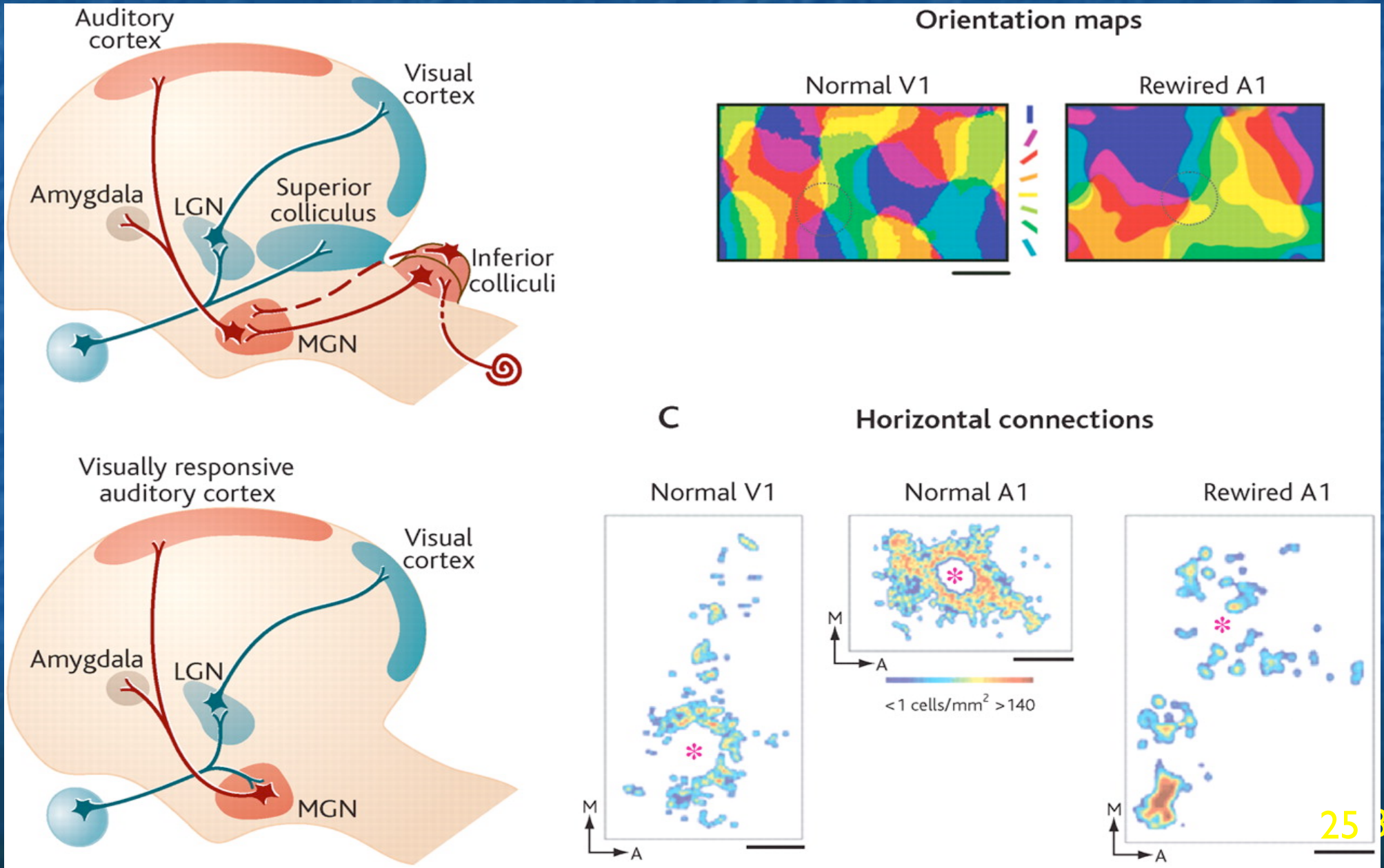


Hubel and Wiesel (1959)

How they did it ...

Cortical equipotentiality

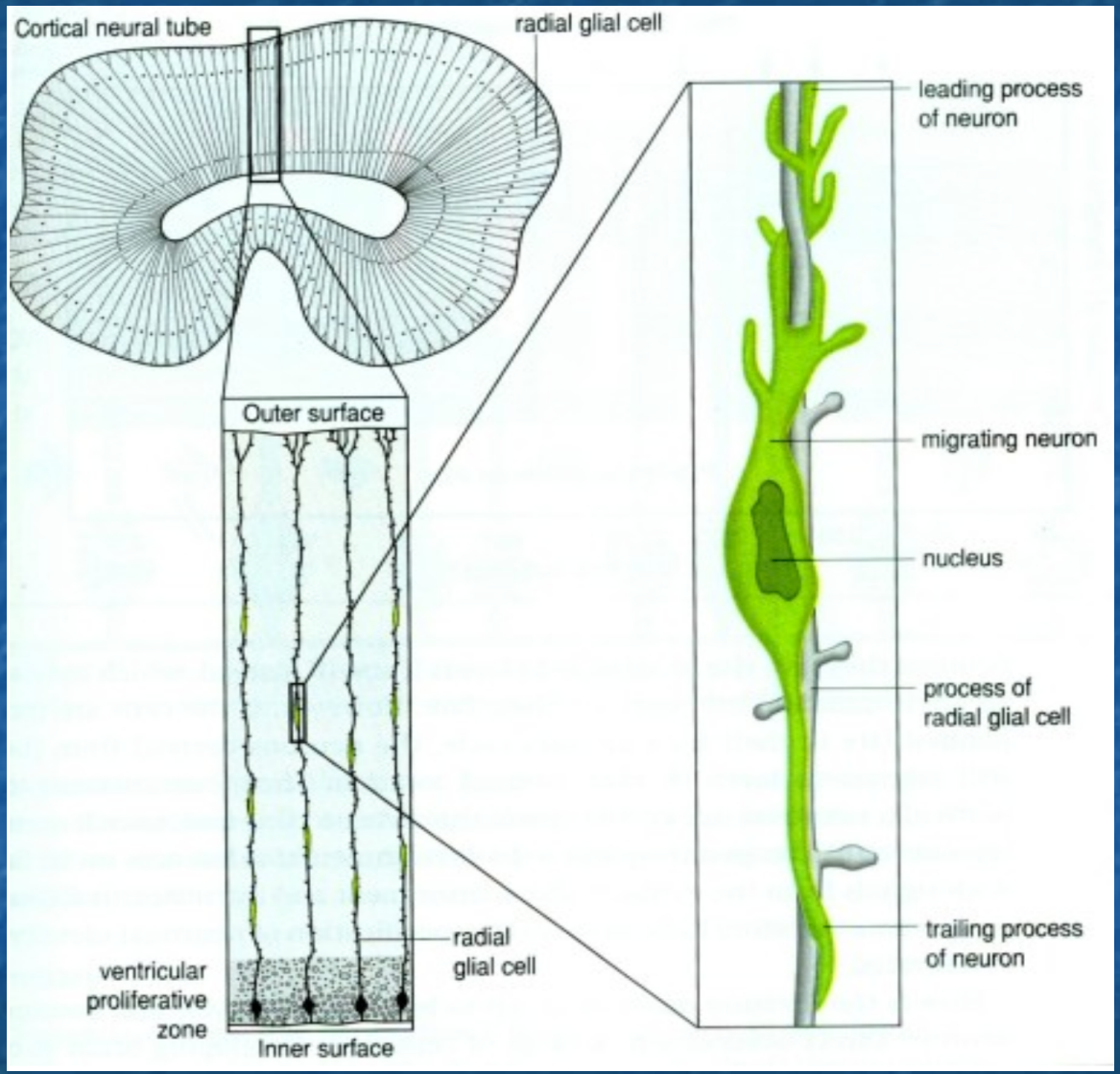
Sur, Garraghty & Roe (1988)



Cortical equipotentiality

There are complexities involving the signalling used to direct growing neurons to their optimal destinations and the role of activity.

There are implications for our understanding of causality.



Challenges

Can we think of all of this neural underpinning of vision in computational terms?

Can we begin to see how these aspects of the nervous system enable people to respond to the environment? (Active reflection of the world, not passive registering of information.)

Can we make the right abstractions so as to be able to model these processes on a computer and make artificial vision systems?

References

Land, M. F., & Fernald, R. D. (1992). The evolution of eyes. *Annual Review of Neuroscience*, *15*(1), 1-29.

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Hubel, D. H., & Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *The Journal of Physiology*, *160*(1), 106-154.

http://www.youtube.com/watch?v=IOHayh06LJ4

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