INF1-CG 2016
Lecture 21

Vision: computational aspects

Richard Shillcock

Today's goals

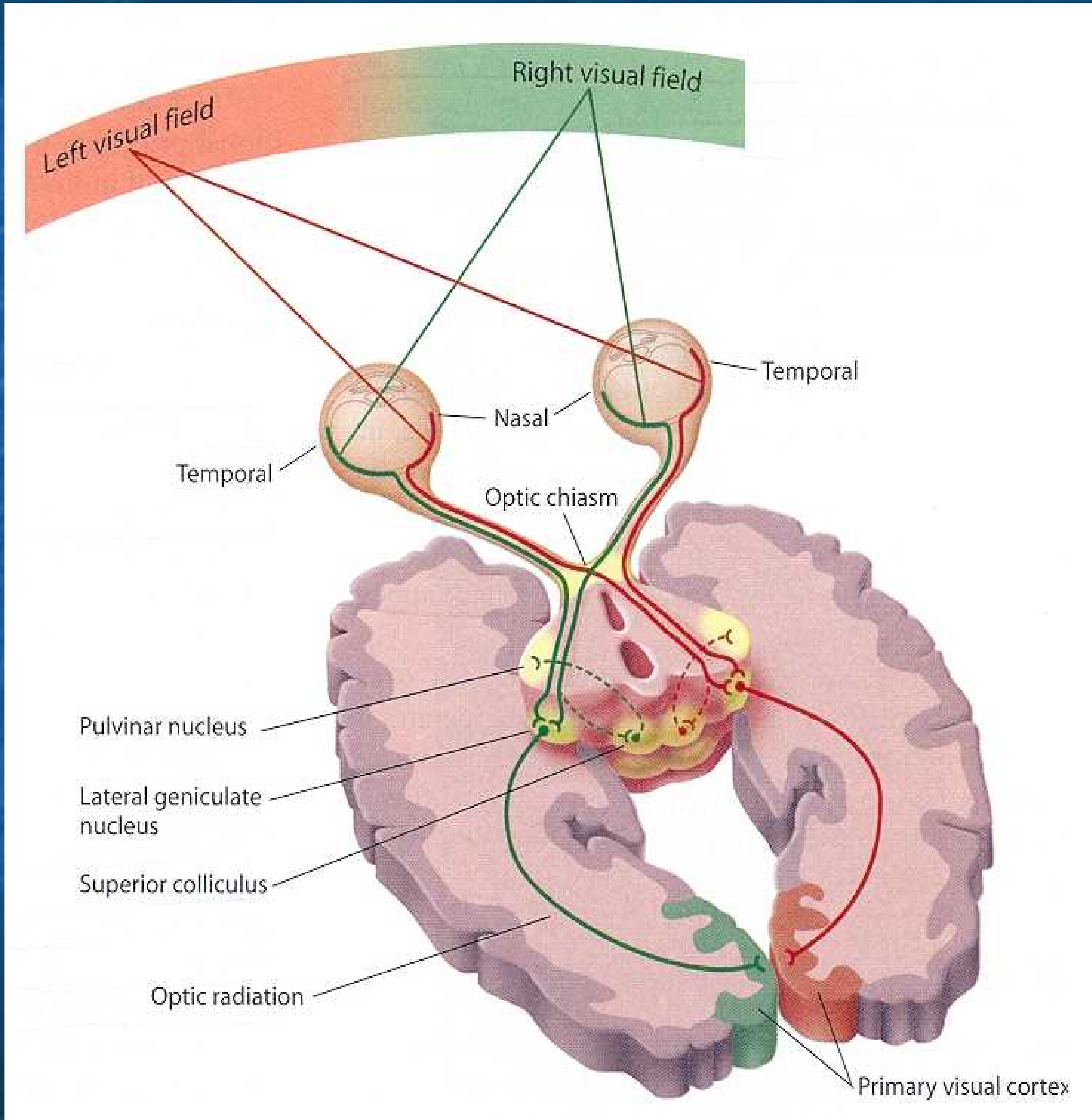
To explore some of the computational aspects of mapping from the visual world to the brain.

Today's readings

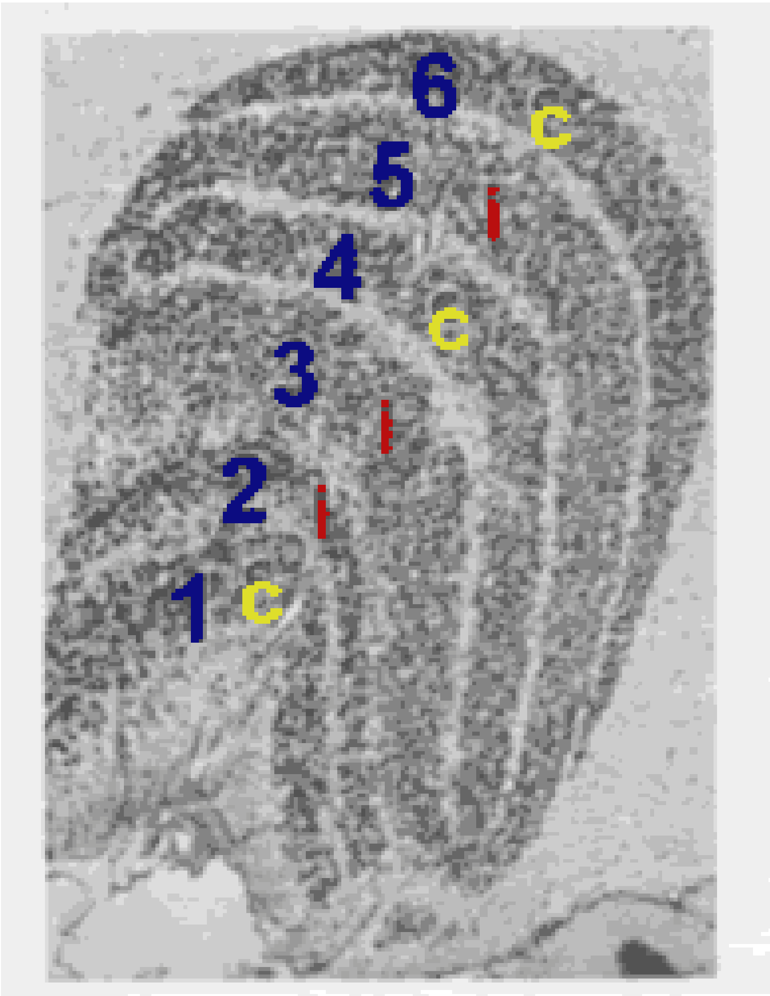
Hirsch, H. V., & Spinelli, D. N. (1971). Modification of the distribution of receptive field orientation in cats by selective visual exposure during development. *Experimental Brain Research*, *12*(5), 509-527.

Hubel, D. H., & Wiesel, T. N. (1963). Receptive fields of cells in striate cortex of very young, visually inexperienced kittens. *Journal of Neurophysiology*, *26*(6), 994-1002.

The visual pathways



Magno- and parvocellular pathways



lateral geniculate nucleus
(LGN)

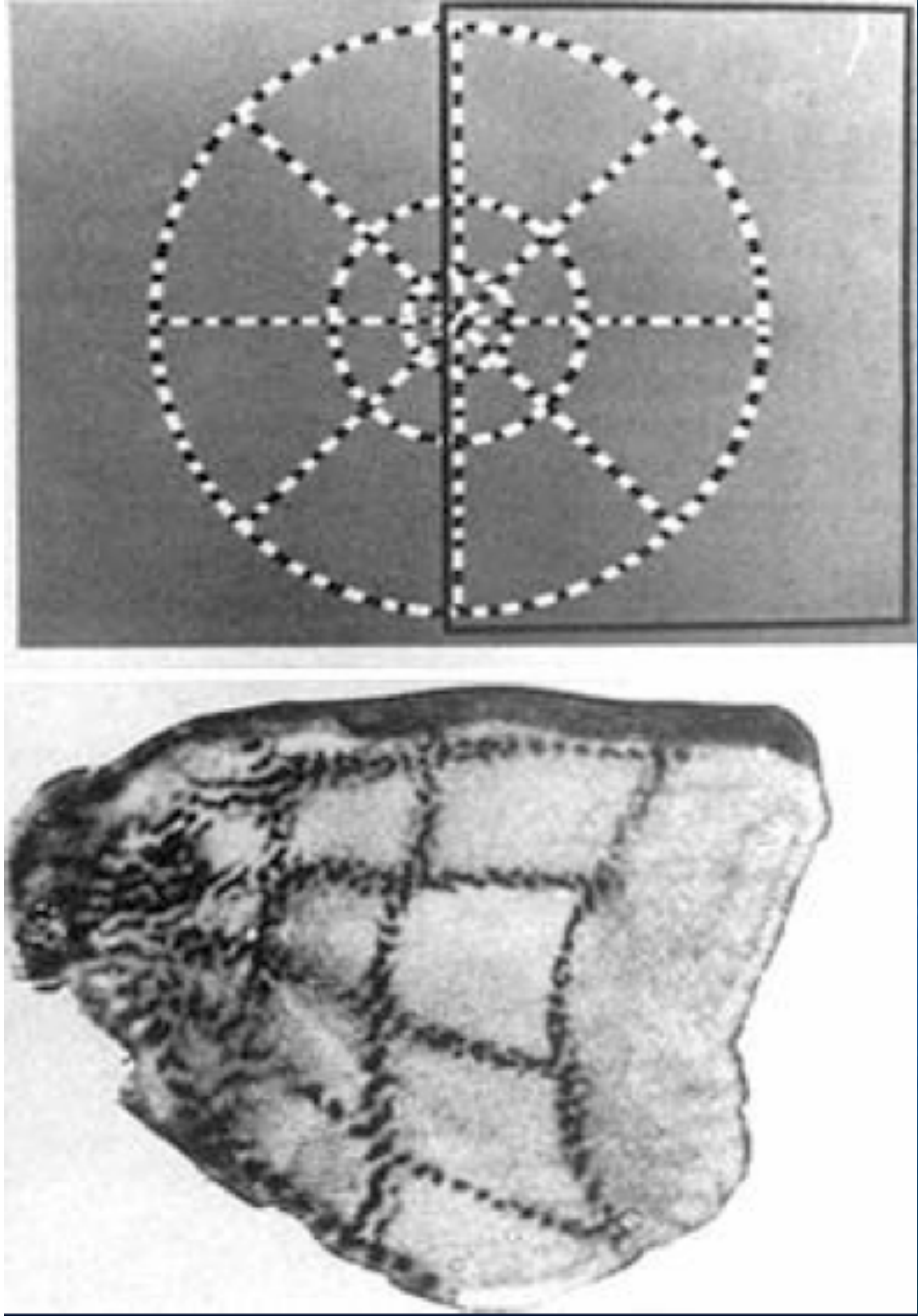
layers 1 and 2
- *magnocellular*

layers 3-6

- *parvocellular*

layers 2, 3 and 5
- *ipsilateral* eye

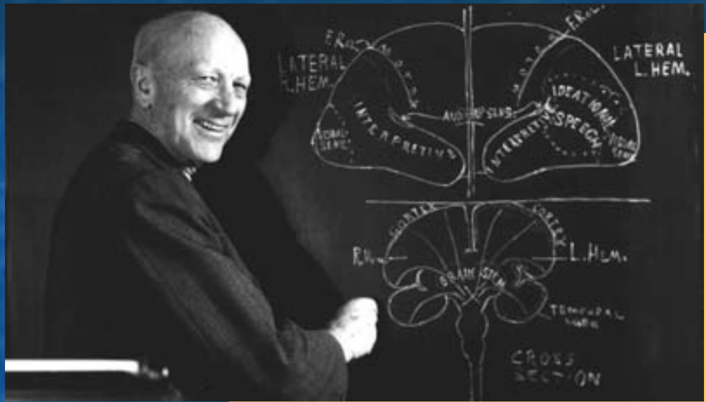
layers 1, 4 and 6
- *contralateral* eye

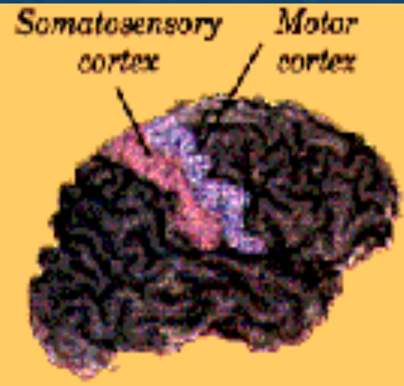


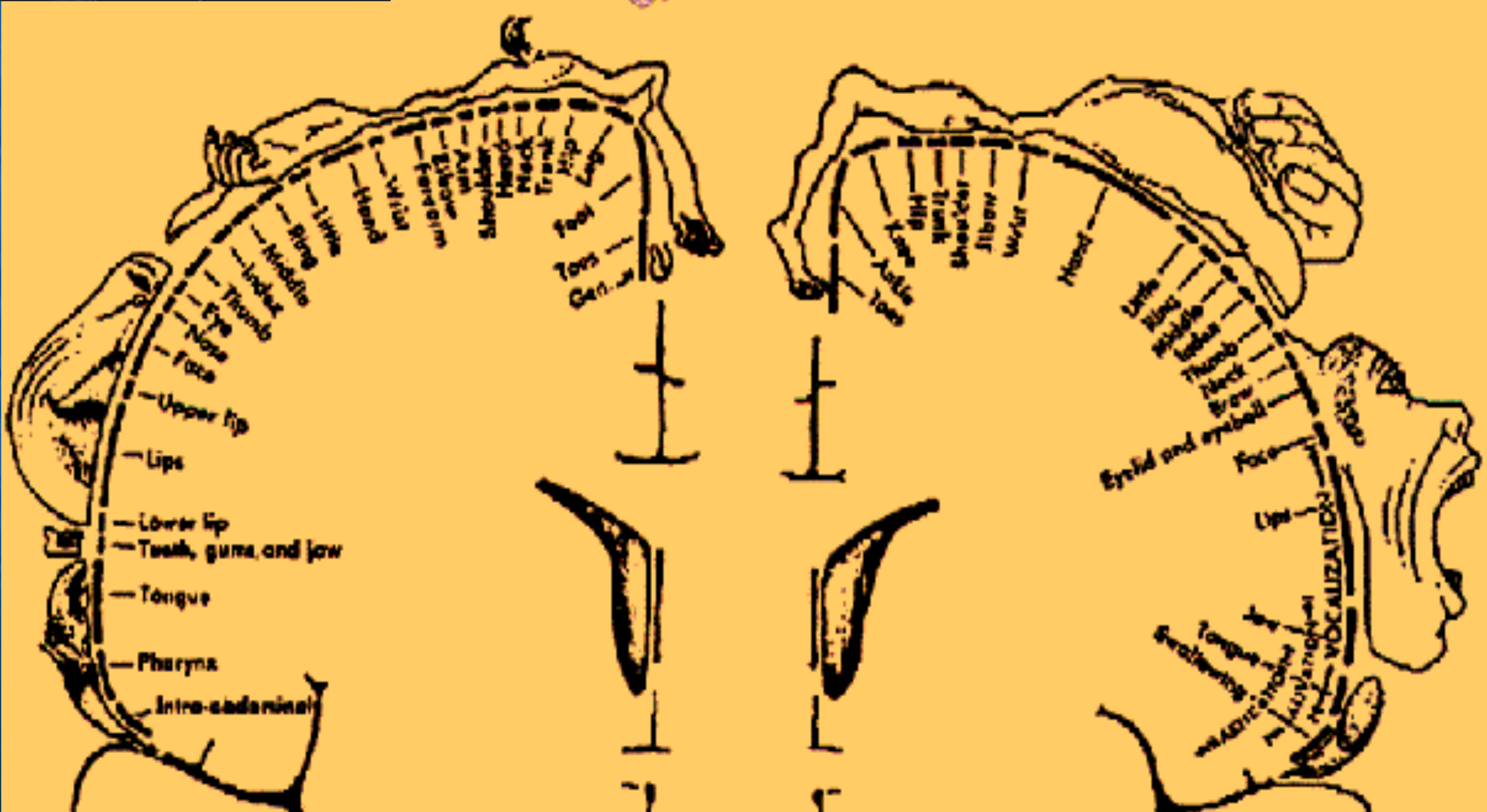
Topographic mapping

Stained V1 in the mouse, showing the areas that were activated by the visual stimulus. (Note also the cortical magnification of the fovea.)

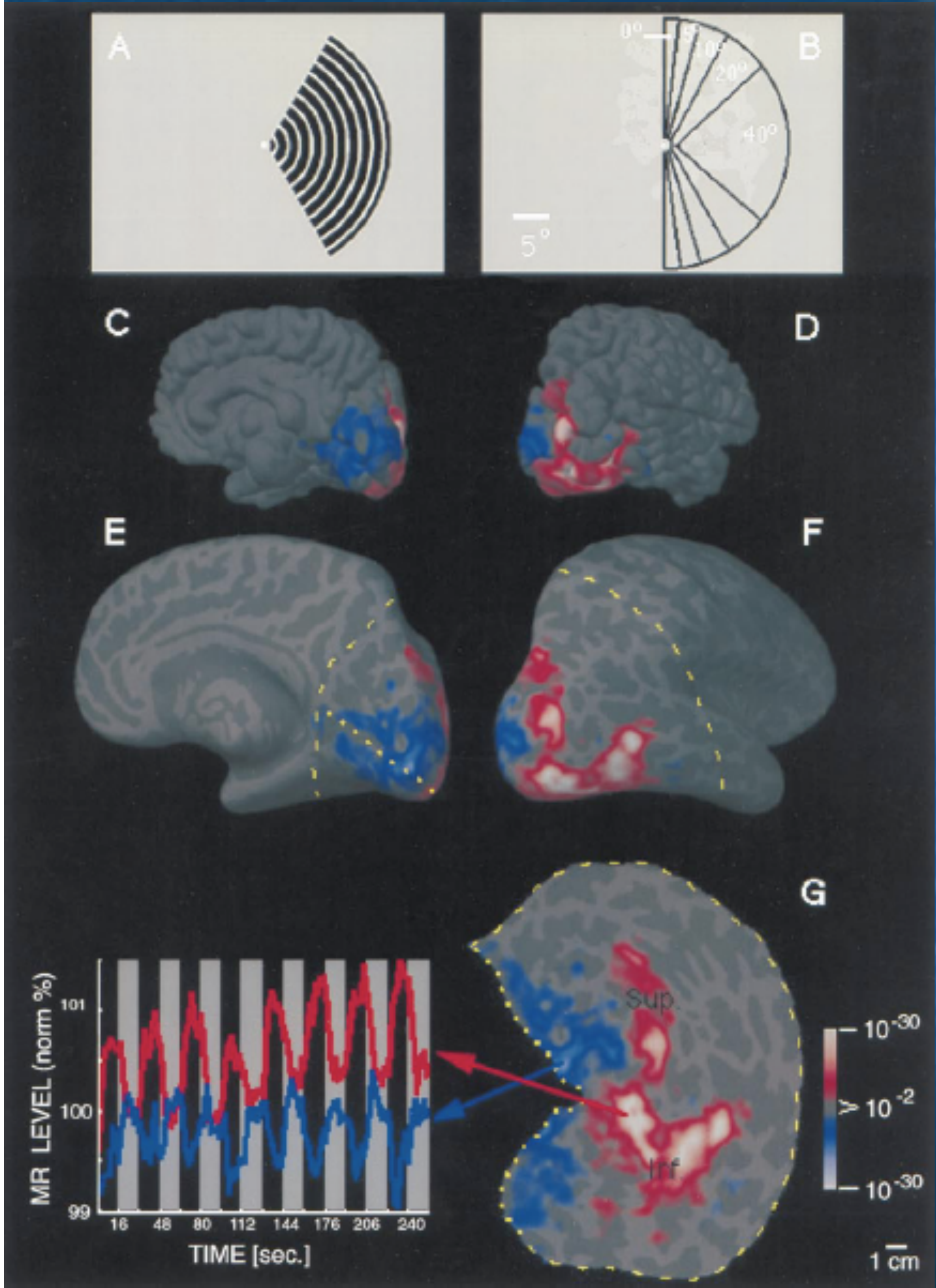
Systematicity: Penfield's homunculus







Visual topographic mapping



The higher visual areas become increasingly attuned to bigger receptive fields, with bilateral inputs (see, e.g., Tootell et al., 1998), and less clear retinotopic mapping.

Does the brain ever throw away information?

Systematicity

Systematicity is pervasive in the brain, most clearly nearer the sensorium. It is a way of importing relationships and larger-scale representation into the brain “for free”.

Vision as serving a purpose

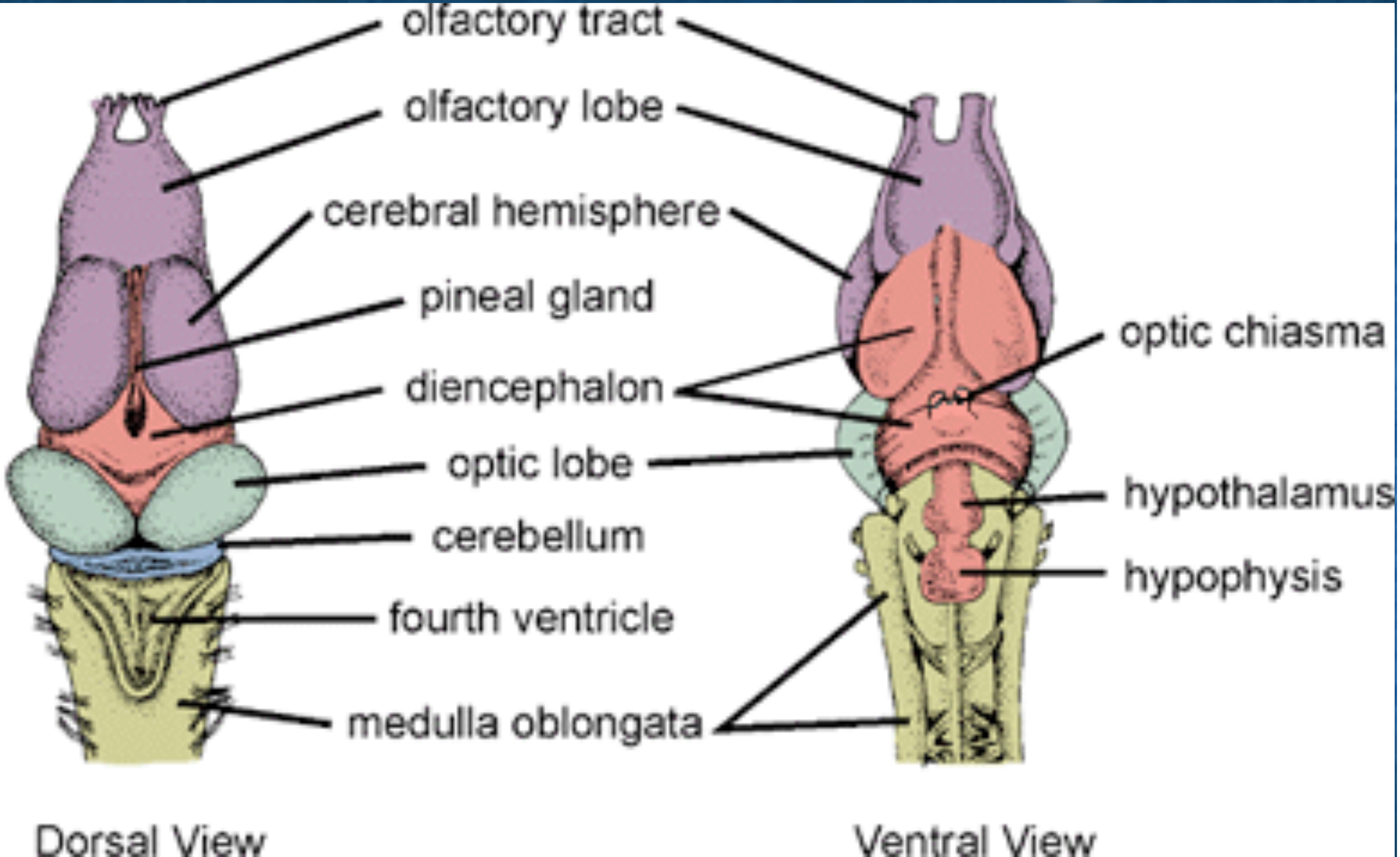
Ecological realism vs abstract stimuli

Pond-like backgrounds versus white backgrounds (Lettvin, Maturana, McCulloch, and Pitts).

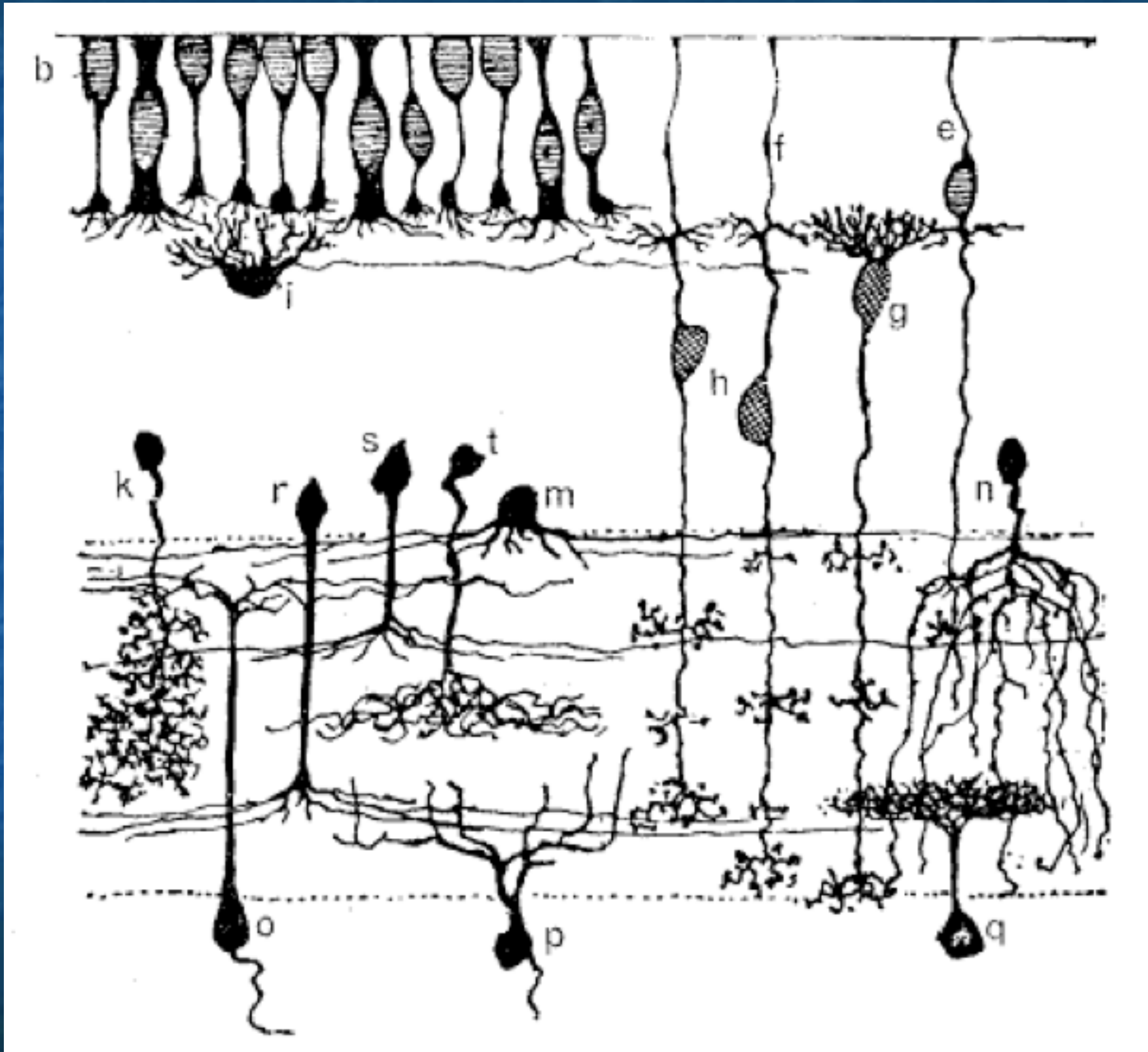
There's never a "null" context.

The risk of researching a technique; the assumptions become incorporated into the science in an invisible way.

The frog's brain



The frog's retina



What the frog's eye tells the frog's brain

Lettvin, Maturana, McCulloch & Pitts (1959)

Five types of ganglion cells – each a"feature detector".

Each is interested in an aspect of the environment.

Contrast detectors (light/dark in a small area).

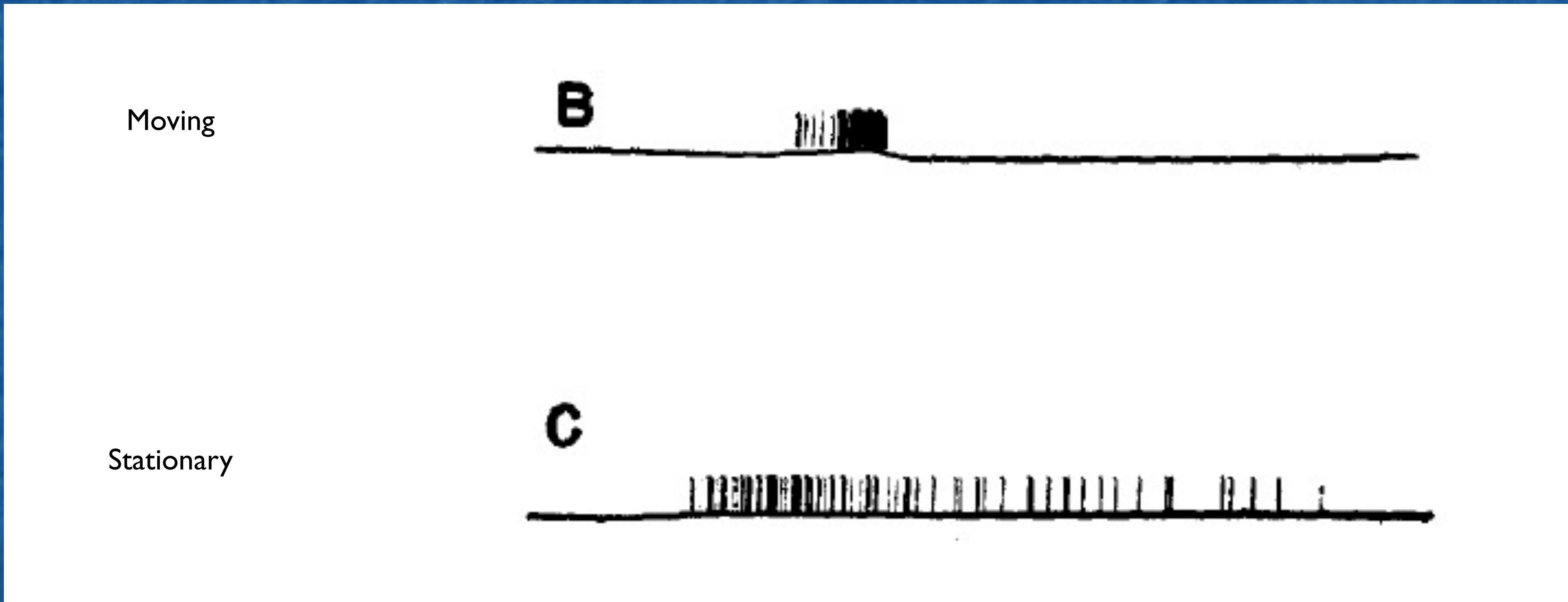
Convexity detectors (small, dark and moving).

Changing contrast detectors (moving edges).

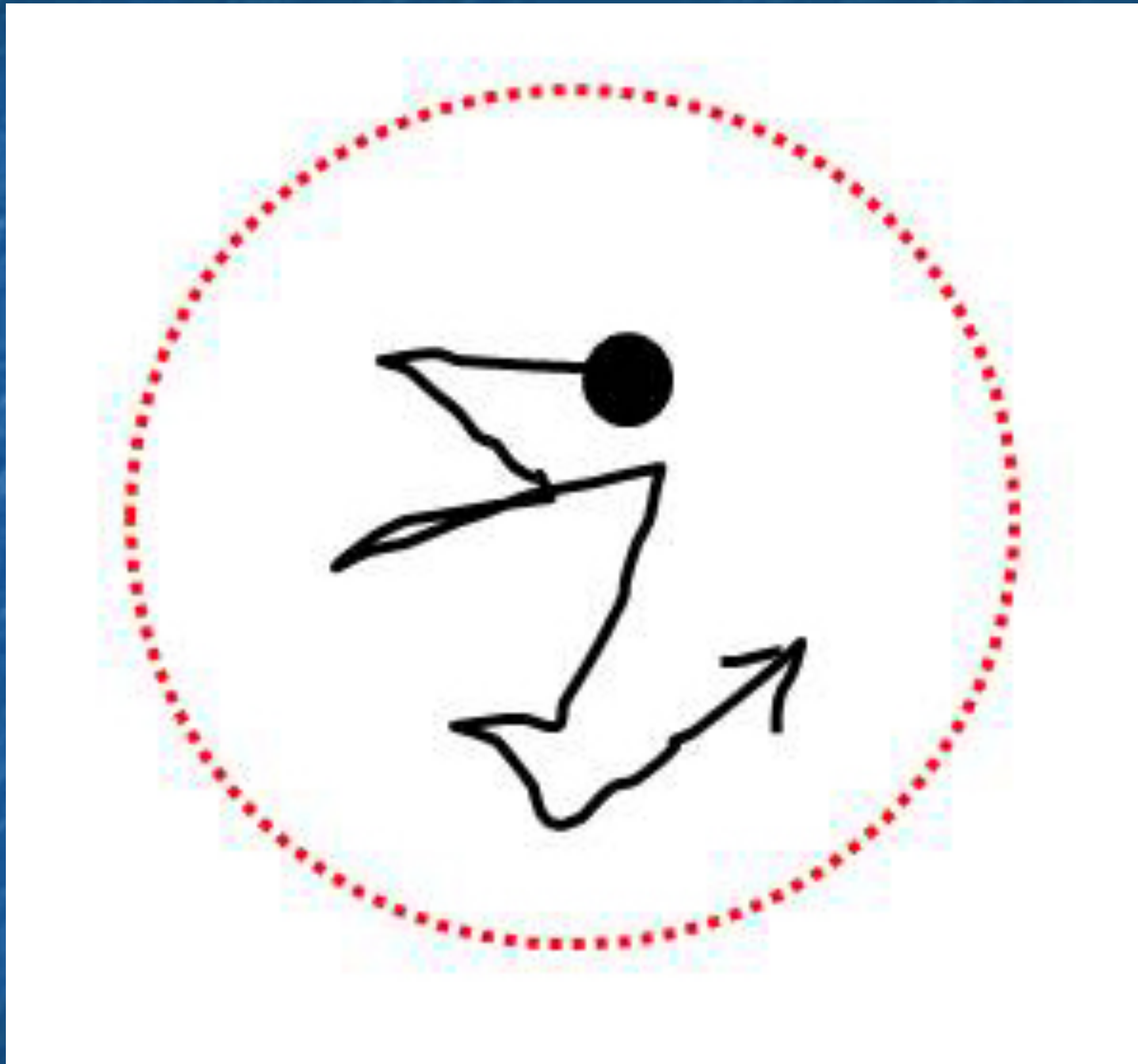
Dimming detectors (dimming from edge or centre of the visual field)

Dark detectors (overall light intensity)

The frog's visual world



Convexity detection



The frog's visual world

Perception, 1981, volume 10, pages 421 – 422

The frog ganglion cell: not a feature detector and not a monkey cortical cell

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Received 3 March 1981

There are two fundamental misconceptions about frog ganglion cells that have been perpetuated in most recent textbooks. A large number of texts written for courses on perception, S and P, and physiological psychology use the frog ganglion cell as an example, par excellence, of a feature detector. Many go further and compare the processing done in the frog retina with that carried out in the cat and monkey cortex. The truth is, the properties of the frog's ganglion cells have *never* fitted the generally accepted definitions of a feature detector. Further, their response properties have recently been shown to be similar to those of other vertebrate ganglion cells.

As generally used the term 'feature dectector' refers to a cell that is most sensitive

Looking further into amphibian vision

"Together, our results indicate that the salamander retina uses a population code in which every point in visual space is represented by multiple neurons with subtly different visual sensitivities" Segev et al. (2006).

We see a history of progress through reinterpretation. New analyses subsume earlier ones and introduce new concepts.

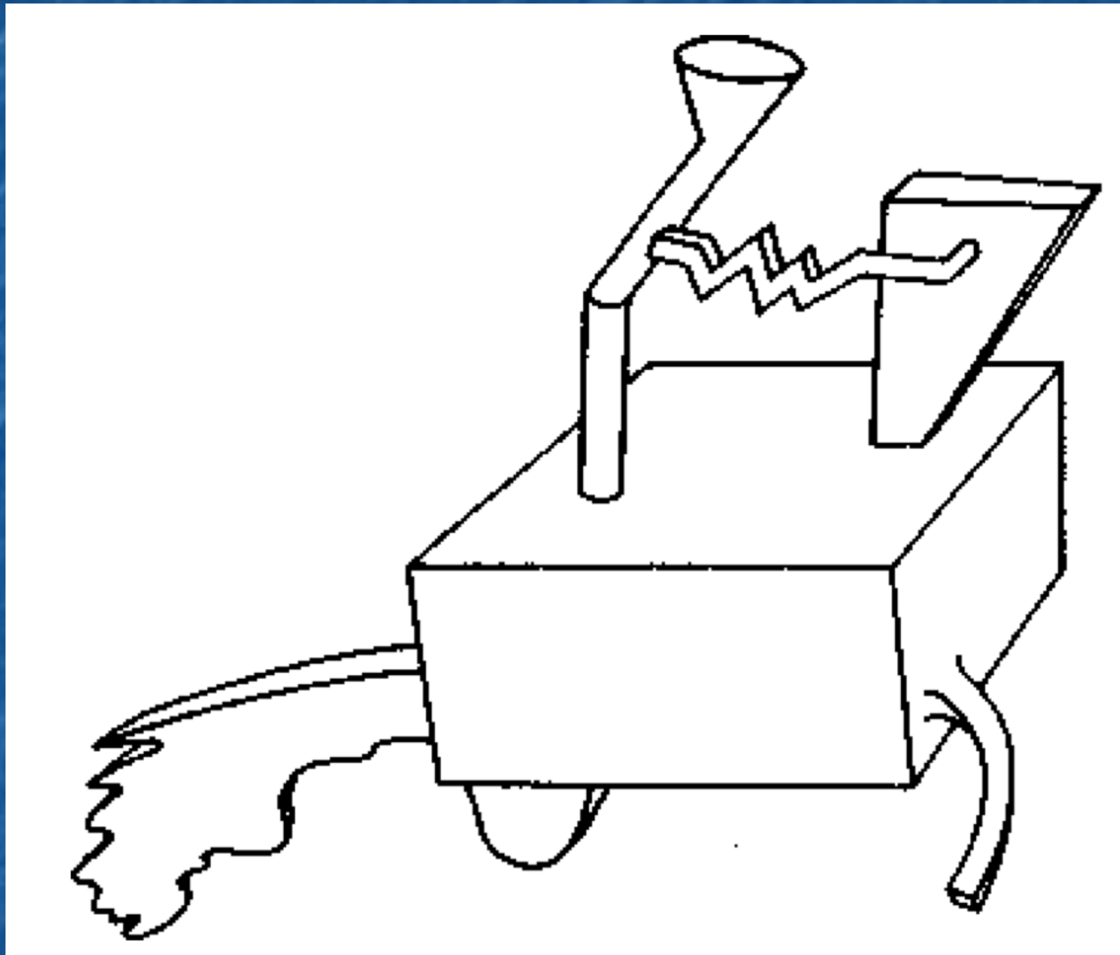
Vision as object recognition

The task becomes one of identifying invariant features.

Vision as search

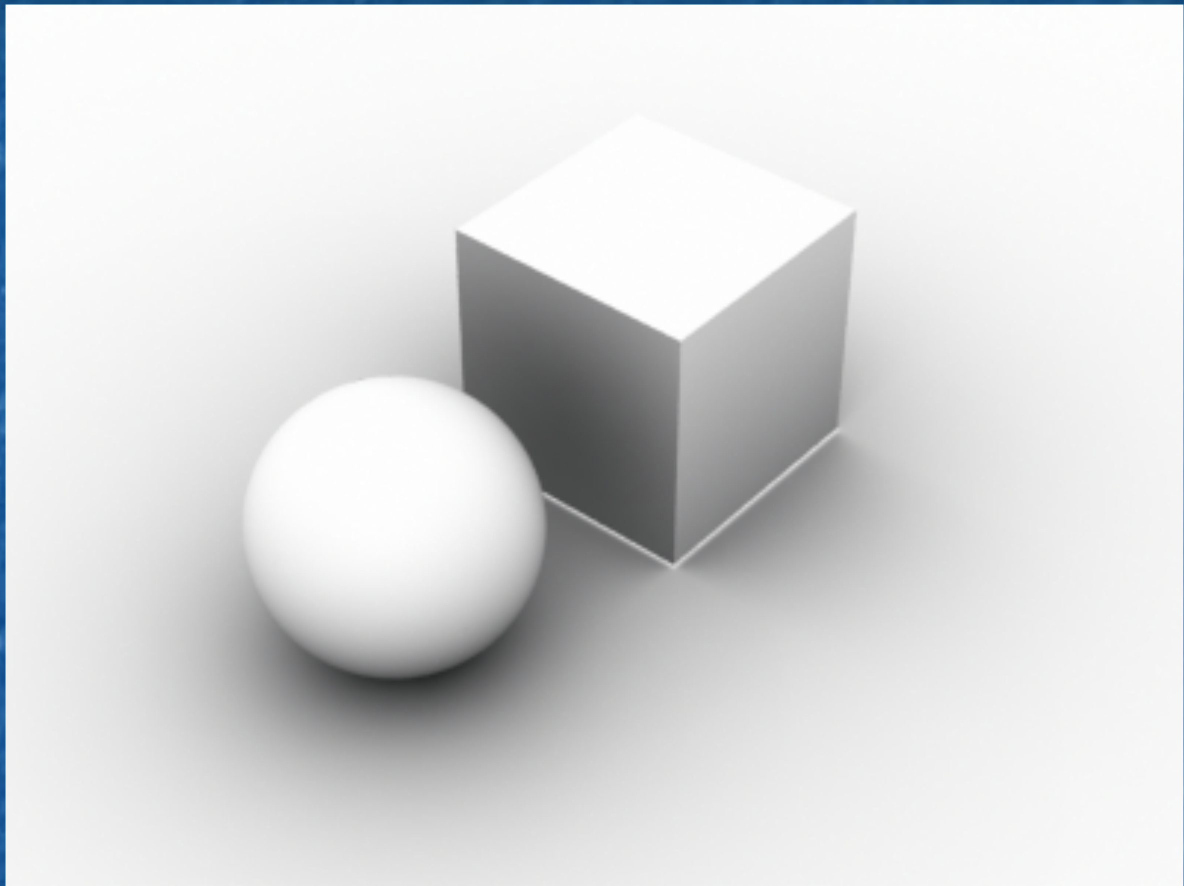
The task becomes one of looking for objects.

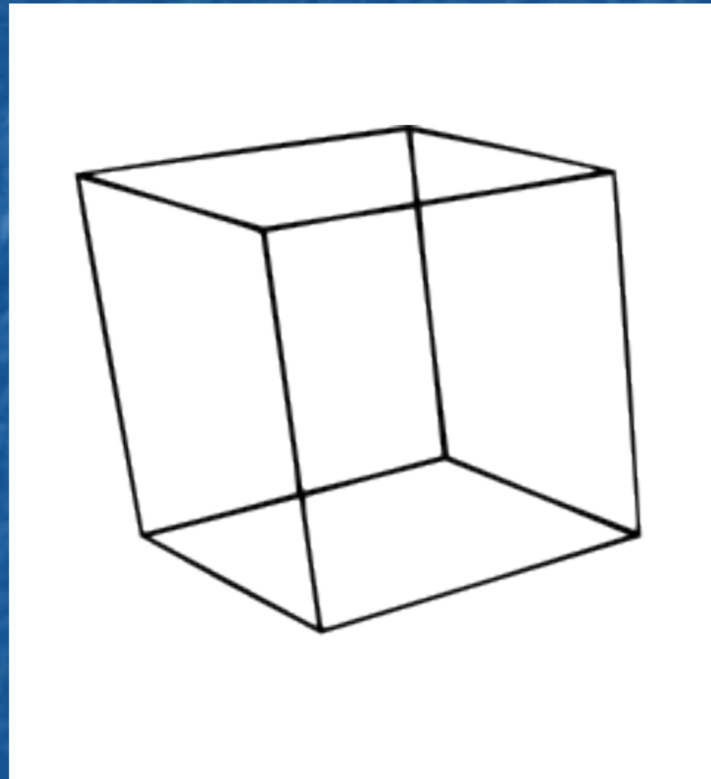
Recognition by components
Biederman (1987)



There is clear agreement on the parts that (some) things contain.

Recognition as parsing

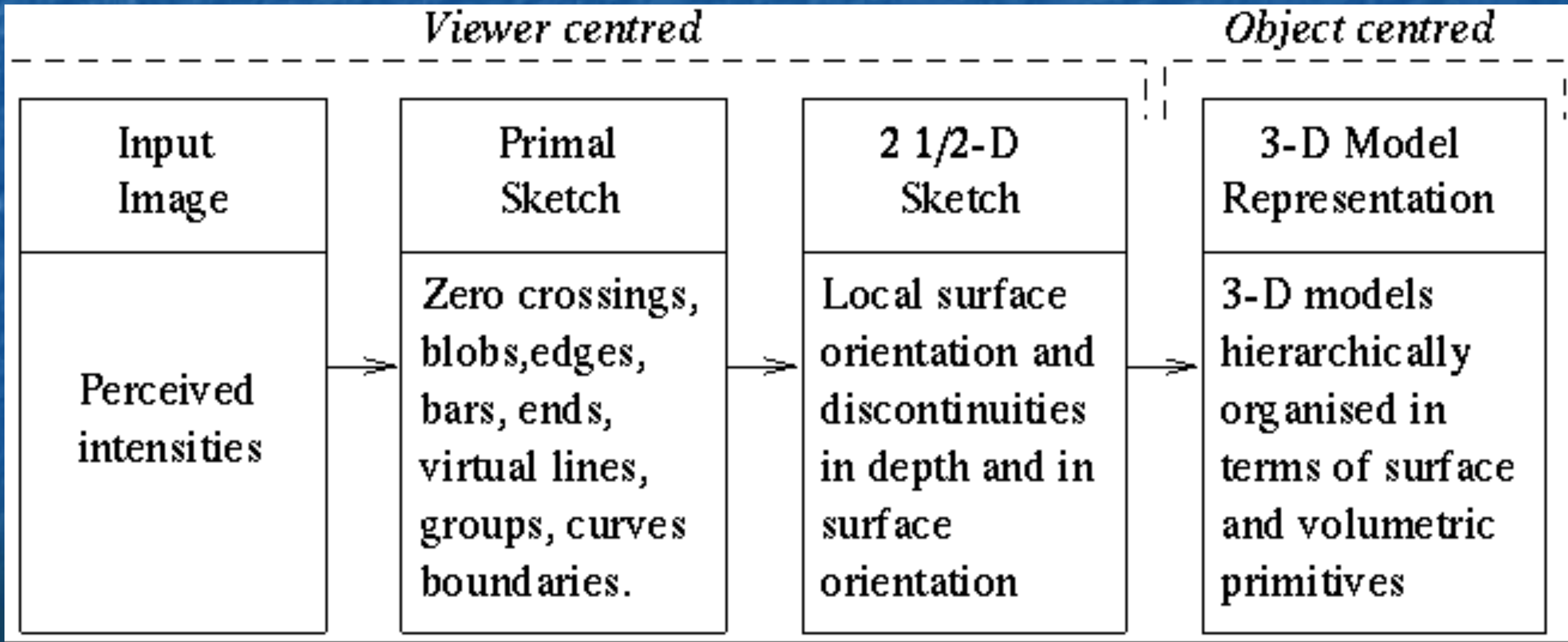




Is something like *syntax* going on? – Combining invariances in a rule-governed way.

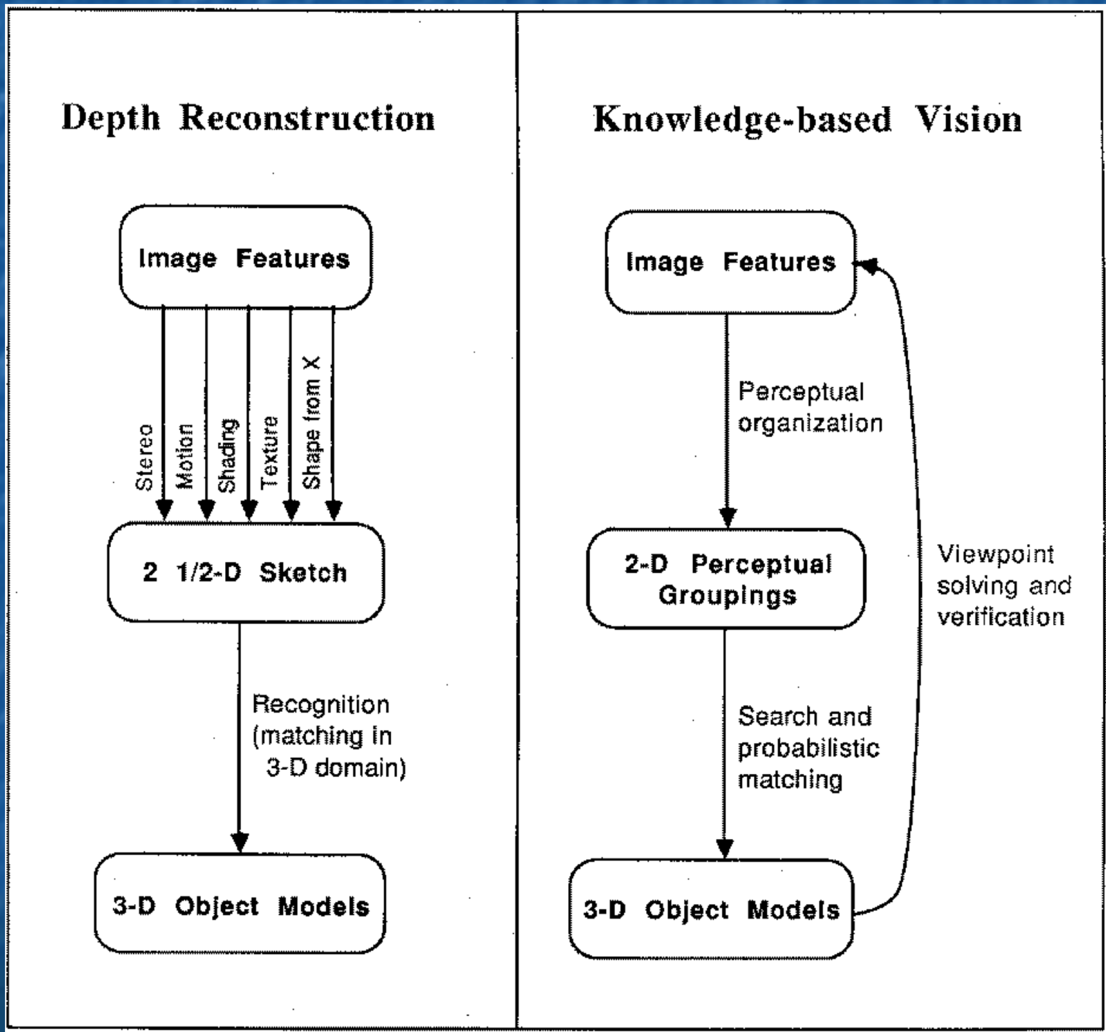
Marr's approach

Is it correct to try and "start simple and work up from there"?



Marr's approach

Building bottom-up *versus* building top-down.



Edges *versus* surfaces
Biederman & Ju (1988)

Naming and verification tasks showed no difference between photographs and cartoons.

The importance of edges
Hochberg & Brooks (1962)

A 19-month old boy had previously only learned to name toys and other objects.

He was given line drawings of known objects.

There was no evidence of learning being required.

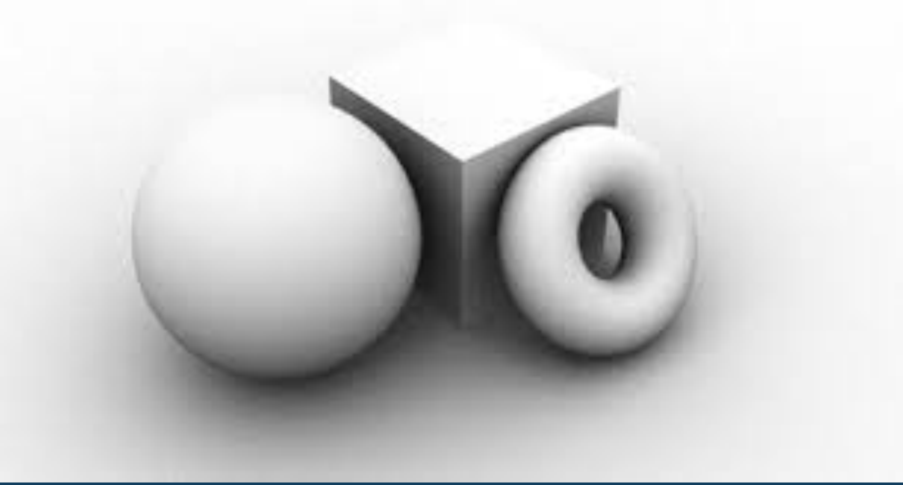
Is *simplicity* really the answer?

Complexity and situatedness

movement parallax

binocularity

light source



Challenges

Understand the relationship between objects, activity and whole scenes.

Decide how much we wish to base artificial systems on human cognition.

Appreciate the relationship between “clever” syntax-like solutions and “dumb” brute-force solutions.

(Never be satisfied with one-or-the-other binary choices.)

References

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Biederman, I. (1987). Recognition-by-components: a theory of human image understanding. *Psychological Review*, *94*(2), 115-147.

Biederman, I., & Ju, G. (1988). Surface versus edge-based determinants of visual recognition. *Cognitive Psychology*, *20*(1), 38-64.

Hochberg, J., & Brooks, V. (1962). Pictorial recognition as an unlearned ability: A study of one child's performance. the american *Journal of Psychology*, *75*(4), 624-628.

Lowe, D. G. (1987). Three-dimensional object recognition from single two-dimensional images. *Artificial Intelligence*, *31*(3), 355-395.

Segev, R., Puchalla, J., & Berry, M. J. (2006). Functional organization of ganglion cells in the salamander retina. *Journal of Neurophysiology*, *95*(4), 2277-2292.

Lettvin, J. Y., Maturana, H. R., McCulloch, W. S., & Pitts, W. H. (1959). What the frog's eye tells the frog's brain. *Proceedings of the IRE*, *47*(11), 1940-1951.