Module # 5—Summing Up

Visual Perception and the Brain

DUKE INSTITUTE *for* BRAIN SCIENCES

Topic 1. Alternative Conceptions of Vision

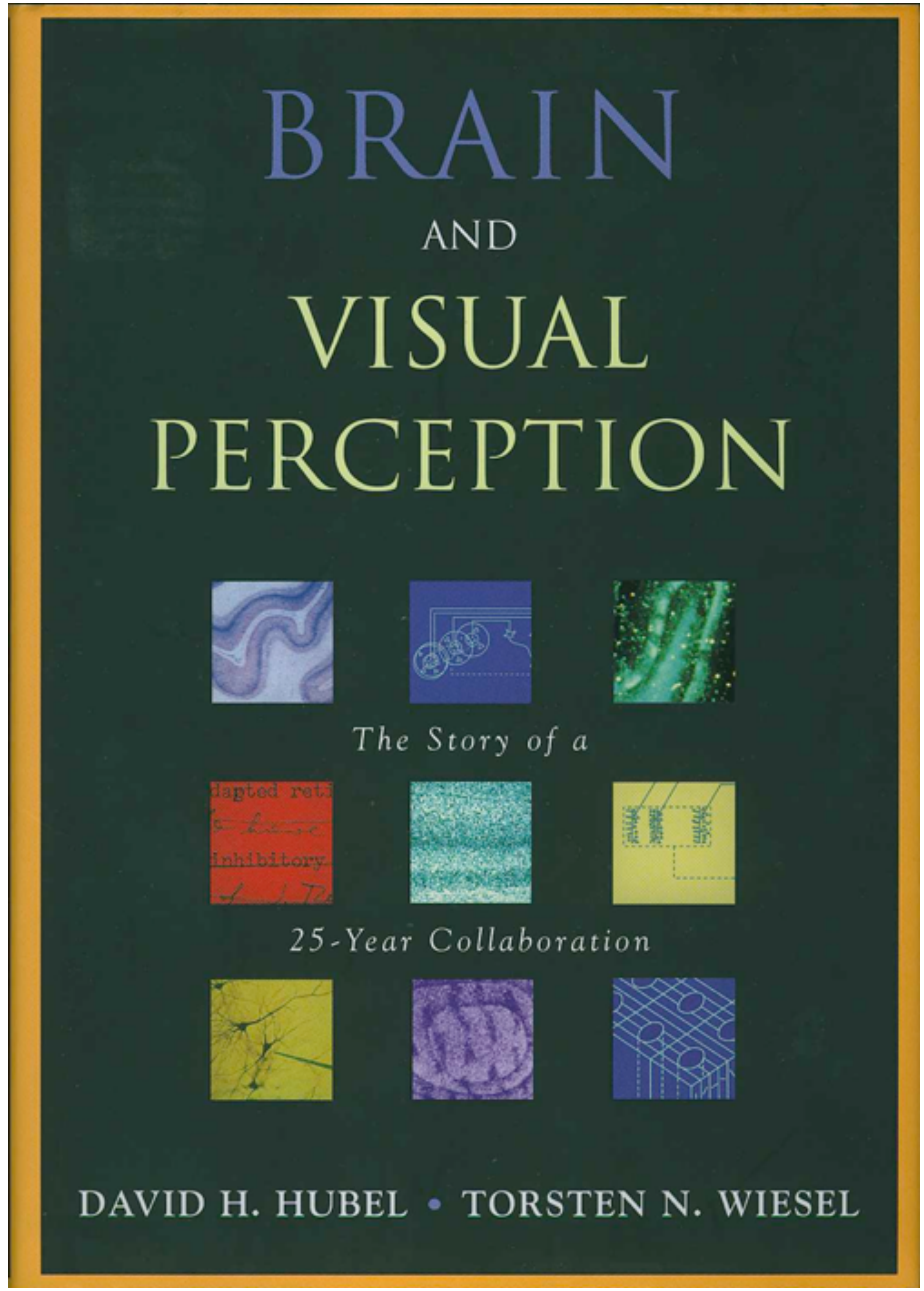
Lesson 1. Some Plausible Alternatives

The Alternatives

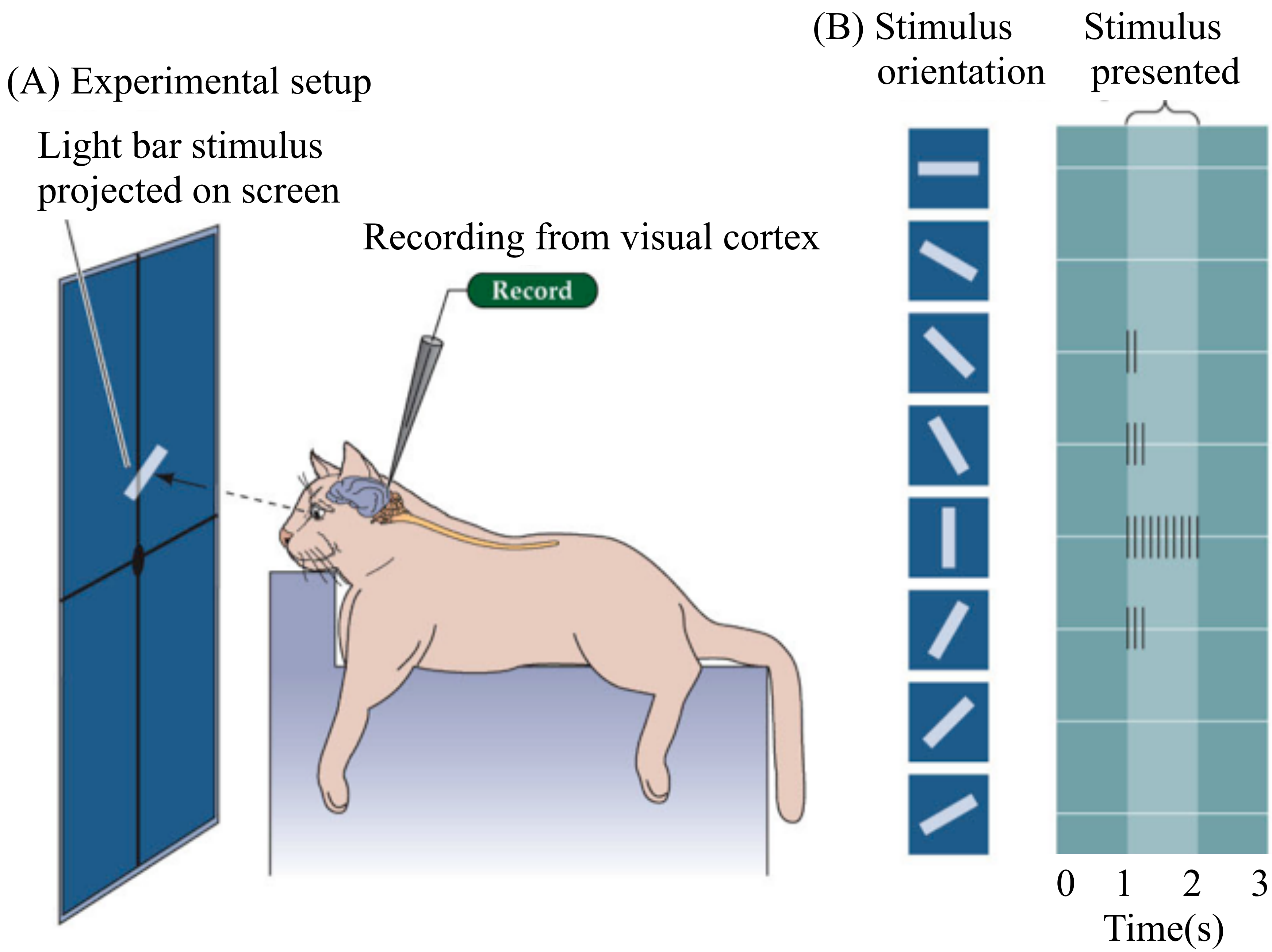
- Feature detection
- Vision as inference
- Vision as efficient coding
- Vision as a way of contending with the inverse problem

Lesson 2. Vision as Feature Detection

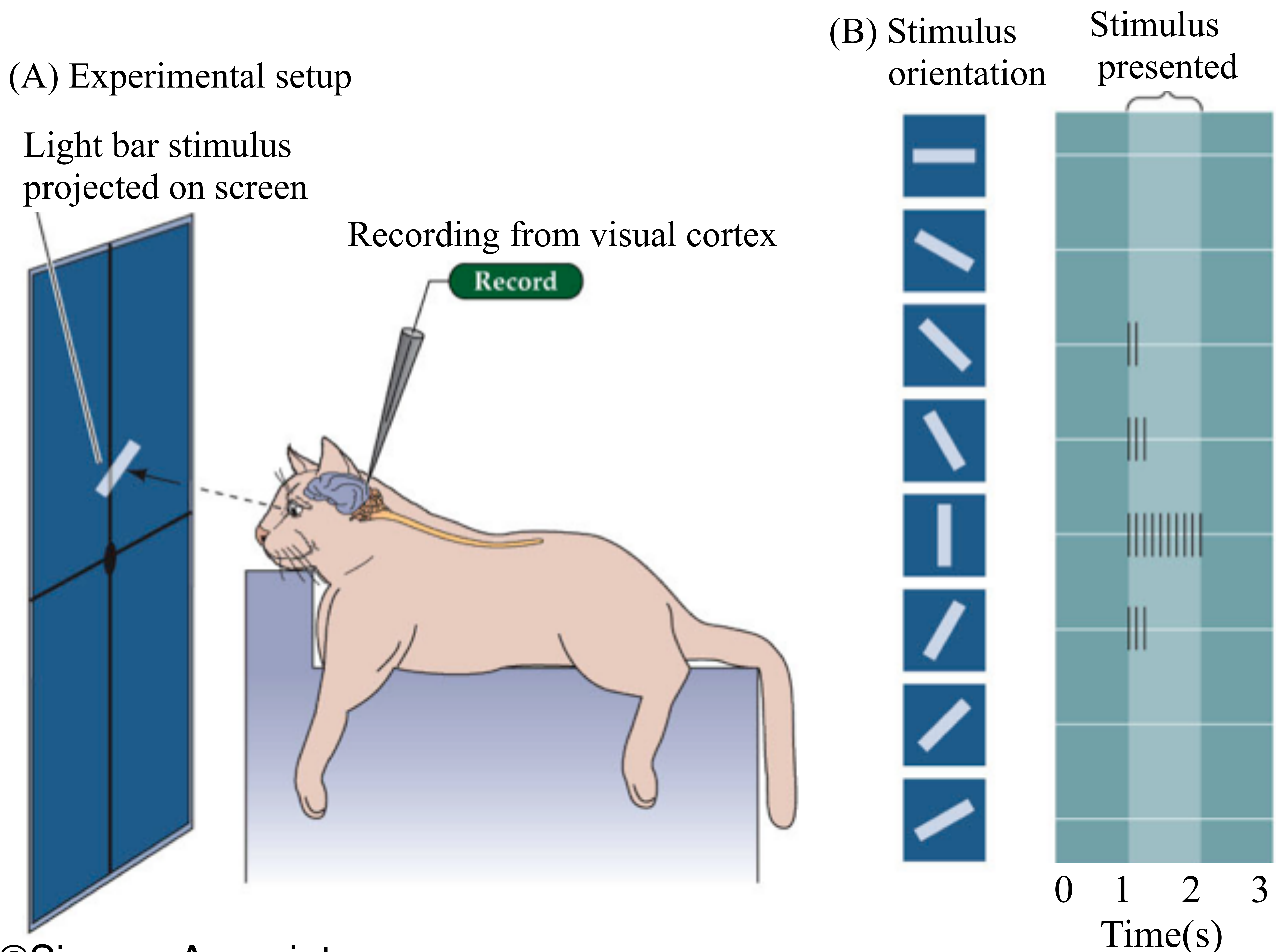
Stephen Kuffler
David Hubel
Torsten Wiesel

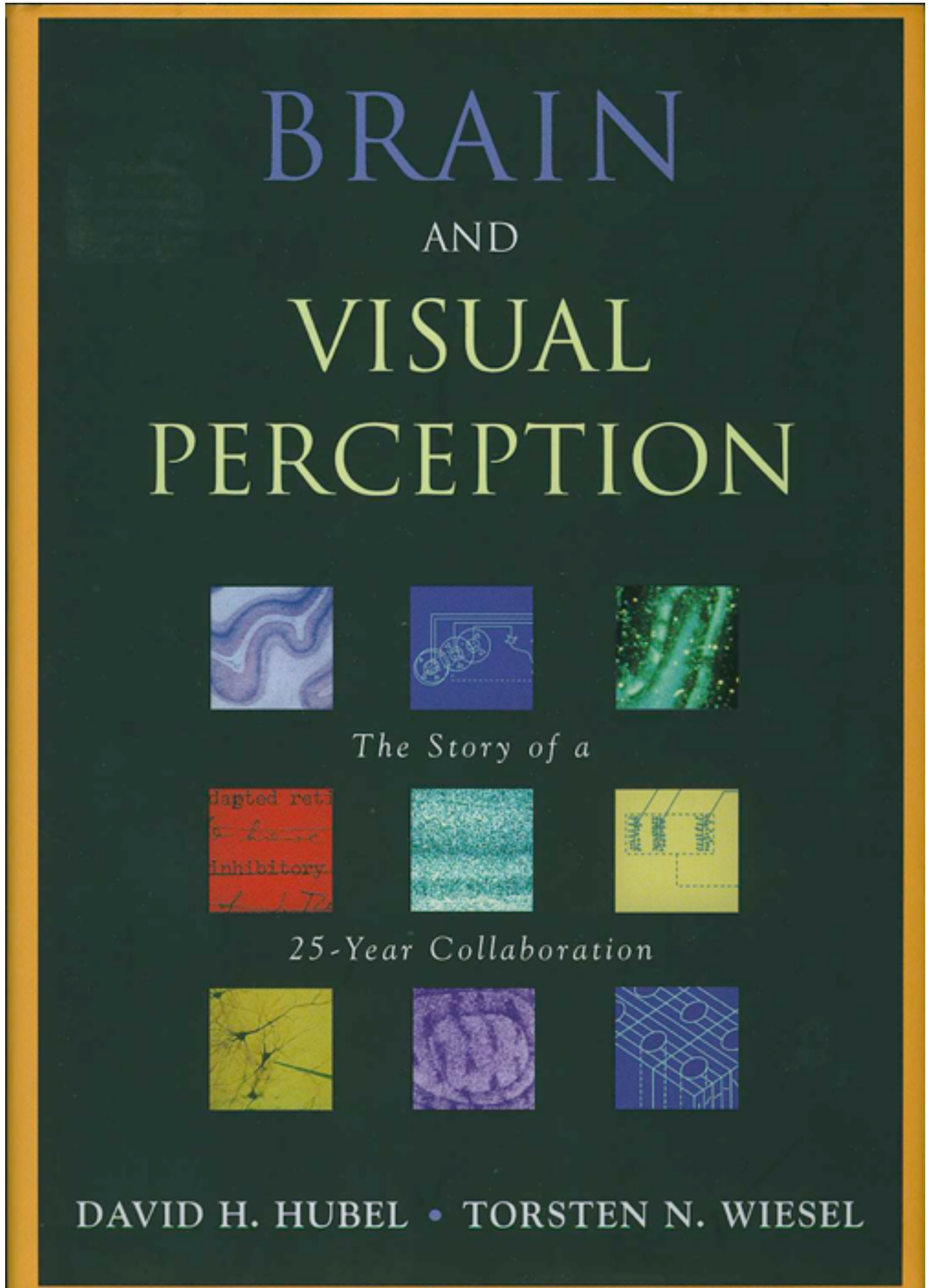


Standard way of thinking about the generation of perceptions

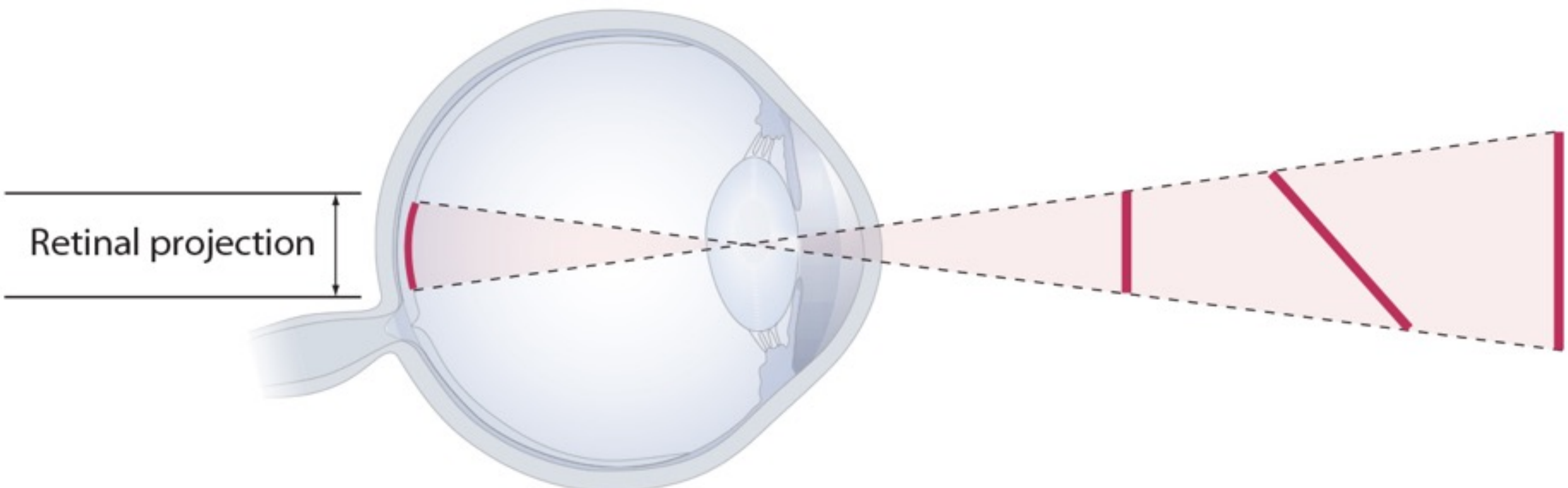


Upshot: neuronal activity represents image features


(A) Experimental setup
Light bar stimulus
projected on screen
Recording from visual cortex
Record
(B) Stimulus
orientation
Stimulus
presented
0
1
2
3
Time(s)


BRAIN
AND
VISUAL
PERCEPTION
The Story of a
25-Year Collaboration
DAVID H. HUBEL • TORSTEN N. WIESEL

The problem with feature detection: Image features are not measures of things in the world!



Lesson 3. Vision as Inference

Hermann von Helmholtz (1821–1894)

Thomas Bayes (1701–1761)

p(A given B)=

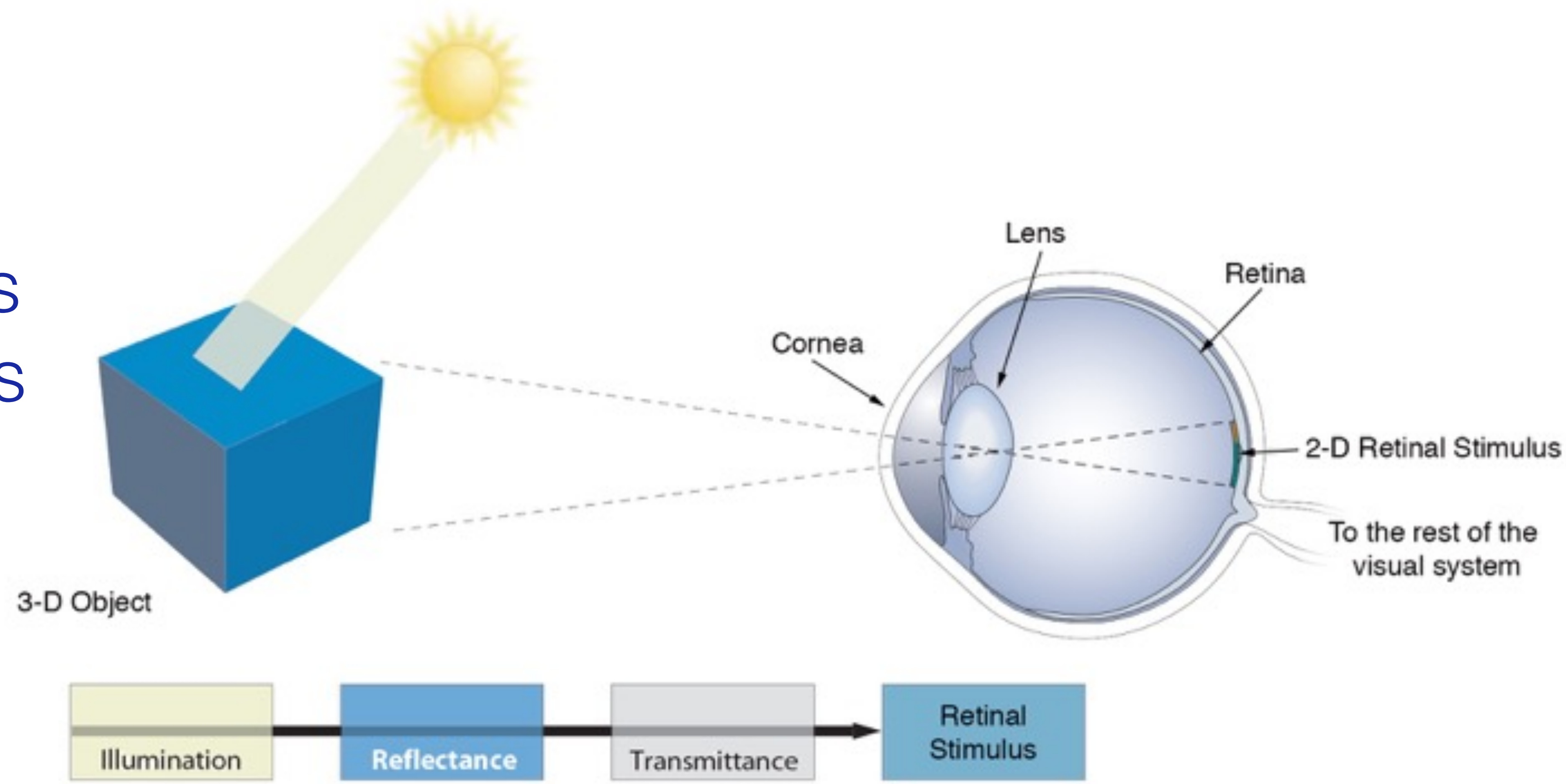
p(B given A) x p(A)

posterior=likelihood x prior

In vision A is an image (stimulus), and B the underlying state of the physical world

Why Bayes' Theorem is Only Marginally Helpful in Understanding Vision

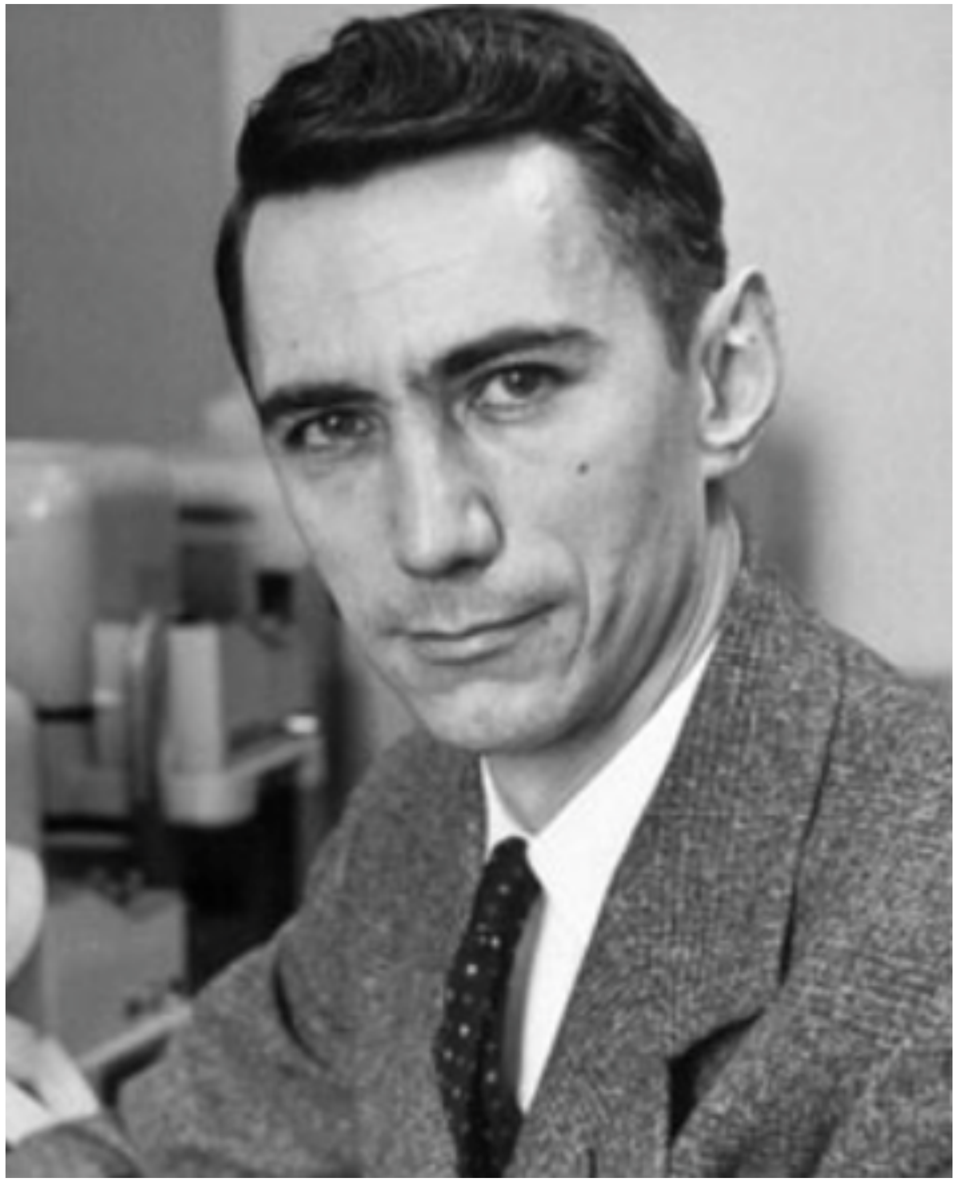
The conflation of features in retinal images precludes biological sensors apprehending states of the world. Thus the 'B' term in Bayes' theorem is not available.



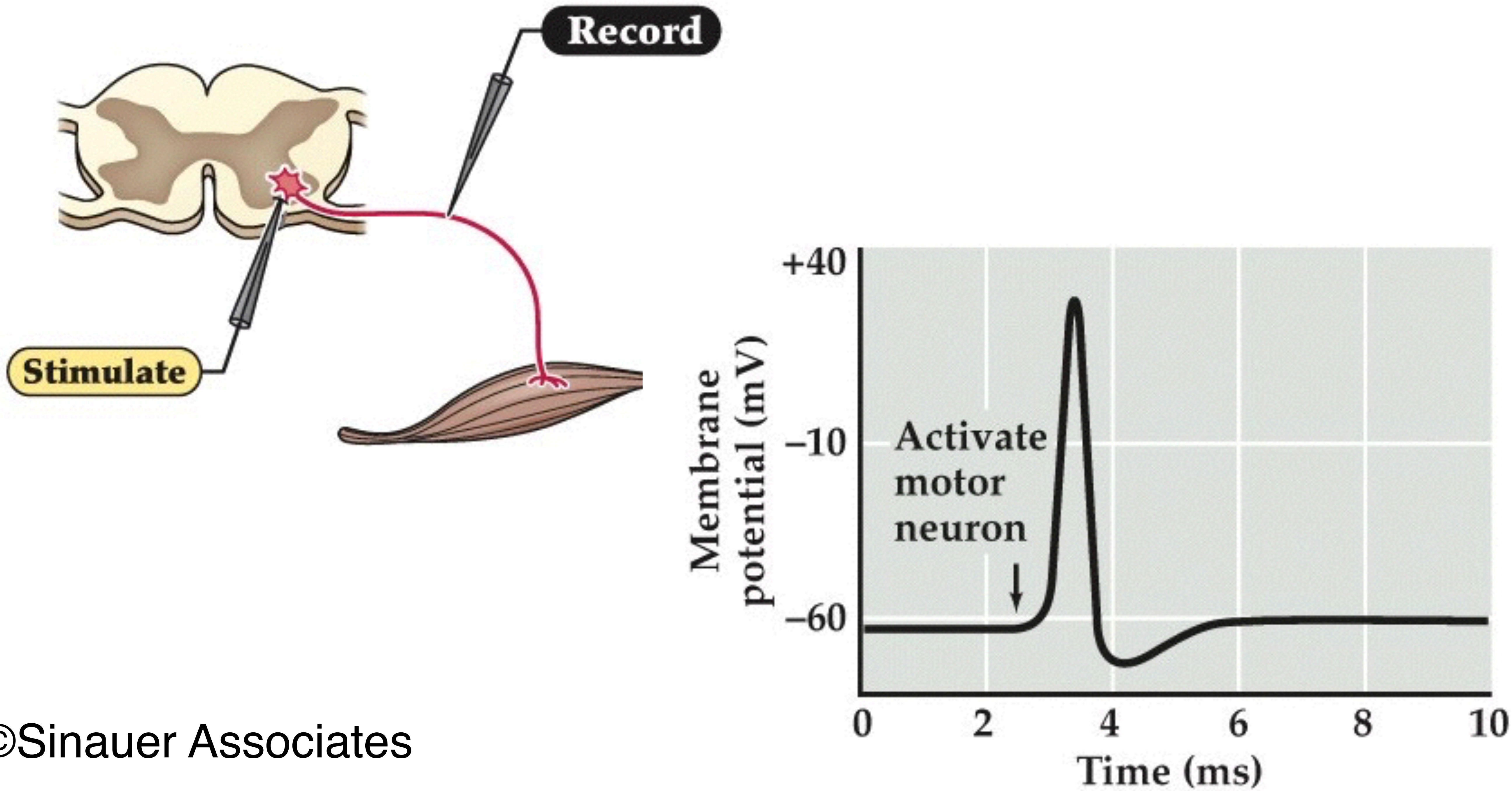
Lesson 4. Vision as Efficient Coding

Claude Shannon
(1916–2001)

Invented information theory to determine the optimal compression of messages in telecommunication



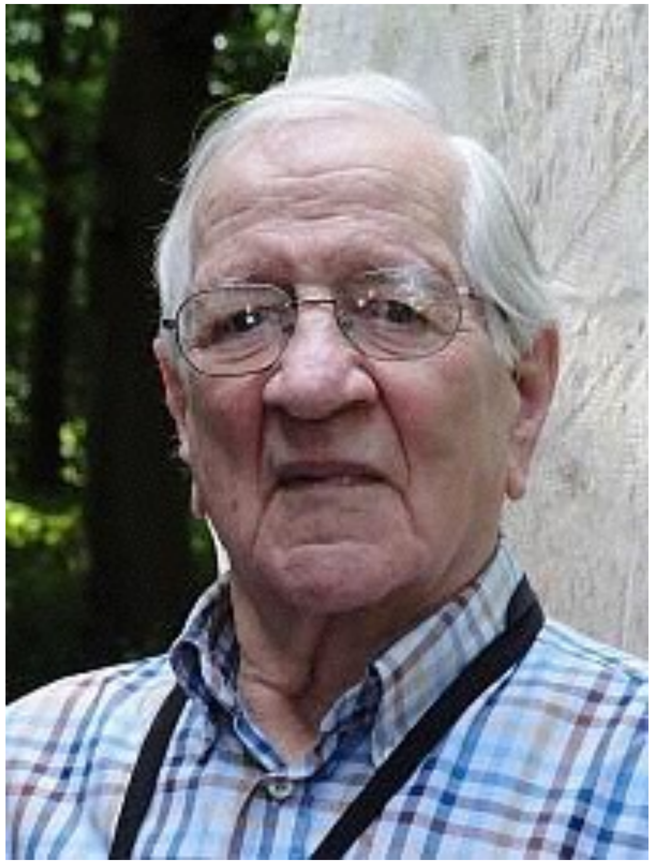
The logic of efficient coding in neuroscience



The surfeit of information in naturally arising retinal images

Horace Barlow
(1921–   )

Using the concepts
of information theory
to reduce redundancy
in images



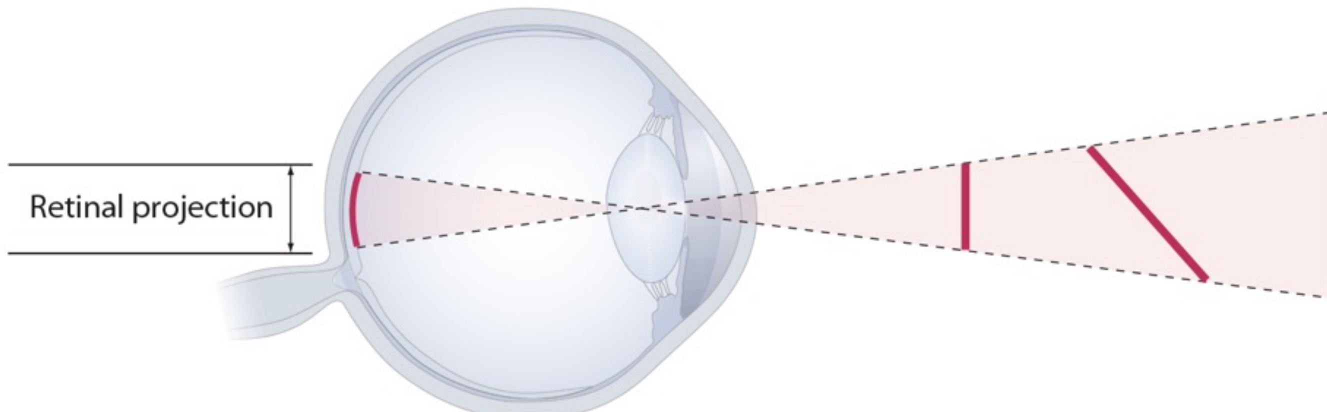
The problem in this case is that the mechanisms of transmission are not those of perception.

Thus efficient transmission over a phone line or over neural circuits is not the same as, or even pertinent to, the message.

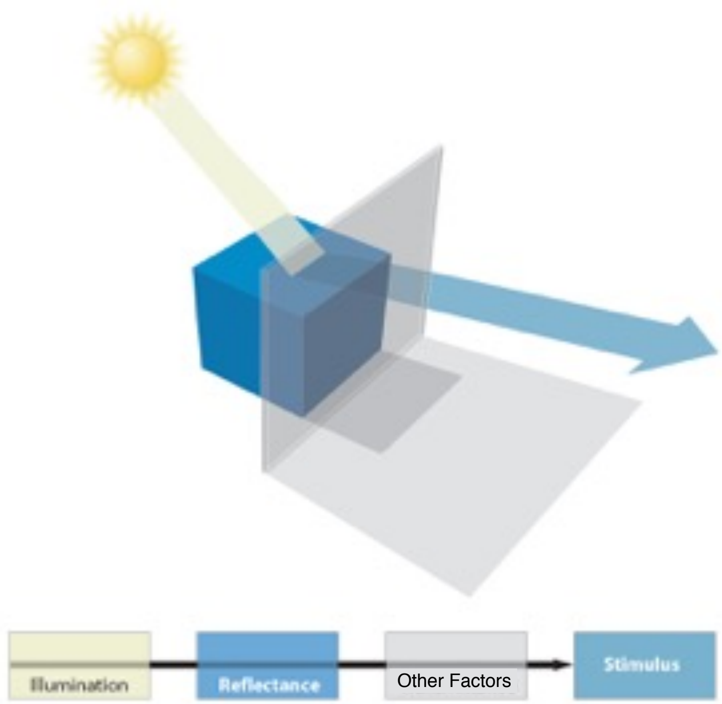
Lesson 5. Vision as a Way of Contending with the Inverse Problem

What about the neural circuitry?

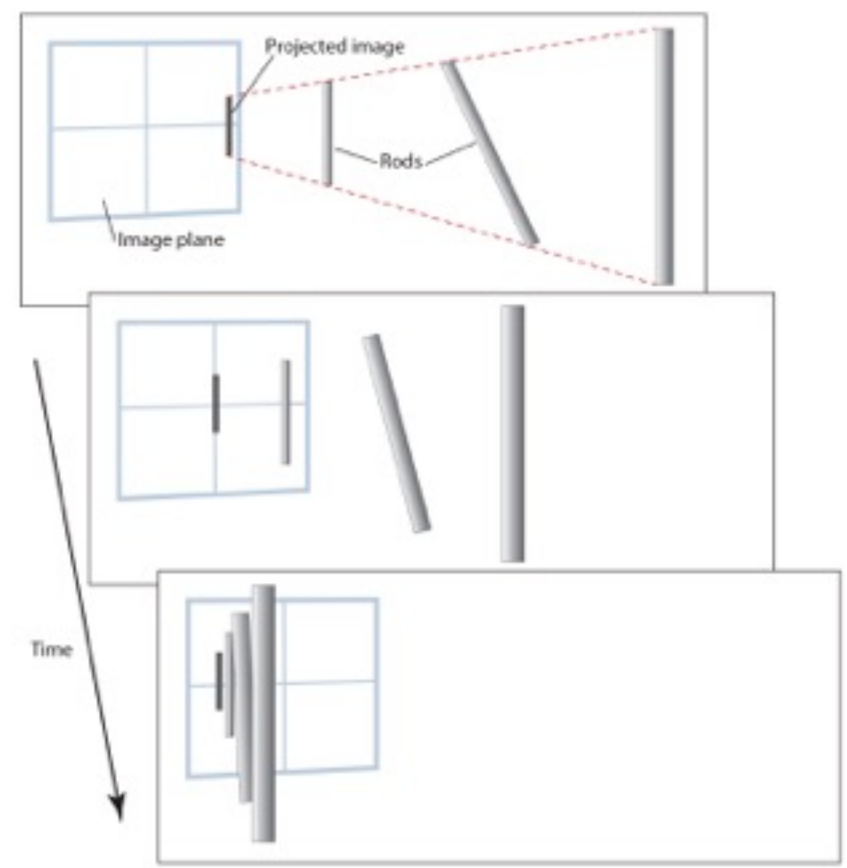
The Inverse Problem for the Basic Qualities of Vision



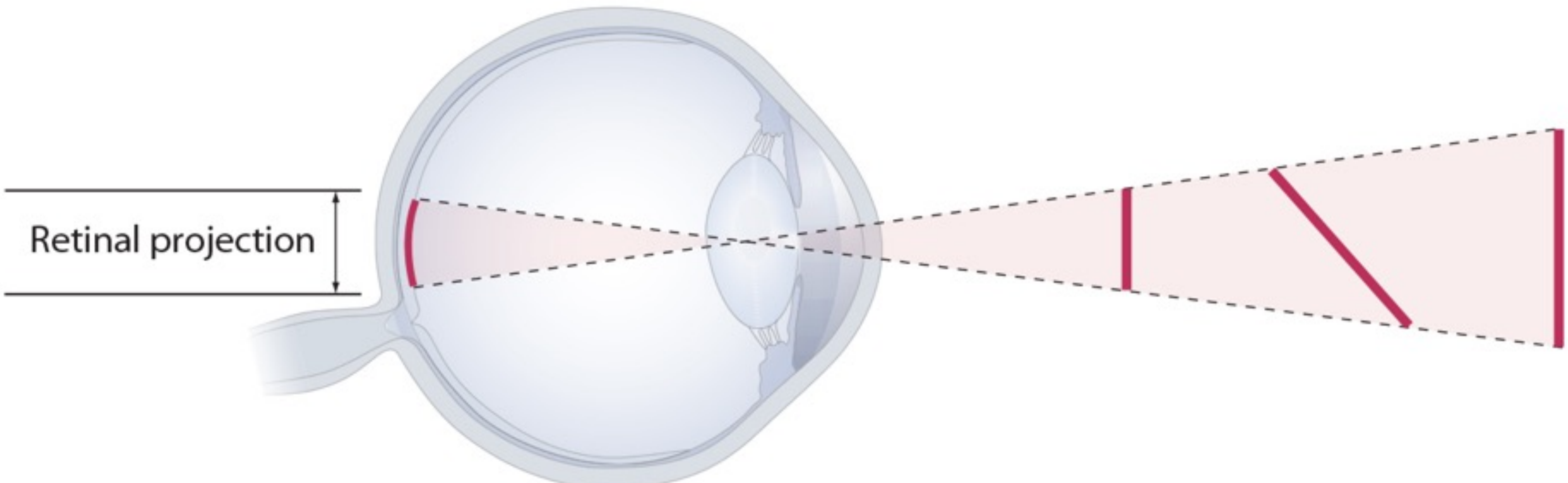
Size, distance and orientation



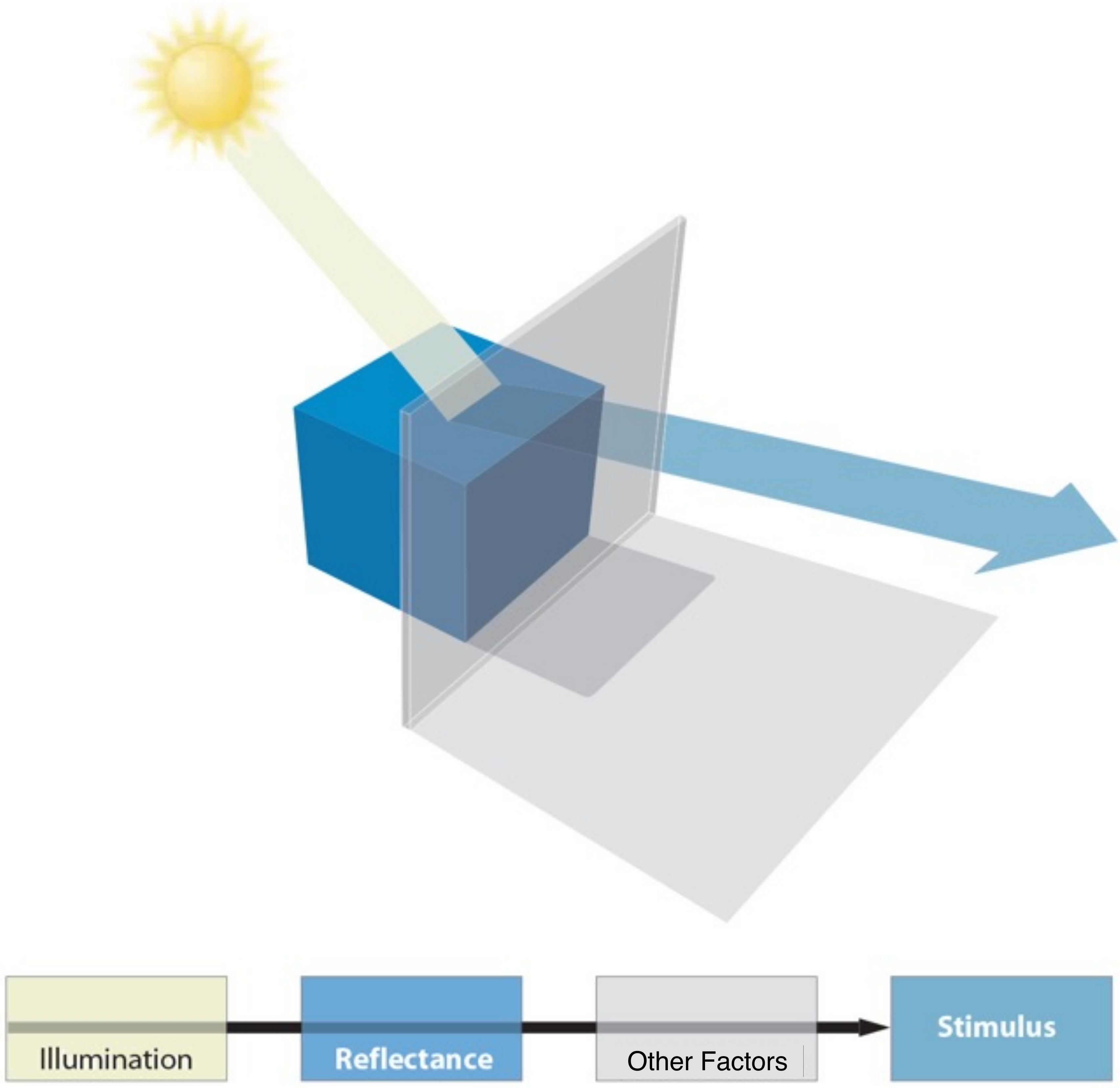
Lightness and color



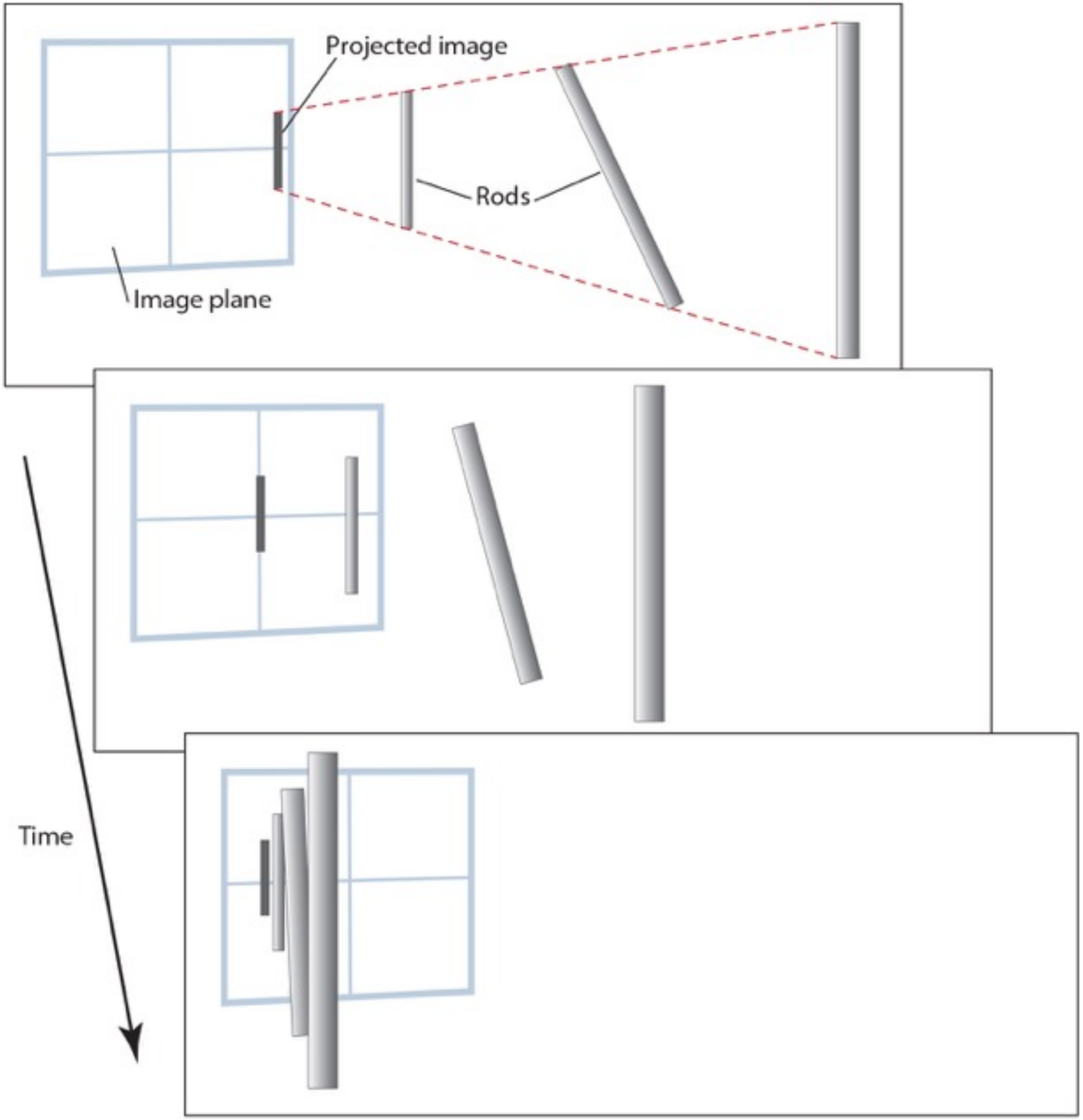
Motion



Size, distance and orientation



Lightness and color



Motion

The idea in this conception of vision is that evolving a way of dealing with inverse problem has determined both how we see and what we see.

A corollary is that peculiar way we see the world is the signature of this strategy of vision.

Summary of the Main Points

- The challenge for visual evolution is circumventing the inverse problem
- Any theory of vision must take this into account
- The major options are feature detection, vision by inference, vision as efficient coding, or vision based specifically on a way of dealing with the inverse problem
- In this last option, the goal of reproductive success substitutes for the intuitive goal of seeing the world the way it “really is”

Credits

- Stephen Kuffler, David Hubel, Torsten Wiesel, McMahan, U. J. *Steve: Remembrances of Stephen W. Kuffler*, Sunderland, MA: Sinauer Associates, 1990
- *Brain and Visual Perception* book cover, ©2004 Oxford University Press
- Cat vision experimental setup, Dale Purves et al. *Principles of Cognitive Neuroscience*, Sinauer Associates Inc., 2013, pg 68
- Perceiving a 3D object, Dale Purves, R. Beau Lotto. *Why We See What We Do Redux*, Sinauer Associates Inc. 2011, pg. 2 and 71
- Claude Shannon, ©2016 Georgi Dalakov, history-computer.com

Credits, cont.

- Coding in neuroscience, Dale Purves et al. *Neuroscience*, Sinauer Associates Inc., 2012, pg. 26
- Nature images, Dale Purves, R. Beau Lotto. *Why We See What We Do Redux*, Sinauer Associates Inc. 2011, pg. 86
- Horace Barlow, ©2016 University of Cambridge

Dale Purves, R. Beau Lotto. *Why We See What We Do Redux*, Sinauer Associates Inc. 2011

- Retinal projection, pg. 92
- Contributions to retinal stimulus, pg. 71
- Inverse problem and motion, pg. 159