Computational Vision

Foundations

- Finish fundamentals of primate vision cont'd

- Start retina and LGN

Fact #1

Ventral (and dorsal) stream of the visual cortex produces a visual representation that is increasingly complex and invariant
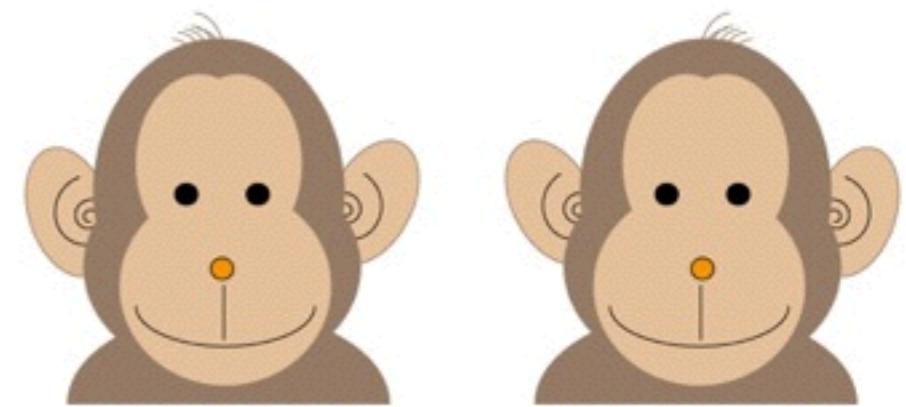
Rapid presentation paradigms

- Ss get the gist of a scene from ultra-rapid image presentations
  - No time for eye movements
  - No top-down / expectations
- Coarse initial **base** representation
  - Enables rapid object categorization
  - Does not require attention
  - Sensitive to background clutter
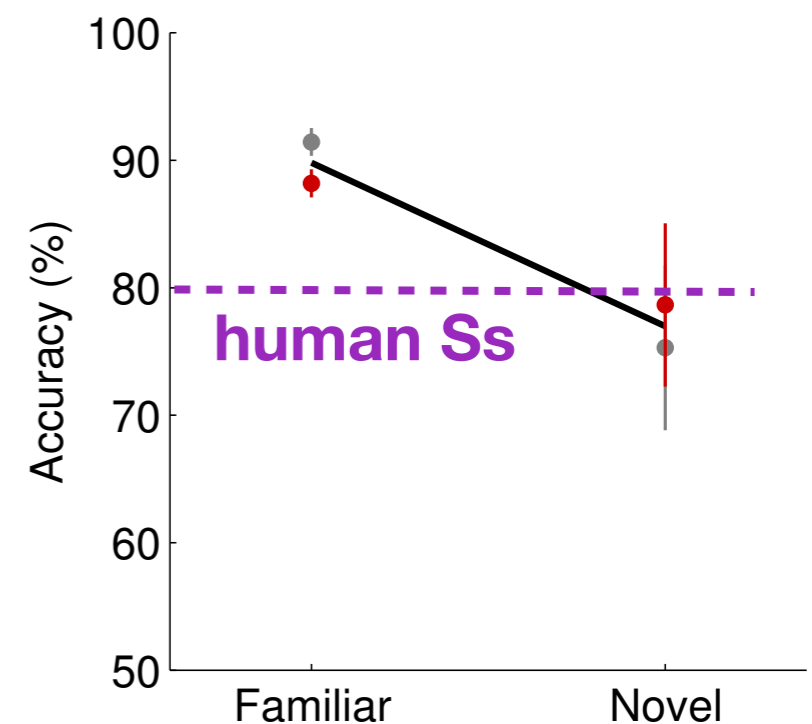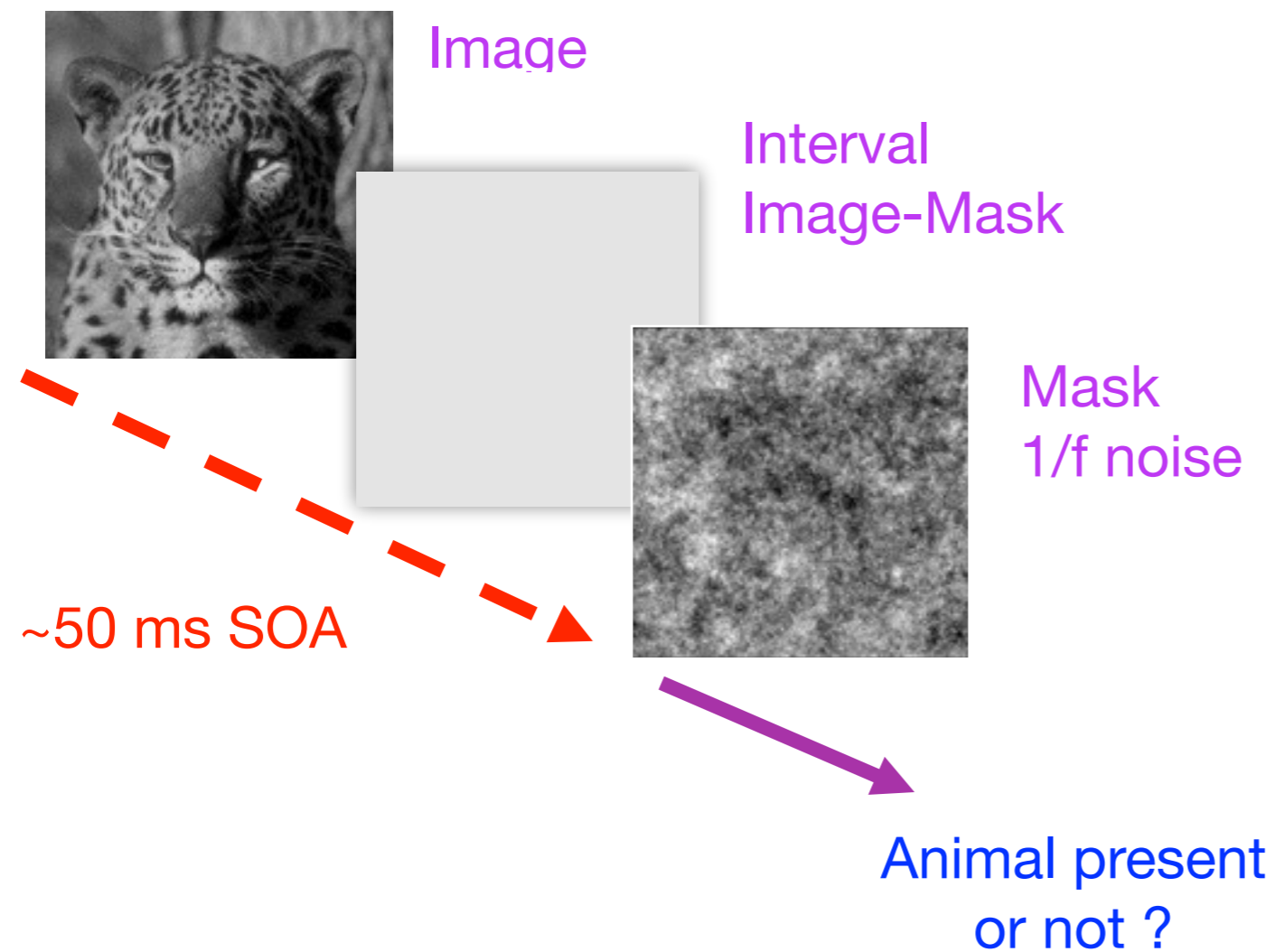 - Insufficient for object localization

Potter 1971; Biederman 1972; Thorpe et al 1996; Li et al 2002; Evans & Treisman 2005; Serre et al 2007; see Fabre-Thorpe 2011 for review
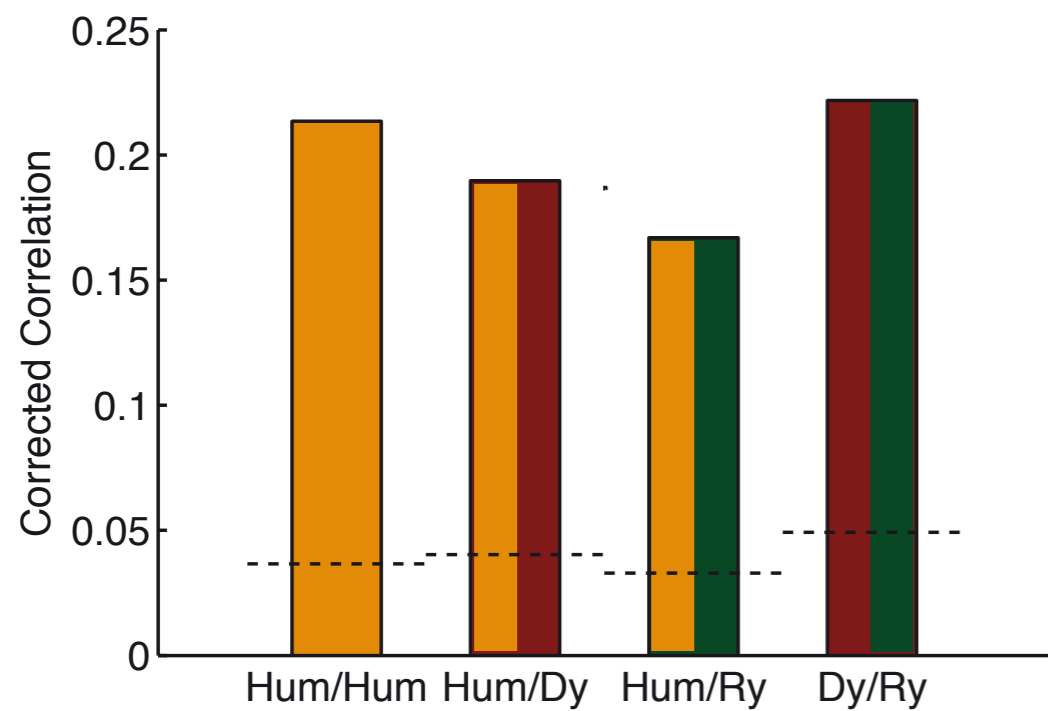
Rapid categorization: Behavior

Dy   Ry

Image

Interval
Image-Mask

Mask
1/f noise

~50 ms SOA

Animal present
or not ?

Cauchoix Crouzet Fize & Serre (unpublished)

Mon: 0.49   Hum: 0.47

Cauchoix Crouzet Fize & Serre (unpublished)

Cauchoix Crouzet Fize & Serre (unpublished)

Feedforward processing
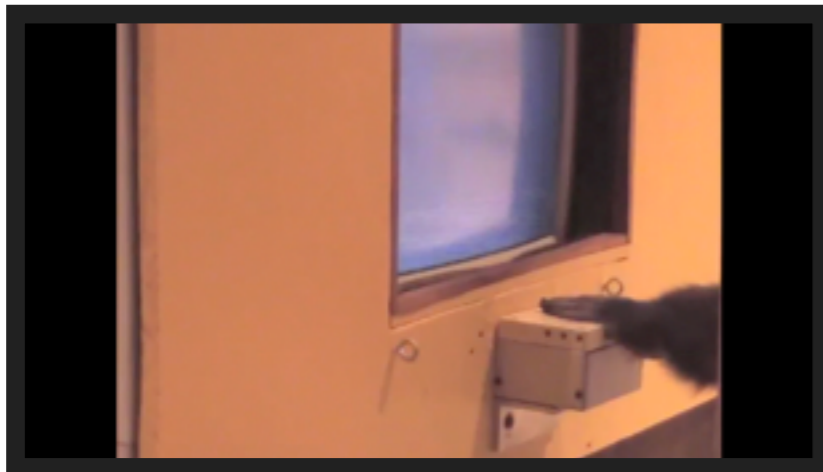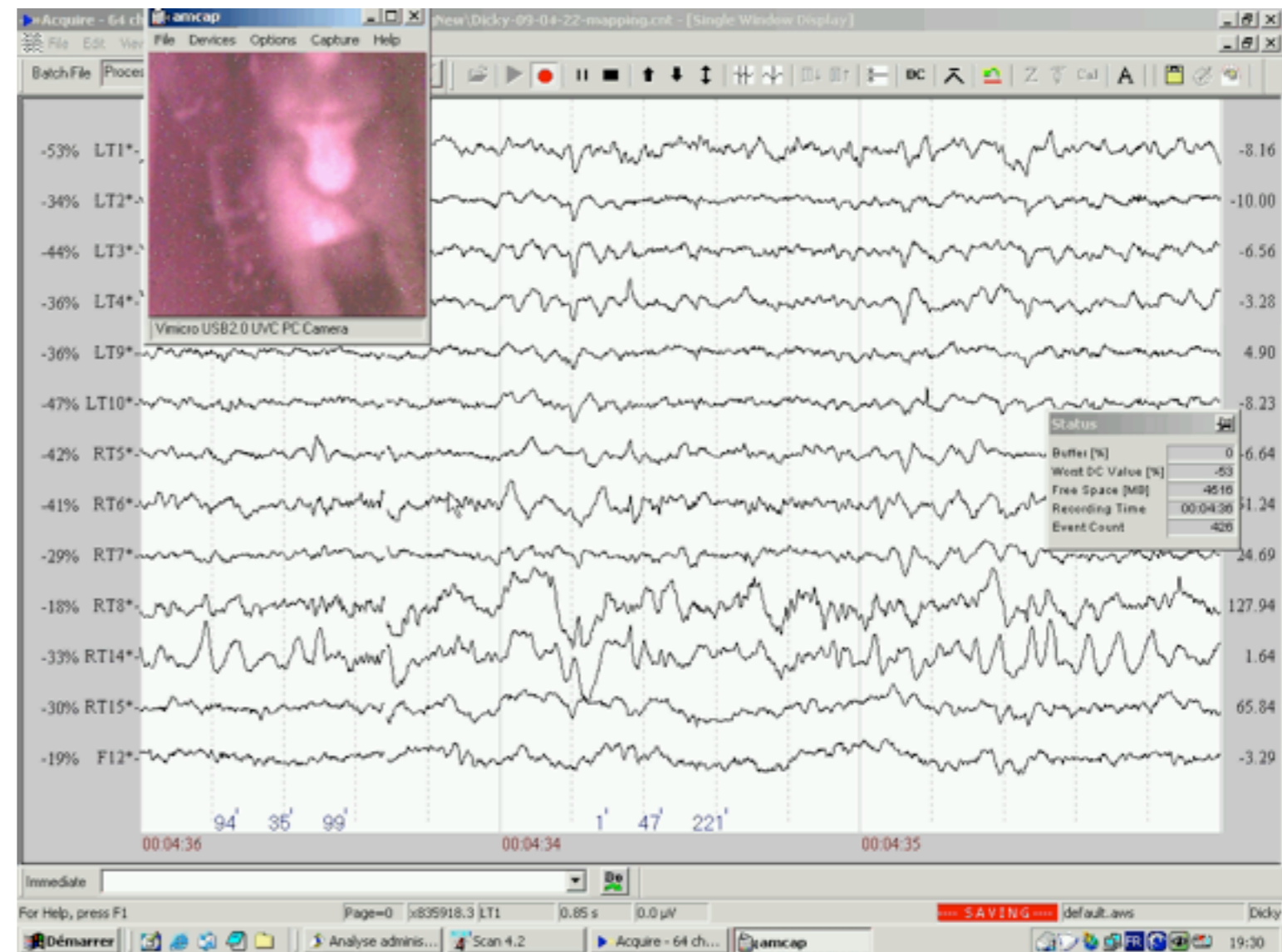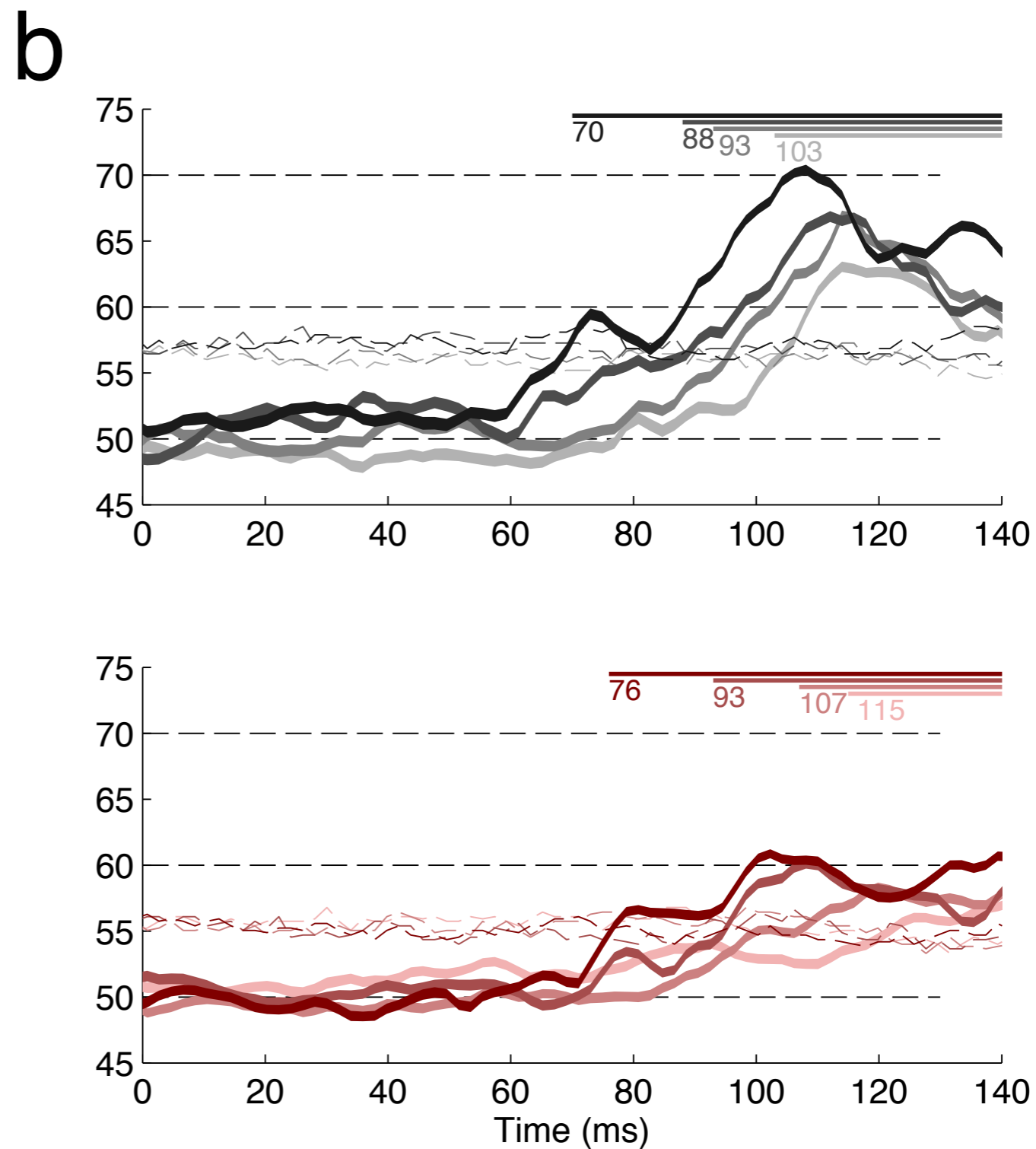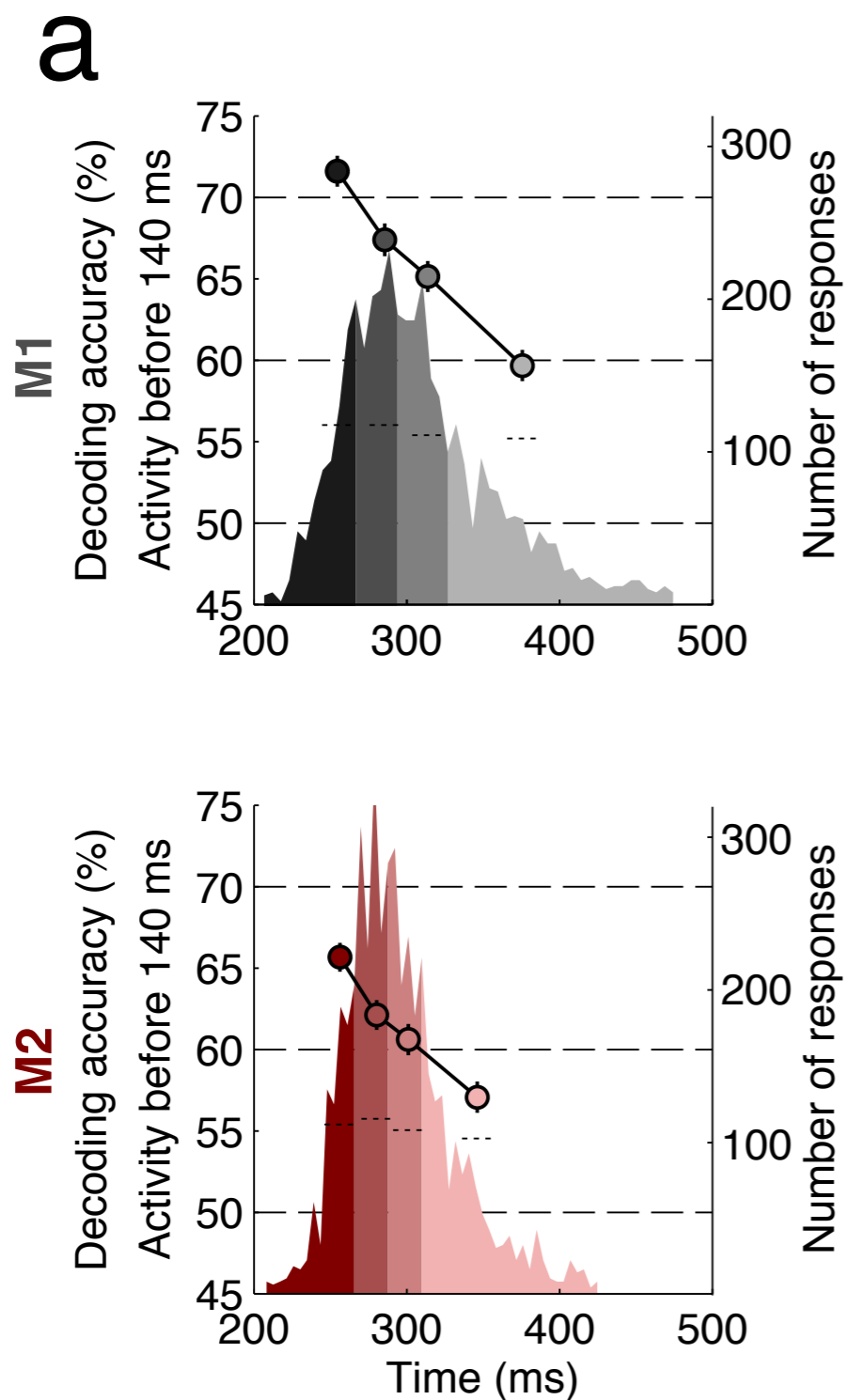

Ventral visual stream
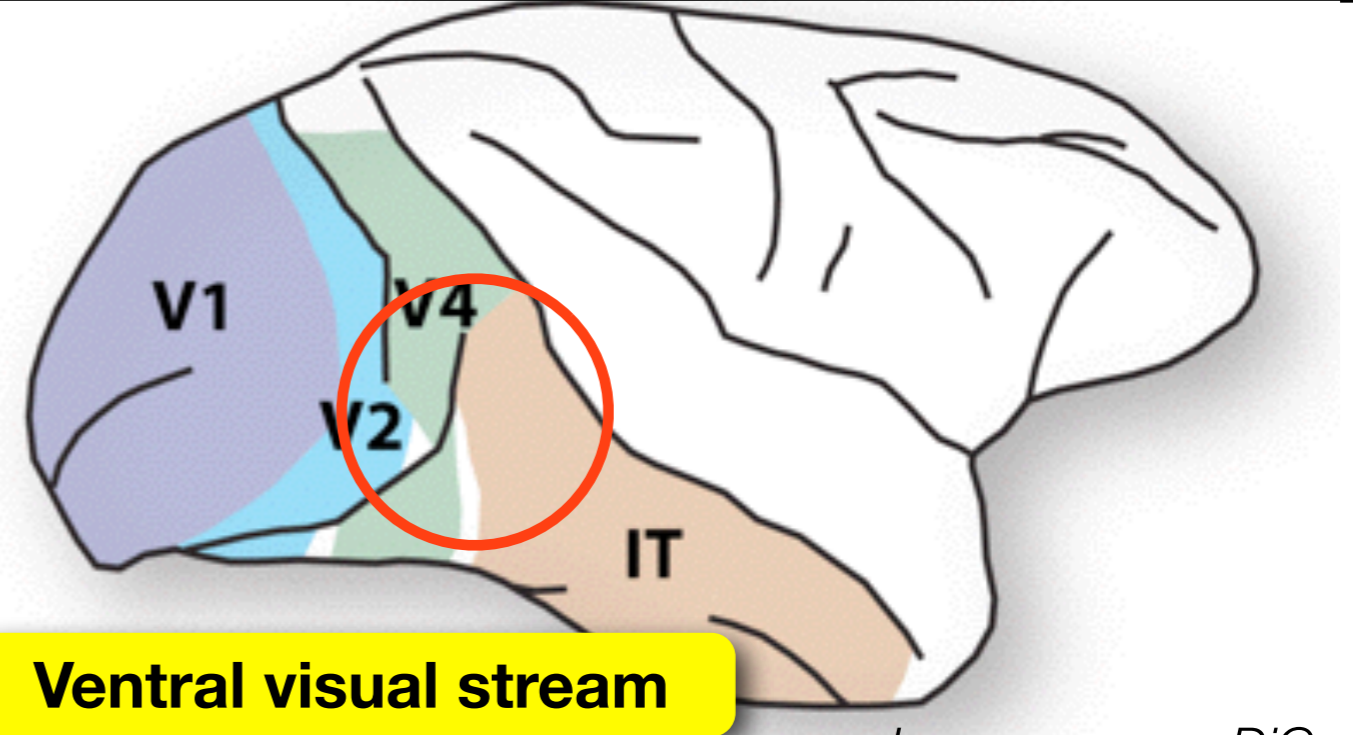
Image source: DiCarlo

Button release and touch screen on targets

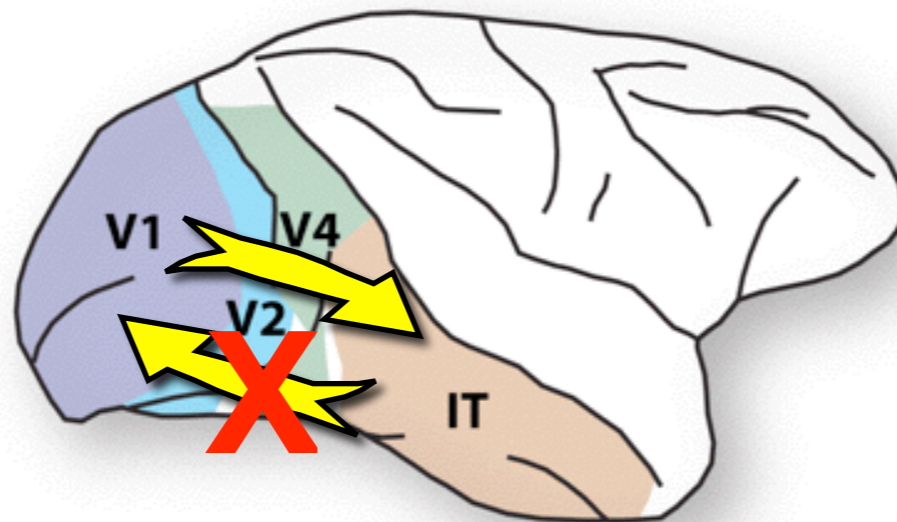*Cauchoix Crouzet Fize & Serre (unpublished)*
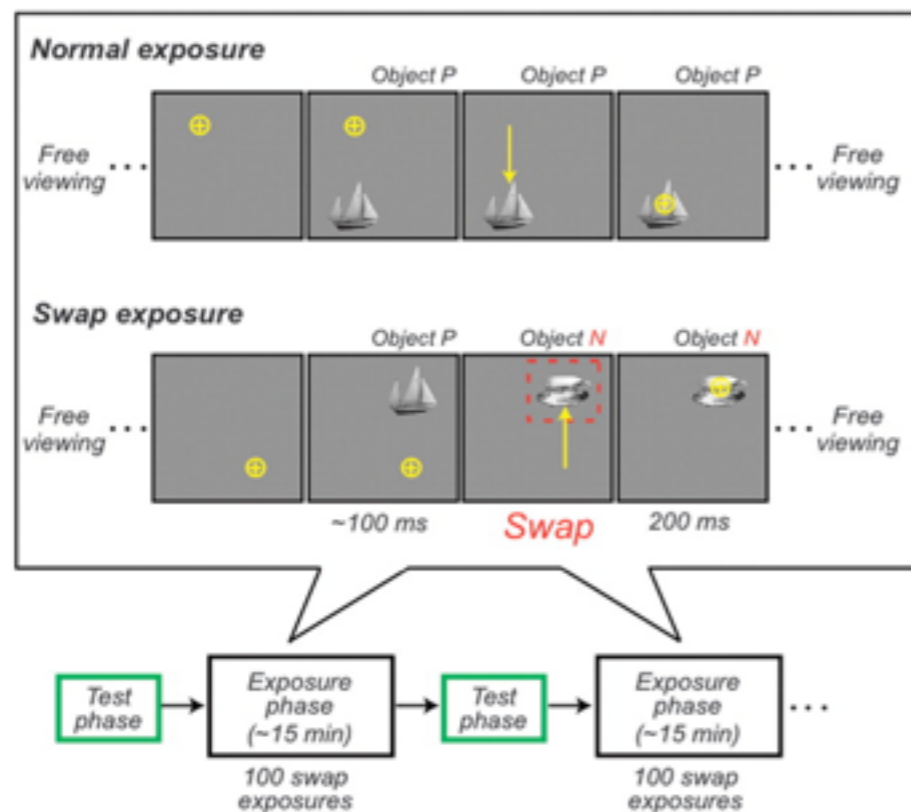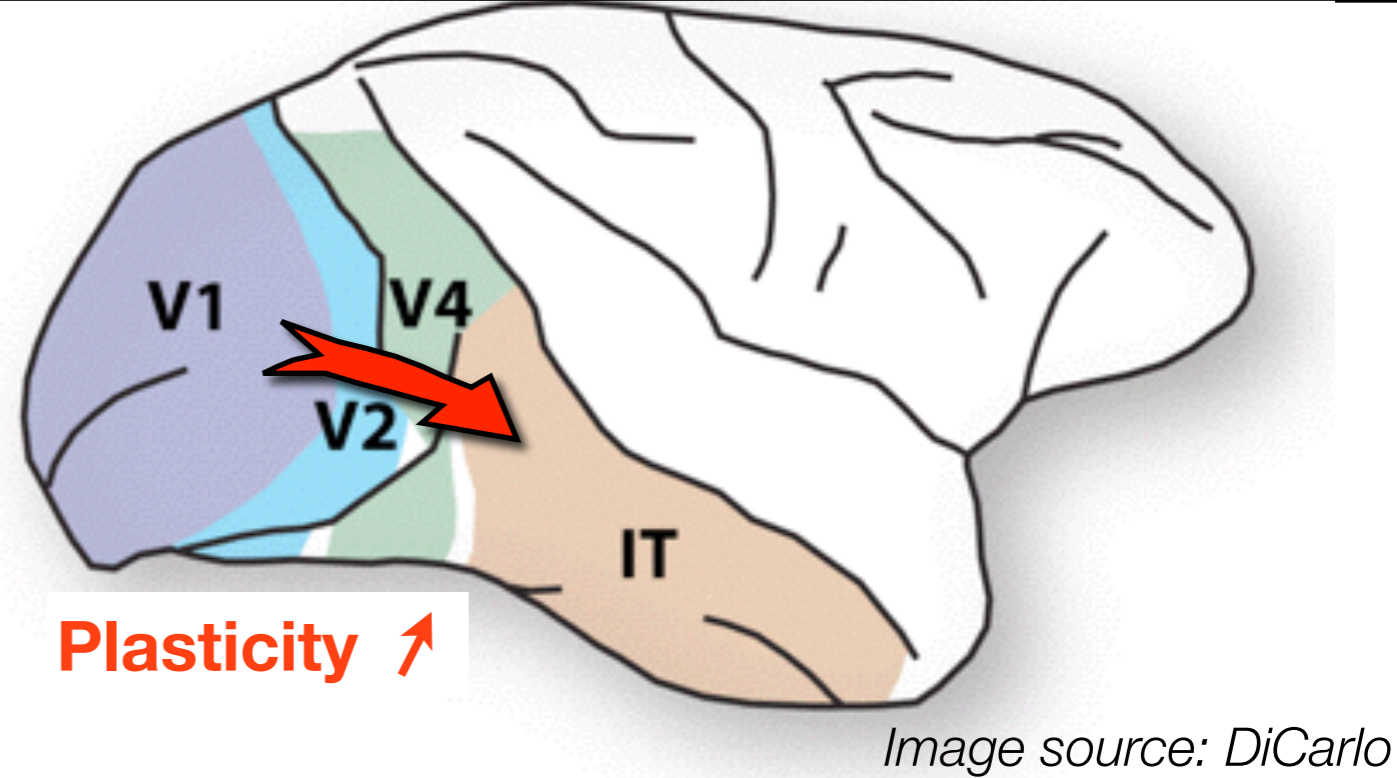
a

M1

b

M2

Feedforward processing

Cauchoix Crouzet Fize & Serre (unpublished)

Fact #2

Rapid categorization is possible in the near absence of cortical feedback (from a single feedforward sweep of activity)

- Very little learning and plasticity in lower visual areas

- Fast learning and plasticity in higher visual areas

Plasticity ↗

Image source: DiCarlo

Very fast (unsupervised) learning in IT

Learning and plasticity | Li & DiCarlo '08

- Very little learning and plasticity in lower visual areas

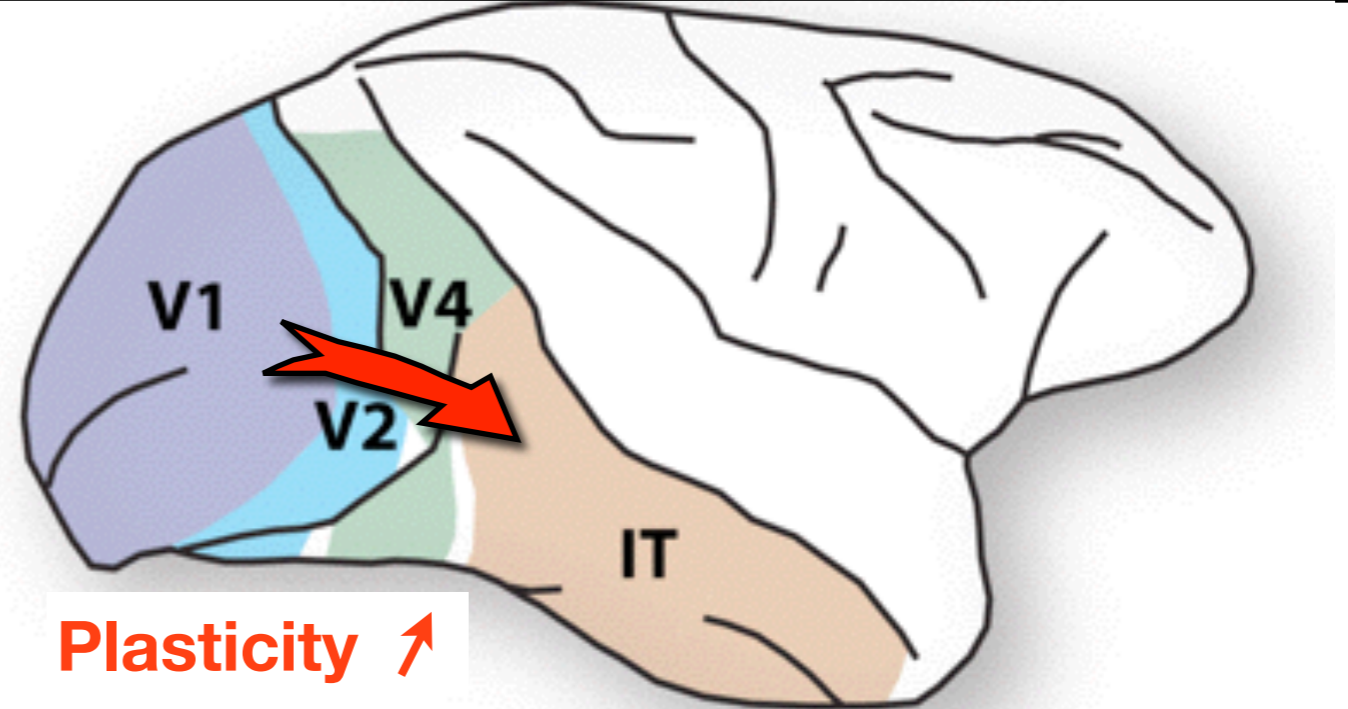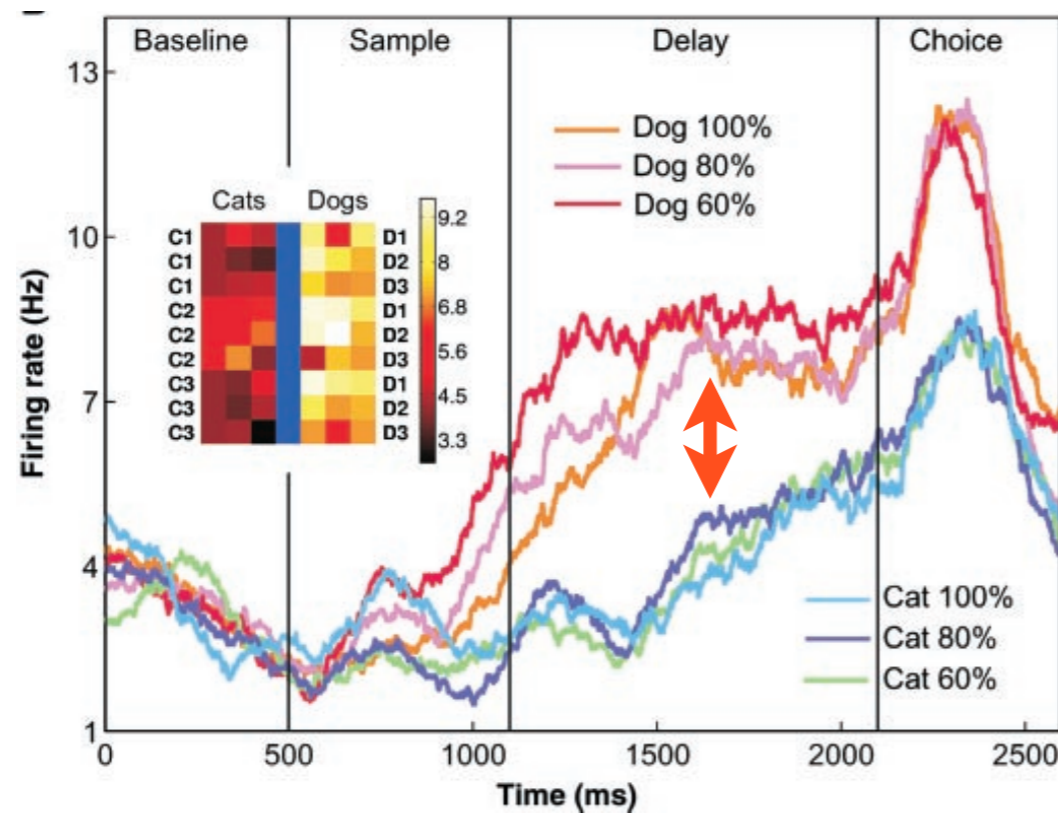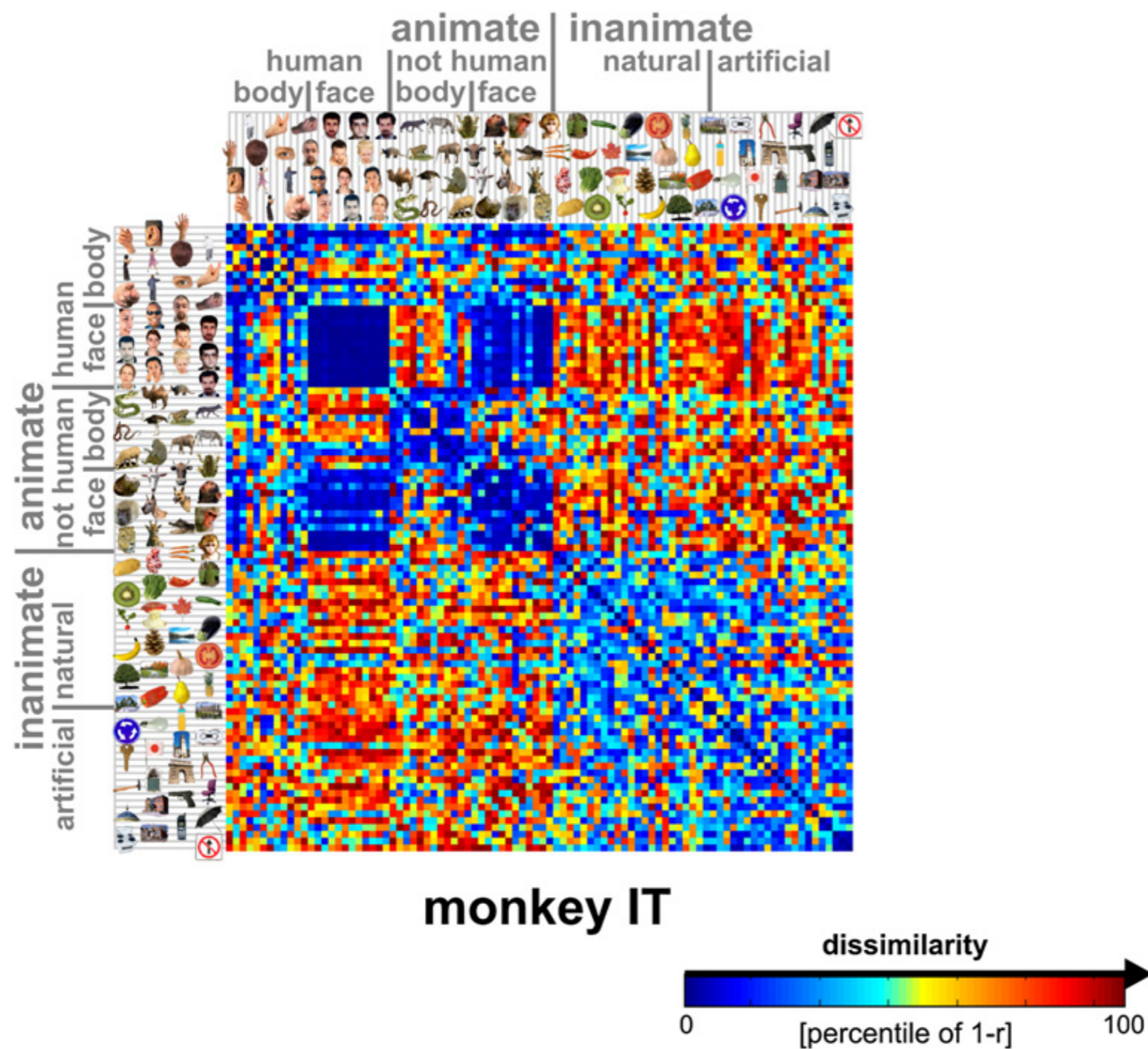- Fast learning and plasticity in higher visual areas

Plasticity ↗

Image source: DiCarlo

Supervised category learning in PFC
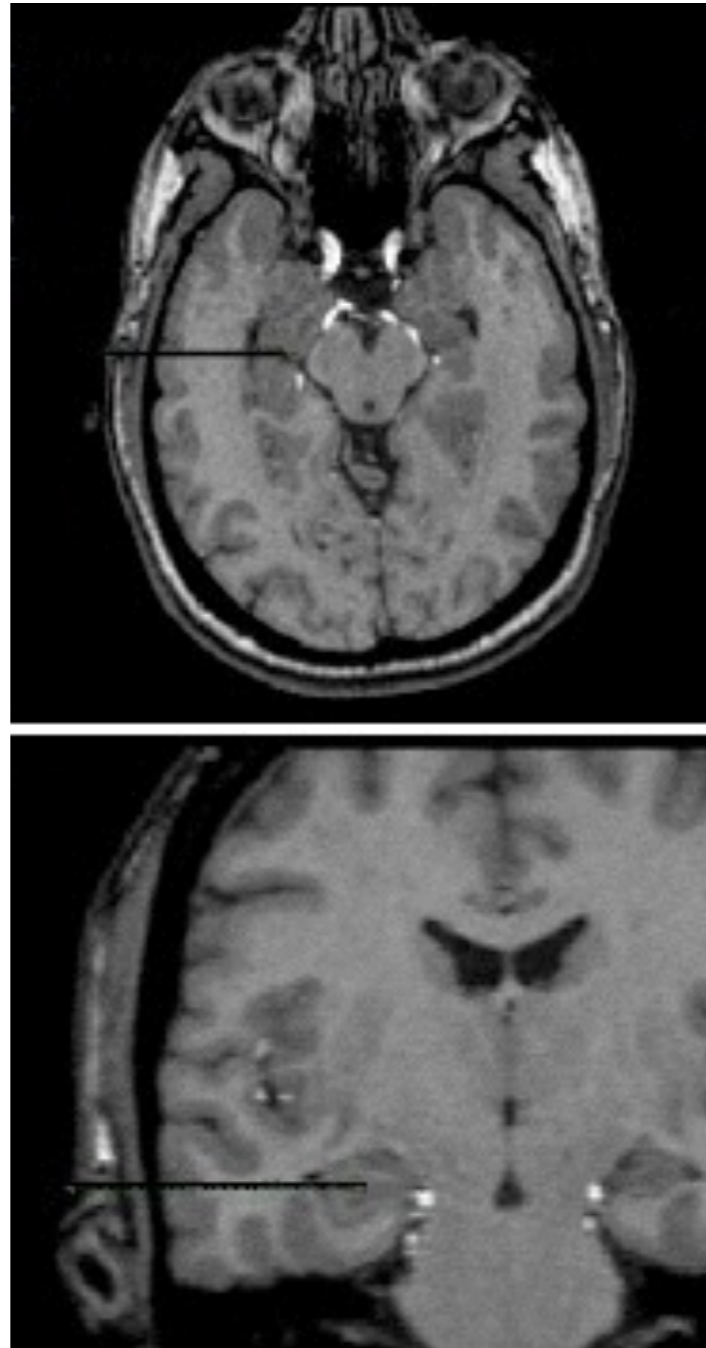
Learning and plasticity | Freedman et al 2001
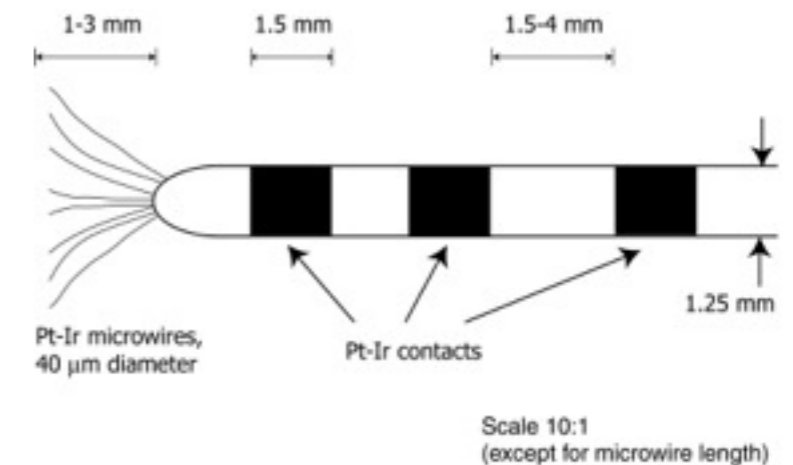
Matching object representations in man and monkey

Kriegeskorte et al '08

Patients with pharmacologically intractable epilepsy
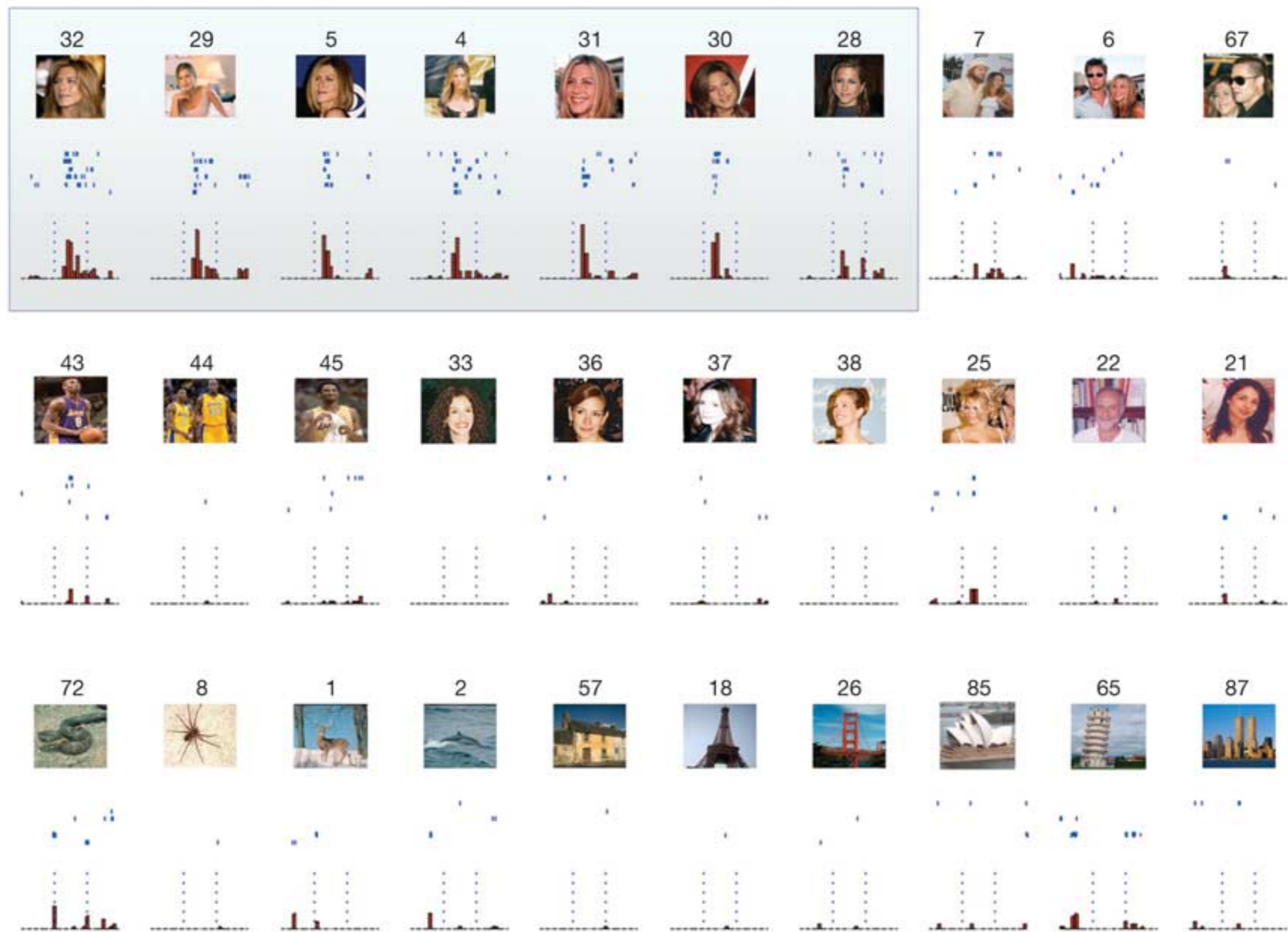
Multiple electrodes implanted to localize seizure focus
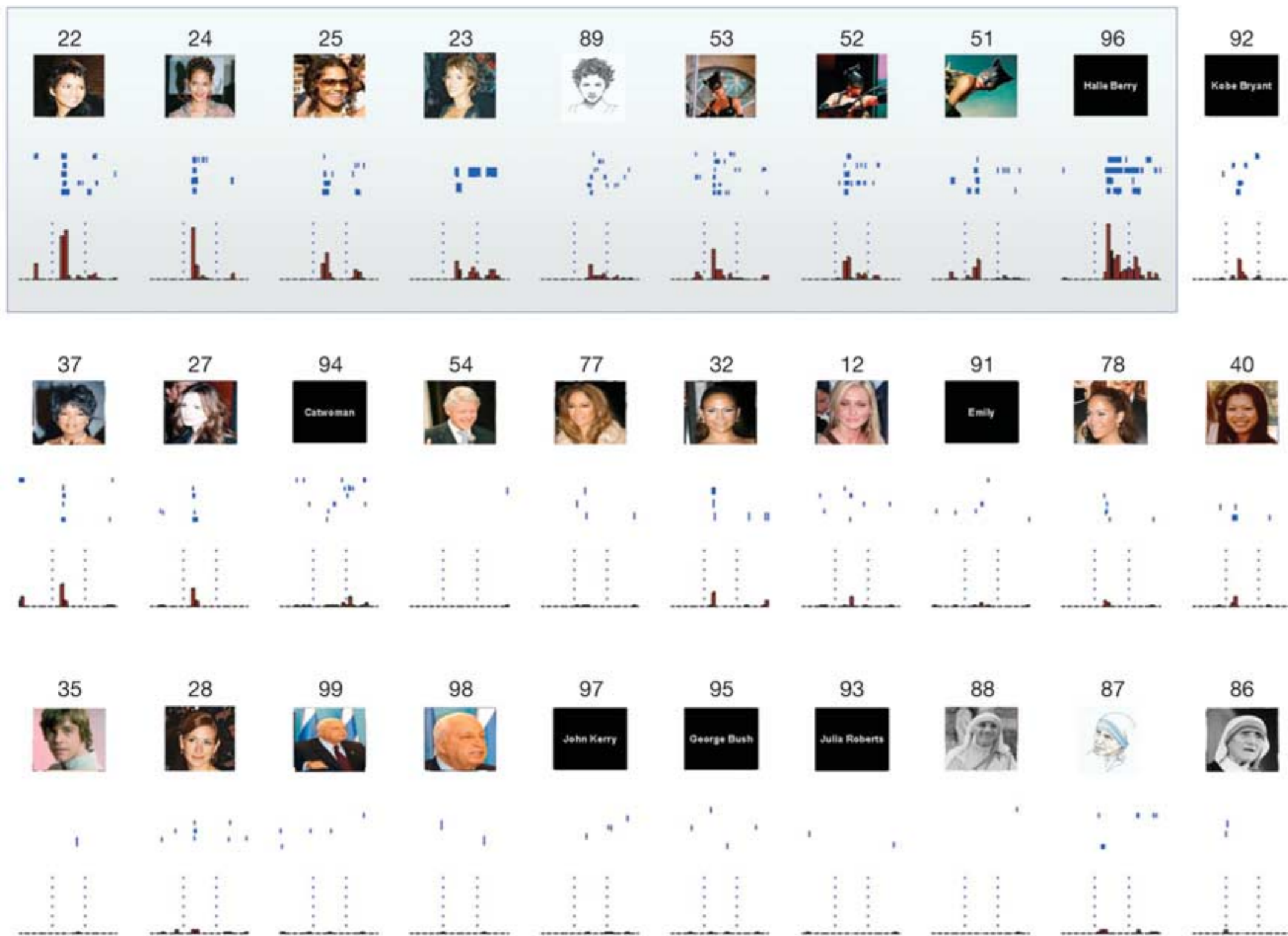
Electrodes

1-3 mm   1.5 mm   1.5-4 mm

1.25 mm

Pt-Ir microwires, 40 µm diameter

Pt-Ir contacts

Scale 10:1 (except for microwire length)
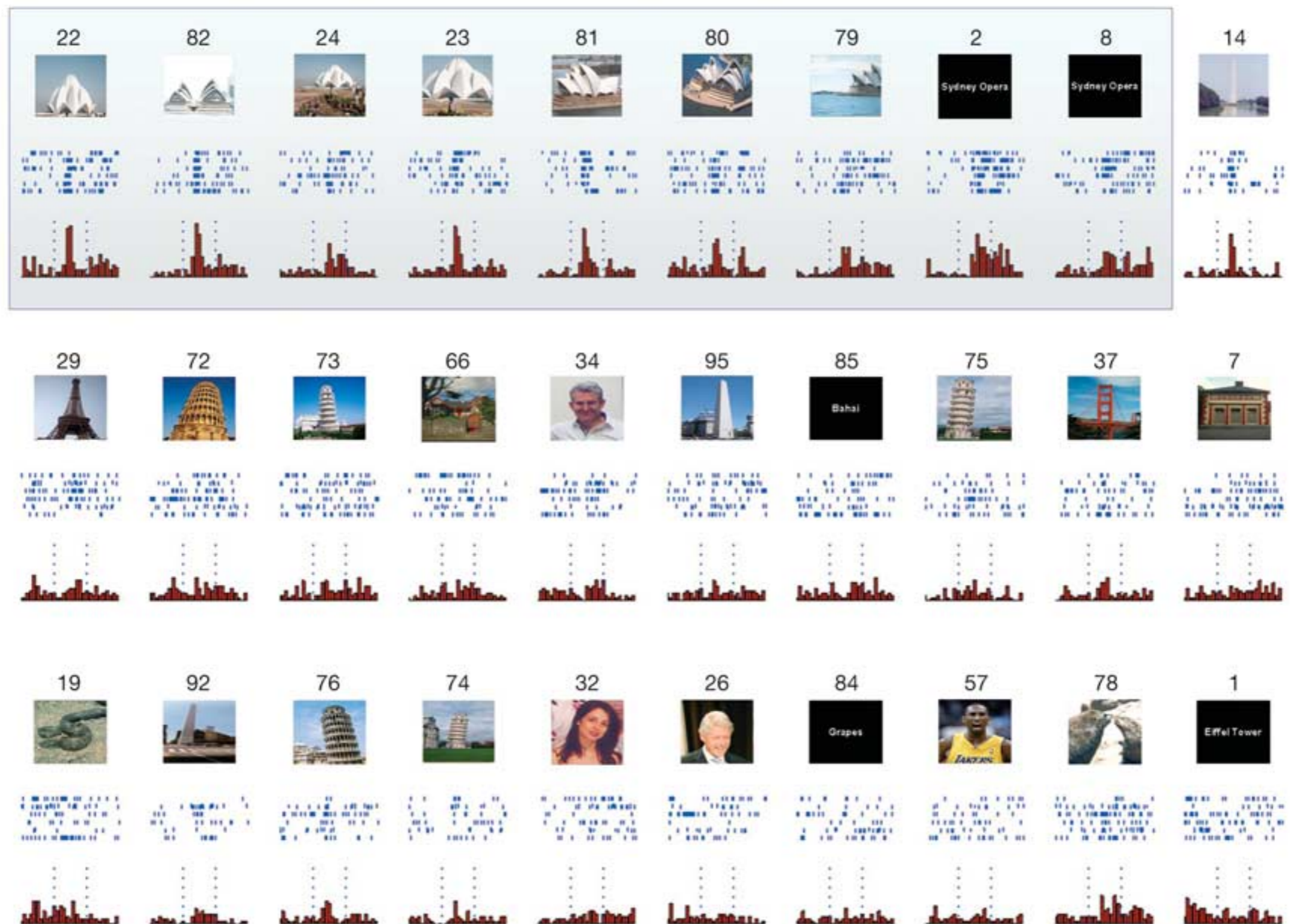
Human electrophysiology

Quiroga et al '05

"Jennifer Aniston" neuron in the

Quiroga et al '05
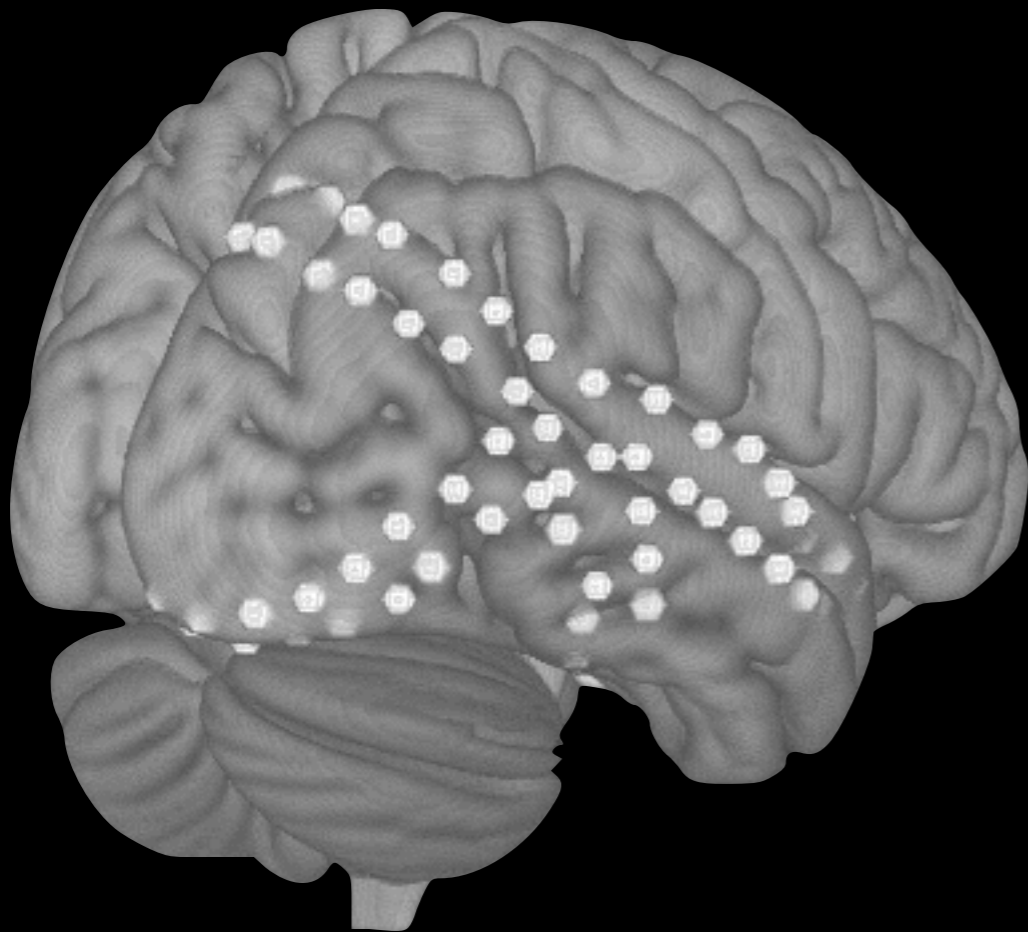
"Hale Berry" neuron in the hippocampus

Quiroga et al '05

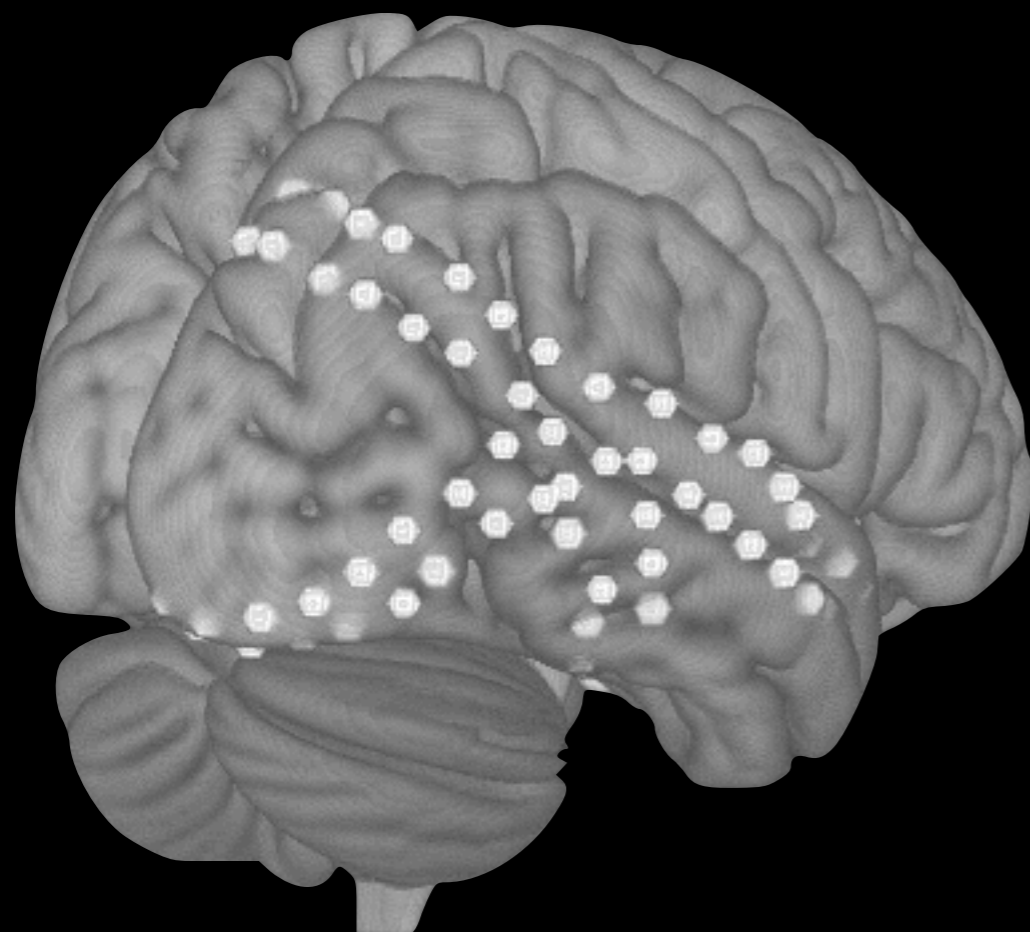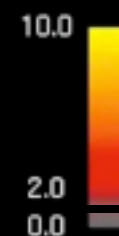"Sydney Opera" neuron in the hippocampus

Quiroga et al '05

patient #004

Classifier-based
importance maps

patient #004

0.00 ms

10.0

2.0
0.0

ERP signals

50.0

25.0

+- 5.0

-25.0

-50.0

0.00 ms

Arslan Singer Madsen Kreiman & Serre (unpublished)
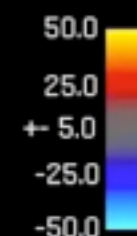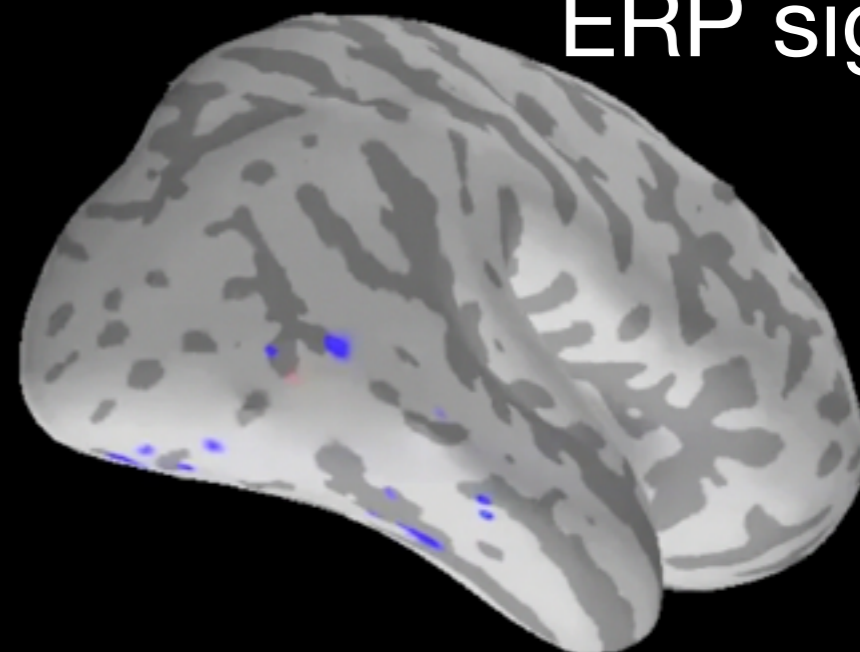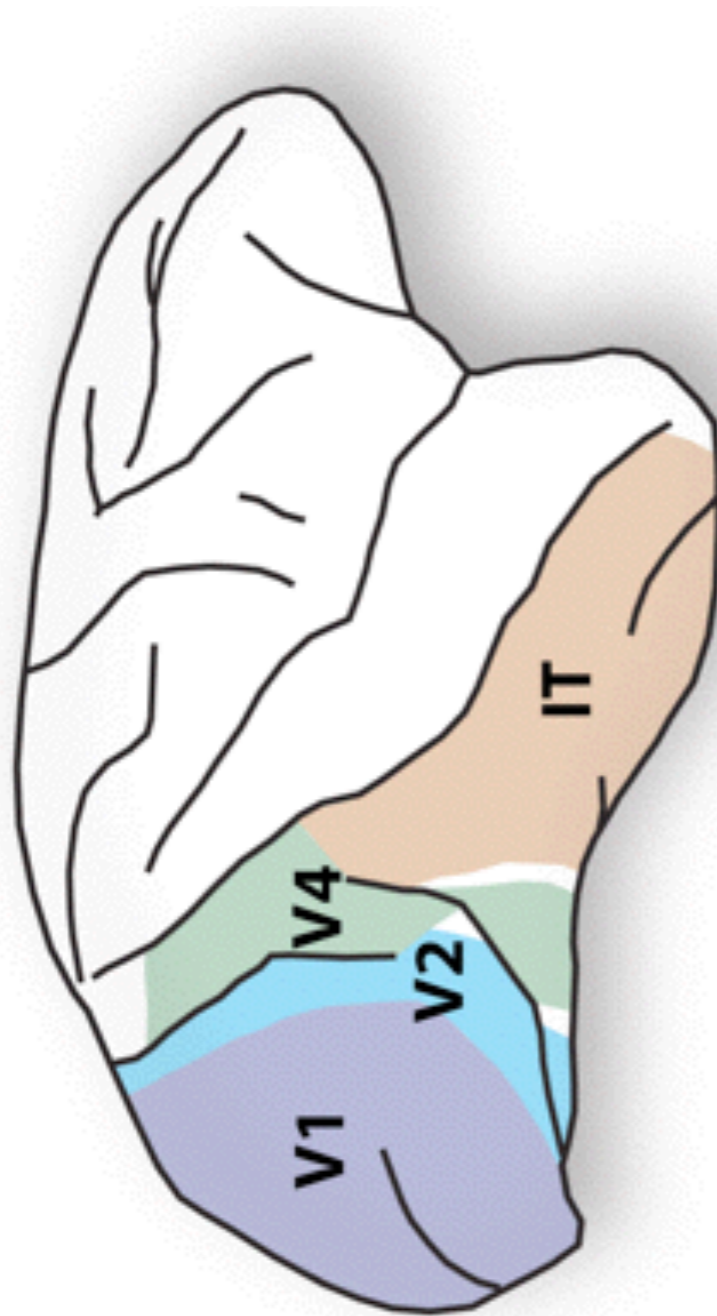
Ventral visual stream
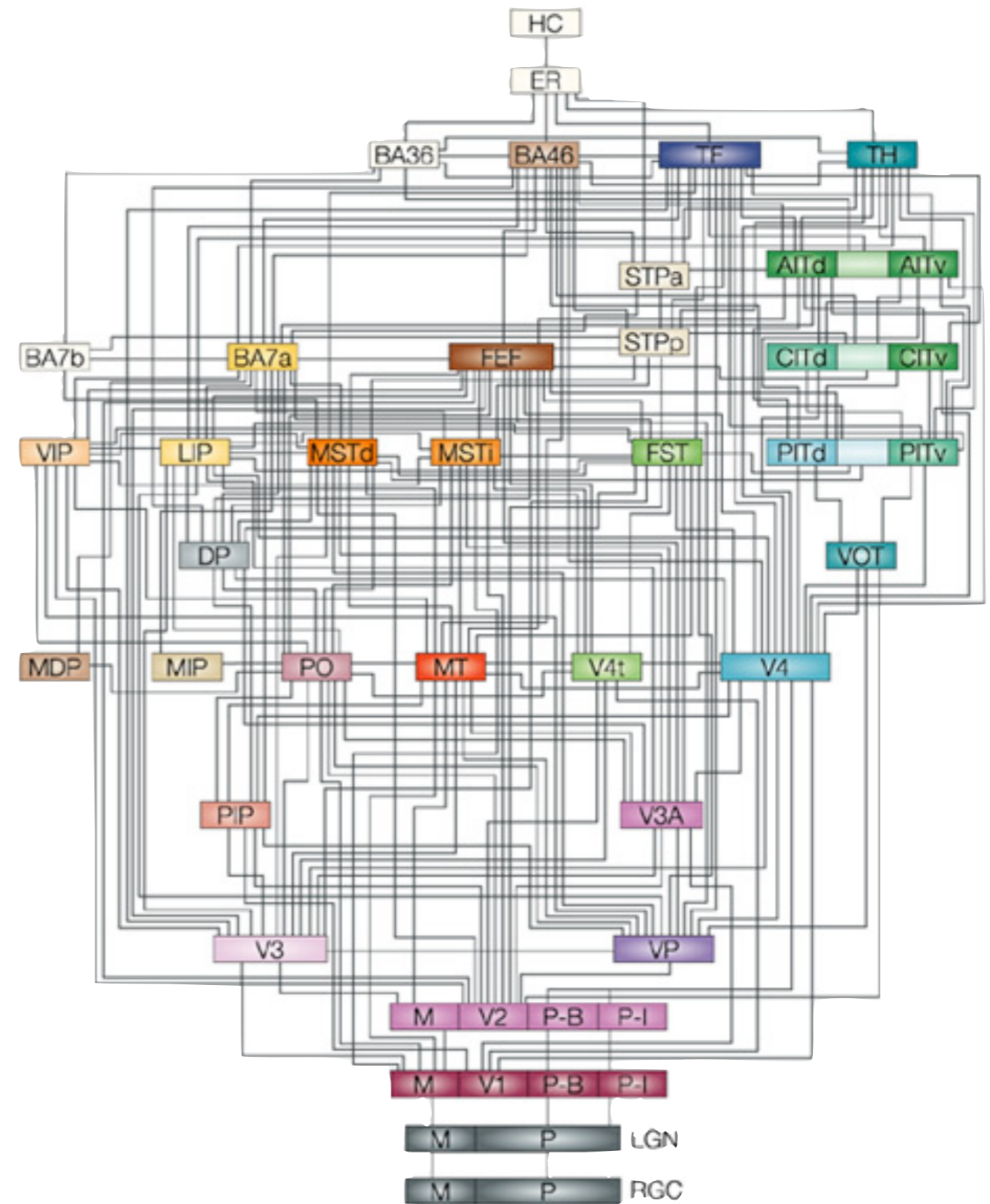
Summary | Hierarchies are ubiquitous:
Anatomy, function & latencies

source: Felleman & VanEssen '90

Dorsal visual stream

V1 V4

V2

IT
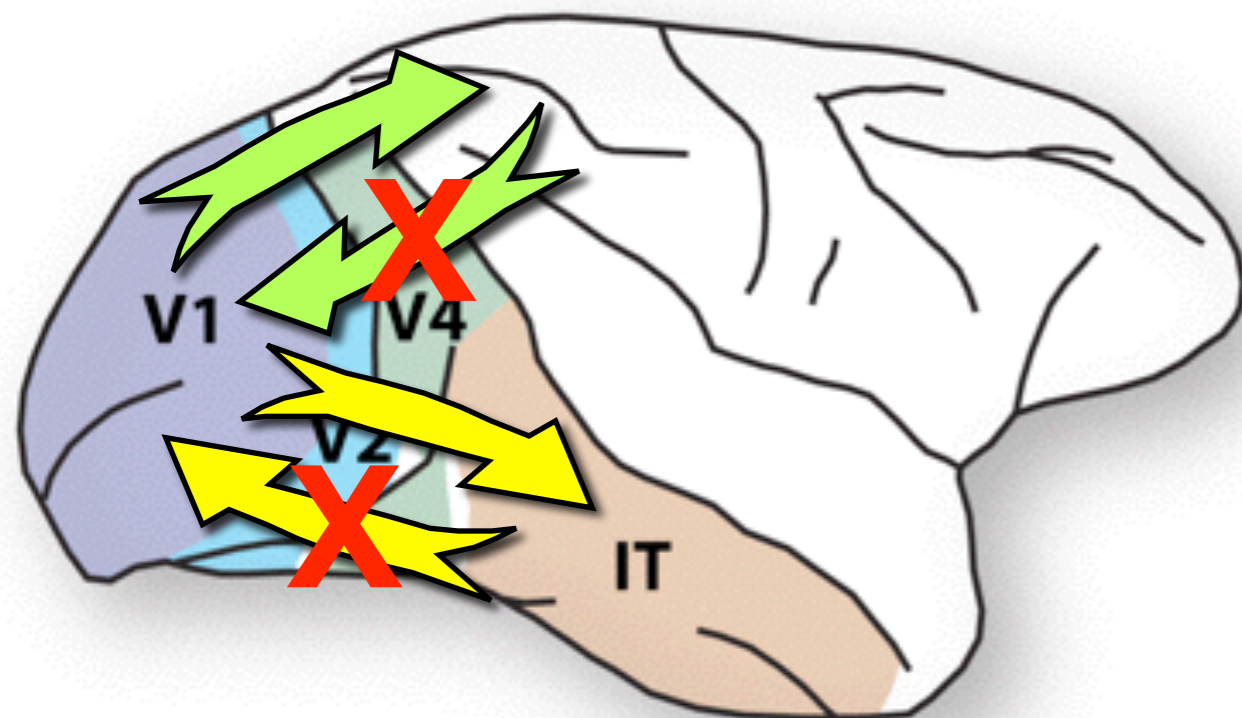
Ventral visual stream

Summary | Two modes of processing: Bottom-up vs. recurrent

Computational Vision

Foundations

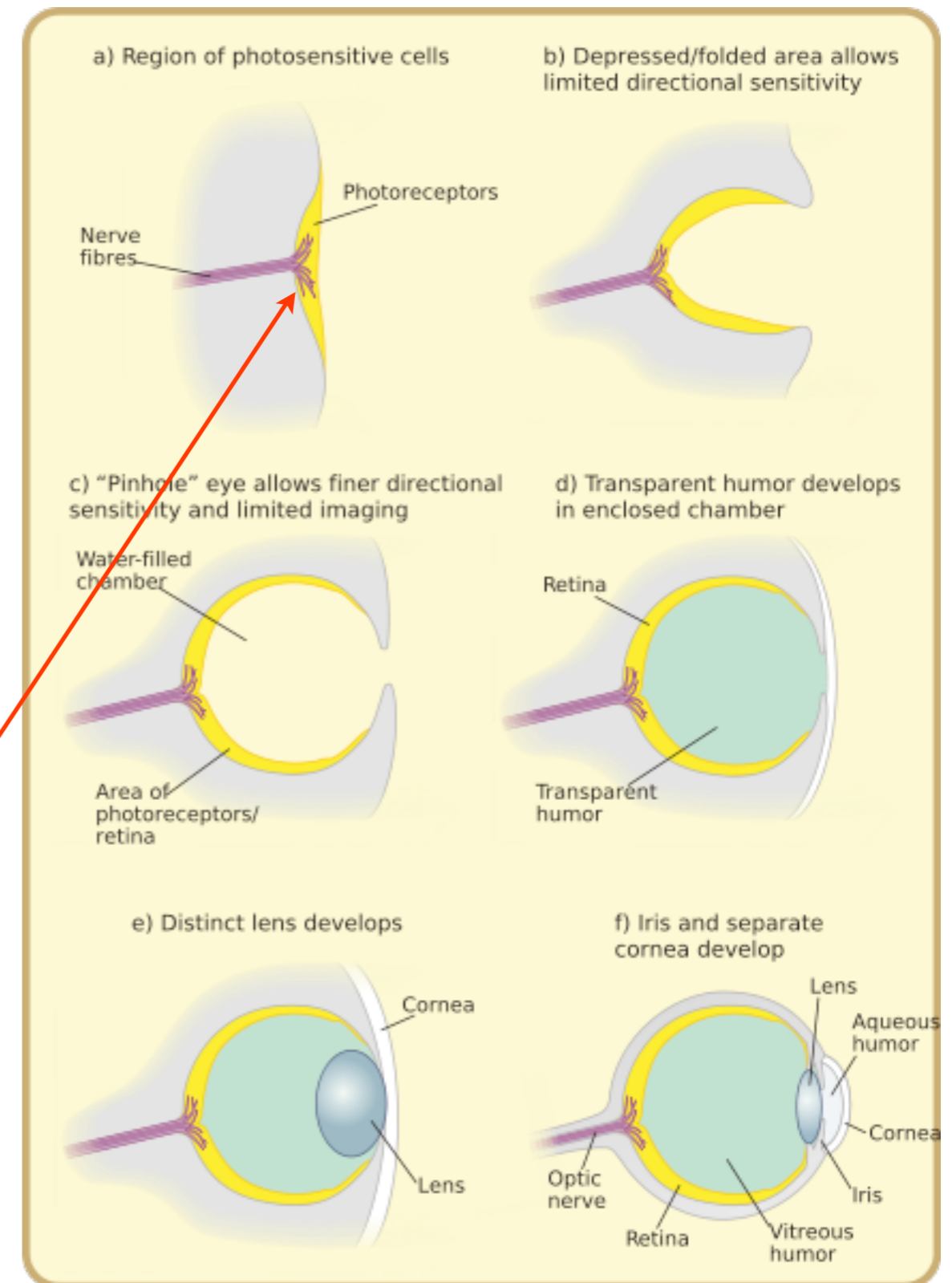- Finish fundamentals of primate vision cont'd
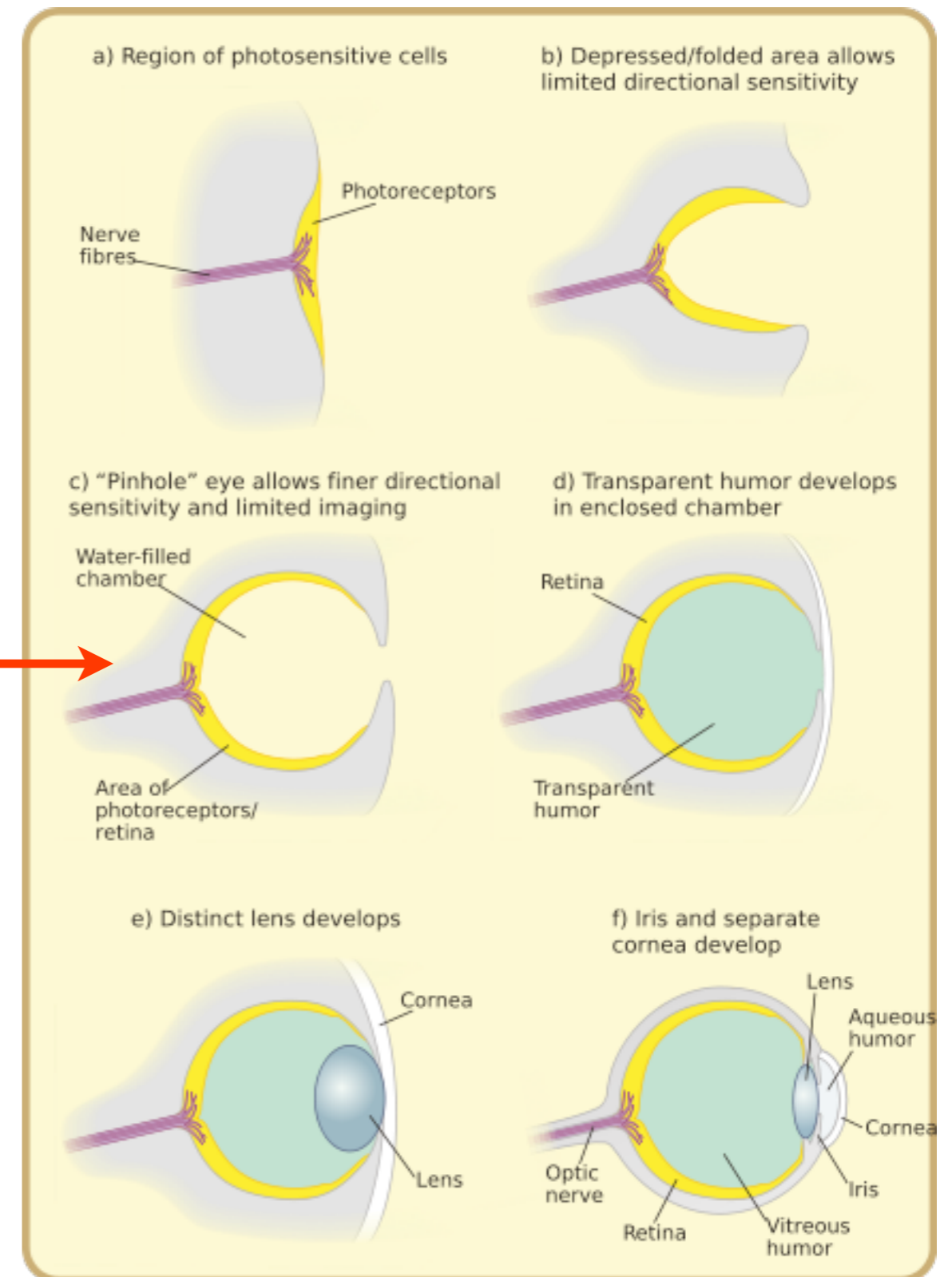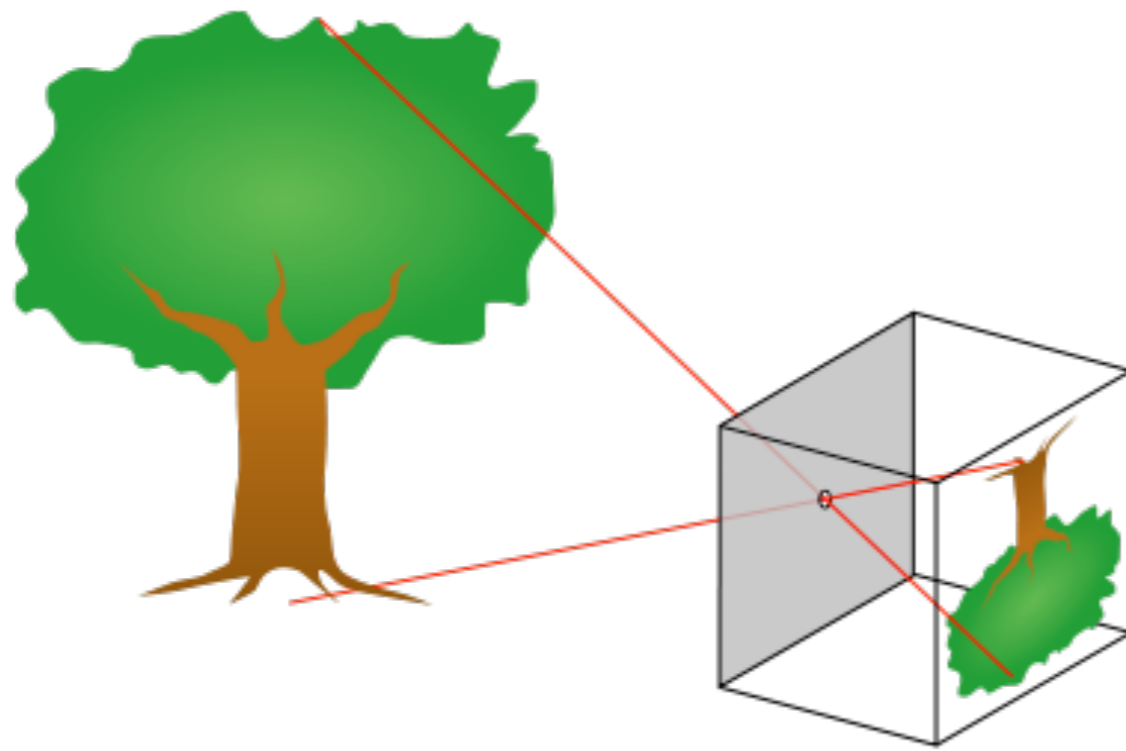
- Start retina and LGN

Evolution of the eye

- Proto-eye believed to have evolved some ~500M yrs ago

- Majority of advancements in early eyes believed to have taken only ~1M yrs to develop

- Wide range of adaptation:

  - Birds of prey have much greater visual acuity than humans, and some can see ultraviolet light!

Can only sense ambient light

a) Region of photosensitive cells

Nerve fibres

Photoreceptors

b) Depressed/folded area allows limited directional sensitivity

c) "Pinhole" eye allows finer directional sensitivity and limited imaging

Water-filled chamber

Area of photoreceptors/ retina

d) Transparent humor develops in enclosed chamber

Retina

Transparent humor

e) Distinct lens develops

Cornea

Lens

f) Iris and separate cornea develop

Lens

Aqueous humor

Cornea

Optic nerve

Retina

Vitreous humor

Iris

Source: wikipedia

Evolution of the eye

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Source: http://static.howstuffworks.com/gif/camera2.jpg

Source: wikipedia

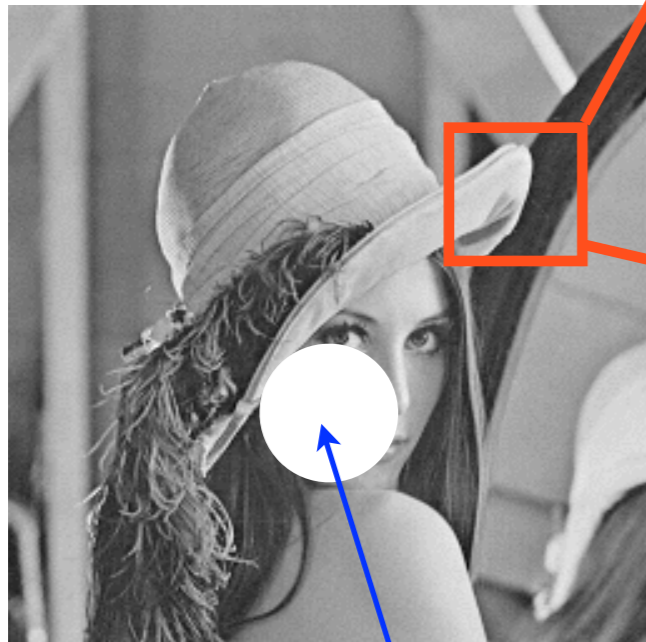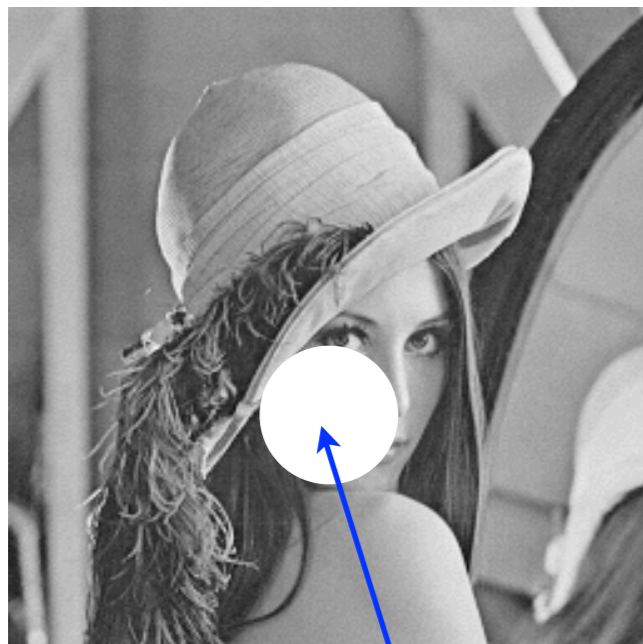# Our retina in matlab

uniform sampling of receptor

Real retinas

blind spot

uniform sampling of receptor

Real retinas

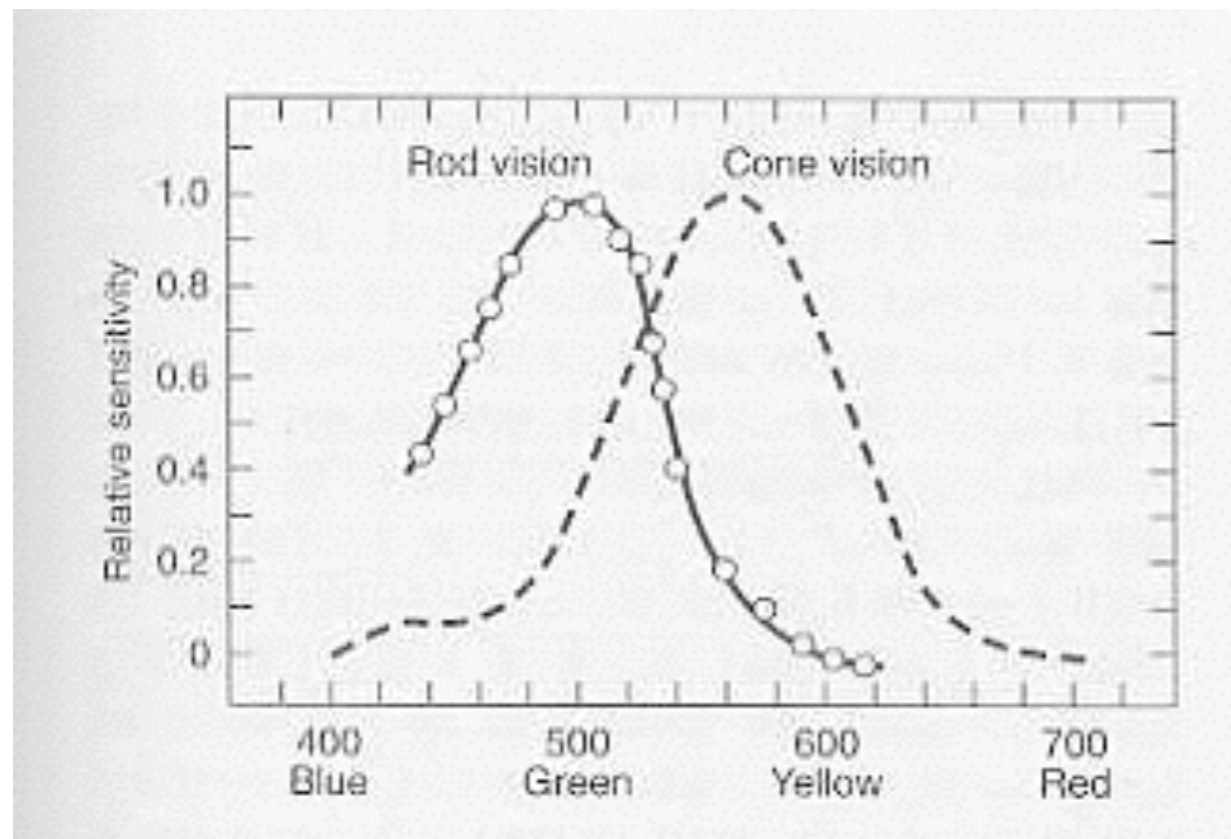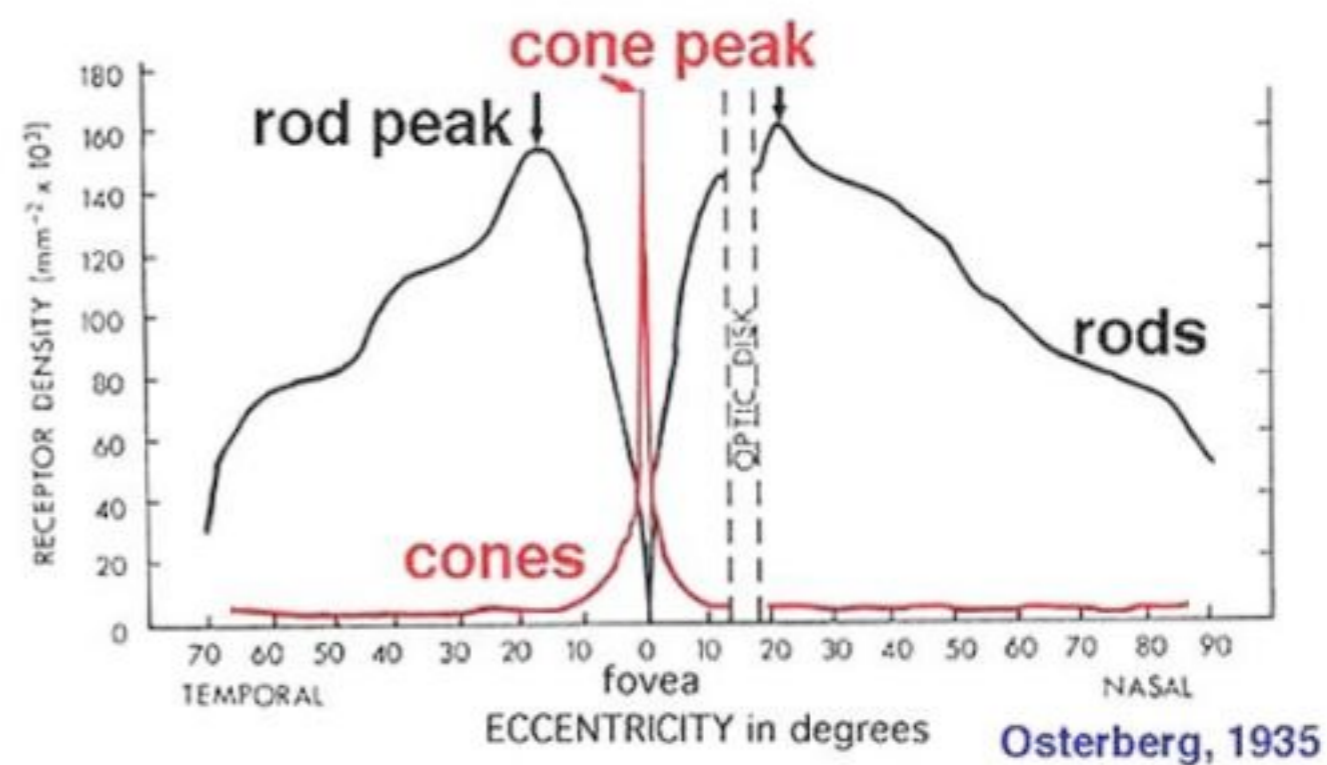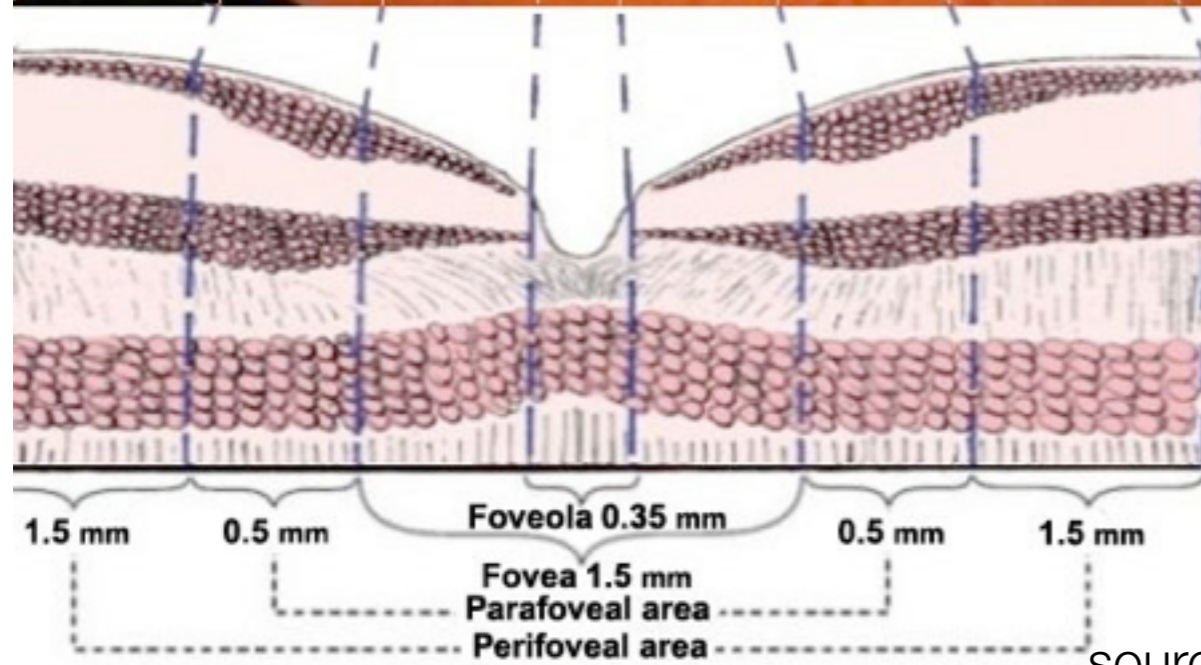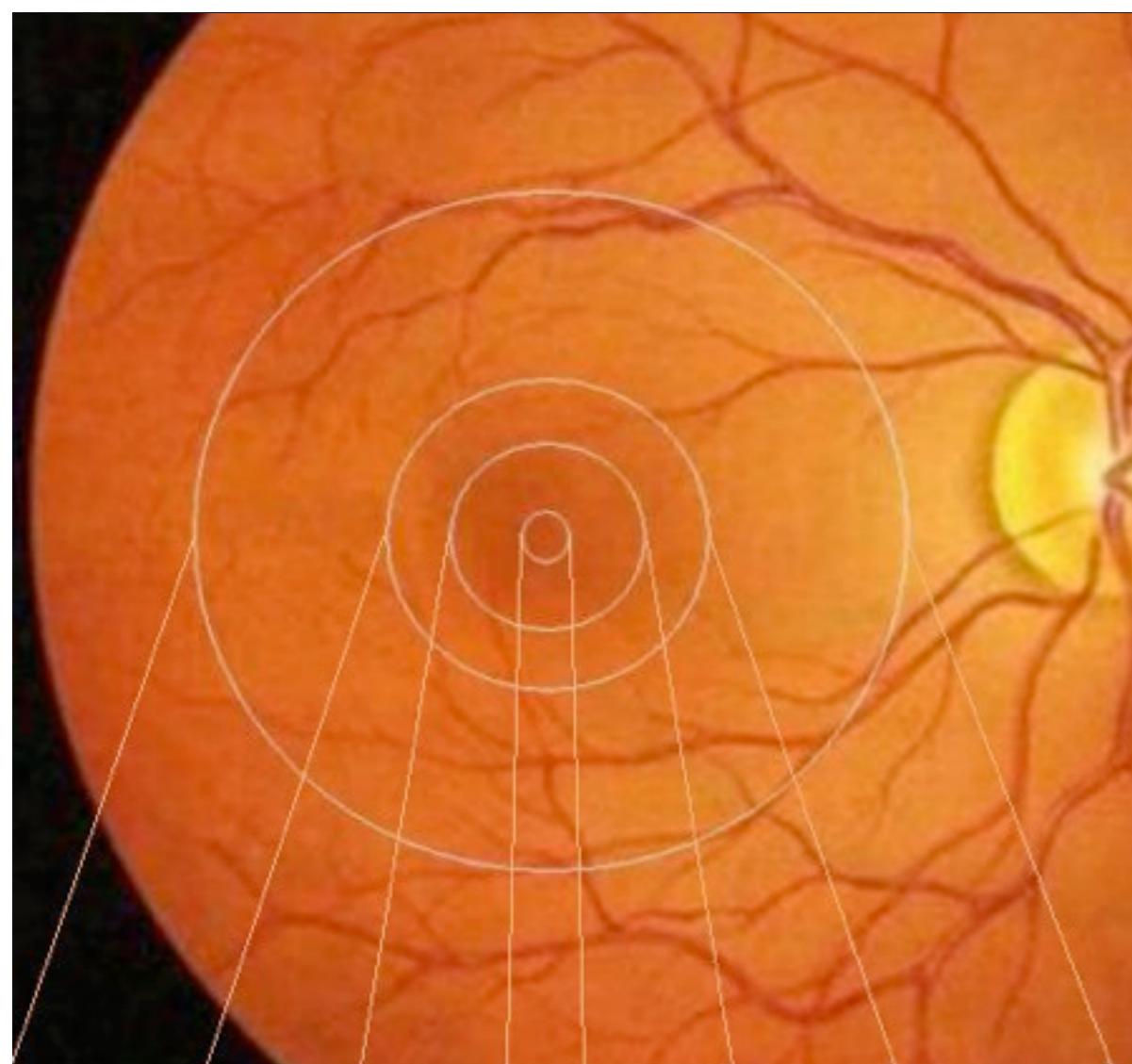blind spot

Rods and cones

- Rods are 100 times more sensitive to a single photon than cones

- 20 times more rods than cones in the retina

- Rods are:

  - Slow

  - More pigments so more sensitive to light

- Cones are:

  - Fast

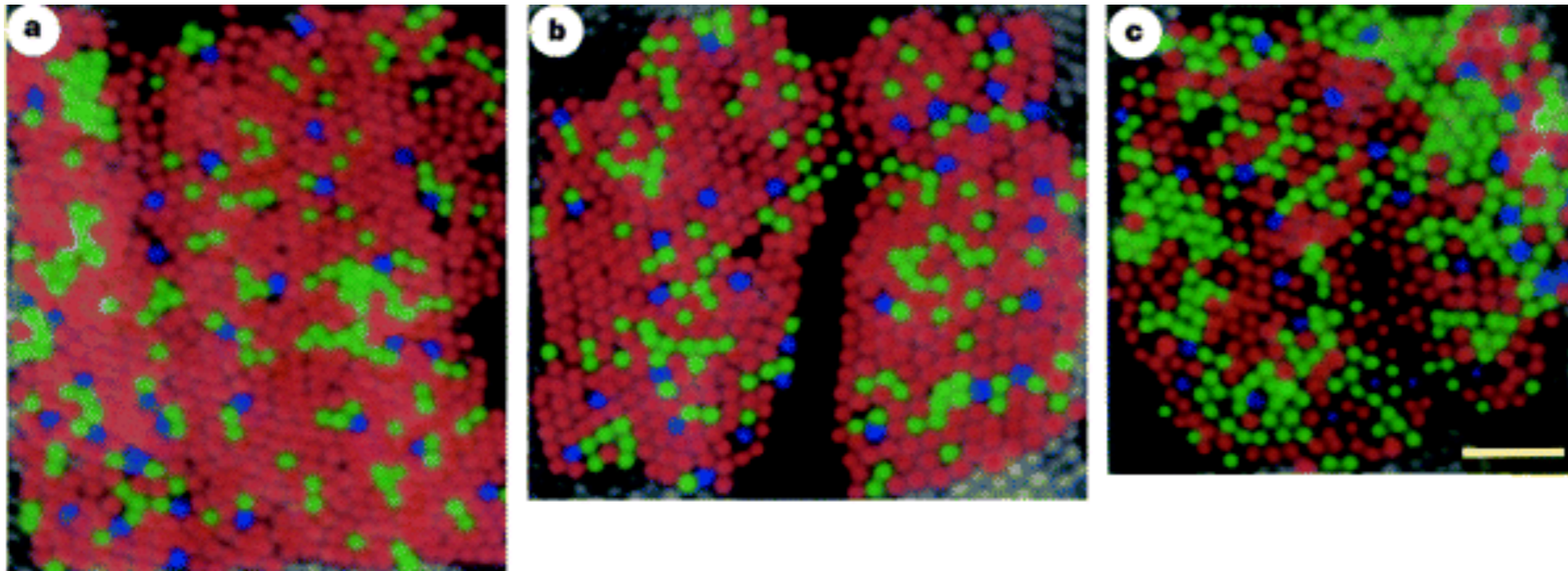 - Less pigments so much less sensitive to light

Rods

Cone

Rods and cones

source: http://www.forbestvision.com/retina-macula-fovea-foveola/
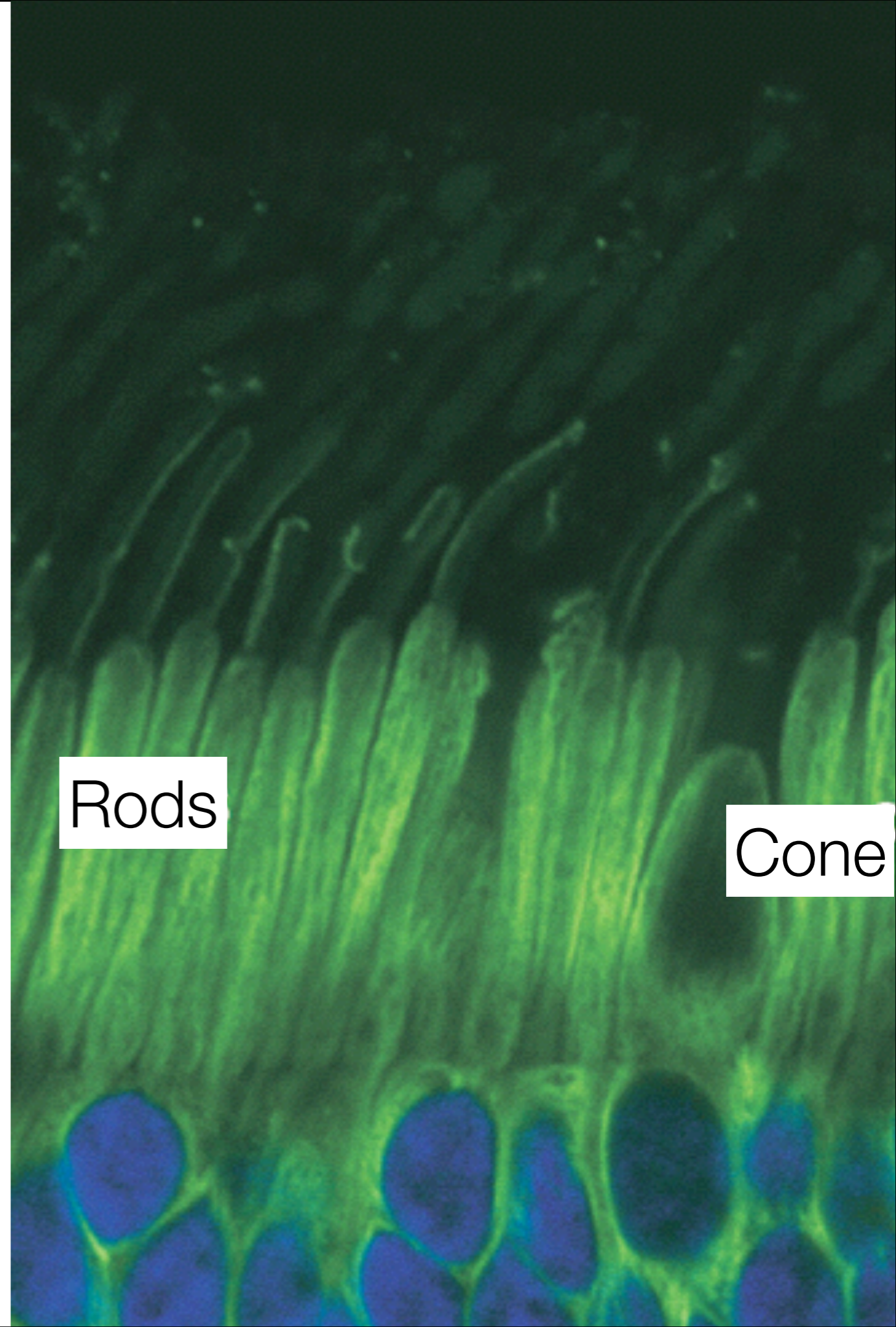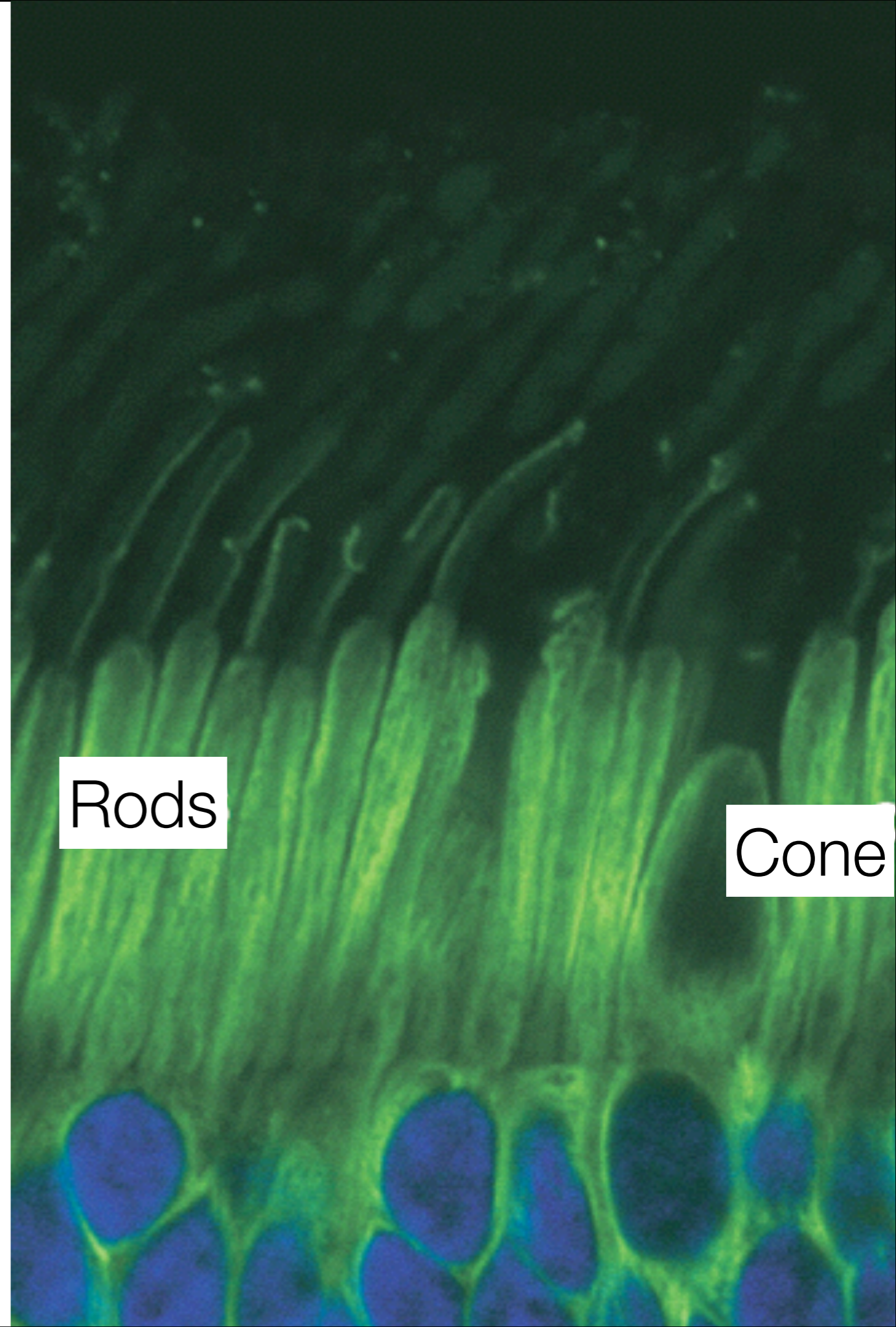
Human retina vs. CCD chip

Roorda & Williams 1999

CCD matrix