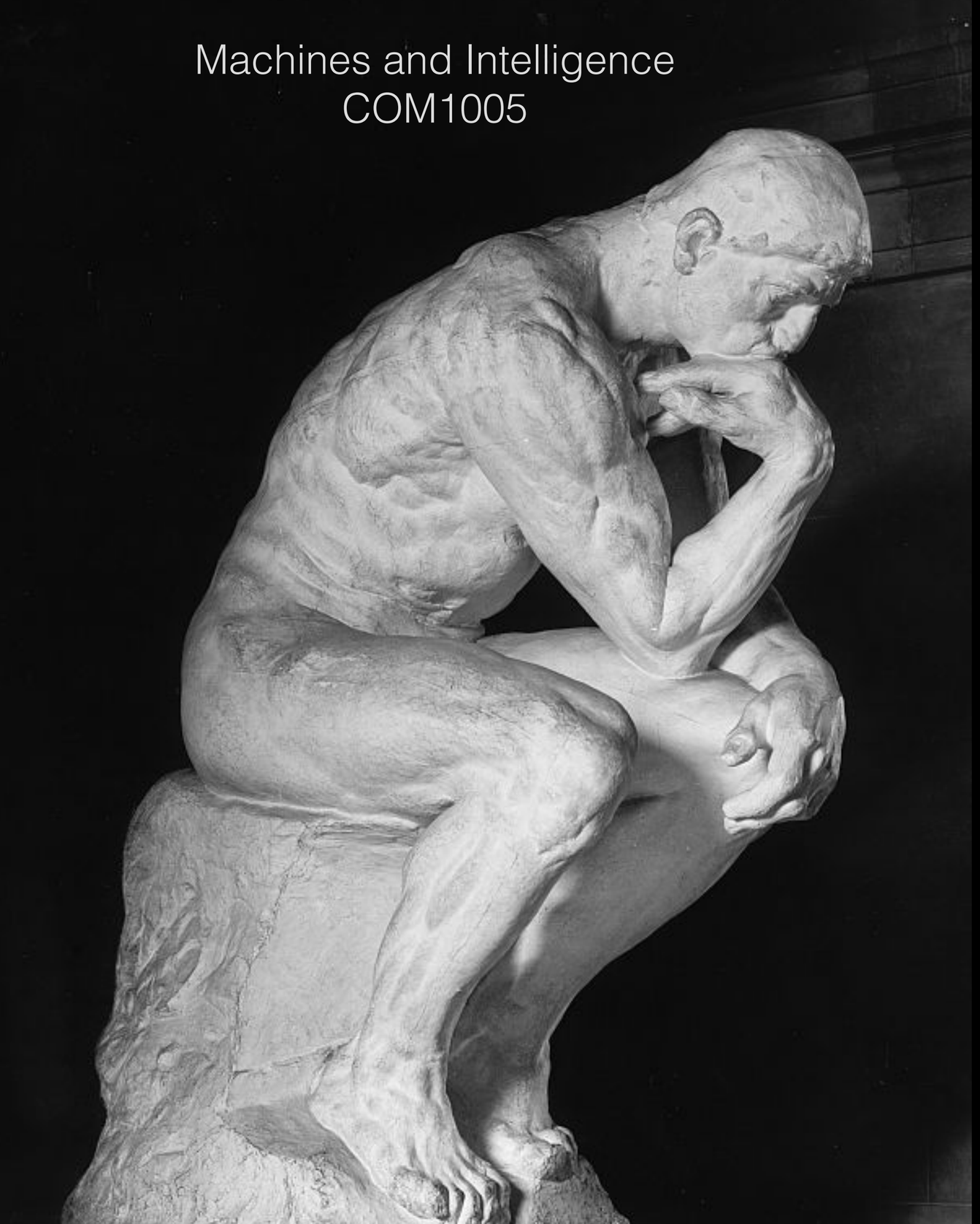
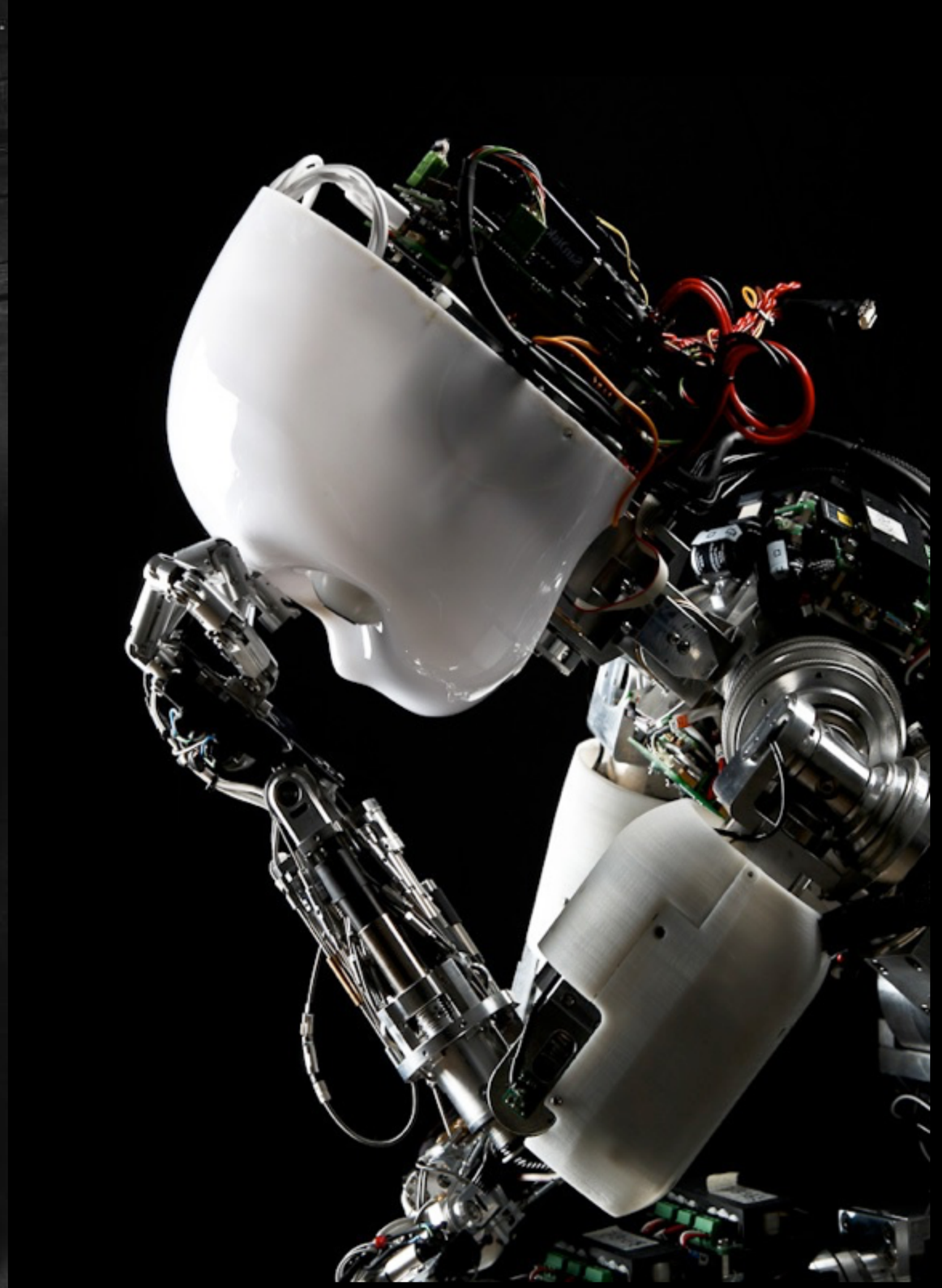
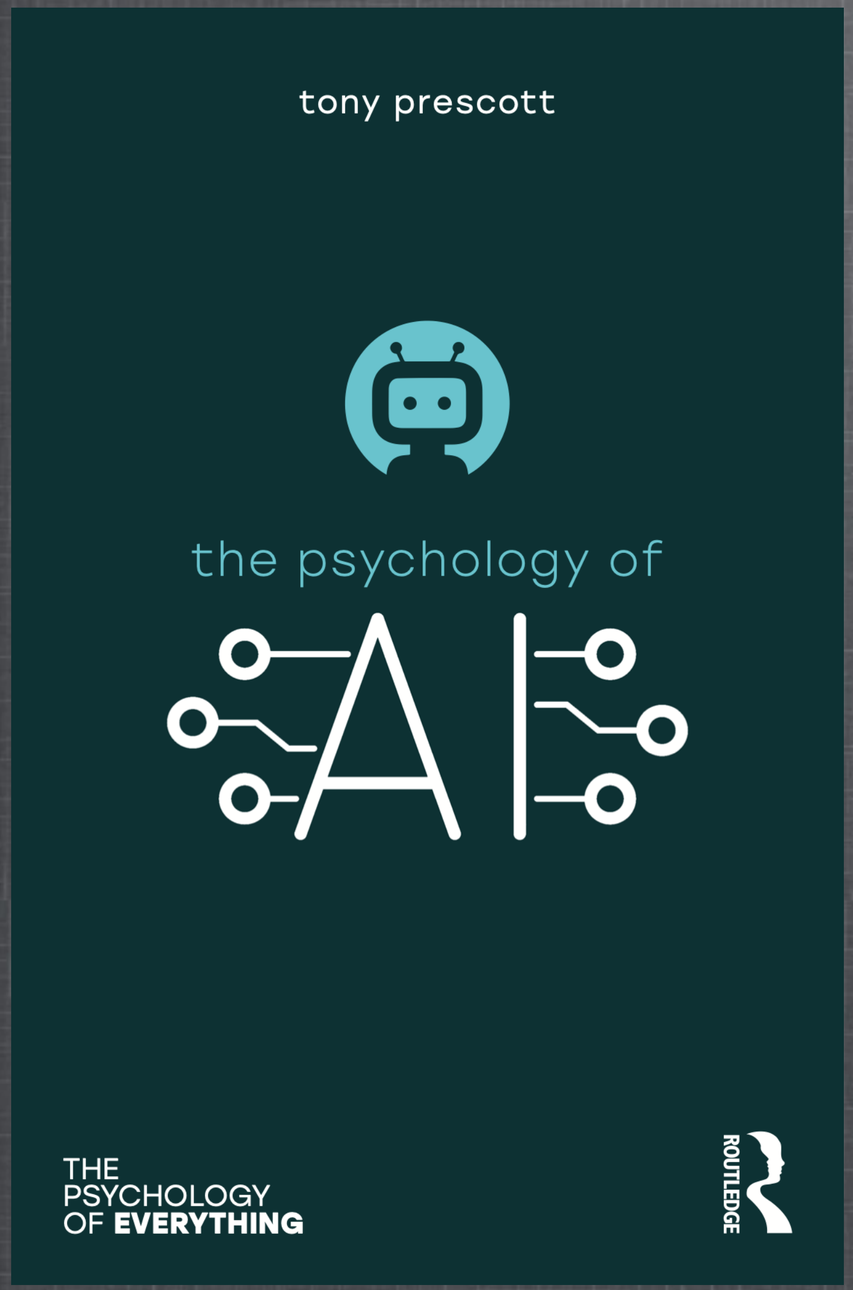
Machines and Intelligence
COM1005





THE PSYCHOLOGY OF AI



- What is intelligence?
- **Brains and computers**
- The building blocks of intelligence
- Learning in neural networks
- Towards Artificial General Intelligence (AI)
- Living with Artificial Intelligence

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£8.95 Kindle
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Published in 2024. Background reading for COM1005

THIS WEEK: HOW VISION WORKS

These lectures explore the nature of human visual perception, to understand the challenges that need to be addressed in creating artificial visual systems

1. How patterns of light are detected by the eye and processed in the brain
2. Principles that make it possible to sense the world through vision
3. Seeing as a form of “unconscious inference”

HOW VISION WORKS

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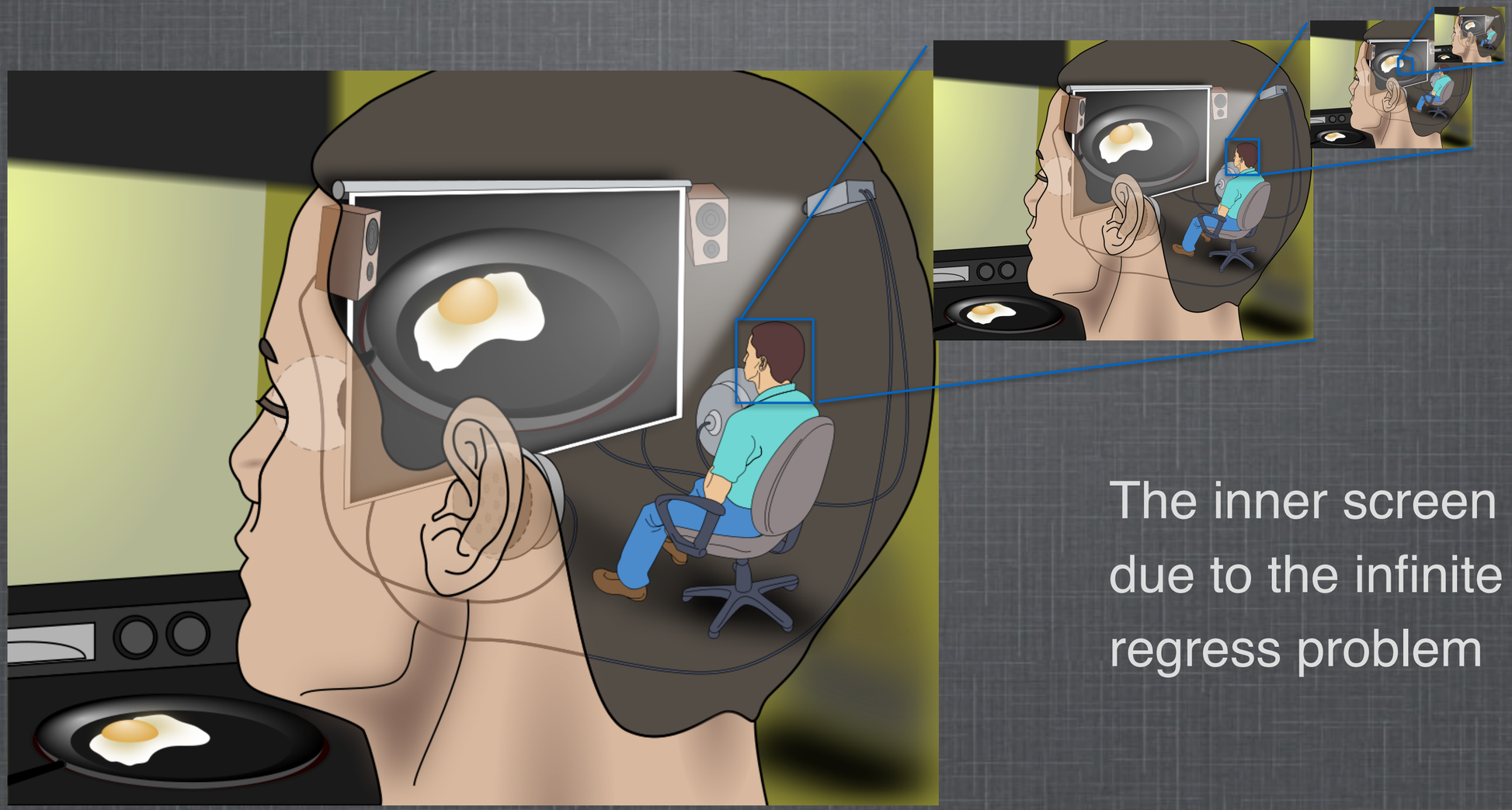
THE “INNER SCREEN” THEORY OF SEEING

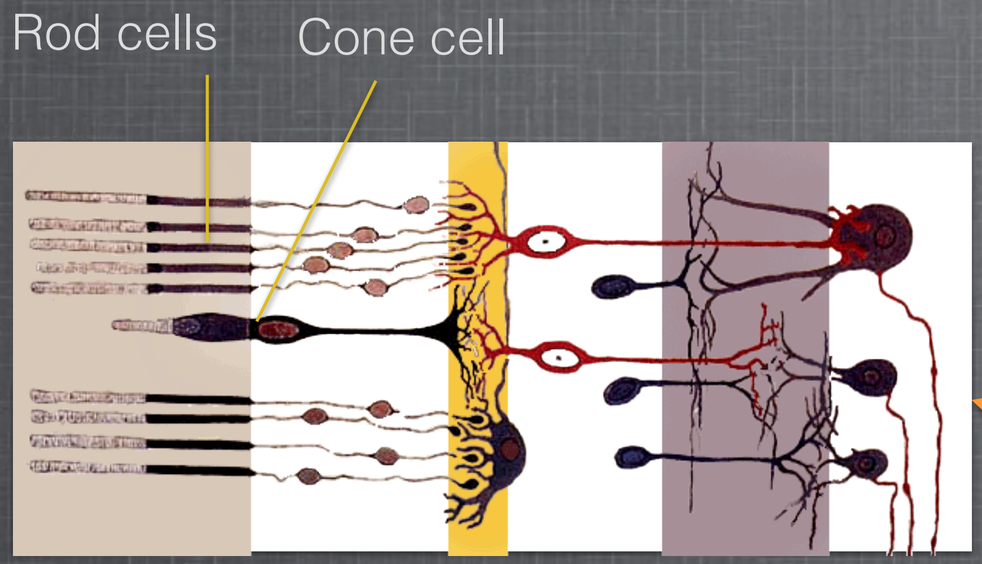


Jennifer Garcia, Wikimedia, CC-BY

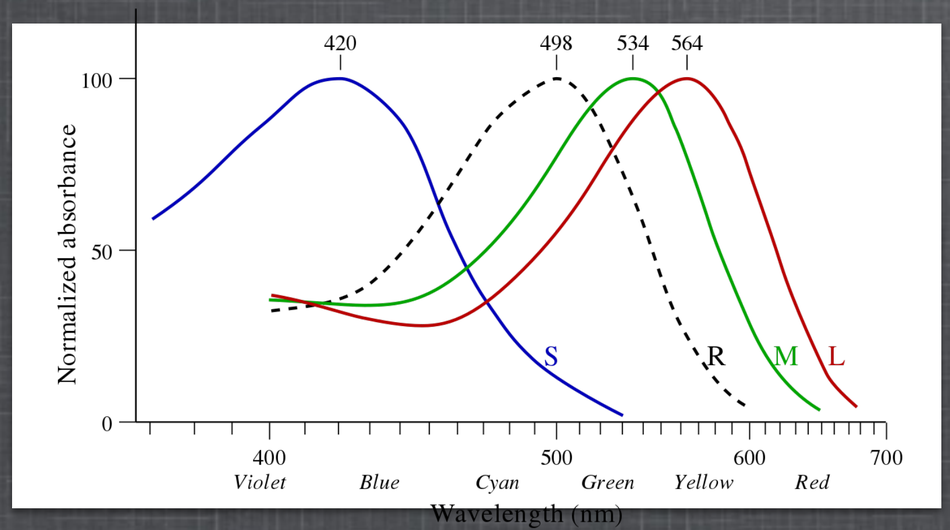
The inner screen fails due to the infinite regress problem

The inner screen ‘theory’ proposes that the brain represents the brightness of points in the scene like a being in a movie theatre (Daniel Dennett called this the “Cartesian Theatre”). Here it is imagined upright to match our perceptions of the world.

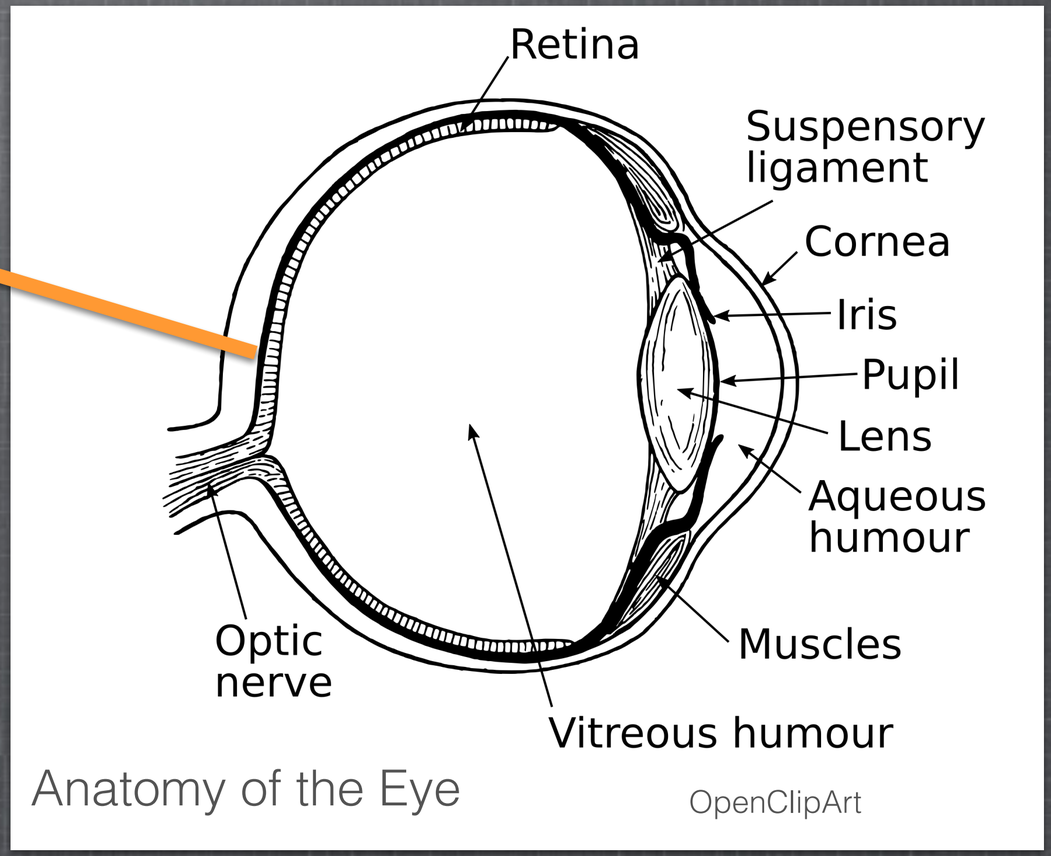
MAKING LIGHT INTO ‘SPIKES’



Organization of the retina (from Cajal, 1911)



Wavelength responses

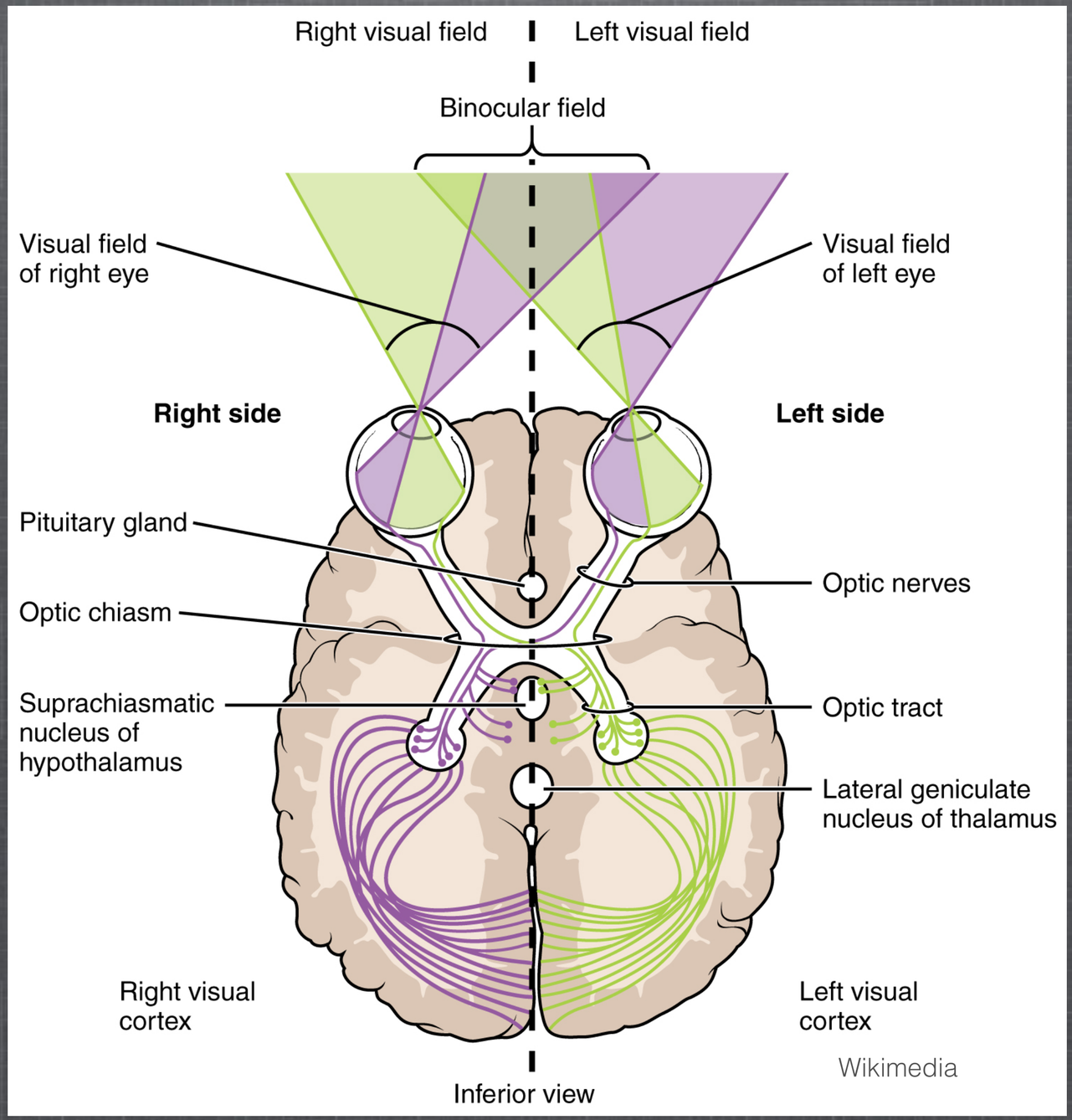


Anatomy of the Eye

OpenClipArt

The human retina is an extension of the brain, it contains about 120 million rod cells and about 6 million cone cells

THE HUMAN VISUAL SYSTEM AS TWO HEMIFIELDS



Left

Visual field 200°

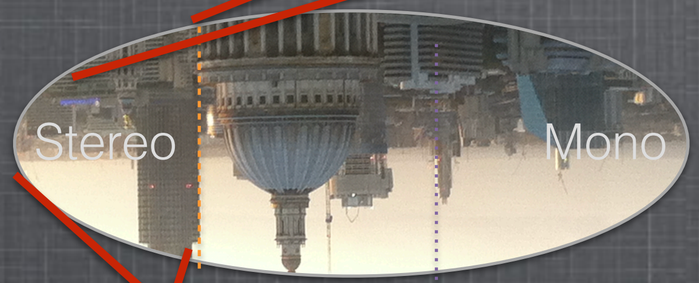
Right

Scene

135°

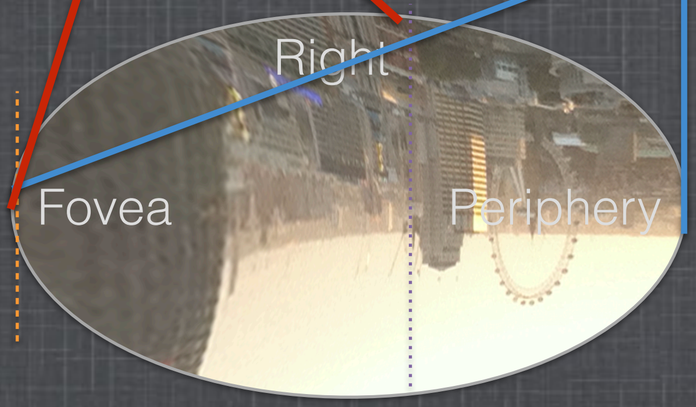
Flipped, overlap 120°

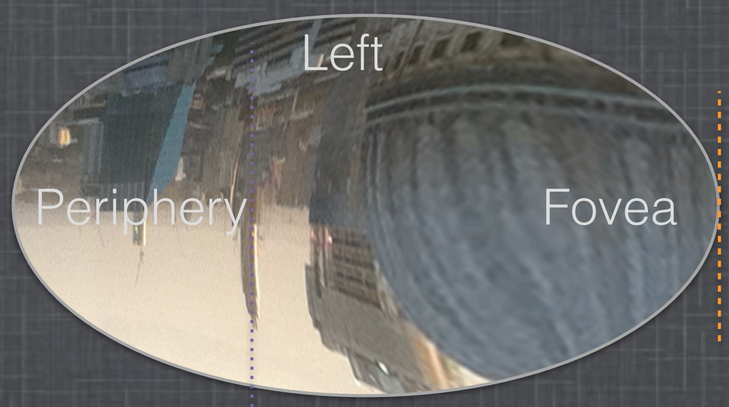
Eye



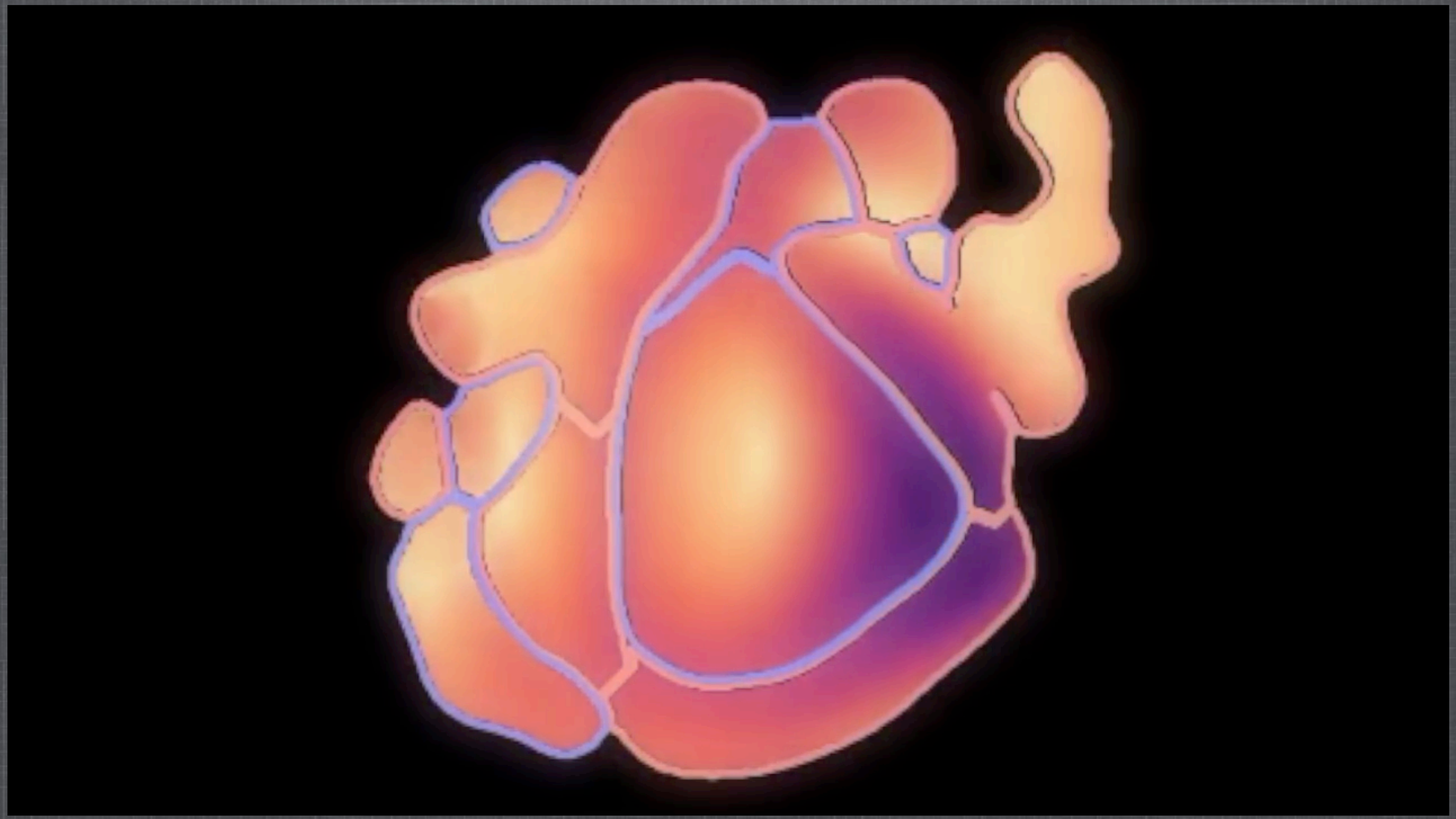
Crossed, distorted, no overlap

Visual Cortex





THERE ARE MANY AREAS IN THE BRAIN THAT ARE ORGANISED AS RETINOTOPIC MAPS



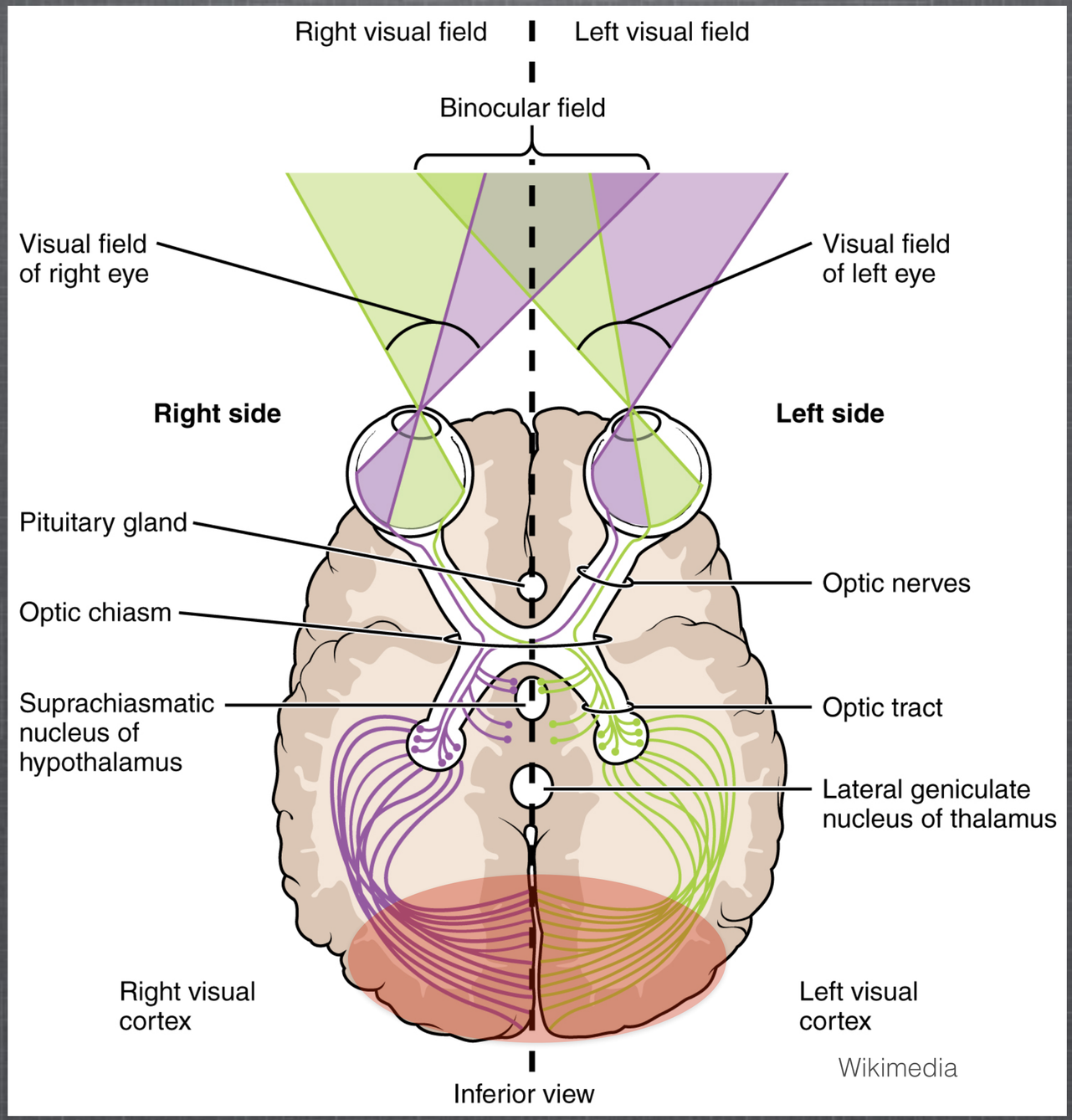
This is a map of the left hemisphere only

Mouse brain simulation from Allen Brain Institute

Full video available on Youtube

Zhuang et al. eLife 2017;6:e1837

CORTICAL PROCESSING OF VISION STARTS FROM THE BACK



VISION PROCESSING IN THE BRAIN FOLLOWS MULTIPLE PATHWAYS

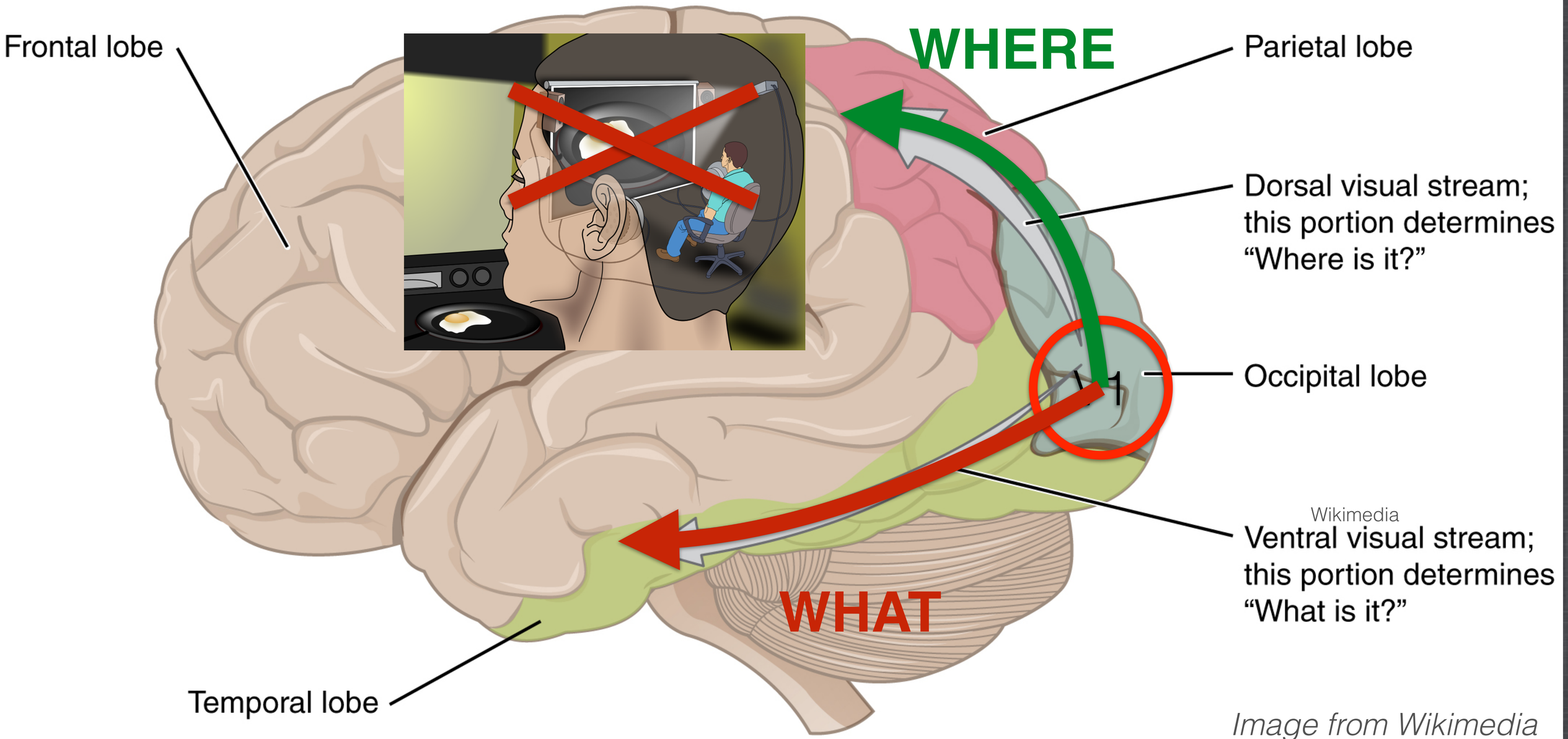
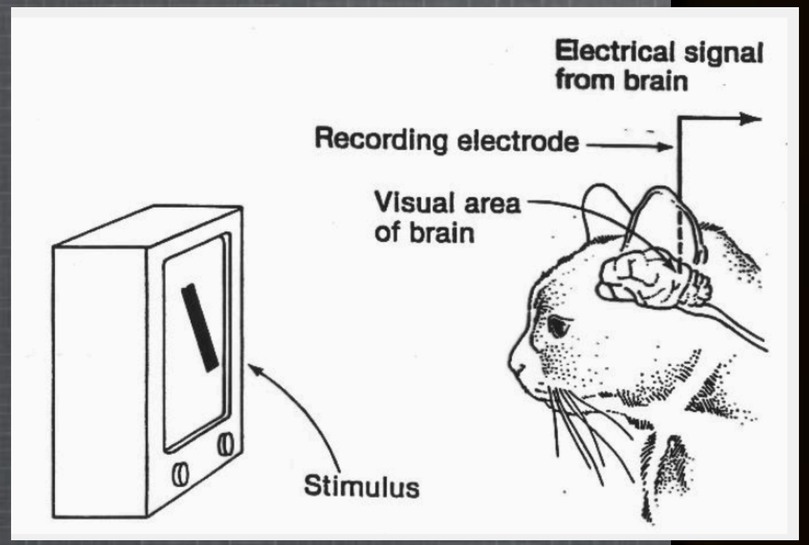


Image from Wikimedia

There is no single location where everything comes together…

EDGE DETECTOR CELLS IN VISUAL CORTEX – HUBEL & WIESEL 1959

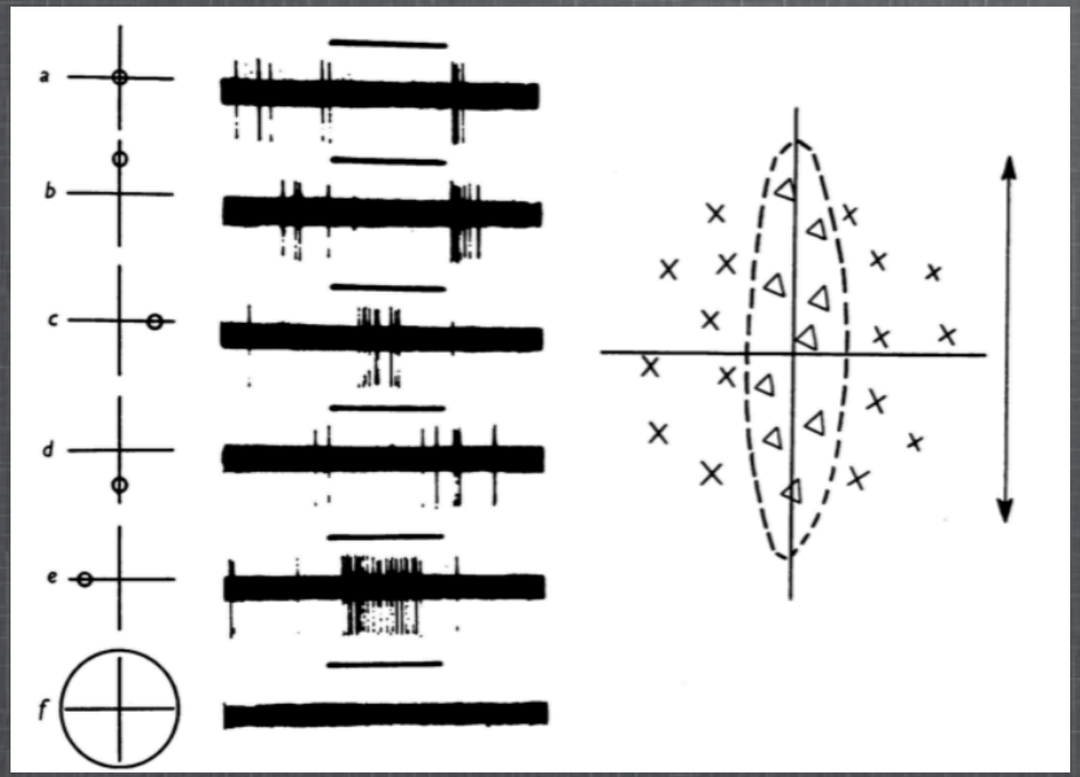


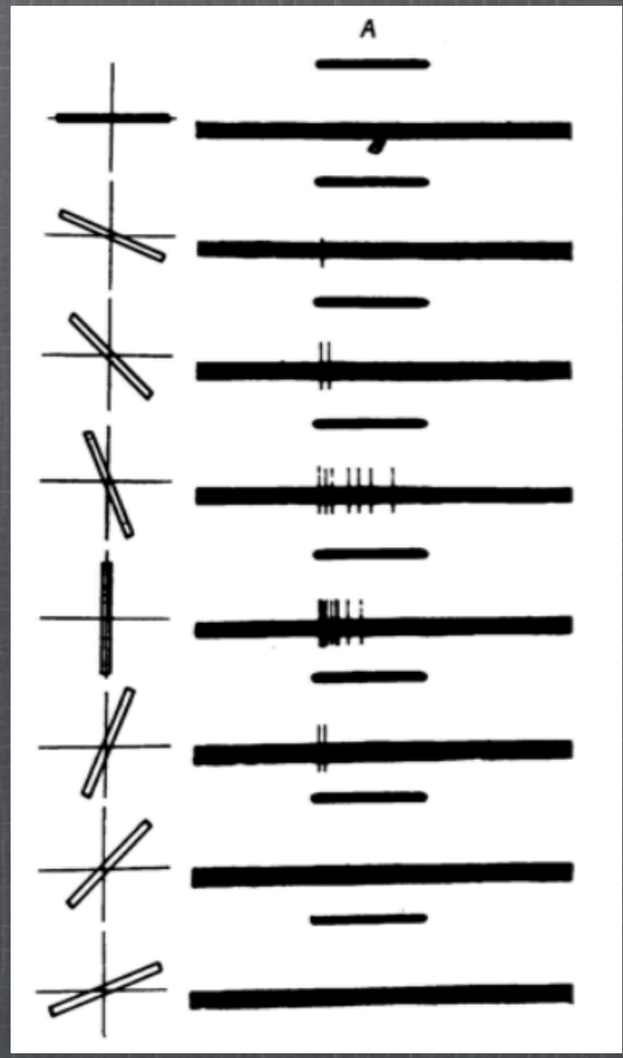
HUBEL, D. H., & WIESEL, T. N. (1959). The Journal of physiology, 148(3), 574–591

Full video available on Youtube

AT THE BASE OF THE VISUAL PATHWAY—SEEING EDGES

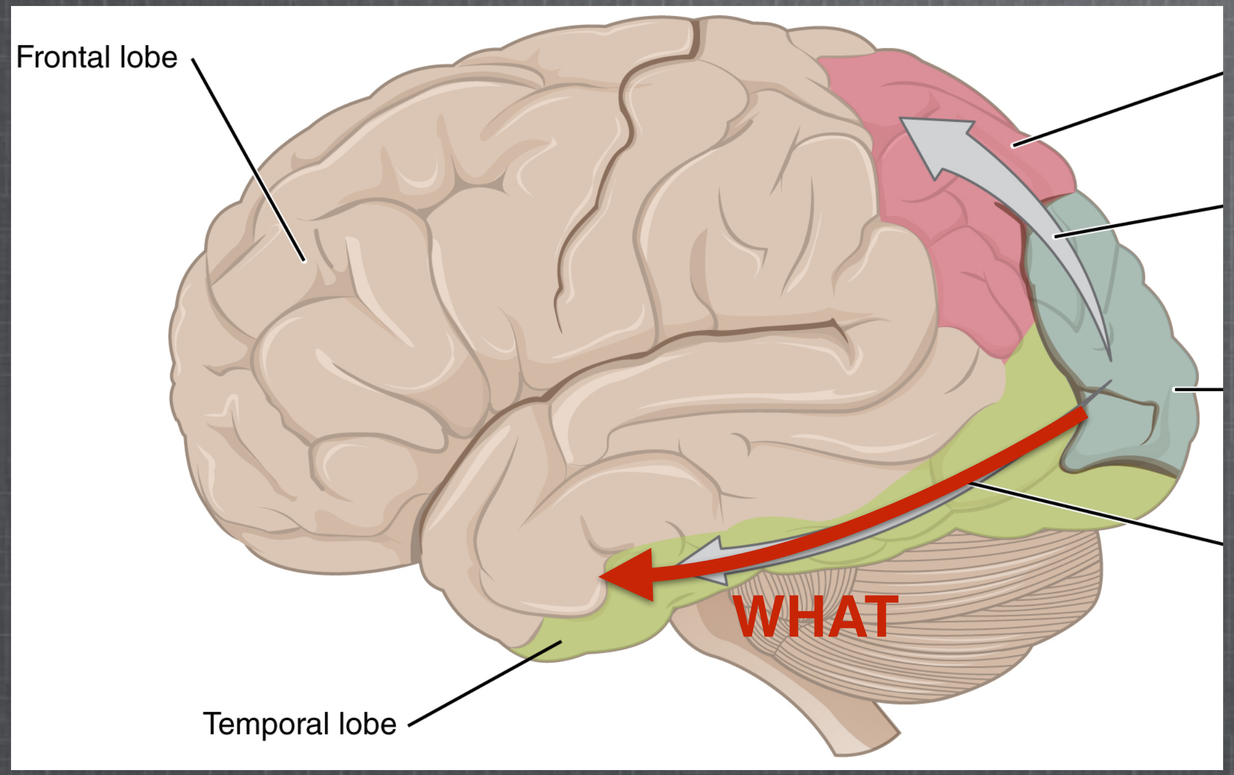
Hubel and Wiesel found that single V1 cells responded preferentially to moving lines at preferred orientations





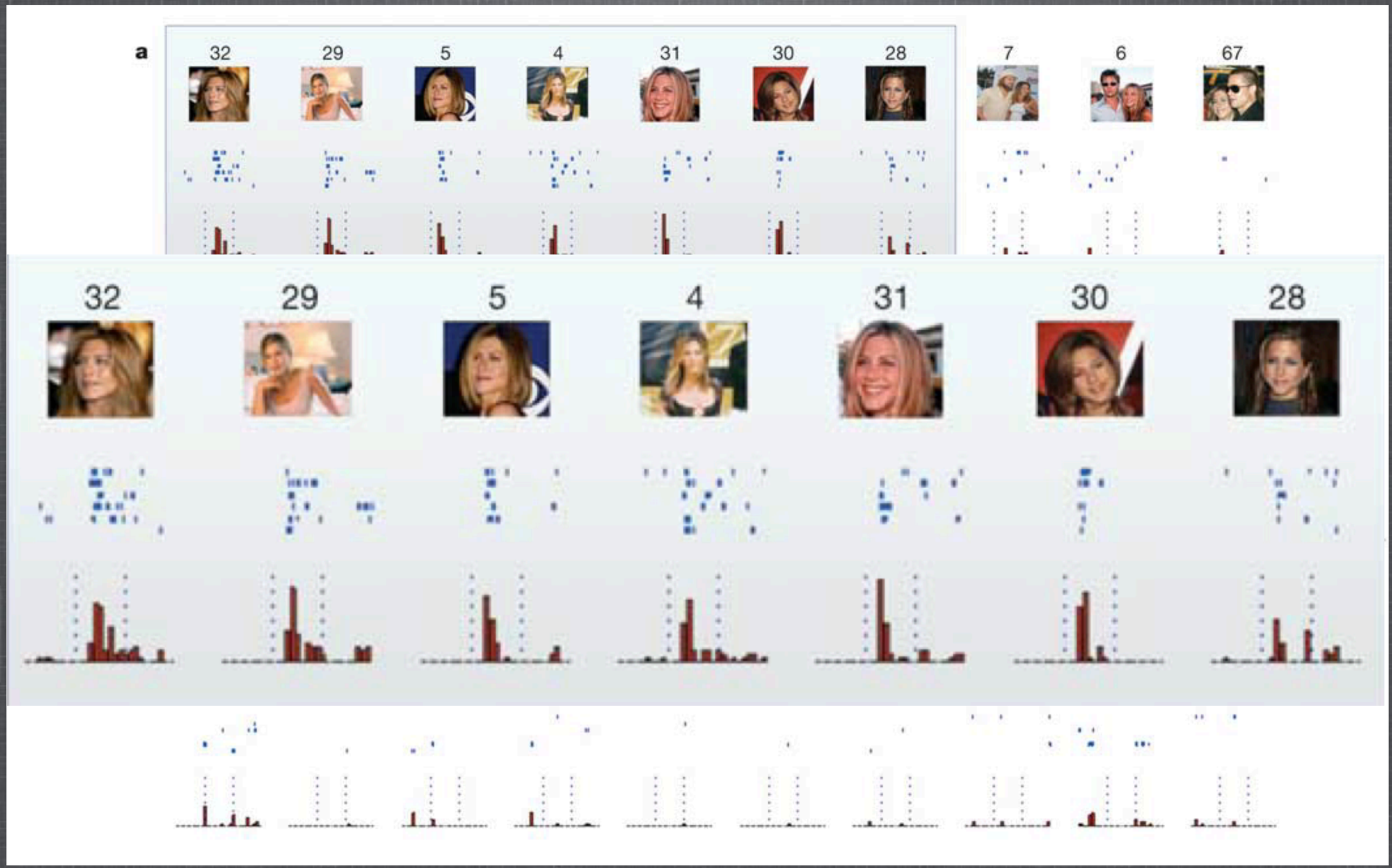
HUBEL, D. H., & WIESEL, T. N. (1959). The Journal of physiology, 148(3), 574–591

AT THE UPPER END OF THE WHAT PATHWAY—HIGH-LEVEL CONCEPTS



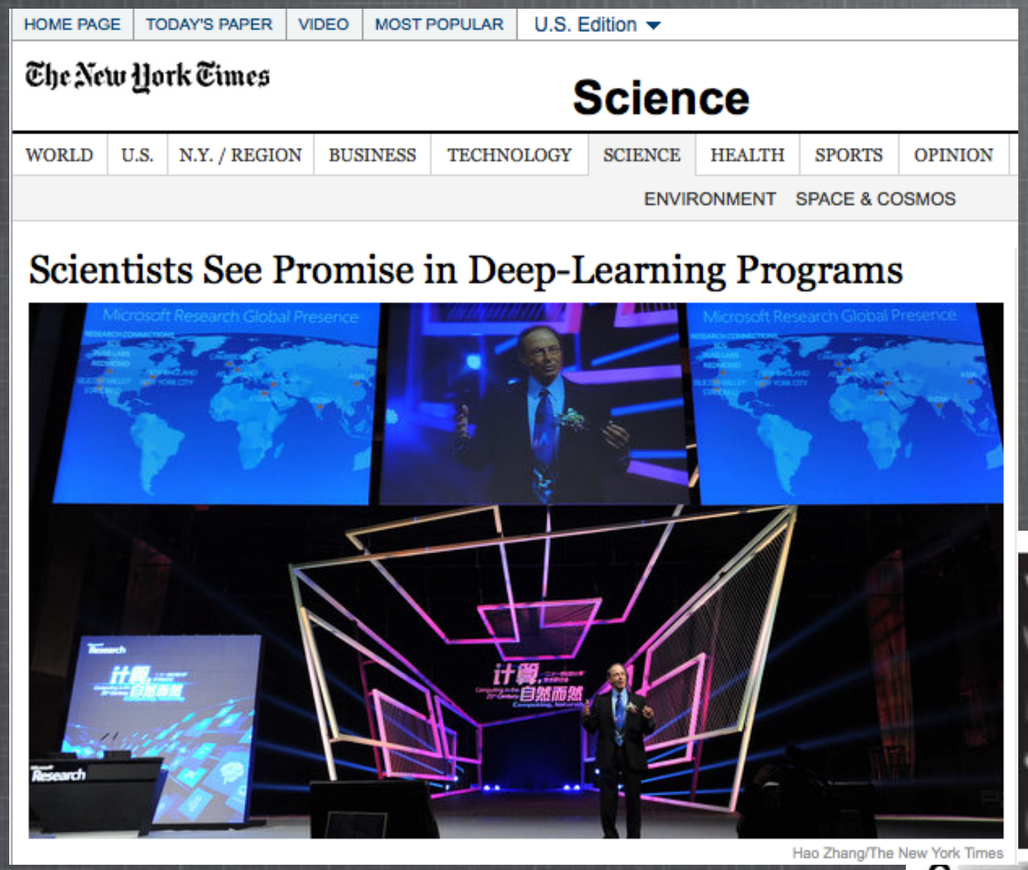
Studies suggest that individual neurons in the temporal lobe respond to stimulus properties that correspond to high-level concepts such as people, place, objects…

A NEURON THAT PREFERENTIALLY RESPONDS TO PICTURES OF JENNIFER ANISTON

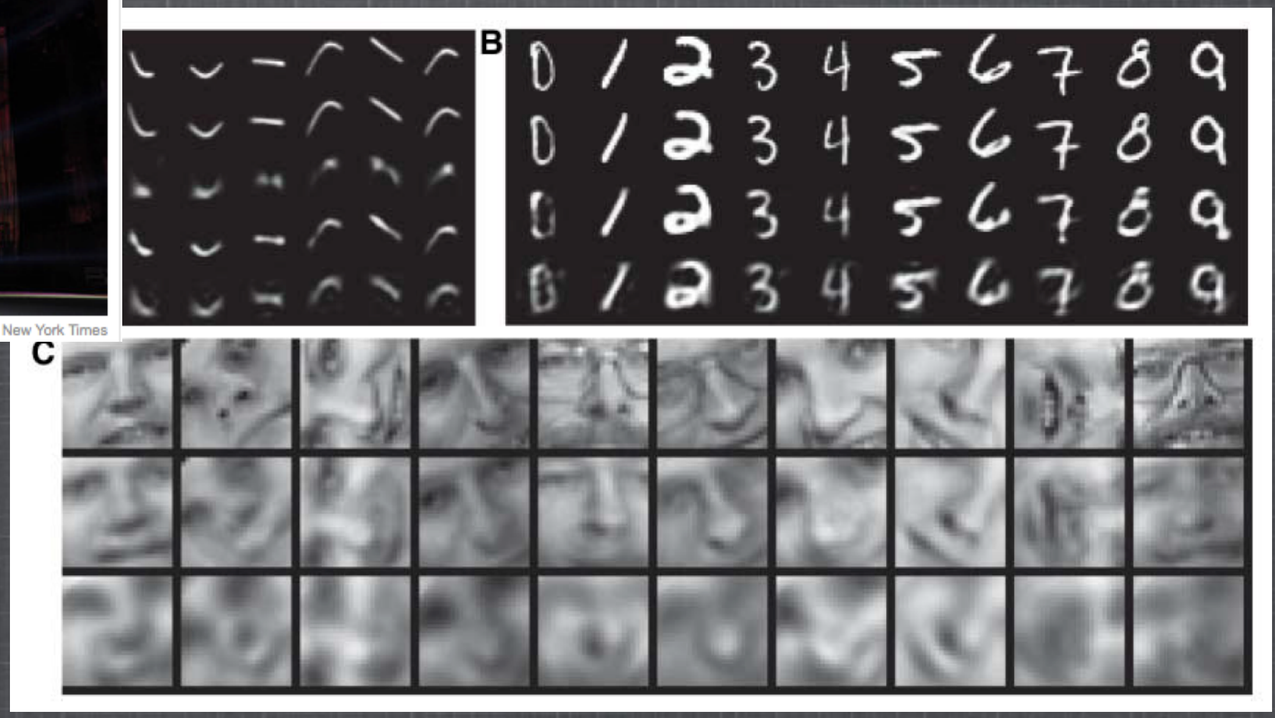


Quiroga et al., Nature, 2005, 435, 1102-1107

DEEP LEARNING IS REVOLUTIONISING COMPUTER VISION

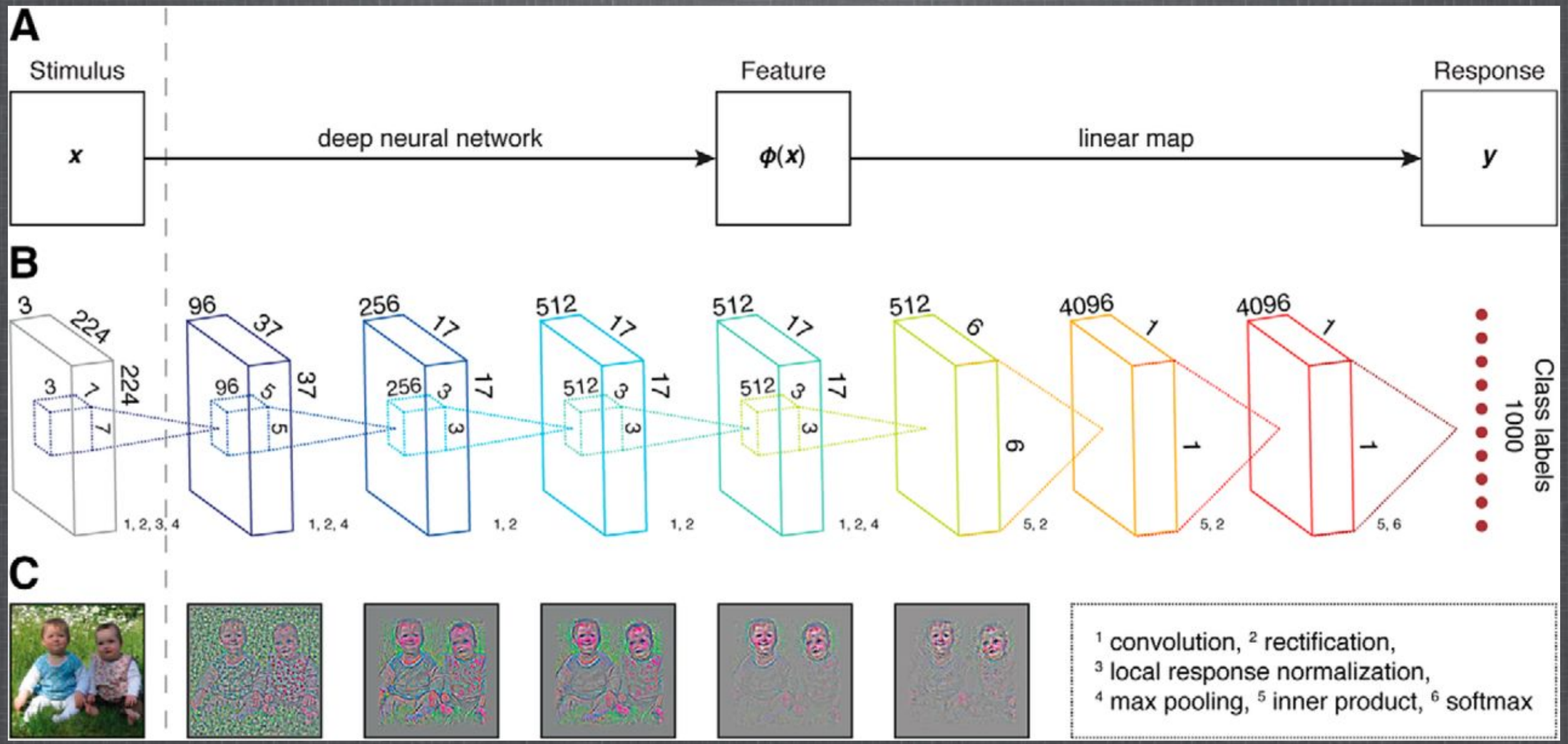


Deep neural networks are inspired by learning in human cortex. Their defining feature is that they have many layers of adaptable weights.



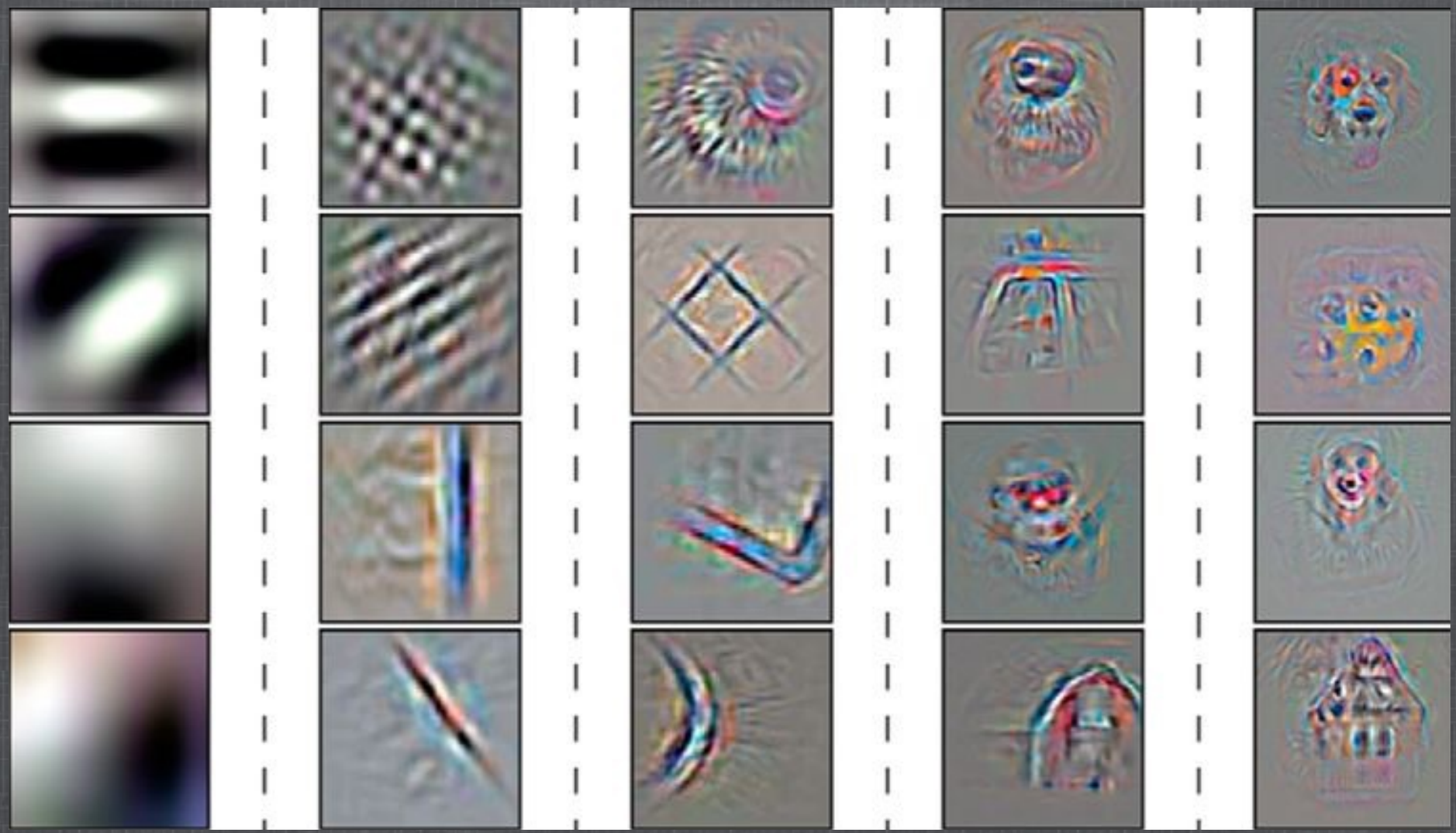
CONVOLUTIONAL NEURAL NETWORK

A convolutional neural network can be thought of as successive banks of feature detectors that where the neurons in layer 2 sample a field of neurons in layer 1 etc.



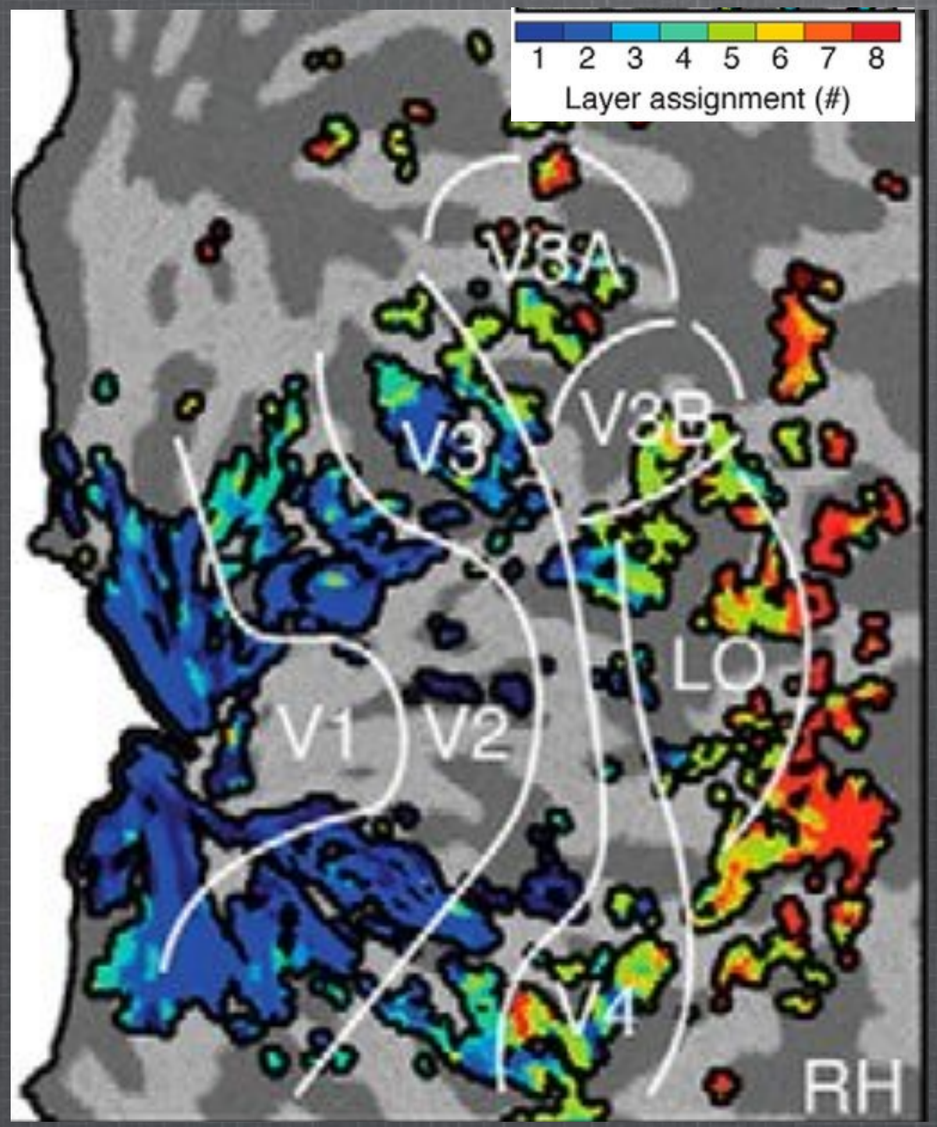
Güçlü, U, van Gerven, MAJ (2015). The Journal of Neuroscience, 35(27):10005-10014.

FEATURE DETECTORS BECOME MORE COMPLEX AS YOU PROGRESS THROUGH THE LAYERS OF ARTIFICIAL “DEEP” NEURAL NETWORKS



Güçlü, U, van Gerven, MAJ (2015). The Journal of Neuroscience, 35(27):10005-10014.

VISUAL CORTICAL AREAS SHOW SIMILAR RESPONSE PATTERNS TO DEEP NETWORKS



Activity in human visual cortex, recorded using functional brain imaging, matches that in the different layers of an artificial deep network.

Areas earlier in the visual stream (V1, V2) match lower layers in the network that have simple features; later layers (V3, V4, LO) match higher layers with more complex features.

Güçlü, U, van Gerven, MAJ (2015). The Journal of Neuroscience, 35(27):10005-10014.

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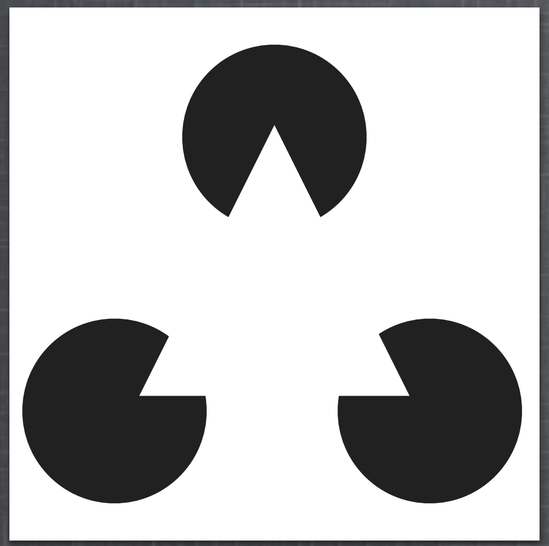
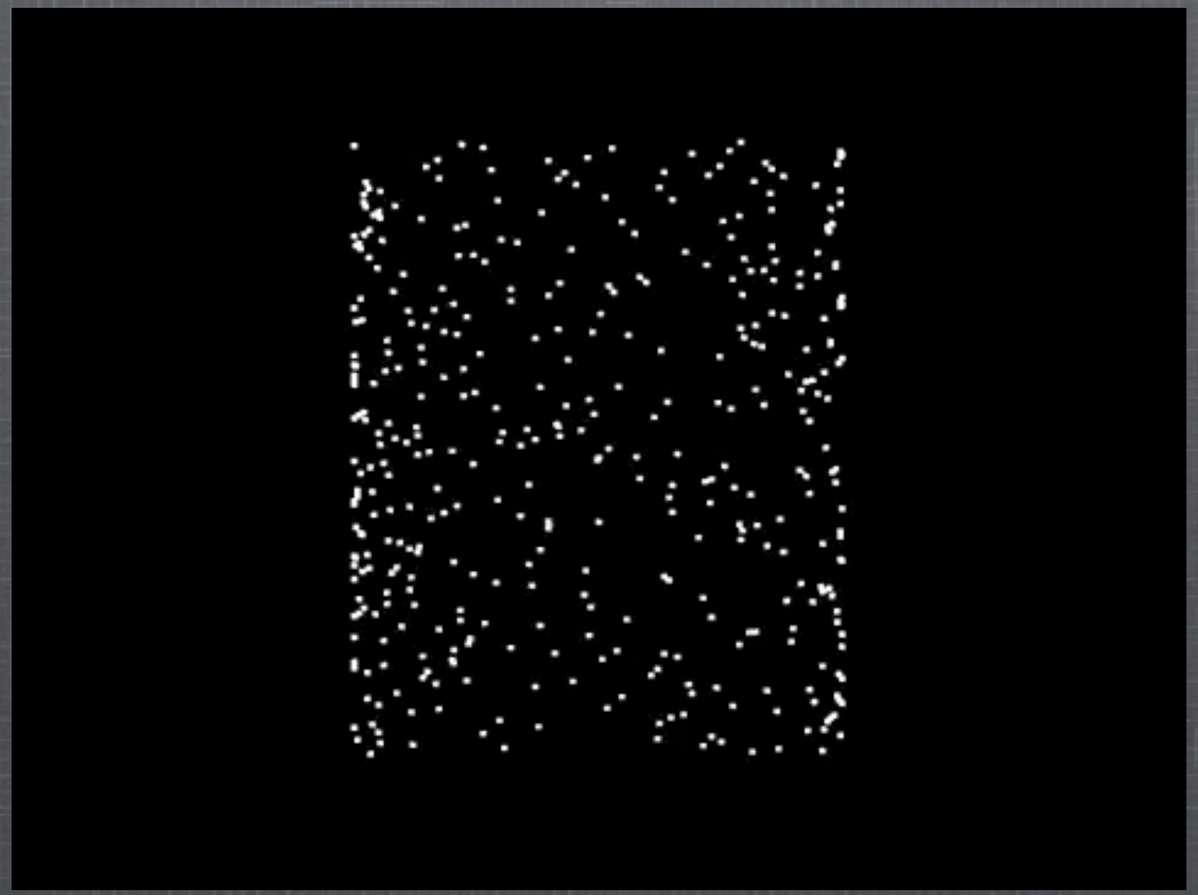
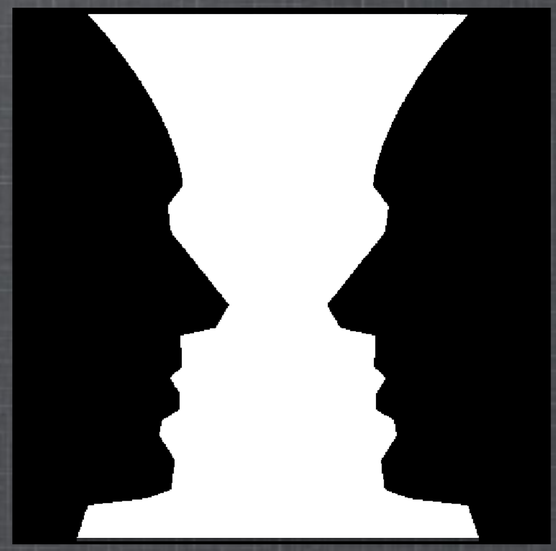
What do you see?
Pixabay

What do you see?







What do you see?

The appearance of a spiral is created by the presence of multiple discontinuous curves of reducing size

The brain likes to see continuity (complete forms)

iIllusions demonstrate that we don’t understand the visual world the way it appears on the retina—our brains impose constraints on what we are able to perceive

EMERGENCE

Dalmatian, photo by R. C. James

LOCAL AREAS OF THE IMAGE ARE NOT VERY INFORMATIVE

Tree

Head

Foot

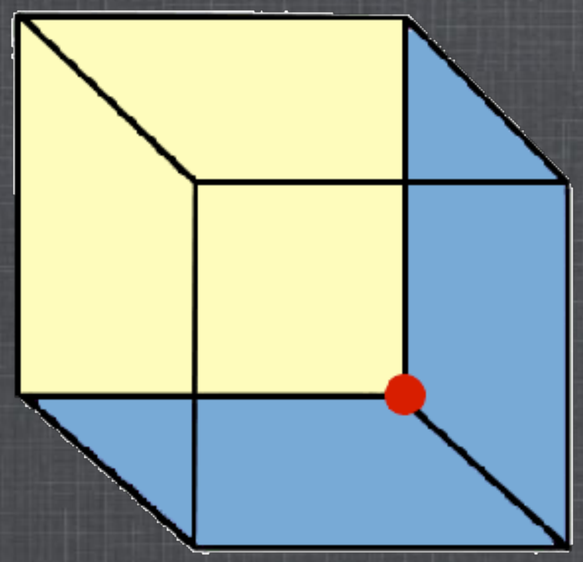
Information about the complete scene must be informing the interpretation of local areas

MULTISTABILITY

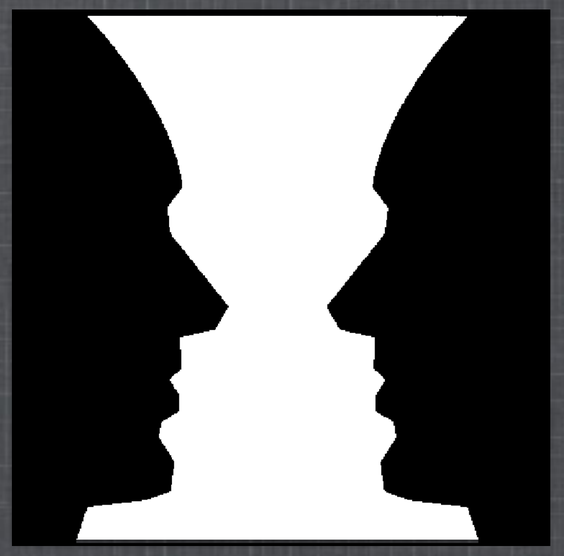
Old woman/Young woman

Reversible Figure/Ground Relationship

M.C. Escher

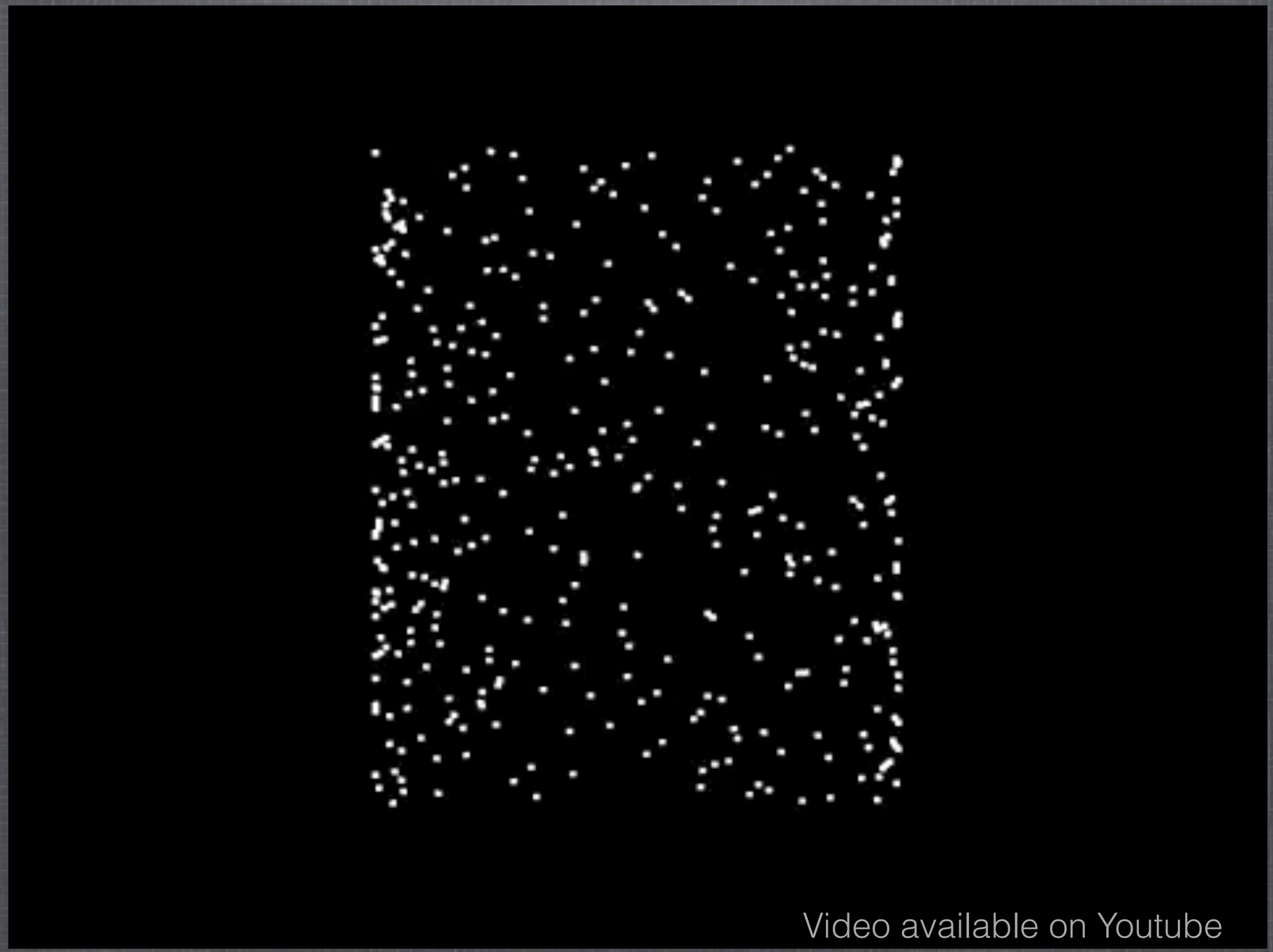


The Necker cube



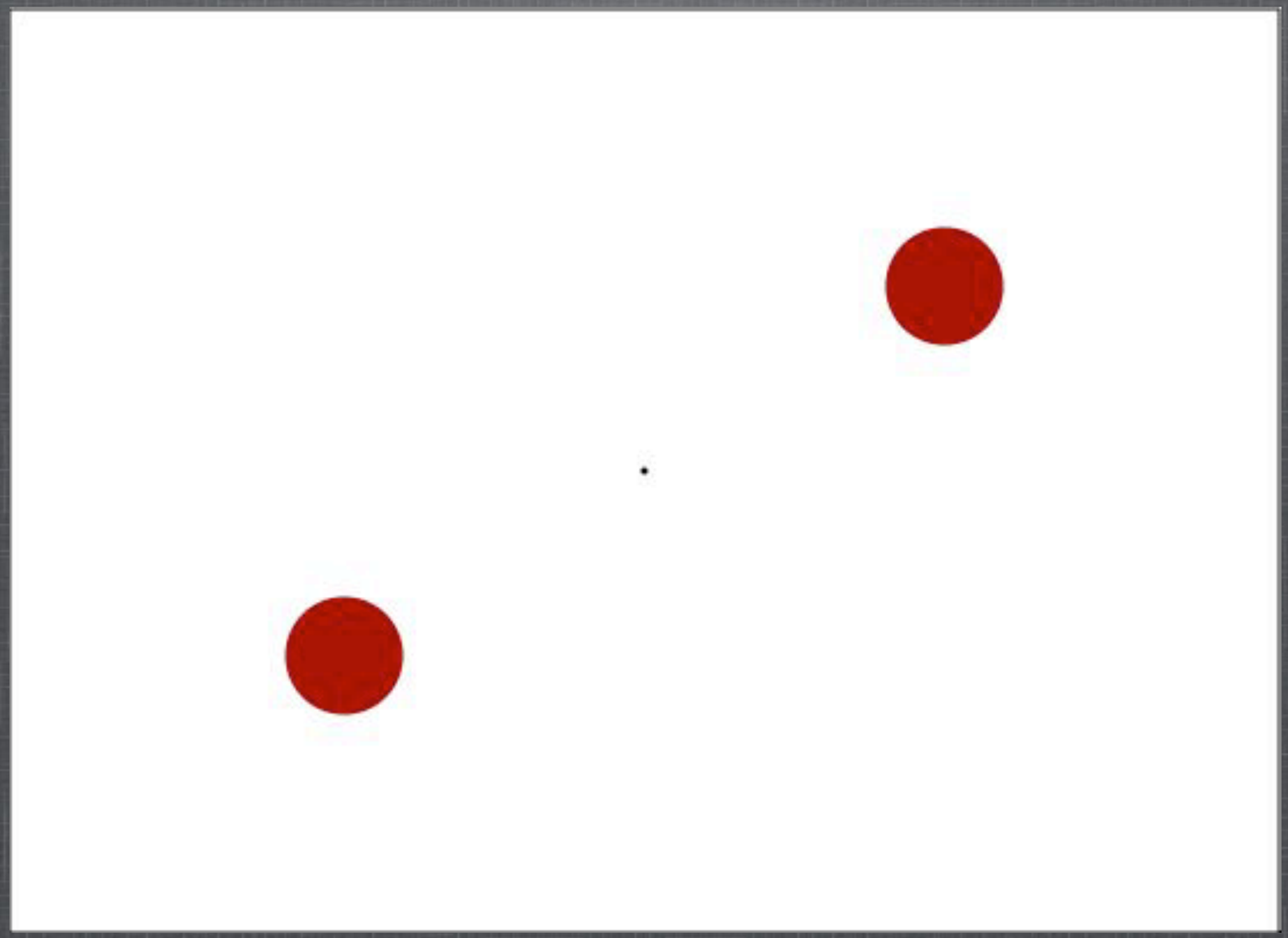
Vase/heads

BISTABLE PERCEPTION OF 3D MOTION



BISTABLE APPARENT MOTION WITH HYSTERESIS

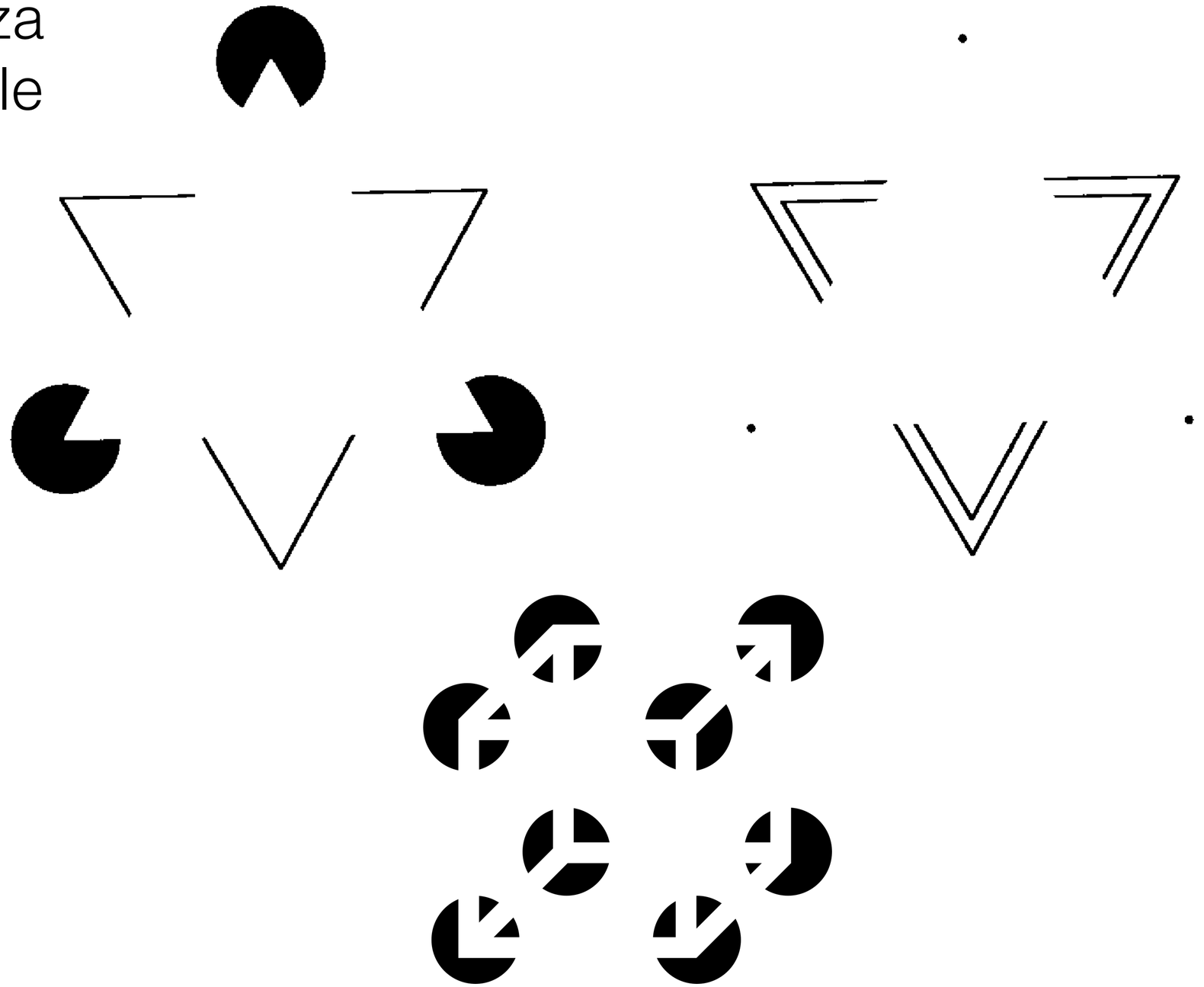
Movie from Wolfgang Tschacher



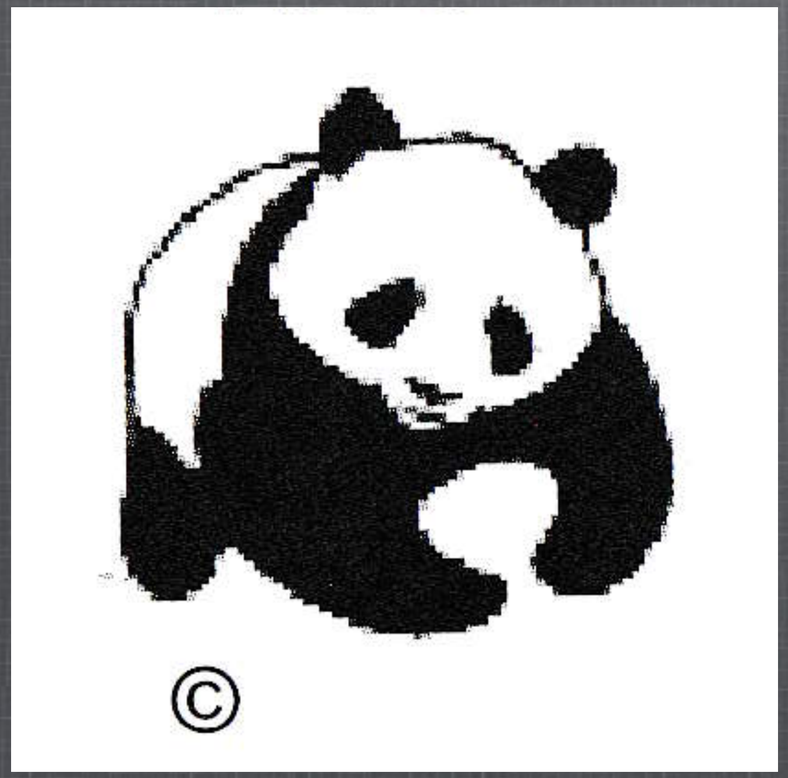
Demonstrates the Gestalt principle of proximity

REIFICATION (RECOGNITION OF WHOLE FORMS)

Kanisza Triangle



THE WORLD WILDLIFE FUND LOGO



1960s/70s

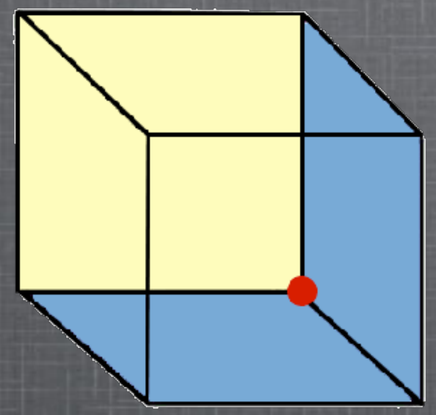
1986–

© WWF-World-wide Fund for Nature.

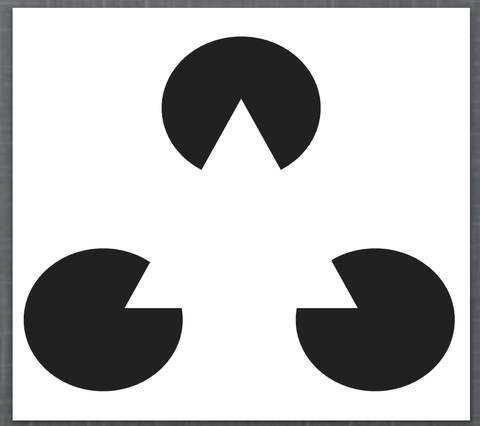
GESTALT PRINCIPLES

Emergence

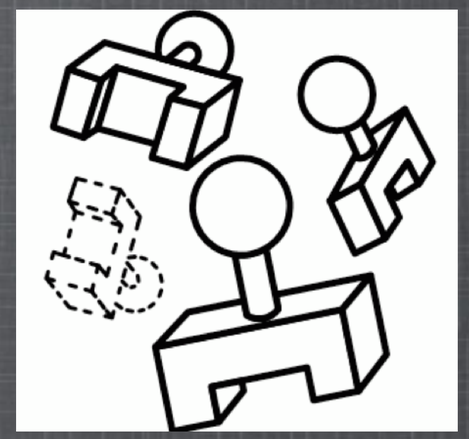
Multistability

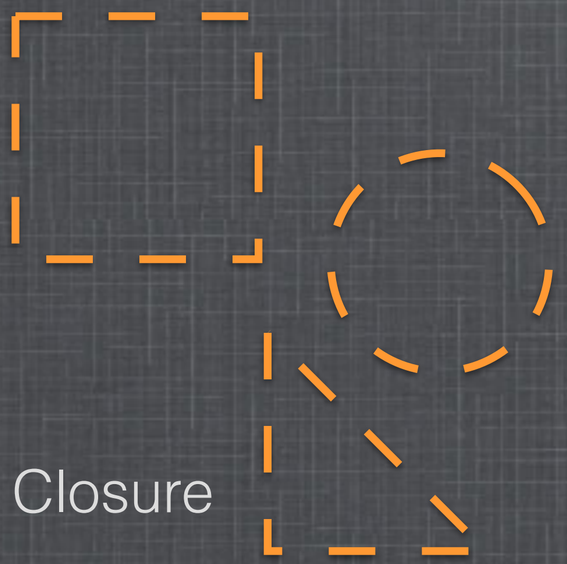


Illusory contours
(Reification)

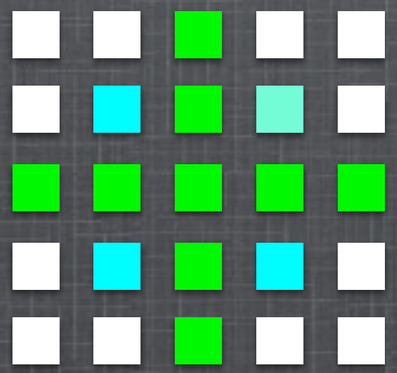


Invariance



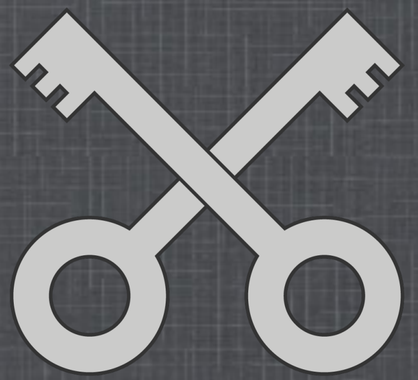


Closure



Similarity

Proximity



Continuity

These constraints were noted by the Gestalt Psychologists in the early 20th c.

INTERIM SUMMARY

- The “inner screen” theory of vision fails because there is no “inner eye” to inspect the inner screen
- The retinotopic maps in our brain are upside-down, flipped L->R, and distorted
- The brain extracts multiple forms of information about vision including separate streams for “what” and “where” information
- As you ascend the “what” pathway neurons respond to increasingly complex features from edges to faces and places
- The responses of cells in the different layers of the visual system can be usefully compared to those of artificial neurons found in deep convolutional networks
- Our brain uses powerful principles to build percepts including closure, similarity, proximity, and continuity