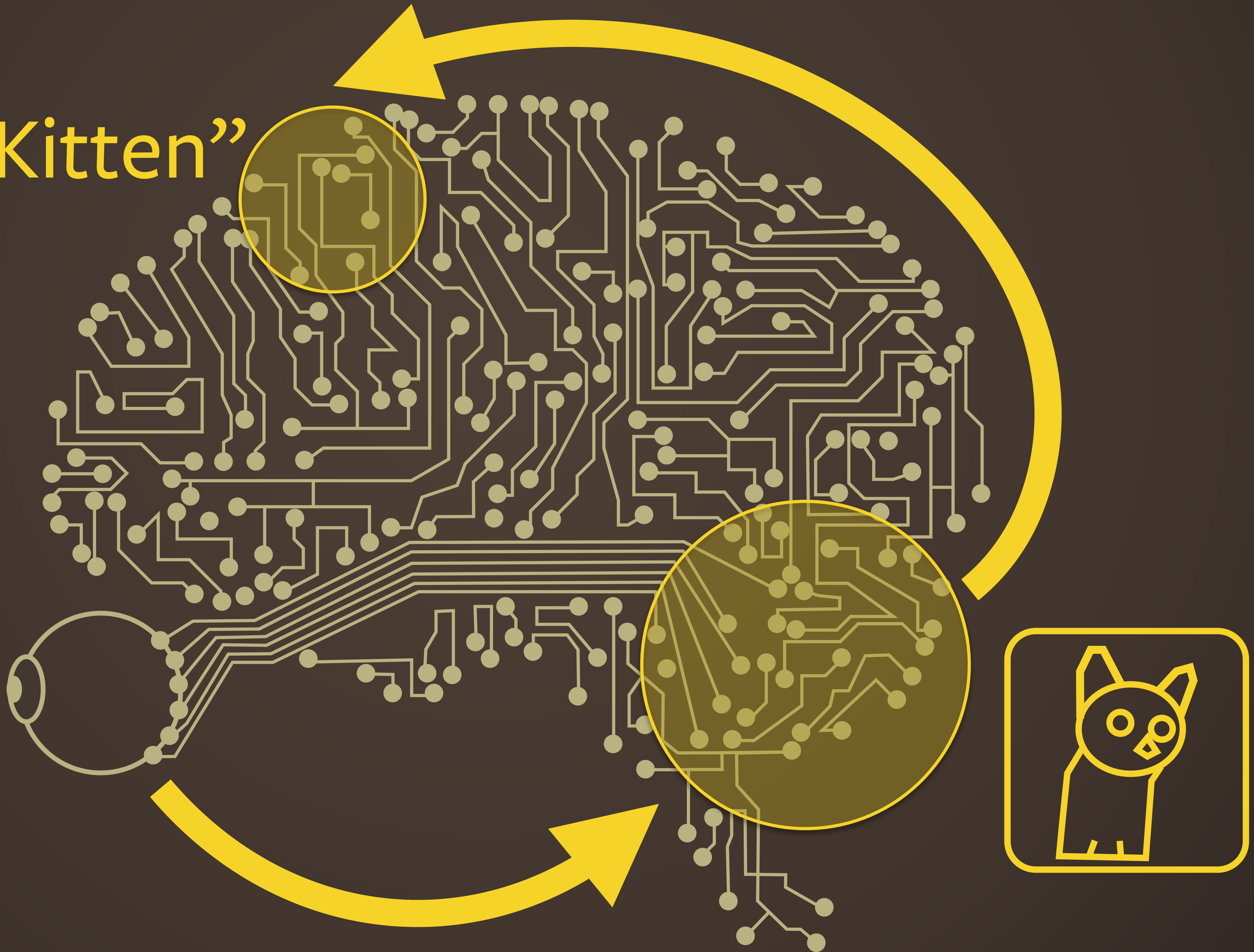
Electronics and
Computer Science

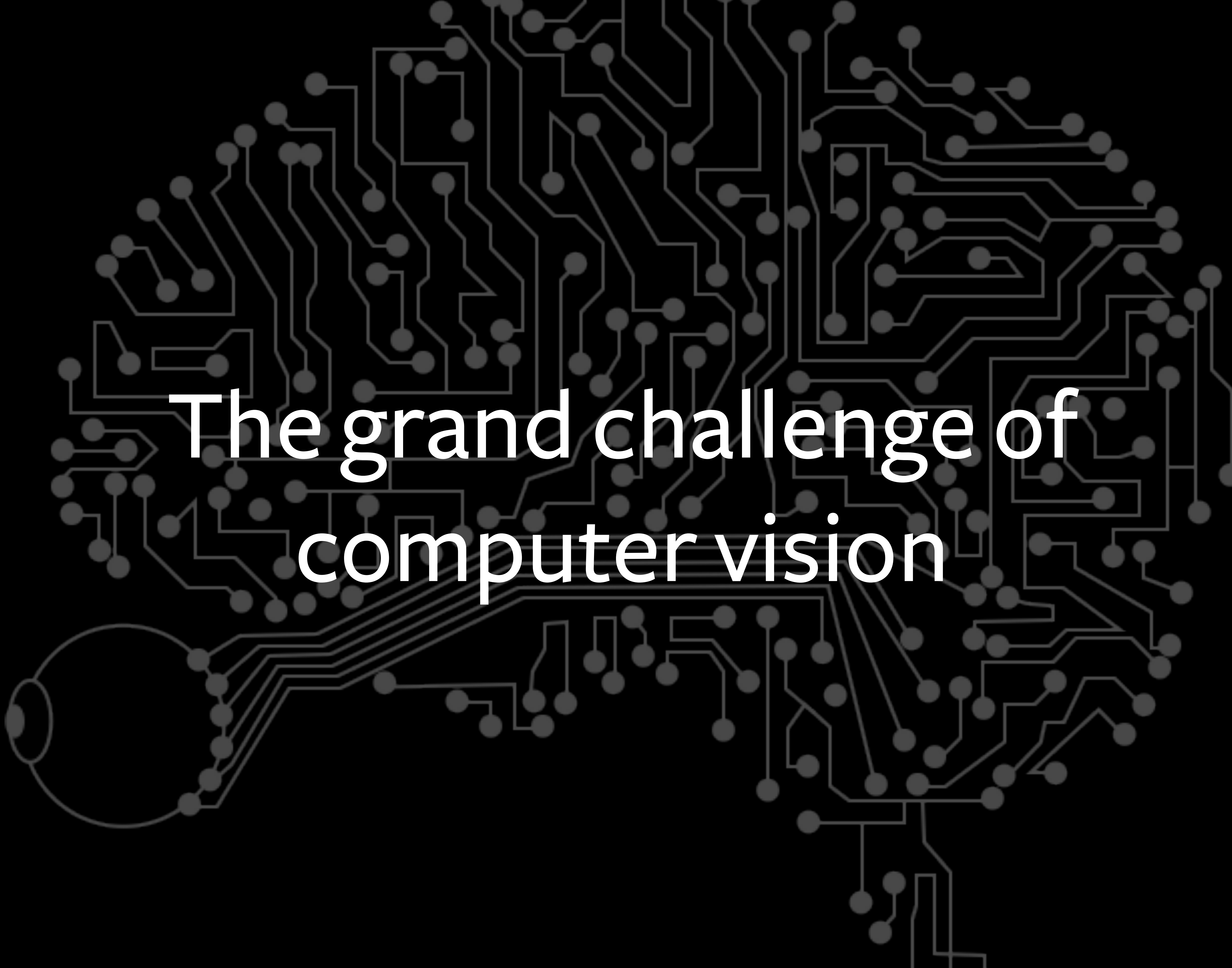
UNIVERSITY OF
Southampton

Computer Vision - A Retrospective: *Teaching* machines to see

Dr Jonathon Hare



The grand challenge of computer vision



Computer Vision research has always been inspired by the way humans "see" and perceive the world

Setting the Scene:

A potted history of our understanding of:

- Biological Vision
- Computation
- Machine Learning
- Computer Vision

Circa 300 BC to AD 200

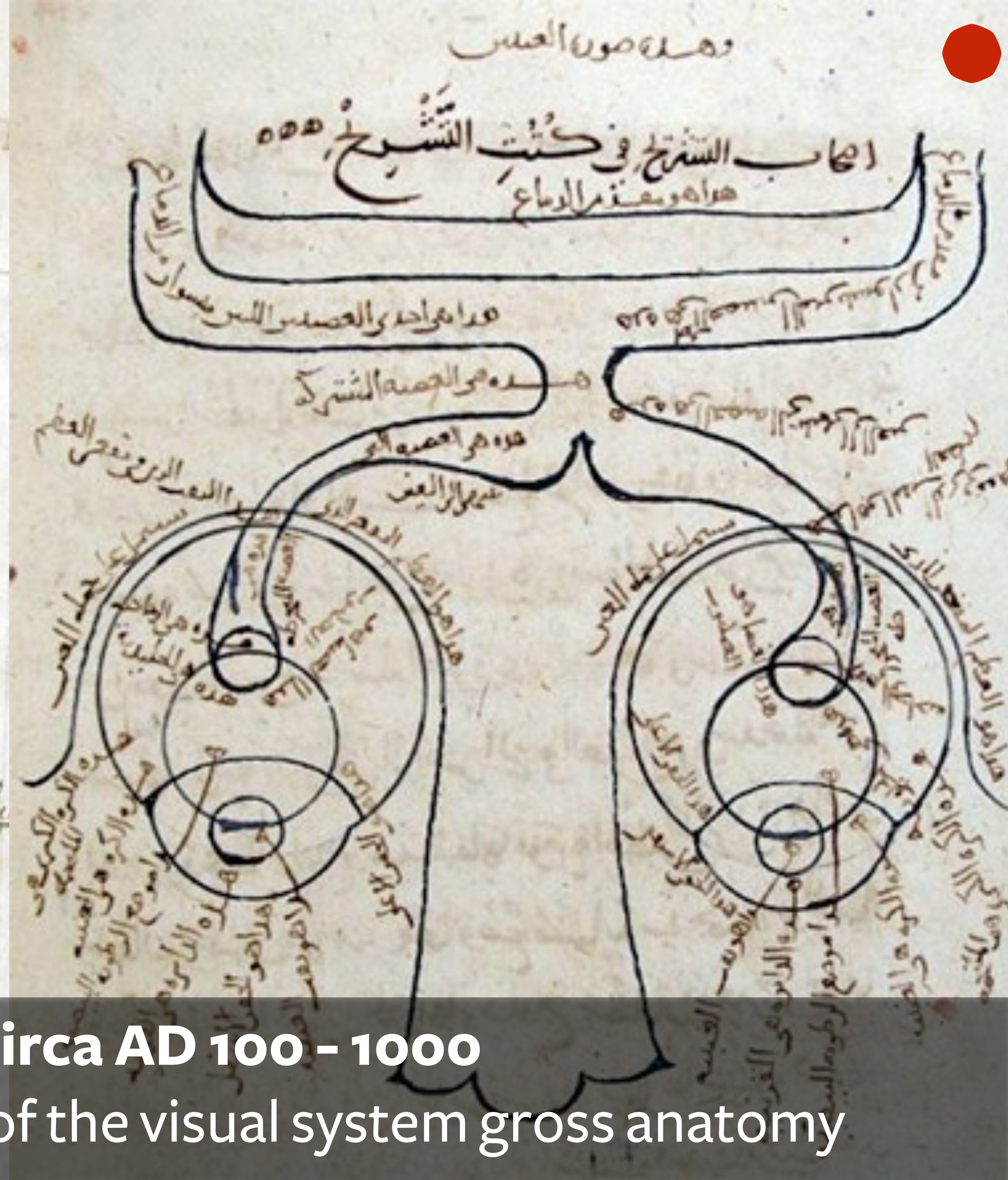
emission/extramission theory
(championed by Euclid & Ptolemy)

versus

intromission theory
(championed by Aristotle)

Euclid

Aristotle

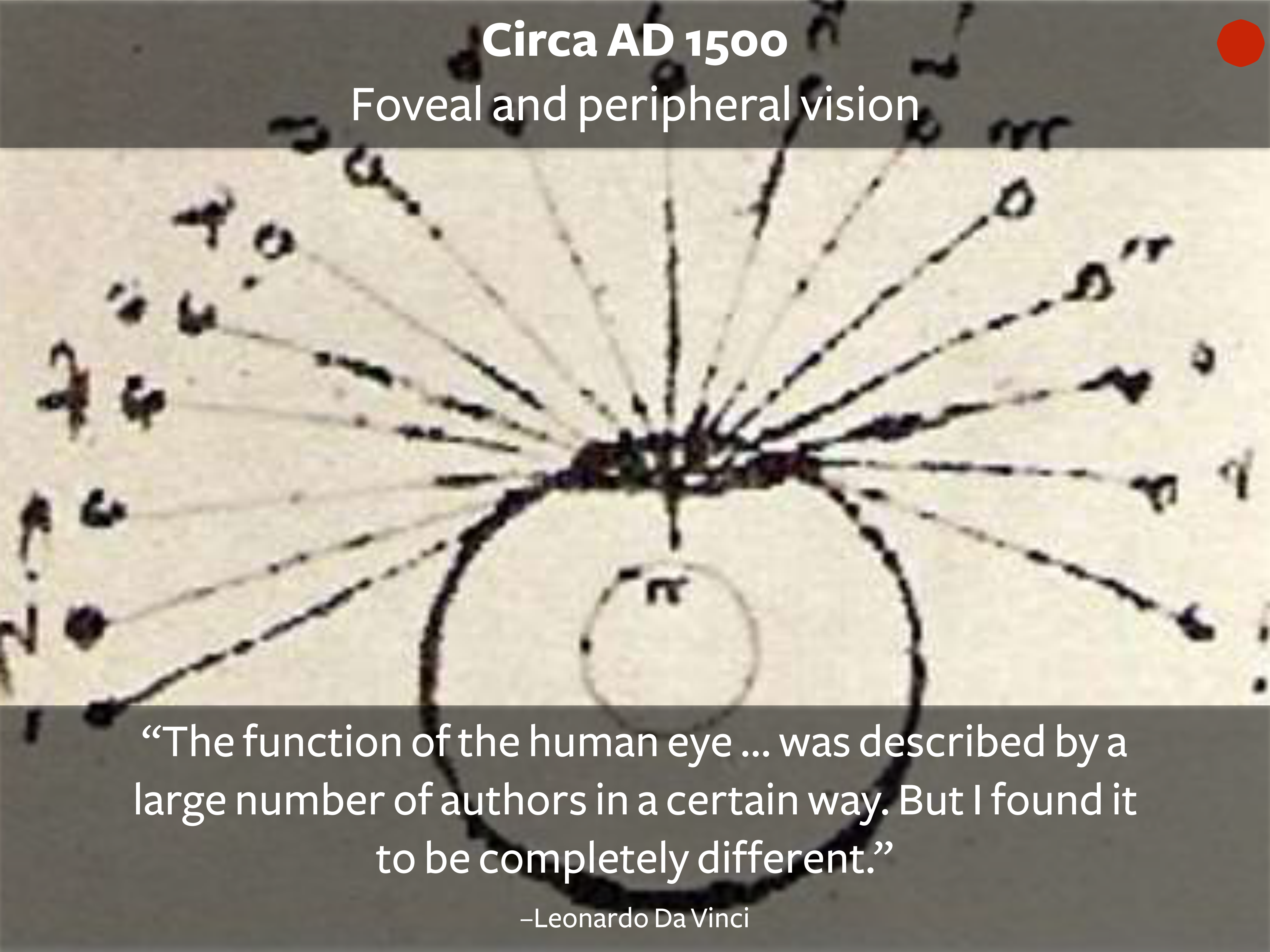


Circa AD 100 - 1000

Understanding of the visual system gross anatomy

Circa AD 1500

Foveal and peripheral vision

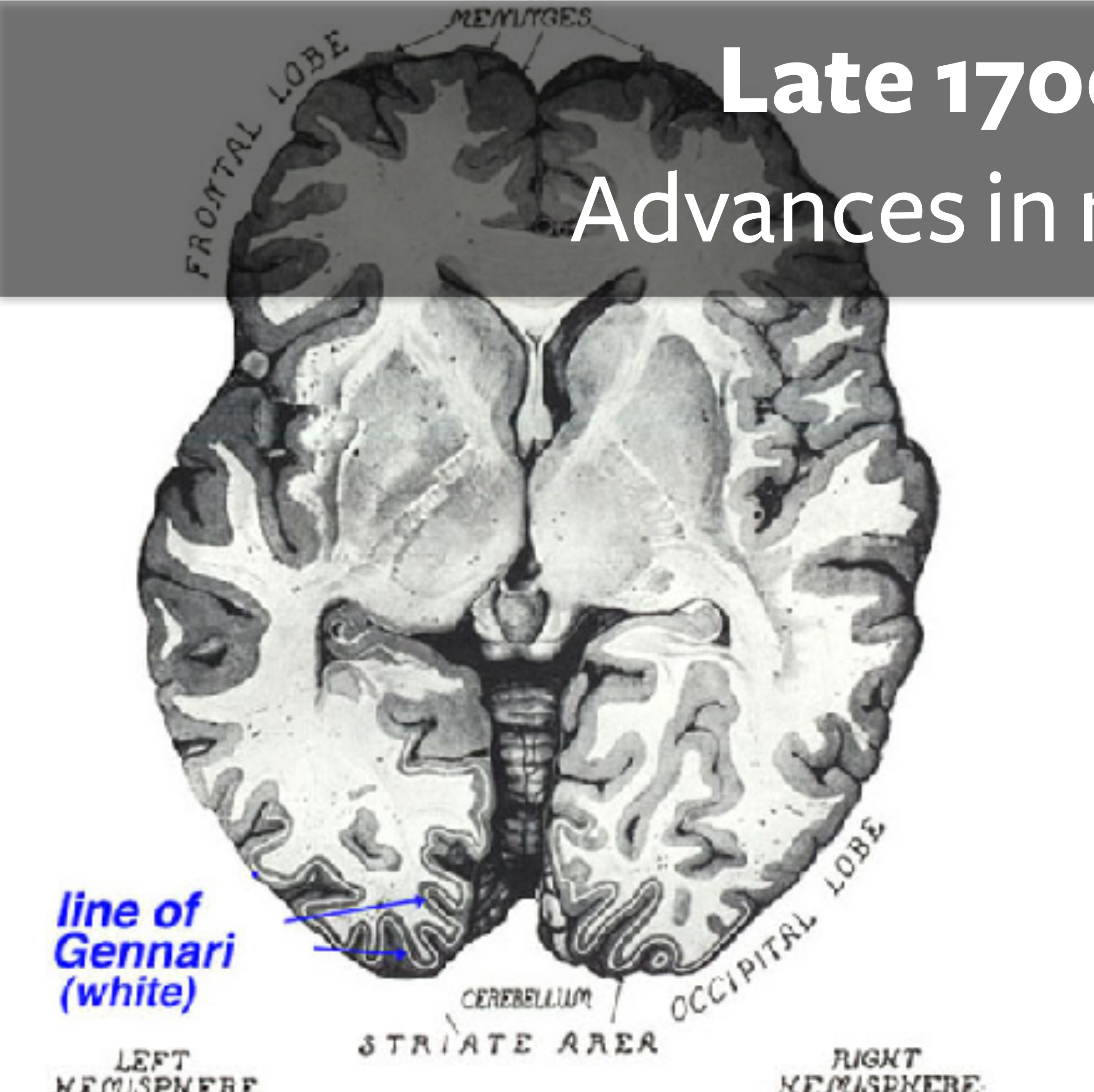


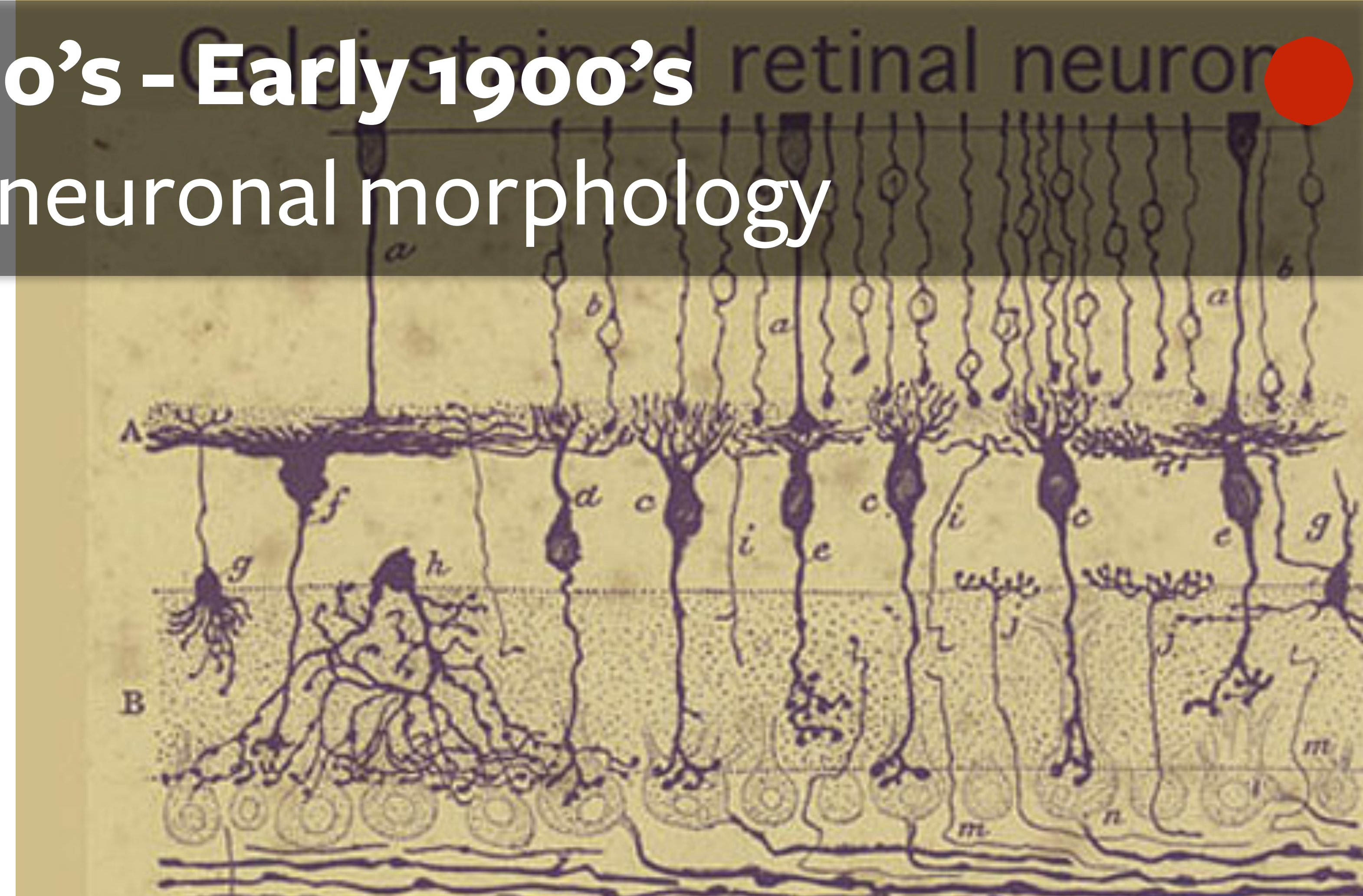
"The function of the human eye ... was described by a large number of authors in a certain way. But I found it to be completely different."

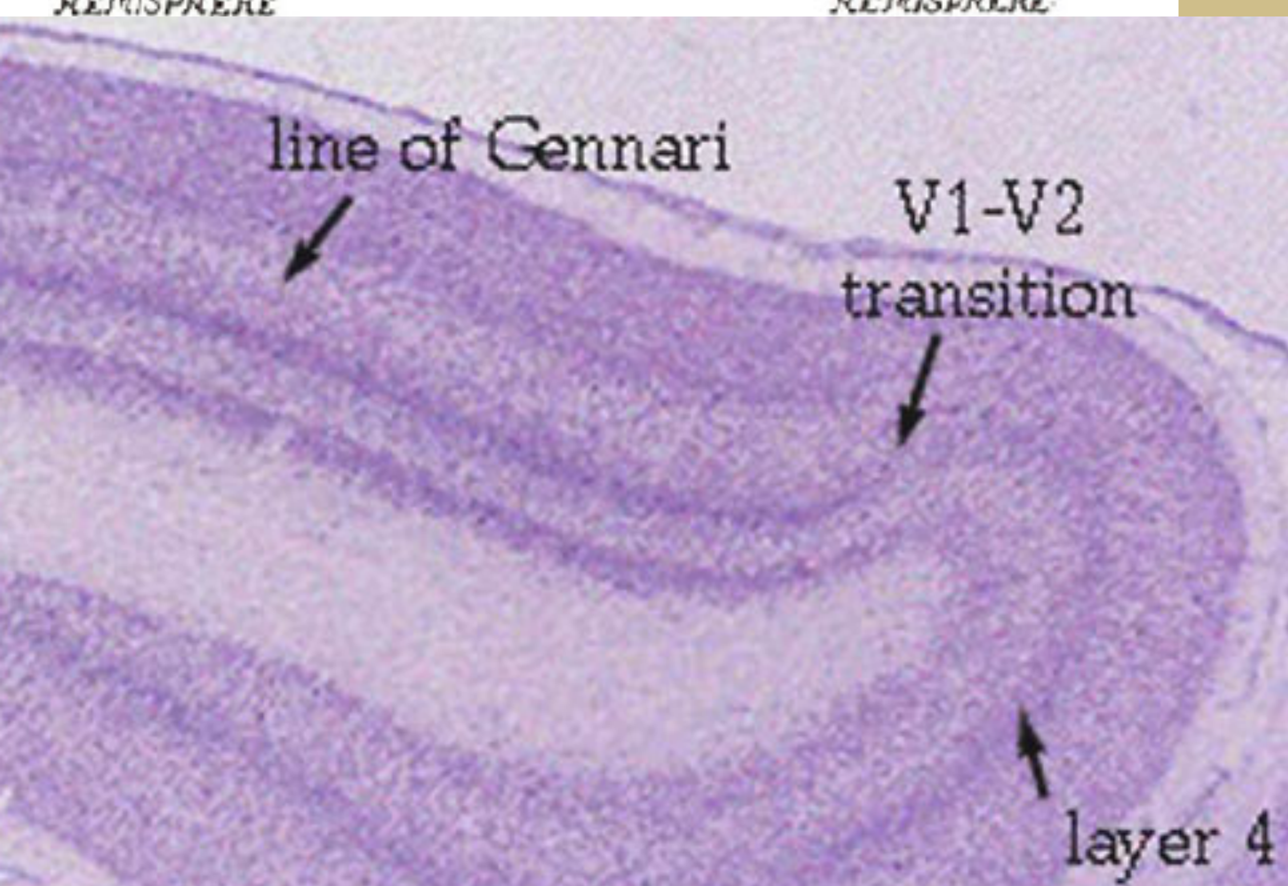
–Leonardo Da Vinci

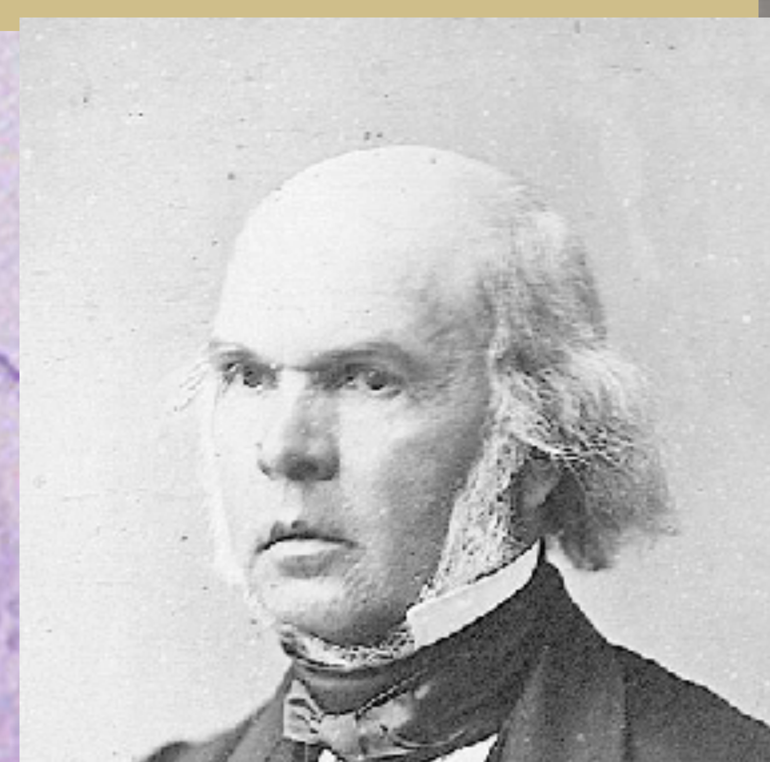
Late 1700's - Early 1900's

Advances in neuronal morphology





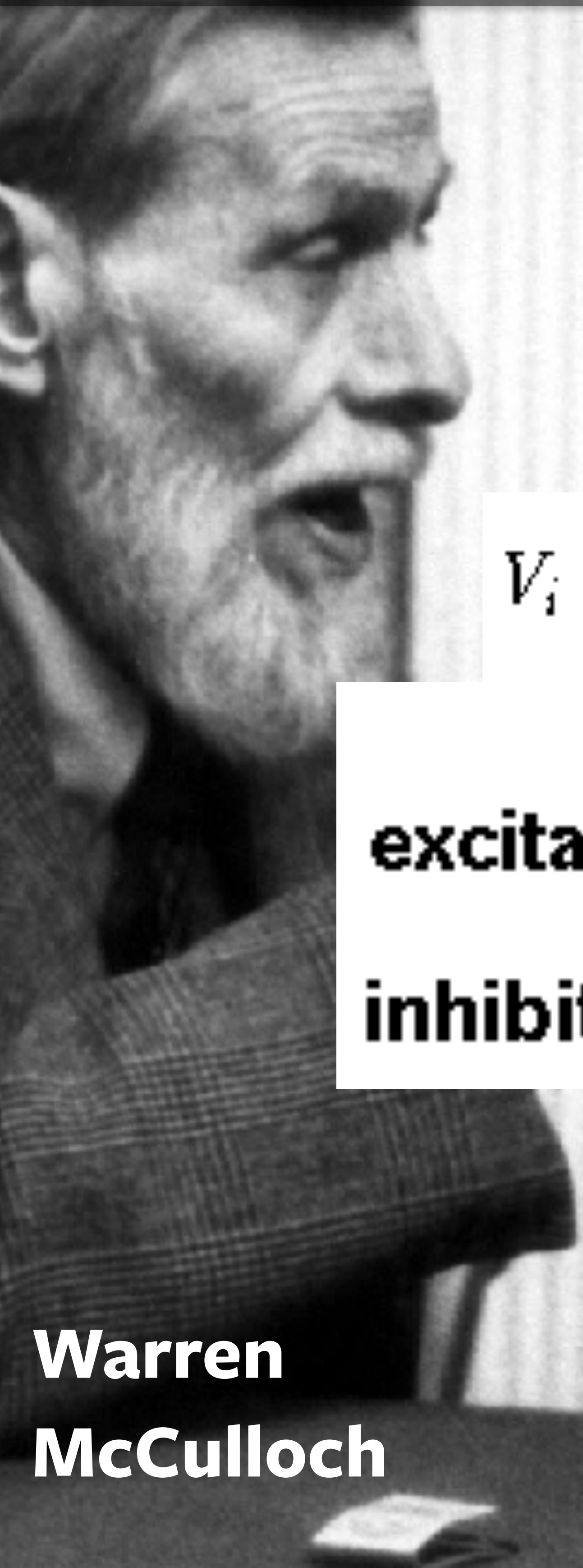




Jules Baillarger

Santiago Ramón y Cajal

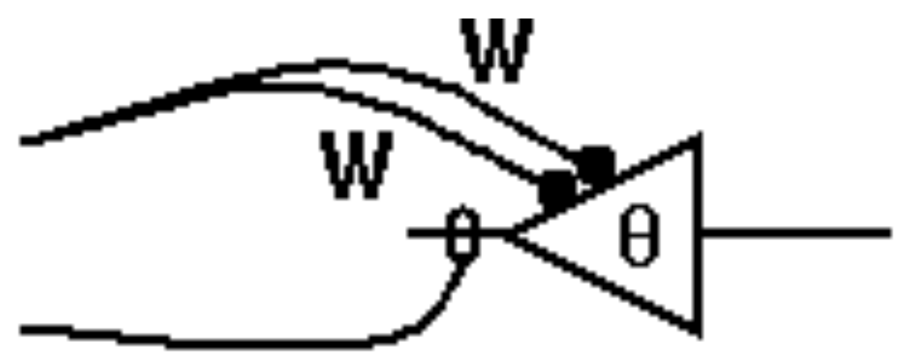
1943
McCulloch-Pitts Artificial Neuron

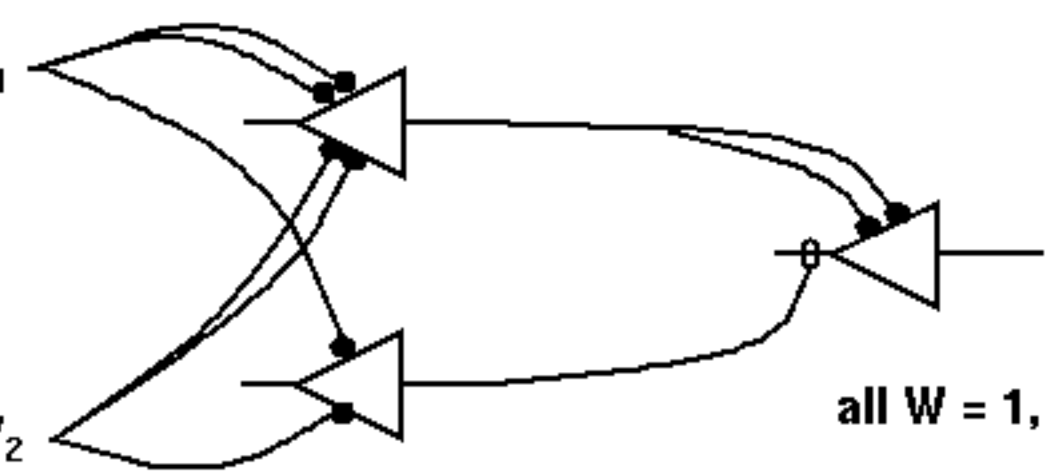


Warren McCulloch

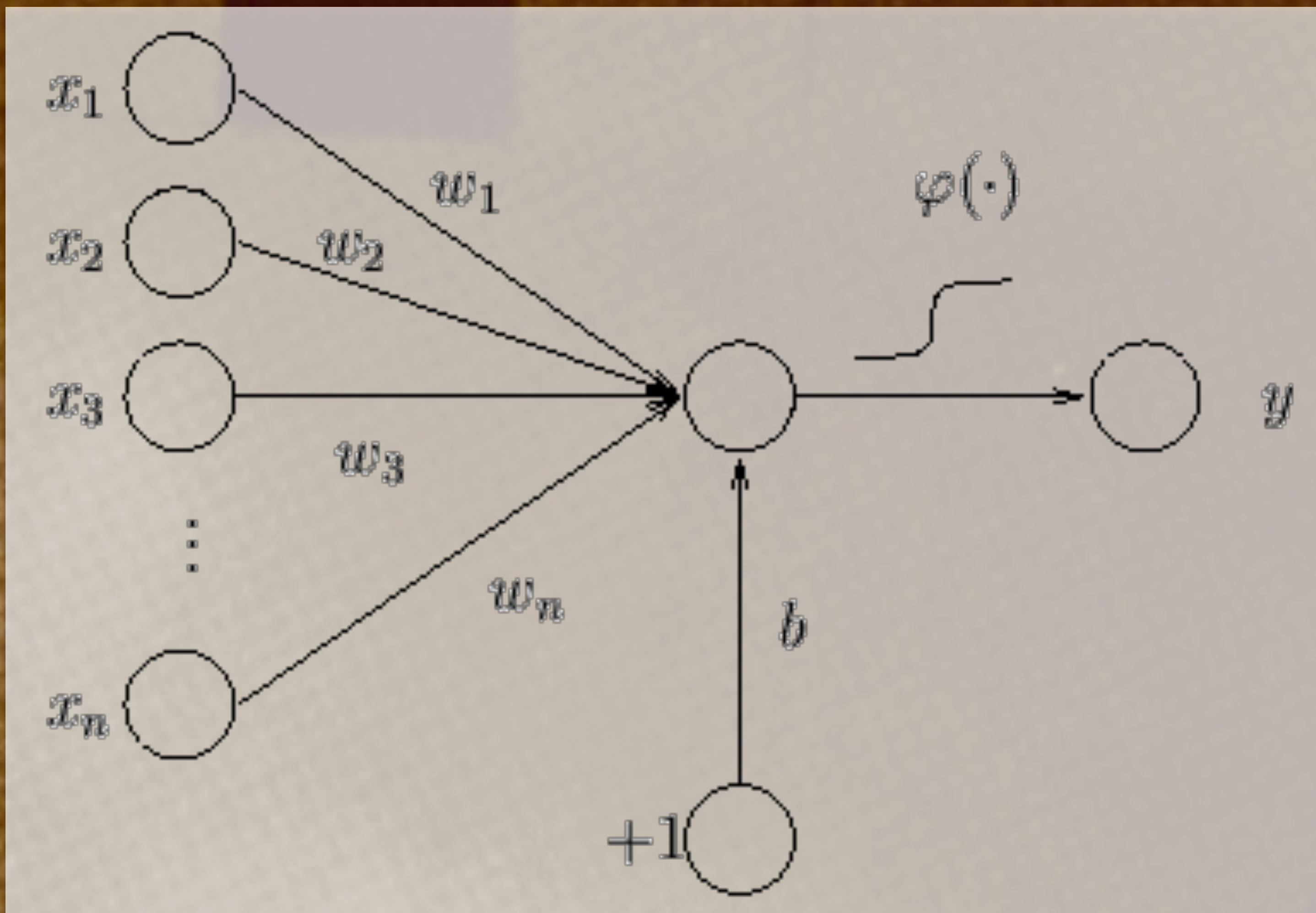
Walter Pitts

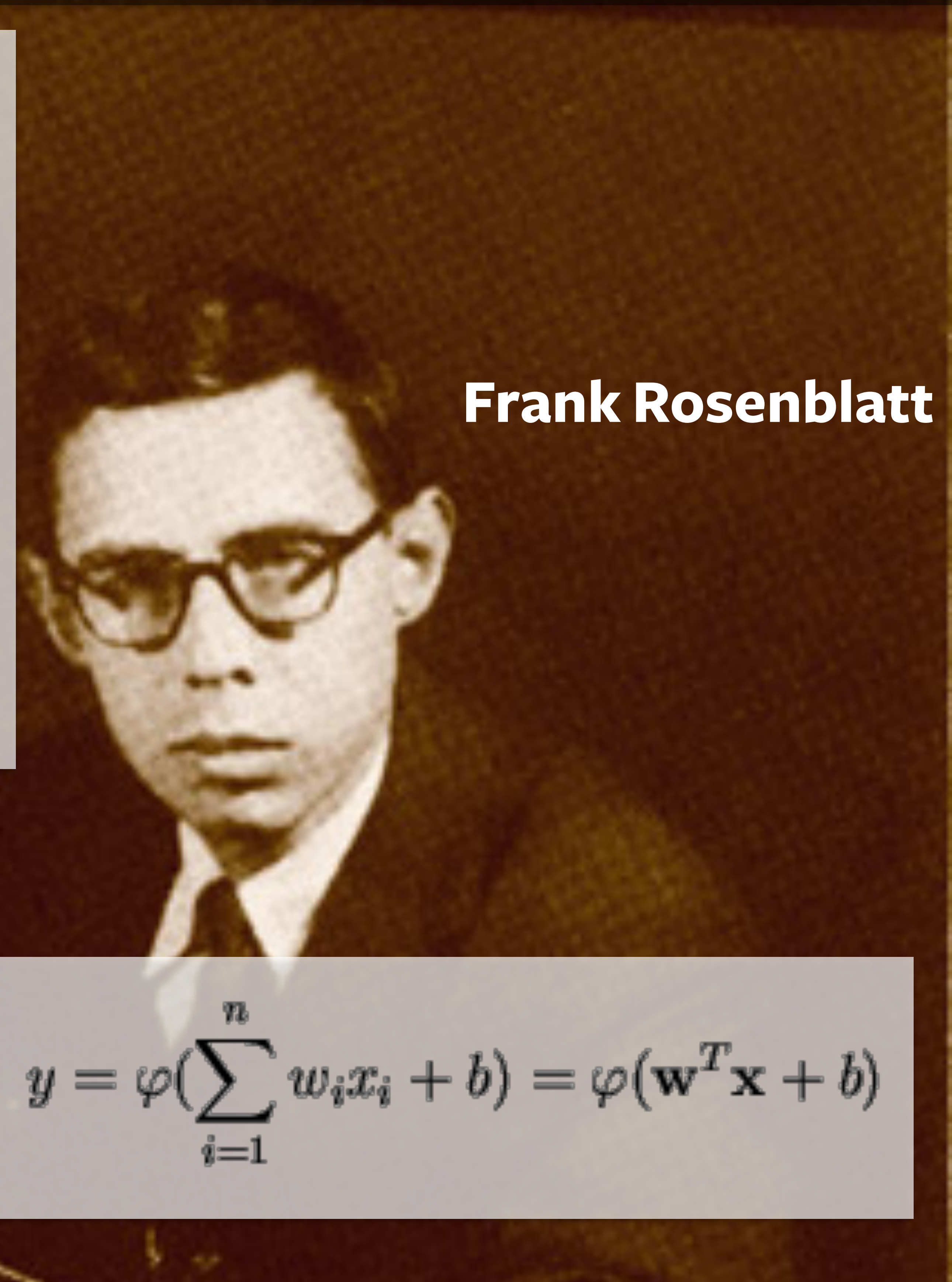
$$V_i = \begin{cases} 1 & : \quad \sum_j W V_j \geq \theta \text{ AND no inhibition} \\ 0 & : \quad \text{otherwise} \end{cases}$$





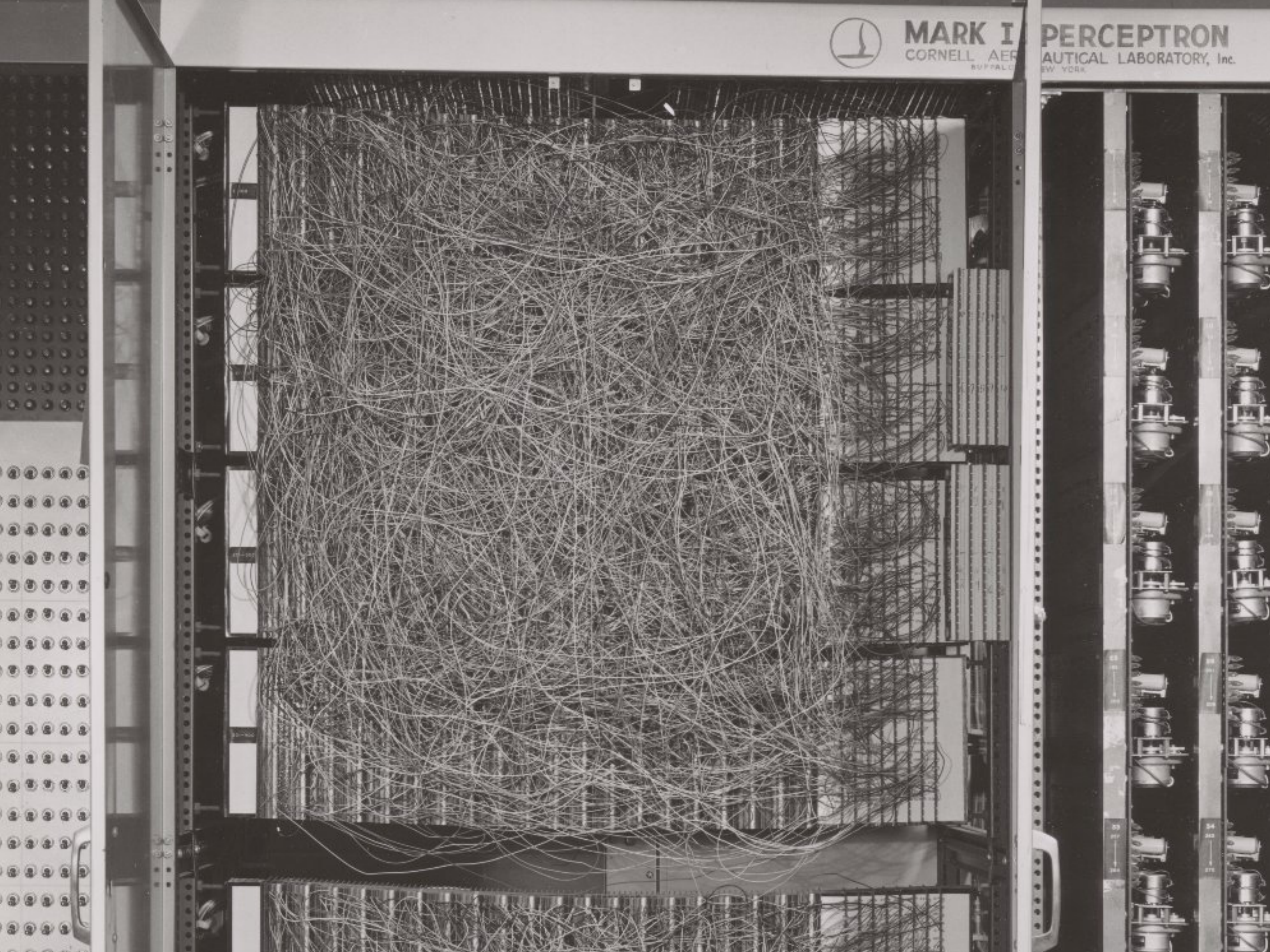
1958
Rosenblatt’s Perceptron

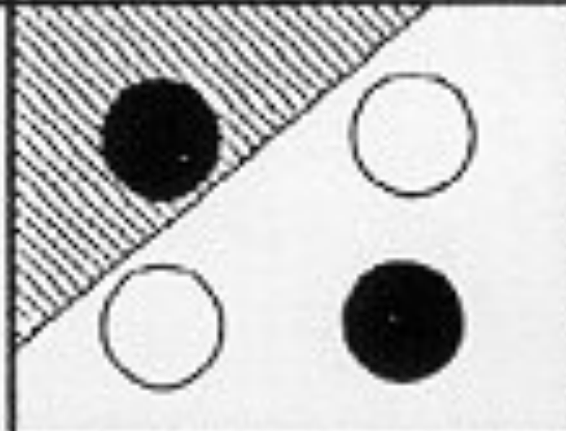
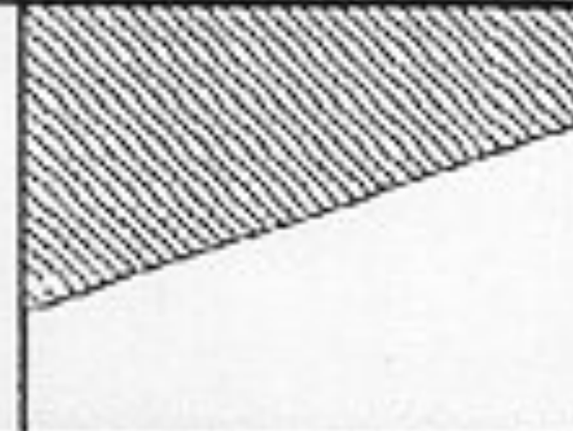
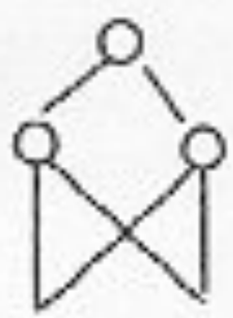
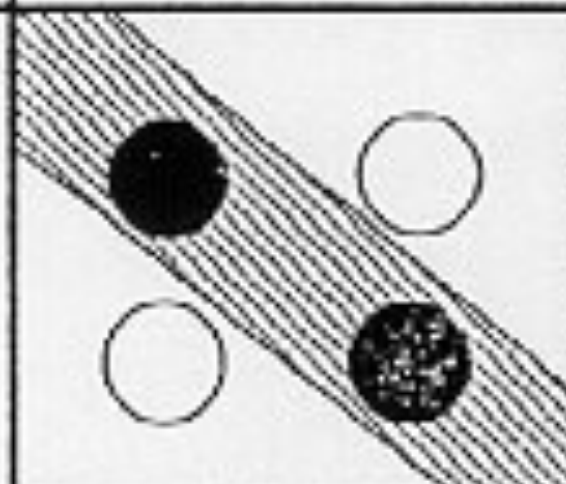
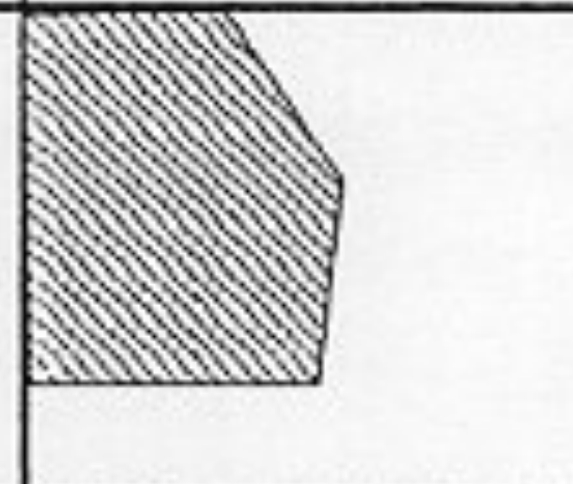
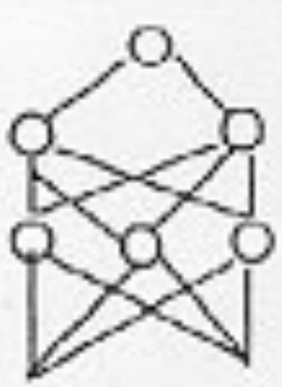
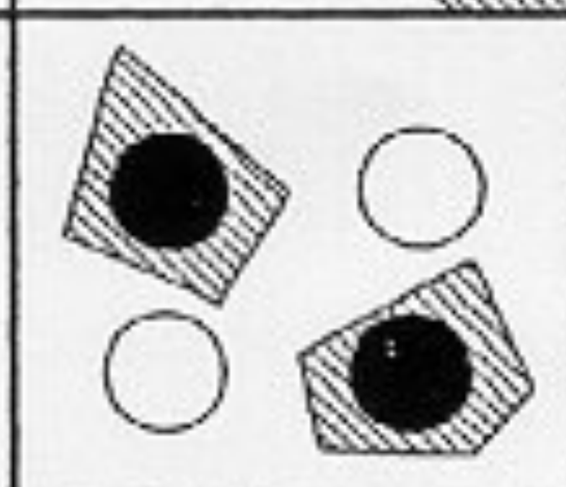
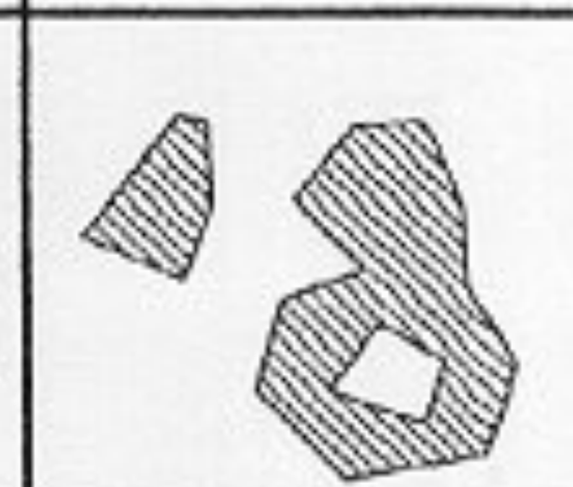




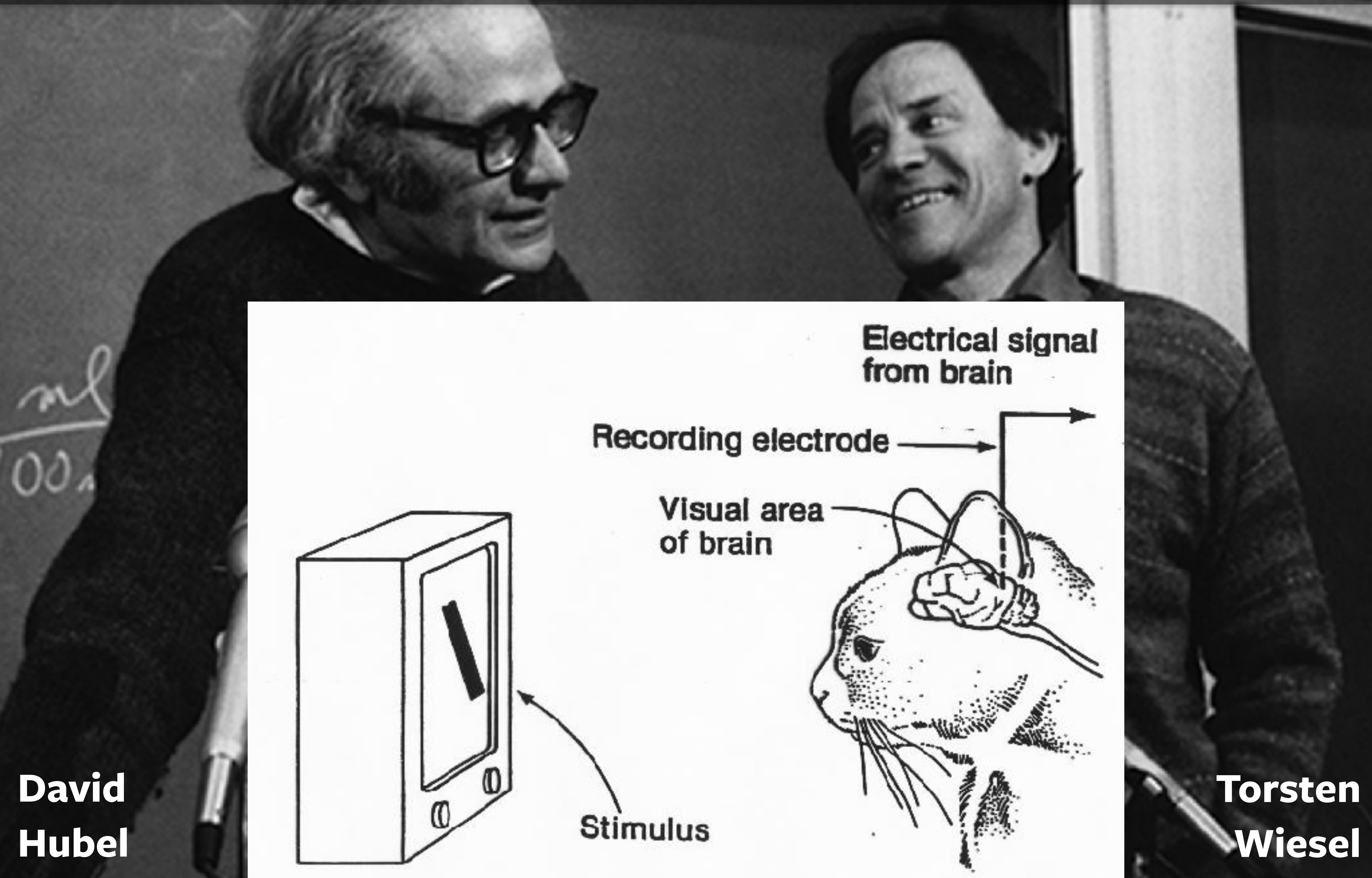
Frank Rosenblatt

$$y = \varphi\left(\sum_{i=1}^{n} w_i x_i + b\right) = \varphi(\mathbf{w}^T\mathbf{x} + b)$$


MARK I PERCEPTRON
CORNELL AER AUTICAL LABORATORY, Inc.

Structure	Description of decision regions	Exclusive-OR problem	Classes with meshed regions	General region shapes
 Single layer	Half plane bounded by hyperplane			
 Two layer	Arbitrary (complexity limited by number of hidden units)			
 Three layer	Arbitrary (complexity limited by number of hidden units)			

1959
Receptive Fields of Single Neurons in the Cat's Striate Cortex



David Hubel

Torsten Wiesel

1966
Computer vision "summer project"

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROJECT MAC

Artificial Intelligence Group July 7, 1966
Vision Memo. No. 100.

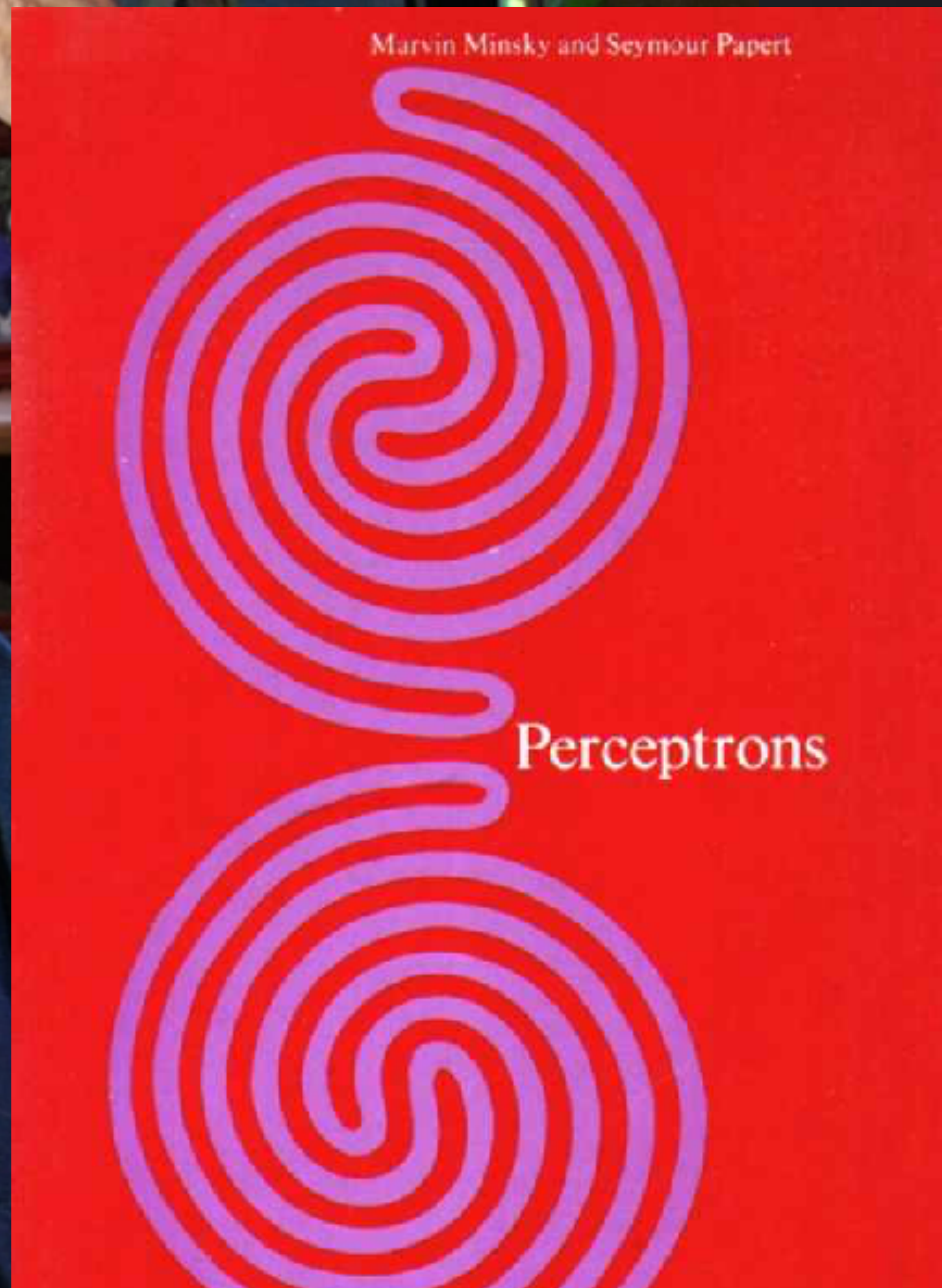
THE SUMMER VISION PROJECT

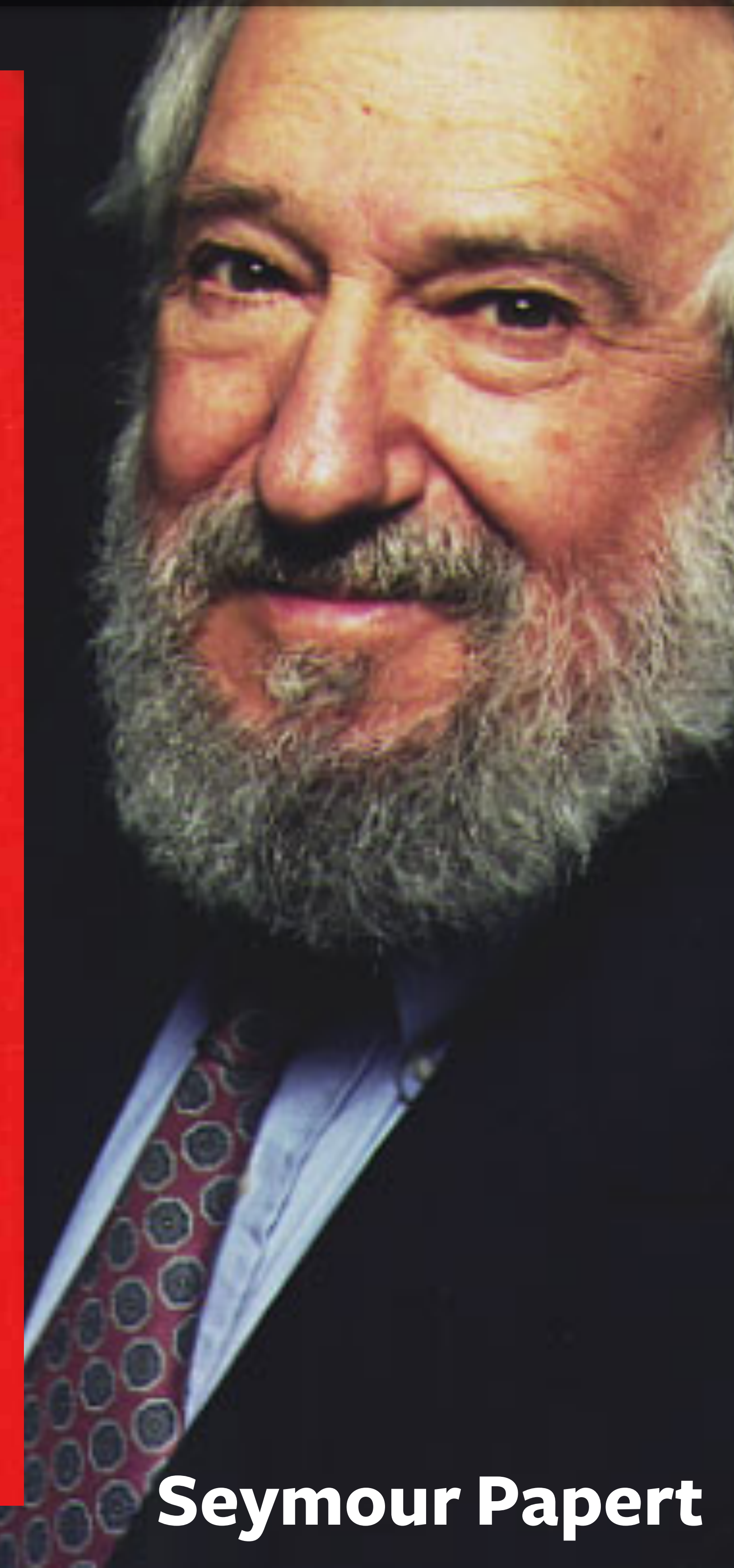
Seymour Papert

The summer vision project is an attempt to use our summer workers effectively in the construction of a significant part of a visual system. The particular task was chosen partly because it can be segmented into sub-problems which will allow individuals to work independently and yet

1969

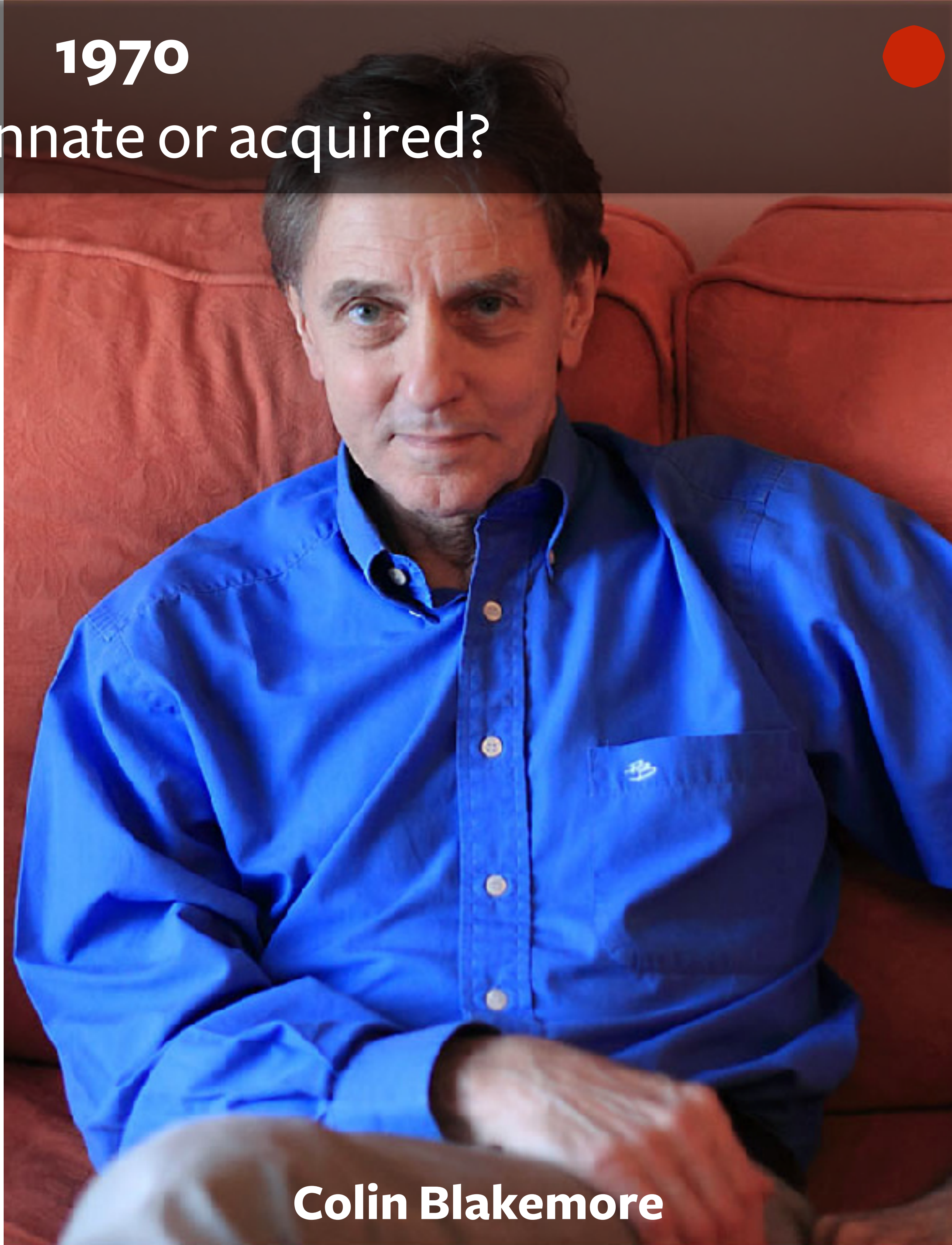
"Perceptrons" and the first AI Winter



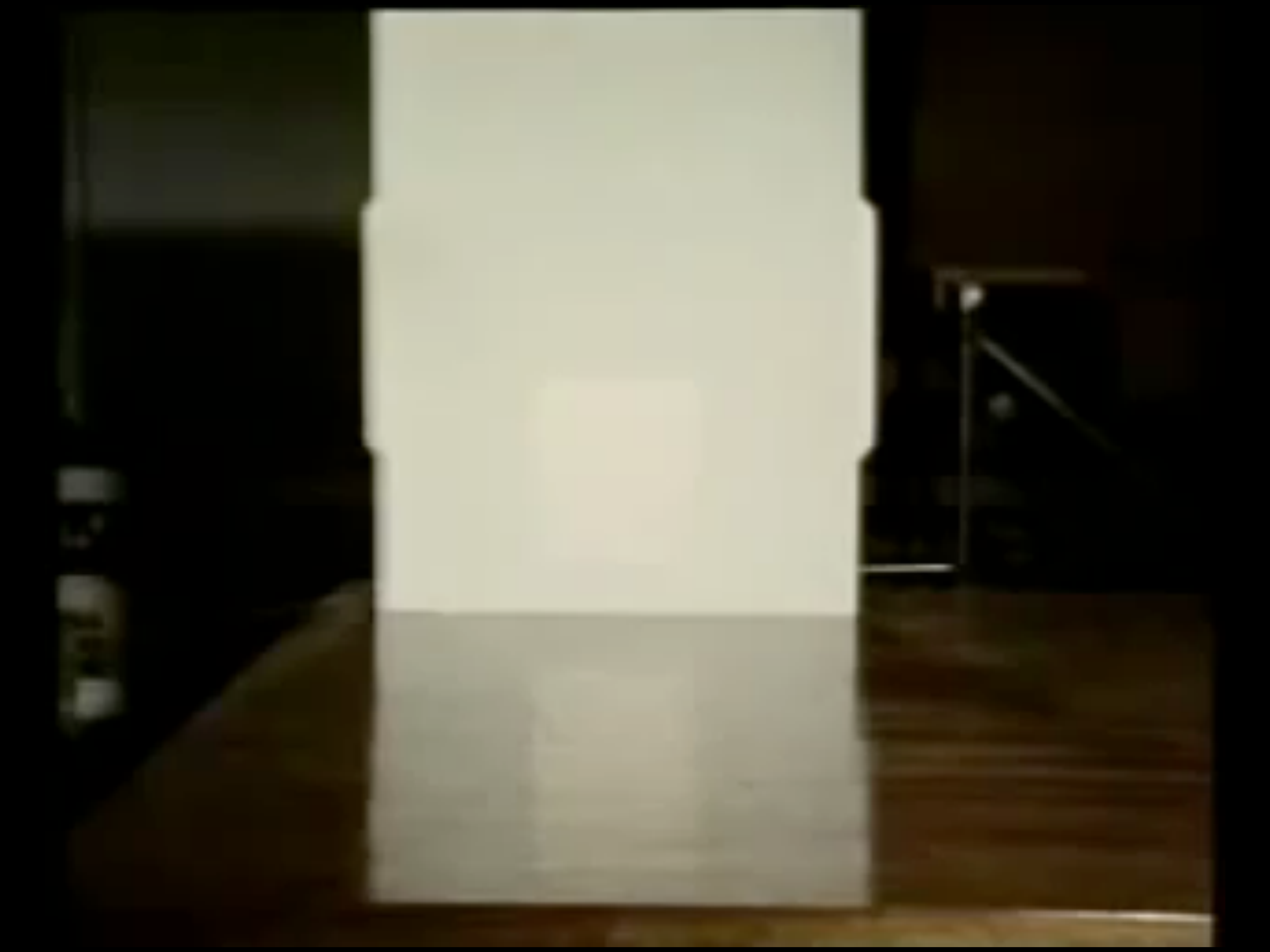


1970

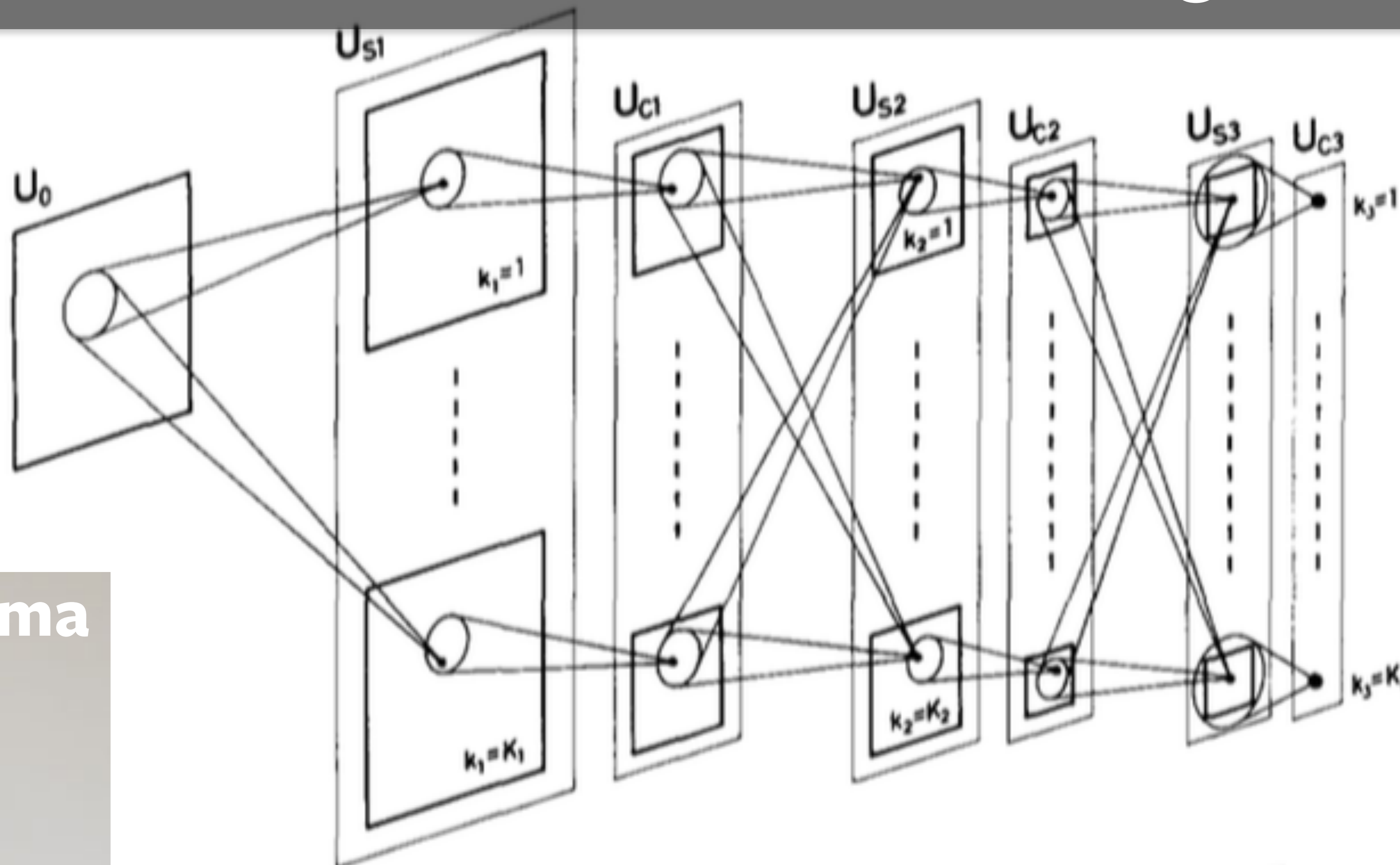
Is vision innate or acquired?

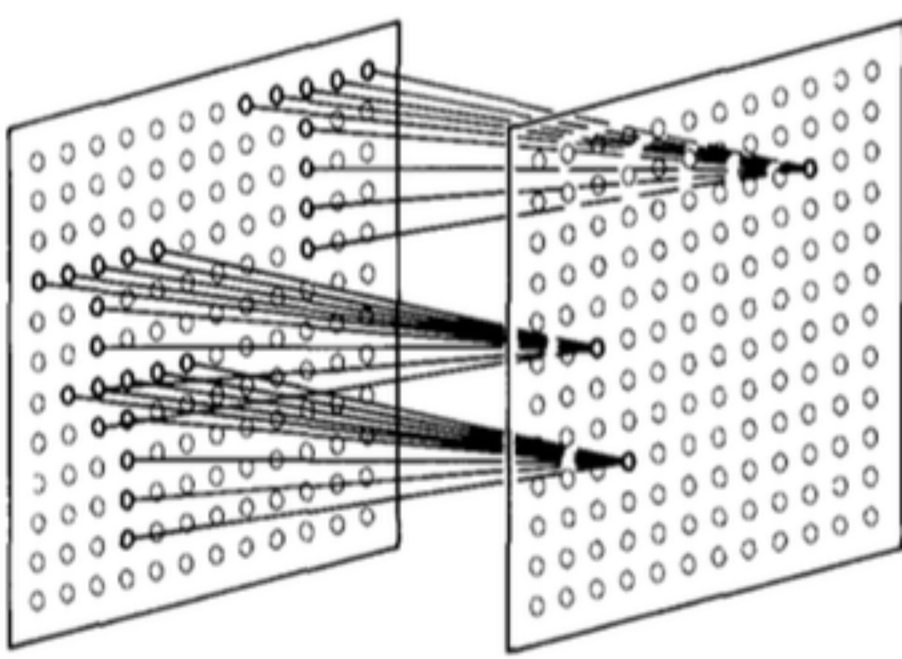


Colin Blakemore



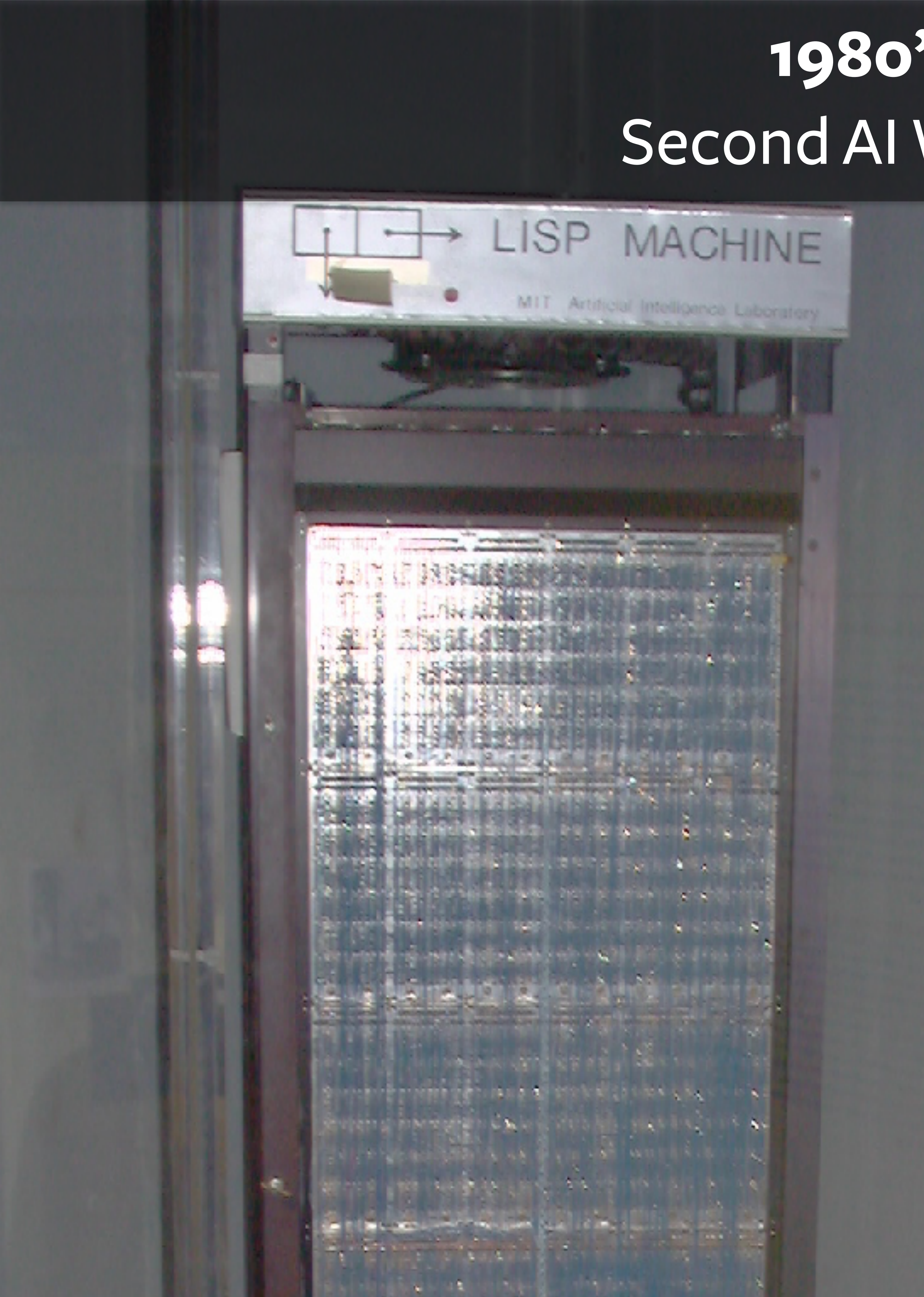
1979
Convolutional Neural Networks & Neocognitron

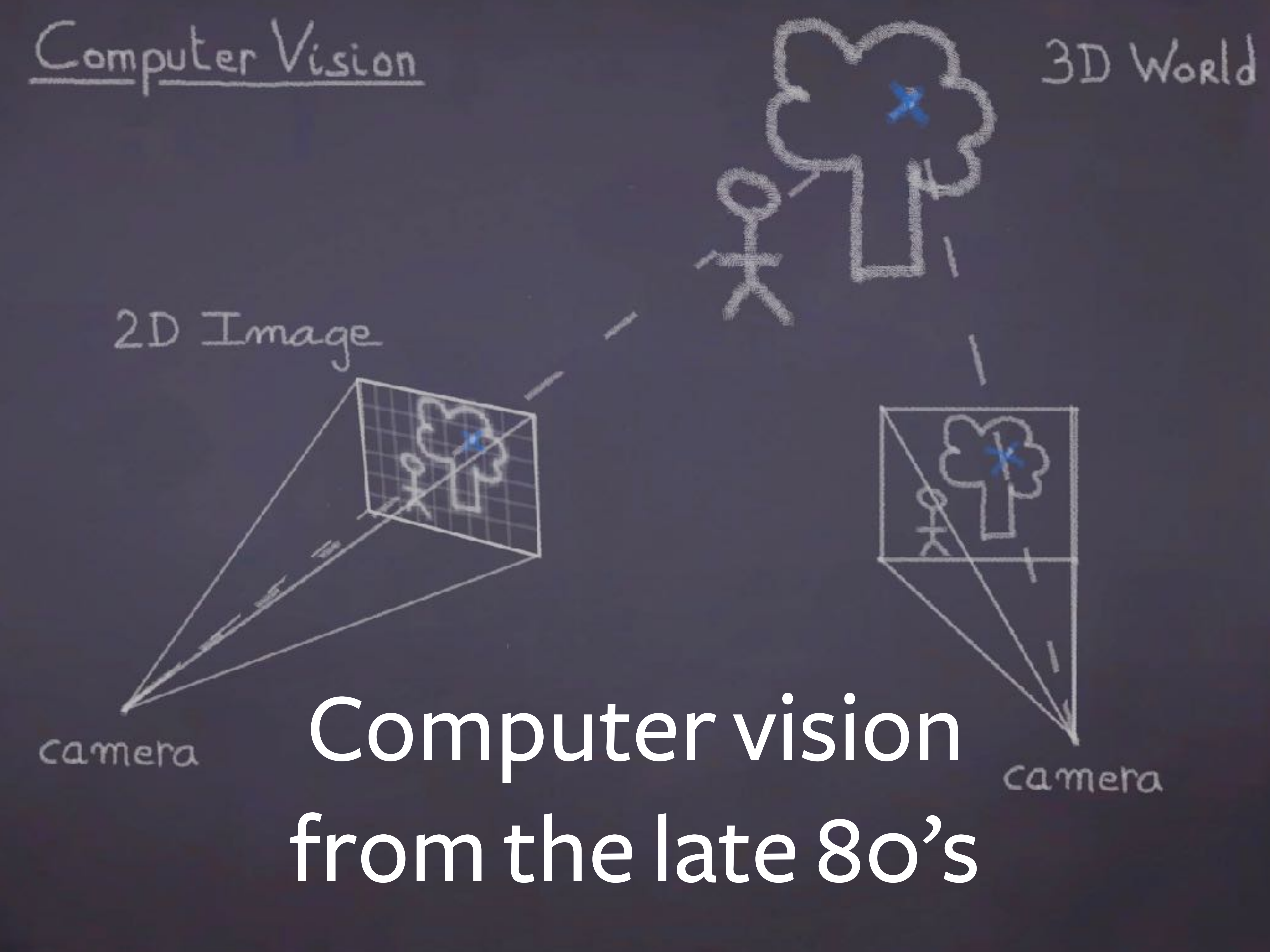




Kunihiko Fukushima

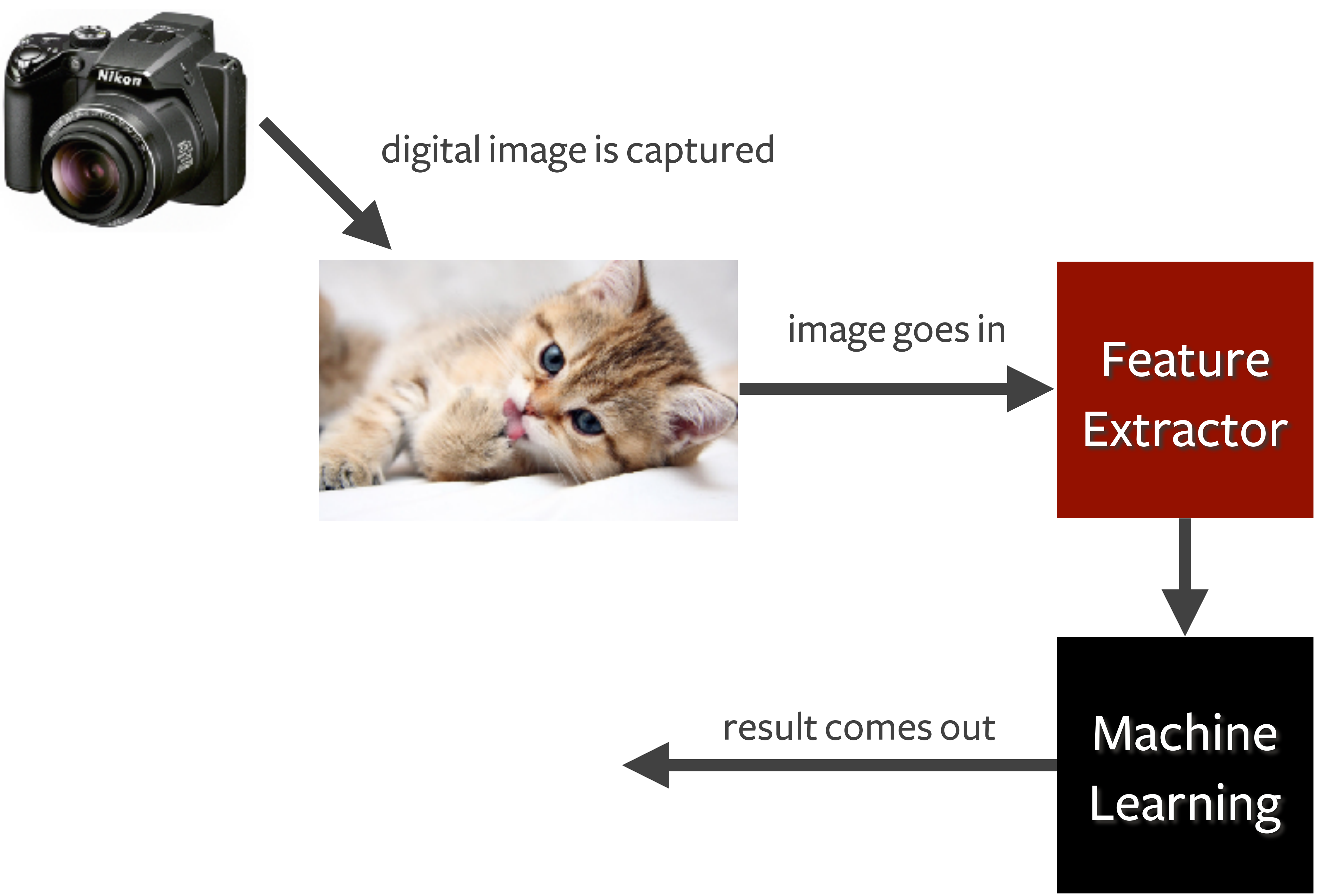
1980's
Second AI Winter





Computer vision from the late 80's

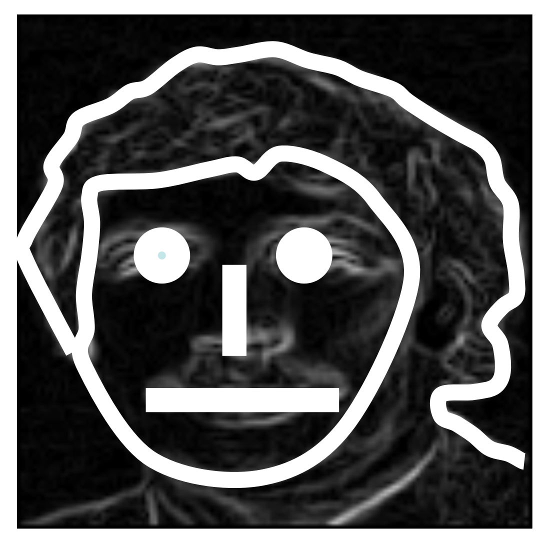
Classical approaches to computer vision take the following form:



Focus on “Feature Engineering”

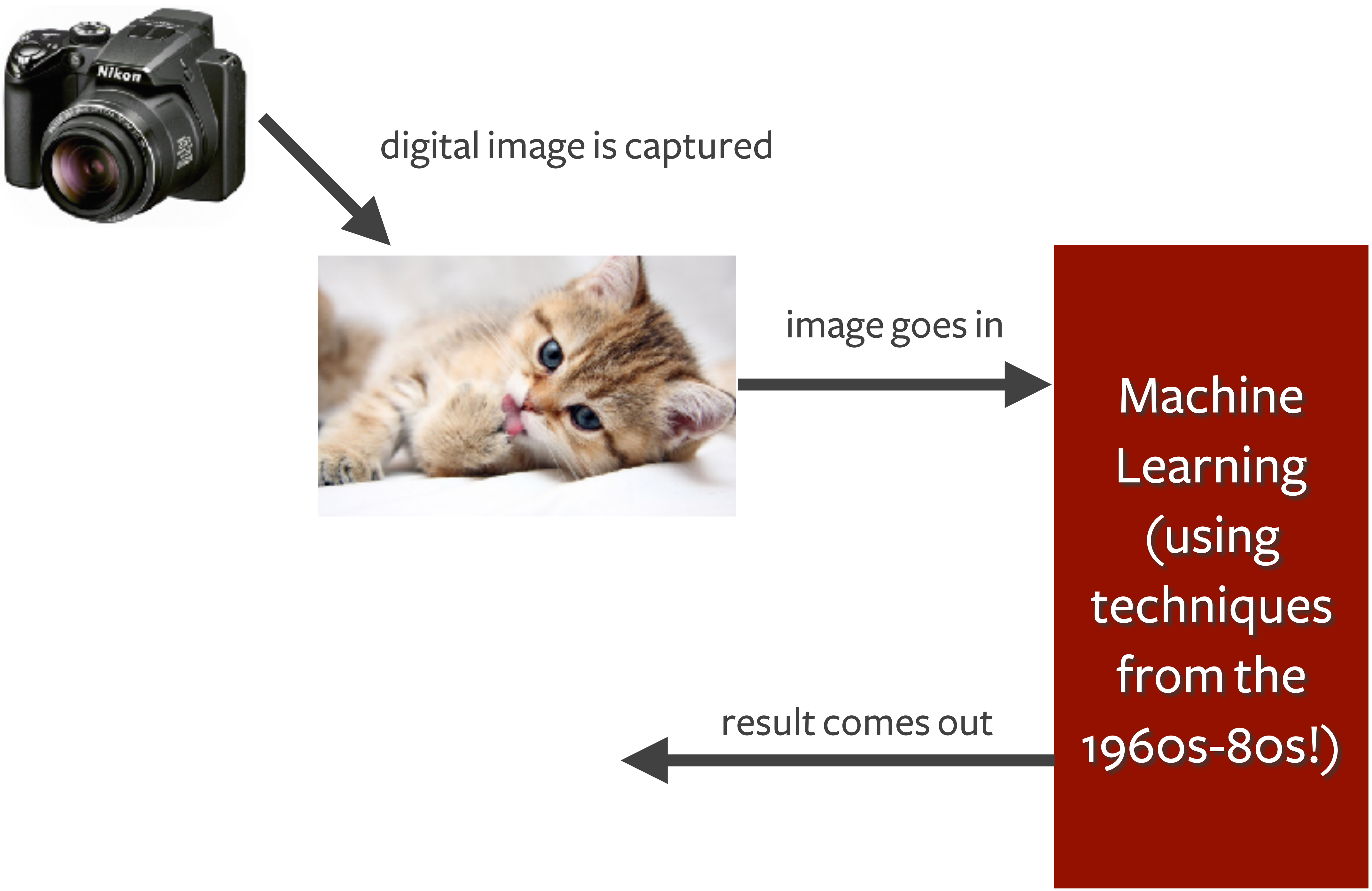
Low-level features:
“Global features”; edges; corners

High-level features:
“Model-based features”; objects; feature combinations

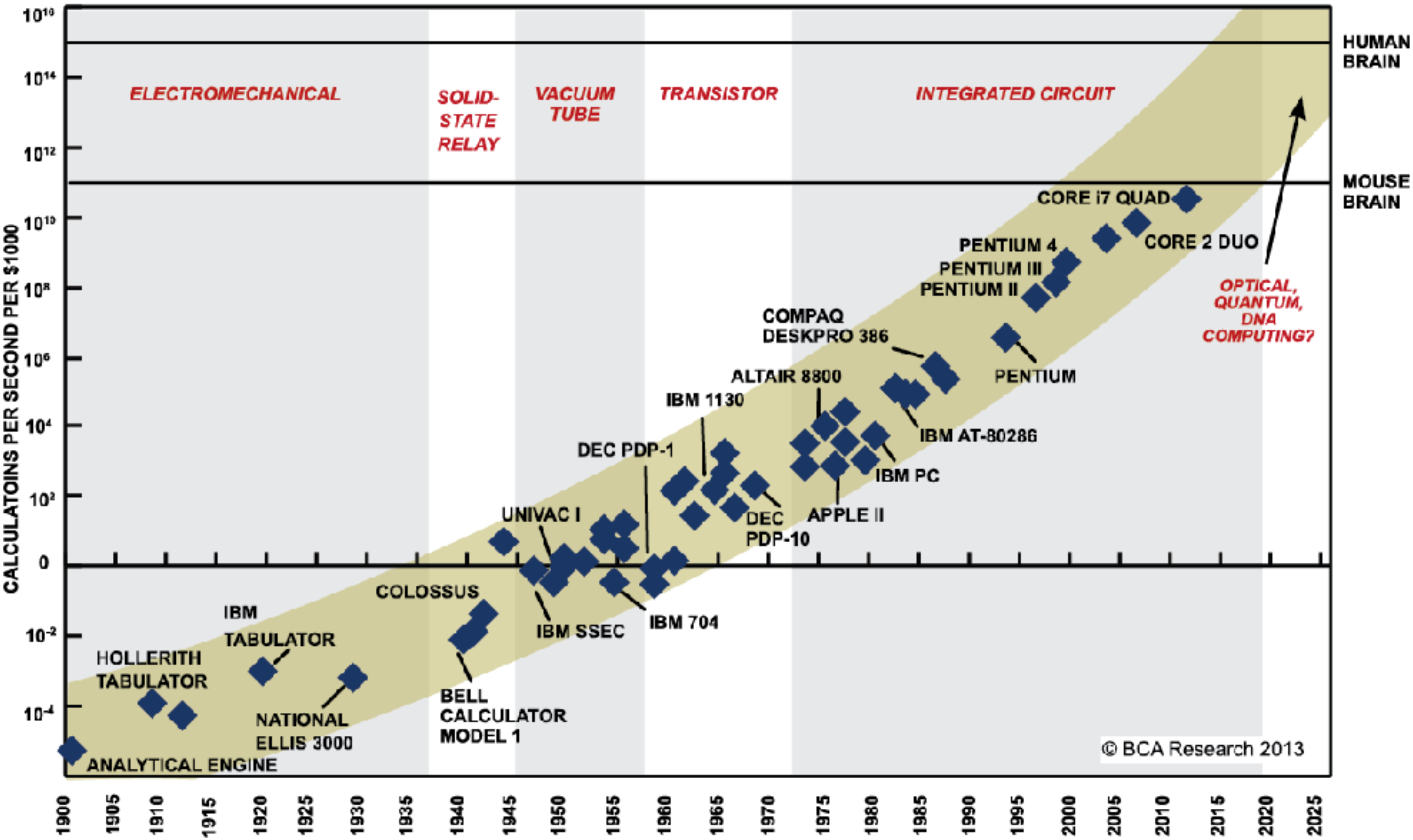


Vision since 2012: *Feature Learning*

Recent approaches to computer vision take the following form:



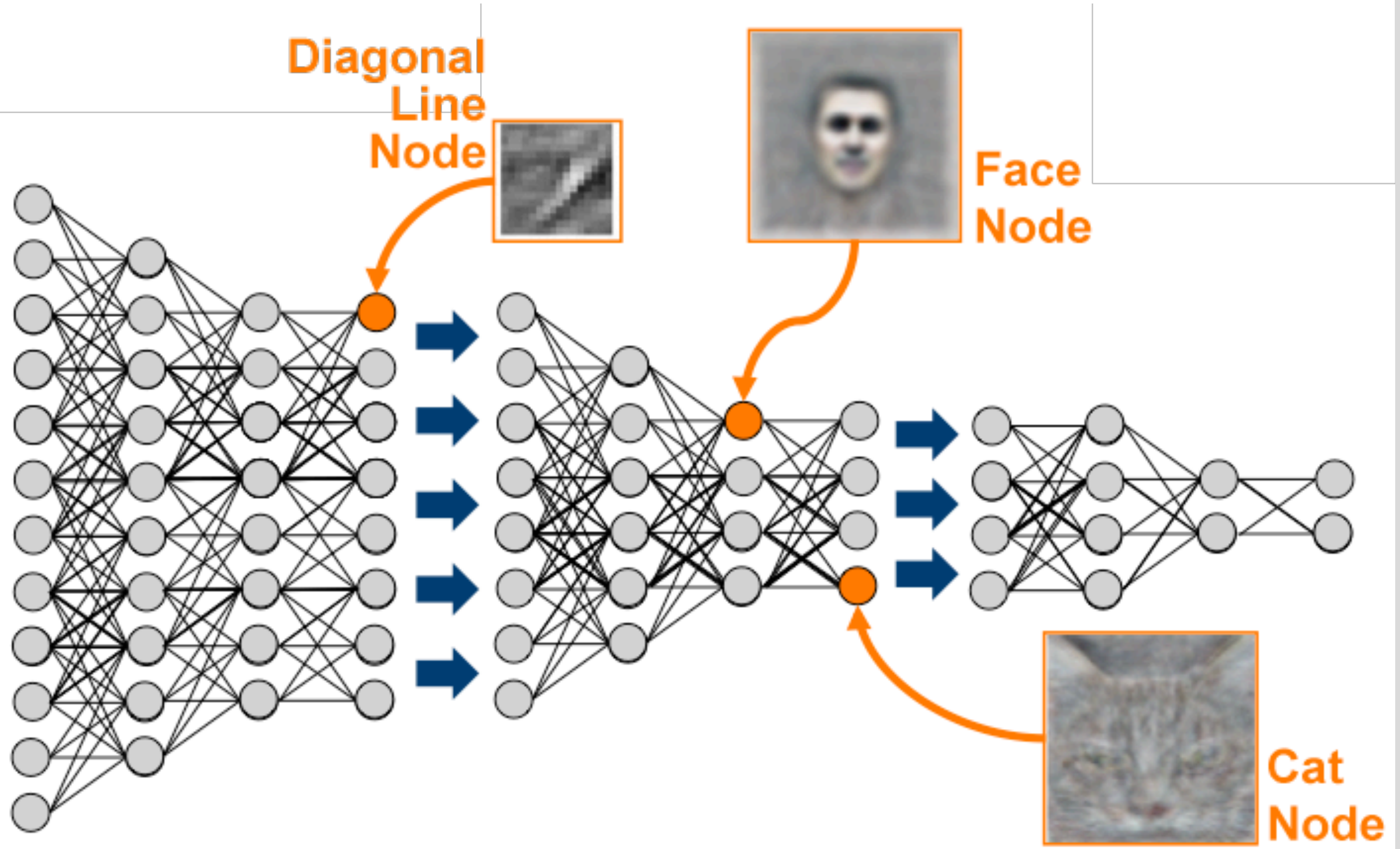
Moore's Law

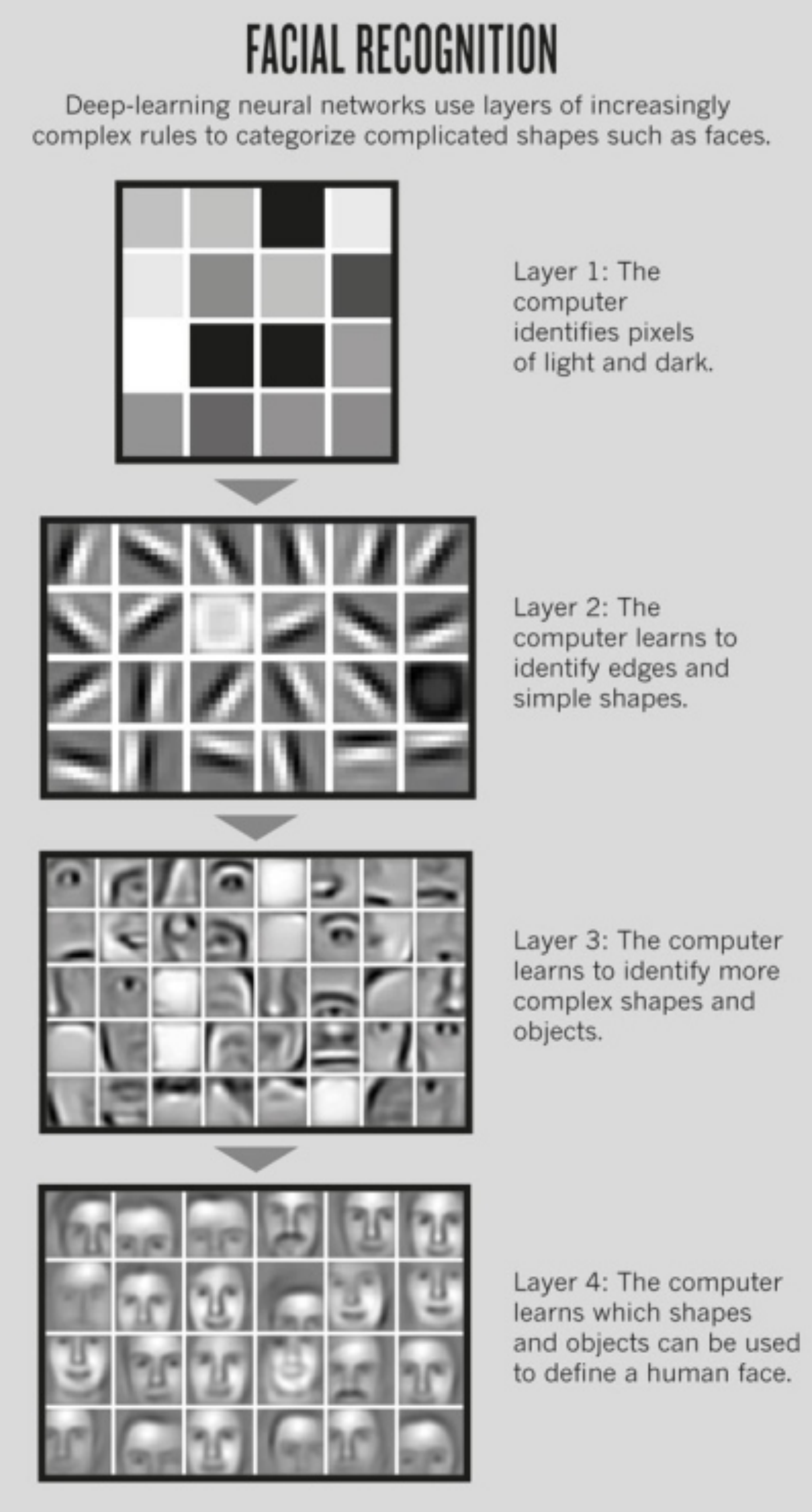


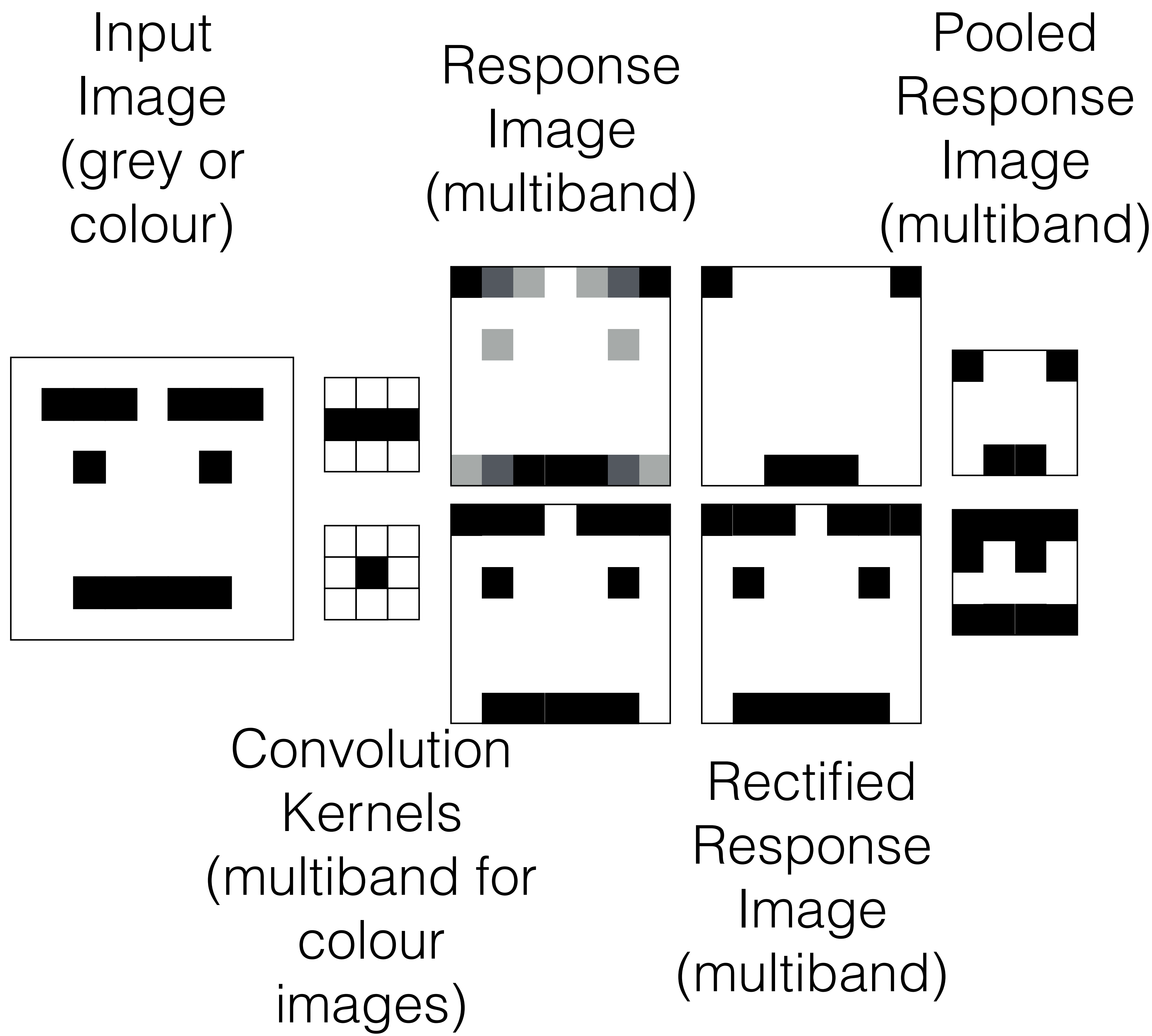
SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

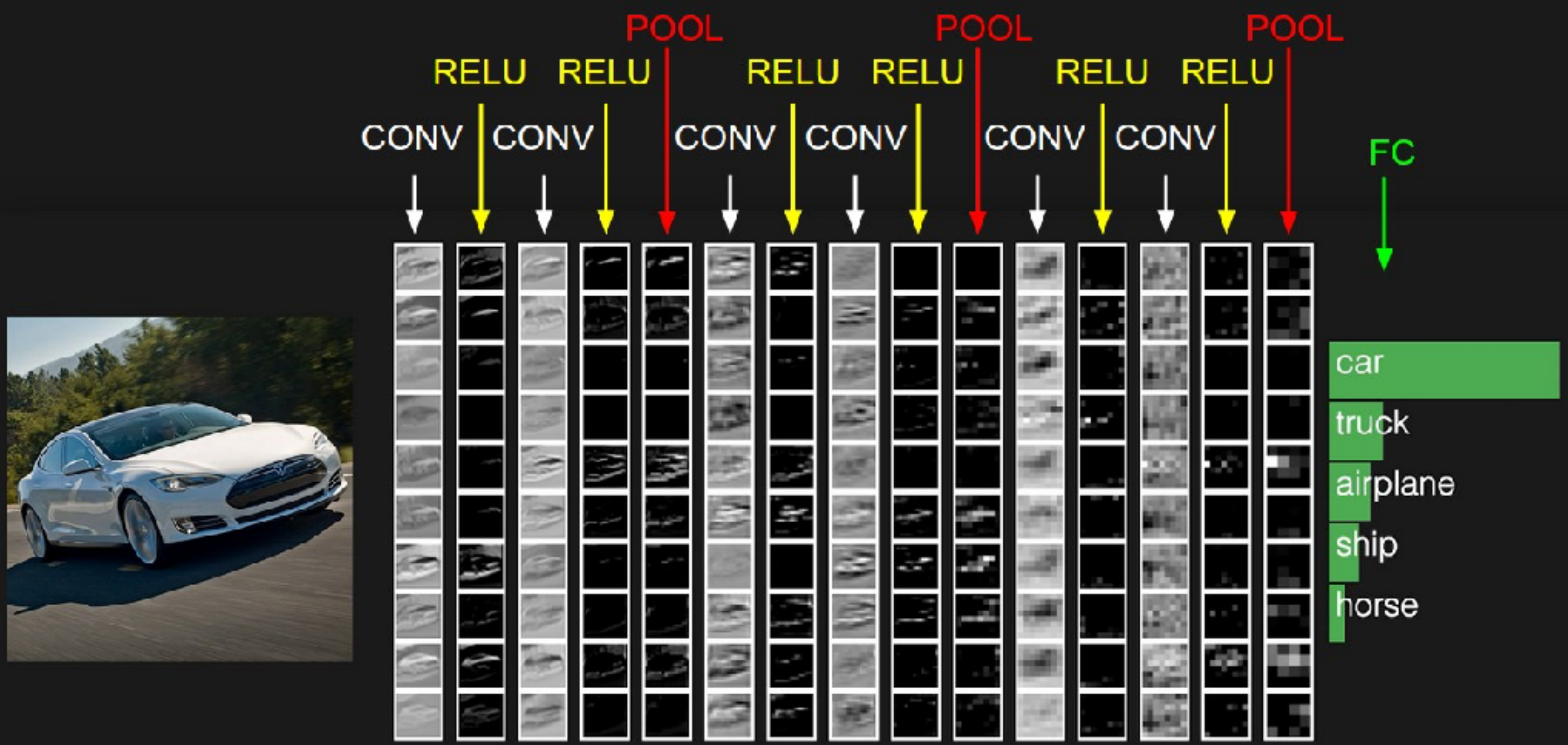
The new Moore's Law: Computer's no longer get faster, just wider

Deep learning: learning layers of features





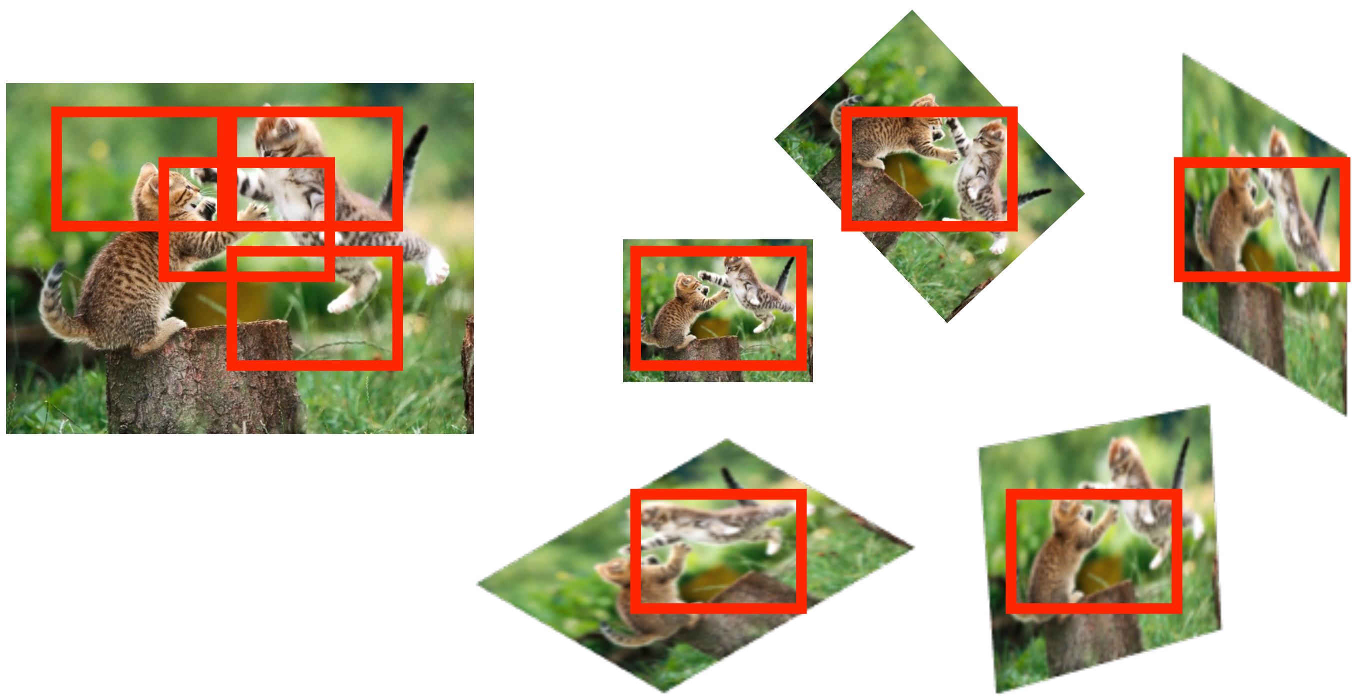

Input Image (grey or colour)
Response Image (multiband)
Pooled Response Image (multiband)
Convolution Kernels (multiband for colour images)
Rectified Response Image (multiband)


POOL
POOL
POOL
RELU
RELU
RELU
RELU
RELU
RELU
CONV
CONV
CONV
CONV
CONV
CONV
FC
car
truck
airplane
ship
horse

Demo

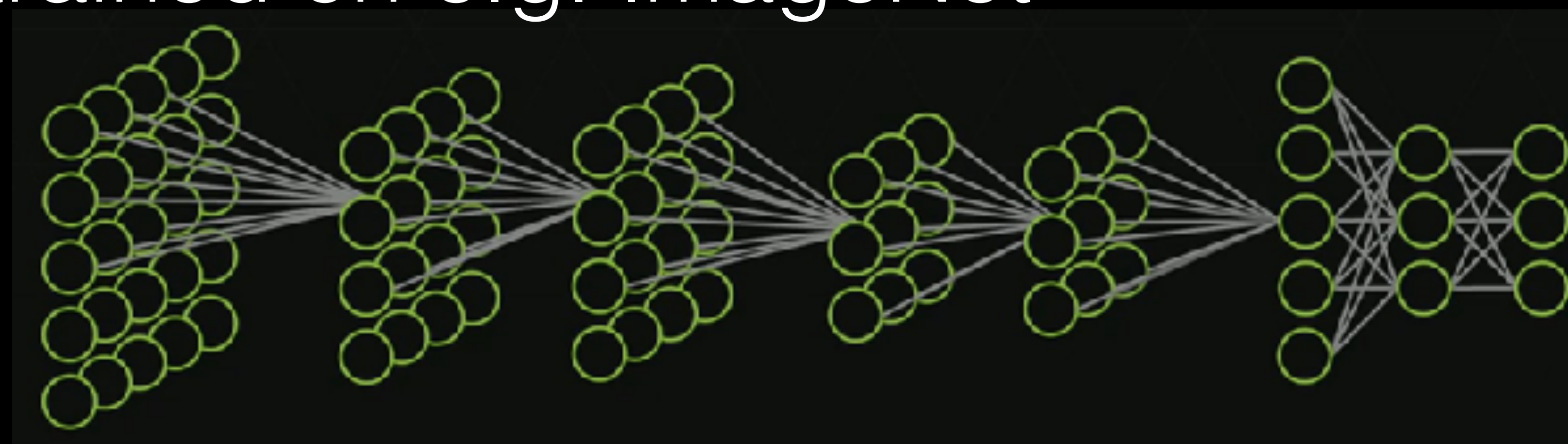
Tricks 'n Tips

- Lots of training data needed…
    - Use **data augmentation** with random transforms to create more from less
- Network overfits…
    - Use **dropout** when learning

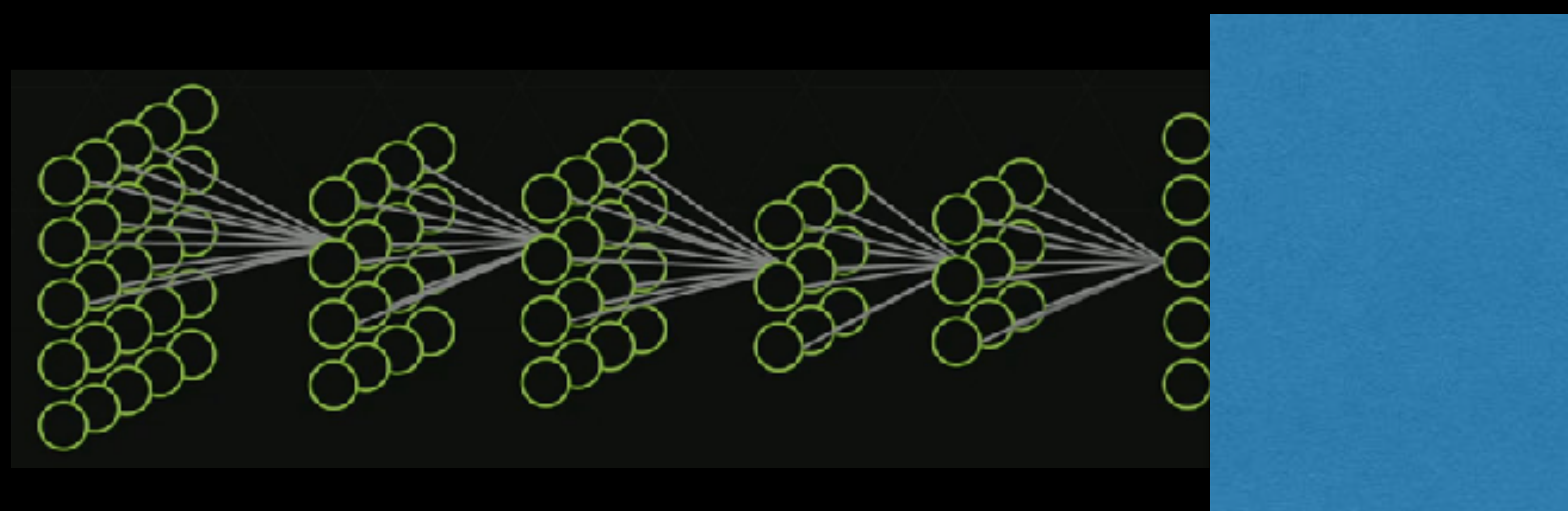


Transfer Learning

ConvNet trained on e.g. ImageNet



Take first bit of network and use as a feature extractor…

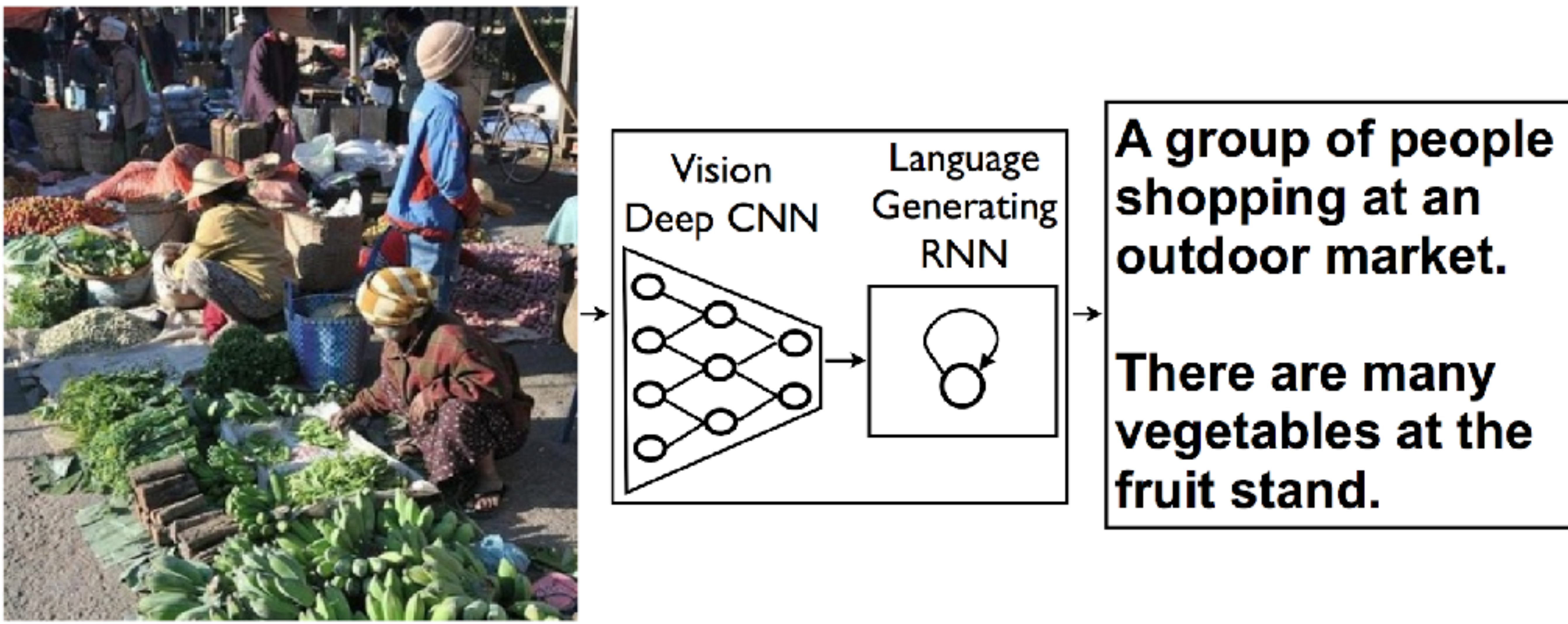


Train an MLP/ SVM/… on your problem using the features extracted from the net

Do computers dream of electric sheep?

Inceptionism and Algorithmic Pareidolia

State-of-the-art computer vision: Recurrent networks for image captioning



“a man is climbing up a rock face”

“a motorcycle racer is driving a turn on a racetrack”

“a basketball player in a red uniform is trying to score a player in the air”

“a man in a red shirt is riding a bike on a snowy hill”

"a surfer is jumping off a snowy hill"

Questions?

Mark & I hope you have enjoyed learning about Computer Vision this semester

We'll meet after Christmas for a revision lecture
(probably in the Tuesday slot - I'll be in touch to confirm)

If you've enjoyed this module, you might also like Advanced Computer Vision (Mark), Advanced Machine Learning (Adam) & Data Mining (me)