Evidence for sparse coding

Mushroom body, locust (Laurent)

HVC, zebra finch (Fee)

Auditory cortex, mouse (DeWeese & Zador)

Hippocampus, rat/primate (Thompson & Best; Skaggs)

Motor cortex, rabbit (Swadlow)

Barrel cortex, rat (Brecht)

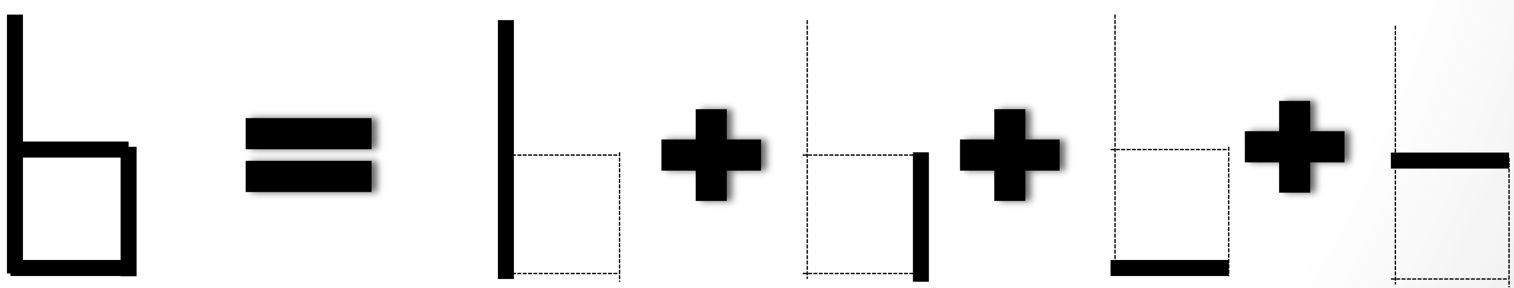
Visual cortex, monkey/cat (Vinje & Gallant)

Visual cortex, cat (Gray; McCormick)

Inferotemporal cortex, human (Fried & Koch)

Olshausen BA, Field DJ (2004) Sparse coding of sensory inputs. *Current Opinion in Neurobiology, 14*, 481-487.

Evidence Slide from B. Olshausen



Sparse Coding

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Outline

- Sparse Coding is both an organizing principle for understanding the brain and a useful machine learning tool

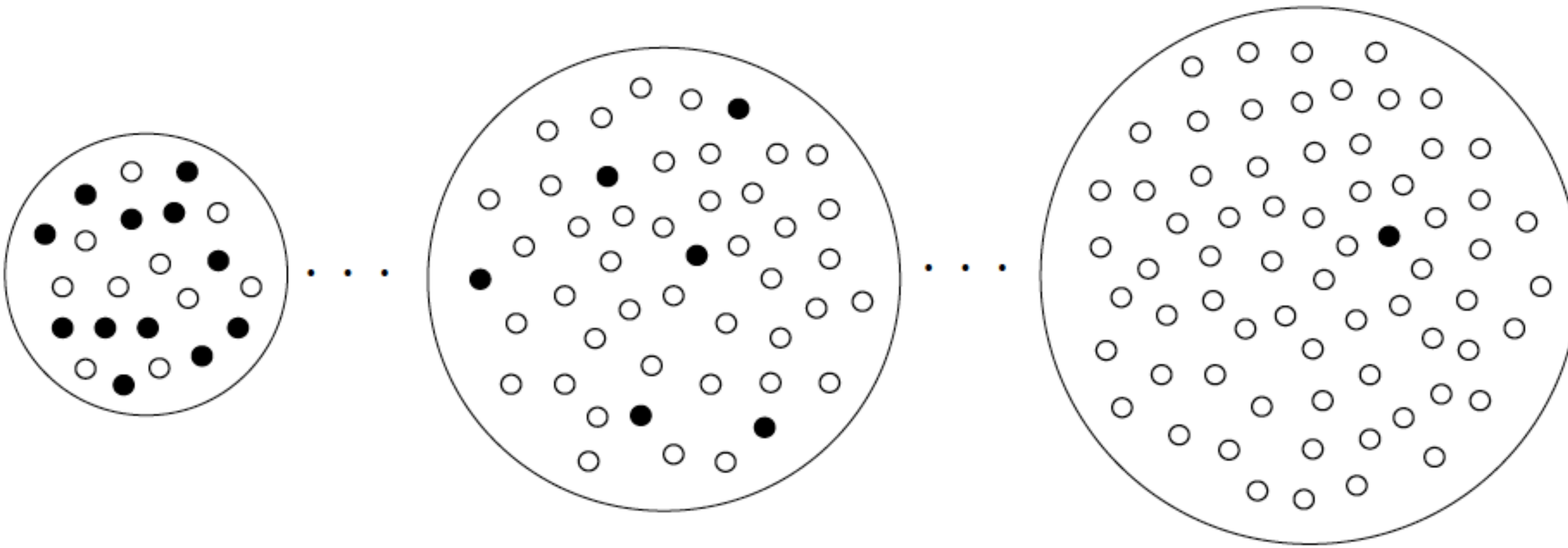
1. What is a sparse code?
2. Mathematical Model?
3. Sparse coding in V1?

WHAT IS A SPARSE CODE?

Dense codes
(e.g., ascii)

Sparse, distributed codes

Local codes
(e.g., grandmother cells)



2^N

$\binom{N}{K}$

N

Slide from B. Olshausen

Barlow (1972)

Perception, 1972, volume 1, pages 371–394

Single units and sensation: A neuron doctrine for perceptual psychology?

H B Barlow
Department of Physiology–Anatomy, University of California, Berkeley, California 94720
Received 6 December 1972

Abstract. The problem discussed is the relationship between the firing of single neurons in sensory pathways and subjectively experienced sensations. The conclusions are formulated as the following five dogmas:
1. To understand nervous function one needs to look at interactions at a cellular level, rather than either a more macroscopic or microscopic level, because behaviour depends upon the organized

2. The sensory system is organized to achieve as complete a representation of the sensory stimulus as possible with the minimum number of active neurons.

neurons, each of which corresponds to a pattern of external events of the order of complexity of the events symbolized by a word.
5. High impulse frequency in such neurons corresponds to high certainty that the trigger feature is present.
The development of the concepts leading up to these speculative dogmas, their experimental basis, and some of their limitations are discussed.

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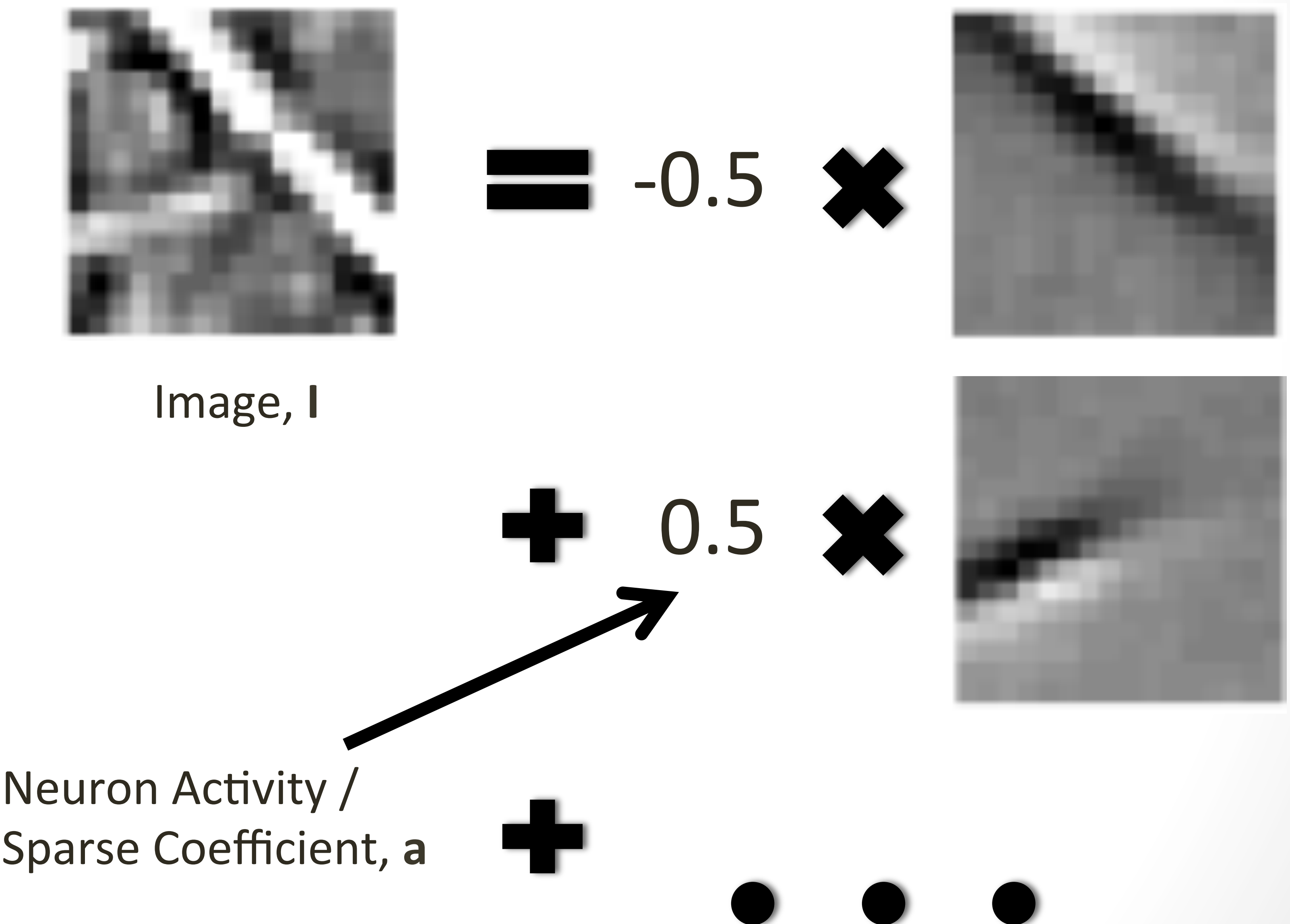
MATHEMATICAL MODEL

Model in Pictures



Sparse Coefficients,
different for each image

Image n

$$I_n = D_1 * A_1(I_n) + D_2 * A_2(I_n) + \ldots$$

Dictionary elements,
one set for all images

Image, fixed and given

Sparse Coefficients, Chosen to reconstruct image and be sparse

Dictionary, to be learned from data

$$E = |I - \sum_i A_i * D_i|^2 + \sum_i abs(A_i) \qquad |D_i|^2 = 1$$

Cost function

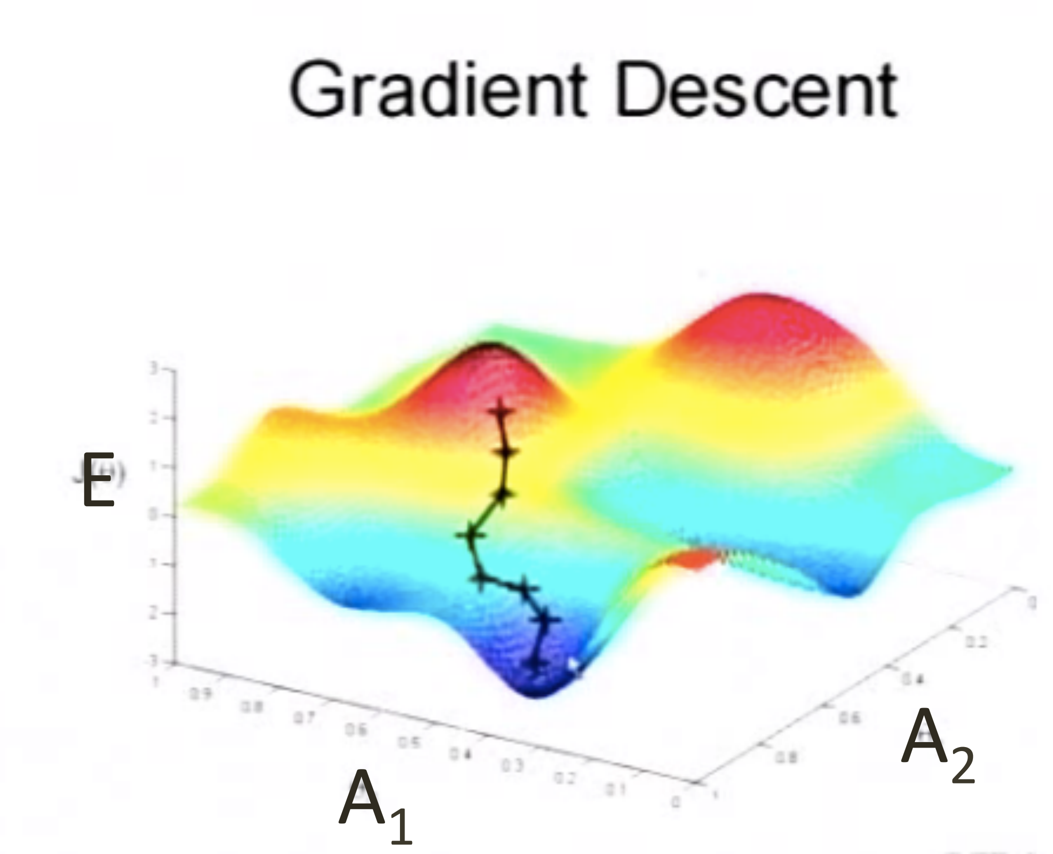
Reconstruction Error

Sparsity

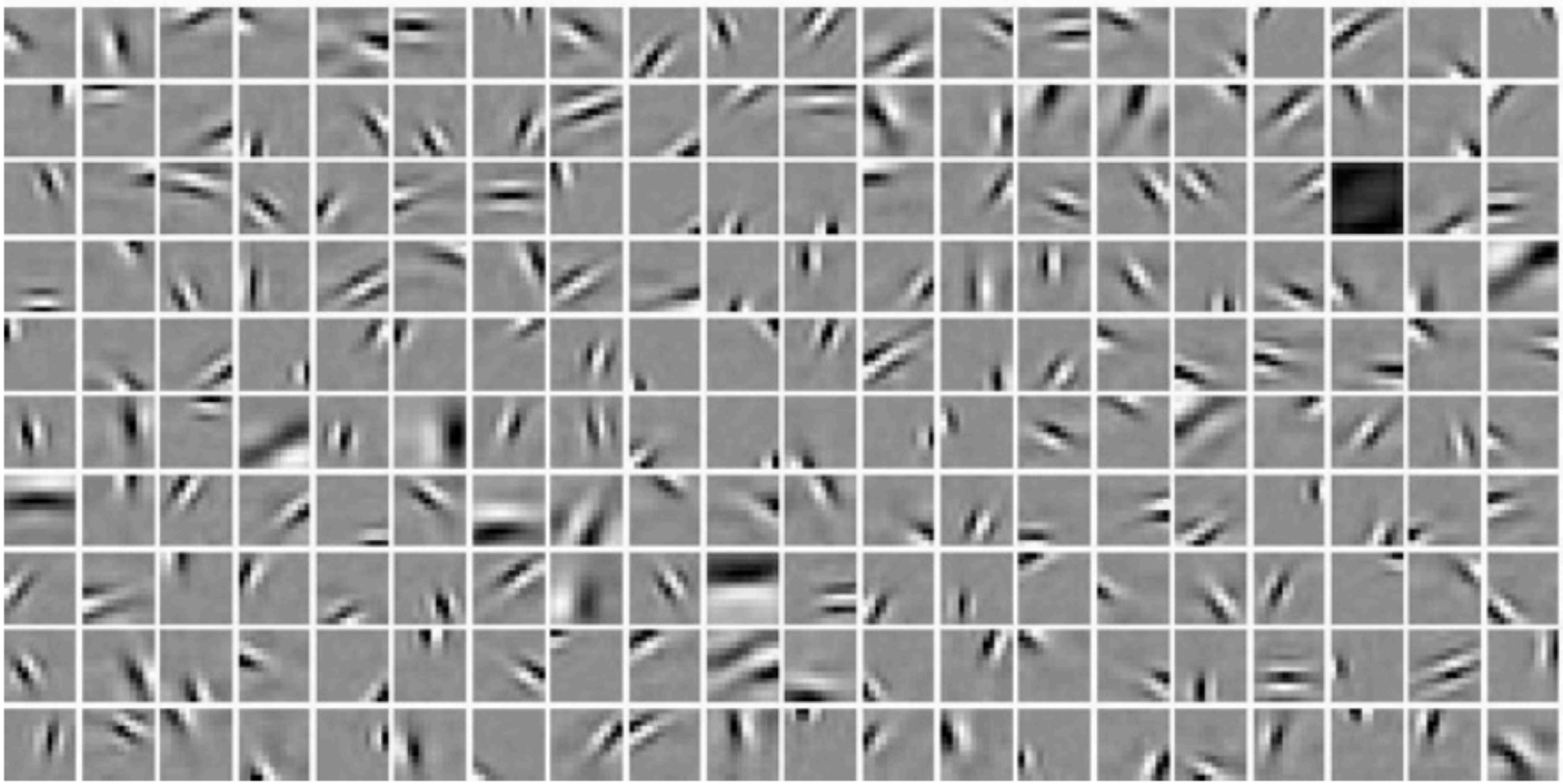
Normed dictionary prevents trivial solution

Inference and Learning

- Given the dictionary D, find the sparse coefficients, A, by minimizing the cost function with respect to A.
- Given the sparse coefficients, take one gradient step with respect to the dictionary (and normalize the dictionary).



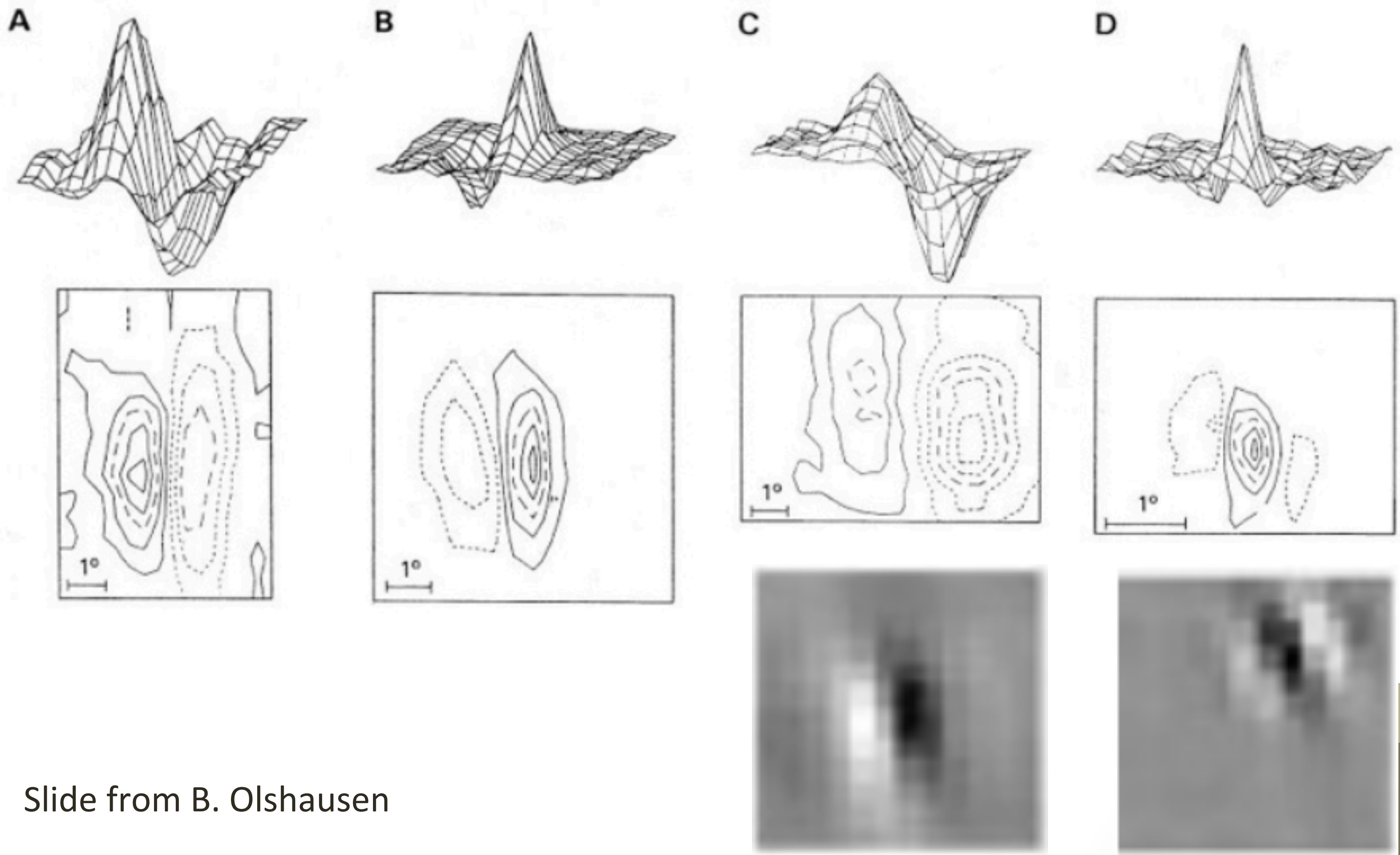
Features learned from natural images
(200, 12x12 pixels)



Slide from B. Olshausen

SPARSE CODING IN V1?

V1 Receptive Fields – Edge Detectors (+more)



Slide from B. Olshausen

Key point!

- Images from a camera + sparse coding
- ~
- V1 simple cell RFs

- Brain is adapted to the incoming data

Onto the tutorial!