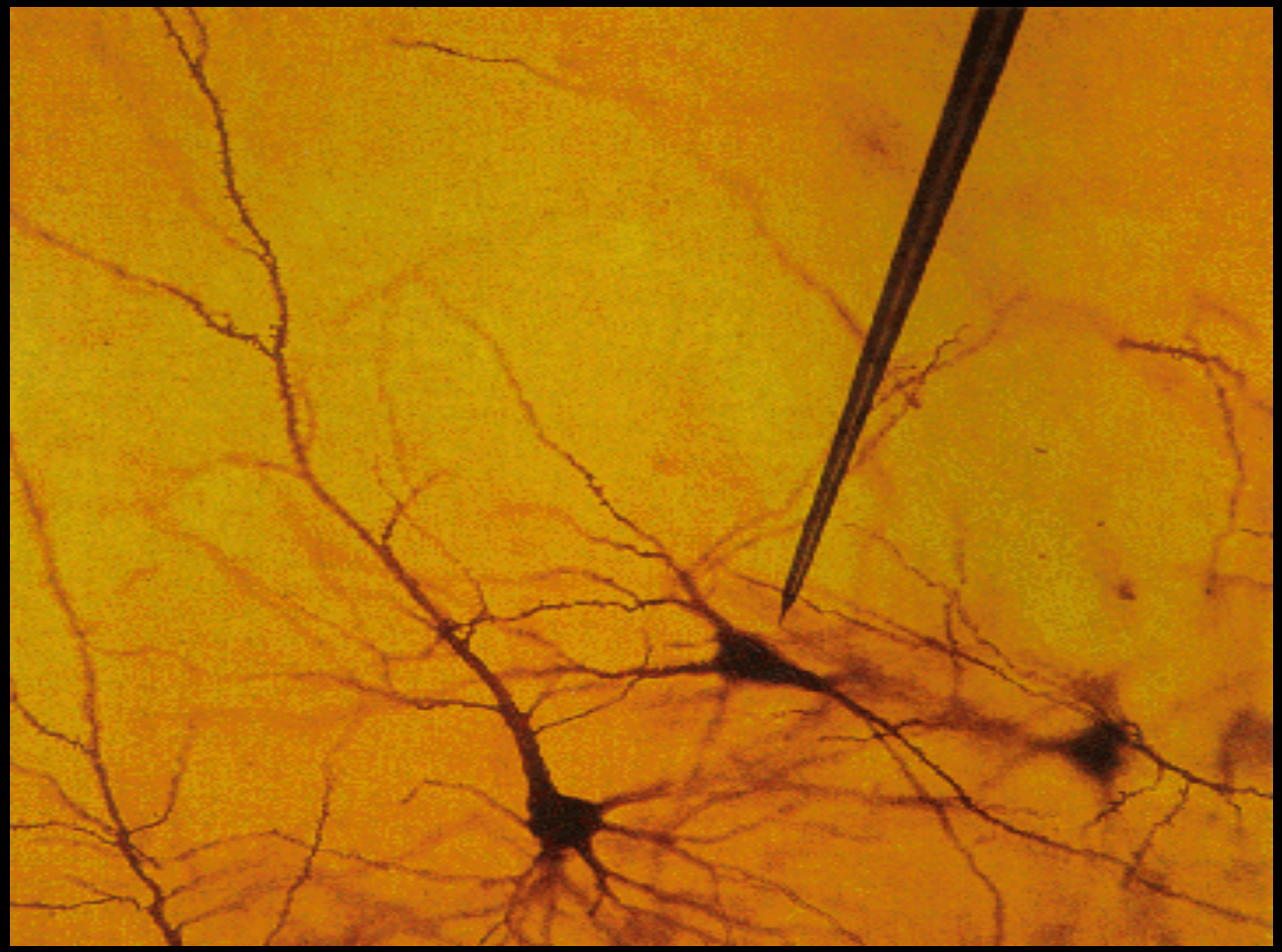
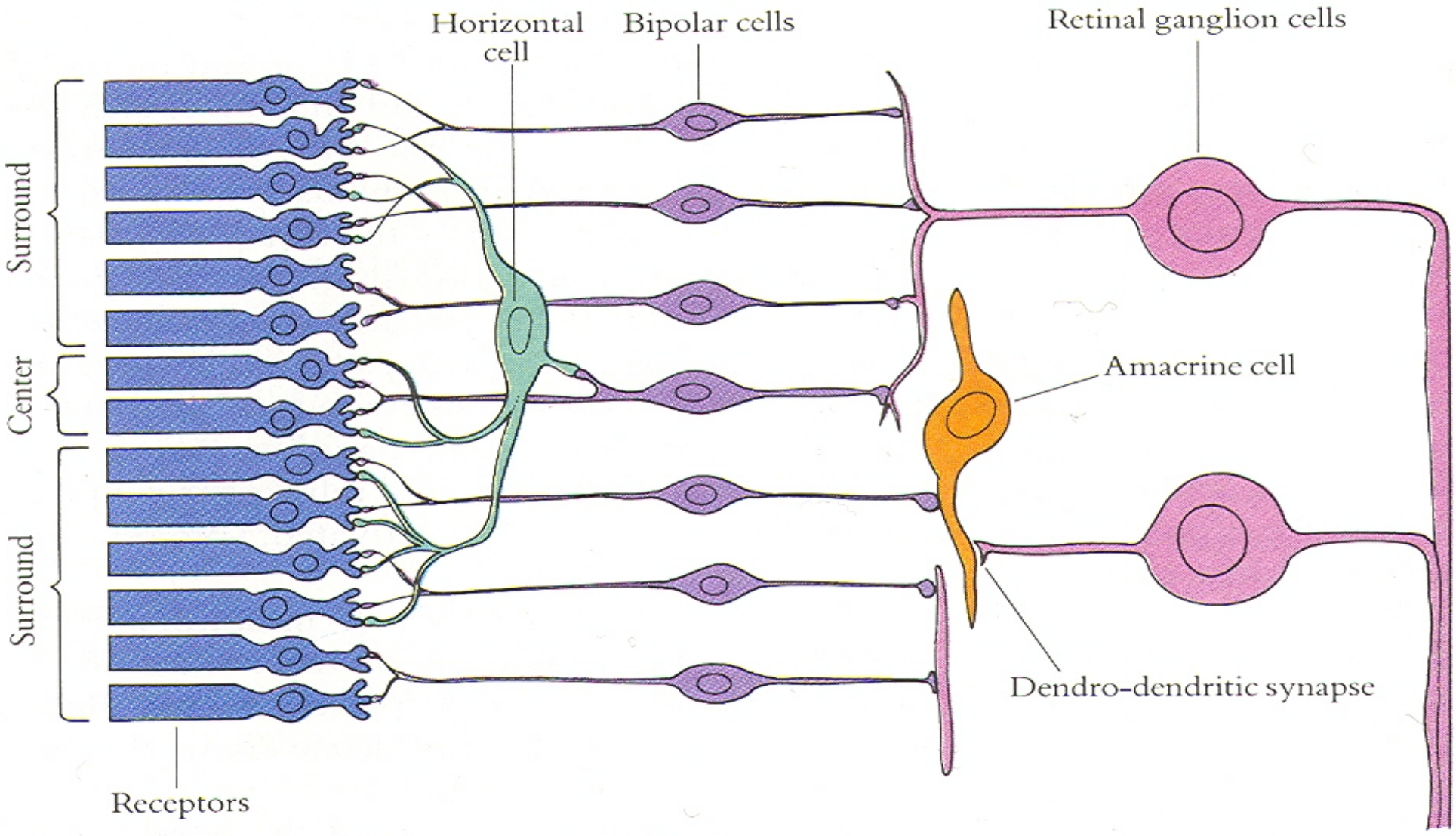
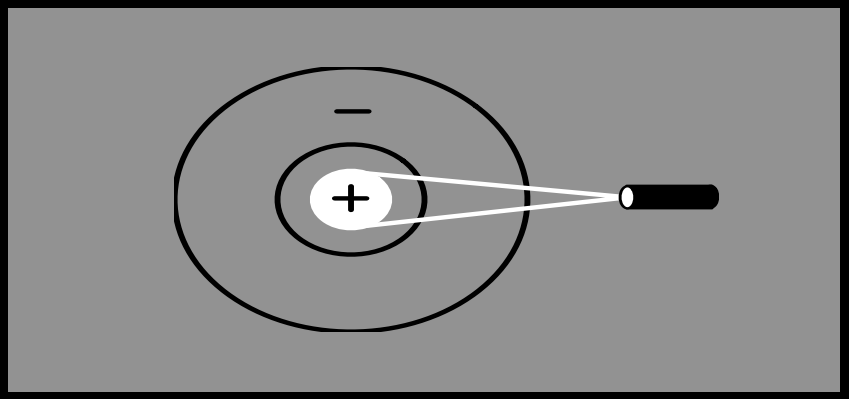
Recording Action Potentials




Horizontal cell
Bipolar cells
Retinal ganglion cells
Surround
Center
Surround
Amacrine cell
Dendro-dendritic synapse
Receptors

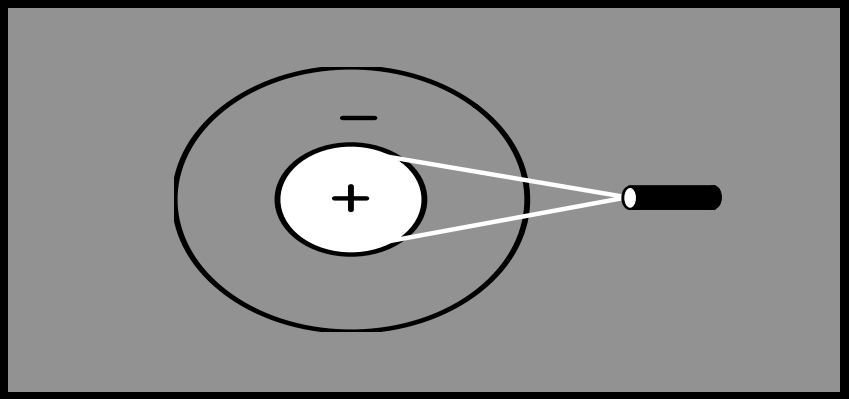
Receptive field structure in ganglion cells:
On-center Off-surround

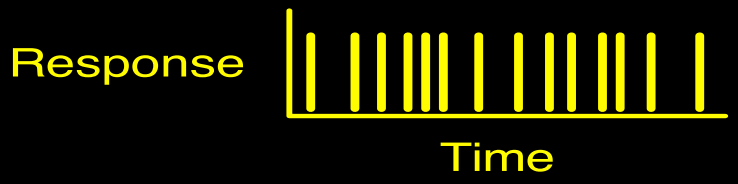


Stimulus

Electrical response

Receptive field structure in ganglion cells:
On-center Off-surround

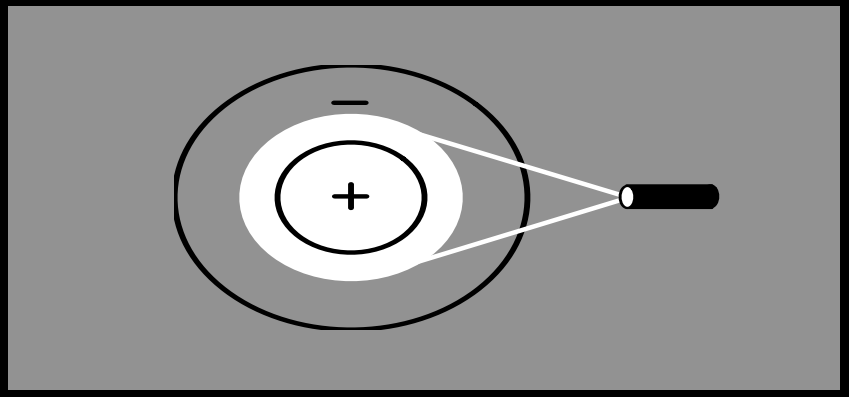


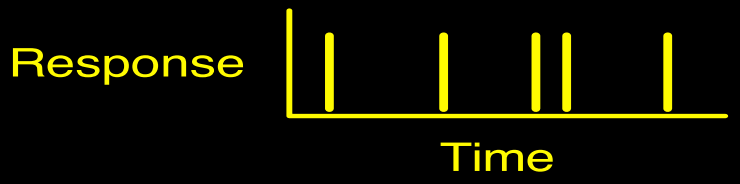


Stimulus condition

Electrical response

Receptive field structure in ganglion cells:
On-center Off-surround

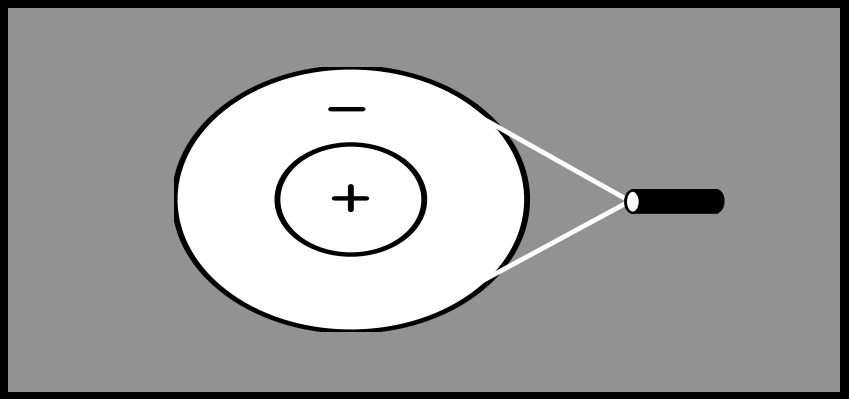


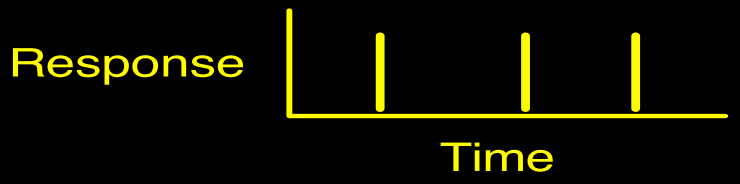


Stimulus condition

Electrical response

Receptive field structure in ganglion cells:
On-center Off-surround



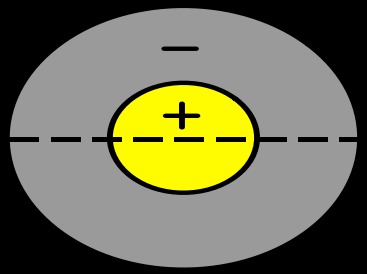


Stimulus condition

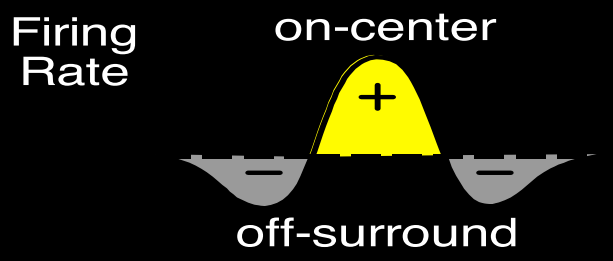
Electrical response

On-center Off-surround cells

Receptive Field

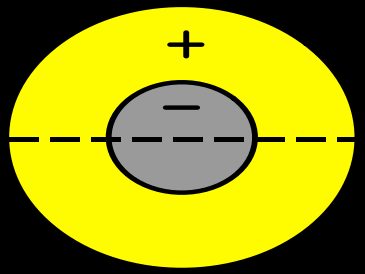


Response Profle

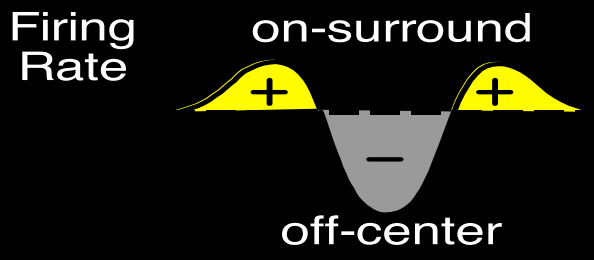


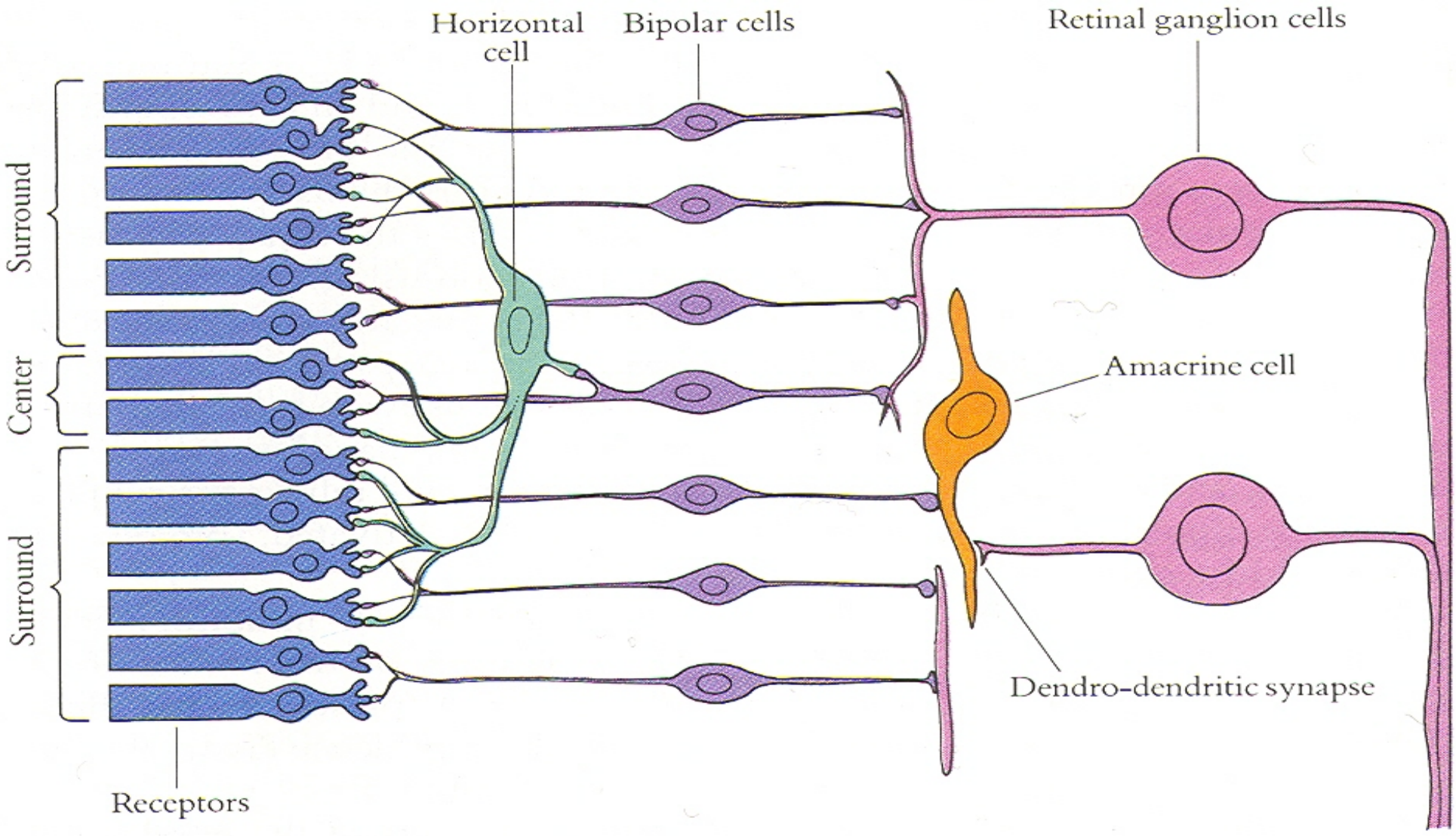
Off-center On-surround cells

Receptive Field

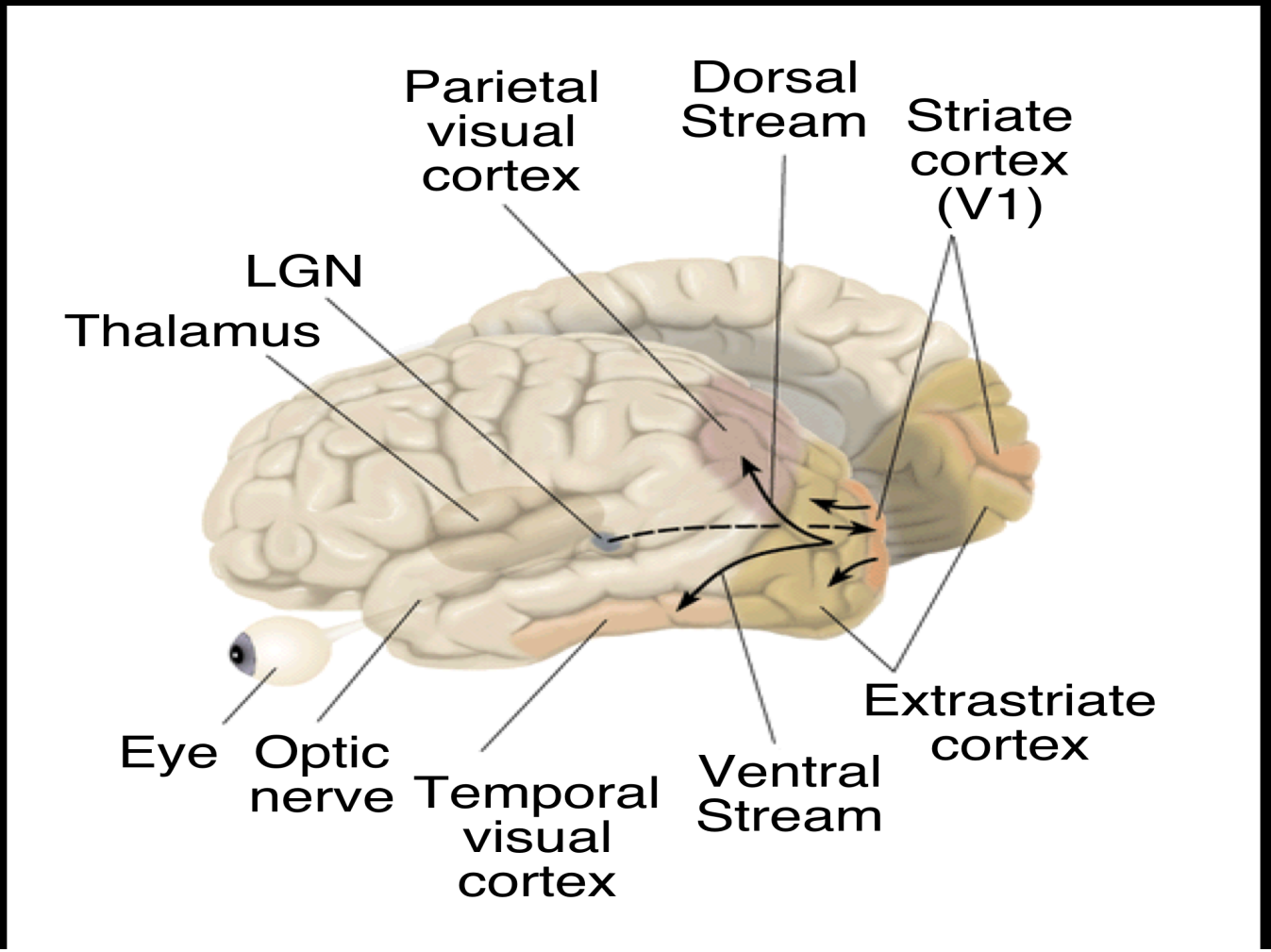


Response Profle




Horizontal cell
Bipolar cells
Retinal ganglion cells
Surround
Center
Surround
Amacrine cell
Dendro-dendritic synapse
Receptors

Cortical Area V1 aka Primary Visual Cortex



Single-Cell Recording from Visual Cortex

David Hubel & Thorston Wiesel

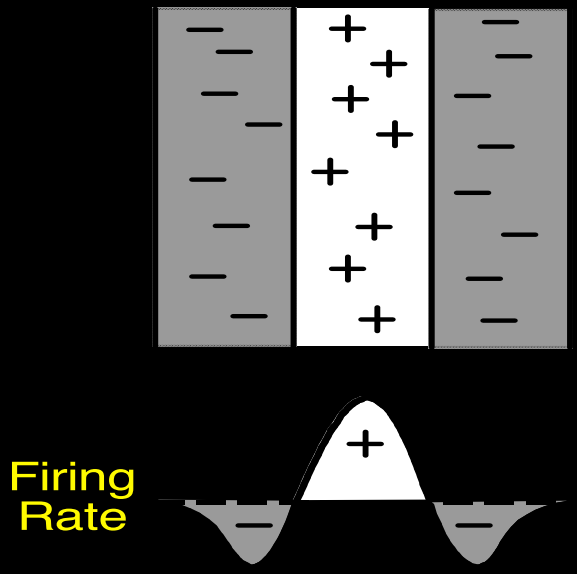
2 Classes of Cells in V1

Simple cells

Complex cells

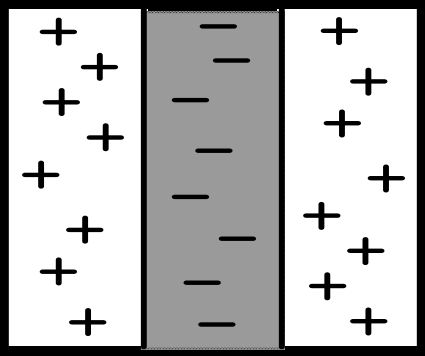
Simple Cells: Line Detectors

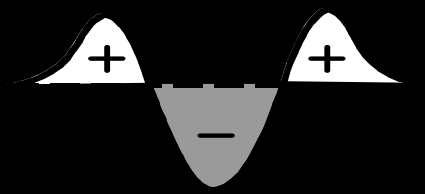
A. Light Line Detector



Horizontal Position

B. Dark Line Detector

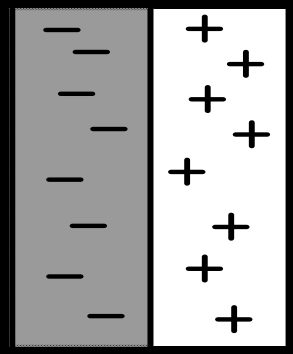




Horizontal Position

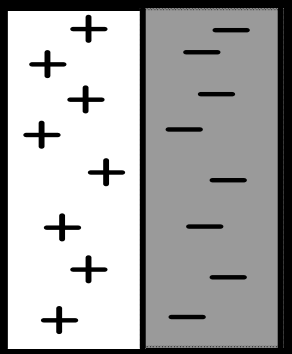
Simple Cells: Edge Detectors

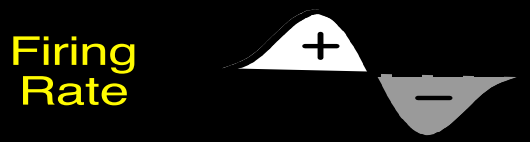
C. Dark-to-light Edge Detector



Horizontal Position

D. Light-to-dark Edge Detector



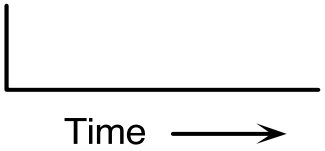


Horizontal Position

Orientation Dependence

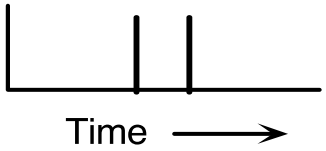
STIMULUS NEURAL RESPONSE

0°



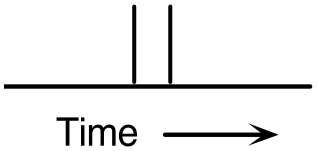
STIMULUS NEURAL RESPONSE

60°



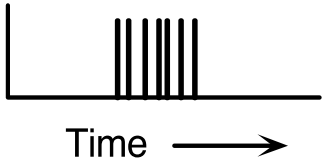
STIMULUS NEURAL RESPONSE

120°

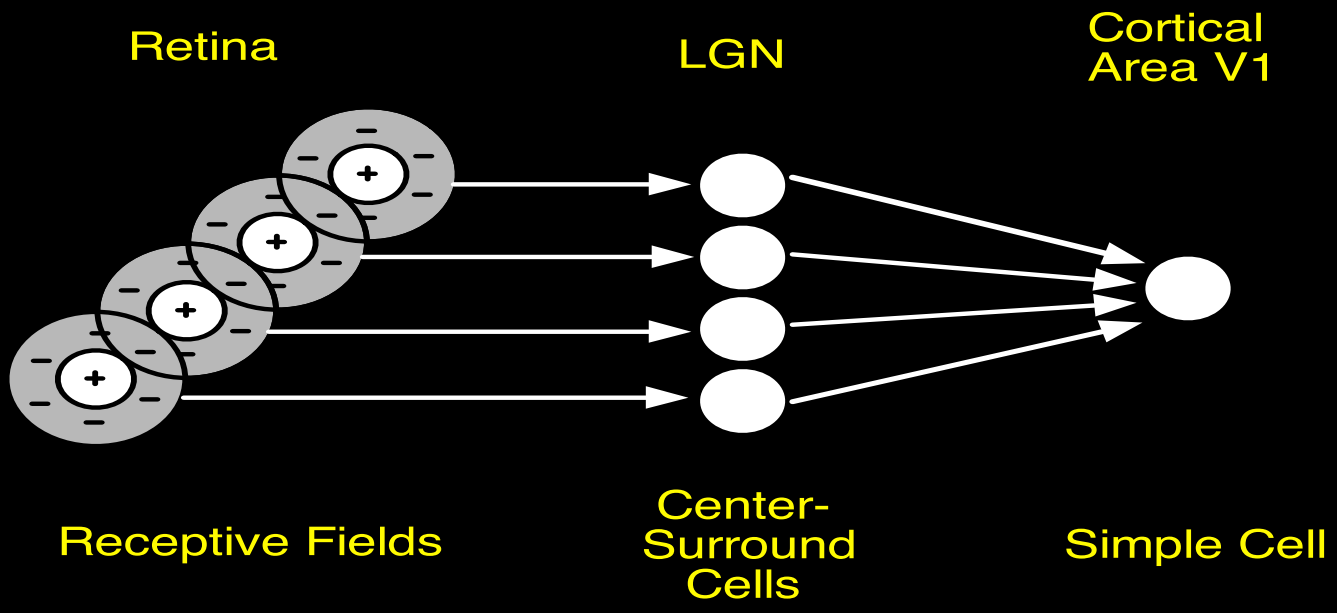


STIMULUS NEURAL RESPONSE

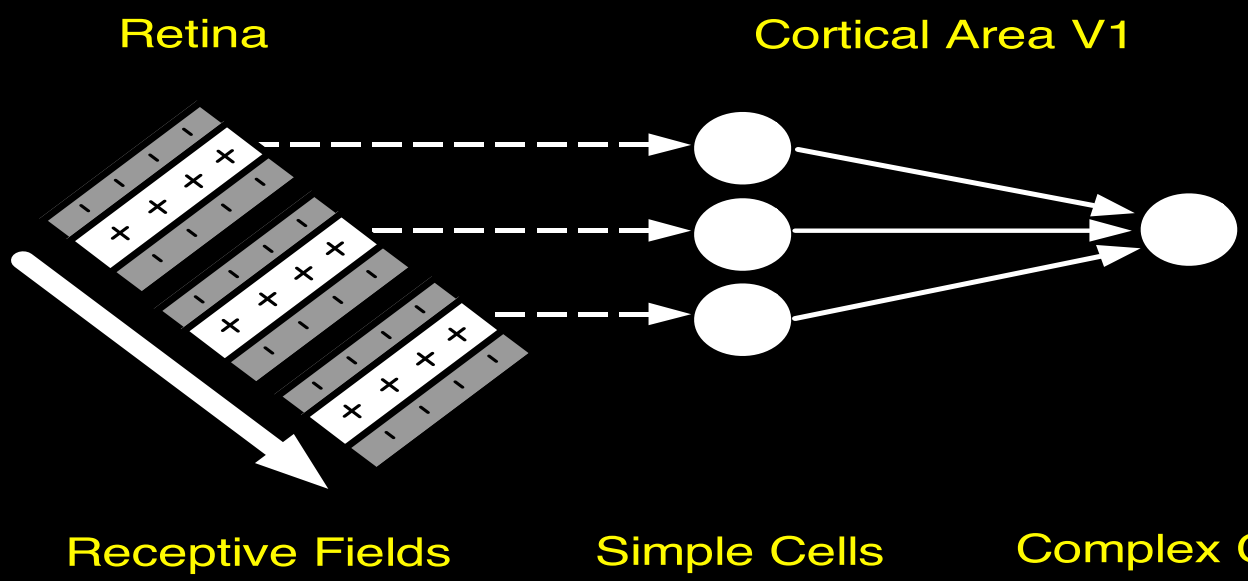
90°



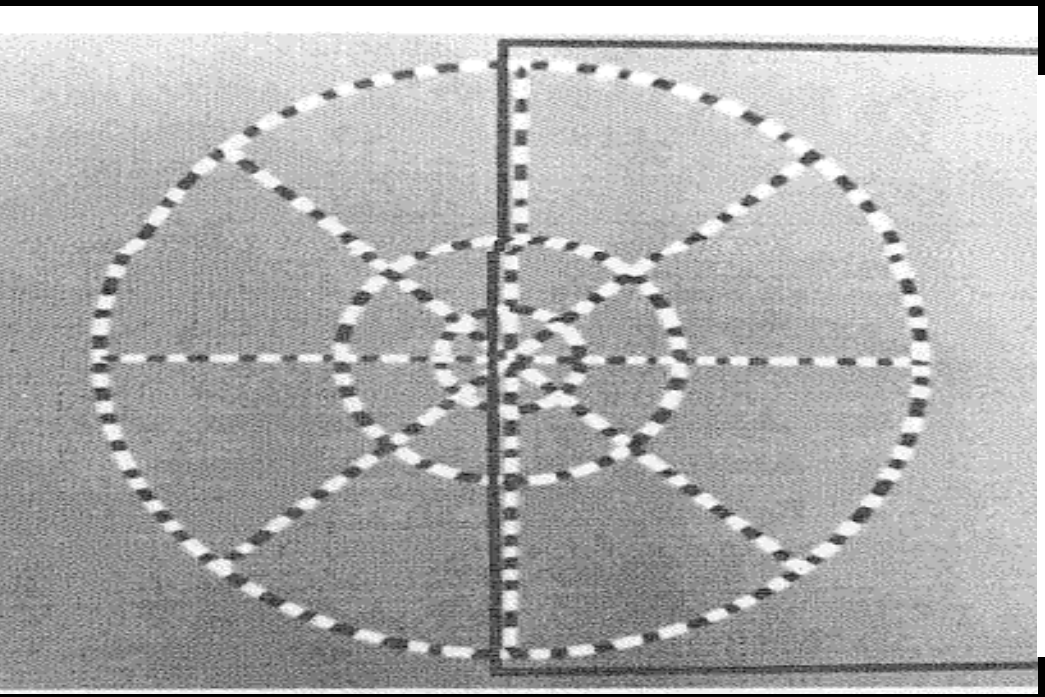
Simple Cell: Line Detector

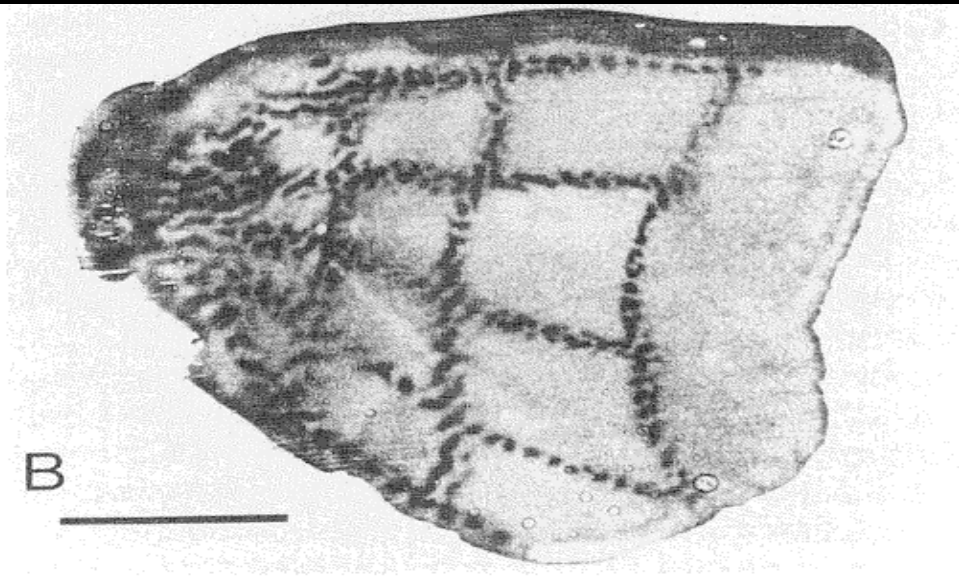


Complex Cell: Location-Independent Line Detector

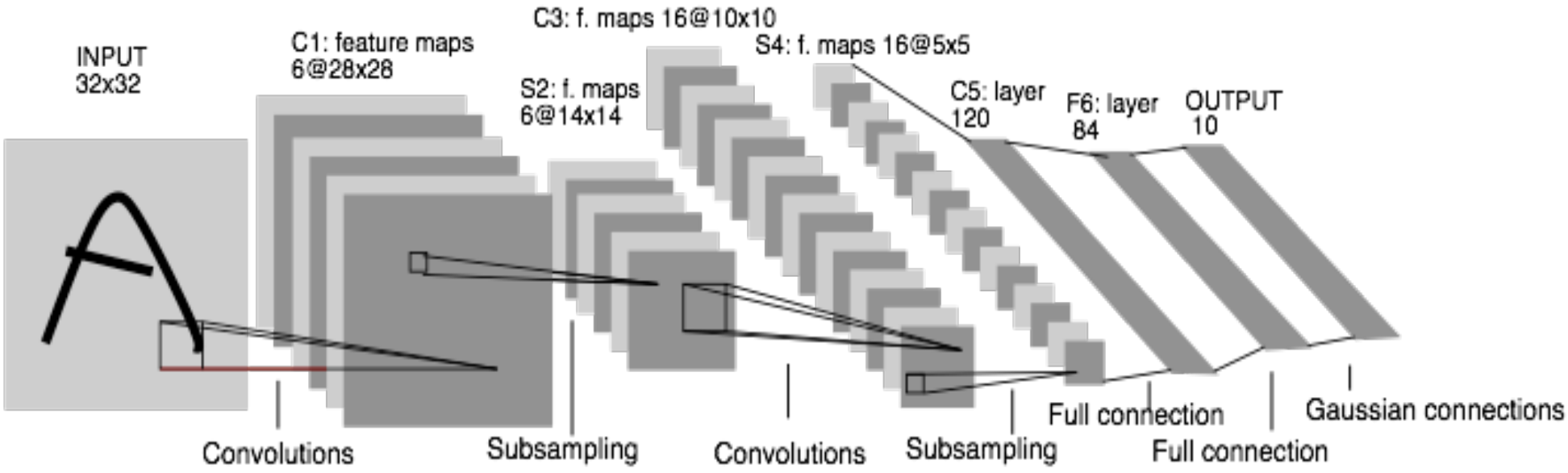


Retinatopic Map from Retina to V1

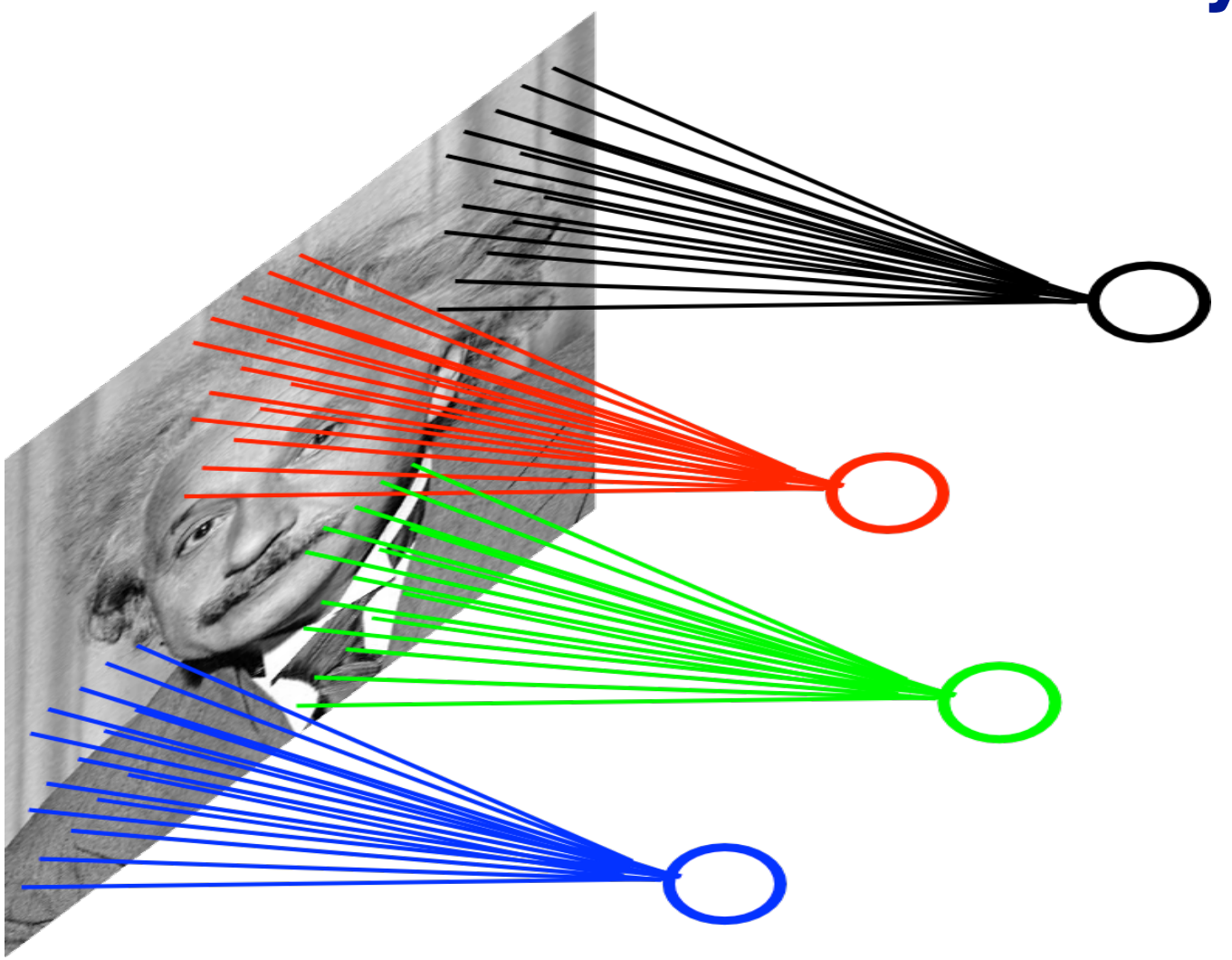




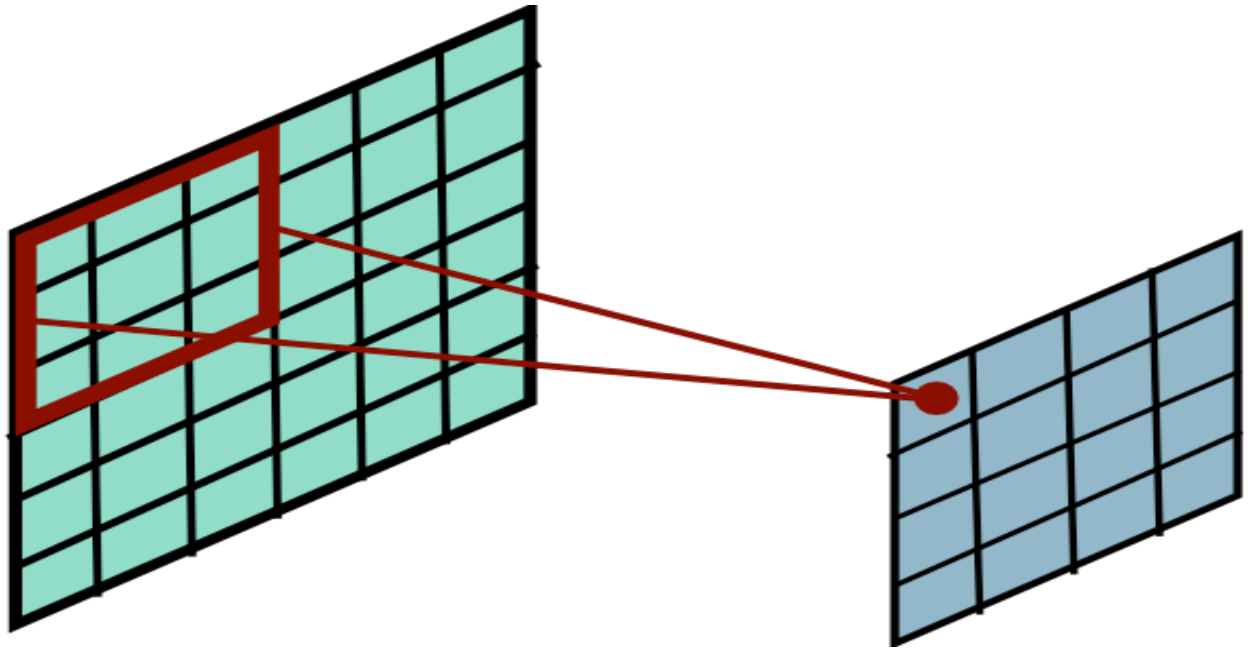
Convolutional neural nets (CNNs), LeCun, 1989.
LeNet 5 classifier for handwritten digits.



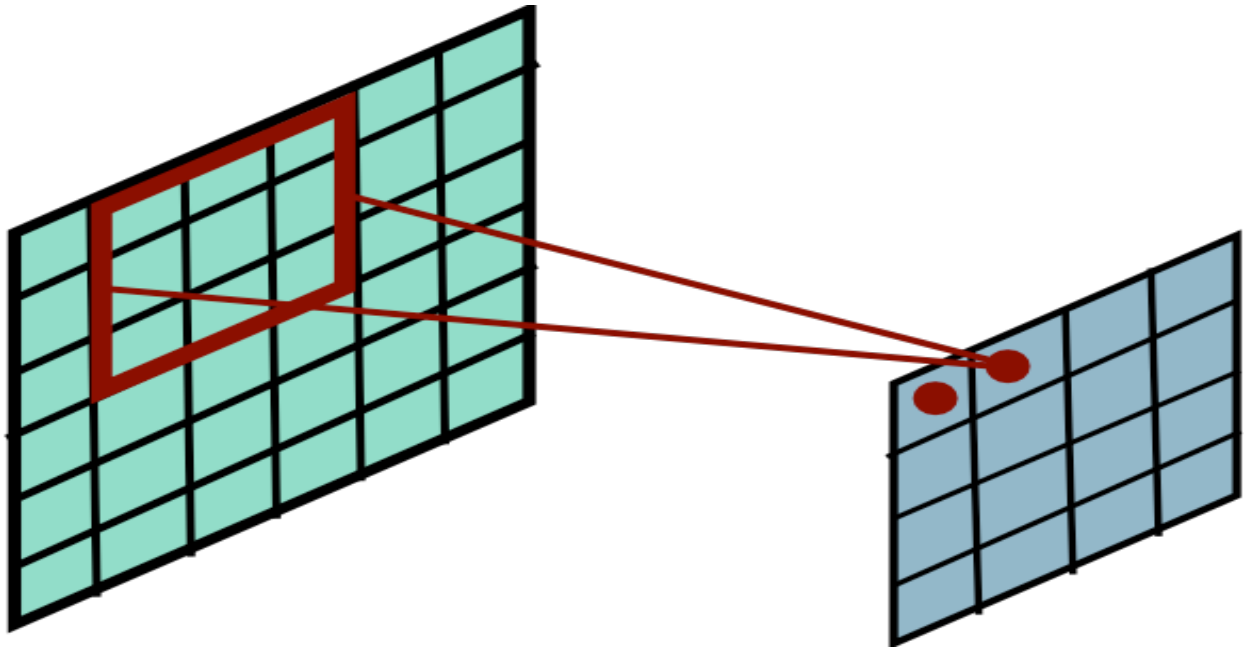
Convolutional Layer



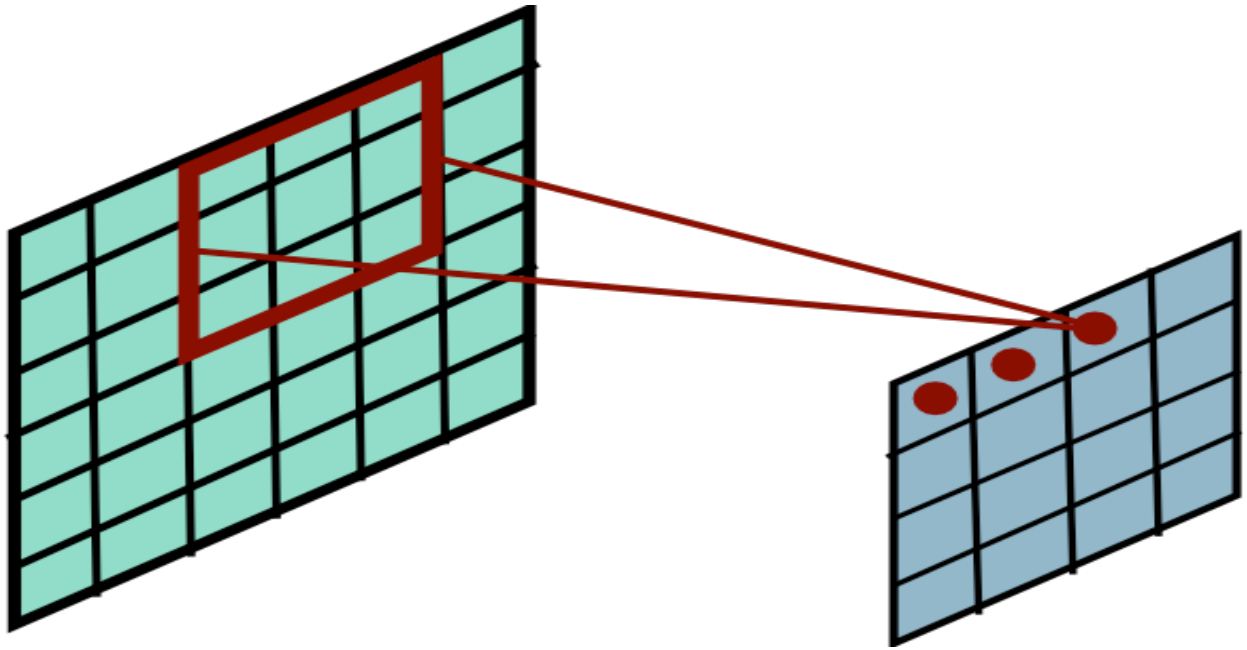
Convolutional Layer



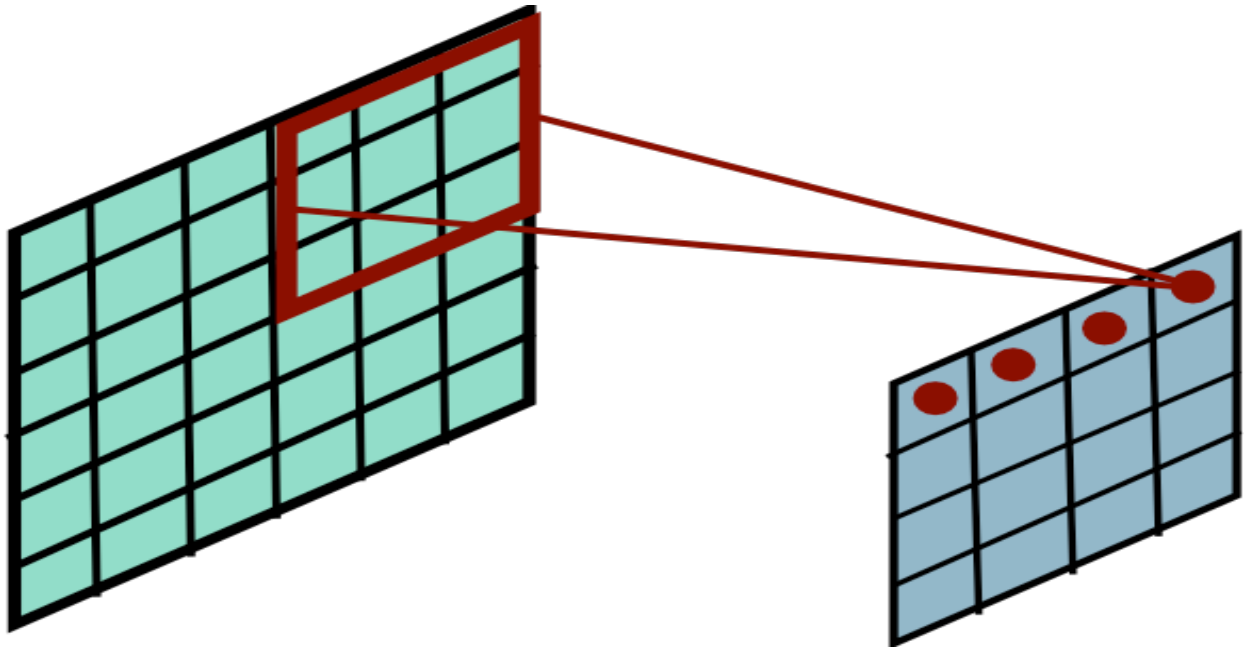
Convolutional Layer



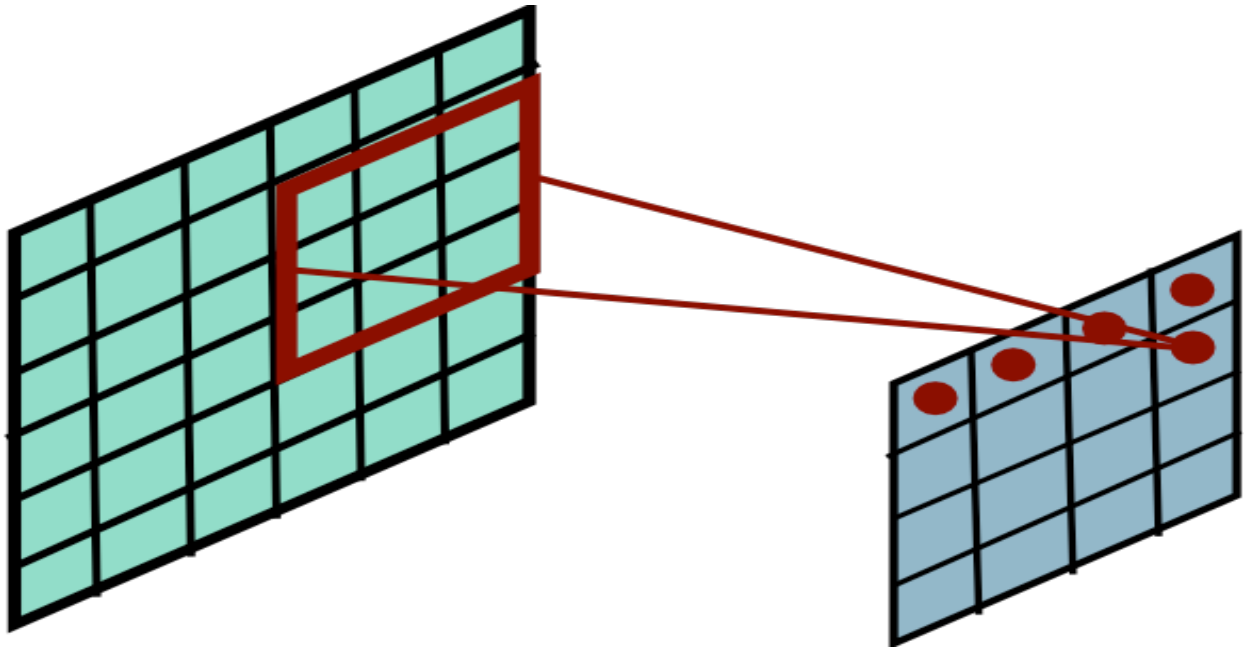
Convolutional Layer



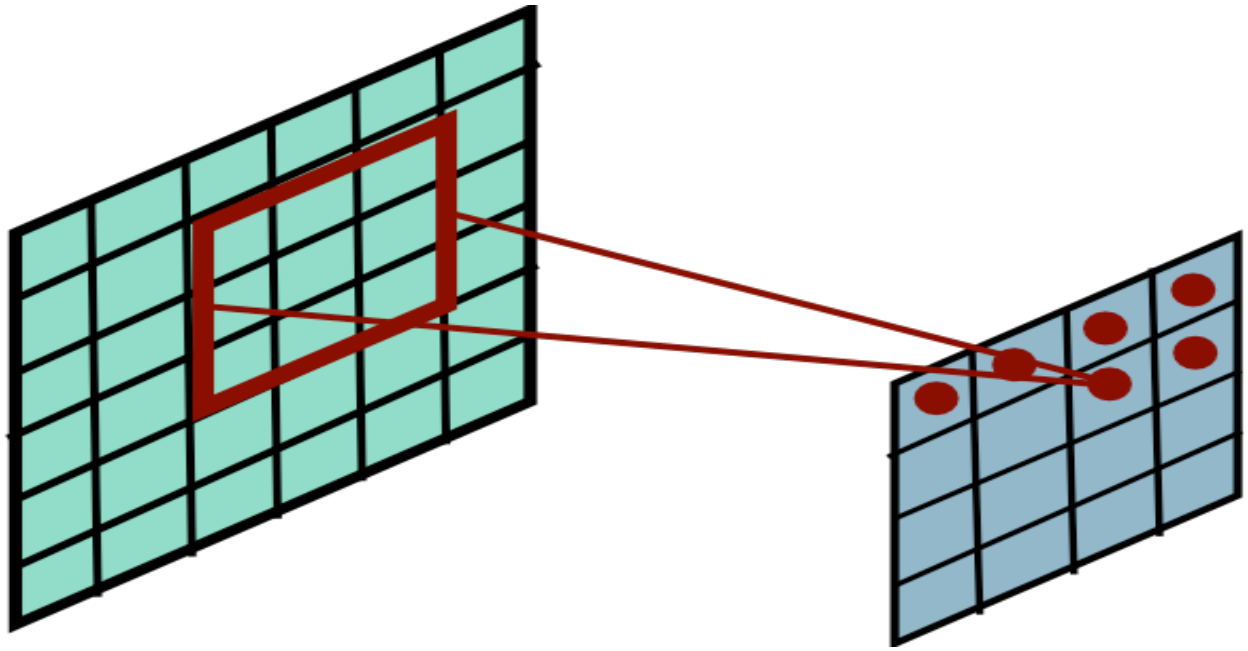
Convolutional Layer



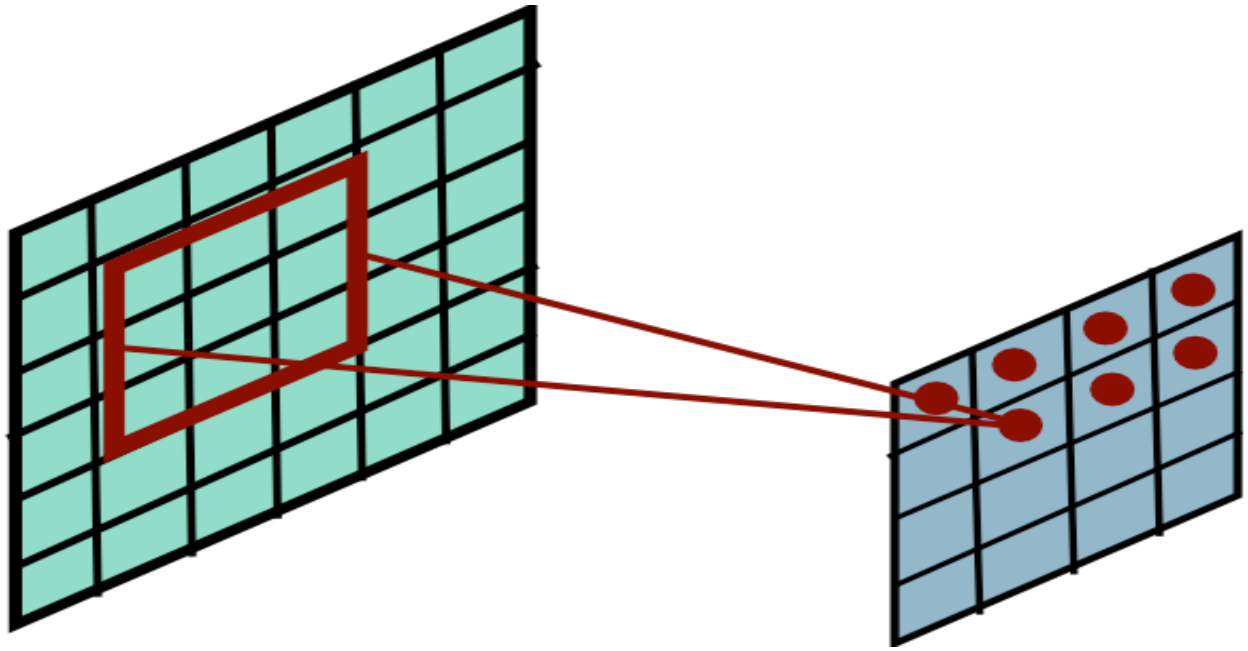
Convolutional Layer



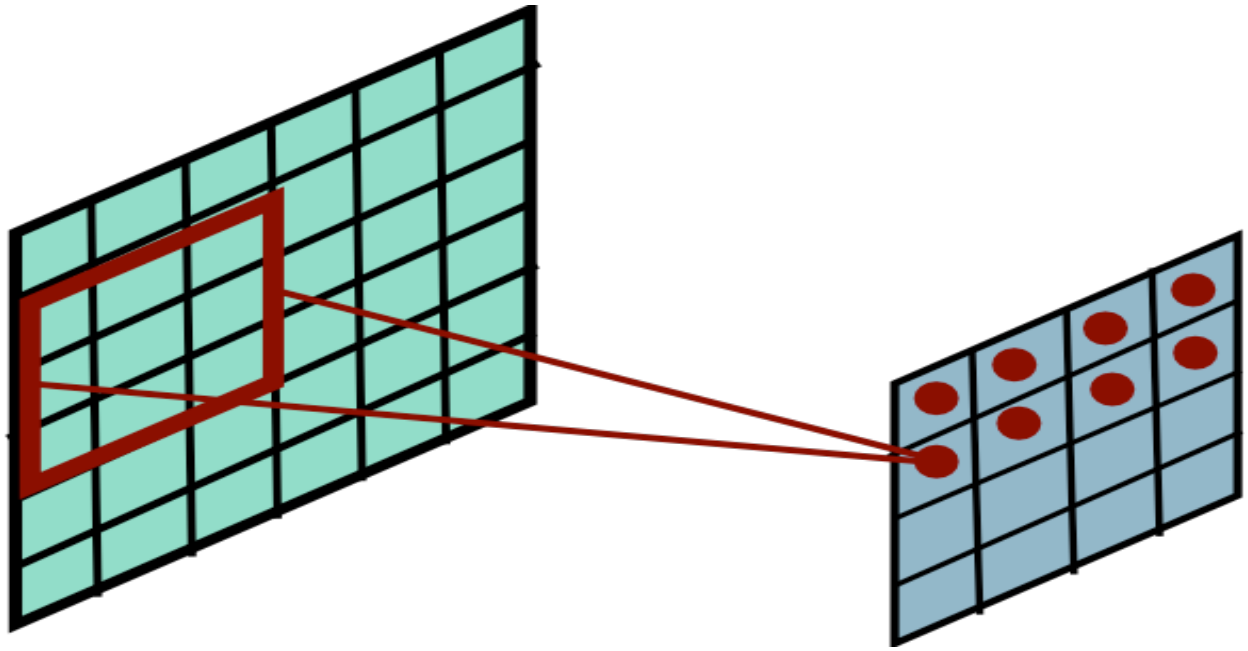
Convolutional Layer



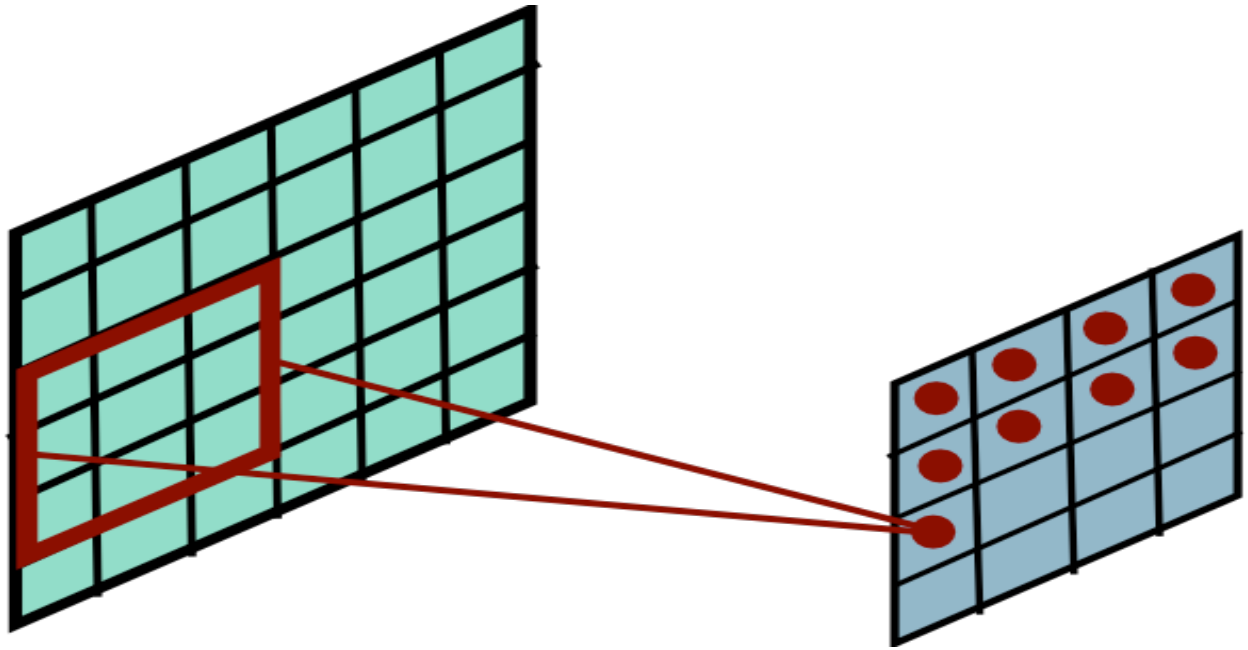
Convolutional Layer



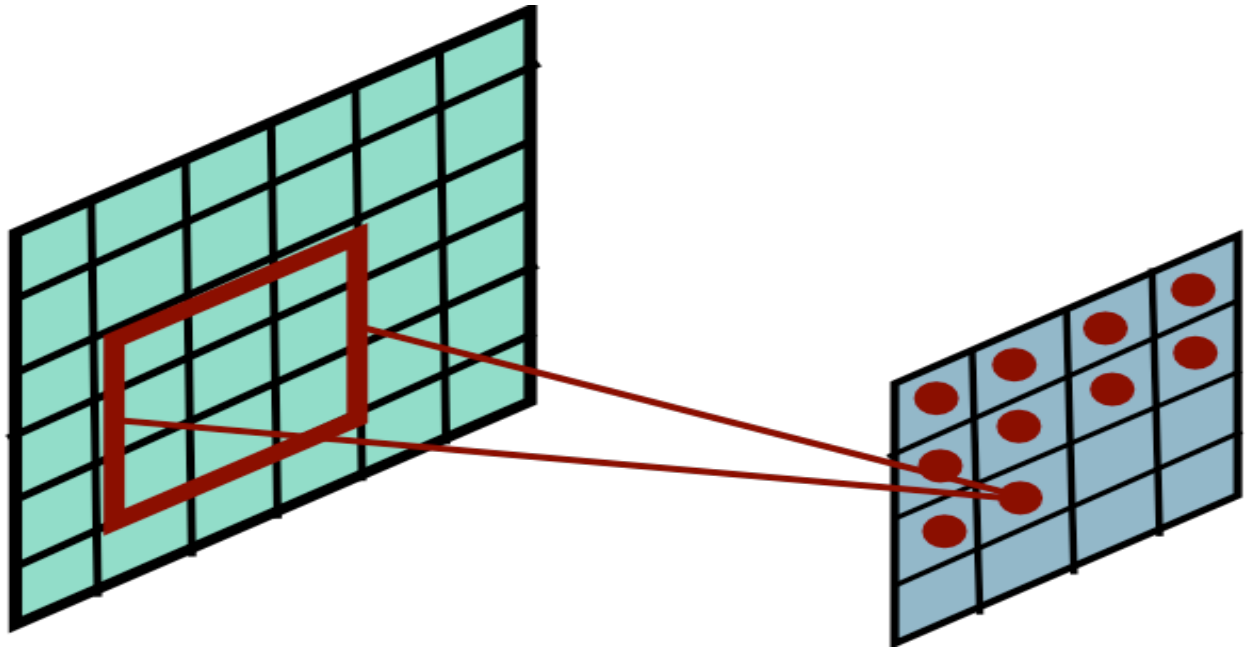
Convolutional Layer



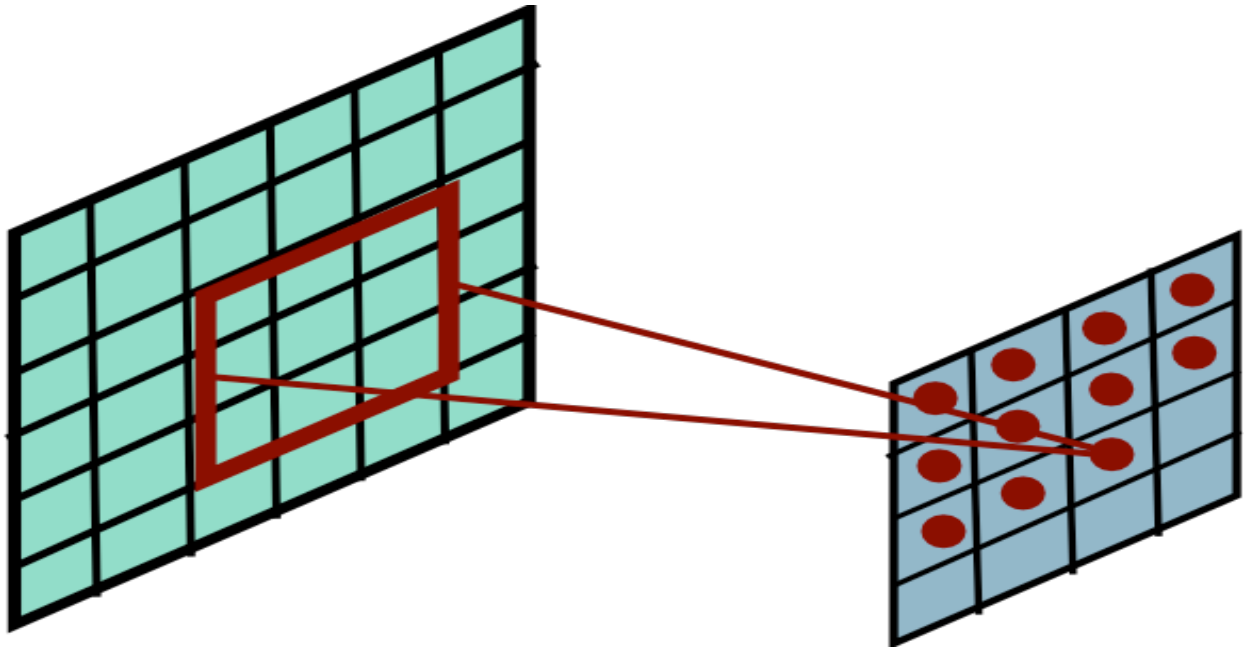
Convolutional Layer



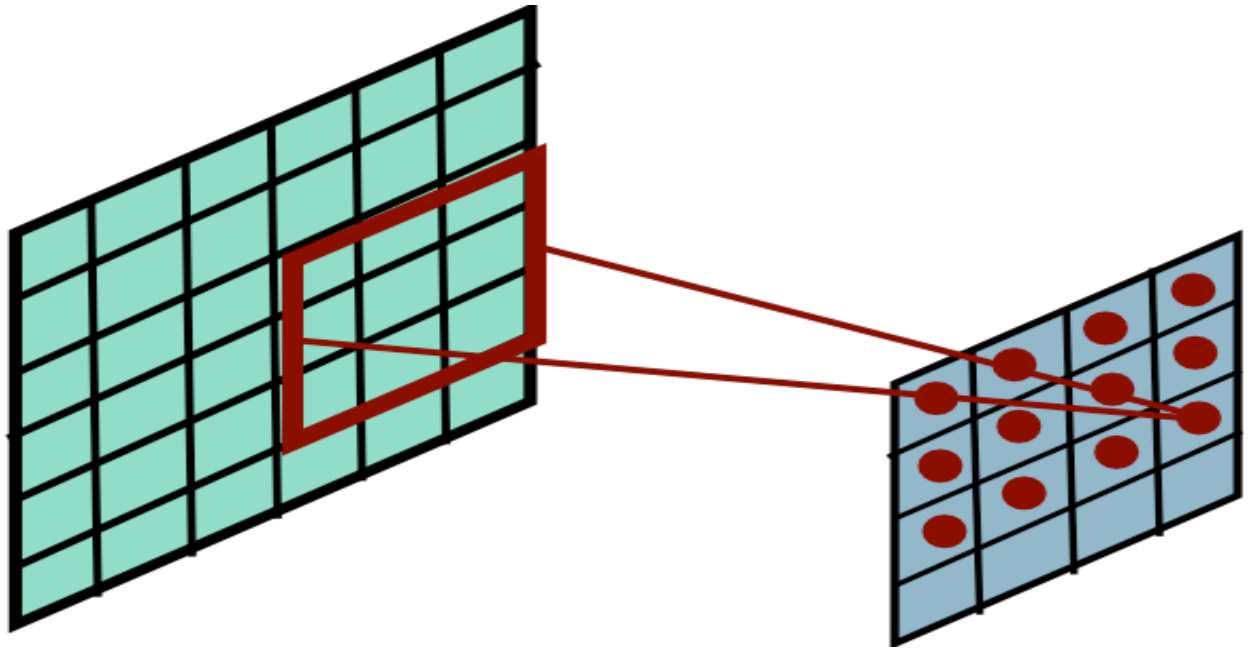
Convolutional Layer



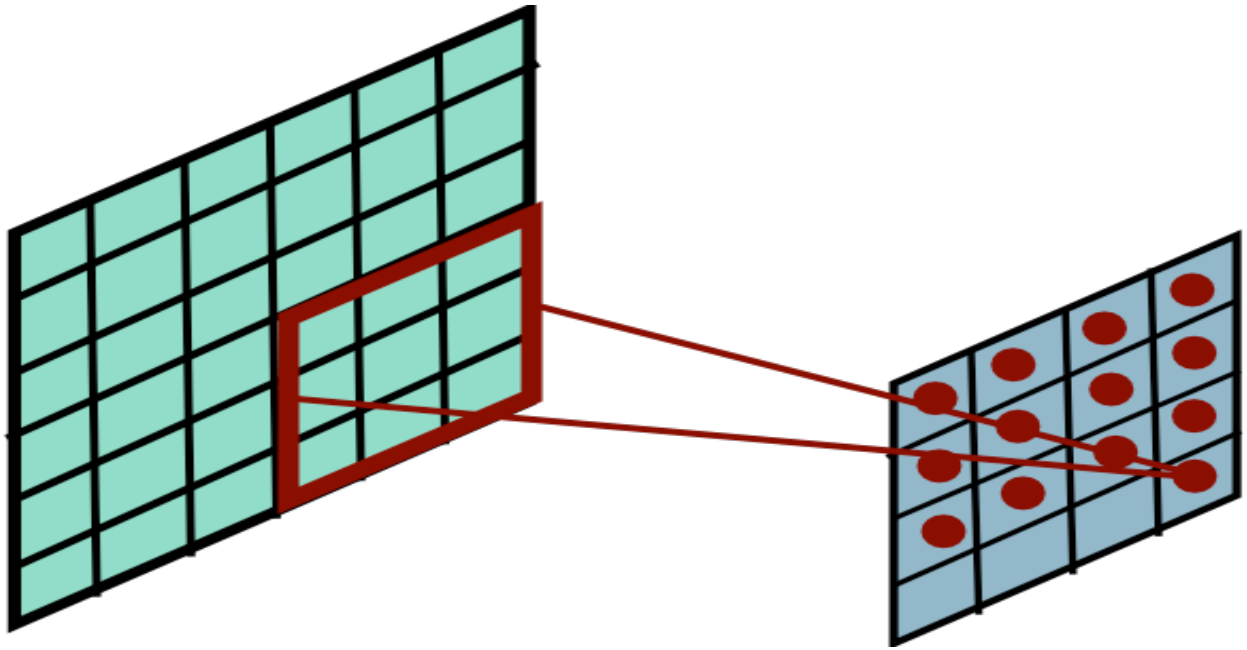
Convolutional Layer



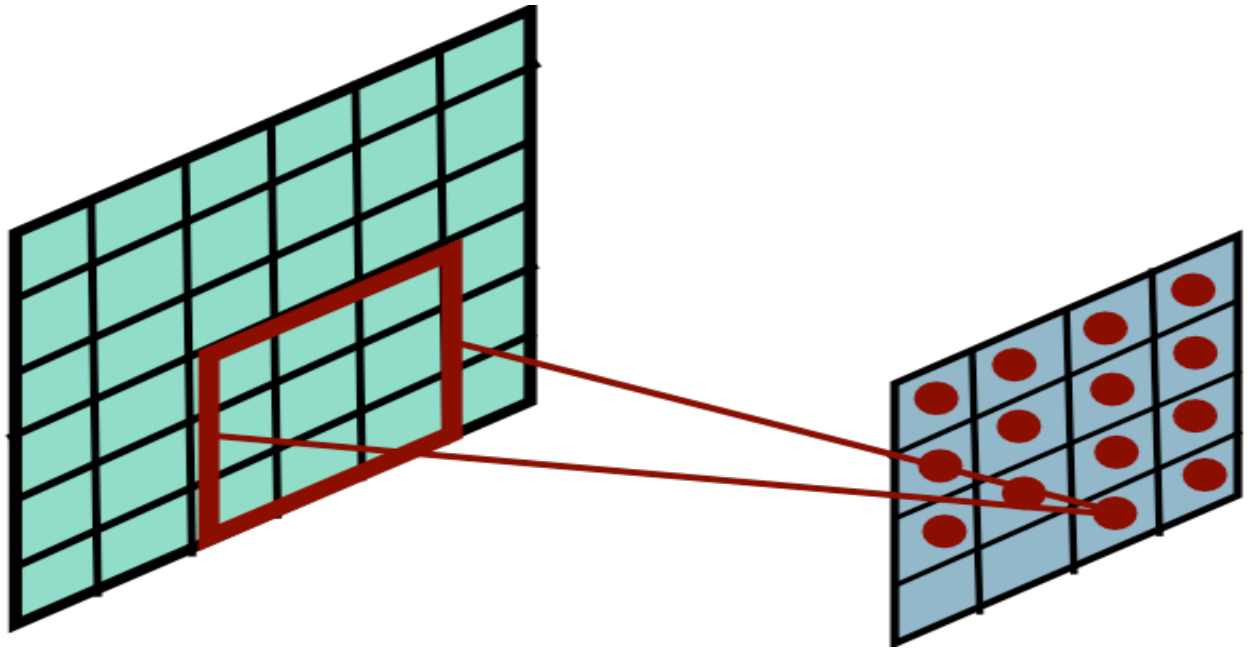
Convolutional Layer



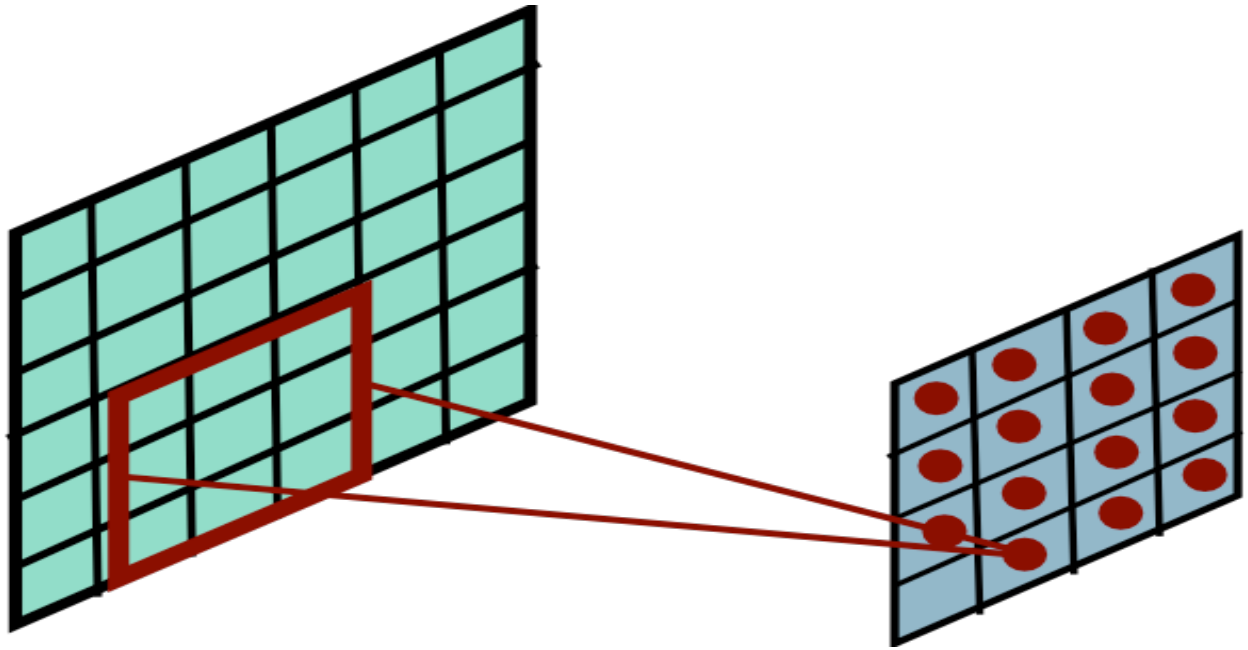
Convolutional Layer



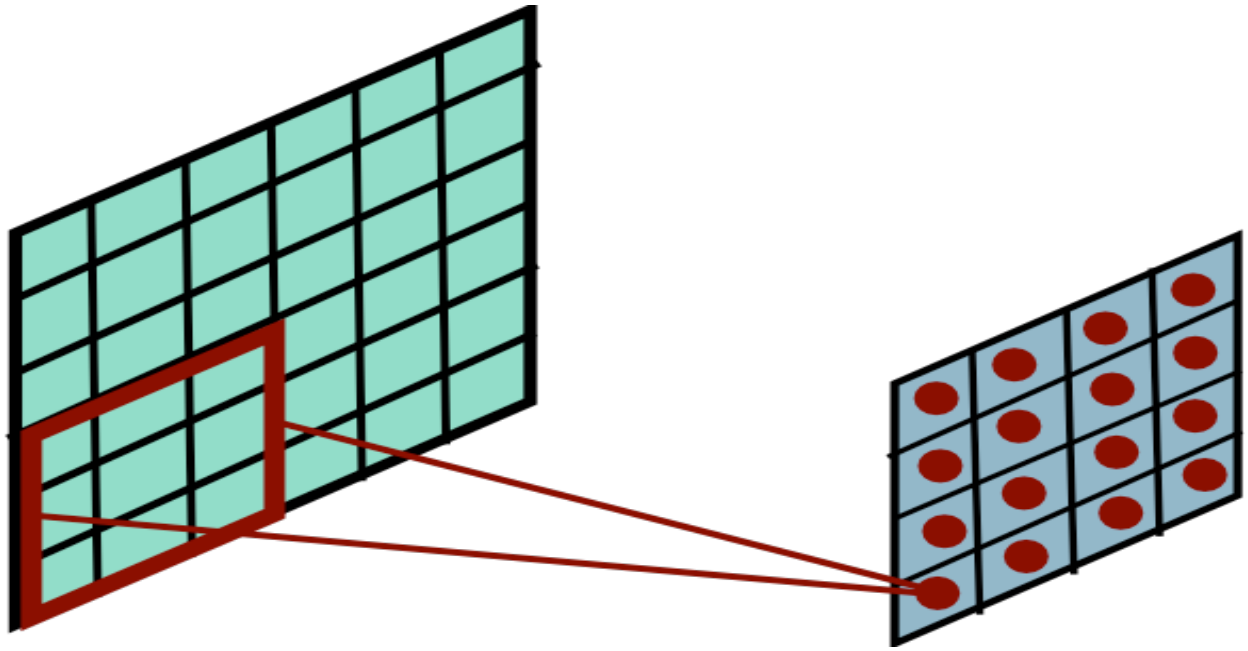
Convolutional Layer



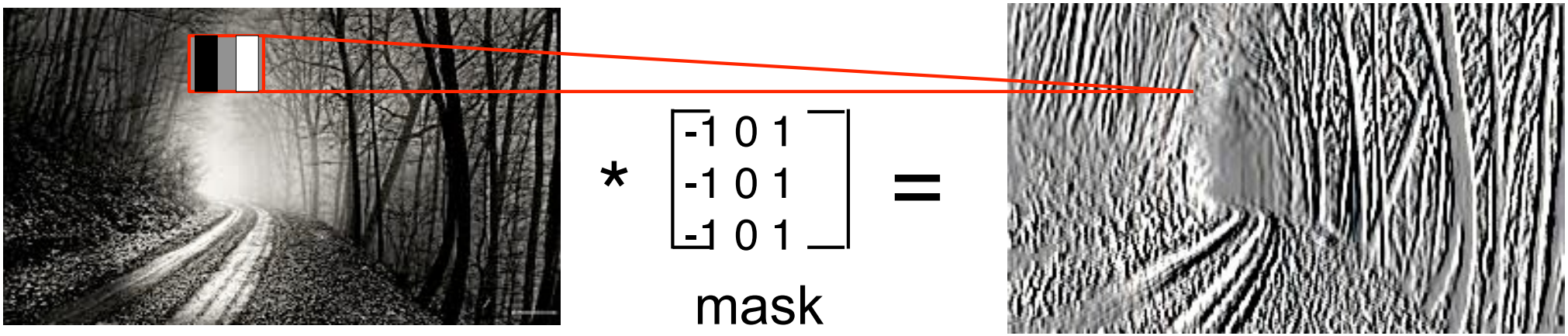
Convolutional Layer



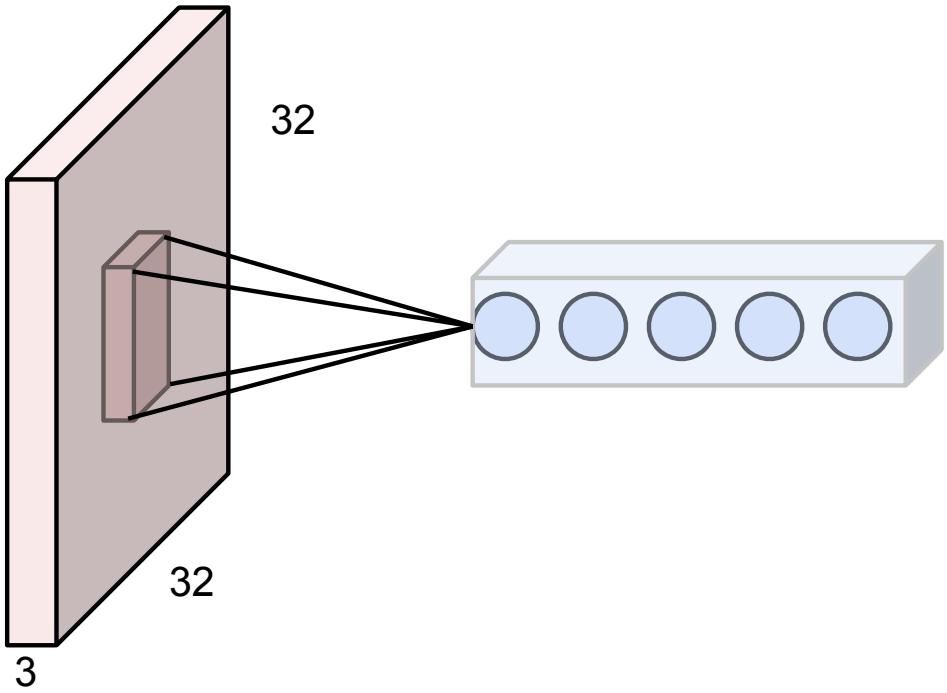
Convolutional Layer



Convolutional of Two Signals



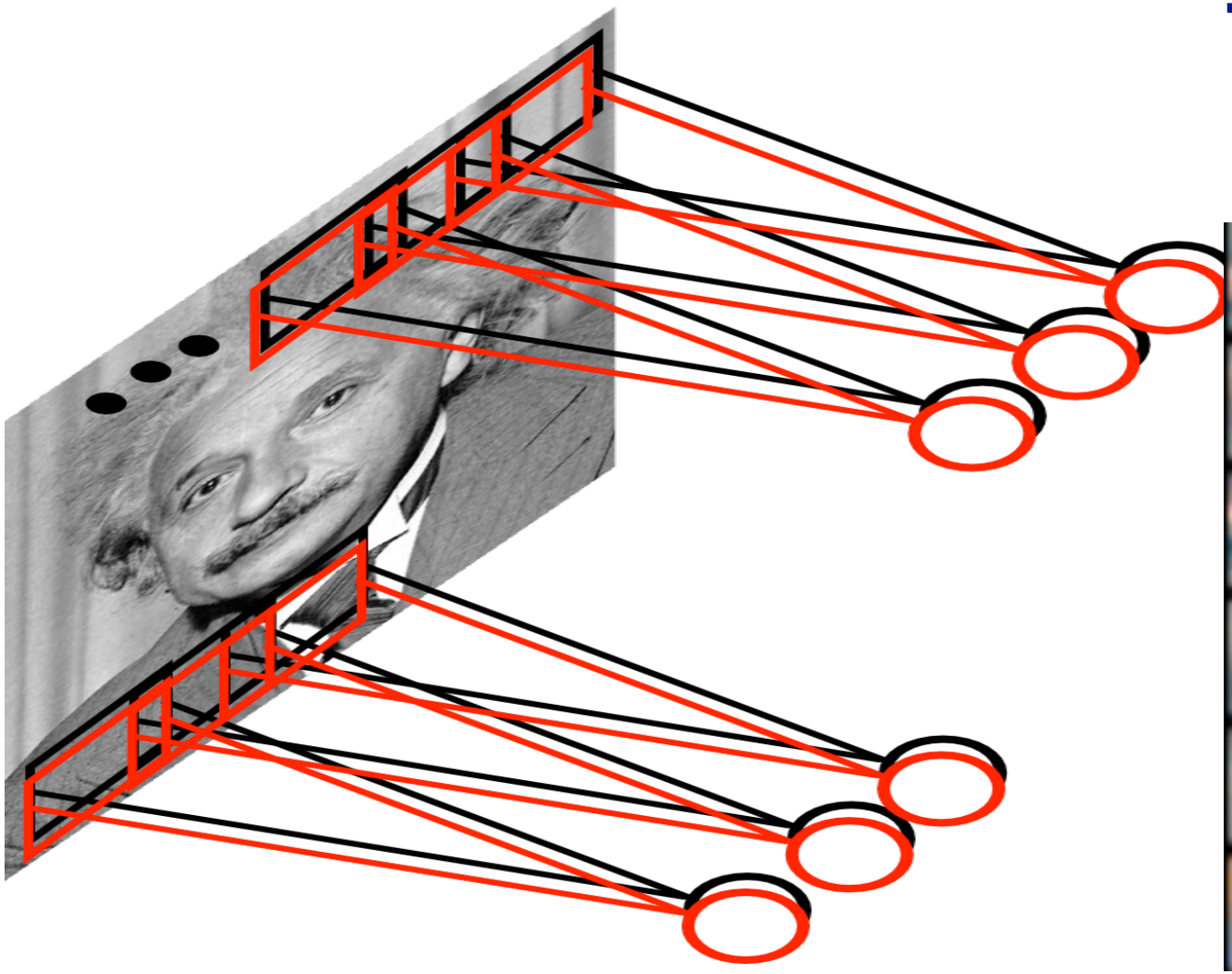
(vector, NOT a matrix!)



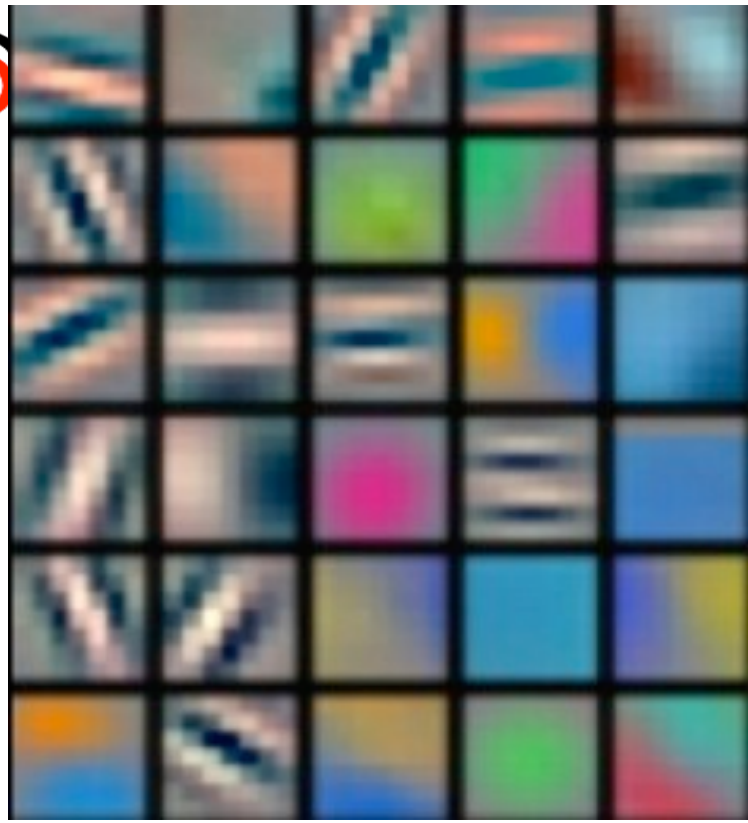
5 hidden units all looking at the same patch; 5 different masks.

Apply the same 5 masks to each patch = 5 units per patch.

Convolutional Layer

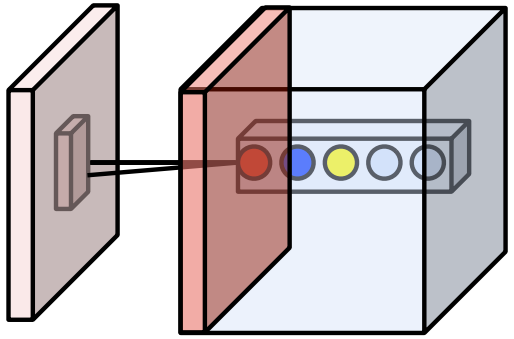


learned masks

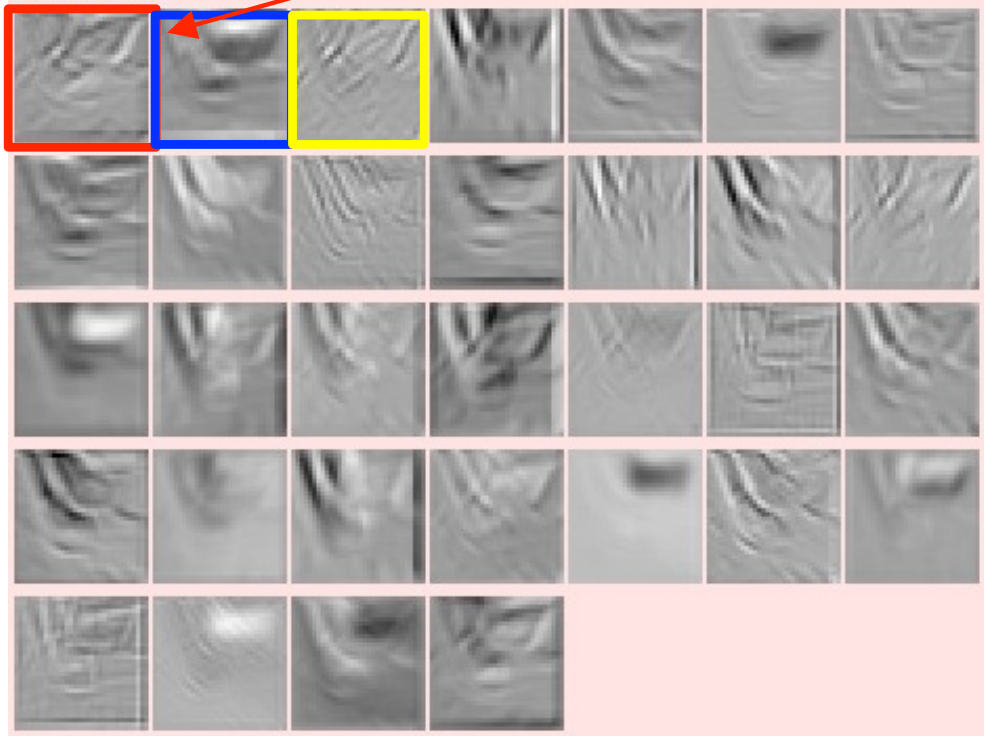


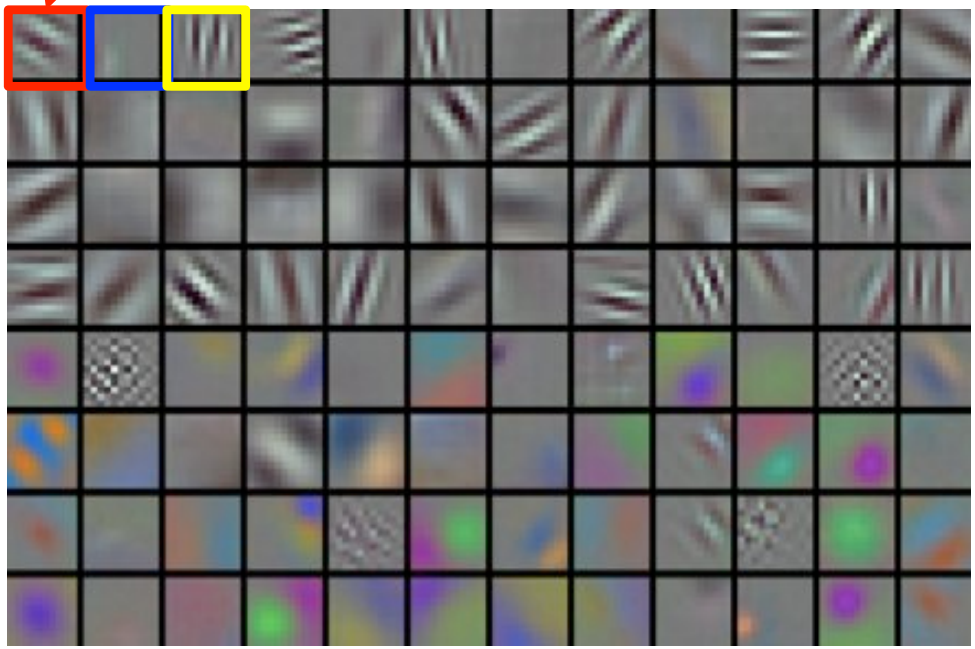
Activations:

convolving the input with the first mask
gives the first output slice

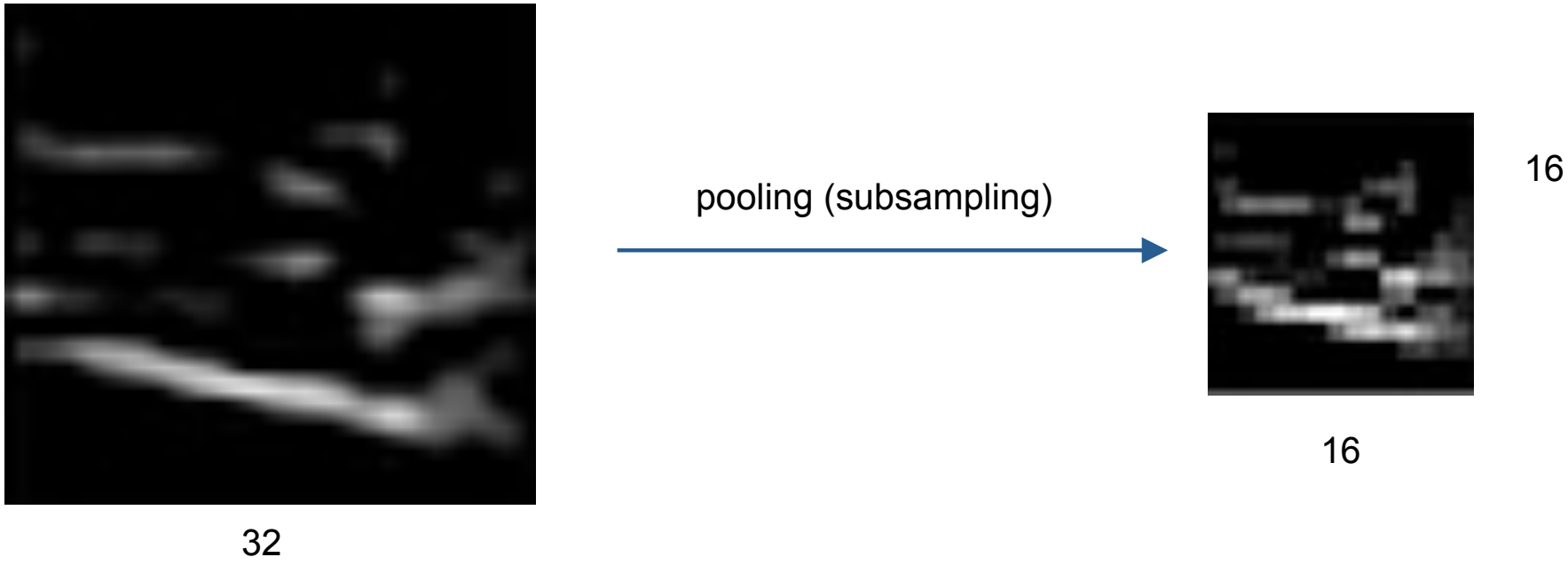


Activations:

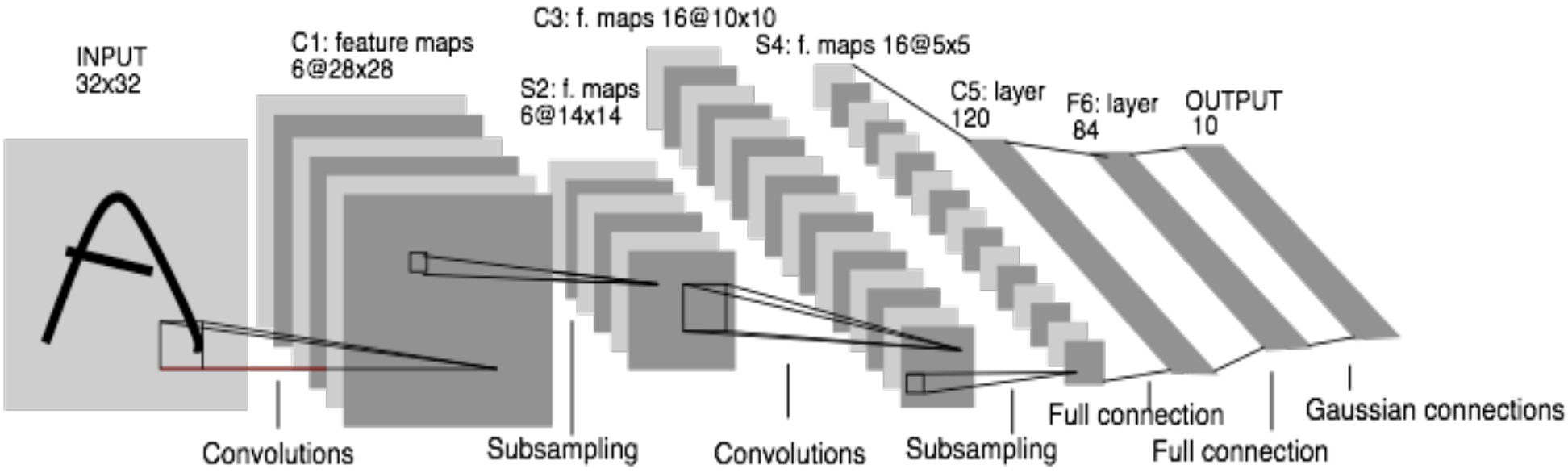




Convolution layers are often followed by pooling layers that shrink the image. Each pooled unit is the maximum of a 4-unit block. Hardwired, no weights to train.



Convolutional neural nets (CNNs), LeCun, 1989.
LeNet 5 classifier for handwritten digits.



IMAGENET Large Scale Visual Recognition Challenge

The Image Classification Challenge:
1,000 object classes
1,431,167 images

Output:
Scale
T-shirt
Steel drum
Drumstick
Mud turtle

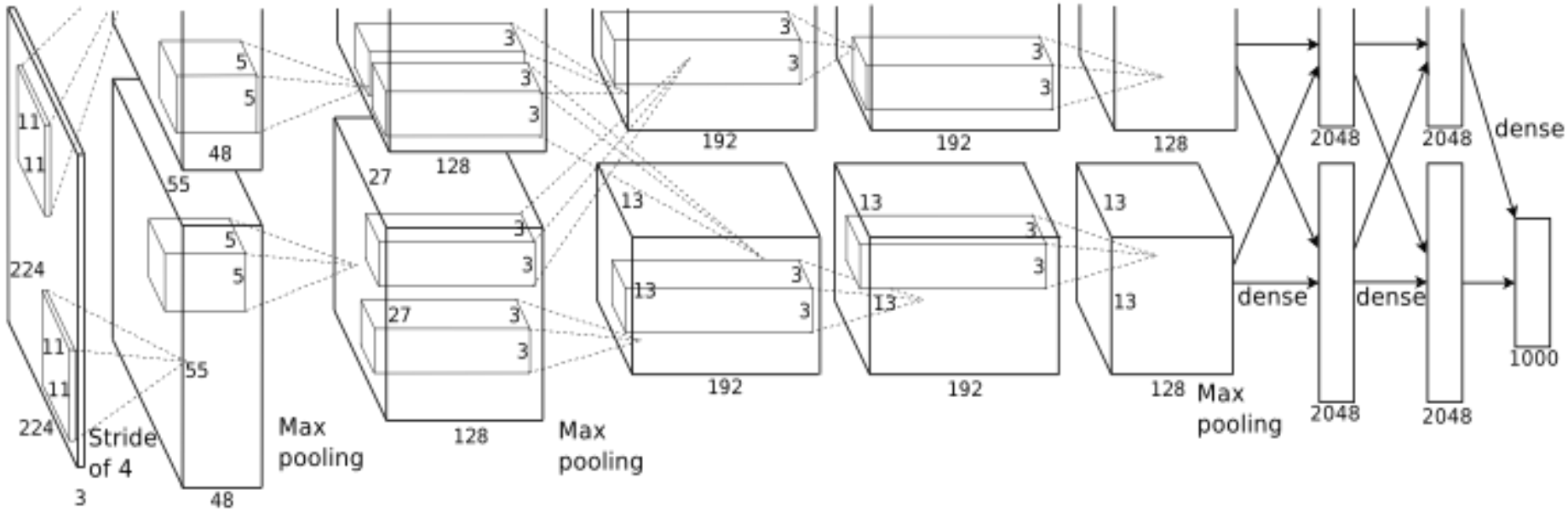
✔

Output:
Scale
T-shirt
Giant panda
Drumstick
Mud turtle

✗

Russakovsky et al. arXiv, 2014

Convolutional neural nets, Krizevsky et al., 2012



AlexNet: A competition-winning classifier for recognizing images in objects. The ImageNet Large Scale Visual Recognition Challenge, 2012.

+ millions of images
+ ReLUs
+ GPUs
+ dropout