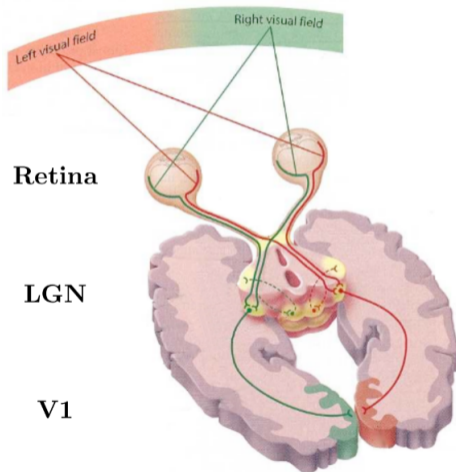# Vision Part 3

Informatics 1 Cognitive Science
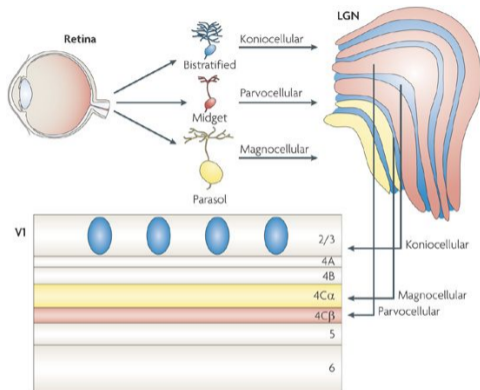
Matthias Hennig

School of Informatics
University of Edinburgh
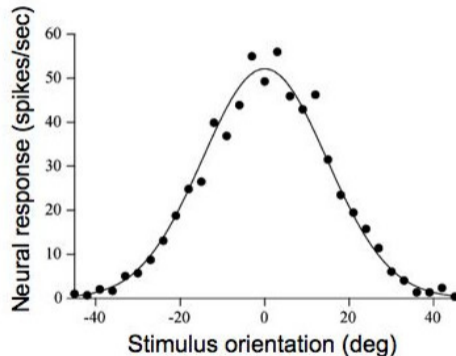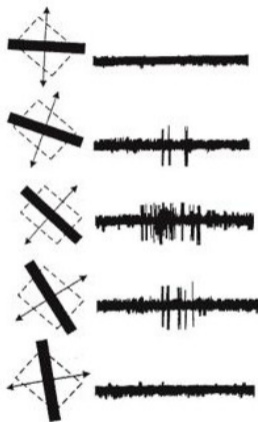mhennig@inf.ed.ac.uk

Early Visual Pathway

From the Retina to the Primary Visual Cortex (V1)


Nature Reviews | Neuroscience

Output from the retina forms several different anatomical pathways, which continue as the ventral and dorsal cortical pathways (what and where pathways).

# V1 Neurons are selective to Stimulus Orientation

Responses of a neuron to a bar at different orientations (Hubel & Wiesel, 1968). A *tuning curve* can be created by plotting activity as function of angle.
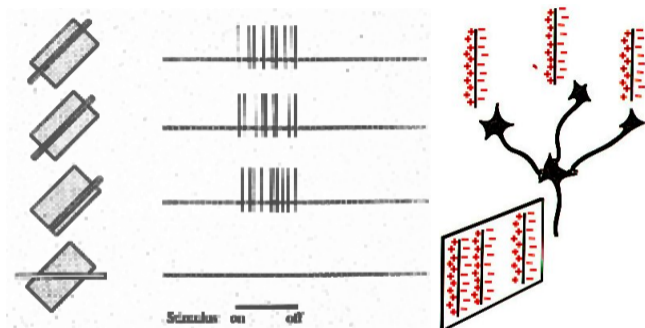
Examples of V1 Simple Cells in a Macaque Monkey
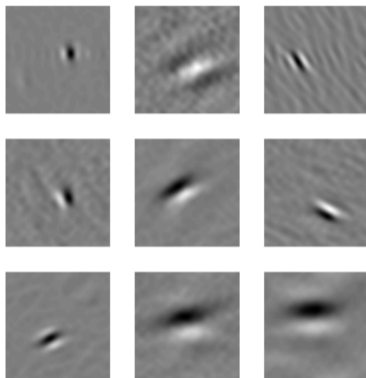
This shows that simple cells cover different different spatial scales and symmetries.
(from Dario Ringach, UCLA)

Why different Channels?
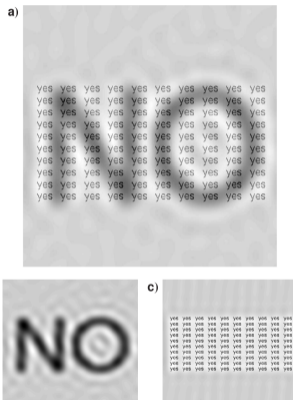
Effect of RF size. **a** original image, **b** image filtered with large receptive fields, **c** image filtered with small receptive fields. The sum of b) and c) equals a).

V1 Complex cells

Like simple cells, but here the response is *position-invariant*. This involves a non-linear computation (pooling of thresholded inputs). Finding invariances is essential to describe objects in images.

Organisation of Orientation Selectivity in V1
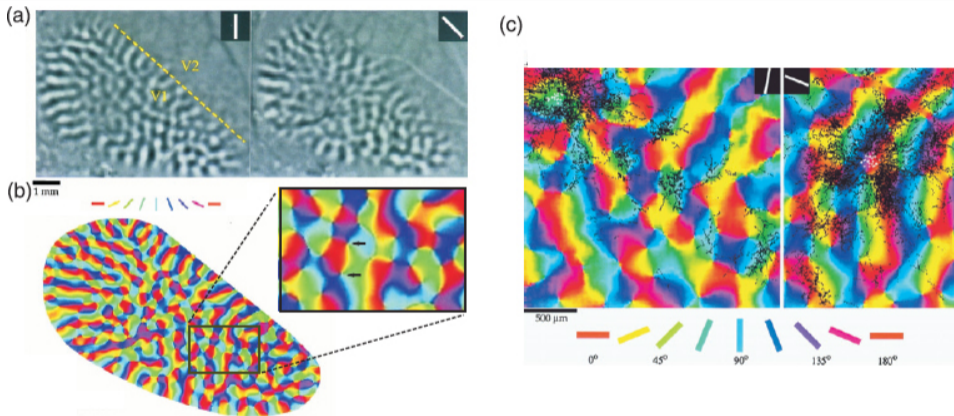
Nearby orientations are represented by neighbouring cells, and superimposed on the retinotopic map. This is called a pinwheel arrangement, and is found in all carnivores, but not in some rodents.

A simple Simple Cell Model
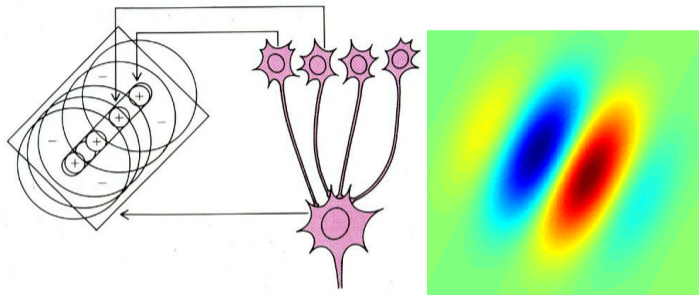
Respond to bars/edges at a preferred orientation and preferred location.
Modelled by a Gabor function:

$$g(\boldsymbol{r}) = A e^{-\frac{\boldsymbol{r}^2}{2\sigma_c^2}} \cos(\boldsymbol{r}\omega - \theta)$$

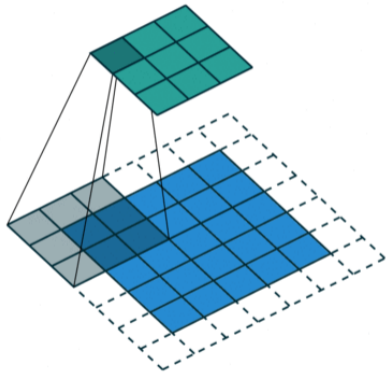## How to predict responses: Convolution

Definition in 1 dimension:

For functions f (image) and g (the receptive field) defined on a set of integers, and g is defined for $-M \ldots M$:
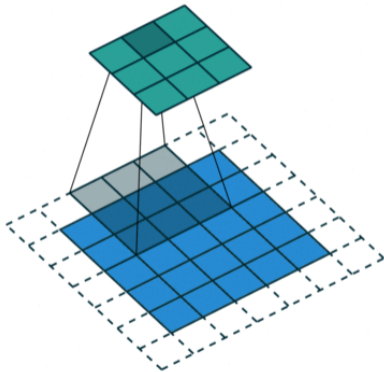
$$(f * g)[n] = \sum_{m=-M}^{M} f[n-m]g[m]$$

Each point $f[n]$ is re-computed by multiplying f with g, where g is centred in n.

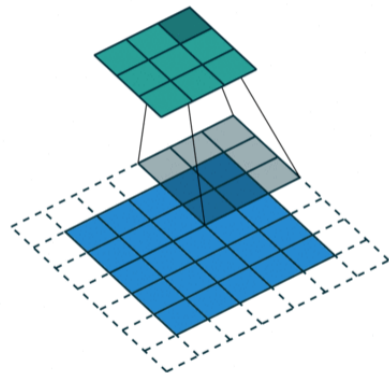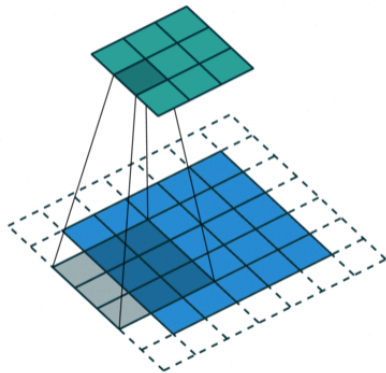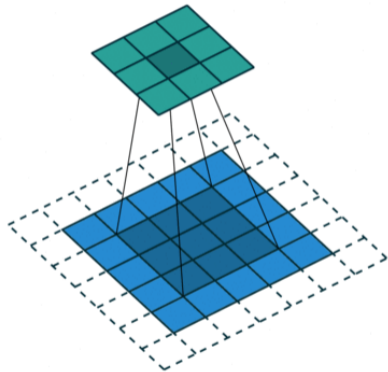Examples: `https://github.com/vdumoulin/conv_arithmetic`

2D Convolution Example

2D Convolution Example

2D Convolution Example
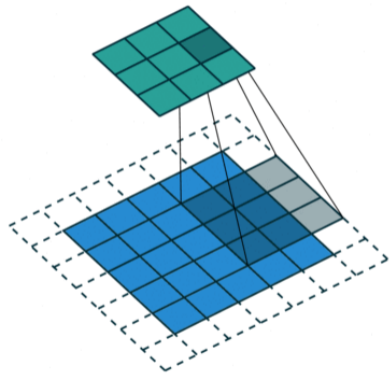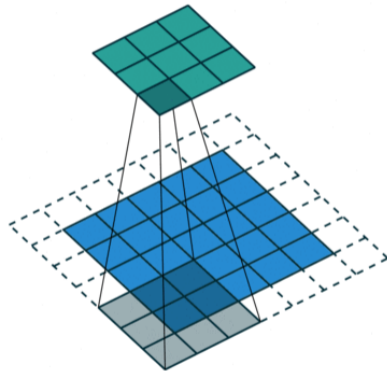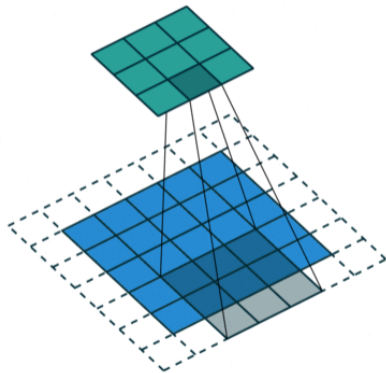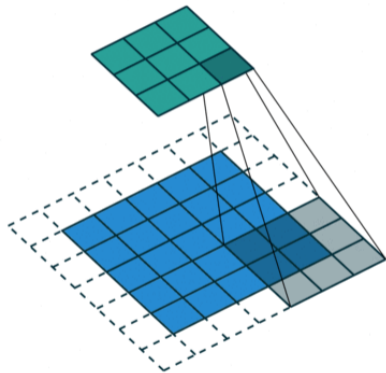
2D Convolution Example

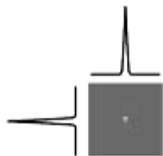# 2D Convolution Example

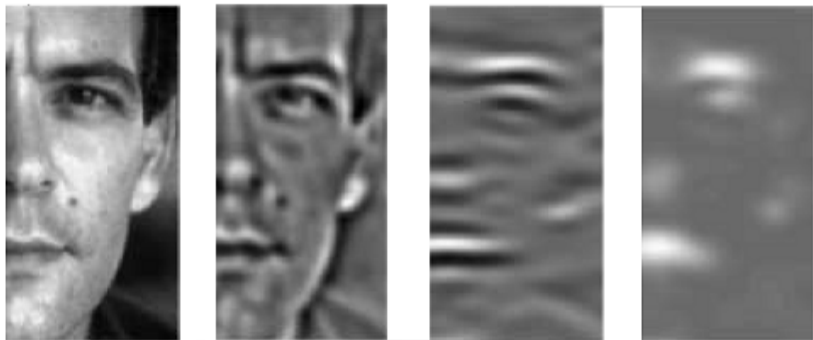# 2D Convolution Example

2D Convolution Example

2D Convolution Example

2D Convolution Example

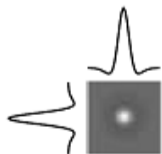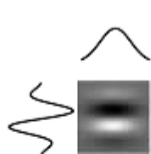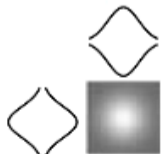# An image along the early visual pathway

photoreceptor   LGN cell   V1 simple cell   V1 complex cell