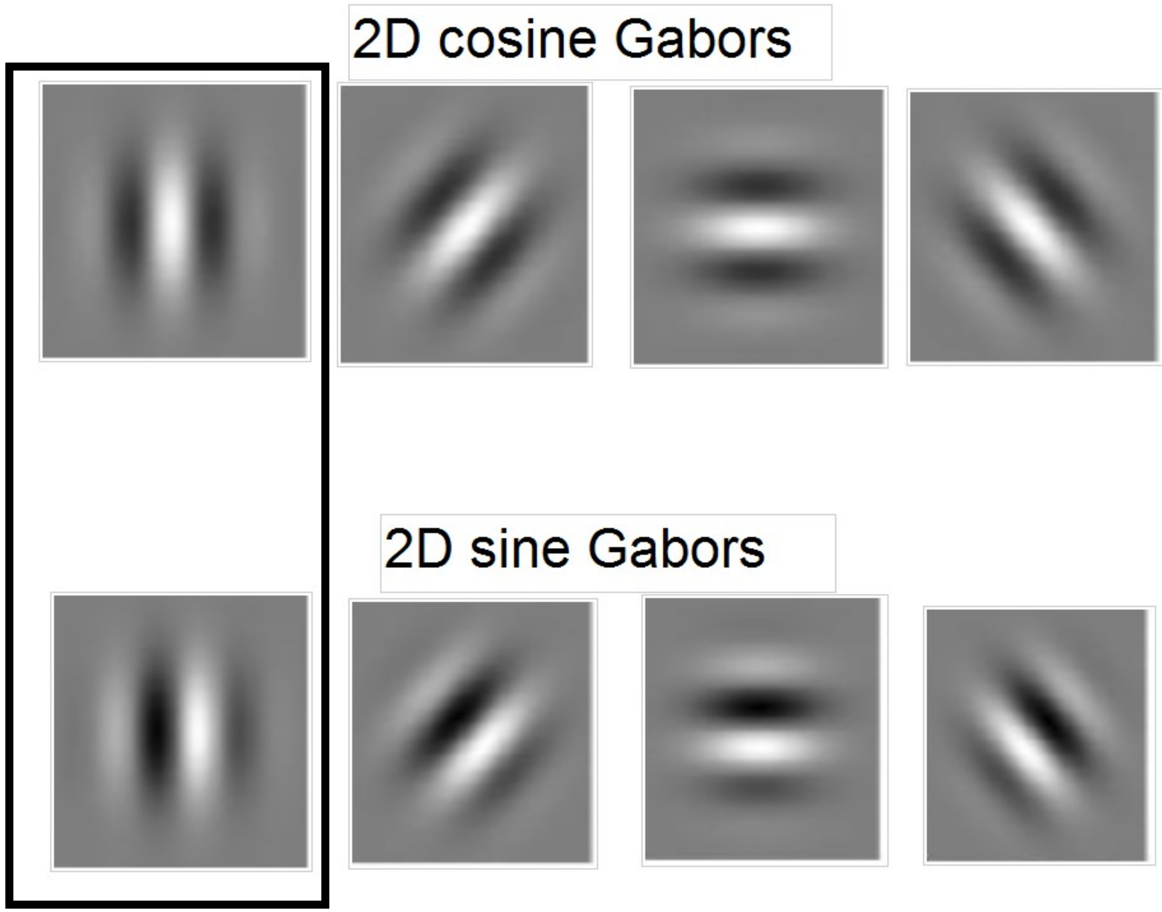
COMP 546

Lecture 7

V1 binocular cells & motion cells

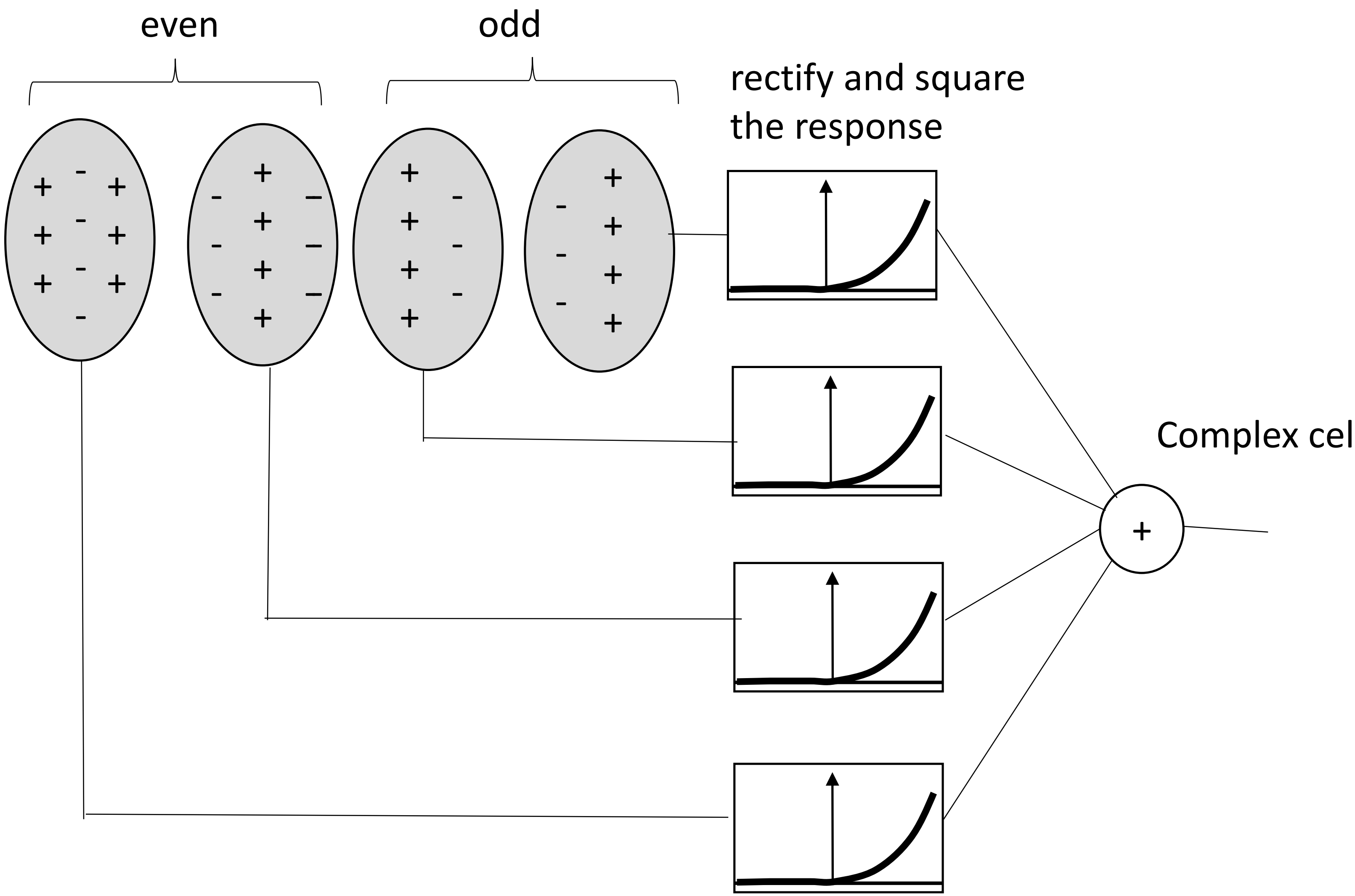
Thurs. Jan. 31, 2019

Recall simple cells in V1



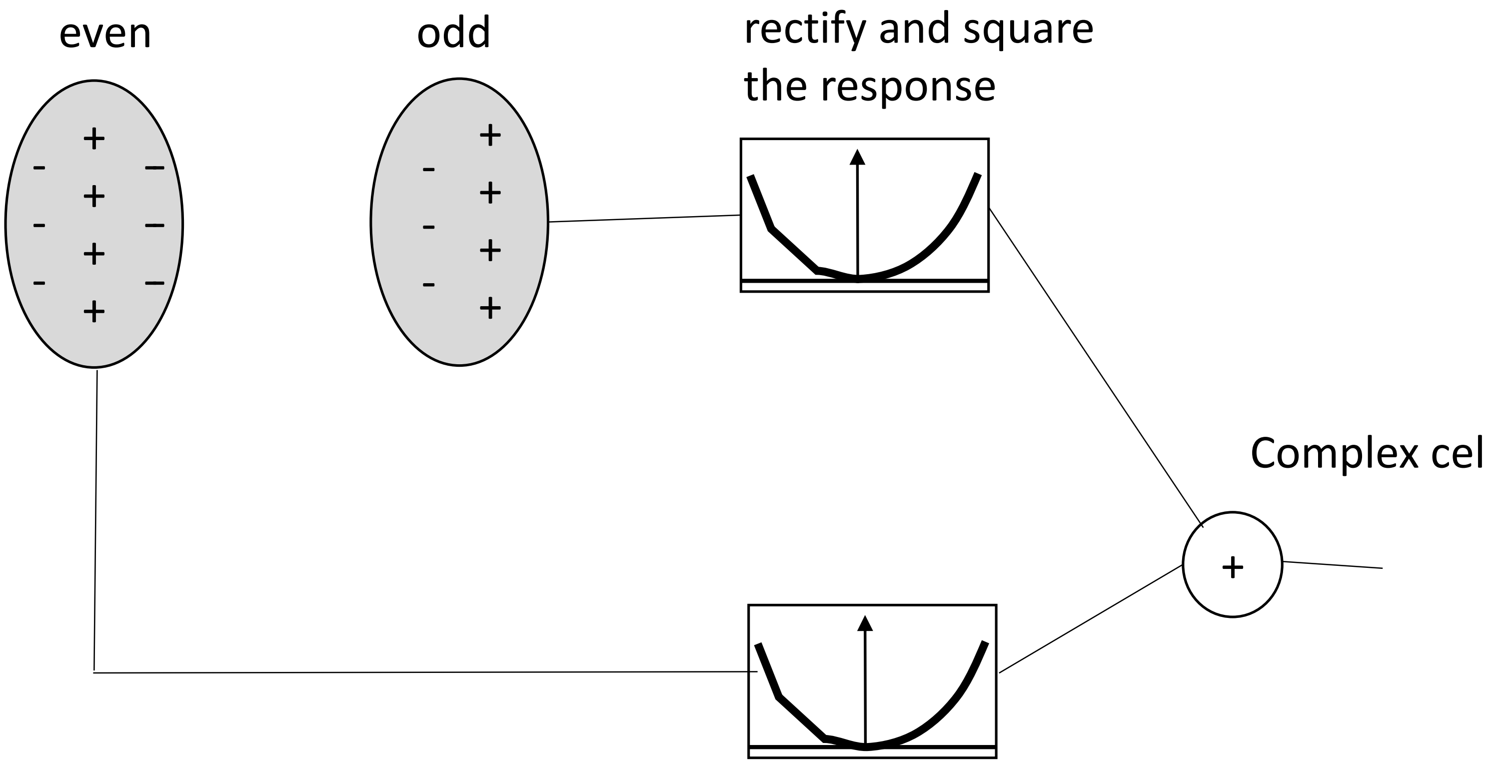
To estimate disparity d between left and right eye images, we will consider vertically oriented cells only.

Recall complex cells in V1 (model 2)



These cells have *the same receptive field locations.*

ASIDE: Mathematically equivalent model



These cells have *the same receptive field locations.*

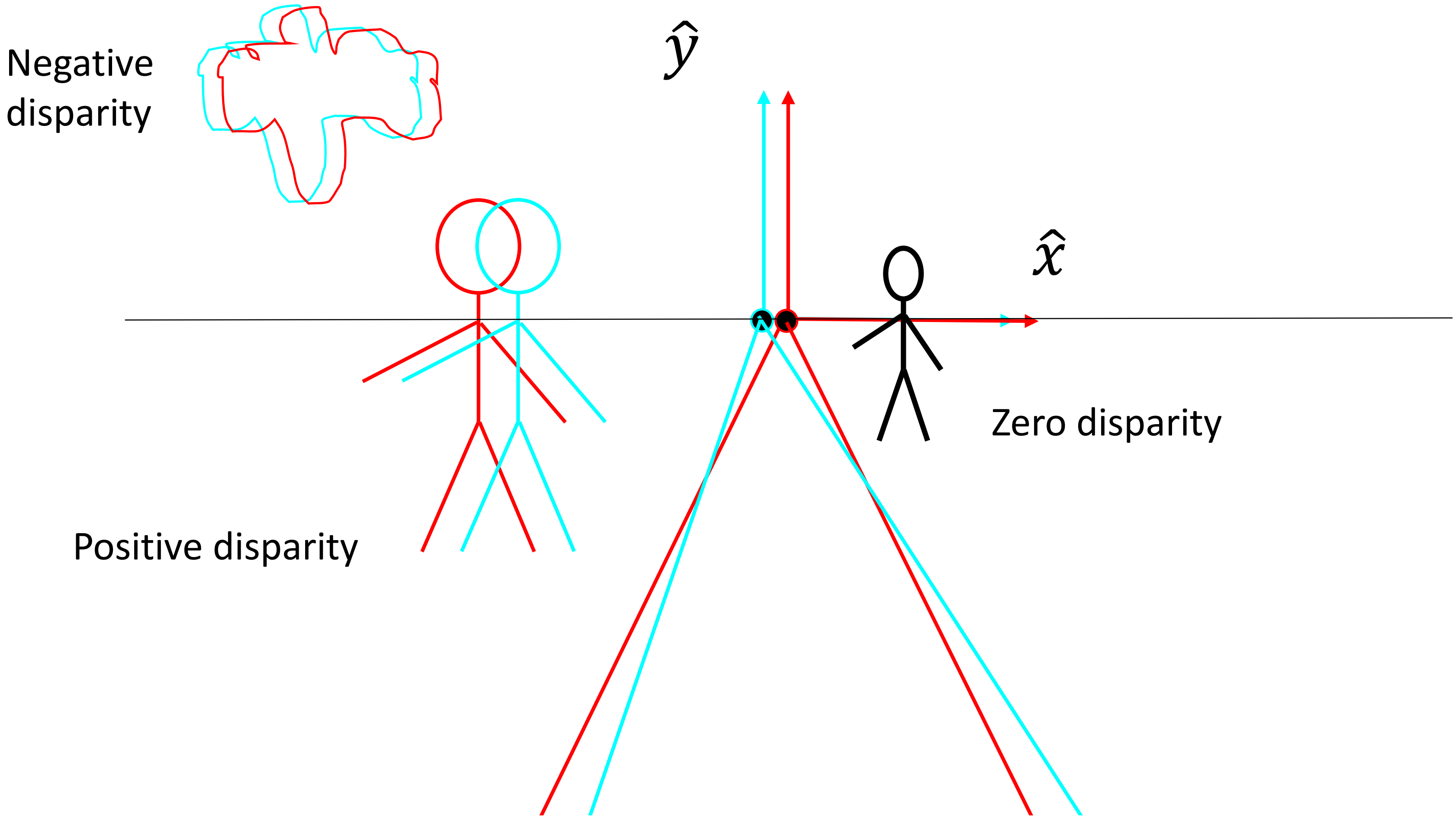
V1 also has binocular cells.

Such cells are sensitive to images in either eye.

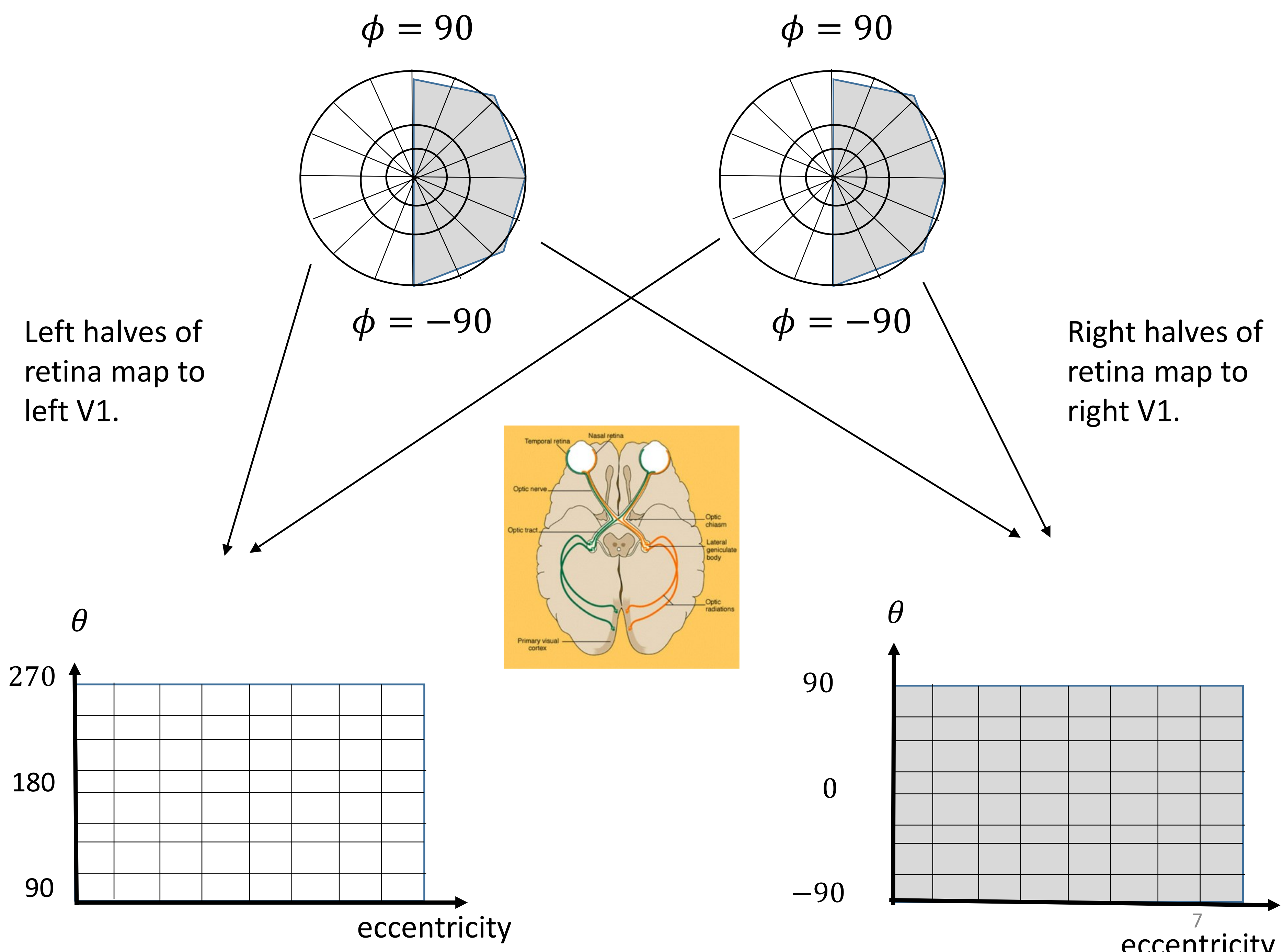
They are “disparity tuned”.

Let’s see the basic idea of how that works.

Superimposed left and right eye images



How to define disparity tuned cells ?



$\phi = 90$
$\phi = -90$
$\phi = 90$
$\phi = -90$
Left halves of retina map to left V1.
Right halves of retina map to right V1.
Temporal retina
Nasal retina
Optic nerve
Optic tract
Optic chiasm
Lateral geniculate body
Optic radiations
Primary visual cortex
θ
270
180
90
eccentricity
θ
90
0
-90
eccentricity

How to estimate binocular disparity at each point ?

Idea: computer vision approach – no cells!

For each (x_0 , y_0), find disparity value d that minimizes:

$$\sum_{x,y} \left(I_{left}(x+d, y) - I_{right}(x, y) \right)^2$$

where sum is over a local neighborhood of (x_0 , y_0).

Shift the left image to undo the disparity. This “registers” the left and right images. If $d > 0$, then we shift the left image to the left.

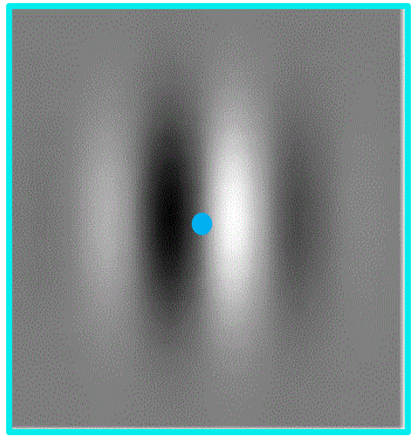
How to estimate binocular disparity at each point ?

Biological vision approach uses cells with shifted receptive fields, not shifted images.

Let's consider the responses of cosine and sine Gabors (monocular simple cells) for the left image and the right image.

$sine\ Gabor(x - x_0 - d\ , y - y_0)$

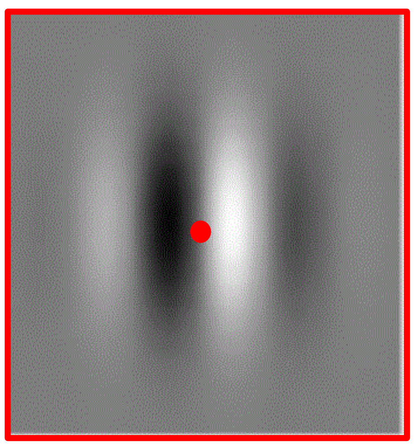
$(x_0 + d\ , y_0)$



This simple cell responds to left (eye) image. It is shifted by d relative to cell below.

d

$(x_0\ , y_0)$

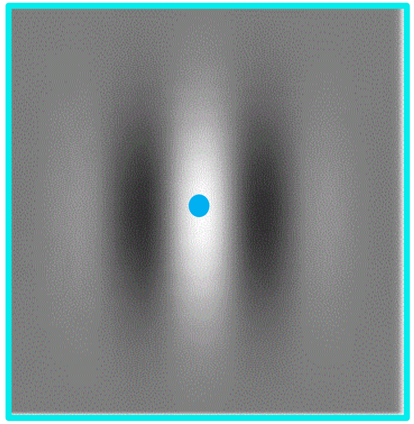


This simple cell responds to right (eye) image

$sine\ Gabor(x - x_0\ , y - y_0)$

$cosine\ Gabor(x - x_0 - d\ , y - y_0)$

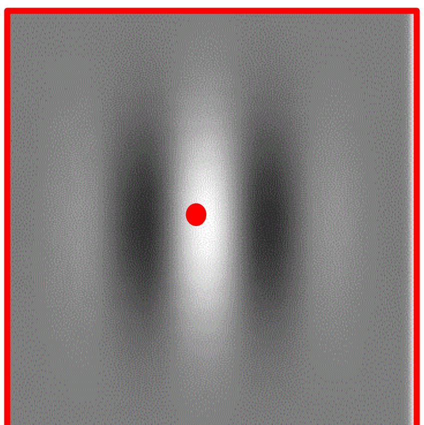
$(x_0 + d\ , y_0)$



d

This simple cell responds to left (eye) image. It is shifted by d relative to cell below.

$(x_0\ , y_0)$



$cosine\ Gabor(x - x_0\ , y - y_0)$

This simple cell responds to right (eye) image

Idea: (similar to what is done computer vision)

To compute disparity at (x_0, y_0), find the shift d of the left image cells whose responses match the responses of the right image cells.

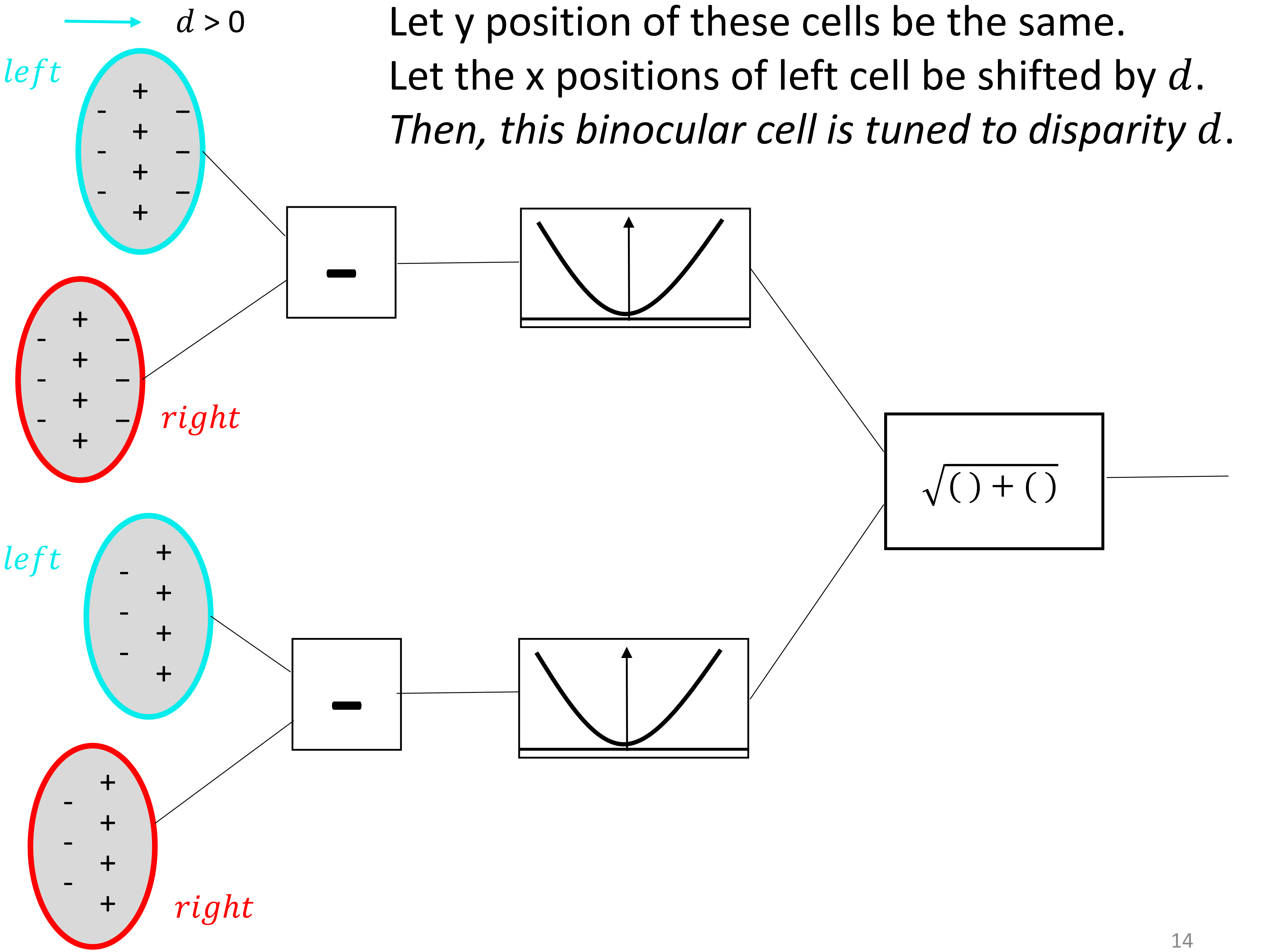
Idea: (similar to what is done computer vision)

To compute disparity at (x_0, y_0), find the shift d of the left image cells whose responses match the responses of the right image cells.

i.e. Find the shift d that *minimizes the sum of squared differences*:

$$
\begin{aligned}
&(< cosGabor(x - x_0 - d, y - y_0), I_{left}(x, y) > \\
&- < cosGabor(x - x_0, y - y_0), I_{right}(x, y) >)^2 \\
&+ \\
&(< sinGabor(x - x_0 - d, y - y_0), I_{left}(x, y) > \\
&- < sinGabor(x - x_0, y - y_0), I_{right}(x, y) >)^2
\end{aligned}
$$

Let y position of these cells be the same.
Let the x positions of left cell be shifted by d.
Then, this binocular cell is tuned to disparity d.



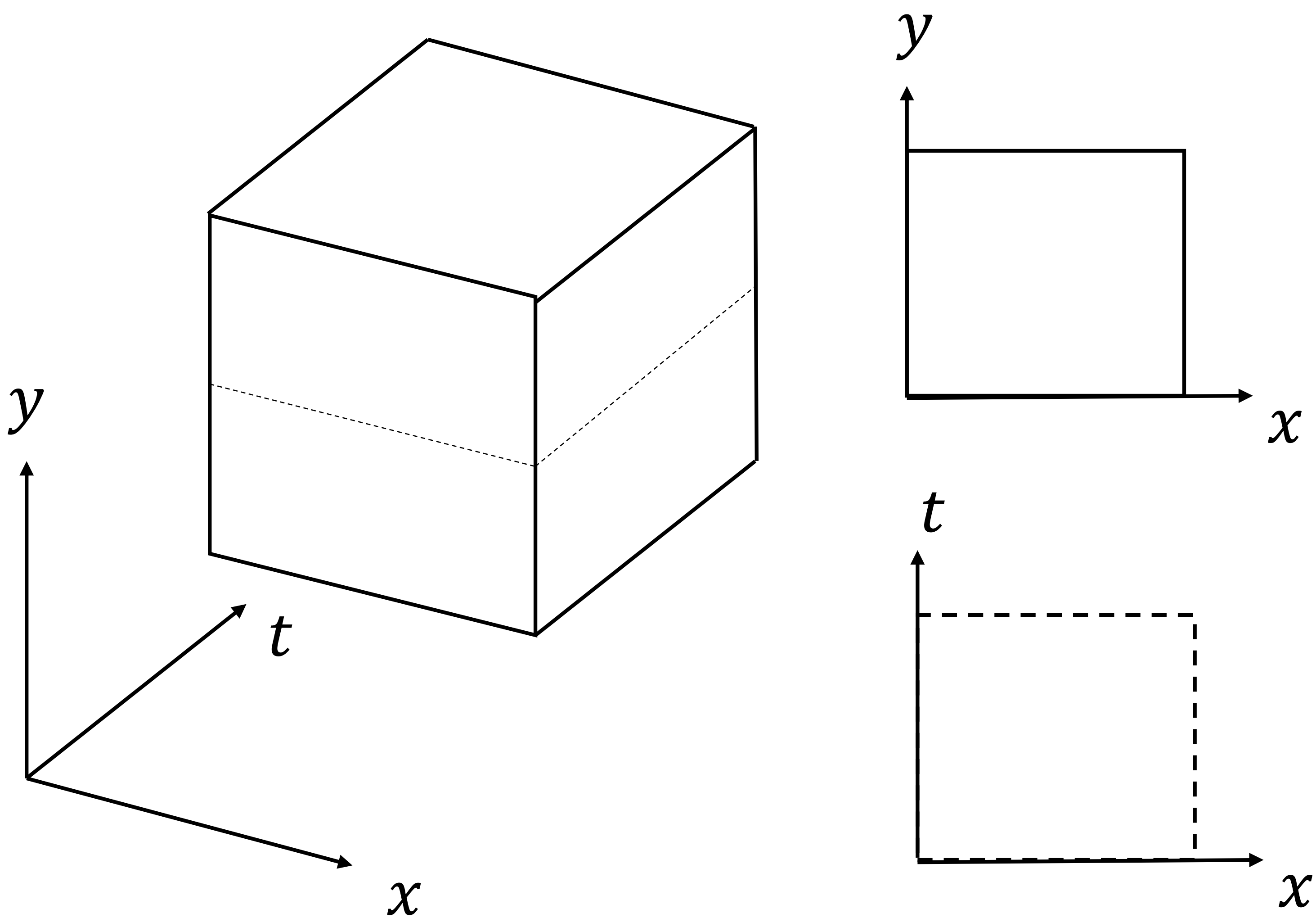
COMP 546

Lecture 7

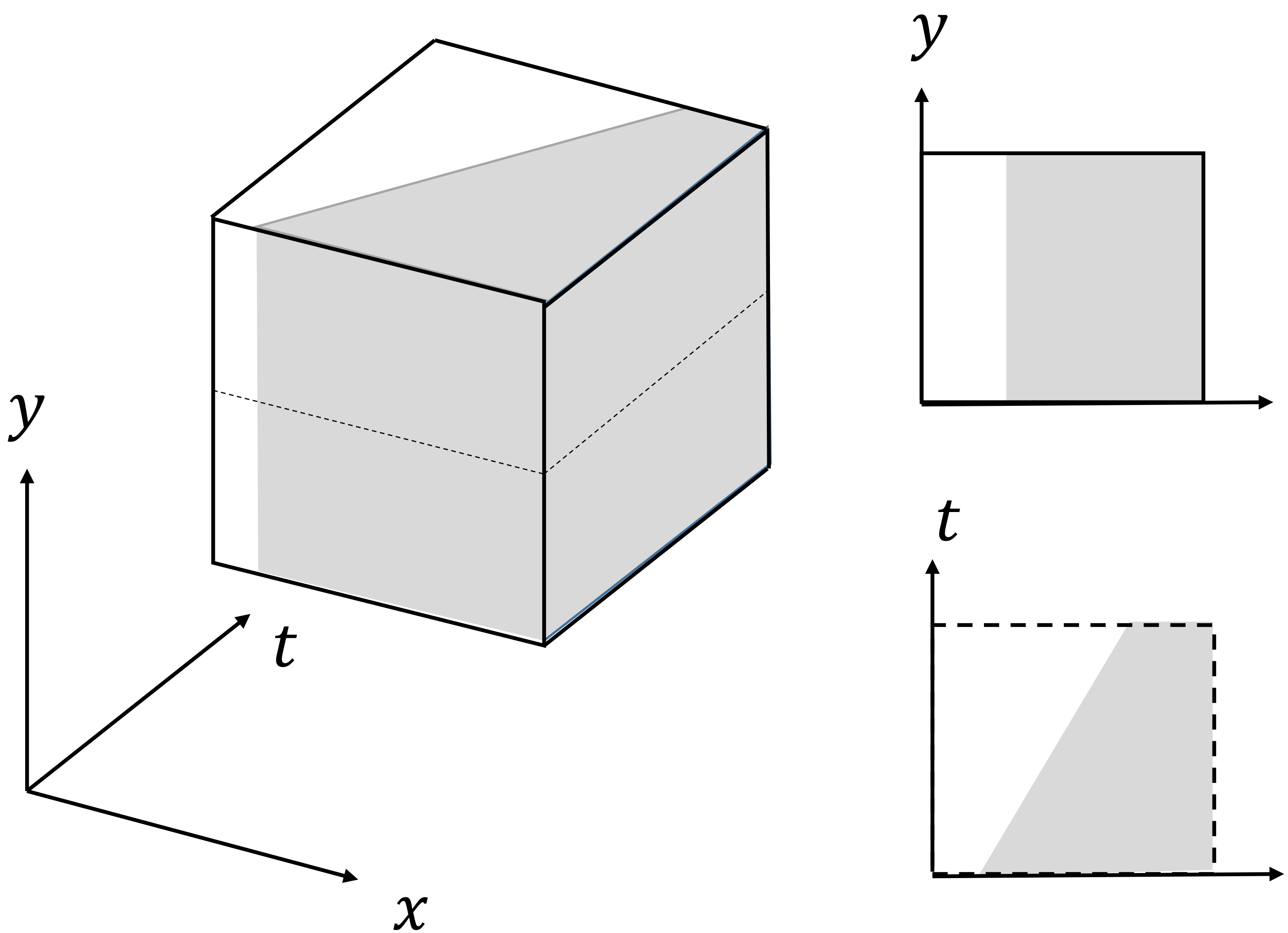
V1 binocular cells &
V1 motion cells

Thurs. Jan. 31, 2019

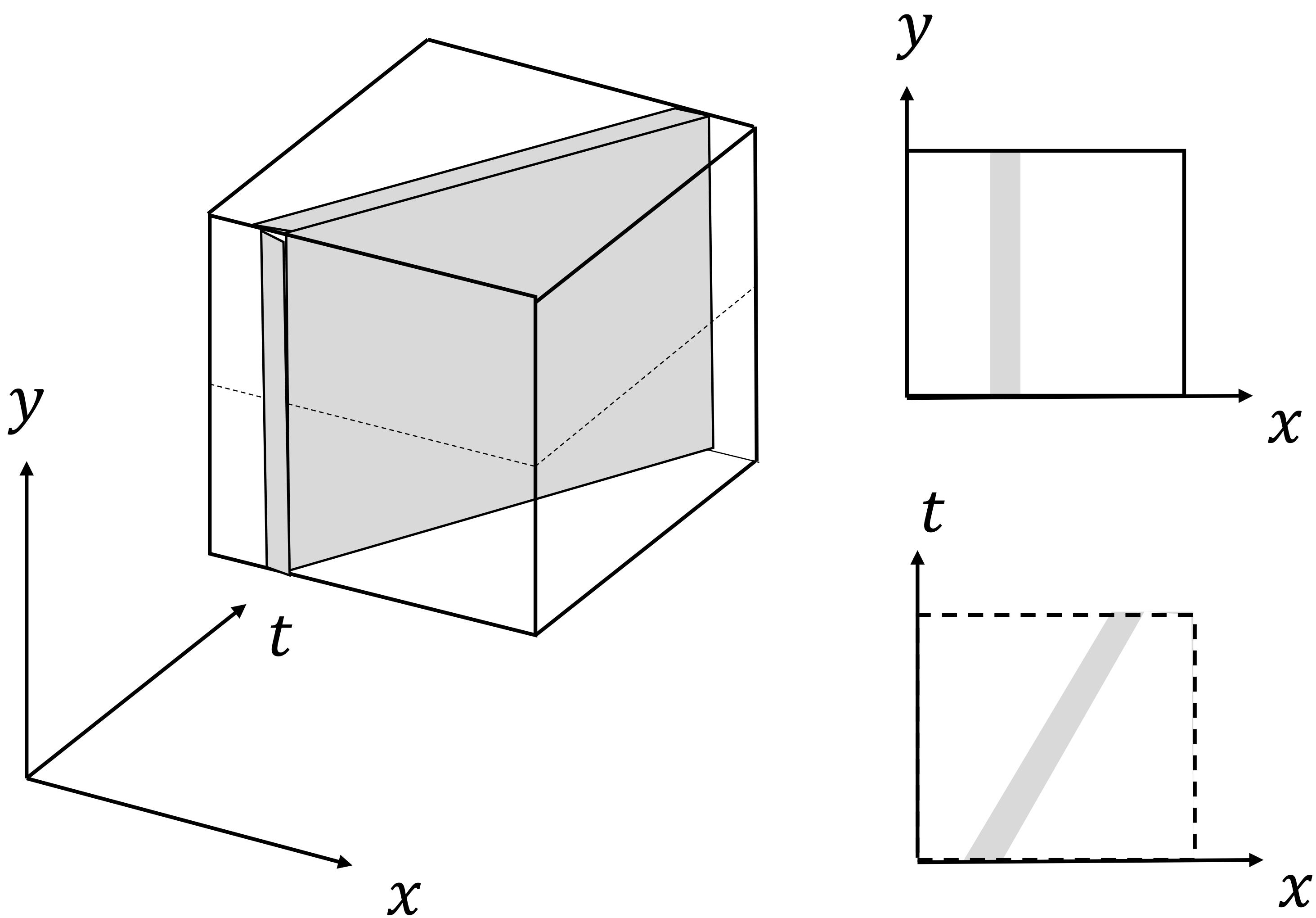
Time varying images (XYT)

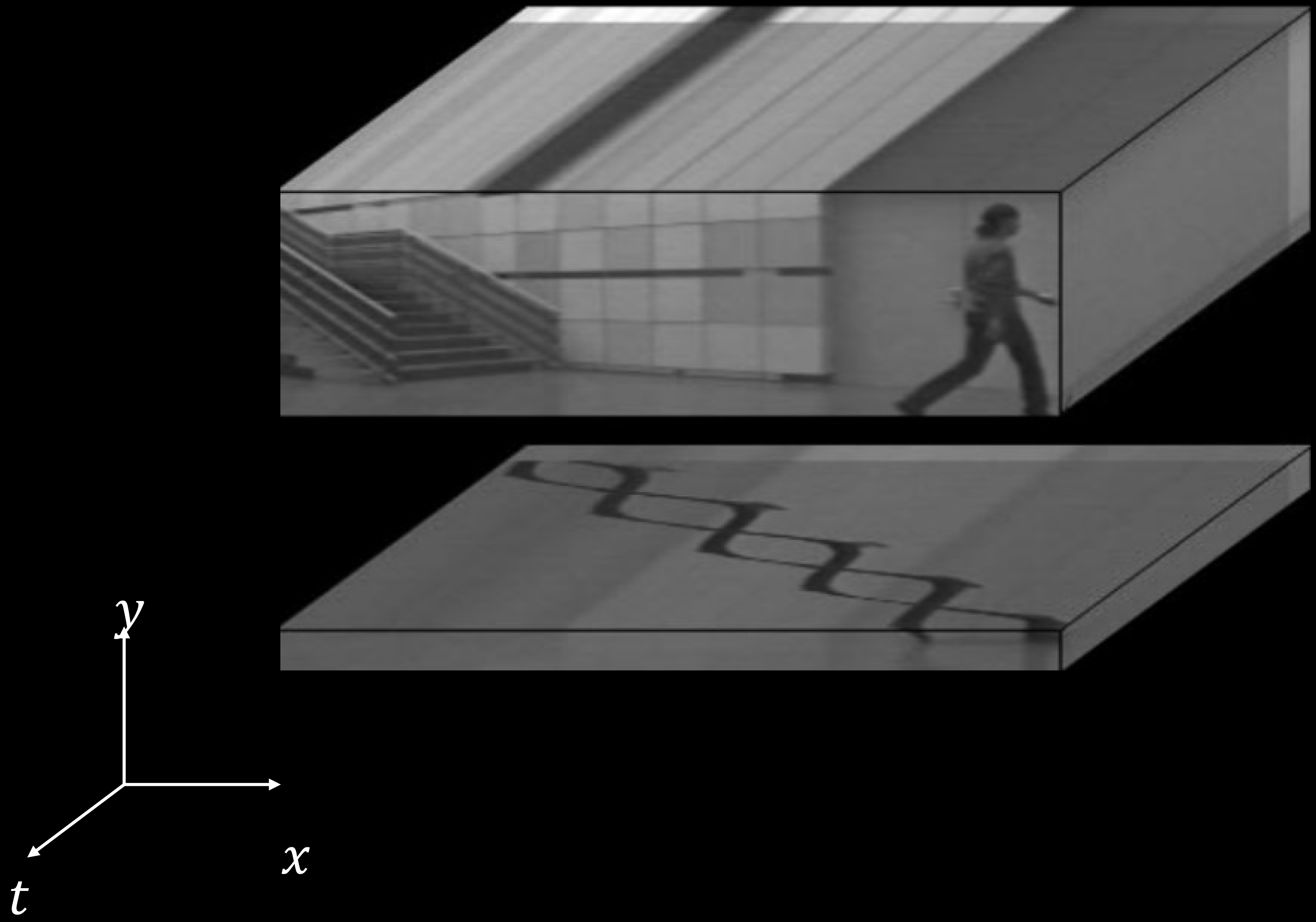


Motion in XYT
e.g. translating vertical edge



Motion in XYT
e.g. translating vertical bar



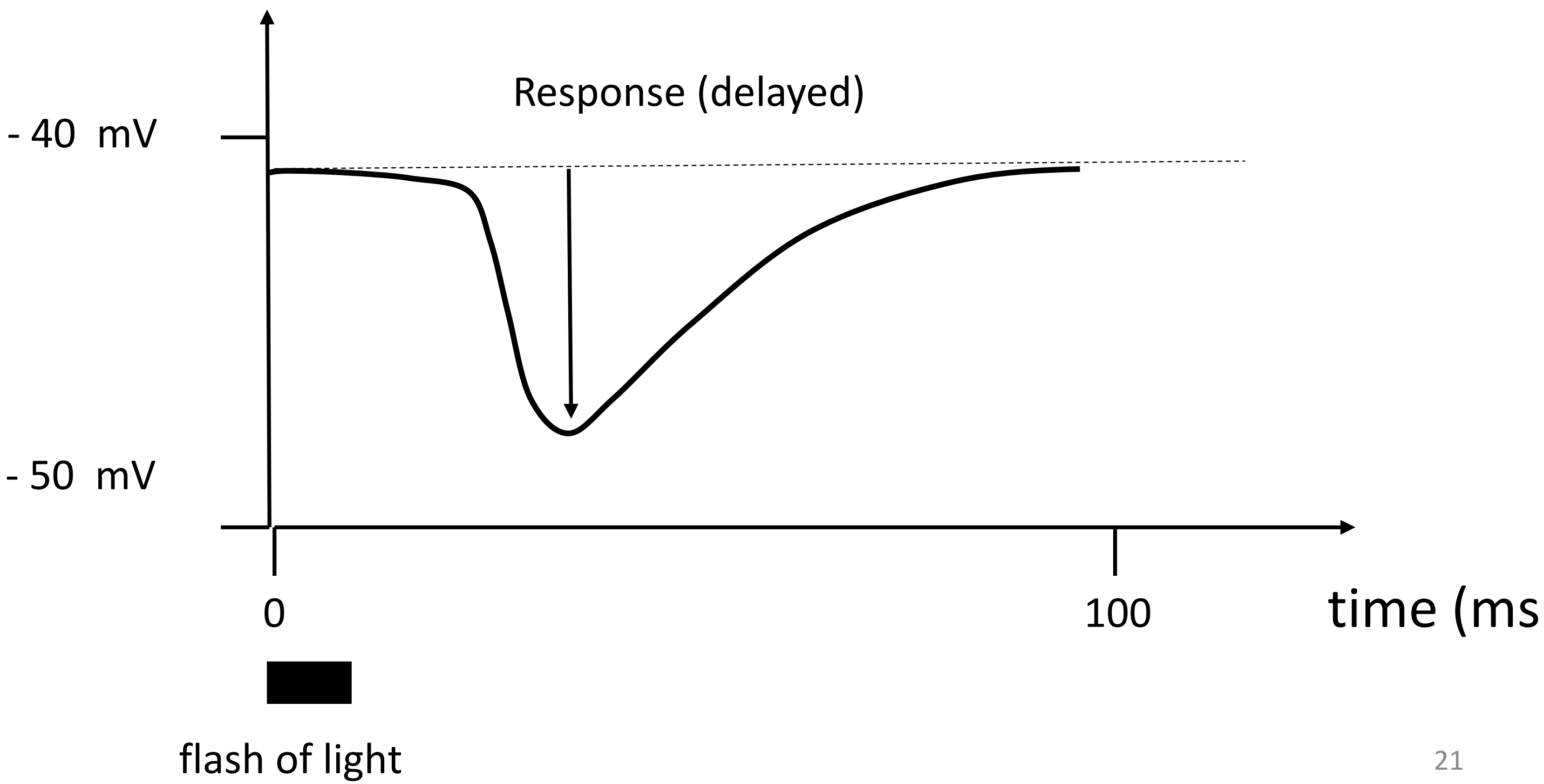


y
x
t

How does the vision system
(retina, LGN, V1, …)
measure image motion?

Photoreceptor response to a *brief flash of light*

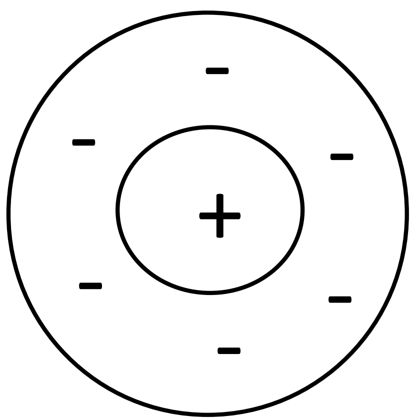
(recall from lecture 3)

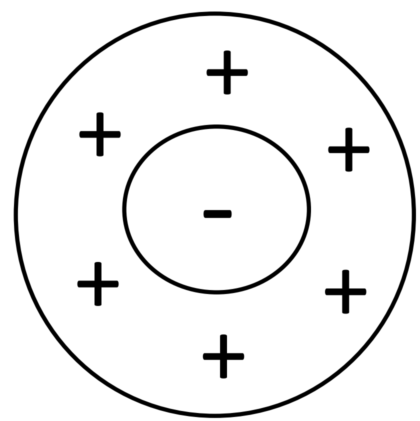


Retinal Ganglion and LGN cells

Our models up to now have ignored temporal aspects.

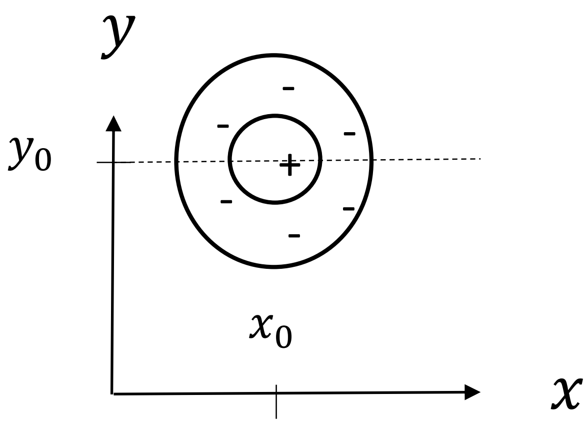
ON center,
OFF surround

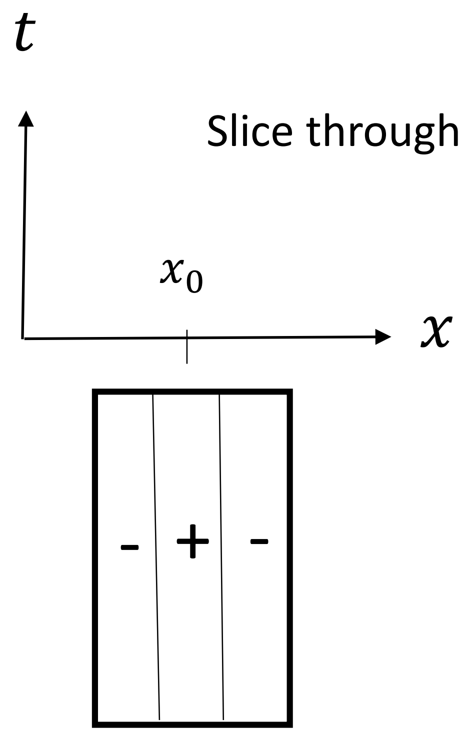




OFF center,
ON surround

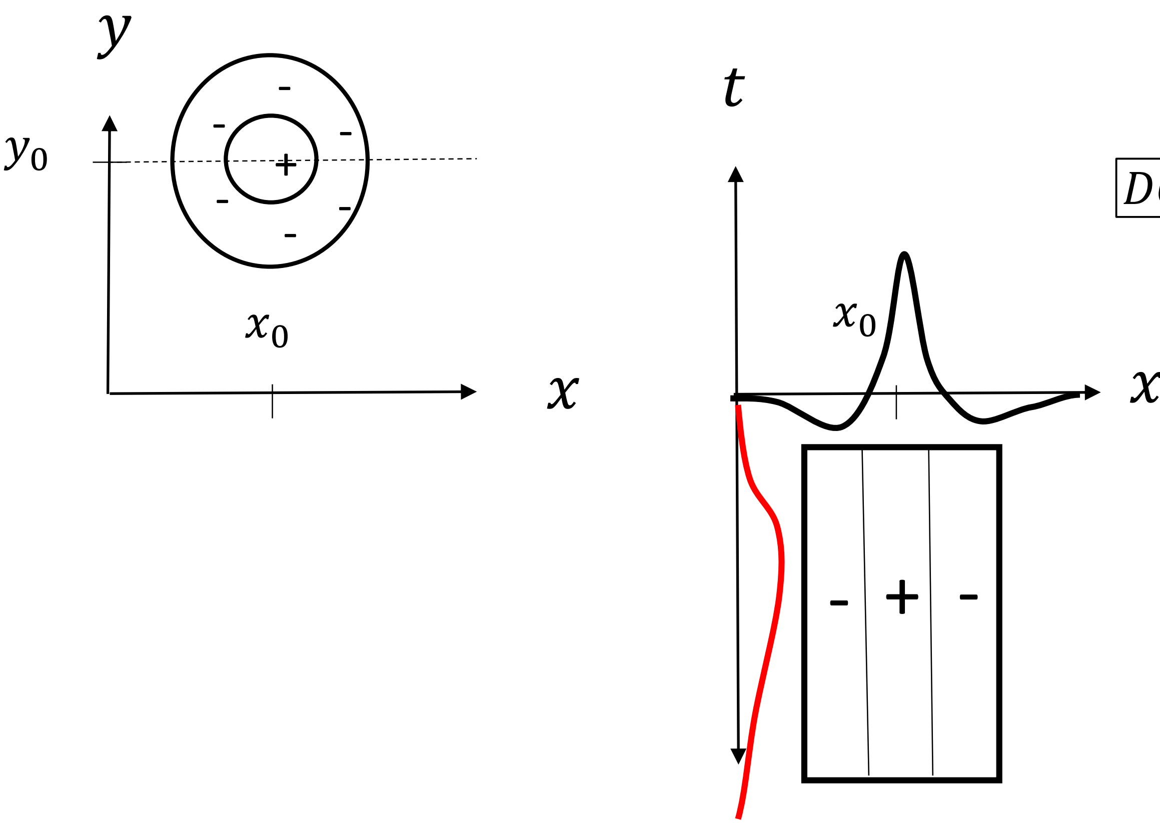
XY and XT slices





Here the response *at t = 0* depends on the image intensities for some interval *in the past (t < 0).*

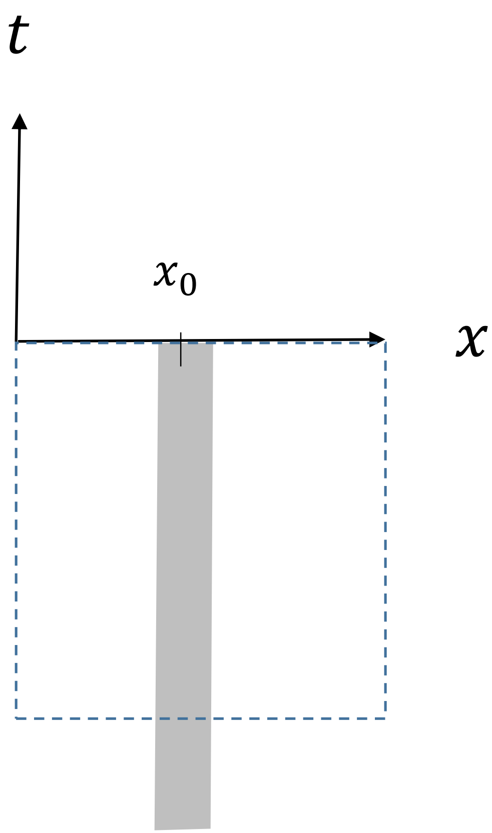
Space-time separable model



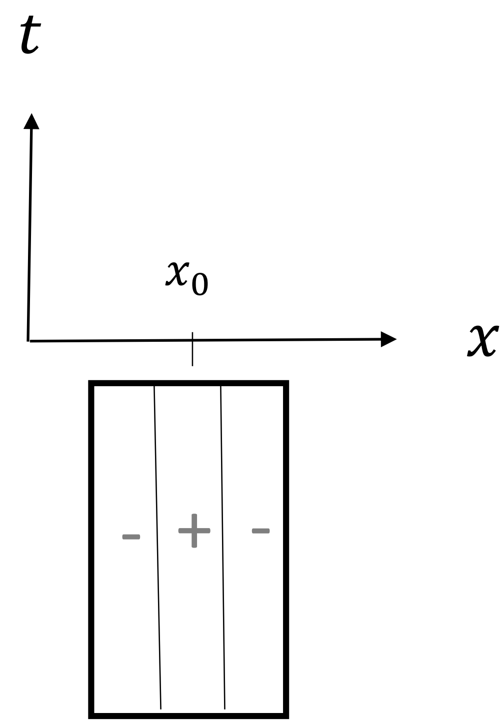
$$\boxed{DOG(x,y,t) = DOG(x,y) \; f(t)}$$

Here the response *at t = 0* depends on the image intensities for some interval *in the past (t < 0).*

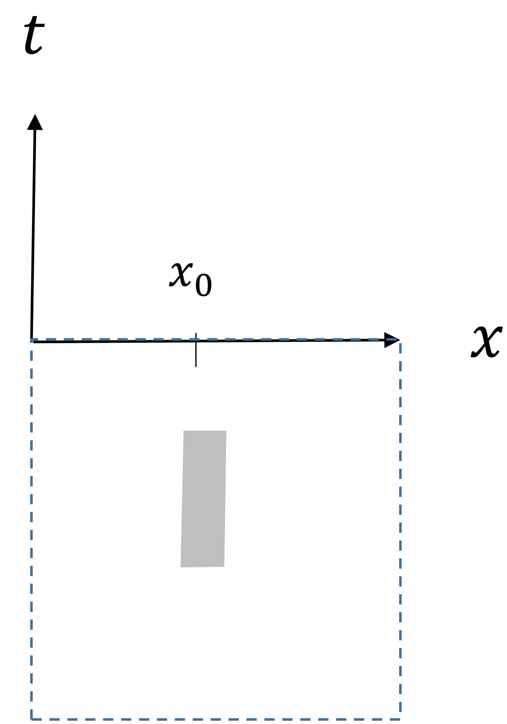
This DOG cell would respond well to a static spot or to a bright flash in the center region.



static spot

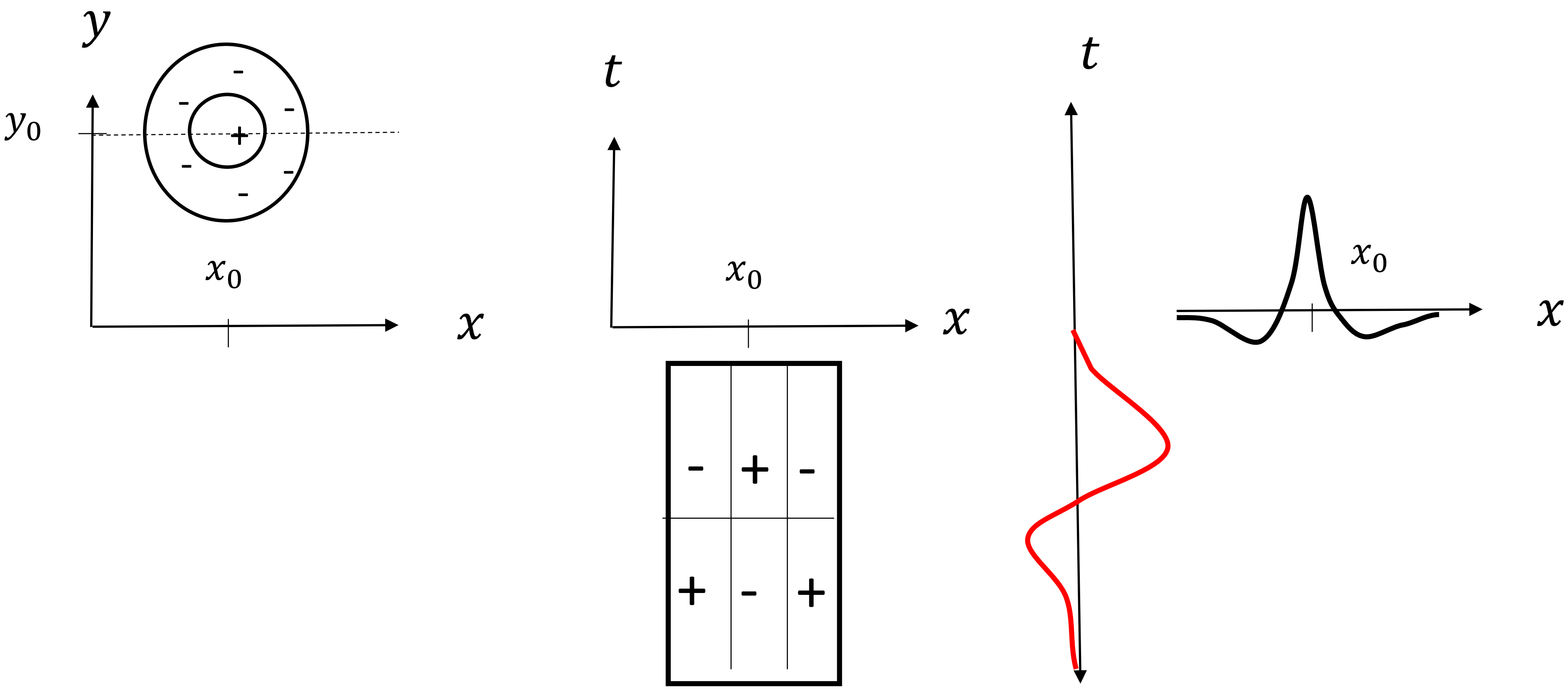


receptive field



flash

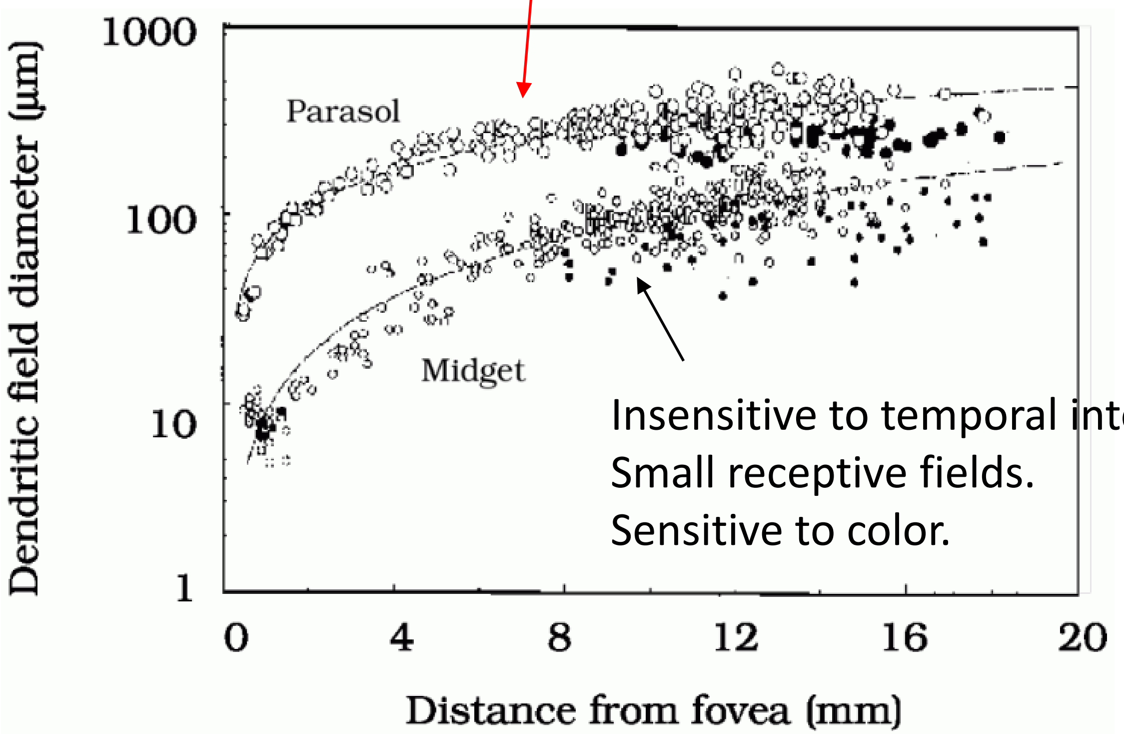
Space-time separable model
(*with temporal sensitivity*)



ASIDE: There are two classes of retinal ganglion cells.

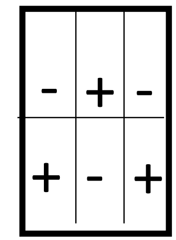
See lecture notes for more info, if you are interested.

Sensitive to temporal intensity variations.
Large receptive fields.

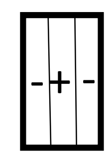


Insensitive to temporal intensity variations.
Small receptive fields.
Sensitive to color.

XT slice

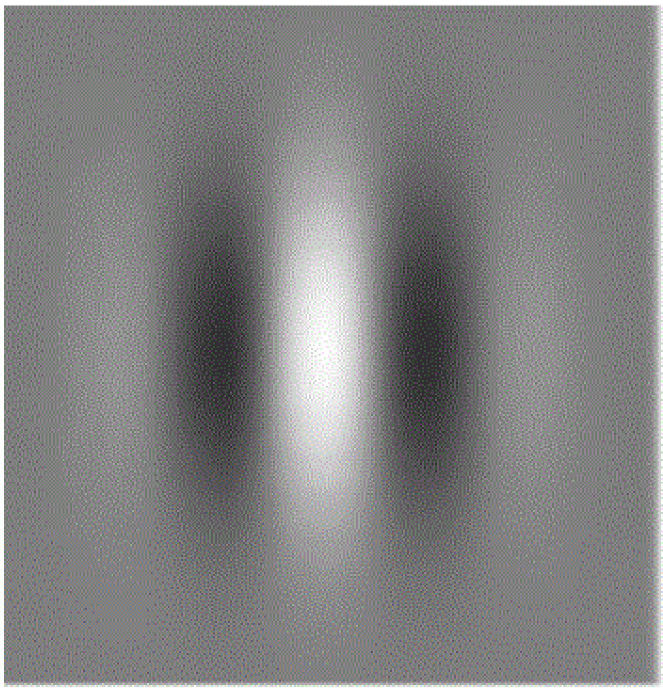


XT slice

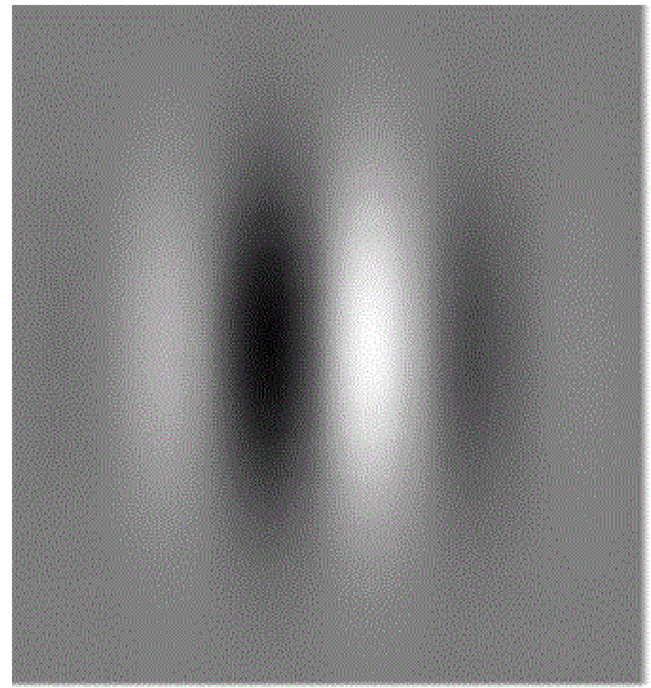


V1 cells detect oriented structure in XY.

cosGabor(x,y)

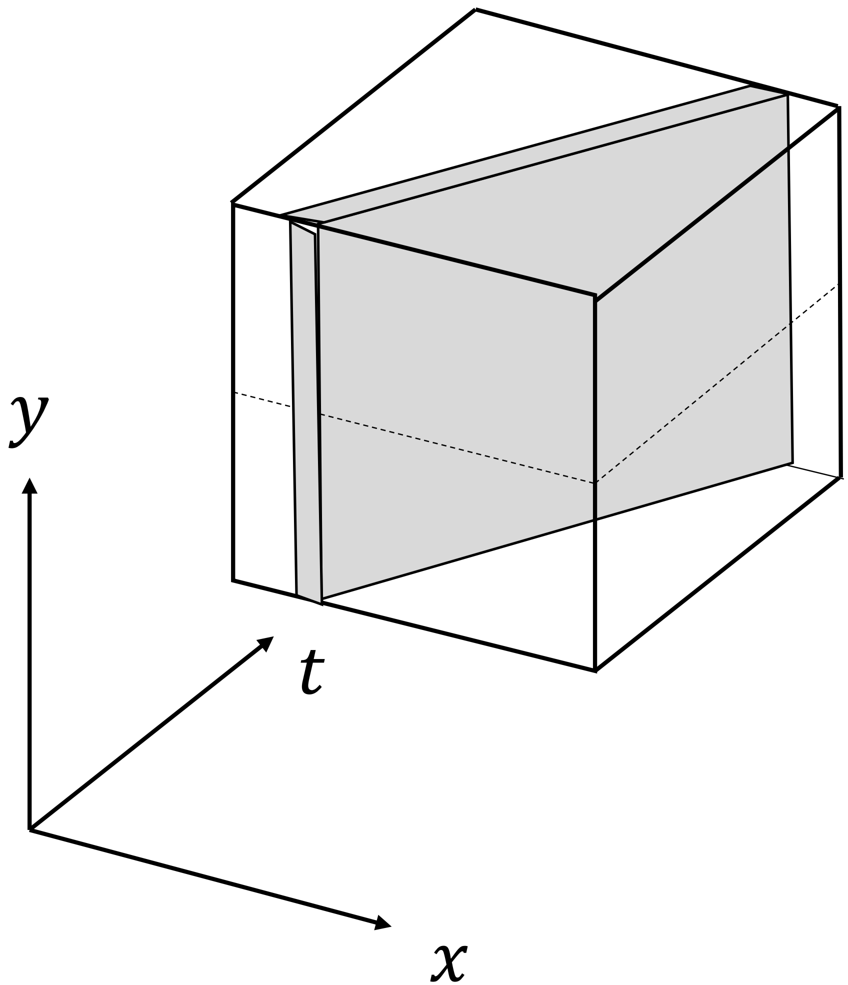


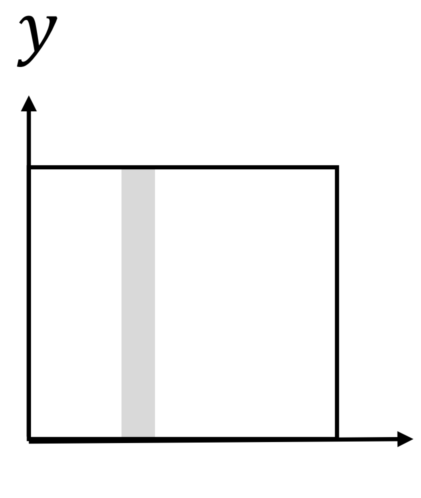
sinGabor(x,y)

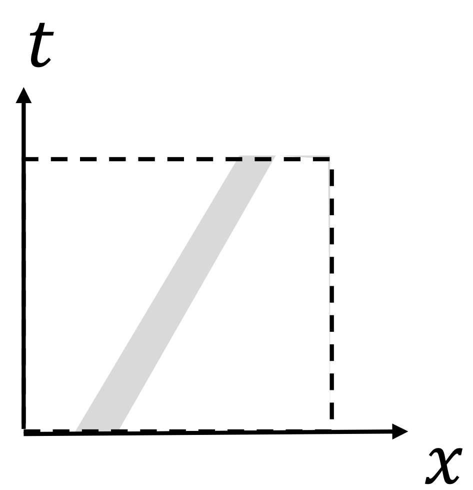


What are the temporal properties of these cells?

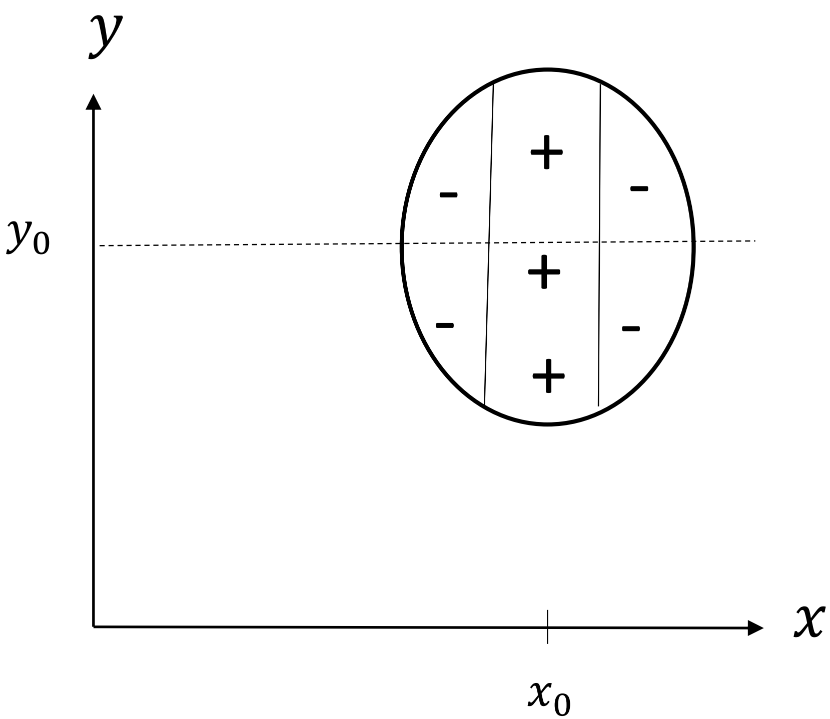
Motion in XYT
e.g. translating vertical bar



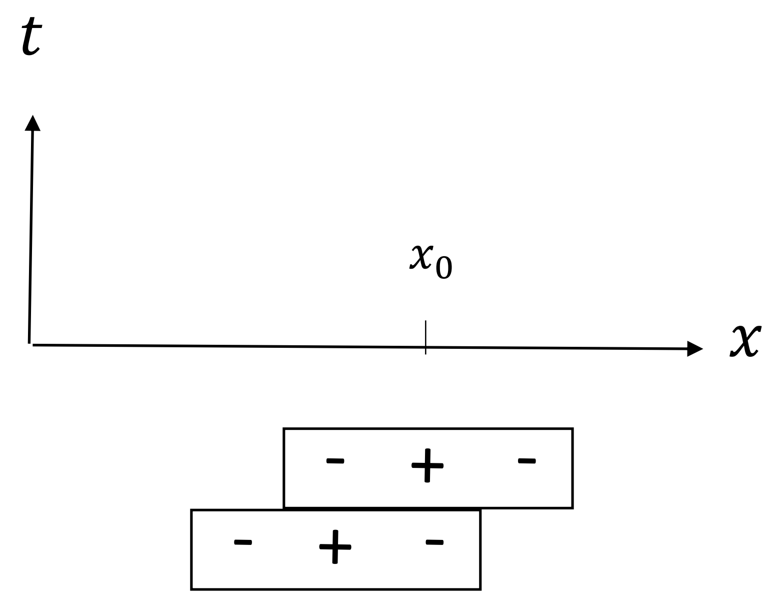




Orientation *and* direction tuned cells in V1

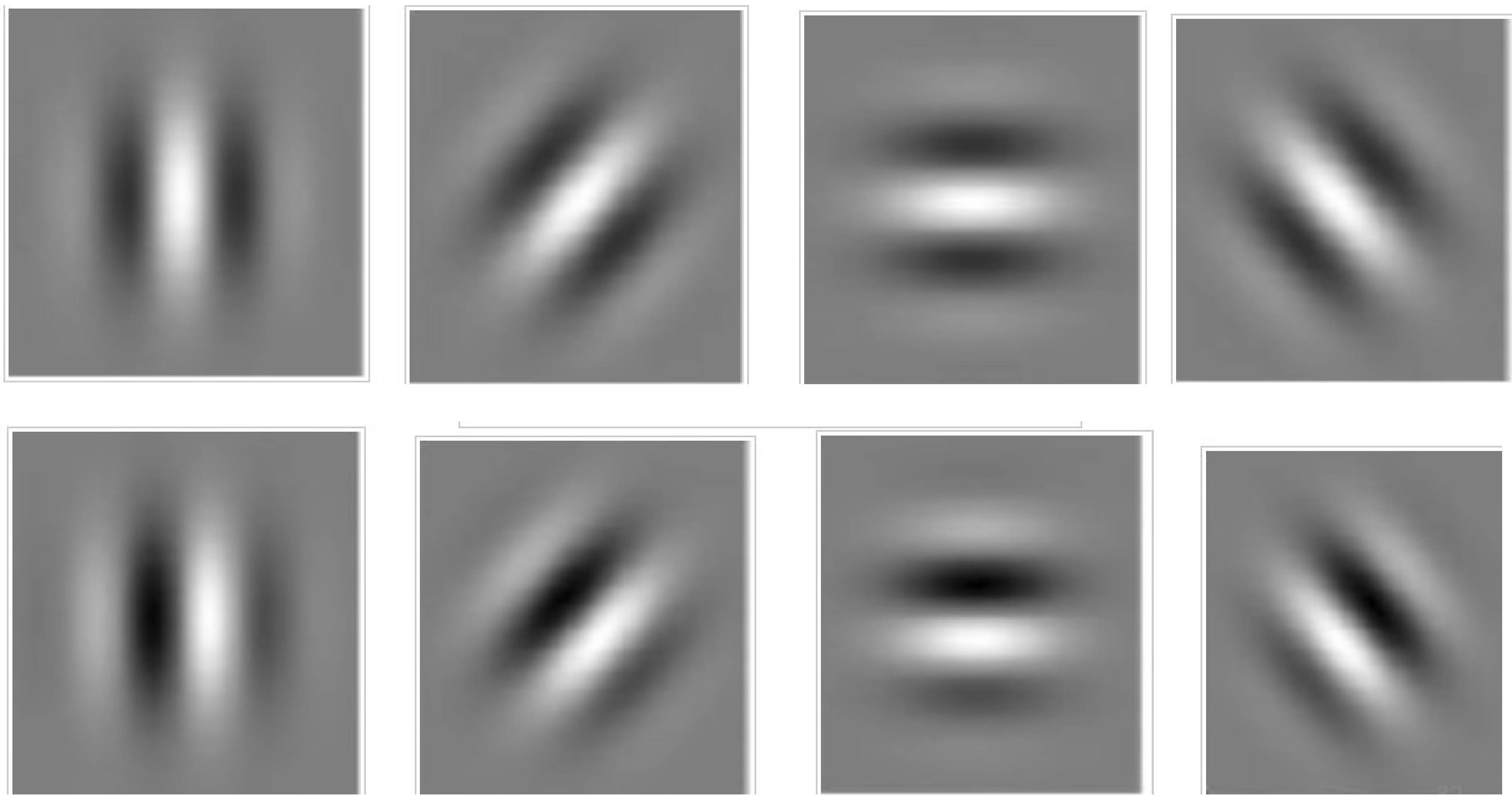


Cell is selective for vertical line. Only one time slice is shown here.

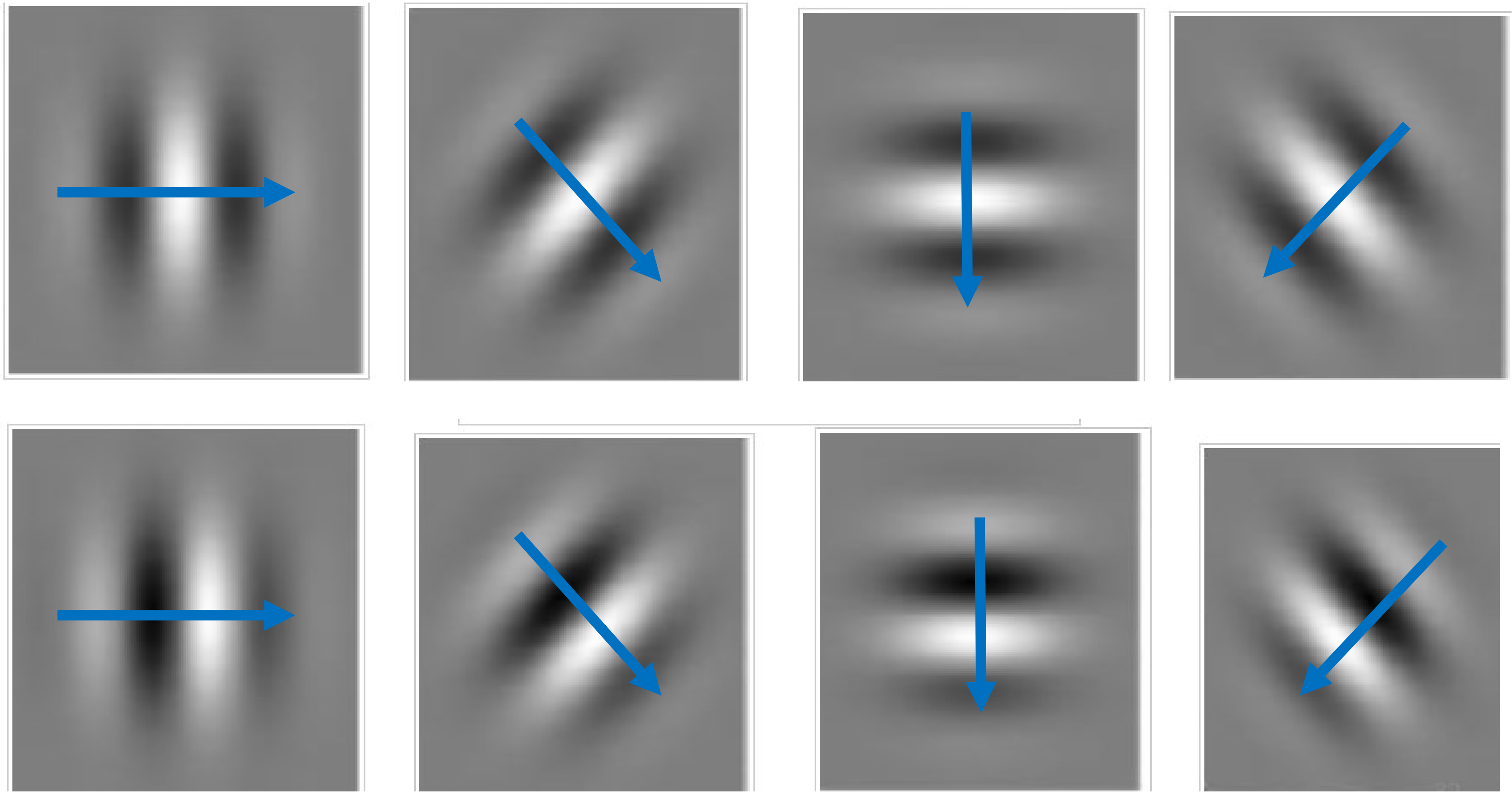


Cell is selective for motion to the right.

Simple and Complex Cells are *Orientation Tuned* (XY slice)
Many are tuned to binocularly disparity also.



Simple and Complex Cells are *Orientation Tuned* (XY slice)
Many are tuned to binocularly disparity also.
Many are also tuned to *motion direction and speed.*



The blue arrows are called "normal velocities".

We will have more to say about how this works next lecture.