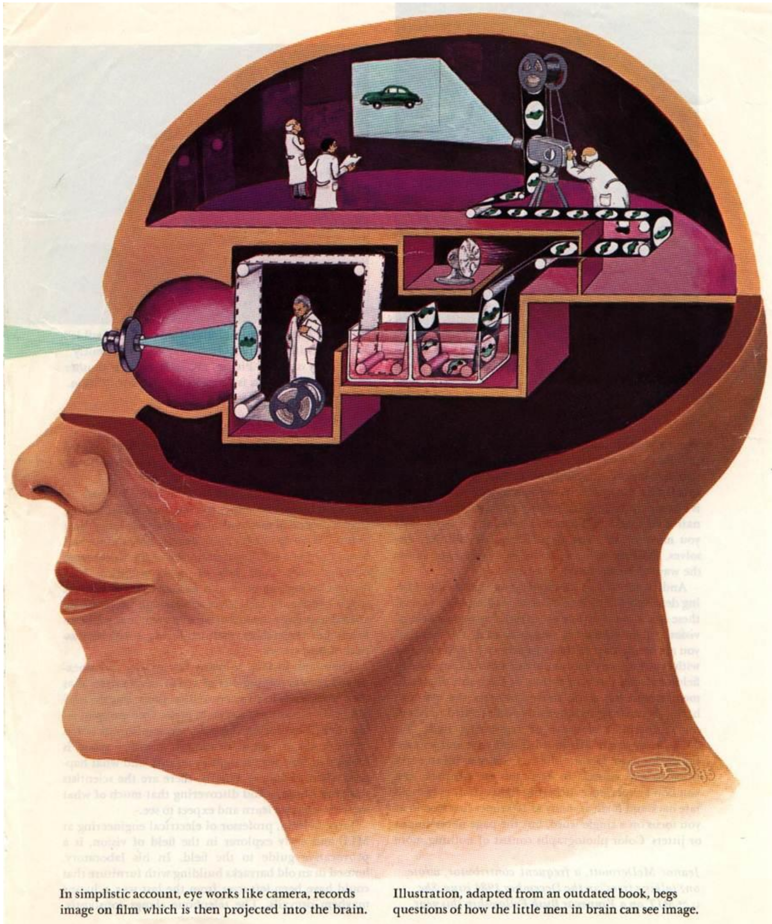


Processing & Encoding Visual Information, Part 2:

From Retina to Cortex

10/22/14

Announcements

Midterm review

- Sunday, 3:00 – 4:50 pm
- Peterson 110 (here)
- Podcast has been requested

Chapter 4 after the midterm.

(Maybe get a flu shot?)

Last time

Processing visual information

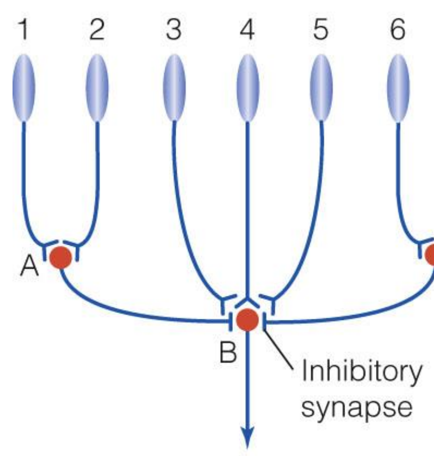
- ✓ Convergence and lateral inhibition
- ✓ Lateral inhibition and lightness perception
- Convergence and receptive fields

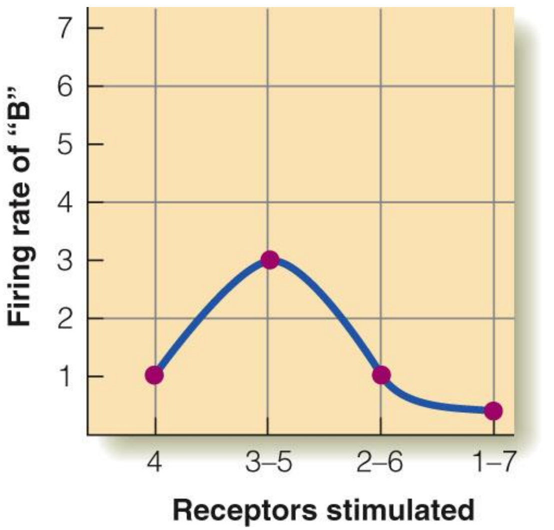
How does neural convergence influence perception?

Earlier: Convergence & receptive fields

The lateral inhibition effects we've seen so far occur at the level of the retina. How does neural convergence affect processing further on in the brain?

The summation of excitatory and inhibitory connections in the retina creates **receptive fields** for neurons in the visual system.

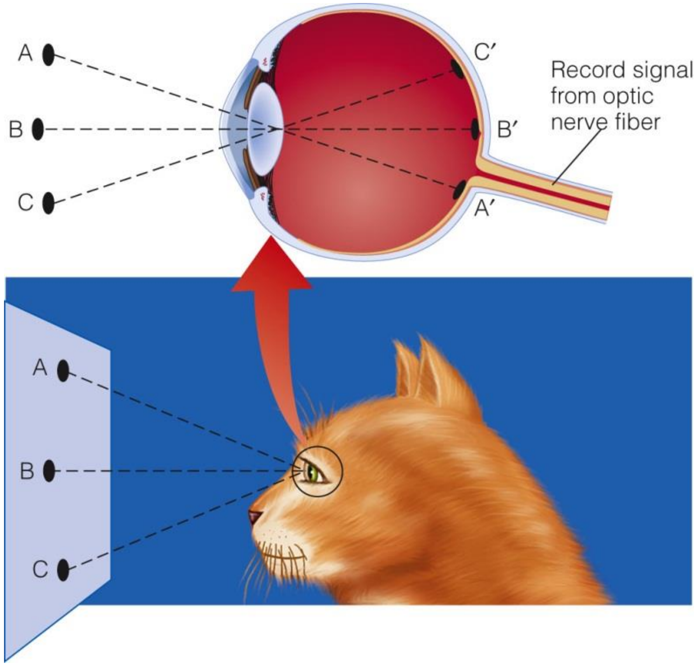




Earlier: Convergence & receptive fields

The **receptive field** of a given neuron is the area on the retina that affects the neuron's firing rate (both excitatory and inhibitory).

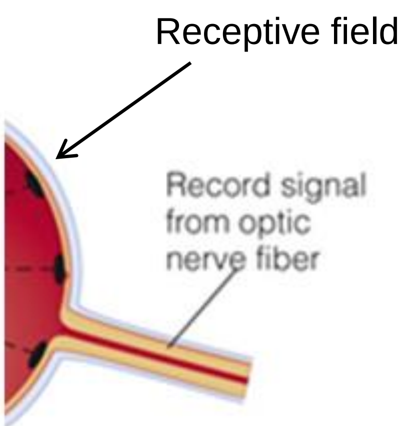
Note that the receptive field corresponds to a region in space (the visual field).

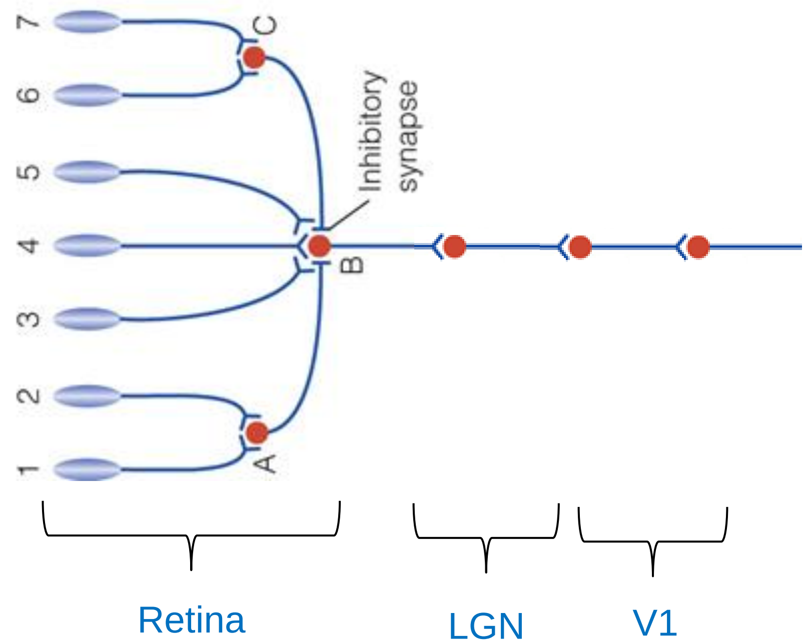


Convergence & receptive fields

The **receptive field** <u>on the retina</u> influences neurons throughout the visual system.

All neurons beyond “B” have the same receptive field in this example.



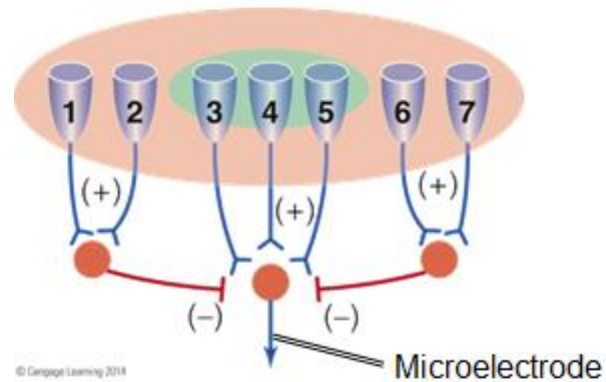


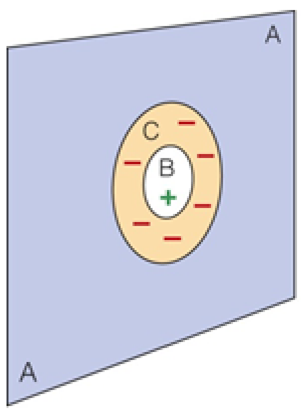
Convergence & receptive fields

Microelectrodes can measure the activity of a neuron while different environmental stimuli are presented in its receptive field.

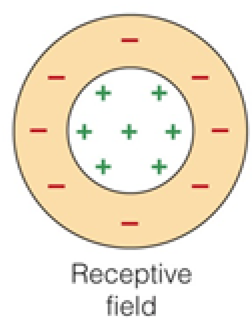
The example here is of an excitatory center-surround receptive field.

See page 62.

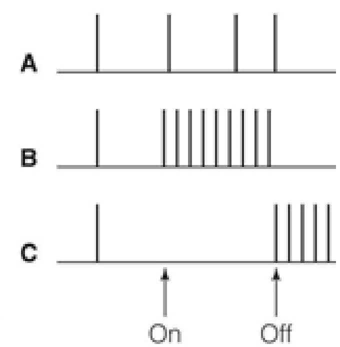




Visual field mapping of receptive field.



Pattern of activation on retina.



Ganglion cell action potentials.

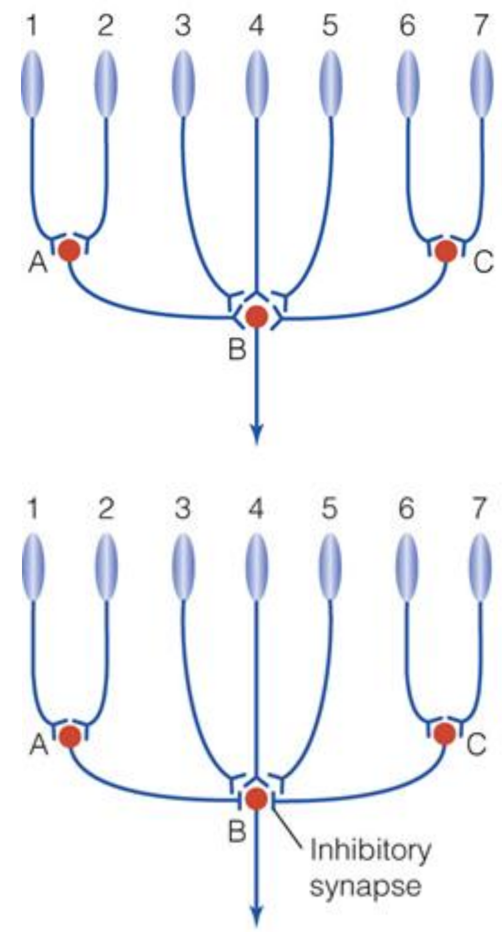
Convergence & receptive fields

Memory check

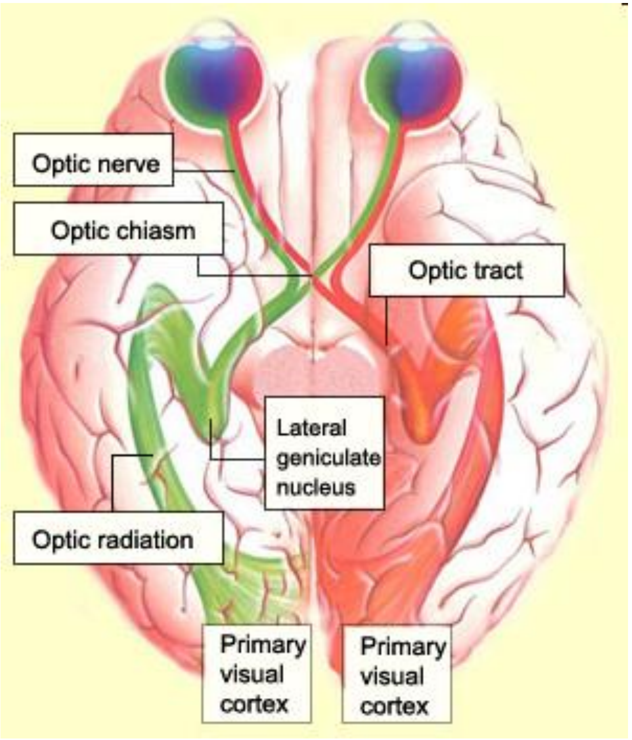
(T/F) In the top diagram, receptor 1 is part of the receptive field for neuron B. However, in the bottom diagram, the receptor 1 in <u>not</u> part of the receptive field for neuron B because it connects to an inhibitory neuron.

A. True

B. False



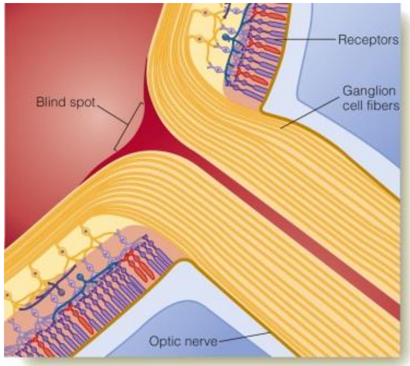
From receptive fields (retina) to visual representation (cortex)

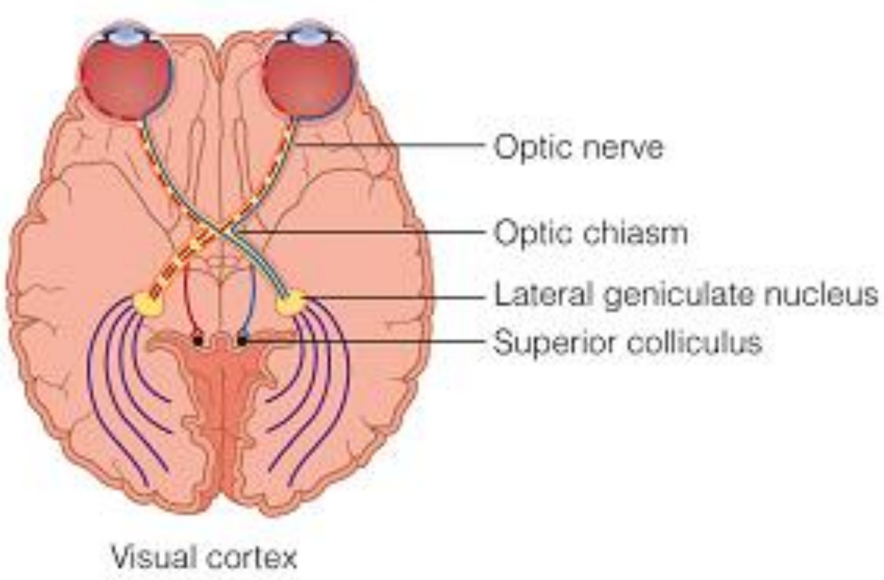


How is visual information transmitted (from receptive fields), processed, & organized in the brain?

- Ganglion axon pathway
- Visual thalamus – lateral geniculate nucleus (LGN)
- Primary visual cortex (V1)
    - Feature detectors
- Using selective adaptation to test features
- Sensory codes and representation
- Organization by streams
- Double dissociations of functional anatomy

Where do retinal signals go?

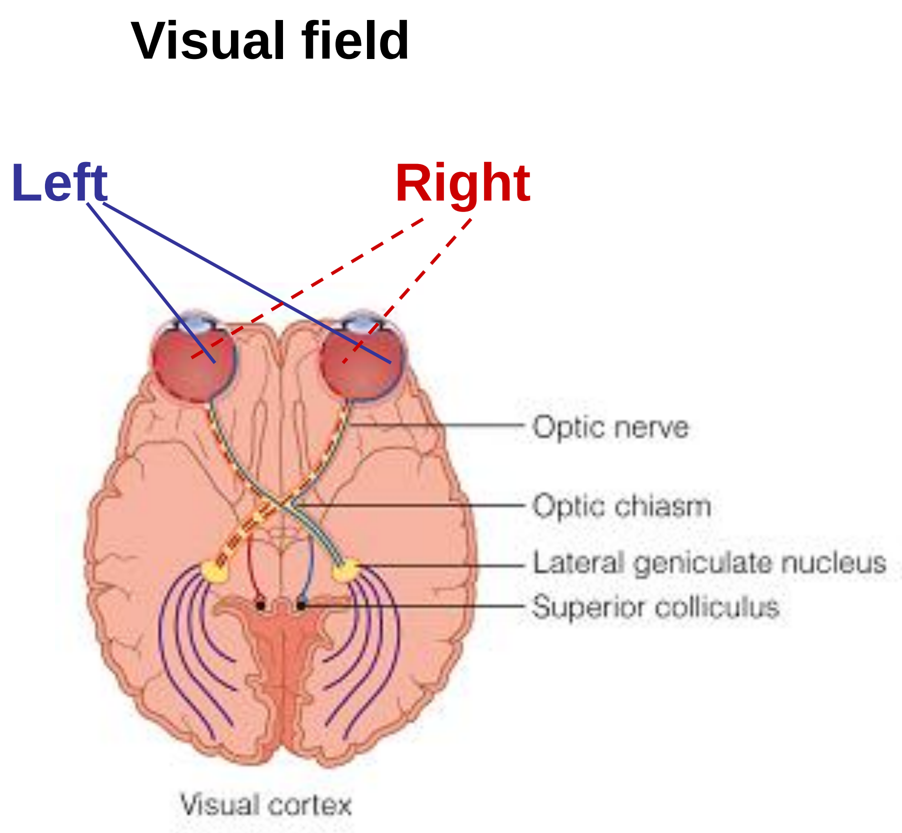




By the numbers:

- Approximately 1 million ganglion cells send axons out of each retina. These axons form the **optic nerve**.
- Approximately 10% of these go to the **superior colliculus**, to aid with orienting and multisensory responses. 90% go to the lateral geniculate nucleus (**LGN**) of the thalamus.
- About 900,000 ganglion axons go to each LGN; about 360,000 LGN axons (40%) go to visual cortex. So, some processing is taking place.

How are retinal signals organized?



Spatially organized transmission:

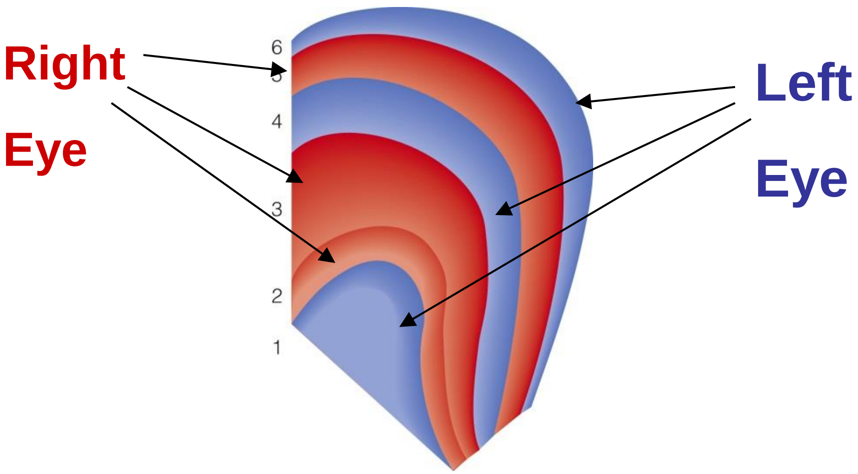
- Items in the left **visual field** go the right side of both retinas.
- Signals from the right side of both retinas go to the right **lateral geniculate nucleus (LGN).**
- Right visual field goes to the left side of the retinas and left LGN.

How are retinal signals organized?

Each LGN has six layers

Each LGN receives signals from both eyes, but the signals from each eye are sent to different layers.

- Layers 2, 3, and 5 receive signals from the **ipsilateral** (same side) eye.
- Layers 1, 4, and 6 receive signals from the **contralateral** (other side) eye.
- Thus, each (half) eye sends signals to both LGNs, but the information from each eye is kept <u>segregated</u>.

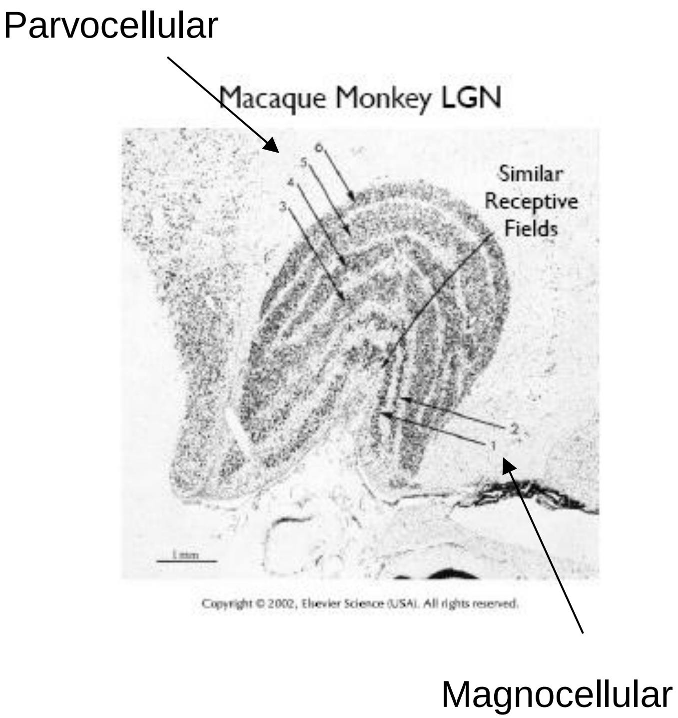


Right LGN

How are retinal signals organized?

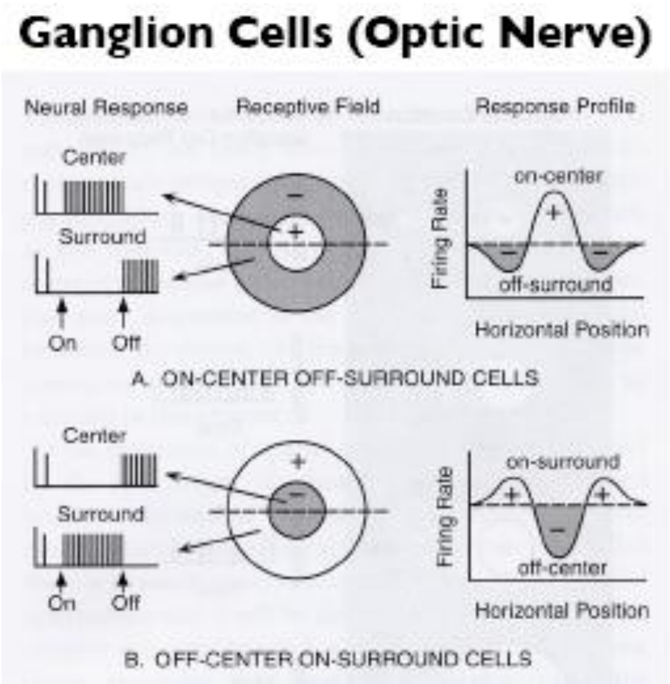
The layers transmit different types of information

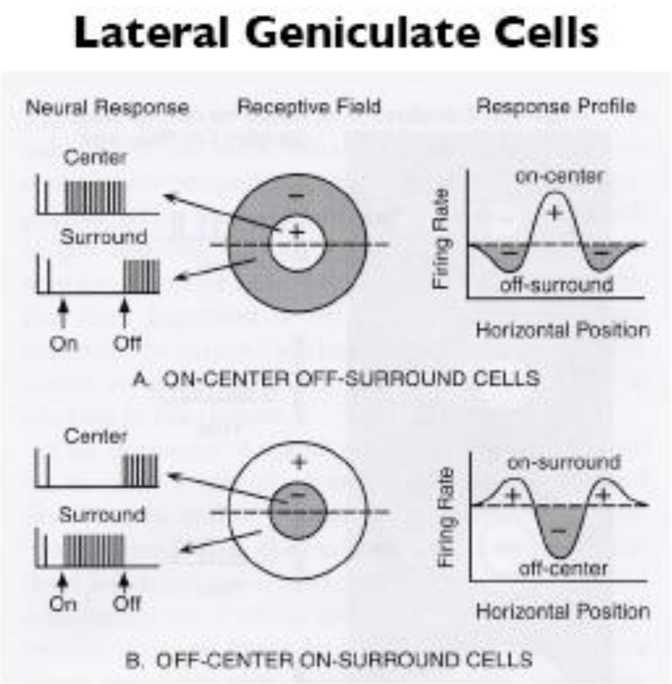
- Layers 1 and 2 are part of the **magnocellular pathway** (M-cells). These layers transmit information on motion and depth.
- Layers 3-6 are part of the **parvocellular pathway** (P-cells) and contain more information about detail and color.
- In-between layers is the **koniocellular pathway**. This seems involved with color vision.



How are retinal signals organized?

Responses properties of LGN cells are similar to those of the retinal ganglion cells. Both have center surround receptive fields.



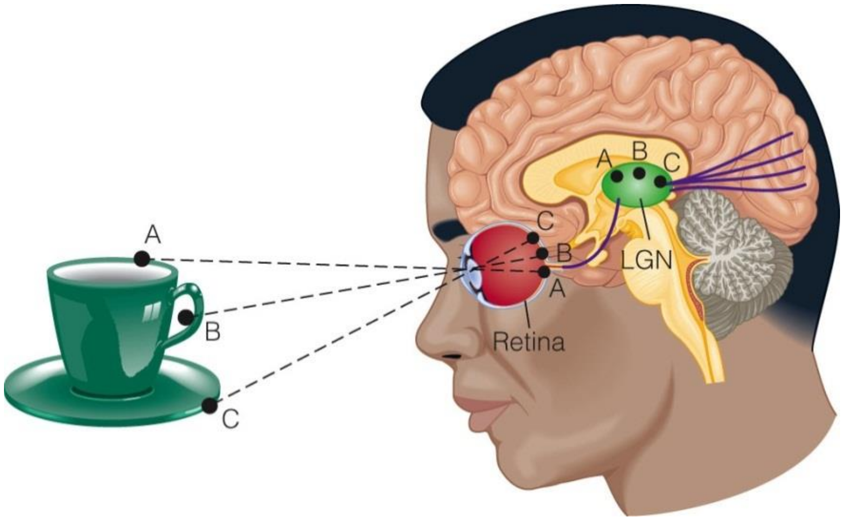


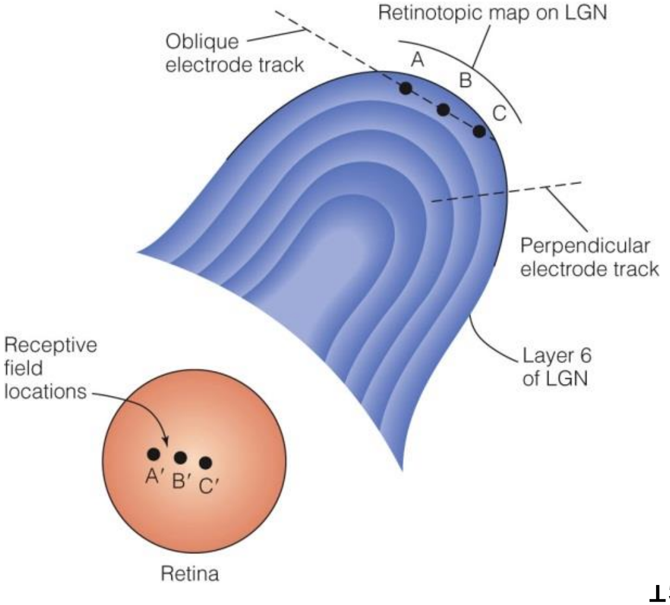
Palmer (1999) *Vision Science*

How are retinal signals organized?

Both the retina and LGN organize activation by spatial maps.

- **<u>Retinotopic map</u>** - each place on the retina corresponds to a place on the LGN
- To determine retinotopic maps, perform single-cell recordings. Record from neurons with an electrode that penetrates the LGN obliquely.
  - Stimulating receptive fields on the retina shows the location of the corresponding neuron in the LGN

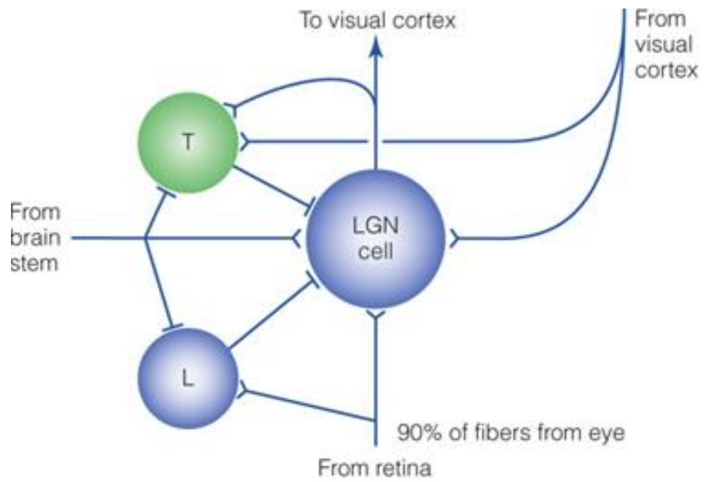


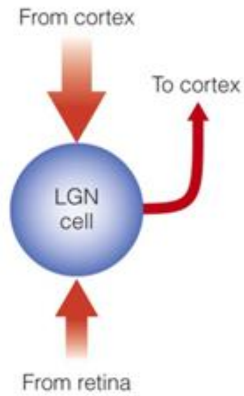


Lateral geniculate nucleus (LGN)

LGN regulates (processes) neural information from the retina *and* cortex before passing it to the primary visual cortex (V1).

- Signals are received from the retina, the cortex, the brain stem, and the thalamus.
- Signals from the eyes (bottom-up data) are organized by visual field, receptor type, and type of environmental information (e.g. color, orientation, motion, etc.).
- **More** signal comes from the cortex than the eyes. This is <u>top-down process information</u>.
- So what is happening?



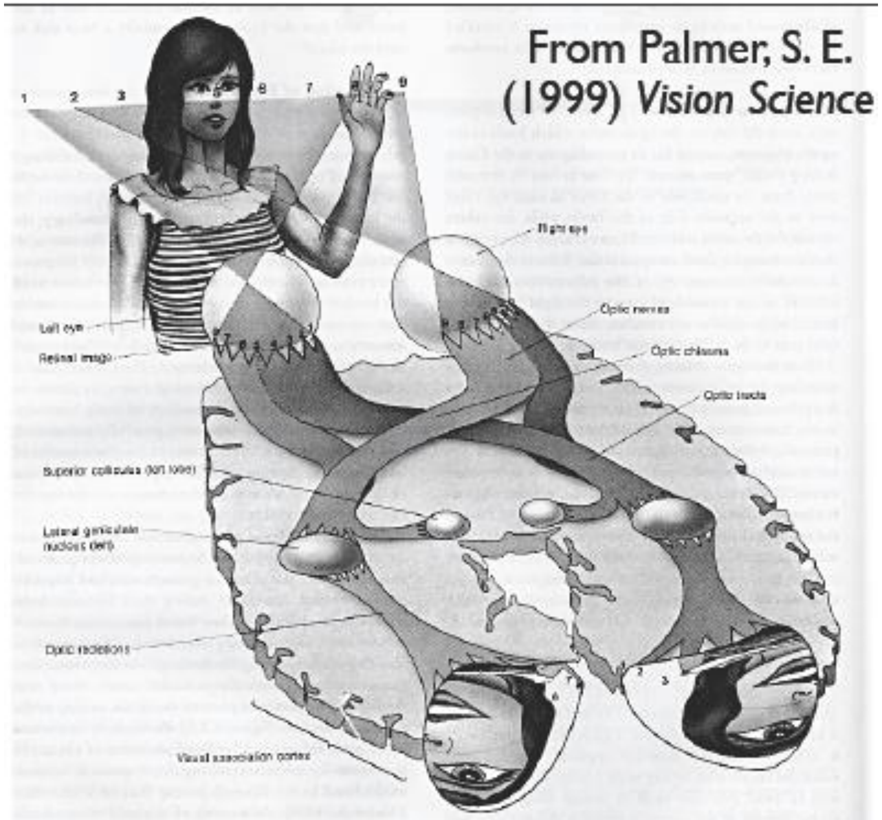


Lateral geniculate nucleus (LGN)

LGN as perceptual gatekeeper?

- **Perhaps** some of the feedback from cortex amplifies signals (or inhibits competing neurons) to enhance certain features in a noisy environment.
- Background knowledge may help select visual images based on what you expect to see.
- Note: this kind of feedback happens at many levels in the brain.

From retina to LGN



Summary so far:

1. Visual field information segregated by hemisphere.
2. Information from each eye kept separate in LGN by layers.
3. Cell receptive fields (center-surround) are similar in retina and LGN.
4. Spatial <u>retinotopic</u> maps are preserved in LGN.
5. Some selective processing occurs – LGN is not simply a relay nucleus.

From retina to LGN

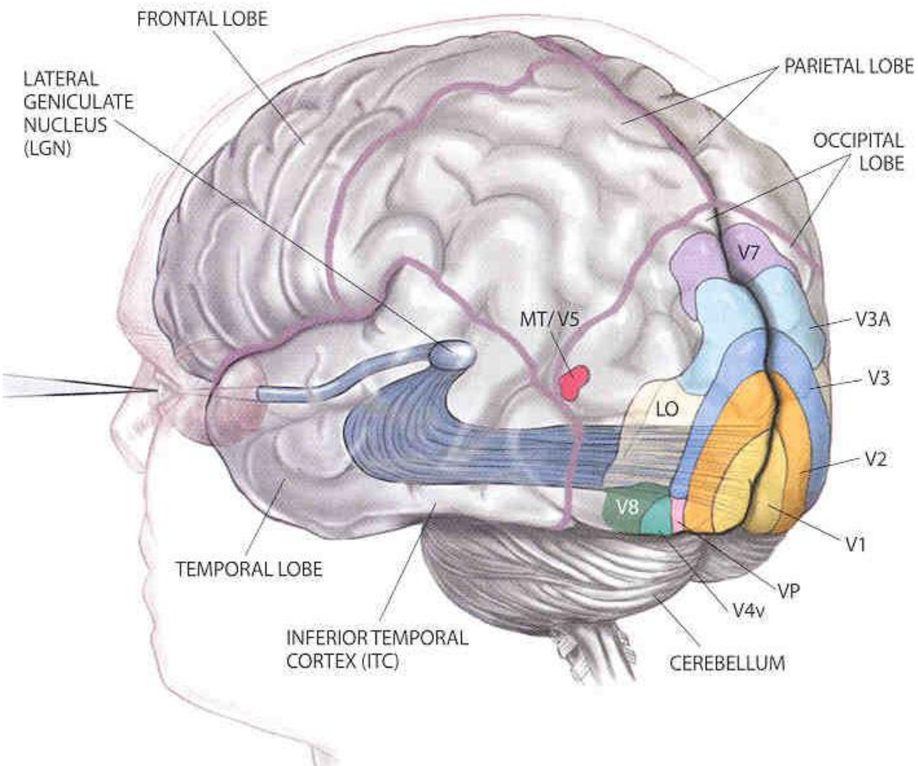
Progress check

[True/False] Because we know that the LGN receives top-down information from cortical regions, the organization of LGN *receptive fields* will differ from the ganglion cells exiting from the retina. [Explain.]

A. True

B. False

How do we get from LGN to Visual Cortex (V1)?



Destination: Occipital lobe

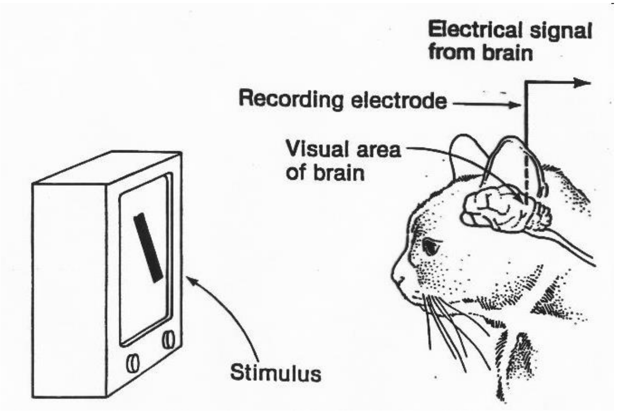
- The **optic radiation** goes from the LGN to **V1**, primary visual cortex.
- V1 has cells with the *smallest* receptive fields in the visual cortex.
- Receptive fields get more complex from here.
- Information across visual fields and eyes is now **integrated** for the first time in V1.

How are signals in V1 organized?

- In a series of papers, Hubel & Wiesel (1959) demonstrated the firing properties of cells in the striate cortex (V1).
- Using the single-cell recording method, they recorded cortical cells of anesthetized cats while presenting different stimuli.
- Received the Nobel prize for physiology and medicine in 1982.

David Hubel

Torsten Wiesel

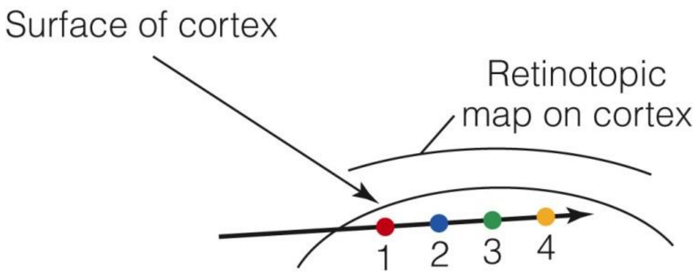


How are signals in V1 organized?

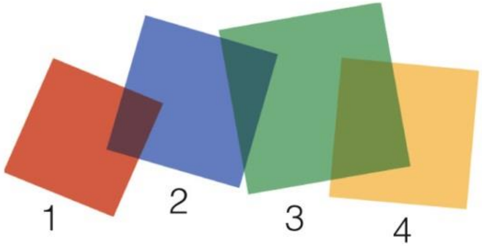
Retinotopic maps retained in the visual cortex.

Electrodes that recorded activation from a cat's visual cortex show:

- Receptive fields on the retina that are near one another are also near each other in the cortex.
- This pattern is seen using an oblique penetration of the cortex, as was done in LGN.



(a) Side view of cortex

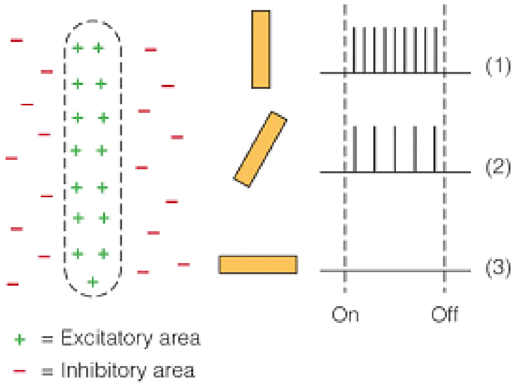


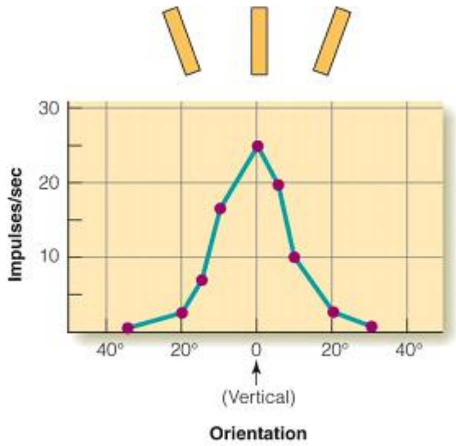
(b) Receptive field locations on retina

How are signals in V1 organized?

However, cells in the cortex respond differently than cells in retina and LGN.

- **Simple cortical cells**
  - Side-by-side receptive fields
  - Respond to spots of light
  - Respond <u>best</u> to bars of light oriented along the length of the receptive field
- **Orientation tuning curves**
  - Shows response of simple cortical cell for orientations of stimuli.
  - Cells respond best to particular orientations, and less well to others.

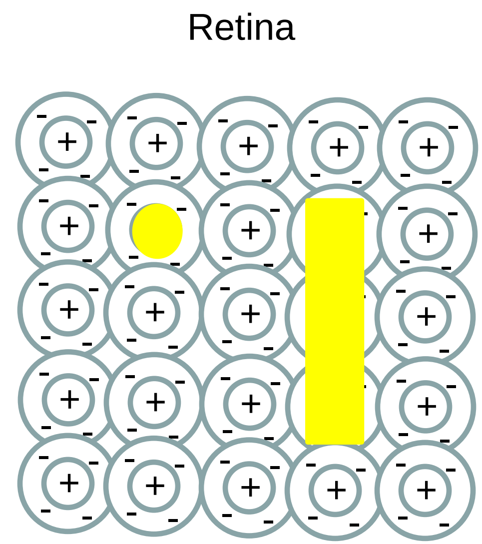


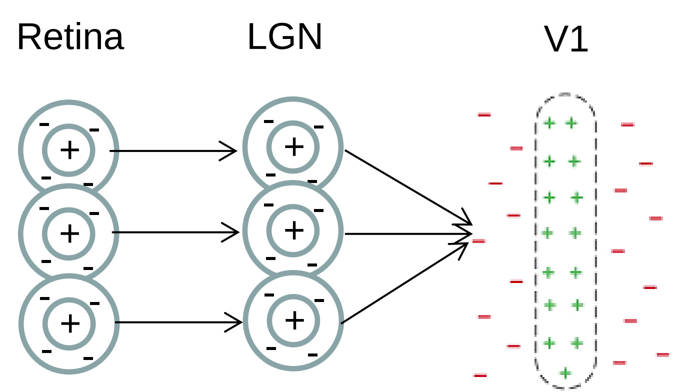


How are signals in V1 organized?

How do simple cells do this?

- Remember that cells in retina and LGN are center-surround.
- Simple cells are created by the <u>convergence</u> of LGN axons.
- Points of light will activate the simple cell; however, it is best activated by the correctly oriented bar.
- This is **hierarchical processing** – representations are built from simple receptive field and become more complex as you go ‘higher’ in cortex.

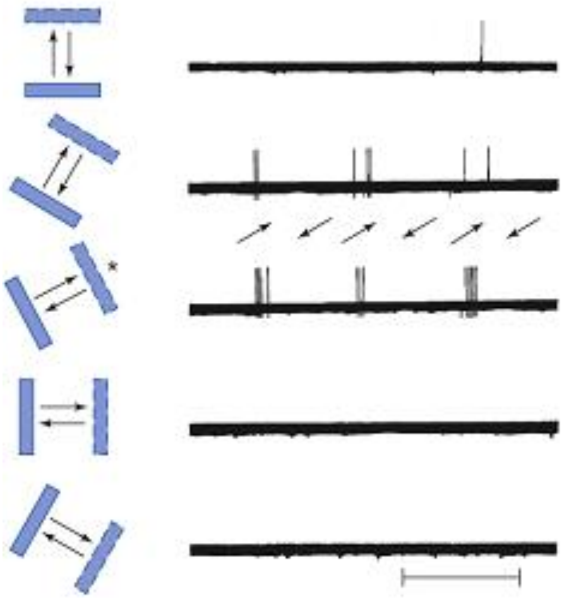




How are signals in visual cortex organized?

Complex cells in the visual cortex (V1 and V2) add greater specificity in response profile.

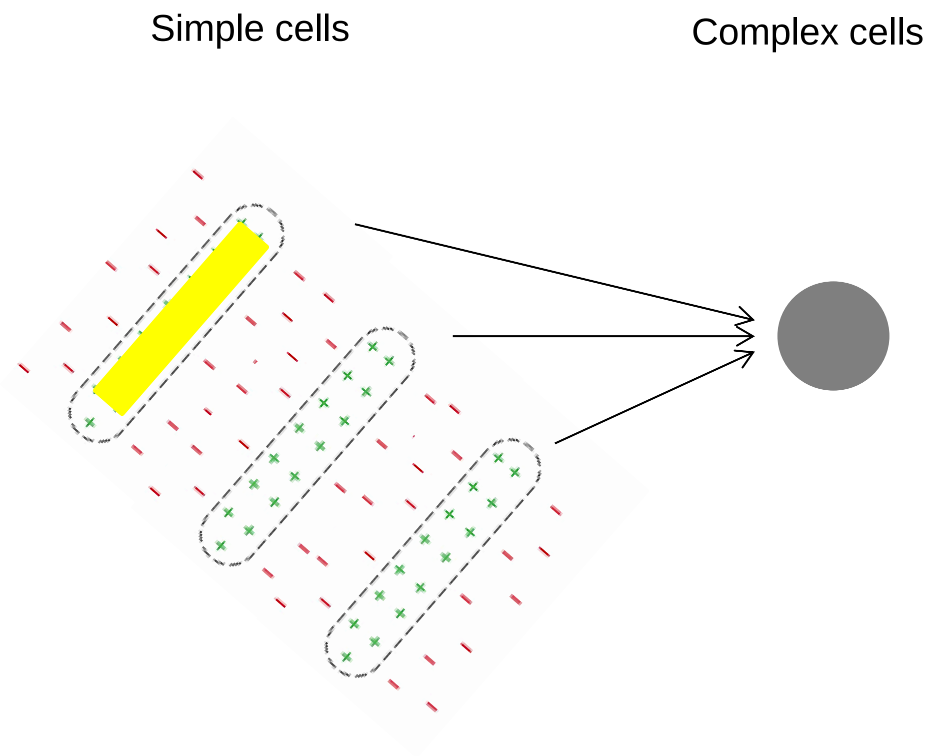
- Like simple cells, they respond to bars of light of a particular **orientation**, but…
- Unlike simple cells, they respond to **movement** of bars of light in specific direction.



How are signals in visual cortex organized?

How are complex cells activated?

- Simple cells were made by the convergence of LGN cells.
- Complex cells are made by converging simple cells (probably).

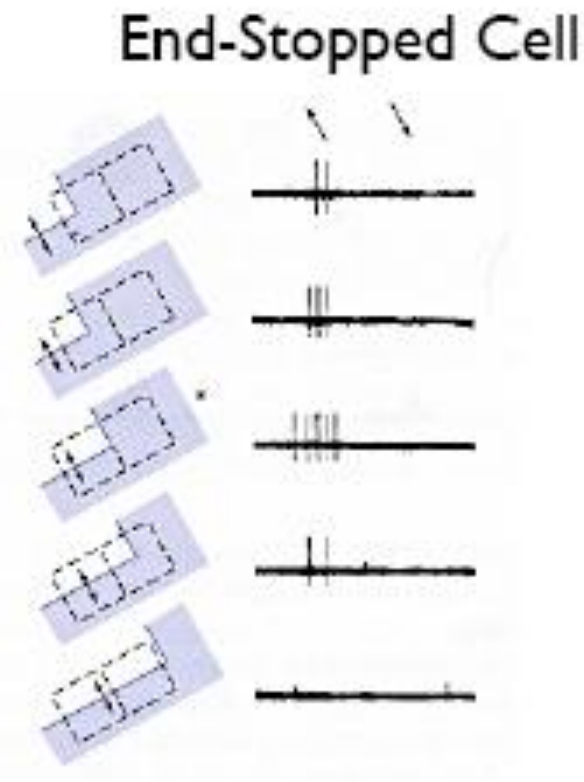


How are signals in visual cortex organized?

<u>End-stopped cells</u> are even more specific:

- Respond to:
  - Moving lines of <u>specific length</u>
  - Moving corners or angles

- No response to:
  - Stimuli that are too long
  - Stimuli moving in the wrong direction

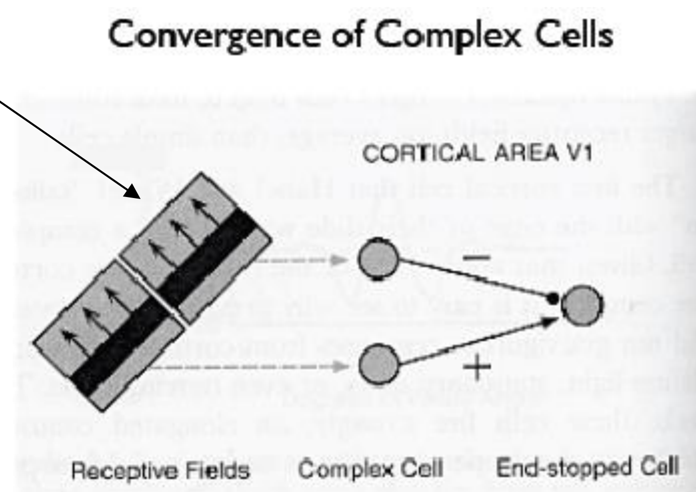


How are signals in visual cortex organized?

How are end-stopped cells formed?

– Made by converging signals from complex cells within striate cortex (V1).

Edge of
receptive
field



Palmer (1999) *Vision Science*

How are signals in visual cortex organized?

V1 Cells as <u>feature detectors</u>

- Cells that are **feature detectors**:
  - Simple cortical cell
  - Complex cortical cell
  - End-stopped cortical cell
- These neurons fire to specific features of a stimulus. [Think of these as object edge detectors.]
- Neurons farther along in the visual pathway fire to more complex stimuli in a hierarchical manner.
- Good to know for the exam.

TABLE 4.1 Properties of Neurons in the Optic Nerve, LGN, and Cortex

TYPE OF CELL	CHARACTERISTICS OF RECEPTIVE FIELD
Optic nerve fiber (ganglion cell)	Center-surround receptive field. Responds best to small spots, but will also respond to other stimuli.
Lateral geniculate	Center-surround receptive fields very similar to the receptive field of a ganglion cell.
Simple cortical	Excitatory and inhibitory areas arranged side by side. Responds best to bars of a particular orientation.
Complex cortical	Responds best to movement of a correctly oriented bar across the receptive field. Many cells respond best to a particular direction of movement.
End-stopped cortical	Responds to corners, angles, or bars of a particular length moving in a particular direction.

Page 66

How are signals in visual cortex organized?

Progress check

You get the results of a single-cell experiment and note that responses were *best* to moving, horizontal bars of light of any length. You deduce that the neuron was most probably:

A. A cell in LGN

B. A simple cell

C. A complex cell

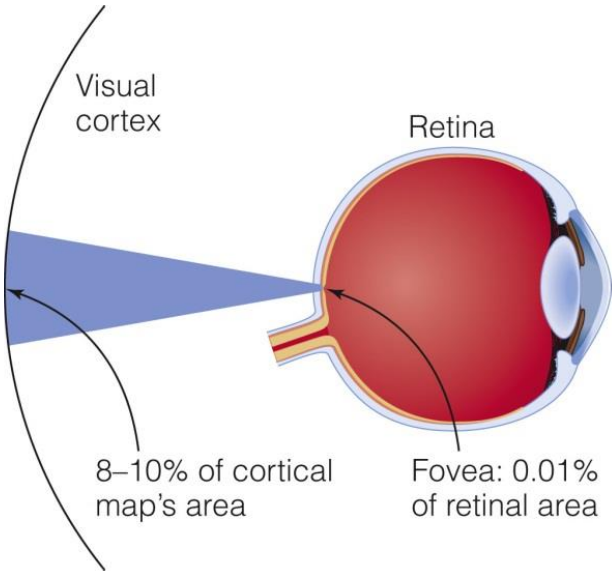
D. An end-stopped cell

E. Need more information

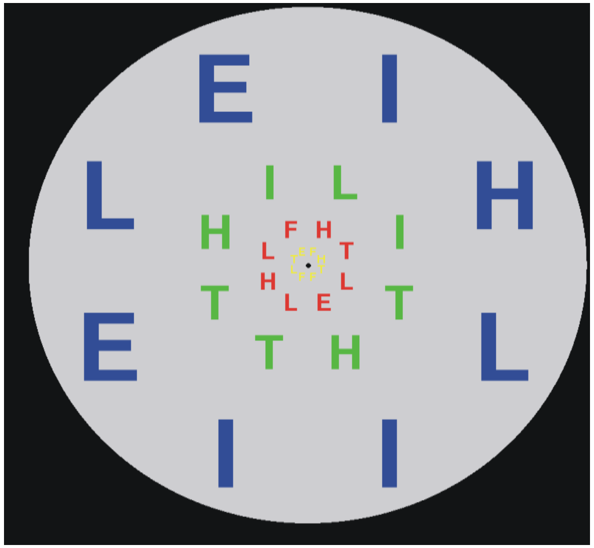
Maps in striate visual cortex

Using functional magnetic resonance imaging (fMRI), it has been found that the fovea has greater representation in the striate cortex (V1) than proportionally anticipated.

- Fovea accounts for .01% of retina
- Signals from fovea account for 8% to 10% of the visual cortex
- This provides additional processing for high-acuity tasks.
- This is called the **cortical magnification factor.**



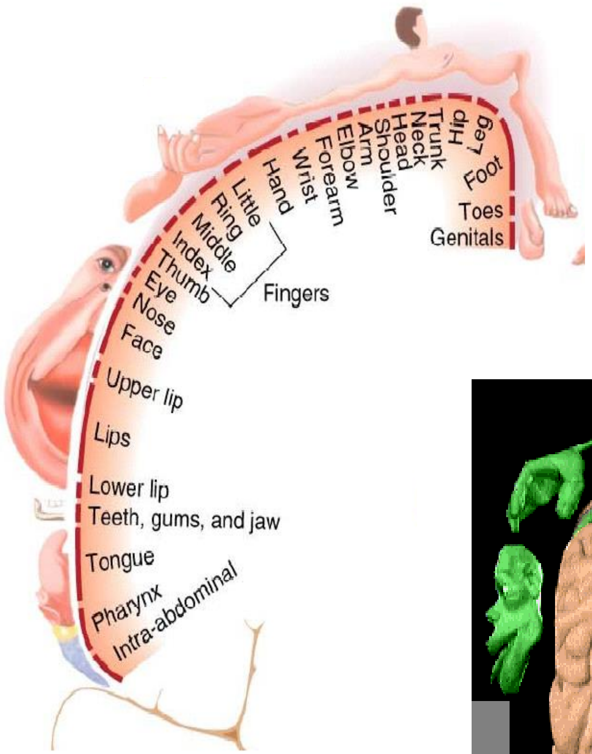
Maps in striate visual cortex



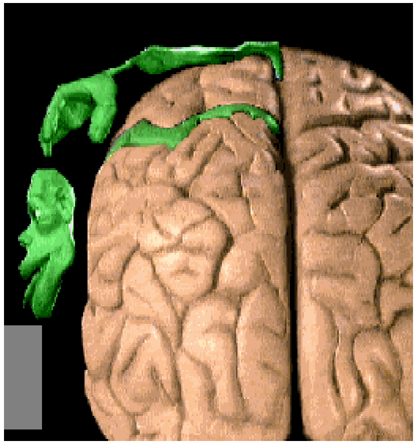
Cortical magnification factor

- Items in the center of foveal vision will have greater representation in V1.
- This facilitates greater acuity for detail and feature processing.
- More cortical processing for areas of greater functional importance.

Maps throughout the brain



We will see that **cortical magnification factor** also applies to other senses, such as somatosensory (body maps).



Cell responses and perception

We have seen, via single-cell recordings, that individual V1 cortical cells (feature detectors) will respond to specific stimuli. But does our perception match the cellular response?

Do the levels of analysis connect?

We can use the phenomenon of **selective adaptation** to help construct a psychophysics experiment to test the connection between feature detector response and perception.

Cell responses and perception

Selective adaptation

- Neurons tuned to specific stimuli (features) fatigue when exposure is long.
- Fatigue or **adaptation** to stimulus results in two main effects:
  - The neural firing rate will decrease.
  - The same neurons will fire less when a similar stimulus is immediately presented again.
- “Selective” means that only those neurons that respond to *the specific stimulus* will adapt (i.e. change firing rate).

Cell responses and perception

Selective adaptation procedure:

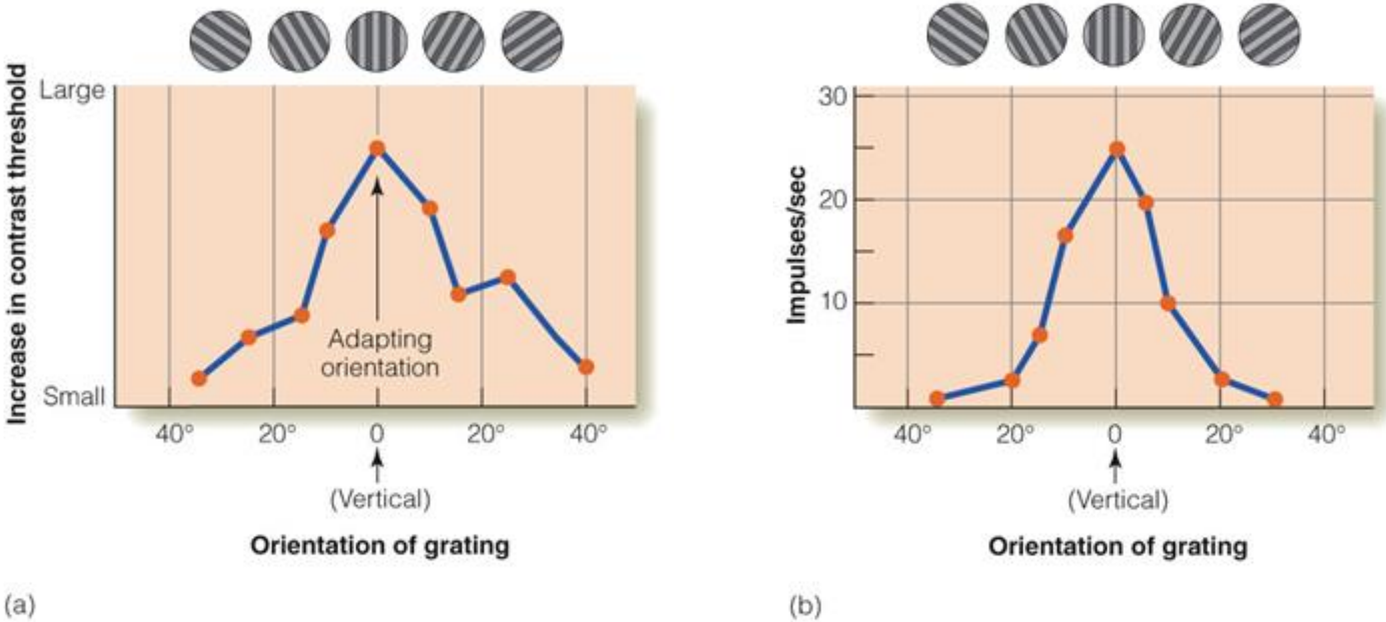
- Measure sensitivity to range of one stimulus characteristic (i.e. contrast of vertical bars).
- Adapt to that characteristic by extended exposure (1-2 min.)
- Re-measure the sensitivity to range of the stimulus characteristic (how much more contrast needed for detection?)


(a) Measure contrast threshold at a number of orientations.

Gratings begin with a certain contrast

Cell responses and perception

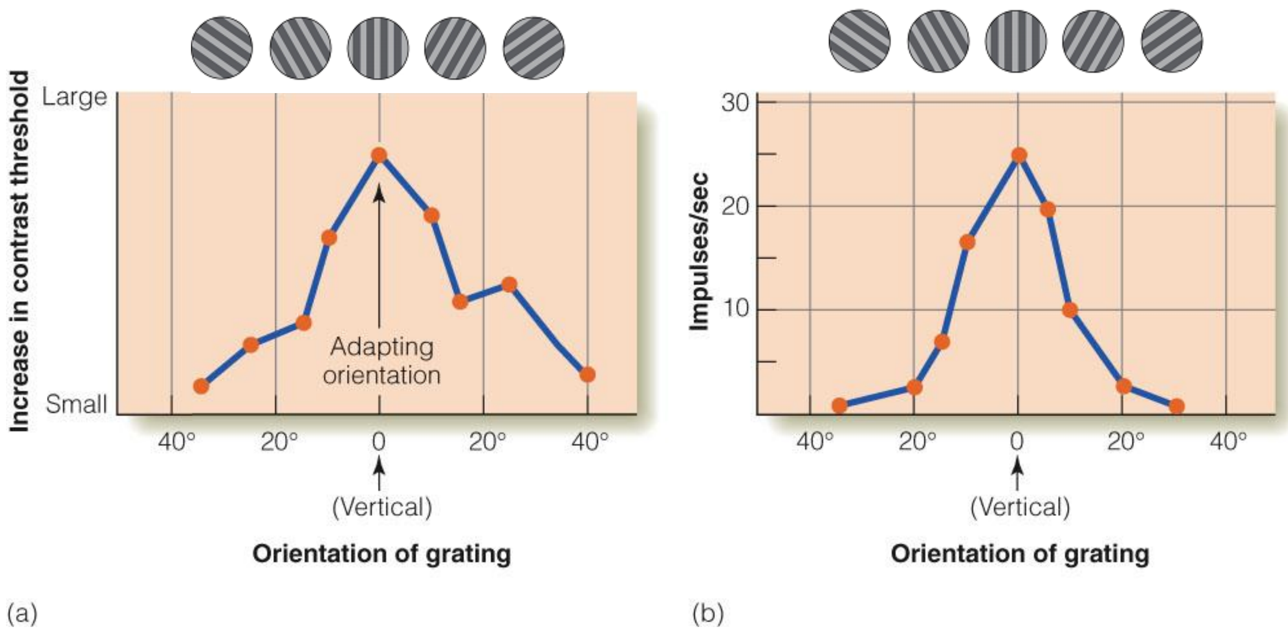
- Psychophysical curve should show selective adaptation for specific orientation if neurons are tuned to this characteristic.
- Recording from the same neuron (right) while responding to gratings of different orientations gives us a *tuning curve* for that cell.



Change in *perceptual* sensitivity (left) matches the selectivity of *neurons* (right).

Cell responses and perception

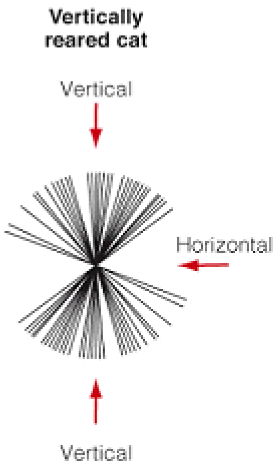
This psychophysics experiment (Marr's computational **level 1**) shows that perception matches the cellular firing patterns seen in single-cell recordings (Marr's implementation **level 3**).



Cell responses and perception

Experience dependent plasticity

- Animals are reared in environments that contain only certain types of stimuli.
  - Neurons that respond to these stimuli will become more predominate due to neural plasticity.
  - Blakemore and Cooper (1970) showed this by rearing kittens in tubes with either horizontal for vertical lines.
  - Both behavioral and neural responses showed the development of neurons specific to the environmental stimuli (and absence of cells responded to opposite orientation).
  - Early experience affects later processing abilities.



Summary

- Most signals from the retina go to the LGN. 40% go onward to visual cortex.
- The information stays spatially segregated and organized. **[retinotopic mapping]**
- Receptive fields are largely center-surround until V1, where features are represented. From there they get more complex. **[hierarchical processing]**
- **Selective adaptation** gives us a means of testing feature selectivity at the psychophysical level.

Next time

- Lab 2 in section
- Read chapter 9