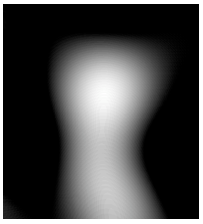
Functional anatomy

PSY 310

Greg Francis



Lecture 06

That's my daughter!

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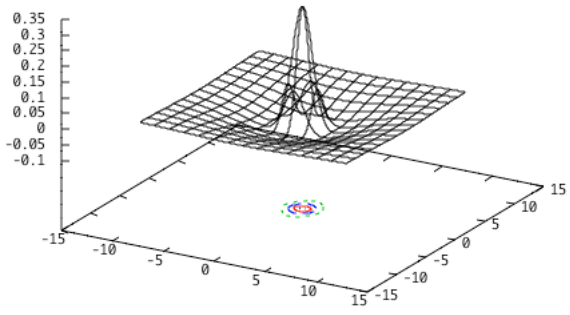
Difference of Gaussians

- Model of ganglion cell receptive fields

$$G(x,y) = \frac{1}{\sigma_c\sqrt{2\pi}} e^{-(X^2+Y^2)/2\sigma_c^2} - \frac{1}{\sigma_s\sqrt{2\pi}} e^{-(X^2+Y^2)/2\sigma_s^2}$$



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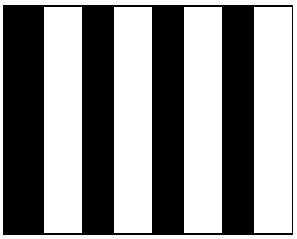
Difference of Gaussians

- What do we do with such a model?
- Describe a spatial pattern of light mathematically
  - I(x,y)

$$I(x,y) = L + C\text{sgn}(\sin(kx))$$



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Difference of Gaussians

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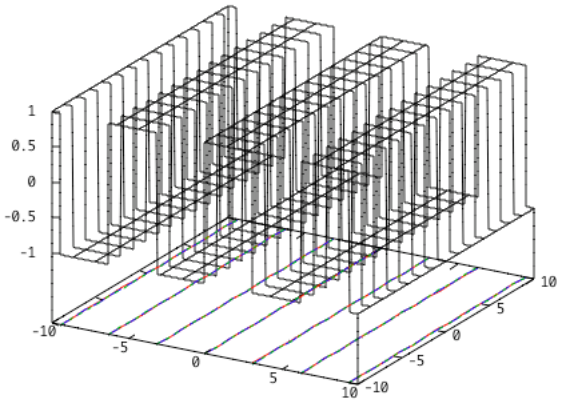

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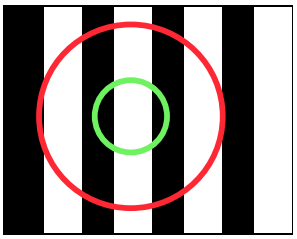
Cell response

- The receptive field of the cell "weights" the light input
  - Multiply point by point
  - Add up across all points

$$\sum_x \sum_y I(x,y)G(x,y)$$



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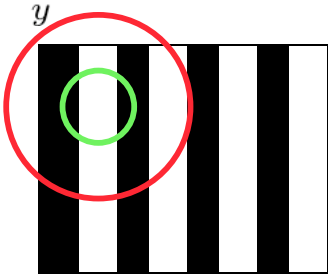
Cell response

- Strength of response depends on position of receptive field relative to stimulus

$$\sum_x \sum_y I(x,y)G(x,y)$$



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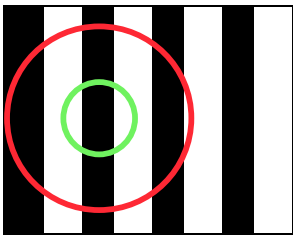

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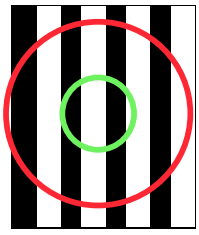
Cell response

- Strength of response depends on the spacing of the bars

$$\sum_x \sum_y I(x,y)G(x,y)$$



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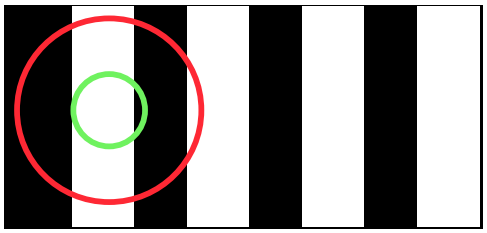

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Model behavior

- Try bar gratings of many different frequencies
- Set parameters to match real ganglion cells
- Dots are for a real cell
- Blue line is model

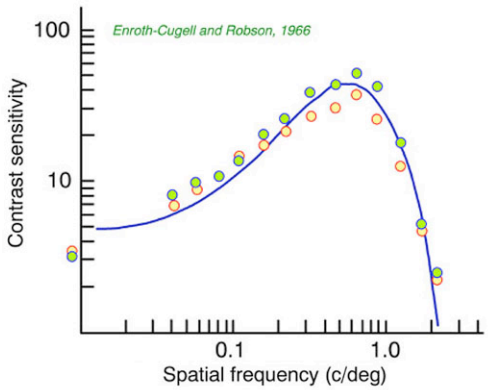

Fig. 8. Contrast sensitivity function of cat retinal ganglion cell. Green and yellow symbols are the data generated with vertical and horizontal patterns respectively, showing a symmetry of size sensitivity (Enroth-Cugell and Robson, 1966).

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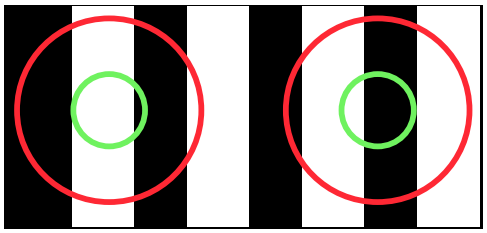
Cell response

- Of course, there is more than one ganglion cell
- Multiple cells with different centers



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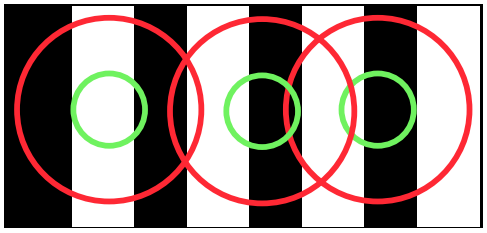
Cell response

- Of course, there is more than one ganglion cell
- Multiple cells with different centers
- And they overlap



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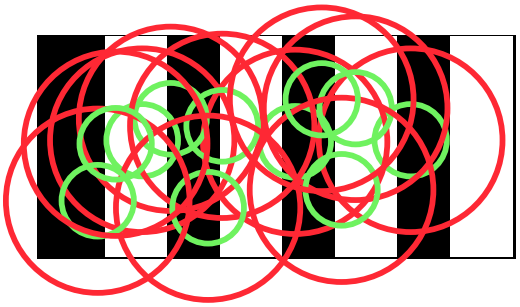
Cell response

- Of course, there is more than one ganglion cell
- Multiple cells with different centers
- And they overlap
- A lot!



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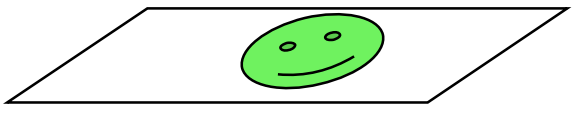
Layers

- It helps to think of each stage of the visual system as a kind of “plane of activity”

Image



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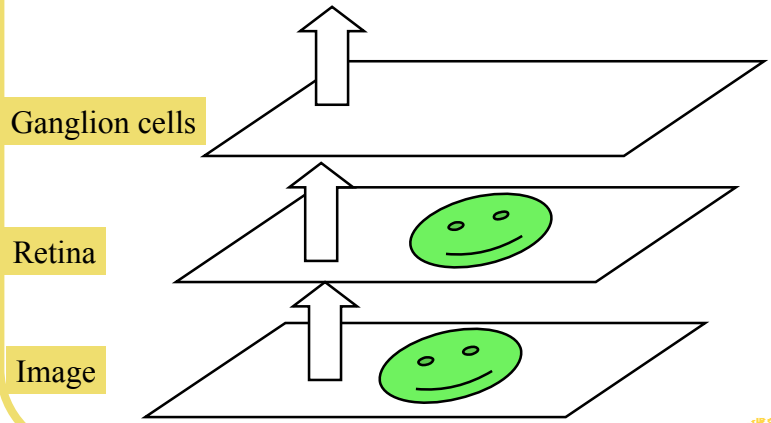
Layers

- It helps to think of each stage of the visual system as a kind of "plane of activity"



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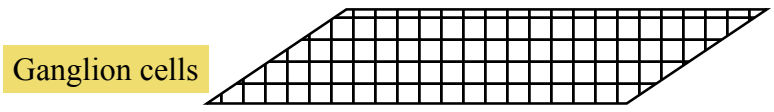
Layers

- Each ganglion cell has a center to its receptive field
  - On the retina
- We'll let that indicate the "pixel position" of the ganglion cell in the plane
- We'll let the response (number of action potentials) of the ganglion cell indicate the "intensity" of a picture we'll draw on the plane
- This gives us a way of understanding what the neurons are doing



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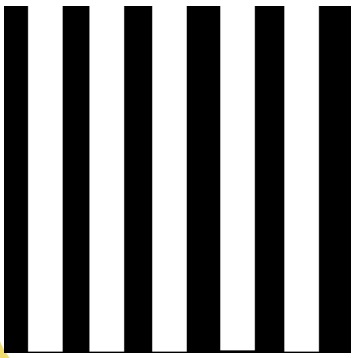
Receptive field

- So, if you have a bar grating as an image



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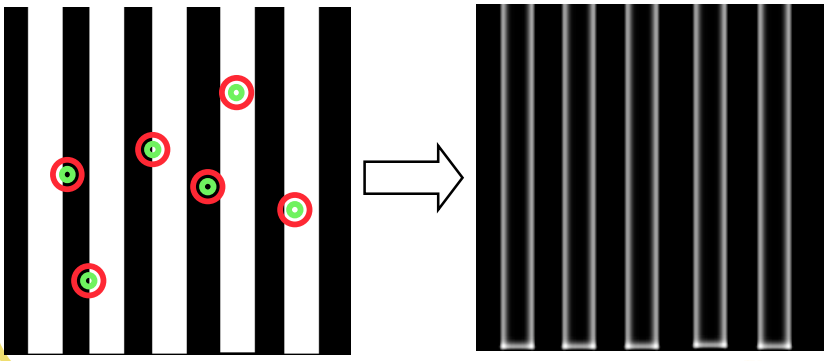
Receptive field

- So, if you have a bar grating as an image
  - Suppose the receptive fields are small relative to the thickness of the bars



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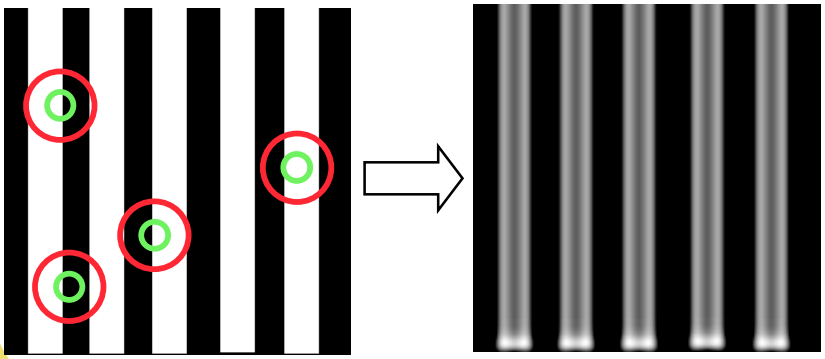
Receptive field

- So, if you have a bar grating as an image
  - If the receptive fields are a bit bigger



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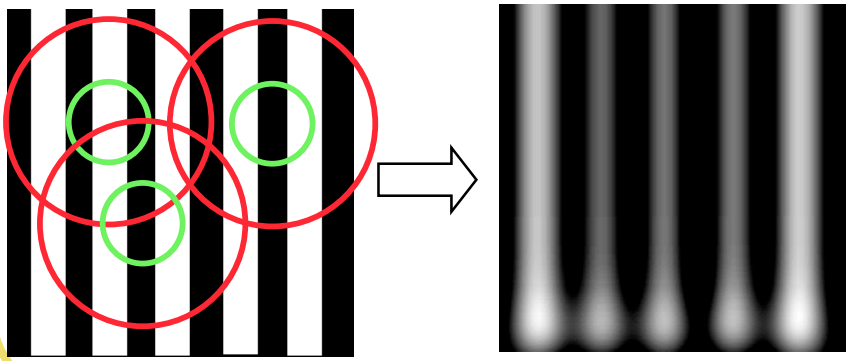
Receptive field

- So, if you have a bar grating as an image
  - If the receptive fields are a lot bigger



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Brightness perception

- The properties of ganglion cells seem to be related to several interesting aspects of brightness perception
- How bright is a region that you are looking at?
- Brightness contrast

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Brightness perception

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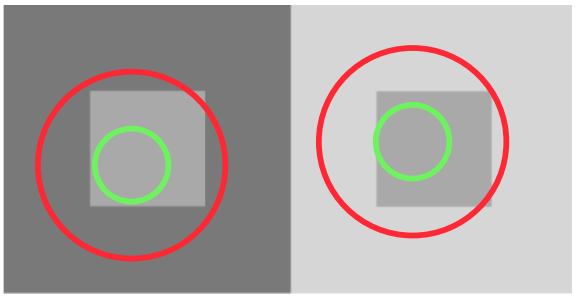

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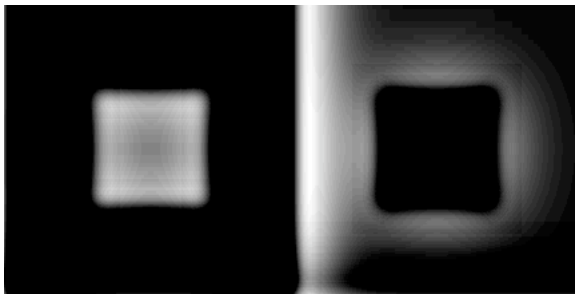
Brightness perception

- Ganglion cell responses show differences that are similar to our percepts



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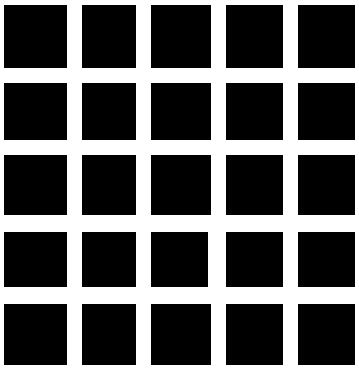
Brightness perception

- Hermann grid



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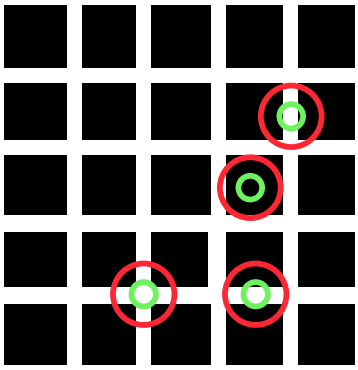
Brightness perception

- Hermann grid
- With receptive fields about this size…
  - More surround inhibition at intersections



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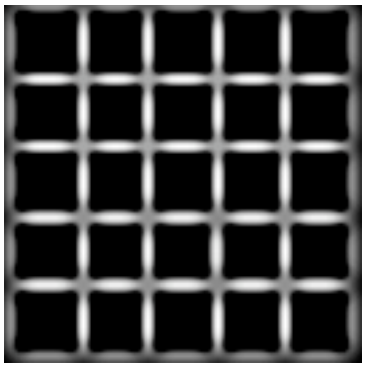
Brightness perception

- Hermann grid
- You get weaker responses at the intersections



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Implications

- For ganglion cells to provide an explanation of these brightness illusions you can to assume
  - The brightness percept can be related to the responses of these cells and not cells with different sized receptive fields
  - The rest of the visual system (e.g., the brain) doesn't muck up things
- Notice that many cells do not respond well to homogeneous light that covers the whole receptive field
  - Inhibition balances out excitation

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An image like this

- With lots of details

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An image like this

- Is treated like this by ganglion cells that are quite small

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An image like this

- Is treated like this by ganglion cells that are fairly large

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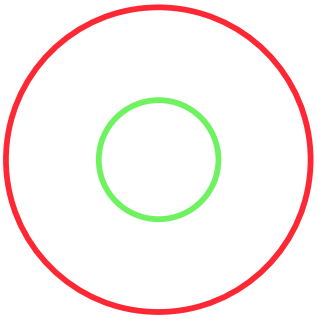
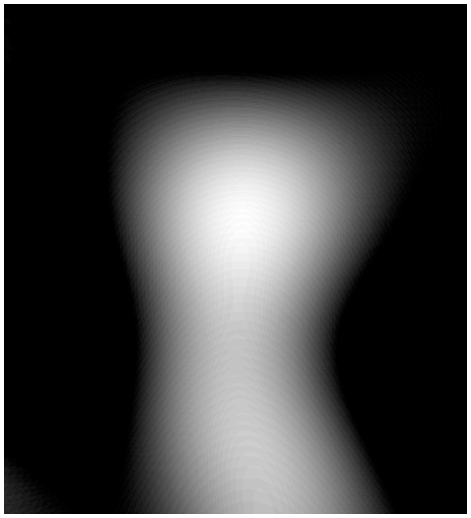
An image like this

- Is treated like this by ganglion cells that are very large





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Which is the percept?

- None of these response patterns seem to match our percept
- Clearly the brain must somehow combine the information in a significant way

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Conclusions

- Ganglion cells
- Center-surround receptive fields
- They respond well to edges
- Parse the retinal pattern in a peculiar way
- Accounts for some brightness illusions
- Other parts of the brain are necessary for perception

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Next time

- Visual cortex
- Orientation sensitive cells
- Decomposing the visual image

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