

Cognitive (Neuro) Psychology

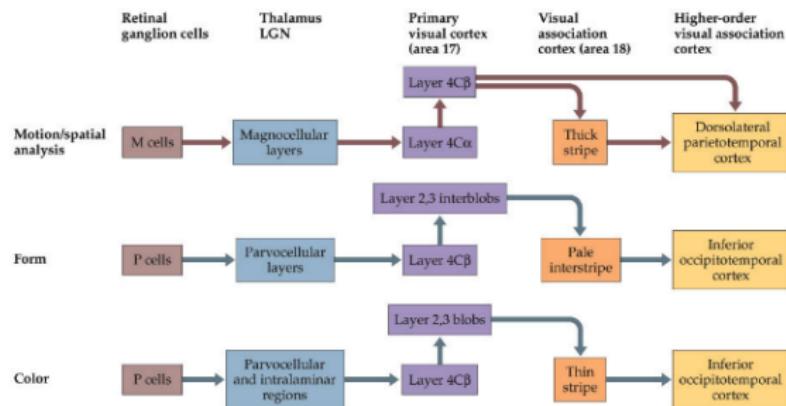
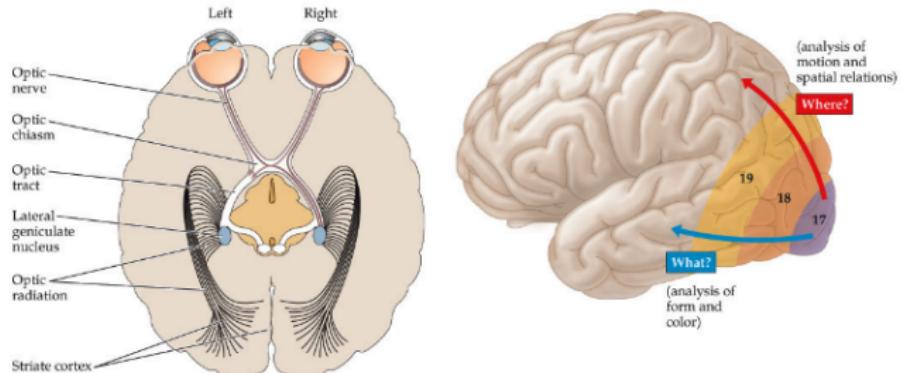
III. Pattern vision

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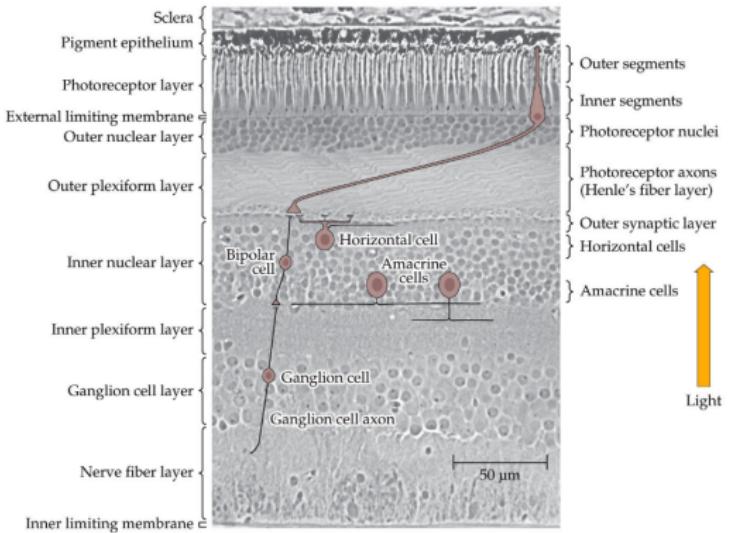
July 2016

Cortical visual pathways



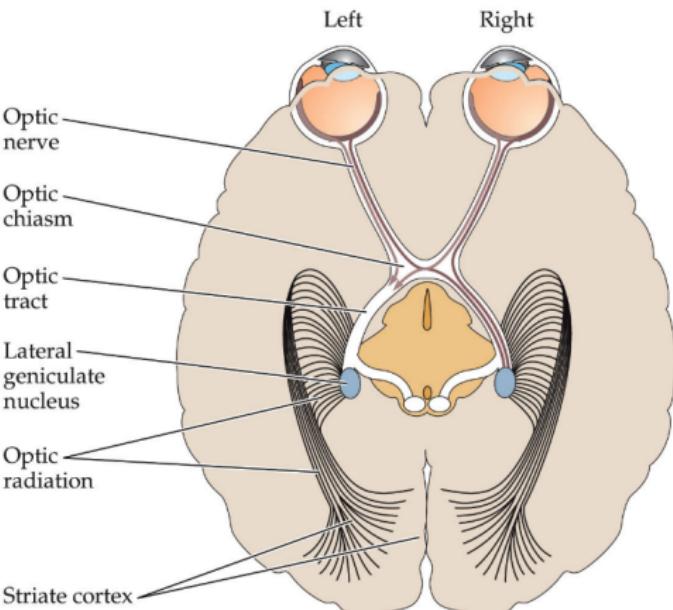
Path of image processing: eye to brain

- eye



Path of image processing: eye to brain

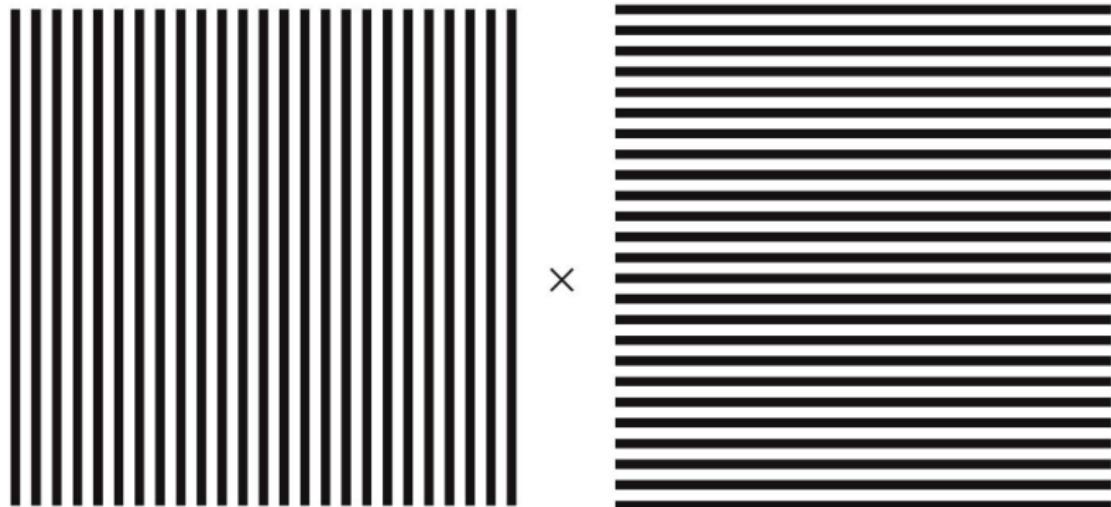
- eye
- lateral geniculate nucleus LGN
- primary visual cortex V1



Overview

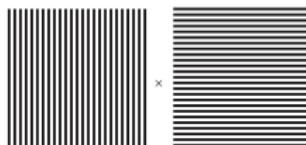
- Acuity limits in human vision: resolution & contrast
- Properties of cells along the path of visual information processing
- Adaptation as a non-invasive tool to study specificity in human vision

Basic visual functions: Acuity



Acuity: the smallest spatial detail that can be resolved

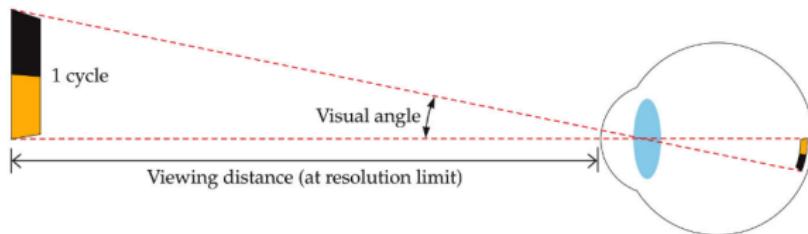
Basic visual functions: Acuity



Acuity: the smallest spatial detail that can be resolved

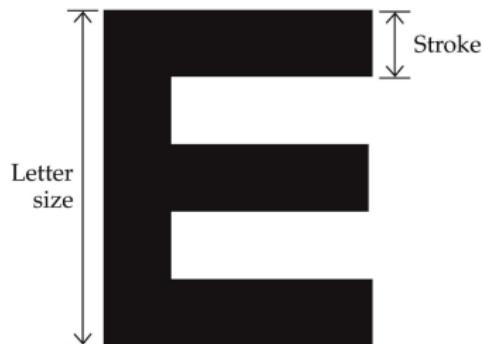
How to measure acuity?

- Vision scientists: **visual angle** subtended by one cycle of the grating
- one cycle is one black and one white bar
- $\text{atan}(\frac{\text{size}}{\text{distance}}) = \text{atan}(\frac{2\text{mm}}{6500\text{mm}}) = .017$



How to measure acuity?

- Eye doctors: **Snellen** test
- uses distance to characterize acuity
- "20/20 vision" your distance/normal vision distance



SENSATION & PERCEPTION 2e, Figure 3.5

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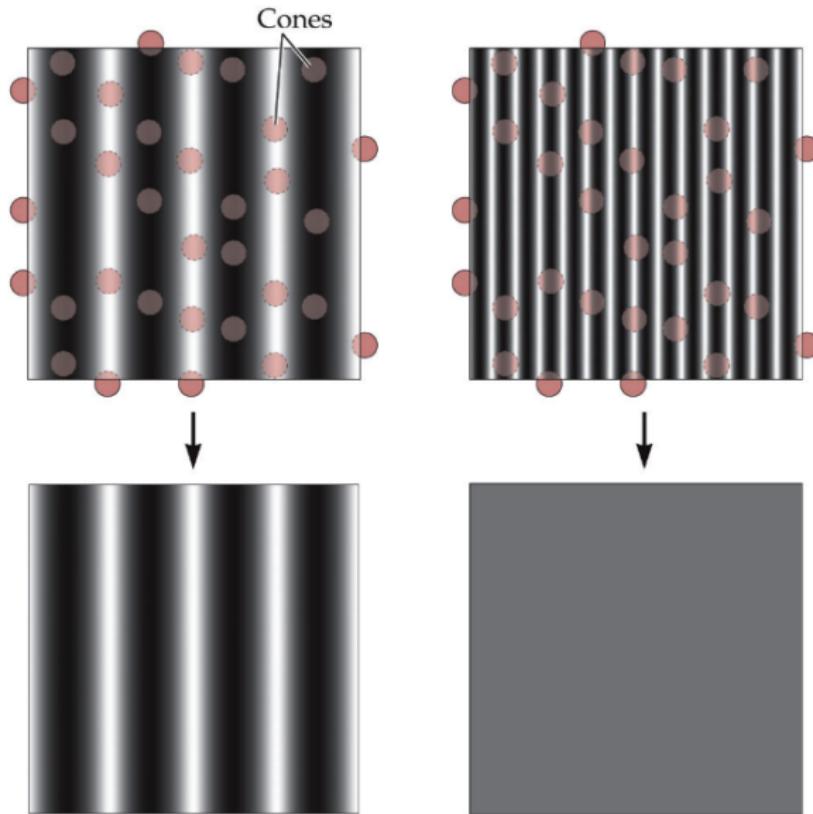
Activity

Go to the following web page

<http://sites.sinauer.com/wolfe4e/wa03.01.html>
and go through the activities

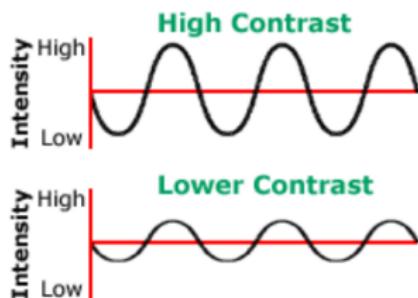
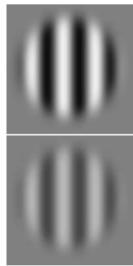
- What is visual angle
- The moon and the sun
- A visual angle illusion

Limits for resolution acuity

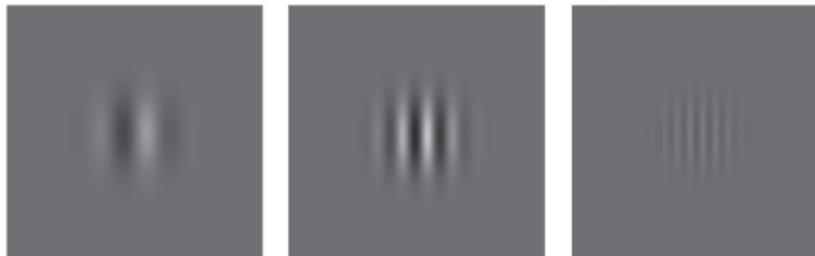


Factors influencing acuity limits

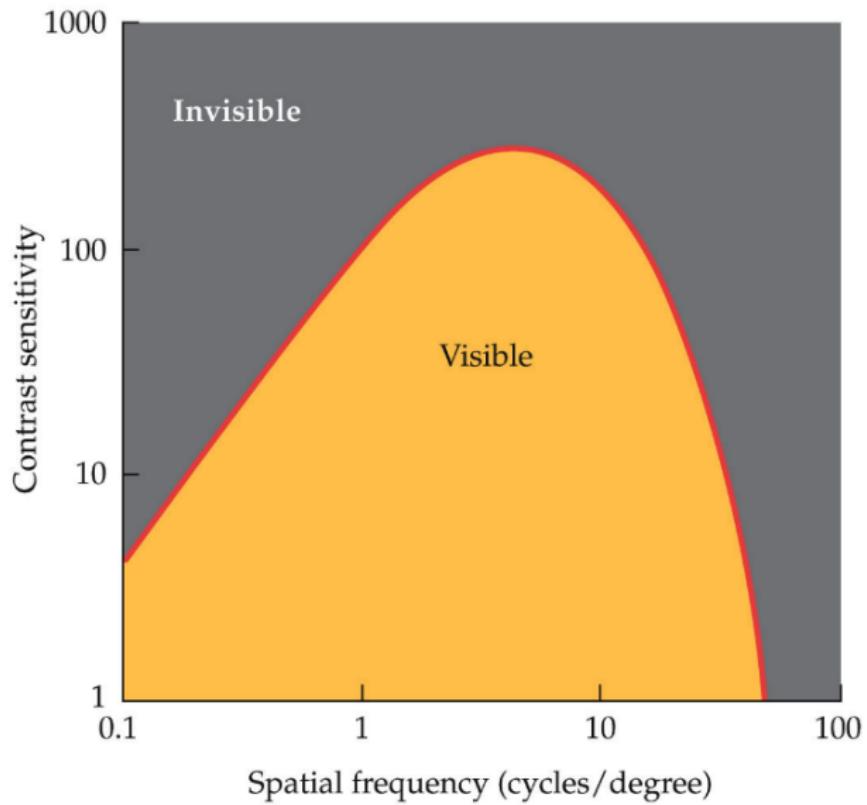
- Contrast: difference in luminance between object and background



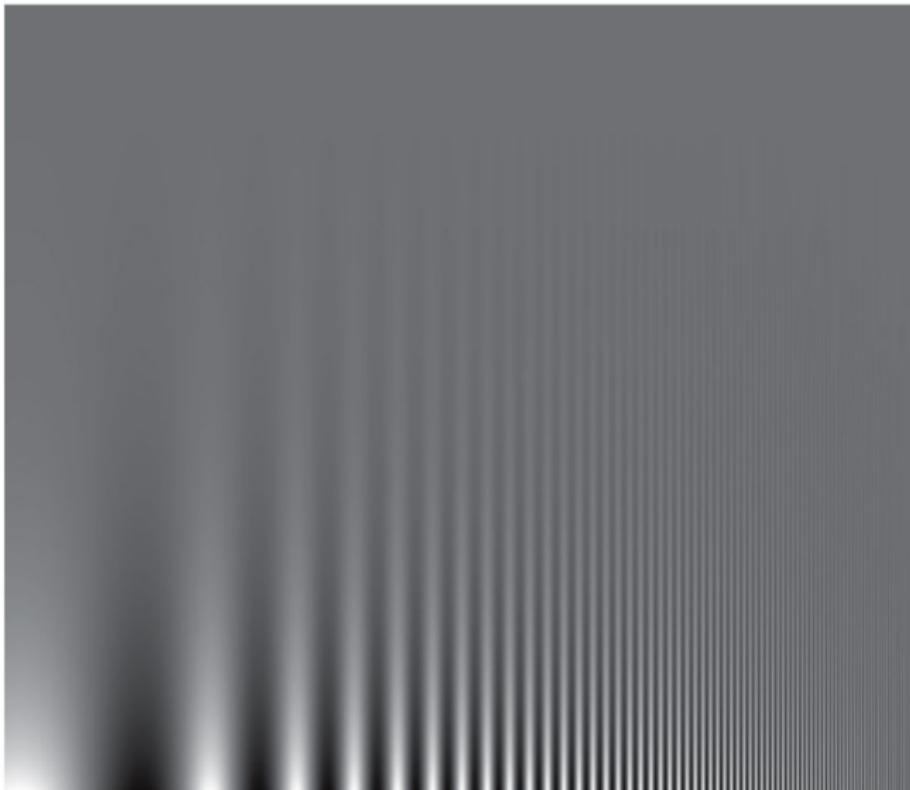
- Spatial frequency: number of cycles in a unit of space



Contrast Sensitivity Function - CSF



Contrast Sensitivity Function - CSF

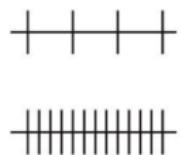
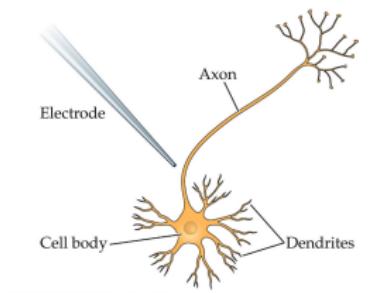
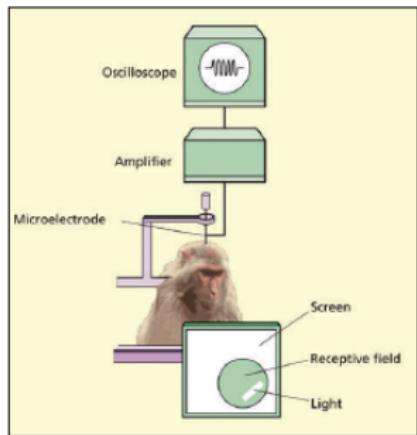


Contrast Sensitivity Function - CSF

Visibility depends on spatial frequency and contrast of a grating.

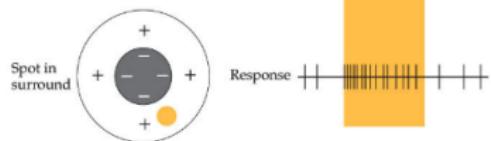
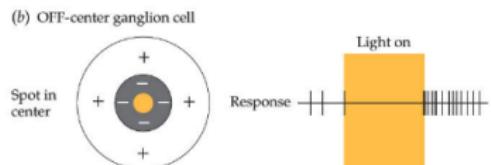
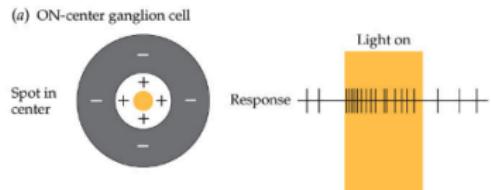
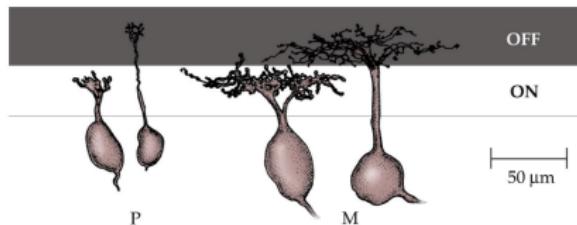
Detour - single cell recordings

- recordings of action potentials in monkeys
- “spike” counts

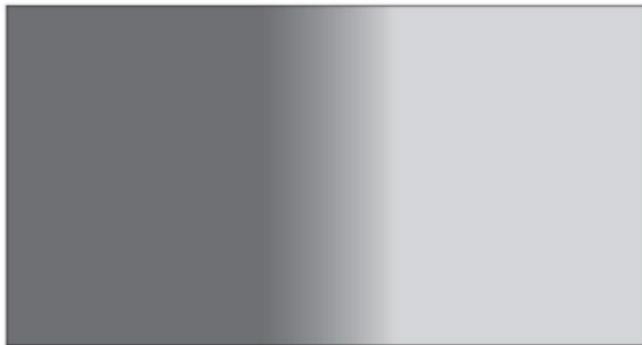


Receptive fields of retinal ganglion cells

- concentric layout of ganglion cells' receptive fields
- act as **filter** by editing information sent on to the brain
- most sensitive to differences

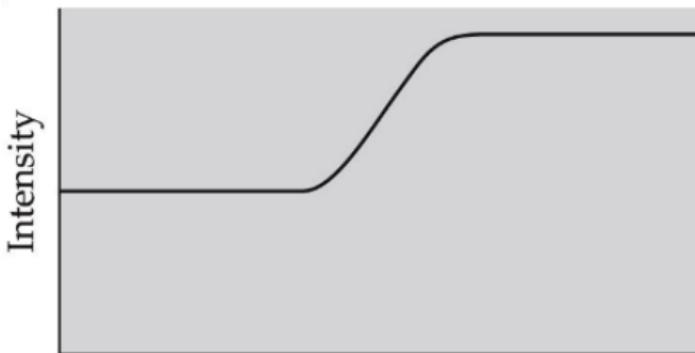


Retinal ganglion cells enhance edges

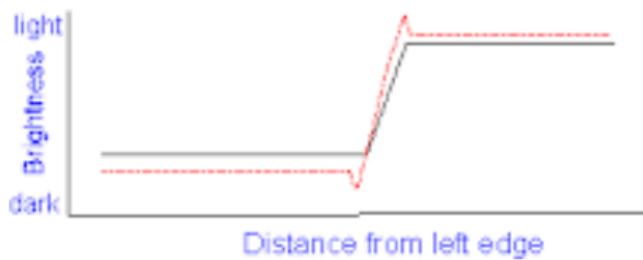
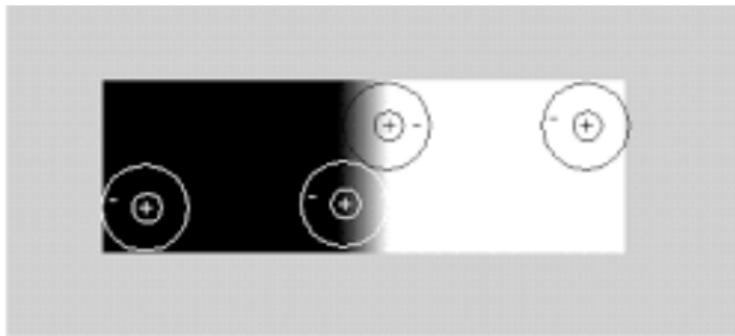


D B

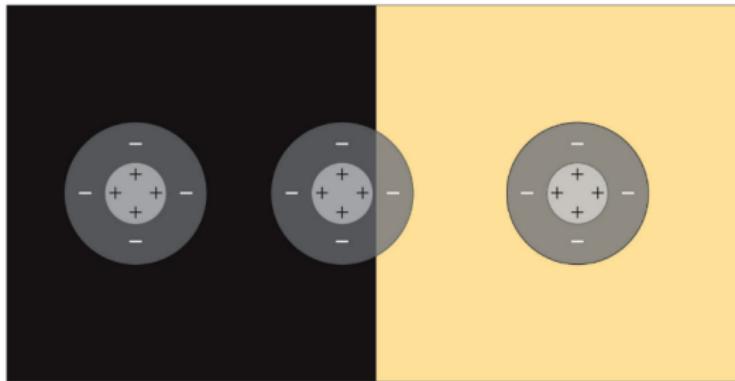
↑ ↑

Two small black arrows pointing upwards, labeled 'D' and 'B' respectively, indicating the positions of the dark and bright edges in the image above.

Retinal ganglion cells enhance edges



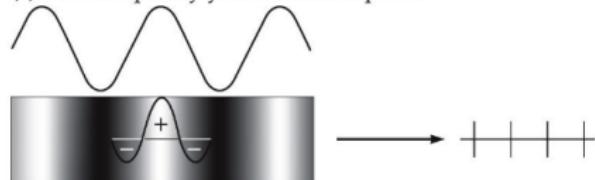
Retinal ganglion cells enhance edges



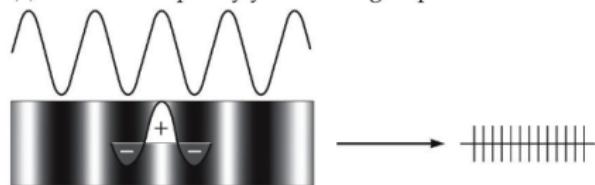
Retinal ganglion cell responses to stripes

- sensitivity to spatial frequency

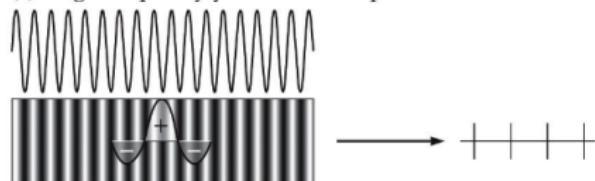
(a) Low frequency yields weak response



(b) Medium frequency yields strong response



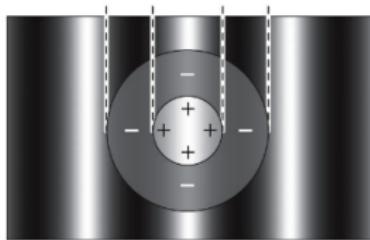
(c) High frequency yields weak response



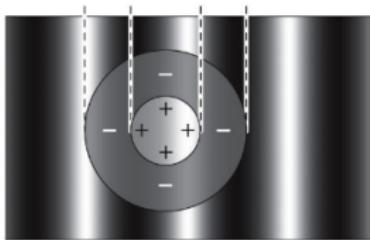
Retinal ganglion cell responses to stripes

- sensitivity to spatial phase

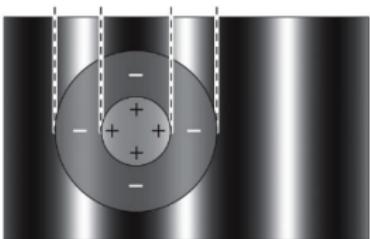
(a) 0° – Positive response



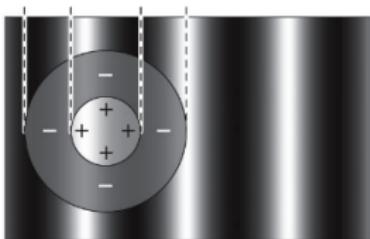
(b) 90° – No response



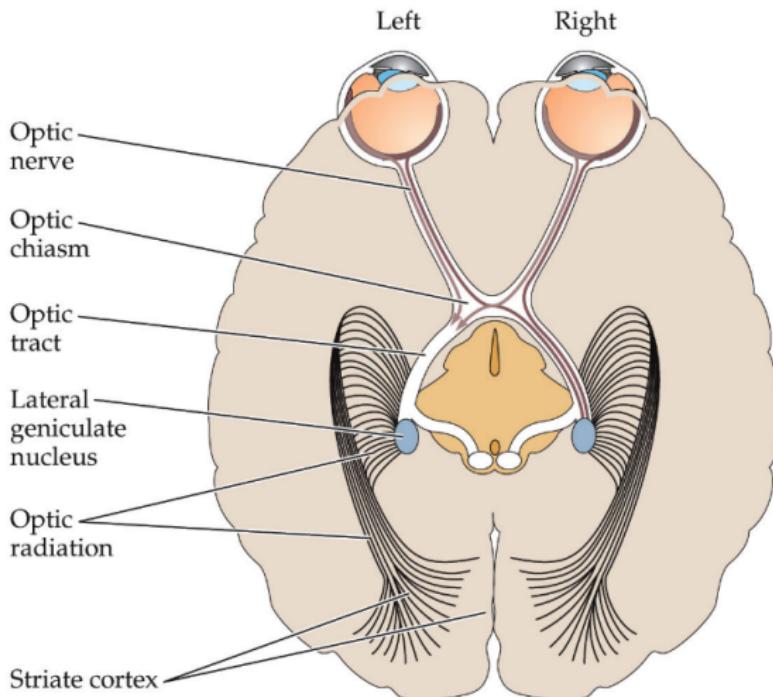
(c) 180° – Negative response



(d) 270° – No response

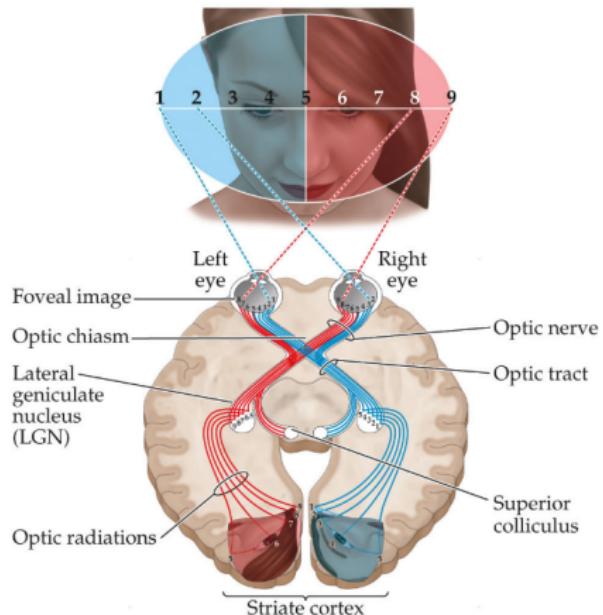


Down the visual pathway



The Primary Visual Cortex - V1

- Topography and magnification



The Primary Visual Cortex - V1

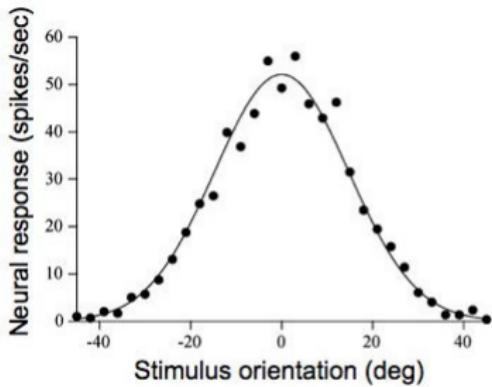
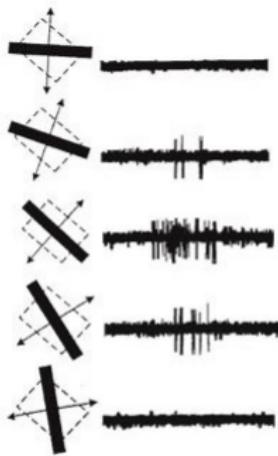
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Activity

Go to the following web page

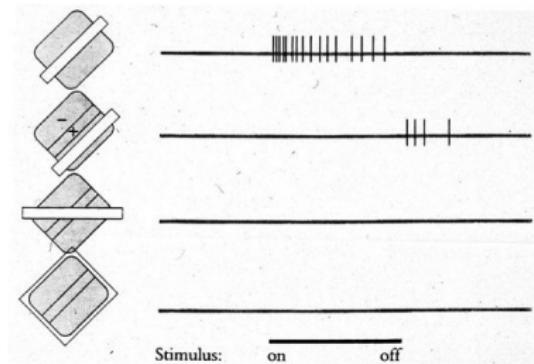
<http://sites.sinauer.com/wolfe4e/wa03.02.html>
and go through the activity

V1 neurons are orientation selective



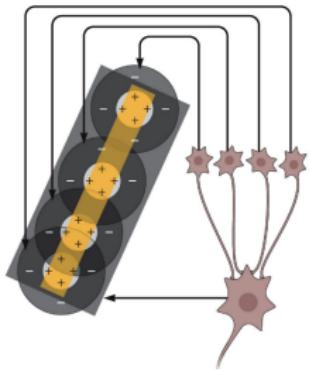
Hubel & Wiesel, 1968

V1 simple cells



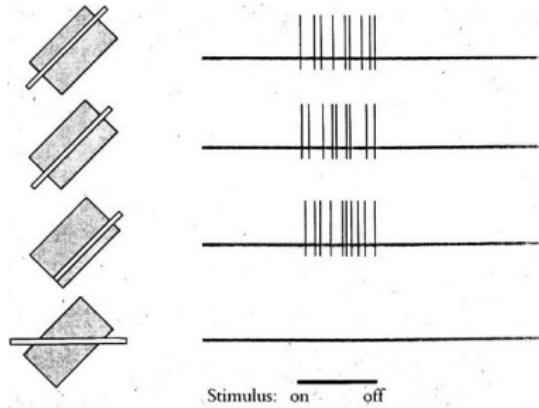
- respond best to elongated bars
- are orientation selective
- have separate ON and OFF subregions
- perform length summation (bigger responses with increasing bar length up to some limit)

V1 simple cells



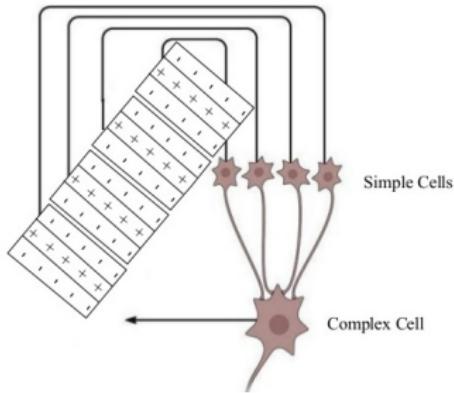
- respond best to elongated bars
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V1 complex cells



- are orientation selective
- have spatially homogeneous receptive fields (no separate ON/OFF subregions).
- perform length summation

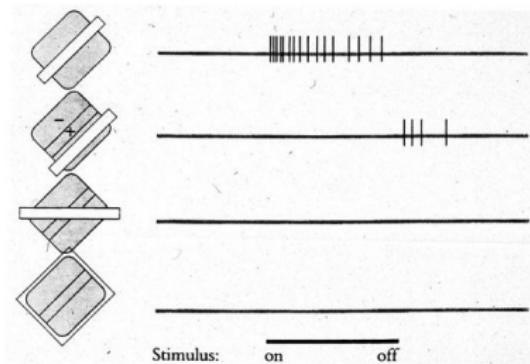
V1 complex cells



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Simple and complex cells in V1

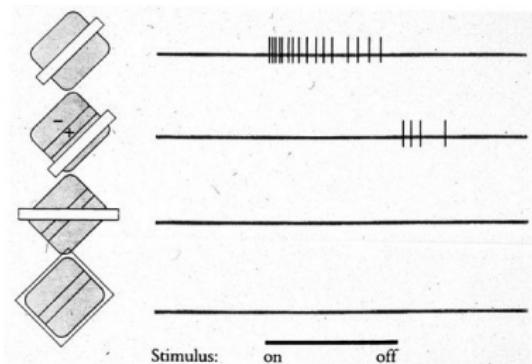
Simple



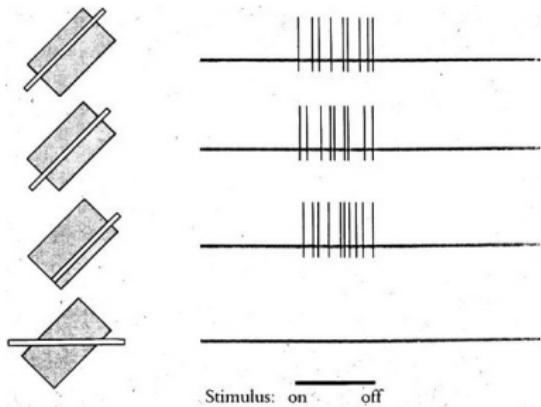
Complex

Simple and complex cells in V1

Simple

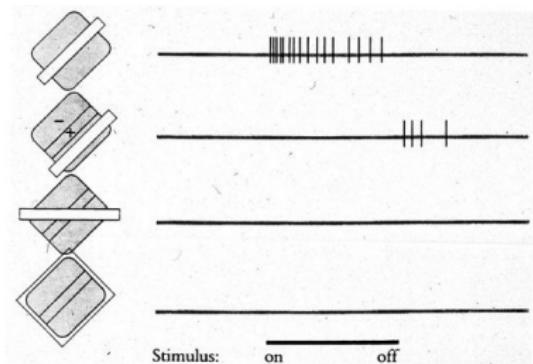


Complex

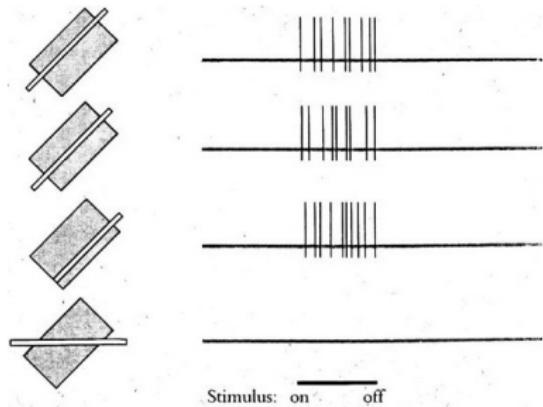


Simple and complex cells in V1

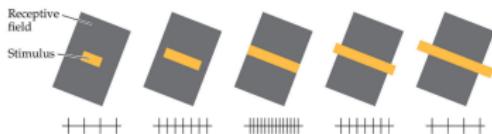
Simple



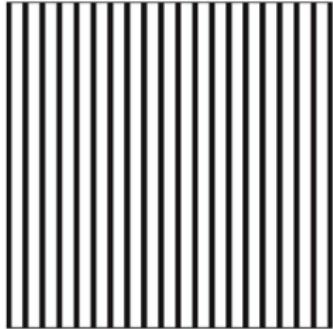
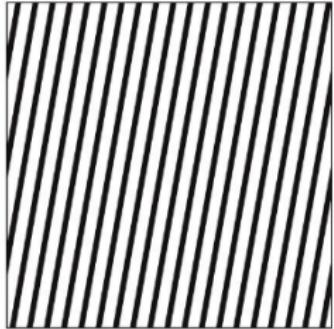
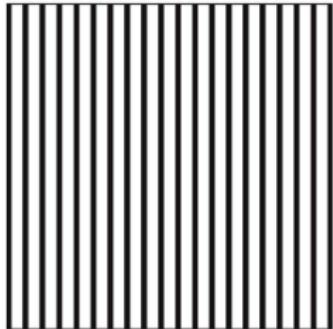
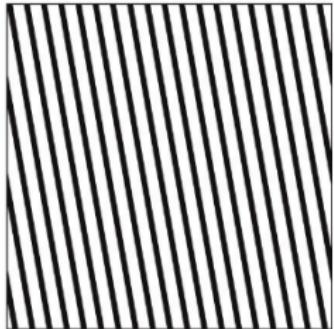
Complex



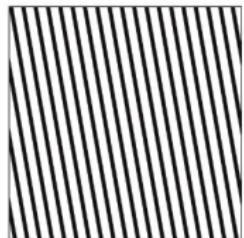
End-stopped



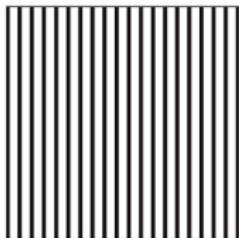
The tilt aftereffect



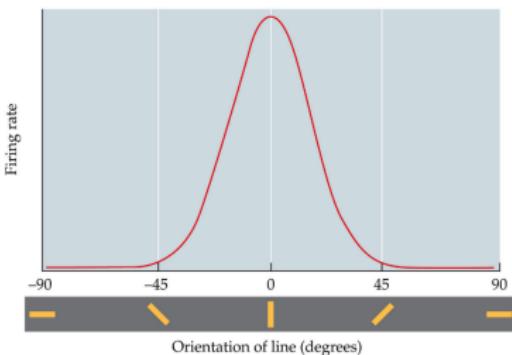
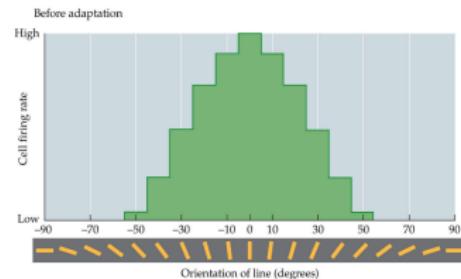
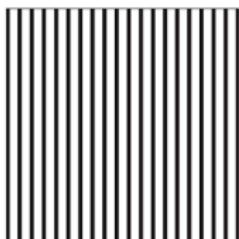
Selective adaptation: the psychologist's electrode



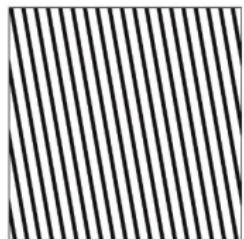
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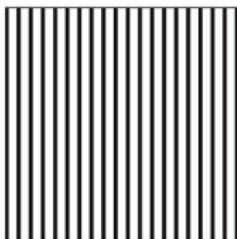
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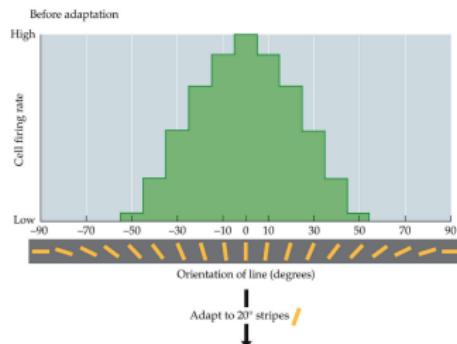
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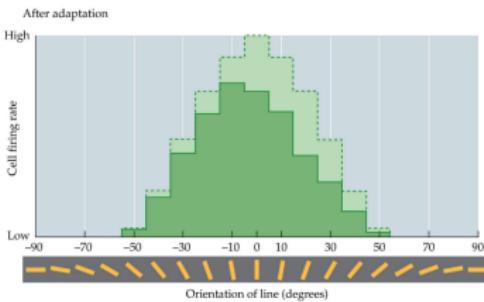
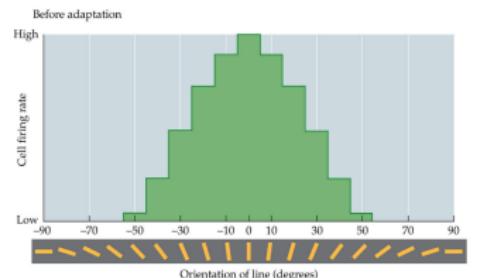
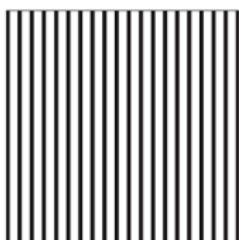
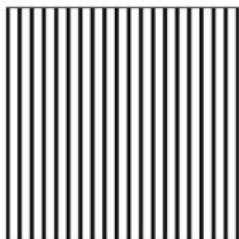
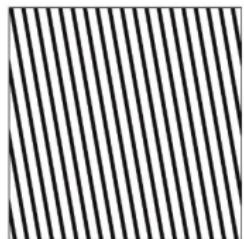
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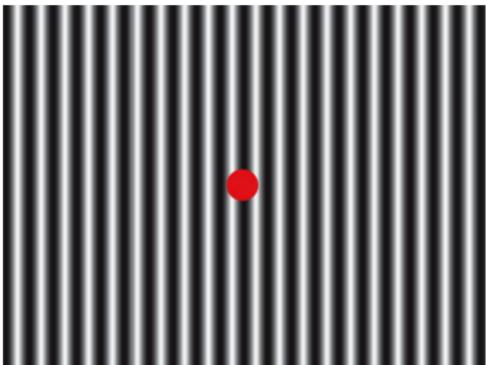
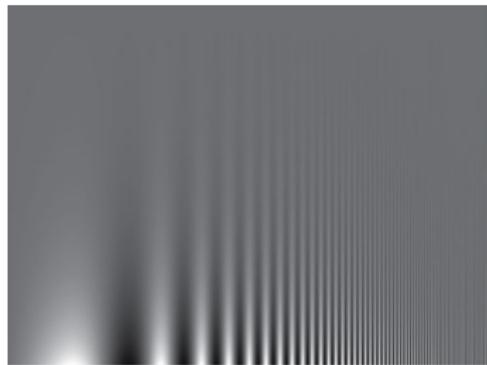
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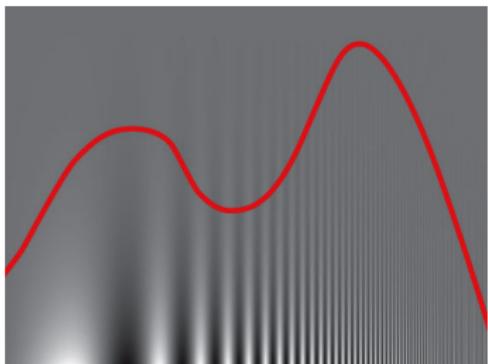
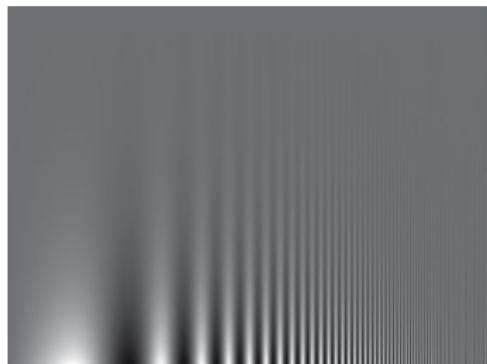
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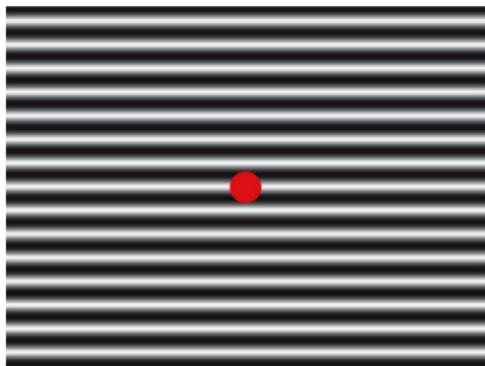
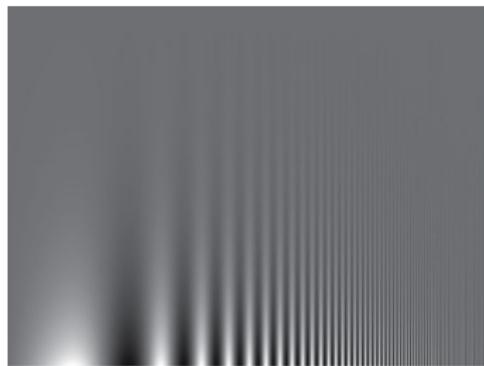
Selective adaptation: the psychologist's electrode



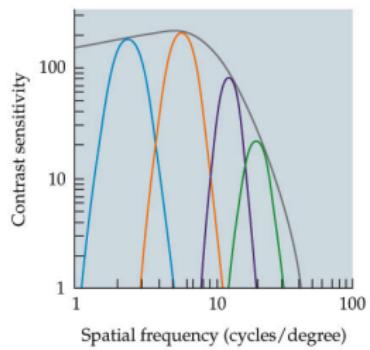
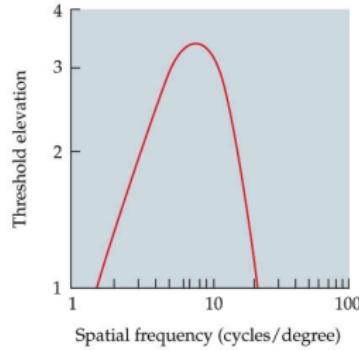
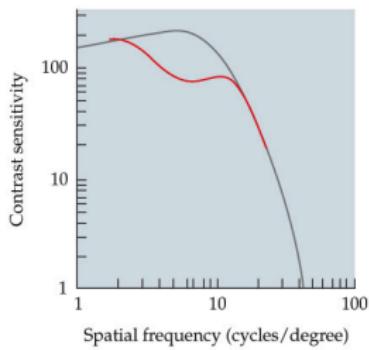
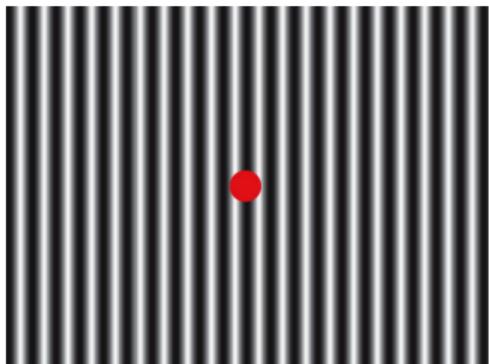
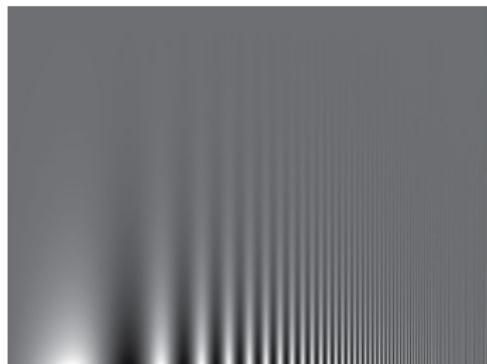
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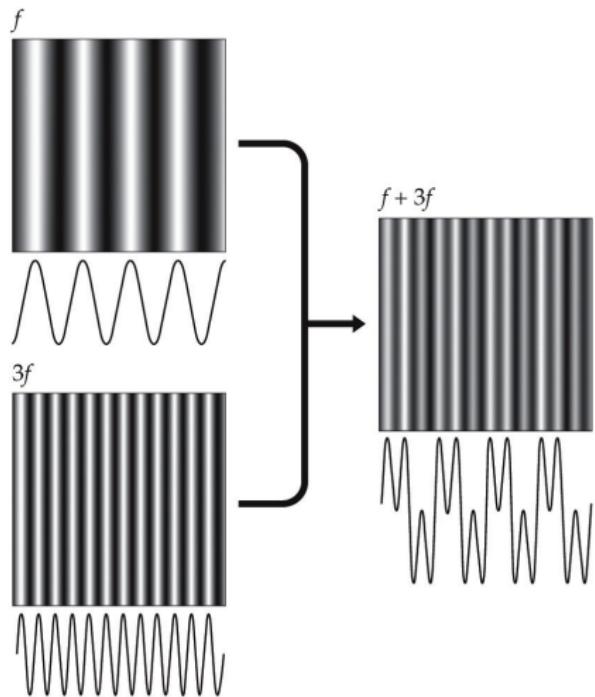
Selective adaptation: the psychologist's electrode



Selective adaptation: the psychologist's electrode



Spatial frequency tuned pattern analyzers in human vision



Summary

- we followed image processing from the eyeball to the brain
- transformation of information from the circular receptive fields of retinal ganglion cells to elongated receptive fields of cortex
- cortical neurons are highly selective along a number of dimensions
- selective adaptation provides a powerful non-invasive tool for learning about stimulus specificity in human vision
- human visual cortex contains pattern analyzers that are specific to spatial frequency and orientation

References

- Wolfe, J.M., Kluender, K.R. & Levi, D.M. (2012). *Sensation & Perception*. Sinauer Associates: Sunderland, MA.