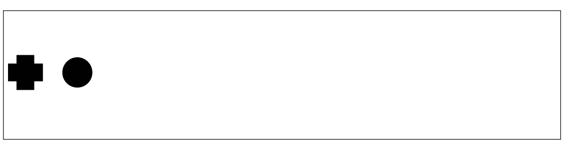
Biology 70, Fall 2007 Handouts
Lectures #2-#3


Biology 70
Part II
Sensory Systems
lectures 2-3

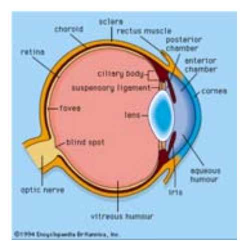
http://www.biology.ucsc.edu/classes/bio70/

better make it a ***triple (3 x)***

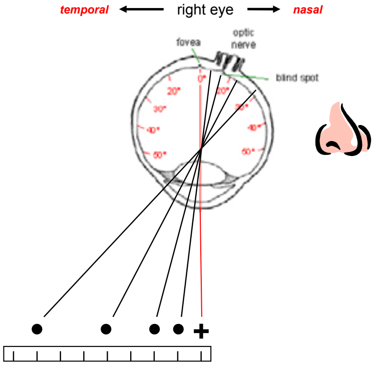
Blind spot demonstration (close left eye)



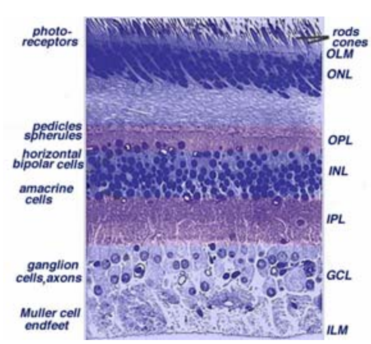
Blind spot



temporal ← right eye → *nasal*



light microscope picture of the retinal layers (≈ fig 6.16 Kalat)



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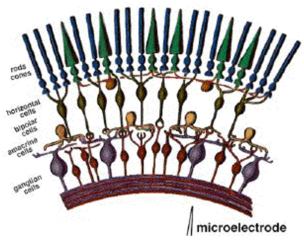
retina is "backwards"

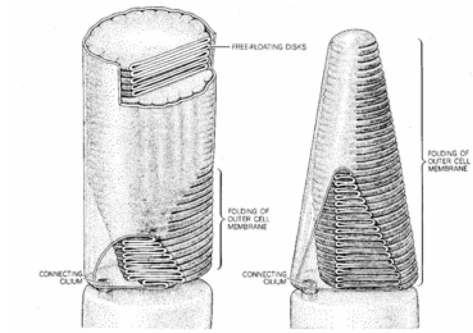
back of eye (choroid)



interior of eye (vitreous humor)

7

rods and cones



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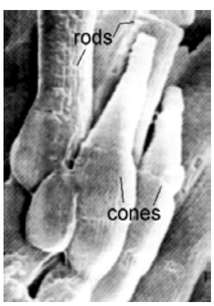
micrograph of rods and cones (≈ fig. 6.8 Kalat)



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from lecture outline

1. What are the differences between the rod and cone receptors with respect to:
   - a. numerosity
   - b. distribution across the retina
   - c. scotoptic and photopic vision
   - d. color vision
   - e. visual resolution

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Receptor Properties

	Rods	Cones
size	2×10^{-6} m	2×10^{-6} m
number	120 million	6 million
light sensitivity	high in dim light SCOTOPIC	higher in bright light PHOTOPIC
distribution	periphery	fovea
connectivity/ acuity	many-to-one low	one-to-one high
photopigments	1 (rhodopsin) *no color vision*	3† *color vision*

† 4-5 photopigments have recently been identified in humans

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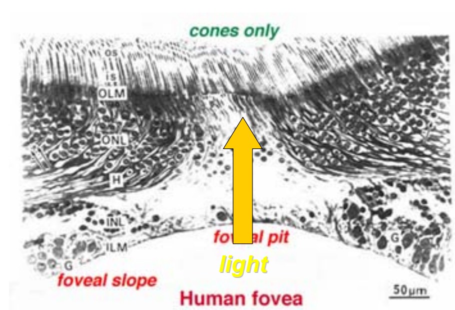
cross section of fovea (note cones only and pit)



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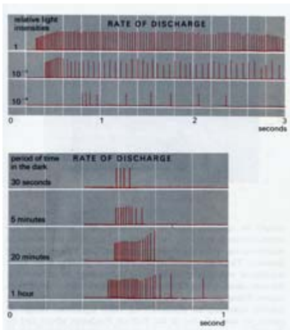
visual cell: firing rate vs intensity and recovery from light adaptation (E&B fig. 5.6)

brighter

longer time in dark



more light
⇨
greater firing rate
(given state of adaptation)

longer in dark
(greater 'dark adaptation')
⇨
higher sensitivity to light

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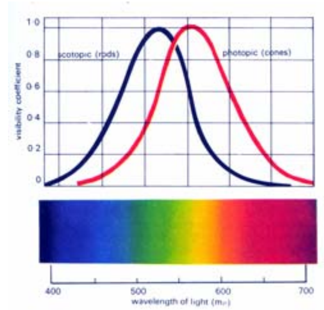
Figure 5.4 E & B scotopic [rods] vs photopic [cones] sensitivity



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from lecture outline

1. What are the differences between the rod and cone receptors with respect to:
   - a. numerosity
   - b. distribution across the retina
   - c. scotoptic and photopic vision
   - d. color vision
   - e. visual resolution

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from lecture outline

5. Understand how the following psychophysical phenomena are related to processes occurring in the retina:
   - a. dark adaptation
   - b. Pulfrich pendulum
   - c. Mach band

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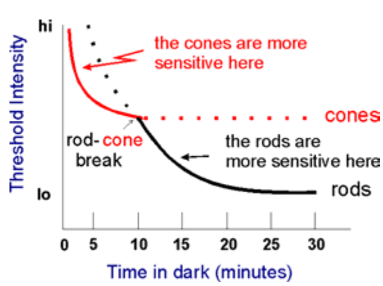
dark adaptation



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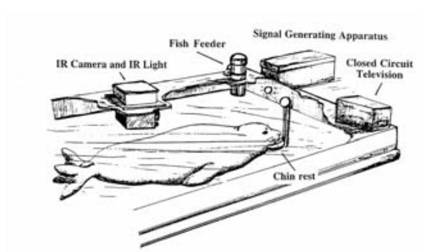
sea lion psychophysics (Long Marine Lab)



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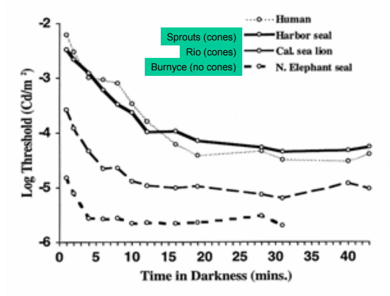
do the marine animals have cones as well as rods ??



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Pulfrich Pendulum

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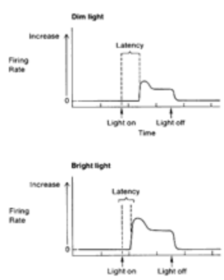
Pulfrich pendulum: latency vs light intensity



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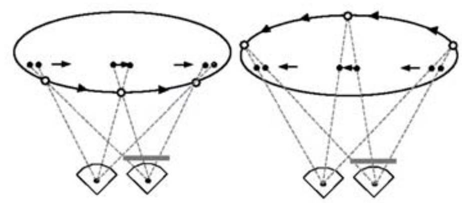
Pulfrich Pendulum



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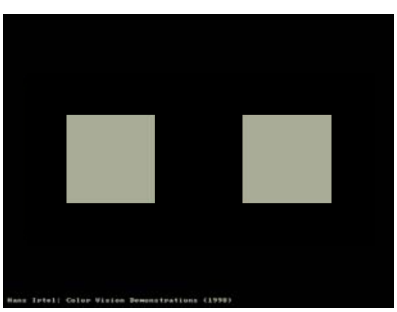
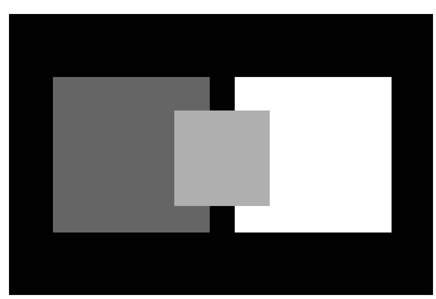
this illustrates: contrast



23

this illustrates: contrast



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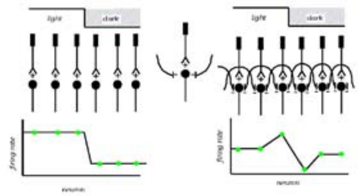
neural network for: lateral inhibition



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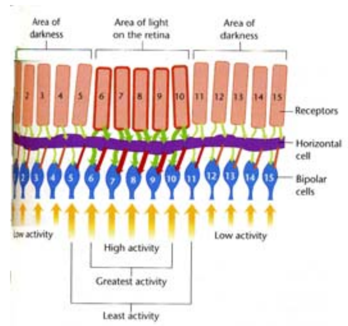
LATERAL INHIBITITION: Kalat figures on pp 168-169



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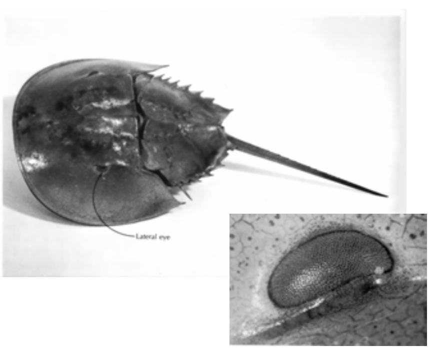
limulus– horseshoe crab



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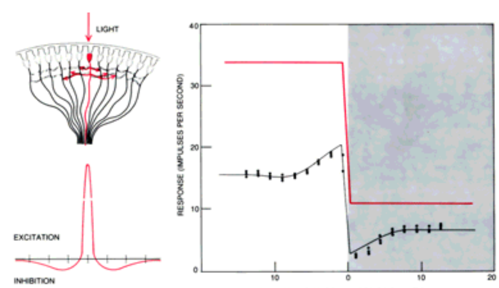
recording from limulus eye



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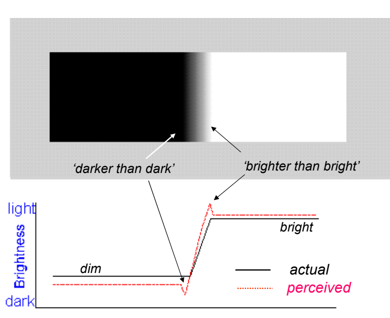

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from lecture #2-#3 outline

5. Understand how the following psychophysical phenomena are related to processes occurring in the retina:
   - a. dark adaptation
   - b. Pulfrich pendulum
   - c. Mach band

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from lecture #2-#3 outline

➽ 4. Lateral inhibition is an important example of coding by neural networks. Be sure to understand the discussion on pp. 167-169 in Kalat and the limulus evidence pictured in the “Lateral Inhibition” figure from *Scientific American* reproduced in “figures for lectures 2-3”. Also the diagram used in class.

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from lecture #2-#3 outline

2. Know the following terms associated with the cells of the retina and retinal structure:
   - a. rods
   - b. cones
   - c. horizontal cells
   - d. bipolar cells
   - e. amacrine cells
   - f. ganglion cells
   - g. ribbon synapse
   - h. optic nerve

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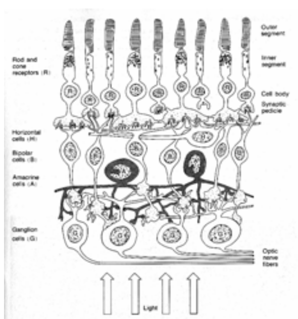
cells of the retina



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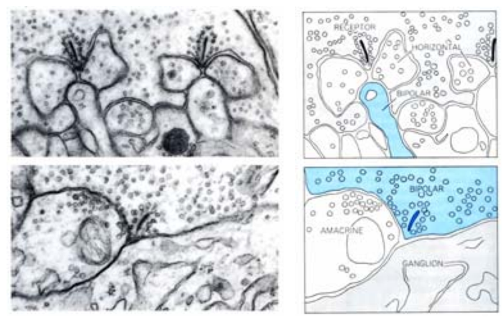

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from lecture #2-#3 outline

2. Know the following terms associated with the cells of the retina and retinal structure:
   - a. rods ➽
   - b. cones ➽
   - c. horizontal cells ➽
   - d. bipolar cells ➽
   - e. amacrine cells ➽
   - f. ganglion cells ➽
   - g. ribbon synapse ➽
   - h. optic nerve ➽

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from lecture #2-3 outline

3. What are the synaptic connections among the cells of the retina? What kinds of information are coded by each cell type (very generally)? In vertebrates, do receptors hyperpolarize or depolarize in response to light? (See figures 6.2 and 6.15 in Kalat and figure in “figures for lectures 2-3”.

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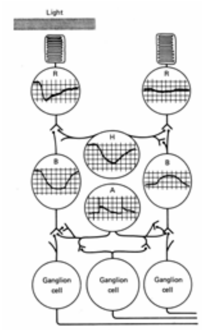
electrical activity in retinal cells: graded vs action potentials



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What types of patterns selectively activate cells in the visual system?

[receptive fields]

Are differing aspects of an image processed by different parts of the brain?

[concurrent pathways or streams]

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Receptive Field (Kalat figure 6.18)

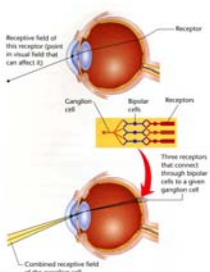

Figure 6.18 Receptive fields
The receptive field of a receptor is simply the area of the visual field from which light strikes that receptor. For any other cell in the visual system, the receptive field is determined by which receptors connect to the cell in question.

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Receptive Field (RF)

Map of how light presented to various positions in the visual field excites or inhibits the firing of a neuron (this map or pattern is the cell's *receptive field*). The **receptive field** indicates the "best" stimulus for the cell (i.e. the feature whose presence in a scene is signaled by the firing of the neuron).

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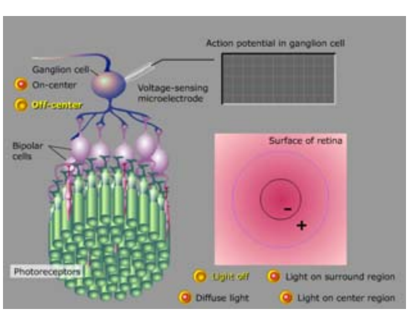
movie of receptive field



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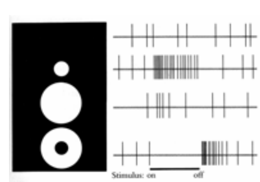
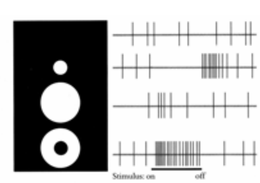
concentric receptive field of retinal ganglion cells



on-center off-surround



off-center on-surround

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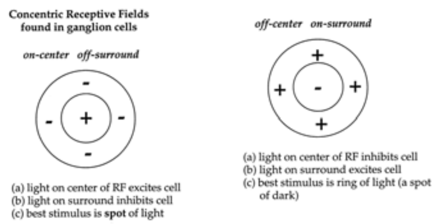
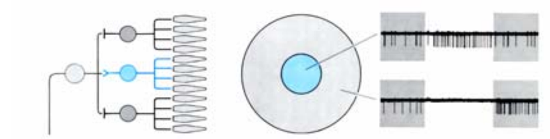
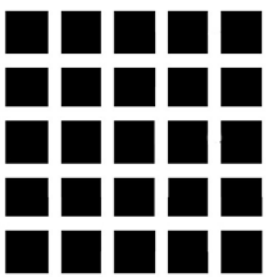
Concentric Receptive Fields
(found for ganglion cells)



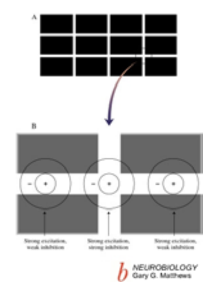
how receptors may be connected for on-center off-surround RF



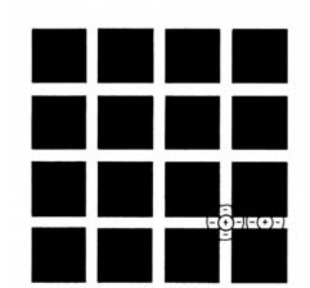
on-center off-surround



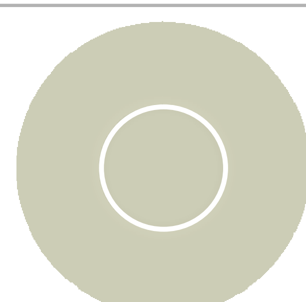
explanation of Hermann Grid illusion



explanation of Hermann grid



Craik-Obrien Illusion



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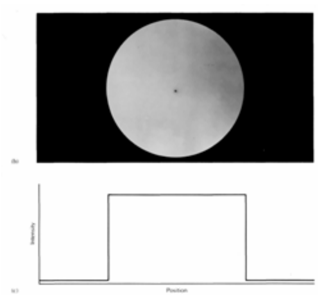
nothing-for-nothing



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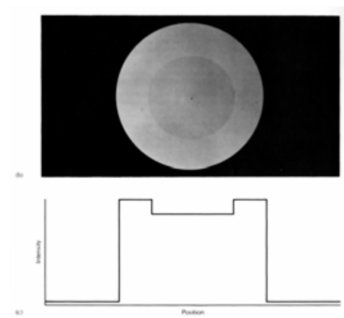
something-for-something



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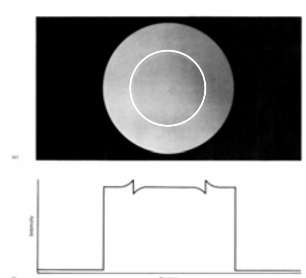
something-for-nothing (Craik-Obrien)



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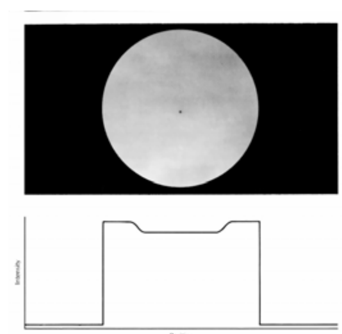
nothing-for-something



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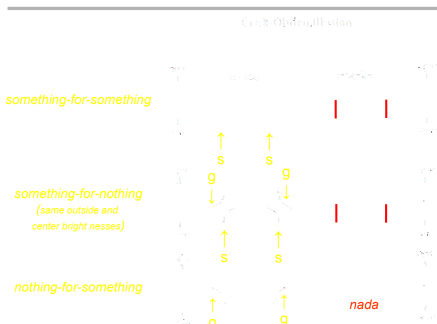
Craik-Obrien Illusion: explanation



sharp change in spatial brightness: **PERCEIVED**
gradual change in spatial brightness: **NOT PERCEIVED**

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from lecture outline: lectures #2-#3

7. Understand the following functional concepts:
   - a. receptive field
   - b. retinotopic map
   - c. feature detector
   - d. concentric on-center receptive field
   - e. concentric off-center receptive field
   - f. orientationally tuned neuron
   - g. simple cell
   - h. complex cell
   - i. "grandmother" cell
   - j. spatial frequency detector
   - k. what vs where pathways

9. What does the Craik-Obrien illusion imply about information processing by the visual system?

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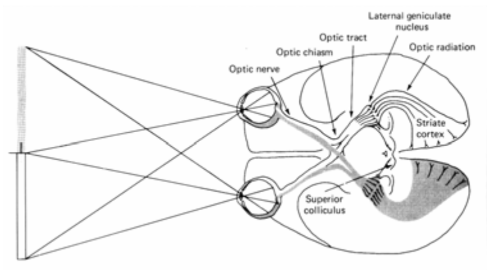
central visual pathways



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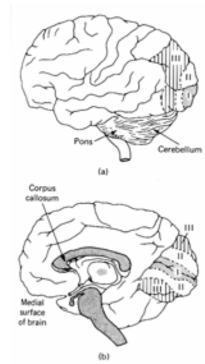

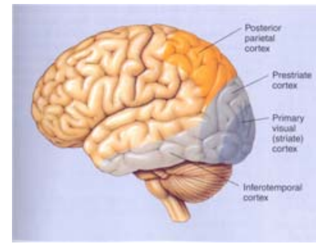

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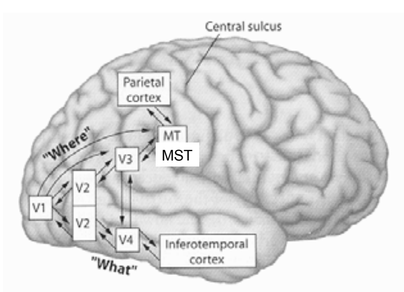
V1, V2, IT, MT, MST



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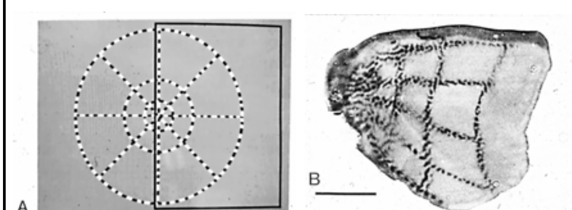

retinotopic map

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Concurrent
Processing
'streams'

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concurrent pathways

magnocellular vs parvocellular [in "low level" streams]

temporal (ventral) vs parietal (dorsal) [in "higher level" processing]

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what (temporal, ventral) vs where (parietal, dorsal) pathways

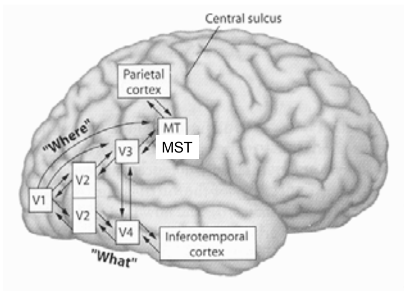

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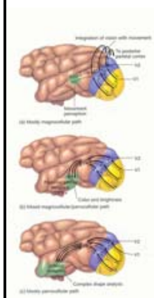
Figure 6.19 Kalat– Concurrent processing streams



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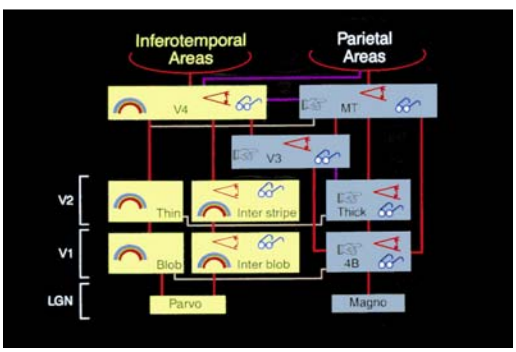

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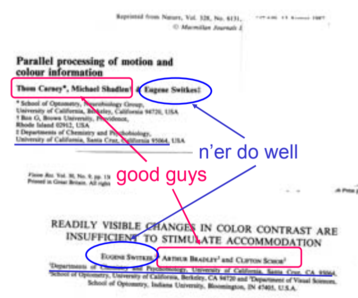

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from lecture outlines: lectures #2-#3

6. Know the following terms related to the gross anatomy of the central visual system and their general function in visual information processing.

a. optic nerve
b. optic chiasm
c. lateral geniculate nucleus (LGN)
d. superior colliculus
e. visual cortex (V1, V2, V4)
f. inferior temporal cortex
g. medial temporal cortex (MT, V5) and medial superior cortex (MST)
h. ventral (temporal cortex) vs. dorsal (parietal cortex) streams
i. fusiform area

9. In the "simple" picture what are the types of information selectively processed by the parvocellular and magnocellular pathways (pp. 162-164, Table 6.2 and Figure 6.2**1** of Kalat)?

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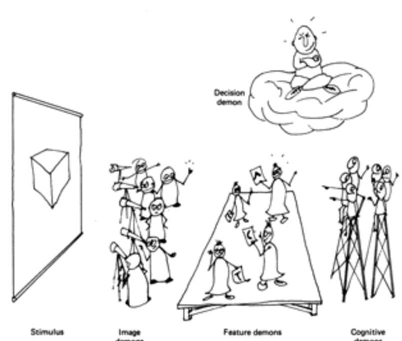

Fig. 10.4. The Pandemonium pattern recognizer of Selfridge (1959).

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the what pathway: form perception

In the initial stages of visual processing the visual system analyzes an image by detecting individual features in the image (ie by the 'feature demons).
These may be thought of as 'letters' of the image alphabet.

Later, the elementary features are assembled into objects ('words of the image' and complex images (by the cognitive demons).

There are two competing theories on the nature of the individual features:

CLASSICAL FEATURE DETECTION
and
SPATIAL FREQUENCY THEORY

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"Classical" Feature Detection

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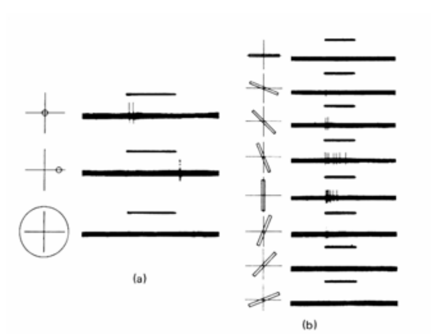

simple cell

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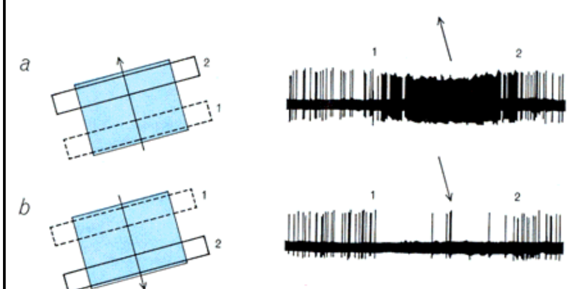

complex cell

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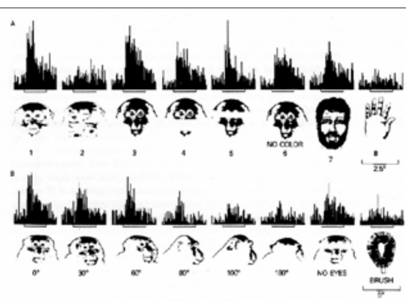
"face cells" in monkey inferotemporal cortex



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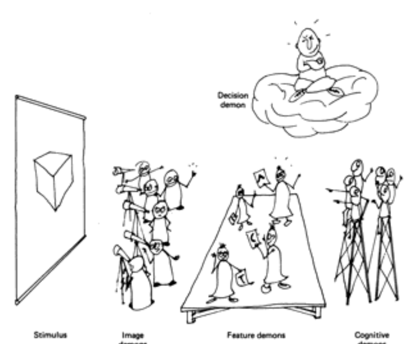

Fig. 10.4. The Pandemonium pattern recognizer of Selfridge (1959).

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Spatial Frequency “Features”

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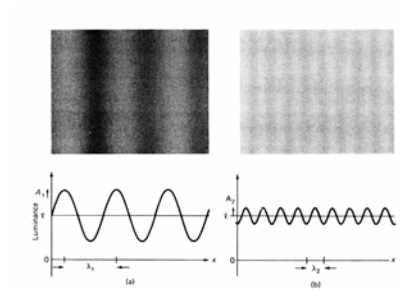
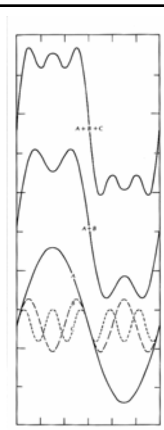
Sinusoidal Gratings



74



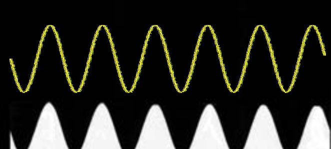
75

Demonstration of Adding Sinusoids

76

Anstis Demo: low frequency sinusoid (f)

vertical blur yields ‘sinusoidal grating’



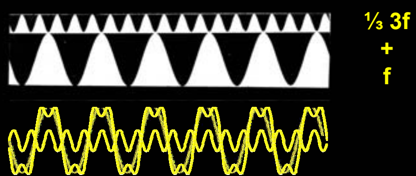
f

Anstis Demo: high frequency sinusoid (⅓ 3f)

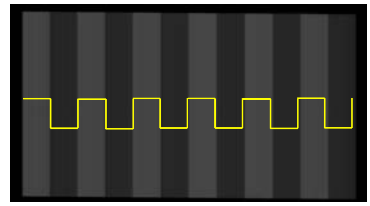
vertical blur yields ‘sinusoidal grating’

⅓ 3f

Anstis Demo: combination (f+ 1/3 3f)

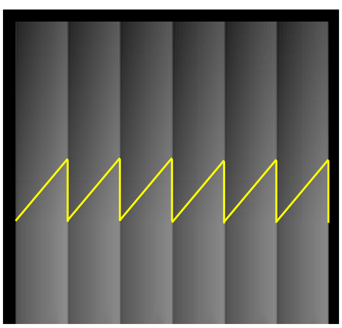


Anstis Demo: combination (f+ 1/3 3f + 1/5 5f ....)



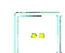
80

Anstis Demo: combination (f+ 1/2 2f + ...)



81

Adding sinusoids (2D-Fourier synthesis)

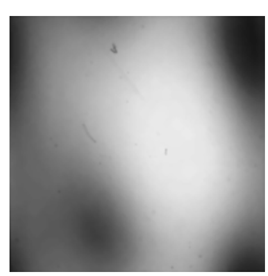


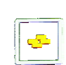
1 frequency component *(out of 32,000)*

82

2 frequency components

83





4 frequency components

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16 frequency components

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32 frequency components (0.1%)

86


64 frequency components (0.2%)

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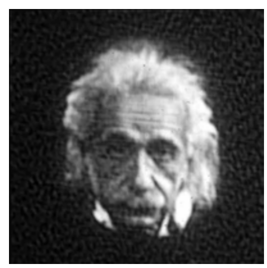
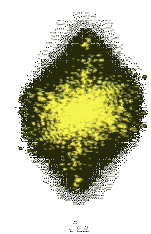
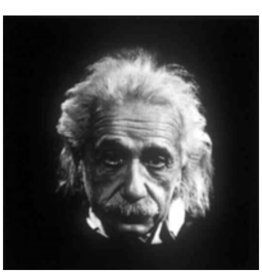
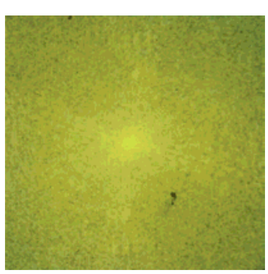



5% of total spatial frequencies

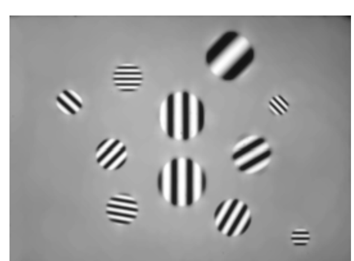
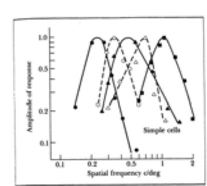
88

100% of total spatial frequencies

89

receptive fields of V1 cells which act as spatial frequency detectors

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SPATIAL FREQUENCY ANALYSIS OF THE VISUAL ENVIRONMENT: ANISOTROPY AND THE CARPENTERED ENVIRONMENT HYPOTHESIS

Spatial frequency specific interaction of dot patterns and gratings

KAREN K. DE VALOIS* AND EUGENE SWITKES†

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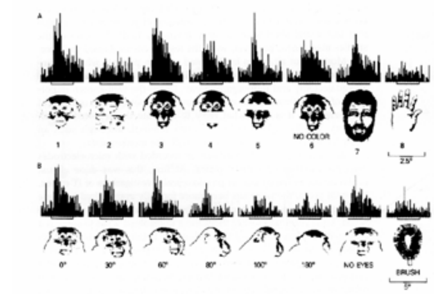
"face cells" in monkey inferotemporal cortex



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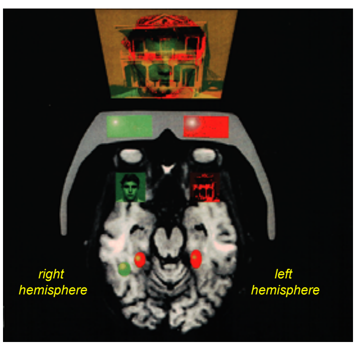

face specific area
(fusiform face area)

place specific area
(parahippocampal place area)

from Prof. Nancy Kanwisher, MIT, 2001
fMRI studies

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from lecture outline: lectures #2-#3

7. Understand the following functional concepts:
   - a. receptive field
   - b. retinotopic map
   - c. feature detector ≈
   - d. concentric on-center receptive field
   - e. concentric off-center receptive field
   - f. orientationally tuned neuron
   - g. simple cell
   - h. complex cell
   - i. "grandmother" cell
   - j. spatial frequency detector
   - k. what vs where pathways

8. What does the Craik-Obrien illusion imply about information processing by the visual system?

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from lecture outlines: lectures #2-#3

6. Know the following terms related to the gross anatomy of the central visual system and their general function in visual information processing.
   - a. optic nerve
   - b. optic chiasm
   - c. lateral geniculate nucleus (LGN)
   - d. superior colliculus
   - e. visual cortex (V1, V2, V4)
   - f. inferior temporal cortex
   - g. medial temporal cortex (MT, V5) and medial superior cortex (MST)
   - h. ventral (temporal cortex) vs. dorsal (parietal cortex) streams
   - i. fusiform area

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from lecture outline: lectures #2-#3

Compare the "classical feature" and "spatial frequency" models of visual image processing.

11. How is psychophysical adaptation used to show feature selectivity in the Blakemore-Sutton demonstration (see Figure in "figures for lectures 2-3" and WWW demo) and the McCulloch effect (see WWW demo)?

12. What types of information are processed by the ventral (temporal) and dorsal (parietal) cortical streams?

13. What is blindsight and which visual pathway may be implicated?

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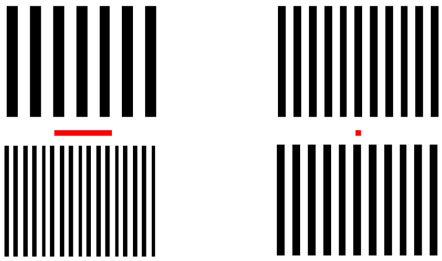

Adapted from Blakemore & Sutton, 1969

Blakemore-Sutton Spatial Frequency Adaptation

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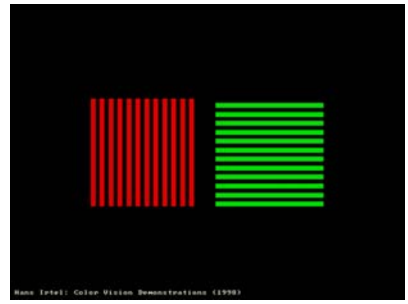

McCullough Adaptation to Specific Orientation (colors)

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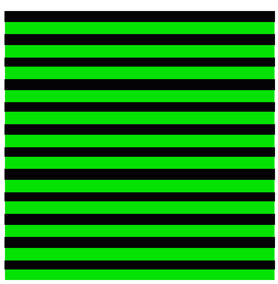

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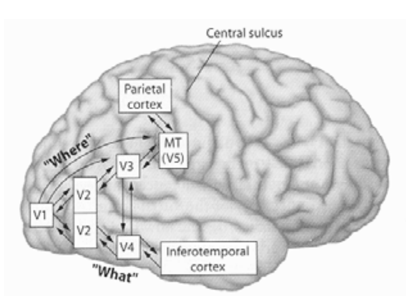
what *(temporal, ventral) vs* ***where*** *(parietal, dorsal) pathways*



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from lecture outline: lectures #2-#3

10. Compare the "classical feature" and "spatial frequency" models of visual image processing.

11. How is psychophysical adaptation used to show feature selectivity in the Blakemore-Sutton demonstration (see Figure in "figures for lectures 2-3" and WWW demo) and the McCulloch effect (see WWW demo)?

12. What types of information are processed by the ventral (temporal) and dorsal (parietal) cortical streams?

13. What is blindsight and which visual pathway may be implicated?

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FINIS

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