Biology 70
Part II
Sensory Systems
lectures 2-3

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

1

Biology 70 Lectures #2-#3

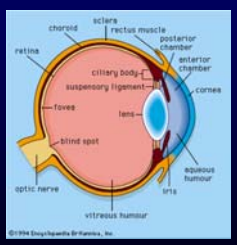
better make it a ***triple (3 x)***

2

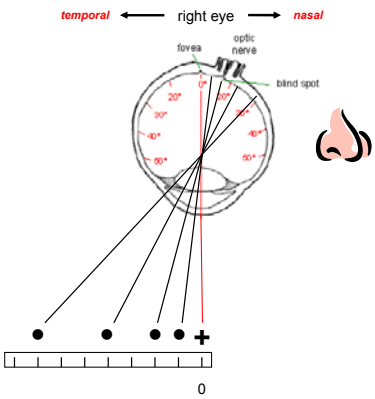
Blind spot demonstration (close left eye)

3

Blind spot

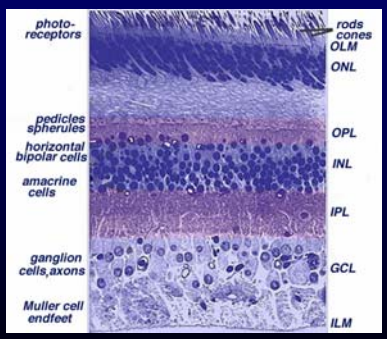


4



5

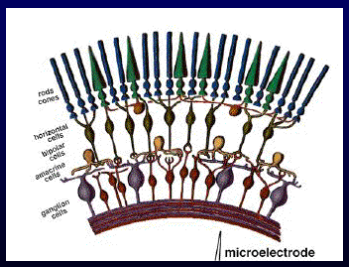
light microscope picture of the retinal layers (≈ fig 6.16 Kalat)



6

retina is "backwards"

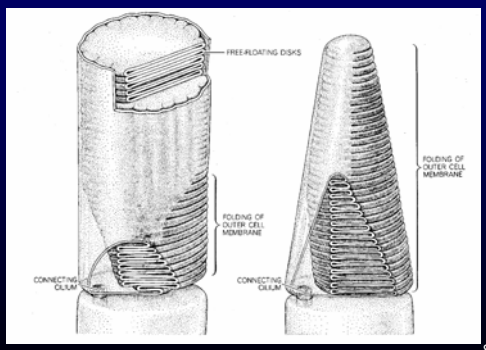
back of eye (choroid)



interior of eye (vitreous humor)

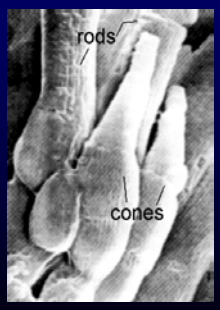
7

rods and cones



8

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



9

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

10

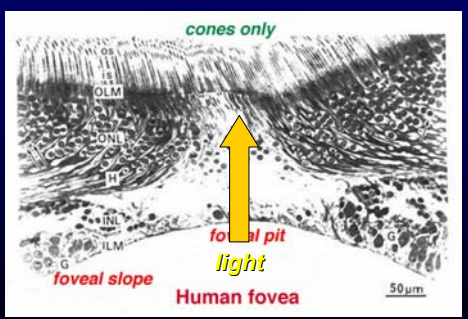
Receptor Properties

	Rods	Cones
size	2 x 10^{-6} m	2 x 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

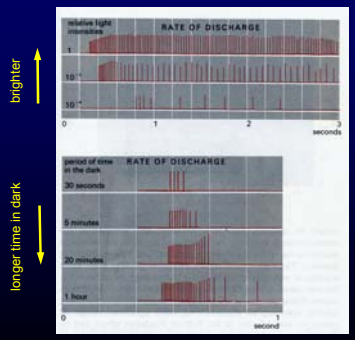
11

cross section of fovea (note cones only and pit)



12

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

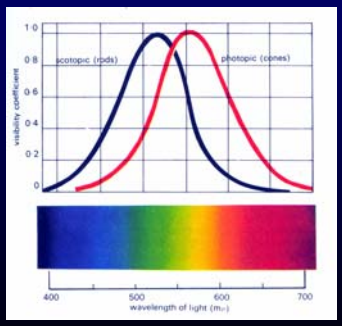


more light
⇨
greater firing rate
(given state of adaptation)

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

13

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



14

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

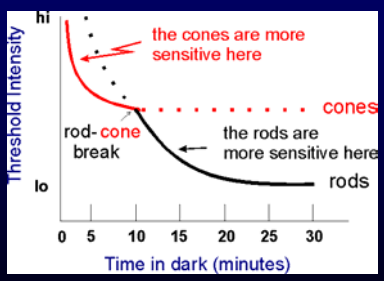
15

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

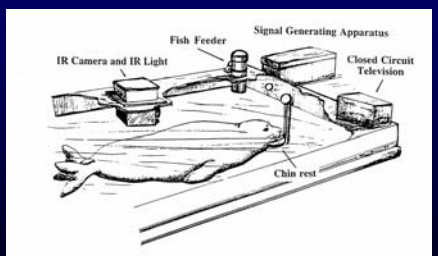
16

dark adaptation



17

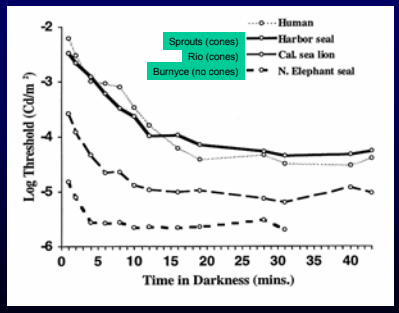
sea lion psychophysics (Long Marine Lab)



Dave Levinson, UCSC

18

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

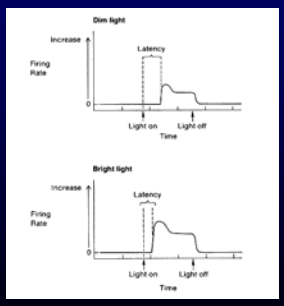


19

Pulfrich Pendulum

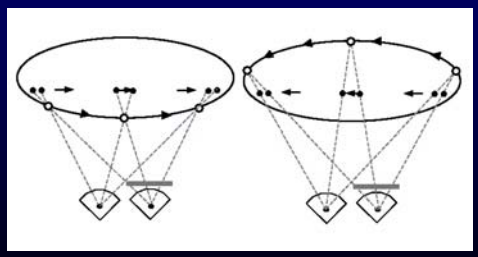
20

Pulfrich pendulum: latency vs light intensity



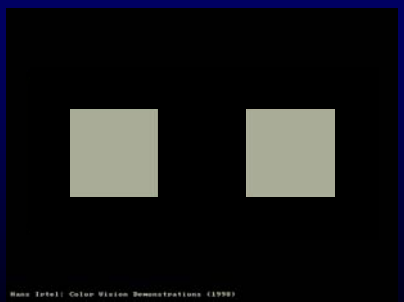
21

Pulfrich Pendulum



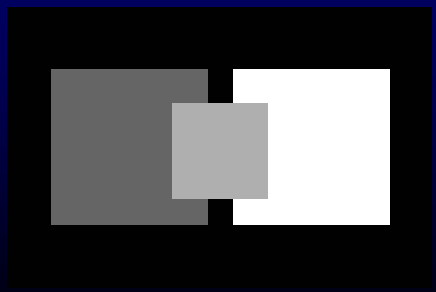
22

this illustrates: ***contrast***



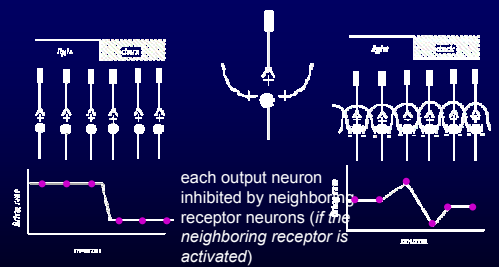
23

this illustrates: ***contrast***



24

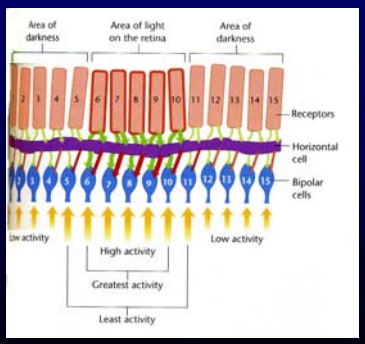
neural network for: lateral inhibition



each output neuron inhibited by neighboring receptor neurons (*if the neighboring receptor is activated*)

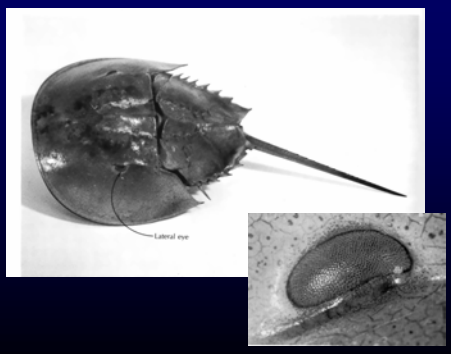
25

LATERAL INHIBITITION: Kalat figures on pp 168-169



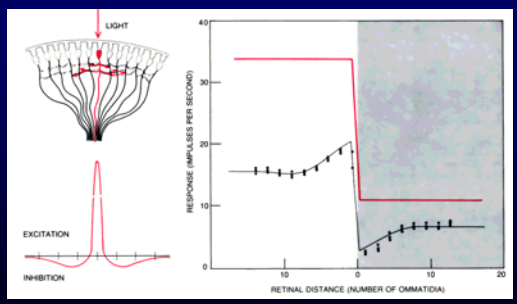
26

limulus– horseshoe crab



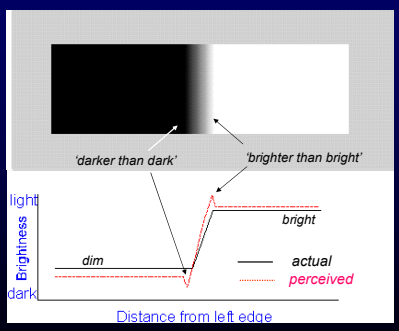
27

recording from limulus eye



28

Mach Bands



29

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

30

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.

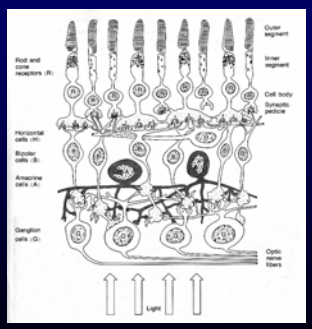
31

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

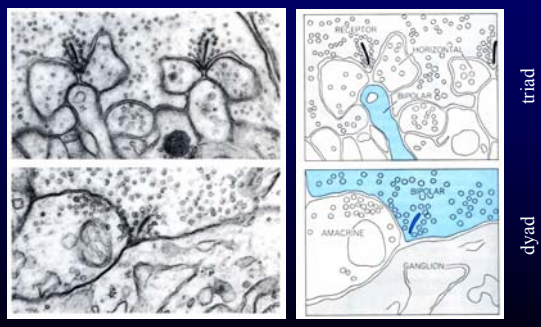
32

cells of the retina



33

Ribbon Synapses



34

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

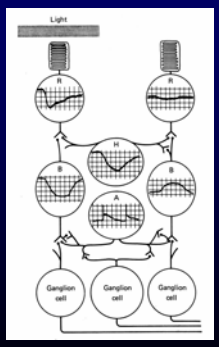
35

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".

36

electrical activity in retinal cells: graded vs action potentials



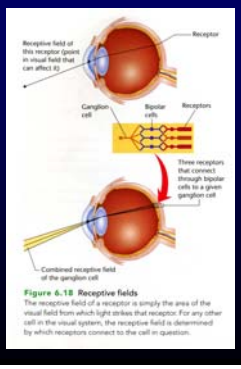
37

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]

38

Receptive Field (Kalat figure 6.18)



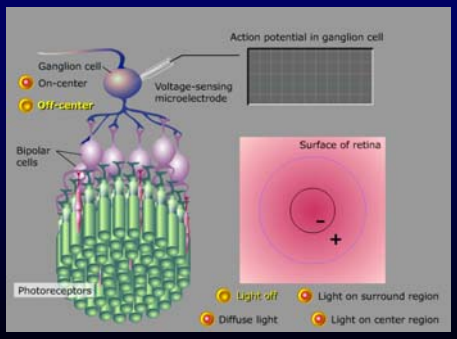
39

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).

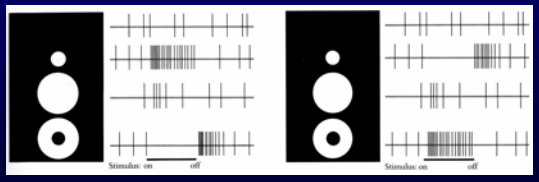
40

movie of receptive field



41

concentric receptive field of retinal ganglion cells



on-center off-surround *off-center on-surround*

42

Concentric Receptive Fields
(found for ganglion cells)

on-center off-surround

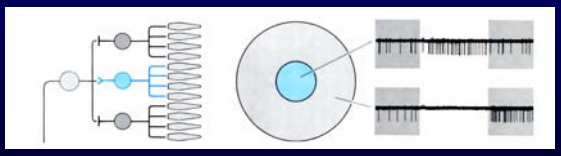
(a) light on center of RF excites cell
(b) light on surround inhibits cell
(c) best stimulus is spot of light

off-center on-surround

(a) light on center of RF inhibits cell
(b) light on surround excites cell
(c) best stimulus is s ring of light (a spot of dark).

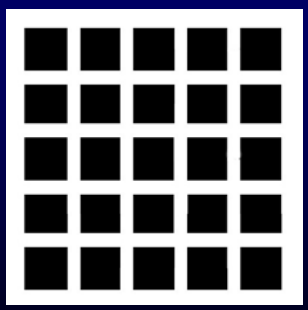
43

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



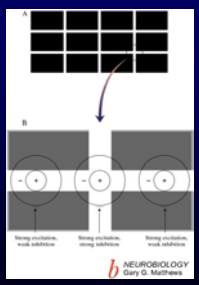
on-center off-surround

44



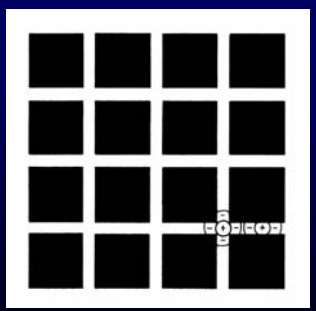
45

explanation of Hermann Grid illusion



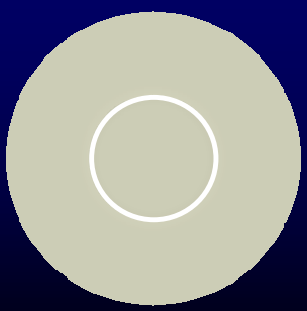
46

explanation of Hermann grid



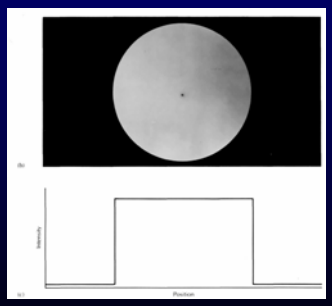
47

Craik-Obrien Illusion



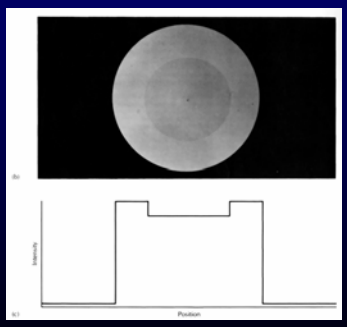
48

nothing-for-nothing



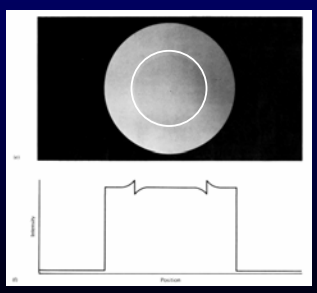
49

something-for-something



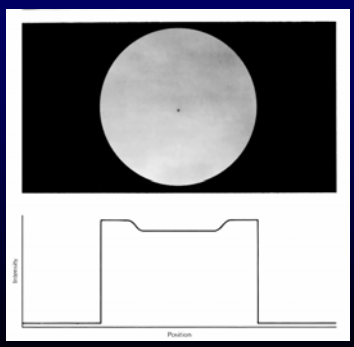
50

something-for-nothing (Craik-Obrien)



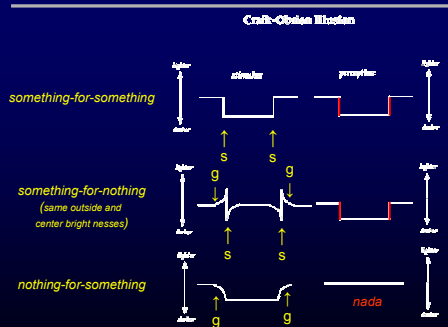
51

nothing-for-something



52

Craik-Obrien Illusion: explanation



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

53

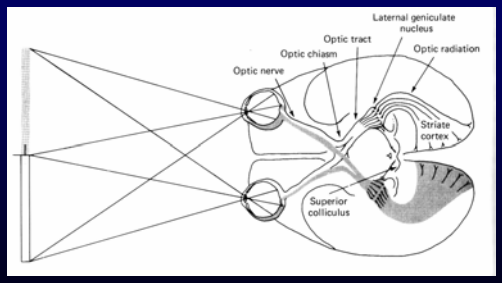
from lecture outline: lectures #2-#3

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

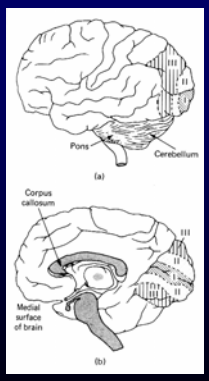
9. What does the Craik-Obrien illusion imply about information processing by the visual system?

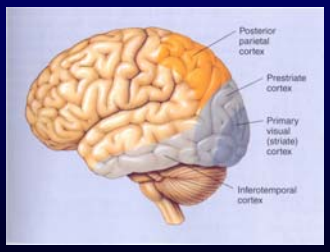
54

central visual pathways



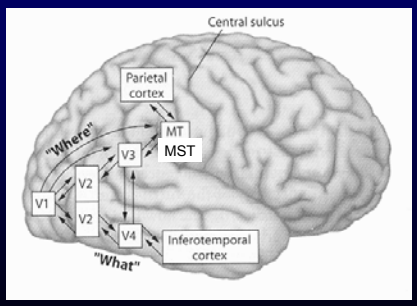
55



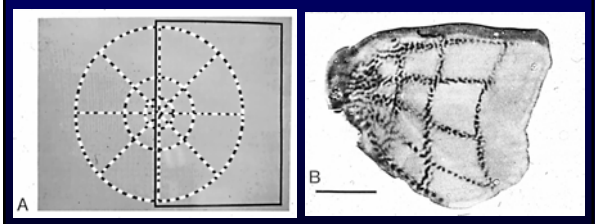


56

V1, V2, IT, MT, MST



57



retinotopic map

58

Concurrent Processing 'streams'

59

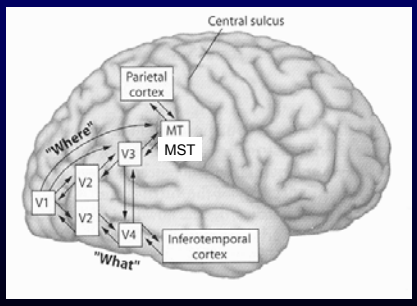
concurrent pathways

magnocellular vs parvocellular [in "low level" streams]

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

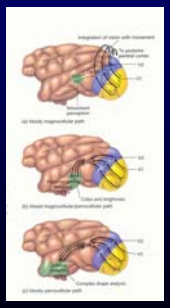
60

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

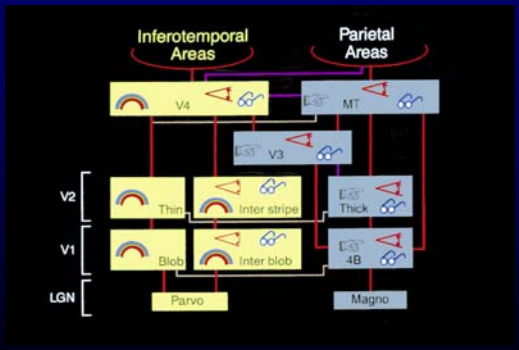


61

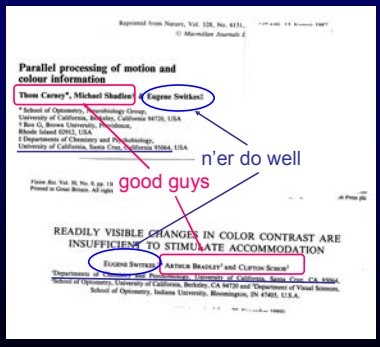
Figure 6.19 Kalat– Concurrent processing streams



62



63



64

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 6.21 of Kalat)?

65

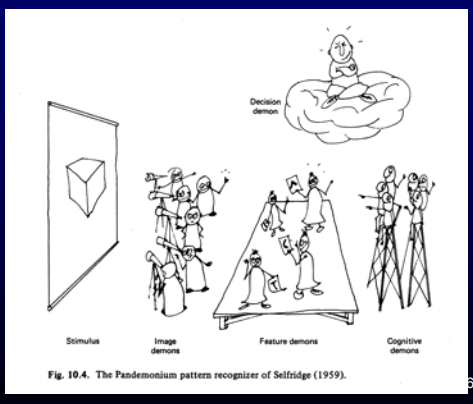


Fig. 10.4. The Pandemonium pattern recognizer of Selfridge (1959).

66

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).

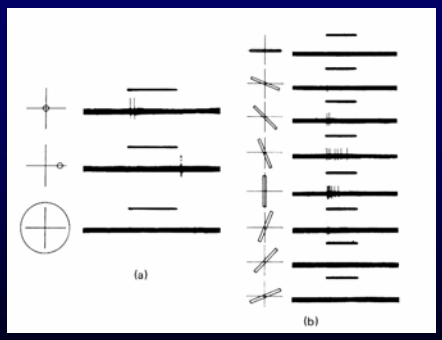
There are two competing theories on the nature of the individual features:

CLASSICAL FEATURE DETECTION
and
SPATIAL FREQUENCY THEORY

67

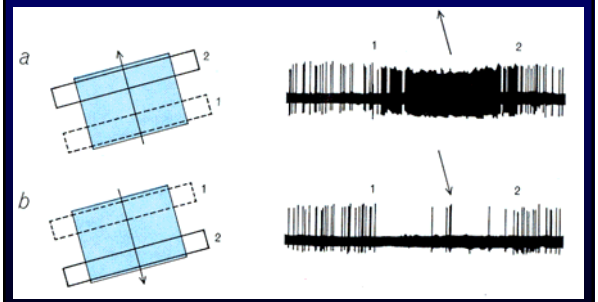
"Classical" Feature Detection

68



simple cell

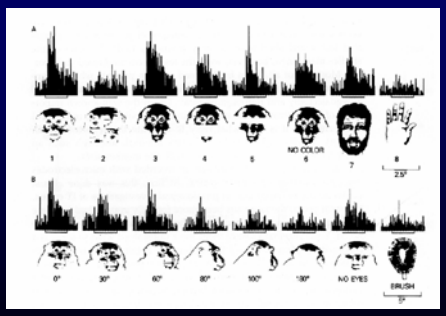
69



complex cell

70

"face cells" in monkey inferotemporal cortex



71

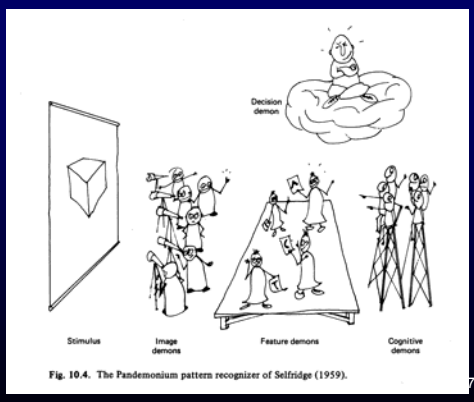


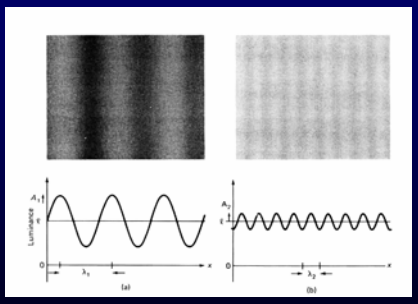
Fig. 10.4. The Pandemonium pattern recognizer of Selfridge (1959).

72

Spatial Frequency "Features"

73

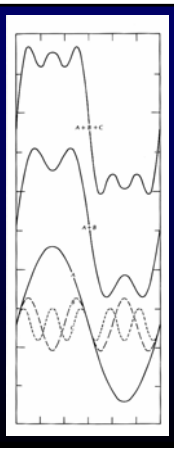
Sinusoidal Gratings



low spatial frequency
high contrast

high spatial frequency
low contrast

74



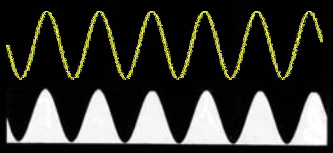
75

Demonstration of Adding Sinusoids

76

Anstis Demo: low frequency sinusoid (f)

vertical blur yields 'sinusoidal grating'



f

77

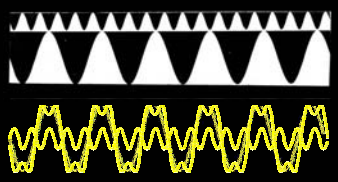
Anstis Demo: high frequency sinusoid (⅓ 3f)

vertical blur yields 'sinusoidal grating'

⅓ 3f

78

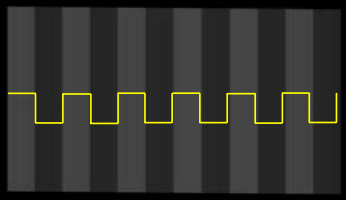
Anstis Demo: combination (f+ 1/3 3f)



⅓ 3f
+
f

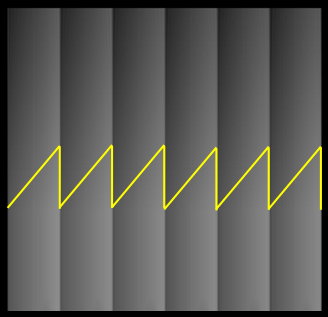
79

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



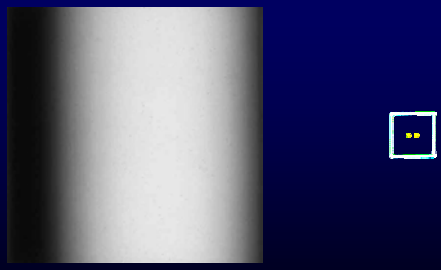
80

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



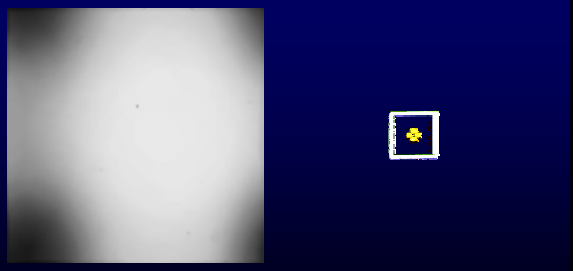
81

Adding sinusoids (2D-Fourier synthesis)



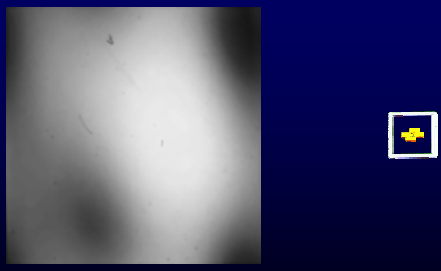
1 frequency component *(out of 32,000)*

82



2 frequency components

83



4 frequency components

84

16 frequency components

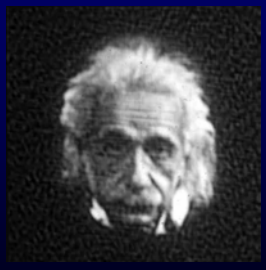
85

32 frequency components (0.1%)

86

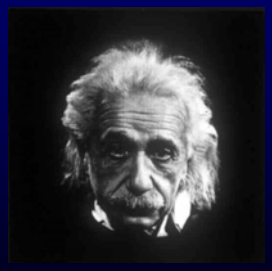
64 frequency components (0.2%)

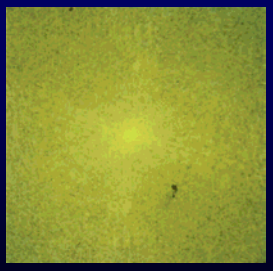
87



5% of total spatial frequencies

88

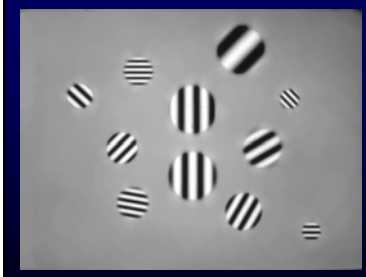


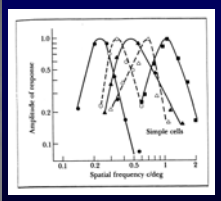


100% of total spatial frequencies

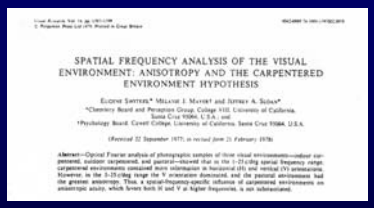
89

receptive fields of V1 cells which act as spatial frequency detectors





90

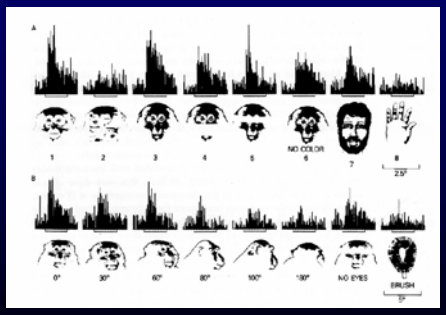


SPATIAL FREQUENCY ANALYSIS OF THE VISUAL ENVIRONMENT: ANISOTROPY AND THE CARPENTERED ENVIRONMENT HYPOTHESIS

Spatial frequency specific interaction of dot patterns and gratings

91

"face cells" in monkey inferotemporal cortex



92

face specific area
(fusiform face area)

place specific area
(parahippocampal place area)

from Prof. Nancy Kanwisher, MIT, 2001
fMRI studies

93

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?

94

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

95

from lecture outline: lectures #2-#3

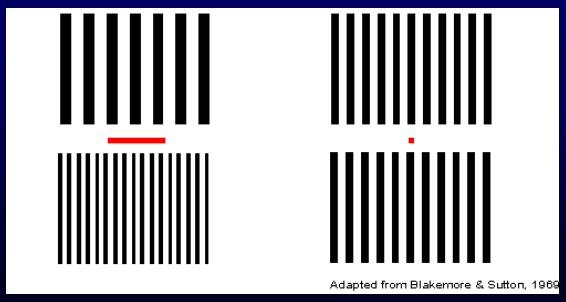
10. Compare the "classical feature" and "spatial frequency" models of visual image processing.

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)?

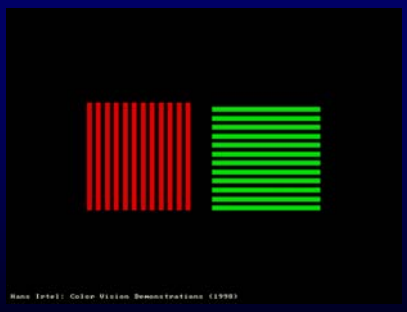
12. What types of information are processed by the ventral (temporal) and dorsal (parietal) cortical streams?

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

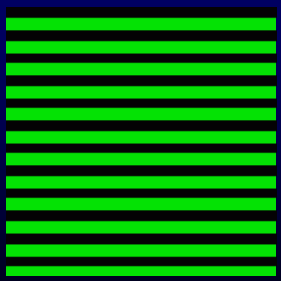
96



Blakemore-Sutton Spatial Frequency Adaptation 97



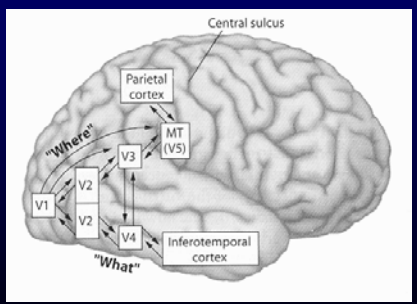
McCullough Adaptation to Specific Orientation (colors) 98



99

100

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



101

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?

102


FINIS
103