SOME RELATIONS BETWEEN VISUAL PERCEPTION AND NON-LINEAR PHOTONIC STRUCTURES

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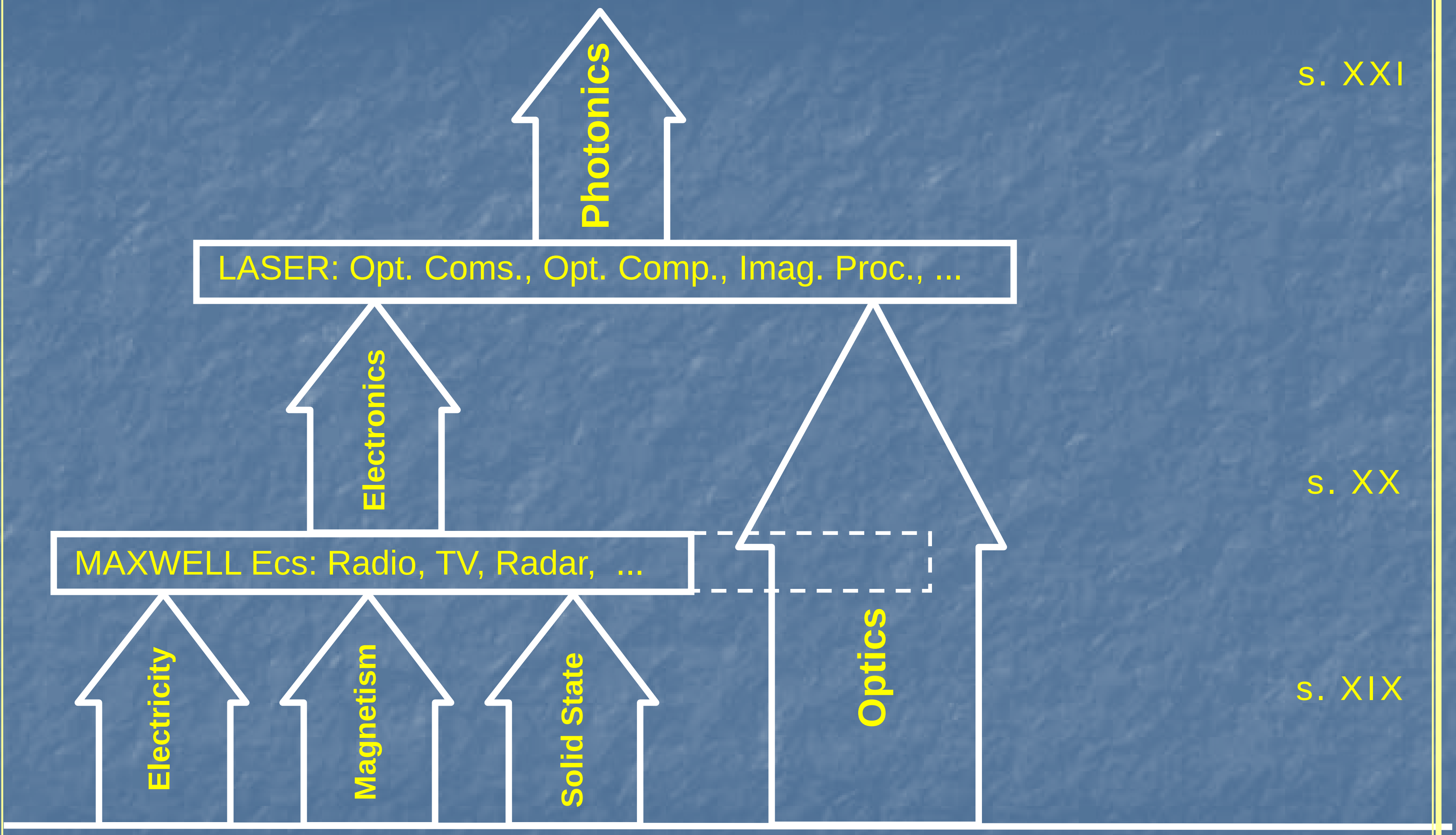
MAIN OBJECTIVE

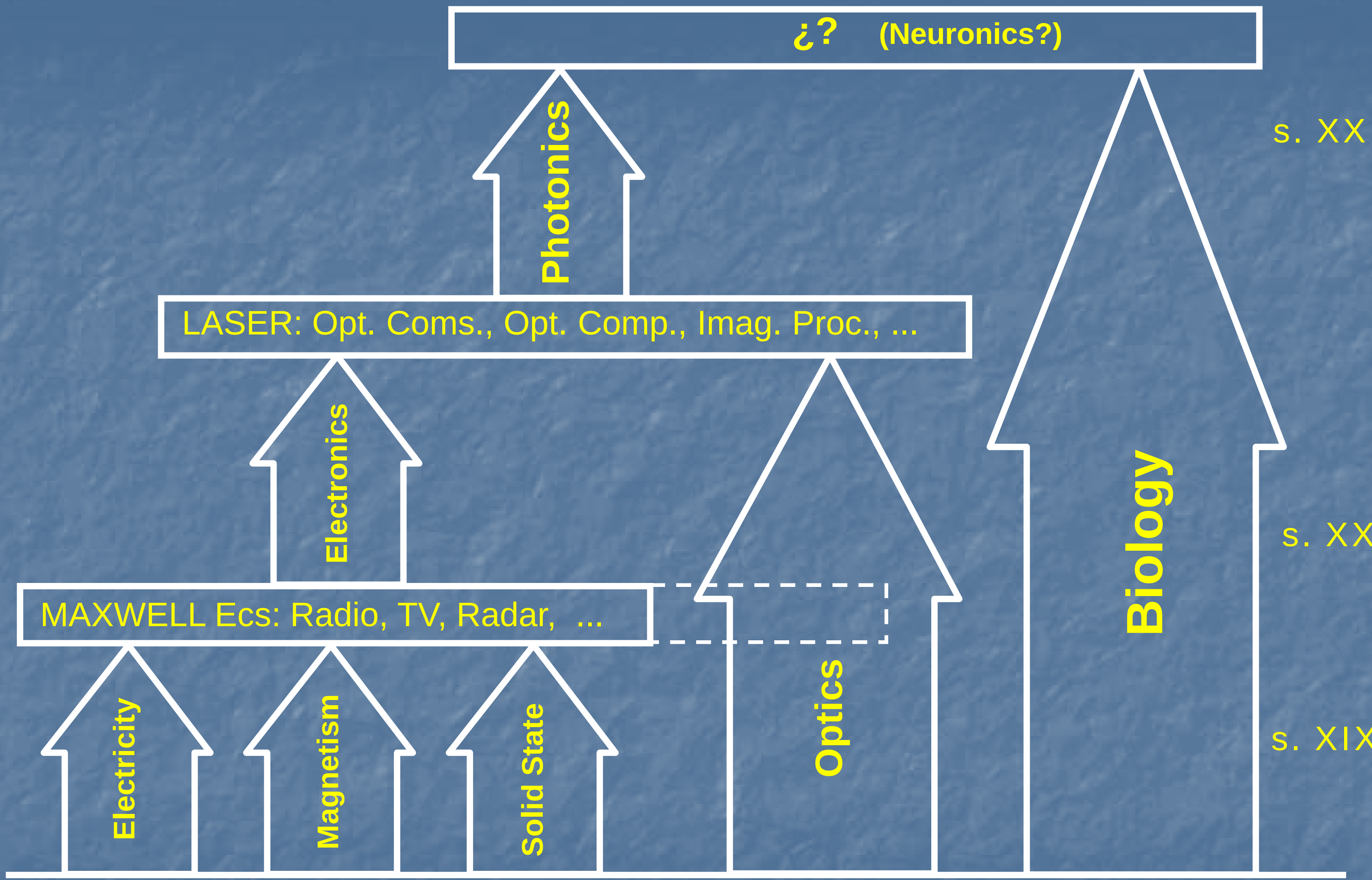
To present a way to emulate some functions of the mammalian visual system and a model to analyze subjective sensations and visual illusions

TOPICS TO BE COVERED

1. Summary of Sensing in Living Bodies
2. Mammalian Visual System: Retina and Visual Cortex
3. Photonic devices with non linear behaviour
4. Retina simulation: motion detection. Ideas from the visual Cortex.
5. Geometrical and Visual Illusions: Analysis of the Müller-Lyer, Zöllner, Wundt and Hering Illusions.
6. Conclusions

SOME PREVIOUS HISTORY TO REMEMBER


Photonics
LASER: Opt. Coms., Opt. Comp., Imag. Proc., ...
Electronics
MAXWELL Ecs: Radio, TV, Radar, ...
Electricity
Magnetism
Solid State
Optics
s. XXI
s. XX
s. XIX


¿?   (Neuronics?)
Photonics
s. XXI
LASER: Opt. Coms., Opt. Comp., Imag. Proc., ...
Electronics
s. XX
Biology
MAXWELL Ecs: Radio, TV, Radar, ...
Optics
Electricity
Magnetism
Solid State
s. XIX

Possible ways for working

- Photonics as a tool to understand biology.

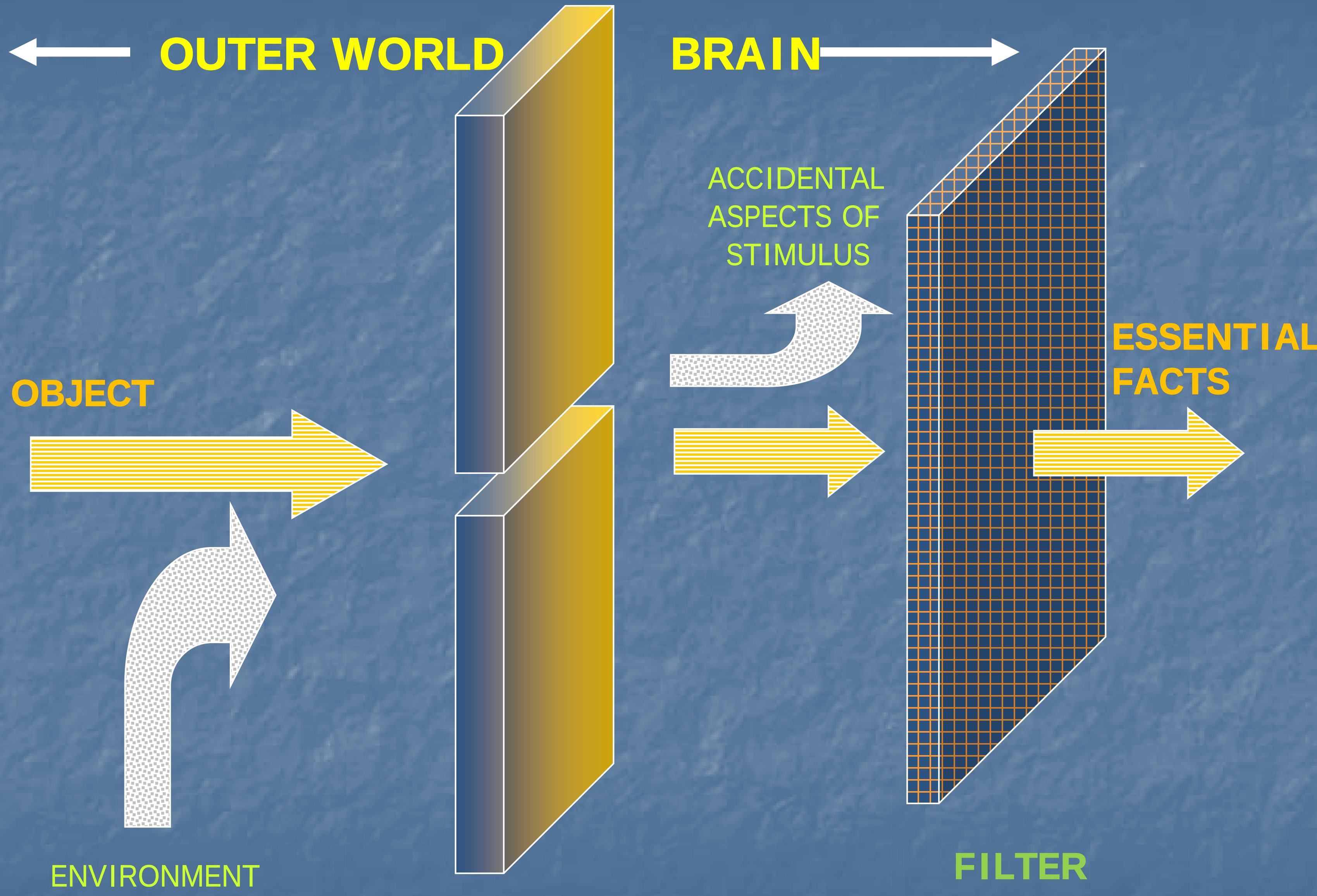
- Biology as a source of ideas for Photonics.

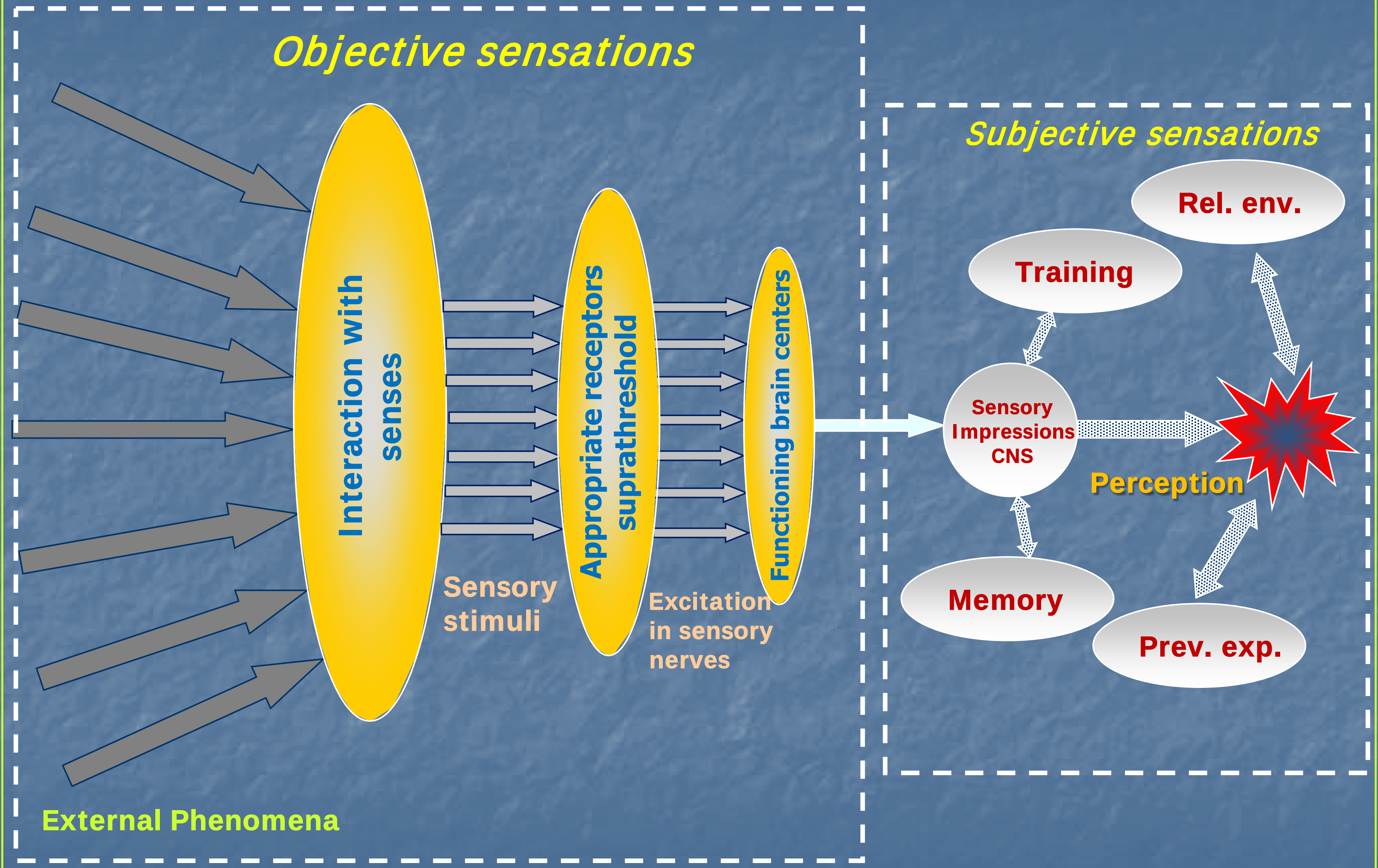
- Photonics as a source of concepts for Biology and viceversa.

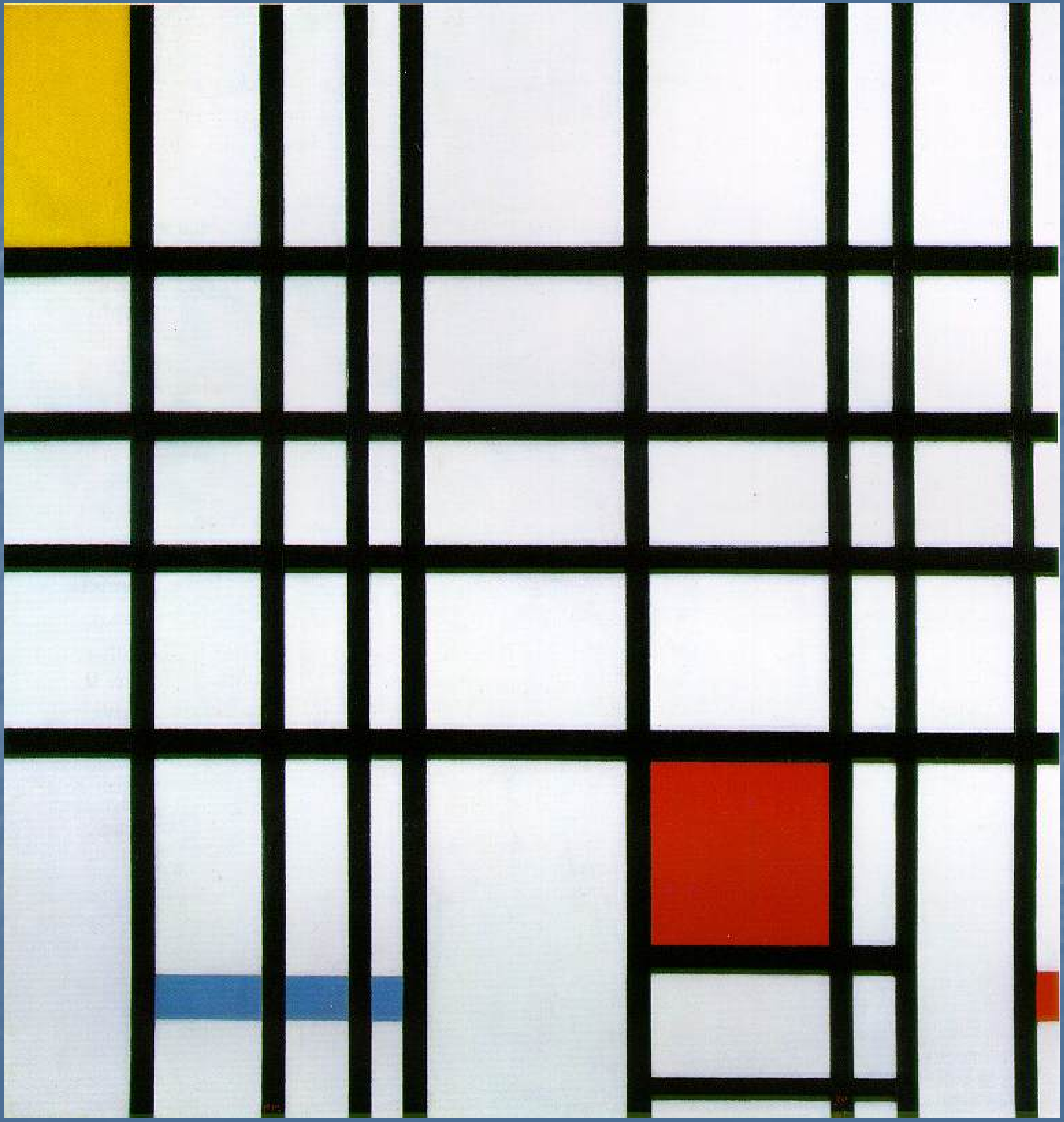
LIVING BODIES AND ARTIFICIAL SYSTEMS

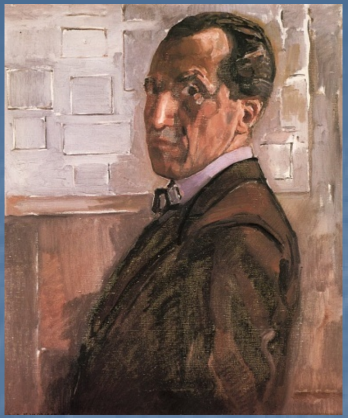
MAIN DIFFERENCE BETWEEN SENSING IN LIVING BODIES AND IN ARTIFICIAL SYSTEMS:

LIVING BODIES ARE ABLE TO INTERPRET STIMULI, THAT IS, ENVIRONMENTAL STIMULI AND THE RESPECTIVE RESPONSES OF SENSE ORGANS CORRESPOND TO STATEMENTS BY THE SUBJECT ABOUT HIS SENSATIONS AND PERCEPTIONS.


OUTER WORLD
BRAIN
ACCIDENTAL
ASPECTS OF
STIMULUS
ESSENTIAL
FACTS
OBJECT
ENVIRONMENT
FILTER

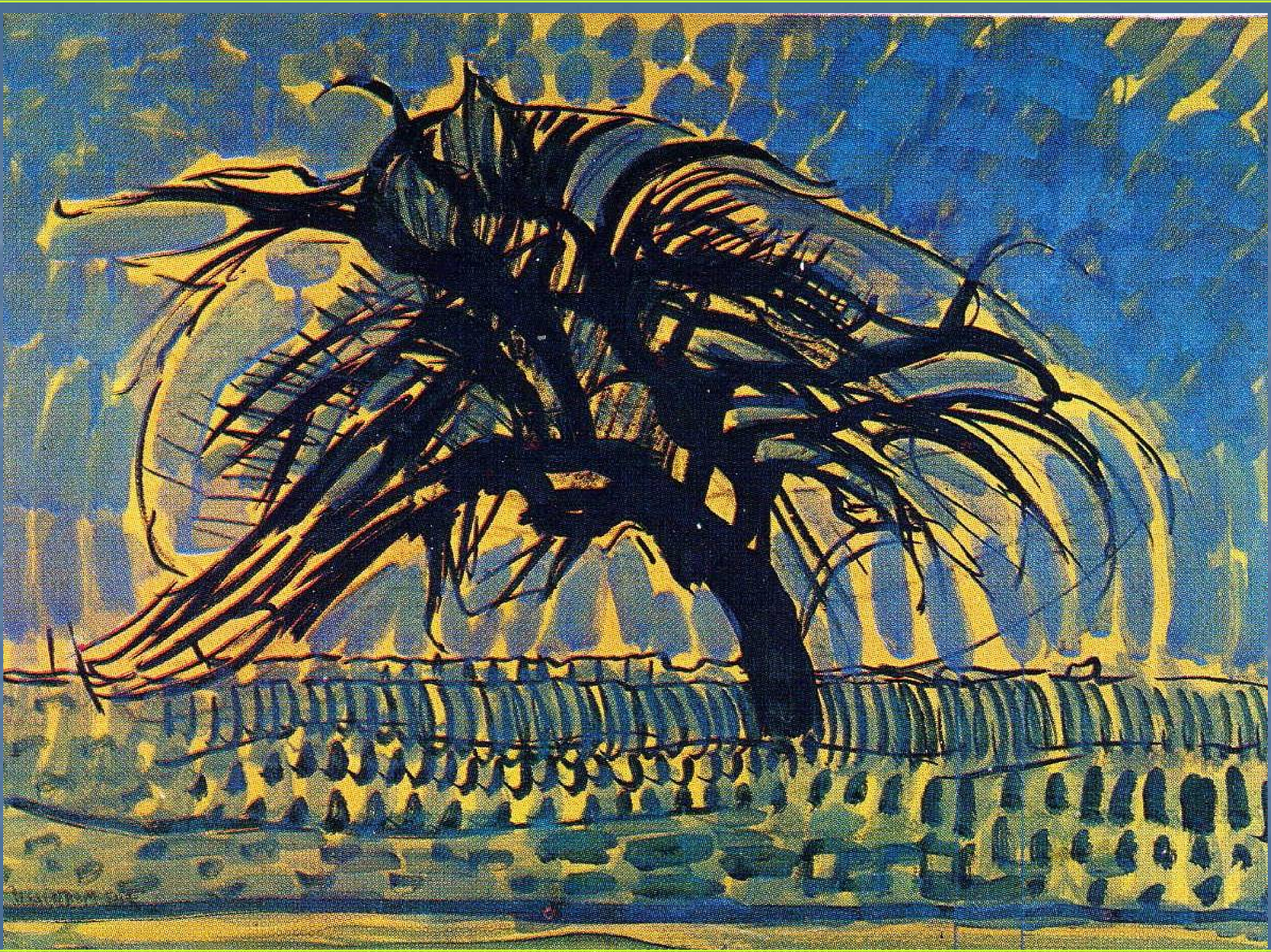

Objective sensations
Subjective sensations
Rel. env.
Training
Interaction with senses
Appropriate receptors suprathreshold
Functioning brain centers
Sensory Impressions CNS
Perception
Memory
Prev. exp.
Sensory stimuli
Excitation in sensory nerves
External Phenomena

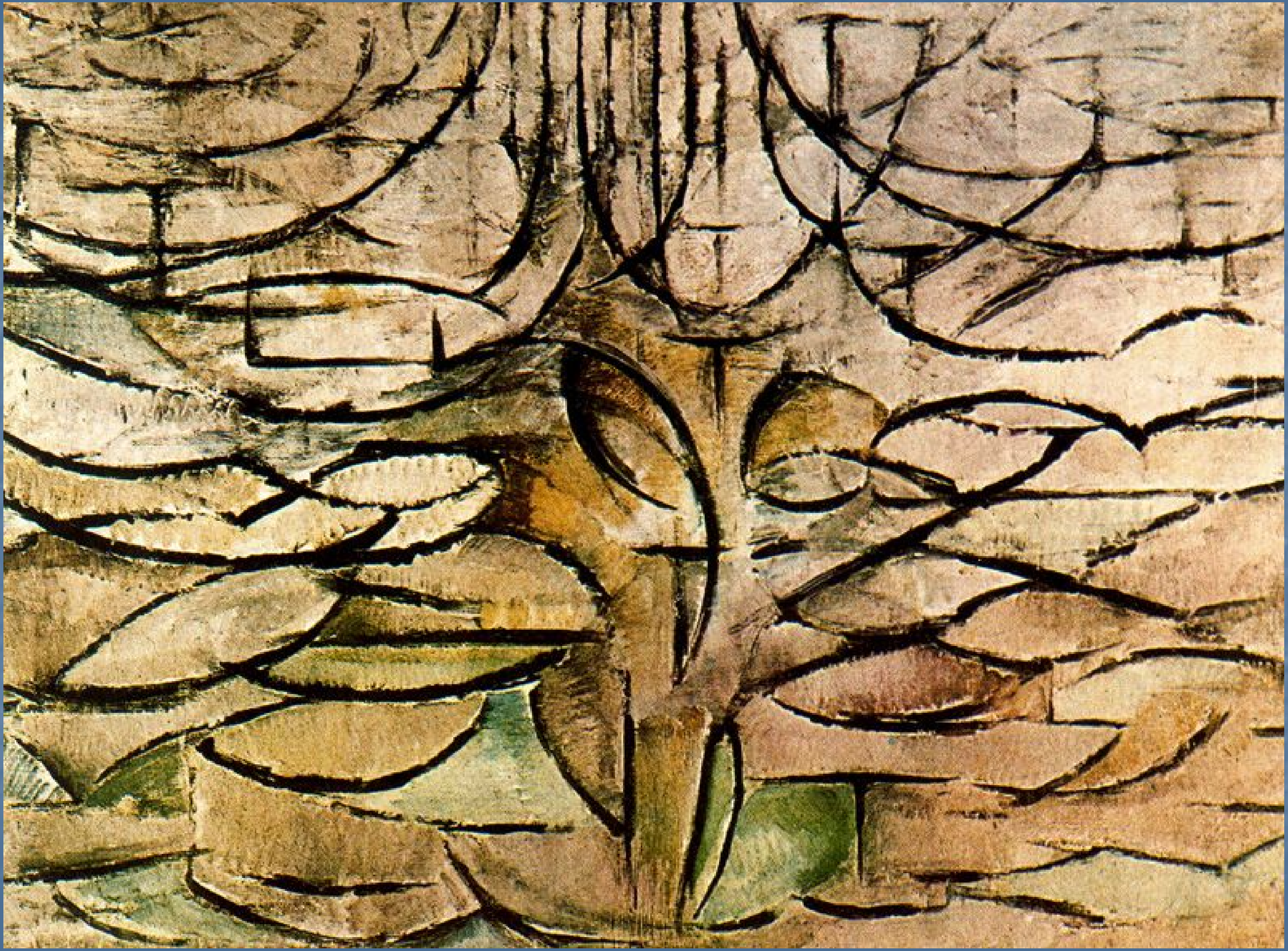




EXAMPLE

(according to P. MONDRIAN)





COUNTEREXAMPLE

(according to R. MAGRITTE)


Ceci n'est pas une pipe.

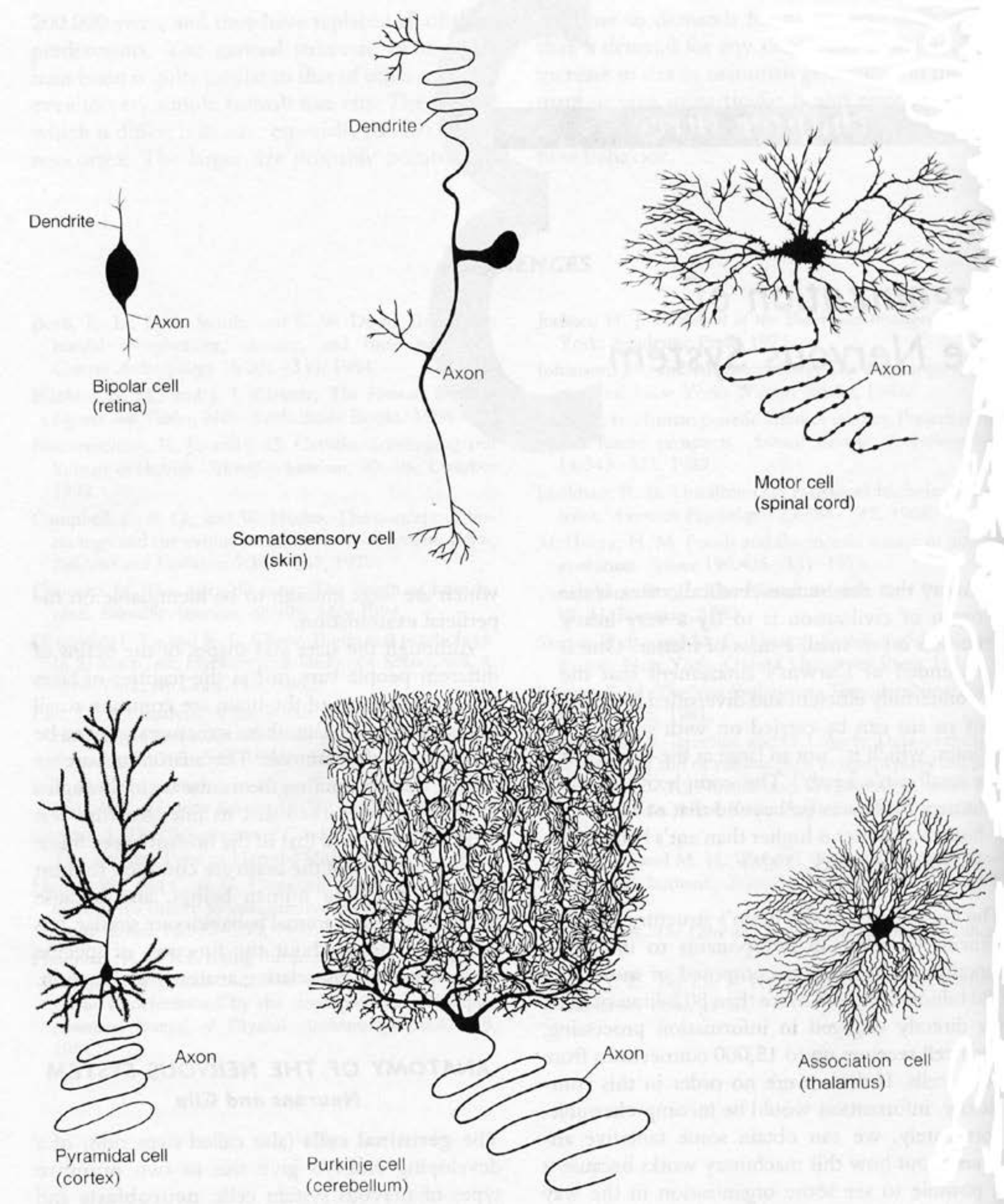
Mammalian Visual System: Retina and Visual Cortex

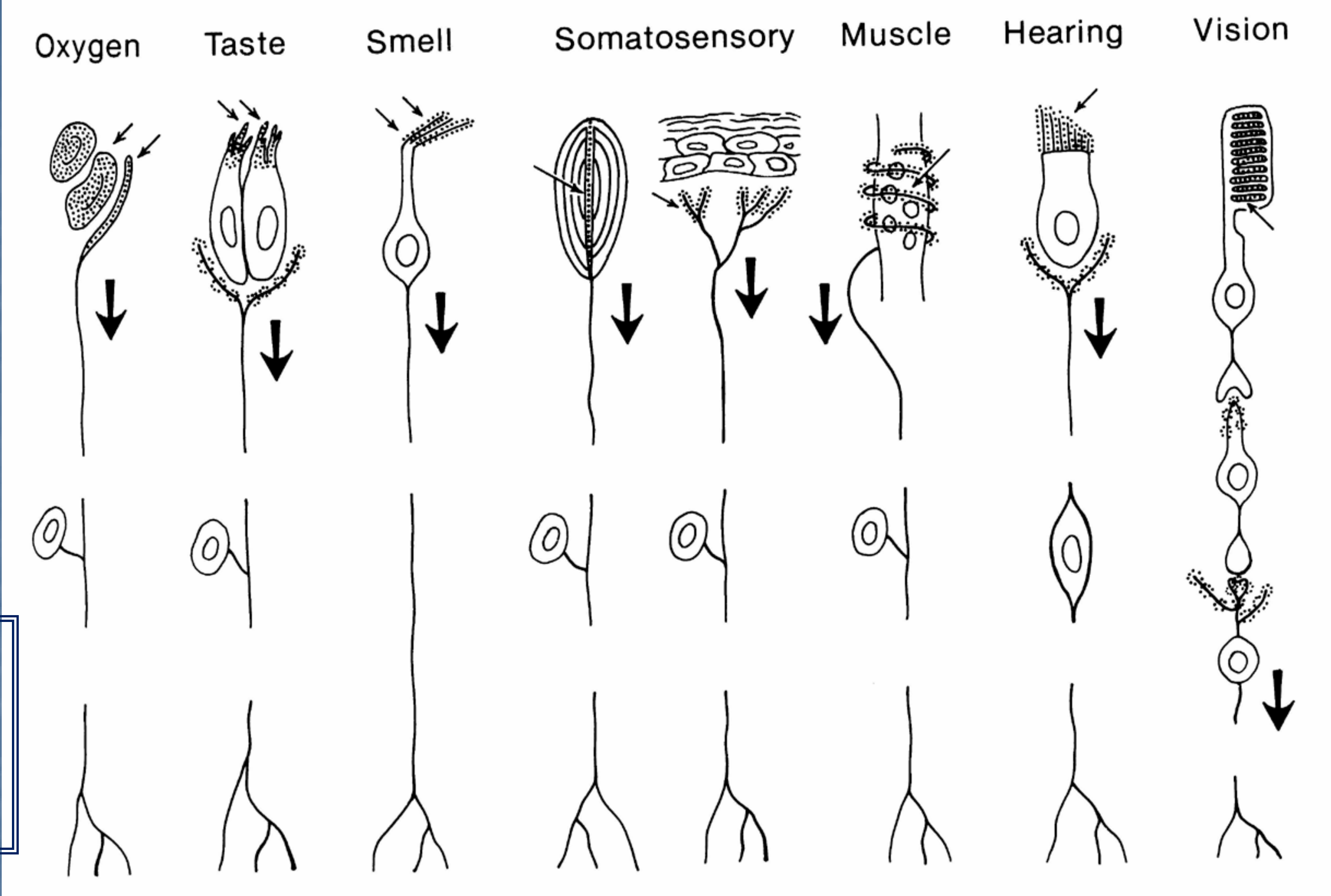
- Building blocks
- Building structures
- Signals involved
- Main characteristics

Building blocks:

Neurons and Receptors

Different neurons from the mammalian cortex





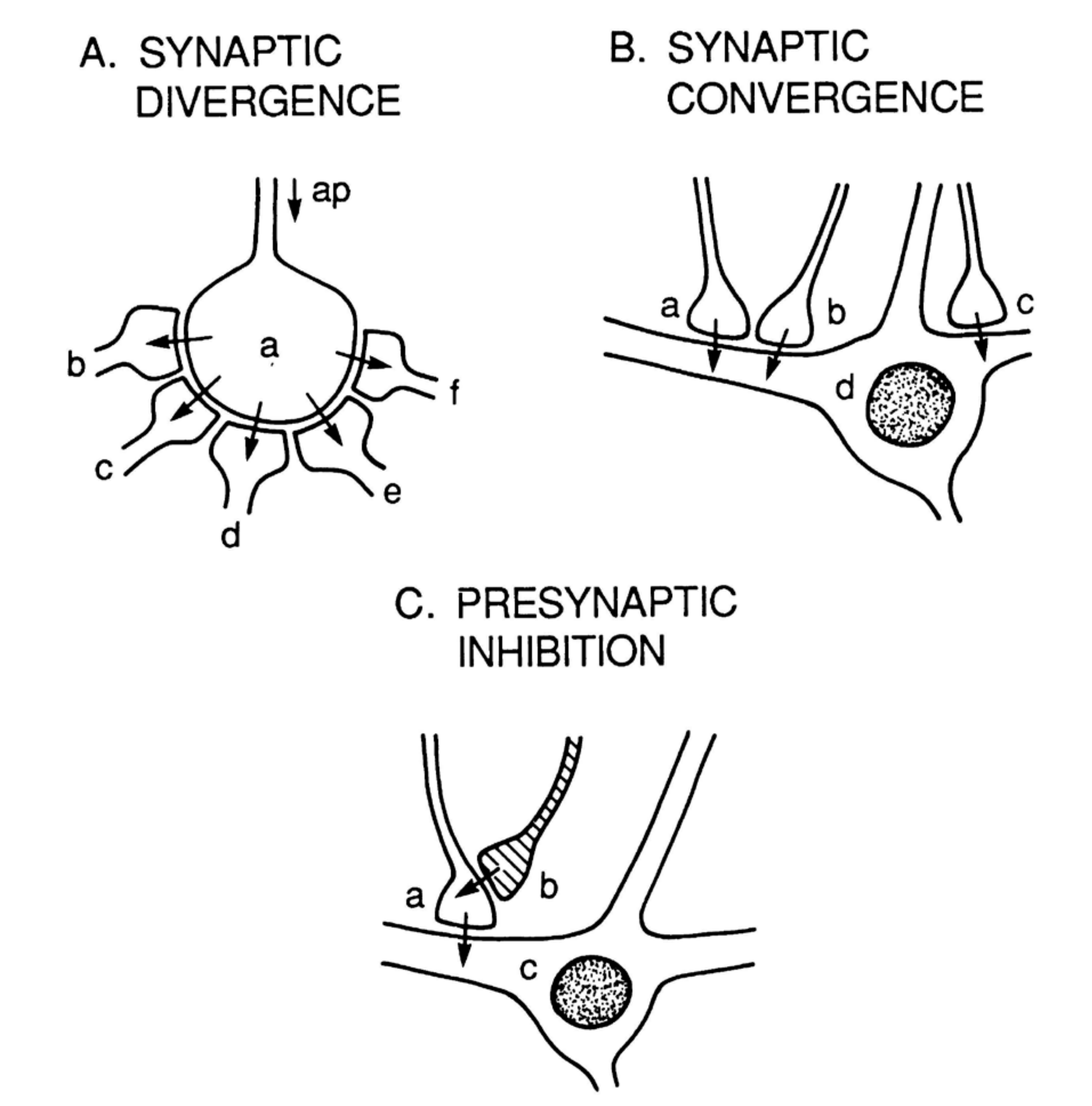
sensory stimuli

impulse initiation

Different types of sensory receptor cells in vertebrates

Building structures:

Circuits and Networks

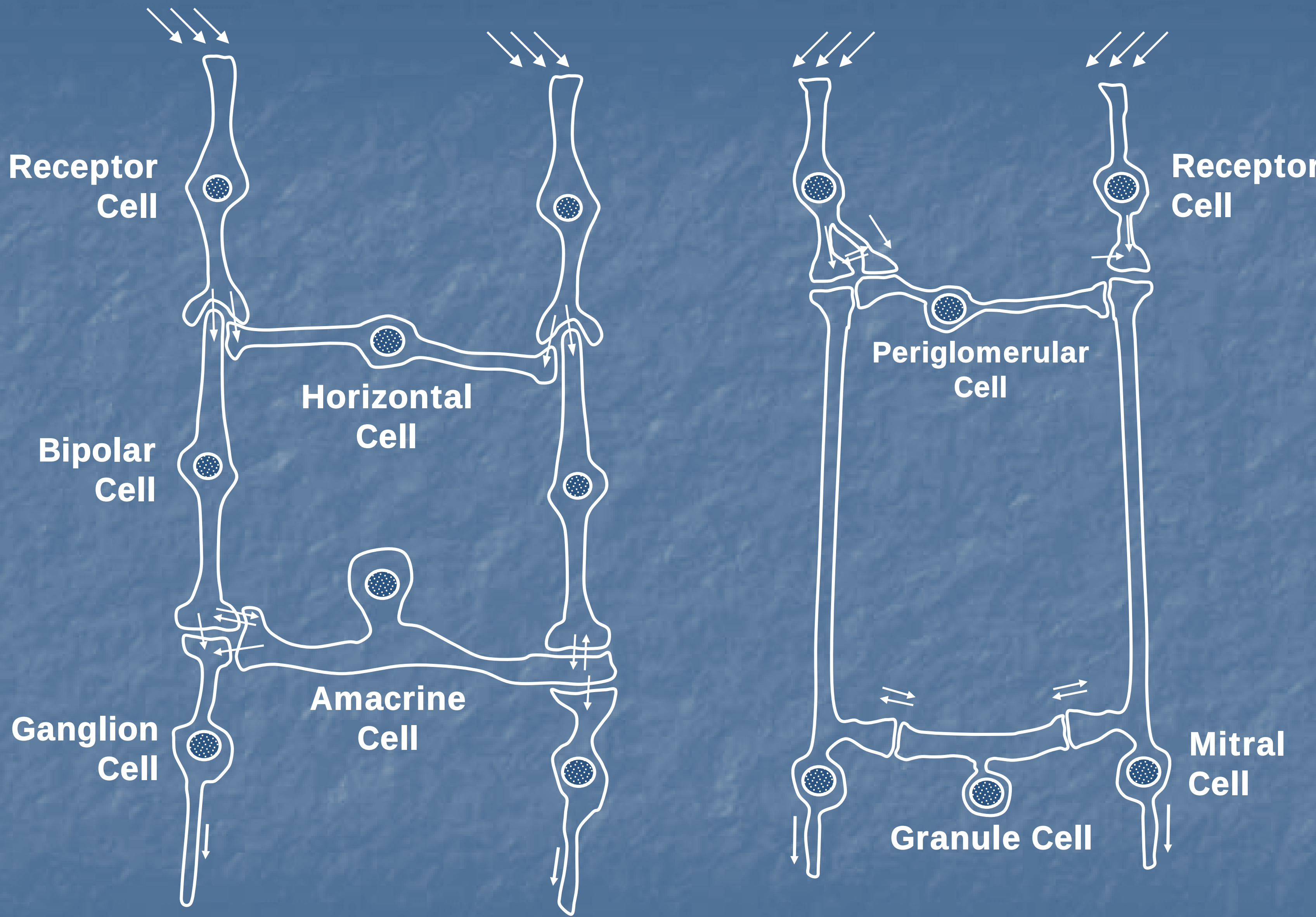


The simplest types of microcircuits

Basic "*circuits*", corresponding to different cortex regions, are similar in outline and in several details.

Common principles:

In each region there is an initial stage of input processing, a second stage of intrinsic operations within the synaptic circuits of the region, and a final stage of output control.



(a) RETINA

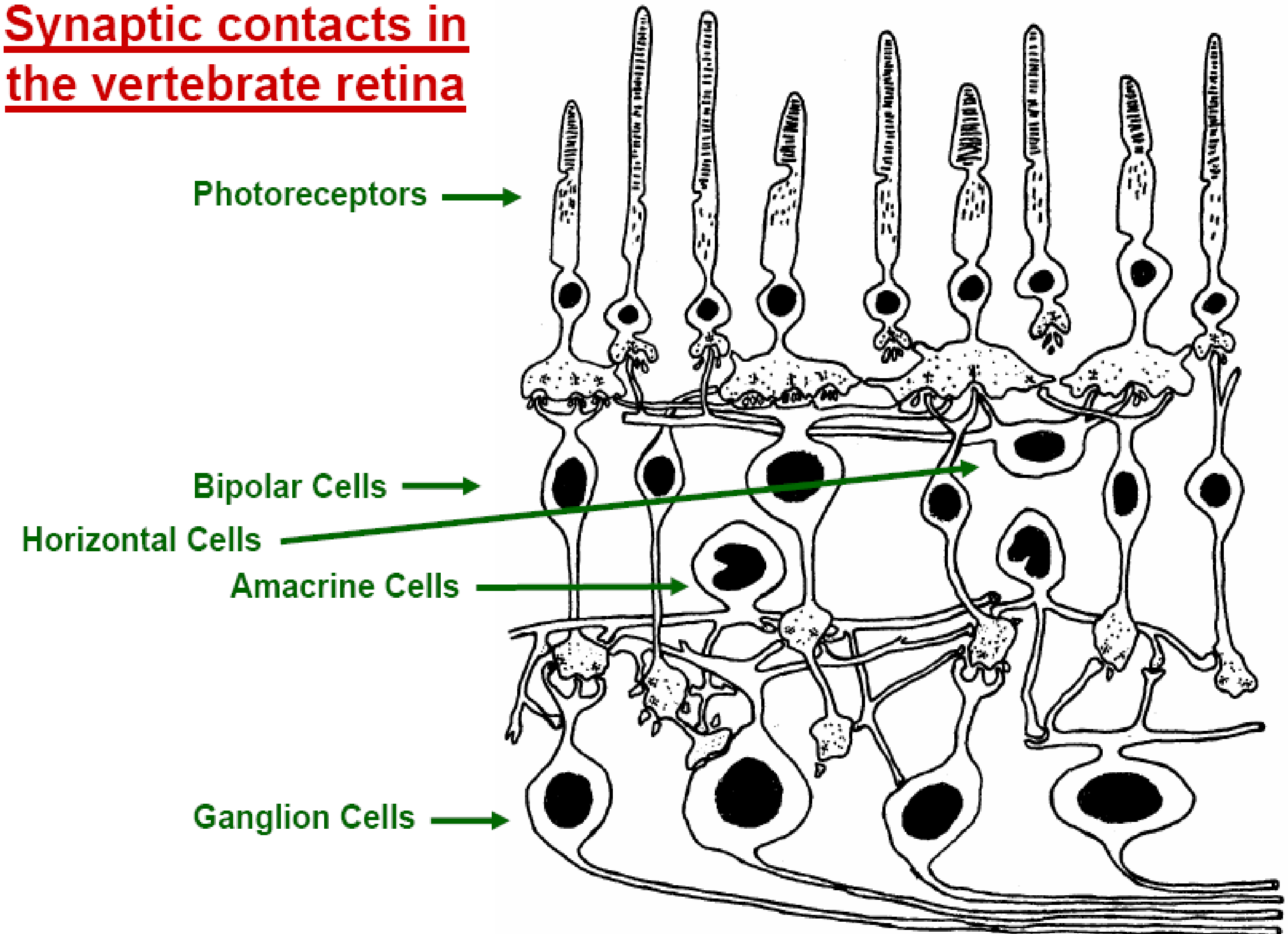
(b) OLFACTORY BULB

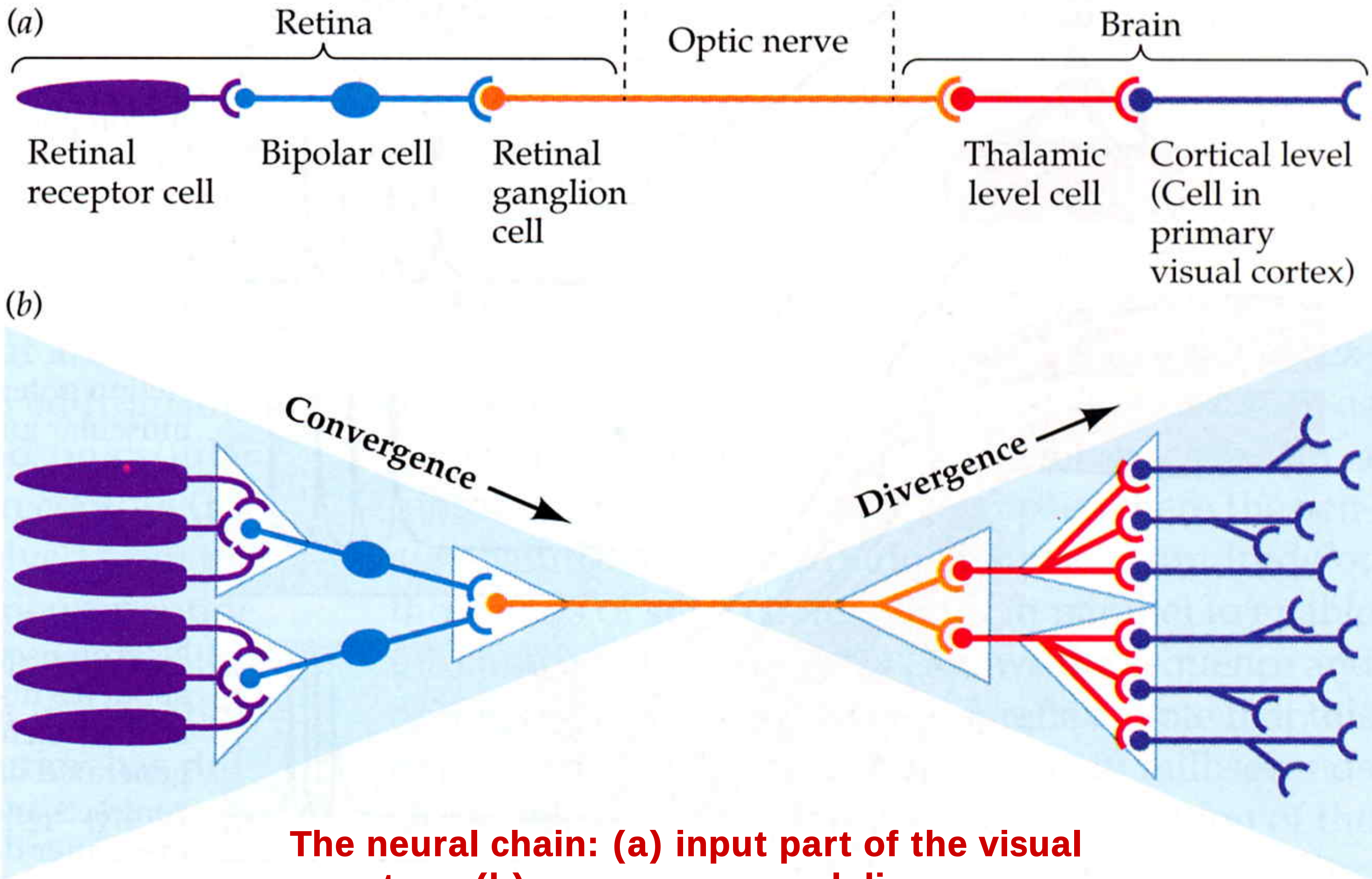
CONVERGENCE AND DIVERGENCE

Once the superficial sensing units have received the external signal, a first processing step is carried out in a few cell layers. Usually, the number of sensing cells, in the first stratum, is much larger than the corresponding to neurons at successive layers.

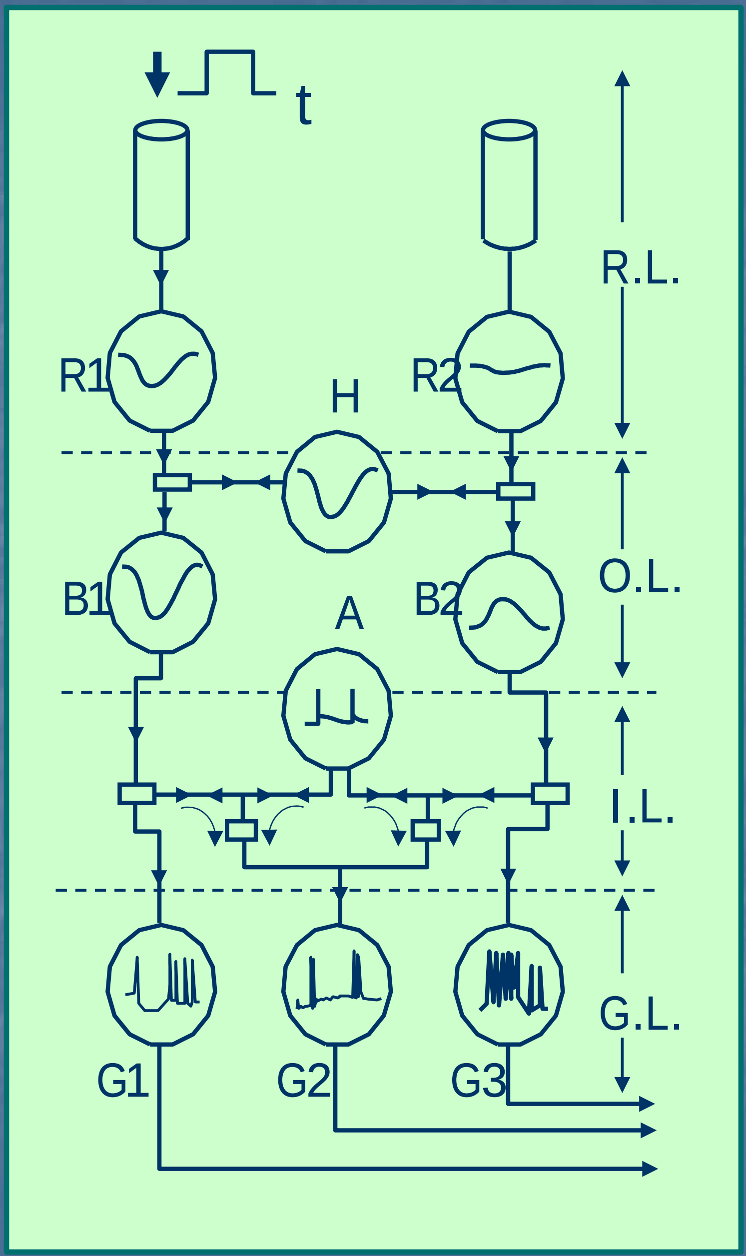
Approaching to the mammalian retina: a model

Synaptic contacts in the vertebrate retina



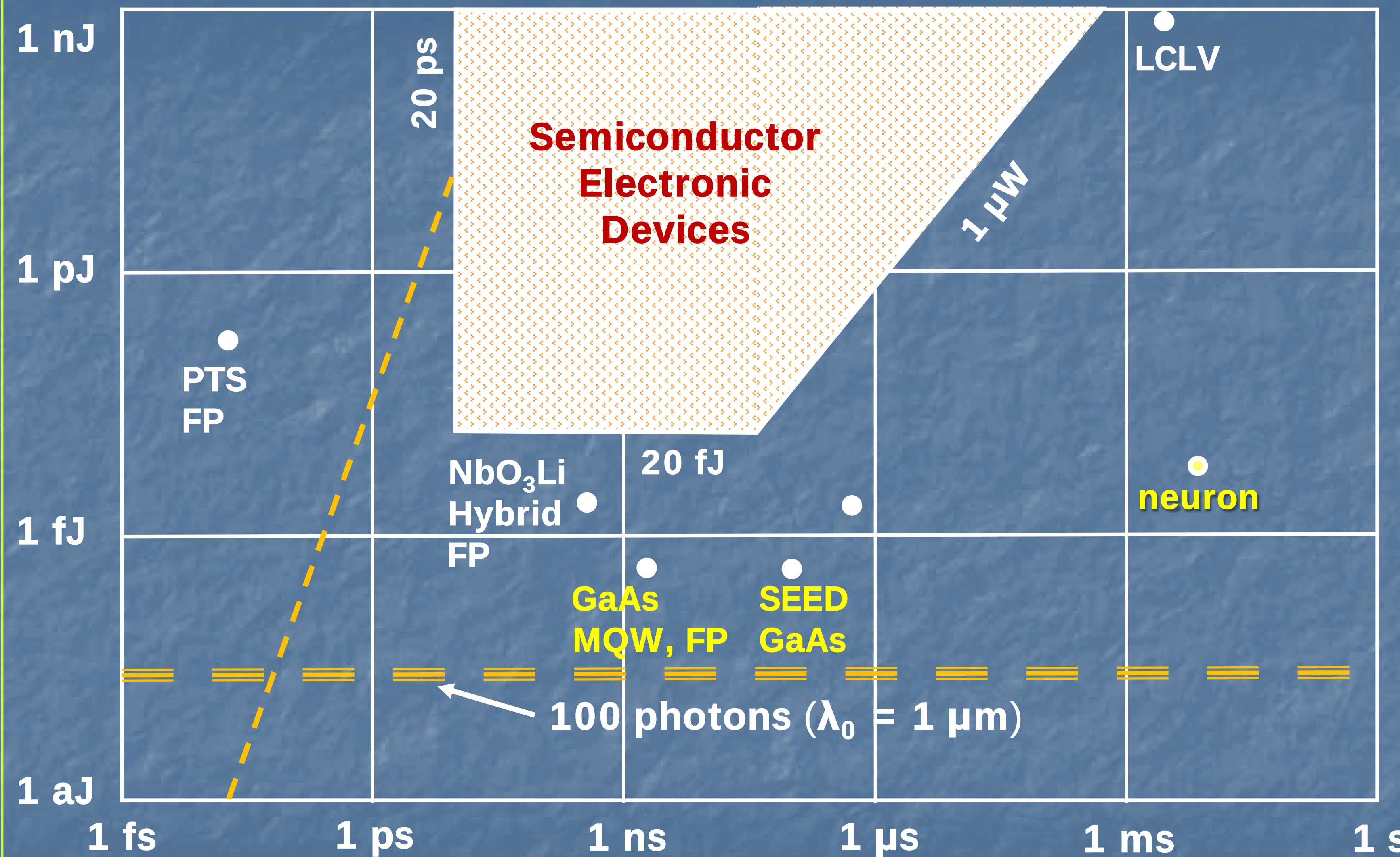


The neural chain: (a) input part of the visual system, (b) convergence and divergence



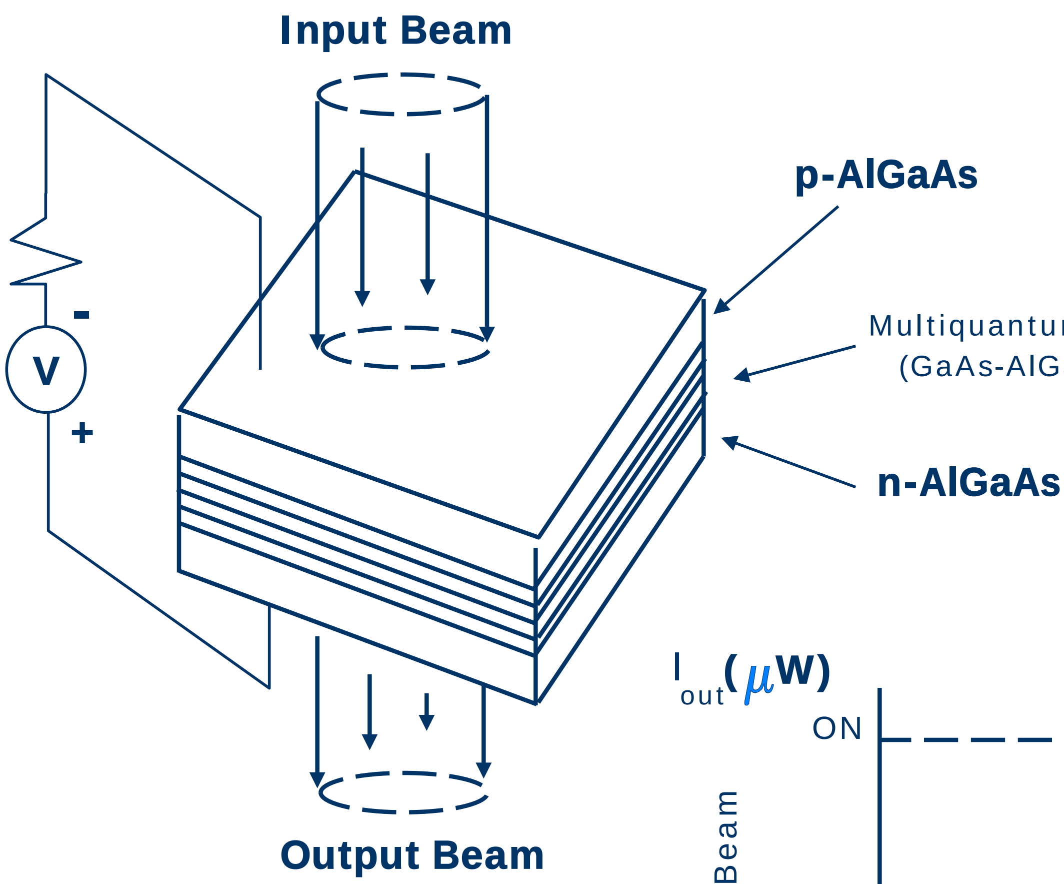
Dowling's model of the mammalian retina

Tools for modeling the mammalian retinal: non linear photonic devices

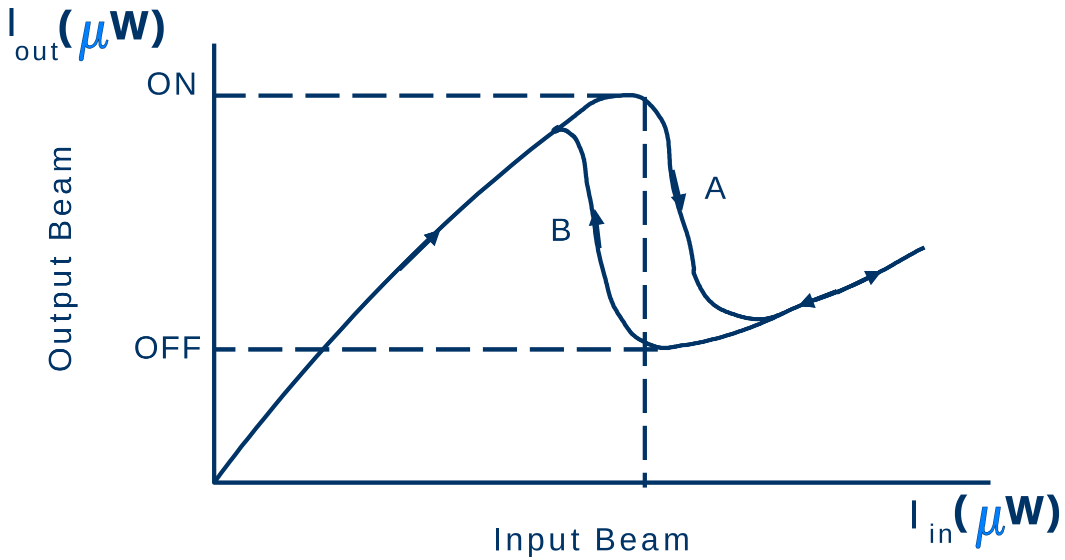


based on P.W. Smith. Bell Syst. Tech. Jour. 1982

SEED

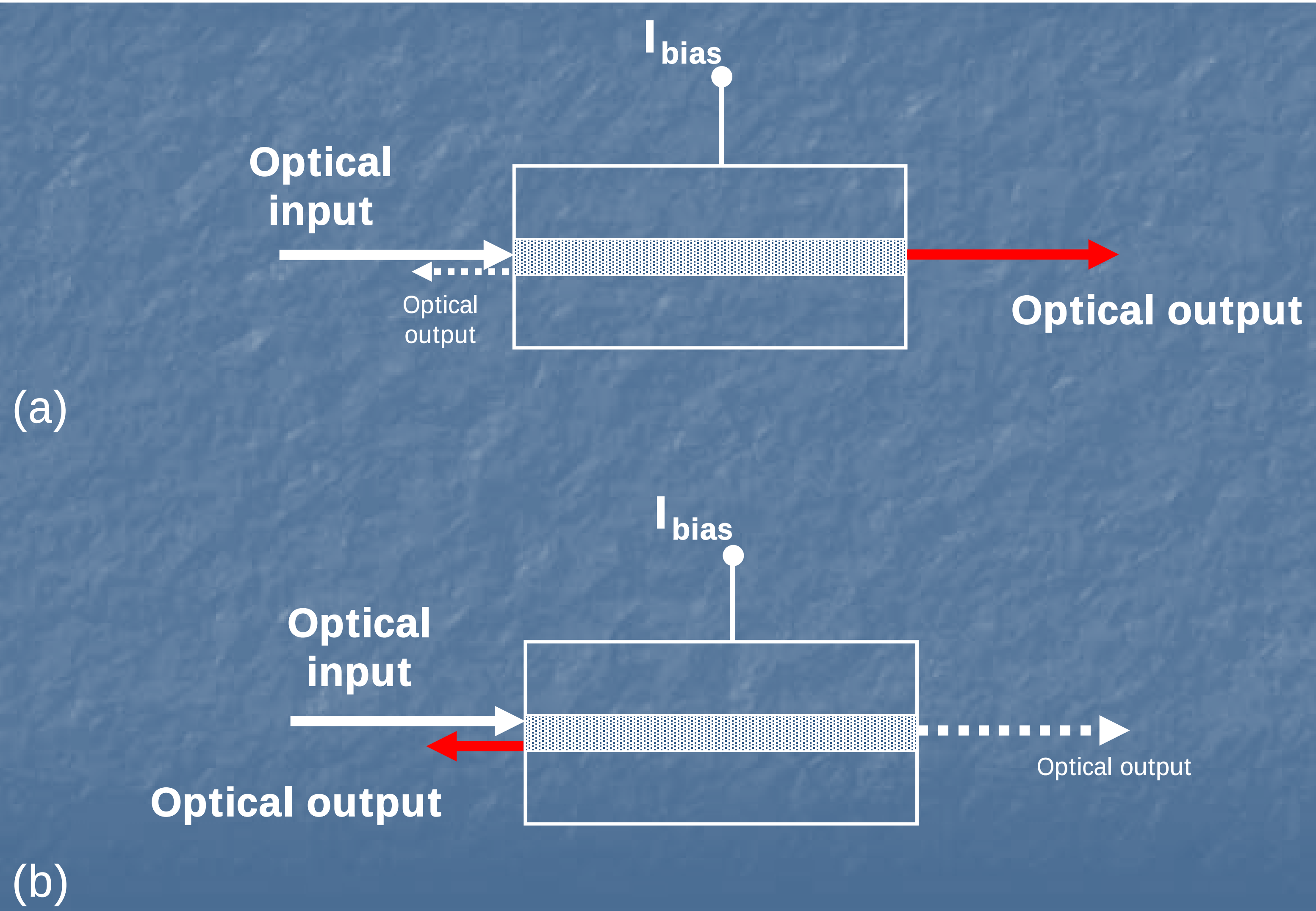


Input Beam
p-AlGaAs
Multiquantum well
(GaAs-AlGaAs)
n-AlGaAs
V
-
+
Output Beam



I out (μW)
ON
OFF
Output Beam
A
B
I in (μW)
Input Beam

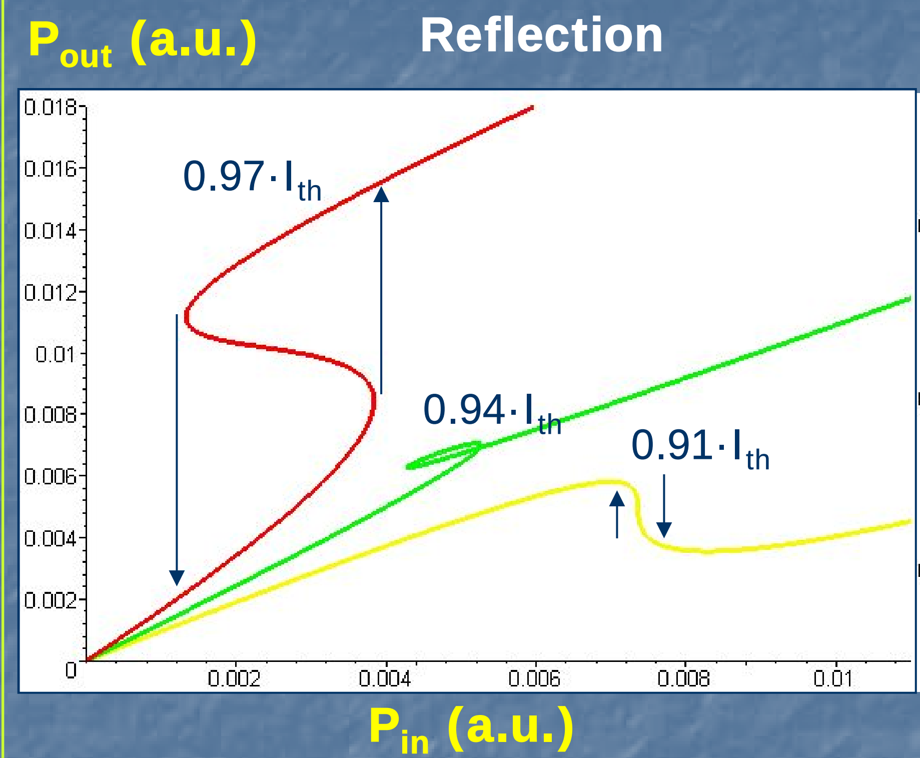
Basic configurations of FP laser diode amplifiers (a) transmission and (b) reflection.

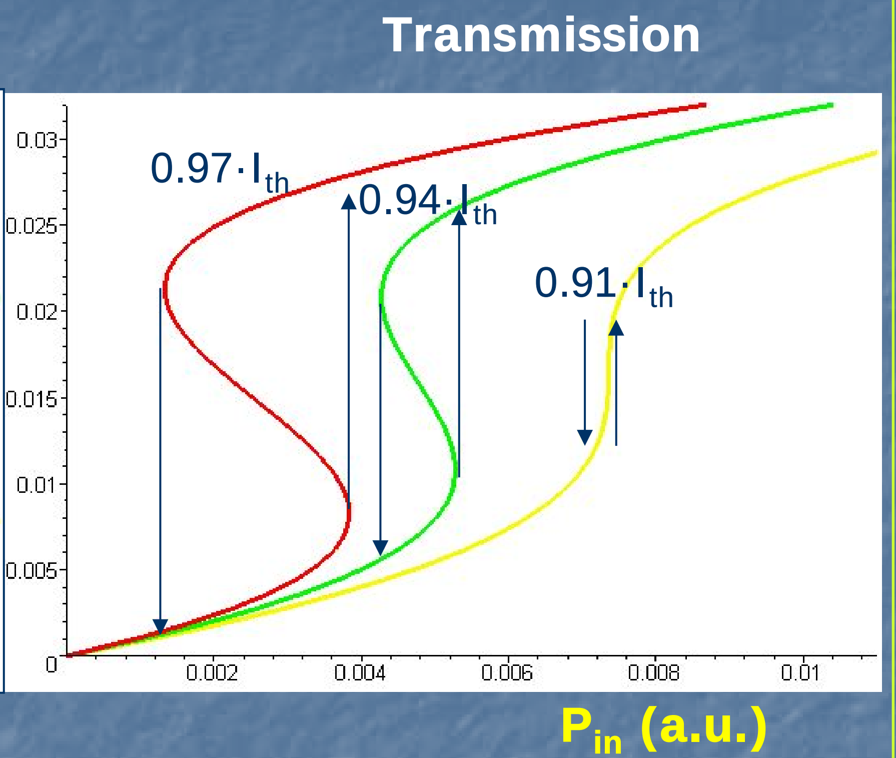


Fabry-Perot Laser Diode Amplifiers

- They exhibit Optical Bistability (OB) under external signal injection.
- Dispersive Optical Bistability.
- Presence of Optical Gain.
- Low Input Power Requirements.
- Different operating Wavelengths.
- Easy to obtain.

Bistability in FPLDAs

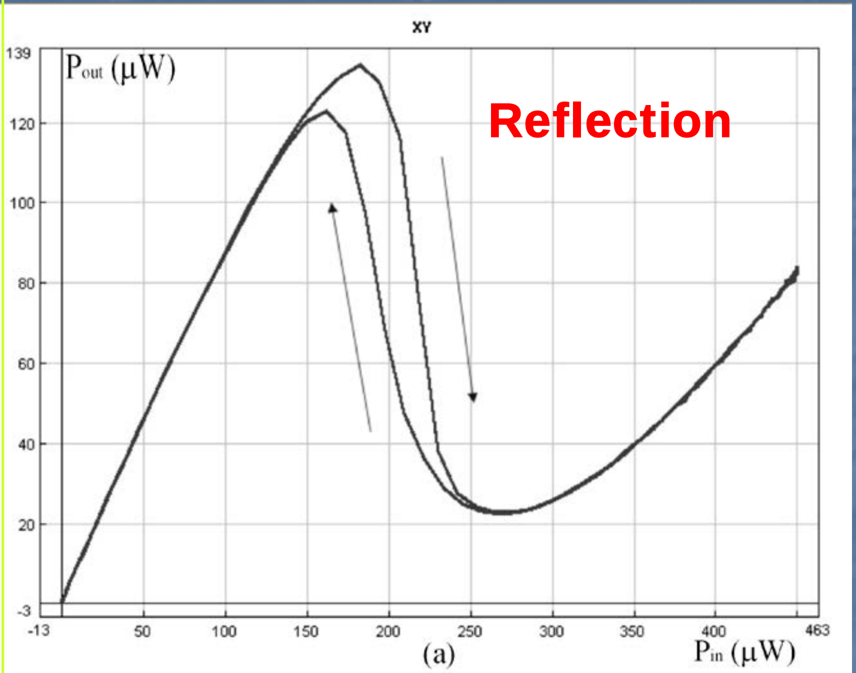


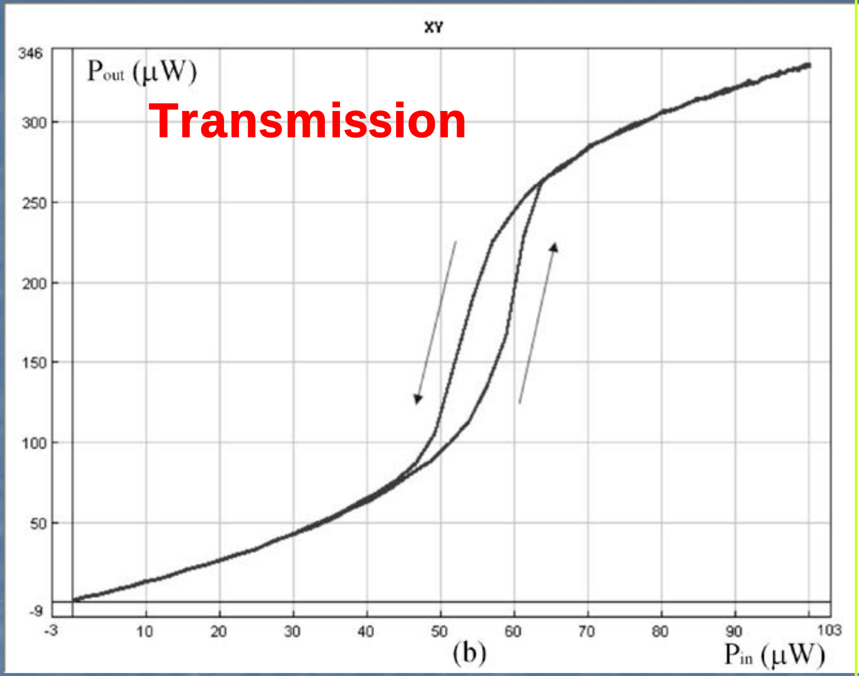


<u>Transmission</u>: Anticlockwise bistable loops.

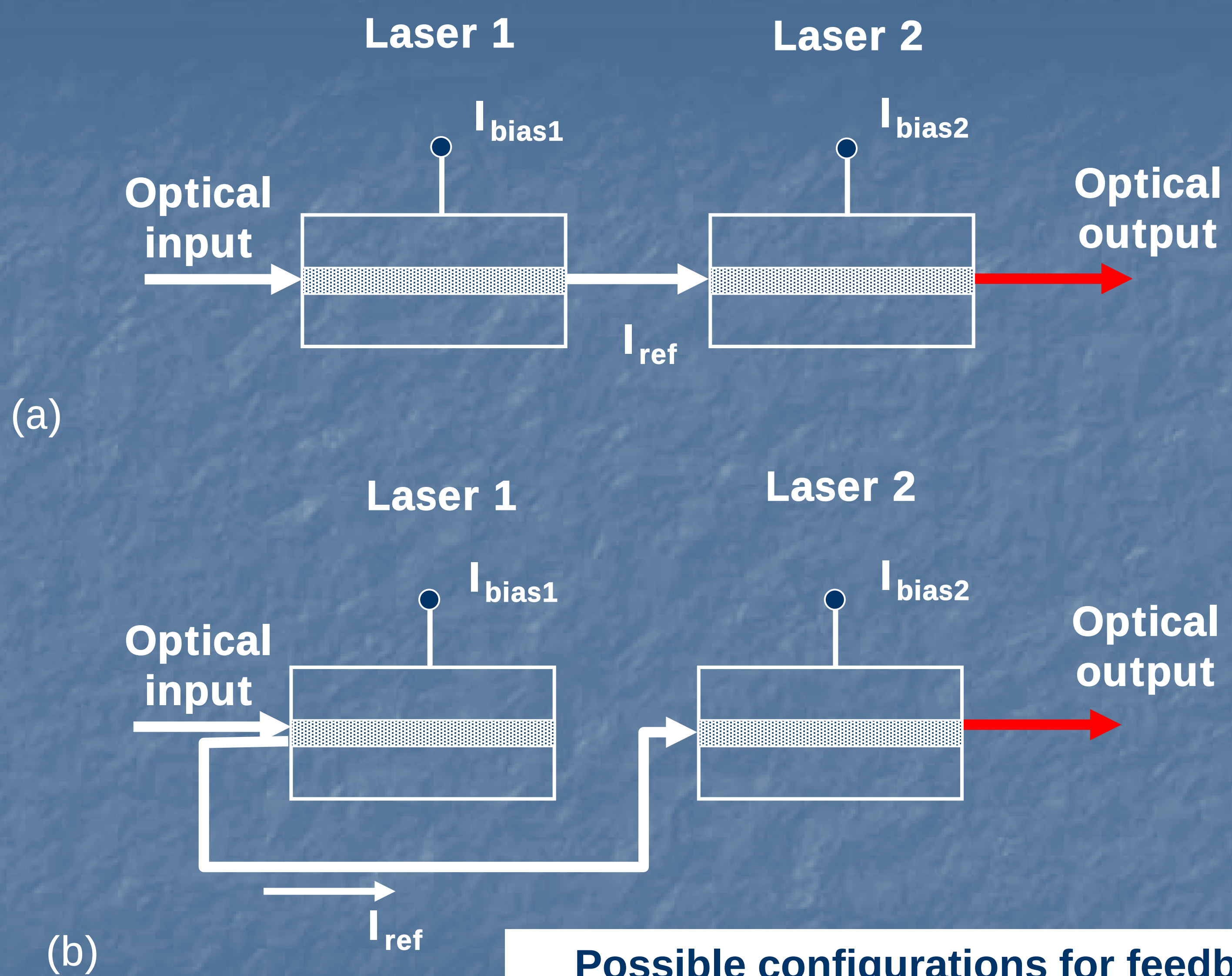
<u>Reflection</u>: Anticlockwise, X- and clockwise bistable loops.

Individual Responses

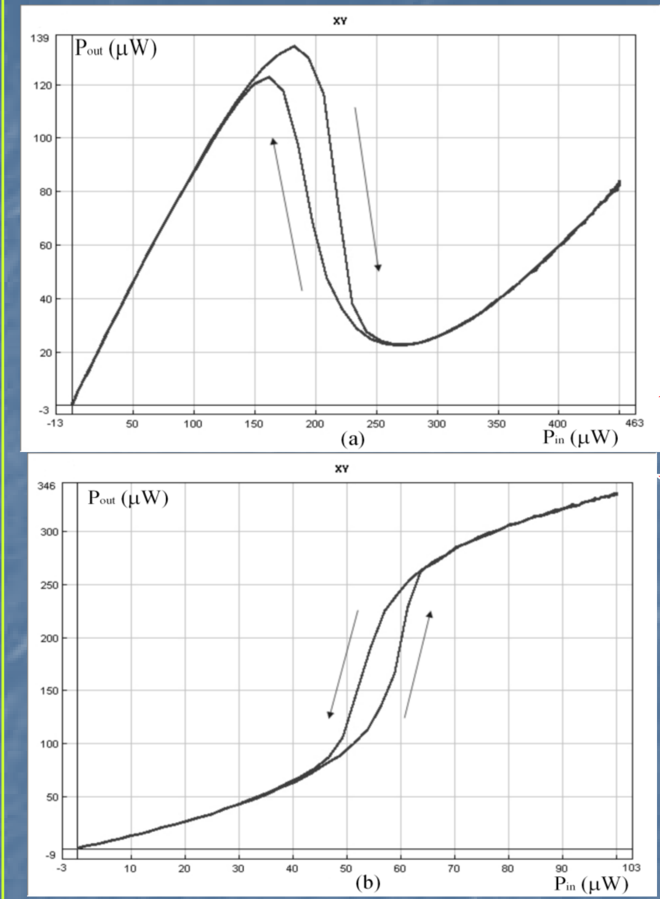




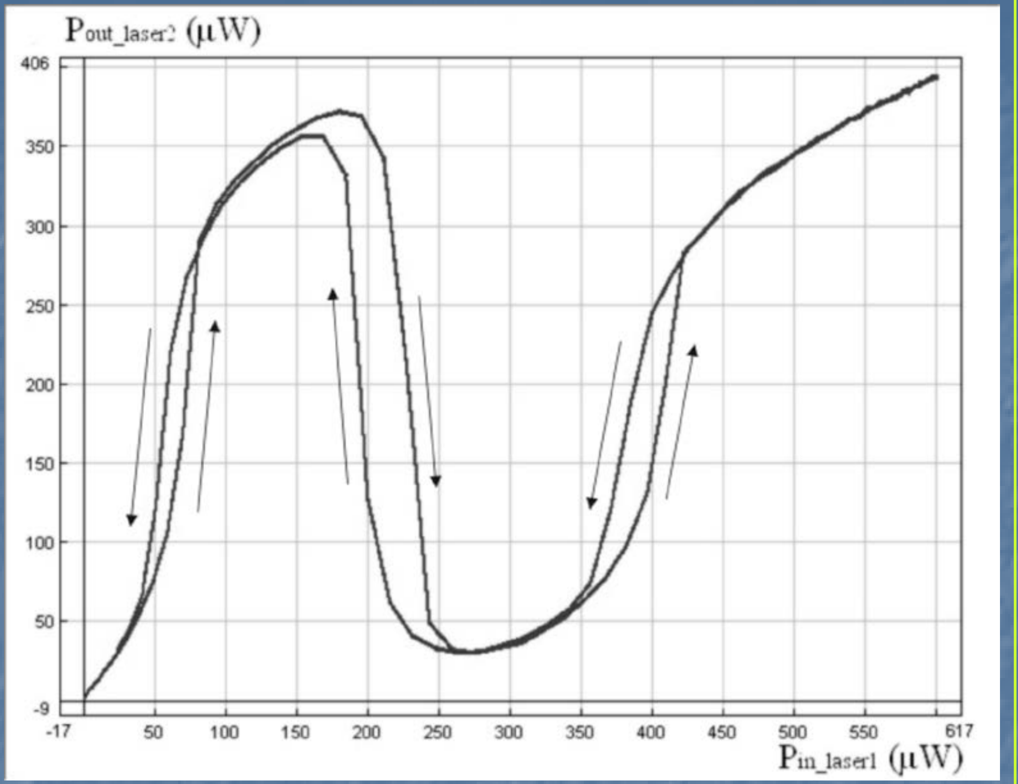
Laser1	Laser Parameter	Laser2
350	Cavity Length (μm)	400
0.3	Left/Right Facet Reflectivity	0.3
0.5	Confinement Factor	0.5
$2.2 \cdot 10^{-16}$	Linear Material Gain Coeff. (cm^2)	$2.2 \cdot 10^{-16}$
6.9	Linewidth Enhancement Factor	6.9
5000	Fixed Internal Loss (1/m)	5000
0.84	Bias/Threshold current	0.92
0.28 π	Initial frequency detuning	0.2125 π



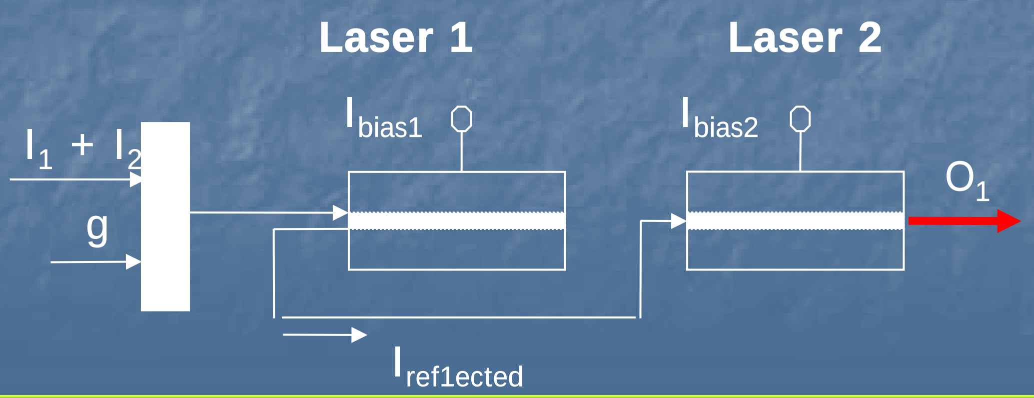
Possible configurations for feedback in laser structures, (a) with transmitting signal, and (b) with reflecting signal from the first laser.



XY
Pout (µW)
(a)
Pin (µW)
XY
Pout (µW)
(b)
Pin (µW)

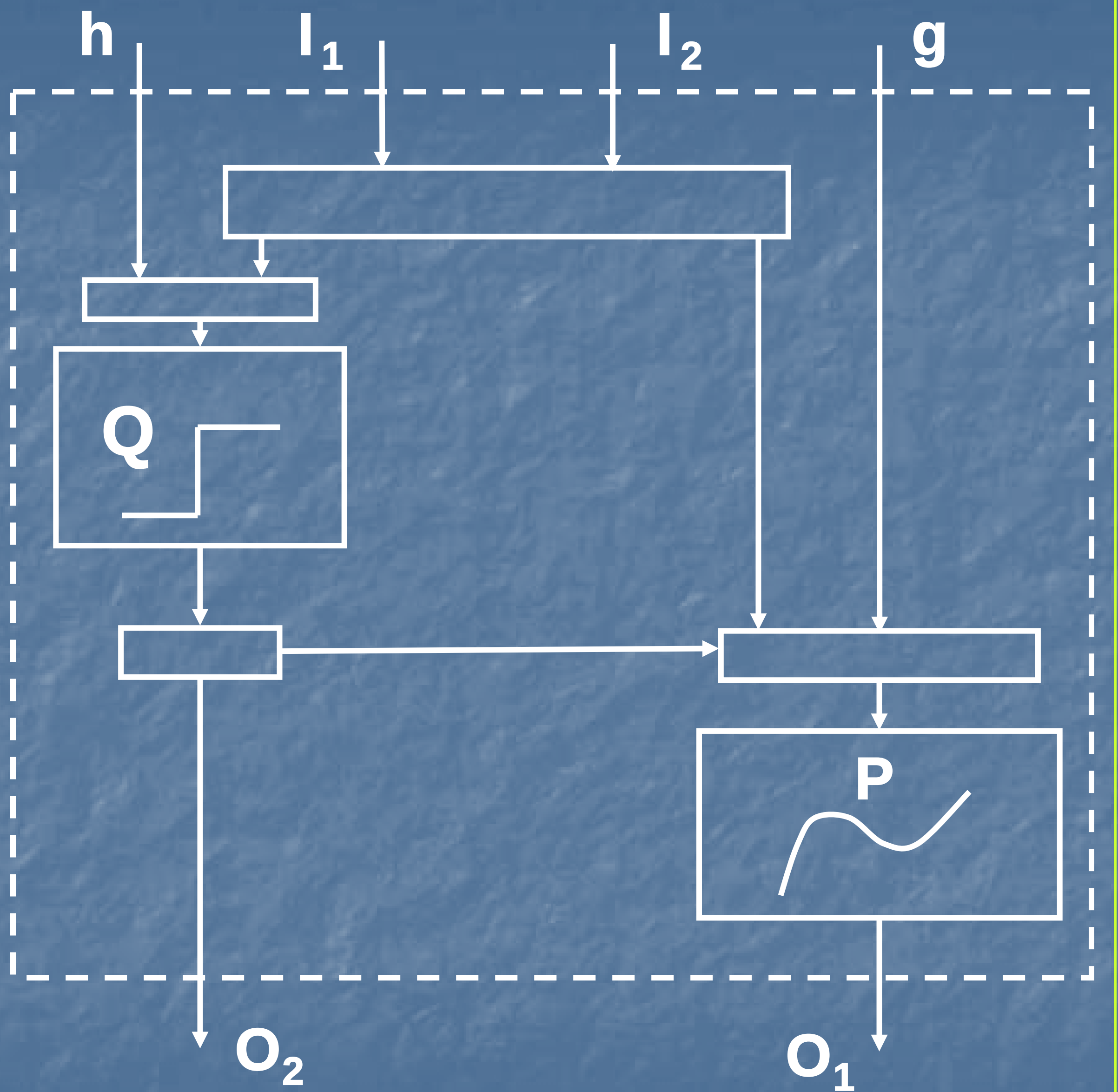


Pout_laser2 (µW)
Pin_laser1 (µW)

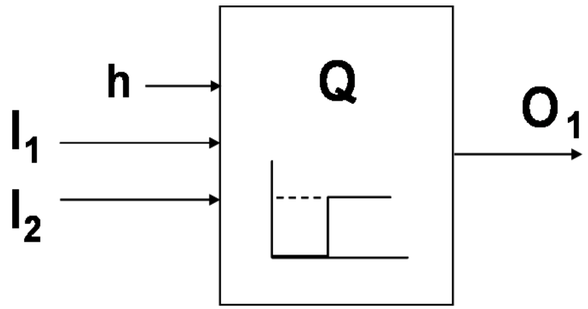


Laser 1
Laser 2
$I_1 + I_2$
g
I_{bias1}
I_{bias2}
O_1
$I_{ref1ected}$

Basic unit to configurate the main architecture: Optical Programmable Logic Cell (**OPLC**)



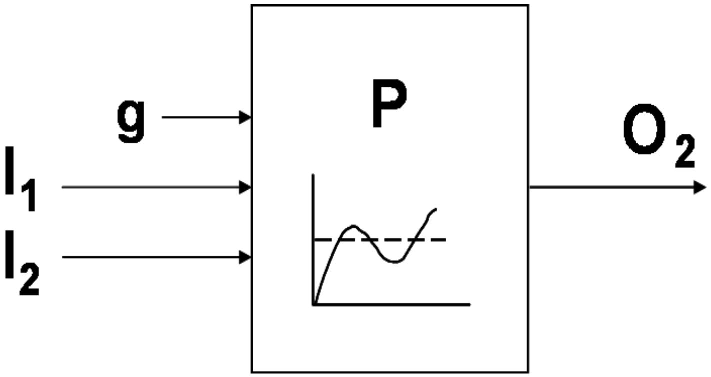
Block Diagram a Q-device



Logic Table for the OLG.

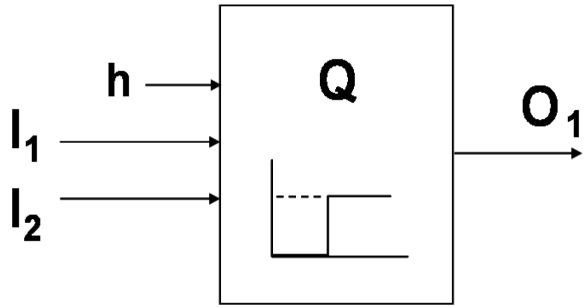
	h_0	h_1	h_2
O_1	AND	OR	ON

Block Diagram of P-Device.



	g_0	g_1	g_2	g_3	g_4
O_2	OR	NAND	NOR	AND	OR

Block Diagram a Q-device

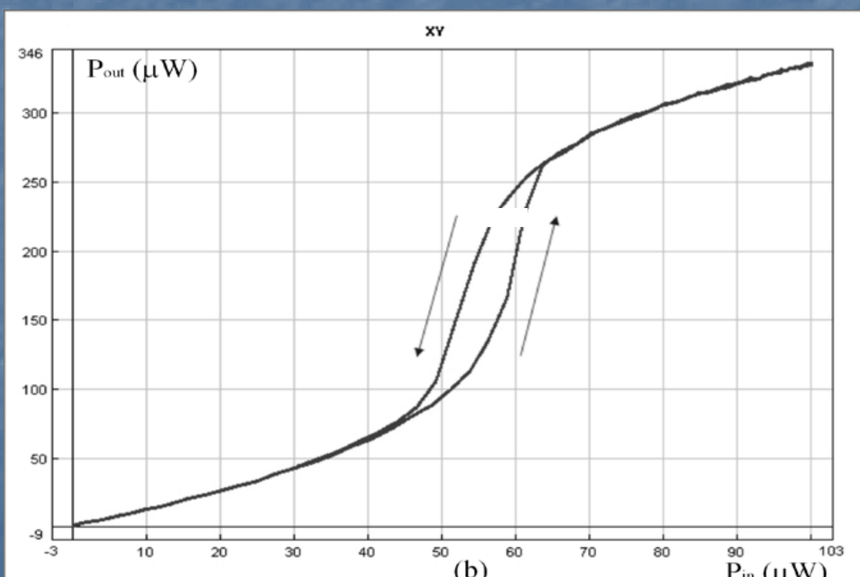


Logic Table for the OLG.

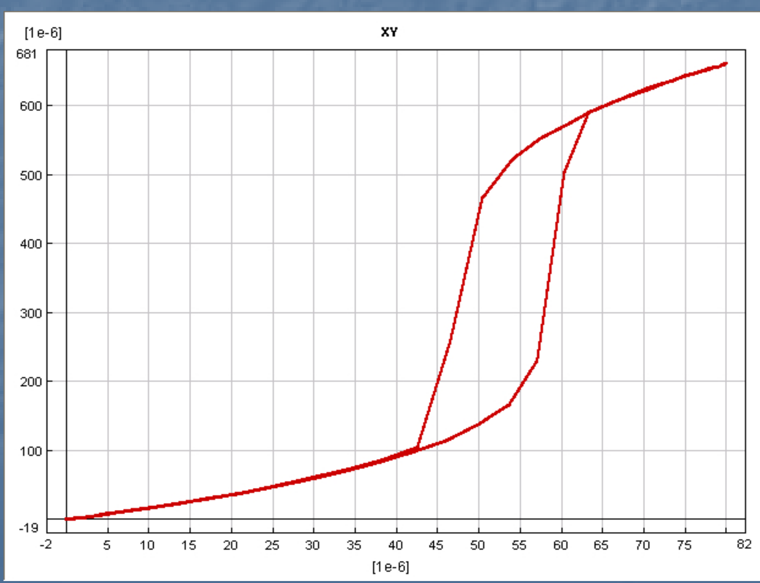
	h_0	h_1	h_2
O_1	AND	OR	ON

Transfer characteristic P_{out} (P_{in})

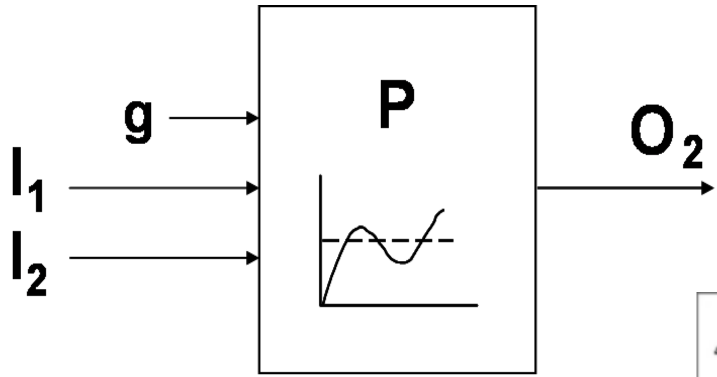
Fabry-Perot Laser Diode



DFB Laser Diode



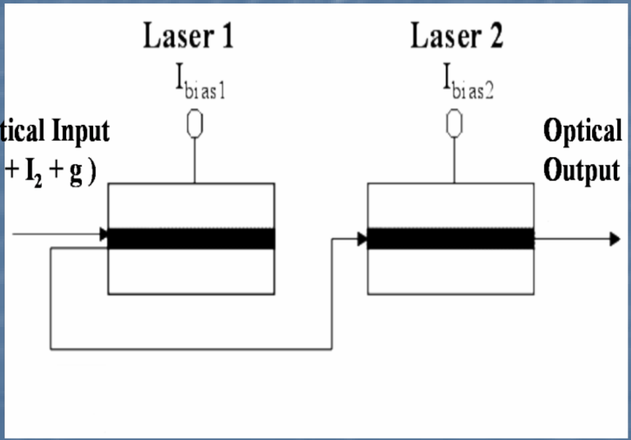
Block Diagram of P-Device.

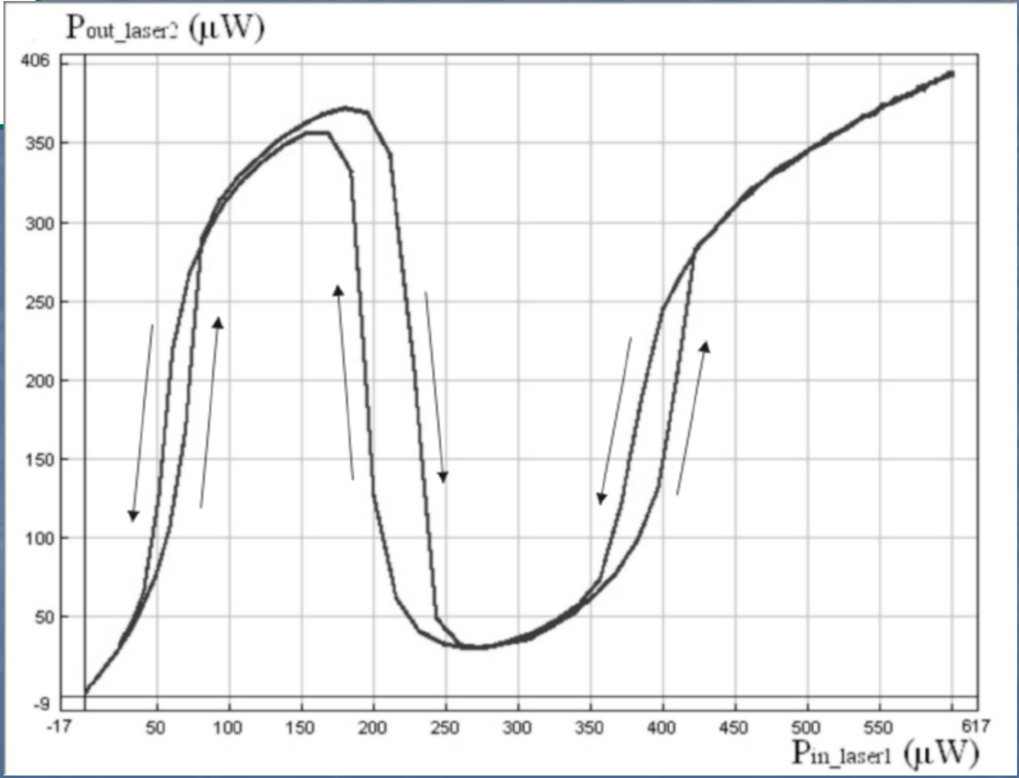


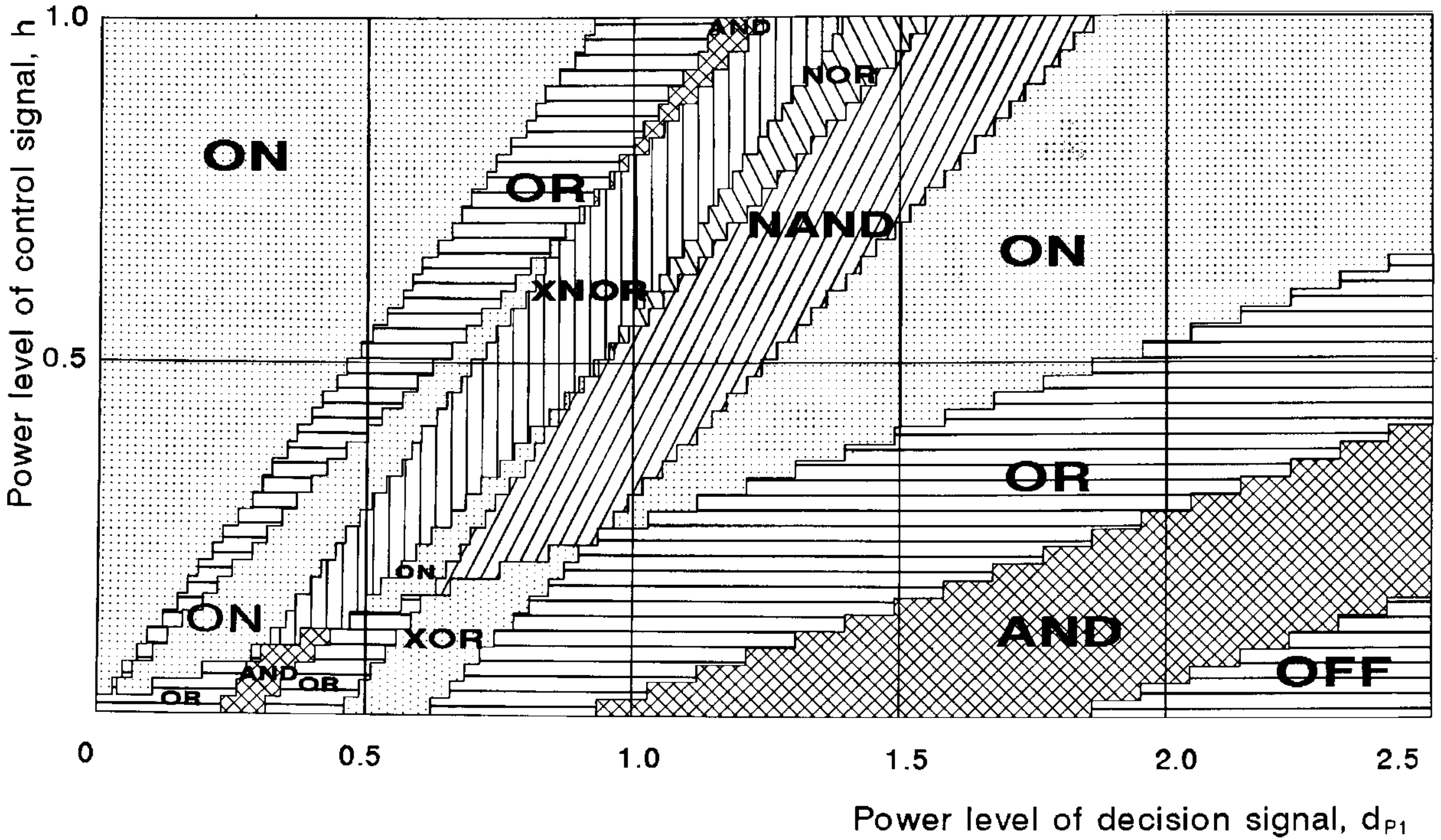
Logic table for OLG.

	g_0	g_1	g_2	g_3	g_4
O_2	OR	NAND	NOR	AND	OR

FP-LD configuration

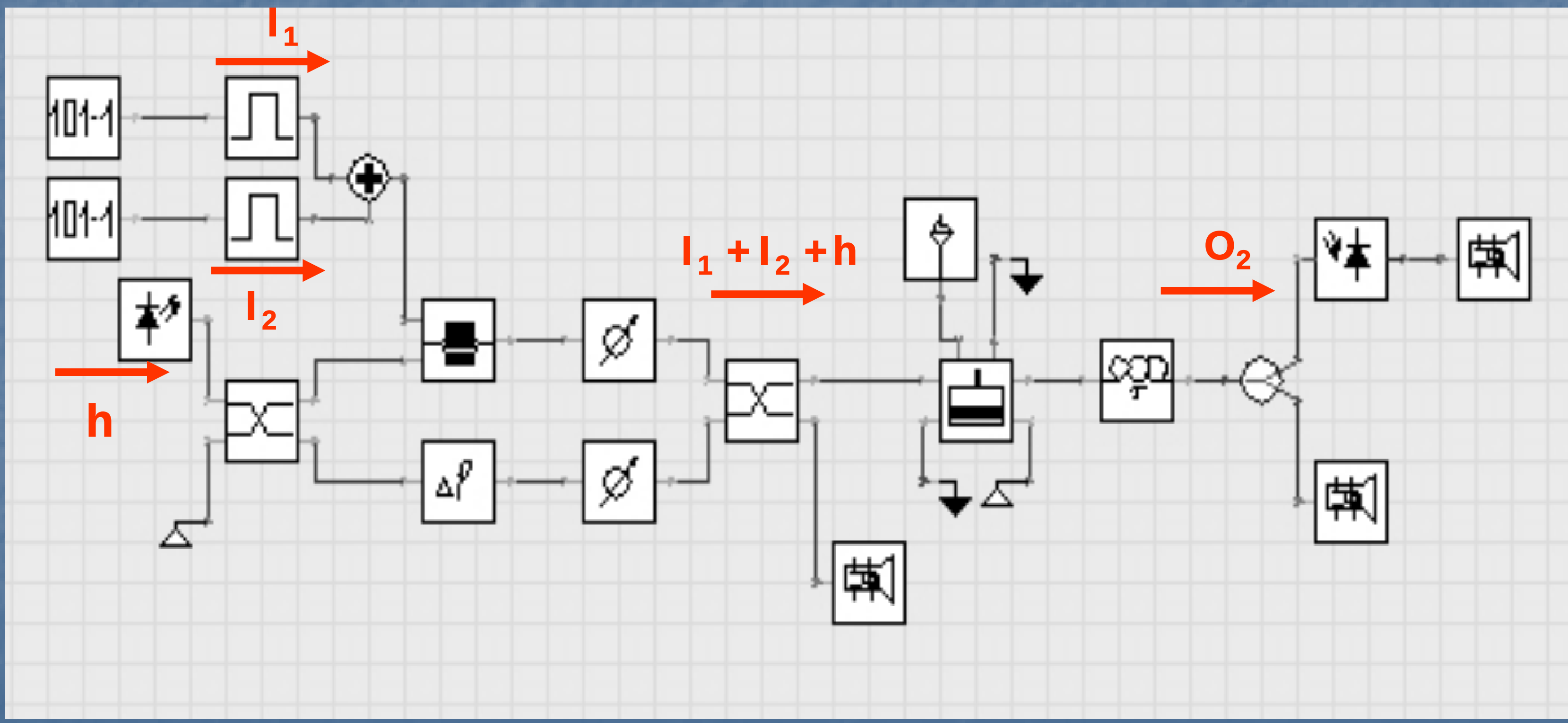




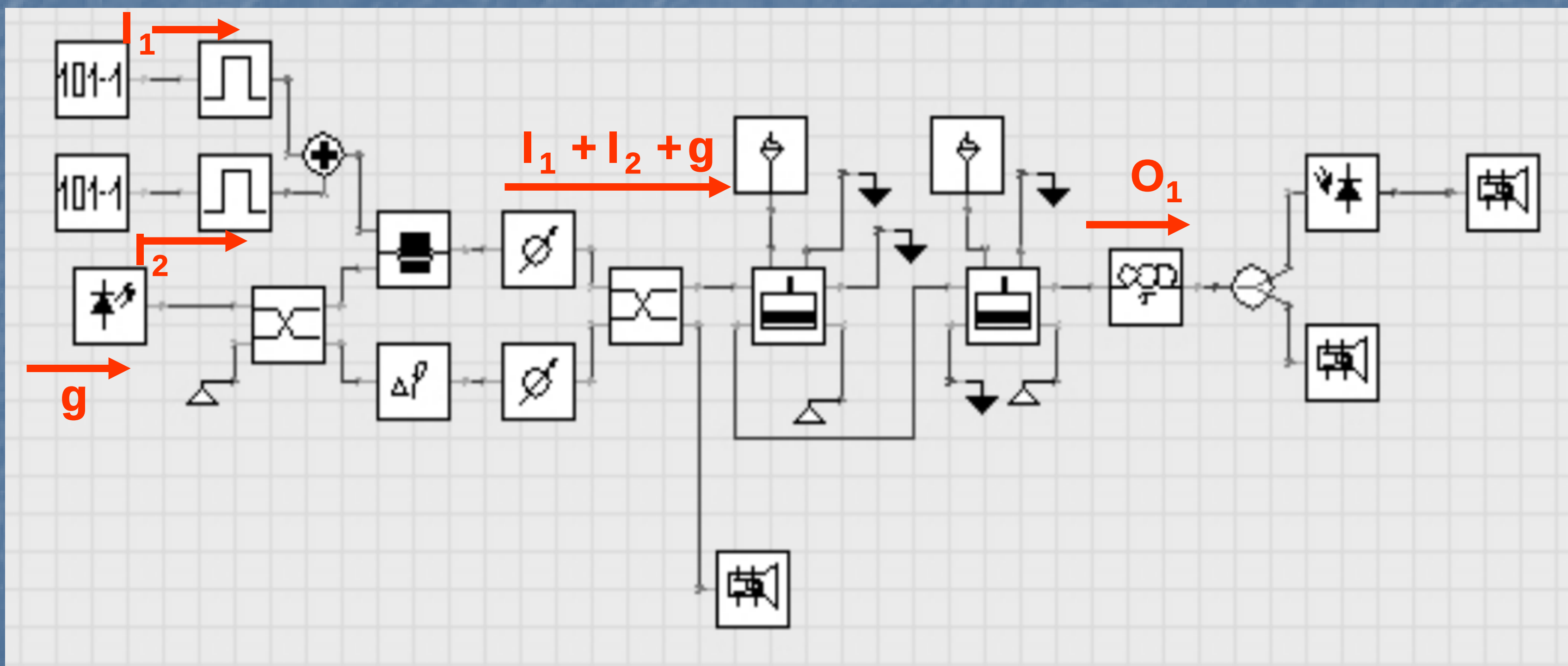


Power level of control signal, h
1.0
0.5
0
0.5
1.0
1.5
2.0
2.5
Power level of decision signal, d_{P1}
ON
OR
AND
NOR
NAND
XNOR
ON
OR
ON
ON
XOR
AND
OR
OR
AND
OFF

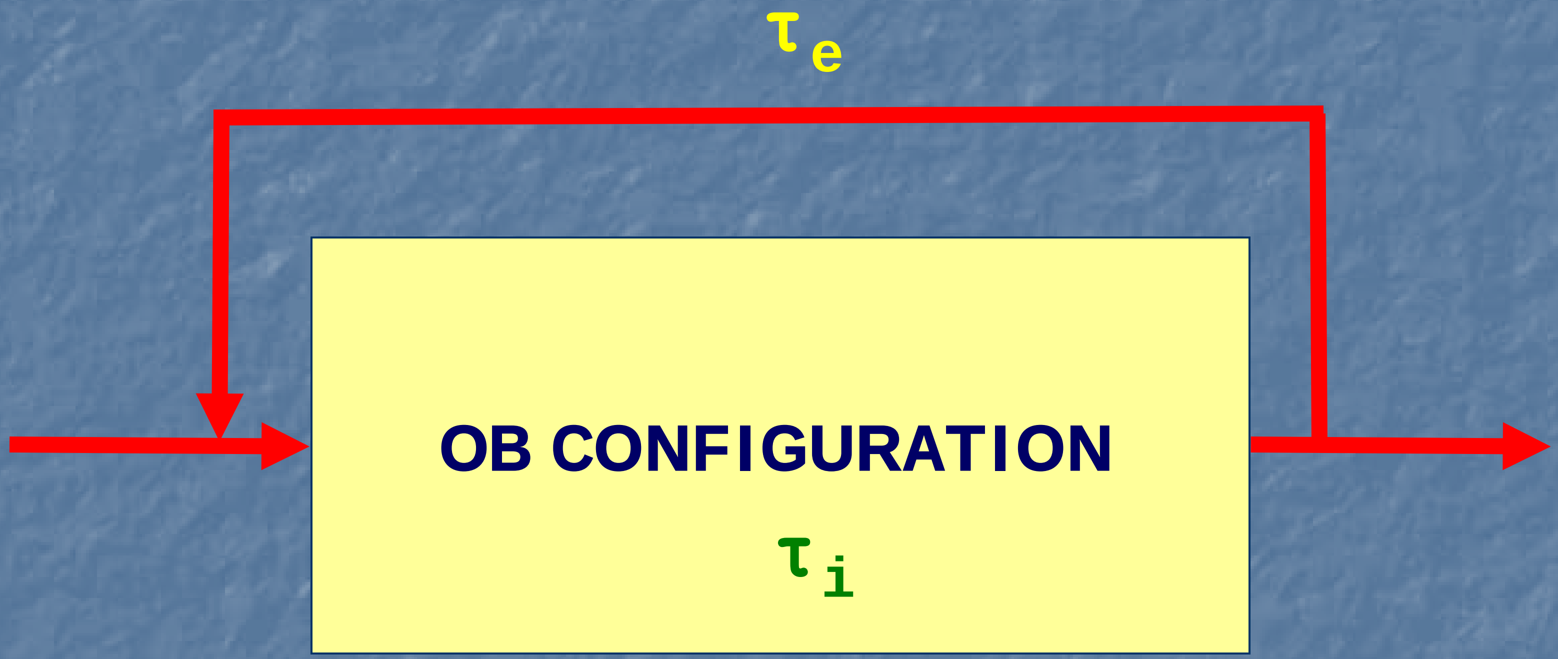
Schematic of the model simulated by VPI_ComponentMakerth software tool for Q-device

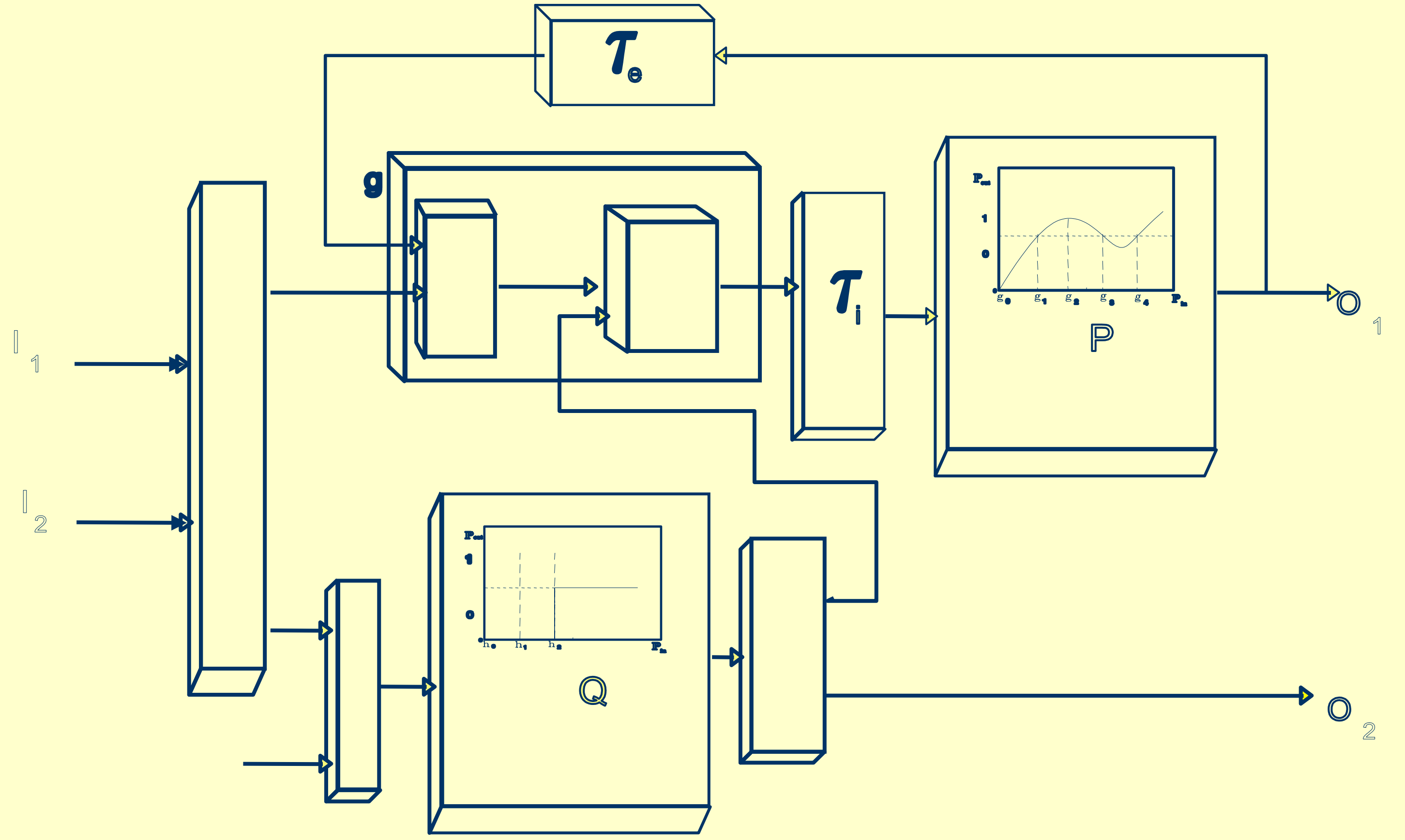


Schematic of the model simulated by VPI_ComponentMakerth software tool for P-device



INSTABILITIES:





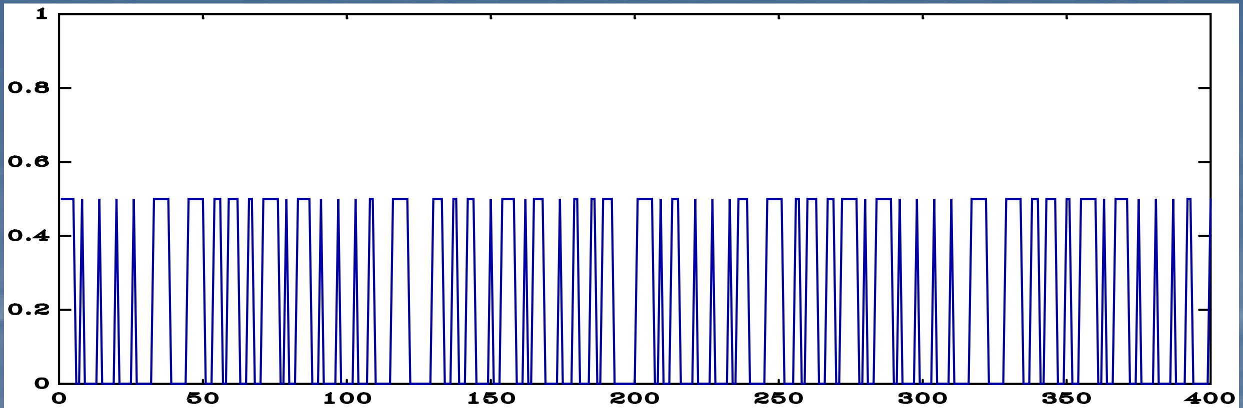
τ_e
g
τ_i
I 1
I 2
O 1
O 2
P
Q

Characteristics of the output signals, according to the delay times.

t_p	τ_e	τ_i	τ_i/τ_e	Period
14	200	2	0.01	280
14	200	4	0.02	140
14	200	12	0.06	70

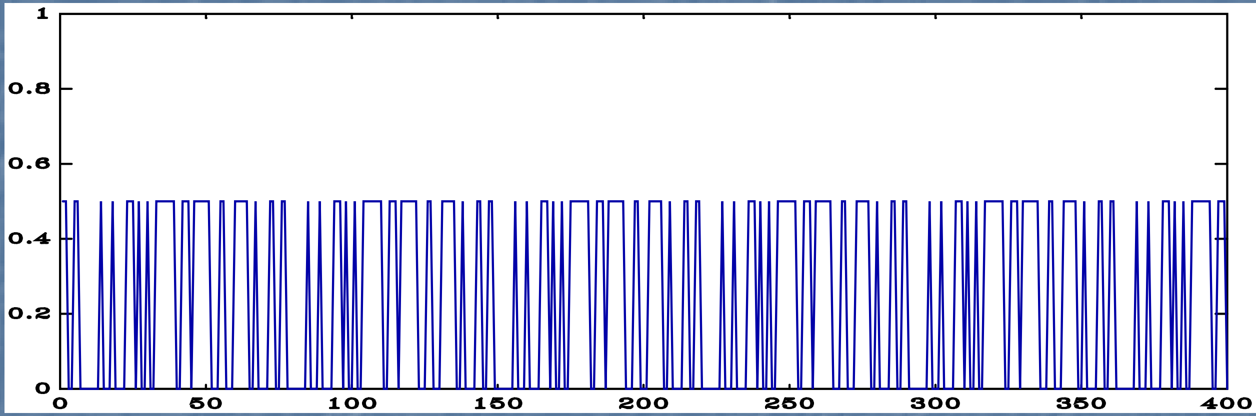
τ_e = external delay time

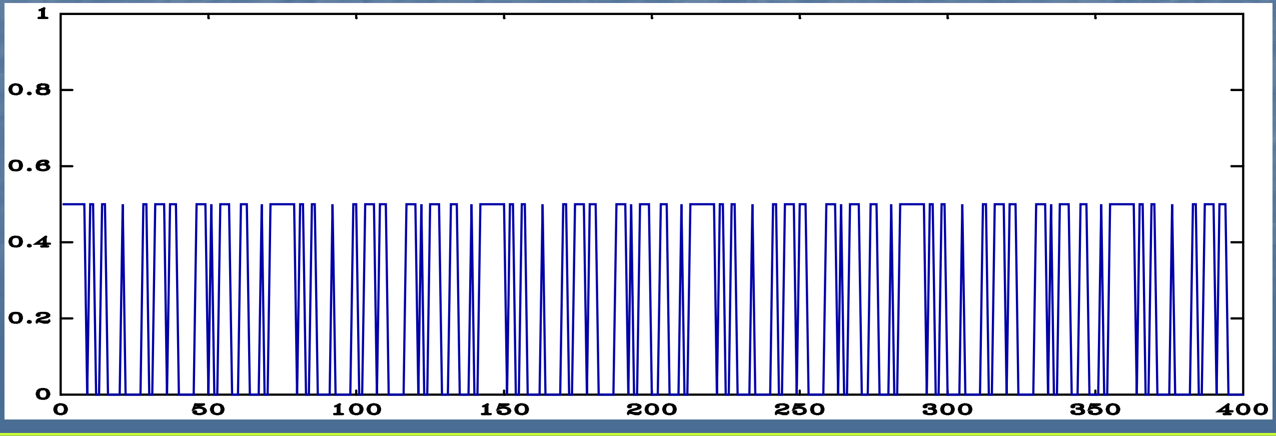
τ_e = internal delay time



Output signal with a period of 280.

Output signal with a period of 140.

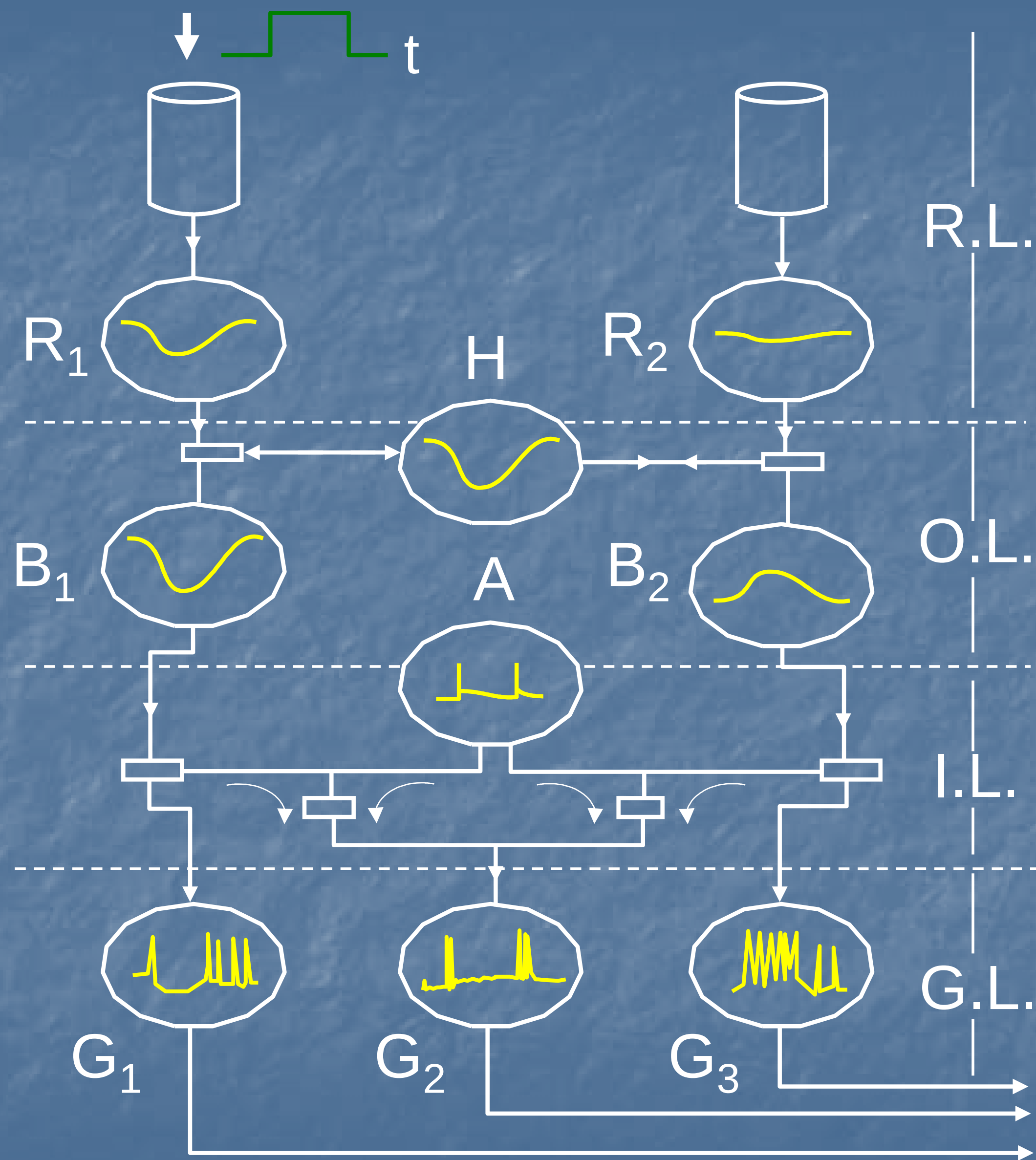


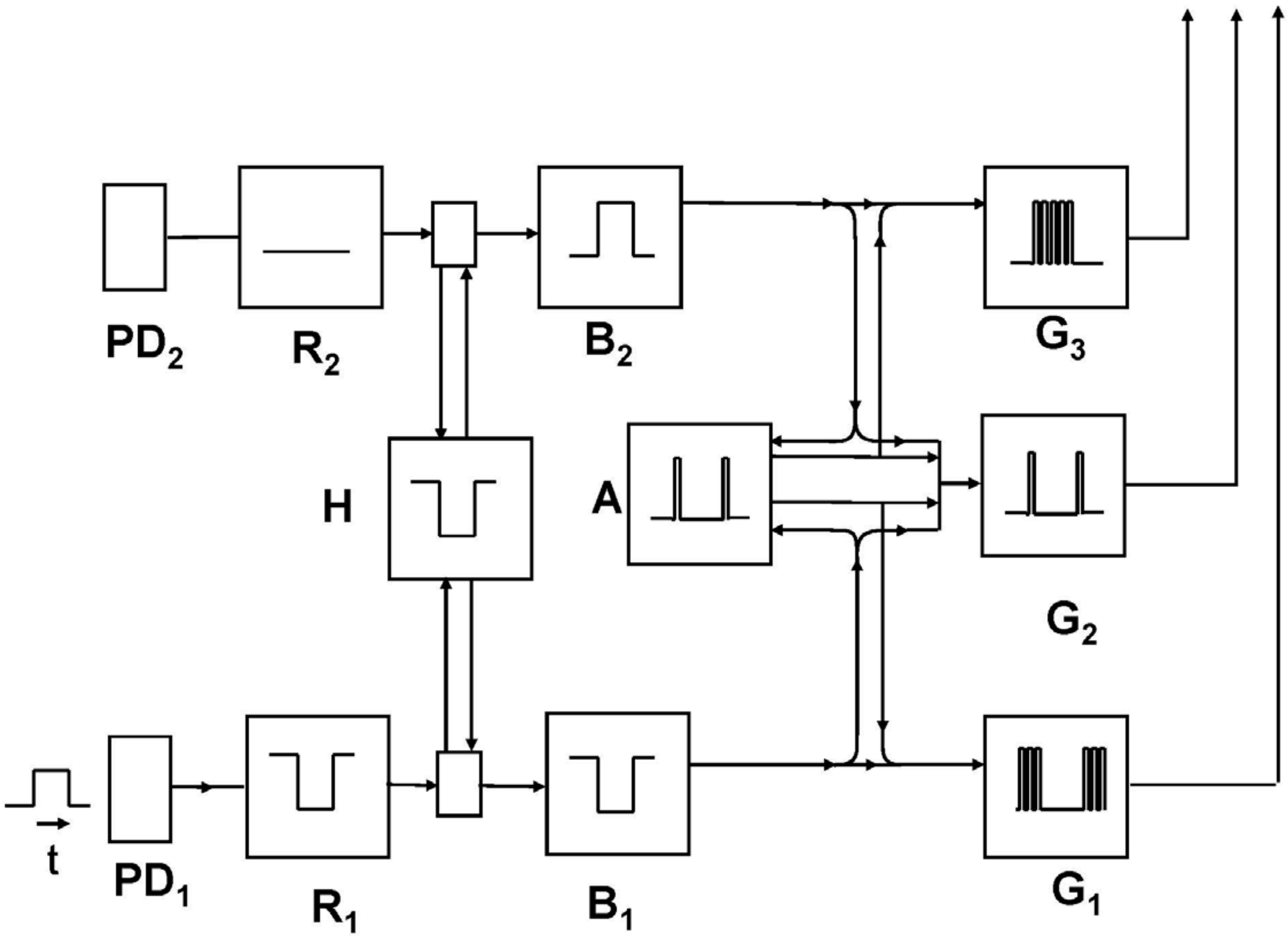


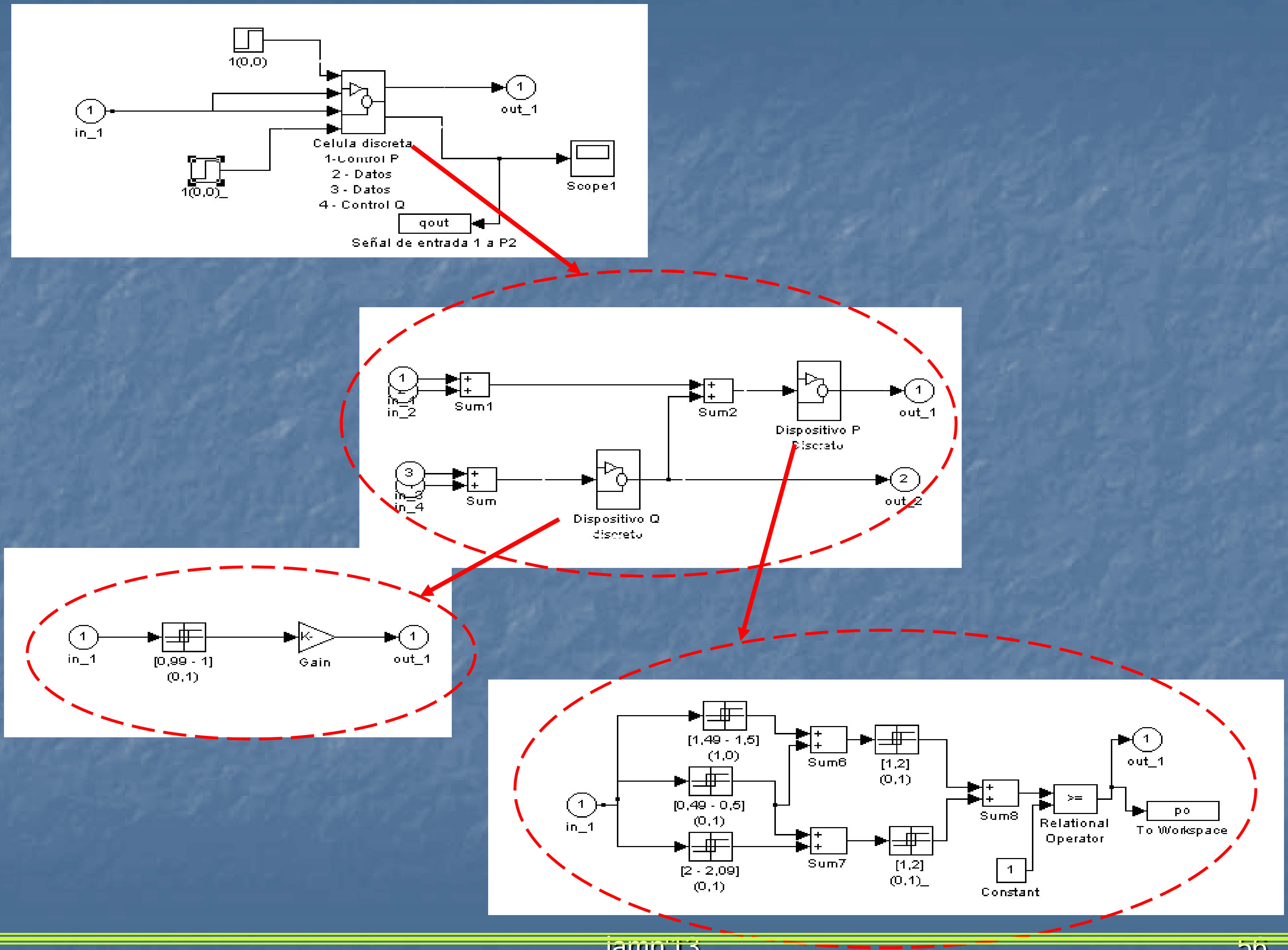
Output signal with a period of 70

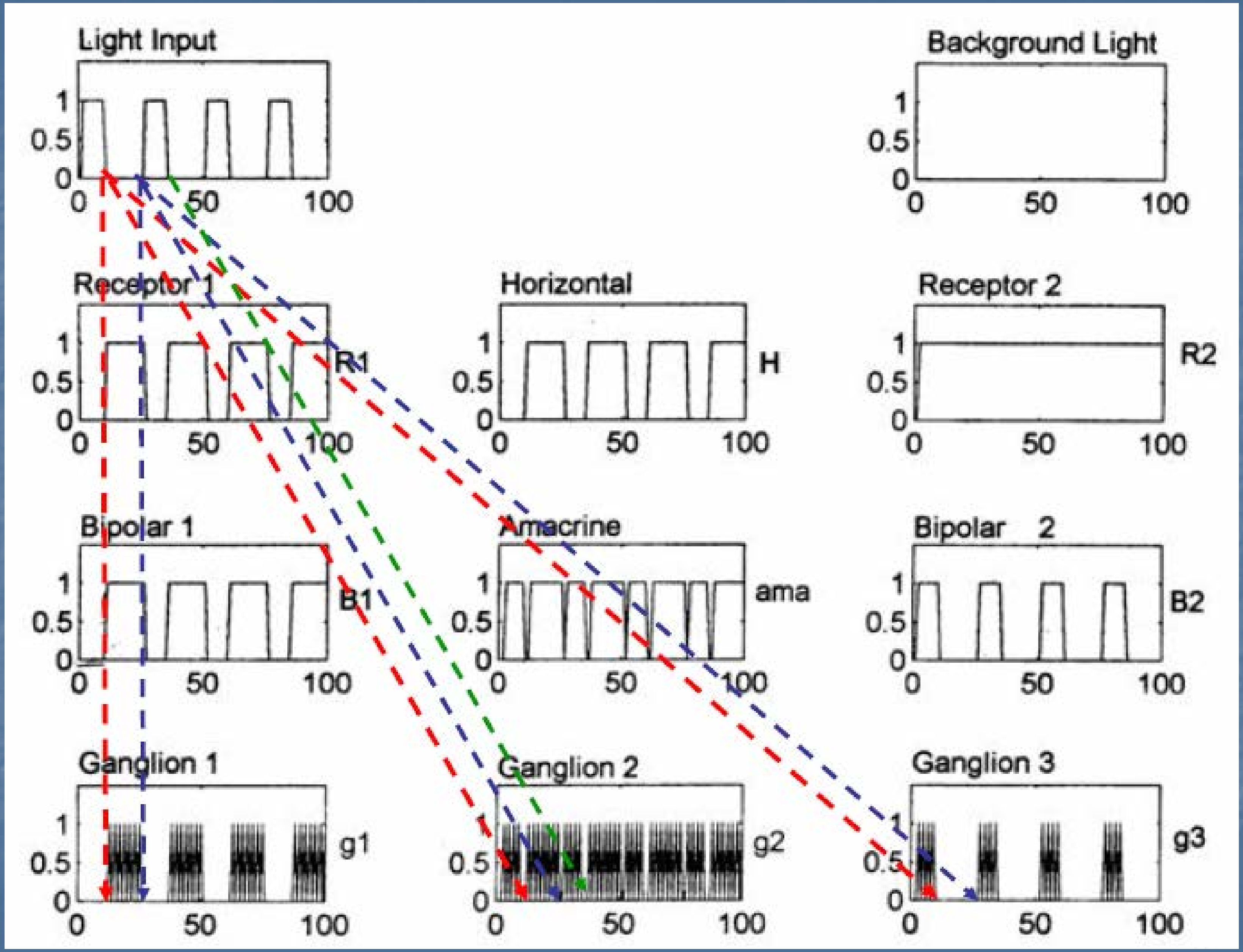
APPLICATION TO THE MAMMALIAN RETINA

Information about the intensity of each one of the scene details are transferred from the third retina **layer to following levels after a conversion from intensity level to frequency. Lower intensities correspond with lower frequencies.**

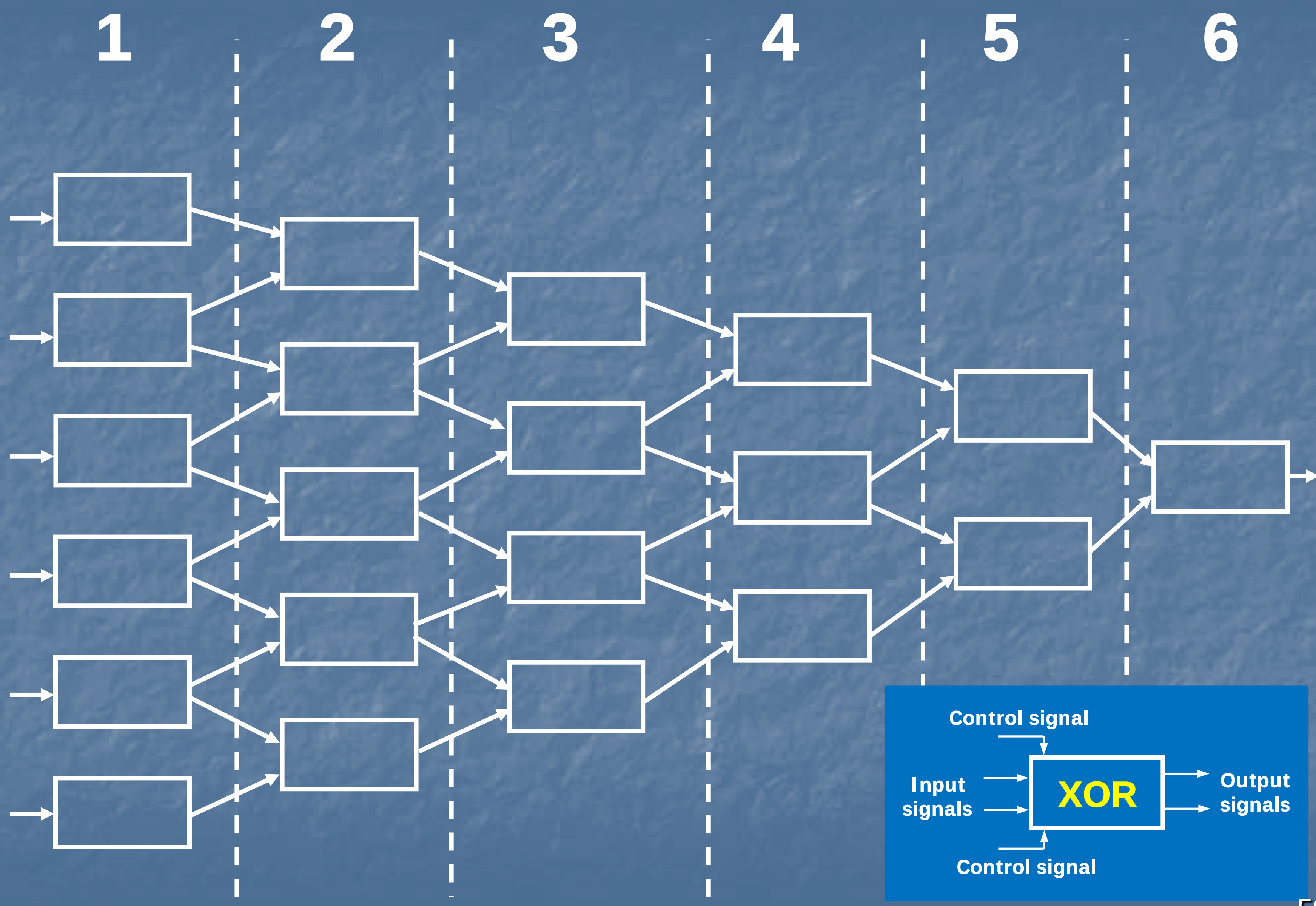



PD2
R2
B2
G3
H
A
G2
t
PD1
R1
B1
G1


1(0,0)
1
in_1
1(0,0)_
Celula discreta
1-Control P
2 - Datos
3 - Datos
4 - Control Q
1
out_1
Scope1
qout
Señal de entrada 1 a P2
1
in_1
in_2
Sum1
Sum2
Dispositivo P
1
out_1
3
in_3
in_4
Sum
Dispositivo Q
2
out_2
1
in_1
[0,99 - 1]
(0,1)
K-
Gain
1
out_1
[1,49 - 1,5]
(1,0)
Sum6
[1,2]
(0,1)
1
out_1
1
in_1
[0,49 - 0,5]
(0,1)
[2 - 2,09]
(0,1)
Sum7
[1,2]
(0,1)_
Sum8
>=
Relational
Operator
1
Constant
po
To Workspace


Light Input
Background Light
Receptor 1
R1
Horizontal
H
Receptor 2
R2
Bipolar 1
B1
Amacrine
ama
Bipolar 2
B2
Ganglion 1
g1
Ganglion 2
g2
Ganglion 3
g3

FIRST STEPS TOWARDS THE DETECTION OF SOME GENERAL PROPERTIES OF IMAGES


1
2
3
4
5
6
Control signal
Input signals
XOR
Output signals
Control signal

59

1 0 0 0 0 1
1 0 0 0 1
1 0 0 1
1 0 1
1 1
0

1 1 0 0 1 1
0 1 0 1 0
1 1 1 1
0 0 0
0 0
0

(a) Symmmetry: A logic "0" is always obtained at the 6th layer

1 0 0 0 0 0
1 0 0 0 0
1 0 0 0
1 0 0
1 0
1

1 1 1 0 0 1
0 0 1 0 1
0 1 1 1
1 0 0
1 0
1

1 1 0 0 0 1
0 1 0 0 1
1 1 0 1
0 1 1
1 0
1

(b) Asymmetry: A logic "1" is always obtained at the 6th layer

Other Asymmetries

1 1 0 0 0 0
0 1 0 0 0
1 1 0 0
0 1 0
1 1
0

1 1 1 1 0 0
0 0 0 1 0
0 0 1 1
0 1 0
1 1
0

1 1 1 0 1 1
0 0 1 1 0
0 1 0 1
1 1 1
0 0
0

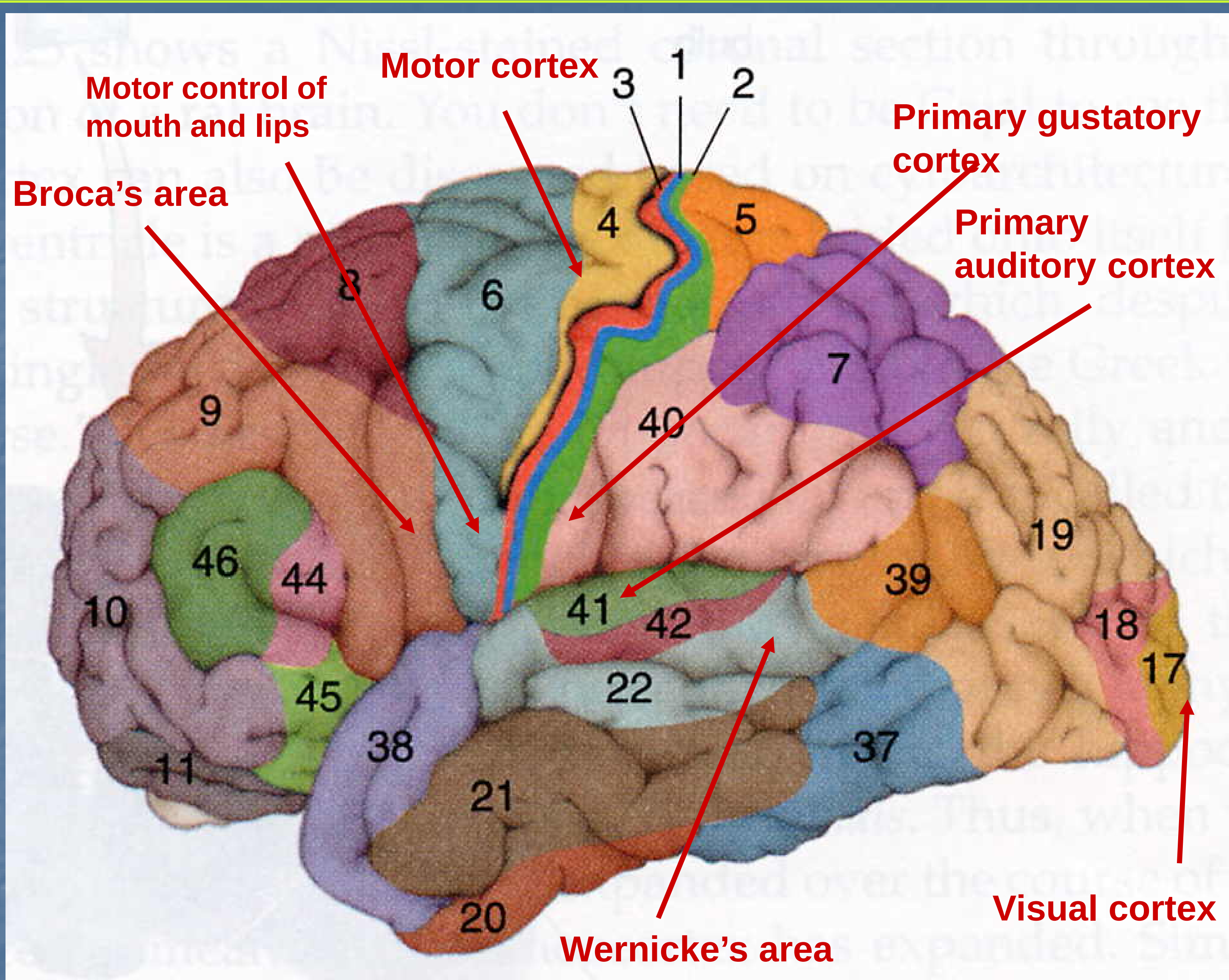
1 0 1 0 1 0
1 1 1 1 1
0 0 0 0
0 0 0
0 0
0

1 0 1 0 0 0
1 1 1 0 0
0 0 1 0
0 1 1
1 0
1

1 1 1 0 0 0
0 0 1 0 0
0 1 1 0
1 0 1
1 1
0

A logic "1" is obtained at the center of an even row

Approaching to the visual cortex: signals processing and sensing

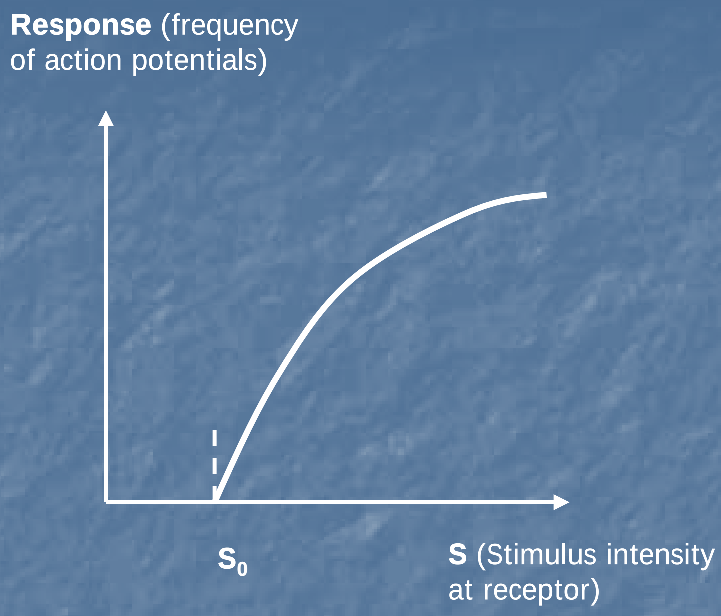


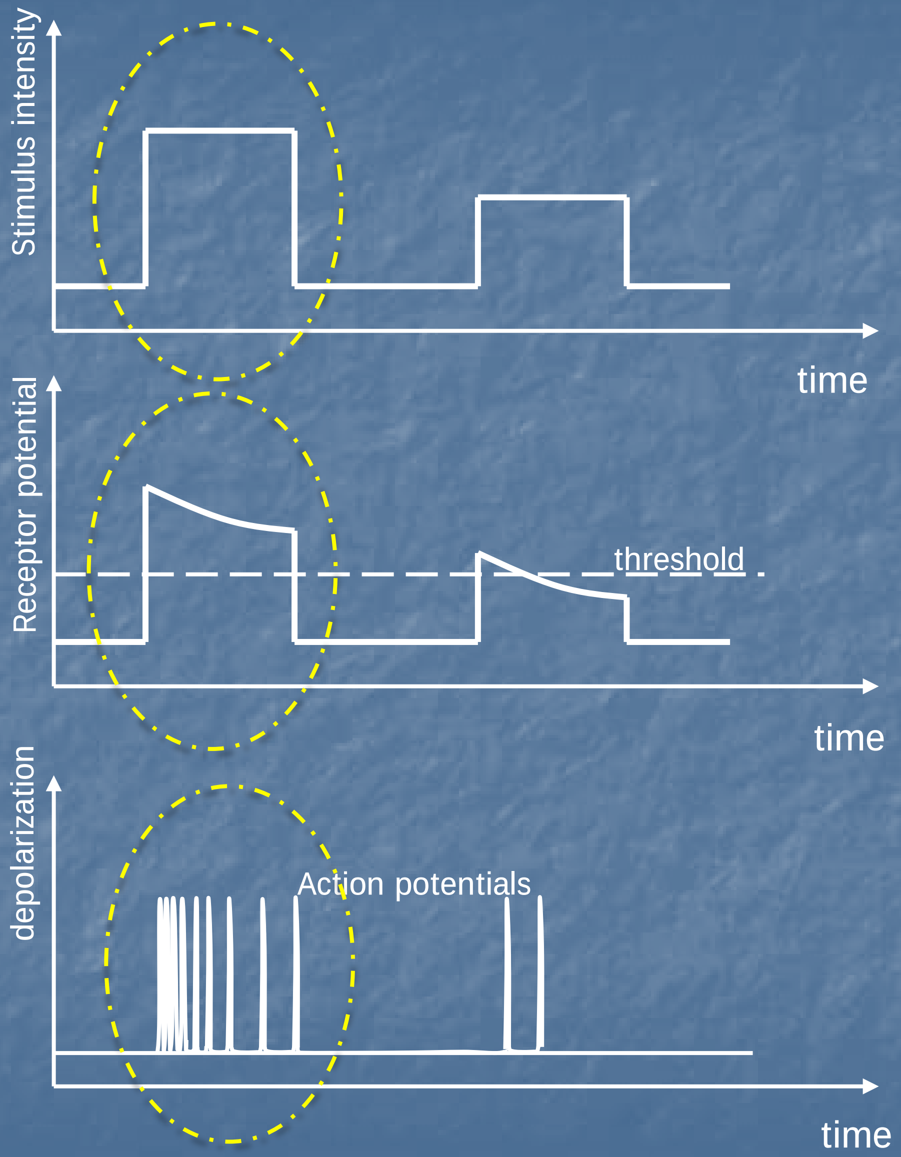
Brodmann's cytoarchitectural map of
the human cerebral cortex

(1)
Information is always transferred in a parallel way. As a consequence, the number of physical paths is very high.

(2)

Each small piece of information goes to a particular area in the cortex where is analyzed with respect to other inputs and memories.

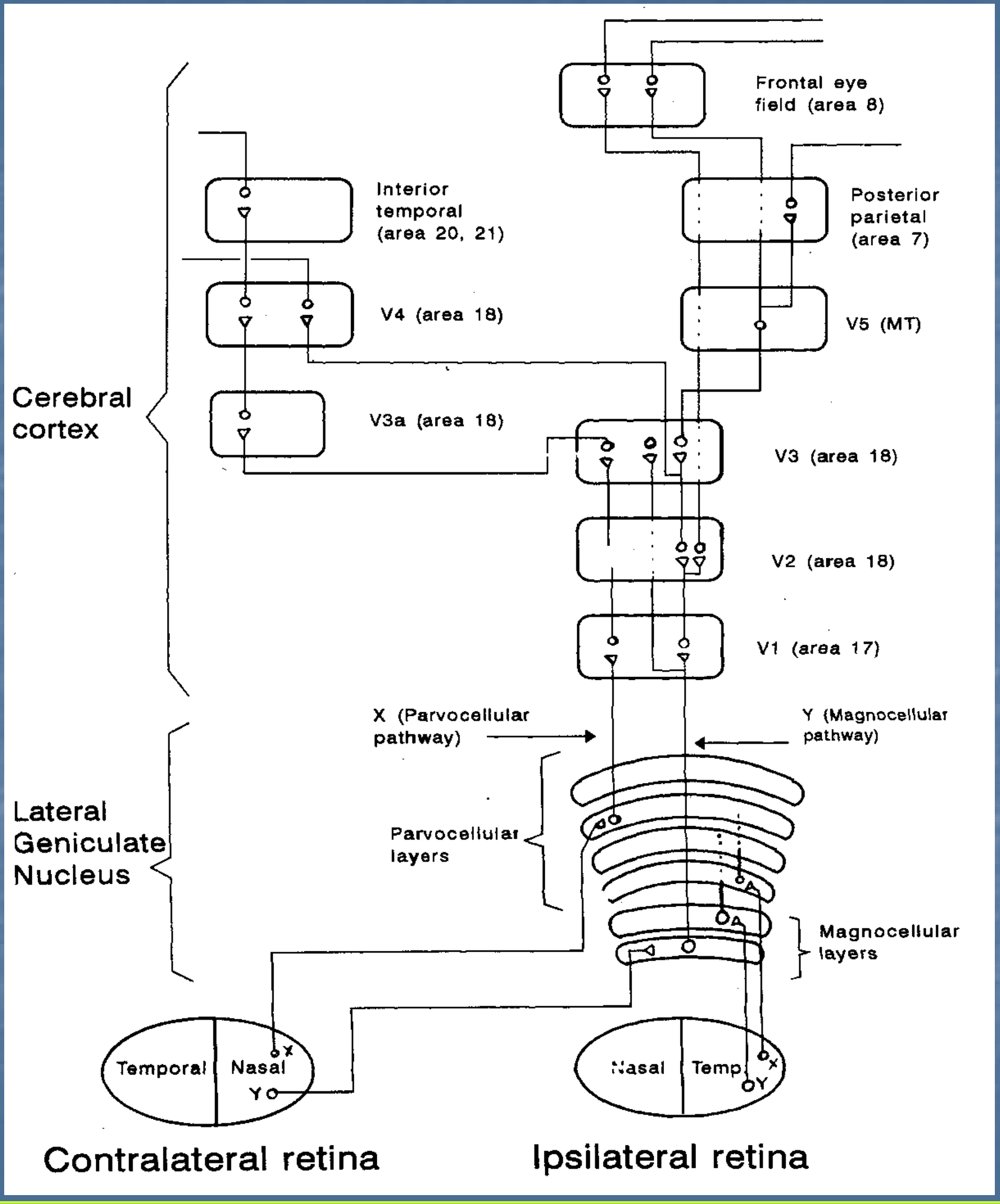


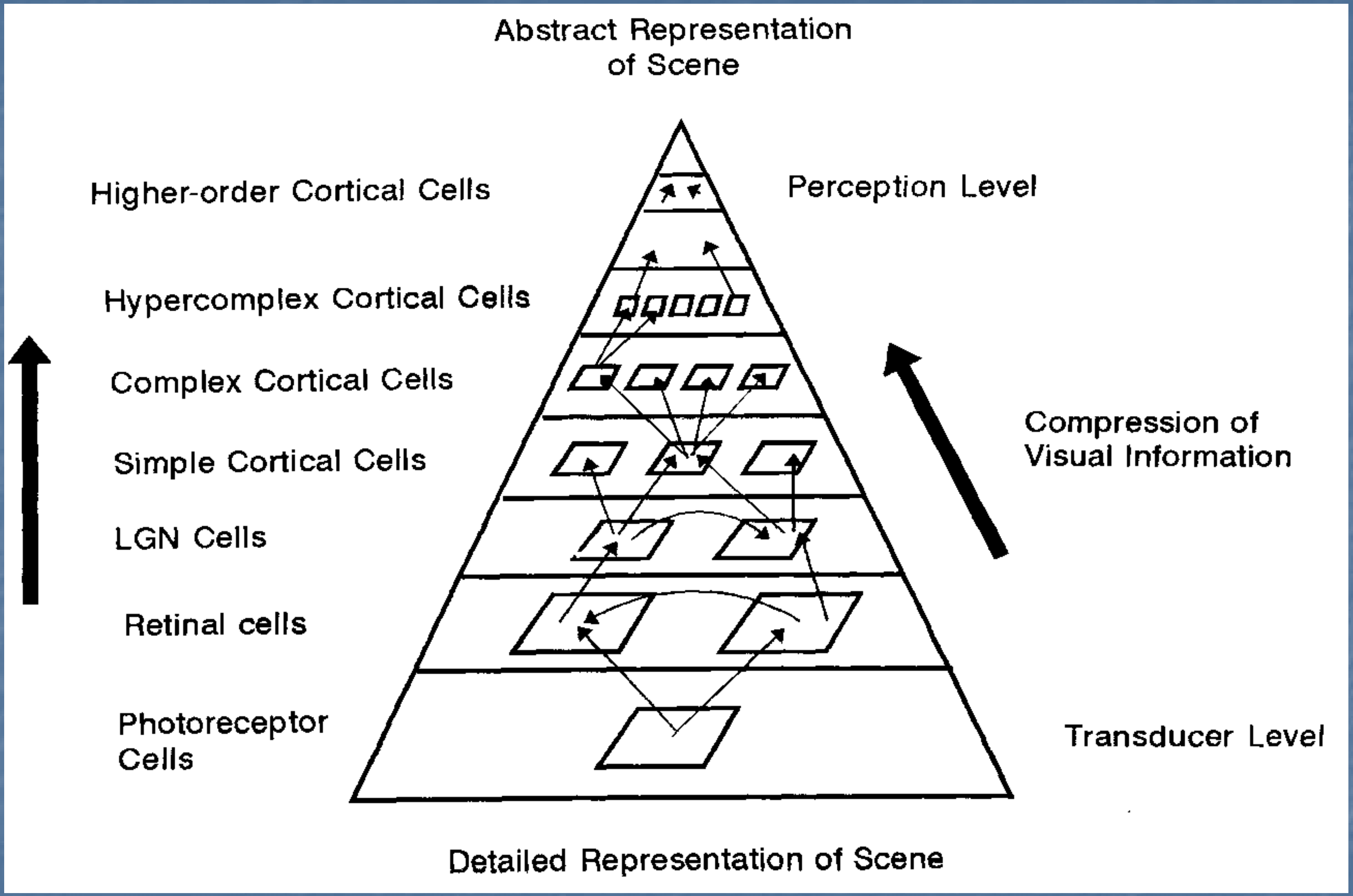


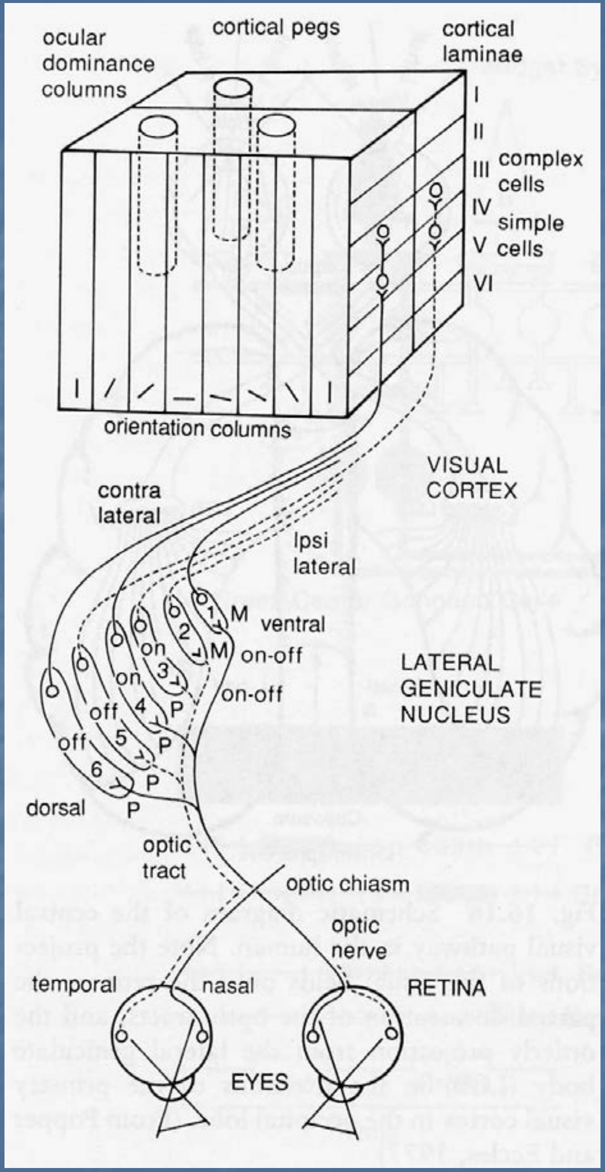
Behavior of the living beings sensors

THE CASE OF THE VISUAL CORTEX

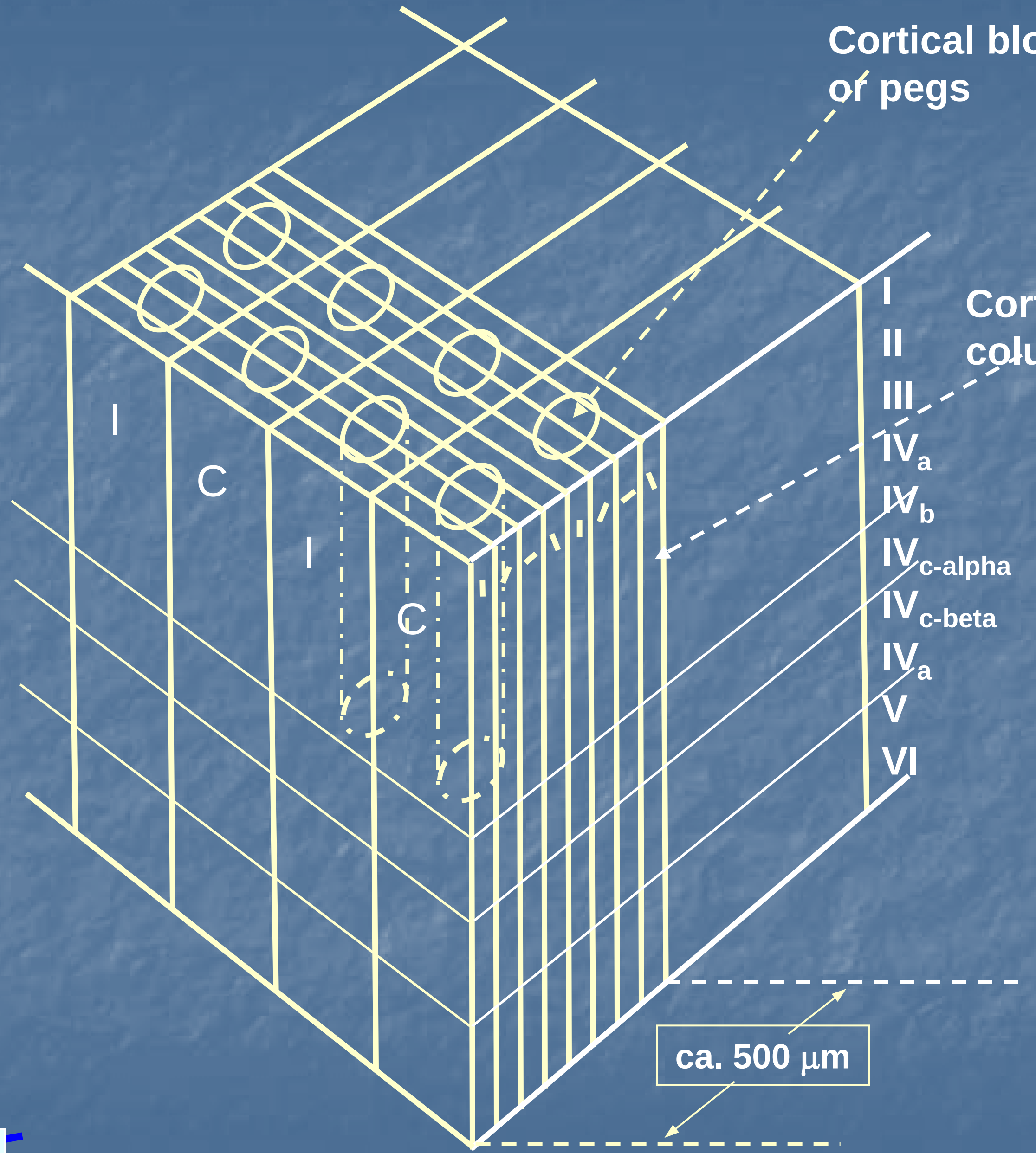
Highly schematic view of the projections from the retina to various visual areas of the cerebral cortex



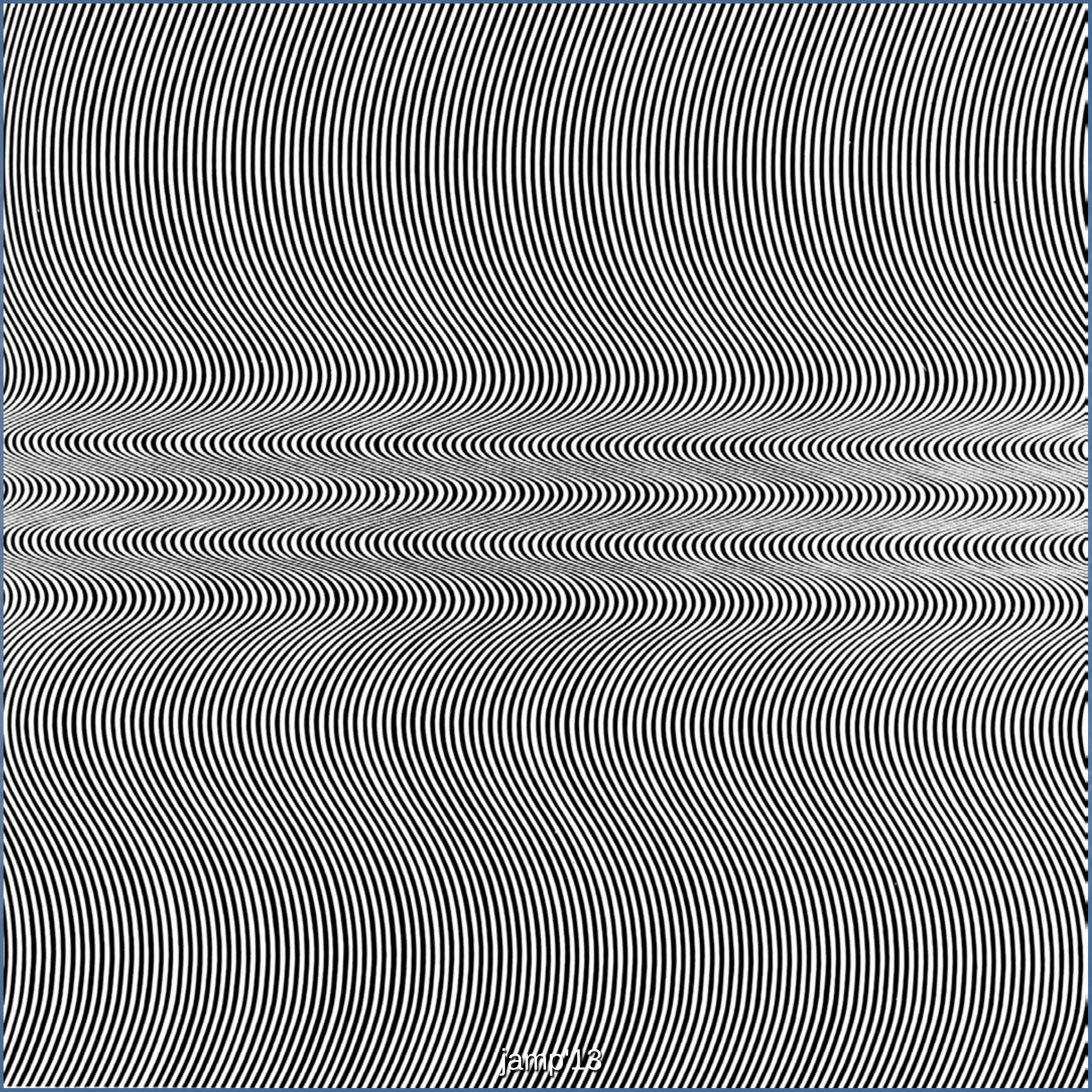

Abstract Representation
of Scene
Higher-order Cortical Cells
Perception Level
Hypercomplex Cortical Cells
Complex Cortical Cells
Compression of
Visual Information
Simple Cortical Cells
LGN Cells
Retinal cells
Photoreceptor
Cells
Transducer Level
Detailed Representation of Scene



PROJECTIONS FROM THE RETINA TO THE OCULAR DOMINANCE COLUMNS

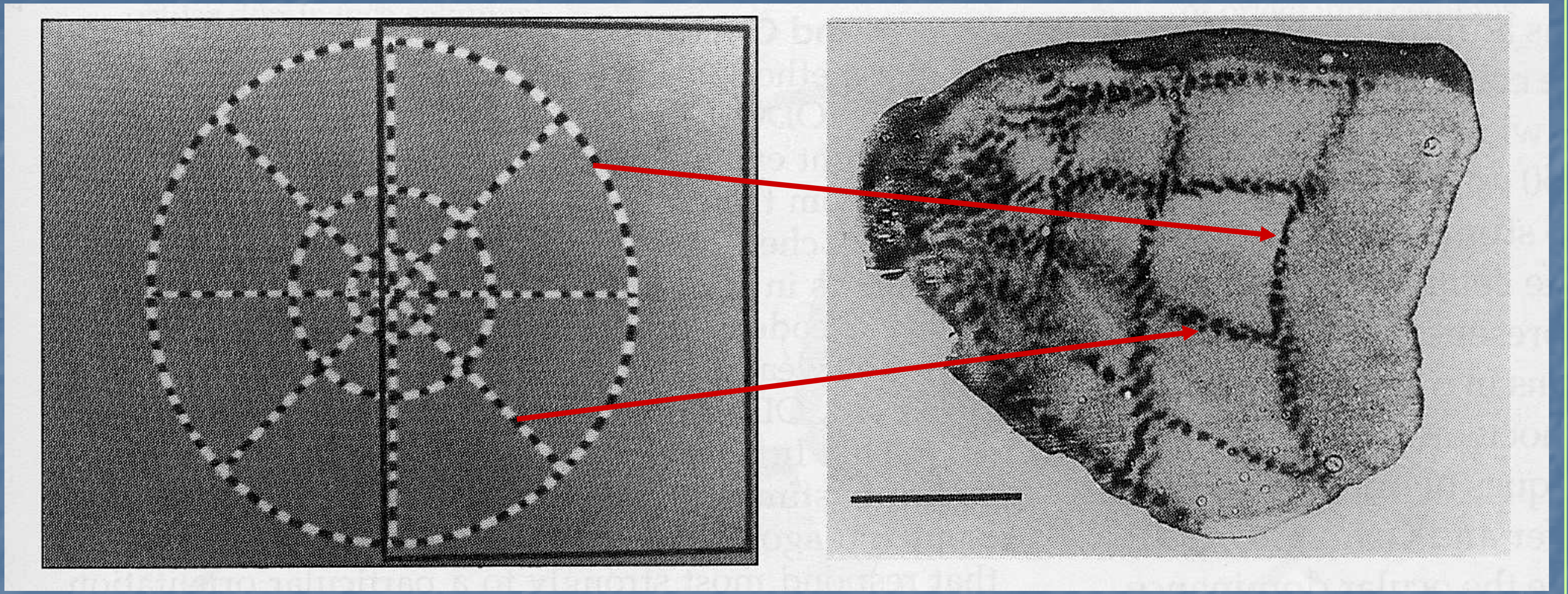


Information about different line orientations is transferred **to selected areas at the visual cortex**. These areas become excited by this information and living beings get a stimulus concerning that orientation in the visual scene.



Each particular orientation, or each particular shape, goes to a precise area in the V1 area of the visual cortex. There is a certain type of "mapping" from the scene to the cortex: distributed measurements are transferred through a "multiplexed" system

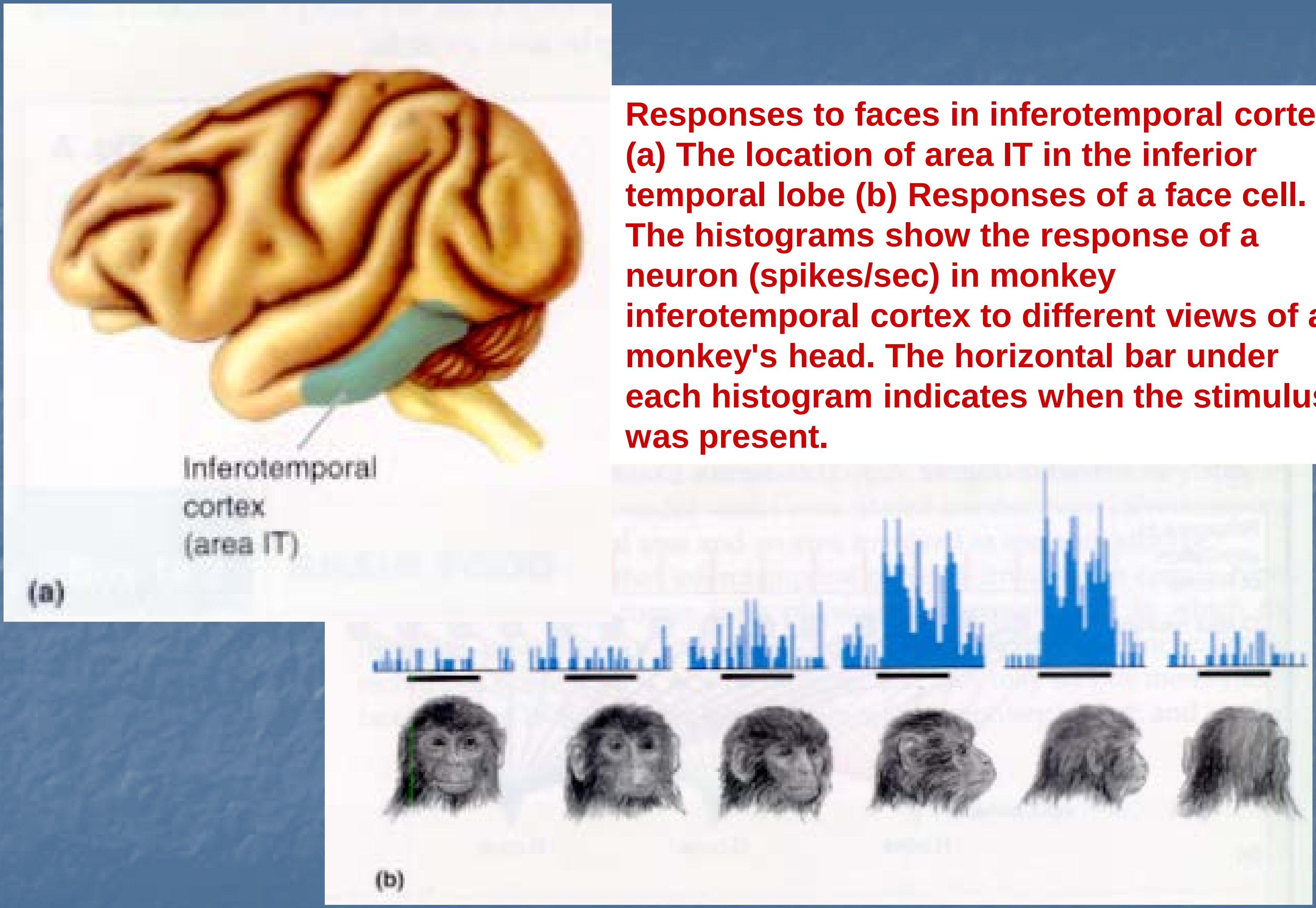
Visual cortex, at area V1, gets a “virtual image” of the real image appearing in the scene as “seen” by the living beings.



Maps of the Visual Field onto Area V1

When a pattern of flickering lights is shown in the visual field of a macaque, a map of striate cortex is revealed by 2-DG uptake

Information about different visual information is transferred to selected areas at the visual cortex. These areas become excited by this information and living beings get a stimulus concerning that information in the visual scene



Responses to faces in inferotemporal cortex (a) The location of area IT in the inferior temporal lobe (b) Responses of a face cell. The histograms show the response of a neuron (spikes/sec) in monkey inferotemporal cortex to different views of a monkey's head. The horizontal bar under each histogram indicates when the stimulus was present.

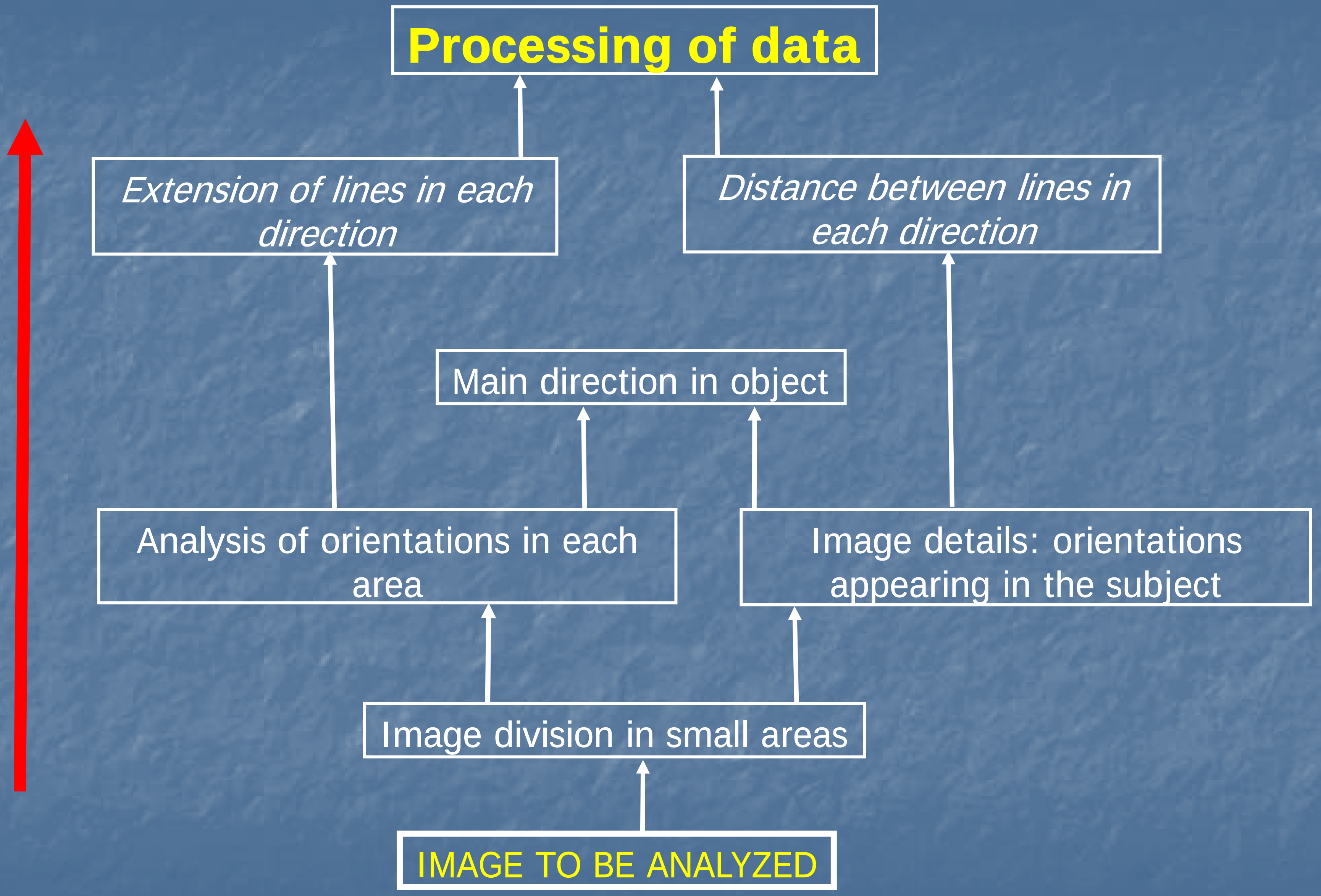
Although different types of information processing appear in the retina and visual cortex this processing is the result of interchange of information among neurons in the same level. No feedback processes appears in the neural network.

Any biological information processing is performed by non linear effects.

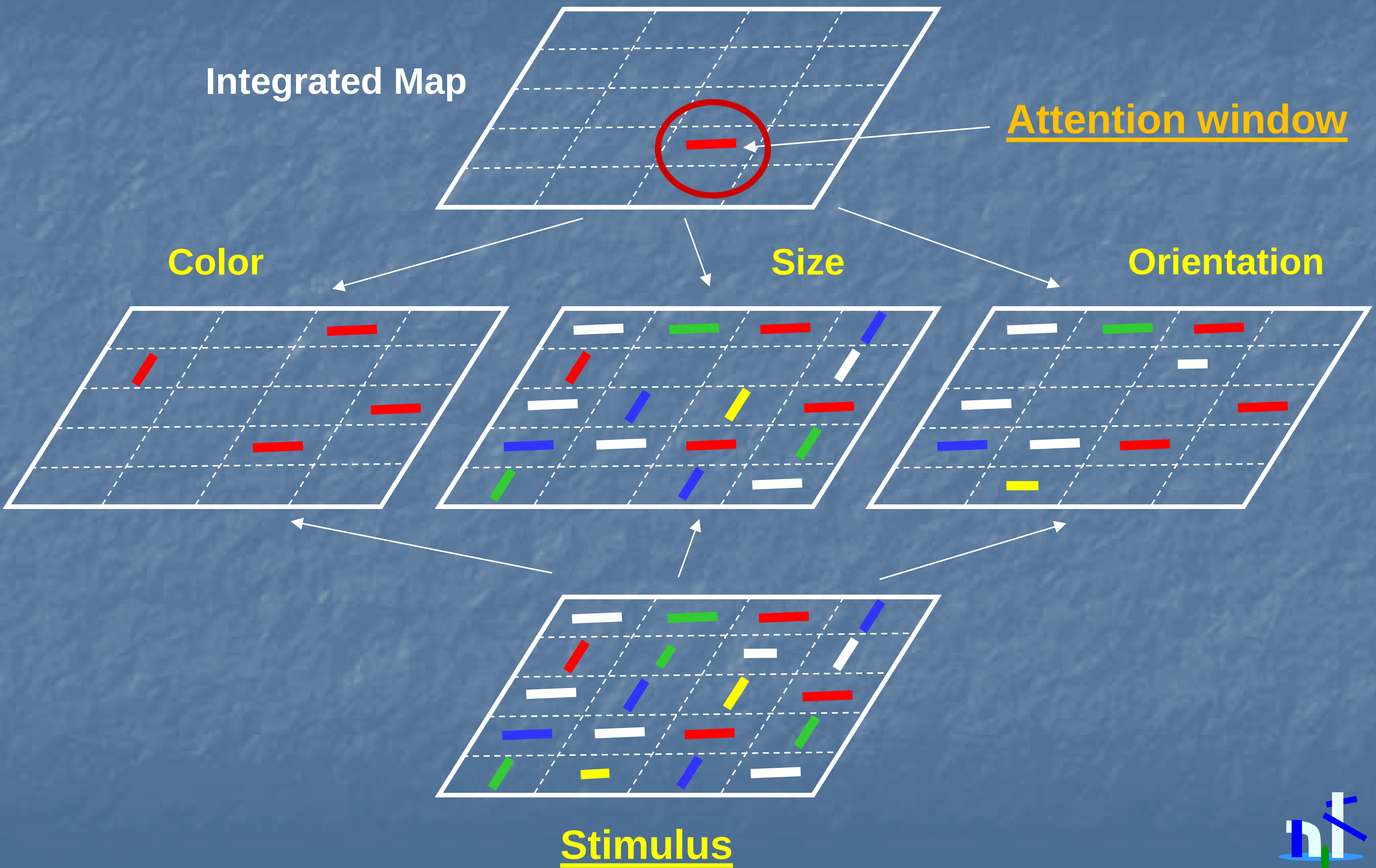
The number of levels needed to go from receptor neurons in the retina to V1 layer in the cortex is lower than 15.

A possible way to implement a similar philosophy is with **WDM techniques**: a large number of information channels may go through the same physical path.

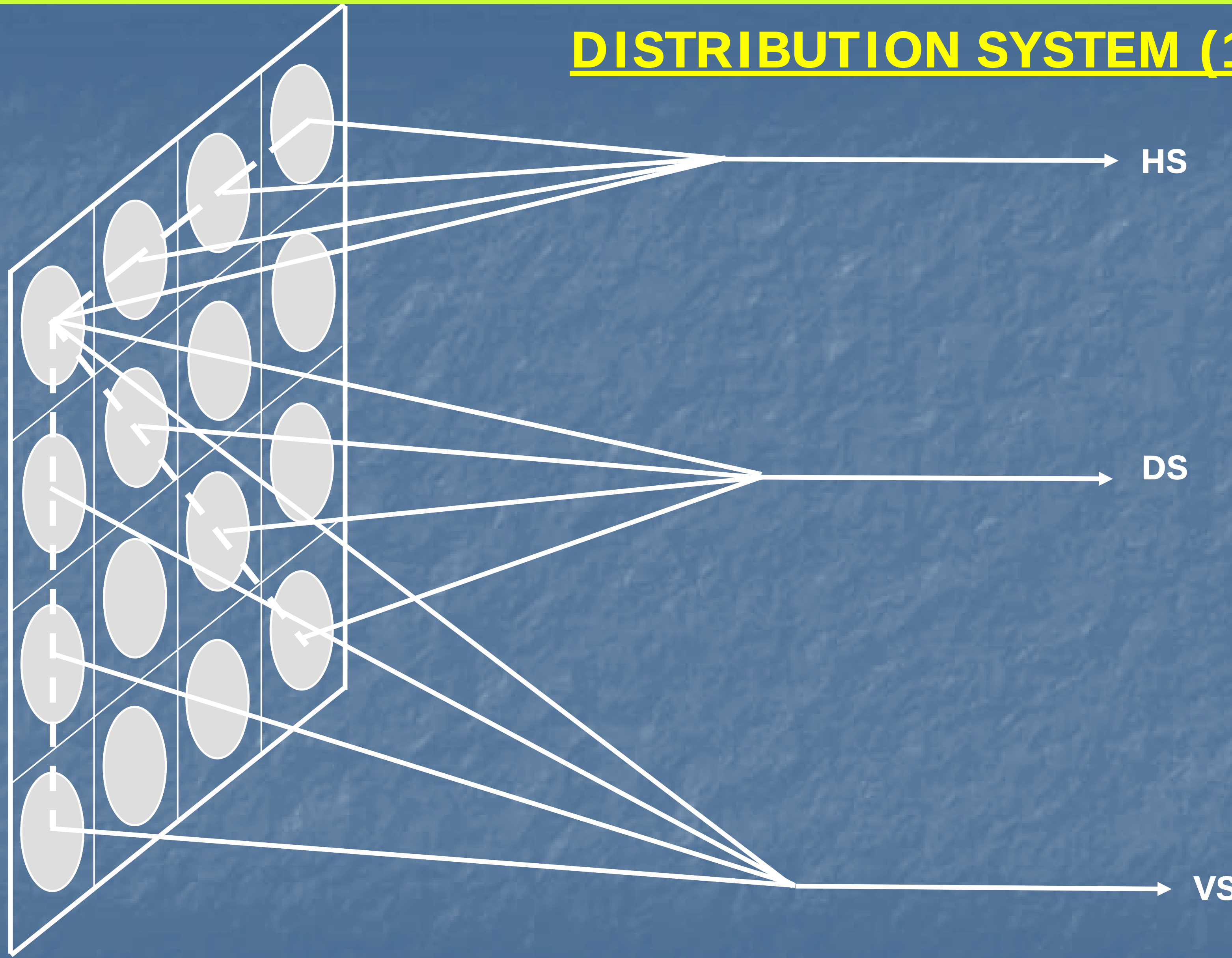
Photonic processing subsystem based on visual cortex architecture



Processing of data
Extension of lines in each direction
Distance between lines in each direction
Main direction in object
Analysis of orientations in each area
Image details: orientations appearing in the subject
Image division in small areas
IMAGE TO BE ANALYZED

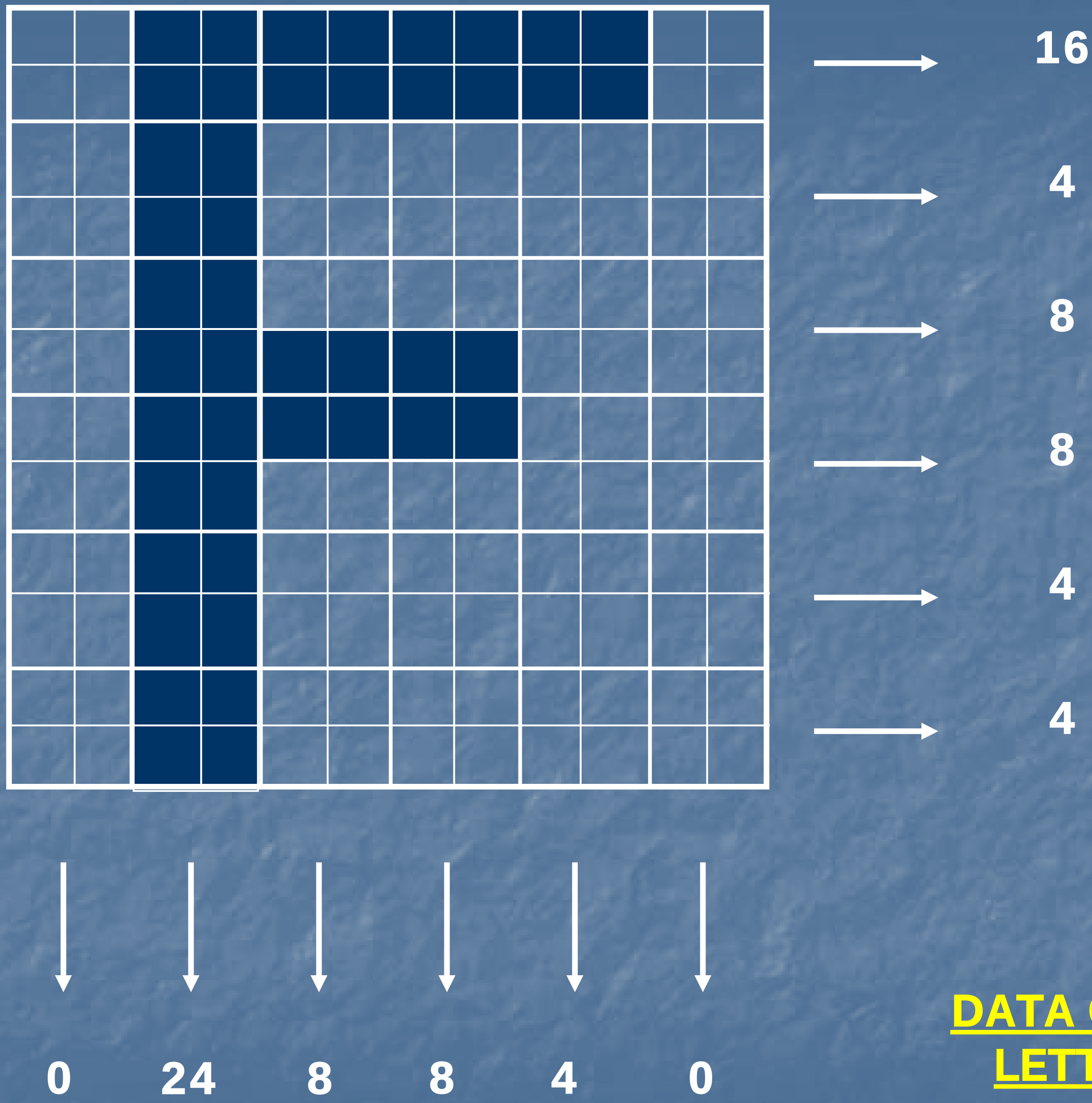

Integrated Map
Attention window
Color
Size
Orientation
Stimulus

DISTRIBUTION SYSTEM (1)

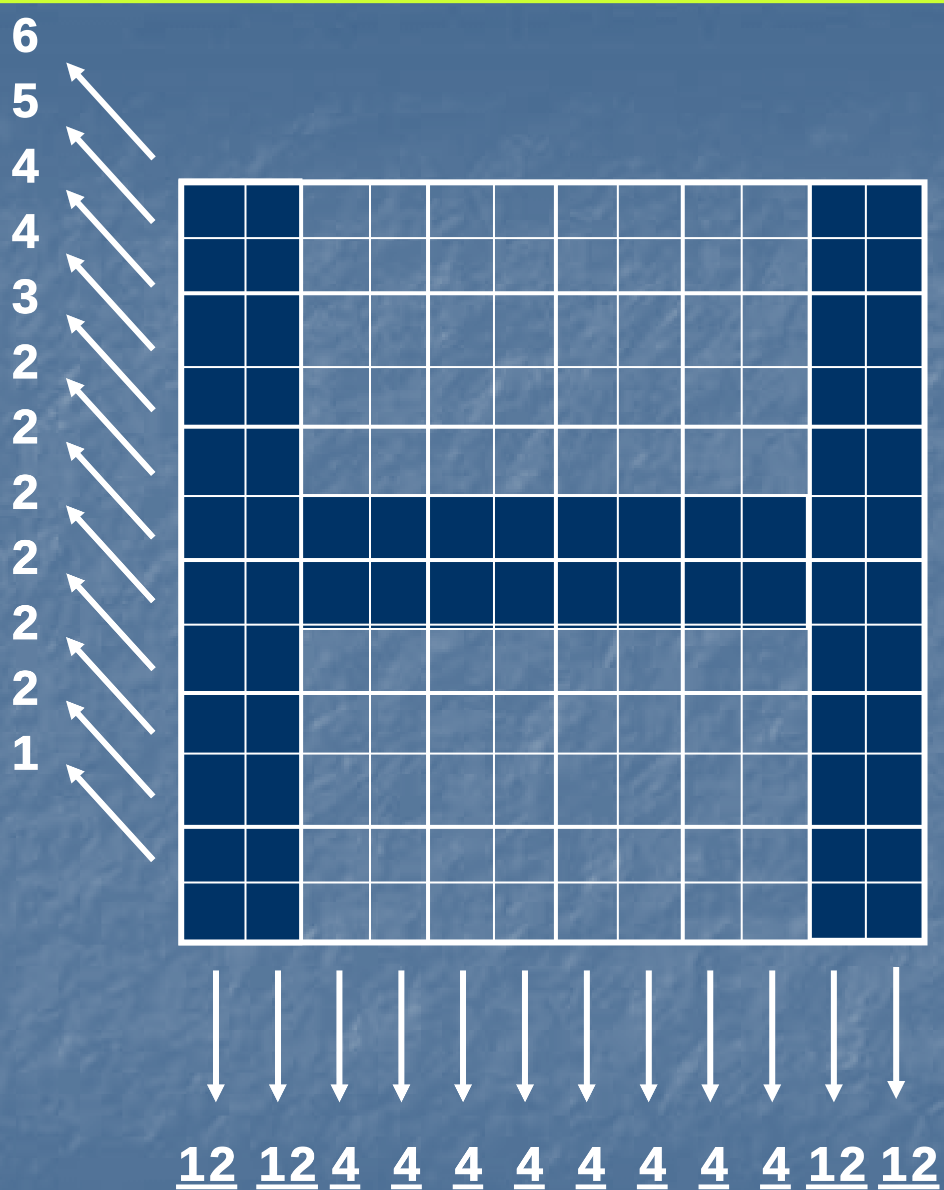


INFORMATION CORRESPONDING TO DIRECTION CHARACTERISTICS

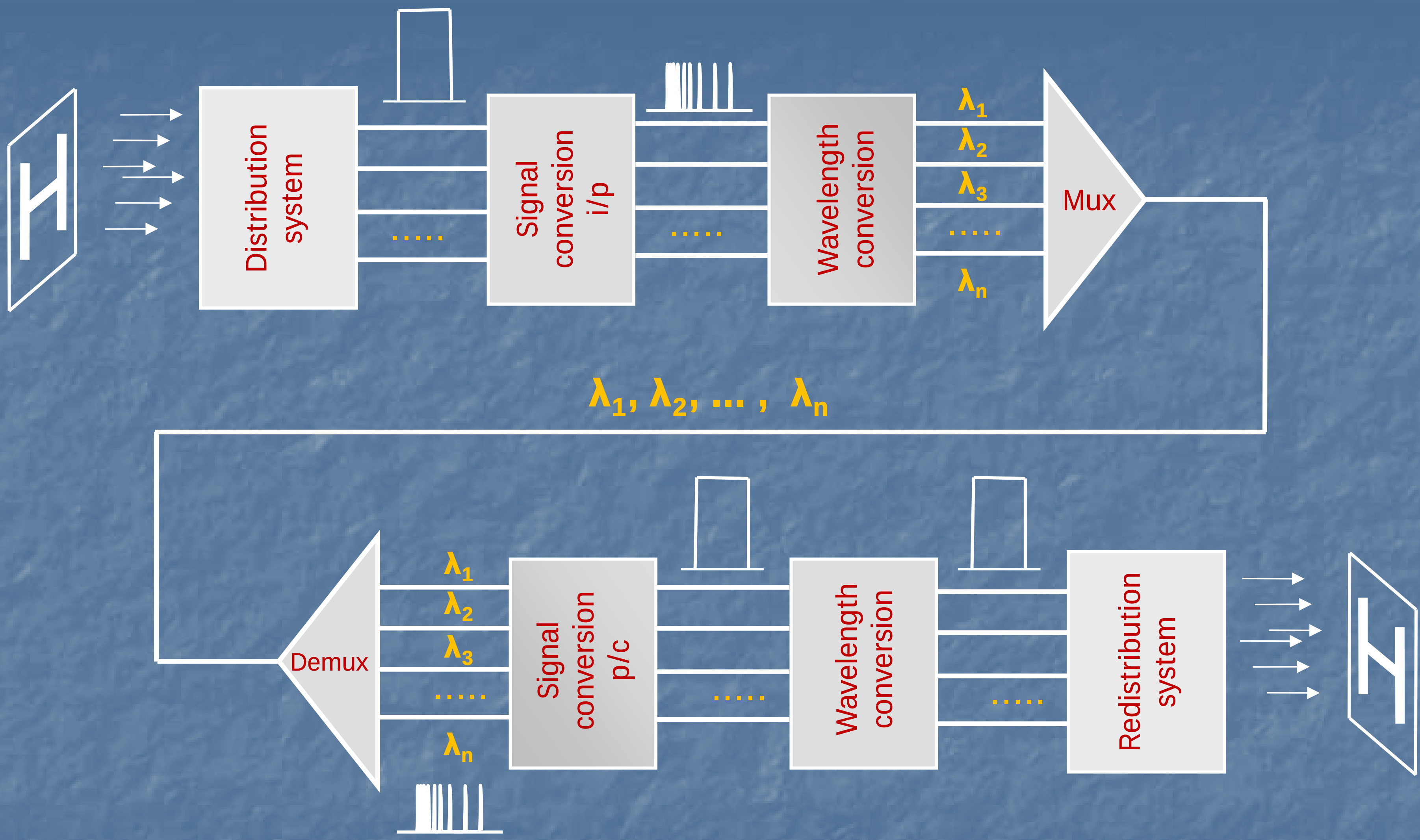
Example: transferring information from a 2 - D image



DATA OBTAINED FROM LETTER “F” (JUST 2 DIRECTIONS)

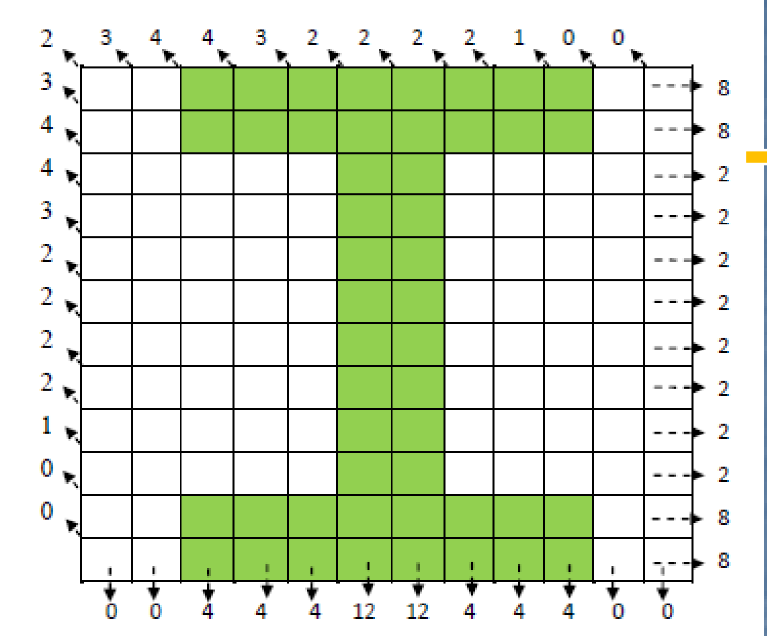


DATA OBTAINED FROM LETTER “H” (JUST 3 DIRECTIONS)



GENERAL STRUCTURE OF THE SYSTEM

Sampling
(4 directions)



Redistribution (4 directions)

0,83	0,94	1,73	1,94	1,88	2,29	2,29	1,78	1,94	1,73	0,94	0,83
0,94	1,17	1,77	1,9	1,78	2,33	2,33	1,78	1,8	1,77	1,17	0,94
0,9	0,94	1,17	1,11	1,19	1,99	1,99	1,19	1,11	1,07	0,94	0,9
1,11	1,07	1,11	0,95	1,15	2,01	2,01	1,15	0,95	1,11	0,97	1,11
1,04	0,94	1,19	1,15	1,11	1,84	1,84	1,11	1,15	1,19	0,94	0,94
0,79	0,83	1,32	1,34	1,17	1,61	1,61	1,17	1,34	1,32	0,83	0,79
0,79	0,83	1,32	1,34	1,17	1,61	1,61	1,17	1,34	1,32	0,83	0,79
0,94	0,94	1,19	1,15	1,11	1,84	1,84	1,11	1,15	1,19	0,94	0,94
1,11	0,97	1,11	0,95	1,15	2,01	2,01	1,15	0,95	1,11	0,97	1,11
0,9	0,94	1,07	1,11	1,19	1,99	1,99	1,19	1,11	1,07	0,94	0,9
0,94	1,17	1,77	1,8	1,78	2,33	2,33	1,78	1,8	1,77	1,17	0,94
0,83	0,94	1,73	1,94	1,78	2,29	2,29	1,78	1,94	1,73	0,94	0,83

Threshold
(1.5 p.e.)

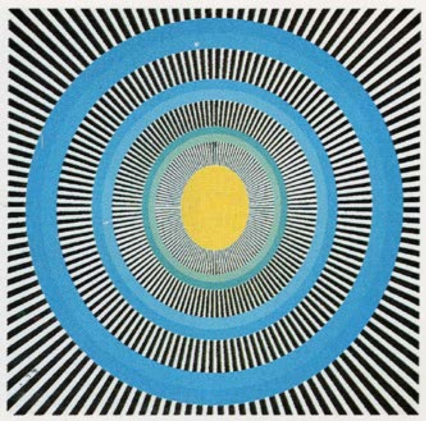
0	0	1	1	1	1	1	1	1	1	0	0
0	0	1	1	1	1	1	1	1	1	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	0	0	0	1	1	0	0	0	0	0
0	0	1	1	1	1	1	1	1	1	0	0
0	0	1	1	1	1	1	1	1	1	0	0

SOME CONCLUSIONS

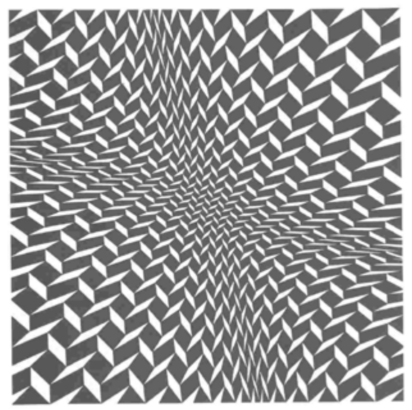
- Once the signal is perceived, similar circuits are in charge of the information processing, without taking into account the type of sensed signal.
- Information is always analyzed, just by hardware tools, as a function of the resulting frequency and no of its absolute value.
- Transferring of information is by parallel paths.
  - Signals travel along long paths without change in their properties.
- Each type of information is processed at specific places in the cortex

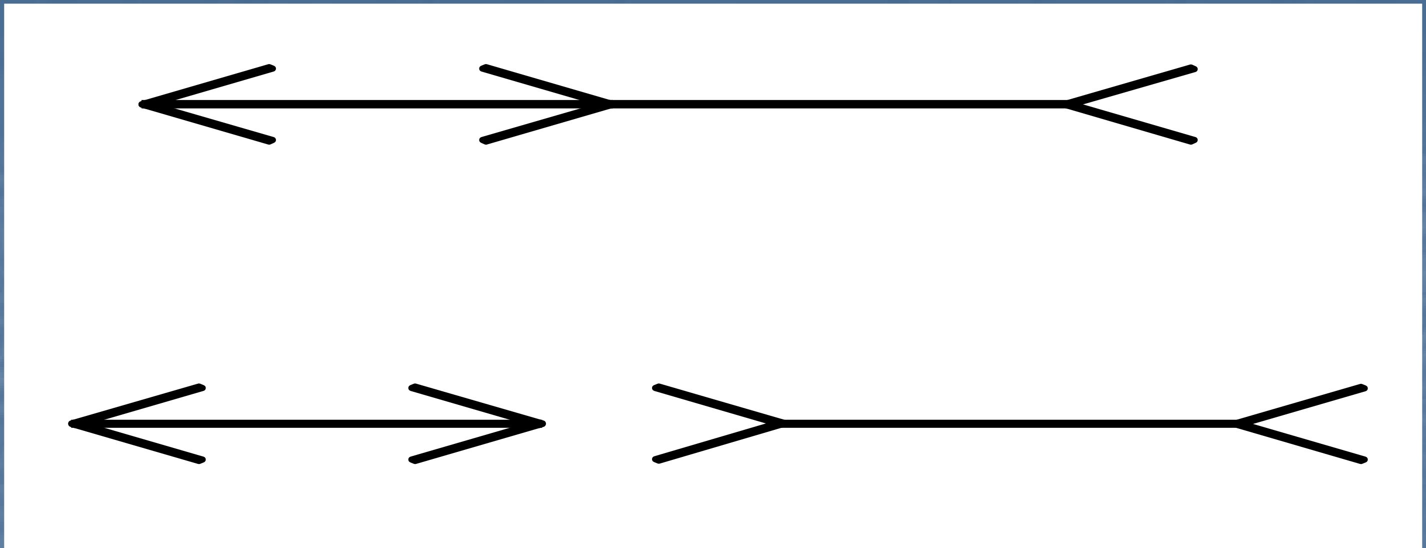
SOME POINTS TO BE CONSIDERED IN THE NEXT FUTURE:

At a high level, in the human brain, many cells cooperate in a purposeful manner to produce perception, thinking, speech, writing and many other phenomena. In all these cases, new qualities emerge at a macroscopic level, qualities that are absent at the microscopic level of the individual

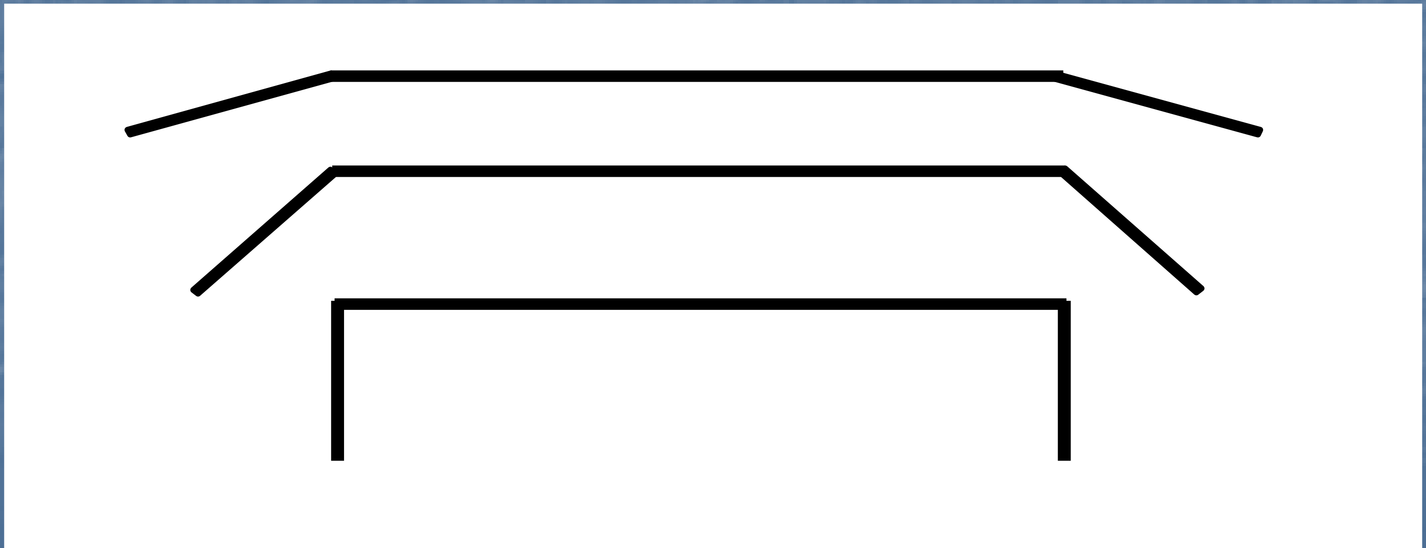


ON SUBJECTIVE IMPRESSIONS
OR
HOW TO PUT NUMBERS TO VISUAL ILLUSIONS

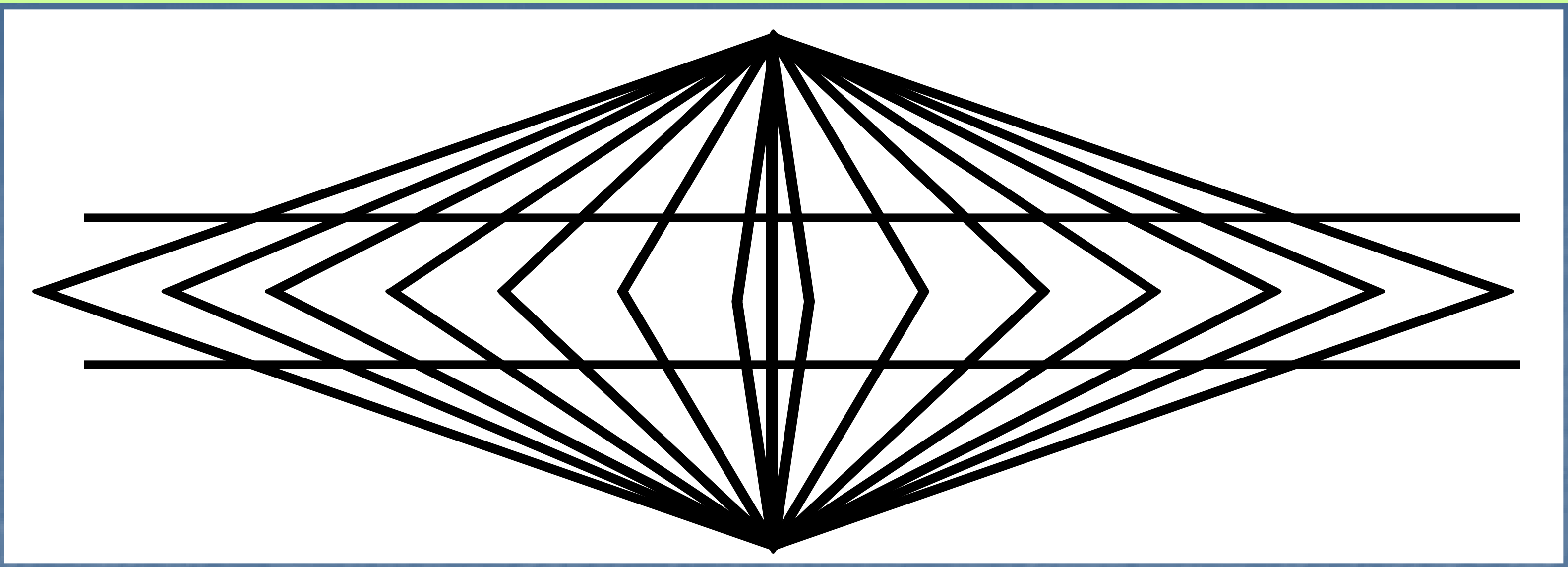




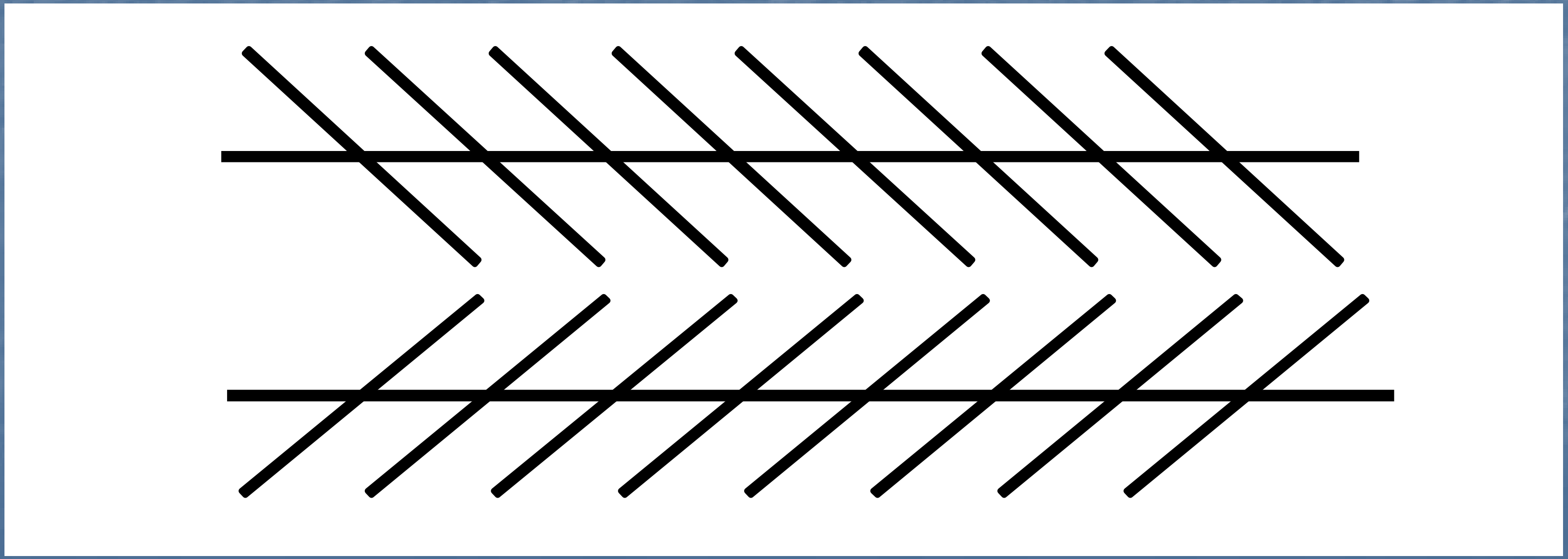
Müller-Lyer Illusion



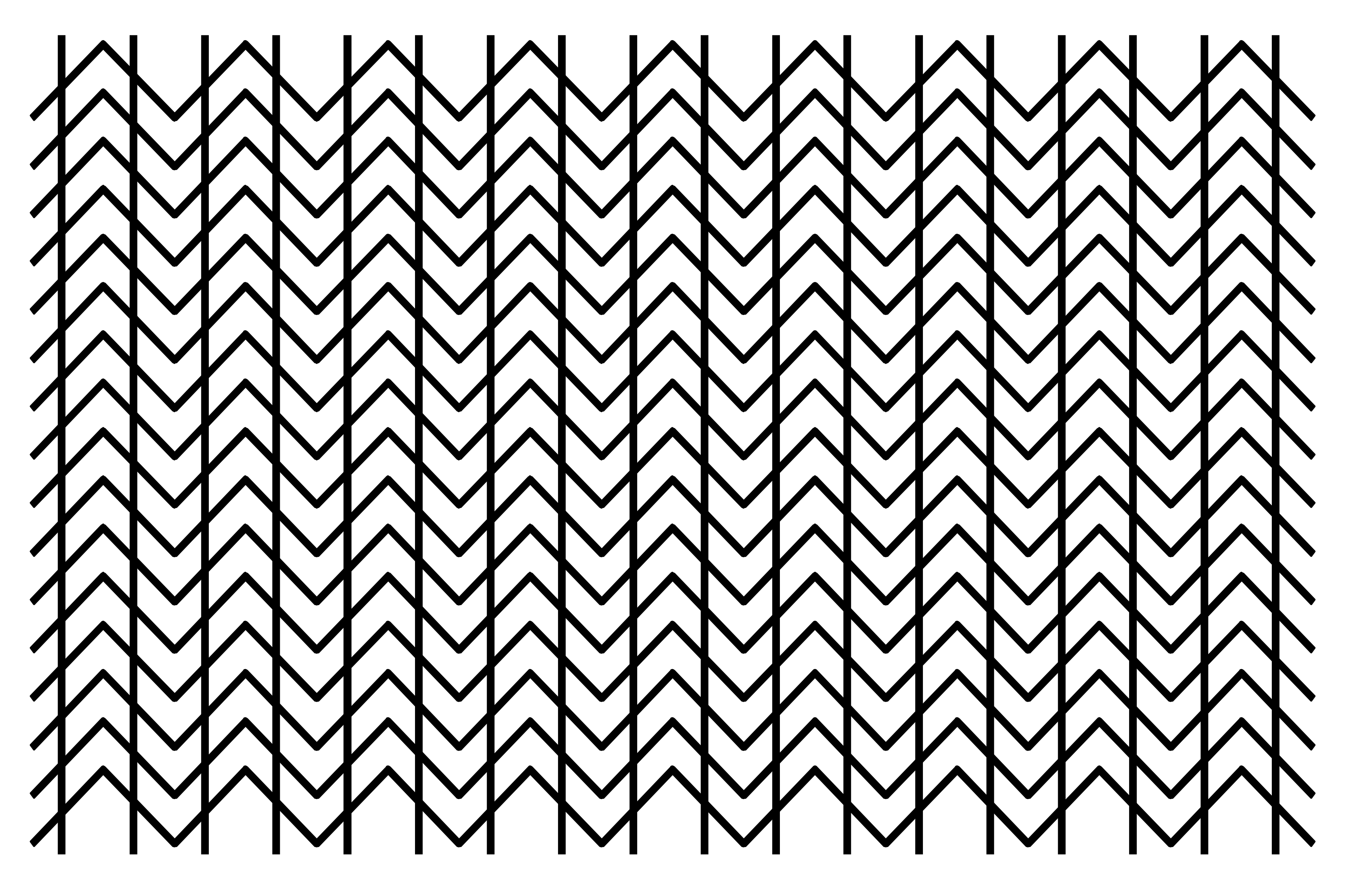
Effect of angles on the length sensation



Hering's Illusion

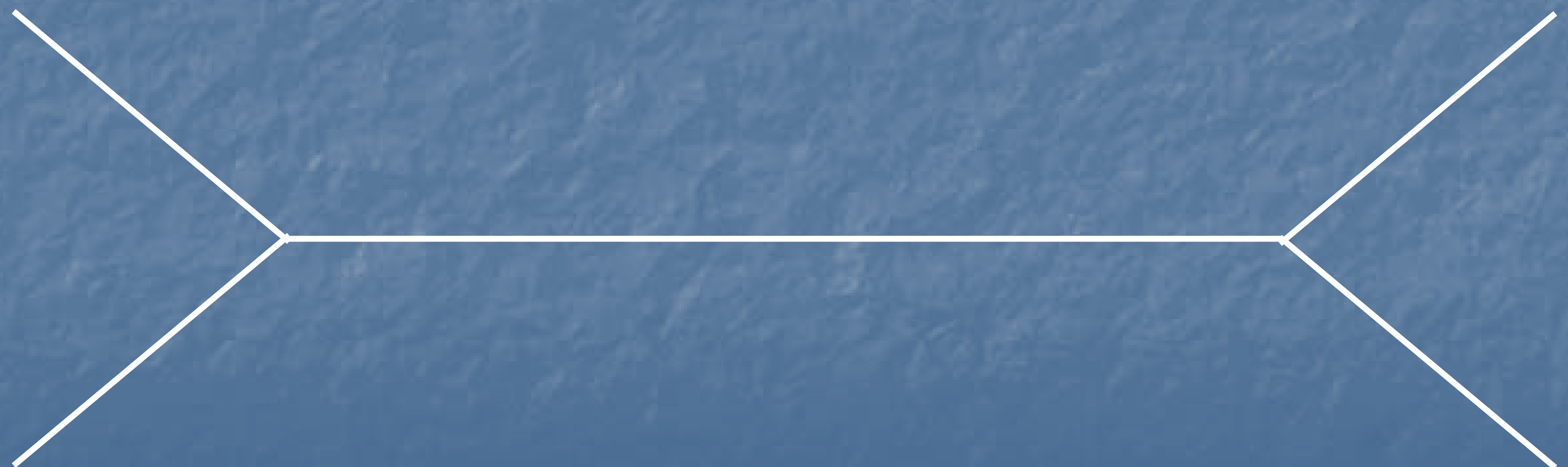


Zöllner Illusion

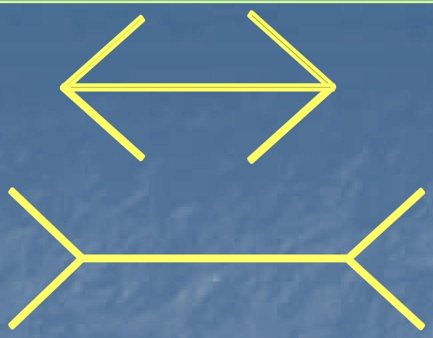


Extended Parallelism Illusion from the Zöllner effect

Analysis of the Müller-Lyer Illusion



MÜLLER-LYER ILLUSION



$$\Lambda = \frac{\sum_{1}^{n} \sigma_{B_n} \lambda_n^2}{\sum_{1}^{n} \sigma_{B_n} \lambda_n}$$

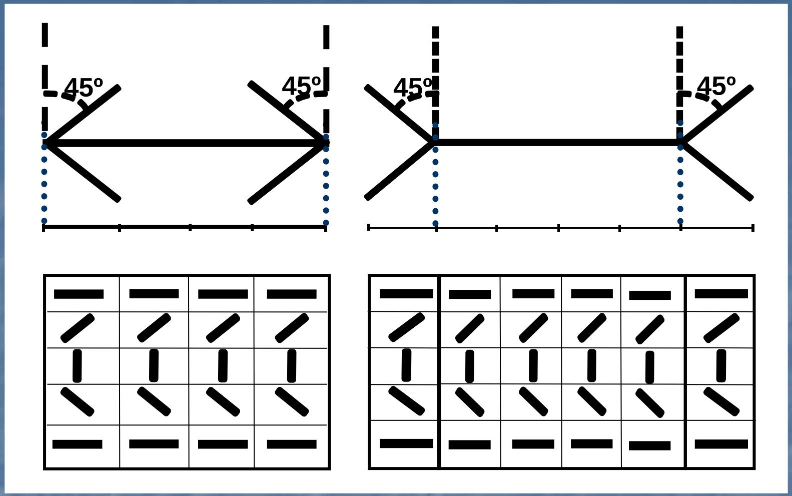
Λ: subjective length

n: total number of excited columns

σ_{Bn}: total number of bits obtained from the nth column

λ_n: distance of column n to the centre of image in column units

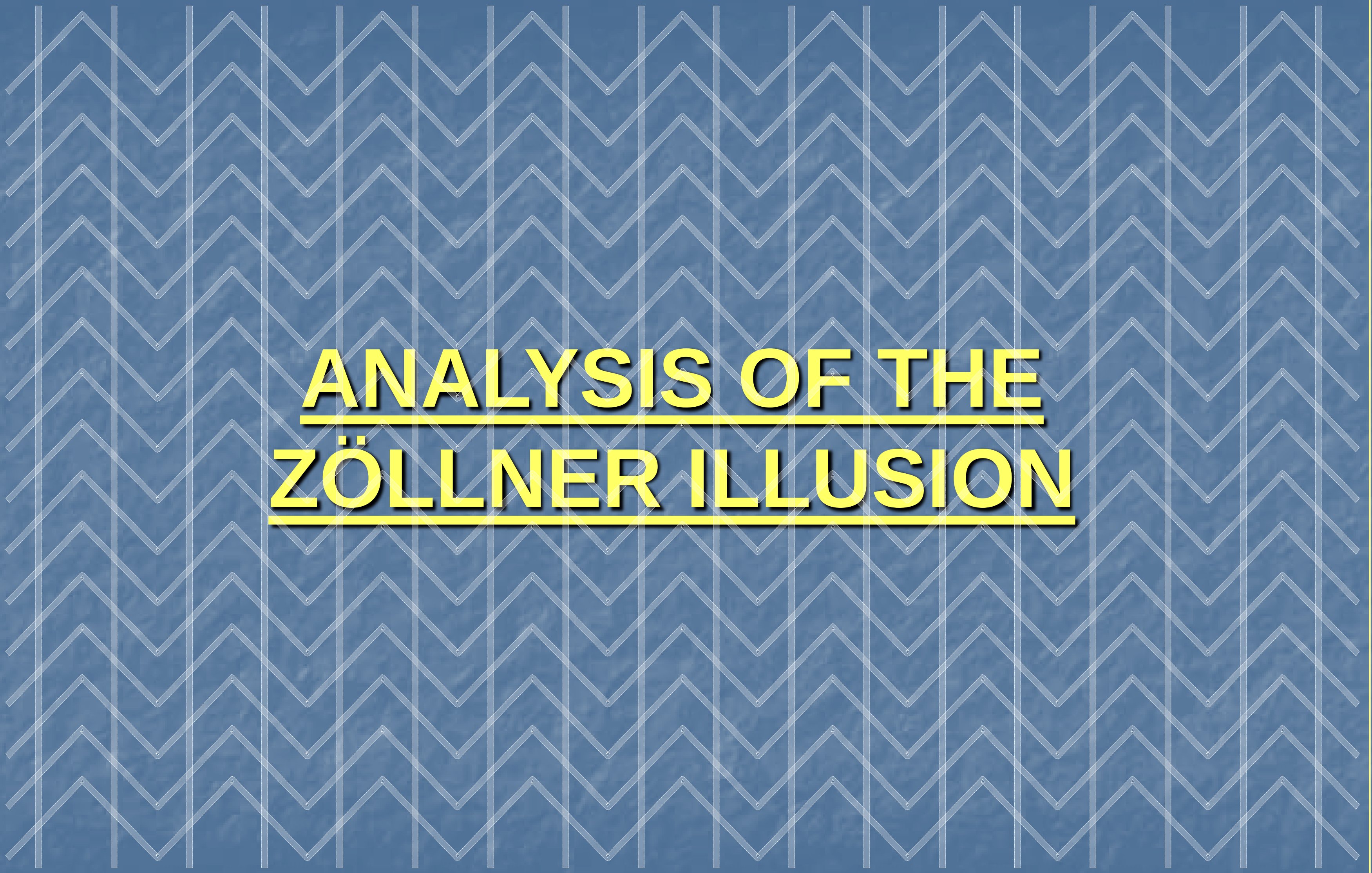
$$\Lambda = \frac{\sum_{1}^{n} \sigma_{B_n} \lambda_n^2}{\sum_{1}^{n} \sigma_{B_n} \lambda_n}$$



A B

	A				B					
Col. num.	1	2	3	4	1	2	3	4	5	6
Bits	3	1	1	3	2	1	1	1	1	2
Tot. Bits	8				8					
Tot. Col.	4				6					
Length	4				4					
Λ	**2 x 13/7 = 3.72**				**2 x 23/9 = 5.1**					

(3.4+1.1+1.1+3.4)/(3.2+1.1+1.1+3.2)



ANALYSIS OF THE ZÖLLNER ILLUSION

ANALYSIS OF PARALLELISM

Main factor: symmetry with respect to the parallel line located at the middle between the two parallel lines.

Main influences: location and angles - "*weight*" - of the intersecting lines.

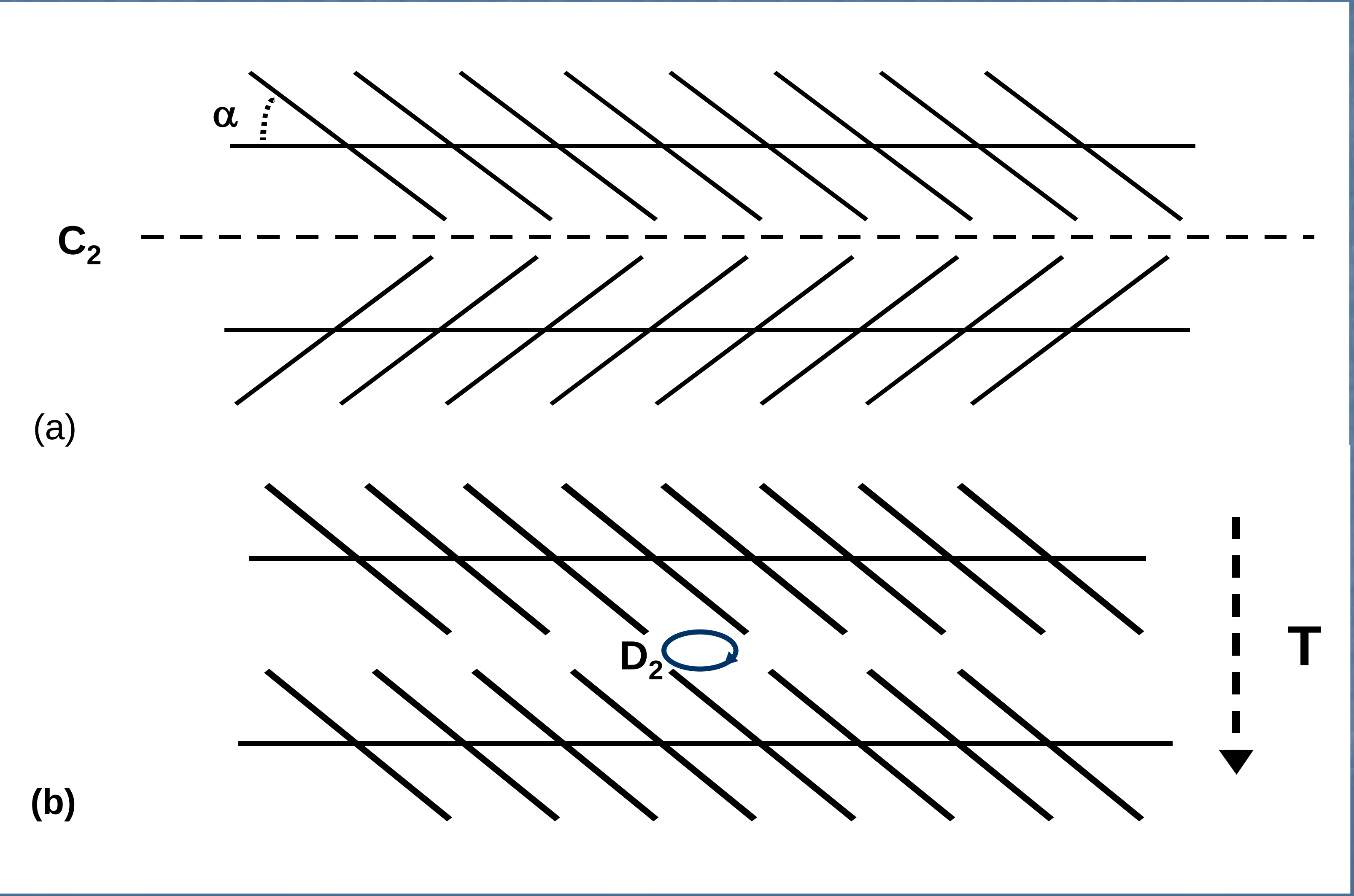
EXPERIMENTAL MEASUREMENT OF THE MÜLLER-LYER ILLUSION

(Black and blue curves correspond to two different conditions of the experiment)(from R. Gregory. “Eye and Brain”. 1990)

MAIN RULES:

1. Take the principal symmetry axis
2. Divide each region in “sensory zones”
3. Analyze each zone with respect to the principal axis
4. Construct the “sensory” matrix with elements from each zone
5. Apply the main symmetry operation to overlap different motives
6. Normalize
7. Reduce to a 1 x 1 matrix

Symmetry operations in two sets of parallel lines with small crossing lines



C_2 = twofold axis T = translation D_2 = inversion

PROPOSED FORMULAE:

$$\sigma_{\alpha k} = \left\{ \sum_{i=1}^{n} \omega_i \delta_i \right\}_{\alpha k} + S \left\{ \sum_{j=1}^{n} \omega_j \delta_j \right\}_{\alpha k}$$

ω = line "weight" δ = distance to the *central* line S = symmetry operation

i, j = each one of the lines α, *k* = each one of the unit intervals

"sensory" matrix: $\sigma_\alpha = [\sigma\alpha 1, \sigma\alpha 2, \ldots.., \sigma\alpha k, \ldots.]$

"reference" matrix: $\wp_\alpha = [\wp\alpha 1, \wp\alpha 2, \ldots.., \wp\alpha k, \ldots.]$

"normalized" matrix: $\pi_\alpha = [\sigma_{\alpha 1}/\wp\alpha 1, \sigma_{\alpha 2}/\wp\alpha 2, \ldots.., \sigma_{\alpha k}/\wp\alpha k, \ldots.]$

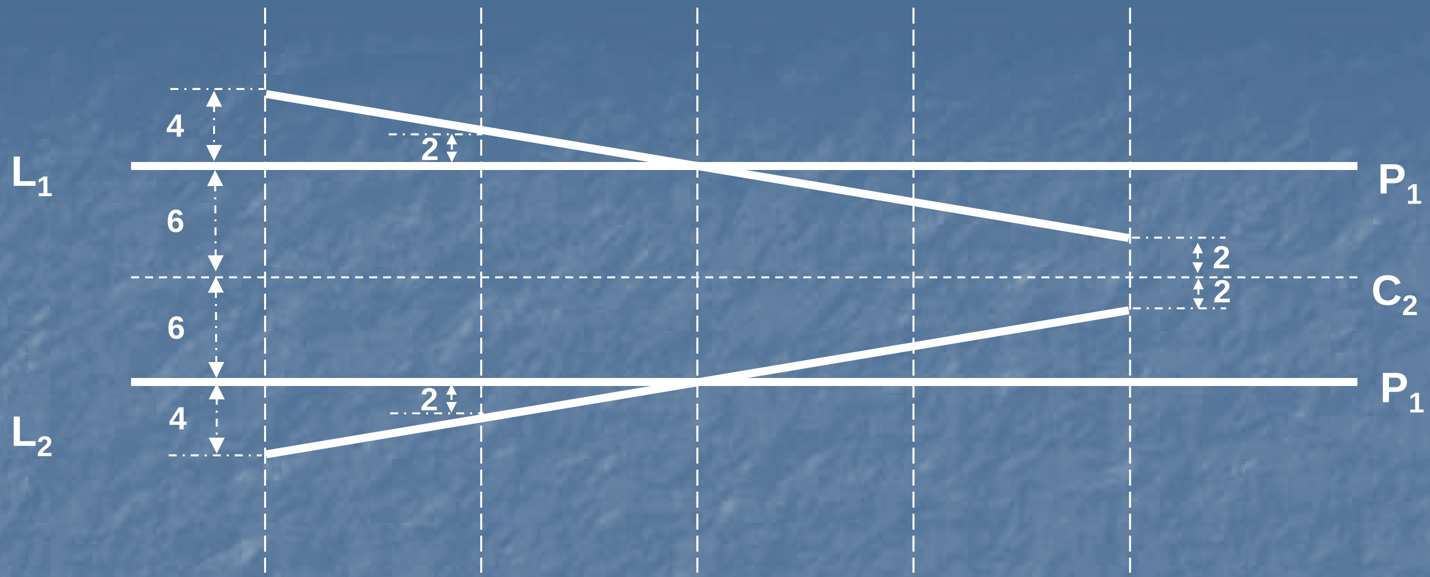
"reduced" matrix: $\pi_\beta = [\pi_{\alpha 1}-\pi_{\alpha 2}, \ldots.., \pi_{\alpha k}-\pi_{\alpha(k+1)}, \ldots.]$

If $\Pi_\gamma = [0,0,\ldots]$ **parallelism is "seen"**

If $\Pi_\gamma \neq [0,0,\ldots]$ **parallelism is not "seen"**

{$\wp$ is a similar effect corresponding to the parallel lines}

Subjective parallelism: Π



σ_1 : (6x1+9x0.5) ; (6x1+7x0.5) ; (6x1+5x0.5) ; (6x1+3x0.5)

σ_2 : (6x1+9x0.5) ; (6x1+7x0.5) ; (6x1+5x0.5) ; (6x1+3x0.5)

$\sigma_T \Rightarrow \sigma_1 + C_2\,\sigma_2 \Rightarrow$ [10.5+10.5; 9.5+9.5; 8.5+8.5; 7.5+7.5]

[21 19 17 15]

$\wp_T \Rightarrow \wp_1 + C_2\,\wp_2 \Rightarrow$ [6+6; 6+6; 6+6; 6+6]

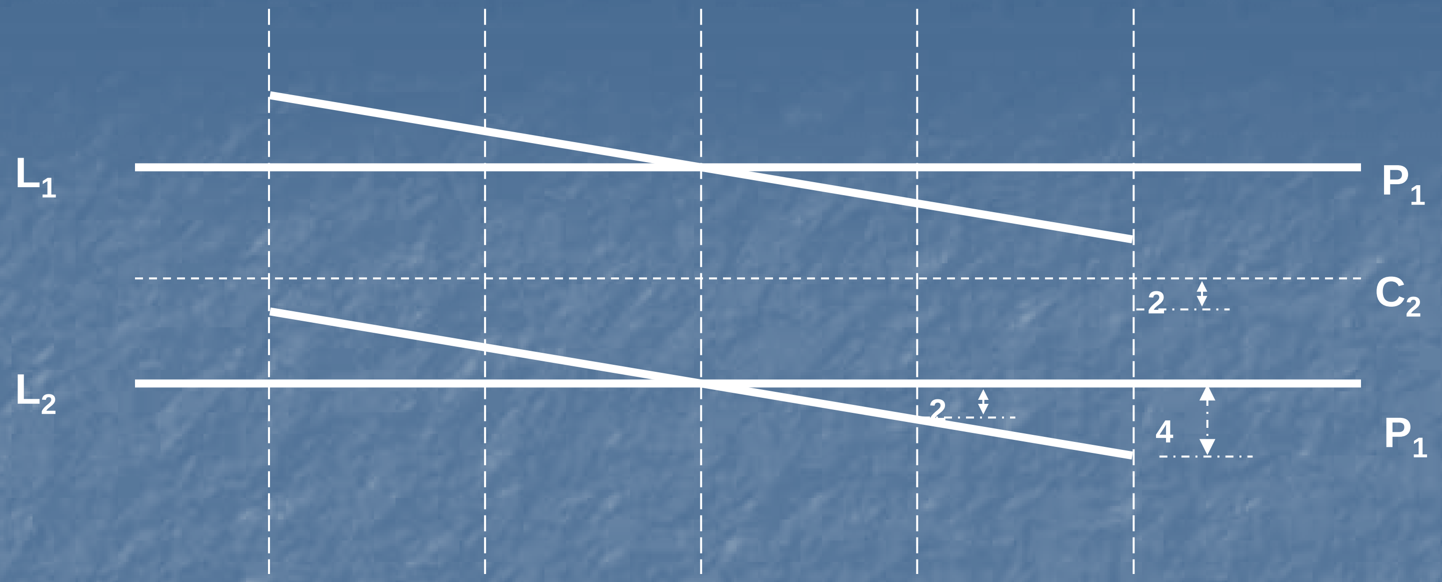
[12 12 12 12]

$\pi_i = (\wp_T / \sigma_T)_i \Rightarrow$ [0.57 0.63 0.70 0.8]

$\pi_l = \pi_i - \pi_{i-1}$: $\longrightarrow$ 0.06 0.07 0.1

$\pi_m = \pi_l - \pi_{l-1}$: $\longrightarrow$ 0.01 0.03

$\pi_n = \pi_m - \pi_{m-1}$: $\longrightarrow$ $\boxed{0.02 \Leftarrow \Pi}$



σ_1: (6x1+9x0.5); (6x1+7x0.5); (6x1+5x0.5); (6x1+3x0.5)

$\sigma_{2:}$ (6x1+3x0.5); (6x1+5x0.5); (6x1+7x0.5); (6x1+9x0.5)

$\sigma_T \Rightarrow$ $\sigma_1 + C_2 \sigma_2$: 10.5+7.5; 9.5+8.5; 8.5+9.5; 7.5+10.5

18 18 18 18

$\wp_T \Rightarrow$ $\wp_1 + C_2 \wp_2$: 6+6 ; 6+6 ; 6+6 ; 6+6

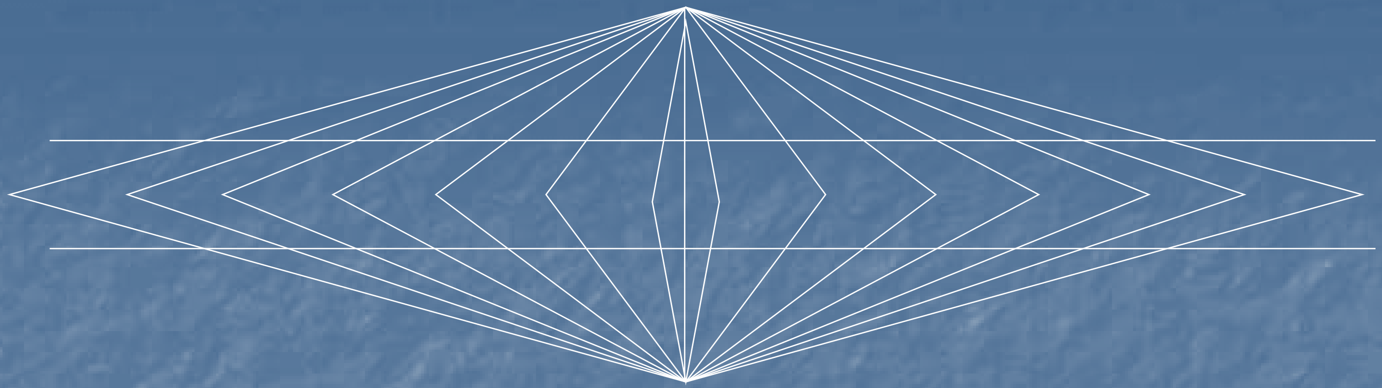
12 12 12 12

$\pi_i = (\wp_T / \sigma_T)_i$: 0.67 0.67 0.67 0.67

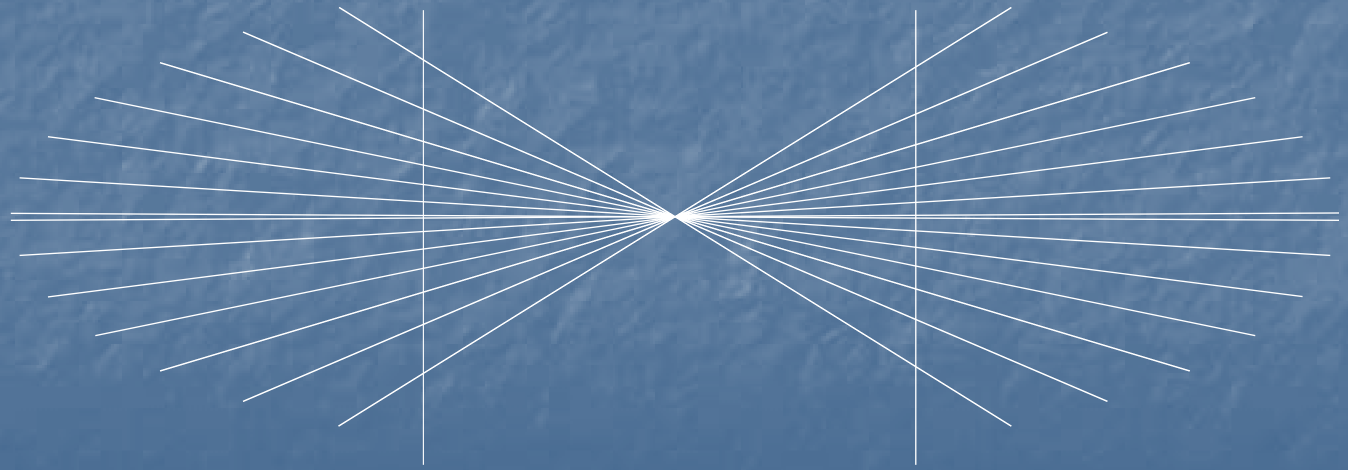
$\pi_l = \pi_i - \pi_{i-1}$: $\longrightarrow$ 0.0 0.0 0.0

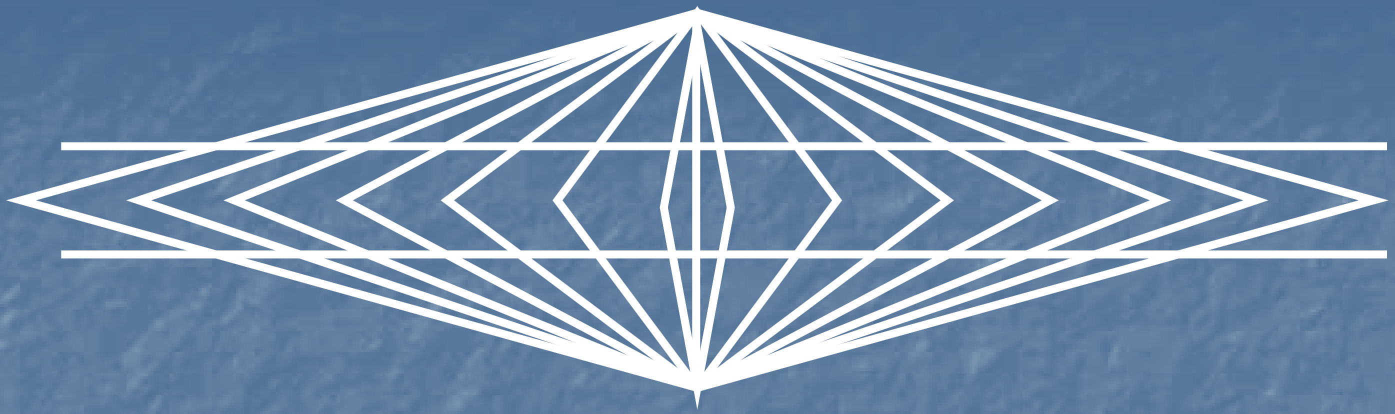
$\pi_m = \pi_l - \pi_{l-1}$: $\longrightarrow$ 0.0 0.0

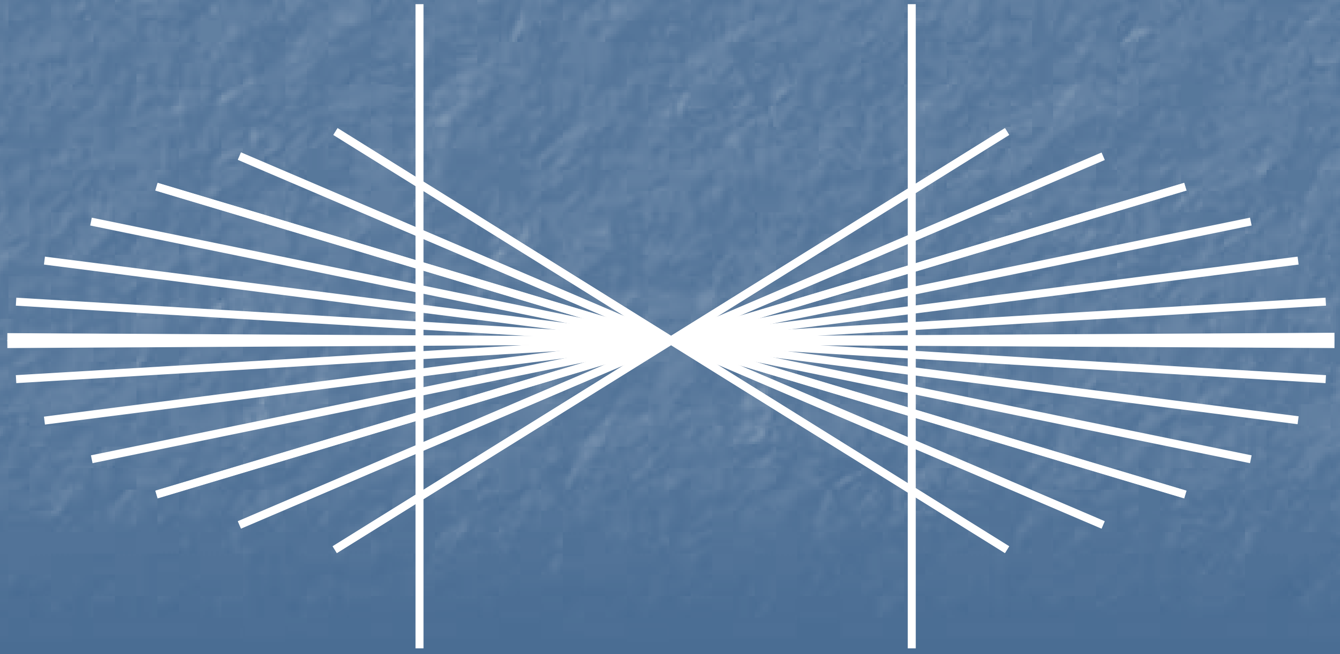
$\pi_n = \pi_m - \pi_{m-1}$: $\longrightarrow$ $\boxed{\underline{0.00} \quad \Leftarrow \underline{\Pi}}$

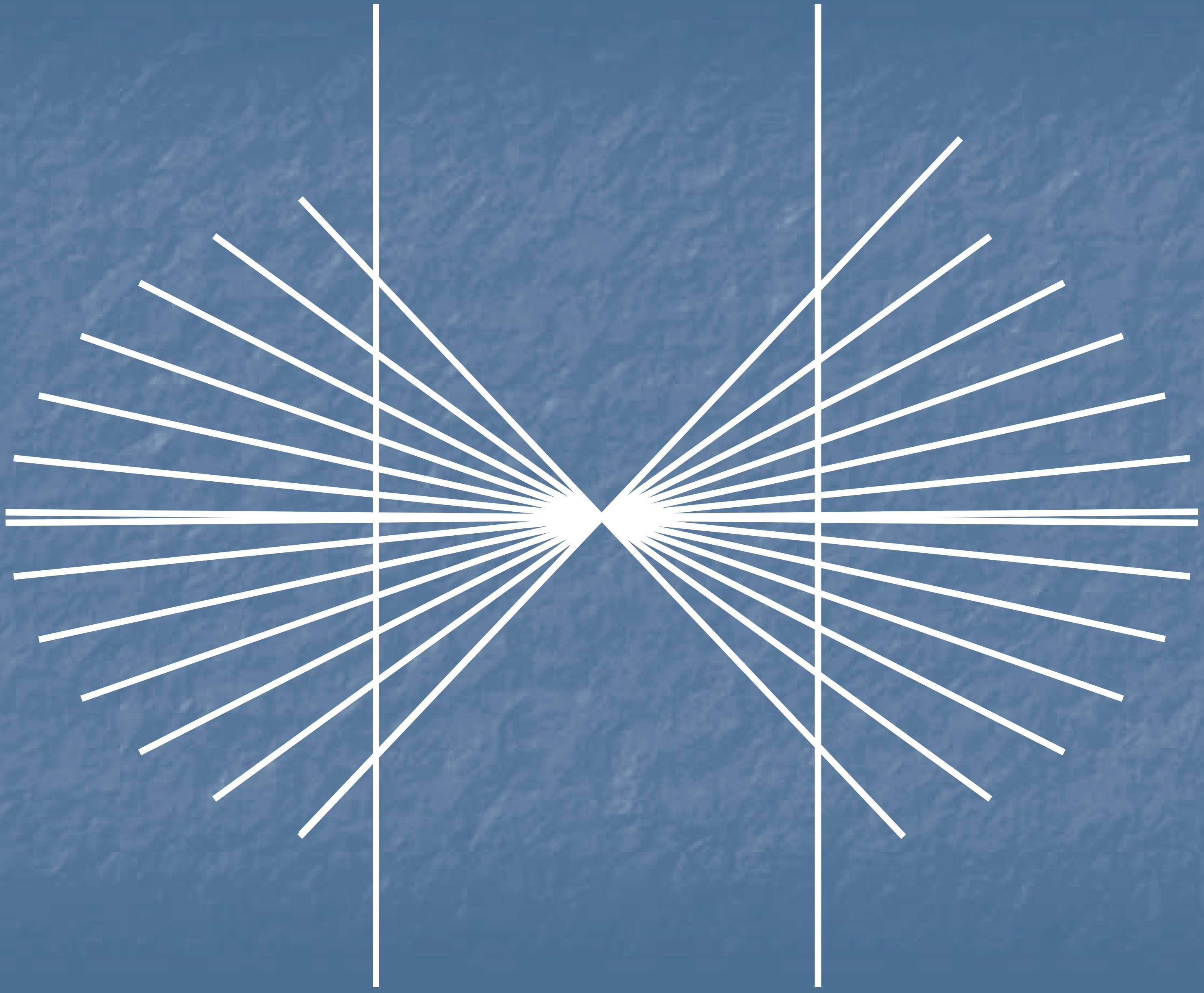


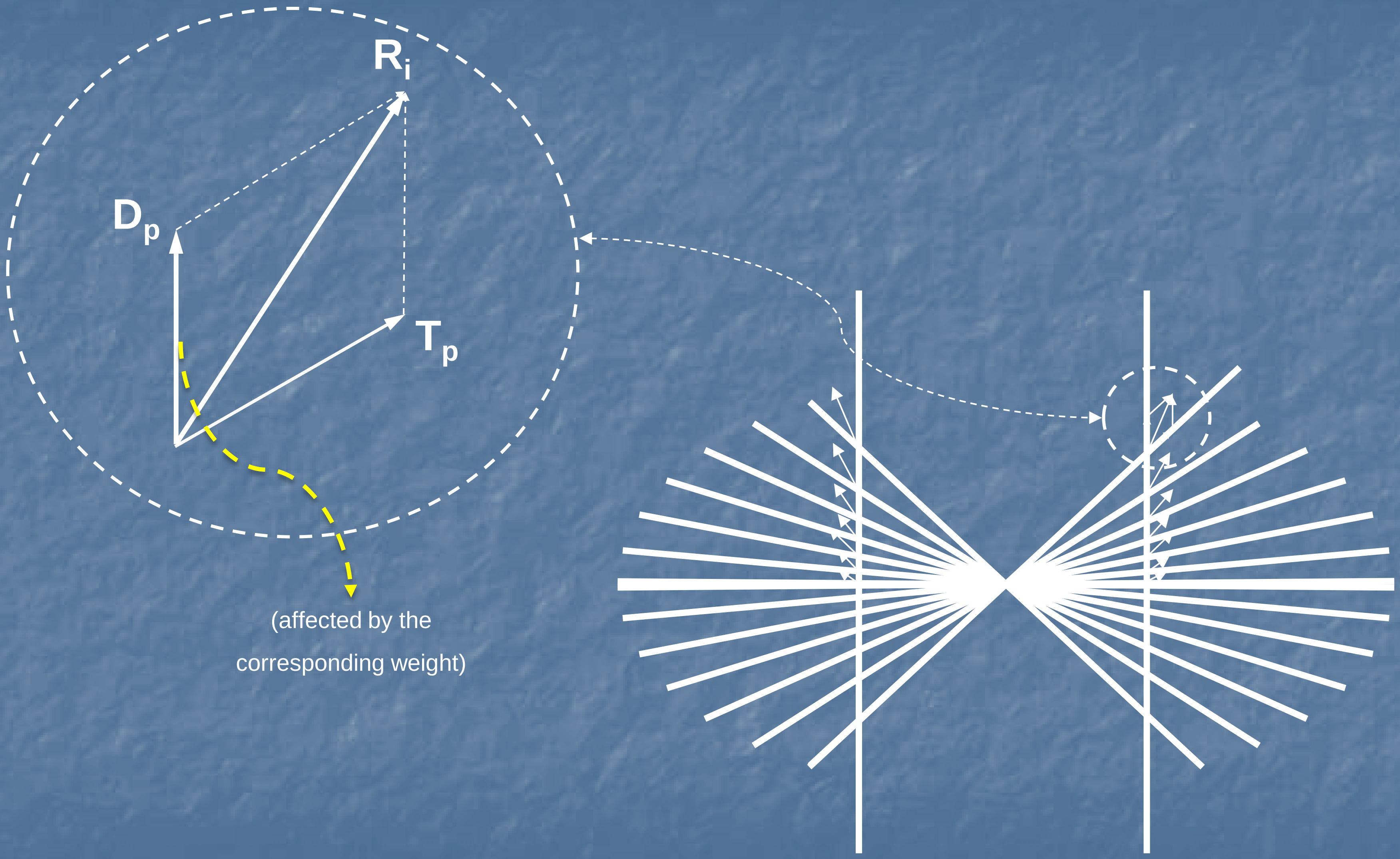
Analysis of the Hering and Wundt Illusions



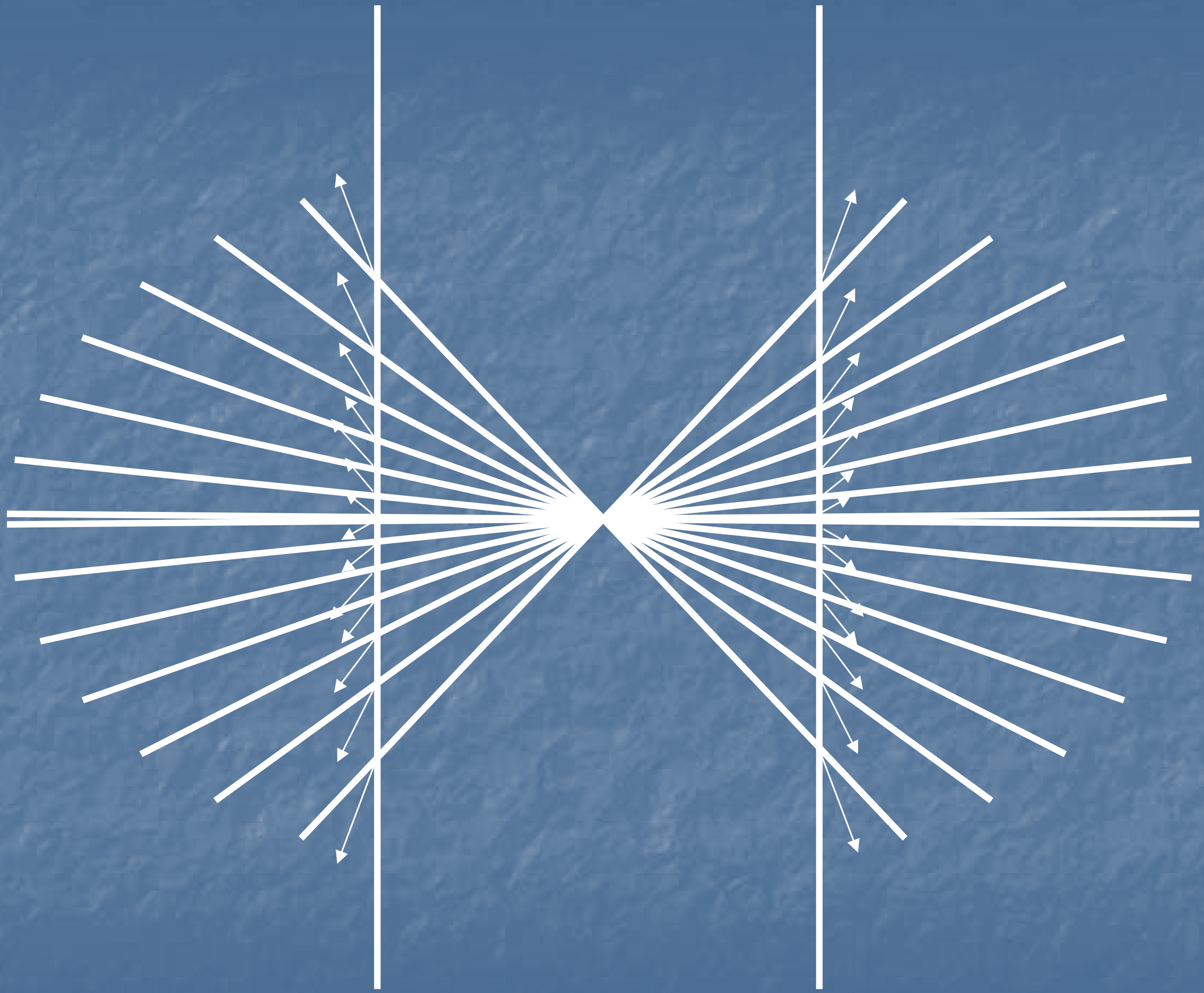


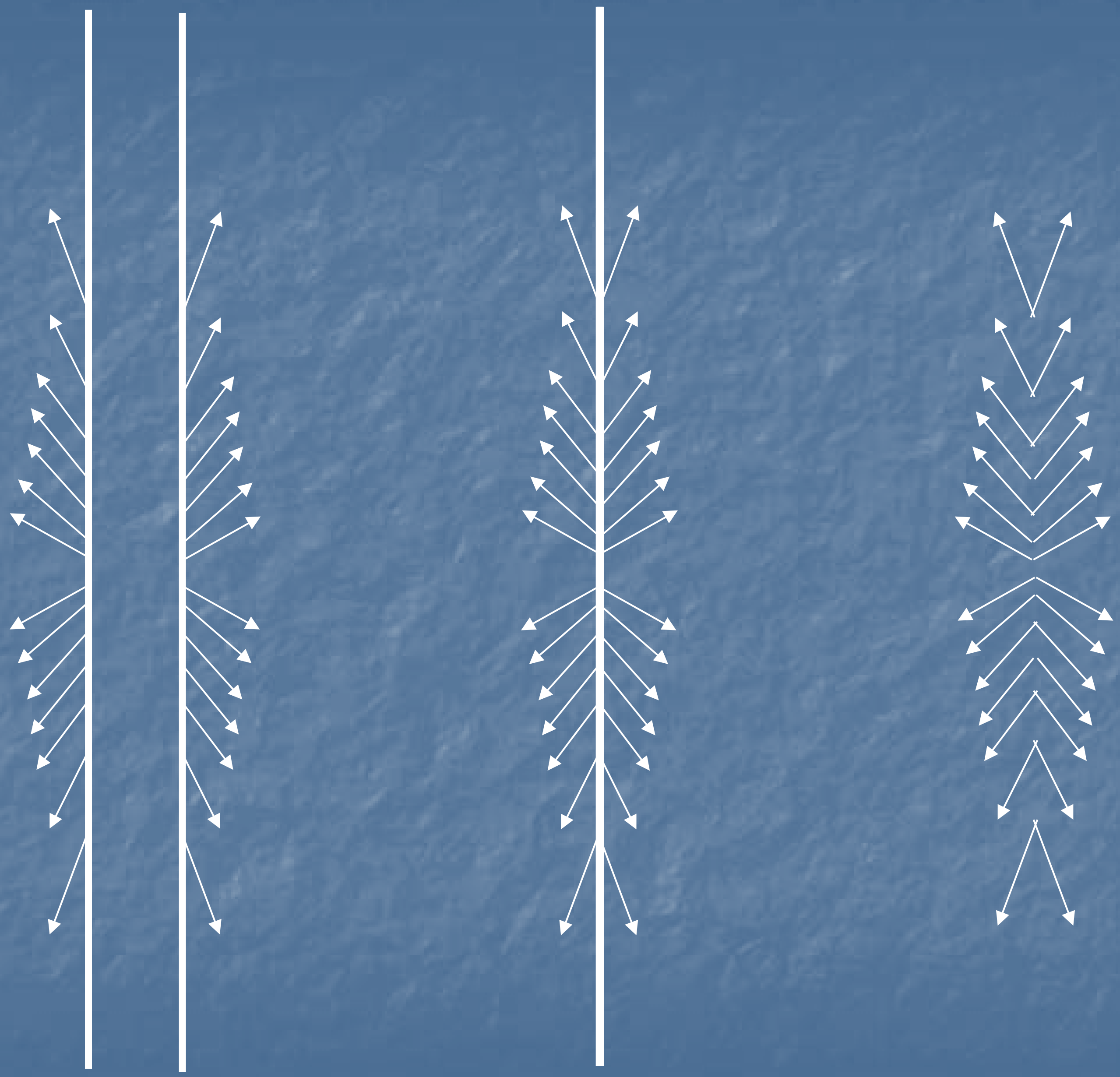


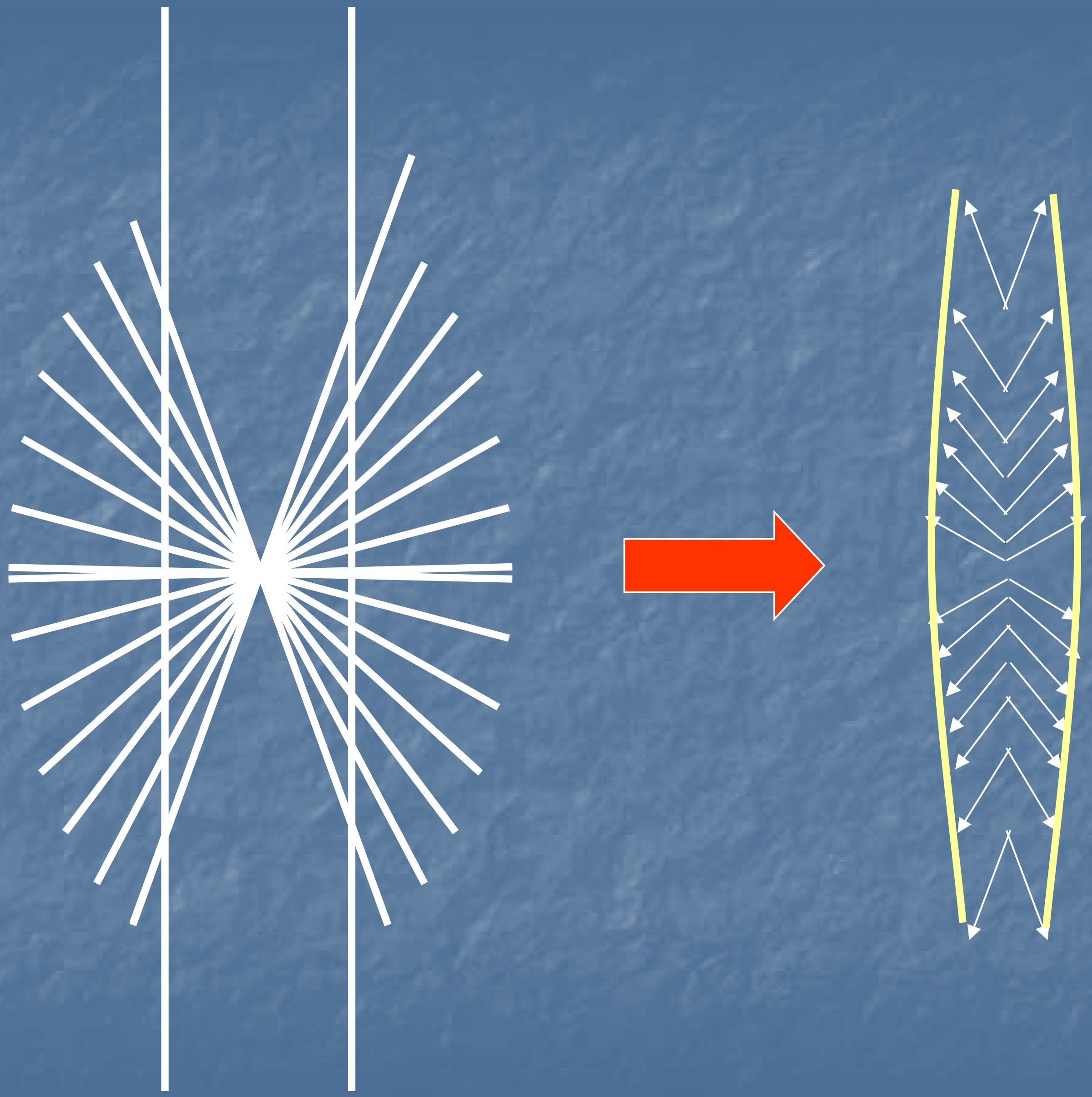


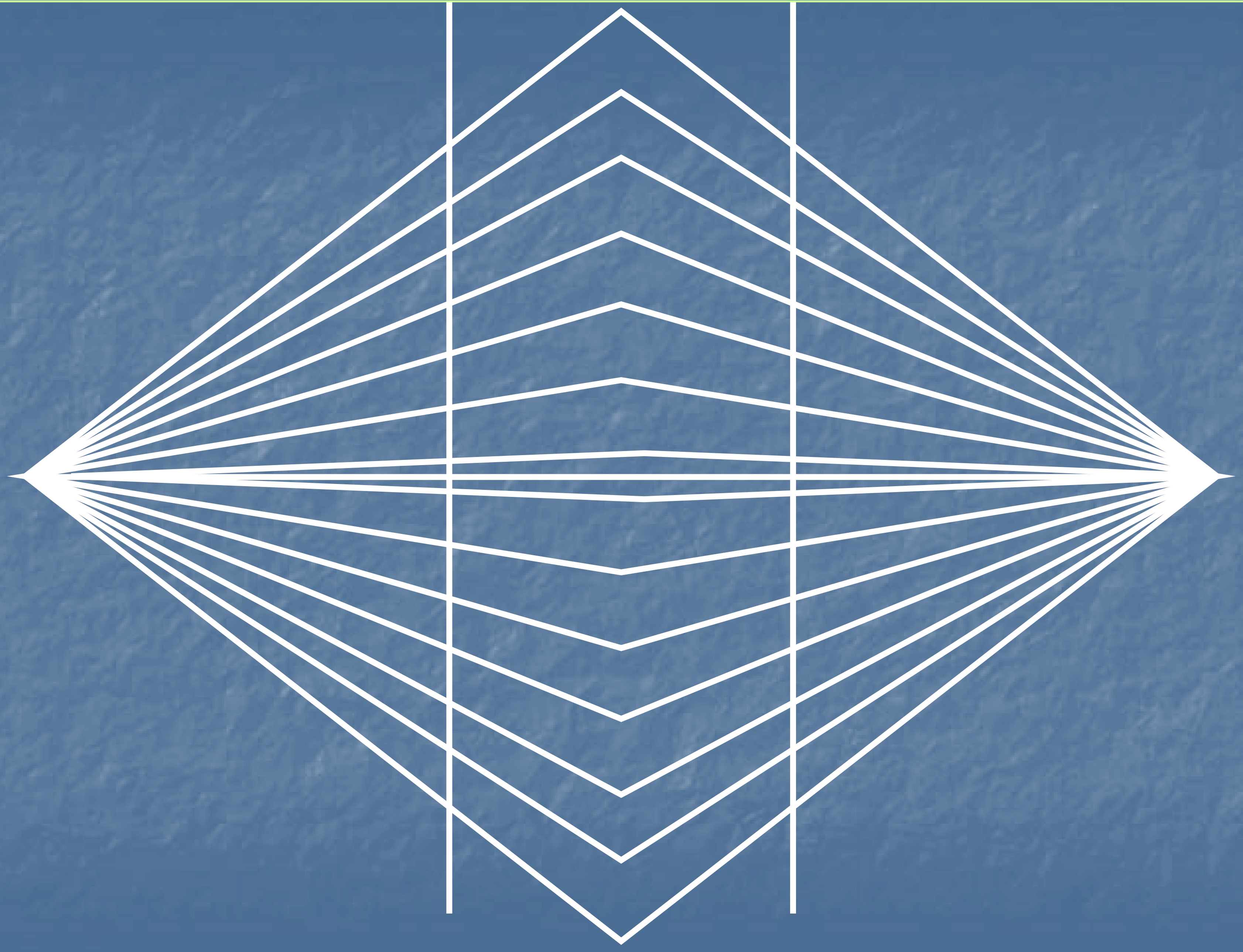


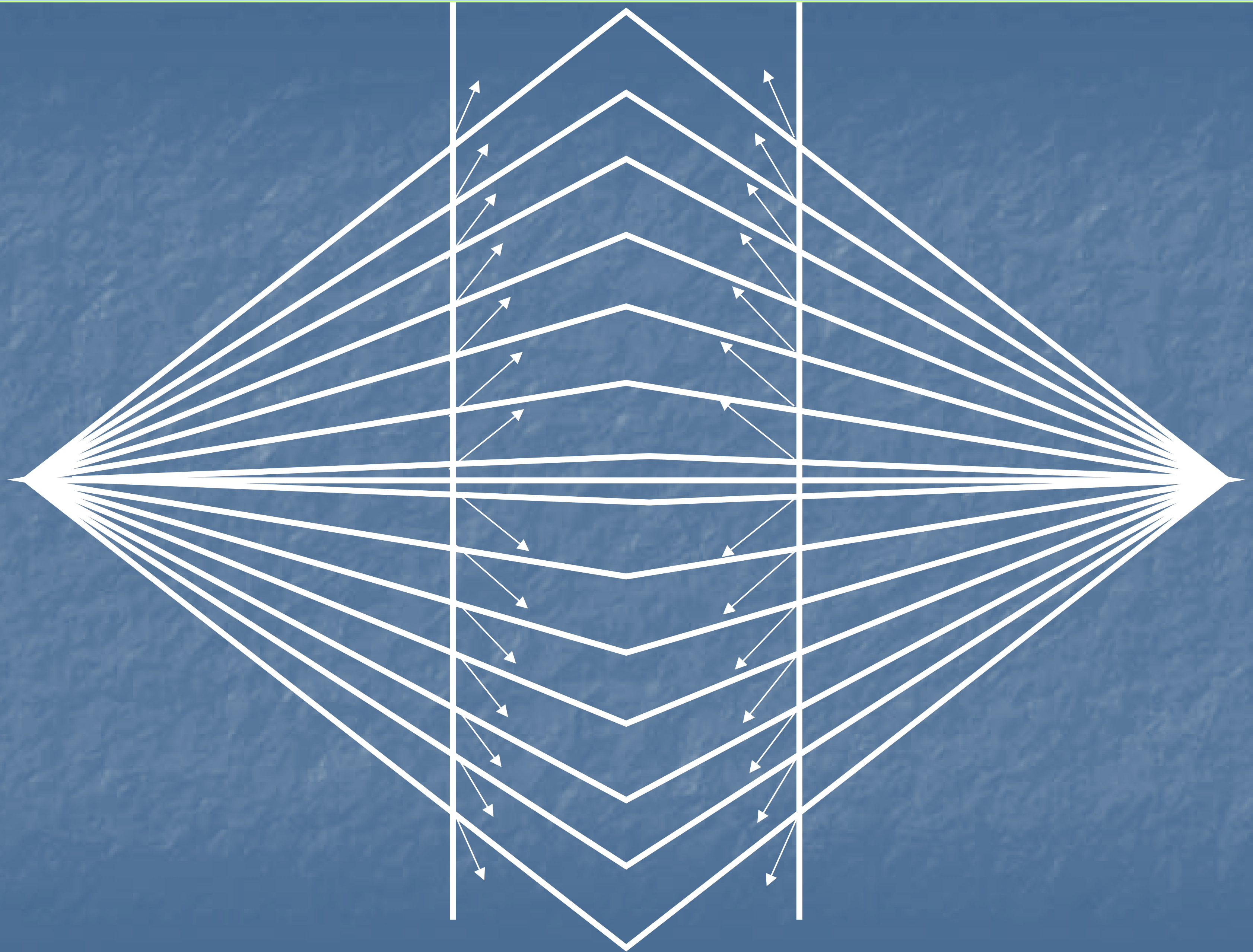
R_i
D_p
T_p
(affected by the
corresponding weight)

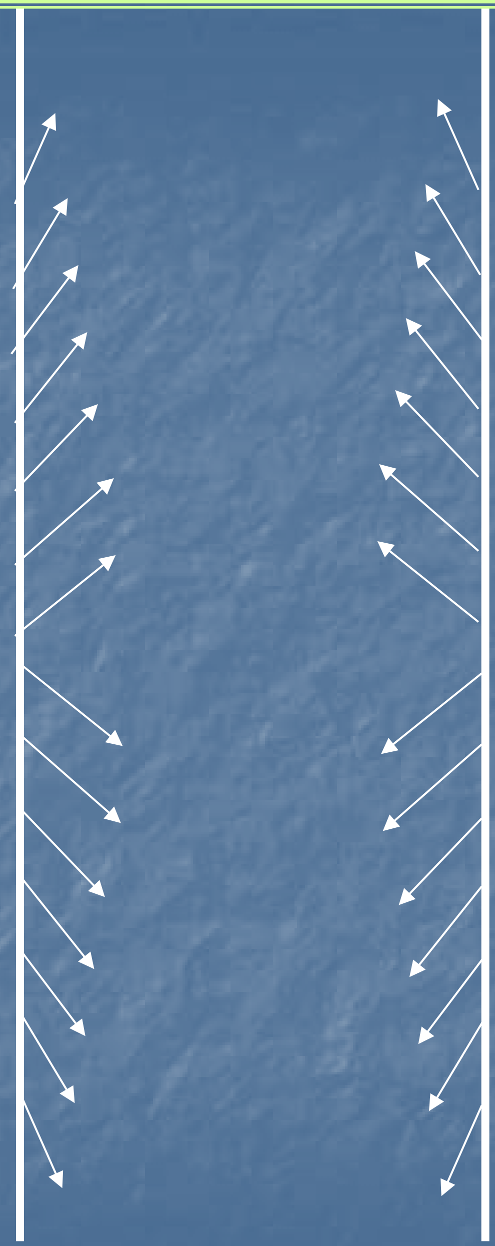


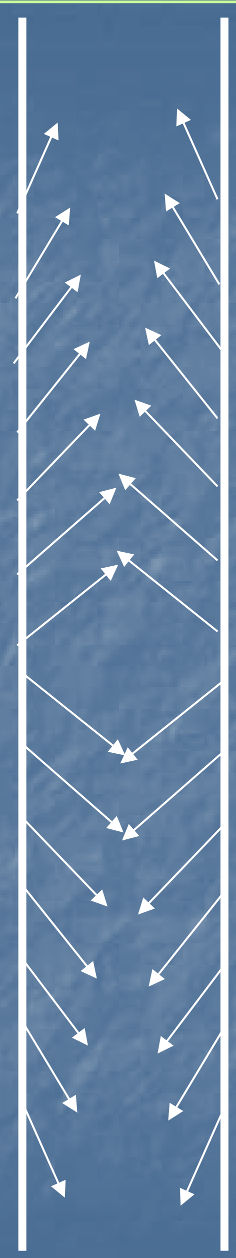


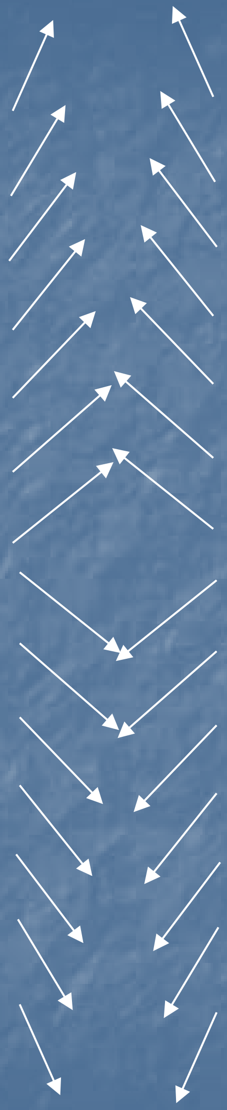


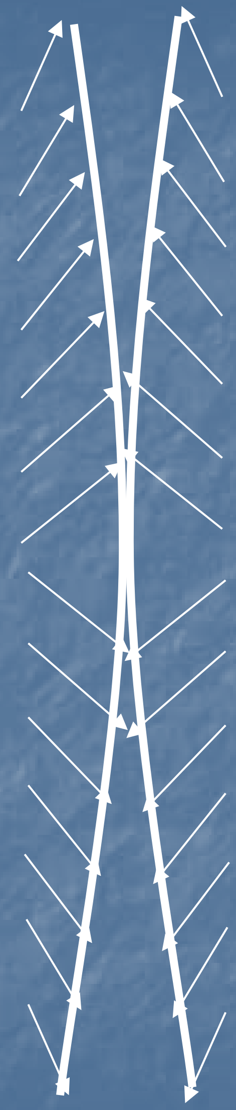


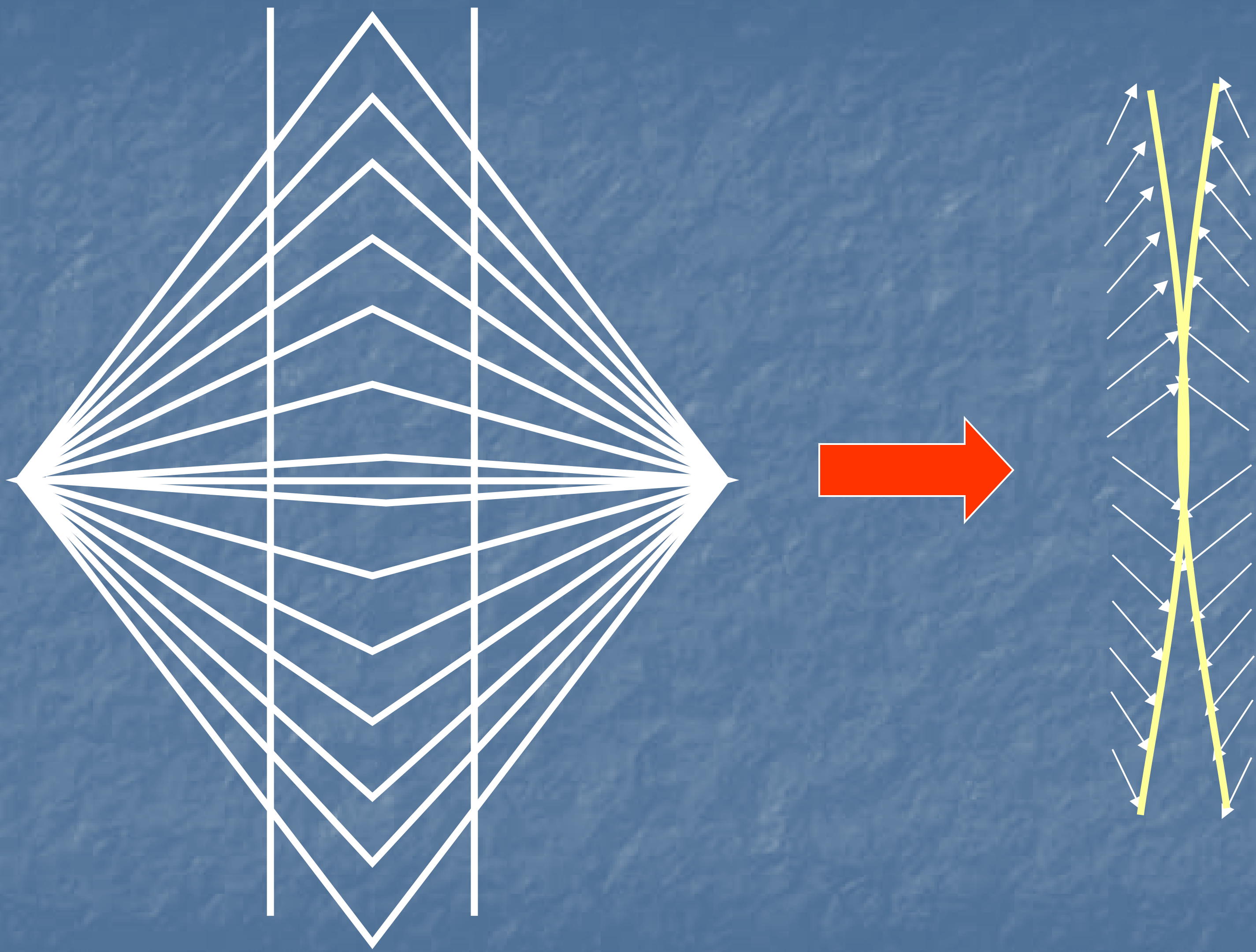












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“Look, what thy memory cannot contain

Commit to these waste blanks, and thou shall find

Those children nursed, delivered from thy brain

To take a new acquaintance from thy mind”

(W. Shakespeare)