Biophysical principles of sensory function

Participants of sensory function

stimuli
from the external
or
internal environment

Specifique
transducers - **receptors**

neurons

Central nervus system

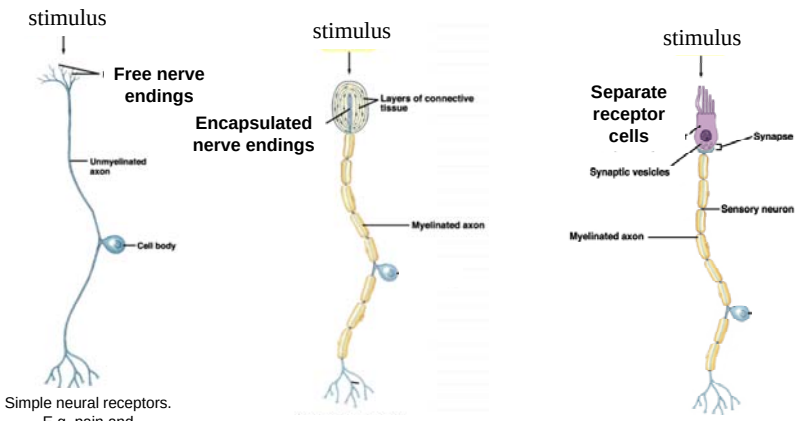
Parameters of the stimulus

What?
Where?
How much?
How long?

Types of Sensory Receptors

Primery receptor

Secunder receptor

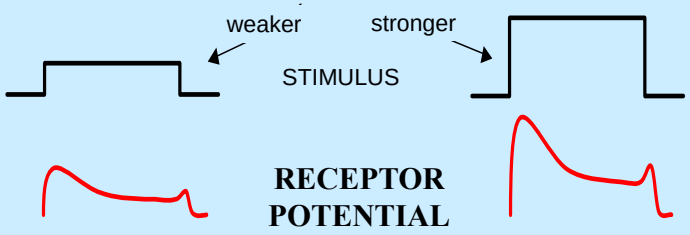


Simple neural receptors.
E.g. pain and thermoreceptors

Complex neural receptors. E.g. pacinian corpuscles

Spetial receptor
E.G. hair cells, photoreceptors and gustatory receptor cells

Reaction of receptor cell for specific stimulus

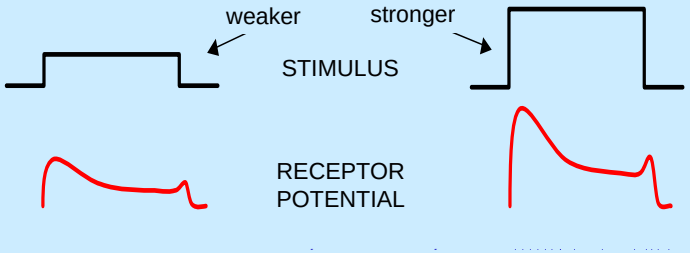


Answer is general and uniform:

alteration of the membrane potential on receptor cell

RECEPTOR POTENTIAL

Analogue signal conversion



Its amplitude is proportional to the stimulus amplitude.

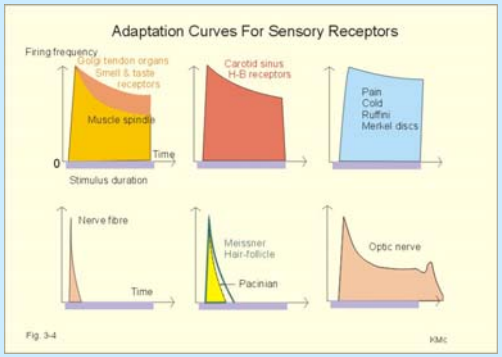
Its duration is identical to the stimulus duration

It is a local potential change.

It is not Na-potential.

Stimulus		Code
What?	⇒	Type of receptor
Where?	⇒	Receptive field
How much?	⇒	Amplitude of receptor potential
How long?	⇒	Duration of receptor potential

Adaptation of Receptors



Rapidly adapting receptors (Rated receptors): e.g. pacinian and hair receptors detect the change in stimulus strength (detect movement)

Slowly adapting receptors (Tonic receptors): e.g. joint capsule, muscle spindle detect continuous stimulus strength (give report to the brain about the status of the body).

Non adapting receptors: pain receptors and chemoreceptor

Transition of information from receptor to neuron / axon

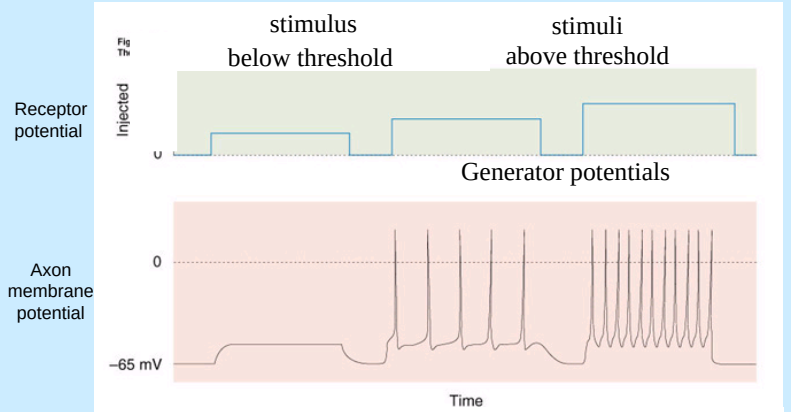
Secunder receptor ⟹ synapse ⟹ axon

receptor potential — neurotransmitter — ?
- quantity
- quality

Primery receptor ⟹ local currents ⟹ axon

receptor potential — current intensity — ?

Receptor potential acting on nerve cell membrane

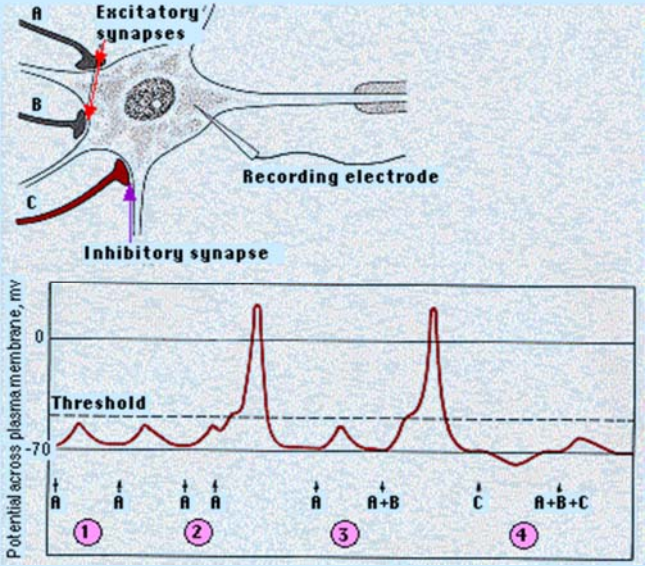


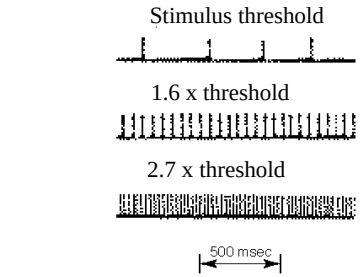
depolarization (or hyperpolarization)

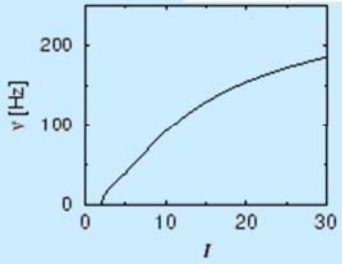
action potential

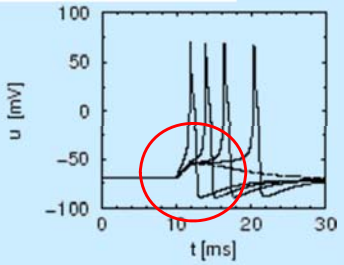
constant amplitude, firing frequency modulated

Temporal and spatial summation

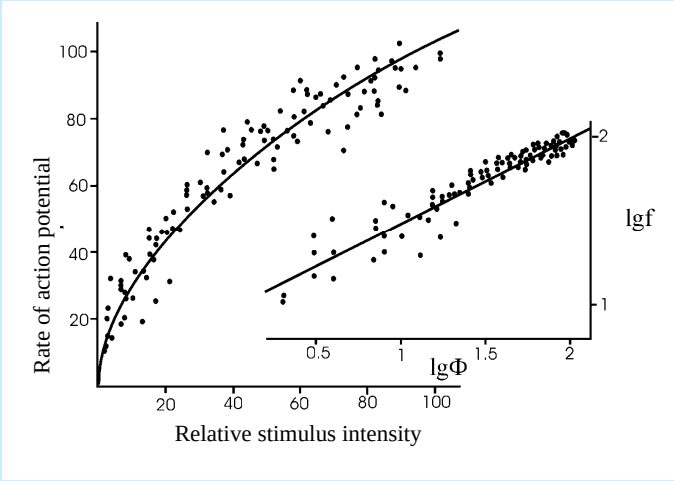




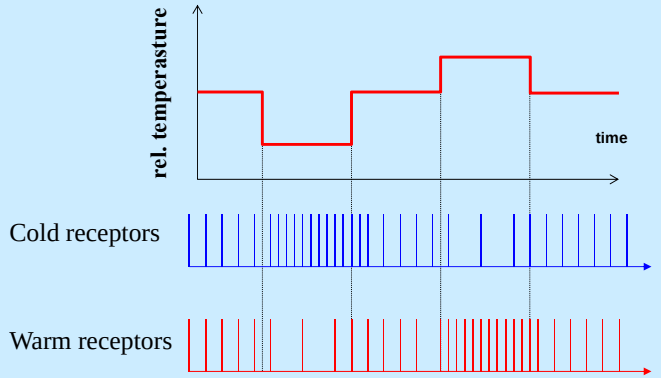




AP frequency and stimulus intensity



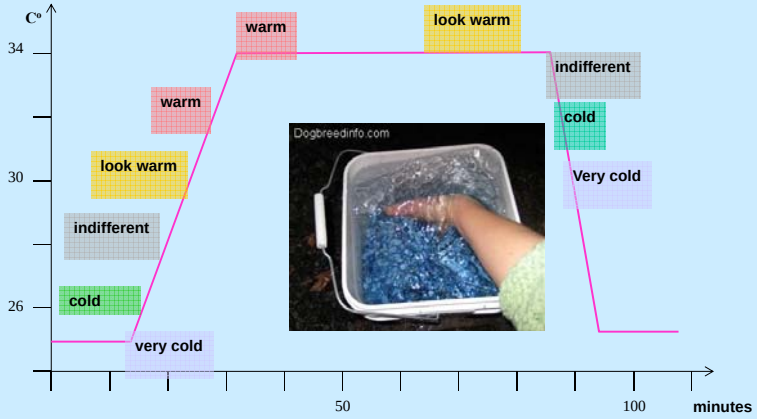
Persistent APs



For a warm receptor warming results in an increase in their action potential discharge rate, cooling results in a decrease in discharge rate. For cold receptors their firing rate increases during cooling and decreases during warming.
Some cold receptors also respond with a brief action potential discharge to high temperatures, i.e. typically above 45°C, and this is known as a paradoxical response to heat.

Thermal receptors

codes absolute and relative changes in temperature

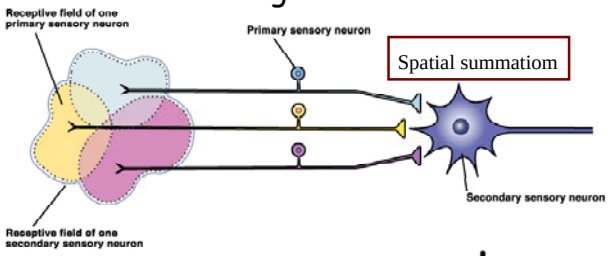


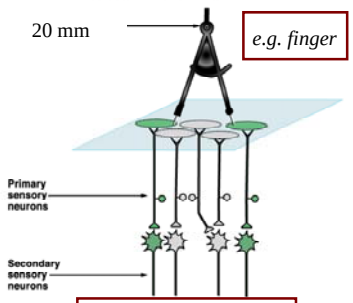
CNS is composed of neuronal pools with

different mechanisms of signal processing.

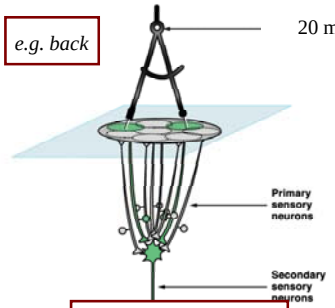
Excitation
Facilitation
Inhibition
Convergence
Divergence

Convergence of Signals: multiple inputs uniting to excite a single neuron



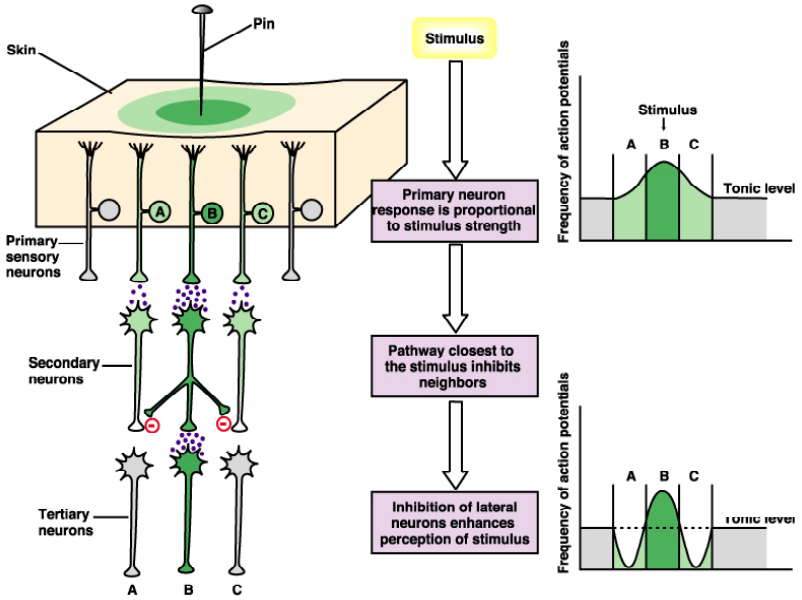


Two signals to the brain



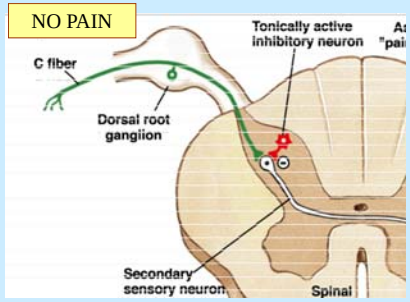
One signals to the brain

Divergence of Signals

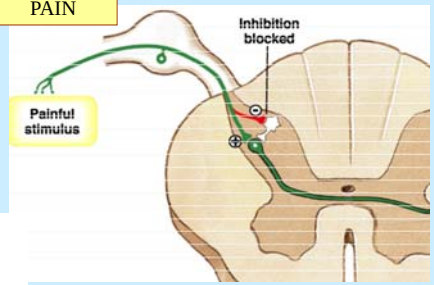


Divergence of Signals

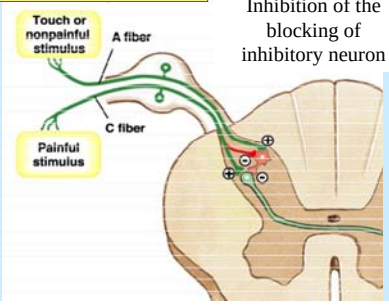
NO PAIN



STRONG PAIN

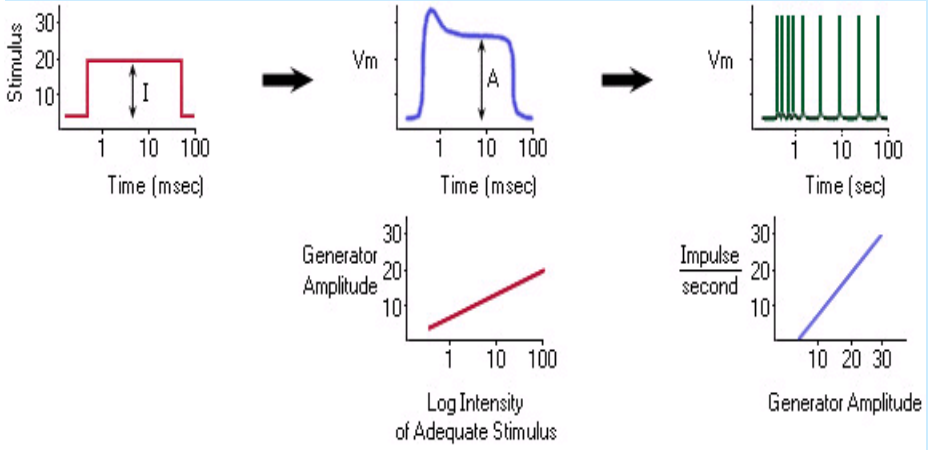


PAIN and TOUCH



Inhibition of the blocking of inhibitory neuron

Summary



Psychophysics

Study the relationship between stimuli
&
our psychological response to them

Investigation of threshold stimulus

Absolute threshold

This is the minimum amount of a stimulus that is necessary for us to notice it 50% of the time

Decision method – yes - no

Determination of threshold by simple decision

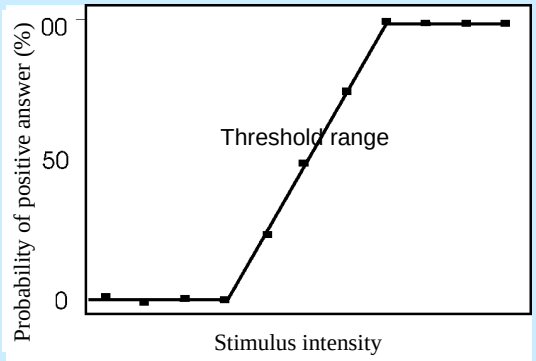
answer

Increasing intensity

stimulus	V1	V2	V3	V4	YES (%)
I1	NO	NO	NO	NO	**0 (0)**
I2	NO	NO	NO	NO	**0 (0)**
I3	NO	NO	NO	NO	**0 (0)**
I4	NO	NO	NO	NO	**0 (0)**
I5	NO	NO	NO	NO	**0 (0)**
I6	**YES**	NO	NO	NO	**1 (25)**
I7	**YES**	NO	**YES**	NO	**2 (50)**
I8	**YES**	NO	**YES**	**YES**	**3 (75)**
I9	**YES**	**YES**	**YES**	**YES**	**4 (100)**
I10	**YES**	**YES**	**YES**	**YES**	**4 (100)**
I11	**YES**	**YES**	**YES**	**YES**	**4 (100)**
I12	**YES**	**YES**	**YES**	**YES**	**4 (100)**

Determination of threshold by simple decision

Absolute threshold



Threshold is a variable

Threshold studies

Absolute threshold – the smallest intensity of stimulus to be recognized

Decision method – yes - no

Adjusting method – (see audiometry experiment)

Differential threshold : smallest difference between two intensities to be recognized as different

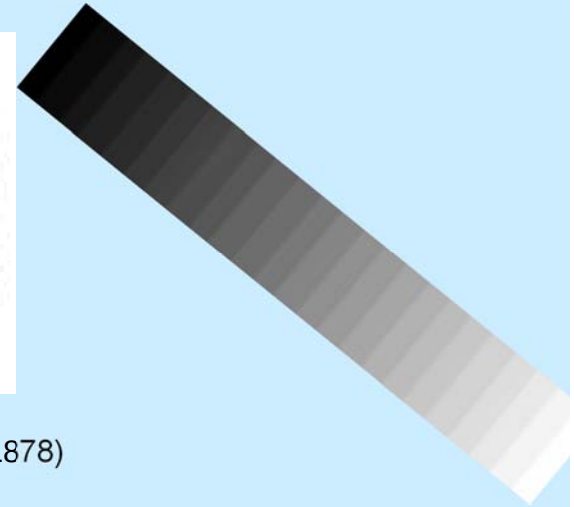
Forced decision method

Just Noticeable Difference: Smallest difference in amount of stimulation that a specific sense can detect

Just Noticeable Difference = $I - I_0$

Intensity recognised as different

Reference intensity



Ernst Weber (1795-1878)

"just-noticeable difference" (JND)

How much more you have to be offered to change your workplace?

50000 + 5000 ☑

500000 + 5000 ∅

JND= $I - I_0$

Higher initial stimulus – bigger JND

Weber's law

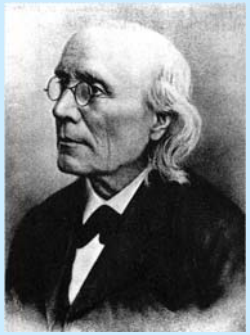
The size of the JND is a constant proportion of the initial stimulus. With other words the ratio of the increment threshold to the background intensity is a constant.

$$\frac{\Delta I}{I_0} = k$$

k : Weber ratio – can be determined by experiments

Each of the sensory perceptions has a consistent sensitivity to change.

stimulus	*Weber ratio*
brightness	0,079
loudness	0,048
touching	0,022
pressure	0,02
tasting (salt)	0,083
electric shock	0,013



Gustav Theodor Fechner
(1801-1887)

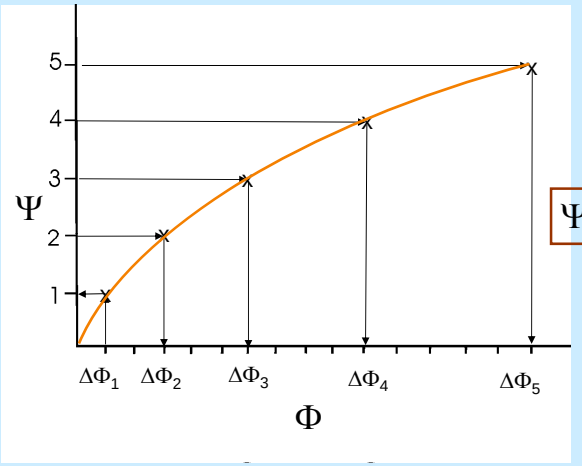
$\Delta I = I - I_0$

ΔI is a function

ΔI is the function of stimulus intensity

Fechner assumed that the relative change of the stimulus is proportional to the change in the sensation magnitude

$$\Delta\Phi/\Phi \sim \Delta\Psi$$



$$\Psi \sim \lg\Phi$$

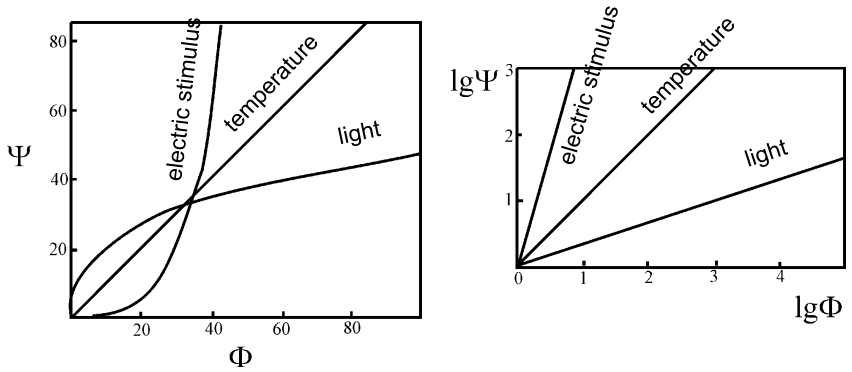
Establish relationship between relative stimulus intensity (Φ/Φ_0) and psychological magnitude (Ψ).

Performed measurements

Stanley Smith Stevens
(1906-1973)

sensation scale

Results of experiment



Sensation intensity increases with some expanding stimulus intensity. Equal stimulus ratios produce equal sensation ratios. This law is the power function

$$\Psi \approx \Phi^n$$

The exponent varies with the particular sensory modality, and also within a modality for different stimulus conditions, such as adaptation, inhibition, size, and duration of stimuli.

$$\Psi \approx \Phi^n$$

stimulus	*exponent*
short light pulses	0,5
smell (heptane)	0,6
loudness (3000 Hz sinus)	0,67
ambient temperature	1,00
taste (salt)	1,30

Summary

Two different approaches:

Weber – Fechner : $\Psi \sim \lg\Phi$

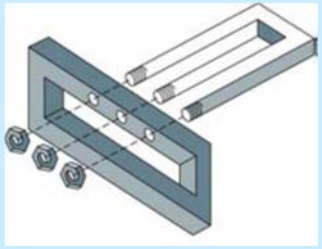
Stevens : $\Psi \approx \Phi^n$

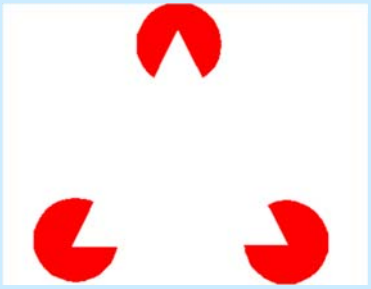
The second one received better experimental support.

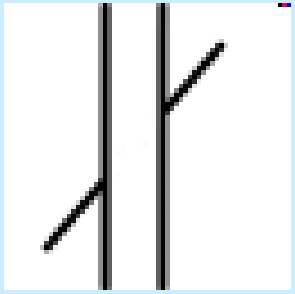
Perception - Organizing sensations into meaningful patterns

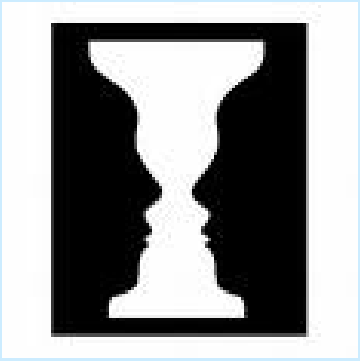
- analyzing
- organizing
- understanding

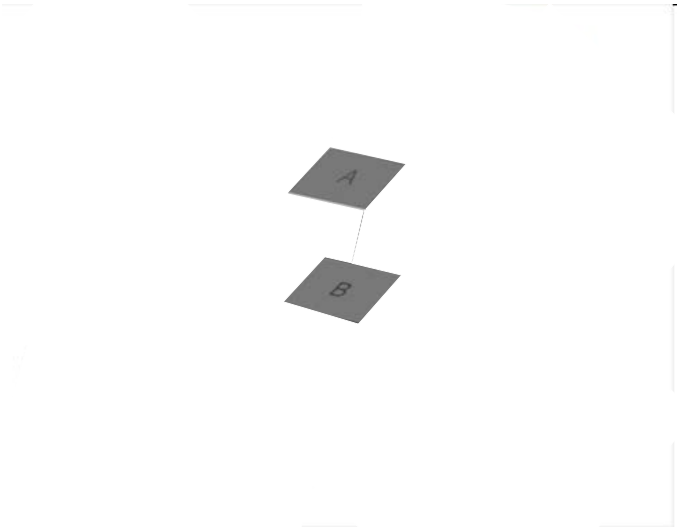
Perception might be correct or false.

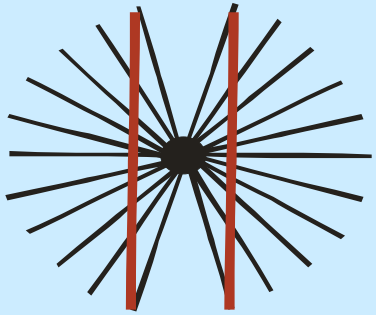


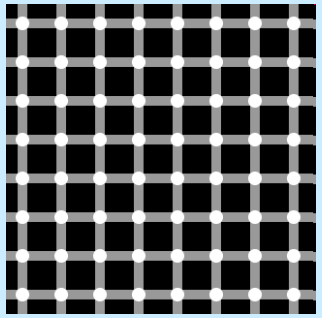


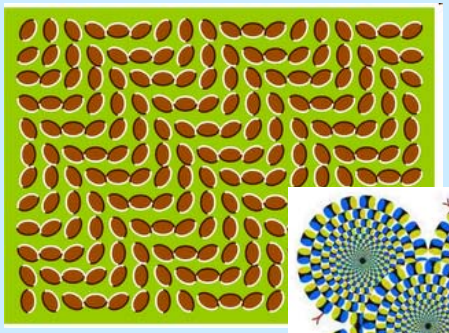


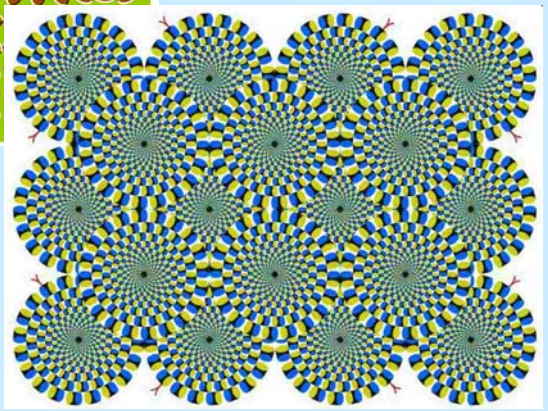


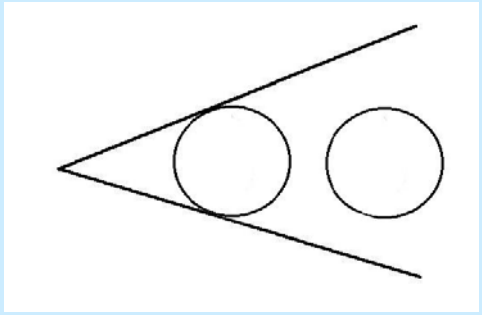


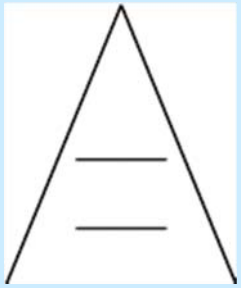












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