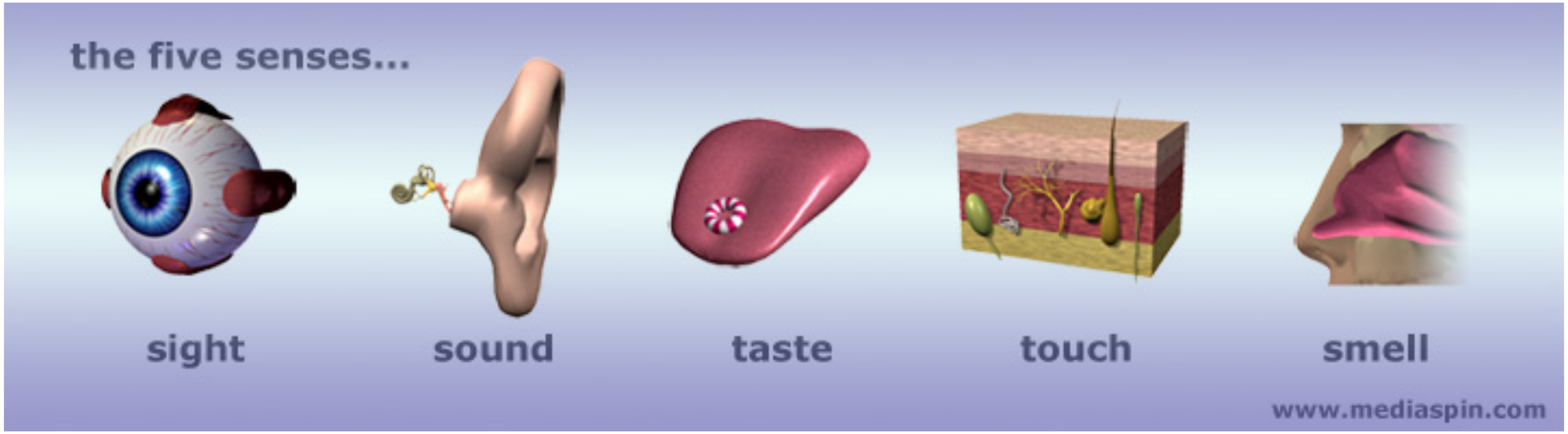
Senses


the five senses...
sight
sound
taste
touch
smell
www.mediaspin.com

Sensory modalities in human

Sensory modality	Form of energy	Receptor organ	Receptor cell
Chemical			
common chemical	molecules	various	free nerve endings
arterial oxygen	O_2 tension	carotid body	cells and nerve endings
toxins (vomiting)	molecules	medulla	chemoreceptor cells
osmotic pressure	osmotic pressure	hypothalamus	osmoreceptors
glucose	glucose	hypothalamus	glucoreceptors
pH (cerebrospinal fluid)	ions	medulla	ventricle cells
Taste	ions and molecules	tongue and pharynx	taste bud cells
Smell	molecules	nose	olfactory receptors
Somatosensory			
touch	mechanical	skin	nerve terminals
pressure	mechanical	skin and deep tissue	encapsulated nerve endings
heat and cold	temperature	skin, hypothalamus	nerve terminals and central neurons
pain	various	skin and various organs	nerve terminals
Muscle			
vascular pressure	mechanical	blood vessels	nerve terminals
muscle stretch	mechanical	muscle spindle	nerve terminals
muscle tension	mechanical	tendon organs	nerve terminals
joint position	mechanical	joint capsule and ligaments	nerve terminals
Balance			
linear acceleration (gravity)	mechanical	vestibular organ	hair cells
angular acceleration	mechanical	vestibular organ	hair cells
Hearing	mechanical	inner ear (cochlea)	hair cells
Vision	electromagnetic (photons)	eye (retina)	photoreceptors

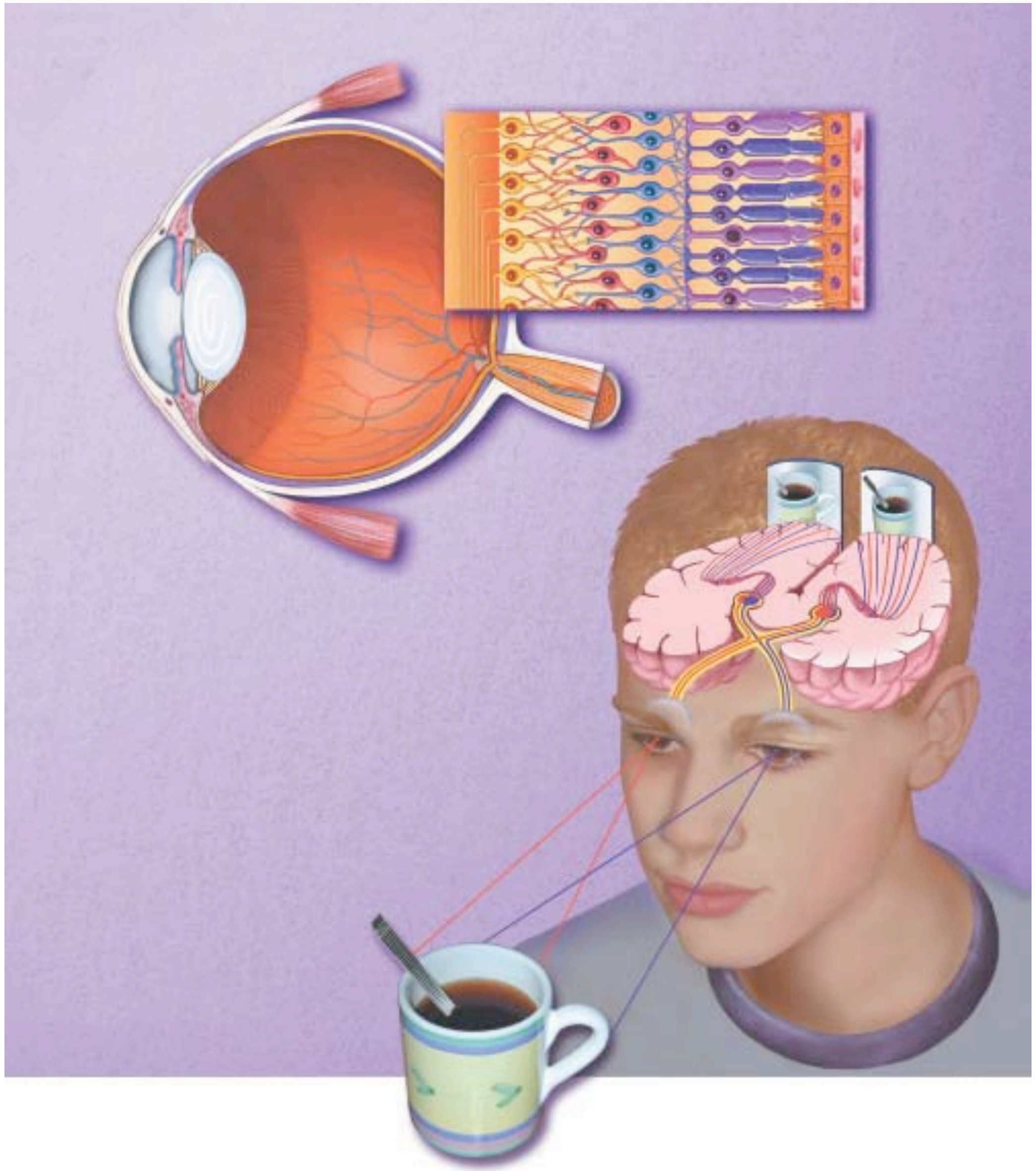
Sensory processing

Levels of organization uderlying
sensory processing:

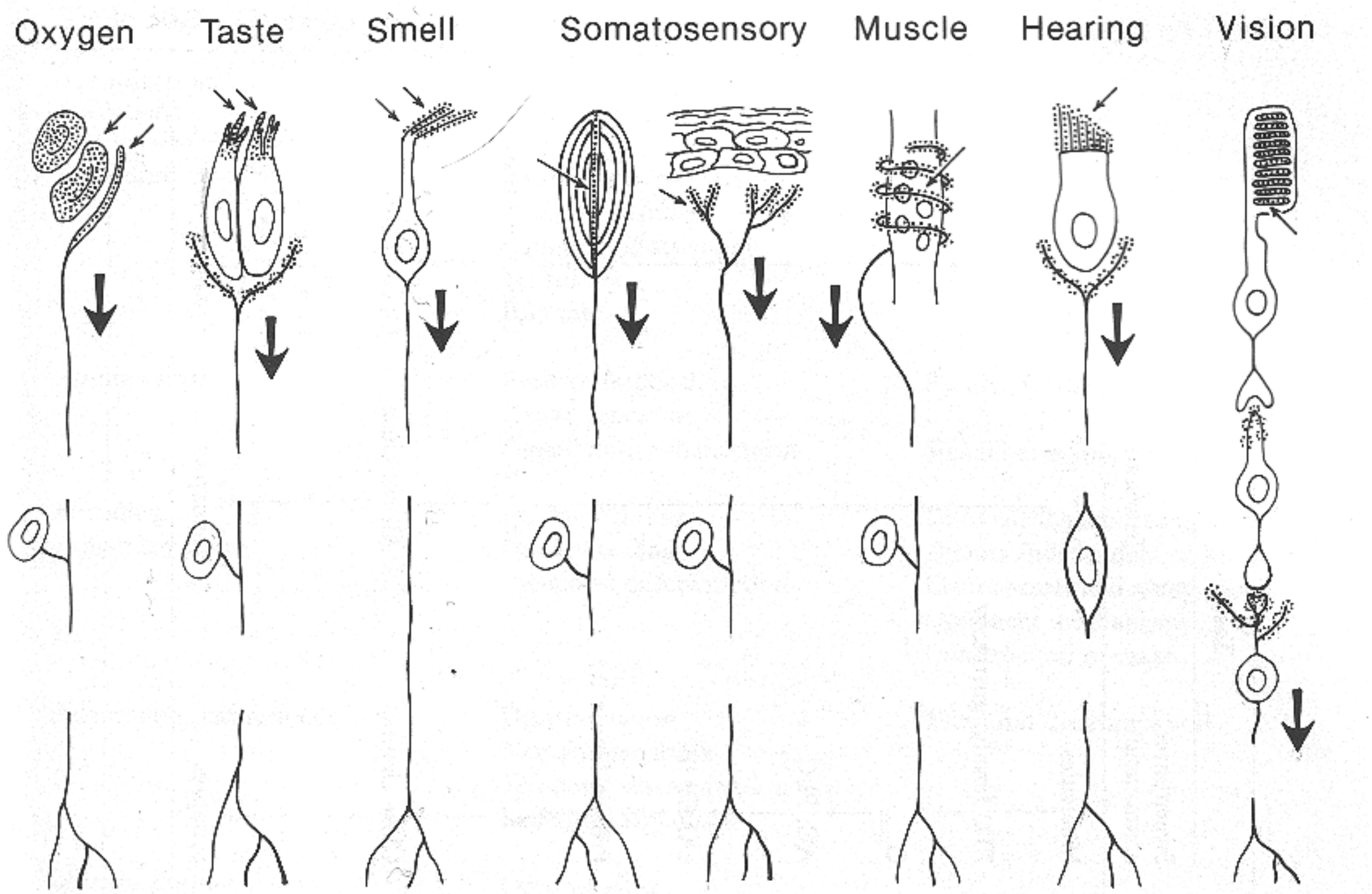
I. Receptors

II. Sensory circuits and pathways

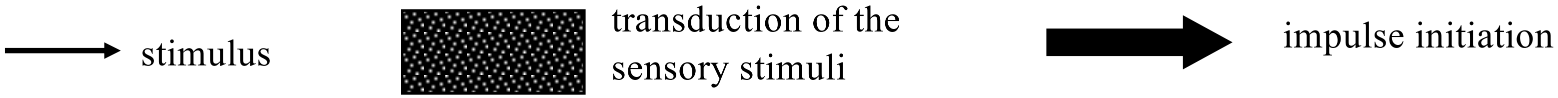
III. Sensory perception



Receptors

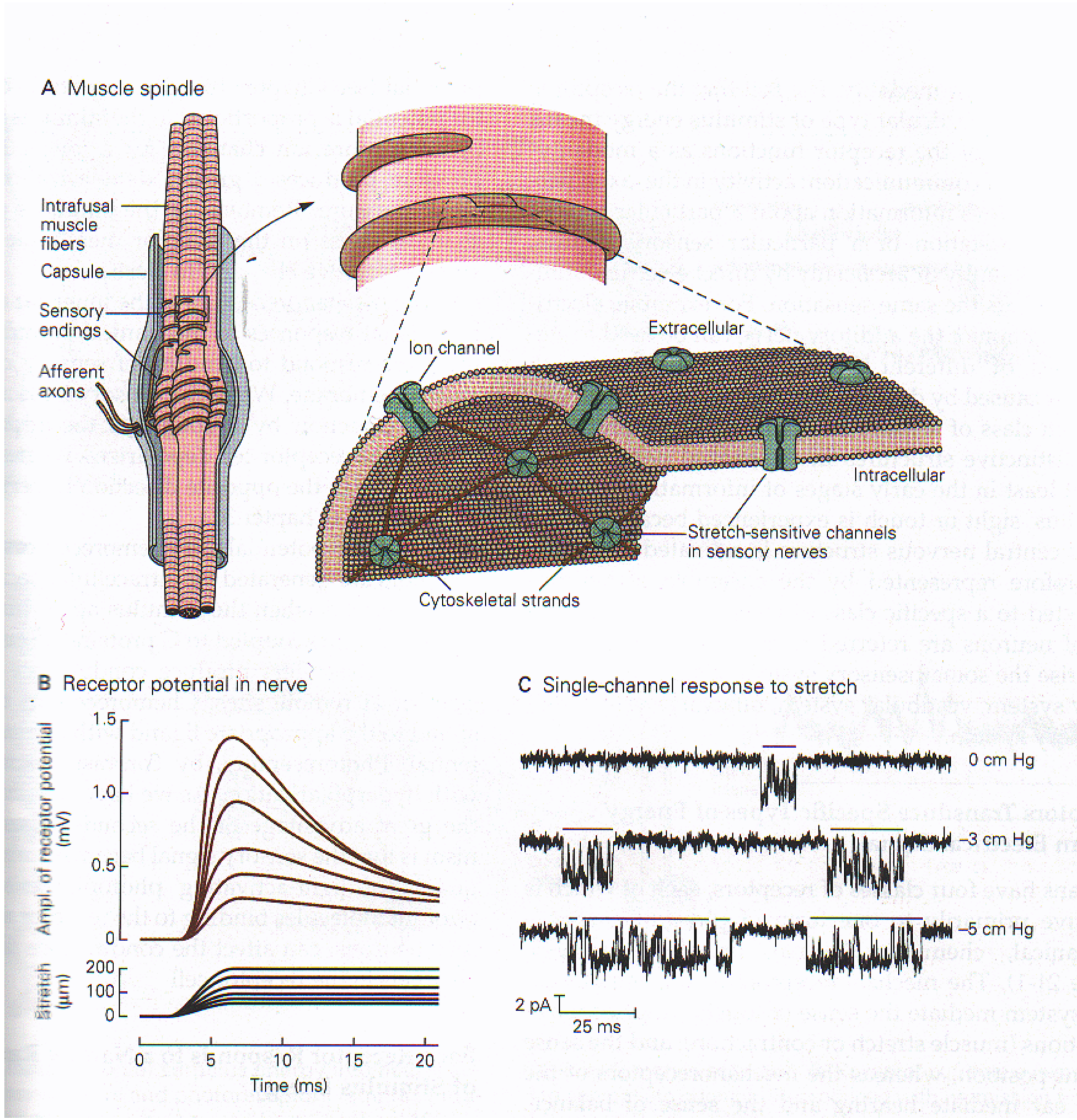


Oxygen
Taste
Smell
Somatosensory
Muscle
Hearing
Vision



stimulus
transduction of the sensory stimuli
impulse initiation

Receptor potential

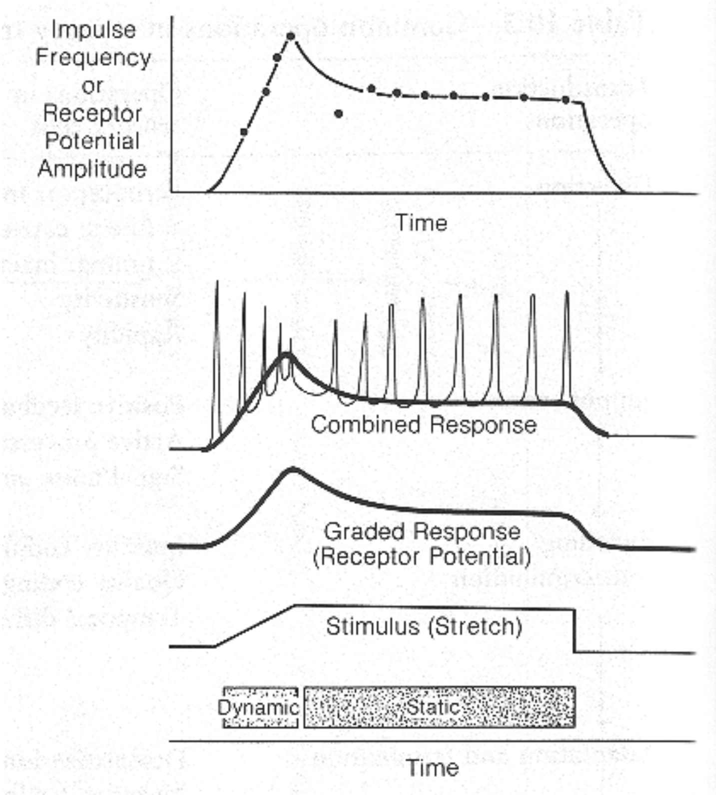


Receptor potential in a muscle stretch receptor (mechanoreceptor). A. These receptors signal muscle length and the speed at which the muscle is stretched. The sensory fiber nerve endings respond to stretch of the muscle fibers. Mechanical deformation of the membrane opens the stretch-sensitive ion channels. The influx of Na+ and Ca2+ depolarizes the nerve ending, producing the receptor potential.

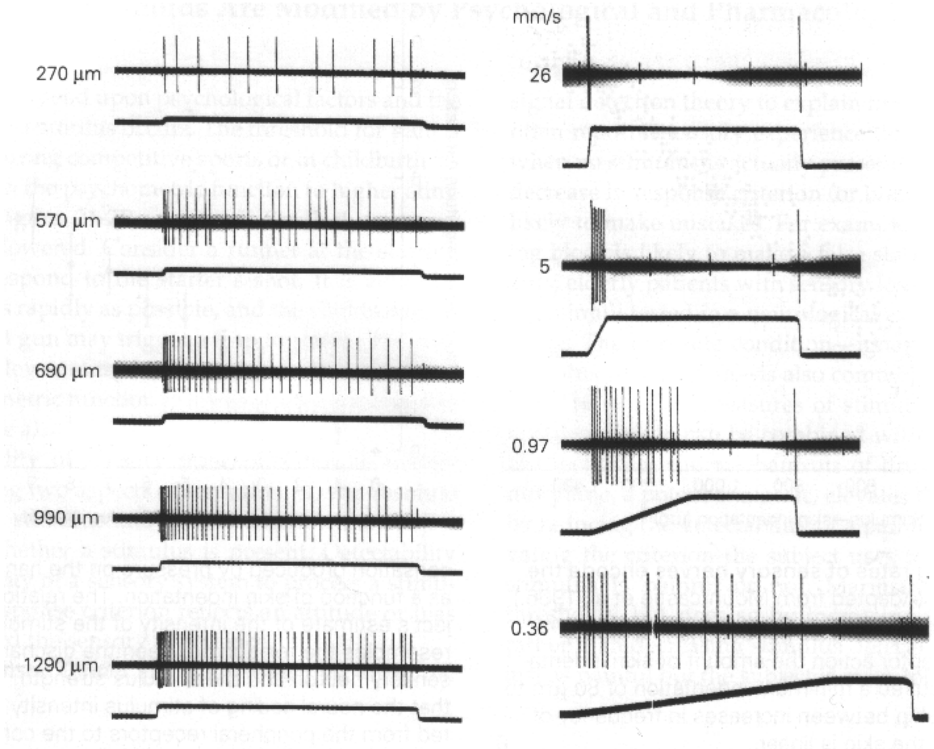
B. Upper records: depolarizing receptor potentials recorded from the sensory axon (APs have been blocked with TTX) when the muscle spindle is stretched to different lengths. Lower records: amplitude and rate of stretch. The initial depolarization of the receptor in response to change in muscle length (dynamic response) is proportional to both the rate and amplitude of stretch. When stretch is maintained, the receptor potential decays to a lower value proportional only to the amount of stretch (static response).

C. Patch clamp records of a single stretch-sensitive channel. As the pressure on the membrane is increased, the channel opens more often and remains in the open state for longer time intervals.

Stimulus encoding



Receptor potential and impulse frequency exhibit close correlation.



Intensity coding in skin touch receptors. Left: in slowly adapting mechanoreceptors the firing rate is higher at the beginning of skin contact than during steady pressure. Right: rapidly adapting mechanoreceptors respond only at the beginning and end of the stimulus, signaling the rate at which the stimulus is applied or removed. The receptor is silent when the indentation is maintained at a fixed amplitude.

Stimulus intensity → Firing rate

Hierarchical information processing

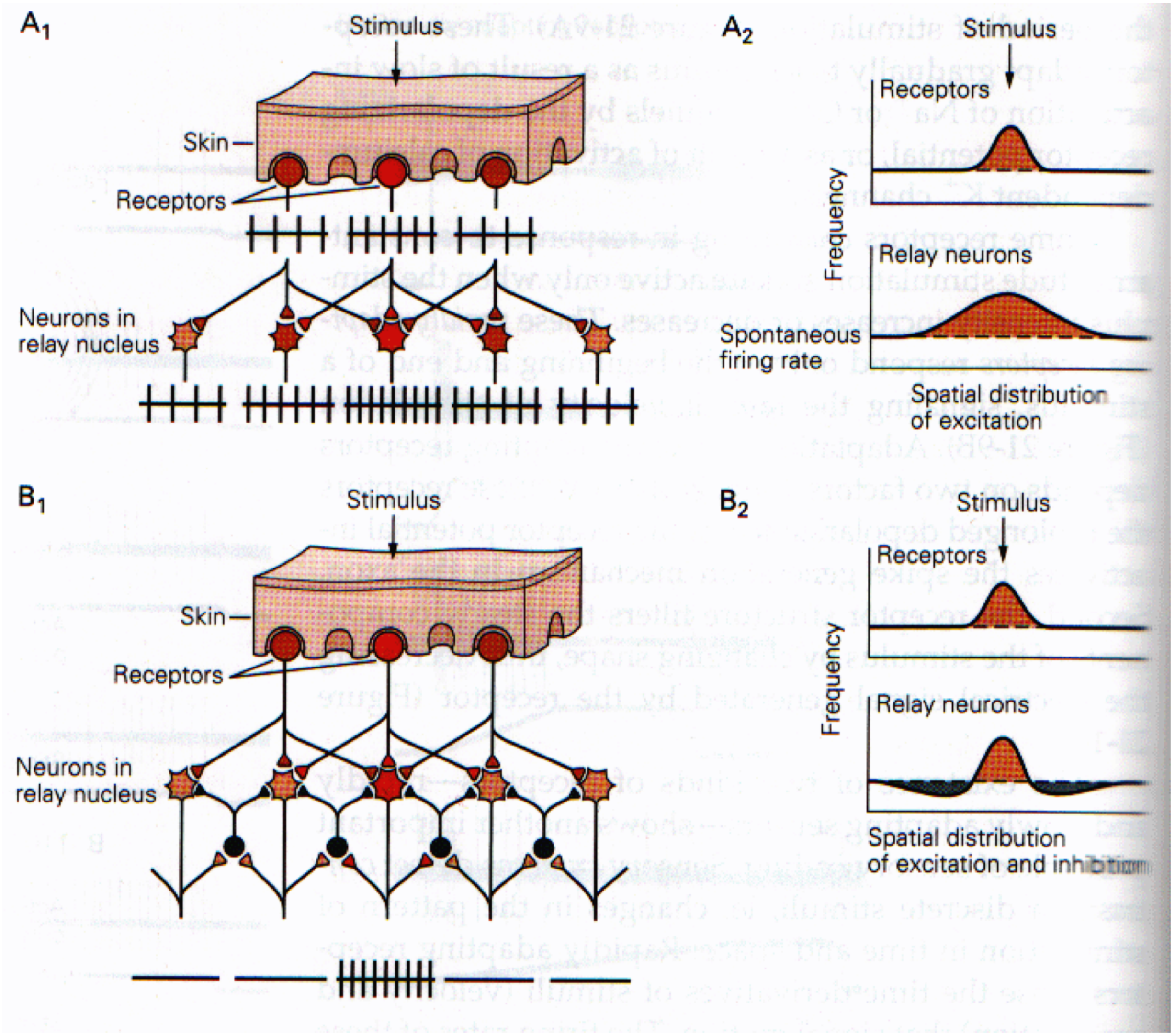
Basic rules:

I. Divergence

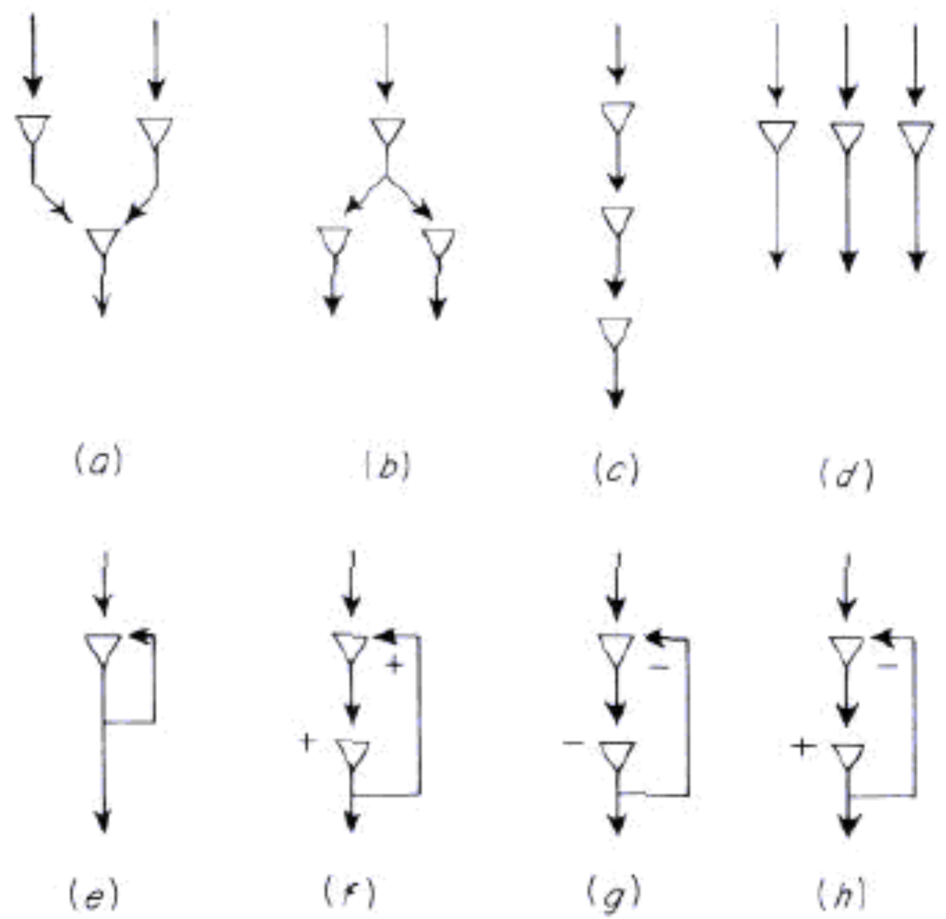
II. Converrgence

III. Parallel processing

IV. Feedback



Connections



Connection patterns between neurons:

a) Converrgence

b) Divergence

c) Serial processing

d) Parallel processing

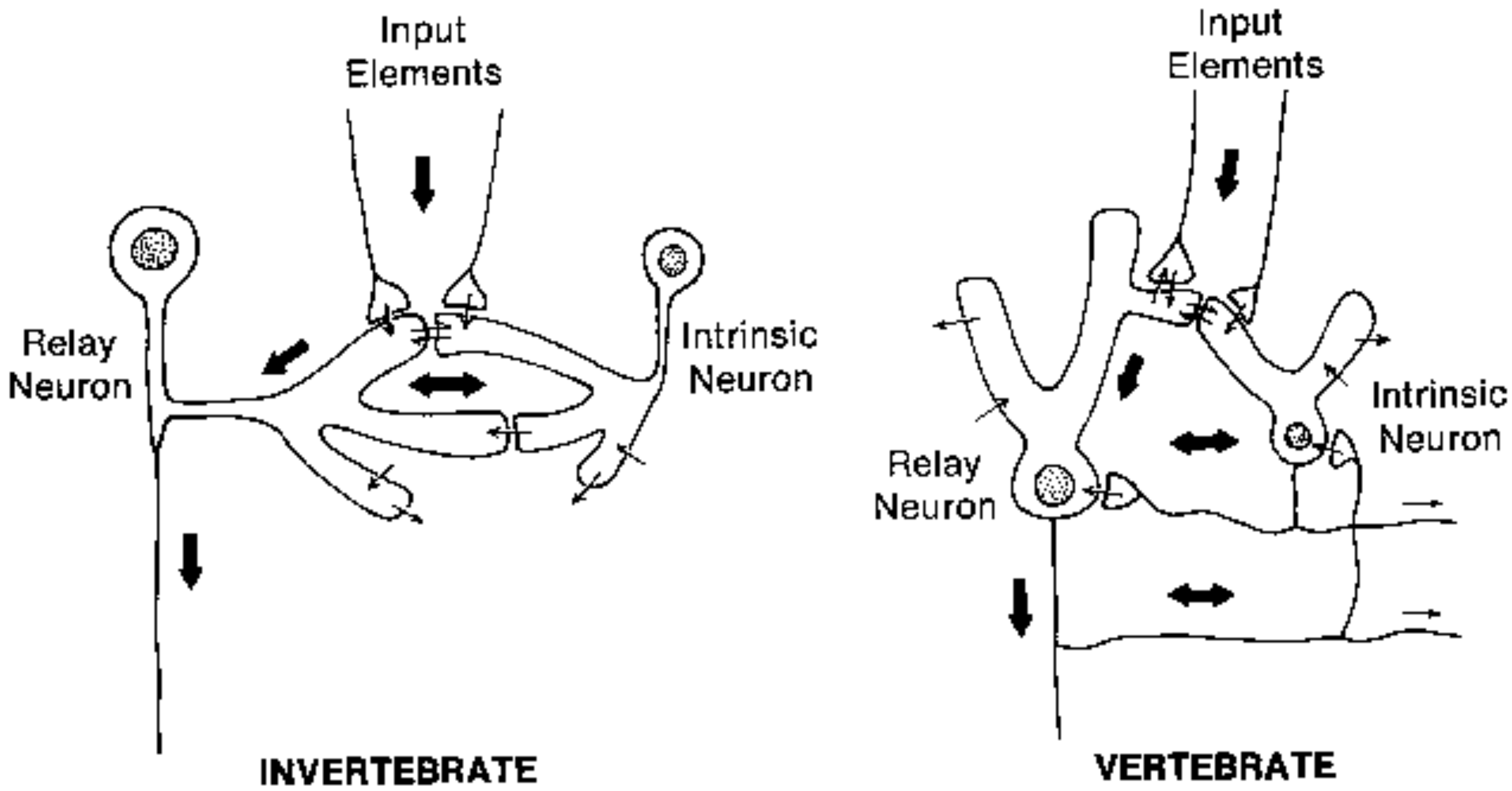
e) Selffeedback

f) Excitatory positive feedback

g) Inhibitory positive feedback

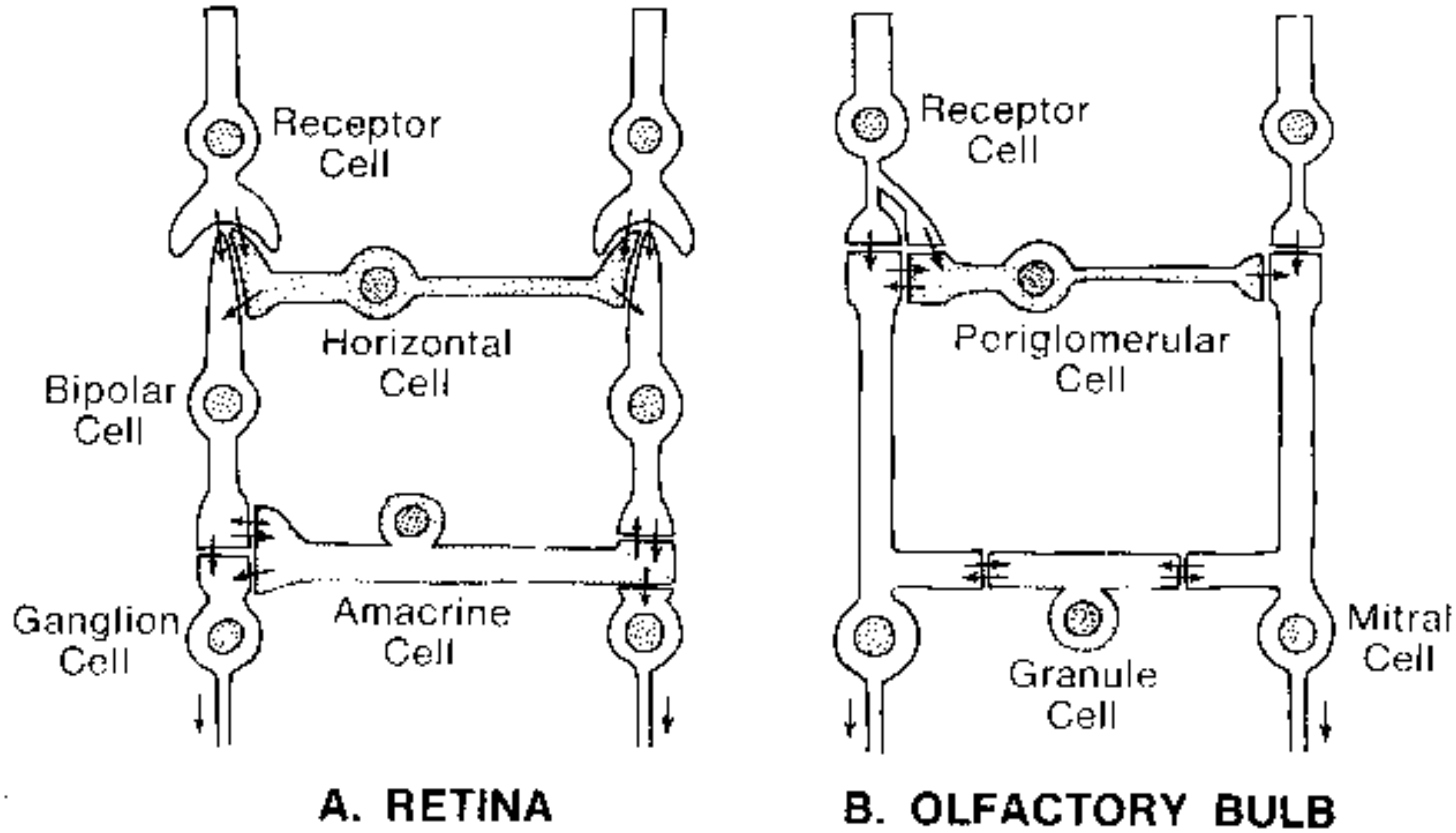
h) Negative feedback

Synaptic triad



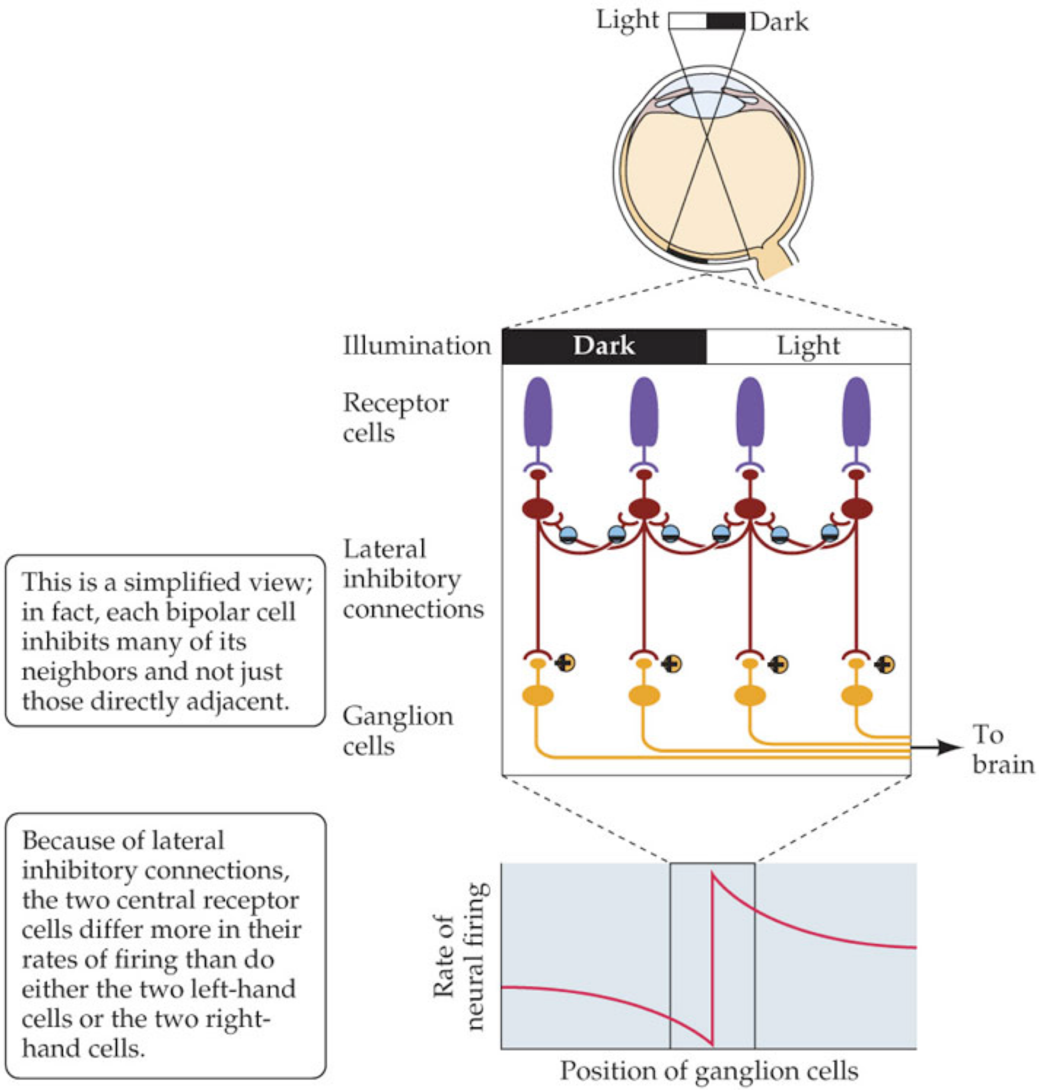
Synaptic triad: input elements, relay neurons, intrinsic neurons,

Microcircuits



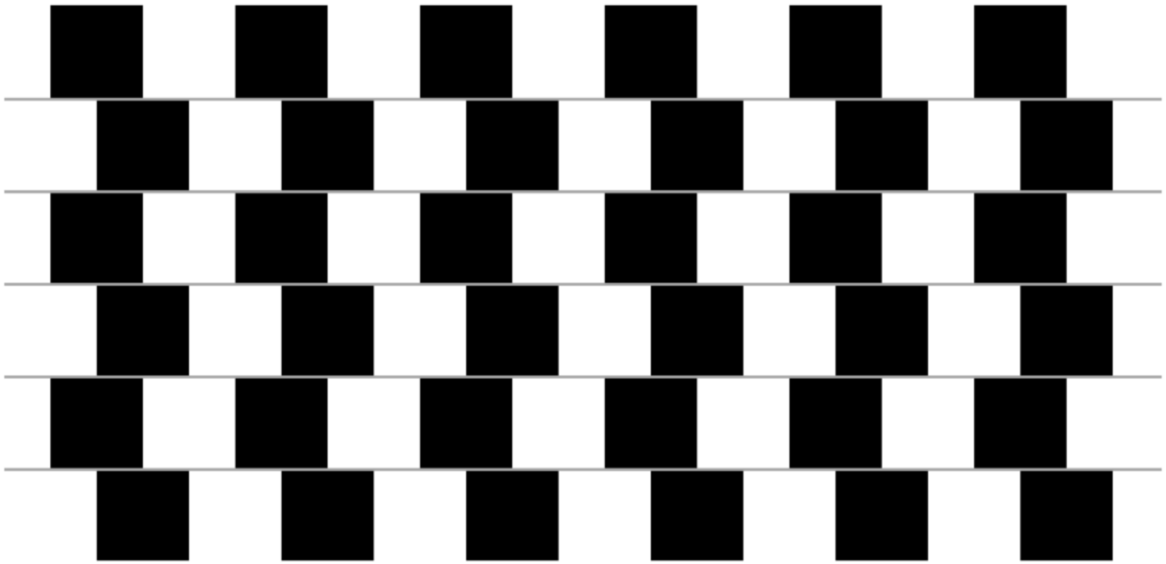
Examples of synaptic triads in sensory systems. There are input elements (the receptors) and output neurons (A; ganglion cells, B: mitral cells). There are interneurons for straight-through transmission and there are interneurons for horizontal interactions. The horizontal connections are organized at two levels. In both cases there is provision for straight-through transfer of signals to the output neuron and local processing of signals through the interneurons.

Lateral inhibition



Pattern of activity in population of ganglion cells in response to light – dark edge stimulus. The enhancement of response on the light side of the edge and depression on the dark side are due to inhibitory interactions at the level of biopolar cells and horizontal cells (not shown in the picture).

The Cafe Wall illusion



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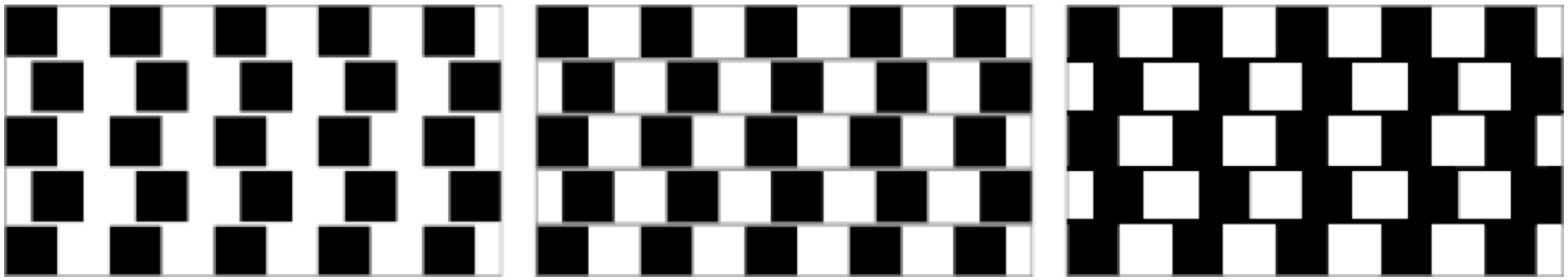
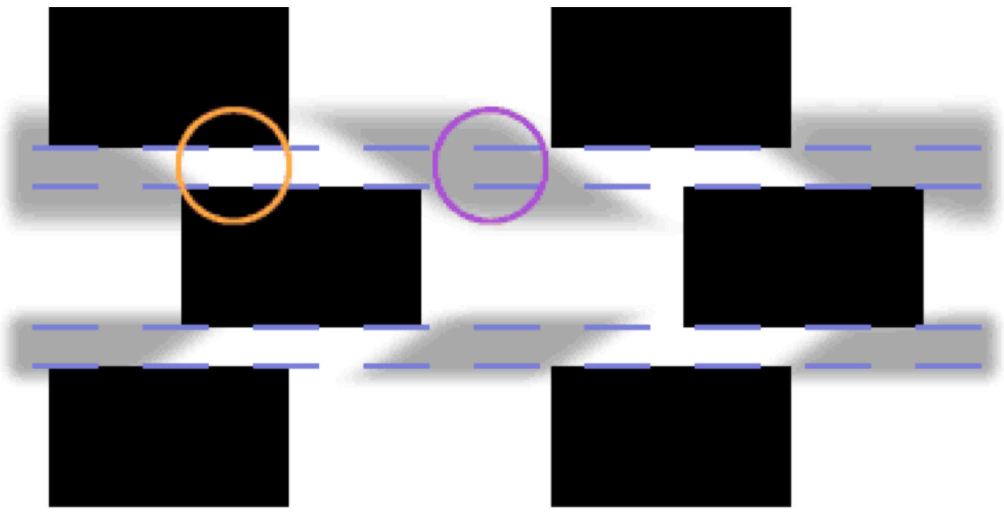


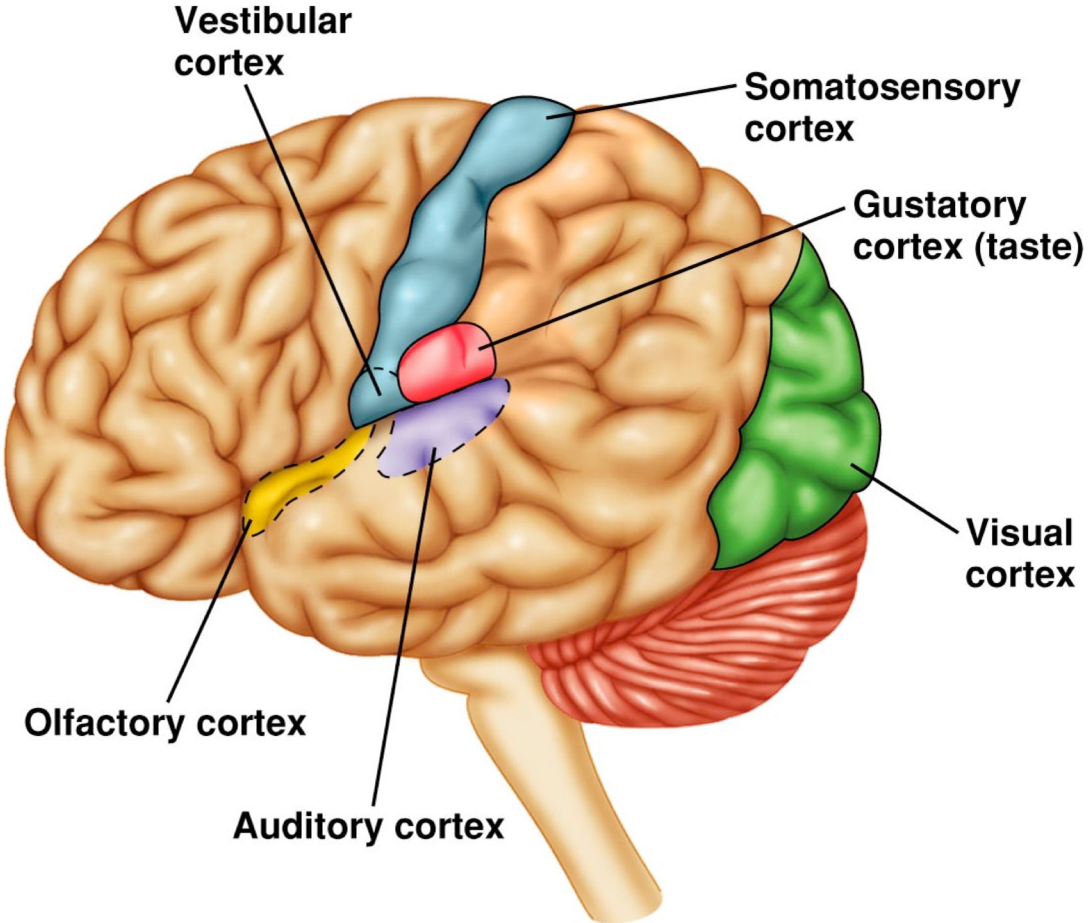
The original of the Café Wall, St Michael's Hill, Bristol.

The Cafe Wall illusion



The part of the line indicated by an violet circle is surrounded by a large white region. These areas will be dimmed in the retina. The part of the line indicated by a orange circle is surrounded by dark regions, and will be slightly brightened in the retina. The result is that each line acquires a slight diagonal striping, which develops into converging slopes.
http://www.positscience.com/brain-resources/brain-teasers/cafe-wall-illusion

Representation of sensory modalities in the human brain



Inputs from different sensory organs are processed in different areas in the brain. Information from different senses is integrated in associational cortices, which occupy large cortical areas.

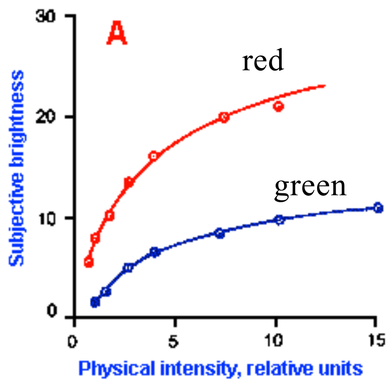
Sensory perception: detection

Modality	Threshold
Vision	Intensity: 1 photon (energy: $3x10^{-19}$J; energy of small apple falling: 1J) Wavelength: 400 nanometers
Audition	Movement of eardrum: 10^{-8} cm (diameter of the hydrogen atom)
Olfaction	Ethyl ether: 5.83 mg/liter of air Artificial musk: 0.00004 mg/liter of air
Taste	Sucrose (sweet): 7g/liter NaCl (salty): 2 g/liter Quinine sulfate (bitter): 0.00015 g/liter
Somesthesia	Pressure (back of hand): 12 g/mm^2 Pain (back of hand): 100 g/mm^2

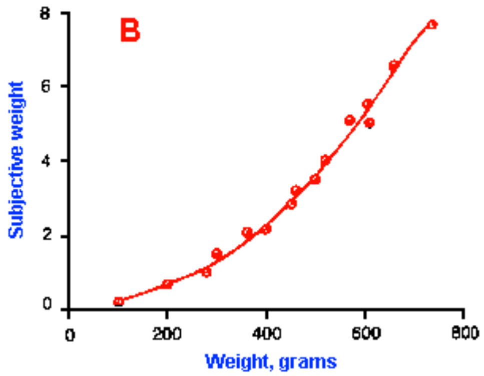
Stimulus - response relationship

- Equal changes in strength do not produce equal change in sensations.
- For most senses (vision, audition) the relationship is logarithimic (equal percentage changes in stimulus strength result in equal changes in response). It expands the range of possible stimuli.
- For some senses (e.g., temperature) the relationship is power law. The range of stimulus values is smaller but extreme values are sensed more strongly.

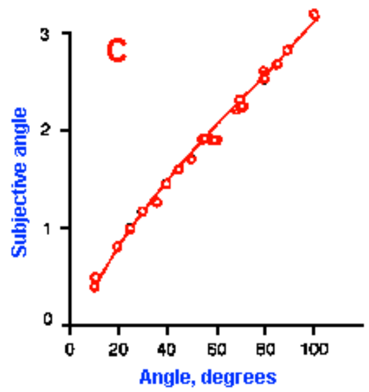
Brightness of light



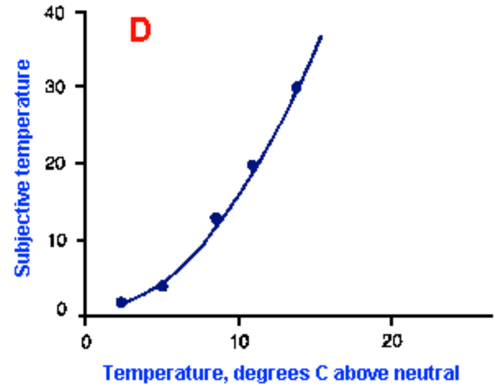
Lifted weight



Angle between two surfaces felt with hands



Warmth



Rules of perception

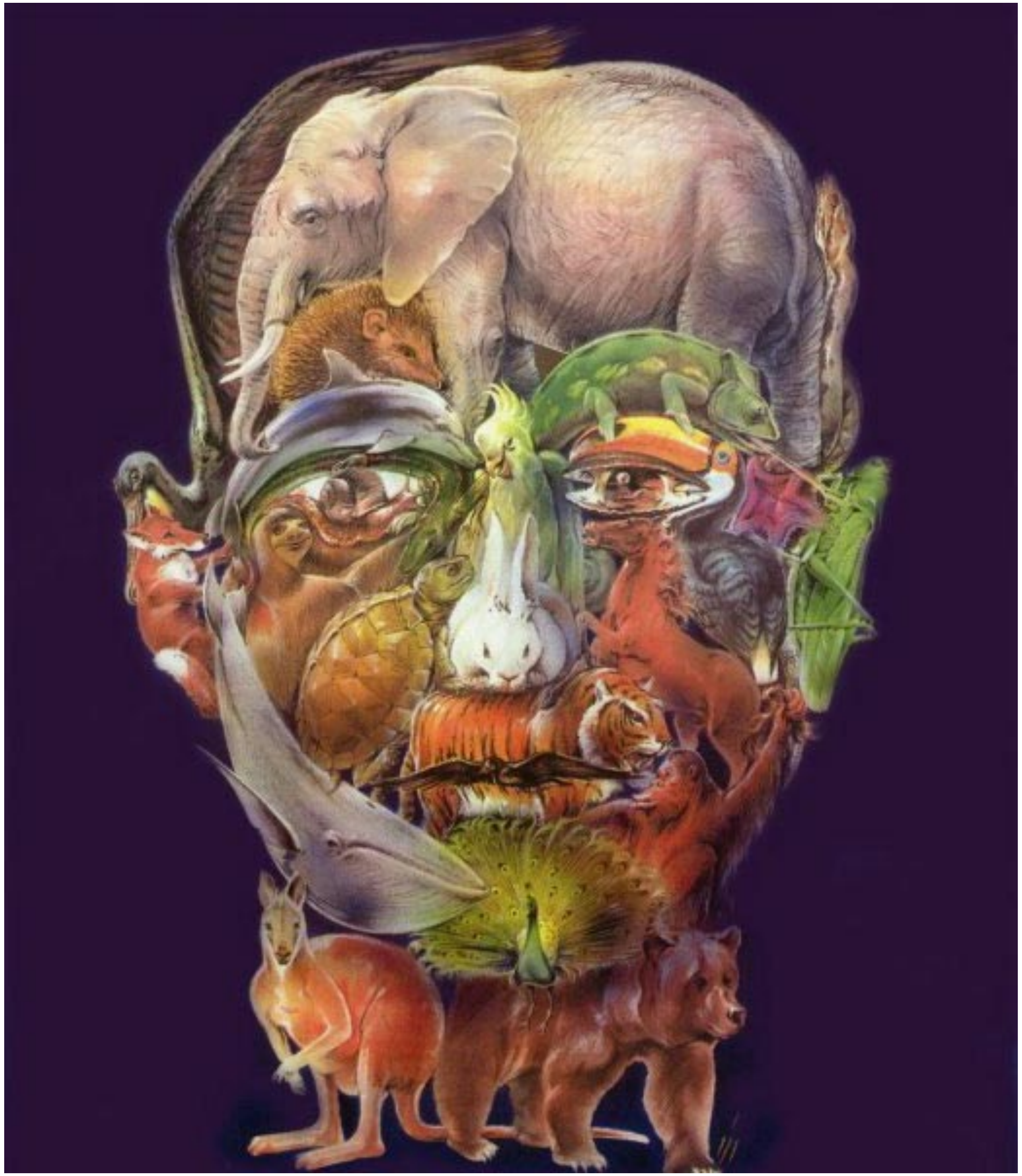
- Gestalt (*germ*. configuration or form) psychologists identified principles of perception. They proposed that the human senses perceive objects in as a whole before perceiving their individual parts, suggesting the whole is greater than the sum of its parts.

- Perception depends not only on the properties of the stimulus element but also on its interaction with other elements simultaneously present. (We recognize relationships, not the components).

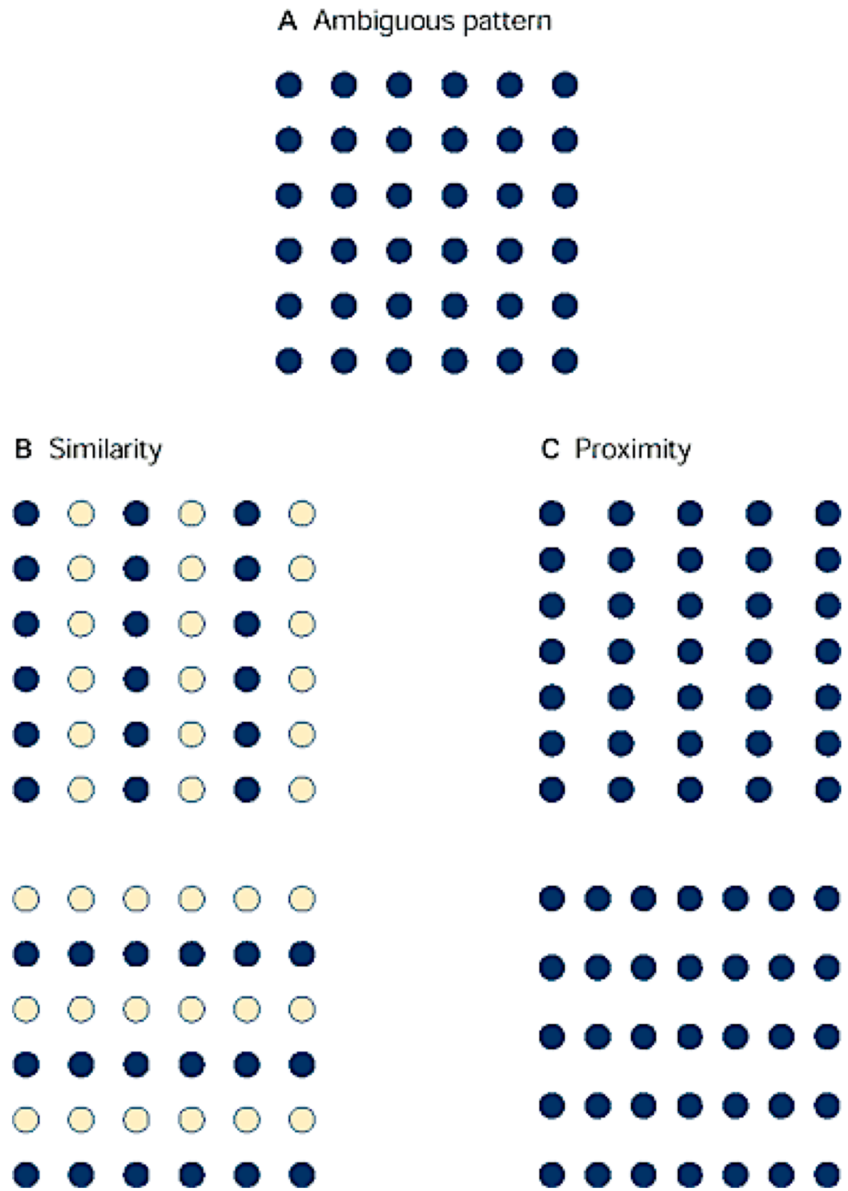
- The brain makes certain assumptions about what is to be experienced. They derive in part from the experience and in part from built-in neural wiring.

- Perception is not gaining an objective impression of the world around us but it is a creative act of the mind.

Pattern recognition I



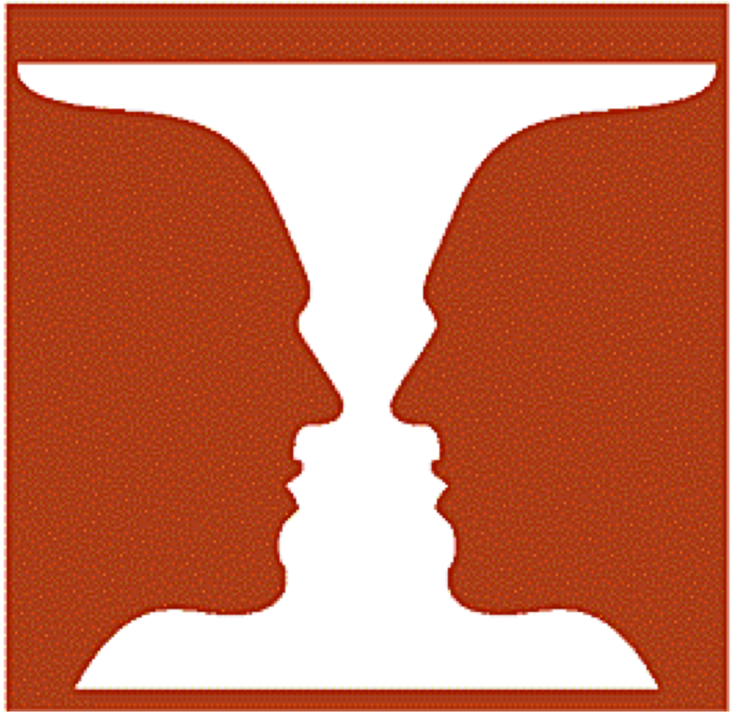
Pattern recognition II

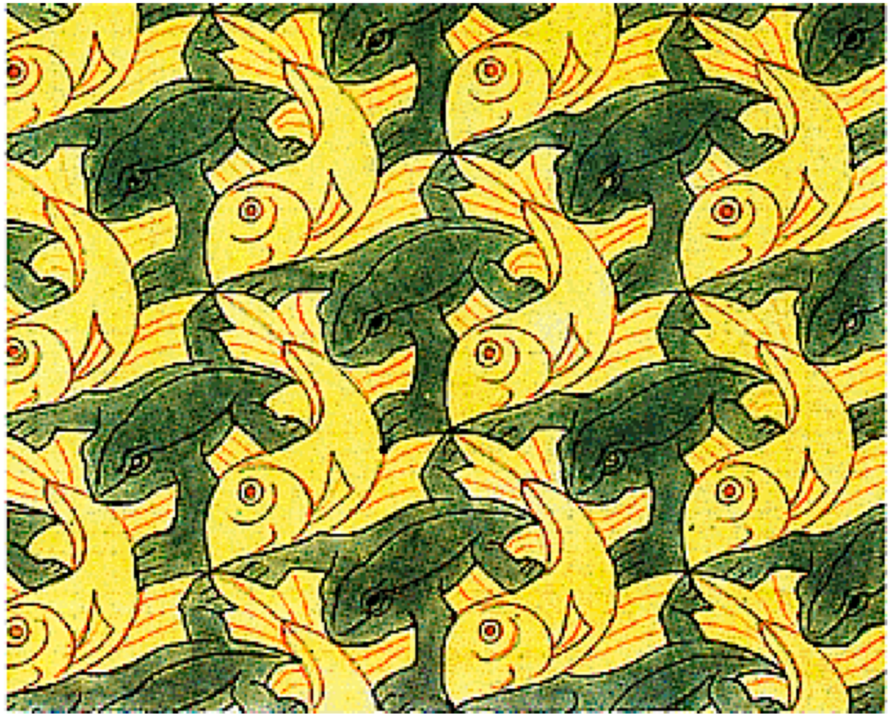


The array of identical dots in A is ambiguous and can be seen alternatively as a pattern of columns or rows. Dots in B, C are not ambiguous because of additional cues (B – colors, C - proximity).

Figure – ground recognition

Brain identifies part of the scene as a recognizable object and considers other parts as background. This process can by dynamic.

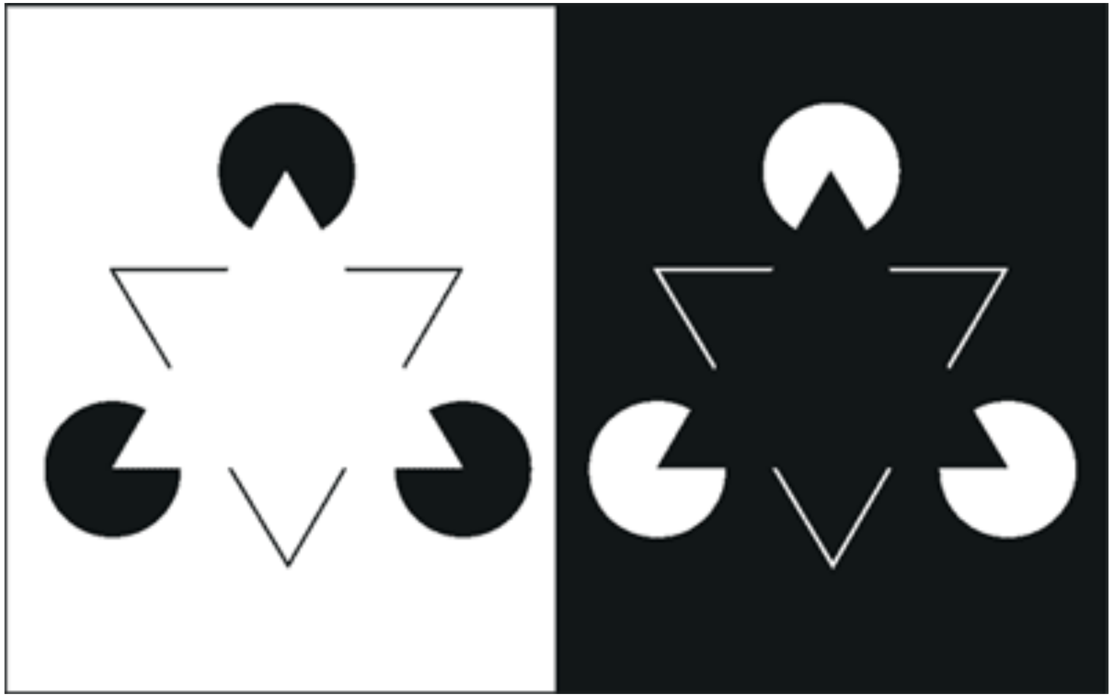




Bistable figures. As we focus on one pattern, the rest is relegated to the background. Perception alternates between two different possible percepts.

Filling-in

Brain is able to interpolate shape and structure from fragmented information.
It can fill-in information that is not directly given in the sensory input.



The Kanizsa triangle. A triangle is perceived in the center of each drawing even though the outline of the triangle does not exist in the drawing and must be inferred from fragments of other objects in the drawing. A white triangle emerges from a white background and a black triangle from a black background.

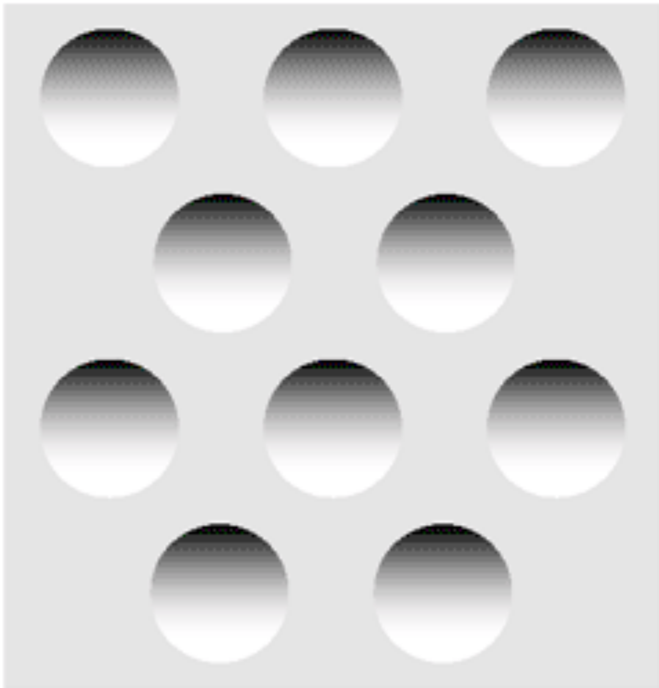
Comparison to surroundings

Brain uses spatial relationships of objects to help to interpret image, e.g., it compares object to surroundings to judge its size.

Left: Both women appear to be the same size. Right: The second woman seems small, because the corridor and tiles around her are not proportional, as they are in the photo at left.

Knowledge-based inference

Perception is based on what we know about our world. This information is built into the wiring of the brain by genetic and developmental mechanisms.



Do we see spheres or cavities? We always assume the light source to be above. By reversing the image one can reverse the depth of these objects.

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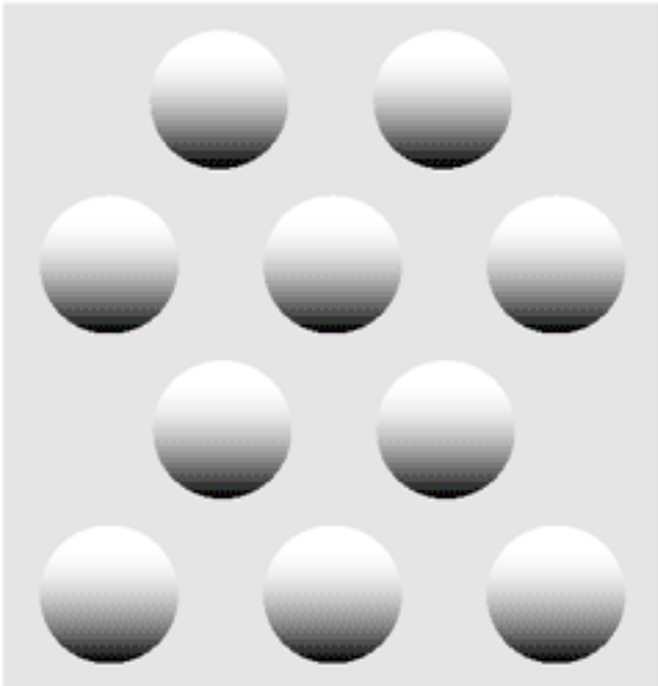

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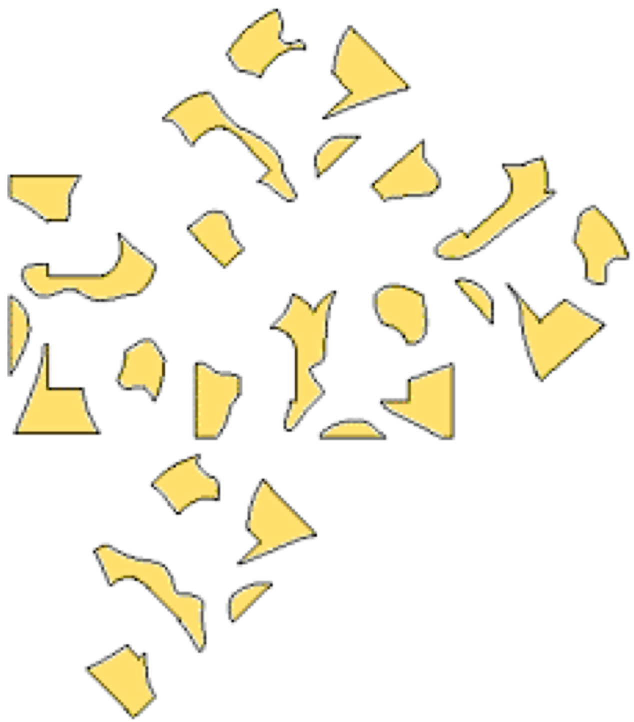
Knowledge-based inference

Brain assumes that closer structures cover those that are more distant. It can "see" a pattern in otherwise unrelated shapes only when the shapes are seen as fragments of an covered background.



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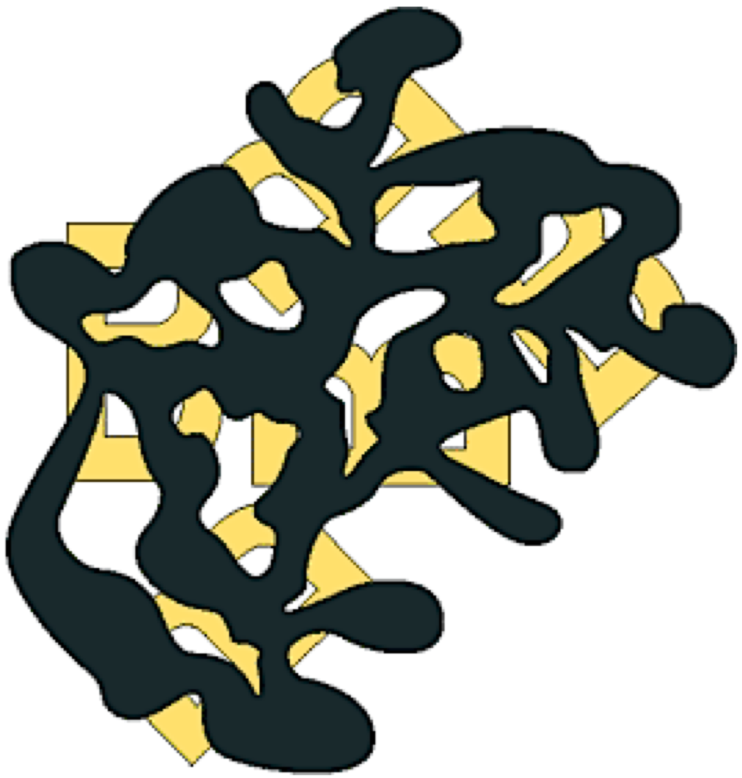

Perception – dependence on experience

The silence of the lambs - poster

Perception – dependence on experience

The silence of the lambs - poster

The silence of the lambs - poster detail

Perception – dependence on experience

The silence of the lambs - poster

The silence of the lambs - poster detail

Salvador Dali *In Voluptas Mors,* 1951