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# Fun with visual illusions

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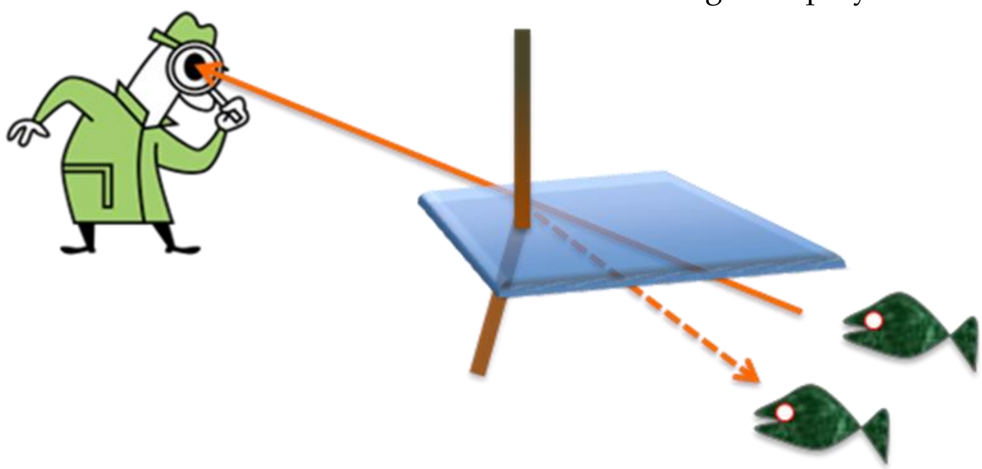
There are many definitions of what constitutes a visual illusion. We commonly think of an illusion as a perceived image that differs from the object "reality". However this begs the question of what we mean by reality. In this tour through visual illusions we will ask questions about what we mean by reality, how do we measure or indeed see the world. Studying illusions gives insight into the computation the brain does to construct visual experiences. The studies are elegant. The explanations often mind boggling but the images remain enigmatic and beautiful. We can still enjoy these, imagining them as tricks of the light or deception of perceptions.
You could argue that as we understand these processes illusions are not illusions at all; just the way optics and our brains work.

The way we see the world and the actuality of the world are not necessarily the same thing. Although it seems counter-intuitive, this has been known for a long time.
In ancient times it was observed that a stick partly immersed in water appeared to bend. This illusion is caused by the difference in refractive indices between water and air. The same effect also gives a false impression of where underwater objects are located when observed from above the surface. Spear fishermen take this into account when catching their prey.

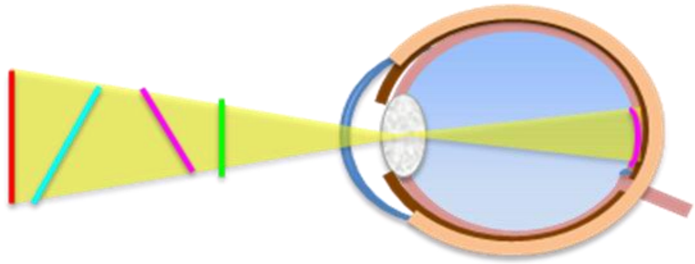


We would not normally classify this effect as an illusion since we know exactly what is going on. What about other optical effects? Or indeed physiological effects such as afterimages causing illusory images. Or perhaps mental processes that compute impossible objects such as those popularised in Escher's art?
We don't fully understand the processes that lead to the illusory perception in all examples. So for the moment we can enjoy their effects and delight in the way they appear to fool our most trusted sense, vision.

However in-depth study is revealing more of the secrets of how our brains compute vision. Using illusions has been a key process in this endeavour.

Why do illusions occur?

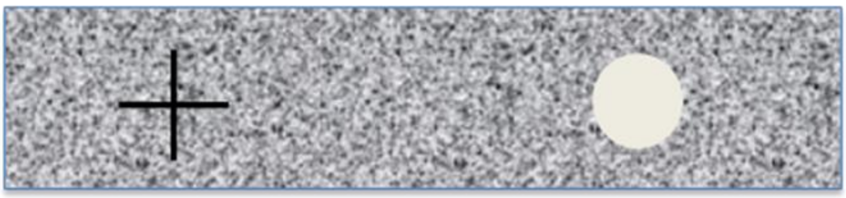
Light from objects is gathered by the eye and focussed to form a two dimensional image on the retina. This image is ambiguous. Many possible objects could give rise to any particular image.
A simplified diagram shows that the image on the retina could arise from any of the four objects shown.

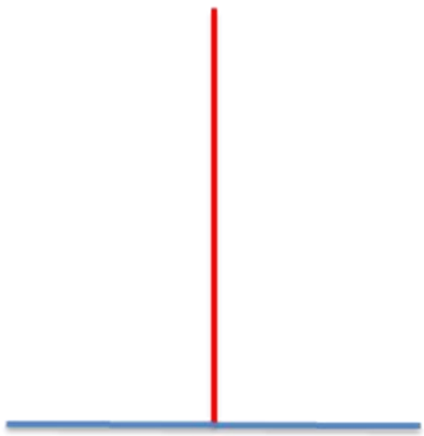


Furthermore, information about the distance of the object from the eye is not carried in the retinal image. Indeed there is a cacophony of signals from objects that bombard the eye and are composed into the retinal image.
Like the clever thermoflask that keeps hot things hot and cold things cold, how does it know which is which? How does the visual system know which signals come from which object and which bits belong to what?
This is where processing of the image comes in. The way processing occurs leads to alternative possibilities and is the source of many visual illusions. Choosing an appropriate version allows us to predict the environment around us, avoiding predators and gathering food. Incorrect decisions reverse this outcome and are unlikely to survive evolutionary pressure.
So vision is a bit of optics, a bit of neural processing and a whole heap of mental activity. It is all effortless and subconscious. Perhaps 50% of our cortex is involved with vision. This is why vision is easy and maths, using a tiny fraction of the cortex, is hard.

Demonstration:

1. Close the left eye and bring the page closer whilst focussing on the cross at the left of the blue bar. At a particular distance the black dot will disappear. This is the physiological blind spot. We do not notice this large hole in our vision because the brain fills in for the missing information.
2. Similarly repeat for the grey bar. Now you will notice that the texture appears and fills in the missing area.
3. Which line is longer? Measure them.
4.

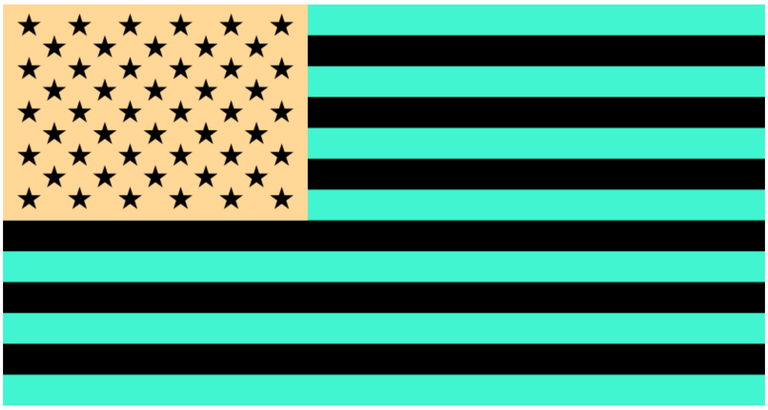


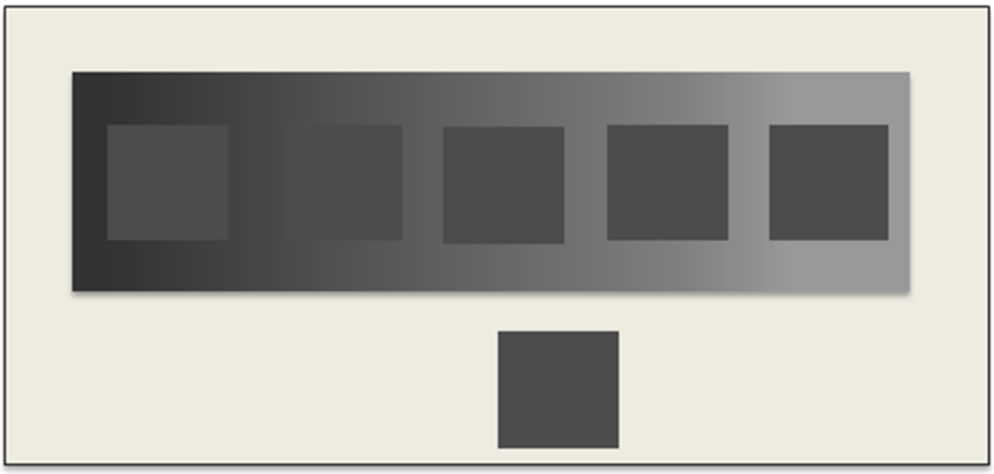


We may not see things that are there. Blind spot demonstration.
We may see things that are not there: Filling in of textures.
We may interpret what is there incorrectly. Geometric and cognitive illusions.

Clearly this is evidence that what we think we see is not what we see. We are using the two dimensional retinal image to generate a model in real-time 3D space through which we will interact with our environment.

The eye is not a light meter and does not capture images pixel by pixel like a digital camera. Instead the retina is composed of circular receptive fields with concentric inhibitory surrounds. This enables a process called lateral inhibition (described in last term's Gresham lecture the human eye and vision). The information from the scene is processed to extract information about differences in brightness and spectral (wavelength) composition from a scene.
Staring at an image for 10 to 30 seconds bleaches the photoreceptor mosaic. If we now transfer our gaze to a neutral background a negative in complimentary shades and colours appears as the opponent system temporarily is unbalanced..
Stare at the central cross for 20 seconds then move your eyes to the blank area of paper below



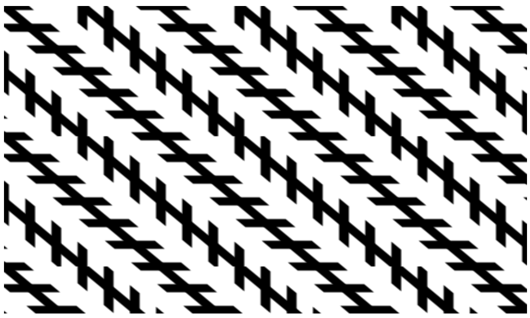


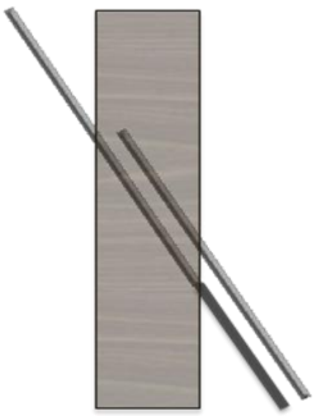
All these squares are the same shade.

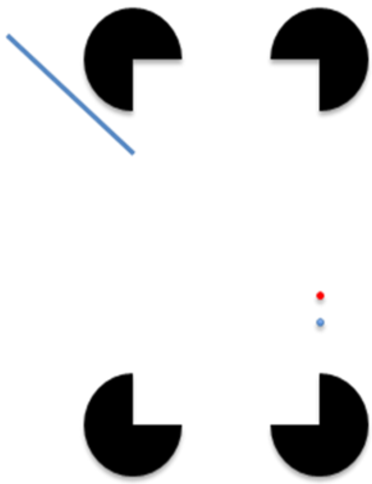
Further up the visual processing system in the brain information about lines and their orientation is extracted. From this borders can be computed and estimates made about what is background. Parallel streams carry information about spatial frequency, (the spacing between objects in the scene) and spectral reflectance from which the brain will derive the perception of colour. Other streams contain signals that stimulate motion detectors (see last terms Gresham lecture on Visual Perception).
We use all this information to construct a scene. Missing out critical bits generates ambiguity which can cause a visual illusion.

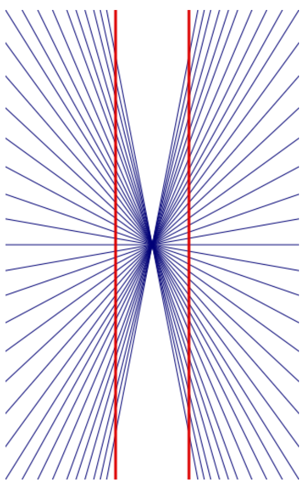
**Geometric illusions**

Discovered in a short by several people in mid 1800's.
Zollner, Poggendorf, Hering and many others.



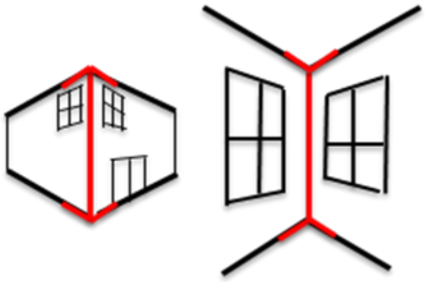


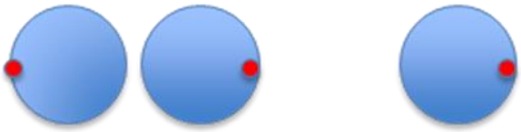




**Shape and size illusions**

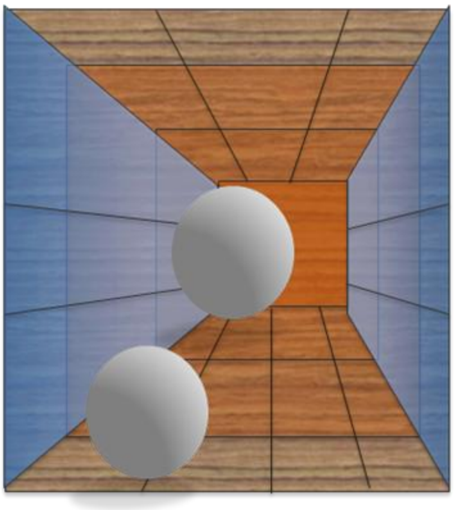
Ponzo, Muller lyer, many others

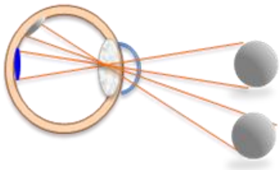


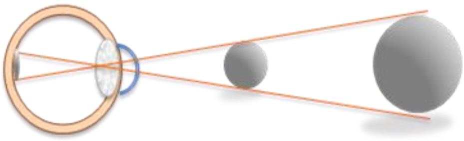


<u>Perspectival illusions</u>

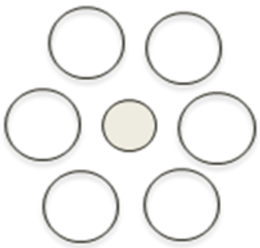
## Size constancy illusions

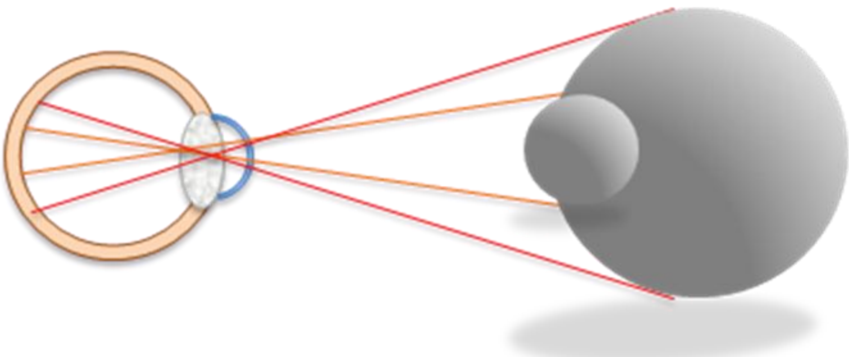






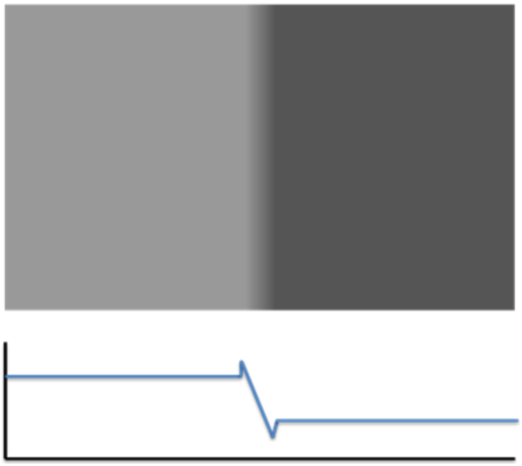
## Moon illusion





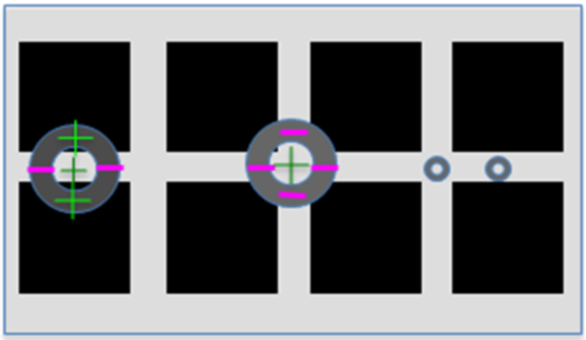
## Illusions of illuminance and lighting

Mach Bands

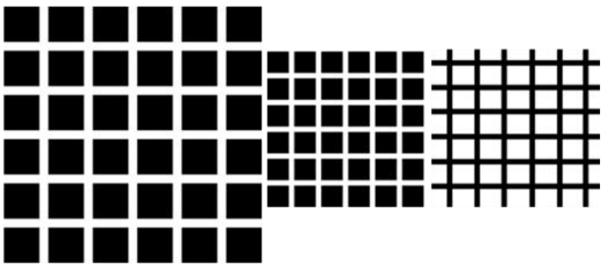


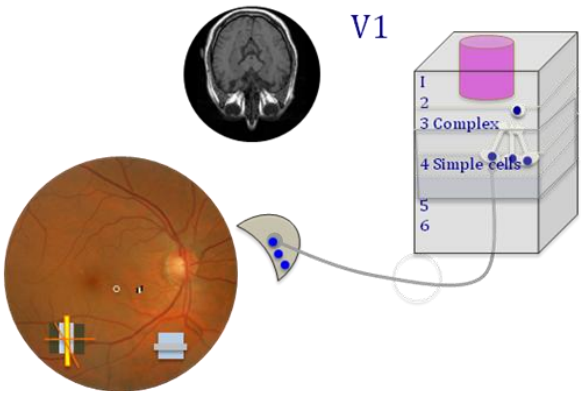
Herman grid

Also explained on basis of centre-surround organisation of receptive fields.

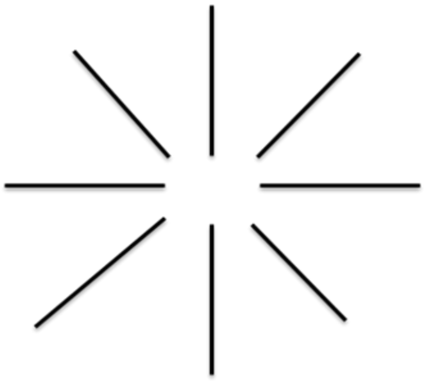


Not now considered correct.
More probably a function of orientation specific cells in the visual cortex.

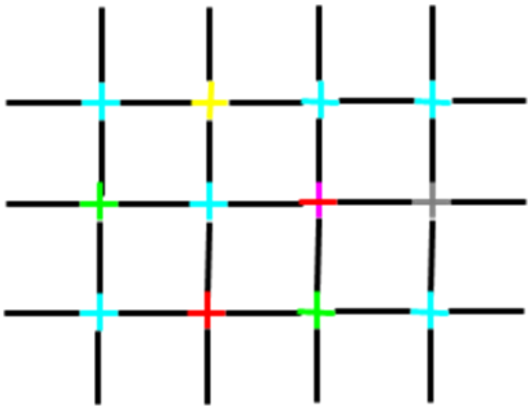




Ehrenstein illusion

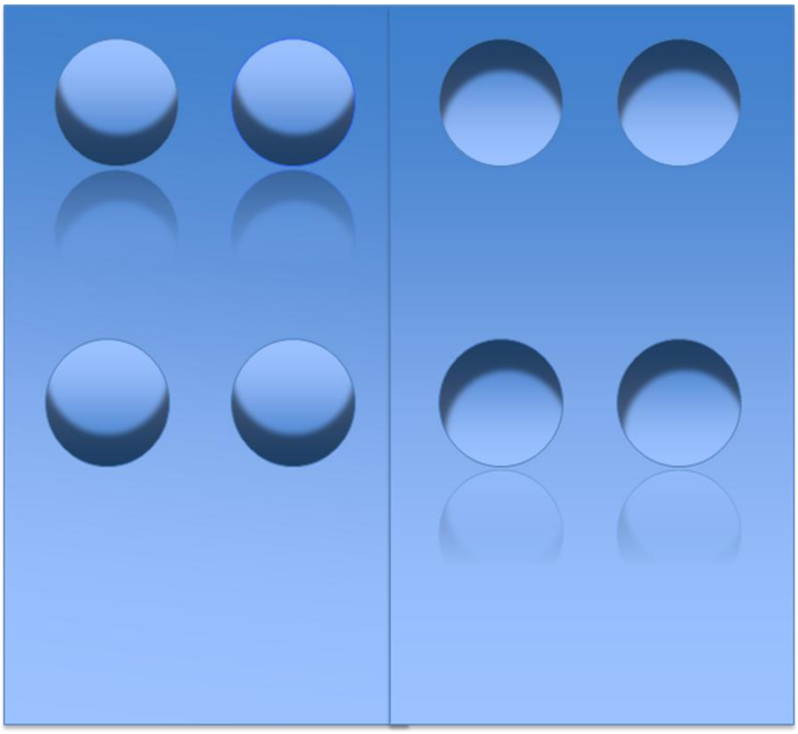


Neon colour spreading

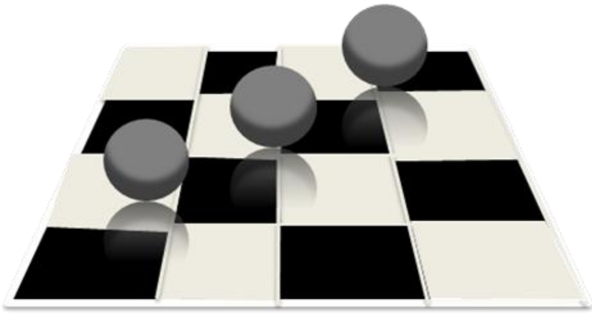


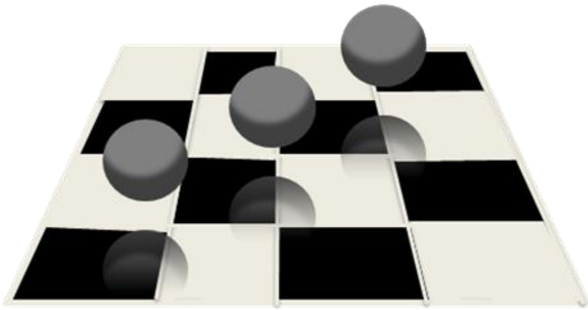
**Shading**

Our visual systems evolved with one major source of light and that came from the sky above. Simple inversion of shaded images can dramatically change our perception of the object. Buttons become dimples



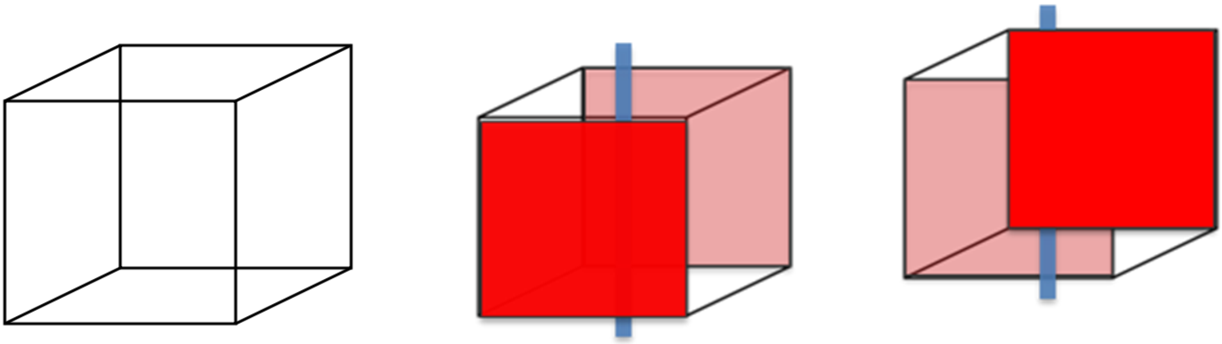
Shadows also determine our perception of the position of objects in space
These balls are in exact same location but appear in the lower drawing to be elevated above the chess board.

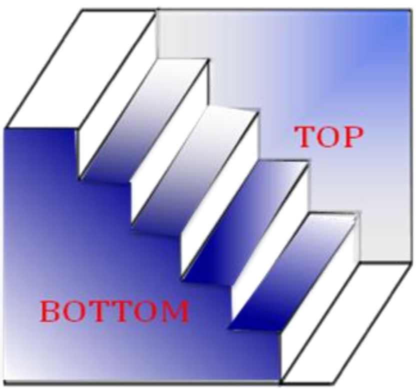


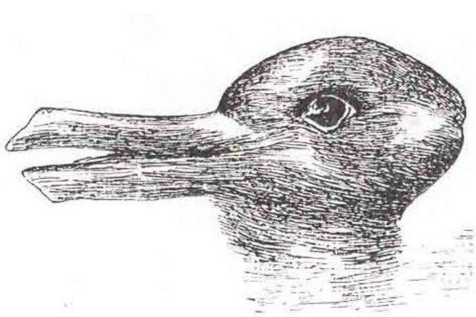


**Ambiguous images**

Sometimes we cannot make up our minds as to which is the correct interpretation of the retinal image. Either interpretation could be plausible so we flip changing our perception at random. Necker cube, Shroeder's stairs, Jastrow'e duck-rabbit

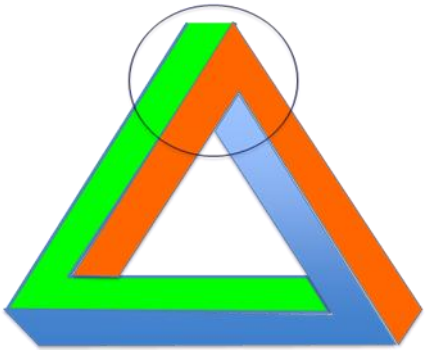




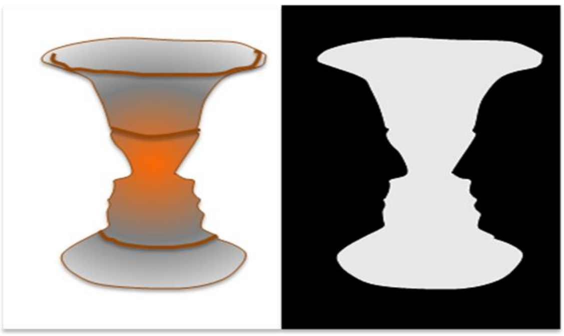
**Impossible figures**

Viewing from one particular angle doesn't give full information and we make guesses about the bits we cannot see to generate a 3D model.
Sometimes this process comes up with surprising results. The impossible triangle, cube and trident (poiuyt) are well known examples. These motifs have been used by illusionary artists for centuries, but were most famous in the drawings by the Dutch artist Escher.



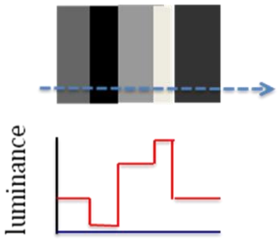
**Background and object discrimination**

This skill is critical to make sense of a scene. It is fooled in nature by camouflage, mimicked by the military. Minimalist drawings designed to not give enough information for the system to work generate ambiguous perceptions. The Rubin vase, FedEx illusion and dalmation illusion all confuse what is the object (figure) and what is background (ground).



**Illusions of motion**

Static images can evoke powerful images of motion. Some of these depend on moving our eyes or heads in relation to the picture. However the sensation of movement can occur when we look just off centre at a drawing with particular contrasts in its borders. When looking at particularly fine meshes random small movements of the eyes generate signals interpreted by the motion detectors in the brain, also generate an illusory percept of movement.
Many beautiful images have been produced, in particular those of Pinna, Fraser Wilcox and Akiyoshi Kitaoka stand out. These techniques for generating the illusion of motion have been used by artists, particularly those involved with the Op-Art movement. This autumn, one of the pioneers and leaders in this field, Bridget Riley, will have an exhibition in the National Gallery, London.


**Summary**

Visual illusions are a consequence of the optics of image formation, physiological processing of the image or how we interpret the result based on our culture and previous knowledge.
As we come to understand these processes many phenomena formerly classified as illusory, such as the apparent bending of sticks in water, are now considered differently. However the understanding of illusions is far from complete, so we can still be mystified, amazed and most importantly enjoy these puzzles of perception.
They are, after all, part and parcel of the normal process of vision.


Wundt/Hering illusion
Bisection illusion
Vertical size illusion
Orbison illusion
Moon/Sun illusion
Colour constancy
Ponzo illusion
Poggendorf
Angular size illusion (size constancy)
Zollner