Visual and non-visual Effects of Light

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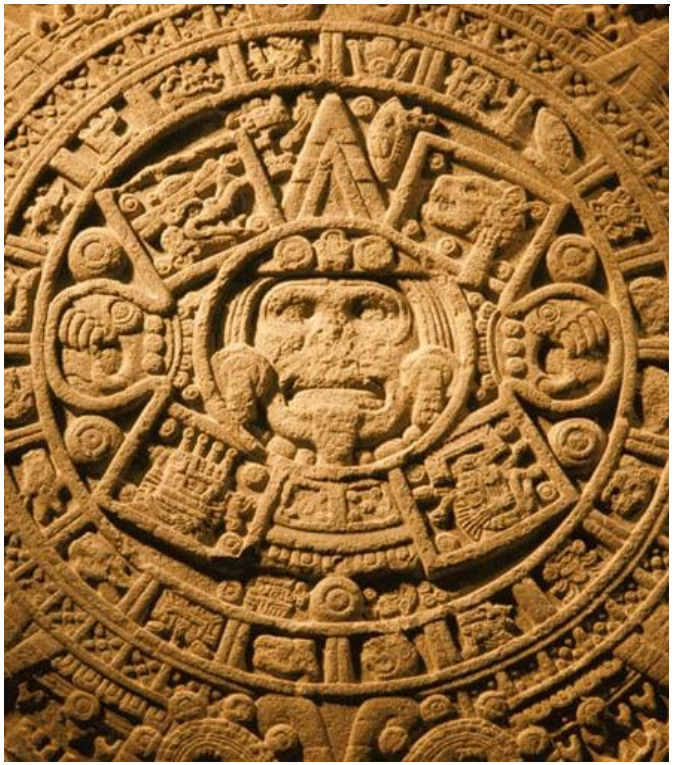
Light is life

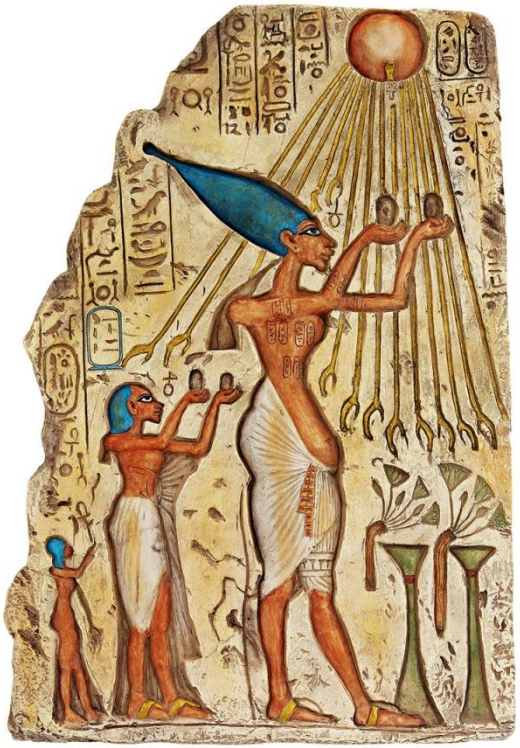
If sun would turn off the life on earth would extinct

Light

Warmth

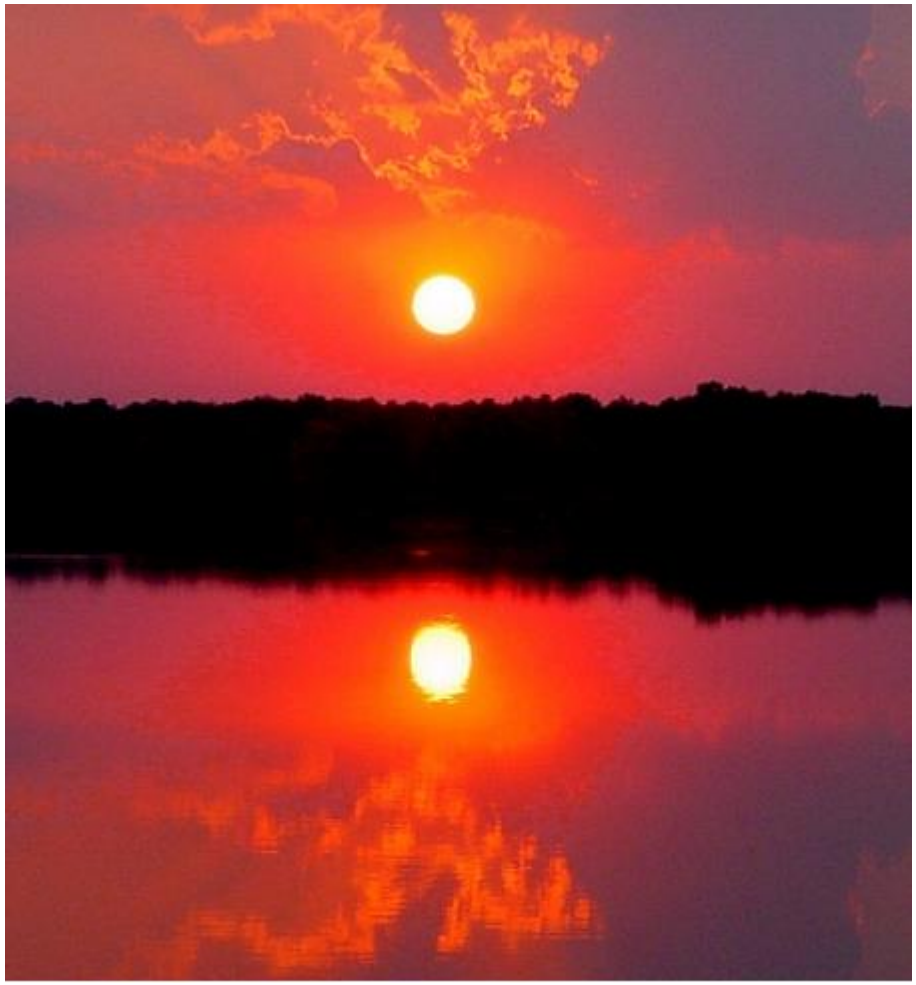
Sun as a deity (god)





Almost all old religions worship a sun as a deity – to assure that it will come out next morning also.

Rhythm of light is rhythm of life



We don't worship sun anymore but we are still dependent on its day-cycle.

Rhythm of light: morning

There is very few light in the morning but it increases with the time.

Colour of light changes from red to orange and to yellow.

Diurnal organisms starts with activities which grow together with the light.

We are sleepy in the morning and we are slowly starting out activities.

Rhythm of light: day

Sun is high, there is plenty of bright white light anywhere.

Diurnal organisms are at the peak of their abilities.

We are at the top of our abilities also and at the middle of our working day (coincidence?).

Rhythm of light: evening

In the evening, the light turns red, and is slowly decreasing.
Diurnal animals are getting less active and are preparing for the resting part of the day.

We are tired so we are concluding our work and are also preparing for the night.

Rhythm of light: night

At night the light is “dull and colorless”.

Organisms are, with exception of nocturnal ones, resting.

We are resting and gathering strengths for the next day also.

Visual and nonvisual effects of light

MIND

VISION

HEALTH

How light influences human being?

EMOTIONS

FEELING

MOOD

Light is the main source of information

We obtain over 80% of information from the environment through the vision.

Light not only enables but also affects our perception of the environment.

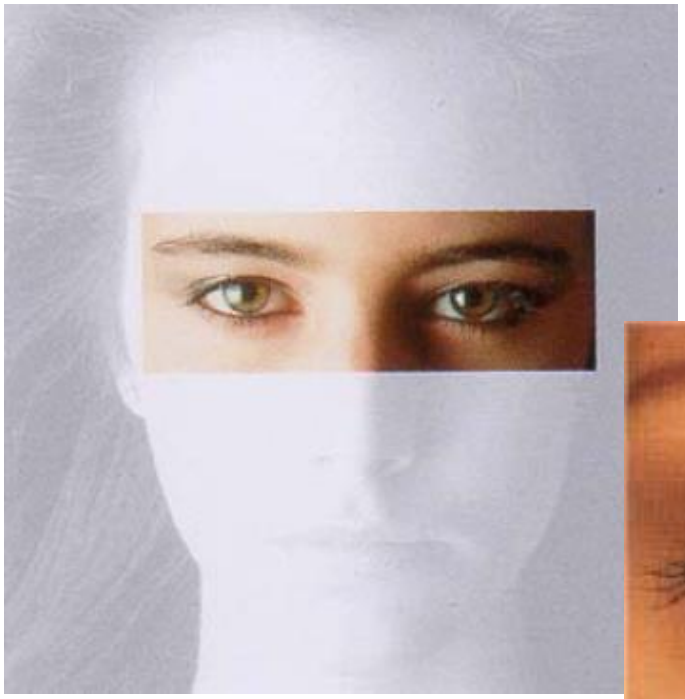
How do we feel if we can not see?

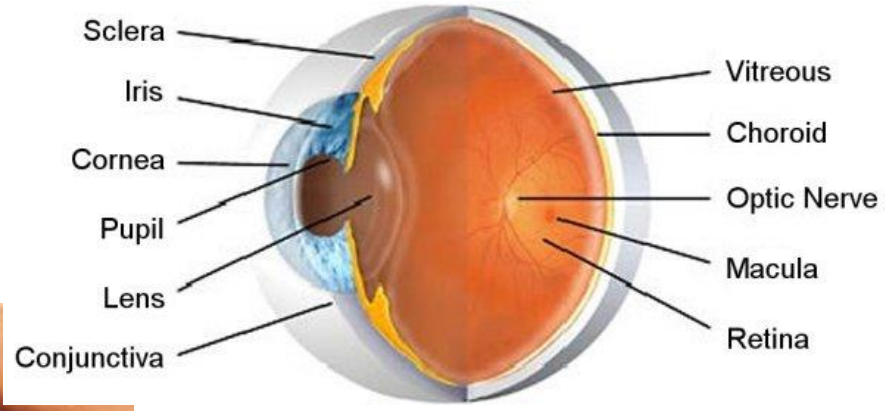
What technology was developed because of vision:

Written language, drawings, formulas, plans, photographs …

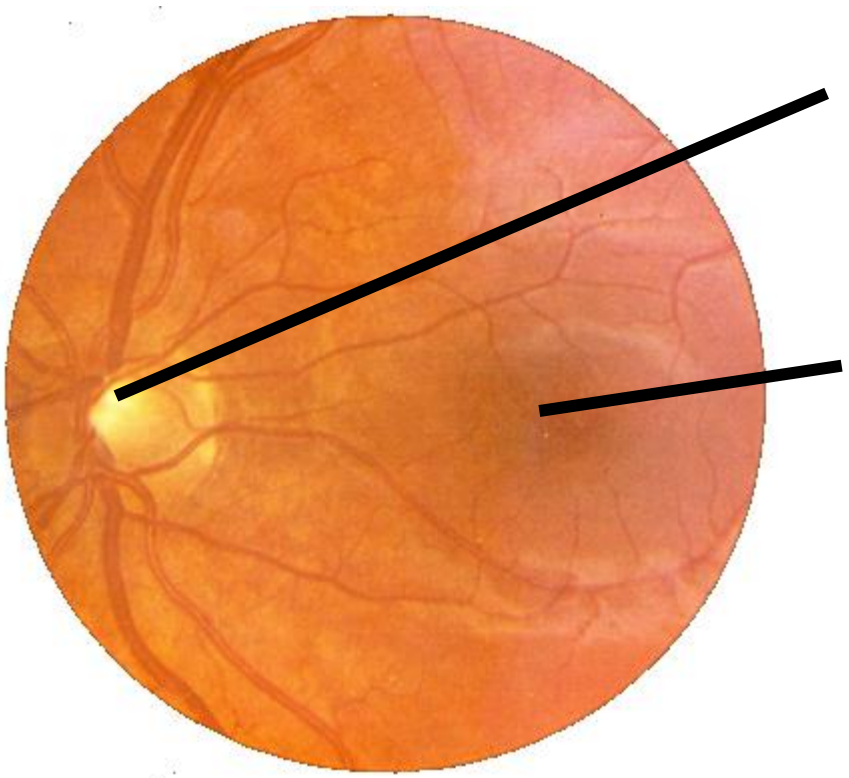
Human eye – the visual organ

- **The human eye, one of the most complete optical instruments.**





How do we see - retina



Blind Spot

Macula with fovea
(without choroid, which would reduce visual acuity)

Retina contains foto-receptors that are sensitive to light.

How do we see - receptors

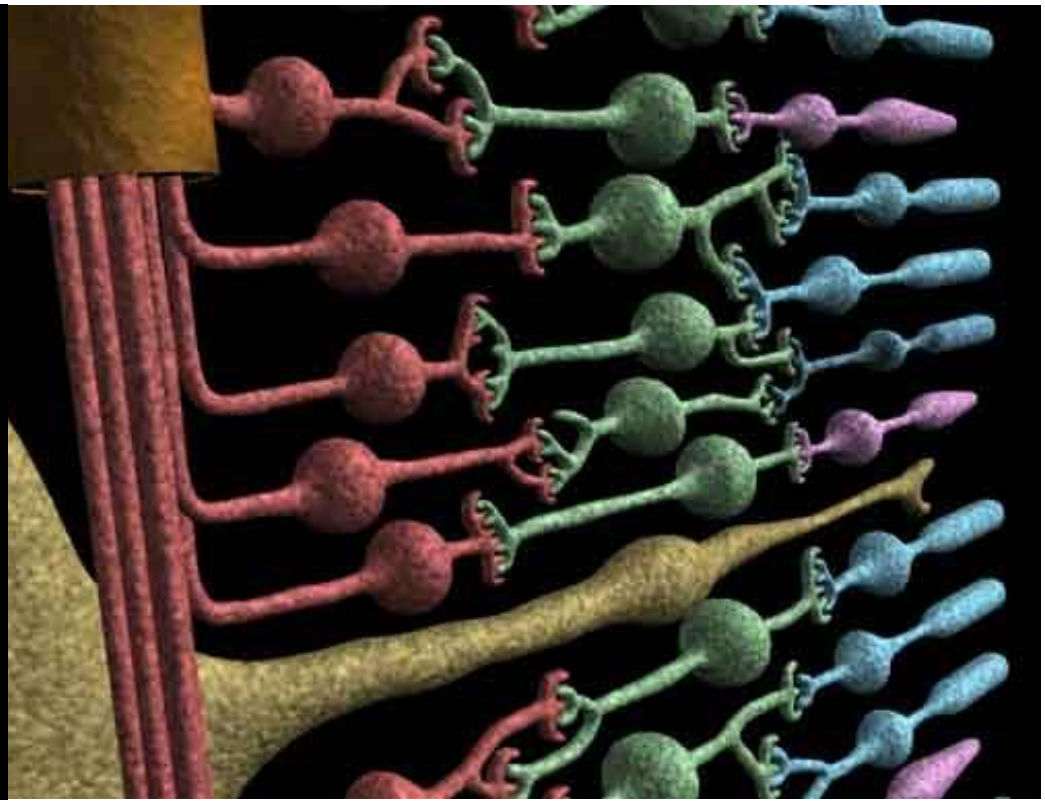
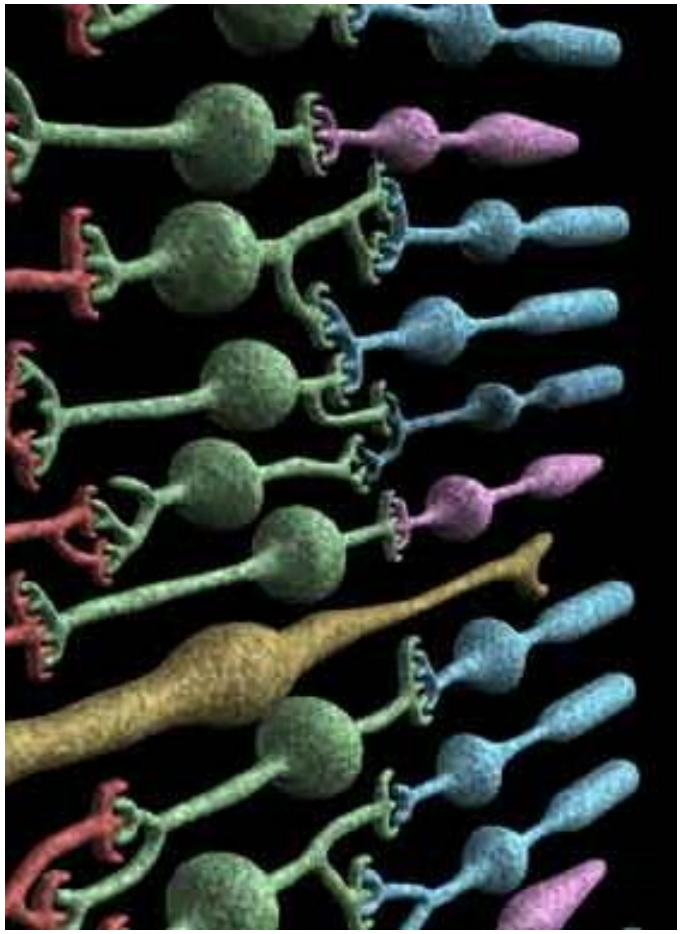


Foto-receptors in the eye convert incident light into pulses that nerves lead to the brain.

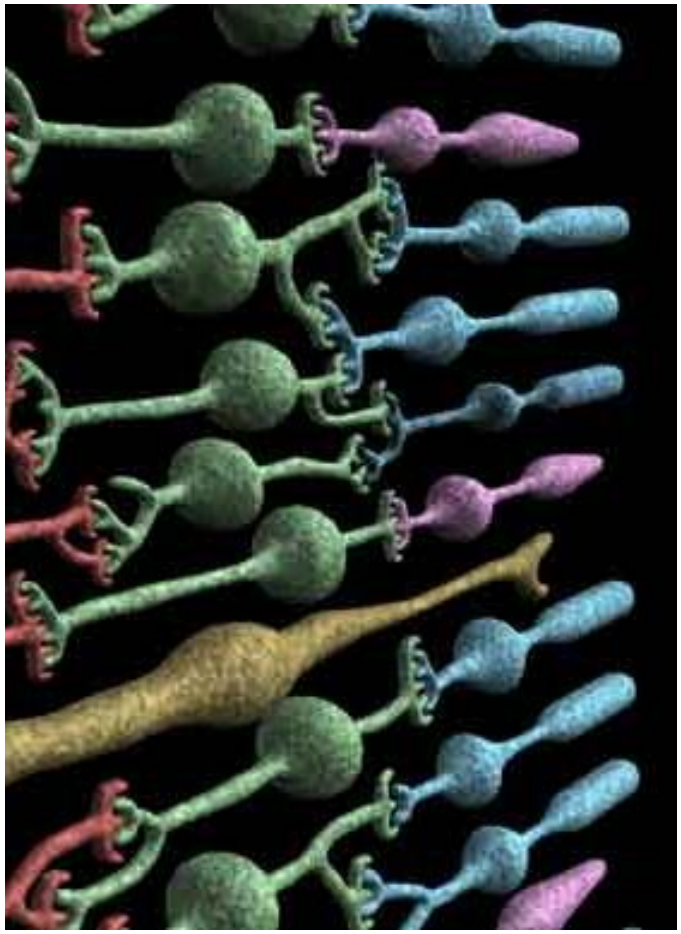
Cones and Rods



Cones

- There are 4.500.000 cones in average eye.
- They are less sensitive to light.
- They distinguish colors.
- They are arranged mostly in fovea and macula.
- They contribute to vision in well lit environment – photopic vision.

Cones and Rods



Rods

- There are 90.000.000 rods in average eye.
- They are more sensitive to light
- They can't distinguish colors.
- They are placed mostly outside macula.
- They contribute to vision in dark environment- scotopic vision.

Cones and Rods

Your manor, which in sunny day looks like this ...

Cones and Rods

... looks in the middle of the night like this.

A black spot in the middle is due to the fact that there is no rods in fovea and therefore this area can not be seen at night.

Characteristics of human eyes

Field of vision

Dynamic range

Visual acuity

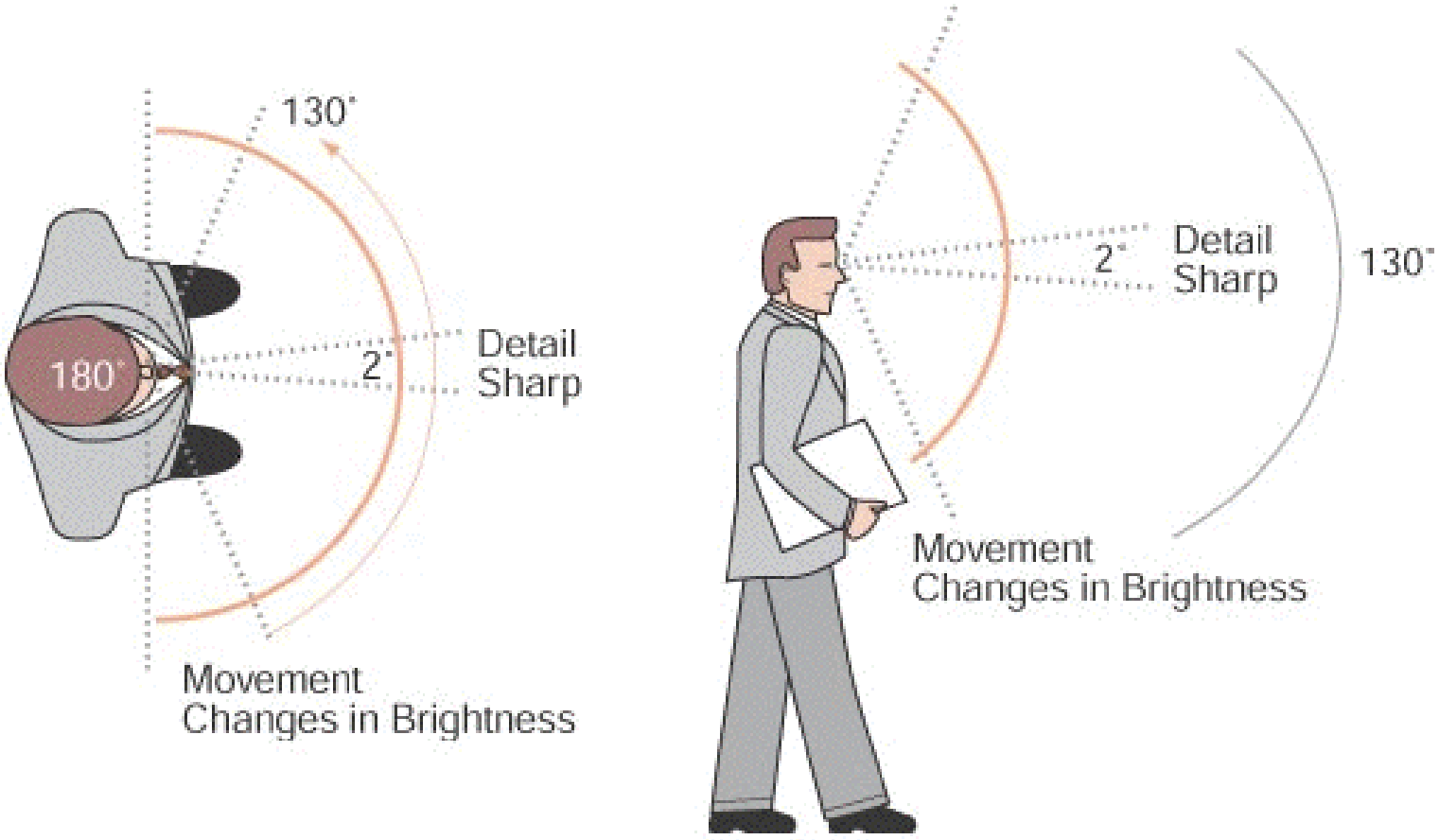
Eye adaptation

Eye accommodation

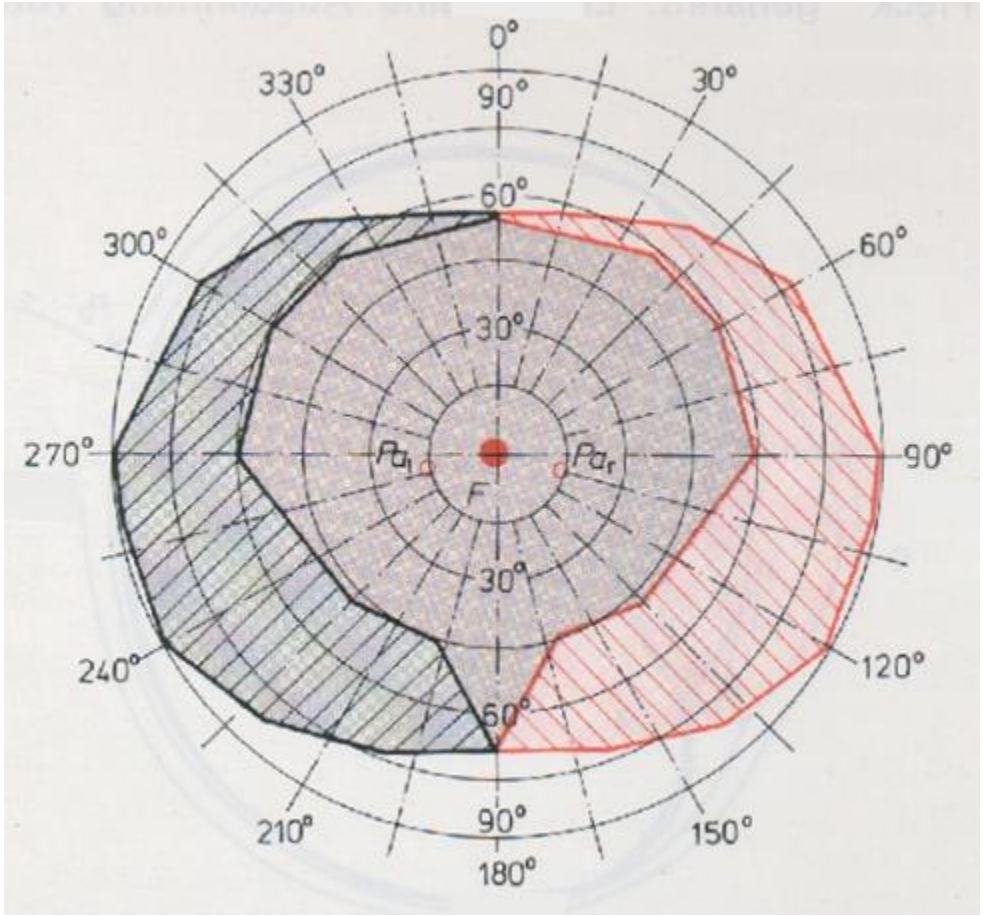
Depth perception

Optical aberration

Field of vision



Field of vision



The approximate field of vision of a human eye is:

95° out,

75° down,

60° in,

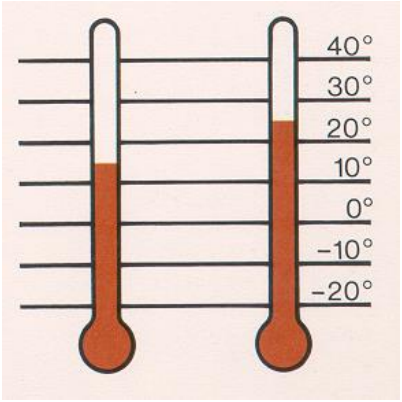
60° up.

Luminance dynamic range

Daylight luminances from 10 cd/m^2 to 10^{+4} cd/m^2

Road lighting luminances from 10^{-2} cd/m^2 to 10 cd/m^2

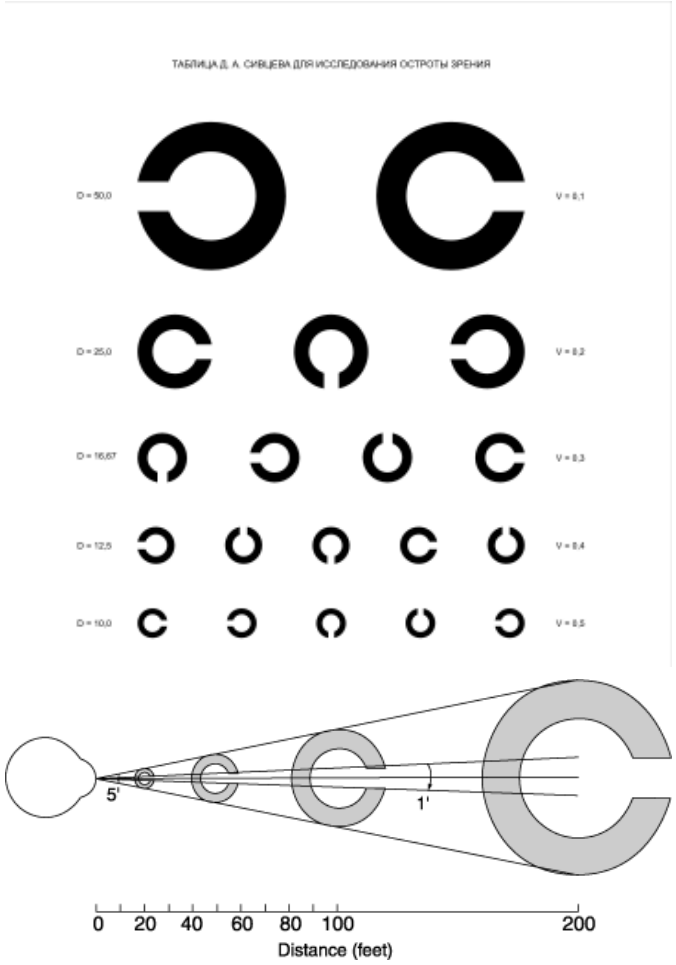
Moonlight luminances from 10^{-6} cd/m^2 to 10^{-2} cd/m^2



Temperature range ? from 15 °C to 25 °C

Static contrast ratio (no adaptation) is 1:100; dynamic range (with adaptation) is 1:1.000.000.

Visual acuity

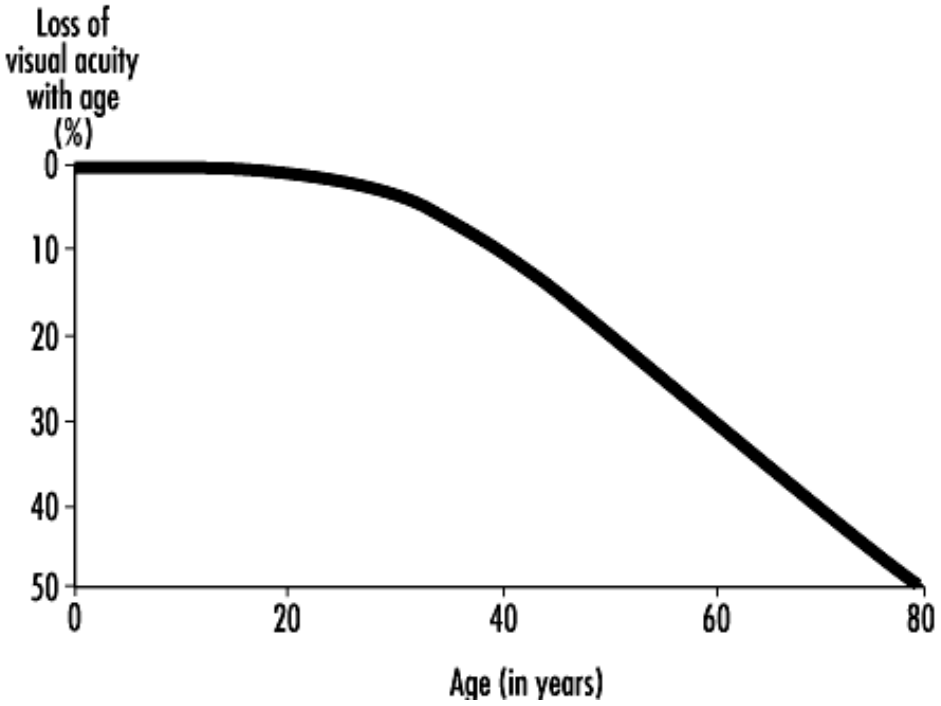


Visual acuity is a measure of the spatial resolution; ability to see a gap in a broken ring.

Vision 6/6 (20/20):
gap is seen from distance of 6 m

the size of the gap is so, that from the distance of 6 m represent 1 arc minute.

Visual acuity



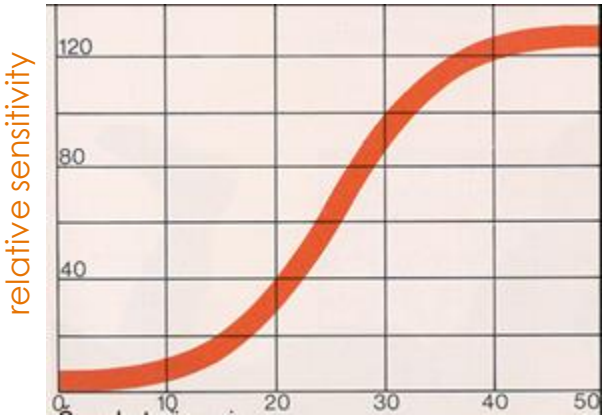
Visual acuity deteriorates with age.

Maximum visual acuity is in centre of the field of vision because of the densely packed cones in the fovea.

Eye adaptation

Eye adaptation is the ability of the eye to adjust to various levels of darkness and light

Eye adaptation



The eye takes approximately 20 – 30 minutes to fully adapt from bright sunlight to complete darkness.

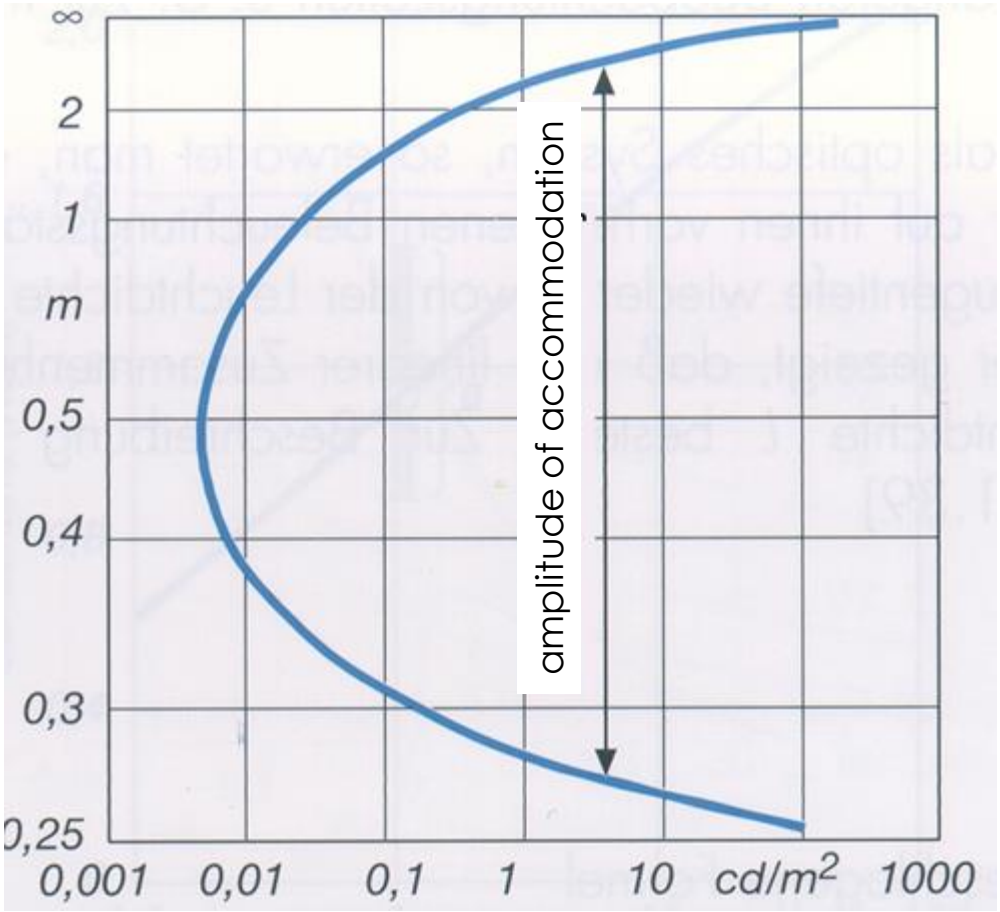
A minor mechanism of adaptation is the pupullary light reflex, adjusting the amount of light that reaches the retina.

Changes in the sensitivity of rods and cones in the eye are the major contributors to dark adaptation.

Eye accommodation

Accommodation is the ability of the eye to focus objects lying at different distances.

Eye accommodation

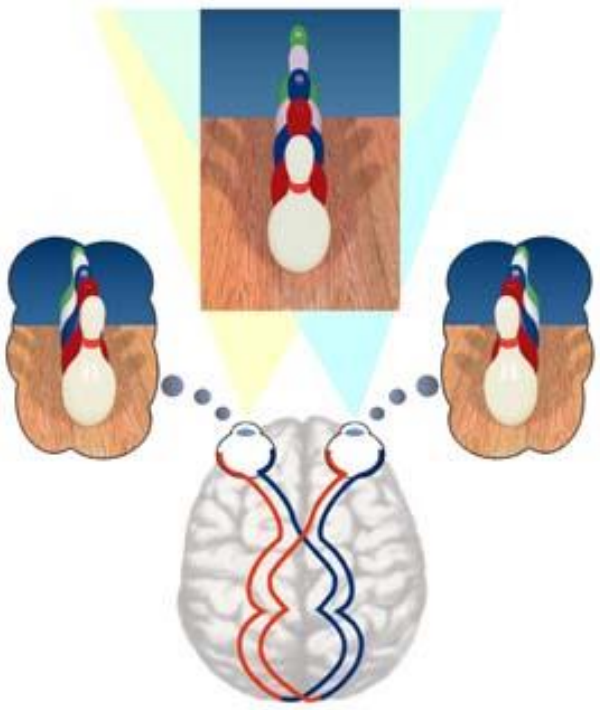


The amplitude of accommodation is influenced by the luminance level to which the eye is adapted.

The amplitude of accommodation declines with age.

Depth perception

Depth perception is the ability to see the world in three dimensions and to perceive distance.



Depth perception arises from a variety of depth cues:

- binocular cues that require input from both eyes and
- monocular cues that require the input from just one eye.

Binocular cues:

- stereopsis,
- convergence,
- shadow stereopsis.

Depth perception

Monocular cues provide depth information when viewing a scene with one eye (or on picture):

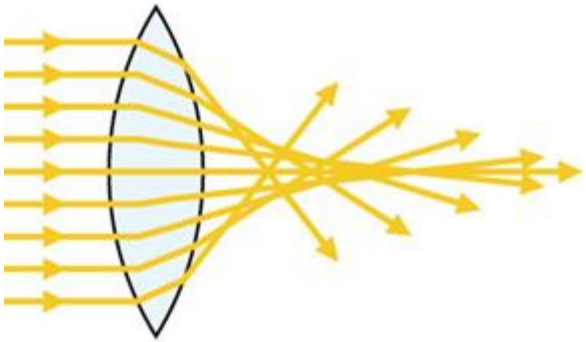
- motion parallax,
- perspective,
- familiar size,
- aerial perspective,
- accommodation,
- peripheral vision,
- texture gradient,
- lighting and shading.

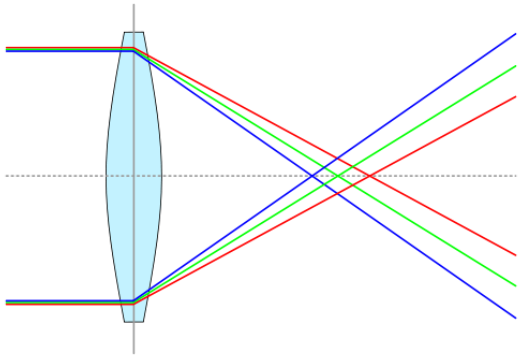
Depth perception

But the monocular cues are not always reliable – optical illusions.

Optical aberration

Optical aberration is an imperfection in image formation by an optical system





Spherical aberration, **which occurs when light rays strike a lens or mirror near its edge**

Chromatic aberration, **caused by differences in refractive index for different wavelengths of light**

Functioning of the eye - vision

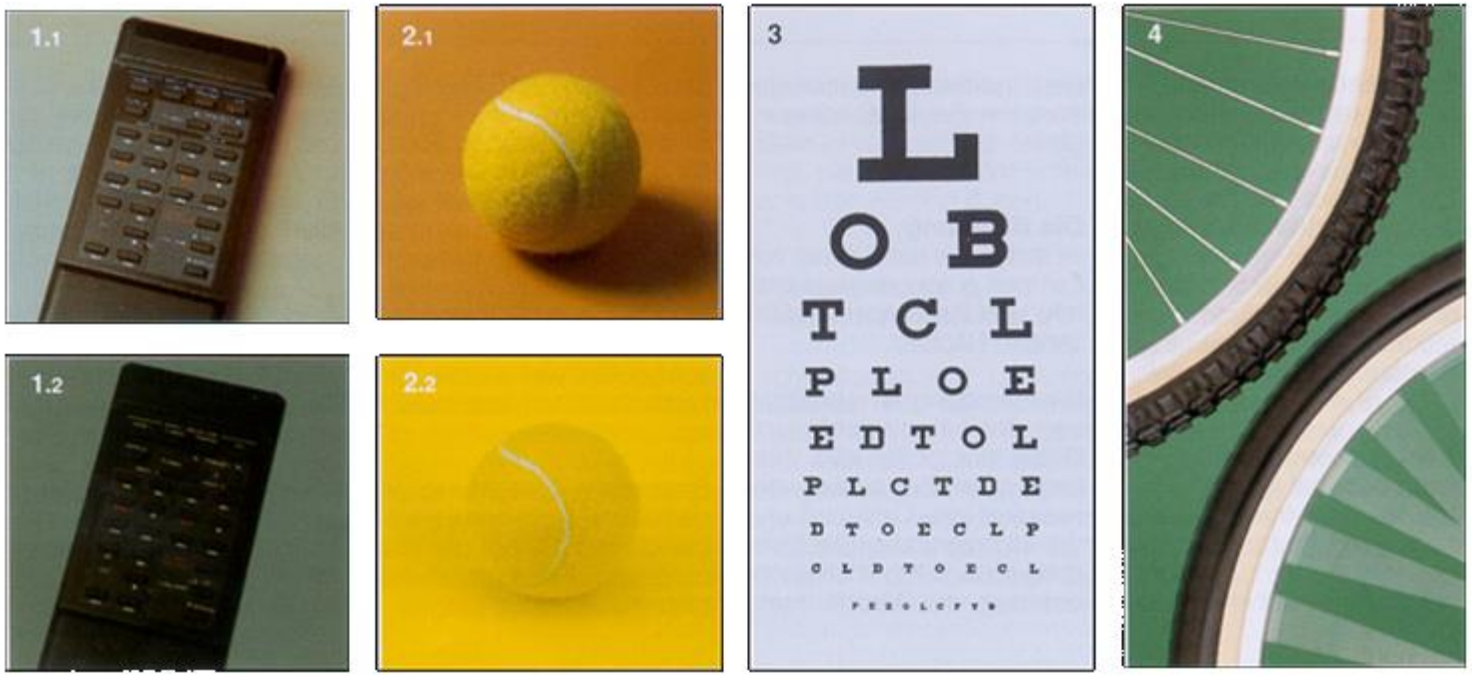
The human eye distinguishes following:

- difference in brightness
- difference in color
- shape
- movements or motion
- distance

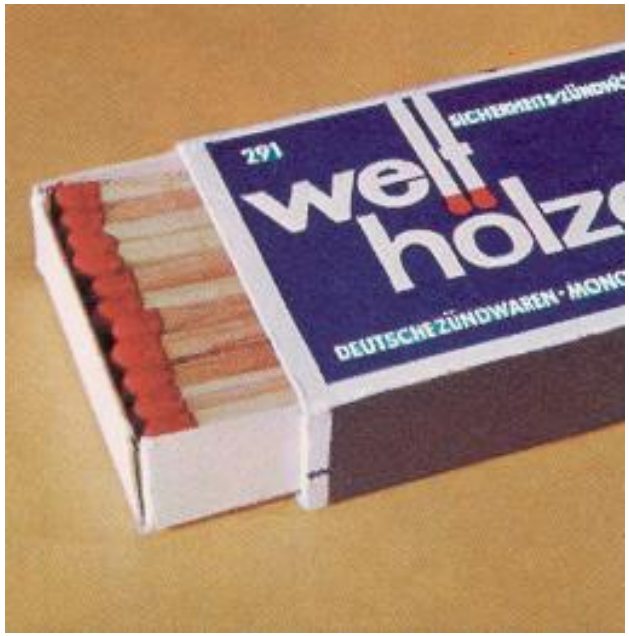
But only if there is enough light. Better the lighting conditions better the performance of the eye.

Functioning of the eye - vision

- **Four minimum requirements need to be met to permit perception!**



Minimum luminance



of observed objects and surroundings

Objects that can be easily identified in detail during the day become indistinct at twilight and are no longer perceptible in darkness.

Minimum contrast

in brightness or colour

Same color but luminance contrast.

Same luminance but color contrast.

Minimum size

Objects need to be of a *minimum size!*

Objects need to be of a *minimum size!*

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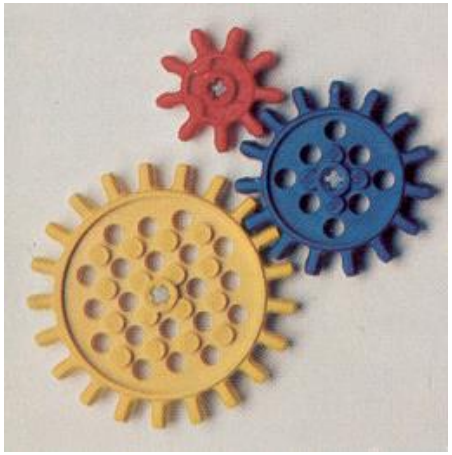
Minimum time

Minimum time for adaptation:

eyes need time to adapt to the environmental luminance.



Minimum time for observation:

wheels turning slowly can be made out in detail but become blurred when spinning at higher velocities.

Perception

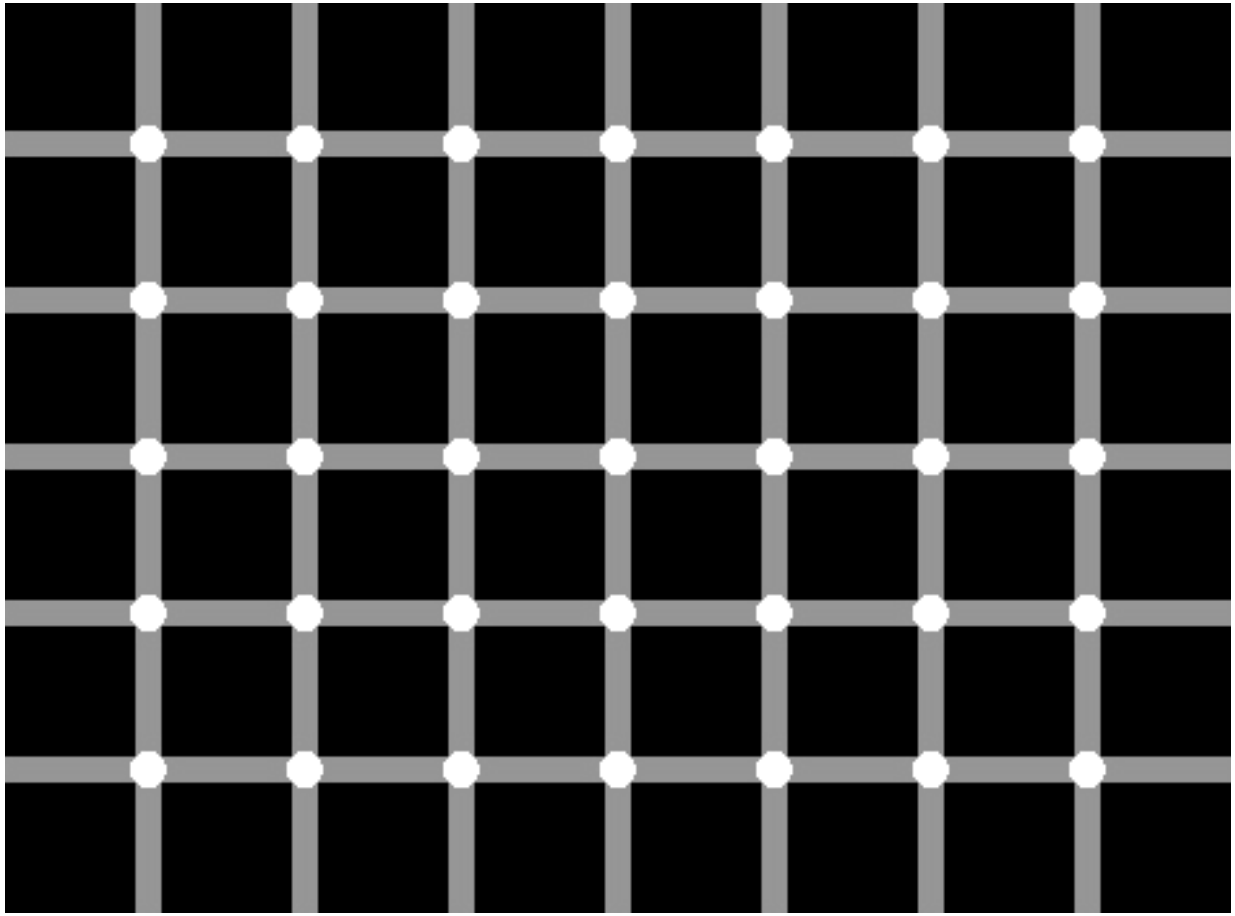
What we see (perceive) is not always the same as what our eyes see.

Perception is the process of attaining awareness or understanding of sensory information. What one perceives is a result of interplays between past experiences, including one's culture, and the interpretation of the perceived.

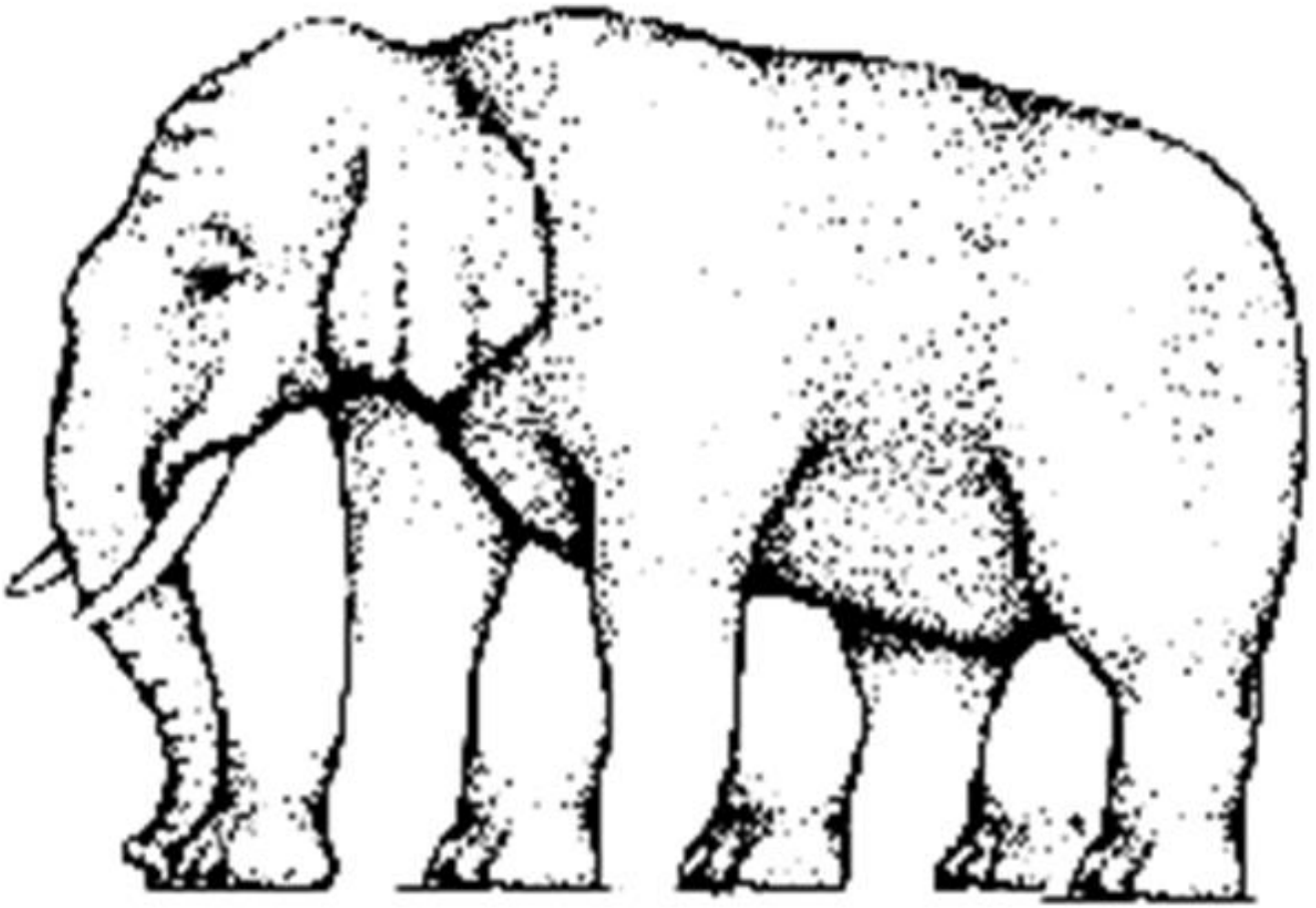
Perception

What was wrong with the previous picture?

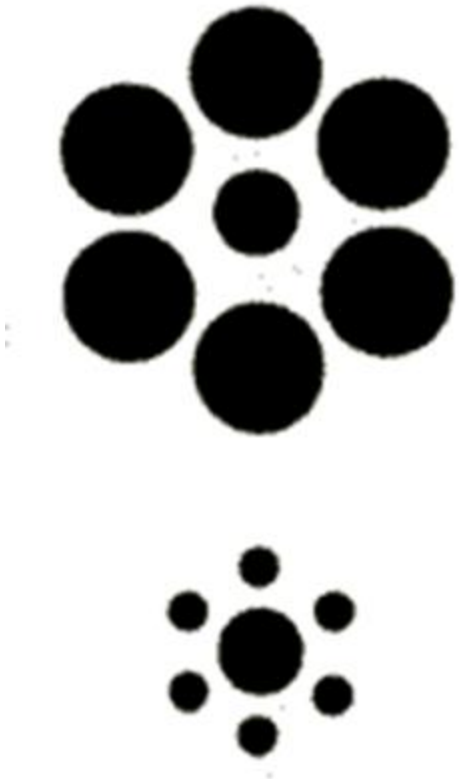
Perception



Perception



Perception

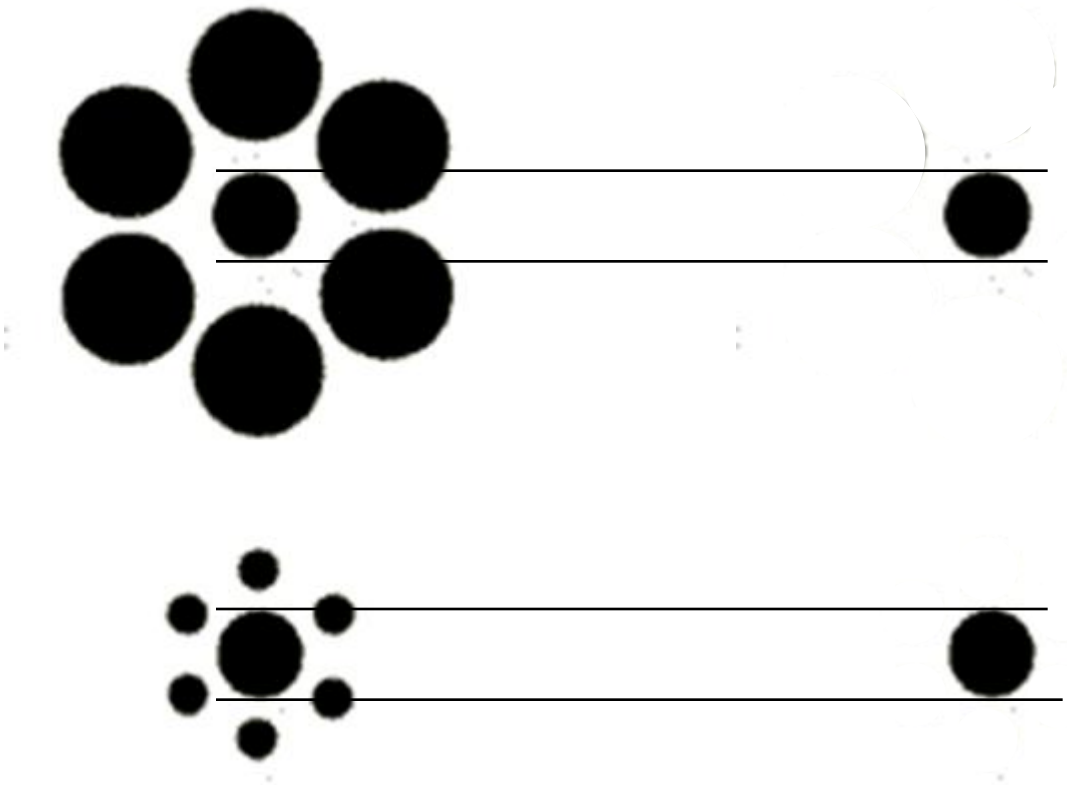


Do dots in the middle look like they are of the same size?

Perception

Do these two dots look like they are of the same size?

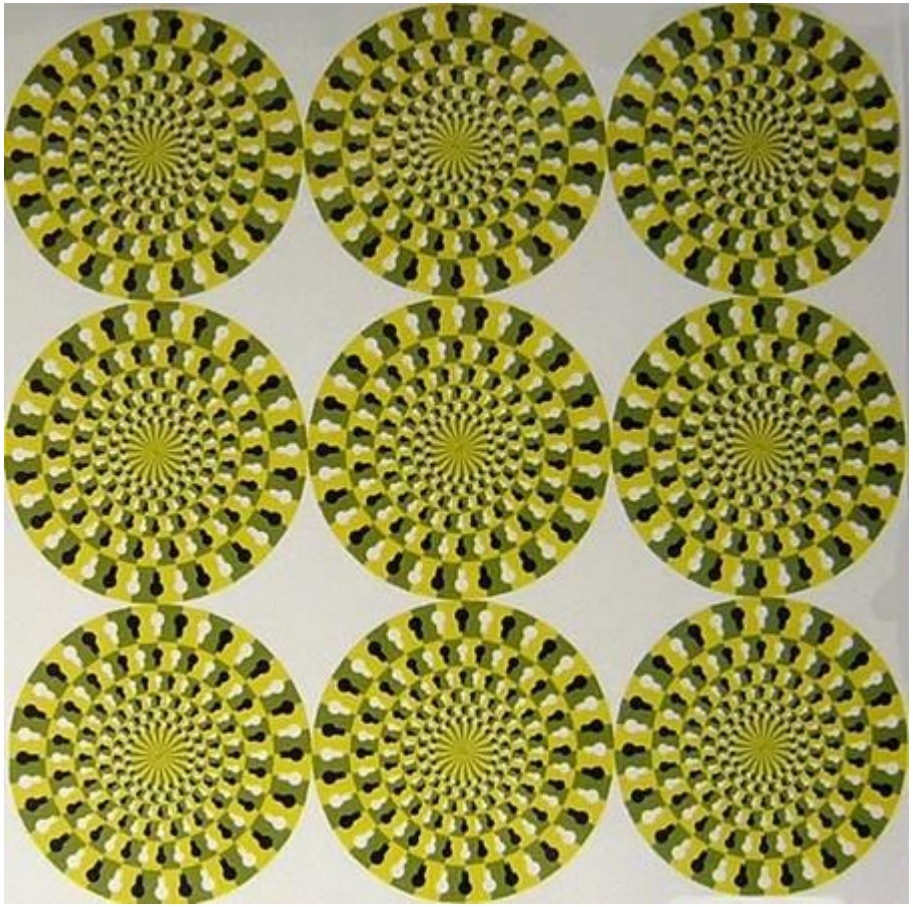
Perception



Perception

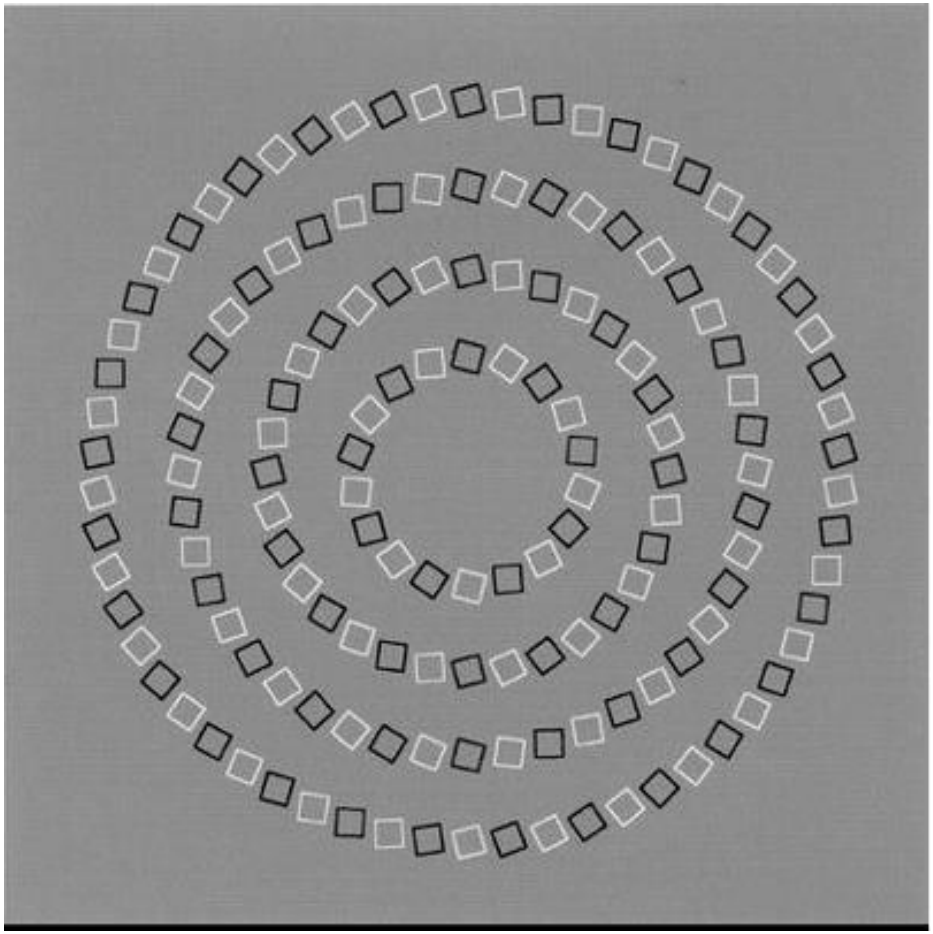
Will the man in the middle jump into the pool or …?

Perception



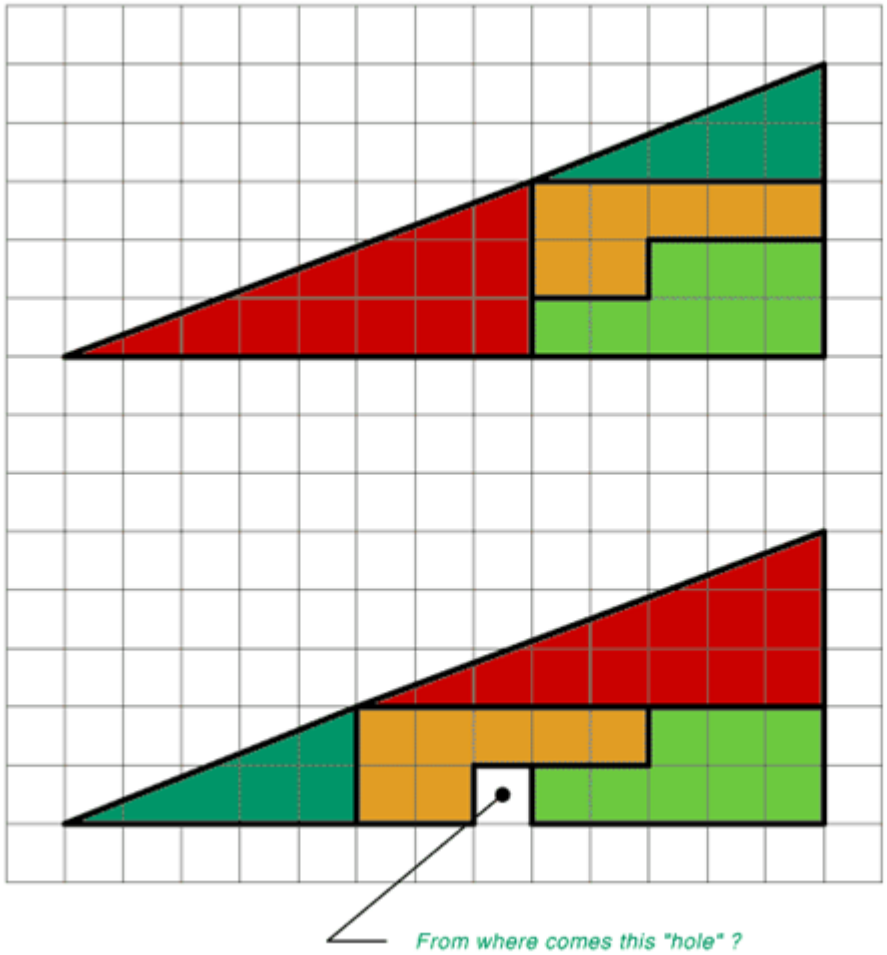
Which of these wheels is turning left and which right?

Perception



Spirals or …?

Perception



Where is the missing square?

Perceptual constancy

There are several types of perceptual constancies in Visual perception:

shape constancy,

size constancy,

color constancy,

lightness constancy,

distance constancy,

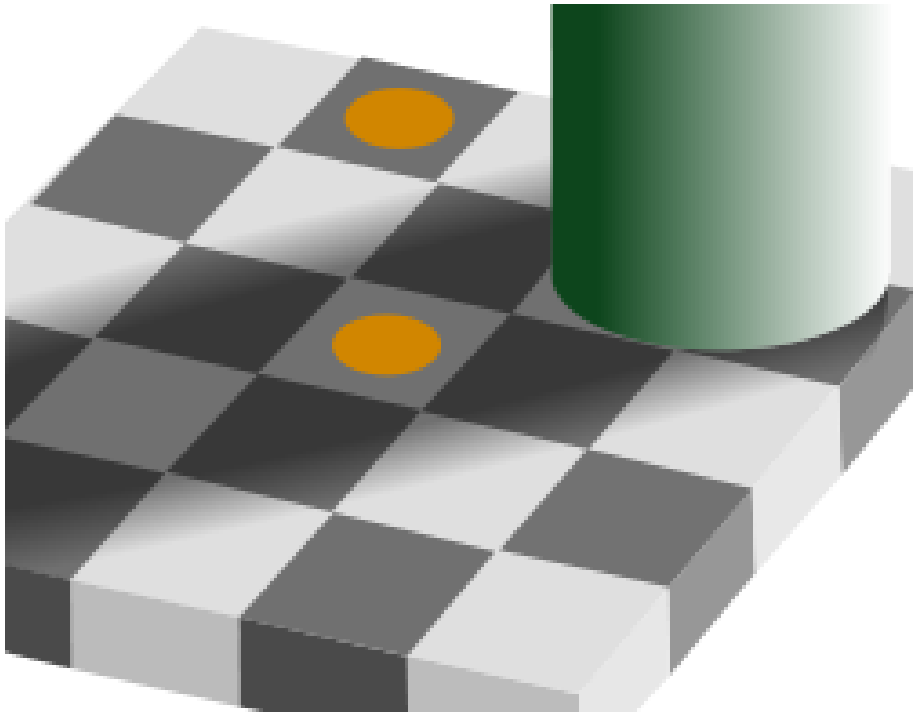
location constancy.

Color constancy means perceiving a color as "constant under changing conditions of illumination" and is the achievement of a very complicated "calculation" by an unconsciously working apparatus within our central nervous system.

Color constancy

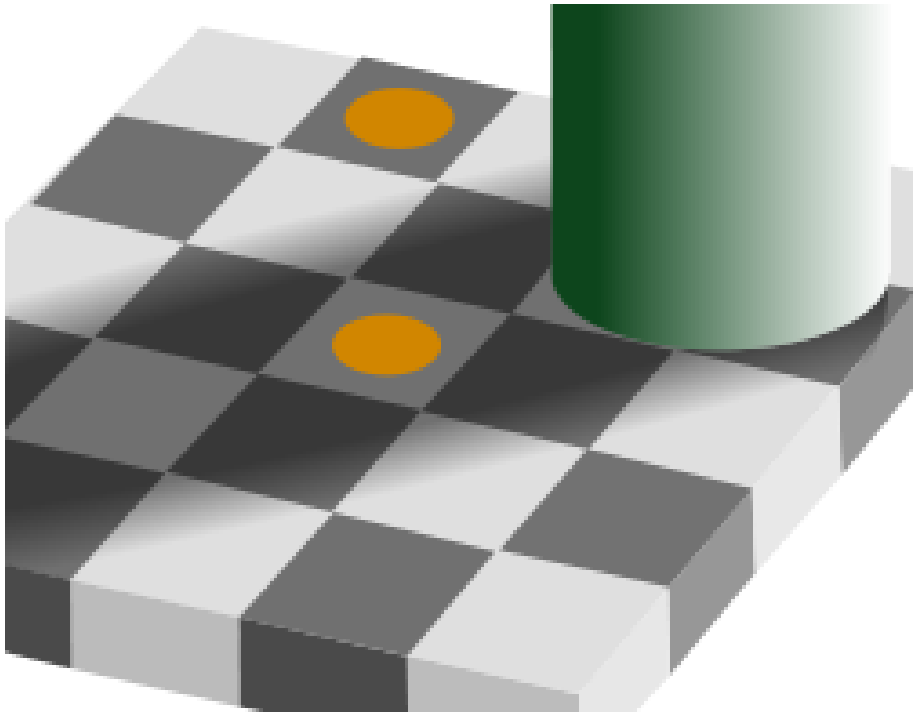
Everybody knows that this mug has just one color. It just looks different because of light and shadow.

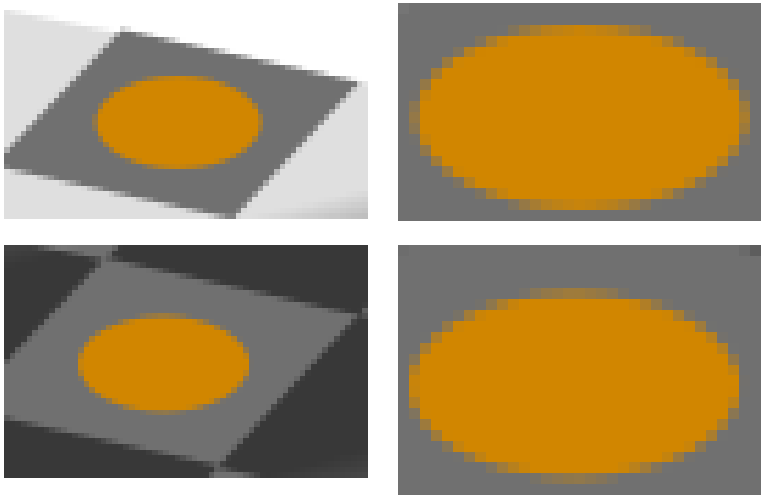
Color constancy



But what about these two orange dots? are their colors same or different?

Color constancy





Light helps at work

Good light(ing) can bring greater productivity, quality and safety.

But not always …

In some cases light might be disturbing.

Disturbing effects of light – glare

Glare is caused by a significant ratio of luminance between the task or surrounding and the glare source.

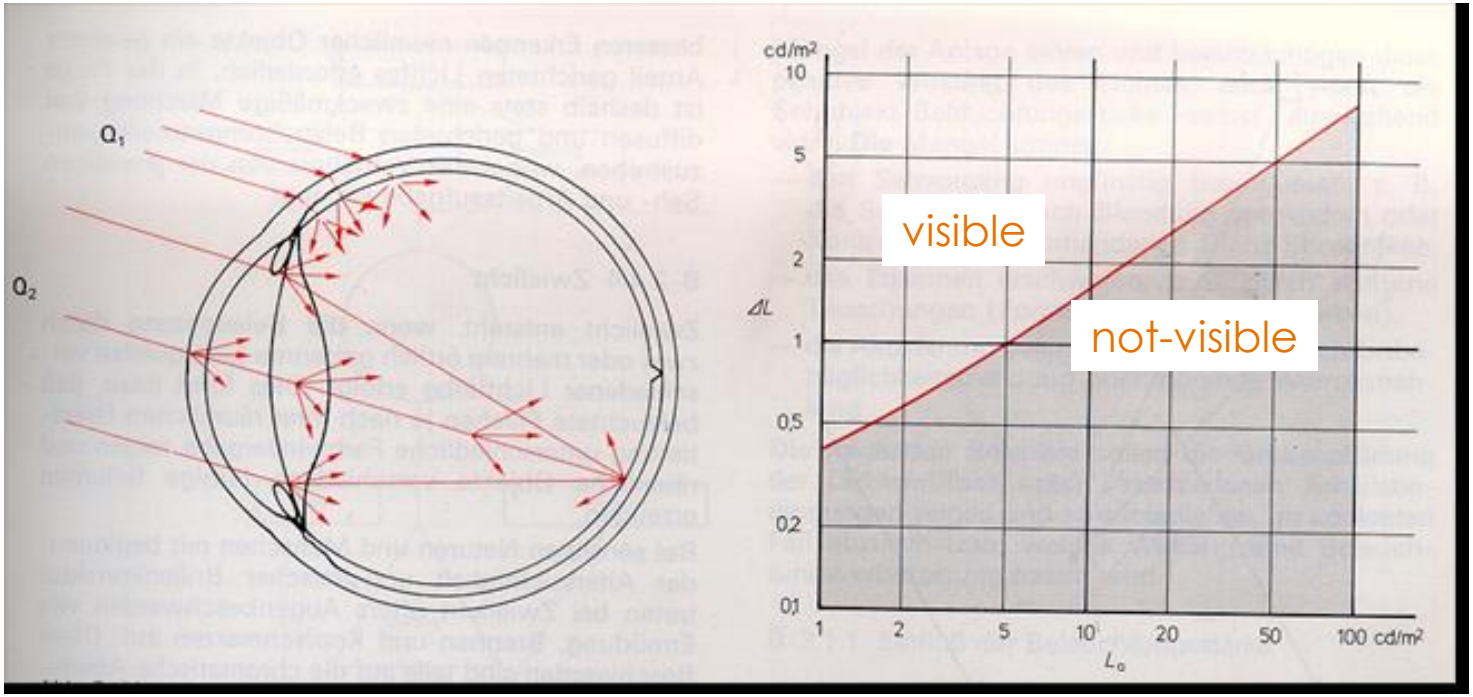
Glare can be divided into two types:

- **discomfort glare,**
- **disability glare.**

Discomfort glare results in an instinctive desire to look away from a bright light source or difficulty in seeing a task. Disability glare renders the task impossible to view, such as when driving westward at sunset.

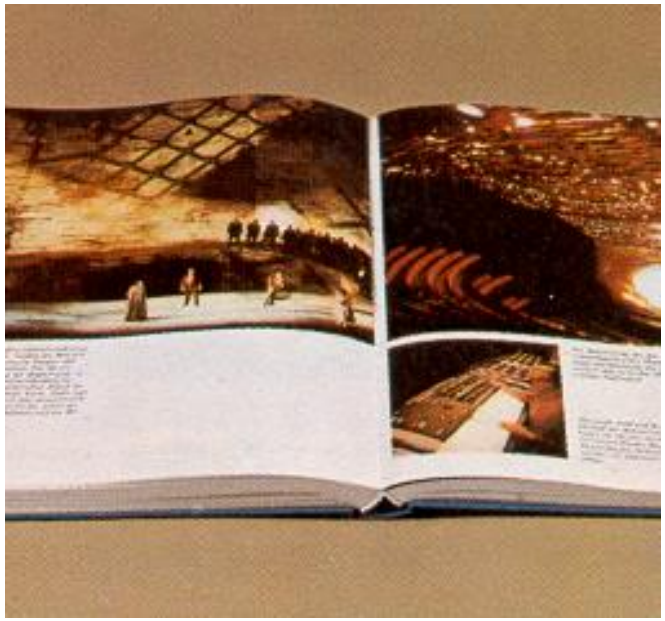
Disturbing effects of light – glare

Glare is caused by the inter-reflection of light within the eyeball, reducing the contrast between task and glare source to the point where the task cannot be distinguished. Glare can be so intense that vision is completely impaired.



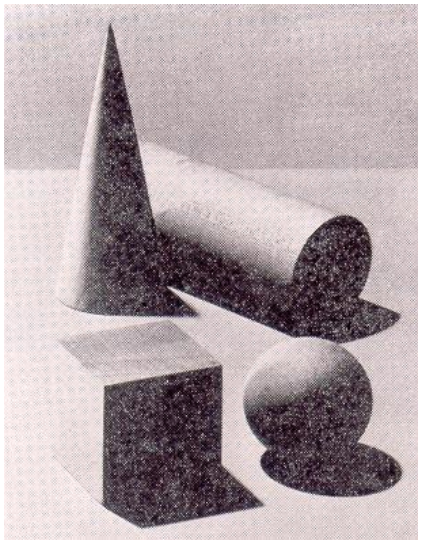
Disturbing effects of light – reflected glare

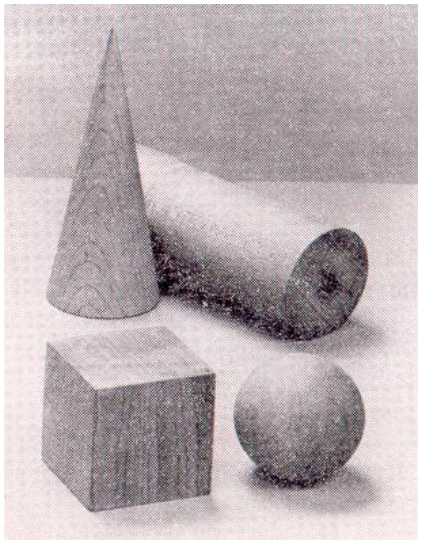
Reflected glare causes the same kind of disturbance as direct glare - reduces the contrasts needed for trouble-free vision.

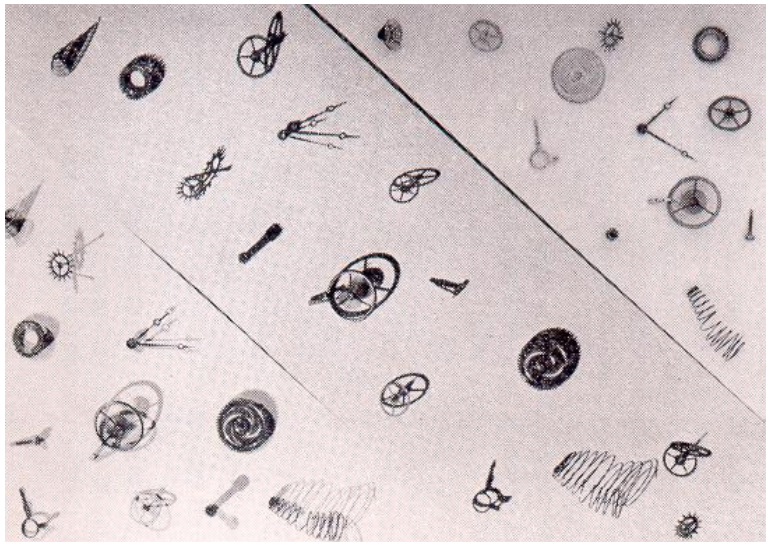


Disturbing effects of light – shadows

Light and shadow are vital to ensure that objects, surfaces and structures are clearly identifiable - shadows make it easier to detect 3D objects. However, within deep shadows with hard edges everything becomes unrecognizable; even potentially dangerous optical illusions can occur







Disturbing effects of light – double light

Double-light is when we place two spatially separated sources with different colors of light in a room. In such case the appearance of the object and the shadow depends on the current position and orientation of the object in space so eyes need to adapt and accommodate to each position.

Double light can causes fatigue, burning eyes and headaches.

Disturbing effects of light – flashing light

If the intensity of the light is not constant, but light is flashing, it can cause similar problems as a double light. In addition, there might be a stroboscopic effect, which prevents the correct perception of moving or rotating objects.

Visual and nonvisual effects of light

MIND

VISION

HEALTH

How light influences human being?

EMOTIONS

FEELING

MOOD

Most important: Rhythms

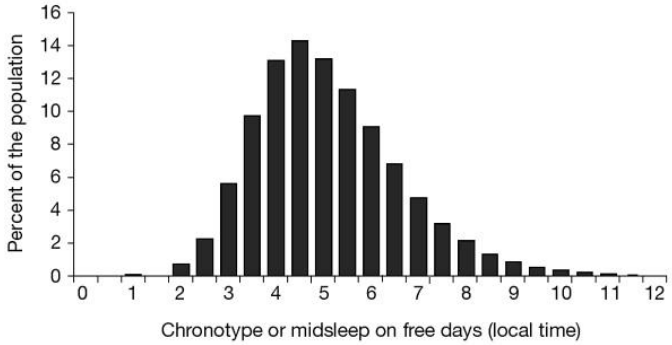
The human body runs on cyclic programs:

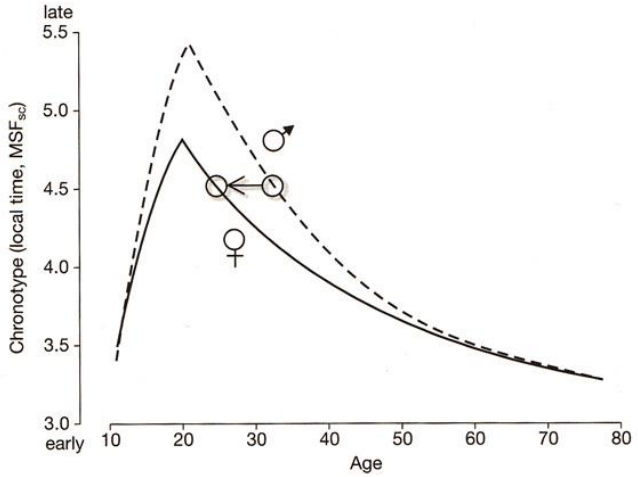
- Ultradian rhythms span only a few hours.
- Circadian rhythms are geared to day and night.
- Infradian rhythms have cycles longer than 24 hours.

Most important: Rhythms

- All organisms have their own rhythms.
- We have the rhythm of day and night anchored in our gens.
- Regular sleep and waking phases are maintained even if they are not stimulated by daylight.

Chronotypes





- **The genetically programmed rhythm for human beings is normally around 24,2 hours.**
- **For some people, the cycle is shorter than 24 hours;**
- **For others, it is considerably longer.**
- **On the basis of these differences, people are divided into „chronotypes“.**

Chronotypes

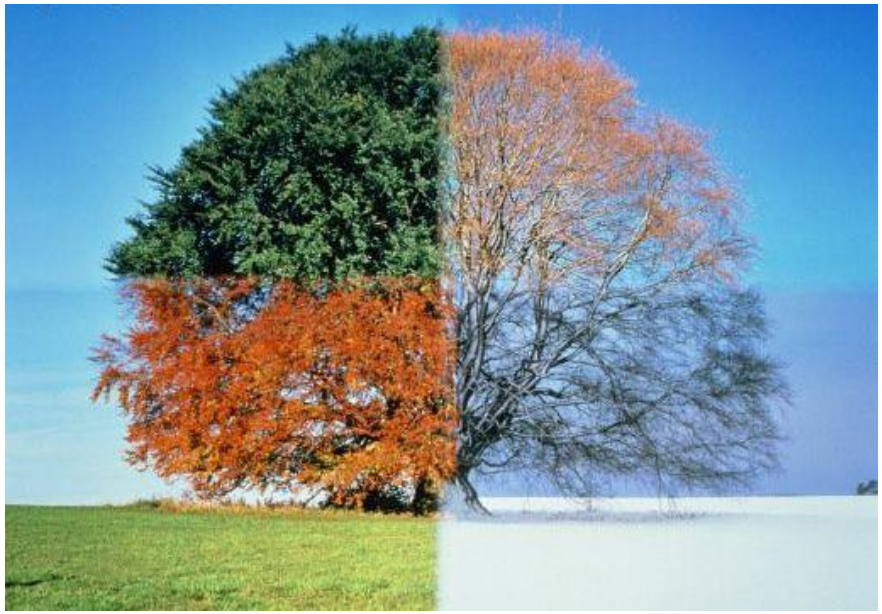
- Chronotypes are identified mainly by their sleeping habits.
- Many people are early risers – “larks” wide awake at the crack of dawn. Their internal clock cycle shorter than 24 h.
- Other are “owls” and need more time to face the new day. Their internal clock runs significantly slower (more than 24 h).

Rhythm and age

- **Infants and toddlers:** ultradian rhythms of three or four hours' duration.
- **Teens:** go to bed late and sleep longer.
- **Arround 20:** sleep requirements decrease to 7-8 hours.
- **From 30 onwards:** the quality of sleep steadily declines.
- **At 70:** our sleep/wake rhythm gets increasingly out of sync with external rhythms.

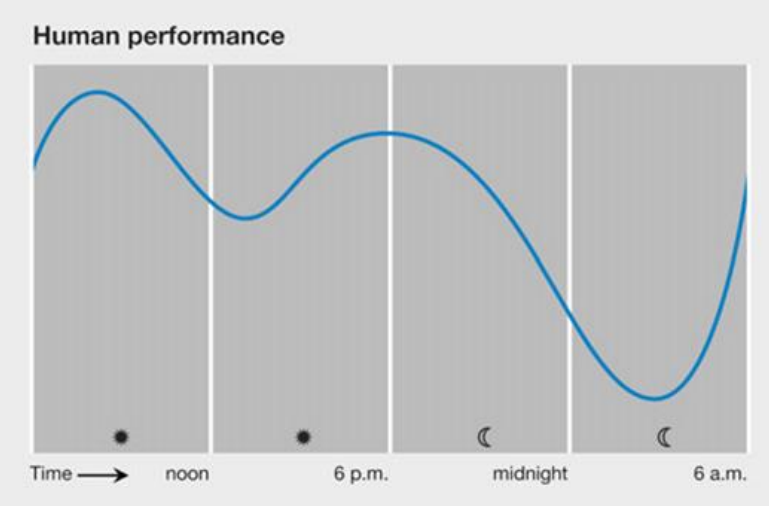
Seasonal differences

- Our chronobiological rhythms are also influenced by summer and winter.
  - In the dark months we tend to be less fit, we have difficulties concentrating and our responses are slower. We also eat more.
  - The seasons also have a psychological impact – seasonal affective disorder (SAD, in Germany up to 10% of adults)



Circadian Rhythm

- Circadian rhythm influences more than just a sleep/wake phases:
  - Heart beat
  - Blood pressure
  - Core body temperature
  - Hormonal regulation
  - Metabolic functioning



Resynchronization

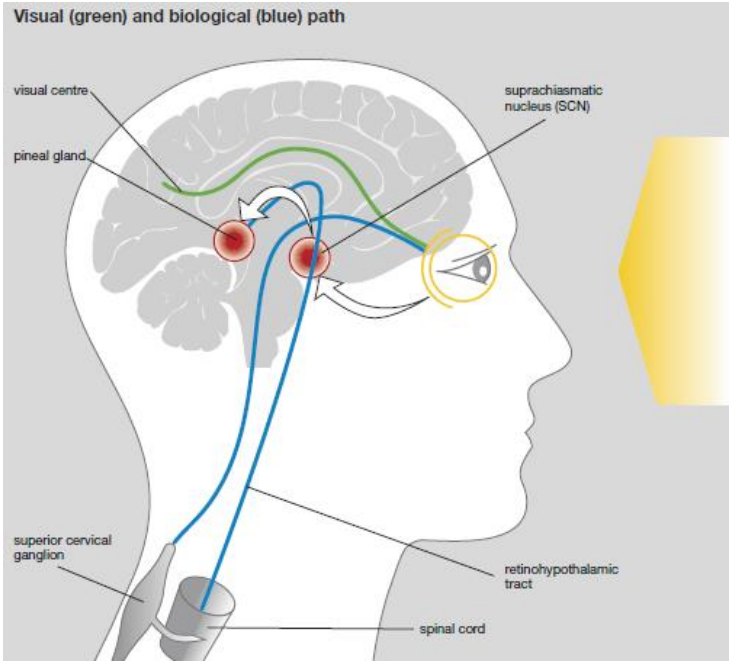
- To keep with the sun‘s 24 hour rhythm, our internal clock needs occasional resynchronization (twice a day?).

- Light acts as pacemaker for our internal clock

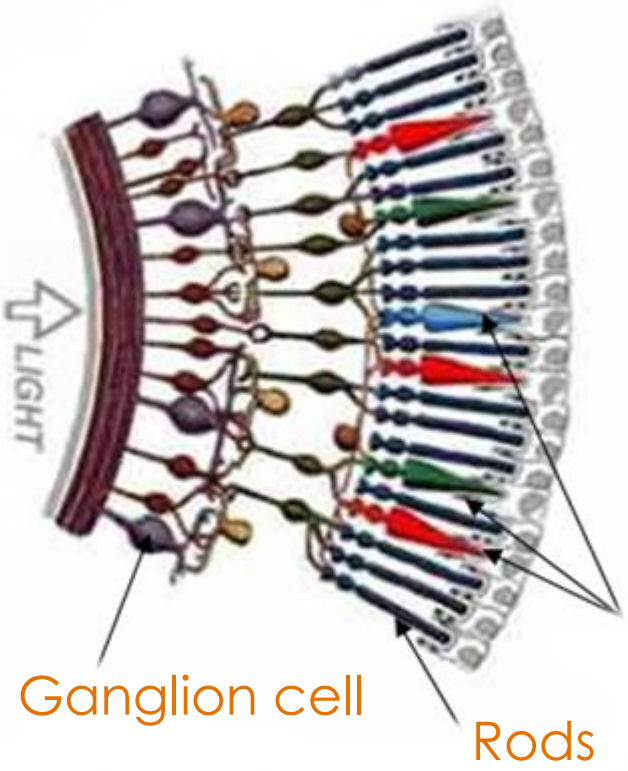
How it works?

Suprachiasmatic nucleus (SCN):

- SCN acts as a master clock for cell activity by using synapses and neurotransmitters to synchronize the various clocks in the body.
- It does this by activating or inhibiting enzyme and regulating the production or prevention of hormones.

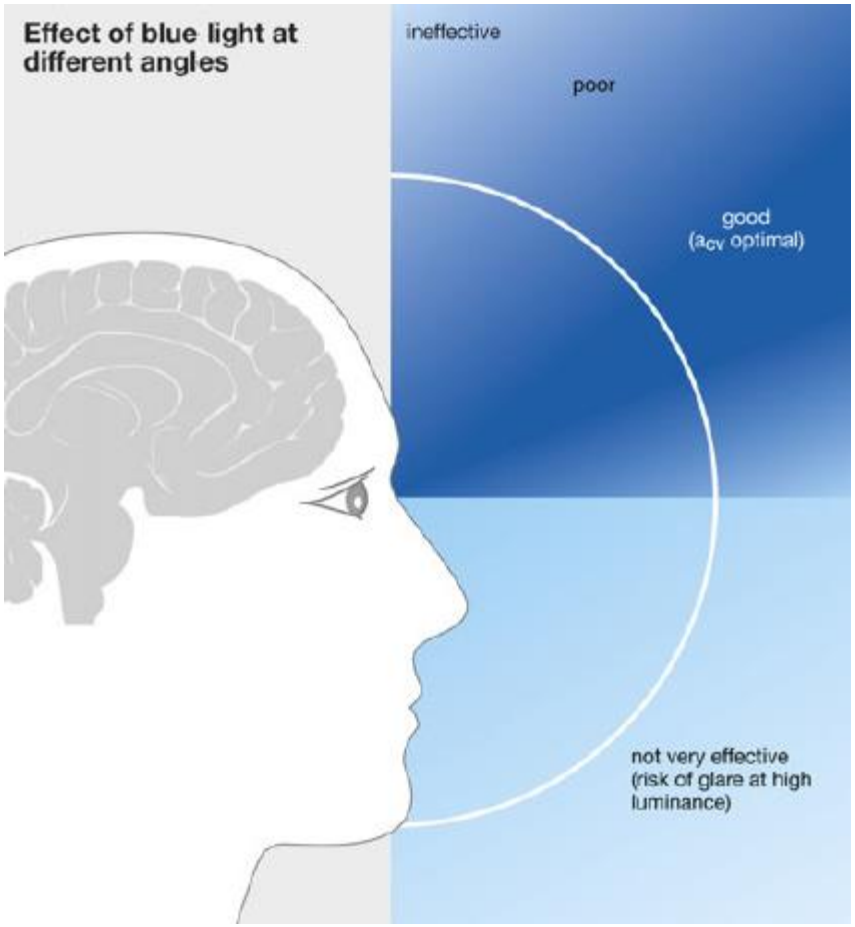


Third photo-receptor



- Scientists in 2002 discovered a third photoreceptor in the retina (ipRGC).
  - Its function is not visual.
  - It is a special ganglion cell, distributed over the entire retina being more frequent and sensitive in lower part of eye.

Third photo-receptor



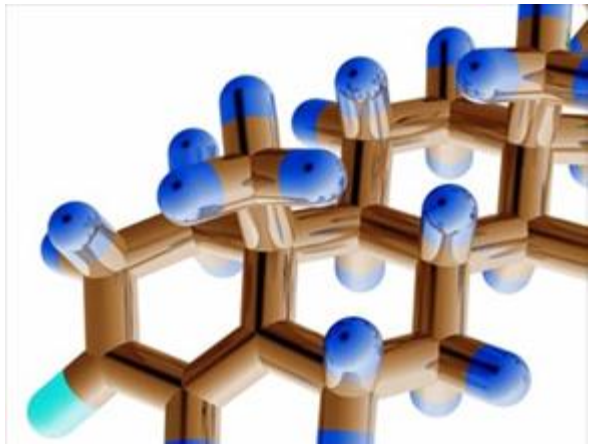
- Thirt photo-receptor (ipRGC) contains melanopsin, a light-sensitive protein .
- Melanopsin is most sensitive to the blue light of the visible spectrum (460 nm).

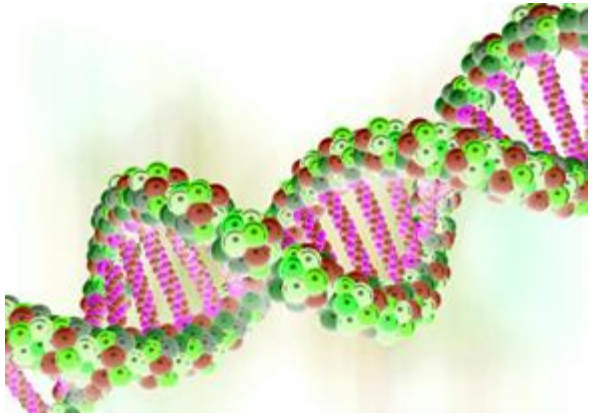
Light acts as pacemaker

- The crucial cues for the SCN are provided by light.

- ipRGC send signals through the retinohypothalamic tract, which connects them directly with the SCN, the pineal gland and the hypothalamus: control center of the autonomic nervous system.

Hormons and genes



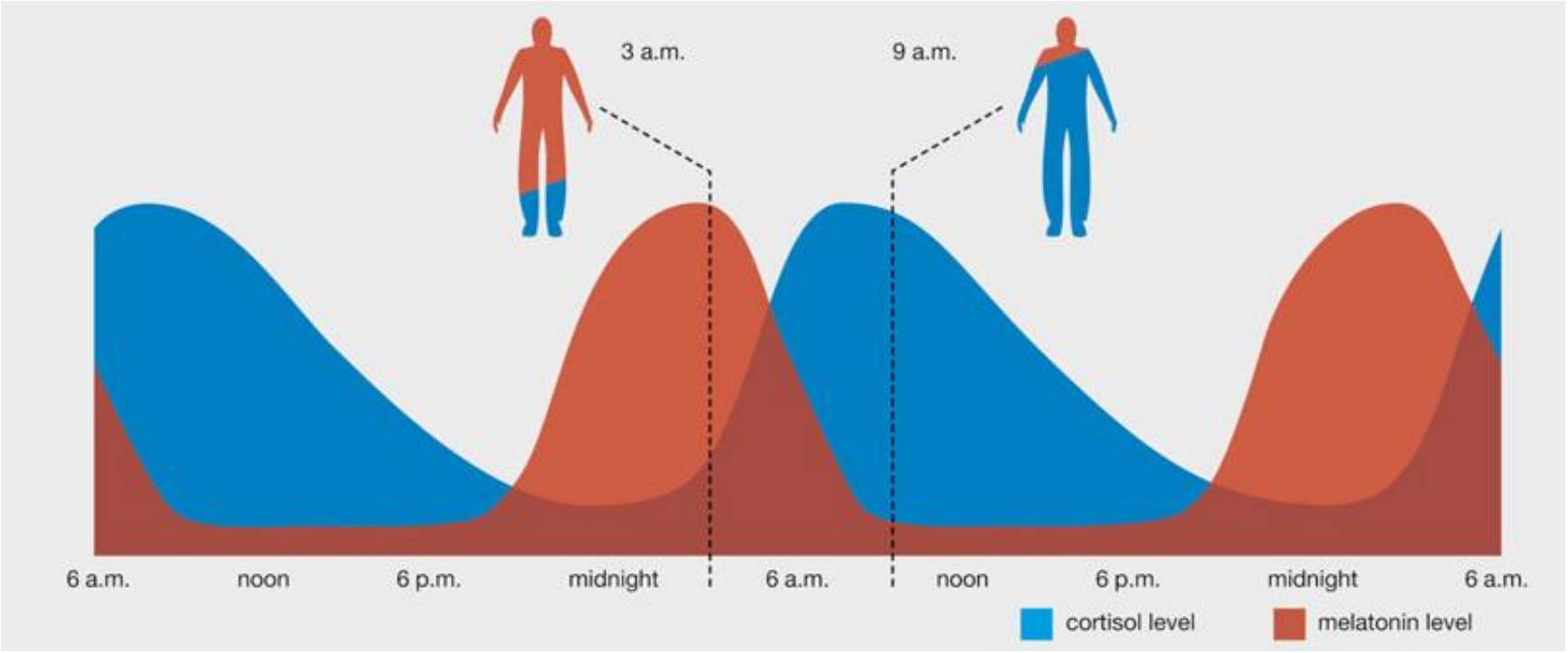


- Digestion, mood, sleep – human beings are governed by complex biochemical processes.

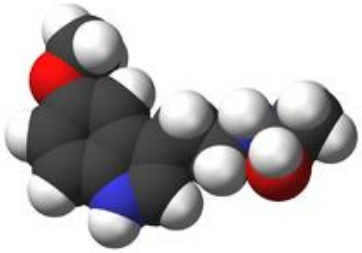
- Hormones and genes regulate when food is easily digested, when performance peaks, when sleep is at its deepest, when our body regenerates … .

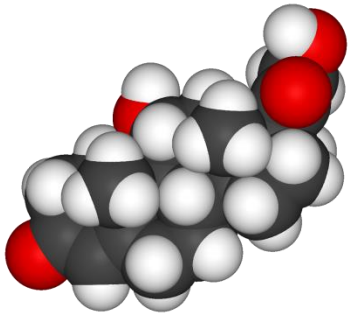
Hormons: internal clock‘s messengers

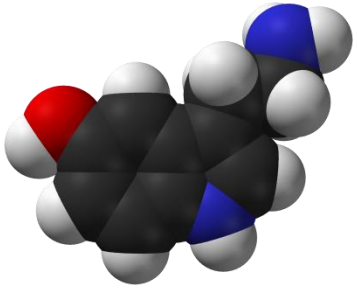
Circadian rhythms are determined particularly by melatonin and cortisol because they impact on the body in opposite cycles.



Hormons: internal clock's messengers



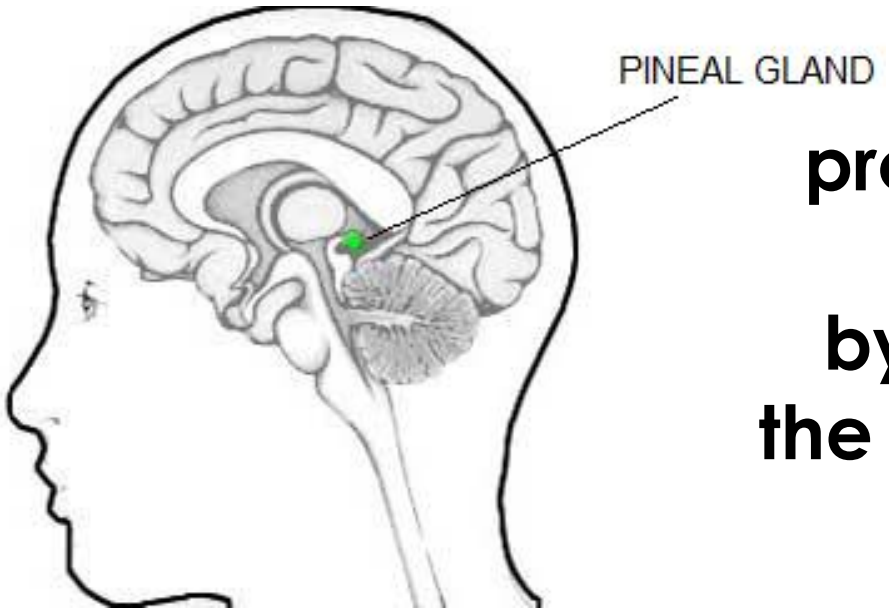




- melatonin – makes us feel drowsy, slows down bodily functions and lowers activity levels to facilitate a good night's sleep,
- cortisol – increases blood sugar, suppresses immune system, aids in fat, protein, and carbohydrate metabolism,
- serotonin – regulate mood, appetite, sleep, as well as muscle contraction

Hormons: internal clock‘s messengers

- In the evening, the pineal gland secretes melatonin, which makes us feel tired.
- In the morning, the level of melatonin in the blood then ebbs.



- The first sunlight promotes this genetically conditioned rhythm by additionally inhibiting the hormone’s production.

Biological darkness

Today life is less connected with natural rhythms:

- **shifts and windowless buildings.**
- **artificial lighting turning night into day.**

Biological darkness

- But even where lighting is fully compliant with standards, the dynamism and biological effects of daylight are missing.

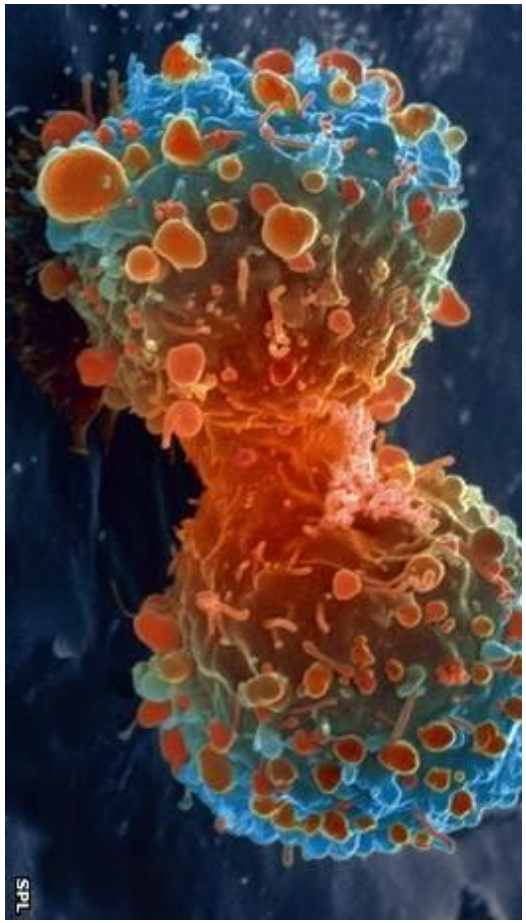
- "Biological darkness" impacts on human beings by disrupting their internal clock.

Biological darkness

Consequences:

- Heart diseases
- Diabetes
- Depresion
- Obesity
- Alzheimer‘s
- Parkinson‘s
- Cancer

Biological darkness



- Too much light = not enough melatonin.
  - Melatonin influences our sleep but also DNE regenerations and tumor suppression.
- Some cancer types like breast cancer and ovarian cancer are more common at nigh-shift workers?

Direct effects of light

Beside

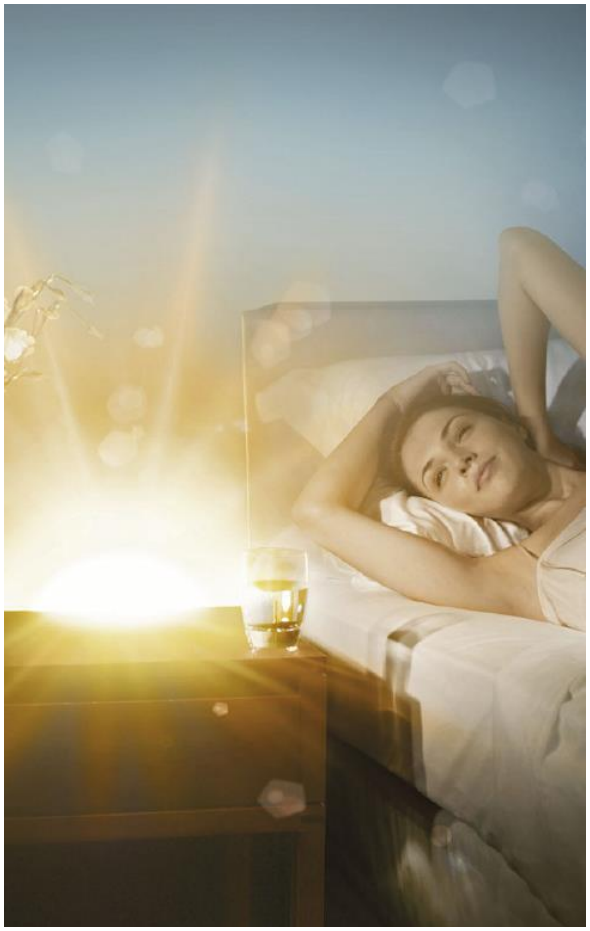
- **Circadian effects,**

which affect the daily rhythm

light also has

- **direct (non-circadian) effects, which have direct impact on welfare and not always affect the daily rhythm.**

Direct effects of light



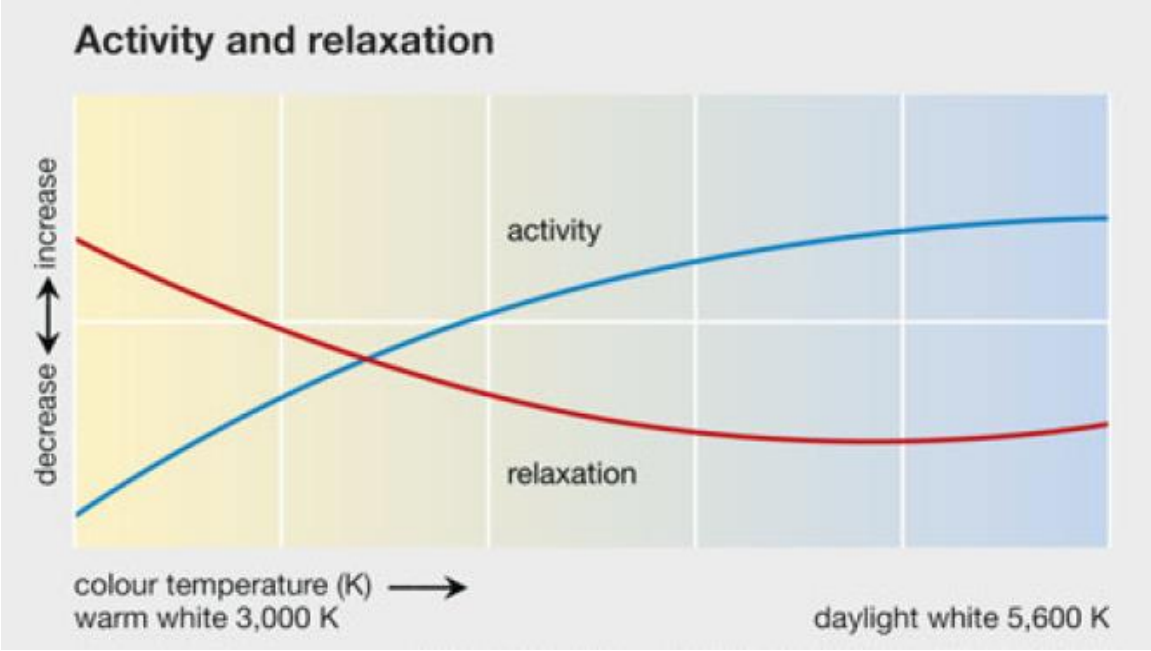
Direct effects include:

- **light at night:** reduces melatonin level and so disturb sleep;
- **bright light during day:** decreased sleepiness and fatigue;
- **bright light in the morning:** very quickly increases the level of cortisol;
- **temporary increased brightness in a room:** increases alertness.

Direct effects of light

Not only luminance but also color of light:

- **warm-white light: relaxes;**
- **day-white light: stimulates work.**



Light as drug

Nature uses light to trigger different (healing) processes in our body (genes express or stay silent).

We will use light in a same way in a future (light on prescription)

Direct effects of light on health

Direct effects of light include also effects on our health:

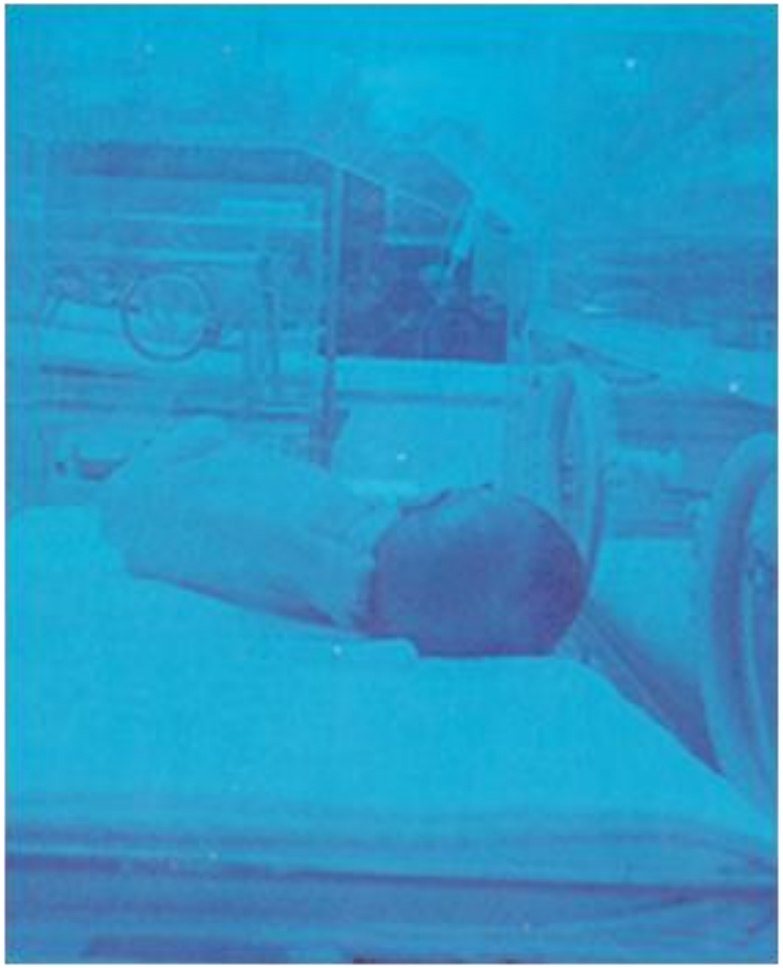
- **Wound healing**
- **Immune response**
- **Muscle coordination**

e.g. patients in daylit rooms with view to outside spent in average 2,7 days less in hospital.

Light and health

Seasonal affective disorder (SAD), a mood disorder that occurs in the darker months of the year, can be successfully treated with light.

Light and health



Light can also be used as a therapy for other diseases:

- neonatal jaundice
- inflammation
- edema
- pain relief
- healing of wounds.

Light and health

Not only visible light influences human health but also infrared (IR) and ultraviolet (UV) light:

- **we feel IR light as heat**
- **UV light causes some chemical reactions: browning, formation of vitamin D, accelerate exchange of substances in the muscles.**

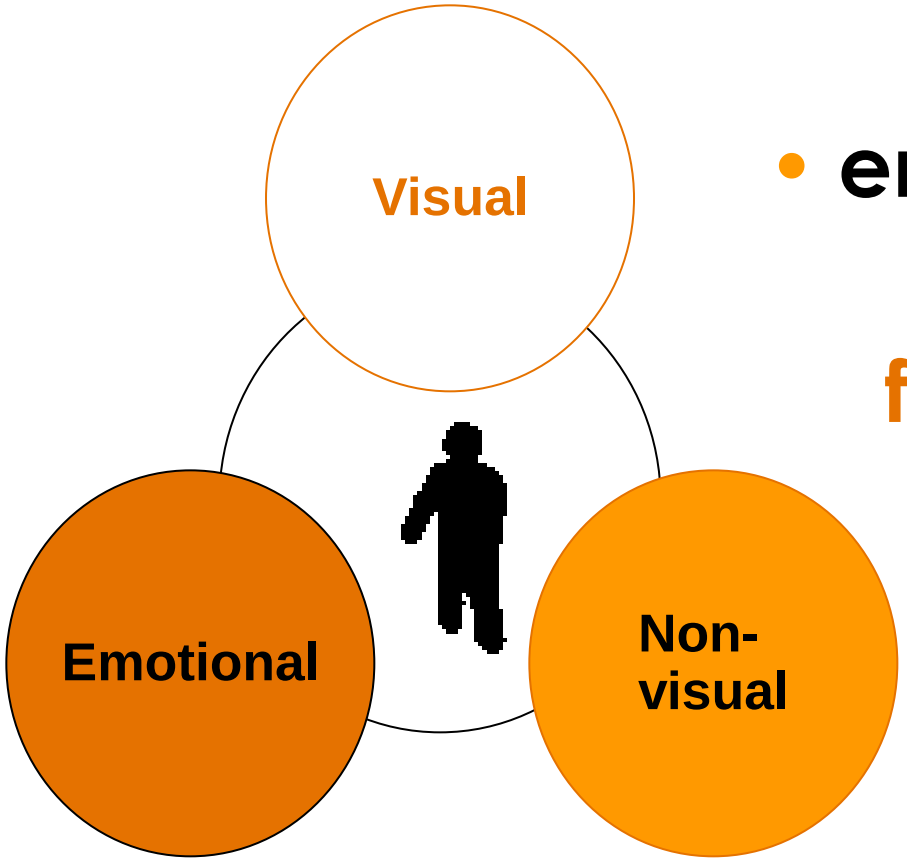
Light and health hazard

UV light

causes also negative effects: sunburns, injuries of the eyes (conjunctivitis – acute inflammation of the conjunctiva, which is 10 times more sensitive to UV light as skin).

Therefore it is necessary to protect the eyes from UV light with a wavelengths below 315 nm.

Emotional effects of light



Light:

- enables our **vision**,
- regulates the **functioning** of our body, and also
- influences our **emotions**.

Light and emotions

Where would you fell better?

Light and emotions

Light also affects the welfare of people:

- Good lighting increases attention and activity which contributes to improving job skills.
- Bad lighting make us fell uncomfortable and our willingness to work will fall

More than just vision

Today we know that lighting is much more than just providing good visibility of the observed objects.

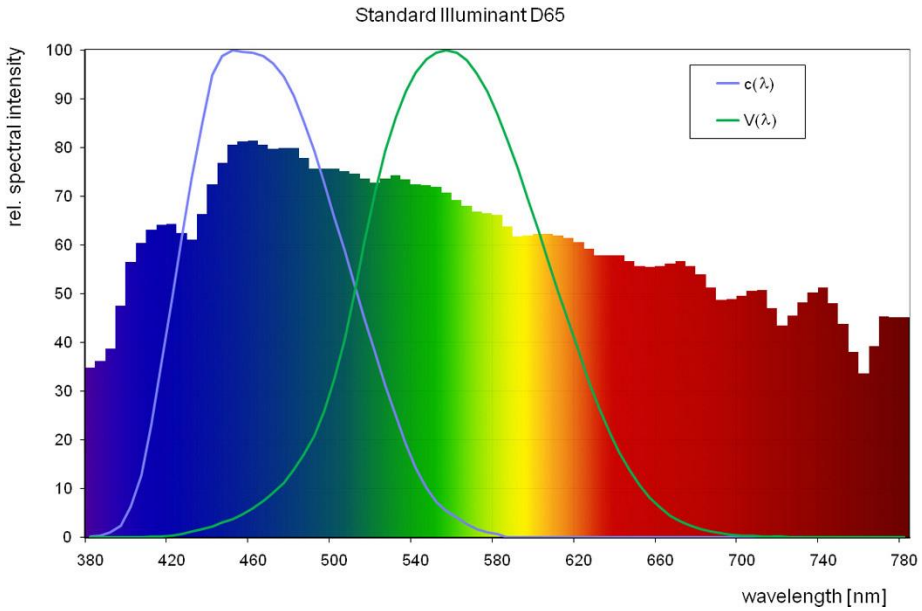
How to make it biologically and emotionally effective?

Biologically effective lighting

In many cases daylight can be used for interior lighting part of the day. For the rest we use artificial lighting.

Daylight is biologically effective so the artificial lighting should complement the daylight in interiors and not to compete with it.

Biologically effective lighting



Needed parameters:

- **Illuminance (500 lx to 1500 lx)**
- **Planarity (ceiling and walls)**
- **Direction of light (from front and above)**
- **Color temperature (daylight)**
- **Dynamism.**

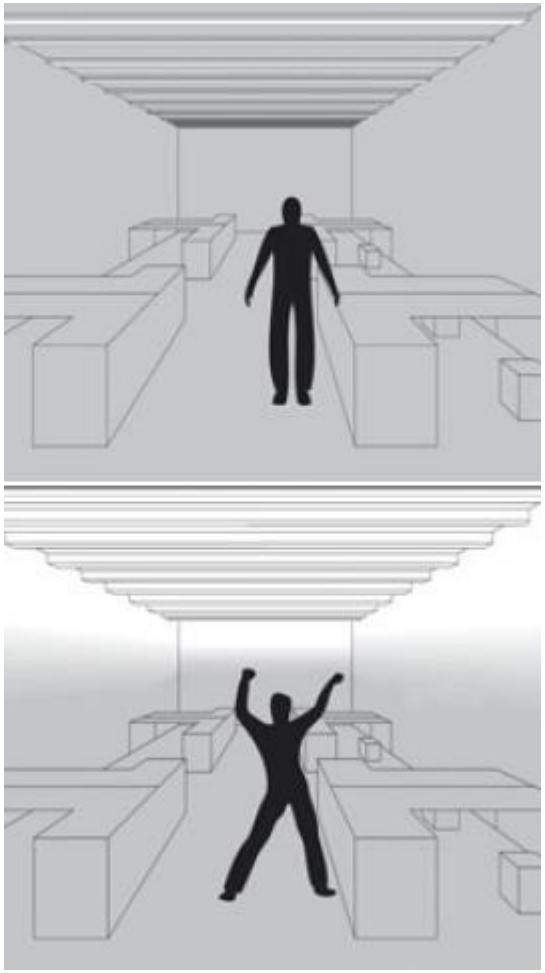
Biologically effective lighting

Biologically effective lighting should mimic daylight:

Dynamic lighting control:

- **changes in illuminance,**
- **changes in color;**
- **changes in direction**

Biologically effective lighting



Biologically effective lighting should mimic daylight:

Natural light distribution:

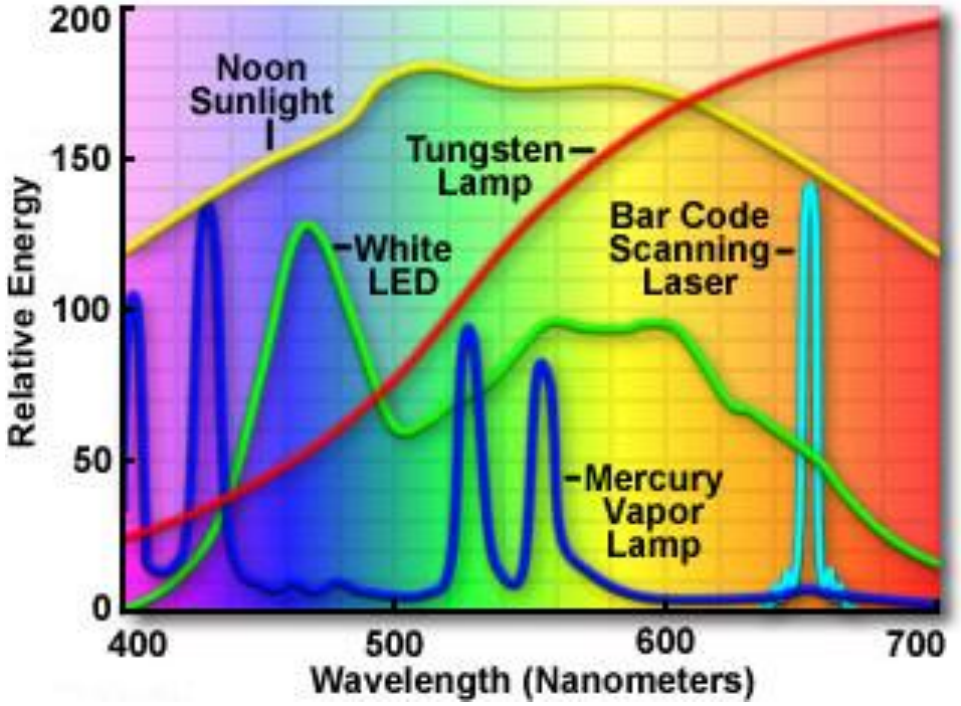
- **Light from above and from the front.**
- **Large area luminaires or reflecting ceiling and walls.**

Biologically effective lighting

Biologically effective lighting should mimic daylight:

Natural light spectrum:

- **The biologically effective range is the blue spectrum around 460 nm.**

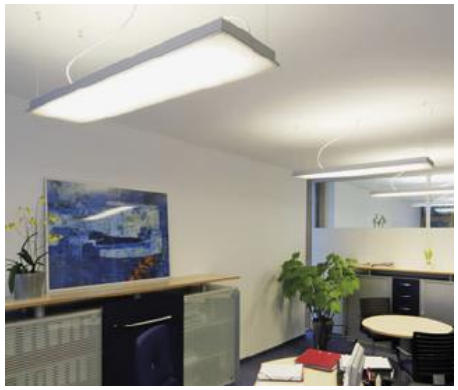


Some lighting design tips

Lighting features:

- It should meet all visual requirements (EN 12464).
- Attention should be given also to luminous distribution.
- No glare or other disturbing effects.

Some lighting design tips



Color of light:

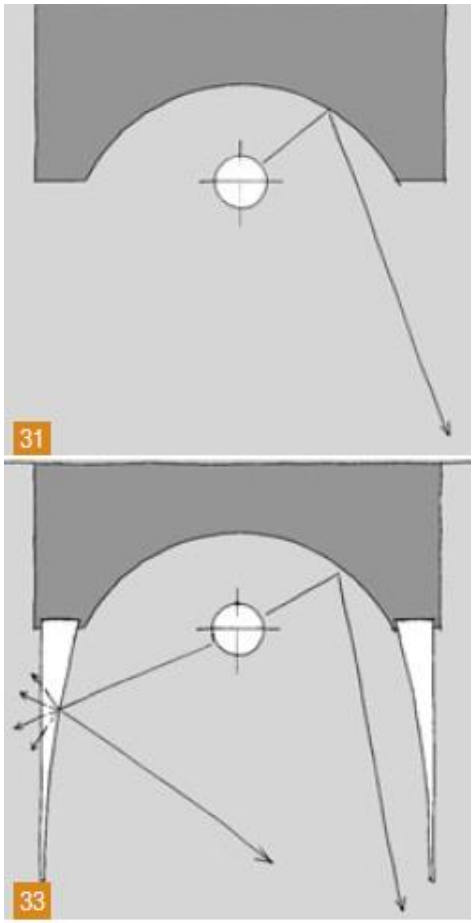
- Dynamic if possible: colder during the day, warmer at evening.
- If not dynamic than according to use of interior: colder for work, warmer for relaxation.

Some lighting design tips

Spatial distribution of light:

- Large area luminaires.
- Indirect luminaires which illuminates ceiling and upper part of walls.
- Ceiling and wall washers.

Some lighting design tips



Materials:

- Optical control elements of luminaires (louvers, enclosures, prisms) should not change the spectrum of light.
- Also the colours of interiorr can change spectrum (red and brown absorb blue light).

I hope you remembered:

- More than 80 % of information from the environment come through the vision!
  - No light no vision!
- Four minimum requirements need to be met to permit perception: minimum luminance, contrast, size and time!
  - Good lighting can help, bad lighting might be disturbing!

At the end

- Light affects not only our vision but also our functionality, health and welfare.
- Daily contact with outside world (daylight) is important for out internal clock.
- Biologically effective lighting has a positive influence on the overall human functioning.

… and now:

Questions?