Depth perception

psychological cues

rely on knowledge
of the world / expectations
(a good painting could use
them to give an impression of depth)

physiological cues

rely on physics
(a painting, however good,
cannot reproduce those cues)

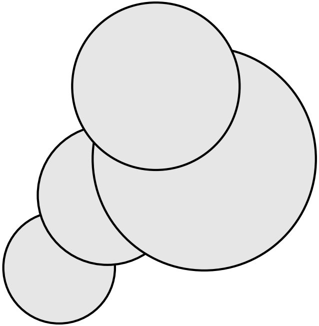
Psychological cues (1): relative size

retinal projection depends on both size and distance

with well-calibrated *expectations* for sizes, can infer depth:

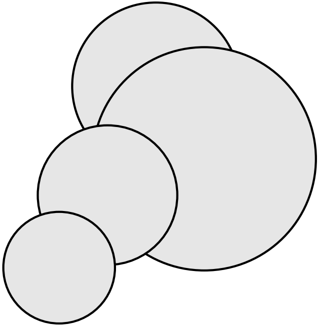
Psychological cues (2): occlusion

objects in the background are occluded by objects in the foreground



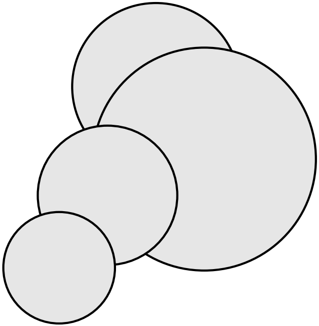
Psychological cues (2): occlusion

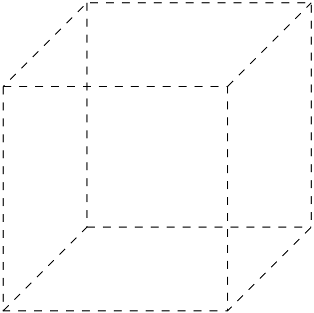
objects in the background are occluded by objects in the foreground



Psychological cues (2): occlusion

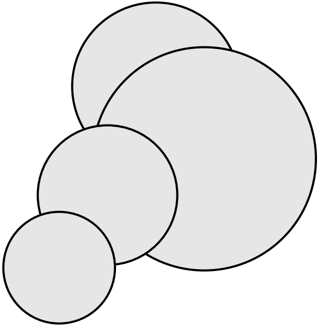
objects in the background are occluded by objects in the foreground

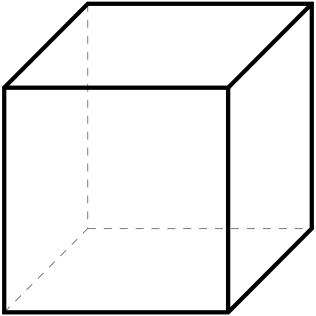




Psychological cues (2): occlusion

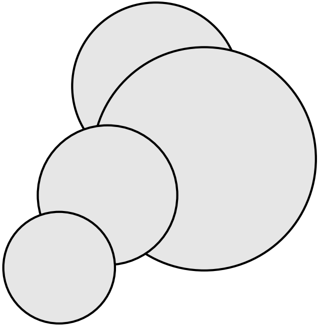
objects in the background are occluded by objects in the foreground

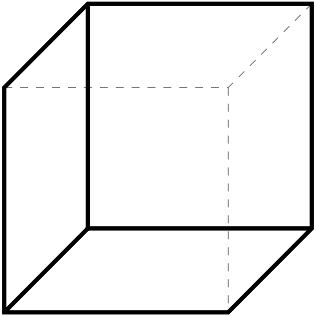




Psychological cues (2): occlusion

objects in the background are occluded by objects in the foreground



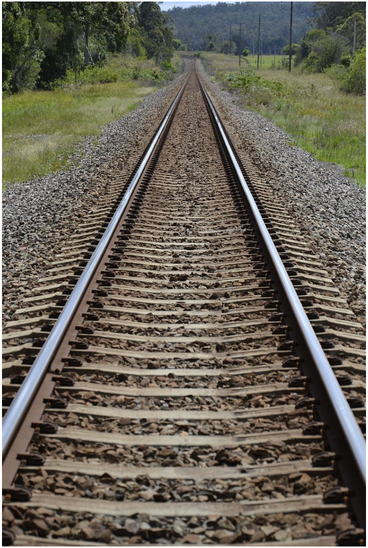


Psychological cues (3): linear perspective

parallel lines converge at the horizon

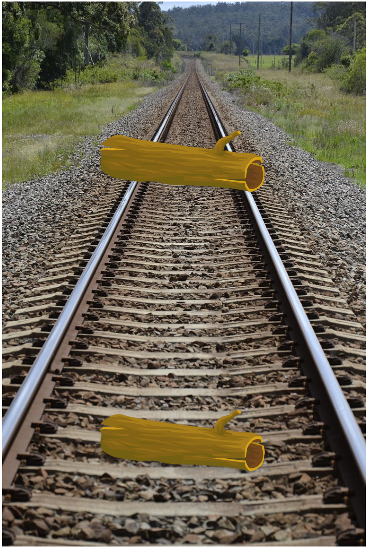
Psychological cues (3): linear perspective

parallel lines converge at the horizon



Psychological cues (3): linear perspective

parallel lines converge at the horizon



(knowledge of relative sizes
make bottom log appear
smaller than top log)

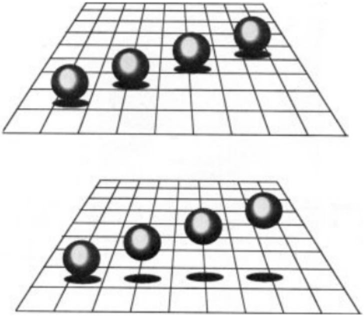
Psychological cues (4): aerial perspective

relative blur: scattering of light means distant objects appear more blurred

relative colour: blue light scatters more, so distant objects appear blueish

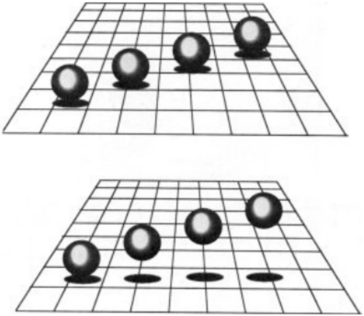
Psychological cues (5): shadow / illumination

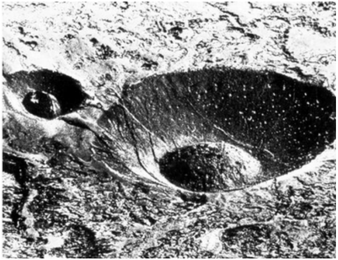
light typically comes from above



Psychological cues (5): shadow / illumination

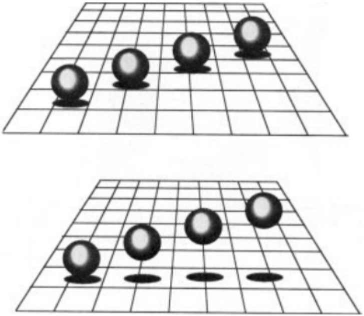
light typically comes from above

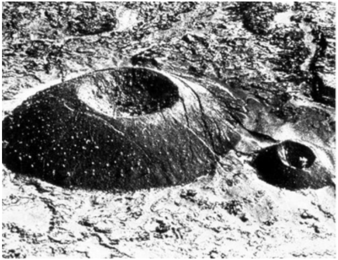




Psychological cues (5): shadow / illumination

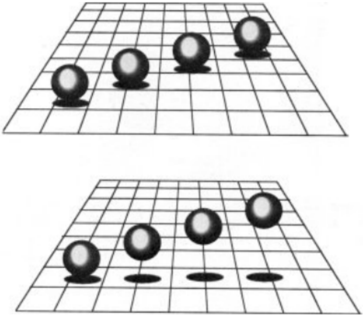
light typically comes from above

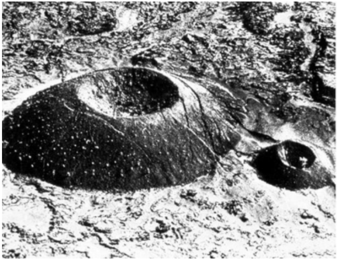


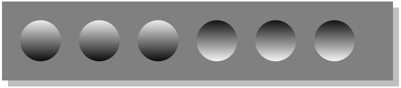


Psychological cues (5): shadow / illumination

light typically comes from above

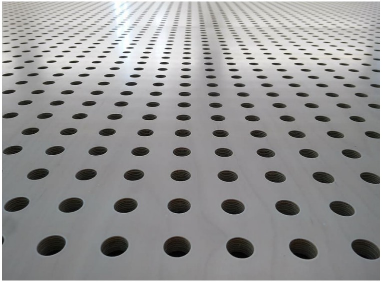






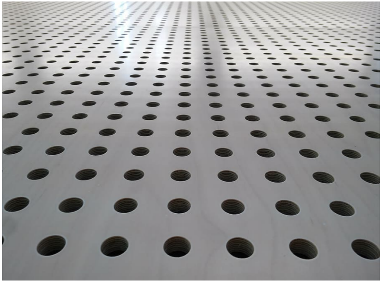
Psychological cues (6): texture gradients

assuming uniform textures, texture gradients tell depth

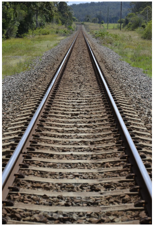


Psychological cues (6): texture gradients

assuming uniform textures, texture gradients tell depth



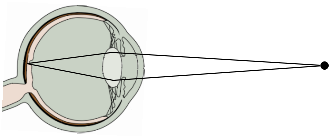
and recall:



Physiological cues (1): accomodation & vergence

the brain adjusts the
focal length of the lenses
to ensure images remain
crisp at any depth

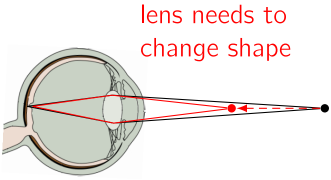
the associated control signals depend on depth!



Physiological cues (1): accomodation & vergence

the brain adjusts the
focal length of the lenses
to ensure images remain
crisp at any depth

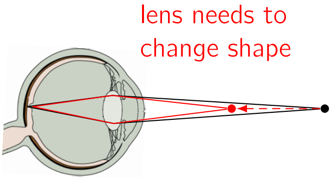
the associated control signals depend on depth!



Physiological cues (1): accomodation & vergence

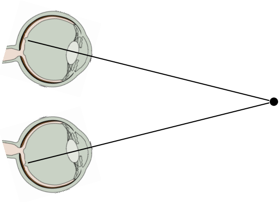
the brain adjusts the focal length of the lenses to ensure images remain crisp at any depth

the associated control signals depend on depth!



the brain controls the angle made by the two eyes to set the fixation point

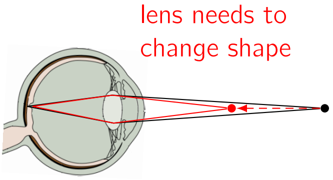
the associated control signals depend on depth!



Physiological cues (1): accomodation & vergence

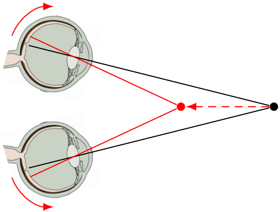
the brain adjusts the
focal length of the lenses
to ensure images remain
crisp at any depth

the associated control signals depend on depth!



the brain controls the angle
made by the two eyes
to set the fixation point

the associated control signals depend on depth!



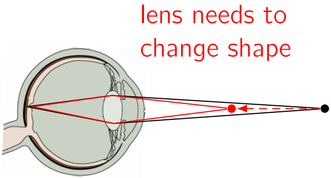
Physiological cues (1): accomodation & vergence

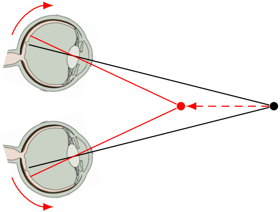
the brain adjusts the
focal length of the lenses
to ensure images remain
crisp at any depth

the associated control signals depend on depth!

the brain controls the angle
made by the two eyes
to set the fixation point

the associated control signals depend on depth!

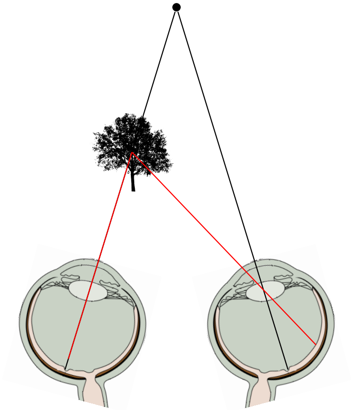




both cues become weak at long viewing distances

Physiological cues (2): binocular disparity

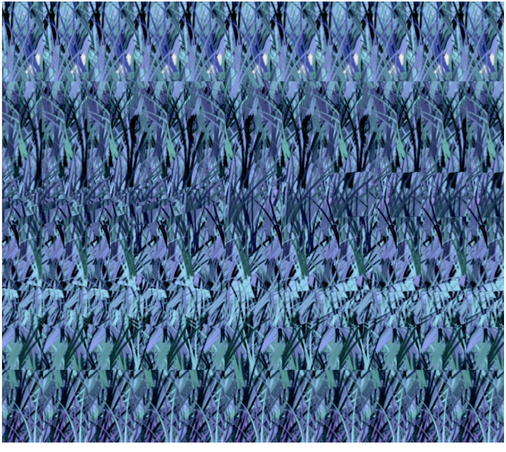
two eyes separated by ~ 6 cm, so each eye sees a slightly different view
$\rightarrow$ yields binocular disparity for < 20 m
which gives information about depth *relative to fixation plane*



Physiological cues (2): binocular disparity

two eyes separated by ~ 6 cm, so each eye sees a slightly different view
$\rightarrow$ yields binocular disparity for < 20 m
which gives information about depth *relative to fixation plane*

depth perception doesn't depend on recognition (random autostereograms)

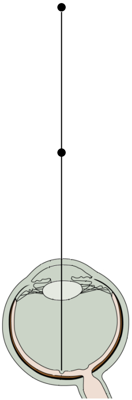


Physiological cues (3): motion parallax

even with one eye closed, we can move our head sideways
and infer depth from the relative motion of objects on retina

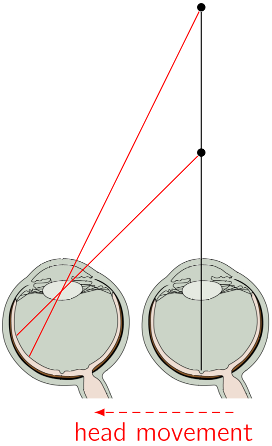
Physiological cues (3): motion parallax

even with one eye closed, we can move our head sideways and infer depth from the relative motion of objects on retina

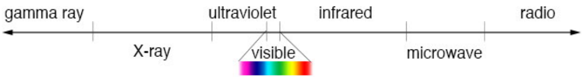


Physiological cues (3): motion parallax

even with one eye closed, we can move our head sideways
and infer depth from the relative motion of objects on retina



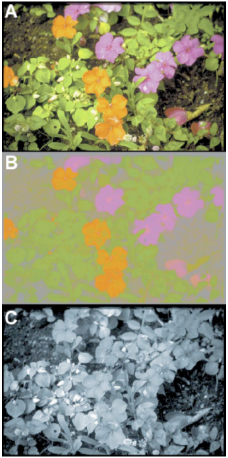
Color vision: why?



380–760nm

benefits in addition to luminance:

- recognise things faster
- remember things better

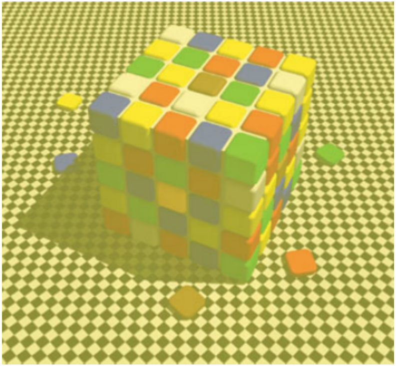


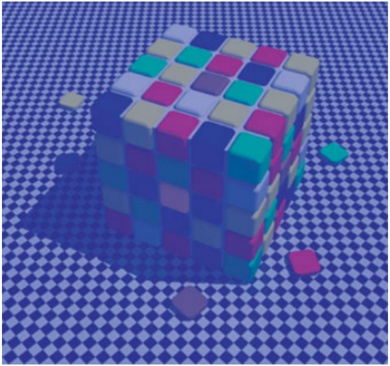
original image

isoluminant version

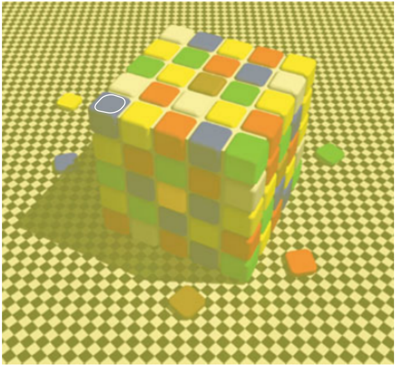
monochromatic version

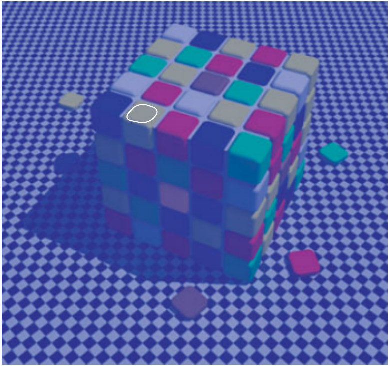
Colour vision is non-trivial: color constancy



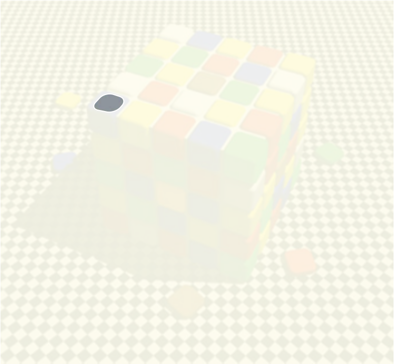


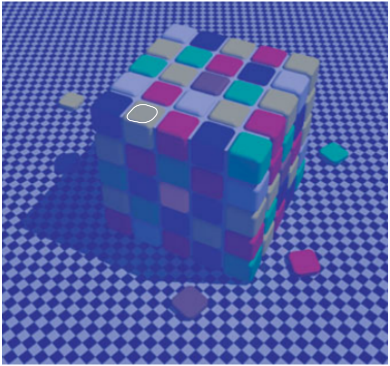
Colour vision is non-trivial: color constancy



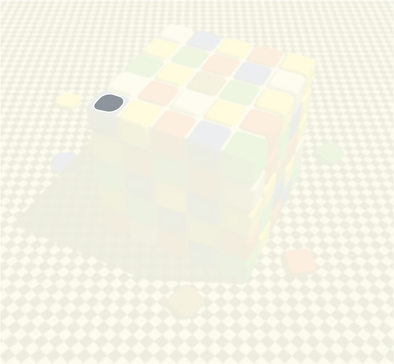


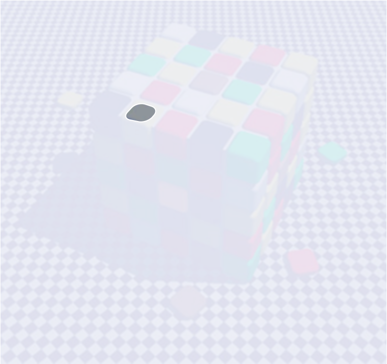
Colour vision is non-trivial: color constancy





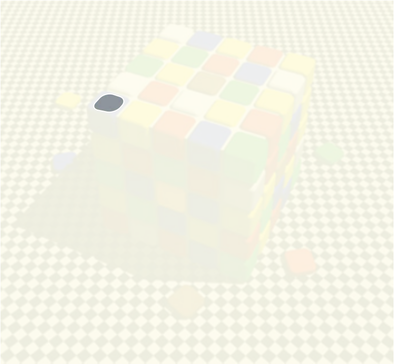
Colour vision is non-trivial: color constancy

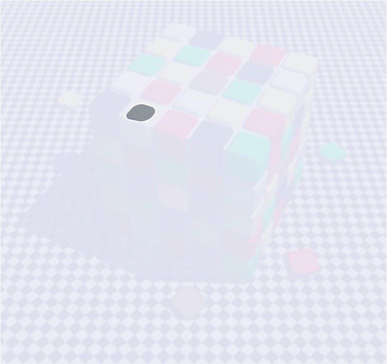




Colour vision is non-trivial: color constancy

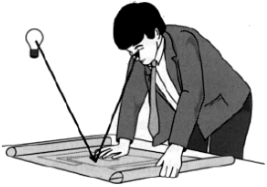
overall illuminant spectrum can be considered a nuisance factor
$\rightarrow$ the brain seems to be able to discount it





Spectral composition of light

how do we even define the "color" of a thing?



spectrum of light reaching the eye
is the product of:

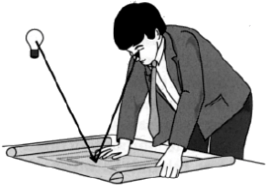
- spectrum of the illuminant
  (but the light source can vary. . .)
- reflectance of the surface
  (a fixed property of an object!)

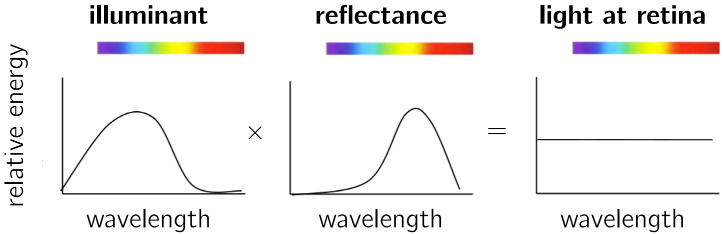
Spectral composition of light

how do we even define the “color” of a thing?

spectrum of light reaching the eye
is the product of:

- spectrum of the illuminant
  (but the light source can vary. . .)
- reflectance of the surface
  (a fixed property of an object!)



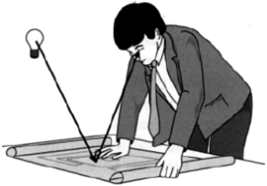


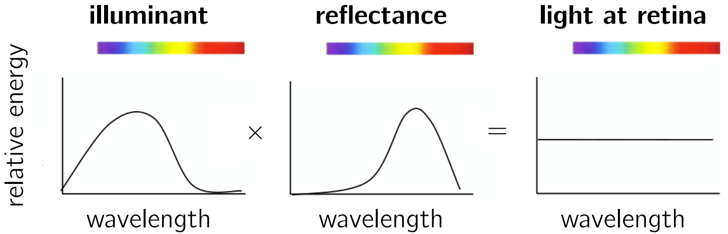
Spectral composition of light

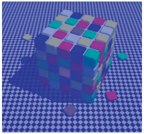
how do we even define the “color” of a thing?

spectrum of light reaching the eye
is the product of:

- spectrum of the illuminant
  (but the light source can vary. . .)
- reflectance of the surface
  (a fixed property of an object!)





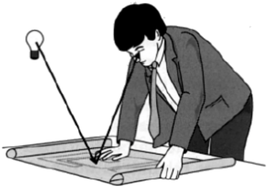


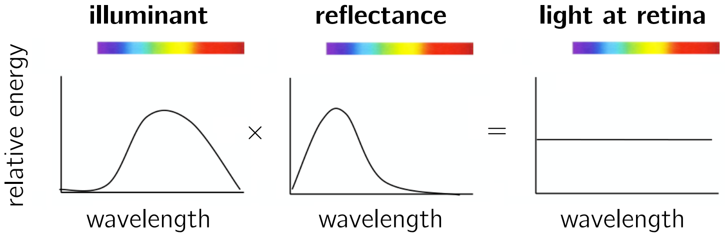
Spectral composition of light

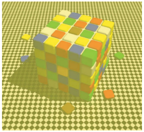
how do we even define the "color" of a thing?

spectrum of light reaching the eye
is the product of:

- spectrum of the illuminant
  (but the light source can vary. . .)
- reflectance of the surface
  (a fixed property of an object!)





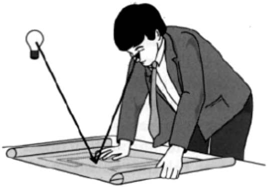


Spectral composition of light

how do we even define the “color” of a thing?

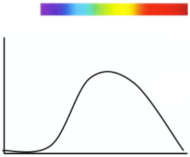
spectrum of light reaching the eye
is the product of:

- spectrum of the illuminant
  (but the light source can vary. . .)
- reflectance of the surface
  (a fixed property of an object!)



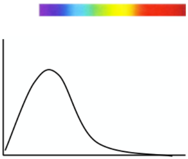
illuminant | **reflectance** | **light at retina**

relative energy



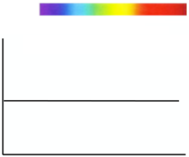
wavelength

×

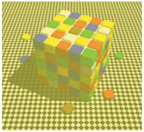


wavelength

=



wavelength



INFERRED | **PERCEIVED** | **OBSERVED**

cf. 3G3
next year

Ambiguity in colour vision

probability of photon absorption varies with wavelength

but once a photon is absorbed, information about wavelength is lost!

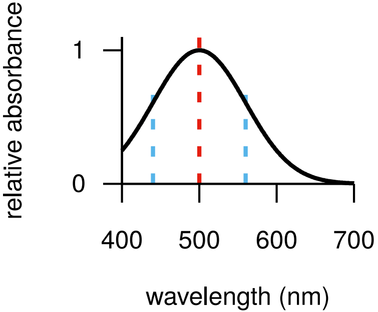
Ambiguity in colour vision

probability of photon absorption varies with wavelength

but once a photon is absorbed, information about wavelength is lost!

so, there is a

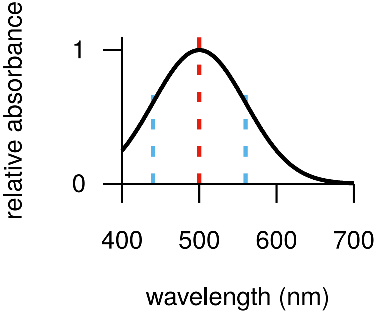
fundamental ambiguity:



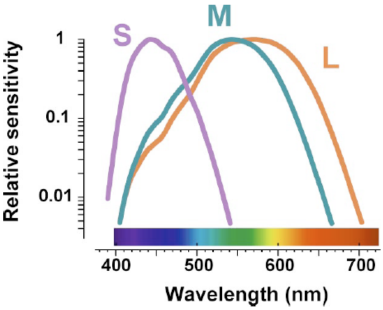
Ambiguity in colour vision

probability of photon absorption varies with wavelength
but once a photon is absorbed, information about wavelength is lost!

so, there is a
fundamental ambiguity:



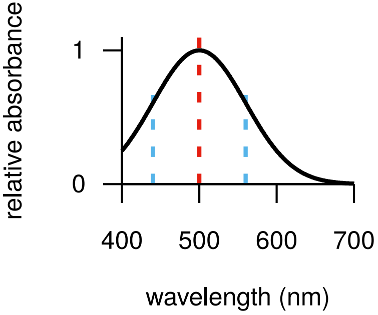
that's why we have
3 types of cones



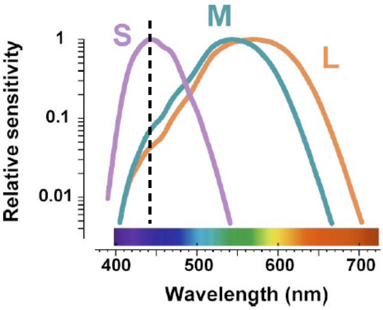
Ambiguity in colour vision

probability of photon absorption varies with wavelength
but once a photon is absorbed, information about wavelength is lost!

so, there is a
fundamental ambiguity:



that's why we have
3 types of cones

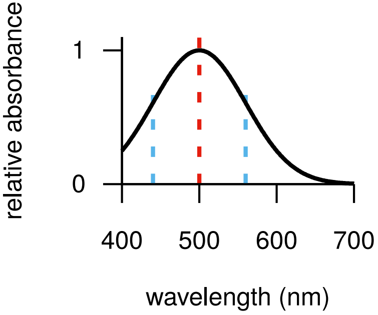


Ambiguity in colour vision

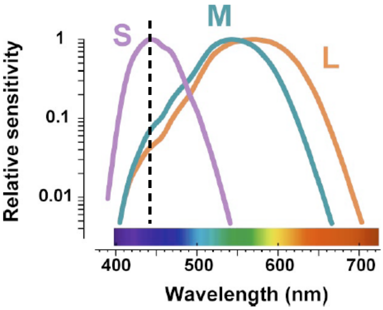
probability of photon absorption varies with wavelength

but once a photon is absorbed, information about wavelength is lost!

so, there is a
fundamental ambiguity:



that's why we have
3 types of cones

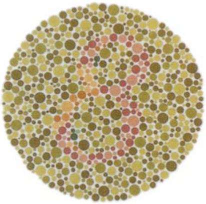


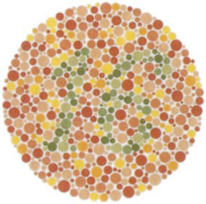
can disambiguate a single wavelength, but most surfaces produce a whole range

our color vision is 3-dimensional $\rightarrow$ there exist imaginary colors!

Colour blindness

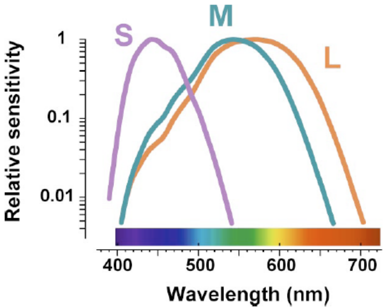
$\sim$ 1% of the population lack L/M distinction





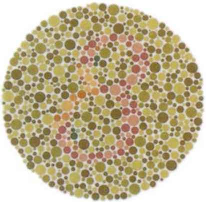
(can you read the numbers?)

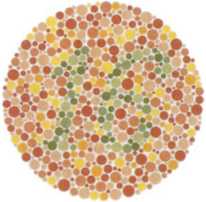
that's why we have **3 types of cones**



Colour blindness

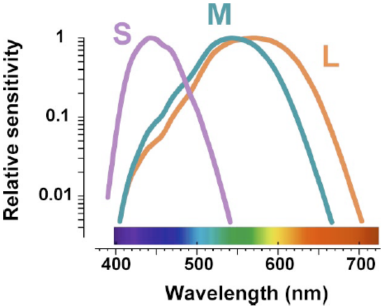
$\sim 1\%$ of the population lack L/M distinction





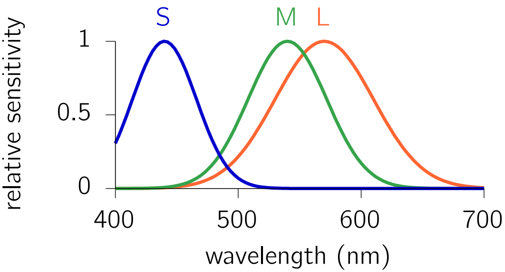
(can you read the numbers?)

that's why we have
3 types of cones



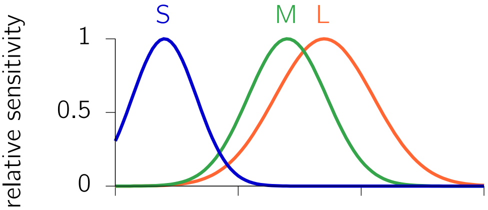
how are signals from 3 cone types assembled / processed downstream?

Color opponent channels

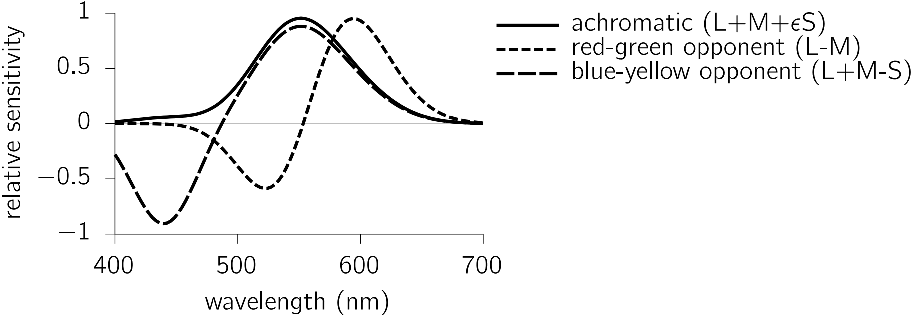


our color vision is three-dimensional

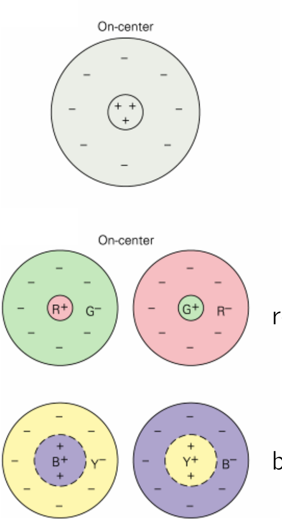
Color opponent channels



our color vision is three-dimensional



Color selectivity in retinal GCs

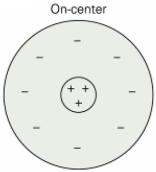


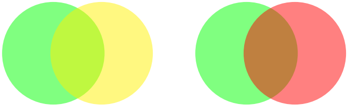
red/green opponency

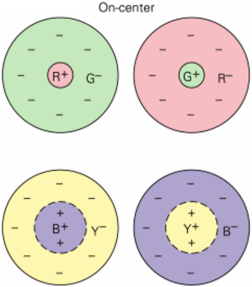
blue/yellow opponency

Color selectivity in retinal GCs

- no "greeny-red" or "bluey-yellow"





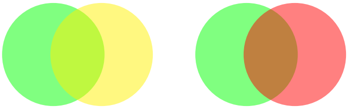


red/green opponency

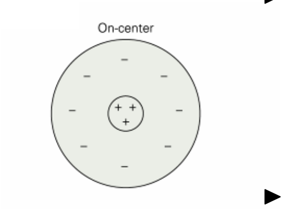
blue/yellow opponency

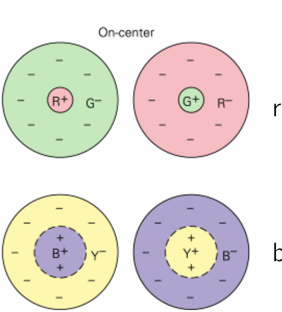
Color selectivity in retinal GCs

- no "greeny-red" or "bluey-yellow"



- explanation for castle colouring effect: aftereffect due to post-inhibitory rebound

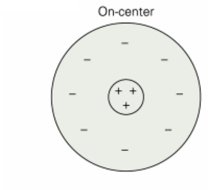




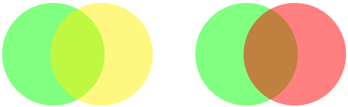
red/green opponency

blue/yellow opponency

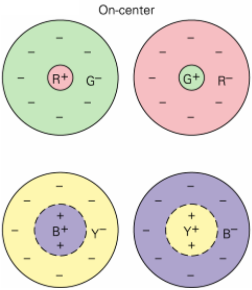
Color selectivity in retinal GCs



- no "greeny-red" or "bluey-yellow"



- explanation for castle colouring effect: aftereffect due to post-inhibitory rebound



red/green opponency

blue/yellow opponency

in what sense are these 3 channels ideal?

PCA for reflectance spectra

- measure reflectance spectra of natural surfaces (obtain a large dataset)
- these are functions of the wavelength $\rightarrow$ infinite-dimensional
- is there a *finite* set of basis functions with which we can express any natural reflectance spectrum with good accuracy?
- PCA: what basis functions capture most of the variations in reflectance across all surfaces?

PCA for reflectance spectra

- measure reflectance spectra of natural surfaces (obtain a large dataset)
- these are functions of the wavelength $\rightarrow$ infinite-dimensional
- is there a *finite* set of basis functions with which we can express any natural reflectance spectrum with good accuracy?
- PCA: what basis functions capture most of the variations in reflectance across all surfaces?