Lenses

Converging lenses

positive
convex

Thicker in the center than on the edge

Diverging lenses

negative
concave

Thicker on the edge than in the center

Ray optics describes light in terms of rays – light rays are lines showing the direction of passing light.

Lenses refract the light rays.

Parallel rays passing through a positive lens converge to a focal point behind the lens.

Parallel rays passing through a negative lens diverge as if they were coming from a virtual focal point in front of it.

Parallel rays: all rays that are parallel to the optical axis will converge to a point behind the lens

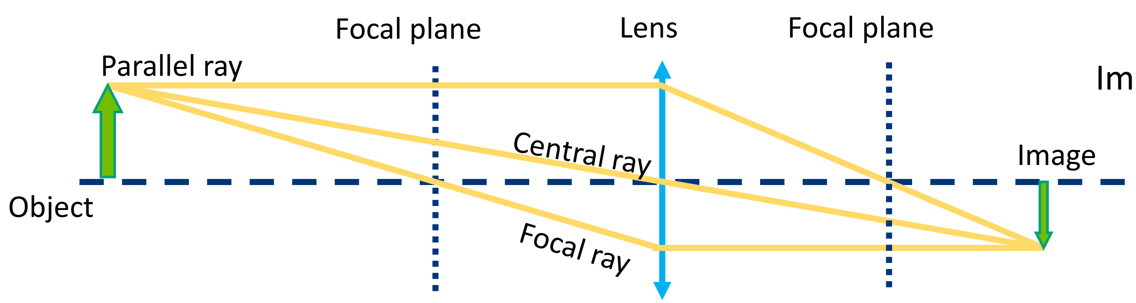

Image formation with lenses

Optical axis that is perpendicular to the lens plane a goes throug its central point

Focal rays: all rays that pass through the focal point will be parallel to the optical axis after passing through the lens a

Central rays: in an approximation, the central rays will pass the lens without being refracted

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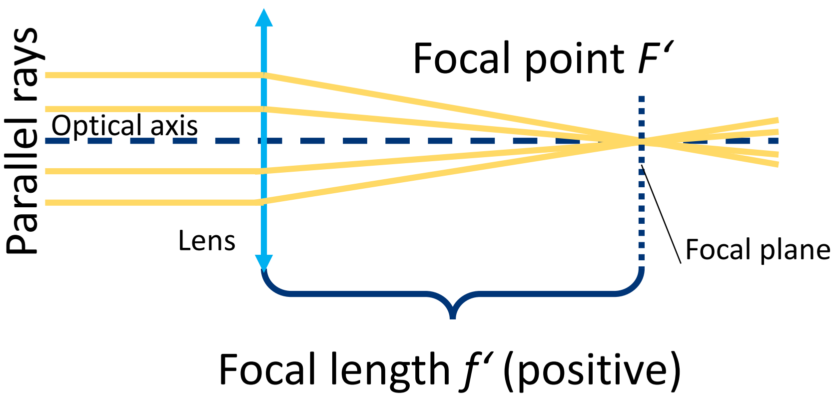
Positive Lenses



Positive lenses refract all rays that are parallel to the optical axis to a single point, which is called focal point.

The magnifying glass, …

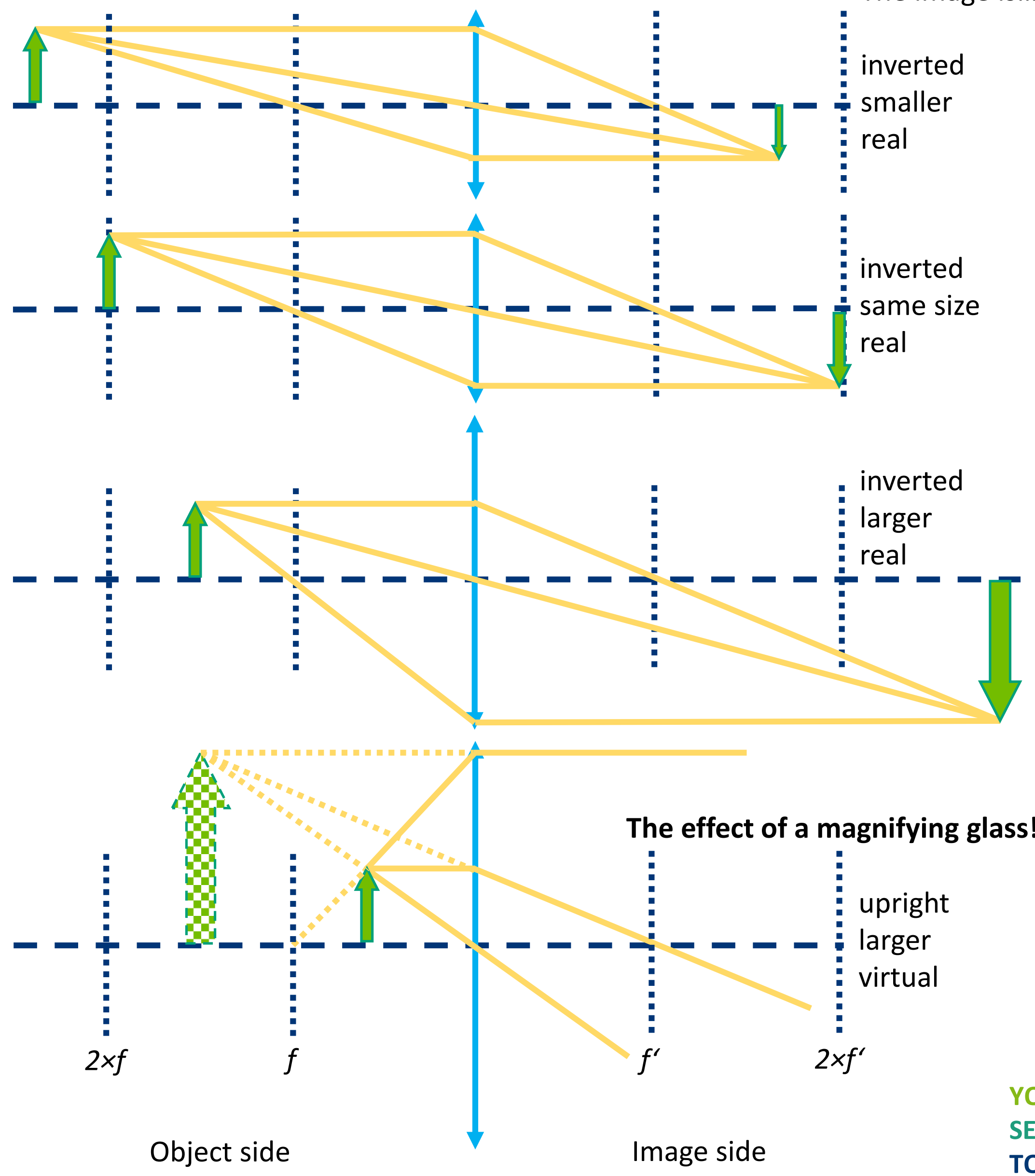
Magnification of the magnifying glass

$$m = \frac{250\ mm}{f'}$$

…, is simply a positive lens of a small focal length.

250 mm is so called conventional near-point distance. It is given by accomodation properties of the eye.

Try the lenses!



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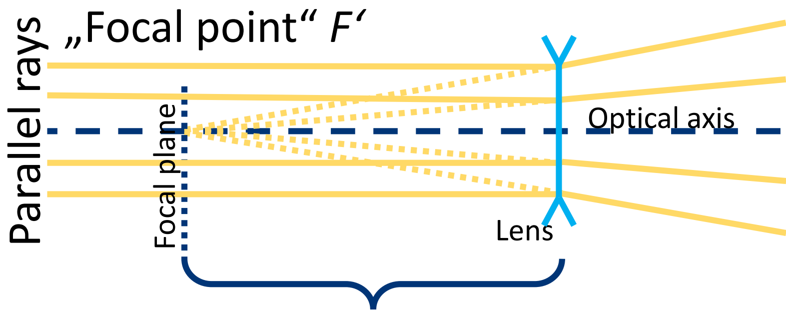
Negative Lenses

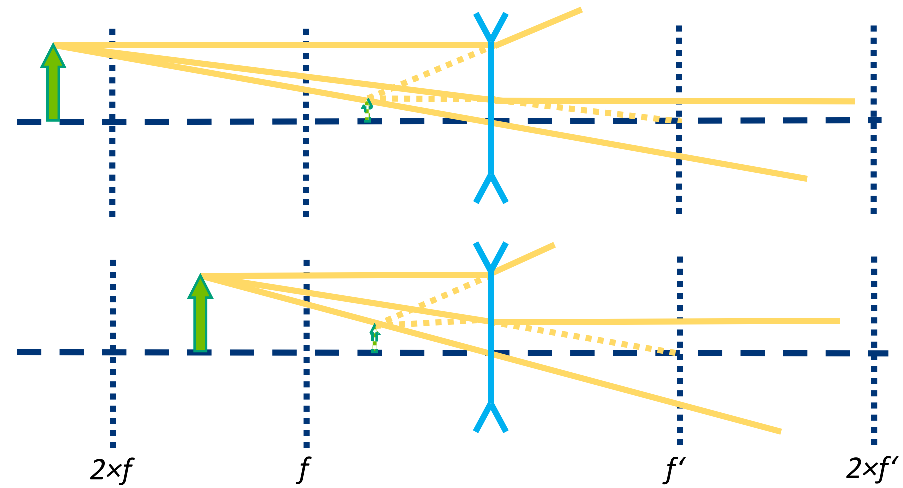


Focal length f' (negative)

The negative lenses refract all rays of light parallel to the optical axis in such a way that it seems like they are coming from a single point in front of the lens.

The image is always...

upright
smaller
virtual

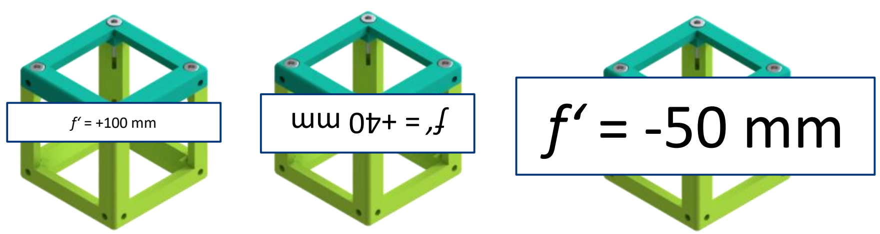


Object side

Image side

Try the lenses!

How does the image look like through different lenses?



The correct text size

With the right lens held in the right distance, the text looks like it has the same size and orientation.

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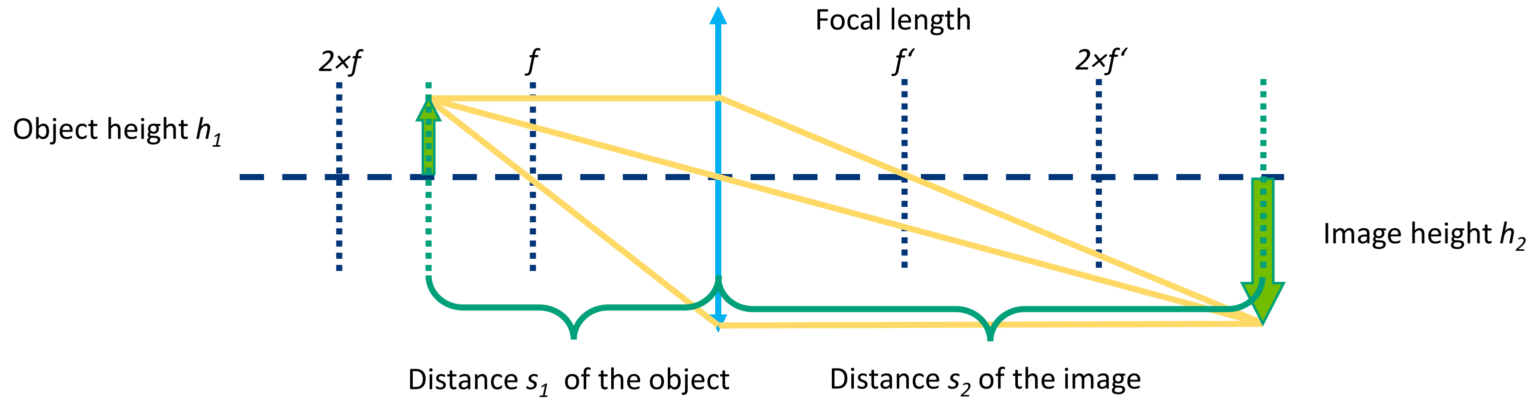
SEE,
TOO

Projector



Lens Equation

$$\frac{1}{f'} = \frac{1}{s_1} + \frac{1}{s_2}$$

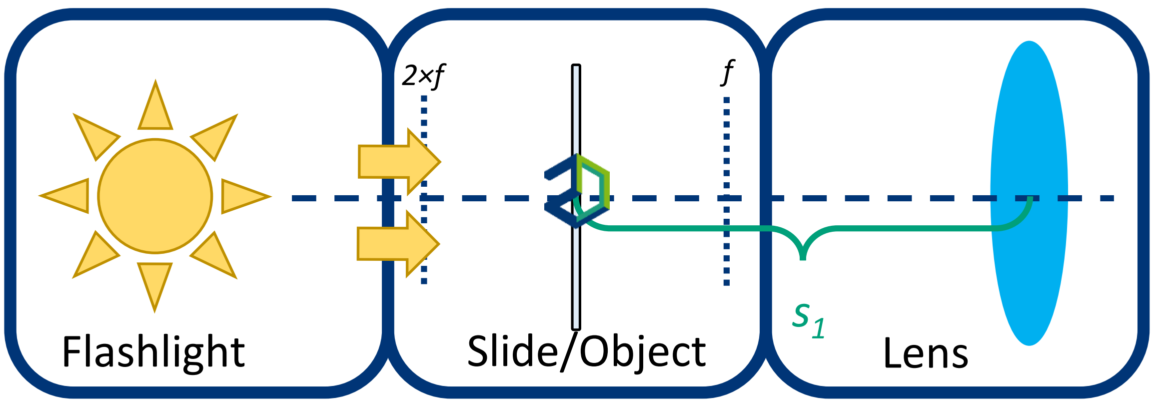
The image is not anywhere!

When imaging an object through a positive lens, the position and size of the image depend on the distance s_1 of the object from the lens and its focal length f'.

Magnification of the lens

$$m = \frac{s_2}{s_1} = \frac{h_2}{h_1}$$

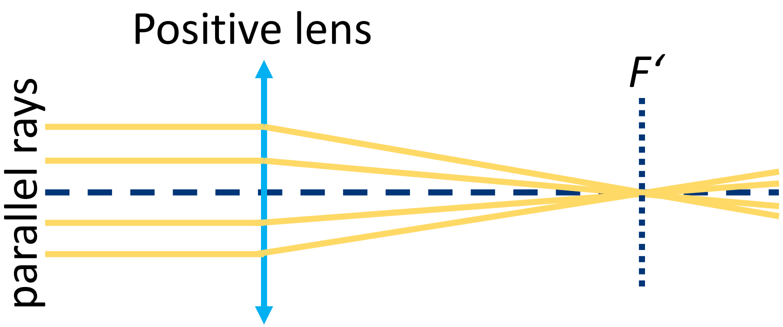
The image is not arbitrarily large!

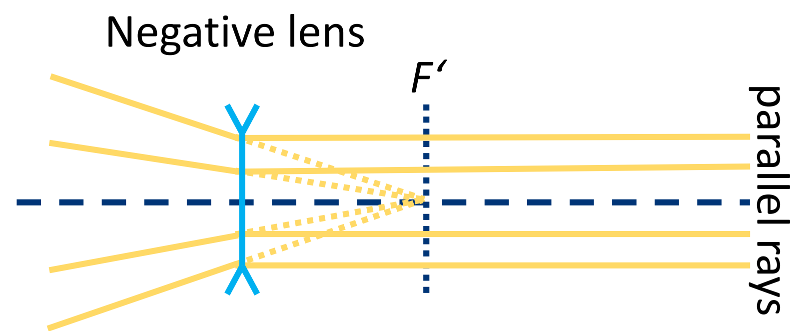


Where is the image?
What is the magnification?

- Change the distance of the lens
- Exchange the lens

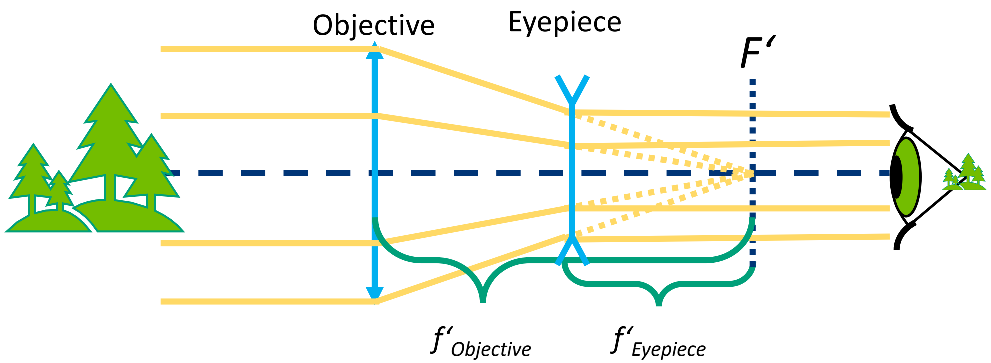
Galileian Telescope





Magnification

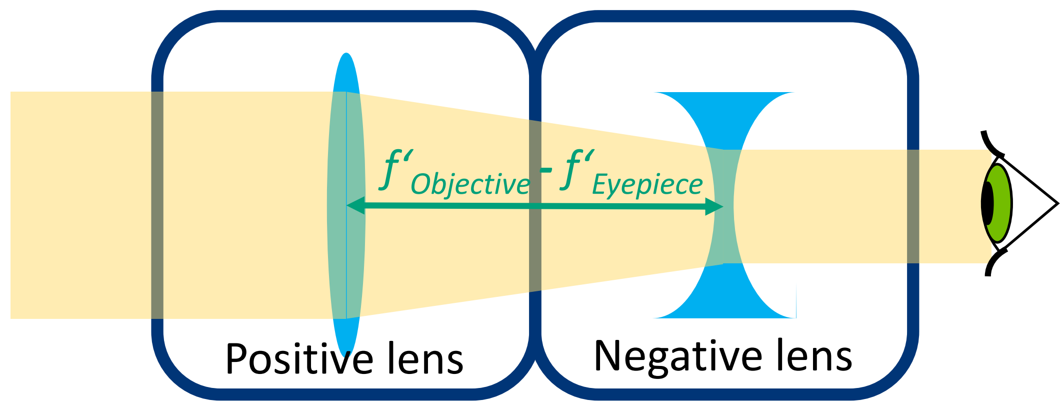
$$m = \frac{f'_{Objective}}{f'_{Eyepiece}}$$



The image is
virtual
and upright

The field of view (FOV) is
small

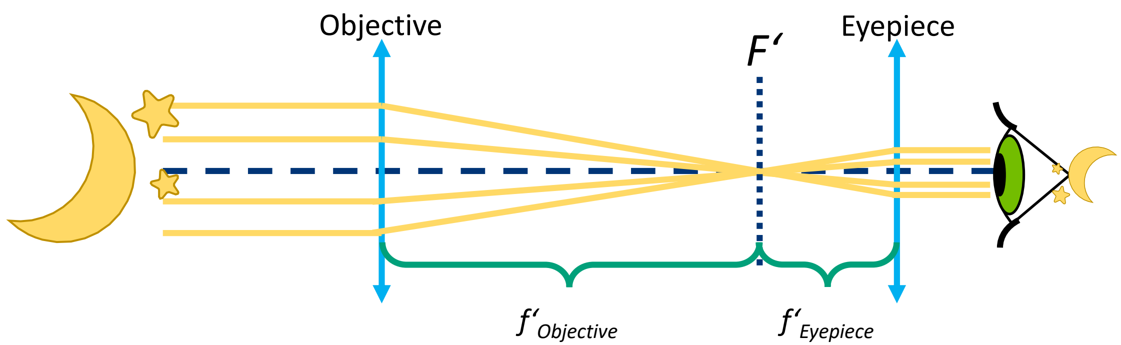
The telescope is an optical instrument that magnifies objects, which are far away.



Keplerian Telescope

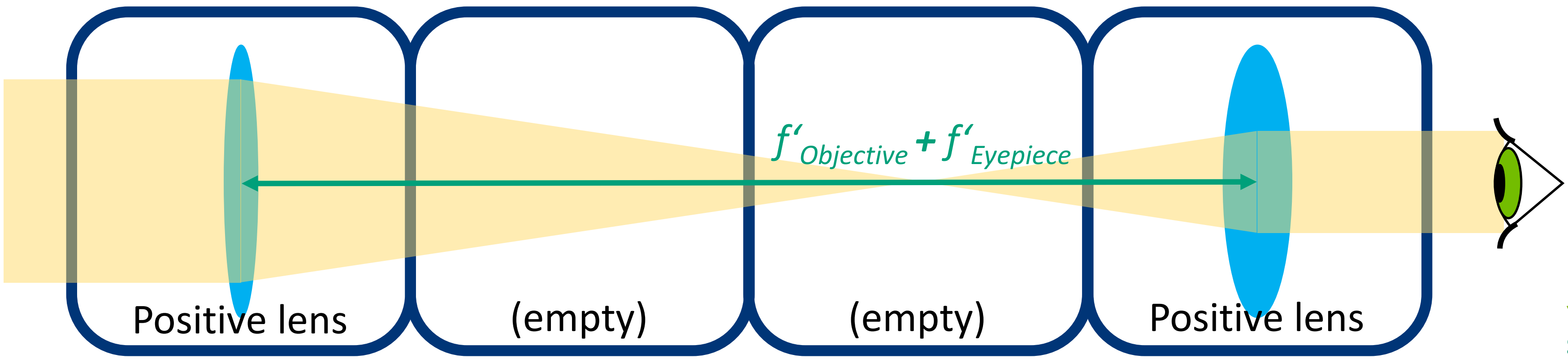
Magnification

$$m = \frac{f'_{Objective}}{f'_{Eyepiece}}$$



The image is virtual and inverted

The field of view (FOV) is larger than with the Galilean telescope



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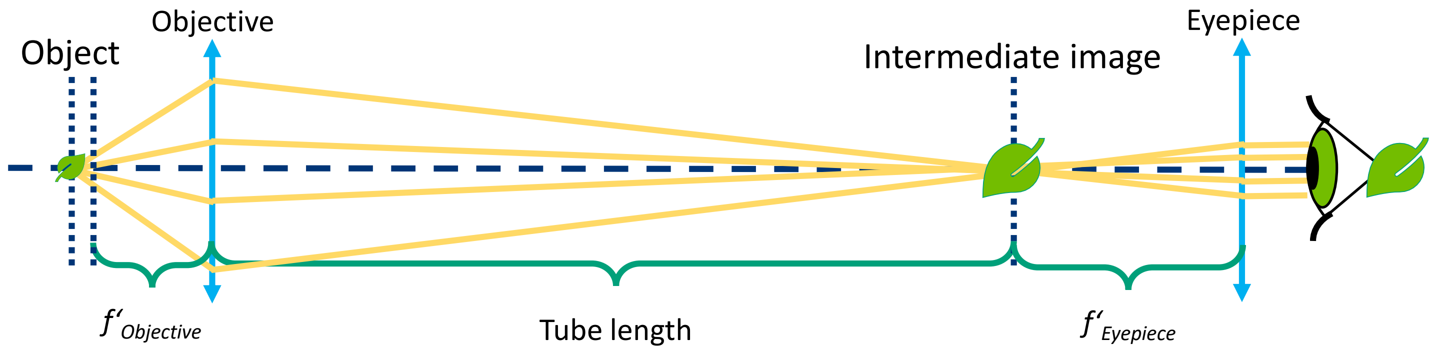
Light microscope

The microscope is an optical instrument that makes it possible to see magnified images of objects that are too small to be seen by the naked eye.



Old or simple microscopes use objectives that are designed for a defined tube length and they form a real intermediate image in a given distance from the objective. The intermediate image is further magnified by the eyepiece. These microscopes are „finite“ optical systems.

The image is...

in the intermediate image plane

inverted

larger

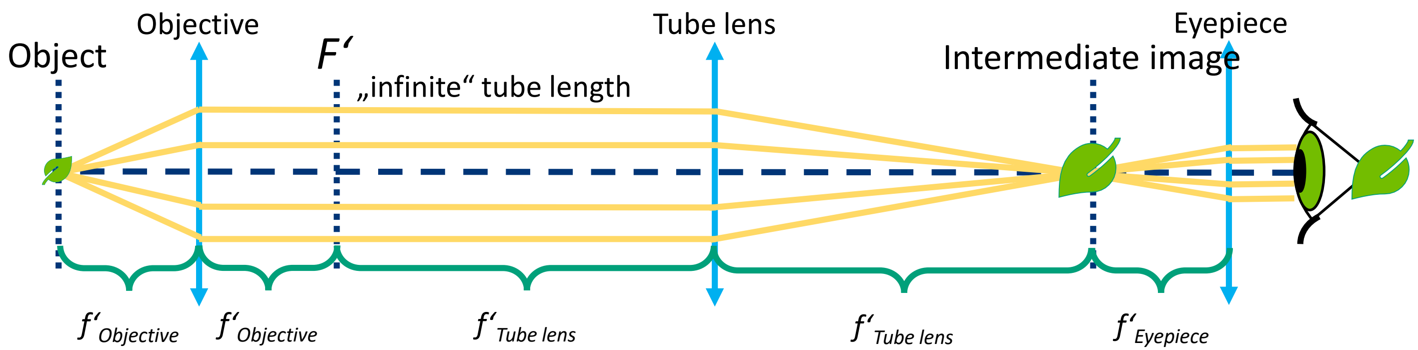
real

through the eyepiece

inverted

larger

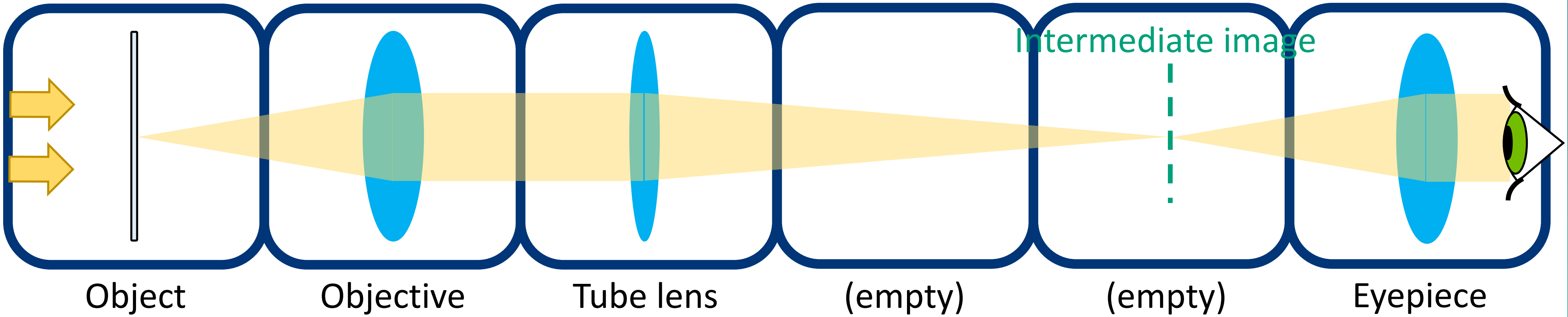
virtual

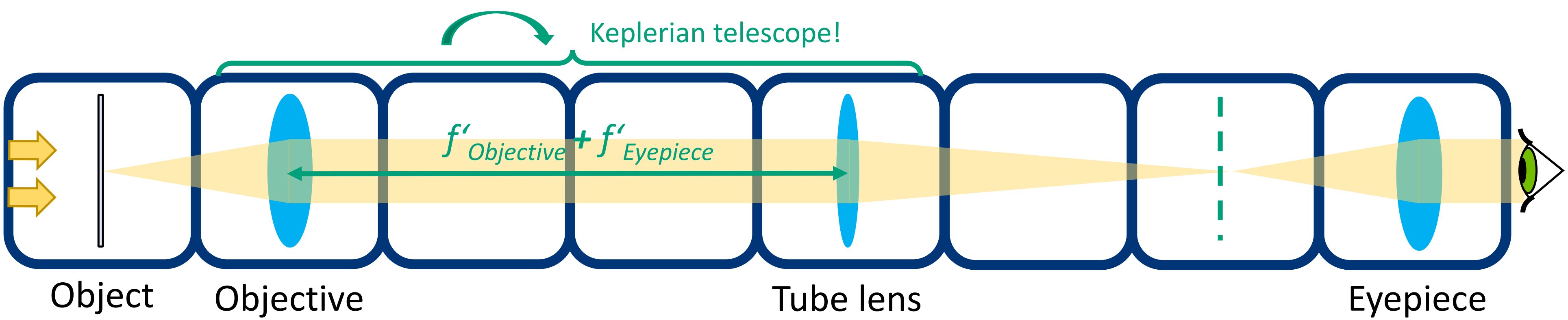


Newer microscopes use so-called „infinity“ optics. In this case, the objective doesn‘t form any real intermediate image. The light rays are parallel after passing through the objective. At the end of the tube, which can be arbitrarily long, is a tube lens that forms the intermediate image, which is then again further magnified by the eyepiece.

Light microscope

„Infinity-corrected“ microscope





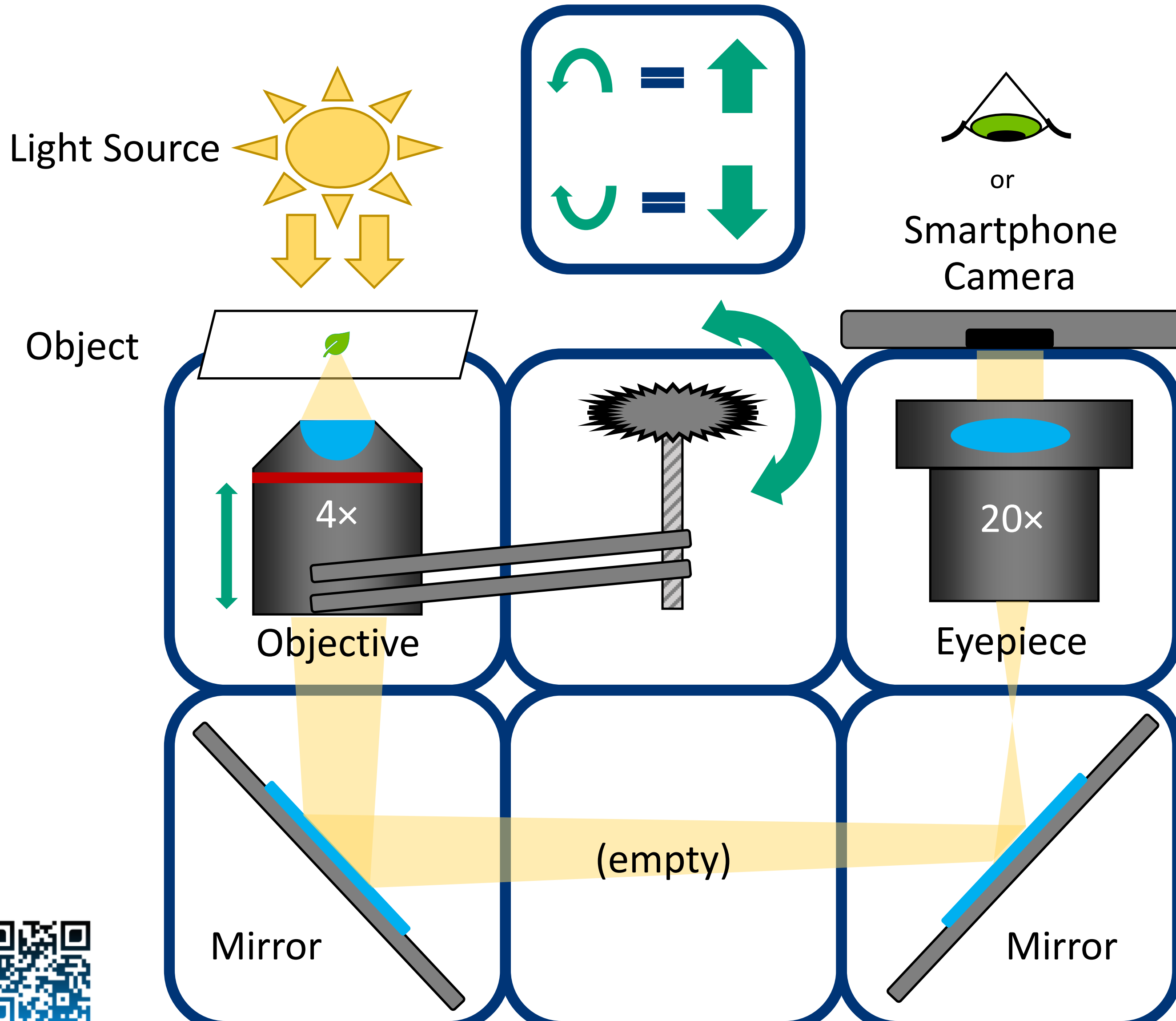
Magnification of the intermediate image

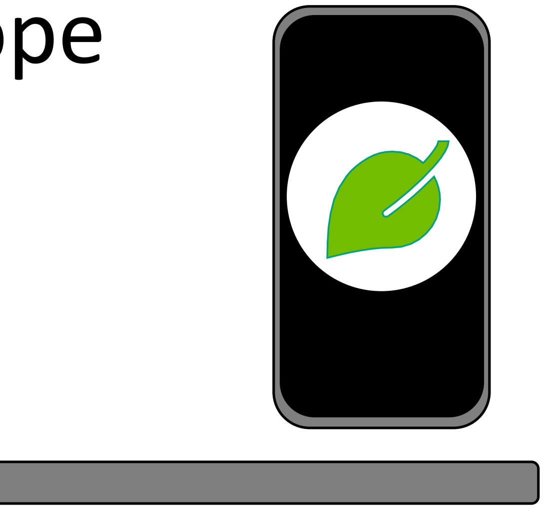
$$m = \frac{f'_{Tube\ lens}}{f'_{Objective}}$$

Total magnification

$$m = \frac{f'_{Tube\ lens}}{f'_{Objective}} \times \frac{250\ mm}{f'_{Eyepiece}}$$

Smartphone Microscope





„Finite-corrected“ microscope

The smartphone camera has a short focal length lens to create an image on the camera sensor. The imaging properties are therefore similar to those of the human eye.

Magnification

$$m = m_{Objective} \times m_{Eyepiece}$$

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