Optics/microscopy club @ MDC

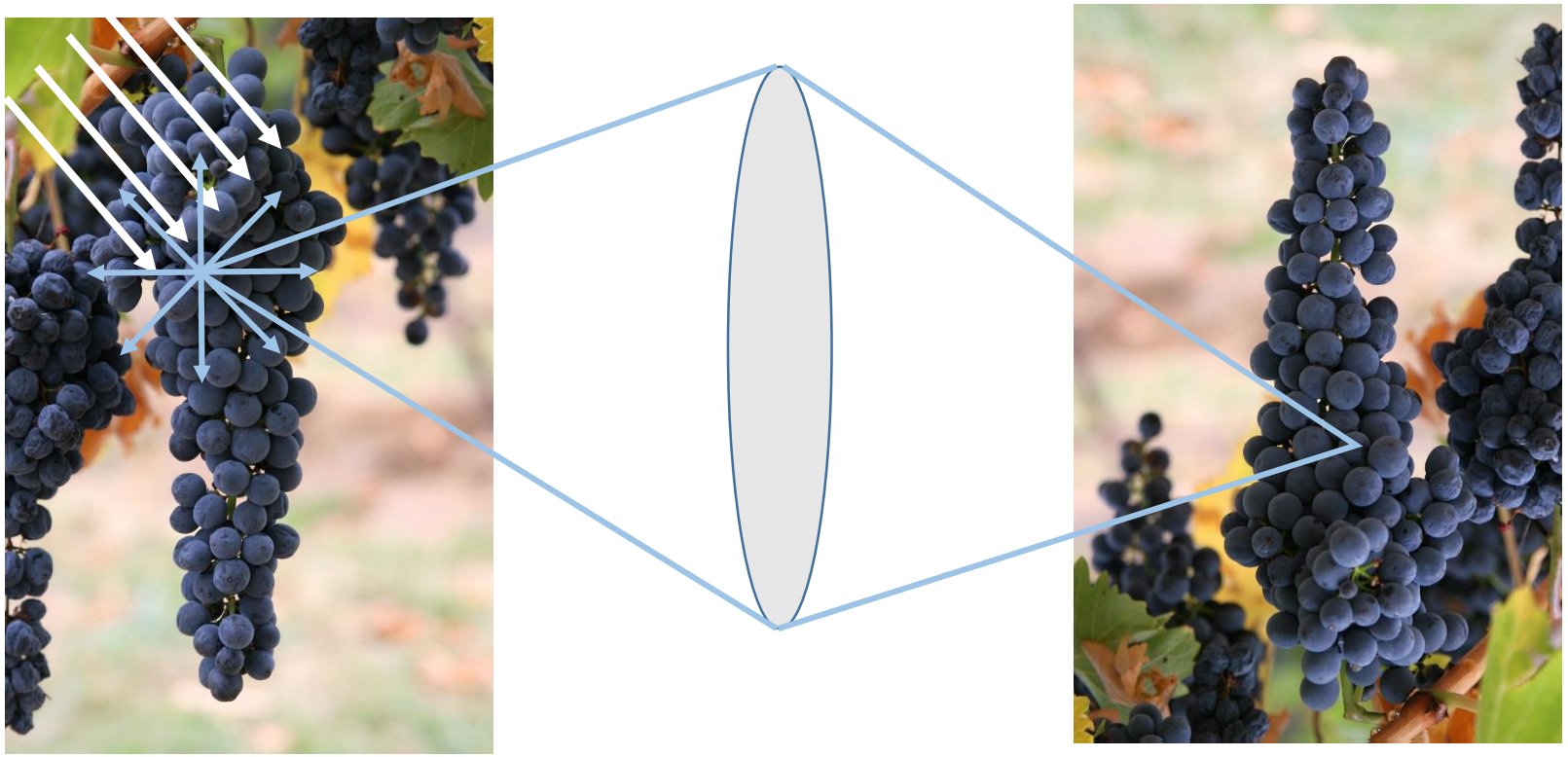
April 2017 meeting (Nikita Vladimirov)

***Why* do we see stuff?**

Light is *scattered* (also absorbed and reflected) by an object surface

The surface can be represented by a myriad of individual *point sources*

An image is formed by collecting (focusing) the light: object points -> image points



https://upload.wikimedia.org/wikipedia/commons/5/5e/Wine_grapes03.jpg

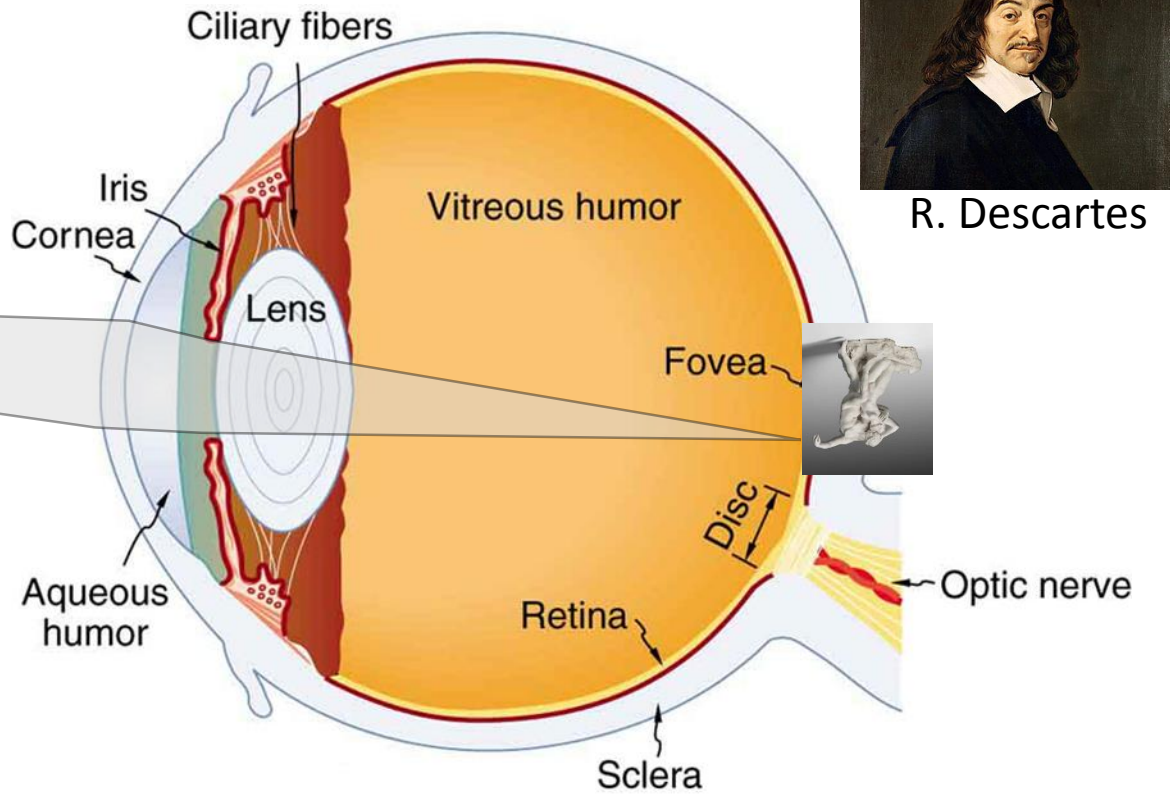
Things to notice

Image is flipped relatively to object (left-right and up-down)

Not all light from an object source is collected -> loss of information (resolution)

There is no such thing as perfect lens.

Human eye



R. Descartes

Fun facts

Our brain actively **inverts** the image.

High-resolution image is formed only on fovea, **1.5 mm** in diameter.

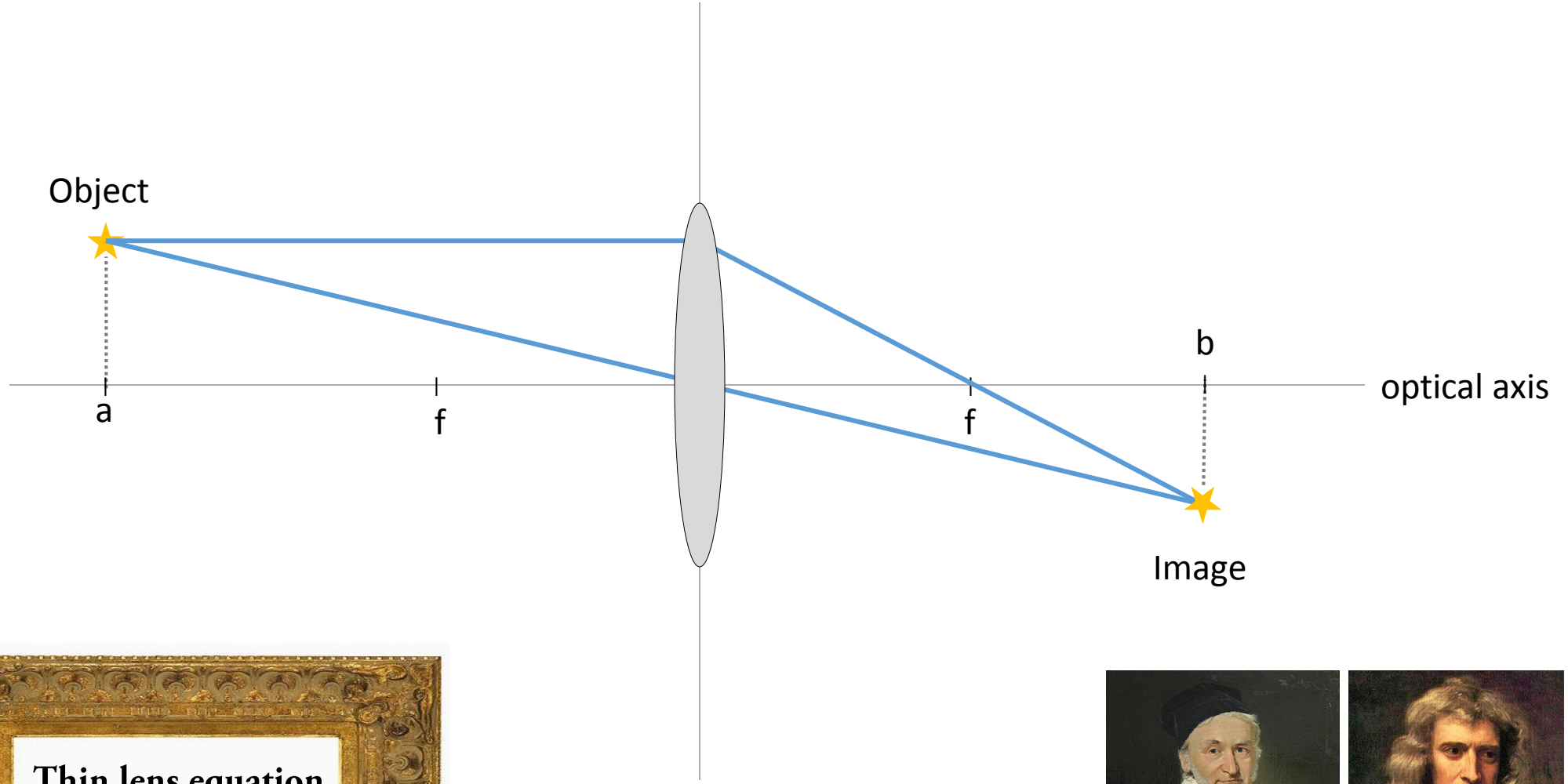
Most focusing occurs at the **air/cornea surface**. That's why we poorly see in the water.

Kids can learn to **see in the water**, because their lens can accommodate more.

We have a **blind spot** in our visual field, but our brain masks it for us (Demo).

Humans and frogs can see *single* photon counts.

Image source: http://figures.boundless-cdn.com/16507/full/eye-20with-20labels.jpeg

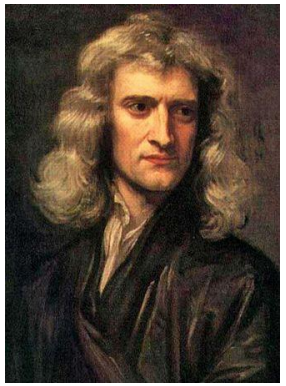


Thin lens equation

$$\frac{1}{a}+\frac{1}{b}=\frac{1}{f}$$

f – focal length,
a, b - distances

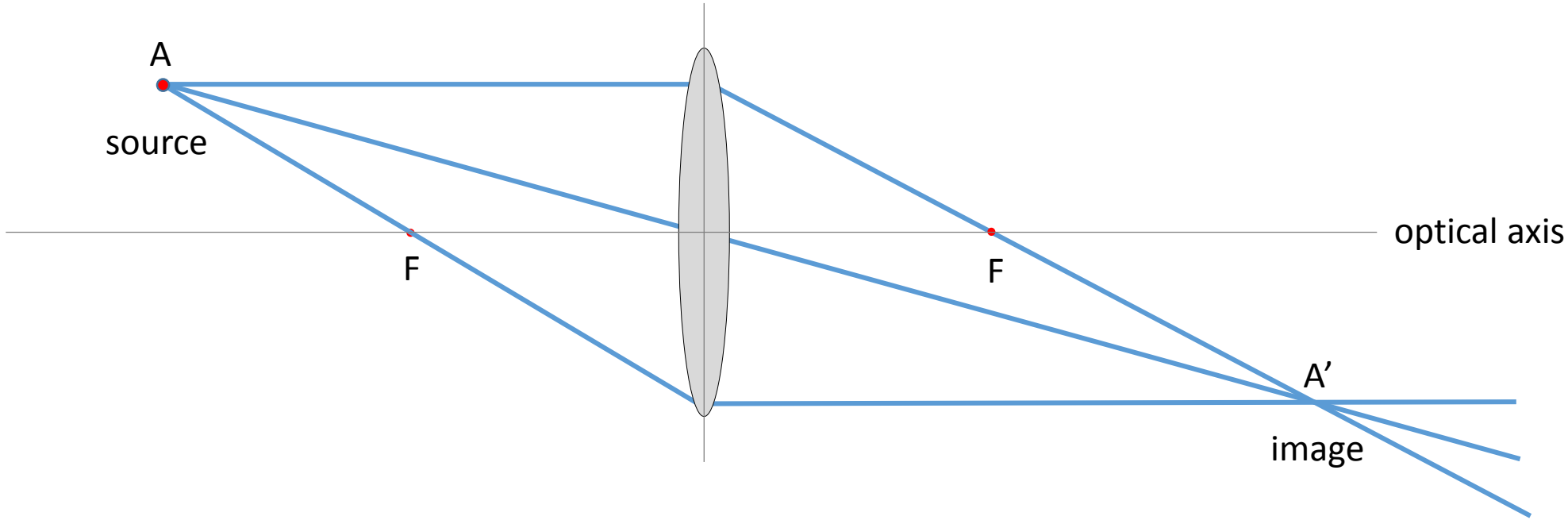
K.F. Gauss



I. Newton

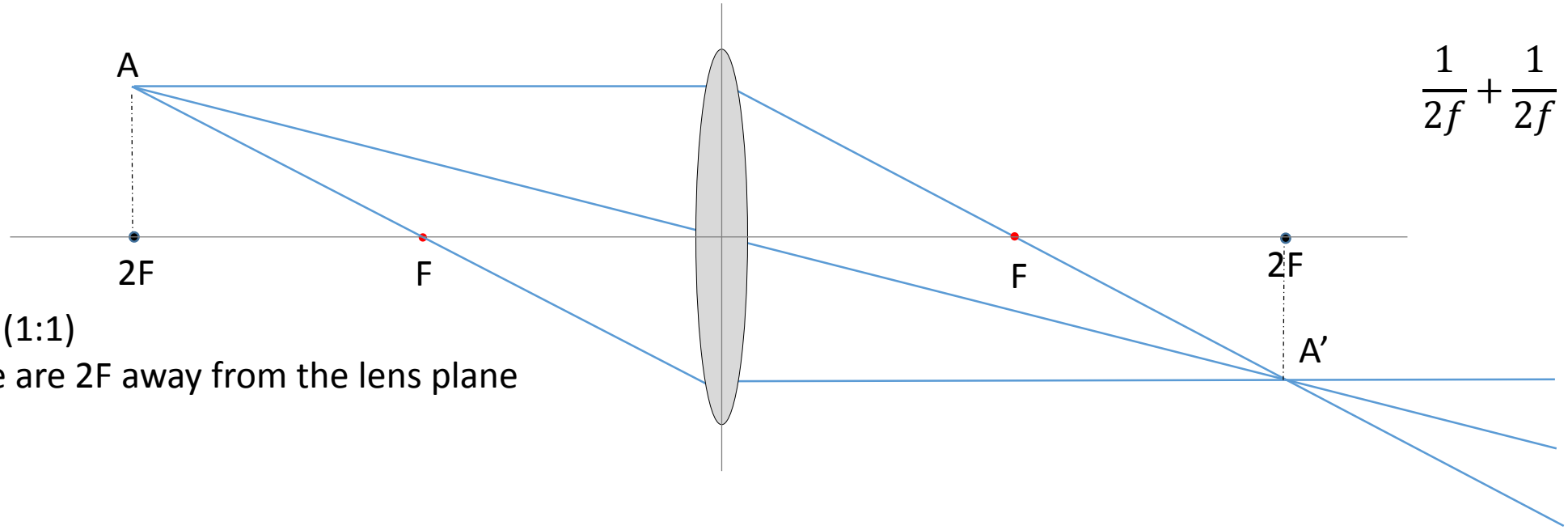
Ray tracing rules

1) Ray parallel to the axis is deflected through focal point F.
2) Ray intersecting the center of lens continues undeviated.
3) Ray passing through F is deflected parallel to the axis (see Rule 1).



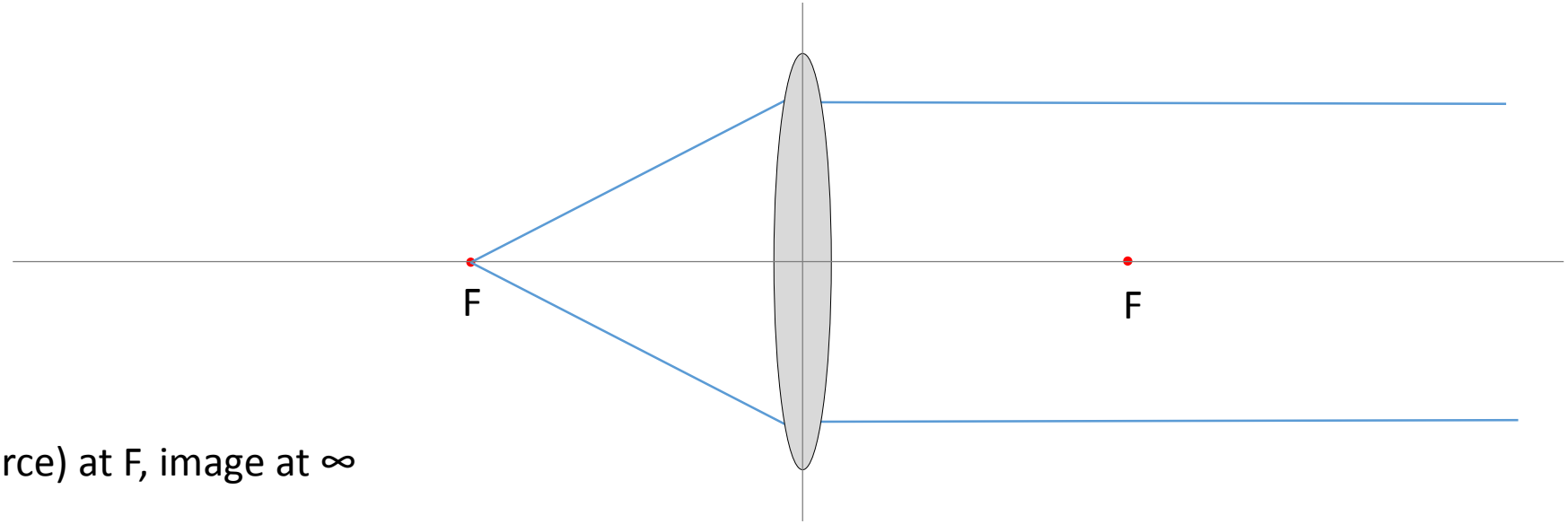
Optical rays have NO direction. Time can be 'reversed' and rays will go backward the same way.

Examples



$$\frac{1}{2f}+\frac{1}{2f}=\frac{1}{f}$$

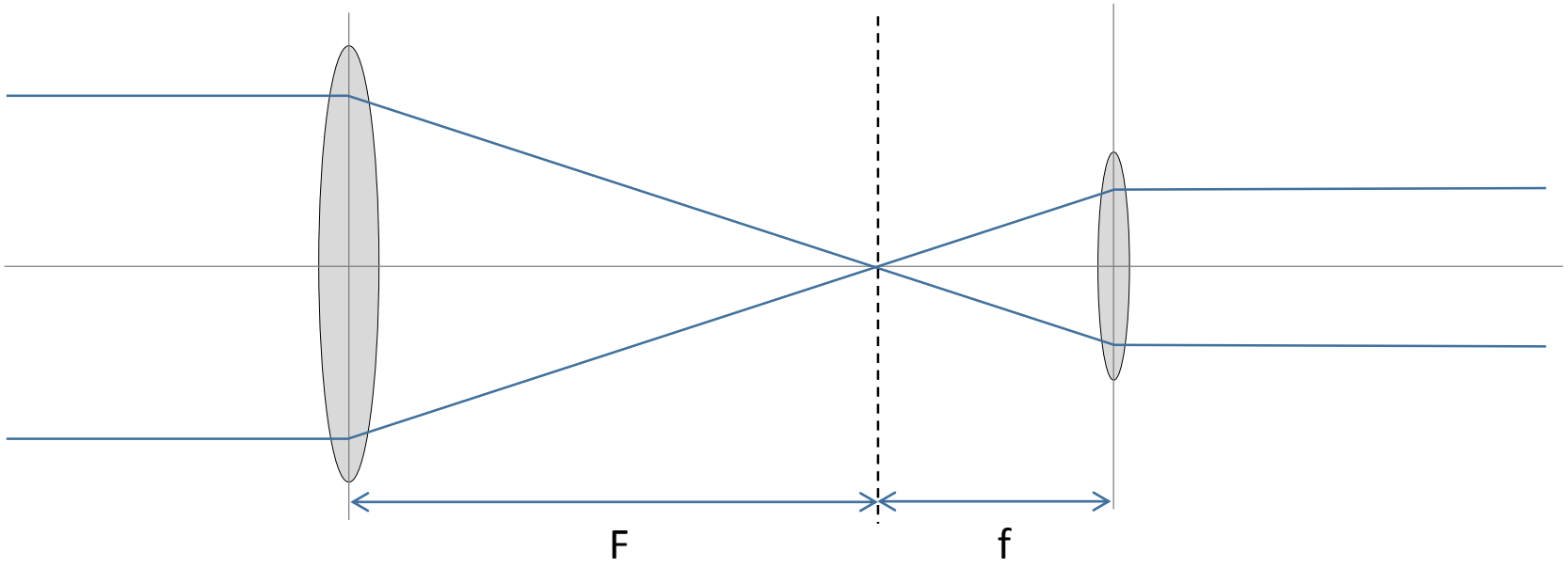
Simple *relay lens* (1:1)
Object and image are 2F away from the lens plane



Collimator
Object (point source) at F, image at ∞
Demo

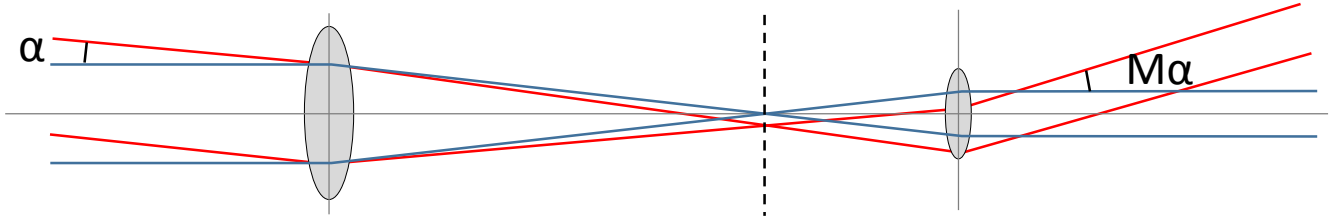
$$\frac{1}{f}+\frac{1}{\infty}=\frac{1}{f}$$

Keplerian telescope



J. Kepler

magnification M = F/f

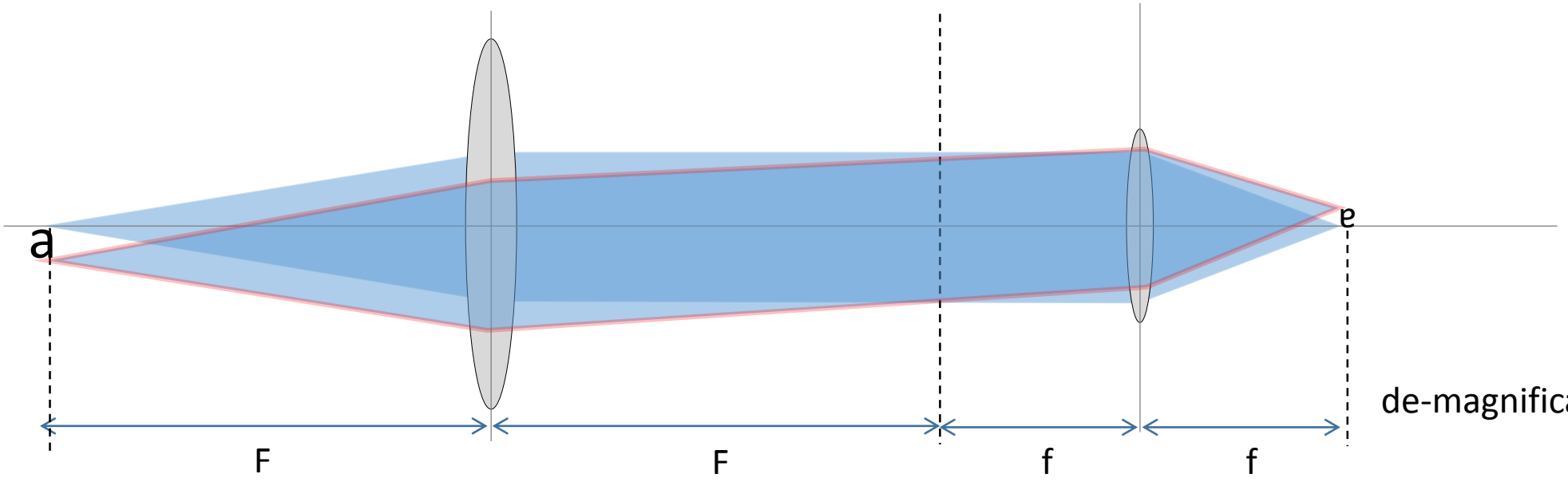


Ray *angles* are magnified by M

image is upside down ☹

Another use: *beam expander* in optical setups (Demo)

Another use: a *relay* system (*4F system*)

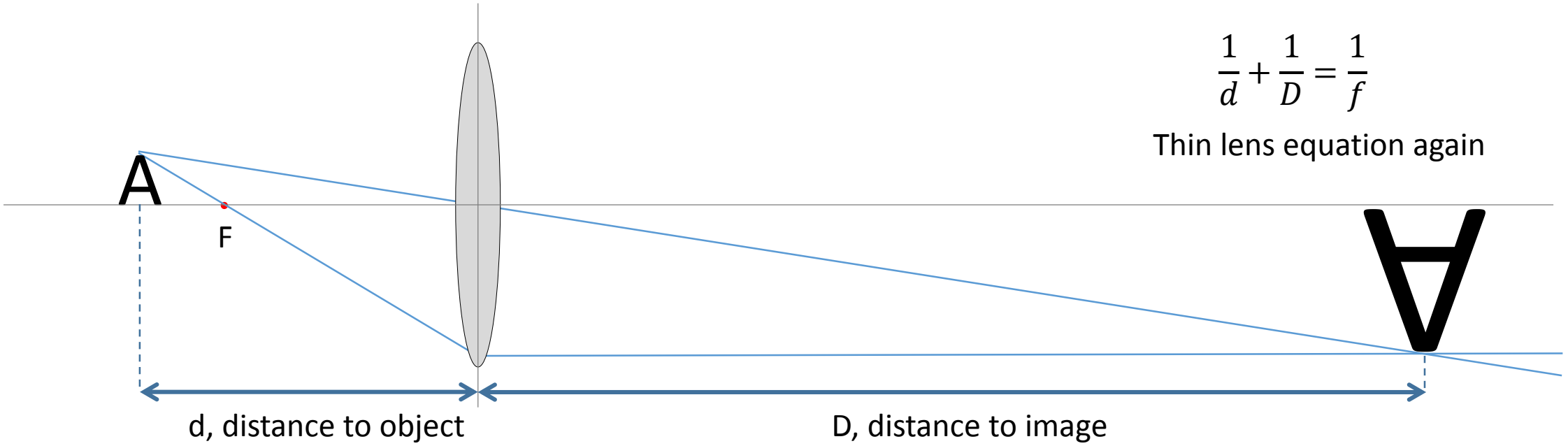


de-magnification M = f/F, < 1

Another use: prototype microscope, just turn it around: M = F/f, > 1

Demo

Lens magnification



$$\frac{1}{d}+\frac{1}{D}=\frac{1}{f}$$

Thin lens equation again

Magnification M = $\frac{D}{d}$.

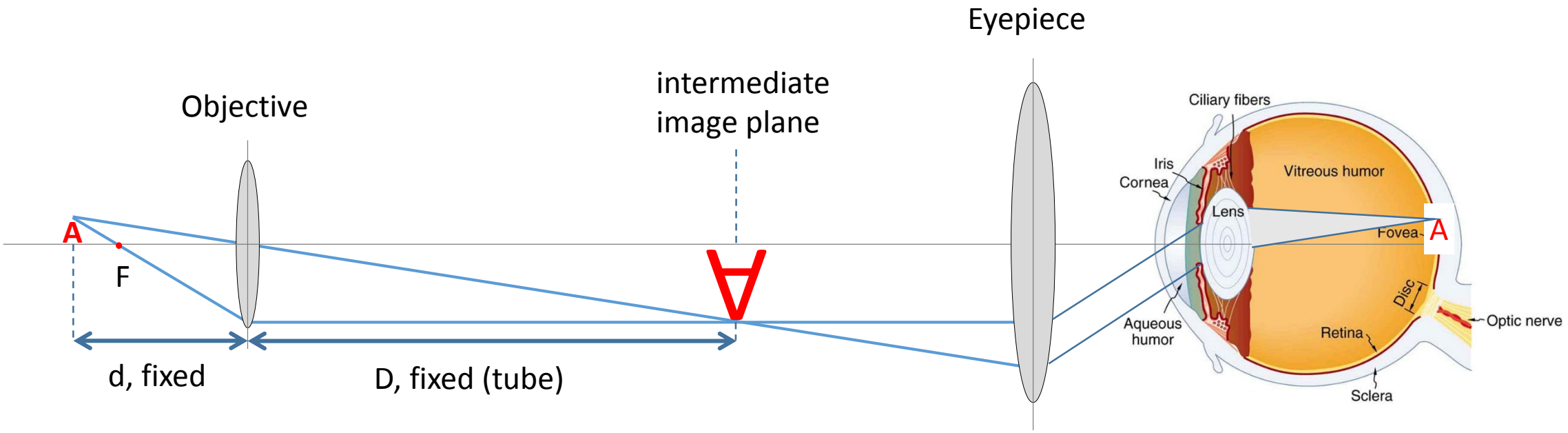
As d → f, D → ∞ and M → ∞

A given positive lens can have, theoretically, any magnification!

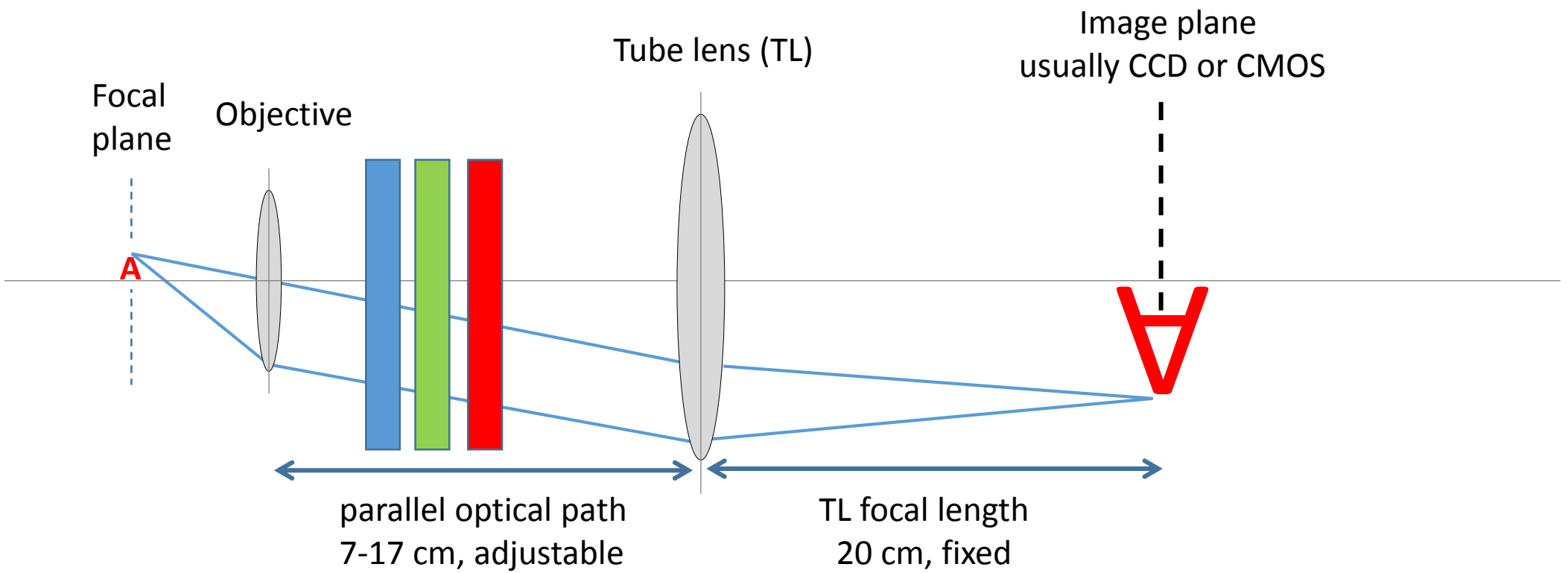
Such a lens is the simplest microscope

Popular microscope systems

1. Compound microscope (fixed tube length)



Infinity-corrected microscope (1980s - now)



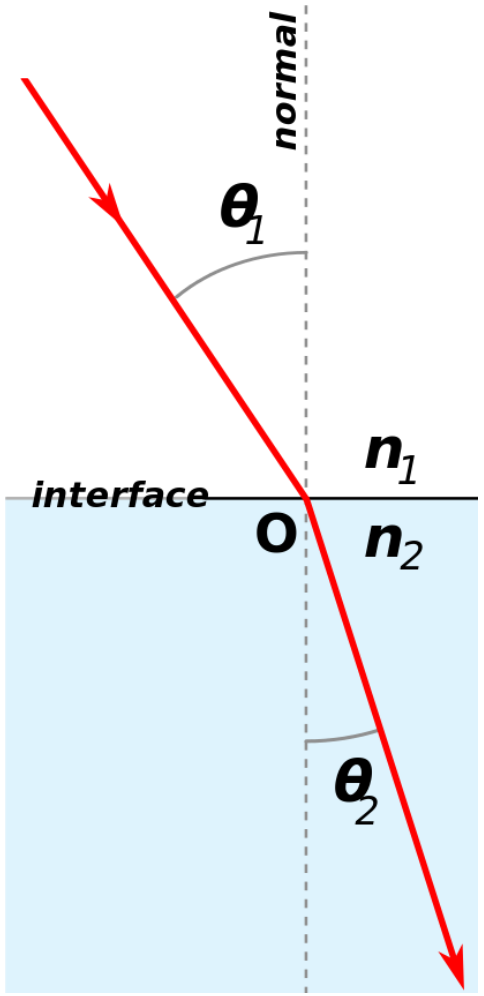
Why lenses work this way?

Snell's law of refraction

$$\frac{Sin(\theta_1)}{Sin(\theta_2)} = \frac{n_2}{n_1}$$

W. Snellius

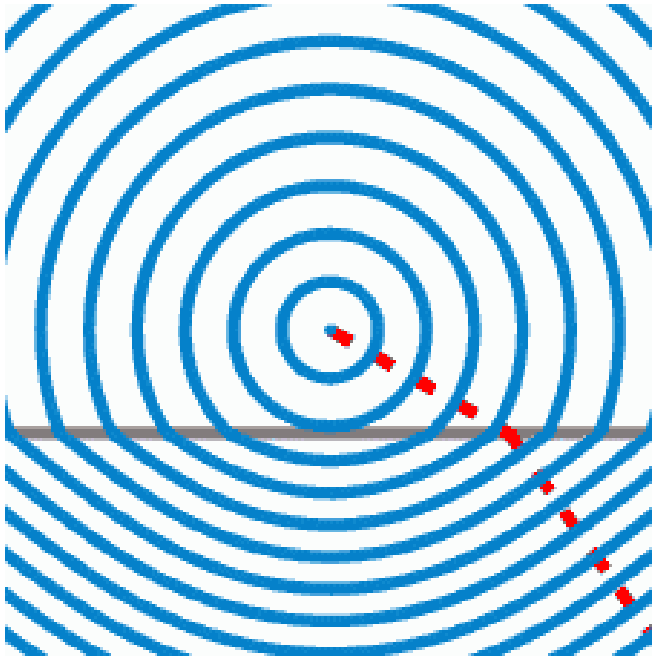
Actually, first discovered by Ibn Sahl, 984



Ray model

(air, $n_1 = 1.0$)

(glass, $n_2 = 1.5$)



Wave model

https://en.wikipedia.org/wiki/Snell's_law