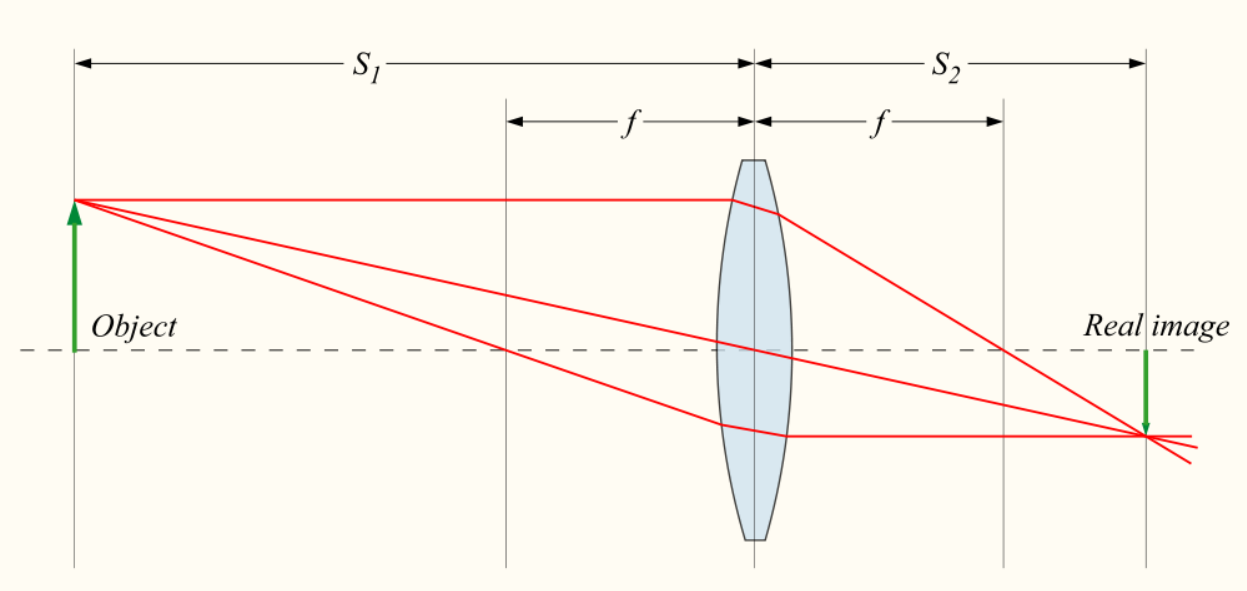
Biophysics 210: Biological Light Microscopy
Discussion Section 1: Ray Optics and Basic Optical Design
Tuesdays 1-2:30pm
Location: GH N114

In the lab, you will be assembling simple microscopes on an optical rail. This microscope has all the same lenses as a research microscope, but they are simple lenses mounted on a rail instead of complex, expensive lenses built into a microscope. This means you can move them around and build the scope yourself to develop an understanding of the light paths in the microscope. To help prepare you for the lab, we'll work through some of the theory in the discussion section. If you complete all the exercises here and understand them, assembling the microscope in lab should be no problem!

Some useful equations:



- The thin lens formula: $1/f = 1/S_1 + 1/S_2$ (See above figure, from Wikipedia). S1 and S2 are the object and image distances, and f is the focal length of the lens.
- Numerical Aperture NA = n sin θ, where θ is the largest angle the lens can collect and n is the refractive index between the lens and the object.
- Resolution (Rayleigh criterion): 0.61 λ / NA

Questions:

1. The microscope you'll be building is infinity-corrected, so there is an objective lens that images your object to infinity, and a tube lens that brings images from infinity in focus on the camera. The tube lens you'll be using has a focal length of 150 mm, and is 25 mm in diameter. How far away from the camera's sensor should the tube lens be placed?

2. To focus the lens at infinity, ideally we'd focus on an object infinitely far away. However, infinitely far away objects are hard to find. Instead we can focus on an object that is very far away. How far away is far enough to achieve a small error? If you want to have an error of less than 1% in the position of the tube lens, how far away does that object need to be from the lens? How about for a 5% error?

3. Which way will the lens move? If you mount the tube lens on your camera and focus it on an object across the room, which direction (toward or away from the camera) will you need to move the lens to get it to image an object infinitely far away?

4. The tube lens will be mounted in a standard Thorlabs SM1 threaded tube. This tube has 40 threads per inch. The lens is mounted in a focusing adapter that can be rotated so that it moves the lens in and out of the tube for focusing. How much will one revolution of the focusing adapter change the distance to the object that is in focus? Why would you care about the threads per inch used for mounting your lens?

5. The objective lens has a focal length of 25 mm and is 12.5 mm in diameter. When used in conjunction with the tube lens described above, where does the sample need to be mounted, relative to the objective lens? How about the distance to the objective lens? What is the magnification of the microscope?

6. Calculate the numerical aperture of the objective lens. What is the resolution achievable with this lens (pick a reasonable wavelength)?

7. Draw a sketch of the microscope, showing the position of the sample, objective lens, tube lens, and camera. Is the distance between objective lens and the tube lens important? Consider points off of the optical axis (the line through the centers of all the components). What limits the field of view of the sample?