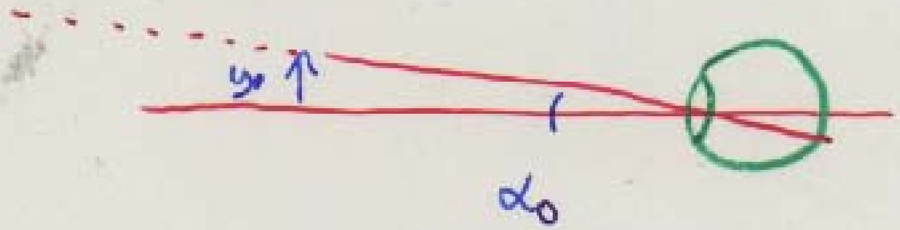
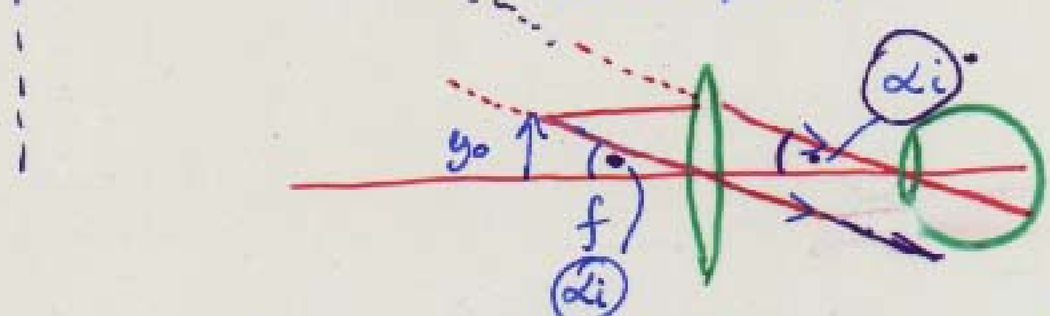
Magnifying Glass

Unaided eye



$\leftarrow d_n \approx \underline{25\,cm} \rightarrow$

Angular size of object (at near point) $\alpha_o \approx \tan\alpha_0 = \dfrac{y_0}{d_n}$



Place object at f $\Rightarrow$ image at ∞ (eye relaxed)

Ang. size of image $\alpha_i \approx \tan\alpha_i = \dfrac{y_0}{f}$

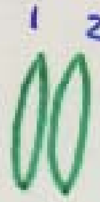
$\Rightarrow$ Ang. Magnification $= \dfrac{\alpha_i}{\alpha_0} = \dfrac{y_0}{f} \cdot \dfrac{d_n}{y_0}$

$$M_A = \frac{d_n}{f}$$

e.g. a "3x" magnifier, with $d_n = 25\,cm$ has focal length $f = \dfrac{d_n}{M_a} = \dfrac{25}{3} = 8.33\,cm$

Lens Combinations

1. Lenses in contact



From geometry, effective focal length of combined lens given by:

$$\boxed{\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}}$$

(cf. resistors in parallel)

e.g.

Take plano-convex lens with $R_1 = \infty$, $R_2 = -r$

and plano-concave lens with $R_1 = +r$, $R_2 = \infty$

From thin lens equation $\frac{1}{f} = \pm(n-1).\frac{1}{r}$ } convex / concave.

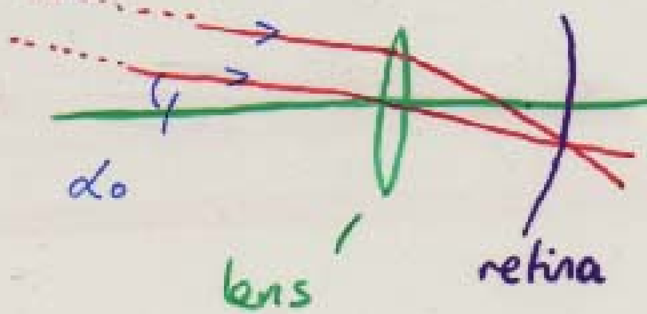
Place lenses in contact $\Rightarrow$ combined $\frac{1}{f} = (n-1)\left(\frac{1}{r} - \frac{1}{r}\right) = 0$

$\Rightarrow f = \infty$

as expected.

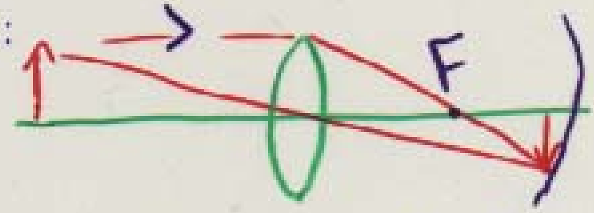
Vision in Nature

- Humans – "relaxed" vision when object at $s_o \to \infty$



Reason: predators! (+ food sources)

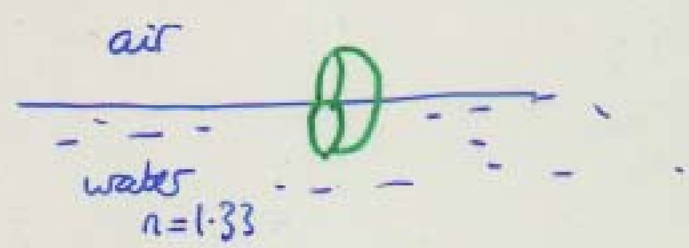
c.f. reading text:



eye muscles must contract ⇒ reduce R_1, R_2 ⇒ reduce f.

- Other animals : anteater, Koala bear : naturally myopic

Amazonian frog :



split lens to focus above/below water simultaneously

Remember $\frac{1}{f} \propto \left(\frac{n_{lens}}{n_{medium}} - 1 \right)$

Note: eyeglasses useless underwater

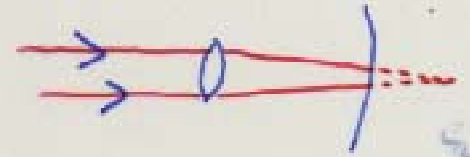
prescription dive mask useless in air (c.f. Notting Hill Hugh Grant / Julia Roberts)

- Evolution and the eye as an organ – still not understood.

Contact Lenses and Eyesight

1. Far-sightedness (hyperopia)
   - lens too close to retina

object at ∞
eye relaxed.



Eye can <u>accommodate</u> diverging rays but only up to a <u>near point</u> > 25 cm

Add a <u>converging</u> lens to force diverging rays from close objects to be focussed

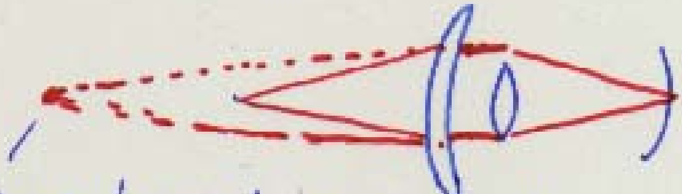
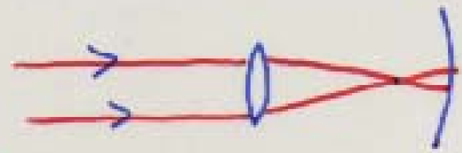


image beyond near point.

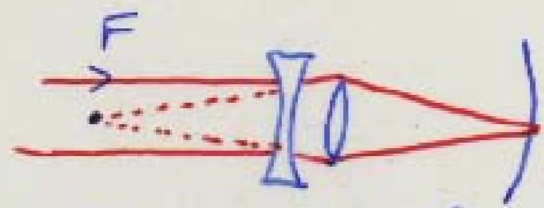
2. Near-sightedness (myopia)

lens – retina distance too long

object at ∞
eye relaxed



Objects from ∞ down to <u>far-point</u> appear blurred. Add a <u>diverging</u> lens to reduce convergence



object at ∞ re-imaged to far point

Images are <u>virtual</u>, erect, formed between eye's far point and near-point.

(Cannot use diverging lens to project images or as "burning glass".

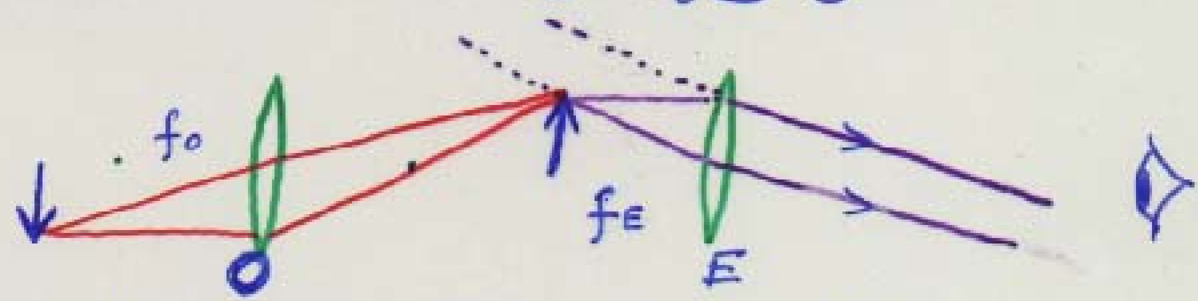
c.f. Lord of the Flies, William Golding)

Microscope

Can use 2 lenses to magnify image (easier to make, less distortion than single lens with small f).

Objective forms real, inverted, magnified image of object placed between f_O and $2f_O$

Eyepiece acts as magnifying glass



Intermediate image placed at focus f_E of eyepiece.

$\Rightarrow$ final image at ∞ (relaxed viewing)

Final angular size of image $\propto$ product of each lens' magnifications, i.e.

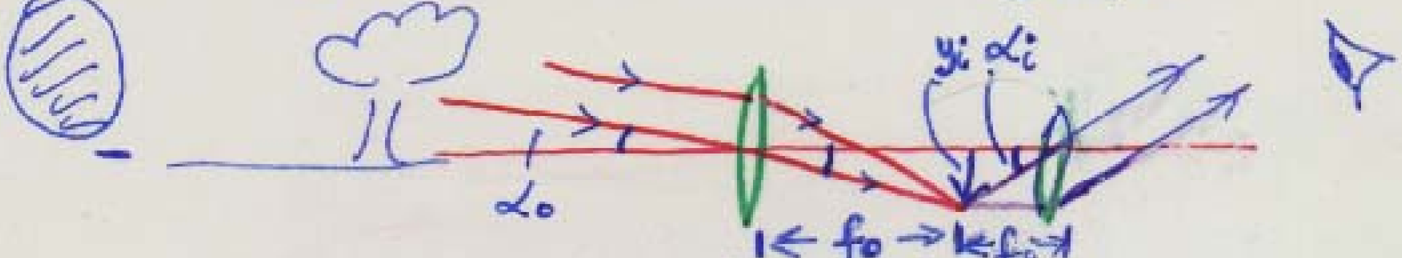
$$M_A \propto \frac{1}{f_O} \cdot \frac{1}{f_E}$$

"Microscope = projector + magnifier"

Refracting Telescope

1. Objective lens acts as a camera – forms real, inverted, minified image at $s_i \approx f_o$ (object $s_o \approx \infty$)

2. Eyepiece acts as a magnifier



If "intermediate object" has height $= y_i$

object ang. size $\alpha_o \approx \tan\alpha_o = \frac{y_i}{f_o}$

image ang. size $\alpha_i \approx \tan\alpha_i = \frac{y_i}{f_E}$

$\Rightarrow$ ang. magnification $M_A = \frac{\alpha_i}{\alpha_o} = \frac{f_o}{f_E}$

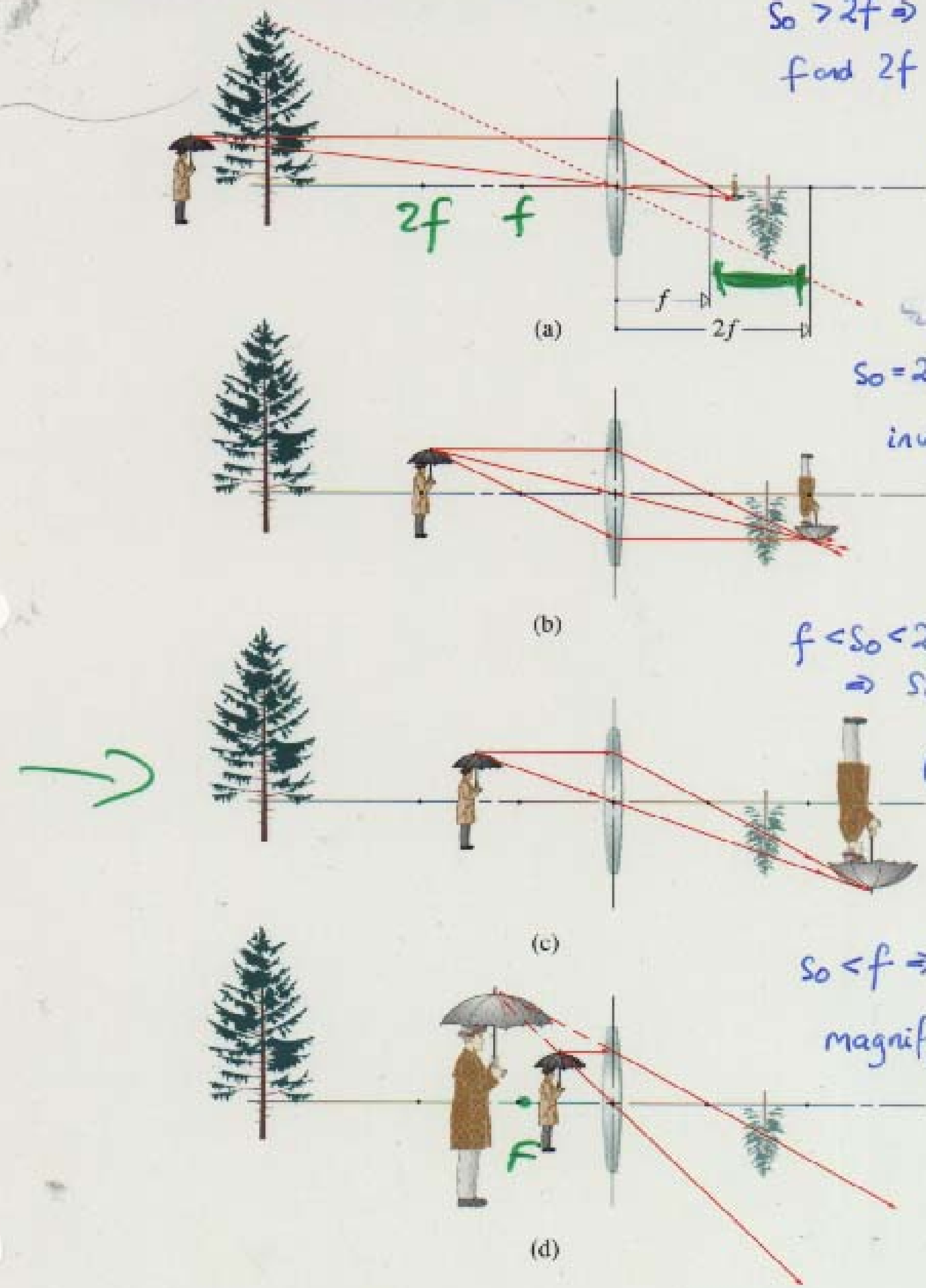
Note: image upside-down! Can add erecting lens with intermediate image at $2f$

objective

eyepiece.

Figure 24.15

Operation of a thin positive lens



So > 2f ⇒ Si between f and 2f

camera

So = 2f, ⇒ Si = 2f

inverting lens

f < So < 2f ⇒ Si > 2f

projector

So < f ⇒ Si < 0

magnifying glass.

Transparency 145

Figure 24.12

Geometry of image formation via a thin convex lens