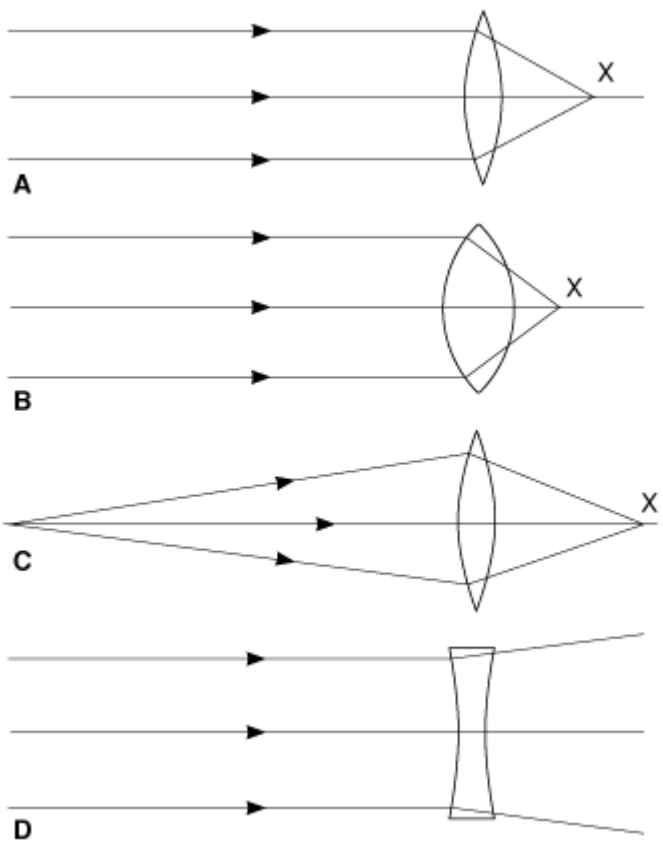
Eye Optics

Last updated: May 9, 2019

- light rays are bent (refracted) when they pass from one medium into medium of different density (except when they strike perpendicular to interface).



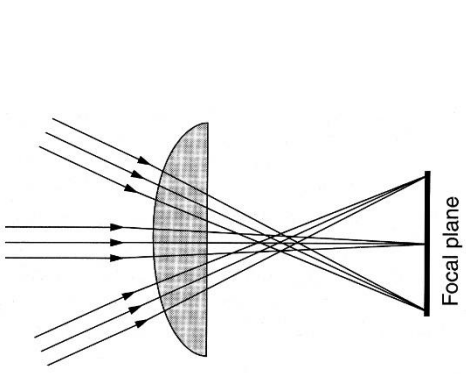
- parallel light rays striking *biconvex lens* are refracted to point (**FOCAL POINT**) behind lens; *biconcave lenses* cause light rays to diverge.
- focal point is on line passing through centers of lens curvature (**principal axis**).
- distance between lens and focal point is ***FOCAL DISTANCE***.
- for practical purposes, rays from object > **6 m** away are parallel (rays from object closer than 6 m are diverging → brought to focus farther back than principal focus).

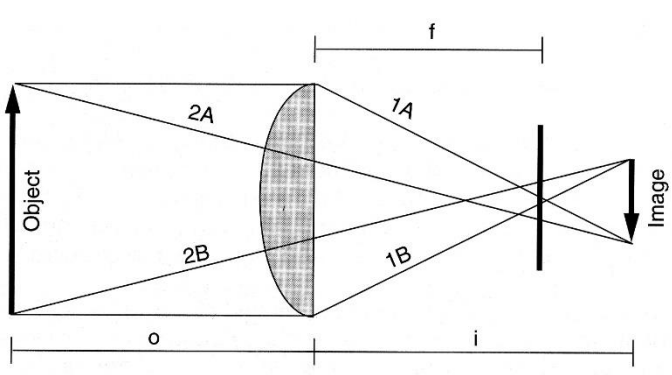
A: Biconvex lens.
B: Biconvex lens of greater strength than **A.**
C: Same lens as **A,** showing effect on light rays from near point.
D: Biconcave lens.
X is focal point

REFRACTIVE POWER

- greater lens curvature, greater its refractive power.
- refractive power (P) is measured in **DIOPTERS** (reciprocal of focal distance in meters);
  P = 1 / focal distance
  e.g. lens with principal focal distance of 0.25 m has refractive power of 4 diopters (i.e.1/0.25).
- human eye has refractive power ≈ **60 diopters** at rest; light is refracted at:
  1) anterior **cornea** surface > 40 D
  2) anterior and posterior **lens** surfaces ≈ 20 D.

- if light rays are *parallel* when they enter lens, they will converge **at FOCAL PLANE.**



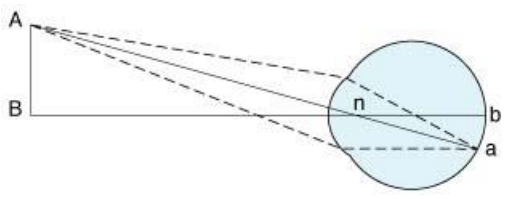


- if light rays are *diverging* when they enter lens, image will be formed **behind FOCAL PLANE**; relationship between *object distance* (o), *focal distance* (f), and *image distance* (i) is given by **LENS FORMULA**:

$$P = P \quad \frac{1}{o} + \frac{1}{i} = \frac{1}{f}$$

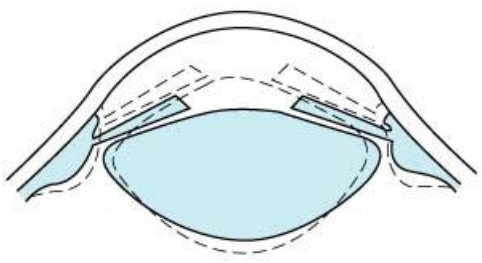
"Reduced" (s. "schematic") eye - drawing eye diagrammatically as if all refraction occurs at *anterior cornea surface*; **nodal point** (optical eye center - light rays pass without refraction) coincides with junction of middle and posterior third of lens.

- if object height (AB) and distance (Bn) are known, size of retinal image can be calculated, because AnB and anb are similar triangles.
- angle AnB is **visual angle** subtended by object AB.
  N.B. retinal image is inverted.

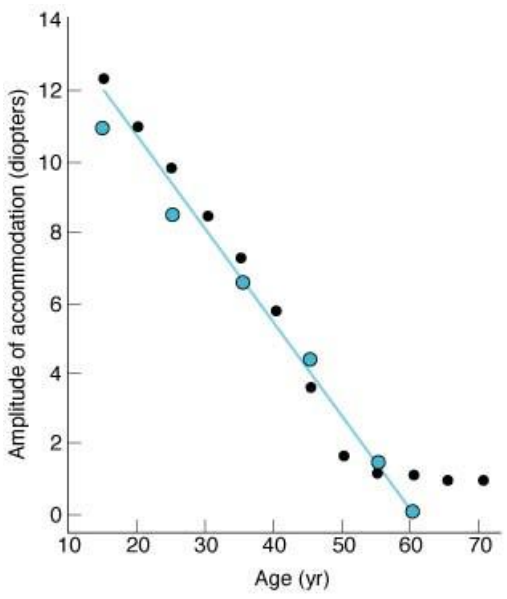


ACCOMMODATION

- when ciliary muscle is relaxed, parallel light rays are brought to focus on retina; rays from objects closer than 6 m are brought to focus behind retina → objects appear blurred.
- in mammals, problem is solved by increasing lens curvature - called **accommodation**.
- at rest, lens is held under tension by lens ligaments (pulled into flattened shape).
- when ciliary muscle contracts, it relaxes lens ligaments → lens springs into more convex shape.
- in young individuals, change in lens shape *may add as many as 12 diopters* (up to 72 D total)!
- relaxation of lens ligaments is produced by contraction of:
  1) **circular** ciliary muscle fibers (sphincter-like action)
  2) **longitudinal** ciliary muscle fibers (that attach anteriorly, near corneoscleral junction - pull whole ciliary body forward and inward - brings edges of ciliary body closer together).
- accommodation affects principally anterior lens surface; posterior lens surface is changed very little.
- accommodation is active process (can be tiring) - *ciliary muscle is one of the most used body muscles*!
- accommodation goes together with convergence and miosis* (**near reaction**).



*Role of pupilloconstriction during accommodation – reducing chromatic and spherical aberrations.
CHROMATIC ABERRATION - difference in focus (or magnification) of image arising because of *difference in refraction of different wavelengths* composing white light.
SPHERICAL ABERRATION - monochromatic aberration when *paraxial* and *peripheral* rays focus along axis at different points.



Decline in accommodation amplitude with advancing age (different symbols identify data from different studies).

- degree to which lens curvature can be increased is limited; **NEAR POINT** (s. **punctum proximum**) - nearest point at which object can still be brought into clear focus by accommodation.
- near point recedes throughout life (due to increasing lens hardness):
  8,3 cm - at age 10 (due to 12 D maximal accommodation);
  83 cm - at age 60;

at age 40-45, accommodation loss is sufficient to make reading and close work difficult (***presbyopia***).

FAR POINT – distance from which object is clearly seen without accommodation; norma – 6 m.

VISUAL ACUITY

- degree to which object details and contours are perceived.

- complex phenomenon - influenced by large variety of factors:
  optical factors (e.g. state of image-forming mechanisms of eye);
  retinal factors (e.g. state of cones);
  stimulus factors (e.g. illumination, brightness of stimulus, contrast between stimulus and background, length of time subject is exposed to stimulus).

Clinically, visual acuity is defined in terms of **minimum separable** (shortest distance by which two lines can be separated and still be perceived as two lines) - determined with Snellen letter charts.
*Minimum separable in normal individual is **visual angle of 1 minute***! see p. D1eye >>

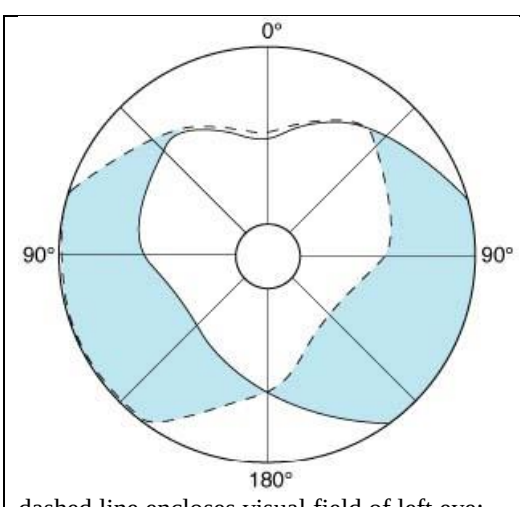
CRITICAL FUSION FREQUENCY (CFF)

- rate at which stimuli can be presented and still be perceived as separate stimuli.

- stimuli presented at higher rate than CFF are perceived as continuous stimuli (e.g. motion pictures; movies begin to flicker when projector slows down).

VISUAL FIELDS & BINOCULAR VISION

- theoretically, visual field of each eye should be circular, but actually it is cut off medially by nose and superiorly by orbit roof.
- *central visual fields* are mapped with **tangent screen** (black felt screen across which white target is moved).
- *peripheral portions of visual fields* are mapped with **perimeter** (process is called **perimetry**).
- central parts of visual fields of two eyes coincide (**BINOCULAR VISION**).
- impulses set up in two retinas by light rays from object are *fused at cortical level* into single image (**fusion**).
- retinal points on which image must fall if it is to be seen binocularly as single object are called **corresponding points**.
- DEPTH perception:
  1) binocular vision
  2) monocular components - relative sizes of objects, their shadows, movement relative to one another (movement parallax).



dashed line encloses visual field of left eye; solid line, that of right eye.
common area (heart-shaped clear zone in center) is viewed with binocular vision; colored areas are viewed with monocular vision.

BIBLIOGRAPHY for ch. "Ophthalmology" → follow this LINK >>