Eye Optics

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

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| D:\Viktoro\Neuroscience\Eye. Ophthalmology\00. Pictures\Light refraction.gif | * 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 |

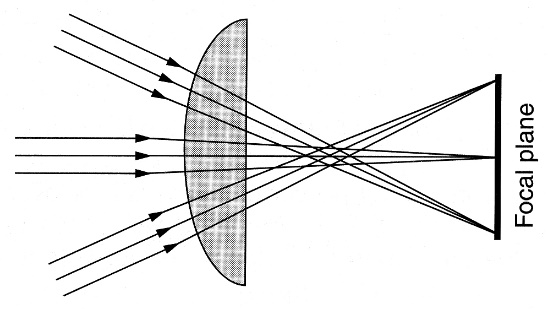
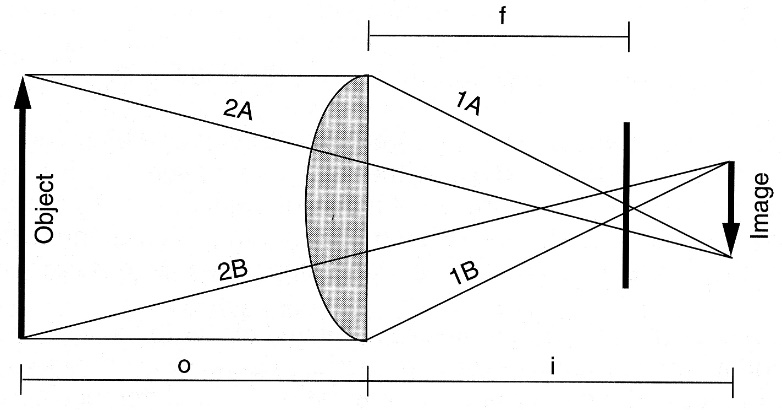
Refractive Power

* 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 | 1 | + | 1 | = | 1 |
| o | i | 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.

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| * 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. | D:\Viktoro\Neuroscience\Eye. Ophthalmology\00. Pictures\Reduced eye.jpg |

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).

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| * 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**). | D:\Viktoro\Neuroscience\Eye. Ophthalmology\00. Pictures\Accommodation.jpg |

\*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.

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| D:\Viktoro\Neuroscience\Eye. Ophthalmology\00. Pictures\Accomodation loss.jpg  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 >>](http://www.neurosurgeryresident.net/D.%20Diagnostics\D1-5.%20Neurologic%20Examination\D1eye.%20Ophthalmologic%20Examination.pdf)

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).

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| * *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). | D:\Viktoro\Neuroscience\Eye. Ophthalmology\00. Pictures\Visual Fields.jpg  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 >>](http://www.neurosurgeryresident.net/Eye.%20Ophthalmology\Eye.%20Bibliography.pdf)

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