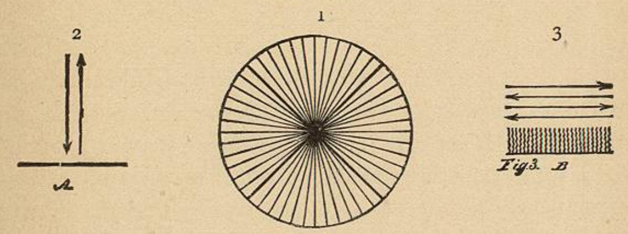
CHAPTER XI.

LIGHT.

Various hypotheses have been made regarding the nature and origin of light. The most important of these are the emission or corpuscular theory and the undulatory theory.

The emission or corpuscular theory of light was supported by Newton. It supposes light to consist of exceedingly small particles, projected with enormous velocity from a luminous body. Although this theory seems to have support in many of the phenomena of light, the velocity of light alone, as at present recognized, would seem to render it untenable, however infinitesimal the projected particles might be. Tyndall has said that a body having the weight of one grain, moving with the velocity of light, would possess the momentum of a cannon ball weighing one hundred and fifty pounds and moving with a velocity of 1,000 feet a second; but the most delicate tests known to science have failed to show that light possesses any mechanical force.

Fig. 199.



Comparison of Sound and Light Waves.

The emission theory of light was opposed first by Hooke, Huygens, and Euler, who believed that the propagation of light was due to wave motion. All other eminent scientists supported Newton for one hundred years, but the undulatory theory was finally established beyond a question, by Young and Fresnel.

Sound is propagated by the alternate compression and rarefaction of air, the movements of the waves being parallel with the line of propagation. But not so with light. The vibrations of light are at right angles with its line of progression. These transverse vibrations, in ordinary white light, are in every conceivable direction across the path of the light beam. Their course is represented by Diagram 1, Fig. 199.

We can readily see how the longitudinal vibrations of air would affect the ear drum; 2 shows this action diagrammatically, the horizontal line, A, representing the tympanum, and the two arrows the forward and backward motion of the air wave.

Comparatively recent microscopical research has shown that the retina is studded with fine rods, as shown at B, which are susceptible of being influenced by the lateral movements of the particles in the wave front of a light beam.

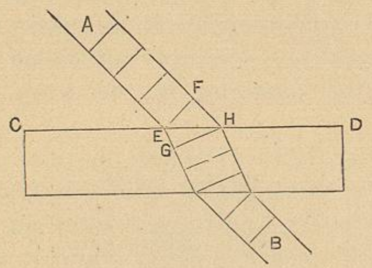
The fact that light is wave motion necessitates the assumption of the existence of a medium far more subtile than ordinary matter, which pervades all matter and all space, and is in the interior of all bodies of whatever nature. It is thin, elastic, and capable of transmitting vibrations with enormous velocity. This hypothetical medium is called *ether*. Every luminous body is in a state of vibration, and communicates vibrations to the surrounding ether.

Although light is propagated in straight lines, its direction may be changed by reflection, by any body that will not wholly absorb it. The reflection of light from a mirror is a well known example of this. The direction of light may also be changed by refraction, by causing it to pass from one medium into another having a different density. By holding a strip of plate glass obliquely before a pencil or similar object, the bending of the light beam is shown by the apparent lateral displacement of the object.

Lewis Wright, in his excellent work on light, gives Huygens' explanation of refraction as follows:

"Any beam of light has a wave front across it, and it is obvious that in meeting any refracting surface obliquely, one part of this wave front will meet it before another. Conceive, then, that while the ether permeates the open structure of all matter, it is still hindered in its motions by it, as wind is hindered, but not stopped, by the trees. Then trace a ray, A B (Fig. 200), to the refracting surface, C D, marking off the assumed length of its waves by the transverse lines. The front will be retarded at E before it is retarded at F, and we may assume the retardation is such that the wave in the denser medium is only propagated to G, while in the rarer medium it reaches H. It is plain that the beam must swing round; but when the side, F, also reaches the denser medium, the whole will be retarded alike and the beam will proceed as before, only slower and in a different direction. The theory exactly fits all the phenomena."

Fig. 200.



Refraction.

As the beam emerges from the denser medium, the reverse of what has been described occurs, and, provided the refracting medium is of uniform thickness and density, the beam proceeds in a path parallel with its former course.

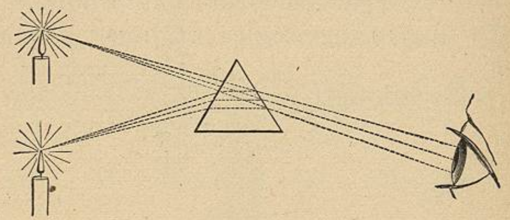
In lenses and prisms the emergent beam takes an oblique path, and in the case of lenses, either convergent or divergent, according to the kind of lens and the position of the lens relative to the object.

PRISMS.

Any refracting body having plane faces inclined to each other is known as a prism. A light beam passing through such a body is permanently deflected. For example, a candle viewed through a prism placed as shown in Fig. 201 will appear to the observer in an elevated position. The light in this case is twice refracted, once on entering the glass, and again on leaving it.

The toy known as the polyprism consists of a plano-convex glass having a number of plane facets on its convex side.

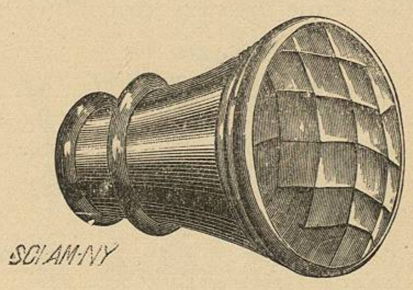
Fig. 201.



Course of Light through a Prism.

The facets being at slightly different angles with the plane face of the glass, the rays are refracted differently at each facet, thus producing as many images as there are facets. One man seen through this instrument appears like an assemblage. A coin viewed through it is multiplied as many times as there are facets, and a grate fire appears like the conflagration of a city.

Fig. 202.



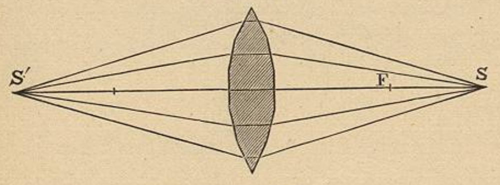
Polyprism.

This toy illustrates in a crude way the principle of the convex lens. The several divisions of the prism are able to so refract a beam of light as to render it convergent, that is to say, each division of the prism will bend as much of the beam as it receives, so that all of the light passing through the prism will be concentrated upon one spot, which will correspond in size with one of the facets. This spot marks the principal focus, a point at which the rays cross, and beyond which they diverge.

LENSES.

A lens may be regarded as an infinite number of prisms of gradually increasing angles arranged around an axis.

FIG. 203.

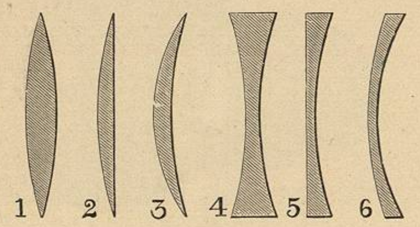


Hypothetical Lens.

This idea is illustrated by Fig. 203, in which is shown a hypothetical lens formed of prisms of different angles.

Rays of light proceeding from the point, S, to the lens are refracted differently, those meeting the outer portion of the lens being more deflected than those passing through the inner portions, while the rays coinciding with the axis are not refracted. The emergent rays converge to the point, S′. Where there is an infinite number of inclined surfaces, the lens will have spherically convex surfaces.

FIG. 204.



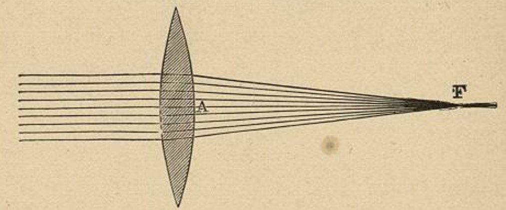
Forms of Lenses.

Of converging or magnifying lenses there are four forms, three of which are shown at 1 2, 3, in Fig. 204; 1 being a double convex lens, 2 a plano-convex, and 3 a convex meniscus. The fourth form, which is a double convex with curved sides of different radii, is known as a crossed lens.

Of diverging or diminishing lenses there are three forms, which are also represented in Fig. 204; 4 being a double concave, 5 a plano-concave, and 6 a concave meniscus.

Parallel rays on entering a double convex lens are refracted, and on leaving the lens they are again refracted so that they all converge at the point F, which is the principal focus. The focal length of the lens is the distance from the lens to the focal point.

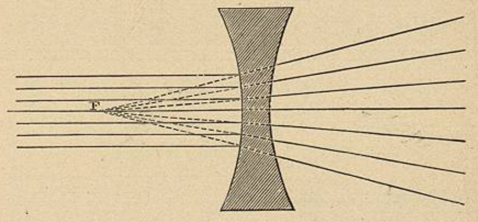
FIG. 205.



Principal Focus of a Convex Lens.

When light proceeds from a point and is rendered convergent by a lens, as shown in Fig. 203, the point to which the rays converge and the point from which the light emanates mark the *conjugate foci* of the lens. Light proceeding from the point, S′, will converge to the point, S, and in like manner light proceeding from S will converge to the point, S′.

FIG. 206.



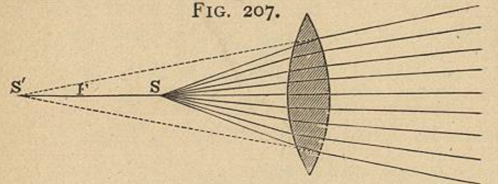
Principal Focus of a Concave Lens.

A concave lens renders a parallel beam divergent, an action which is the reverse of that of the convex lens. If the divergent rays, after passing through a concave lens, are produced backward, as indicated by the dotted lines in

Fig. 206, they will meet in the point, F, which is called the principal focus.

Rays of light which converge toward the point, S′, Fig. 207, before refraction, will, after refraction, converge to the point, S, between the principal focus, F, and the lens, and light emanating from the point, S, will diverge after passing through the lens.

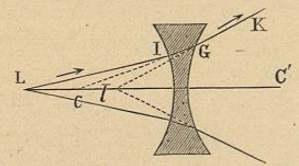
Fig. 207.



Converging Rays, Convex Lens.

Converging rays passing through a concave lens will become less convergent or parallel according to the distance of the point toward which they converge.

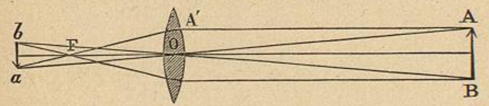
Fig. 208.



Diverging Rays, Concave Lens.

Rays proceeding from the point, L (Fig. 208), to and through the concave lens are rendered more divergent. If, in this case, the divergent rays, after passing through the lens, are produced backward, as indicated by dotted lines, they will converge toward the point, *l*, between the principal focus, C, and the lens.

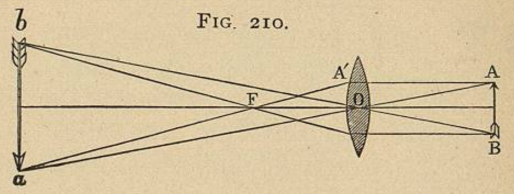
Fig. 209.



Real and Diminished Image.

An object, A B (Fig. 209), placed in front of a convex lens at a distance greater than its principal focal length will have a real image, *a b*, on the other side of the lens. This image is inverted and may be either larger or smaller than the object. By holding a double convex lens between the object and a white wall or screen, the image may be seen.

Fig. 210.

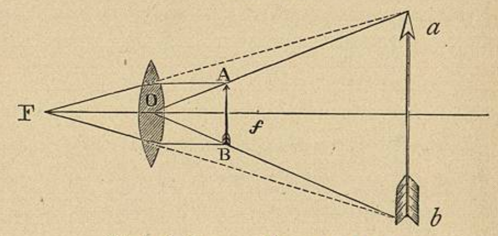


Real and Magnified Image.

By changing the relative distances of the object, the lens, and the screen, the size of the image may be varied. In Fig. 209 the object is distant more than twice the focal length of the lens. The photographer's camera exemplifies this principle.

In Fig. 210 is illustrated a case in which the lens is nearer the object, A B. A magnified real image is produced. In this case the distance of the object is greater than the single focal length of the lens, but less than twice its focal length. The projecting lantern exemplifies this principle.

Fig. 211.



Virtual Image, Convex Lens.

When an object, A B (Fig. 211), is placed between the lens, O, and its principal focus, *f*, a virtual image, *a b*, is formed which is erect and magnified, and which appears at a greater distance than the object. This figure illustrates the manner in which objects are viewed by an ordinary magnifying hand glass.