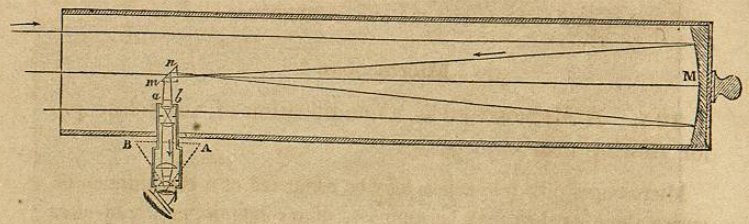
deviation, and strike its second face so as to be totally reflected, which causes the image to be formed at *ab*. The image thus formed is viewed by an eye-piece through the



side of the telescope. The eye-piece in this telescope is made of two plano-convex lenses, as shown in the figure, the combined effect of which is to cause the image to appear in the position BA, giving a great power to the telescope.

Fig. 216 shows the manner of viewing the image. It also shows a small *seeker* attached to the tube of the main instrument, which is used in directing the telescope to any required object.

Herschel's Telescope.

323. Sir William Herschel, of London, modified the Newtonian telescope by inclining the mirror, M, so as to throw the image to one side of the tube, where it could be viewed by a magnifying eye-piece, the observer's back being turned towards the object.

The large telescope made by this eminent astronomer was forty feet in length, and the speculum had a diameter of about five feet. It was with this gigantic instrument that he made some of his most brilliant discoveries.

Lord Ross's Telescope.

324. Lord Ross, of Ireland, has recently constructed a reflecting telescope still larger than Herschel's. The tube is 56 feet in length, and the diameter of the reflector is more than 6 feet. The speculum weighs over 4 tons, and the entire instrument more than 18 tons. This telescope is supported by two walls of masonry 48 feet high, 72 feet long, and 24 feet distant from each other. The instrument is said to have cost the owner $60,000.

Explain Fig. 216. (**323.**) What modification did Herschel make in the Newtonian telescope? *Describe* Herschel's *telescope.* (**324.**) Describe Lord Ross's telescope.

Microscopes.

325. A Microscope is a modification of the telescope, for viewing near objects.

Microscopes, like telescopes, may be composed of a combination of lenses alone, or they may be composed of a combination of reflectors and lenses. Reflecting microscopes are but little used. We shall only describe the refracting microscope, of which there are two kinds, the *simple* and the *compound.*

The Simple Microscope.

326. The Simple Microscope consists of a double convex lens of short focal distance. It is usually set in a frame of metal or of horn, and held in the hand.

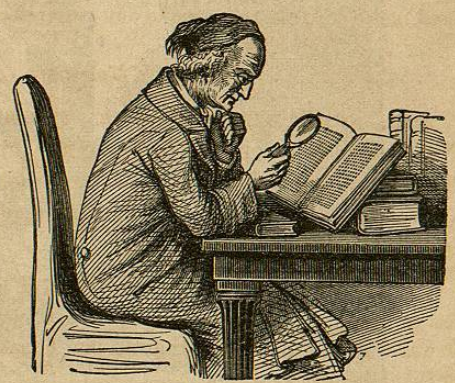


Fig. 218.

Fig. 218 shows the manner of using it. It is held at a distance from the object to be viewed, a little less than its principal focal distance. In this case, each pencil of light falling upon it will be deviated so

(**325.**) What is a Microscope? *How may a microscope be constructed?* (**326.**) What is a Simple Microscope? Explain Fig. 218.

as to form a beam, whose axis passes through the point from which the pencil proceeds, and the optical centre.

The object appears of the same size that it would if the eye were placed at the optical centre of the lens. Since the least limit of distinct vision is about eight inches, it follows that a single microscope whose focal distance is one inch, would magnify an object

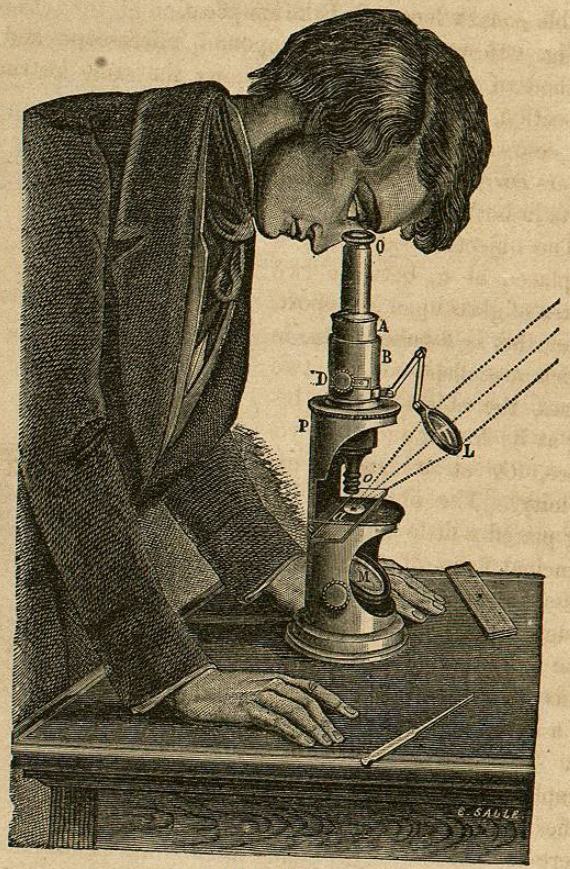


Fig. 219.

How is the magnifying power determined?

eight times. If the principal length were only one quarter of an inch, it would magnify thirty-two times.

The Compound Microscope.

327. The Compound Microscope consists essentially of a double convex lens called the *object-lens*, and a second double convex lens called the *eye-piece.*

Fig. 219 represents a compound microscope and the method of using it. Fig. 220 shows the same instrument in section, and makes known the course of the rays. The letters correspond to the same parts in both diagrams.

The object to be observed is placed at *a*, between two plates of glass upon a support. Over this is a tube, *OAo*, in which are disposed the two lenses, the object-lens, *o*, being at its lower, and the eye-piece, *O*, at its upper extremity. The object, *a*, being placed a little beyond the principal focus of the object-glass, this lens produces a real image, *bc*, which is inverted. The object-glass, *O*, is so placed that its principal focus is a little beyond the image, *bc*. This lens then acts as a simple microscope, and magnifies the image as though it were at *BC*.

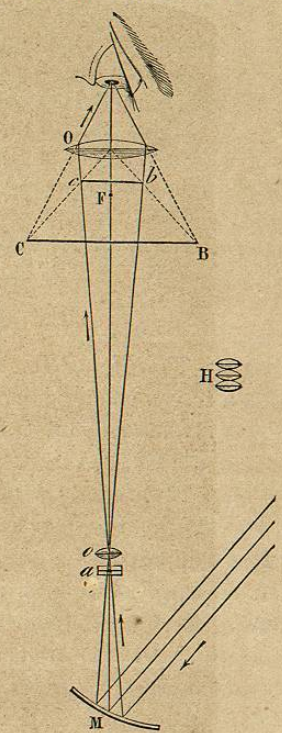


Fig. 220.

(**327.**) What is a Compound Microscope? Explain its construction, and the method of using it.

The magnifying power depends upon the object-lens. This power is increased by combining two or three lenses, as shown at *H*, on the right of Fig. 220. A second lens is often added to the eye-piece, as shown in the Newtonian telescope, Fig. 217, for the purpose of remedying the defect arising from spherical aberration. Moreover, all of the lenses are made achromatic.

Microscopes of this kind are constructed whose magnifying power is 1800; but what is gained in power is often lost in distinctness. A good magnifying power is 600 in length and breadth, which gives 360,000 in surface.

The object, when transparent, is illuminated by a mirror, *M*, which concentrates the light upon it. When the object is opaque, it is illuminated by a lens, *L*, which concentrates the rays upon it.

The microscope is used in the study of botany to discover the laws of the vegetable world; in entomology to study the habits of minute insects; in anatomy and medicine to study the laws of animal physiology; in the arts, to discover the composition of mixtures; in commerce to detect the nature of stuffs, and so on. Its use is almost universal, either as an instrument of research or of curiosity.

The Magic Lantern.

328. The MAGIC LANTERN is an apparatus for forming upon a screen enlarged images of objects painted on glass. It was invented about two hundred years ago, by Father KIRCHER, a German Jesuit.

Fig. 221 represents a magic lantern in use, whilst a section of the same instrument is shown in Fig. 222.

It is composed of a box, in which a lamp is placed before a reflector, *M*; the light is reflected upon a lens, *L*, and is converged so as to illuminate strongly the plate of glass, *ab*, upon which the picture is painted. Finally, a combination of two lenses, *m*, acting as a single convex lens, is placed so

Upon what does the magnifying power depend? Why is a second lens added to the eye-piece? How great may the magnifying power be made? How is the object illuminated? What are some of the uses of the microscope? (**328.**) What is a Magic Lantern? By whom invented? Describe the construction and method of using the magic lantern.

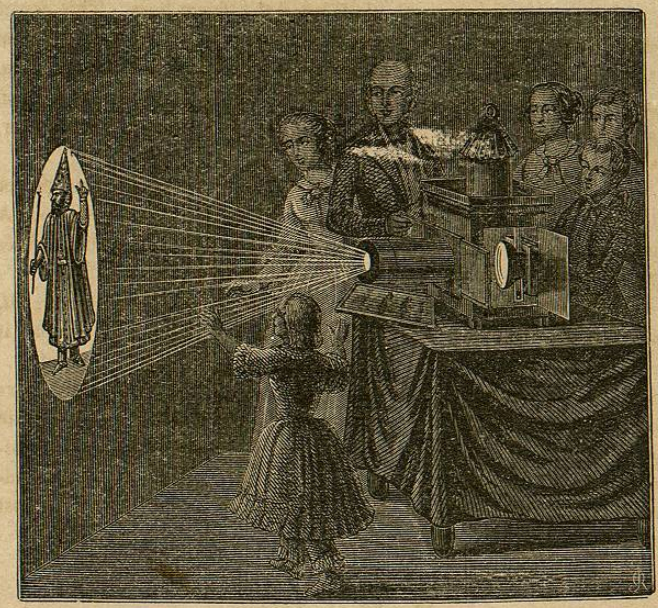


Fig. 221.

that the plate, *ab*, shall be a little within its principal focus. At this distance the lenses produce (as shown in Fig. 196) a magnified and inverted image of the picture painted on

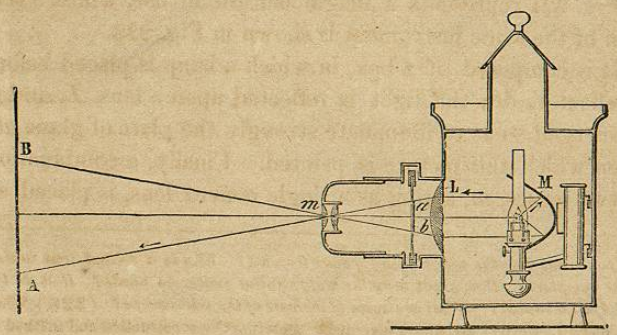


Fig. 222.

the glass. The picture on the glass should be inverted, in order that its image may appear erect.

The image on the screen will be the more magnified, as the plate, *ab*, approaches the principal focus of the compound lens *m*. It will also be the more magnified as the compound lens increases in power.

The Phantasmagoria.

329. The PHANTASMAGORIA differs only from the magic lantern in having an arrangement by which the size of the image on the screen may be increased or diminished at pleasure.

This modification will be understood from an inspection of Fig. 222, which represents the magic lantern. In it the lenses, *m*, being always at a fixed distance from the picture, *ab*, the image, *AB*, will always be at a fixed distance from the instrument, and of the same size.

If we suppose the lenses, *m*, to approach the glass, *ab*, the image, *AB*, will recede and become larger. We see then that the effect sought requires two motions: one which causes the lens, *m*, to approach the glass, *ab*, and a second which causes the whole apparatus to recede from the screen, *AB*, so that the image may always fall upon it.

To effect this double motion, the tube which contains the lenses is arranged to slide out and in, whilst the whole apparatus is mounted on wheels, covered with cloth so as to prevent sound in moving it.

Fig. 223 shows an apparatus arranged in this manner, which is composed of two magic lanterns united in one. For the present let us only take note of the nearest lantern. To exhibit the effects of the phantasmagoria, a screen of white muslin is stretched between the instrument and the spectators, and the exhibitor, by placing the lens at some distance from the picture, forms a small image on the screen, which is seen through the muslin by the spectators, who

(**329.**) How does the Phantasmagoria differ from the Magic Lantern? Explain the modification in detail. Explain the action of the phantasmagoria. *Explain Fig.* 223.

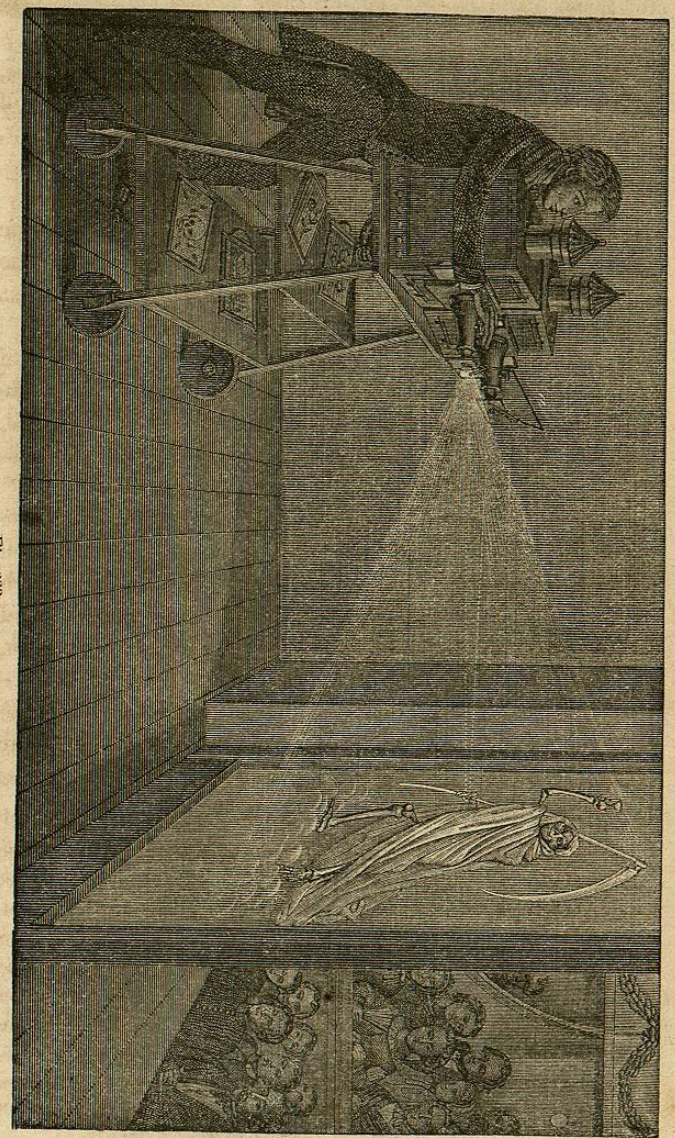


Fig. 223.

are in profound darkness. The exhibitor now pushes in the lens with one hand, whilst with the other he draws back the apparatus, causing the image to enlarge upon the screen. The gradual enlargement of the image causes the spectators, who have no means of judging of its exact location, to suppose that the image is approaching them.

It has been suggested that a similar effect, produced by a combination of mirrors, was used in ancient times for the purpose of frightening those who were initiated into the mysteries of Isis and Ceres, by causing images of the dead to appear when invoked.

The Polyrama and Dissolving Views.

330. The POLYRAMA consists of a double magic lantern, as shown in Fig. 223. The DISSOLVING VIEWS are obtained by using both lanterns. Thus, if a picture of a daylight scene be painted upon one of the slides, and of the same scene by moonlight be painted on the other, the first picture is thrown upon the screen strongly illuminated, the other one being entirely excluded by a screen which covers the second lens. By an arrangement operated on the exhibitor, the light is gradually cut off from the first picture and admitted upon the second, the first fading away insensibly, whilst the second as insensibly grows brighter. In this way all of the effects intermediate between full daylight and full moonlight may be obtained in succession.

In this way a volcano, calm, and only surmounted by a light cloud of smoke, may be followed by a picture of the same volcano sending forth volumes of flame and smoke. A storm may be made to succeed a smiling landscape, and so on; the illusion is complete.

The Photo-Electric Microscope.

331. The PHOTO-ELECTRIC MICROSCOPE is constructed on the same optical principles as the magic lantern, except

(**330.**) What is the Polyrama? Explain the method of producing the Dissolving Views. *Illustrate.* (**331.**) What is the Photo-Electric Microscope?

that the light employed is obtained by passing an electric current between two charcoal points. The pictures on the shades are also made smaller than in the magic lantern, which requires a greater illumination.

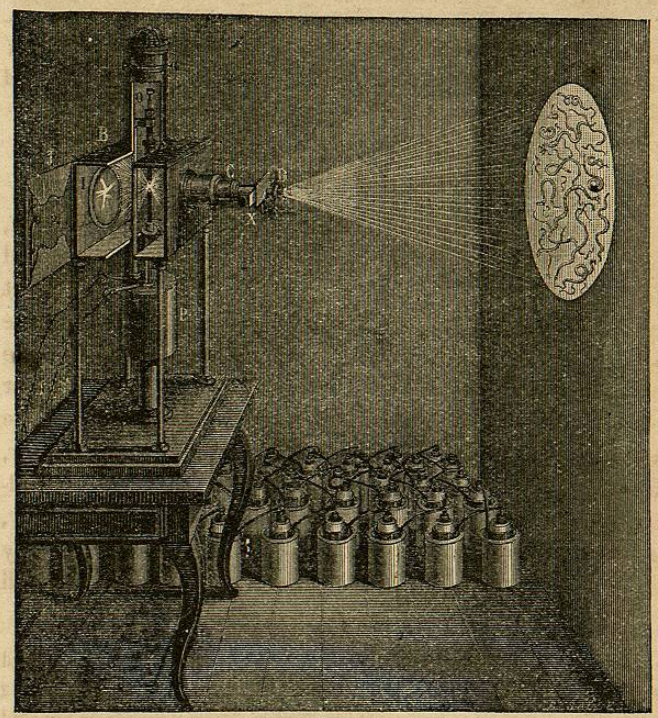


Fig. 224.

Fig. 224 represents in detail the arrangement of this instrument. At the foot of the apparatus is a battery for generating electricity, which will be described hereafter. The electricity is conveyed to the charcoal points in the box, *B*, by means of two copper wires, one going to the

Explain the arrangement of parts.

upper, and the other to the lower point. The points being slightly separated, the circuit is only completed by the electricity passing across the interval, which gives rise to a light of extreme brilliancy.

In the figure, *I* represents a parabolic reflector for concentrating the light upon the slide, *X*, through a lens, *C*. *D* is a lens which forms a magnified image of the minute object on a screen. The tube in which the lens, *D*, is placed, may be drawn out or pushed in to vary the magnifying power of the apparatus.

The magnifying power of this instrument may be made extremely great, and by suitable management it serves to show to a large company the wonders of the microscopic world.

One of the most remarkable experiments made with it, is to show the circulation of the blood. Instead of a picture on the slide, let the tail of a tadpole be placed between two plates of glass and introduced. There will appear upon the screen what seems an illuminated map, all of whose streams flow with a rapid current. It is but the blood circulating with great velocity through the arteries and veins.

The phenomena of crystallization are exceedingly beautiful when seen by this microscope. If a drop of a solution of sal ammoniac, for example, be poured upon a plate of glass, and then introduced into the instrument, the heat will cause the water to evaporate, producing one of the most beautiful examples of crystallization that can be exhibited.

The minute animalculæ of solutions and stagnant water can be shown by this microscope.

When the light of the sun is used instead of the electric light, the apparatus is called the *solar microscope*.

The Diorama.

332. The DIORAMA consists of two pictures, one on each side of a transparent muslin screen, these pictures, as in

How is the magnifying power varied? *What are its advantages? How is the circulation of the blood shown? The phenomena of crystallization? Animalculæ? What is a solar microscope?* (**332.**) What is the Diorama?

the polyrama, being different effects of the same scene. One of these pictures is seen directly, and the other by transmitted light, and the illusion arises from the light being

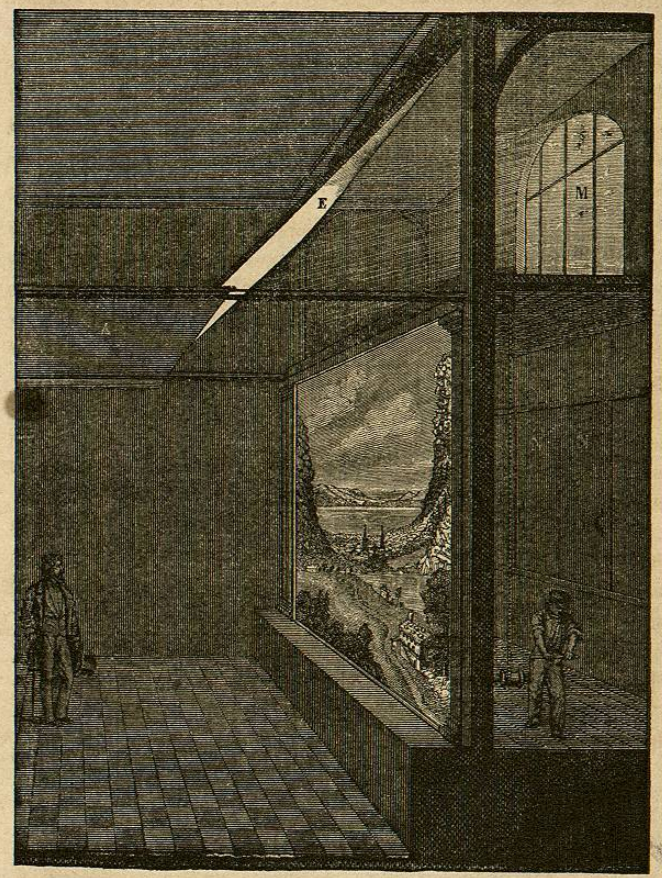


Fig. 225.

managed so as to produce either of these effects at pleasure. Fig. 225 explains the manner of exhibiting this kind of

From what does the illusion arise?

picture. The two views are painted on opposite sides of a vertical screen. The first effect is painted upon the front of the screen, and is seen by light that enters a window, *M*, and falling upon a movable mirror, *E*, is thrown so as to illuminate the front of the screen. The room behind the screen being dark, no part of the picture on the other side of the screen is seen.

If, now, the mirror *E*, be lowered gently, the shutters, *NN*, being at the same time slowly opened, the picture on the front of the screen will fade away, to be replaced by that on the other side, now seen by transmitted light. When the mirror is let completely down, and the shutters, *NN*, are completely opened, the only effect that will be seen will be that from behind.

The diorama was invented and perfected by DAGUERRE, the celebrated discoverer of the daguerreotype. Many of his pictures of this kind had a high reputation, among which may be mentioned his *Midnight Mass*, and his *Valley of Goldeau*.

The Camera Obscura.

333. The CAMERA OBSCURA is an instrument used for forming a clear picture of objects upon a screen of ground glass or paper.

It consists, Fig. 226, of a closed box mounted on a stand, having a small hole on one side and a screen for receiving the image on the opposite side. The hole may be of any dimensions, if a concave lens be placed in it capable of filling it, and of such power as to bring the rays to a focus on the opposite screen.

Fig. 226 shows how the image is formed in the camera obscura. The pencil of rays coming from the soldier's cap goes to form an image at the bottom of the box, whilst that coming from his feet goes to form an image at the top of

Explain the method of exhibiting. *Who invented the diorama?* (**333.**) What is the Camera Obscura? Describe it. Explain the course of the rays.

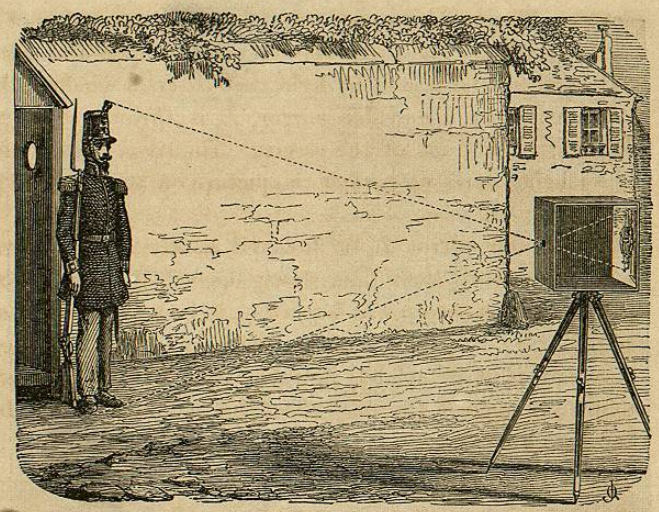


Fig. 226

the screen. The image is inverted and reversed in a horizontal direction, but in every other respect, including color, it is a perfect representation of the object pictured.

The camera obscura affords aid in sketching the outlines of a landscape or building, but its principal importance at present consists in its application to the various branches of Photography. It may also be used as a source of amusement.

The images formed by a camera obscura possess the remarkable peculiarity of being entirely independent of the shape of the opening in the box, provided it be quite small. The shape of the images is the same, whether the opening be square, round, triangular, or oblong.

To show this, let us consider the case of a beam of solar light entering a dark room through a hole in a shutter, Fig. 227. With respect to the sun, the hole in the shutter is but a point, hence the group of rays which enter it form in reality a cone whose base is the sun. The prolongation of these rays into the room makes up another

For what is the camera used? What remarkable property do the images possess? How is this illustrated?