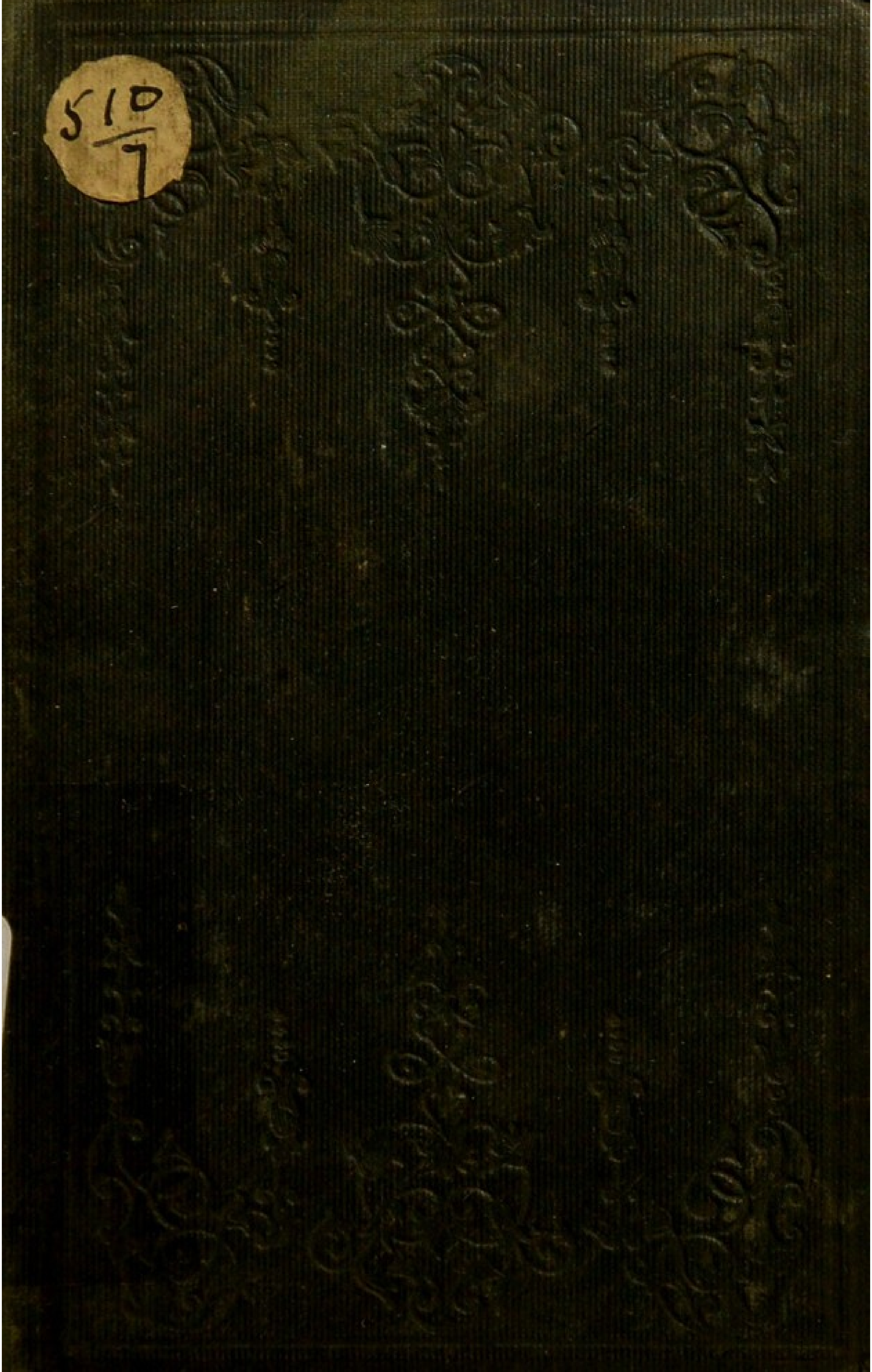
The telescope and microscope / by Thomas Dick.



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[1851]

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THE TELESCOPE AND MICROSCOPE.

PART I.

THE TELESCOPE.

God has been pleased, in various ages, to guide men to those discoveries, which have enlarged their views of his perfections, and increased their knowledge and happiness. Among these discoveries may be placed the construction and the uses of the telescope.

Section I.—*The invention of the telescope.*

The telescope is an instrument for looking at distant objects. Its name is compounded of two Greek words, *tele*, at a distance, and *scopein*, to view.* By this instrument, the most distant

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* Τηλε, σκοπειν.

objects seem to be brought near to the eye, and many of those which are obscure, and without its aid invisible, are clearly seen. A terrestrial object, at the distance of six miles, is as distinctly visible as if it were within eighty or a hundred yards; and worlds, which were for ages concealed in the remotest depths of space, or which shine only as luminous points in the heavens, are made so accessible to our sight, that their appearance, magnitude, and movements, may be described and calculated.

It is difficult to determine to whom we are indebted for the telescope, and what is the precise date of its invention. No discoveries have been handed down to us, which would lead to the conclusion that it was known to the ancients. Before the end of the thirteenth century, glass lenses were used to assist the eye in obtaining distinctness of vision. There can be no doubt, also, that the celebrated Roger Bacon, who died in 1292, was aware that lenses might be so arranged, as to magnify the appearance of objects seen through them; but there are good reasons for believing, that his knowledge was derived only from reflection, and that he never carried his theory into practice. Whatever were the ideas, or the experiments of the learned, the telescope was not much known before the beginning of the seventeenth century. If, as some have supposed, its existence may be traced back to a much earlier period, its importance was not discovered until an accidental circumstance brought its wonderful power into public notice. The children of a spectacle maker, residing at Middleburgh, in Holland, were playing in their father's workshop, and observed, that when they held between their fingers two spectacle glasses, at some distance one before another, and looked through them at the weathercock of the church, it seemed inverted, but very near to them, and greatly increased in size. Having called the attention of their father to this strange sight,* he adjusted two glasses on a board, supporting them on two brass circles, the distance of which from each other might be increased or diminished at pleasure. Many persons visited his

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* The same change in the appearance of objects may be seen by any one who has glasses at command. Take a convex glass or lens, suppose of fourteen inches focal distance, and another of two inches focal distance, hold them in a line sixteen inches asunder, and look through the glass of two inches focus, and objects will appear inverted, and seven times larger and nearer than to the naked eye, that is, in the proportion of fourteen to two.

workshop to see his experiments, which afforded amusement, and awakened curiosity. To this incident we may probably attribute the expression of Huygens, an astronomer of the seventeenth century, who described the telescope as a "casual invention."

For some time the contrivance of the Middleburgh optician remained unimproved, and was applied to no valuable purpose. At length, about the year 1609, two workmen of the same city, by giving to his discovery a new form, made all the honour of it their own. These men, whose names were Zachariah Jans, or Jansen, and Hans Lapprey, or Lippersheim, are said to have been spectacle makers. One of them placed the glasses in a tube, the inside of which he blackened, to prevent the glare, which would be occasioned by the reflection of light from a bright surface, and which would produce indistinctness of vision. The other placed the glasses in tubes, sliding one within another, to make the instrument portable by diminishing its length. When Jansen had completed his telescope, he presented it to prince Maurice of Nassau. The United Provinces were then at war with France, and the prince, perceiving the advantage which he might obtain in the field over the enemy by means of this gift, desired that its invention should be kept a profound secret. But the time had now arrived when the telescope was to be employed for nobler purposes than those of war, and, as the medium of most astonishing discoveries, to justify what soon afterwards was said of it, that the wit and industry of man had produced nothing so worthy of his faculties.*

Before the time of Galileo, who was born at Pisa, in 1564, the observations which had been made in the heavens were few and imperfect. He has been frequently supposed to be the inventor of the telescope, because he was the first who successfully applied it to astronomy. In the following passage, translated from a small work, written in Latin, which he published in 1610, under the title of "*Sidereus Nuncius*," he confutes this notion, and shows what prompted his first efforts to make such an instrument. "Nearly ten months ago, it was reported that a certain Dutchman had made a perspective, through which many distant objects appeared as distinct as if they were near. Several expe-

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* Huygens.

riments were reported of this wonderful effect which some believed, and others denied ; but, having had it confirmed to me a few days after, by a letter from Paris, I applied myself to consider the reason of it, and by what means I might contrive a like instrument, which I attained to soon after by the doctrine of refractions. And, first, I prepared a leaden tube, in whose extremities I fitted two spectacle glasses, both of them plain on one side, and on the other side, one of them spherically convex, and the other concave. Then, applying my eye to the concave, I saw objects appear pretty large, and pretty near me ; they appeared three times nearer, and nine times larger in surface, than to the naked eye. And soon after I made another, which represented objects above sixty times larger ; and at last, having spared neither labour nor expense, I made an instrument so excellent as to show things almost a thousand times larger, and about thirty times nearer, than to the naked eye."

When Galileo had finished his best telescope, he directed it first to the moon, the nearest of the heavenly bodies, and saw it, as he says, at a distance within two diameters of the earth.

He perceived on its surface two kinds of spots, one very clear, and the other dusky, resembling clouds. He also remarked, that the boundary between its dark and enlightened parts was neither a straight line nor a regular curve, but that it was jagged and uneven, indicating the existence of mountains and valleys. On examining the sun, he discerned several large dark spots, and ascertained from their motion across its disc, that it revolved round its axis in about twenty-six days. Jupiter presented to him new wonders. He perceived three small stars close to the line in which it was moving. By subsequent observation, he saw that they frequently changed their position, and sometimes disappeared. After watching them for a long time, he found that they were small planets, revolving round the larger one, as the moon revolves round the earth. He afterwards discovered a fourth satellite. Looking through his glass at Saturn, he was astonished to find it had the appearance of a planet of large dimensions between two smaller ones. They seemed almost to touch each other, and to have their centres in a straight line. This observation was made early in 1610. Galileo was still more astonished in 1612, to find that the two smaller planets had disappeared. About ten months afterwards they were again visible. They soon assumed various shapes, and were sometimes round, and then oblong; at other times semicircular, and then lunar, with horns pointing inwards, and growing by degrees so long, and so wide, as nearly to encompass the one in the middle. To some the three appeared to be conjoined, and to others to be disunited. Considering the imperfection of the first telescopes, it is, perhaps, not surprising that more than forty years elapsed before any satisfactory explanation could be given of these phenomena. In 1659, Huygens published his discovery, that Saturn is surrounded by an immense ring, the two lateral parts of which had been erroneously supposed to be two smaller planets. In his description * of it, he established the position of the ring, and explained the causes of its occasional disappearance, and of the different forms under which it is seen. Venus was the next object which engaged the attention of Galileo. He observed this planet when near its superior conjunction. At first it looked nearly globular; shortly afterwards its phase was gibbous, or deficient in roundness; it quickly became lunated, or like a half

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* "*Systema Saturnium.*"

moon, and then it dwindled into a slender crescent, like the moon when three or four days old. From these observations he concluded, first, that the planets are opaque bodies like the earth and moon, deriving all their lights from the sun; and, secondly, that Venus moves round the sun, and not, as was generally imagined, round the earth. He then examined the fixed stars, and beheld many, invisible to the naked eye, nearly as large as those of the first and second magnitude. Within the range of the Pleiades, he counted no less than thirty-six stars, and almost as many in the constellation of Orion, which are not visible to the unaided sight. Præsepe, which looks but a dim speck in the sky, he perceived to be a cluster of forty stars, and the Galaxy, or Milky Way, to be an innumerable multitude, powdering * the heavens with light. The doubts of former philosophers respecting this remarkable tract were at once solved, and many of their speculations respecting it were shown to be scarcely less absurd than the fables of the mythologists.

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* ———"The galaxy, that milky way,
Which nightly, as a circling zone, thou seest
Powder'd with stars." MILTON.

Milton visited Galileo, and entertained the highest opinion of his philosophy, to which he makes some beautiful allusions in his "*Paradise Lost.*"

Intelligence of the discoveries of Galileo rapidly spread throughout Italy and other European countries. His book, already mentioned, entitled "*Sidereus Nuncius*," produced an extraordinary sensation among the learned. His statements were opposed to the philosophy of Aristotle, and that was a sufficient reason with many for their rejection. Some endeavoured to reason against his facts, but others satisfied themselves with asserting, that such things were not, and could not possibly be. The principal professor of philosophy at Padua, lest he should be convinced of their reality, refused to look through the glass of Galileo. Martin Horkey, another of his opponents, is reported to have said to Kepler,* "I will never concede his four new planets to that Italian from Padua, though I should die for it;" and in a book which he published he solemnly declared, that he did not more surely know that he had a soul in his body, than that reflected rays were the entire cause of Galileo's errors. Sizzi, a Florentine astronomer, reasoned in this way: "There are seven windows given to

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* An able mathematician and astronomer. He was born at Weil, in the duchy of Wirtemberg, in 1571, and died in 1630. Between him and Galileo the warmest friendship subsisted.

animals in the domicile of the head, through which the air is admitted to the rest of the tabernacle of the body, to enlighten, warm, and nourish it; two nostrils, two eyes, two ears, and a mouth; so in the heavens, or the great world, there are two favourable stars, two unpropitious, two luminaries, and Mercury alone undecided and indifferent. From which, and many other similar phenomena in nature, such as the seven metals, we gather that the number of the planets is *necessarily seven.* Moreover, the satellites are invisible to the naked eye, and therefore can exert no influence over the earth, and therefore would be useless, *and therefore do not exist.*" An agreeable contrast to this senseless bigotry is presented in the conduct of the senators of Venice, who were eminent for their learning and patriotism. They invited Galileo to their city, to make a trial of his new instrument in their presence. Having complied with their invitation, one fine night, neither cold nor cloudy, he erected his telescope on the top of the tower of St. Mark. Jupiter was shining brightly on the meridian, the moon was displaying its silver horns towards the west in the form of a crescent, and Venus was in full splendour in the same direction. The senators gathered round the astronomer. Jupiter, with its three satellites, the fourth being eclipsed by the body of the planet; Venus, at its furthest distance from the sun, not a completely illumined sphere, but one half obscured; and the crescent of the moon, with its internal mountainous-looking border, passed in succession under their review. The senators acknowledged the truth of Galileo's discoveries, and alternately poured upon him their compliments, and pressed him with their inquiries. When he had answered all their questions, he delivered a long lecture to his distinguished auditors on the true system of the universe. He showed that the ancient system of Ptolemy could not be reconciled with the motions of the heavenly bodies, and that the changes of day and night, the revolutions of the seasons, the precession of the equinoxes, and other phenomena, could only be explained on the theory of Copernicus. That night was fatal to the system of the ancient schools. The admirable discourse of Galileo carried conviction to every mind. The Venetian nobles acknowledged the perfect agreement of all they had seen with the Copernican system.* From this time it began to obtain

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* Copernicus was born towards the close of the fifteenth

credit throughout Europe, and the improvement of the telescope became important to all who appreciated these early fruits of its invention.

SECTION II.—*Preliminary definitions, and optical principles to be recognised in the construction of the telescope.*

It is not necessary to enter into what is abstruse in optical science, in order to understand the general principles on which a telescope is constructed. But there are certain facts respecting light, and its refractions, reflections, and their effects, of which some information may be useful.

Light is an ethereal matter, distributed throughout the universe, and rendering perceptible to the eye scenes and objects, at once the nearest and the most remote. It is essential to life and happiness. Without it, creation would be lifeless and unadorned. Like a per-

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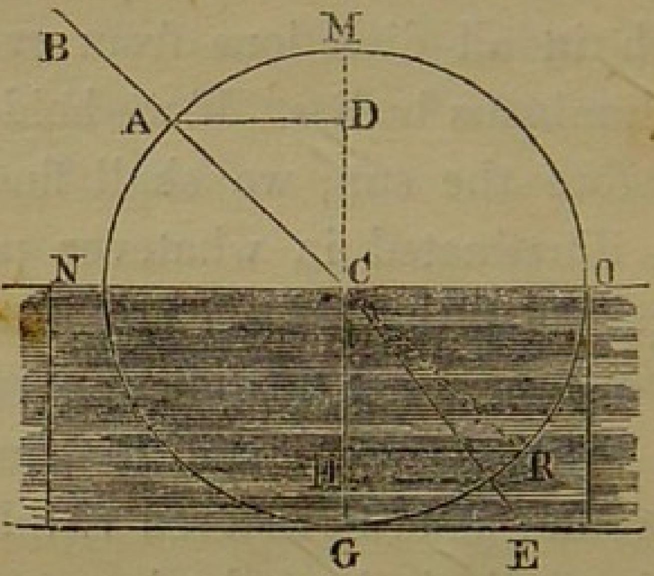
century, at Thorn, in Prussia. In his system he made the sun the centre, about which the planets revolve at different distances, and with different degrees of velocity. Above the planets he placed the starry heavens, which are boundless and immeasurable.

vading spirit, it animates what it reveals. It has become associated in our minds with order, beauty, and goodness. It is so glorious, that it is said to be the "garment" (Psa. civ. 2) of the Almighty. It is so pure, that it is an emblem by which He himself is represented, (1 John i. 5.) It is so transforming, that light is the written name of that new creation, which it is the work of the Holy Spirit to accomplish in the heart of man, (Ephes. v. 8.)

As the properties of light form the foundation of the structure of the telescope, some of these may be briefly stated. 1. Light emanates or radiates from luminous bodies, when passing through the same medium, *in a straight line.* This is proved by the impossibility of seeing light through bent tubes, or small holes pierced in metallic plates, put one behind another, unless the holes be placed in a straight line. 2. The particles of light are almost infinitely small. Dr. Niewentyt computed that more than six billions' times as many particles of light flow from a candle in one second of time, as there are grains of sand in the whole earth, supposing each cubic inch of it to contain one million. 3. Light moves with amazing velocity. It travels across the earth's orbit, a space 190 millions of miles in extent, in the course of sixteen and a half minutes, or at the rate of 192,000 miles every second, which is more than a million times swifter than a cannon ball flying with its utmost velocity. 4. Light is sent forth in all directions from every visible point of luminous bodies. If we hold a sheet of paper before the sun, we shall find that the paper is illuminated in whatever position we hold it, provided the light is not obstructed by its edge or any other body. 5. It is by light reflected from opaque bodies that most of the objects around us are rendered visible. When a lighted candle is brought into a room, not only the candle, but all the other bodies in the room become visible. In like manner, the light of the sun falling upon the moon and planets, which are opaque bodies, is reflected from their surfaces, and renders them visible to our sight.

When the rays of light continue in any medium of uniform density, they proceed in straight lines, but when they pass *obliquely* out of one medium into another, which is either more dense or more rare, they are refracted towards the denser medium, and this refraction is more or less, as the rays fall more or less obliquely on the refracting surface which divides the mediums. This may be illustrated

Fig. 1.

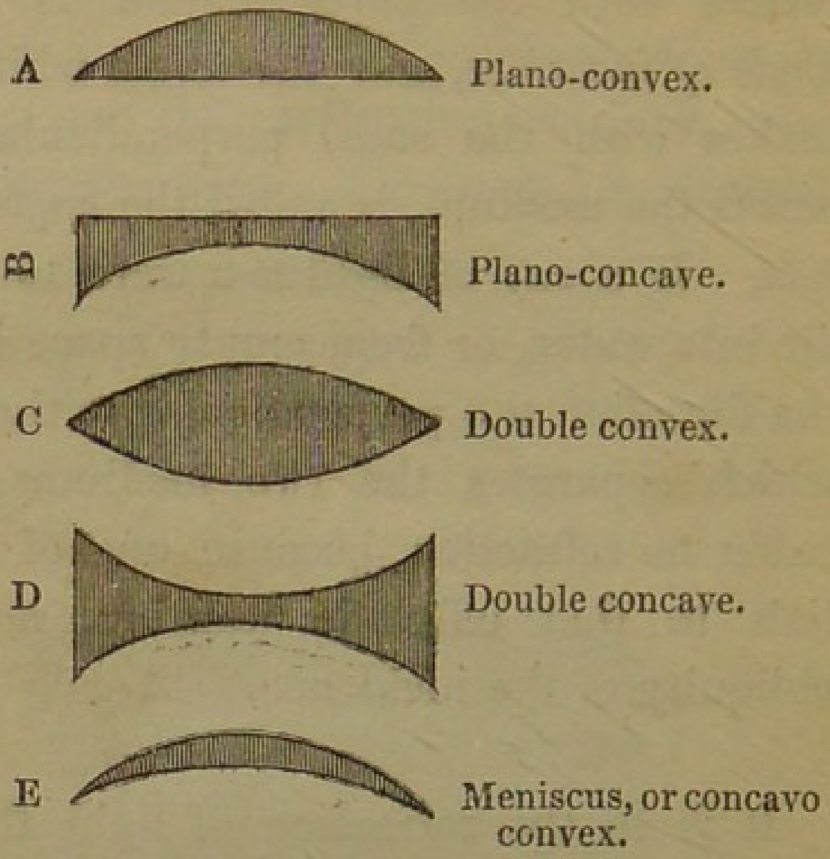


by fig. 1, where B C is the incident ray which falls upon the medium N O, which suppose to be water; C E is the refracted ray, D G the perpendicular, A D the sine of the angle of incidence A C D, and H R the sine of the angle of refraction G C E. Now it is a proposition in optics, that the sine A D of the angle of incidence B C D, is in a given proportion to the sine H R of the angle of refraction G C E. The ratio of the sines is as 4 to 3, when the refraction is made out of air into water, that is, A D is to H R as

4 to 3. The angle which the incident ray makes with the perpendicular is called the *angle of incidence*, and the angle which the ray makes with the same perpendicular after it enters the medium, is called the *angle of refraction.* If a ray of light M C were to pass from air into water, or from empty space into air, in the direction M C perpendicular to the plane N O, which separates the two mediums, it would suffer no refraction, because one of the essentials to that effect is wanting, namely, the obliquity of the incidence.

It is to the refraction of light that we are indebted for the use of lenses to aid the powers of vision. A lens is a transparent substance, usually glass, having two surfaces, either both spherical, or one spherical and the other plain. A convex glass is thick in the middle, and thinner towards the edges. A concave glass is thin in the middle, and thicker towards the extremities. Of these there are various forms. In the annexed fig. 2, A is a plano-convex, B a plano-concave, C a double convex, D a double concave, E a meniscus, or concavo-convex, which is partly convex and partly concave, the convex side being a portion of a smaller sphere than

Fig. 2.



the concave. The rays which proceed from visible objects are either parallel, converging, or diverging. *Parallel* rays are those which are equally distant from each other, as those which proceed from the sun and planets, and from distant terrestrial objects. *Converging* rays are such as approach nearer and nearer in their progress to a certain point where they unite. *Diverging* rays are those which continually recede from each other, as the rays which proceed from near objects, such as a window in a room or an adjacent house.

When a convex lens, whether plano or double convex, is placed opposite to any object, the rays of light which pass through it *form an image or picture of the object* in its focus, if a paper or card be placed to receive it. Let L N,

Fig. 3.

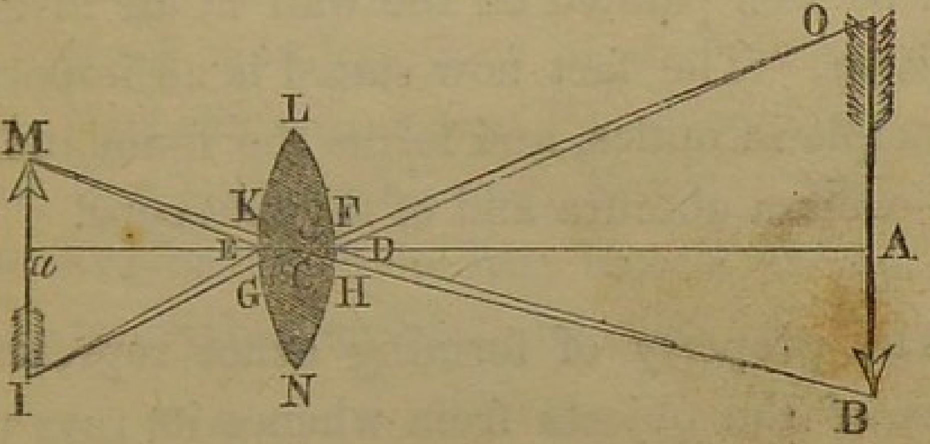


fig. 3, represent a double convex glass, A C its axis, and O B an object perpendicular to it. A ray passing from the extremity of the object at O, after being refracted by the lens at F, will pass on in the direction F I, and form an image of that part of the object at I. In like manner, B C M is the axis of that parcel of rays which proceed from the extremity of the object B, and their focus will be at M, and all the points of the object between O and B will have their foci between I and M, and an image of the whole object O B will be depicted in an *inverted position*, because the rays cross at C, the centre of the lens. This may be illustrated by experiment. Take a convex glass of eight or ten inches focal distance, a reading glass, for example, and holding it at its focal distance from a white wall, in a line with a gas lamp or burning candle, the flame of the candle or lamp will be seen painted on the wall in an inverted position. The fact now stated is an important principle in optics, and forms the foundation of the camera obscura and of the telescope.

The property of forming exact representations of the objects from whence its rays proceed is possessed by light, whether emanating directly from the sun, or reflected from the objects it illuminates, or coming from bodies artificially enlightened. This property in light is not peculiar to the system to which we belong. If it were, our field of vision would have been comparatively limited. The telescope would have been useless for the observation of those distant stars, which are the suns of other systems beyond our own, and we should have remained in profound ignorance of worlds, " in number beyond number," which now " declare" to us " the glory of God." In this point of view, we cannot regard as accidental an invention which has made us better acquainted with His omnipotence and wisdom in the existence and arrangements of the universe. It reveals to us His providential care displayed in all the departments of nature. In every ray of light it teaches us the lesson that "God is love." It leaves us, however, to learn from another source the highest manifestations of that love. The Bible *alone* can tell us that "God so loved the world, that he gave his only begotten Son, that whosoever believeth in him should not perish, but have everlasting life," John iii. 16.

Before describing the structure of a telescope, it may be proper to state the manner of finding the focal distance of a convex lens. Let *a b*,

Fig. 4.

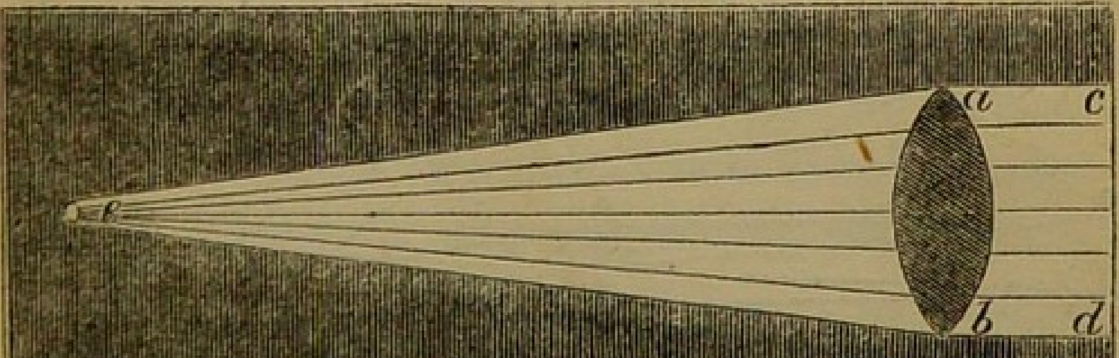


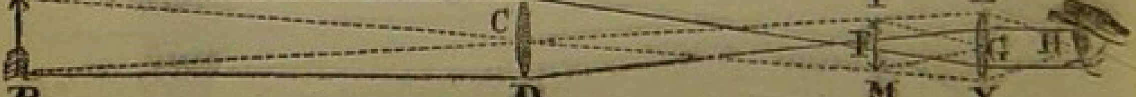
fig. 4, be a convex lens, and *c d* parallel rays proceeding from the sun ; those rays, after passing through the lens, will converge to a point *e*. Hold the lens opposite to the rays of the sun, and observe where the rays converge to a small spot as at *e*. This spot is the image of the sun formed by the lens; measure the distance between the lens and the spot; it is the focal distance required.

SECTION III.—*Description of common refracting telescopes.*

There are various kinds of refracting telescopes, which we shall describe in their order, commencing with that which is the most simple, and most easily understood.

1. *The astronomical telescope.*— The only parts essential to this telescope are two lenses, A D and E Y, fig. 5. A D is the object glass, and E Y is the eye glass. Let O B be a distant object, from which rays proceed nearly parallel

Fig. 5.



to A D, the object lens. The rays passing through this lens will form an image of the object in its focus at I M, and as the rays cross each other it will be inverted. E Y, the eye glass, is placed exactly at its focal distance from this image, and must be of a much shorter focal distance than the object glass. The magnifying power in this telescope is in the proportion of the focal distance of the object glass to that of the eye glass. Suppose the object glass to be of 24 inches focal distance, and the eye glass 1 inch, the magnifying power is then as 1 to 24 ; in other words, it makes a distant object appear 24 times nearer, and 24 times larger in size than it is to the naked eye. If the eye glass had been 1½ inch focal distance, the magnifying power would have been only 16 times. Through this telescope all objects appear inverted, like the image at I M. This telescope was much in use by astronomers in the seventeenth and eighteenth centuries. In order to obtain a considerable magnifying power, it was sometimes made more than a hundred feet long ; and as it was found inconvenient to have a tube of this length, the telescope was used without one. A high pole was erected, the object glass was placed at the top of it, and capable of being turned in every direction by a cord which descended to the station occupied by the observer, who held the eye-piece at the height of his eye, resting it on a pedestal. But these long instruments are now entirely superseded by the invention of achromatic and reflecting telescopes.

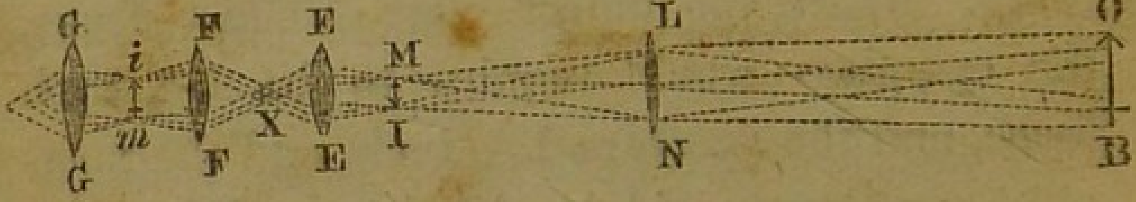
A telescope of the kind described may be easily constructed, and at a small expense, Procure a double convex lens, about 36 inches focal distance, place it at the end of a tube, as at A B, fig. 6; at 37 inches distance from this glass fix another, C D, whose focal distance is 1 inch. This glass must be fixed in a separate short tube, E F, which should be made to slide backwards and forwards in the large tube, for the purpose of adjusting the focus of the telescope to the eye. Such a telescope will magnify objects in the proportion of 1 to 36, or 36 times, and will show the spots in the sun, the shadows of the mountains and cavities in the moon, Jupiter's satellites, the

Fig. 6.

crescent of Venus, and other celestial phenomena. In constructing such a telescope, the following particulars require to be attended to:—1. The aperture, or opening which lets in the light at the object glass, should not exceed 1 inch in diameter, otherwise the image of the object will be somewhat confused. 2. There should be a hole or aperture in the focus of the eye glass rather less in diameter than the breadth of the eye glass, for the purpose of excluding the extraneous rays. Were a telescope of this kind to be constructed with an object glass 6 feet focal distance, the eye glass would require to be $1\frac{1}{2}$ inch focal distance, and the aperture of the object glass $1\frac{1}{2}$ inch diameter, and the magnifying power would be 45 times. Were the object glass 10 feet focus, the eye glass would require to be $1\frac{8}{10}$ inch focus, and the aperture $1\frac{7}{10}$ inch, and the magnifying power would be 63 times. Were the object glass 20 feet focus, the eye glass would be $2\frac{1}{2}$ inches focus, the aperture $2\frac{4}{10}$, and the magnifying power would be 89 times. It is found, that in order to magnify twice as much as before, with the same light and distinctness, the telescope must be lengthened 4 times; to magnify three times as much, 9 times; four times as much, 16 times; that is, suppose a telescope of 3 feet to magnify 36 times, in order to procure a power four times as great, or 144 times, we must extend the telescope to the length of 48 feet, or 16 times the length of the other.

2. *The common refracting telescope for land objects.*—The telescope just described, in consequence of its showing every object in an inverted position, is not fitted for land objects. In order to adapt it for terrestrial objects two additional eye glasses are required. In fig. 7, let O B represent a distant object, L N the object glass which forms the image I M in an inverted position; let E E represent another glass placed at its focal distance from this image, as in the astronomical telescope, and F F a second glass, placed at twice its focal distance from E E. By this glass (F F) a second image is formed at *i m*, contrary to the first image I M, and, conse-

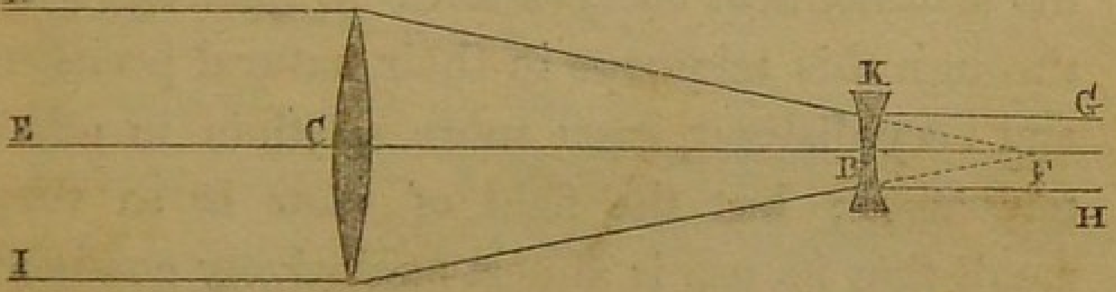
Fig. 7.



quently, erect. This last image is viewed by the third lens, G G, in the same manner as the first image I M would be viewed by E E. All these eye glasses are understood to be of the same focal distance, and are placed at double their focal distance from each other. Such a telescope represents land objects in their natural positions. But this arrangement of glasses is different from the eye-piece now adapted to achromatic telescopes, of which we shall afterwards give a short description.

3. *The Galilean telescope.*—This telescope consists of two glasses, a convex glass, C, next the object, and a concave, K, next the eye, fig. 8.

Fig. 8.



Let I D represent rays proceeding from an object; these rays would converge to their foci, and form an inverted image at F, if they were not intercepted by the concave lens K. But this lens being a double concave, occasions the rays to diverge more than before, so that the rays D I emitted from the object, instead of converging to F, are made to proceed parallel to G H, and it is parallel rays that produce distinct vision. The concave lens, K, is placed as much within the focal distance of the convex, C, as is equal to its own focal distance, and the magnifying power, as formerly, is in proportion to the focal distance of the object glass to that of the eye glass. Thus, suppose the focal distance of the object glass to be 12 inches, and that of the concave eye glass 1 inch, the concave must be placed at 11 inches from the object glass, and the magnifying power will be as 1 to 12, or 12 times. This was the kind of telescope constructed by Galileo, and with which he made his astronomical observations. Objects are seen through this telescope in their natural position, and very distinct, even more so than in other telescopes; but the field of view is so very small that its use is almost exclusively confined to the common opera glasses. A good telescope, however, can be made on this principle capable of showing much to interest the observer. If we take a convex lens, 40 inches in focal distance, we may apply to it a concave lens of only

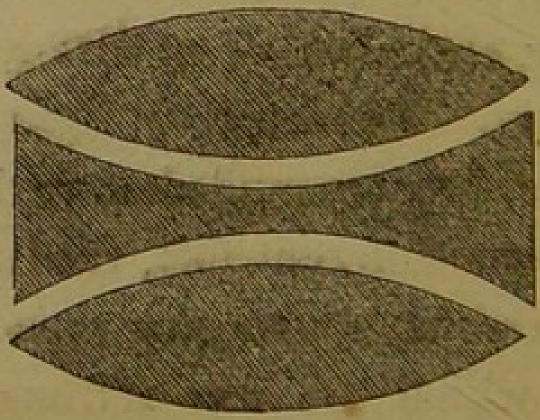
1 inch focal distance, at the distance of 39 inches from the object glass, and the magnifying power will be 40 times, which will show us Jupiter's satellites, the crescent of Venus, and Saturn's ring. There is some difficulty in finding an object with this telescope, and only a part of the sun and moon can be seen through it at one time.

SECTION IV.—*The achromatic telescope.*

The common astronomical refracting telescope was very imperfect, and was also so unwieldy that its use was attended with much trouble and inconvenience. To obtain a considerable magnifying power, it was found necessary to increase its length to 60, 80, 100 feet, and upwards. To get a power, for example, of about 200 times, the telescope required to be 120 feet in length. Its other imperfections consisted, 1, in the rays of compounded light coming to their foci at different distances from the glass. Every ray of light, as is found by the prism, is compounded of various colours, and these have different foci, the more refrangible, as the *violet*, converging sooner to a point than those which are less refrangible, as the *orange* and the *red.* Hence the image of an object formed by a single lens is in some degree confused and indistinct, and, therefore, will not bear to have a high power put upon it. 2. Another imperfection was this, that spherical surfaces do not refract the rays of light accurately to a point. The rays which pass near the extremities of such a lens meet in foci more distant from the lens than those which pass nearly through the centre, and hence are invariably coloured.

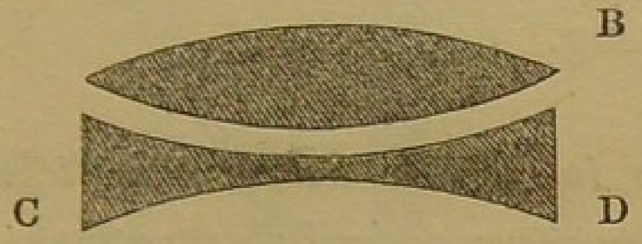
To remedy these defects is the intention of the achromatic telescope, the theory of which was first made known by Mr. Dollond, an optician of considerable celebrity in London. The object glasses of this telescope are frequently composed of three distinct lenses, two of which are convex and the other concave.

Fig. 9.



The two which are convex are made of London crown glass, and the middle one of white flint glass, or that kind of glass of which wine glasses and tumblers are made. Fig. 9 represents this compound triple object glass, as it is fitted up in its cell, and placed at the object end of the telescope. But it is now more frequently the practice with opticians to form this object glass double, as in fig. 10, where A B is the convex of crown glass, and C D the concave of flint glass. The convex is placed outside next the object, and the concave in the inside. By this combination of glasses, when accurately adjusted to each other, an image of the object is formed without being blended with the prismatic colours. Hence the word achromatic, by which this telescope is distinguished, signifies free of colour. In consequence of this property, such glasses will bear a much larger aperture, and a much greater magnifying power, than common refracting telescopes. While a common telescope, whose object glass is $3\frac{1}{2}$ feet

Fig. 10.

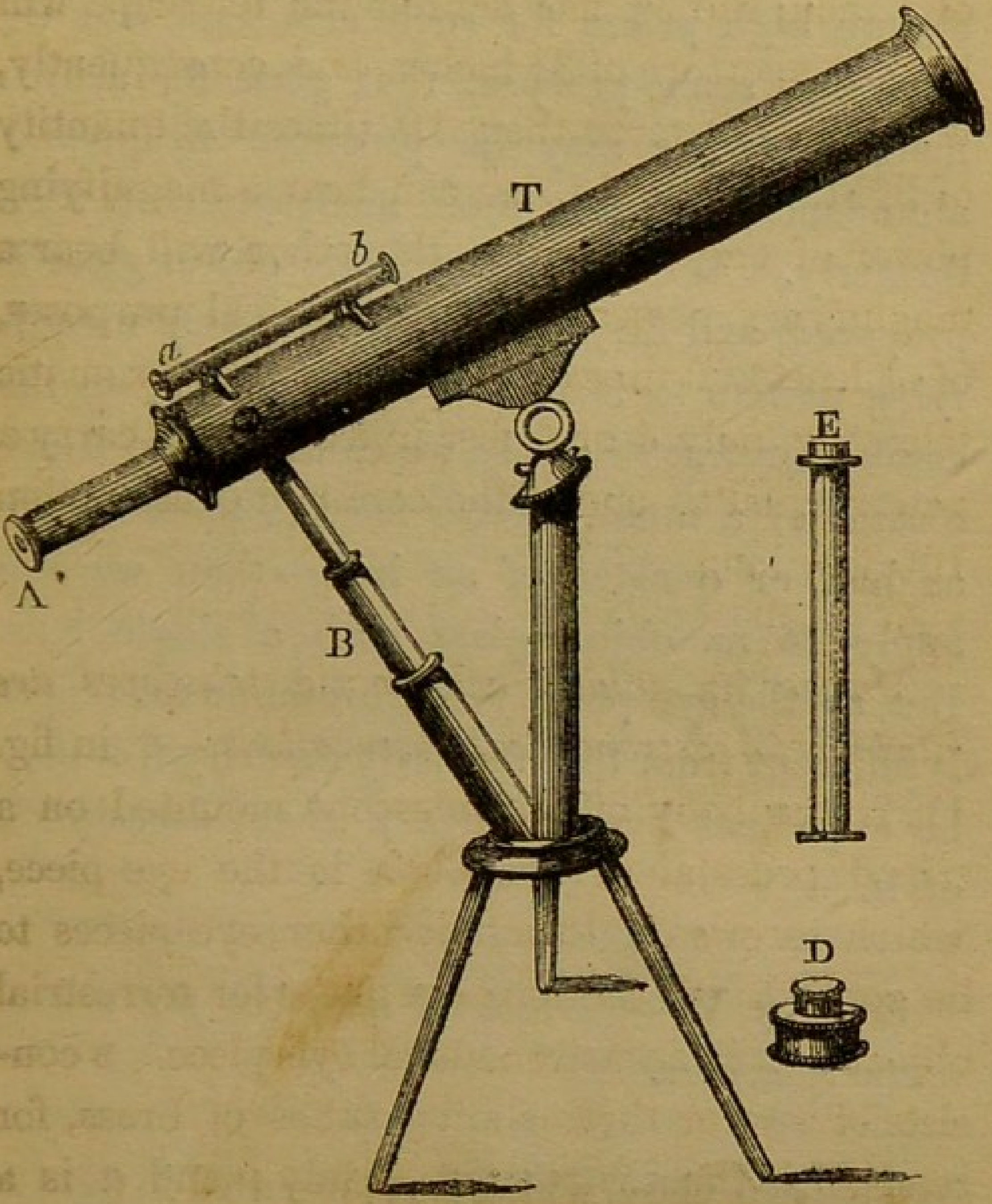


focal distance, will scarcely bear an aperture of 1 inch, the 3½ feet achromatic telescope will bear an aperture of 3¼ inches, and, consequently, will transmit more than 10 times the quantity of light. While the one can bear a magnifying power of only 36 times, the other will bear a magnifying power, for astronomical purposes, of at least 200 times ; so that a good achromatic telescope, only 4 or 5 feet in length, will carry a power equal to one of the common construction 100 feet long.

Manner in which achromatic telescopes are fitted up for astronomical observations.—T, in fig. 11, is the body of the telescope mounted on a tripod pedestal of brass. A is the eye-piece, which screws off to admit other eye-pieces to be applied. E is the long eye-piece for terrestrial objects. D is an astronomical eye-piece. B consists of two or three sliding tubes of brass, for rendering the instrument steady ; and *a* is a brass knob, which moves a piece of rack work for adjusting the focus. *a b* the finder.

This telescope is now generally used. If flint glass of a large diameter, and without blemishes, could easily be procured, it would

Fig. 11.

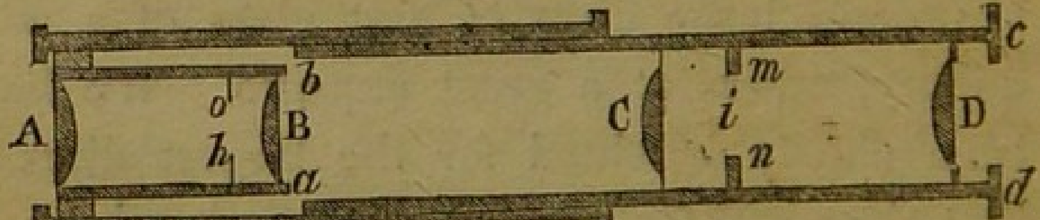


soon supersede almost all other telescopes. But hitherto it has been very difficult, in Britain, to procure large discs of flint glass, of a good quality, unless at a great expense. We have been chiefly indebted for the largest discs of flint glass, and for the best achromatic telescopes we possess, to the French and Germans, who charge high prices for such articles. But we have now some prospect that glass for achromatic purposes may be procured in greater abundance, and at a more moderate cost, than formerly. When an achromatic object glass is prepared, and fitted in a tube, we apply magnifying powers to it in the same way as to the common refractor ; only we can apply to it eye glasses of a much shorter focal distance—such as half or quarter of an inch—than we can apply to an object glass with a single lens. But as the eye-piece for achromatic telescopes is different from that formerly described, it may be expedient here to give a short description of it.

SECTION V.—*Terrestrial eye-piece for achromatic telescopes.*

This eye-piece, which is represented in fig. 12, consists of four lenses, combined on the prin-

Fig. 12.

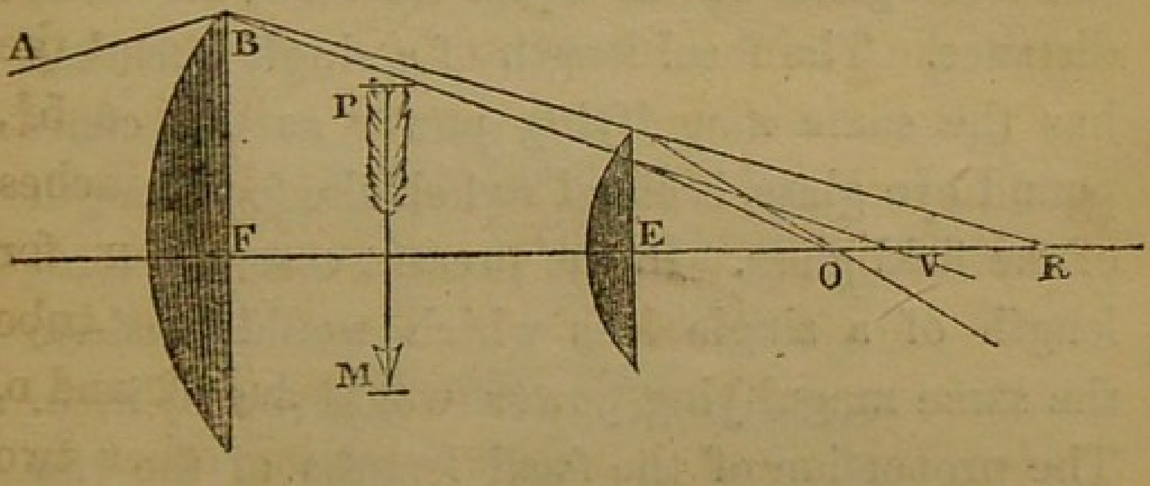


ciple of a compound microscope. A is the object lens, or that which is next the object, B is the amplifying lens, C the field lens, and D the eye lens, or that next the eye. An image is formed near the glass A by the object glass. From the image a second is formed at the point *i*, in the same position as the object. This image at *i* might be formed by the lens A, but it would not be well defined, owing to the great spherical aberration, and therefore the lens B is placed at a little distance beyond the focus of A, with a diaphragm, having a hole of a small diameter, *o h*, at the focus of A, to cut off the coloured rays. The glass C is intended to enlarge the field of view, and the image at *i* is viewed by the eye glass D. At the place where the second image is formed, there should be a stop, *m n*, to prevent any false light passing through to the eye. As to the focal distance and arrangement of these glasses, suppose the lens A $1\frac{7}{8}$ inch focal length, B may be $2\frac{1}{2}$ inches, C 2 inches, and D $1\frac{1}{2}$; and their distances A B $2\frac{1}{2}$, B C $3\frac{5}{8}$, and C D $2\frac{3}{8}$. In a small pocket achromatic telescope, whose object glass was $8\frac{1}{2}$ inches focal length, and its magnifying power $15\frac{1}{2}$, the focal lengths of the eye glasses were found to be, A 0.775 of an inch, B 1.025, C 1.01, D 0.79; the distances, A B 1.18, B C 1.83, and C D 1.105. This eye-piece would be nearly equivalent, in magnifying power, to a single lens of half an inch focal distance.

For the sake of those young persons who may wish to construct an eye-piece of this kind, I shall state the dimensions of one or two in the possession of the writer. In one of these, adapted to an achromatic object glass 5 feet 3 inches focal distance, and 4 inches diameter, the lens A is 3 inches focal length, plano-convex; the plain side next the object B $3\frac{1}{4}$ inches, C $1\frac{7}{8}$ inches, D $1\frac{1}{4}$ inch. They are all plano-convex, with the plain sides next the eye, except the lens A. Their distances are, A B $3\frac{3}{4}$, B C $5\frac{3}{4}$, C D 2 inches. This eye-piece is $11\frac{1}{2}$ inches long, and produces a magnifying power for land objects of about 96 times. The tube containing the two glasses next the eye, C and D, being taken out, a tube containing other two glasses is inserted, the focal distances of which are, C $2\frac{1}{4}$ inches, D 2 inches, and their distance 3 inches. This, in combination with the other glasses, produces a power of about 60 times. If the glasses, C D, be placed in a movable tube, *c d a b*, by pulling out this tube, and consequently increasing the distance between B and C, the magnifying power may occasionally be increased to one-half, or nearly double what it had in its original state. On this principle, Kitchener's Pancratic eye tube is constructed.

Astronomical eye-pieces.—The combination of lenses now most frequently used for astronomical observation is that which is denominated the *Huygenian eye-piece*, which is a great improvement on the eye-piece with a single lens, as it produces a more distinct and enlarged field of view. Let A B, fig. 13, be a compounded pencil of white light proceeding from the object glass, B F a plano-field glass, with its plain side next the eye glass E. The red rays of the pencil, A B, after refraction, would cross the axis in R and the violet rays in V, but meeting the eye

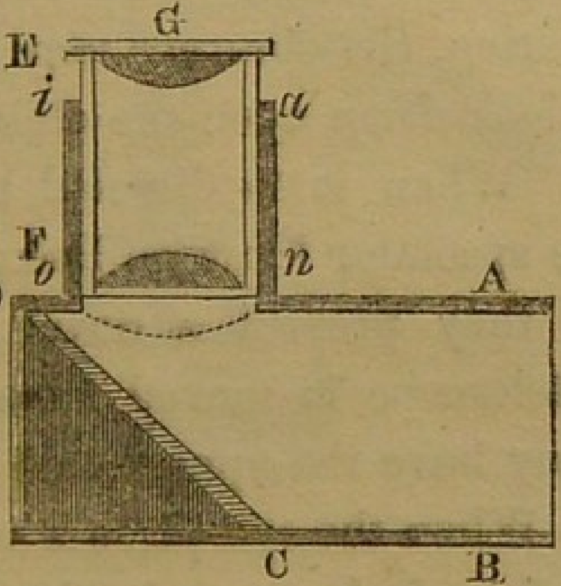
Fig. 13.



glass E, the red rays will be refracted to O, and the violet nearly in the same direction, when they will cross each other about the point O in the axis, and unite, so as to form an eye-piece almost without colour. The distance of the two glasses, F E, to produce this correction, must be equal to half the sum of their focal distances. Suppose the focal distance of the field lens F to be 3 inches, and that of E, the lens next the eye, 1 inch, the two lenses should be placed exactly at the distance of 2 inches; in other words, the glass next the eye should be placed as much *within* the focus of the field glass as is equal to its own focal distance. The focal length of a single lens that has the same magnifying power as this compound eye glass, is equal to half the focal length of the field glass. In the present case, the focal length of a single lens which would produce the same magnifying power would be 1½ inch. The proportion of the focal lengths of the two lenses to each other should be as 3 to 1, that is, if the field be 1½ inch, the eye glass should be ½ inch. An astronomical eye-piece may also be formed with two plano-convex glasses, placed with their convex sides towards each other, and at a very small distance from each other, namely, somewhat less than the focal distance of the lens next the eye. If, for example, one of the lenses were 1 inch focal length, and that next the eye $\frac{3}{4}$ of an inch, they might be placed at somewhat less than $\frac{1}{2}$ inch asunder.

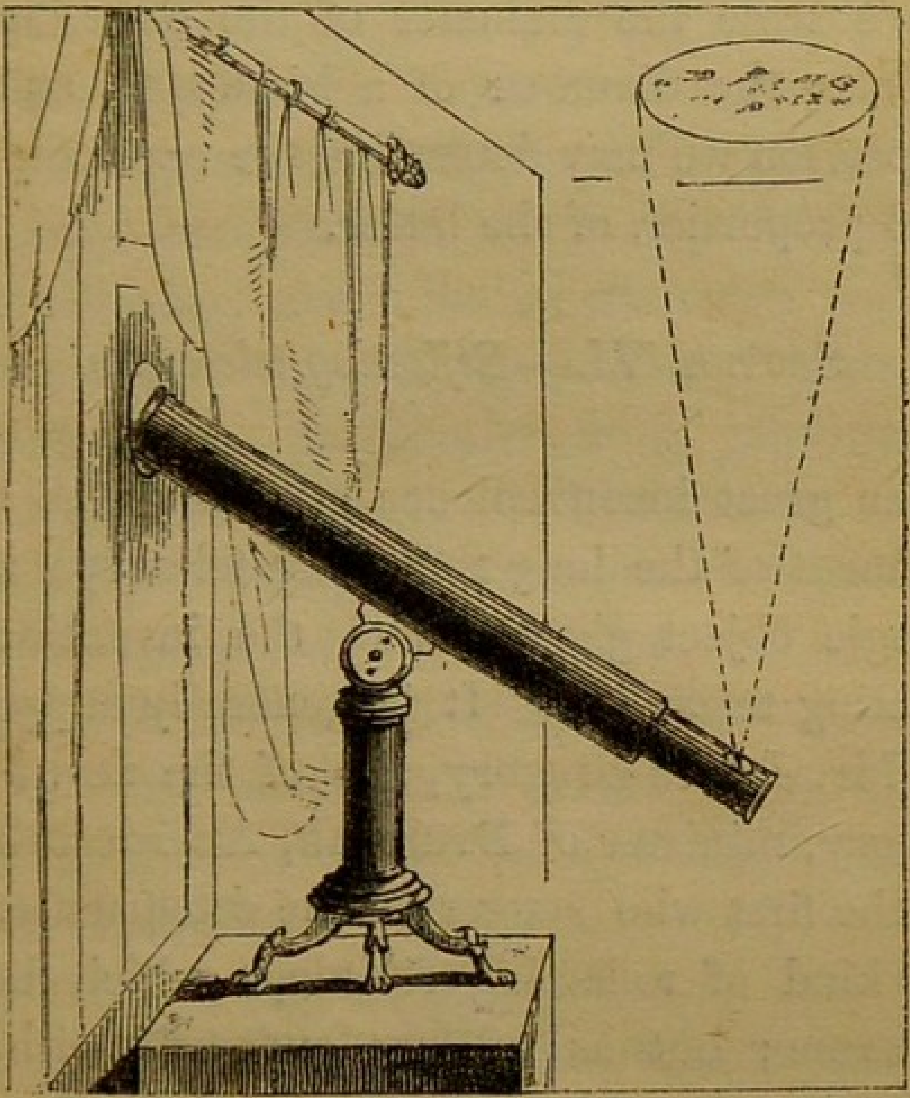
Diagonal eye-pieces.—When a celestial object is at a high altitude, the observer is obliged to put his head in a very inconvenient position, and to direct his eye nearly upwards, in which position a steady view of the object can scarcely be obtained. The diagonal eye-piece has been invented to remedy this inconvenience. This is effected by placing a flat piece of polished speculum metal, D C, fig. 14, at an angle of 45° to the axis of the tube, A B. This part slides

Fig. 14.



into the tube of the telescope, E F; the tube containing the lenses stands at right angles to the position of the telescope, and slides into an exterior tube, *a n*, *i o*, and the eye is applied at G. This construction of the diagonal eye-piece may be used either with the Huygenian eye-piece before described, or with that which is formed of two plano-convex lenses, with their convex sides towards each other. They may be of any magnifying powers generally applied to the telescope, and may be changed at pleasure. The rays proceeding from the object glass and falling upon the plain speculum, D C, are reflected in a perpendicular direction to the eye-piece, E F, and enter the eye at G. When this eye-piece is directed to celestial objects at a high elevation, the observer may either sit or stand, and look *down* upon the object with perfect ease. When it is directed to terrestrial objects, the spectator likewise looks down upon them, but they present a novel aspect, and when the telescope is moved from one side to another, they have the appearance of a moving panorama. When the eye-piece is turned round a quarter of a circle towards the right, those objects which are in the south will appear as if they were in the east; when it is turned a quarter of a circle towards the left, they will appear as if they were in the west; and when it is turned half round from its first position, they will appear as if they were above us, suspended in the air.

Fig. 15.



A telescope furnished with a diagonal eyepiece is the most convenient for exhibiting the spots in the sun. The window shutters should be all closed, having a small opening sufficient to admit the solar rays, and when the telescope is properly adjusted, a large and beautiful image of the sun, with all the spots which then happen to diversify its surface, is thrown upon the ceiling of the room, which must be of a white colour. In this way we may measure with a scale the diameter of the solar image, and also the diameter of a large spot, and by comparison we may determine the exact diametrical proportion of the latter.

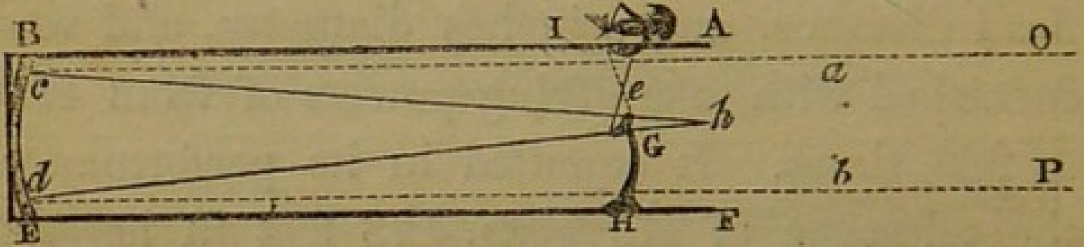
SECTION VI.—*Reflecting telescopes.*

The great inconvenience attending the management of the long refracting telescope with a single object glass, led to the invention of reflecting telescopes. It is generally supposed that Mr. James Gregory, son of the rev. John Gregory, minister of Drumoak, Aberdeenshire, was the first who suggested the construction of that kind of reflecting telescope which bears his name; but as he was endowed with no mechanical dexterity, he never actually formed a telescope according to his own theory. Several years after he had published his description of it, sir Isaac Newton directed his attention to this subject, and, in the year 1672, completed two small reflecting telescopes, the construction of which somewhat differed from the plan Gregory had proposed in 1663. They were only 6 inches long, but were considered as equal in magnifying power to a common refracting telescope 6 feet in length. Nothing more was heard of reflecting telescopes till about half a century afterwards, when, in the year 1723, Mr. Hadley made a reflector on Newton's plan, the large speculum of which was 62$\frac{5}{8}$ inches focal distance, and 5 inches diameter, and was furnished with magnifying powers of from 190 to 230 times. It equalled in its performance the telescope of Huygens, 123 feet in length. Reflecting telescopes have been ever since in general use among astronomers, and have entirely superseded the long refractors of the seventeenth century. We shall give a brief description of each of the telescopes to which we have alluded.

1. *The Newtonian reflector.*—This instrument is represented in fig. 16, where B A E F is the tube, in which is placed the concave speculum B E, which reflects the parallel rays O *c*, P *d*, to a *plane* speculum G, which is placed at half a right angle to the axis of the tube, as much

nearer the speculum than its focus as the centre of the small mirror is distant from the tube, that is, the distance G h of the small speculum from the focus of the great one should be equal to G H, half the diameter of the tube. This small speculum should be of an oval form, the length of which should be to the breadth as 7 to 5. It is supported by an arm fixed to the side of the tube. The rays, O c, P d, which form the image of the object by reflection, instead of proceeding to form it at h, are intercepted by the plane speculum at G, and reflected upwards to an aperture in the side of the tube A B, where the image is formed, and magnified by a convex lens of a short focal distance, to which the eye is applied, looking *downward* on the object, which appears inverted; or, the eye glass, instead of being on the upper part of the tube, may be placed on one of the sides, and for viewing land objects a terrestrial eyepiece may be applied. The magnifying power of this telescope is in the proportion of the

Fig. 16.



focal distance of the speculum to that of the eye glass. Thus, if the focal length of the speculum be 60 inches, and that of the eye glass a quarter of an inch, the magnifying power will be 240 times. This is the form of the reflecting telescope which was most generally used by the late sir W. Herschel. The following table exhibits a statement of the diameters of the specula of Newtonian reflectors, the focal distances of their eye glasses, and their magnifying powers :—

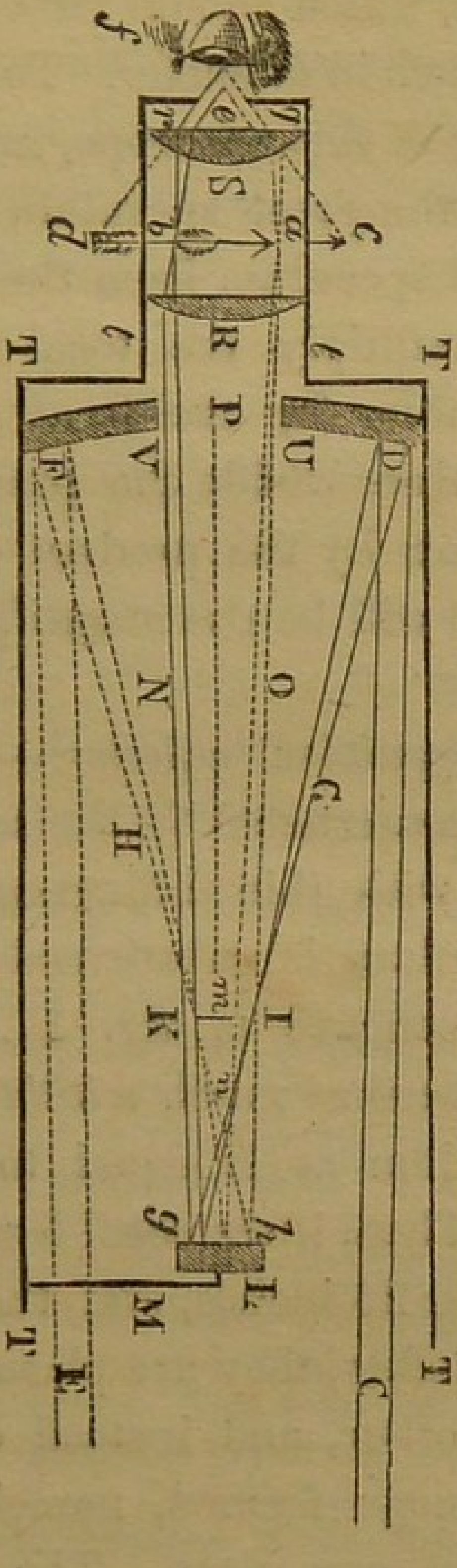
Focal distance of concave speculum.	Aperture of concave metal.	Focal distance of single eye glass.	Magnifying power.
Feet.	In. Dec.	In. Dec.	
1	1 · 44	0 · 99 or ⅕	60
2	2 · 45	0 · 236	102
3	3 · 31	0 · 261	138
4	4 · 10	0 · 281	171
5	4 · 85	0 · 297	202
6	5 · 57	0 · 311	232
7	6 · 24	0 · 323	260
8	6 · 89	0 · 334	287
9	7 · 54	0 · 344	314
10	8 · 16	0 · 353	340
12	9 · 36	0 · 367	390
15	11 · 04	0 · 391	460

It will generally be found, that the power produced by multiplying the diameter of the speculum by thirty or forty, is most satisfactory for planetary observations.

2. *The Gregorian reflector.*—This form of the reflecting telescope is constructed in the following manner:—T T T T is the great tube, open at the end next the object, in which the large concave speculum D U V F is placed, whose principal focus is at *m*, and in its middle is a round hole P, opposite to which is placed the small mirror L, concave towards the great speculum, and so fixed on a strong wire M, that it may be moved further from or nearer to the great mirror, by means of a long screw on the outside of the tube. The rays proceeding from the object A B, and falling on the speculum D F will be reflected to its focus *m*, where an inverted image of the object will be formed.

This image is formed at a little more than the focal distance of the small speculum from its surface, and the small mirror acting upon it, this first image is reflected through the glass R to *a b*, where a second image is formed erect, and larger than the first in the proportion of *b* K to K *g*. This image is again magnified by the eye glass S, to which the eye is applied.

Fig. 17.



The rays from the glass s pass through the small hole *e*, which should seldom be more than $\frac{1}{25}$th of an inch in diameter. To find the magnifying power of this telescope, multiply the focal distance of the great speculum by the distance of the small speculum from the image next the eye; and multiply the focal distance of the small speculum by the focal distance of the eye glass; then divide the product of the first multiplication by the product of the last, and the quotient will be the magnifying power.

3. *Cassagrainian reflector.*—This kind of reflector is constructed in the same way as the Gregorian, with this difference, that a small *convex* speculum is substituted in the room of the small concave L, fig. 17. This convex mirror is placed as much *within* the focus of the great speculum as is equal to its own focal distance. Thus, if the focal length of the large speculum be 24 inches, and that of the small convex $2\frac{1}{2}$ inches, they are placed at $21\frac{1}{2}$ inches from each other, and instead of two, there is only one image formed, namely, that in the focus of the eye glass. The length of this telescope is less than that of a Gregorian by twice the focal length of the small mirror.

From the experiments of Short, Ramsden, captain Kater, and others, it appears that there is more light in this telescope than in the Gregorian; and that it is, on the whole, superior in its performance, but it represents the object in an inverted position.*

Short account of some large achromatic and reflecting telescopes.

1. *Large achromatic telescopes.*—(1.) *The great Cambridge telescope, in Massachusetts, United States.*—This instrument was procured from Munich, in Germany, at a vast expense,

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* Besides the telescopes described above, there are plans of others by which distant objects may be viewed. 1. A telescope may be made of a single lens of a long focal distance. The writer has a lens 26 feet focal distance and 11½ diameter, which, without any other glass, produces a magnifying power of nearly 30 times, and by which he has read the hour of the day on a public clock two miles distant. The observer stands at a distance of about 25 feet from the lens, his eye serving as the eye glass, on the principle of the Galilean telescope. 2. The aërial telescope, constructed by the writer, which has only one speculum, and in looking through which the observer sits with his back to the object. This telescope has no tube, but only a short socket to hold the speculum. An arm at one side extends the length of the focal distance of the speculum, at the end of which is the eye-piece. 3. The Newtonian telescope may also be fitted up *without a tube*, which saves considerable expense. The writer has fitted up one on this plan, which performs admirably. It may be changed at pleasure into the aërial telescope.

and it is considered as one of the best instruments of the kind now in existence. The object glass is 15 inches in diameter, and its focal length 23 feet. It is placed on a block of granite, thirteen tons in weight, adapted to an equatorial apparatus, and clock-work is applied to it, to give it a quiet sidereal motion. Almost everything which has lately been discovered by lord Rosse has been seen through this telescope. It has magnifying powers from 250 to above 1,000 times. (2.) *Sir J. South's telescope.*—The object glass of this telescope, which was procured at Paris, is $11\frac{2}{10}$ inches diameter and 19 inches focal length. This telescope is erected on an equatorial stand, at sir J. South's observatory, Kensington. (3.) *The Northumberland telescope*, in the observatory at Cambridge, is among the largest of the kind in Great Britain. The object glass is said to be 25 feet focal distance, and of a corresponding diameter. (4.) *Paris Observatory.*—In this observatory, when visited in 1837, there were two large achromatic telescopes, which appeared to be from 15 to 18 feet long, and the object glass from 12 to 14 inches diameter. (5.) *The Dorpat telescope.*—This telescope was made by Fraunhefer of Munich, for the observatory of the

Imperial University of Dorpat, in the year 1825. The aperture of the object glass is 9½ inches, and its focal length 14 feet. Its magnifying powers range from 175 to 700. It is mounted on an equatorial stand, with clock-work, and it cost £900. (6.) *The Cincinnati telescope.*—This telescope was procured from Germany, and fitted up by professor Mitchell, of Cincinnati, United States. It is mounted on equatorial machinery, accompanied with clock-work. Its object glass is nearly 18 inches focal length, and 12 inches diameter, with magnifying powers from 100 to 1,400 times. The instrument with its machinery weighs about 2,500 pounds. (7.) *Mr. Cooper's telescope.*—Mr. Cooper, M.P. for Sligo, is in possession of a telescope, 26 feet long and the diameter of the object glass is 14 inches. (8.) *Dr. Pearson's telescope.*—This gentleman, who is secretary to the Astronomical Society, is in possession of a telescope made by the late Mr. Tulley, the object glass of which is 12 feet focal length, and 7 inches diameter. (9.) *Mr. Lawson's telescope.*—This gentleman, who is a diligent astronomical observer, possesses a most beautiful telescope, 12 feet focal length, and 7 inches diameter, made by one of the Dollonds. It is said to bear powers of

1,100 or 1,200. (10.) *Mr. Bridges's telescope.*—This gentleman has fitted up at Blackheath a telescope on equatorial machinery, whose object glass is 5½ feet focal length, and 5½ inches diameter. The object glass cost 200 guineas, the equatorial machinery 150, and the observatory 100 guineas; in all, 450 guineas. (11.) *Captain Smith's telescope*, at Bedford.—This instrument is 8½ feet focal length, and 6 inches diameter, and will bear a magnifying power of 1,200.

2. *Large reflecting telescopes.*—Mr. James Short, of Edinburgh, was the first who made reflecting telescopes on a large scale. In 1743, he constructed one for lord Spencer, of 12 feet focal length, for which he received 600 guineas; and, in 1752, he finished a still larger one for the king of Spain, for which he received £1,200. This was considered the noblest instrument of its kind till Herschel constructed his large reflectors. About the year 1780, the late sir W. Herschel constructed a Newtonian reflector, 20 feet long, with which he explored the Milky Way, and other objects in the sidereal heavens. In 1789, he finished his large 40 feet telescope, which at that time was unrivalled. Its speculum

was 4 feet diameter, and it had neither a concave nor plane small speculum, but the observer sat with his back to the object, and looked down upon the great speculum. This telescope was dismantled a few years ago. A large telescope, 20 feet in length, has lately been constructed by Mr. Larsels, of Liverpool, with which he has discovered several small planets. But the largest reflectors now in existence are those which have been lately erected by the earl of Rosse. One of these, in the lawn before his lordship's mansion, is 27 feet long, and its speculum 3 feet diameter. Another, called the "monster telescope," is 56 feet long, and its speculum 6 feet in diameter, and weighs above 3 tons. This is the largest telescope in the world, and its erection cost his lordship £12,000. It is of the Newtonian form.

Prices of telescopes, of a moderate size, as made by the London opticians.—To such of our readers as may be desirous of pursuing astronomical studies, the following list may be useful.

The instruments specified in the preceding pages are only made to order, and are, consequently, very expensive. The more common sizes of telescopes for astronomical purposes are the following :—

1. *Achromatic telescopes.*—"The improved 2½ feet achromatic, on a brass stand, mahogany tube, with three eye-pieces, two magnifying about 40 or 50 times, and the other about 75 for astronomical purposes, in mahogany case, £10. 10*s.*; ditto, with brass tube, £11. 11*s.*; ditto, with vertical and horizontal rackwork motions, £15. 15*s.*" This telescope, if the object glass be good, will bear a power of 90 or 100 times for celestial objects. Its object glass is 2¼ inches diameter. "The 3½ feet achromatic, plain mahogany tube, 2¾ aperture, £18. 18*s.*; ditto, brass tube, £21; ditto, all in brass, with rackwork motions, £26. 5*s.*; ditto, the object glass of 3¼ inches aperture, and the rack motions on an improved principle, from £37. 16*s.* to £42." The magnifying powers of these telescopes are from 130 to 180 or 200 times. This is the telescope which we would recommend to astronomical observers. It will show all the common phenomena of the solar system. The 5 *feet achromatic* is also frequently made; diameter of the object glass $3\frac{8}{10}$ inches; powers, 65, 110,

190, and 250. Its general price is above 100 guineas. Achromatic object glasses for such telescopes may sometimes be purchased separately, at such prices as the following:—Focal length 30 inches, diameter 2¼ inches, from 2 to 2½ guineas; focus 42 inches, diameter 2¾ inches, from 5 to 8 guineas; focal length 42 inches, diameter 3¼ inches, from 12 to 20 guineas. Eye-pieces may be procured from 10*s.* 6*d.* to 14*s.*

2. *Reflecting telescopes.*—The reflectors commonly made and sold in London are the following:—

A 4 feet 7 inch aperture, Gregorian reflector, with the vertical motions upon a new principle, with apparatus to render the tube more steady for observation, according to the additional apparatus of small specula, eye-pieces, micrometers, etc., from £80 to £120; 3 feet long, mounted on a brass stand, £23. 2*s.*; ditto, with rackwork motions, improved mountings and metals, £39. 18*s.*; 2 feet long, without rackwork, and with 4 magnifying powers, £15. 15*s.*; ditto, improved, with rackwork motions, £22. 1*s.*; 18 inch, on a plain stand, £9. 9*s.*; 12 inch ditto, £6. 6*s.*

SECTION VII.—*Discoveries which have been made by means of the telescope.*

The human eye is a most wonderful piece of mechanism; it is a natural telescope, nearly spherical in its form, and exquisitely delicate and beautiful in its structure. The completeness of its organization, and the perfect ease and rapidity with which it fulfils all its functions, show that He by whom it was "formed" designed it to minister continually to our instruction and happiness. We need not endeavour to imagine what would have been our helpless and hopeless state of uncertainty, confusion, and distress, had we been without the faculty of sight. Almighty wisdom and benevolence could not fail to render our existence harmonious, to adapt our perceptions to our condition, and to endow us with those senses which are necessary to a wise and satisfactory enjoyment of life. "Of all our senses." says Mr. Addison, "our sight is the most perfect and delightful; it fills the mind with the largest variety of ideas, converses with its objects at the greatest distance, and continues the longest in action without being tired and satiated with its proper enjoyments." Above all is it valued by those who, in the consciousness of their relation to God as believers in Christ, rejoice to commune with him in the works of creation. "The endless volume of nature, full of beauty, and illuminated by heaven, seems to them sufficient to fill the soul with satisfaction for ever, because here they learn familiarity with the attributes of a Power they may trust as thoroughly as they can admire."*

But our vision, at the best, is feeble, and it is limited within a very narrow range. From the brow of a hill we may look on an extensive landscape, but it is only within two or three miles that its varied beauties are distinctly seen. Even at this distance we cannot distinguish a friend, or read a sign, or accurately describe the actions of our fellow men. If we gaze up into the sky on a clear evening, we see the moon, it may be a slender crescent, or a full enlightened orb, or one of the varied phases between those two extremes; we see five or six hundred gleaming sparkles of light, which we call stars, and we see a lustrous cloud encompassing a considerable part of the

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* The Influence of the Body in relation to the Mind. By George Moore, M.D.

heavens, but here the discoveries of unassisted vision terminate. Some more intelligent and scrutinizing inquirer may, indeed, detect differences which others overlook, and perceive order where they only find confusion; and these observations may suggest to him truer and sublimer conceptions of the universe than the unassisted organs of vision can give. But he can be satisfied with nothing less than certainty, and he is bewildered and oppressed by doubt and mystery. To him how valuable are the discoveries of the telescope, and how important are they to all, for the stupendous proofs which they afford of the omnipotence of the Creator, and of the vastness of his dominions.

We shall now give a brief sketch of these discoveries, both within the solar system and in the sidereal heavens.

Discoveries in the solar system.

The moon.—The nearest to the earth of the heavenly bodies is the moon. By the telescope it has been discovered that a very large number of mountains diversify its surface. They are from half a mile to five miles in perpendicular elevation, and are almost universally rounded in their form. They may be classed in the following order: — 1. Insulated mountains which rise from plains nearly level, like a sugar-loaf on a table. 2. Ranges of mountains, extending in length three or four hundred miles, resembling our Alps and Apennines. 3. Circular ranges, surrounding either a cavity or an extensive plain, from which rises centrally a mountain of considerable height. There are also caverns in the moon, some of which are more than two miles in perpendicular depth. Their diameter varies from three to forty or fifty miles, and the larger ones have flat bottoms. Nearly a hundred of these caverns may be seen on the south-western part of the planet. Although there are large regions in the moon perfectly level, and which seem to be of an alluvial character, no seas or large collection of waters can be discerned in it, and in its atmosphere there is no appearance of clouds. It has been ascertained that the moon always turns the same side to the earth, so that we see nothing of its other hemisphere.

The Sun.—Among the first discoveries of the telescope was the motion of certain dark spots across the disc of the sun. They have since been more closely observed, and by them it has been calculated that the sun revolves on its axis in twenty-five days and ten hours. These spots are of various sizes, from $\frac{1}{20}$th of the sun's diameter to $\frac{1}{500}$th and under. They have a dark centre, surrounded by a border of fainter shade, called an *umbra.* Sometimes the same *umbra* includes one or two large spots and a number of very small ones, and at other times the latter accompany the former in a kind of train. Occasionally the sun appears almost free from spots, but often nearly a hundred may be seen on its surface at one time. The sun is supposed to be a solid globe, surrounded by a luminous atmosphere, from whence heat and light are diffused through the planetary system, and it is probable the spots are its opaque body seen through that atmosphere, when any portions of it are more rare or thinner than usual.

Venus and Mercury.—Venus is the brightest of the planets, and is known as the morning and the evening star; it is the morning star when it is west of the sun, and rises before it; and the evening star when it is east of the sun, and sets after it. One of the earliest discoveries of the telescope was the fact that Venus passes through the same phases as the moon, appearing, after its inferior conjunction with the sun, and when its dark side is turned towards the earth, first as a crescent, then as a half moon, then gibbous, and at length as a full enlightened hemisphere. This discovery was an important confirmation of the theory of Copernicus, that this planet did not move round the earth, as was formerly supposed, but round the sun, and in an orbit between the earth and the sun. It proved, also, that the planets are dark bodies, and derive all their light from the central luminary. From subsequent examinations it was found that Venus turns round its axis in twenty-three hours and twenty-one minutes. With the telescope it has been observed on different occasions to transit the sun's disc, by which the distance of the sun has been more accurately determined.—Few discoveries have been made in Mercury, on account of its nearness to the sun. It has been found, however, that it passes through all the phases of the moon, in the same way as Venus; that it moves round its axis in twenty-four hours and three minutes, and that high elevations project from its surface.

Mars.—This planet is remarkable for its colour, which is a glowing red. Sometimes it looks nearly as large as Jupiter, and at other times it appears as if it had dwindled to the size of a small star. These variations are owing to its different distances from the earth, the two extremes of which are fifty, and two hundred, and forty millions of miles. It moves in an orbit more distant from the sun than that of the earth, and accomplishes its revolution in one year and ten months. Spots have been discovered on its surface, which seem to indicate the existence of land and water. A white spot has likewise been discovered near its south pole, which is supposed by some to arise from the reflection of the sun's light around the polar regions. The red hue of Mars is occasioned by the dense atmosphere with which it is surrounded. By watching its spots it has been found to have a rotation round its axis in twenty-four hours and thirty-seven minutes. This planet is of a spheroidal figure, like the earth, having its polar diameter two hundred and sixty-three miles shorter than its equatorial, which is four thousand two hundred miles. From these and other observations, it has been concluded that about one-third or one-fourth of its surface is covered with water, that there are strata of clouds of considerable extent occasionally floating in its atmosphere, and that it has a change of seasons similar to our own.

The new planets between the orbits of Mars and Jupiter.—Within the limits of the present century, certain comparatively small anomalous bodies have been discovered, revolving around the sun in the regions between the orbits of Mars and Jupiter. The great distance which intervenes between Mars and Jupiter led astronomers to suppose that a planet existed somewhere within that part of the planetary system. But they were astonished when it was found that not only one planet, but a considerable number, were running their courses in that region. The first of these planets was discovered on January 1st, 1801, by Piazzi, at Palermo, which is named *Ceres;* the second, named *Juno*, by professor Harding of Göttingen, in 1804; the third and fourth, named *Pallas* and *Vesta*, in 1802 and 1807, by Dr. Olbers of Bremen. No further discoveries were made till December 8th, 1845, when professor Hencke of Driessen discovered *Astræa;* and on the 5th July, 1847, the same gentleman discovered the planet *Hebe.*

Mr. Hind, at the Observatory, Regent's Park, London, August 18th, 1847, discovered *Iris*, and on the 18th of October, the planet *Flora.* On April 25th, 1848, Mr. Graham discovered *Metis.* On the 12th April, 1849, M. De Gasparis, of the Observatory at Naples, discovered *Hygeia;* and on the 11th May, 1850, another, which he *calls* Parthenope. On September 13th, 1850, Mr. Hind discovered another planet in the constellation Pegasus, which appeared like a star of the ninth magnitude, and with a pale bluish light; he intends to call it *Victoria.* This forms the twelfth of the group of the new planets, of which eight have been discovered within the space of little more than four and a half years. All these planets are invisible to the naked eye, and consequently their existence would never have been known without the telescope. Their magnitudes are not yet accurately decided. Shroeter, a celebrated German astronomer, calculated the diameter of Vesta at 276 miles, of Juno at 1,425 miles, of Ceres at 1,624 miles, and of Pallas at about 2,000 miles. There is a considerable degree of mystery connected with these planets, which it is not easy to unravel. Their orbits have a much greater degree of inclination to the ecliptic than those of the other planets; they are more eccentric, and several of them cross each other; they revolve nearly at the same distances from the sun, they perform their revolutions nearly in the same periods, and they are all much smaller than those previously discovered. It has been thought, therefore, by some, that these planets are the fragments of a greater planet, which had formerly circulated between Mars and Jupiter, and which an immense irruptive force from its interior had burst asunder. This, however, is mere speculation.

Jupiter.—This is the largest planet in the solar system. It is eighty-eight thousand miles in diameter, and in bulk exceeds that of the earth about thirteen hundred times. Dark belts, which frequently shift their position, and vary in breadth as well as in situation, embrace its whole circumference. These belts are, probably, its real surface, and the intervals between them some astronomers suppose to be the clouds in its atmosphere. Large spots have been seen in Jupiter, and by these it has been shown that it revolves round its axis in nine hours and fifty-six minutes. It is attended by four moons, or satellites, which, it will be remembered, were among the first discoveries made by Galileo with the telescope. These satellites are seen in different positions. Sometimes, two are seen on one side of their primary, and two on the other side ; and sometimes, all four are seen in their regular distances on one side, nearly in a straight line from each other and from the centre of the planet. At other times, only two are visible, the other two being eclipsed by the shadow of Jupiter. The first satellite, or that nearest the planet, revolves round it in forty-two hours and a half, and suffers an eclipse eighteen times in every month. The eclipses of these satellites are of considerable use in determining the longitude of places on the earth. Jupiter, with his moons, which are all invisible to the naked eye, is a most splendid object when seen through a powerful telescope, and presents a field for contemplation which never fails to astonish and delight by its magnificence and variety.

Saturn.—The planet Saturn is nine hundred and six millions of miles from the sun, which is nearly double the distance of Jupiter. It is seventy-nine thousand miles in diameter, and nearly a thousand times larger than the earth. It has eight satellites. Some dusky spots have been occasionally seen on its surface, by the motion of which its diurnal rotation has been found to be accomplished in ten hours and sixteen minutes. Belts have likewise been discovered in Saturn, almost resembling those of Jupiter, but fainter, and invariable in their position. The belts of Saturn also cover a larger zone on the disc of the planet. But the most remarkable discovery which the telescope has made in connexion with Saturn is, that, at a distance from it of more than twenty thousand miles, it is surrounded by an immense double ring. This ring, or rather these rings, are concentric with the planet and with one another, both lying in one plane, and separated from each other by an interval of more than two thousand miles. The outside diameter of the exterior ring exceeds two hundred thousand miles, its circumference is upwards of six hundred and thirty thousand miles, and its breadth is seven thousand two hundred miles. The outside diameter of the interior ring is one hundred and eighty-four thousand miles, and its breadth twenty thousand miles. These rings, reckoning the extent of surface on both sides, contain an area of more than twenty-eight thousand eight hundred millions of square miles; that is, it is equal to one hundred and forty-six times the number of square miles on our own terraqueous globe. The rings revolve round the planet every ten hours and a half, which is at the rate of more than a thousand miles every minute. They preserve an invariable distance from the planet at all times, and along with it are carried round the sun in the space of twenty-nine years and a half. If viewed from the planet itself, they would appear like magnificent luminous arches, stretching from east to west across the heavens, and diffusing at night a mild radiance. From our distant point of observation, we may learn by these stupendous phenomena that Omnipotence is everywhere present, and that He who regulates and keeps in perfect harmony the movements of all worlds, must be as infinite in goodness as he is in power.

Uranus.—This planet is 1,800 millions of miles from the sun, and about 900 millions of miles beyond the orbit of Saturn. It remained invisible till the year 1781, when the telescope revealed it to sir W. Herschel. It revolves round the sun in an orbit 11,314,000,000 of miles in circumference, in the course of about 84 years, at the rate of 15,000 miles an hour.

Owing to its great distance from us, no spots or belts are discernible on its surface, and consequently the period of its diurnal rotation is unknown. Its magnitude is estimated at 35,000 miles in diameter, or about eighty-two times larger than the earth. It has four satellites, and probably five or six, but their periods are not ascertained with accuracy, and their orbits present remarkable peculiarities.

Neptune.—This planet was discovered on the 23rd of September, 1846, by Dr. Galle, of the Royal Observatory at Berlin. Its place had been calculated, even before it was discovered, by Mr. Adams of Cambridge, and M. Leverrier of Paris, by whom its position in the heavens was pointed out within a degree of the spot where it was actually found. It is probably the planet whose existence and position had been also calculated, by professor Challis of the Observatory of Cambridge, on the 4th and the 12th of August, 1846, but he declined publishing his observations at that time. Neptune appears like a star of the eighth magnitude; its distance from the sun is about thirty times that of the earth, or more than 1,000 millions of miles beyond the orbit of Uranus. Its diameter is 50,000 miles; it is therefore 250 times larger than the earth, and its revolution round the sun is accomplished in 164 years. Mr. Larsels of Liverpool, from several observations has concluded that it is *surrounded by a ring*, and professor Challis and others have formed the same conclusion. Mr. Larsels has also ascertained that it has two satellites, one of which revolves round it in 5 days 20 hours 50 minutes.

Discoveries made by the telescope in the sidereal heavens.

Of late years, the telescope has been more particularly directed to the starry heavens than in former times, and many wonderful discoveries have been made, of which it is impossible to give more than a meagre outline.

1. *The distance and magnitude of the fixed stars.*—The determination of the distance of a star depends on the angle of parallax formed by viewing it from opposite parts of the earth's orbit, which gives a base line 190 millions of miles in extent. But the angle formed by this line at the stars is so small, that astronomers

have had great difficulties to encounter in order to adjust it. Of late, however, this point has been settled in reference to some of the fixed stars. Professor Bessel, some years ago, determined the angle of parallax of the star 61 *Cygni* to be somewhat more than $\frac{1}{3}$ of a second, which makes the distance of that star to be above *sixty billions four hundred thousand millions* of miles, a distance through which light, flying at the rate of 192,000 miles every moment, would require ten years to pass. Another star, *a Centauri*, has had its parallax determined to be the $\frac{10}{11}$th of a second, which makes the distance above *twenty billions* of miles. And as the magnitude of a star depends upon our knowing its distance, the magnitude of these stars must be much larger than that of our sun.

The Milky Way.—This is an irregular white zone, which, with some variations, encompasses the heavens in a great circle, inclined at an angle of 63° to the equinoctial. The telescope has enabled us to ascertain that the whiteness of this zone is owing to the countless multitude of stars which it contains. In a powerful glass, the field of view will be filled with more than a hundred stars, and turning the instrument to the right and left, or up and down for a considerable distance, a similar number will appear with every change of its position. So crowded are the stars in some parts of this zone, that sir W. Herschel, by counting the number in a single field of his telescope, concluded that 50,000 had passed under his review during an hour's observation. It has been calculated that in the Milky Way, there cannot be less than twenty millions of stars, which is twenty thousand times the number of those visible to the unassisted eye. And if every star be a splendid sun, surrounded with planets, as we have every reason to believe, how overpowering is the sense of indefiniteness as to the extent of the universe! And, yet when we see "confused clouds of glory revolving themselves into systems of orderly worlds," we rejoice in the thought, that He who made them "telleth the number of the stars; he calleth them all by their names," Psa. cxlvii. 4; and that with him order and arrangement indicate a ceaseless and beneficent superintendence of all "the works of his hands."

Double stars.—There are numbers of stars in the heavens, which appear single to the naked eye, but when viewed through a telescope are discovered to be *double*, and sometimes triple, or quadruple. These double stars are generally of different magnitudes ; and it has been frequently found, after a long series of observations, that the smaller star performs a revolution around the larger one. Above fifty instances have been ascertained in which one star revolves round another, and although in some of these a complete revolution has not yet been witnessed, yet from what has been observed, the period of entire rotation has been determined. One of these stars, η Coronæ, accomplishes its revolution in 43 years ; another, α Leonis, in 82 years ; and another, α Castor, in 252 years. Here we have the astonishing spectacle of suns revolving around suns, and systems around systems ! Another interesting fact is, that these stars frequently exhibit *contrasted colours ;* the large star is usually of an orange hue, while the smaller one appears blue or green ; in other cases, the large one is a white star, and the smaller one a rich ruddy purple. What a dissimilar illumination must these suns afford, yet how beautifully do their colours harmonize ! The works of God are as perfect as they are inexhaustible in wonders and in variety.

New and variable stars.—New stars have frequently appeared in the heavens in places where none existed before, and, after shining for a year or two, have again disappeared. On the 28th of April, 1848, Mr. Hind observed a star of the fifth magnitude, where he was certain, up to the 5th of that month, no star so bright previously existed. It continued to diminish, without any change of place, and in a few months it was nearly extinct. Some stars are variable, or periodical. One, in the constellation Cetus, appears 12 times in 11 years. It has a period of 331 days, and remains at its greatest brightness about a fortnight, like a star of the second magnitude; after which it decreases for 3 months, till it becomes completely invisible to the naked eye, in which state it continues 5 months, and then increases again during the remainder of its period. Another, called *Algol*, is visible as a star of the second magnitude for 2 days 13 hours, when it suddenly begins to decline in splendour, and in 3½ hours is reduced to the fourth magnitude; it then begins to increase, and in 3½ hours more is restored to its usual brightness. Nearly forty of these variable stars are known, and almost every year adds to their number. The cause of their variation is unknown, though, in some instances, there can be little doubt that it is occasioned by the interposition of opaque bodies, such as the planets.

Clusters of stars and the Nebulæ.—When we look up to the heavens in a clear evening, we perceive groups of stars compressed within narrower limits than other constellations. There is a remarkable cluster, called the *Pleiades*, in which a common telescope shows about sixty large stars crowded together. There is another, scarcely visible to the naked eye, in the constellation Cancer, called *Præsepe*, which contains about forty or fifty brilliant stars; and in the sword handle of *Perseus* there is a most beautiful group, which can only be seen with a telescope. These are called clusters, and are supposed to be drawn together by the influence of certain physical laws. *Nebulæ* is the name given to small cloudy spots which are seen in the heavens. Many of these nebulæ are found to be thick set with stars, which powerful telescopes alone enable us to distinguish. They are not to be reckoned by hundreds, but by thousands. "On a rough calculation," says sir J. Herschel, "it would appear that many clusters of this description must contain at least five thousand stars, compacted in a round space not more than a tenth part of that covered by the moon." More than three thousand nebulæ have been discovered in different parts of the heavens; and if they are all resolvable into as many stars as this calculation supposes, it will add fifteen millions to the number before believed to exist. But some of the distant nebulæ are thought to equal the Milky Way in the number of stars; for if that galaxy had been placed at such a remote distance from us as some of the nebulæ, it would have appeared no larger than these now do, when beheld as dim specks even through the telescope. The *planetary nebulæ* are a very extraordinary class of objects; they have a near resemblance to planets, presenting discs round or slightly oval. One of these is situated somewhat south of the parallel of *β Ursæ Majoris*, and about 12′ following that star. Its apparent diameter is 2′ 40″; and "supposing it placed," says sir J. Herschel, "at a distance no greater than that of sixty-one cygni, would imply a linear diameter seven times greater than that of the orbit of Neptune." Now, a body seven times the diameter of the orbit of Neptune would be nearly twenty thousand millions of miles in diameter. Of such a body we can have no adequate conception. We are overwhelmed by its magnitude, and can only be persuaded of its existence by remembering that there are no bounds to the power of the Infinite.

Such is a very brief sketch of the discoveries in the heavens which have been made by the aid of the telescope. Before its invention, only seven of the heavenly bodies were known to belong to our system, namely, the Sun and Moon, Mercury, Venus, Mars, Jupiter, and Saturn. Since its invention, fourteen primary and twenty secondary planets have been discovered, together with millions of fixed stars, the existence of which had not been previously imagined. To its assistance we also owe all that is known of variable stars, double stars, clusters, nebulæ, the Milky Way, and of the true magnitudes of the bodies which compose the solar system.*

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* Those who wish to see more particular details of the discoveries which have been made in the heavens, are referred

Reflections suggested by the discoveries of the telescope.

1. How impressively do the discoveries of the telescope illustrate the almighty power of God! Let the reader reflect for a moment upon the view which this admirable instrument presents of *the extent of creation.* There was a time, when the conception of neither poet, philosopher, nor divine, soared beyond the sphere of unaided human vision; and when, looking upon the earth as the largest body in the universe, and the sun, moon, and stars, as mere appendages to enlighten and adorn it, they imagined all the Creator's works to be confined within these narrow bounds. But the telescope has opened to us a field to which no limits can be assigned. Within our own planetary system, it has discovered to us bodies more than a thousand times larger than the globe we inhabit; and in the distant starry regions, beyond our nearer circle, it has shown to us myriads of suns,

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to a volume entitled "Celestial Scenery; or, The Wonders of the Planetary System displayed;" and to another, entitled "The Sidereal Heavens, as illustrative of the Perfections of Deity, and of an Infinity of Worlds." The Monthly Volumes, entitled "The Solar System," Parts I. and II., contain also much interesting information on the subject.

equal in magnitude to the one which rules our day, and each the centre of other worlds, all of which are probably teeming with happy dwellers. Nor is this all; for as one bright scene of splendour rises above another, in almost boundless perspective, who can doubt that others, yet more wonderful and sublime, lie beyond the range of the most powerful telescope? When it has taken us to the farthest line of observation it can reach, who will say that "the wonders of the Almighty are at an end, because we can no longer trace his footsteps?—that his omnipotence is exhausted, because human heart can no longer follow him?"

Scarcely less calculated to raise our conceptions of the almighty power of God, is the *magnitude* of the objects which the telescope brings under our notice. The planet Jupiter is computed to be more than thirteen hundred times larger than the earth. The sun is five hundred times larger than all the planets and comets would be, were it possible to unite them in one vast globe. The star α Lyræ is reckoned to be three million two hundred and seventy-five thousand miles in diameter, and more than fifty-four thousand times larger than the sun. Omnipotence is implied in the existence of an atom as well as of a world, but we realize that attribute more vividly in the latter than in the former. We look at our own globe, with all its mighty oceans and continents, containing more than two hundred and sixty thousand millions of cubical miles of solid matter, and we are astonished at the power of the Creator; but how is that astonishment increased, when we learn from the discoveries of the telescope, that, instead of being distinguished from other worlds, it is one of the least of them—a mere atom in creation; and that, in comparison with other systems, the one in which this atom is found is but a mere shred, which, though scattered into nothing, would leave the universe of God one entire scene of greatness and of majesty!

To these considerations may be added the *velocity* with which these stupendous bodies move in their courses. The planet Saturn, with its rings and moons, moves in its circuit round the sun at the rate of twenty-two thousand miles an hour. The planet Venus performs its revolution at the rate of eighty thousand miles an hour, and the planet Mercury flies through its orbit at the extraordinary speed of one hundred and nine thousand miles an hour. The motion of some of the fixed stars, a million times larger than the earth, has been calculated to be one hundred and seventy thousand miles an hour, and the velocity of some of the comets is known to be no less than eight hundred thousand miles an hour, or more than thirteen thousand miles a minute. When we reflect, too, on the size and number of the heavenly bodies, on the probability that they all move with a rapidity which, if it be not impossible to calculate, is most difficult to conceive, and that there is an order and harmony in their motions which prove them to be controlled and regulated by a will as omnipotent as that which called them into existence, we cannot refrain from exclaiming with the psalmist, when he thought upon the glories of the firmament, "Great is our Lord, and of great power," Psa. cxlvii. 5.

2. How striking and beautiful is the coincidence between these discoveries of the telescope and the representations of Scripture! It is impossible to determine whether the wonders which modern astronomy has brought to light

were revealed to the sacred writers. But how remarkably consistent is their language with all the wonders which the telescope has revealed! Where would the devout astronomer, laying down the instrument with which he has explored the heavens, find the most suitable expression for those feelings which have been awakened by what he has there seen of the glory and power of the eternal Creator? Where would he find language more elevated and appropriate than in the sacred volume? And in this concurrence between science and Scripture, have we not an additional confirmation of the fact, that the God of nature is the God of the Bible?

3. All subjects, as they are exhibited in the Bible, have reference to the great work of redemption. The cross of Christ is a centre from whence the Christian will survey the universe. The hill of Calvary will be his observatory. Oh! how unutterable will be the emotions with which he will "consider" the heavens, when he remembers that their almighty Maker is his Redeemer! "All things were made by him; and without him was not anything made that was made," John i. 3.

There is a rapture felt in gazing on the starry sky, which can be only known to him in whose heart the Saviour is enthroned. He will see all the glories of creation reflected on the mediatorial work of that Saviour, and every discovery which expands his views of the former will exalt his conceptions of the latter. "Those worlds of light," he will say, "those countless suns and systems which the telescope brings within my sight, and in the contemplation of which, either individually or collectively, I am lost in astonishment and filled with awe, are all the workmanship of my Redeemer. And is it so? Then how transcendent must be his glory! Do I go to Bethlehem, the place of his incarnation, and see him,

> "On whom the vast universe hung,"

as an infant cradled in a manger? What an infinite depth of condescension! Do I visit the place of his crucifixion, and see him bearing "our sins in his own body on the tree?" 1 Pet. ii. 24. How inestimable must be the value of the sacrifice! Does my faith follow him from the scene of his abasement to that of his exaltation? Do I behold him as Mediator, invested with absolute and unlimited sovereignty? How is my confidence strengthened! Surely "he is able also to save them to the uttermost that come unto God by him," Heb. vii. 25.

Nor let it be imagined that the magnitude of creation affords any reasonable objection to the scheme of redemption as revealed in the Bible. The objection has been made, but its whole force is met in the one simple consideration, "that God, in addition to the bare faculty of dwelling on a multiplicity of objects at one and the same time, has this faculty in such wonderful perfection, that he can attend as fully, and provide as richly, and manifest all his attributes as illustriously, on every one of these objects, as if the rest had no existence, and no place whatever in his government or in his thoughts."* And in illustration and proof of this position, let it be remembered, that soon after the invention of the telescope, which put infidelity in possession of the objection, another instrument was found, "which laid open a scene no less wonderful, and rewarded the inquisitive spirit of man with a discovery which serves to neutralize the whole of this argument. This was the microscope. The one," said that great

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* "Discourses on the Christian Revelation, viewed in connexion with modern Astronomy," by Rev. Dr. Chalmers.

man whose language we quote, " led me to see a system in every star. The other leads me to see a world in every atom. The one taught me that this mighty globe, with the whole burden of its people and of its countries, is but a grain of sand on the high field of immensity. The other teaches me that every grain of sand may harbour within it the tribes and the families of a busy population. The one told me of the insignificance of the world I tread upon. The other redeems it from all its insignificance; for it tells me that in the leaves of every forest, and in the flowers of every garden, and in the waters of every rivulet, there are worlds teeming with life, and numberless as are the glories of the firmament. The one has suggested to me, that beyond and above all that is visible to man, there may lie fields of creation which sweep immeasurably along, and carry the impress of the Almighty's hand to the remotest scenes of the universe. The other suggests to me, that within and beneath all that minuteness which the aided eye of man has been able to explore, there may lie a region of invisibles, and that, could we draw aside the mysterious curtain which shrouds it from our senses, we might there see a theatre of as many wonders as astronomy has unfolded—a universe within the compass of a point so small as to elude all the powers of the microscope, but where the wonder-working God finds room for the exercise of all his attributes, where he can raise another mechanism of worlds, and fill and animate them all with the evidences of his glory.

"Now mark how all this may be made to meet the argument of our infidel astronomers. By the telescope they have discovered that no magnitude, however vast, is beyond the grasp of the Divinity. But by the microscope we have also discovered, that no minuteness, however shrunk from the notice of human eye, is beneath the condescension of His regard. Every addition to the powers of the one instrument, extends the limit of his visible dominions. But, by every addition to the powers of the other instrument, we see each part of them more crowded than before with the wonders of his unwearying hand. The one is constantly widening the circle of his territory. The other is as constantly filling up its separate portions with all that is rich, and various, and exquisite. In a word, by the one I am told that the Almighty is now at work in regions more distant than geometry has ever measured, and among worlds more manifold than numbers have ever reached. But, by the other, I am also told, that, with a mind to comprehend the whole in the vast compass of its generality, He has also a mind to concentrate a close and separate attention on each and on all of its particulars; and that the same God who sends forth an upholding influence among all the orbs and movements of astronomy, can fill the recesses of every single atom with the intimacy of his presence, and travel, in all the greatness of his unimpaired attributes, upon every one spot and corner of the universe he has formed."*

For the introduction of a passage so long, and so well-known, the reader will find an apology in its great beauty and appositeness. It may also be added, that it would be impossible to supply a more appropriate preface to the subject of the following pages. It is a link of exquisite workmanship, connecting the two parts of this little volume.

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* Rev. Dr. Chalmers's Astronomical Discourses.

PART II.

THE MICROSCOPE AND ITS OBJECTS.

A MICROSCOPE is an optical instrument, by which very small objects are magnified. By means of it many discoveries have been made, which are, in some respects, even more wonderful than those of the telescope. We naturally associate ideas of magnitude with power; but to discover the infinite in the invisible, not because it is remote, but because it is too diminutive to be discerned, baffles all our attempts to "find out" Him whose greatness is as unsearchable in the minute as in the mighty.

Invention of the microscope.—The microscope appears to have been invented not long after the telescope, and it is probable that the invention of the one instrument led to that of the other. All that we can be assured of is, that microscopes were first used in Germany, about the year 1621, or nearly twelve years after the invention of the telescope. According to Borellus, who gives the most particular details of its invention, we are indebted to Zachary Jansen and his son for the microscope. Others, however, claim the honour of inventing it, particularly Cornelius Drebell, a man of science and ingenuity, who invented the thermometer, and Fontana, who professed that he made the discovery in 1618, although he published no account till 1646. Borellus informs us that the Jansens presented the first microscopes which they made to prince Maurice and Albert, archduke of Austria. A minute description has been given of these instruments, from which it is evident they were either compound microscopes, or telescopes adapted to the examination of near objects by a different arrangement of the glasses. In No. 42 of the "Philosophical Transactions" of the Royal Society for 1668, we have an account of a microscope made by Eustachio Divini, at Rome, which consisted of two plano-convex glasses, so placed as to touch each other in the middle of their convex surface. It is described as sixteen inches long, the eye glass almost as broad as the palm of a man's hand, and the tube in which it was inclosed almost as thick as a man's leg; it was adjusted at four different lengths; in the first, which was the least, it showed objects 41 times larger than to the naked eye, in the second 90 times, in the third 111 times, and in the fourth 143 times.

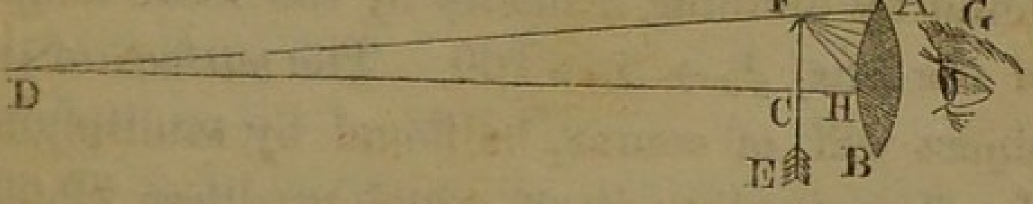
About the period now referred to, M. Hartsoeker proposed using small globules of glass, instead of lenses. A microscope, containing a globule $\frac{1}{10}$th of an inch in diameter, may be demonstrated to have a magnifying power of 100 times in diameter. Were it not for the difficulty of applying objects to these magnifiers, the want of light, and the small field of distinct vision that can be obtained in them, they would perhaps be the most perfect of single microscopes, since they could be made to magnify above 300 times, but they are now seldom used. Few distinguished themselves more, in the seventeenth century, by their microscopical observations and discoveries, than the famous M. Leuwenhoek, a native of Holland. His microscopes all consisted of small double convex lenses, set in a socket between two silver plates riveted together, and pierced with a small hole, and the object was fixed on the point of a needle, so contrived as to be placed at any distance from the lens. These microscopes were bequeathed to the Royal Society, and on examining them it was found that the highest magnifier increased the diameter of an object 160 times, but that all the rest fell much short of that power.

General description of microscopes.

There are different kinds of microscopes, and they are constructed in a great variety of forms. A brief description will now be given of those which are most simple and most commonly used.

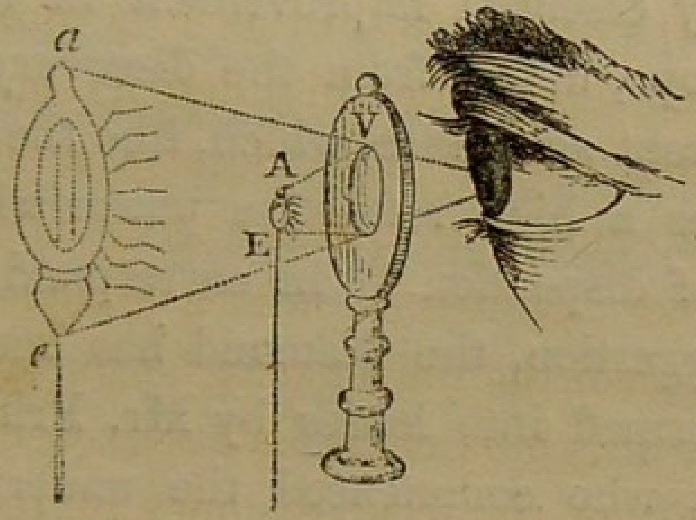
1. *The single microscope.*—This simplest of all microscopes is nothing more than a convex lens, whose focal distance is extremely short.

Fig. 18.



Let A B, fig. 18, be a double convex lens, F E the object at its focus C, G the eye very near the lens A B; the rays coming from the object will, after their refraction, fall parallel upon the eye, and, consequently, make distinct vision. Therefore, a minute object E F, seen distinctly through a small glass lens A B, by the eye put close to it, appears so much greater than it would to the naked eye placed at the distance H D, as this distance is greater than H C. To illustrate this, let us suppose the focal distance of the glass A B to be half an inch, and the distance H D eight inches, the usual distance at which we view minute objects, then the object may be said to be magnified as much as eight inches exceed the small space H C, or the focal distance of the lens A B, that is, in the proportion of 16 to 1, or 16 times. If the focal distance of the lens were $\frac{1}{5}$th of an inch, the magnifying power would be 40 times; if $\frac{1}{10}$th of an inch, 80 times; and if $\frac{1}{20}$th of an inch, the diameter of any object would be magnified 160 times, which is found by dividing 8 inches by the focal length of the lens, $\frac{1}{20} \div 8 = 160$. The surface of the object will, of course, be found by multiplying the diameter into itself, which produces 25,600 times, and the solidity or bulk would be magnified 4,096,000 times, that is, the surface multiplied by the diameter. A single microscope may be represented by fig. 19, where V is the lens fixed into a socket with a handle, A E a small object placed at its focal distance from the lens, and *a e* the magnified picture of the object.

Fig. 19.



The performance of the single microscope depends, in a great measure, on the clearness and purity of the glass of which it is made, and on the accuracy with which it is polished, so as to keep it of a true spherical figure. When completed—that is, when ground and polished—it should be as thin as it can possibly be rendered with a sufficient aperture. When a lens is thick, approaching to the figure of a globe, it is not so transparent as when thin, and the field of view at the edges is partly distorted. And it must be of a sufficient diameter or aperture, that the eye may take in a moderate field of view, and that there may be as little deficiency of light as possible. Lenses have been made whose focal length did not exceed $\frac{1}{40}$th, $\frac{1}{60}$th, or $\frac{1}{60}$th of an inch; but such high powers are difficult to be used. Sir D. Brewster has remarked, that "we cannot expect any essential improvement in the single microscope, unless from the discovery of some transparent substance, which, like the diamond, combines a high refractive power with a low power of dispersion." In correspondence with this suggestion, the diamond has been of late years formed into lenses by Mr. Pritchard, of London, who commenced the undertaking in July, 1824. The first diamond lens was completed at the end of that year, and notwithstanding the difficulty of working this substance into a perfect figure, he ultimately overcame it, and finished the first diamond microscope in 1826. The focal distance of this magnifier, which was double convex, is about $\frac{1}{30}$th of an inch. The principal advantages of employing diamonds in the formation of microscopes arise from the naturally high refracting power they possess, by which we can obtain lenses of any degree of magnifying power, with comparatively shallow curves. The indistinctness occasioned by the figure of the lens is thus greatly diminished, and the dispersion of colour in the substance being as low as that of water, renders the lens nearly achromatic. Mr. Pritchard has also formed lenses of sapphire and other precious stones, but they are not preferable to the diamond. The following table exhibits the magnifying powers of Mr. Pritchard's sapphire microscopes :—

Parts of an inch.	Magnifying Power. Linear.	Magnifying Power. Superficial.
$\frac{1}{10}$	80	6,400
$\frac{1}{15}$	120	14,400
$\frac{1}{20}$	160	25,600
$\frac{1}{25}$	200	40,000
$\frac{1}{30}$	240	57,600
$\frac{1}{40}$	320	102,400
$\frac{1}{50}$	400	160,000
$\frac{1}{70}$	560	313,600
$\frac{1}{80}$	640	409,600
$\frac{1}{100}$	800	640,000

In mounting the diamond and sapphire lenses there are advantages which glass lenses do not possess. Their extreme hardness enables them to be burnished with brass settings, which is very difficult with those of glass. This facility of mounting renders them more extensively useful in experimental researches, from their capability of being applied in every possible way with regard to the object, the light, or the eye. But it is evident that such lenses, both from the difficulty of grinding and polishing, and from the costliness of the material, must be very expensive.

There are various simple methods of procuring small lenses for microscopes, some of which may be here stated. Take a small slip of window glass, about $\frac{1}{10}$th of an inch broad; melt it in the flame of a lamp, then draw it out into fine threads, then hold one of these threads with its extremity in or near the flame, till it runs into a globule. The globule may then be cut off and placed above a small aperture, so that none of the rays which it transmits pass through the part where it is joined to the thread of glass. Lenses composed of fluids have also been made, which are frequently useful where better microscopes are not at hand. Take up a drop of water on the point of a pin, and place it in a small hole in a thin piece of brass, about $\frac{1}{20}$th of an inch in diameter. The hole should be in the middle of a small spherical cavity, about $\frac{1}{4}$th of an inch in diameter, and a little more than half the thickness of the brass, which should not exceed $\frac{1}{10}$th of an inch in thickness. On the opposite side of the brass should be another spherical cavity, half as broad as the former, and so deep as to reduce the circumference of the small hole to a sharp edge. The water being placed in these cavities will form a double convex lens with unequal convexities, which will produce a pretty high magnifying power. A better substitute for water is a drop of very pure and viscid turpentine varnish, which may be taken up on the point of a piece of wood and dropped upon a piece of thin and well-polished glass. Sir D. Brewster describes the following as the best method of constructing fluid microscopes:—Take Canada balsam, castor oil, or pure turpentine varnish, and drop either of them on a piece of glass, the surfaces of which are parallel, when a plano-convex lens will be formed. Their power may be varied by the quantity of the fluid employed, or by allowing the plate of glass to be horizontal with the drop above or beneath it: if the plate be uppermost, the gravity of the fluid will make it more convex; if the drop be above the plate, the lens will be flattened. When turpentine is used, it soon becomes indurated, and, if kept from dust, very durable. Sir David informs us, that he has made both the object and eye lenses of compound microscopes in this manner, which performed extremely well, and lasted a considerable time.* A single *reflecting* microscope may be formed by a concave speculum, having the object placed on its axis, and nearer to the surface of the reflector than the focus, when an enlarged view of the object will be seen on looking into the mirror. This instrument may be employed to enable a person to view his own eye, and will show a magnified representation of the ball, the pupil, the iris, and the ramifications of the blood vessels. On the same principle, if the reflector be large, for example, six inches in diameter, the whole head and face may be seen magnified three or four times in length and breadth, and above ten times in surface. There is a species of lens, sometimes called the Coddington lens, formed of a piece of glass nearly half an inch in thickness. The upper and lower surfaces are convex. The sides are hollowed out, giving the lens somewhat the shape of an hour-glass, and reducing the stem to a very small size. These lenses are

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* Treatise on New Philosophical Instruments, pp. 414, 415.

of a very short focal distance, have a great magnifying power, and serve either as single

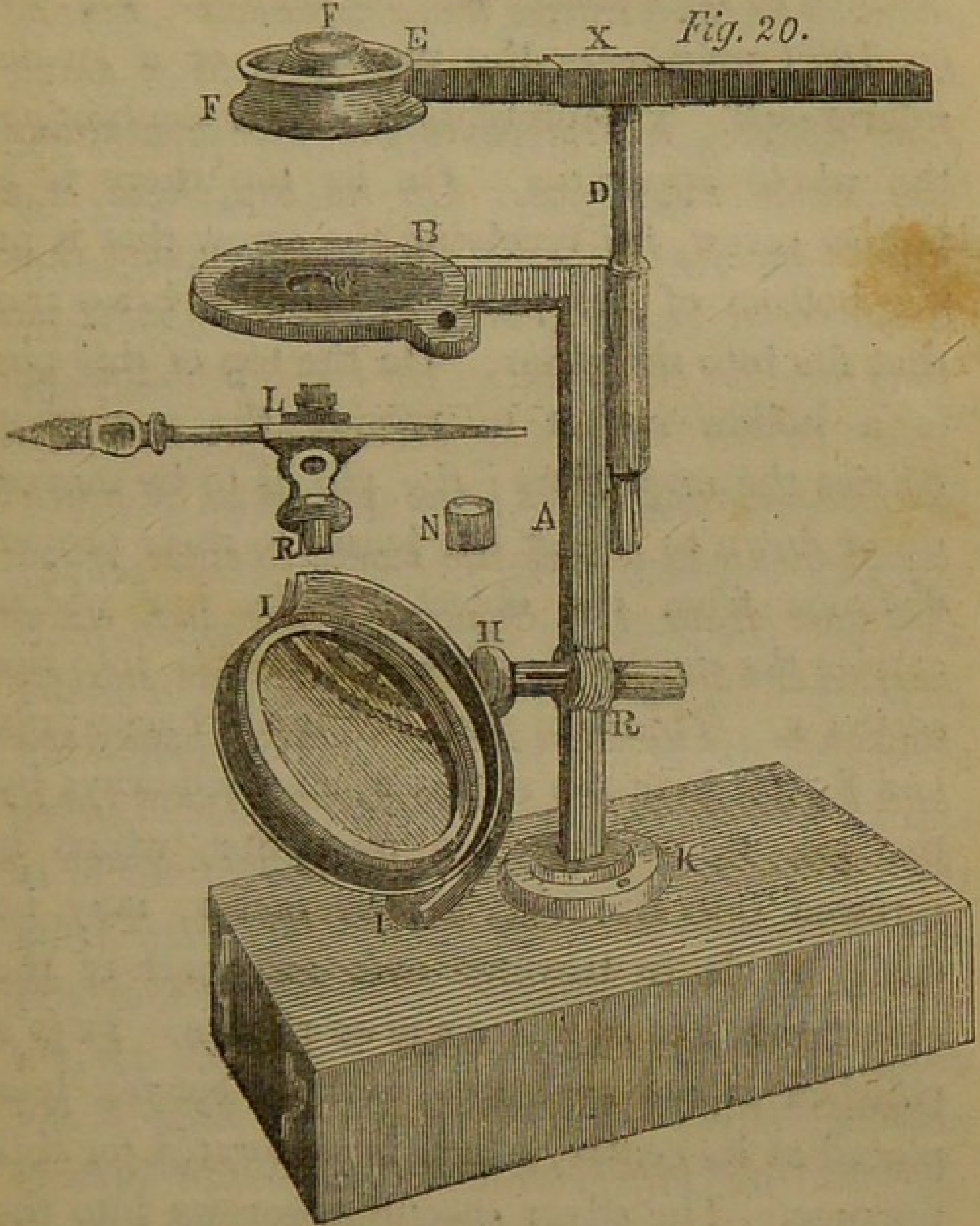


Fig. 20.

microscopes, or for the object glasses of compound ones.

There are various modes of fitting up single microscopes, some of which are complex and expensive. The following plan may be recommended as both simple and convenient. Fig. 20 (p. 107) represents the mounting of a single microscope. K represents the box containing the whole apparatus. On its top there is a hollow screw, for receiving the screw that is in the bottom of the pillar A. D is a brass pin that fits into the pillar. On the top of this pin is a hollow socket to receive the arm that carries the magnifiers; the pin is to be moved up or down to adjust the lenses to their proper distance from the object. E the bar which carries the magnifying lens, which fits into the socket X. This arm may be moved backwards and forwards in the socket X, and sideways by the pin D, so that the magnifier, which is screwed into the ring at the end E, may be easily made to traverse over any part of the object that lies on the stage or plate B. FF is a polished silver speculum, with a convex lens placed at its centre, which is perforated for this purpose. The silver speculum screws into the arm E, as at F. H the semicircle which supports the mirror I. B the stage or the plane on which the objects are to be placed. L a pair of nippers which are fixed on the stage by the pin R. N an ivory slider which occasionally screws to the point of the nippers. The silver speculum is intended to throw light on the upper surface of an opaque object, but when transparent objects are viewed, there are other lenses which may be used without the speculum. Additional apparatus is connected with this and other microscopes, which it is unnecessary here to describe.

2. *The compound microscope.*—When a microscope consists of two or more lenses or specula, it is called a *compound* microscope. In this microscope the *image* is contemplated instead of the object; one of the lenses of which it is composed forms an image or picture of the object, as in the telescope, and this image, in a magnified state, is viewed by an eye glass, which produces an additional magnifying power. Let L N, fig. 21, represent a double convex lens, and O B a small object, so applied that the pencils of rays which emerge from it and pass through the lens may converge to their respective foci, and form an inverted image at I M. This image will be so much larger than the object, in proportion as its distance exceeds that of the object from the lens. For example, if the

distance of the lens L N from the object O B be half an inch, and the distance L M, where the image is formed, be 7 inches, the image will be 14 times larger than the object; and if it be viewed through the lens F G, which suppose to be

Fig. 21.

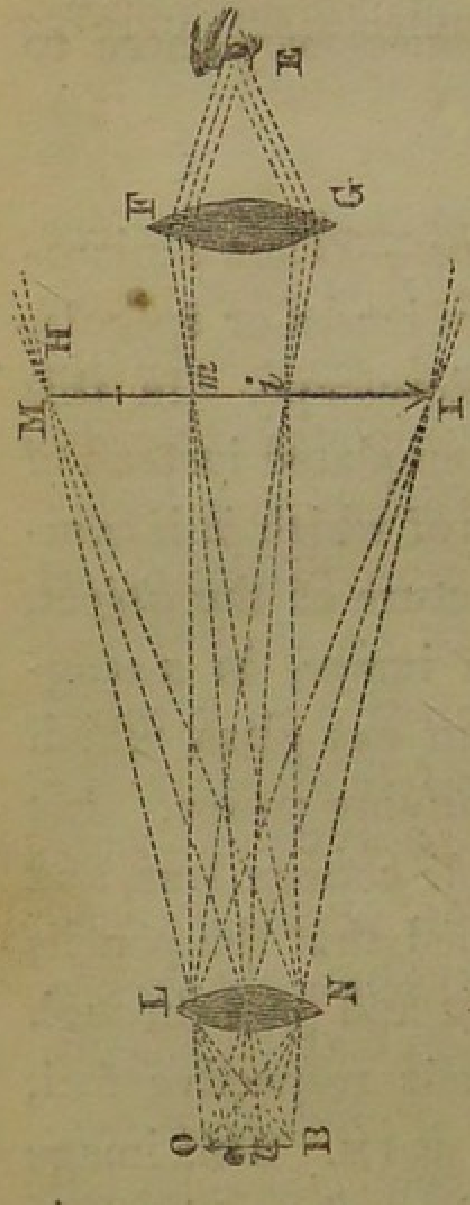
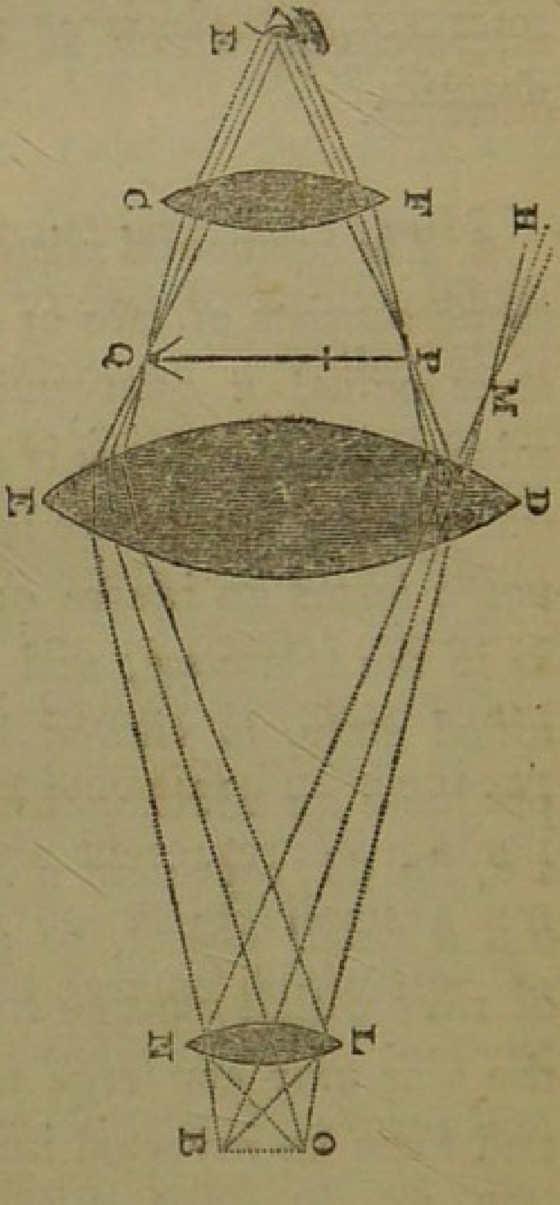


Fig. 22.



1 inch, it will again be magnified 8 times, on the principle of the single microscope, and the whole magnifying power will be 8 × 14 = 112

times. But the pencil of rays emitted from B in the object, and made to converge by the lens to M, proceeds afterwards diverging towards H, and, therefore, never arrives at the lens F G, nor enters the eye at E. Only the rays that proceed from the points *o* and *b* will be received on the lens F G, and by it be carried to the eye; the parts of the image *i* and *m* will be visible, but those situated towards I and M will not be seen. This quantity (*i m*) of the image I M is called the *field of view*, which is comparatively small when only a single glass is used. In order to enlarge the field of view, it is requisite that a broad lens, D E, fig. 22, be interposed at a small distance from the focal image; for by that means the pencil B M, which would otherwise have proceeded towards H, is refracted to the eye, as shown in the figure. In the same manner, the other extreme of the image is seen at Q, and the intermediate points are also rendered visible. On these considerations it is that compound microscopes are usually made to consist of an object lens, L N, by which the image is formed and enlarged, an amplifying lens, D E, by which the field of view is enlarged, and an eye glass, F C, by which the eye is allowed to approach very near, and to view the image

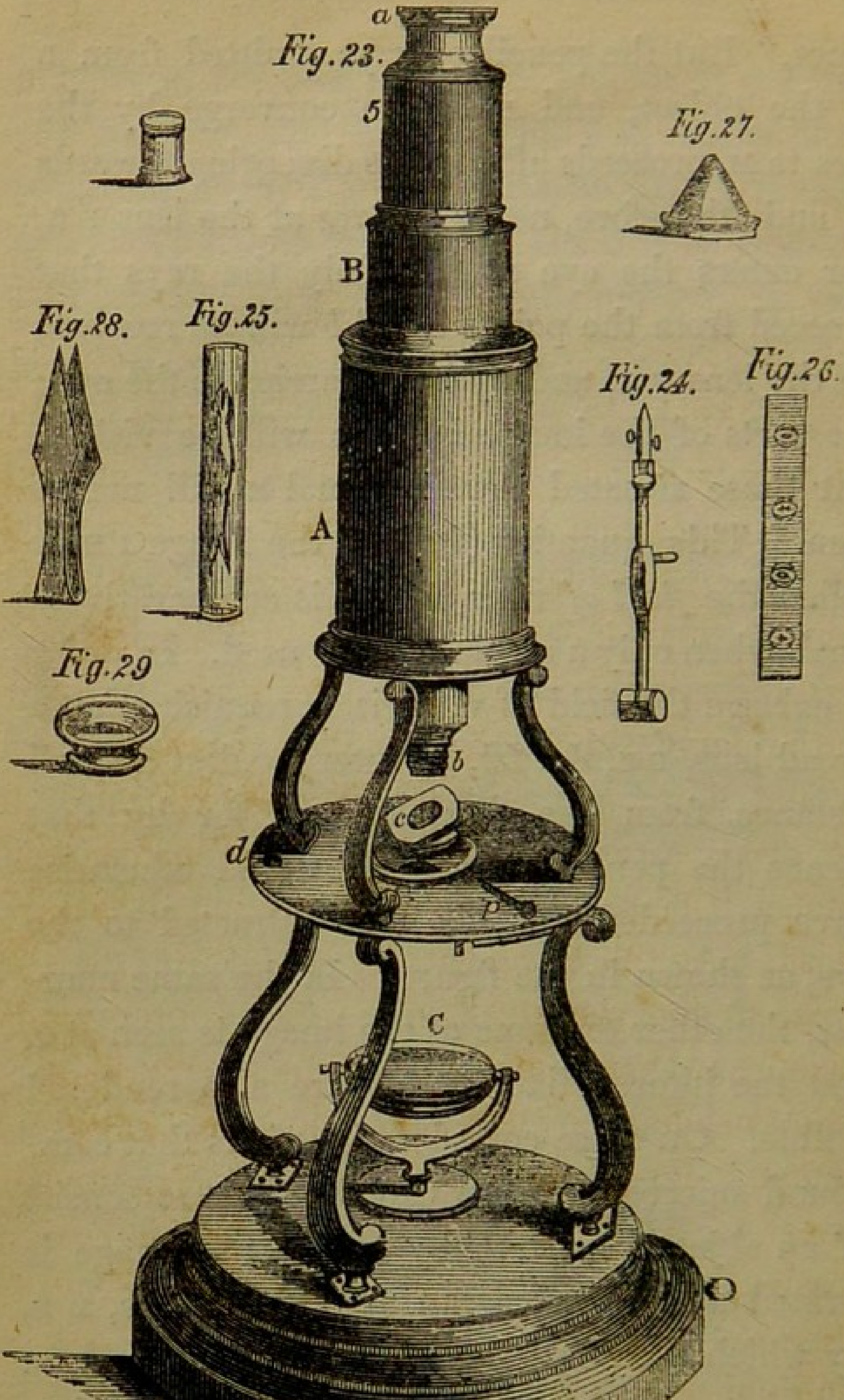


Fig. 23.
Fig. 24.
Fig. 25.
Fig. 26.
Fig. 27.
Fig. 28.
Fig. 29

under a great angle of apparent magnitude. For similar reasons three, and sometimes four eye glasses are substituted in place of the amplifying lens.

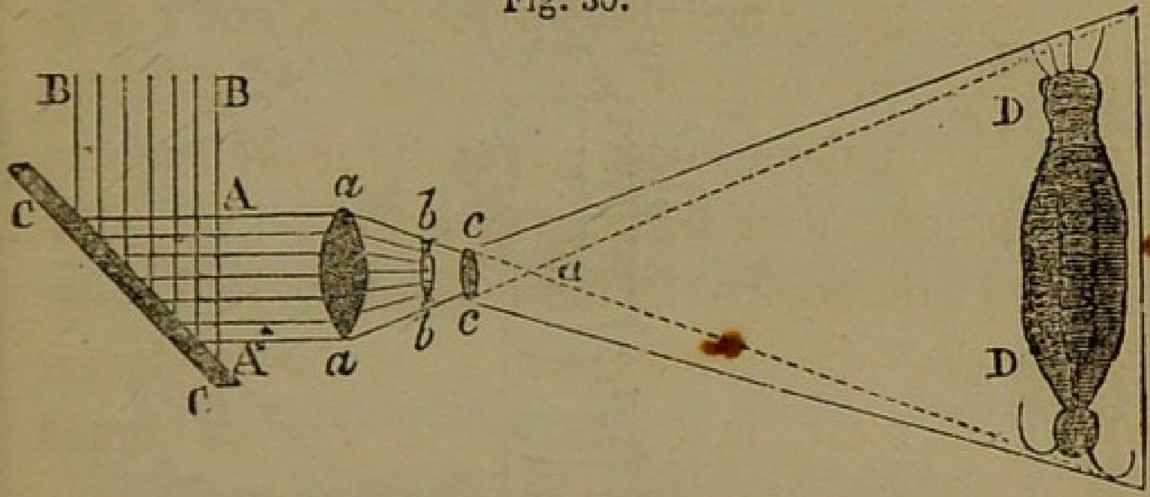
Having briefly described the theory and principle of this microscope, we shall now give a description of the finished instrument, and the way in which it is used. The large figure, fig. 23, represents the body of the microscope ready for use, which, including the pedestal, is from 12 to 15 inches in height. In this figure it is represented as consisting of three tubes. In the large tube, A, the smaller one, B, slides up and down. At the upper part, *a*, one or two eye glasses are contained, and at some distance beneath them the amplifying lens is placed. At the lower part, *b*, the object glass is placed, and the small tube which contains it is connected with the tube B, by which it is made to slide up or down, to adjust the focus to the eye. Below the object glass is *c*, a kind of spring to receive the sliders, which may be occasionally taken out, and a plane glass laid across the opening in the stage on which any small object may be laid. D is the pedestal on which the instrument stands. C is a glass concave mirror, which turns in all directions, to reflect the light from a candle, or from a window, through the hole *c*. Fig. 24 represents nippers for holding insects, or other small objects. Fig. 25 is a small glass tube, capable of containing a live fish, when observing the circulation of the blood in its tail. Fig. 26 represents one of the sliders for holding objects, which are placed between two pieces of talc, or two thin slips of glass. Fig. 27 is a hollow cone, to be placed occasionally under the stage *d*, to diminish the quantity of light. Fig. 28 is a pair of brass forceps, to take up a minute object. Fig. 29 represents a round piece of glass, to which is fitted a concave glass, for the purpose of confining animalcules, and other small living creatures, for minute inspection.

Compound microscopes have been much improved of late, by using small achromatic lenses for the object glasses. They have been made as small as $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{2}$, and 1 inch focal distance, and sometimes two or three of them are occasionally combined together, which produces a very high magnifying power, with great distinctness. But such lenses add considerably to the expense. About ten years ago £1. 3*s*. was the cost of one of these lenses 1¼ inch focal distance, and those which were of a shorter focal distance were charged at two guineas and upwards. A person who feels himself unable to purchase an expensive compound microscope, may construct a pretty powerful one for a few shillings, by attending to the following directions:—Procure for the object glass a lens about ½ an inch focal distance, another for the amplifying lens 2½ inches focal length and 1½ inch diameter, and a third glass 1 inch focal distance, to be placed next the eye. The distances at which these glasses should be placed from each other are as follows:—The object glass, ½ inch focal distance, should be placed at the end of a small tube next the object, and the aperture or hole that lets in the light should not exceed *one-tenth of an inch* in diameter. At the distance of about 7 inches from this glass the amplifying lens should be placed, and the glass next the eye, 1 inch focal distance, should be placed about 1¾ inch from the amplifying lens. Such a microscope, reckoning the combined eye glasses to magnify the image 6 times, and the object glass to magnify the object 14 times, will produce a magnifying power of 84 times in lineal dimensions, and in surface 7,056 times—a power which will show a small creature, such as a flea, as if it were 8½ inches long and of a corresponding breadth, and will bring to view all the larger species of animalcules. The stage and its supports may be made of wood, and the tubes of paper or very thin pasteboard. The tube 5, in which the eye glasses are placed, should be made so as to pull out occasionally, to increase the distance between the eye glasses and the object glass, and consequently the magnifying power. Any person with mechanical talent can easily make such an instrument at a trifling expense. The compound microscope is more pleasing in its use than the single microscope; it has a larger field of view, and the eye is not so much strained as in looking through very small lenses.

3. *The solar microscope.*—This microscope is constructed in the following manner. In a closed window shutter, or in a board fitted into the window, make a hole about 3 inches in diameter, through which the sun may cast a cylinder of rays, A A, into the darkened room, fig. 30. Into this hole place the end of a tube, containing two convex glasses and an object, namely, a convex glass, *a a*, of about 2 inches

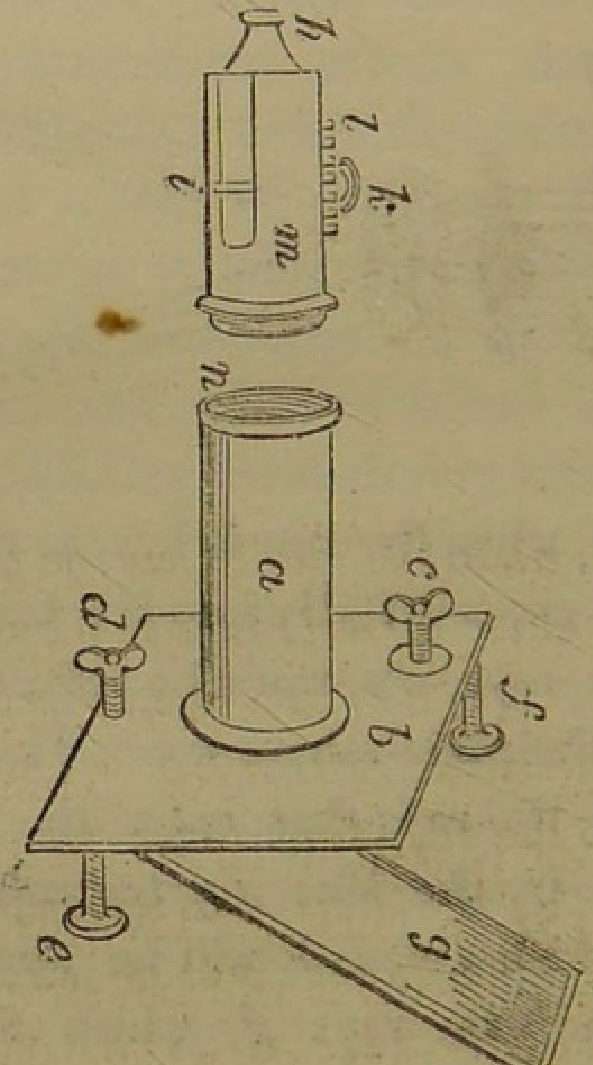
diameter and 3 inches focal distance, is to be placed in the end of the tube, which is put into the hole. The object, *b b*, is placed about $2\frac{1}{2}$ inches from the glass *a a*. If the object be a living animal it must be put between two concave glasses. A little more than a quarter of an inch from the object is placed the small convex lens *c c*, whose focal distance may be about a quarter of an inch. The tube may be

Fig. 30.



so placed, when the sun is low, as that his rays, A A, may enter directly into it; but when he is high, his rays, B B, must be reflected into the tube by the plain mirror C C. Things being in this state, the rays that enter the tube will be conveyed by the lens *a a* towards the object *b b*, by which means it will be strongly illuminated, and the rays *d*, which flow from it through the lens *c c*, will form a large inverted picture of the object at D D, which being received on a white screen, will represent the object magnified in length, in proportion of the distance of the picture from the glass *c c* to the distance of the object from the same lens. Thus, suppose the distance of the object from the lens to be half an inch, and the distance of the image 14 feet, or 168 inches, the object will be magnified in length and breadth 336 times, and in surface 112,896 times.

Fig. 31.



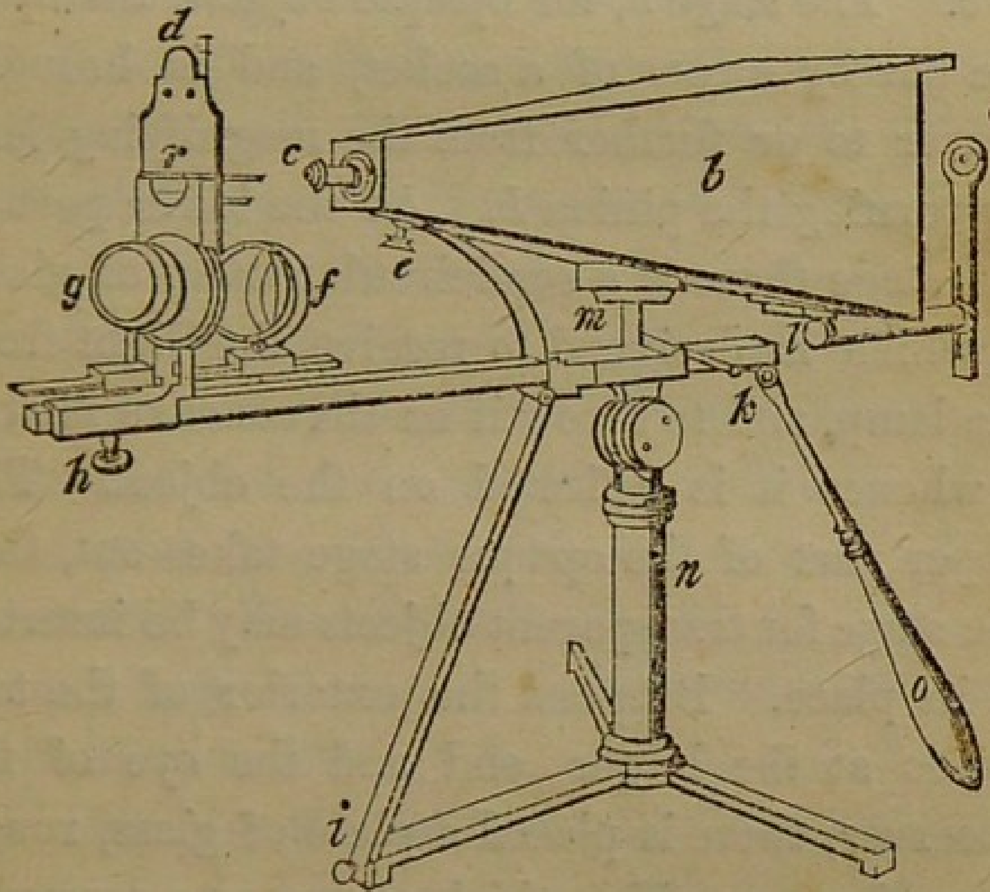
In fig. 31, some of the parts of this instrument are more particularly represented. The square plate, *b c d*, is attached to the window shutter by the screws *e f*. The mirror *g* is mounted on a wooden frame, and may be elevated or depressed by a screw at *d*. A rotary motion is communicated by a pinion and handle at *c*. The first lens is placed in the tube *a*, immediately adjoining the mirror. Another tube, *m*, is attached by a screw at *n*, and contains the small lenses for magnifying the object, and the rack-work *k l* for adjusting the focus of the instrument. The objects are introduced at *i*. When lenses of high power are employed at *h*, they are now constructed on the achromatic principle.

This instrument is not so much used as formerly, in consequence of the invention of the oxyhydrogen microscope, which is not dependent on the sun, but may be used either by day or by night, provided the room be darkened, the oxyhydrogen light being substituted for that of the sun. This is the microscope which is now exhibited in lecture-rooms, and in our Polytechnic Institutions. It may not be improper here, to give a hint to some persons not much acquainted with such exhibitions. One of the objects shown by this microscope (the oxyhydrogen) is the appearance of a heterogeneous mass of animals, which appear to be fighting with each other on a very large screen, intermixed with vegetable fibres. It has been taken for granted by some spectators, that these animals were all contained in a drop or two of water, and that they consorted together in the manner represented. This is by no means the case; no such associations are to be found in the animalcular world. A number of small animals of different kinds, most of them visible to the naked eye, are collected by the exhibitors, and put into a small glass vessel, perhaps an inch or two in diameter, along with water and a few vegetable fibres. It forms a striking exhibition, but persons should beware of deducing from it erroneous conclusions.

4. *The lucernal microscope.*—This instrument was invented by Mr. George Adams, an optician in London. It consists of a hollow pyramidal box of mahogany, which forms the body of the microscope. Fig. 32 exhibits a view of this instrument, mounted to examine opaque objects. *b* is the large pyramidal box, supported firmly on the brass pillar *n*, by means of the socket *m* and the curved piece *e*. *a* is a

guide for the eye, to direct it in the axis of the lenses; it consists of two brass tubes *l*, one sliding within the other, and a vertical flat piece, at the top of which is the hole for the eye. The inner tube may be pulled out or pushed in, to adjust it to the focus of the glasses. The vertical piece may be raised or depressed, that the hole through which the object is to be viewed may coincide with the centre of the field of view. At the small end of the cone is placed a tube, which carries the magnifiers, one of which is represented at *c*; the tube may be unscrewed

Fig. 32.



occasionally from the wooden body. Beneath the cone is placed a long square bar, which passes through, and carries the stage or frame that holds the objects; this bar may be moved backwards or forwards, to adjust it to the focus, by means of the pinion *k*. A handle, with an universal joint for turning the pinion, is shown at *o*. The stage *h*, for opaque objects, fits upon the bar by means of a socket, and is brought nearer to or further from the magnifying lens by turning the pinion *k*. At the lower part of the stage there is a semicircular lump of glass, *g*, which is designed to receive the light from the lamp, and to throw it on the concave mirror *f*, whence it is reflected on the object. The upper part of the opaque stage takes out, that the stage for transparent objects may be inserted in its place. Between the exterior of the two lenses at the larger end and the eye of the observer, there is placed a plate of glass, rough ground on one side, which serves as a screen to receive the rays of light proceeding from the object whose representation is to be viewed. An Argand lamp, or the oxyhydrogen light, is placed beyond the object, before the glass lump *g*.

By this instrument, opaque objects may be seen with ease and distinctness. The beautiful colours with which most of them are adorned are rendered more brilliant, without changing in the least the real tint; and the concave and convex parts retain also their proper form. The facility with which all opaque objects are applied to this instrument is another considerable advantage, and one almost peculiar to it. The lucernal microscope does not in the least fatigue the eye; the object appears like nature itself, giving ease to the sight and pleasure to the mind; and there is no occasion to shut the eye that is not directed to the object. The outlines of every object may be taken even by those who are not accustomed to draw, while those who can draw well will receive great assistance. Transparent objects as well as opaque may be copied in the same manner. This instrument may be used at any time of the day, but the best effect is by night, in which respect it has a superiority over the solar microscope, which can only be used when the sun shines. Such are some of the properties of the lucernal microscope, as stated by the inventor.

Besides the microscopes we have already

described, different forms of this instrument have been constructed on the principle of reflection, by a combination of speculums both convex and concave. These microscopes were constructed as early as the year 1738, by Dr. Smith, Mr. Baker, and others, but they had been abandoned for many years, till, in the year 1815, Amici, a Frenchman, directed his attention to their construction, and greatly improved them; and they were still further improved in England by Dr. Goring and Mr. Cuthbert; but owing to the difficulty in constructing the reflectors, and the great trouble in managing them, they again fell into disuse, and even Amici himself returned to his former experiments with achromatic object glasses.

If it be asked which of the microscopes now described we would recommend for making researches into the minute parts of nature, we answer, without hesitation, the *compound microscope furnished with achromatic object glasses.* The compound microscope as now improved, to use the words of an eminent optician, "has, within the last sixteen years, been elevated from the condition in which it was previously found, to that of being the most important instrument ever yet bestowed by art upon the investigator of nature." The application of achromatic object glasses to compound microscopes has only been attempted within the last twenty-six years. In 1824, the late Mr. Tulley, of London, succeeded in making the first English achromatic object glass for a compound microscope. It was composed of three lenses, and was capable of transmitting a pencil of rays of 18°. He soon after constructed another combination, to be placed in the front of the first mentioned, which increased the angle of the pencil to 38°. Mr. Tulley's object glass exhibited a flat field, and was perfectly corrected; to it was applied an eye-piece, by which the magnifying power produced was 120 diameters, but when the second combination was added, the power was increased to 300. These object glasses have since been improved by Messrs. Lister, Powell, Ross, and Smith. Their focal distances vary from 1½ inch to ⅛th of an inch, and they may be used either separately or in combination. Sometimes three sets of them are combined together, which produces a very powerful effect. Magnifying powers equal to 1,200 diameters have thus been obtained with great distinctness, that is, the surfaces of objects have been magnified one million four hundred and forty thousand times. Some of the powers thus obtained have been equal to even 2,000 diameters, and consequently the surface magnified four million times. But such instruments, as formerly stated, are expensive.

Objects to which the microscope may be applied.

Every part of creation demands our attention, and proclaims the power and wisdom of the Creator. The microscope has shown to us these perfections in objects which the unassisted eye has never seen, no less than in those which may attract our notice in all the walks of life. It has unfolded to our view wonders unknown and unthought of in former ages. Three hundred years ago, who would have conceived it possible to distinguish myriads of living creatures in a single drop of water? Or, that blood could be distinctly seen circulating through veins and arteries, smaller than the finest hair? Or, that not only the exterior form, but even the internal structure of the viscera, and the motion of the interior fluids, should be rendered perceptible to the sight? Or, that numberless species of animated beings should be made visible to the eye, though so minute that a million of them are less than a grain of sand?

The various sections of animal and vegetable life are full of beauty, and in their minutest details exhibit a completeness and a finish infinitely transcending the most exquisite and admired pieces of art. The scale of a sole, so small to be overlooked by us, is a work of most admirable regularity and delicacy. It is a kind of web, with a number of small points at one end, which fasten it to the back of the fish. There is not a single fish whose scales are not more beautifully woven than any texture which is found in the finest handiwork of man. The fibres that compose the scale of a pike are formed in a manner quite different from those we admire in the scale of a carp or a perch; still one order is invariable in all the scales of the same species. Equal regularity is found in the structure of the feathers of birds, in the fibres of the flesh of animals, in the grain of the several kinds of wood, and in the figures of the different salts. The dust on the wing of a moth or a butterfly, a single particle of which is so minute as to be invisible, is found, when magnified, to be a beautifully formed feather, and exhibits the most delicate and admirable arrangement in all its parts. In a moth there is a configuration entirely distinct from that of a butterfly; each species has feathers of a different form from those of another. The same variety and exquisite mechanism prevails in every department of the vegetable kingdom.

The following objects, among many others, may afford amusement and instruction to those who are possessed of microscopes :—the scales of fishes; the dust on the wings of butterflies, moths, gnats, flies, and other insects ; the flea, and mites in cheese ; the eels, serpents, or little worm-like animals found in vinegar and paste; the animalcules existing in infusions of pepper, as well as of hay, grass, flowers, and other vegetable substances ; the eye of the house fly, the dragon fly, and of various other insects ; the legs of spiders ; the claws of beetles ; the wings of small flies ; the eye of a lobster ; slices of broom, lime tree, dogwood, and oak ; transverse sections of plants of various kinds, every one of which has a different configuration from another ; the farina of flowers, particularly of the sunflower; the leaves of trees, plants, and flowers ; the fibres of a peacock's feather, and the feathers of other birds; the human hair; the hair of a mouse, and the hair of an Indian bat; the sting of a bee or a wasp; the stings of a nettle; small flies which infest fruit and trees; the beard of a wild oat; seeds of poppies and other small seeds; mouldiness, which is a species of vegetation, or a forest of mushrooms; the small nimble insects existing among pinks, roses, and sunflowers; water spiders, not larger than a grain of sand, found in ditches; the silkworm in its various transformations; the nymph, aurelia, or chrysalis of moths, butterflies, and other insects; the proboscis of a butterfly, which winds round in a spiral-form like the spring of a watch, serving both for mouth and tongue; mosses of all kinds; sponge, reckoned a plant-animal, composed of minute vessels resembling veins and arteries; grains of sand, which are of various forms, having all numerous sides and angles, some of them finely polished; the flakes of snow before they melt; the tails of fishes, the fins of water newts, and the webs between the toes of frogs, in which the circulation of the blood may be beautifully seen; and fresh water polyps, with arms in the form of horns.

The above are only a few specimens of ten thousand objects in the minute parts of creation, which display beauties, contrivances, and instances of Divine mechanism, of which no one who has not looked at them through the microscope can form any adequate conception. There is, in fact, scarcely a particle of matter in creation, in which this instrument does not show something worthy of being admired. In addition to natural objects, however, we may further mention the following artificial productions, which afford entertaining materials for microscopic observation. 1. The *silver tree;* the preparation of which is as follows :—Dissolve a little silver in a small quantity of *aqua fortis;* then add twice the quantity of common water to it. When it is applied to the microscope, a little of it should be dropped on a plain glass, and a short piece of small brass wire put into it ; immediately trees will appear growing, till they have spread as far as the liquid extends. 2. The *crystallization of salts:*—Dissolve a little sal-ammoniac in common water, place it upon the glass as stated above, and while viewing it, hold a hot iron near the glass, in order to make it more expeditious in evaporating. As soon as evaporation takes place, appearances are presented like the branches of trees, in the most beautiful variety. Every different kind of salt forms a new arrangement and a different figure.

Among the multitude of objects which nature presents for the employment of the microscope, our limits will permit us to select only a few for *particular* notice. We shall commence with a description of a few species of—

ANIMALCULES.—This term is now generally used to distinguish animals of a size so diminutive that their true figure cannot be discerned without the assistance of glasses; and more especially, it is applied to such as are altogether invisible to the naked eye. By the microscope we are brought into acquaintance with new tribes of the living world, and innumerable animated beings, which, from their minuteness, would without it have escaped our observation. How many of these invisible tribes there may be throughout the air, the waters, and the earth, is still unknown, but they doubtless far exceed the number of all other classes of living creatures combined. To know that there are myriads of atoms, endued with vitality, existing in a single drop of water, executing all their various functions and evolutions with as much rapidity and ease as if the range afforded them were boundless as the ocean, must powerfully interest every mind which takes pleasure in the works of God.

It is almost impossible to convey a correct idea of the various shapes of these singular forms of life to those who have not actually beheld them. They appear to have little or no similarity to the other diversified orders of animal existence. Some of the smallest appear merely like moving points or atoms; the large ones exhibit an astonishing variety; some are like spheres, others are egg-shaped, some are like hand-bells, others are like wheels turning on an axis; some represent fruits and vegetables of various kinds, others resemble eels, serpents, and snakes; some are like double-headed monsters, and others like cylinders; some have the appearance of funnels, tops, pitchers, and flasks; others are worm-like; some have horns, fins, and feet; others resemble small fishes, playing in the rivers or the sea; some are like long hairs, a hundred times longer than they are broad; others are like spires and cupolas; some of them are almost visible to the naked eye; others so small that a human hair would cover more than a hundred of them; while millions of millions of them might be contained within the compass of a square inch. They, however, possess peculiar habits, adapted to their respective forms. While some move through the water with the greatest rapidity, darting, leaping, or swimming, others creep or glide along, and many are so passive, that it requires patient observation to discover any of their movements. We may now give a brief description of some individual species of animalcules.

1. The *Monads.*—This genus of animalcules includes the smallest forms in which a voluntary motion has been observed under the most powerful microscopes. Motion appeared to be the only property of life they possessed, till Dr. Ehrenberg, an eminent observer of animalcular existence, demonstrated an organization equally perfect with creatures of much larger dimensions. Their forms are spherical, or cylindrical, and they are colourless, and transparent as the clearest crystal. They increase by a spontaneous division of the parent into two or more parts, and these parts again divide, as do

also the young when they have attained their full size. These animalcules are chiefly interesting from their extreme minuteness. They form the limit of man's acquaintance with animated nature. Their diameters vary from the $\frac{1}{24000}$th part of an inch to the $\frac{1}{1200}$th. What is called the *end monad* is so very minute that its existence cannot be discovered in the best instruments with a less power than 400 linear, or 160,000 times in surface. They are often so abundant on the surface of infusions that many millions in a single drop may be taken up on the head of a pin. If we take some of these animalcules, and suppose them to be arranged in a line of only one inch in length, it would require 9,600 to form it, so that a cubic inch would contain 884,736,000,000. Some of these monads are found in various vegetable infusions, and are very numerous about the infused stalks of the spider-wort.*

2. *Animalcules found in infusions of pepper.*— If the bottom of an open vessel be covered to the depth of half an inch with black pepper,

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* For a more particular account of these minute animalcules, and their different species, the reader is referred to "Pritchard's Natural History of Animalcules."

grossly bruised, and rain or river water be poured in until it rises above the pepper about an inch, and if the water be well stirred and exposed to the air, in a few days a little pellicle or skin will be perceived on its surface. This skin, examined by the microscope, will be found to contain millions of animalcules, scarcely discernible at first by the greatest magnifier, but continually growing larger, till they attain their full size. Their numbers, too, will every day multiply, and at length the whole fluid will seem alive. About the quantity of a pin's head of this scum, taken up with the point of a pen, or a small hair pencil, and applied to the microscope, will show several sorts of animalcules, differing both in size and in shape. The following are some of their varieties:—

Fig. 33 represents the largest kind. The length of the body is about the diameter of a small hair, and three or four times more than its breadth. It is very thin and transparent, but that side which appears to be the back is darker than the other. They frequently turn themselves in the water, and show both back and belly, as seen in figs. 1, 2. The edges of


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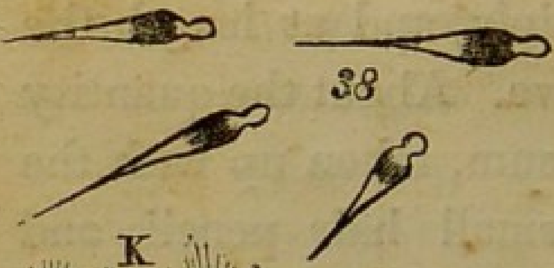
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the body are fringed with a great number of exceedingly minute feet, which are chiefly perceptible about the two extremities. At one end, there are likewise some bristles, longer than the feet, resembling a tail. The motion of these animalcules is swift, and by their turns, returns, and sudden stops, they seem to be continually hunting about for their prey. They can employ their feet in running as well as in swimming; for, on putting a hair among them, they often creep along it from end to end, bending in several strange postures.

There is another kind of animalcule in this infusion, whose length is about one-third of a hair's breadth, with tails five or six times as long and sometimes longer. Fig. 34, No. 1, exhibits one of them with the tail extended. No. 2 represents another of them, with its tail in a screw-like form, which is very common. Occasionally, when they lie still, they thrust out or pull back again their bearded tongues. A third kind, about the size of the last, but without tails, appear sometimes in an oval shape, as in fig. 35, No. 1; and sometimes a little longer, resembling a flounder, as No. 2.

Their little feet may be plainly seen when the water is just evaporating, for then they move very swiftly. Now and then two of them are seen conjoined, as at No. 3. A fourth kind appear like slender worms, fifty times as long as broad. Their thickness is about the one-hundredth part of a hair, and they swim with the same facility backwards as forwards. A fifth kind is so exceedingly small that a hundred of them in a row would not equal the diameter of a grain of sand, and consequently a million of them are but equal to a grain of sand in bulk. Their shape is almost round.

3. *The eels in paste and vinegar.*—To procure these, boil a little flour and water, and such paste as bookbinders commonly use. It should neither be very stiff nor very watery, but of a moderate consistence. Expose it to the open air in an open vessel, and prevent its hardening, or becoming mouldy on the surface, by beating it well together. After some days it will turn sour, and then, if examined attentively, multitudes of small, long, slender, wriggling animalcules will be discerned, which increase daily in size. To promote their development a drop of vinegar may now and then be

let fall upon the paste. After the eels are once produced, they may be kept all the year by applying to them occasionally a little vinegar and water. They may be taken to the microscope on a piece of talc or thin glass, a drop of water for them to swim in being previously provided. They are very entertaining objects. Sometimes the motion of their internal parts may be distinguished. In vinegar itself, after standing a few days uncovered, especially in summer, a species of eels will frequently be found. The figure of these eel-like animalcules is shown at fig. 36.

4. *Animalcules in infusions of hay, grass, oats, wheat, and other vegetable productions.*—When the above substances are infused in water, after some days a sort of whitish scum will appear upon the surface, which, examined by a microscope, will be found to contain an immense number of living creatures, of various sizes and forms. The most common is an oval animalcule, somewhat in the shape of an emmet's egg, as shown fig. 37. They are extremely nimble, and in continual motion backwards and forwards; but sometimes they stop on a sudden, and turn round on their axis numberless times,

and alternately in different directions, with surprising velocity.

In the summer season, the water that is stagnant in small pools and ditches appears frequently of a greenish, and occasionally of a reddish hue. On examining it by the microscope, it is found that immense multitudes of animalcules are crowded together on its surface, giving it a coloured appearance. The bodies of these animalcules are oval, and transparent at both ends, but the middle is either green or red. There is reason to believe, that in one of these ponds or ditches the number of living creatures enjoying a happiness suited to their natures, exceeds that of all the human inhabitants peopling the globe. The liquid which drains from dunghills, presenting a deep brown colour, is sometimes so thronged with animalcules, that it seems to be all alive, and must be diluted with water before they can be sufficiently separated to distinguish their various kinds. Among these is sometimes found a species represented in fig. 38. Their middle part appears dark, and beset with hairs, but both ends of them are transparent. Their tails are tapering, with a long sprig at the extremity, and their motion is slow and waddling.

Our limits will not permit us to prosecute this subject much further. We may just remark, that an infusion of any herb, grain, fruit, flower, leaves, or stalks of any description of vegetable, in common water, will be found, after a few days, to contain animalcules in immense numbers, and of a species peculiar to the different substances which are infused. M. Joblot, of Paris, has given us a description of numerous experiments he made on this subject. He examined the infusions of pepper—black, white, and long—of senna, pinks, blue-bottle, roses, jasmine, raspberry stalks, tea, barberries, fennel, sage, marigold flowers, sour grapes, mushrooms, and rhubarb, and found different animalcules. Hay, new and old, abounded with many kinds. Rhubarb, mushrooms, sweet basil, and citron flowers, had their particular animalcules. The anemone afforded a very wonderful species, with a satyr's face upon the back. Celery produced many kinds, as also did wheat-ears, straw, rye, oats, and Turkish corn. Oak-bark, new and old, afforded great variety. Some of these infusions M. Joblot kept a whole year, and observed that not only each infusion had animalcules of shapes quite different from those in others, but likewise that in the same infusion different kinds of animalcules appeared at different times.

5. *Description of some animalcules of uncommon forms.*—In all the productions of nature there is a wonderful diversity, particularly in the forms of animalcular life. An infusion of anemone, prepared after the ordinary manner, with cold water, at the end of eight days will afford a new and uncommon animalcule, which is represented at fig. 39. All the surface of its back is covered with a very fine mask, in the form of a *human face*, perfectly well made. It has three feet on each side, and a tail coming out from under the mask. Another curious animalcule, found in an infusion of hay, is represented at fig. 40. A shows its head, B its forked tail, C its heart, which may be seen in a regular motion, and D its intestines. When this creature rests, it generally opens its mouth very wide, as at A. Its lips, which it moves quickly, are furnished with hairs. There are ringlets lying one over another round its body. Another animalcule, which bears a certain

resemblance to this, was found in an infusion of pinks, jasmine, and other flowers. It is represented at fig. 41. It differs from the one above described, in being longer, in its tail being composed of three points instead of two, in having two little arms, L M, one on each side of its heart, marked *a*, in its intestines, *b*, being without any visible separation, and in having neither ringlets, teeth, nor hairs in its tail.

Another curious animalcule is found connected with duck-weed roots. This little creature is represented at fig. 42. It has two wheels, *d e*, with a great many teeth, or notches, coming from its head, each turning round upon an axis. At the least touch it draws the wheel-work into its body, and its body into a sheath, after which it appears as in fig. 43. But when all is quiet, it thrusts itself out again, and the rotation of the wheel-work is renewed. One of these animalcules has been noticed whose case seemed composed of minute globules, as *a*, fig. 44, and in this the wheel-work, *c*, was discovered to consist of four round parts, with little divisions between each. In the water of slimy matter, found in leaden pipes or gutters, various kinds of animalcules are discovered, and among the rest, multitudes that appear to have a sort of wheel-work, turning round in the manner now described.*

The immense multitude of these animalcules, the strange forms they assume, the minute and delicate organization of their bodies, and all the marvellous diversities of their existence, render them objects of unfailing interest. In the contemplation of these wonders of the Divine workmanship, indicating the probability of life as far below the reach of the microscope as worlds and systems to which the telescope points are above its highest range—who does not see that Omnipotence is as gentle as it is mighty, and as bountiful as it is universal?

It will neither be uninteresting nor uninstructive to inquire, whether these minute living atoms are endowed with that faculty of thought which is usually described by the word sagacity. Mr. Baker informs us, that a small

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* Those who wish a more particular description of animalcules, may be referred to Adams's "*Micrographia Illustrata*," his "Essays on the Microscope," Leuwenhoek's "*Arcana Naturæ*," and Pritchard's "Natural History of Animalcules," where there are hundreds of figures of animalcules of all forms delineated.

quantity of the matter containing the *hair-like* animalcules having been put into a jar of water, it so happened that one part went down immediately to the bottom, while the other continued floating on the top. When things had remained for some time in this position, each of these swarms of animalcules began to grow weary of its situation, and had a mind apparently to change its quarters. Both armies, therefore, set out at the same time, the one proceeding upwards and the other downwards, so that, after some hours' journey, they met in the middle. A wish to know how they would behave on this occasion led the observer to watch them carefully, and to his surprise, he saw the army that was marching upwards open to the right and left, to make room for that which was descending. Thus, without confusion or intermixture, each held on its way; the body that was going up proceeding in two columns to the top, and the other journeying in one phalanx to the bottom, as if each had been under the direction of a leader. "After viewing animalcules in a microscope," says a writer, "I was in the habit of returning the drop which contained them to the vessel holding the fluid out of which it was taken, washing it off the slider with a little pure water.

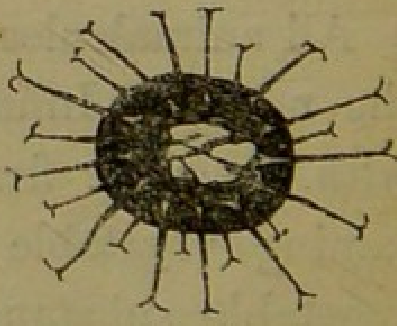
On one occasion, I looked again at the slider through the microscope, and found a little creature in a very small drop which had been left behind. Feeling itself somewhat confined, it attempted to get out of the drop; it went from side to side, and tried five or six places in order to extricate itself from its confinement; but finding no opening, it placed itself in the middle, and whirled itself round its axis like a windmill, till the drop was quite evaporated, and then, after a few throbs, it ceased to move. At another time, I happened to be looking at the spots in the sun, and was not a little surprised to see one of them, as I supposed, moving across its disc. This I soon found to be a small animal, about the size of a mite, on one of the glasses of the telescope which I inclosed between two concave glasses. I afterward watched its movements through the microscope, and observed that it seemed very desirous to free itself from its confinement. It moved first to one point where there seemed a slight opening, but finding none, it tried other apparent crevices, and when at last it gave up its attempts, it returned to the centre of its place of confinement. In these cases, the little creatures seem to have reasoned and acted as rational beings might have done in similar circumstances."

Among those who stand foremost in the rank of microscopic naturalists, professor Ehrenberg, to whom we have already alluded, takes the lead. In various parts of the earth he has studied minute organic productions; and the results of his persevering inquiries have been given to the world. His researches, during baron Humboldt's last journey, extended to more than fifty degrees of longitude, and fourteen degrees of latitude. He went as far as Dongola in Africa, and the Altai mountains in Asia; and examined animalcules in a great variety of situations. He found them on Mount Sinai; swarms of various species were in the wells of the Oasis of Jupiter Ammon, and at a considerable depth in some Siberian mines, in places entirely deprived of light.

All animalcules were once confounded under the name of Infusoria, because they were met with, by their first discoverers, in water containing vegetable matter, or in infusions of vegetable substances. But the propriety of a general appellation will be apparent, when a due consideration is given to the circumstances in which these minute beings appear. It is an astounding yet well-attested fact, that organized beings, possessing life and all its functions, have been discovered so small, that a million of them would occupy less space than a grain of sand. The absolute number of these "miniatures of life" far exceeds that of all other living creatures on the surface of our globe.

Their reproduction is perfectly astonishing. In some instances, a single individual gives birth to millions in a very short space of time. After their death, the accumulation of their shields or hard outer coverings, mixed up with various earthy or flinty particles, produces layers of various earths and rocks. These become consolidated by time into clays, flints, and marbles, in which the shape of their shields and their characters are so clearly to be distinguished, that the very species can be determined. The hones on which razors, penknives, and other cutting instruments are sharpened, are made of a Turkish stone, which is a mass of the fossil

Fig. 45.



Animalcules in Flint.

coverings of animalcules. Tripoli, or rottenstone, has long been well known in the arts—being used in the form of powder for polishing stones and metals. It has been procured, among other places, from Bilin in Bohemia; where a single bed, extending over a wide area, is no less than fourteen feet thick. Immense mountain-masses consist of symmetrical bodies, between one five-thousandth and one ten-thousandth of an inch in diameter, articulated together in the form of rings, as in chalk; or of slender threads, as in limestone and the quartz of granite. An exact counterpart of this curious structure in the mineral kingdom is exhibited in the vegetable by the mouldiness of paste, and in the animal by the creature called *Gaillonella ferruginea.*

The tripoli just mentioned consists almost entirely of an aggregate of animalcules, in widely-extended layers, without any connecting medium. A cubic inch of this substance would contain, on an average, about forty-one thousand millions of these gaillonellæ; the shield of each one weighing about the one thousand one hundred and eighty-seven millionth part of a grain. At every stroke that is made with this polishing powder, several millions, perhaps tens of millions, of perfect fossils are crushed to atoms.

Even where the shields cannot be separated in a distinct form, as in the consolidated nodules of various flints, opals, and other substances, traces of them and of similar remains are found. It is scarcely possible to imagine the countless multitudes of these beings which must have existed in former ages, for their very coverings to have thus accumulated. It is peculiarly interesting to trace such occurrences in progress at the present time. Water, brought from a lake in the island of St. Vincent, has been seen crowded with the shields of races of animalcules at present inhabiting it; and the mud which is being deposited abundantly at the bottom of the lake is stated by Dr. Carpenter, to whom we owe the fact, to be almost entirely composed of them.

Some remarkable appearances of the ocean are to be traced to these little creatures. In the voyage of the "Beagle, on the coast of Chili, a few leagues south of Conception, the vessel one day passed through great bands of muddy water; a degree south of Valparaiso the same appearance was still more extensive. Some of the water having been drawn up in a glass, it was found to be filled with living beings. Their shape was oval, and contracted by a ring round the middle, from which proceeded the organs of motion; it was difficult to examine them, for almost the instant motion ceased their bodies burst. Sometimes both ends burst at once; sometimes only one, and a quantity of coarse brownish matter was thrown out. They were exceedingly minute, and quite invisible to the naked eye, only covering a space equal to the square of the thousandth of an inch." "In one day," adds Mr. Darwin, "we passed through two spaces of water thus stained, one of which alone must have extended over several square miles. What incalculable numbers of these microscopical animals! The colour of the water, as seen at some distance, was like that of a river which has flowed through a red clay district; but, under the shade of the vessel's side, it was quite as dark as chocolate. The line where the red and blue water joined was distinctly defined; the weather, for some days previously, had been calm, and the ocean abounded, to an unusual degree, with living creatures." The luminous appearance of the ocean is also partly accounted for by innumerable multitudes of phosphorescent animalcules.

In Sweden, on the shores of a lake near Urnea, a vast quantity of extremely fine matter is found, much like flour in appearance, and called by the natives mountain meal; it is used as food, being mixed with flour, and is nutritious. But what is this mountain meal when examined by the microscope? Nothing more than the shelly coverings of certain animalcules! As the animals perish, these coverings accumulate from age to age at the bottom of the waters, and form a deep layer. This, drying on the shore, or on places which are no longer covered by water, assumes the appearance whence it has its name, each particle being the relic of a microscopic animal.*

The minuteness of some animalcules is almost inconceivable. Under the most powerful microscope, they appear only as moving points, of

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* Readers desirous of further information on this subject, may be referred to "Curiosities of Animal Life, with recent Discoveries of the Microscope," published by the Religious Tract Society.

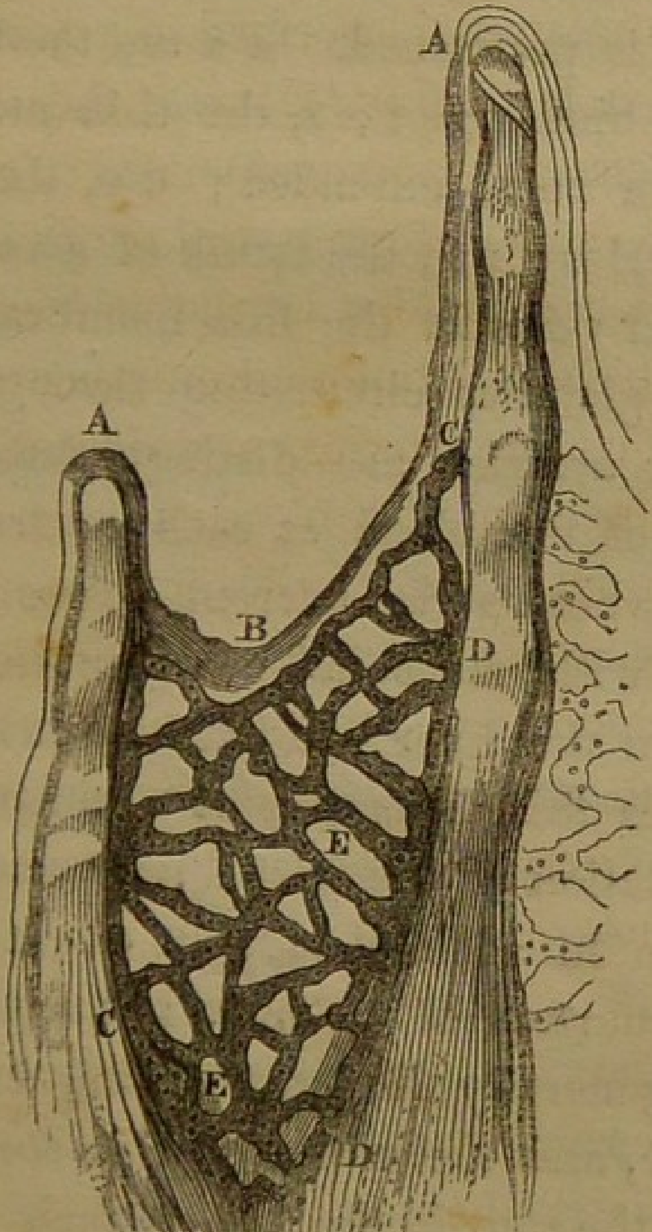
which, by the use of the micrometer — an instrument for measuring very minute bodies— eight hundred thousand millions are calculated to occupy a cubic inch of the water in which they are found. Superior instruments, in refinement and accuracy, would probably disclose creatures far inferior in size. Let it not be supposed that such statements are extravagant and baseless. These are facts, which have been repeatedly observed; and, startling as the statement may be, it is proved that a drop of water, tenanted by the smallest animalcules, termed monads, (to which we have already alluded,) contain a number equal to that of the whole human population of the globe.

The phenomena of blood.

The blood of man and of land animals is found by the microscope to consist of round red globules, floating in a transparent water or *serum*. Each red globule is made up of six smaller and more transparent ones, and each of these again, according to Leuwenhoek, is composed of six globules still more minute and colourless, so that every common red globule is compounded of at least thirty-six smaller ones. The diameter of a common round globule of human blood has been found to be equal to the $\frac{1}{1940}$th part of an inch. In order to view the blood with a microscope, take a small drop of warm blood as it comes from the vein, and, with the tip of a hair pencil, spread it as thinly as possibly on a slip of glass. It may also be diluted with a little warm water.

Circulation of the blood.—This wonderful phenomenon, the existence of which was first ascertained by the celebrated Harvey, about the year 1619, was never actually witnessed by him, as microscopes were at that time scarcely known. As regards microscopic life, it appears to have been first discovered in the water newt, by Mr. William Molyneaux, in the year 1683. Leuwenhoek, so much famed for his skill, has given many illustrations and descriptions of the method of examining it in eels and small fishes. In order to observe the blood circulating in the veins and arteries, such small creatures as by their transparency permit us to look through their external cuticle, and see what passes within them, are fittest to be used. Such are the frog, the water newt, tadpoles, eels, spiders, and some other insects. The transparent membrane between the toes of the hind foot of a frog, is the object most commonly selected for viewing the circulation of the blood, and in

Fig. 46.



this it may be seen distinctly and beautifully, both in the veins and arteries. A more striking object than this can scarcely be imagined, or one more calculated to fill our minds with admiration of the Divine skill manifested in every part of the organization of the creatures of God.

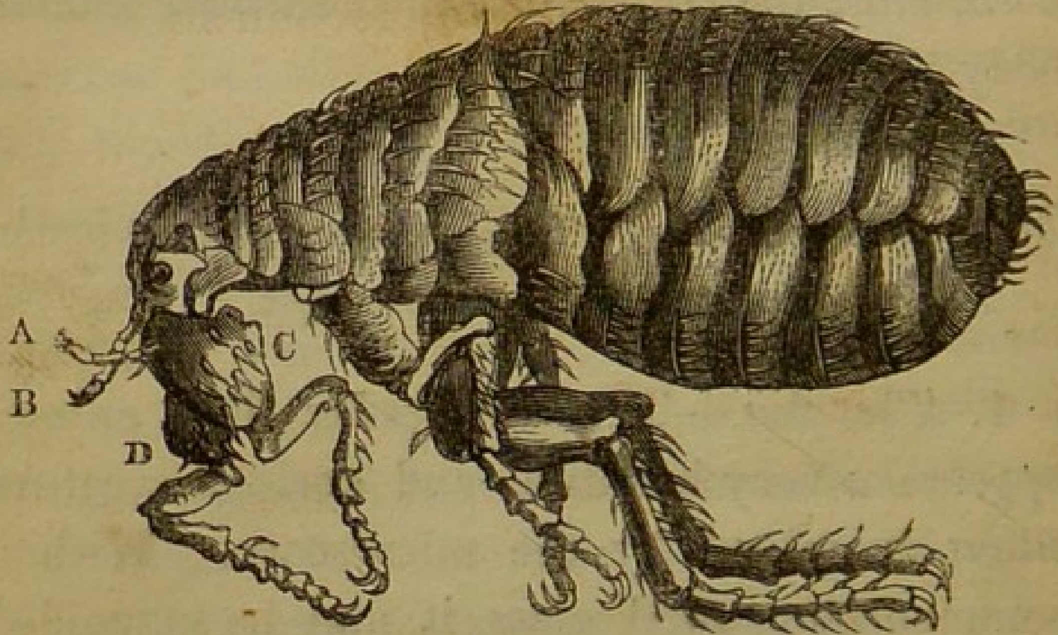
Fig. 46 exhibits the vessels in which this circulation is performed. A A are the two toes of a frog's hinder foot; B, the thin membrane between the toes, extended; C C, the trunks of the arteries; D D, the trunk of a vein; E E, arteries and veins in the fine membrane, with the blood globules circulating through them. The larger arteries are distinguishable by a protrusion of the blood at each contraction of the heart, whereas the current passes through the veins with an equal and unintermitting stream. In the finer and extreme branches of the arteries this difference is not perceptible. The circulation of the blood may also be distinctly seen in a small tadpole, about an inch or three quarters of an inch in length. This creature generally lies quite still under the microscope, and the circulation is seen in the vessels of the tail, in the fins on each side, and near the head. M. Leuwenhoek tells us, that in the tail of a fish not more than half an inch in length, he has seen the blood running towards the extremities through arteries, and returning back again through veins which were evidently a continuation of those arteries, and of the same diameter with them. He remarks, "It is easy to conceive how small the tail must be, and yet in it there were sixty-eight vessels which carried and returned the blood, and these vessels were far from being the most minute of all. How inconceivably numerous, then, must the *circulations* in the whole human body be!"

Description of the parts of some small animals, as seen in the microscope.

1. *The flea.*—This unpopular little animal appears a very beautiful and curious creature when examined by the microscope. With a common compound glass, it may be magnified to the extent of eight or ten inches in length and a corresponding breadth. It is adorned with a curiously polished coat of armour, or hard shelly scales, neatly jointed and folded over each other, and studded with long spikes, somewhat like the quills of a porcupine. The general appearance of the animal is that of a beautiful piece of variegated tortoise-shell. Its neck is finely arched, and in shape resembles a

lobster's tail. Its head is furnished on each side with a beautiful, quick, and round black eye, behind which appears a small cavity, in which moves a thin film, with many transparent hairs, forming, as is supposed, its ears. From the fore part of its head proceed two little jointed hairy horns or feelers, A and B, fig. 47. Between these and its two fore legs, C D, is situated its *piercer* or sucker. This includes a pair of darts, which, after the piercer has made its entrance, are thrust further into the flesh, to make the blood flow; thus is formed that round red spot, with a hole in the centre of it, called a *flea-bite*. Besides its feelers, this insect has six legs, four of which are joined at the breast. When the flea intends to leap, it folds up its six

Fig. 47.



legs together, and then throws them all out at the same instant, and thereby exerting its whole strength at once, so as to carry its little body to a considerable distance. The legs have many joints, from each of which proceed long hairs or bristles; and each foot is furnished with a pair of hooked claws or talons, that the insect in leaping may cling the better to what it lights upon. It is interesting to notice the surprising agility with which this little creature can leap, as many experiments have proved, a hundred times its length. Its prodigious strength is no less remarkable. It has been made to draw loads, hundreds of times heavier than its own bulk. Its muscles must therefore be very strong and vigorous. How weak and sluggish, in proportion to their size, must be the horse, the camel, and even the elephant, when compared with this puny insect: Fleas are male and female, and they pass through the same changes as the silkworm. When their eggs are hatched, they come out in the shape of worms or maggots; they afterwards put on the chrysalis or aurelia form, and when they issue from this state they are perfect fleas.

2. *Mites.*—Mites are very small creatures found in cheese, meal, and other substances. To the naked eye they appear like dust in motion; but the sharpest eye is unable to distinguish their parts without the assistance of glasses. By the microscope we perceive that they are animals, perfect in all their members, and that they perform all the offices of life in as regular a manner as those which are ten thousand times larger. The mite is a crustaceous animalcule. It has a small head in proportion to its body, a sharp snout, and a mouth like that of a mole. It has two small eyes, and six and sometimes eight legs, each of which terminates in two hooked claws. Each leg has six joints, surrounded with hairs. The hinder part of the body is plump and bulky, ends in an oval form, and is covered with a few long hairs, some of them as long as the animal itself. Other parts of the body and the head also have hairs. The female lays eggs, and the young ones issue forth with all their members entire. The diameter of a mite's egg is about the diameter of the hair of a man's head, and 600 such hairs are equal to the length of an inch. It would take 91,120,000 of these eggs to equal in size one pigeon's egg. The mite is very vora-

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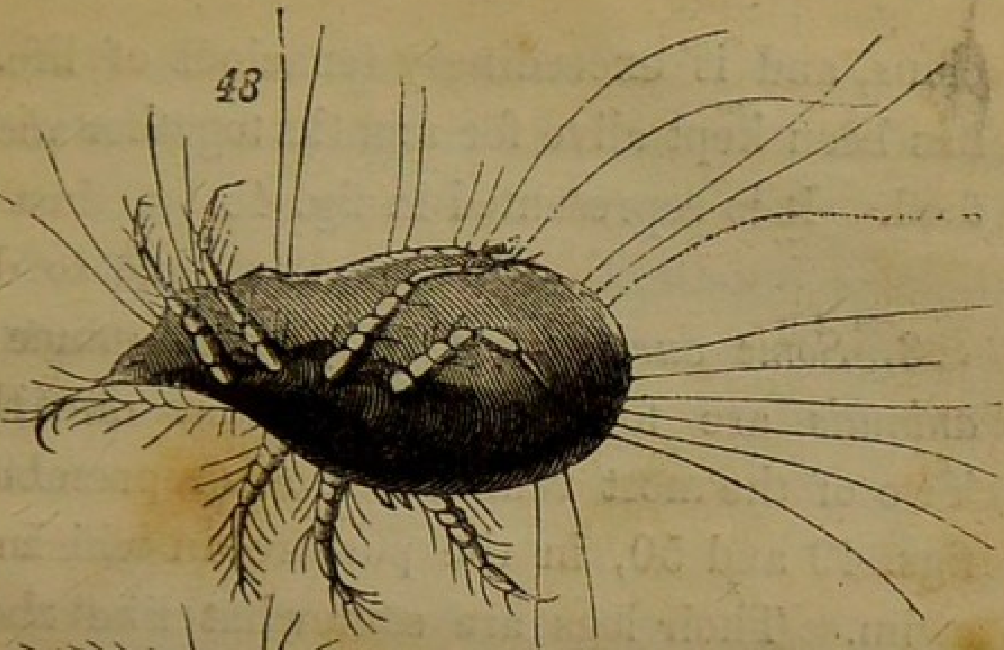

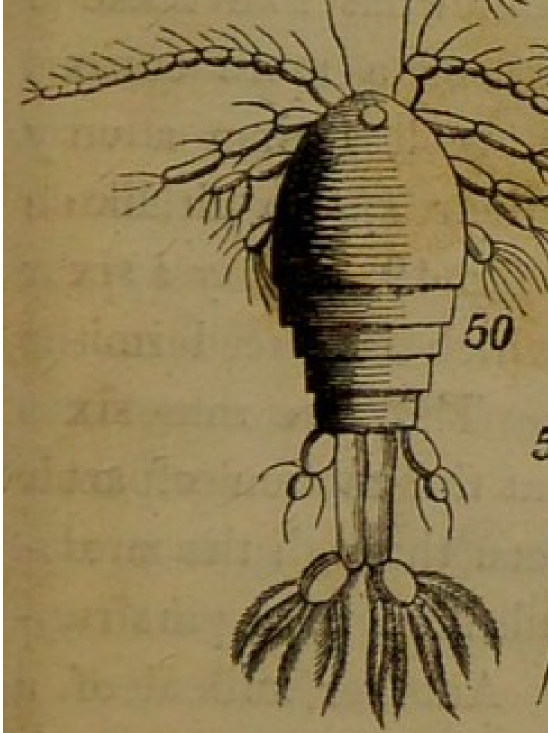

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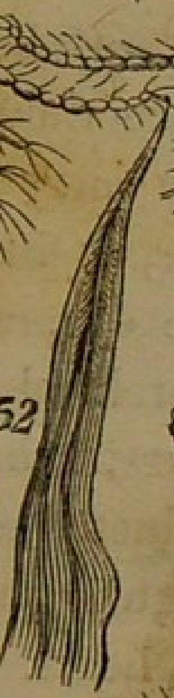

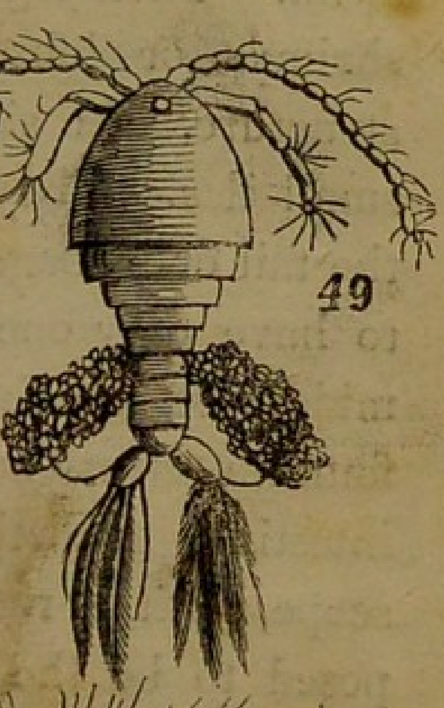

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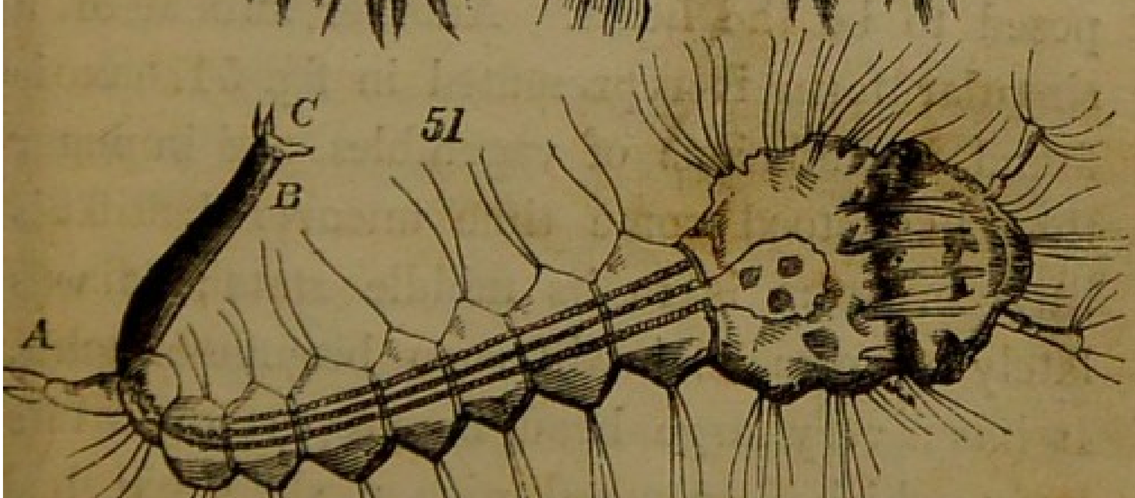


cious, and is exceedingly tenacious of life. It has been kept alive for months together without food. It is represented in fig. 48.

3. *Some curious species of small crustaceous animals* are found in the waters of ditches. Two of the most remarkable are represented in figs. 49 and 50, in the posture in which they swim. Their legs are somewhat like those of shrimps or lobsters, but of a more curious structure. In size they are less than a very small flea. They carry their spawn either on the tail or in bags, as in fig. 49. They appear to have only one eye, which is placed in the middle of the forehead. They are sometimes found so transparent that the motion of their intestines is distinctly seen through the microscope, with a regular pulsation in a part supposed to be the heart. Another animal of a singular form is represented in fig. 51. It is found in infusions of vegetables, and in water that has stood some time uncovered. This little creature is in its middle state; it was lately a worm, and will soon become a gnat. It has a very large head in proportion to its body, which is covered with a shell. It has several tufts of hair, two horns, and a large

mouth. The hinder part of the belly consists of eight joints, from the midst of which, on either side, issue small bristles. The tail is divided into two parts, very different in their structure. One of them, A, has several tufts of hair, by which it can steer itself in the water as it pleases; the other part, B, appears to be the ninth division of its body. From the part C to the head appears a coloured intestine, through which the peristaltic motion is discernible. After having lived in the water its allotted time, a remarkable change ensues. It assumes a different form, and having cast off skin, eyes, horns, and tails, it appears the insect of a different element. The most beautiful and elegant plumage adorns its head, its wings are curiously fringed and ornamented, it springs into the air with astonishing freedom and swiftness, and the creature which a few minutes before was an inhabitant of the water, would now be drowned if it were plunged into it.

4. *The stings of animals.* — These are sharp and penetrating instruments, with which the tails of wasps, bees, hornets, and some other insects are furnished, for defending themselves against their enemies. The sting of a bee and

of a wasp are similar; it is a horny sheath which includes two bearded darts. The sheath tapers to a very fine point, and near it is an opening, through which, at the time of stinging, the darts are protruded. One of them is a little longer than the other, and they penetrate alternately deeper and deeper, taking hold of the flesh by hooks, till the whole sting is buried in the wound, when a venomous juice is injected from a little bag at its root, which occasions an acute pain. The sheath with its darts is represented in fig. 52. If the wounded person starts before the bee can disengage the sting, it is left behind sticking in the wound; but if he can have patience to stand calm and unmoved, the bee brings down the lateral points, and clinches them round the shaft of the dart, by which means the weapon is recovered, and less pain is given to the sufferer.

5. *The hairs of animals.*—These supply materials also for microscopical observation. All hairs are found to be *tubular*, that is, they consist of extremely minute tubes or pipes. There is a great variety in the hairs of different animals when examined by the microscope. Hairs taken from the head, the eye-brows, the

nostrils, the beard, the hand, and other parts of the body, appear dissimilar, both in the roots and in other parts, varying as plants do of the same genus but of different species. They have each a round bulbous root, which lies very deep in the skin, and imbibe their proper food from the adjacent humours. The hair of a mouse seems to be one single transparent tube, with a pith made up of a fibrous substance running in dark lines, in some hairs transversely, and in others spirally. A bat's hair, especially that of the Indian bat, presents a most beautiful structure. It is remarkable for a series of scale-like projections, arranged in the form of a whorl around the central part, or shaft. In some hairs, the succession of whorls resembles very much a series of conical bags, placed one within the other.

6. *Scales of fishes.*—The outside coverings of fishes are scales, formed with inconceivable beauty and regularity, and are very curious objects for the microscope. Some are long, some round, some square, some triangular, and others of all imaginable shapes. Some are armed with sharp prickles, as those of the perch and the sole, while others have smooth edges.

There is likewise a great variety of scales, even in the same fish, for the scales taken from the belly, the back, the sides, the head, and other parts, are different from each other. There is no work of art we can compare with their beautiful mechanism. The finest needle-work which has ever been wrought cannot for a moment be put in competition with the beautiful net-work, and interweavings, and divarications which appear in the contexture of these scales. The scales of eels are among the most remarkable. Many imagine that these fish are without scales, on account of their being firmly imbedded in a thick epidermal mucus. In order to procure them, a sharp knife must be passed underneath the epidermal layer, and a portion of it having been raised, a few scales may be detached. They are of an oval figure, and rather softer than those of other fishes. To view the scales of any fish to advantage, they should be soaked in water for a few days, and then carefully rubbed, to clean them from the skin and dirt which may adhere to them.

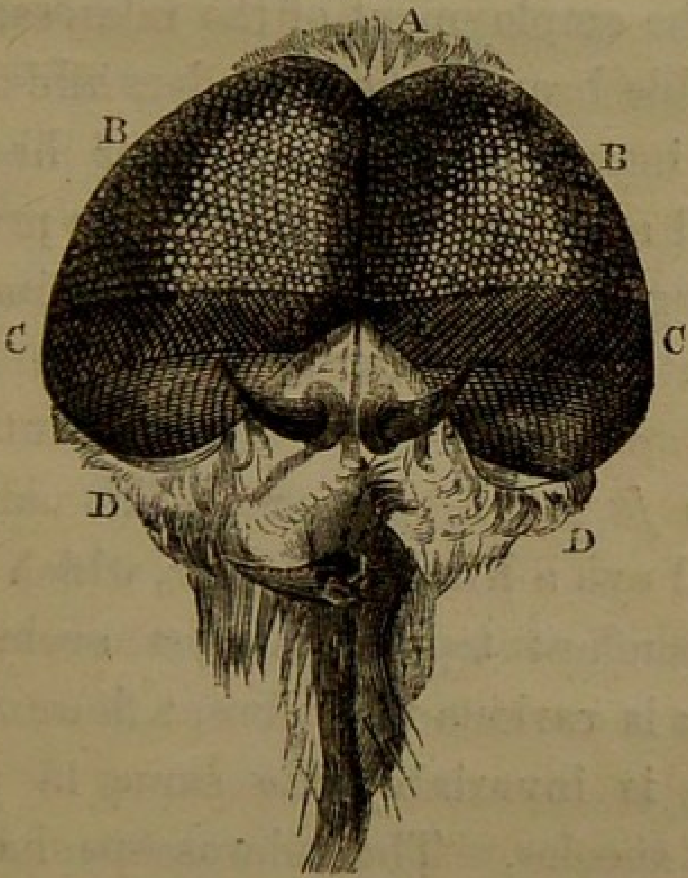
7. *The dust on the wings of the moth and butterfly.*—On the wings of these insects is a mealy dust, or down, which is a beautiful object

for the microscope. The lines on its minute particles have been used of late years for testing the defining powers of simple lenses and achromatic combinations. The dust is easily removed from the wing by gently pressing it upon an ordinary slider, or upon a thin piece of glass, to which it will firmly adhere. It consists of feathers of different shapes, with ten or twelve lines on each, proceeding from a point, like the radii of a circle, and terminating in well-defined points at the other end. Those in one part of the wing often differ from those in another part of it. On its fringes, and near the thorax and shoulder, they have the appearance of hair rather than of feathers. The feathers of the moth are longer and more beautiful than those of the butterfly. But when some quantity of dust from the wing of either is laid upon a slider, or a thin slip of glass, under the compound achromatic microscope, with a power which will make the feathers appear two or three inches in length, they present a variegated and splendid appearance.

8. *The eyes of insects.*—In all creatures the eye is a striking object; but the eyes of insects, so peculiar as to excite our highest admiration,

would have been unknown to us without the assistance of the microscope. On the heads of beetles, bees, wasps, common flies, ants, dragon-flies, butterflies, and other insects, may be perceived two protuberances, which contain a prodigious number of small transparent hemispheres, placed with the utmost regularity in lines crossing each other, and resembling lattice-work. These are a collection of eyes, so perfectly smooth and polished, that, like so many mirrors, they reflect the images of all external objects. The image of a candle or a window-sash may be seen multiplied to an astonishing extent. Figure 53, taken from Adams's "*Micrographia*," exhibits a representation of the eye and some other parts of a drone-fly. That half of the hemispheres, C D E, C D E, which looked towards its legs, was observed to be smaller than the other half, A B C E, A B C E, which looked upwards and sideways. The surface of these hemispheres was so smooth and regular, that in each of them the observer was able to discover a landscape of those objects which lay before the window, part of which was a large tree, whose trunk and top he plainly saw. These little hemispheres have each a minute transparent lens in the middle, which has a distinct optic nerve ministering to it. While other animals are obliged to turn their eyes to objects, the fly has eyes nearly all around it. The number of the hemispheres or globules in the drone-fly was reckoned to be 14,000, being 7,000 in each eye. Leuwenhoek reckoned 6,236 in a silkworm's two eyes,

Fig. 53.



3,180 in each eye of a beetle, and 8,000 in the two eyes of a common fly. In a dragon-fly he reckoned in each eye 12,544 lenses, or in both 25,088, placed in a hexangular position, each lens having six others around it. A portion of these transparent hemispheres may be seen by allowing the rays of the sun to shine upon the eye of a dead fly, when placed under a microscope on a slip of glass.

Vegetable substances.

Vegetable nature presents to us an immense field for the employment of the microscope, and innumerable beauties and wonders which, without this instrument, would never have been discovered or imagined. Our limits prevent us from doing more than briefly noticing a few examples. We may notice—

1. *The farina of flowers.*—This appears to the naked eye a kind of powder, which is found on the pendant tops of almost every flower. Its colour is various in different flowers, but its structure is invariably the same in plants of the same species. The microscope has shown us that this powder, in former ages supposed to be a mere excrementitious and unnecessary part of the plant, is produced with the utmost care, in vessels wonderfully contrived to open and discharge it when it becomes mature; and that there is a pistil, or seed-vessel, in the centre

of the flower, ready to receive the minute grains of this powder, either as they fall of themselves, or are blown out of their little cells. From numerous experiments, it is found that on this the fertility of the seed entirely depends; for if the farina vessels are cut off before they open and have shed their powder, the seed is unprolific. When intended for the microscope, the farina should be gathered during a dry sunny day, and gently brushed off with a soft hair pencil on a piece of white paper, and put upon a slip of glass to be applied to the microscope. A collection of the most remarkable kinds of farina of different flowers will amply repay the care and attention of all who delight to examine the works of God.

2. *The leaves of plants and flowers.*—The leaves of trees, shrubs, or flowers, are found to be full of innumerable ramifications, which convey the perspirable juices to the pores for their discharge. The fibres of the leaf do not stand in even lines from the stalk, but always in an angular or circular position. This arrangement tends to the more erect growth and greater strength of the leaf, and also to the security of its sap. M. Leuwenhoek, having

torn a leaf of box to pieces, that he might examine it thoroughly, computed one side of it to contain 172,090 pores; and as the other side had the same number, the total amount of pores in a box leaf was thus ascertained to be 344,180. Leaves in general exhibit a great variety of beautiful ramifications. The back of a rose tree leaf, but especially of a sweet-briar leaf, looks as if diapered with silver. A sage leaf appears as if tasselled with white silver thrums, and embellished with fine round crystal beads, fastened by little foot stalks. The little globules which appear on these and other aromatic plants are supposed to give rise to their fragrance. The back of the leaf of the English mercury plant looks as if rough-cast with silver, and as if all the ribs also were set round with white transparent balls. Fig. 54 represents a magnified view of the sweet-briar leaf. Fig. 55 is the sage leaf magnified. The leaves of plants and flowers are indeed a striking comment on the words of our Saviour: "Consider the lilies of the field, how they grow; they toil not, neither do they spin; and yet I say unto you, That even Solomon in all his glory was not arrayed like one of these," Matt. vi. 28, 29. So beautiful and delicate is the fabric of the leaves of plants, and especially of flowers, as

Fig. 54.

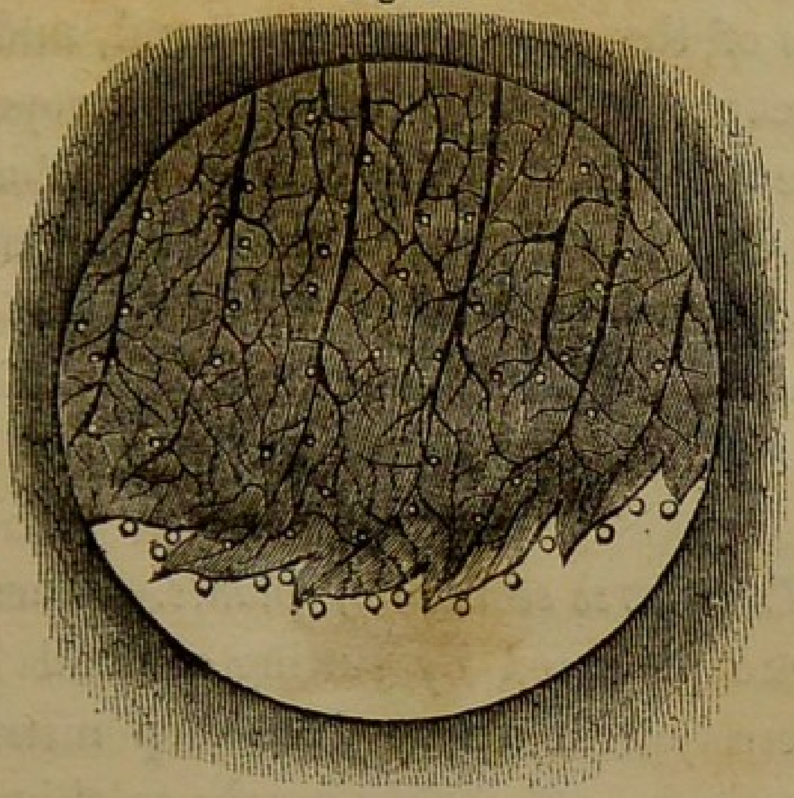
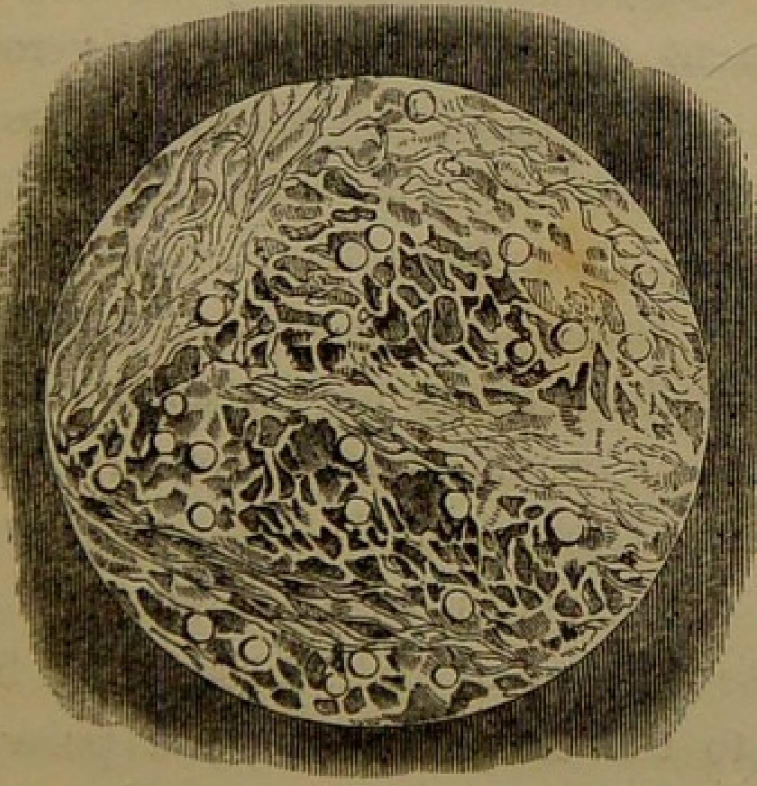


Fig. 55.

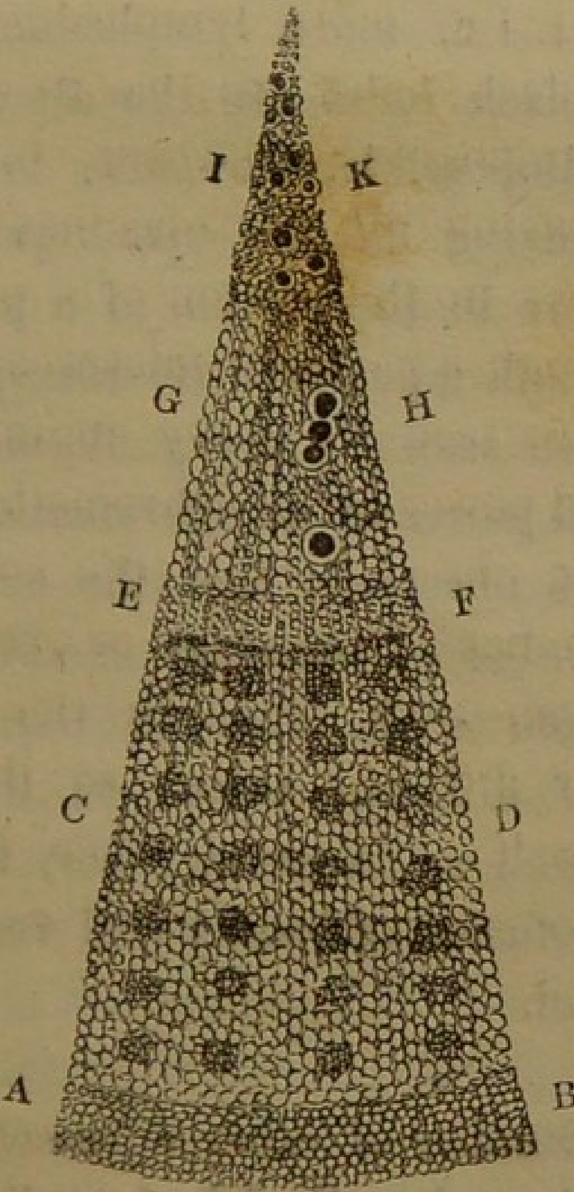


seen in the microscope, that it infinitely exceeds in these respects all the finest pieces of workmanship that art has ever produced. The threads of the most delicate riband, under the microscope, look like the coarsest rope-yarn, and the silk itself like the substance of a common door-mat. But the more we magnify the leaves of plants, the more do we recognise the hand of Him who fills the universe with light and every flower with beauty.

3. *Transverse sections of plants.*—These sections are procured by cutting a small branch transversely with a very fine sharp instrument, so as to take off a slice nearly as thin as the human skin, which then may be viewed as a transparent object; while the air vessels, sap vessels, and pores of the wood, will be seen in their variegated figures, incalculable numbers, and beautiful arrangement. The writer has several of these sections, one of which he can never behold without the greatest admiration. It is little more than a quarter of an inch in diameter. It consists of a number of concentric circles or divisions in its diameter, with an immense number of radii proceeding from the centre to the circumference, and pores, or sap and air vessels of different sizes, distributed in

beautiful symmetrical order throughout the whole. From a calculation made, it appears that there are not less than 1,200,000 pores, or the openings of tubes, contained within its circumference. And all nature is full of these "marvellous works!"

Fig. 56.



The above figure represents a portion of a transverse section of the root of *mallows*. The diameter of the section was about three-eighths of an inch, and the one-eighth part of that section was cut out from it, and placed under the microscope, when it appeared as represented in the figure. A B shows the skin ; C D, the bark, or all that part of the root which answers to it. E F, the common lympheducts ; G H, the pithy part of the root ; I K, more lympheducts, in both which the black holes are the air vessels. It is next to impossible, however, to represent in an engraving *all* the openings or vessels which appear in the section of a plant, when viewed through a powerful microscope, as new apertures are seen by every augmentation of the light and power of an achromatic glass. It may also be observed, that the configuration and the number of openings or vessels are all different from each other in the roots and branches of different trees ; so that in this respect, as well as in every other, there is an immense profusion of beauty and variety in the works of God.

A great number of other microscopic objects might have been described, had our limited space permitted, but we shall briefly mention only the following. By the microscope it has been discovered that there are scales on the human skin, so small that, according to the calculation of Leuwenhoek, 200 of them may be covered by a grain of sand. The perspirable matter is supposed to issue between these scales, which lie over the pores through which the watery humours exude. The pores of the skin are exceedingly numerous. If a slice of the upper skin be cut off with a sharp razor, as thin as possible, and a second slice from the same place be immediately applied to the microscope, innumerable pores will be perceived. M. Leuwenhoek supposes that there are 100 pores in a line one-tenth of an inch long. An inch will, therefore, contain 1,000 in a row, and a foot 12,000. According to this computation, a foot square must have in it 144 millions of pores; and if the superficies of a middle-sized man be 14 square feet, there will be in his skin 2,016 millions of pores. If the hand be well washed, and examined with a magnifying lens in the palm, or upon the ends or the first joints of the thumb and fingers, innumerable ridges, parallel to each other, will be found. On these ridges, pores may be perceived, lying in rows; and when viewed through a good glass, every pore seems a little fountain, with the perspiration standing in it as clear as water ; if wiped away, the perspiration will be found immediately to spring up again.

The threads with which a spider weaves its web are worthy of our attentive consideration, on account of their extreme fineness. M. Leuwenhoek, having dissected the body of the longest spider he could find, and nicely examined each part, at last discovered a vast number of instruments, as they may be termed, from which the spider draws threads of various fineness ; these thread vessels he judged to be at least 400, lying, not close together, but in several distinct clusters. Having laid a spider on its back, so that it could not stir, he pulled out, with a very fine pair of pincers, a thread that he perceived sticking out of one of the working instruments. At the same time he saw a great many other very fine threads issuing from the insect's trunk, which, at the distance of a hair's breadth or two from the body, were joined together, and made thick threads. Some of these filaments were so extremely fine as almost to elude his sight, though he made use of his most powerful glasses. Hence it appears that the threads of a spider's web, which to the naked eye seem to be single, do really consist of several plies, some of which are so exceedingly fine, that Leuwenhoek thought that 100 of them put together would not make one-hundredth part of the thickness of a hair of his head. Ten thousand, therefore, of the fine threads of a full-grown spider are not so thick as a human hair; and if we add to this, that 400 young spiders, when they first begin to spin, are not, one with another, bigger than a full-grown one, and yet that each of these spiders is provided with all the instruments of the old one, it will follow that the smallest thread of a young spider is 400 times smaller than that of a great one; and if so, then 4,000,000 of such threads are not so thick as the hair of a man's head, a fineness quite astonishing, and beyond our conception.

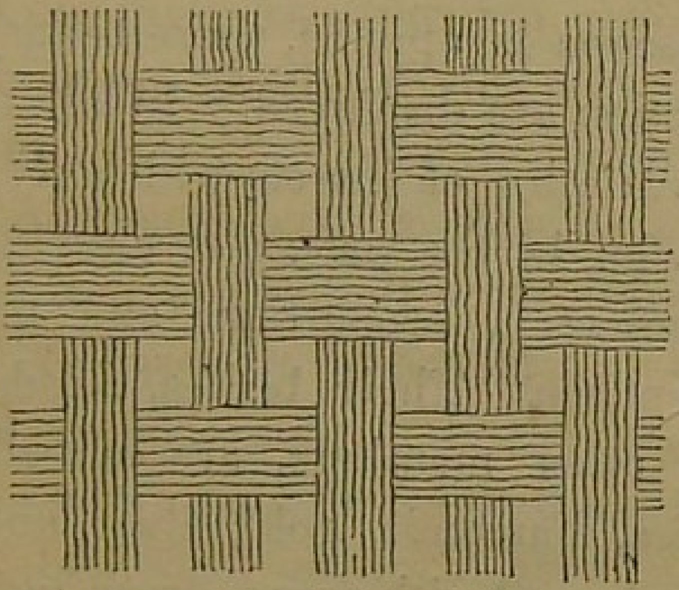
Test objects.—About the year 1826, Dr. Goring discovered that the structure of certain bodies could be readily seen by some microscopes, but not by others. These bodies he called *test* objects. In the course of his experiments, he was led to the conclusion that there were two distinct powers in a microscope, namely, *defining* and *penetrating*, and that an object glass might possess the one almost to perfection, and yet be totally devoid of the other, or might be perfect in both. At present, however, it is the opinion of the most celebrated opticians that the terms *definition* and *defining power* are the only expressions requisite to be employed to denote the good or bad qualities of any microscope. The test objects now generally employed for ascertaining the merits of any achromatic combination may be divided into three kinds, namely, hairs of animals, scales from the wings and bodies of insects, and the siliceous coatings of recent and fossil infusoria, those of the latter kind being the most difficult of all to define. The following list contains a few of the test objects to which allusion has been made :—

Hairs.—The *Bat.*—The hair which forms one of the test objects is obtained from the species of bat before mentioned inhabiting some parts of India. The principal parts of the hair that form a test of the defining power of a half-inch object glass, are the delicate points, or scale-like projections, that surround the upper edge of each whorl, which should be shown exceedingly sharp. In some of the species of English bats, the whorls are arranged in a spiral form. *Mouse hair.*—The hair of this little animal differs materially both in structure and in size from that of the bat. In some parts of the hair the internal structure is cellular, there being three or more cells in each row, the colour of the hair depending upon the greater or less amount of the black pigment contained in the cells. When viewed with a power of 100 or 200 diameters, all the light parts should be shown distinctly from the dark, and the line of separation of the two correctly defined. When viewed as an opaque object, this hair is very beautiful. *Hair of the dermestes.*—This very remarkable hair is obtained from the larva of a small beetle, commonly met with in bacon, hams, and other dried animal substances. It is covered over with brownish hairs, the longest specimens of which should be selected. When one of these is viewed with a magnifying power of 200 diameters, the upper part may be said to consist of a shaft and expanded extremity or head. The upper part of the shaft, near the head, is provided with several larger and more obtuse spines, forming a knob. This very beautiful hair now forms a good test of the defining power of a half-inch object glass. The hairs of the mole, the rabbit, and the squirrel, are also used as test objects.

Scales on the wings or bodies of insects.—*Hipparchia Janira*, the common meadow brown butterfly. The scales of this butterfly consist of longitudinal striæ, with a number of brown spots of irregular shape. When the magnifying power is increased to 1,200 diameters, the brown cells are made more evident.—*Pontia Brassica*, the common cabbage butterfly. This scale, like that of the former, is provided at its free extremity with a brush-like appendage. Its striæ are longitudinal, and with a power of 500 diameters, it appears to be composed of rows of little squares or beads.—*Scales of Podura*, the common spring tail. The body and legs of these tiny creatures are covered with scales of great delicacy. The surface of them appears covered with immense numbers of wedge-shaped dots, arranged so as to form both longitudinal and transverse wavy markings; when magnified 1,200 diameters, the scales are seen to stand out boldly from the surface; at the upper part of the scale, they also project beyond the edge. These insects abound in damp cellars, where they may be seen running or skipping on walls.—*Scales from a gnat's wing.* These, when magnified 500 diameters, exhibit very bold longitudinal bands or striæ, which project beyond the end in the form of spines. In the membrane between the longitudinal striæ there is sometimes an appearance like the watering in silk.—*Scale of Morpho Menelaus.* A scale of this splendid butterfly, when magnified 500 diameters, exhibits strongly marked longitudinal and very delicate transverse striæ, the former frequently bifurcating. A half-inch achromatic object glass should show them readily. Several other tests, besides those above enumerated, have been discovered by modern microscopes, which our confined limits prevent us from noticing.

Comparison of the works of nature and art.—There is nothing that more conspicuously displays the perfection of the works of God than a comparison of them with the finest works of art. The contrast between the one and the other is exceedingly striking, and humbling to the pride of man. His best performances, when examined by the microscope, appear coarse and shapeless; but the more closely and clearly we are enabled to inspect the works of God, the more apparent is their supreme excellence. This may be exemplified by a few illustrations. The point of an exceedingly small needle, highly polished, when viewed with a high magnifying power, appears neither round nor flat, but full of holes and scratches, and as broad and blunt as the end of a poker, and looks as if it had been hammered on the anvil. On the other hand, the sting of a bee or of a gnat, the proboscis of a butterfly or flea, appear, when examined by the microscope, to be formed with the most surprising beauty, and with exact regularity. The sting of a bee shows a polish without the least flaw, blemish, or inequality, and ends in a point too fine to be discerned; yet this is only the *sheath* of instruments still more refined. The adjoining figure represents a piece of exceedingly fine lawn, as it appeared through the microscope. From the great distances between its threads it looks like a lattice, and the threads themselves appear coarser than ropes. Compare this with any leaf of the forest, or grass of the field, under the same magnifying power, and a most striking contrast will be perceived.

The small dot or point, which is generally the mark of a full stop or period, when greatly magnified appears to be rough, jagged, and uneven all round its edges, and very far from being truly round. The smoothest and most exquisitely engraved lines and points, when examined by the microscope, seem like so many furrows and holes, or like daubings on a mat made with a blunt extinguished brand. On submitting to the microscope the edge of a very keen razor, it appears as broad as the back of a thick knife, rough, full of notches, and furrows, sharper in some places than others. Compare these works of human art with the operations of a puny insect, directed by instinct, or the wisdom and intelligence of its Creator, and the contrast appears most striking and admirable. A silkworm's web, examined by the microscope, appears perfectly smooth and shining, everywhere equal, and as much finer than any thread which the most dexterous spinner in the world can make, as the thinnest twine



is smaller than the thickest cable. The web woven by a spider is still more delicate. Every thread of it is many thousands of times smaller than a human hair. In short, every minute hair and fibre on a flea, a gnat, a fly, and other insects, is not only smooth and beautifully polished, but, when magnified thousands of times, appears as sharp at the point as a needle.

Thus sink the works of man when placed in comparison with the works of God. Wherever the microscope is applied, there beauty, order, and perfection are displayed. In all the innumerable varieties of insects which fly through the air, swim in the waters, or crawl along the earth, symmetry, proportion, and uniformity are perceptible. Their bodies, heads, wings, feet, and other members, are embellished as with rubies, diamonds, gold, silver, and pearls ; they are coloured with azure, green, yellow, red, and vermilion hues ; yet in all there is nothing gaudy or incongruous. How unutterable the Perfection of which these are the creations !

Method of using microscopes.—1. In applying the microscope to use, examine in the first place whether the glasses be clean ; if not, they must be carefully wiped with very soft leather, taking care not to soil them with the fingers, nor to place them in an oblique situation. 2. The object should be brought as near the centre of the field of view as possible, for there only it will be exhibited in perfection. In a compound microscope, the eye should be moved up and down till the situation is found where the largest field and the most distinct view of the object are to be had. 3. A small magnifying power should always be first used, by which means an observer will best obtain an exact idea of the connexion and situation of the whole. In general, it may be remarked, that there is no advantage in examining any object with a higher power than what shows it distinctly. A moderate power affords a greater light, and shows objects more clearly, than the highest powers, although sometimes these are required. 4. The eye should be protected from all extraneous light, and should not receive any but what is transmitted through or reflected from the object. 5. According to sir D. Brewster, the best position for microscopical observations is when the observer is lying horizontally on his back. This, he says, arises from the perfect stability of his head, and from the equality of the lubricating film of fluid which covers the cornea. The worst of all positions is that in which we look downwards, vertically. If we stand up and look horizontally, parallel markings or lines will be seen most perfectly when their direction is vertical, being the course in which the lubricating fluid descends over the cornea. 6. Every part of the view should be excluded except that which is under immediate observation. 7. In every case of microscopical observations, homogeneous yellow light, procured from a monochromatic lamp, should be employed. 8. In viewing opaque objects, an opportunity should be taken when the sun shines of making his rays strike upon the surface of the object. In this way we may view to advantage the body and the eye of a fly, the fibres of a peacock's feather, and similar objects. Or, a broad convex lens, about three inches focal distance, may be so placed as to throw the light of a lamp upon the object, the surface of which would then be distinctly visible. The best mode, however, of viewing opaque objects is by means of a contrivance called the Lieberkuhn, from the name of its inventor. This consists of a concave silver speculum, highly polished, in the centre of which is placed a magnifying lens. This speculum has a small hole in its centre, and may be applied immediately below the object glass of a compound microscope. For this purpose the speculum must be placed at the end of a small tube, to slip over the tube which holds the object glass. The light proceeding from the mirror falls upon the speculum, and is reflected perpendicularly on the upper surface of the object.

It seems almost trite and needless to say, that the discoveries which we have been considering, equally with those of the telescope, demonstrate the existence of GOD, and teach us lessons of confidence in him, by showing us that there is nothing too minute for his notice, or too humble for his care Why is it, then, we may inquire, that any should habitually live as if He could nowhere be seen in "the things that are made?" Why is it that He should be so little thought of, acknowledged, and adored, when his glory is reflected by every object in nature, from the blazing sun to the atom which floats in its beam—from the mountain to the flower which blooms beneath its shelter—and from "the great and wide sea" to that drop of water which is as an ocean to the numberless and invisible creatures which it contains? To these solemn questions we have a reply in the words of the great reformer, Luther: "HAD NOT MAN SINNED," said he, "how would he have recognised the glory of God in all his creatures, and have loved and exalted his holy name; so that in the smallest flower he would have acknowledged the Almighty power, wisdom, and goodness of God!" MAN HAS SINNED, and therefore it is that "God is not in all his thoughts."

It is sometimes said, as if it were a maxim not to be disputed, that "nature leads us up to nature's God." It is not true. MAN HAS SINNED, and he "will not seek after God," till he knows more than nature, with all its light, can teach him. He is surrounded, as we have seen in the preceding pages, by proofs of wisdom and power, infinitely surpassing the highest efforts of human intelligence and skill. This may be confessed. There may be admiration, and even gratitude, awakened by these displays of the Divine perfections, and yet there may be no knowledge of God. Such a recognition of him is better than atheism, better than indifference, better than absolute forgetfulness; and yet it is compatible with mournful ignorance of the *moral* perfections of God, and with the absence of all desire to retain him in the mind.

MAN HAS SINNED, and he needs the word of God to teach him how Divine holiness and justice may be harmonized with mercy in his pardon and restoration to happiness. He is conscious of estrangement and danger; and before he can know God in nature, so as to delight in him, he must know him in Christ as a Father "reconciling the world unto himself." Has the reader, then, we may appropriately ask, been thus reconciled? If not, then, "as though God did beseech you, by us: we pray you in Christ's stead, be ye reconciled to God. For he hath made him to be sin for us, who knew no sin; that we might be made the righteousness of God in him," 2 Cor. v. 19—21. The telescope and the microscope, whose revelations we have been considering, may be said to lend emphasis to this appeal. In the views which they open to us of the majesty of God, they proclaim his infinite power to bless those who love him, no less than his awful ability to punish such as obstinately reject the proclamation of his grace. How dreadful must it be to die at enmity with so great a Being!—how delightful to be his adopted child, through faith in Christ! Now, then, while it is the accepted time, may the reader, if he has not yet done so, close with the proffers of his pardoning love. Repent, and believe the gospel. "For God so loved the world, that he gave his only begotten Son, that whosoever believeth in him should not perish, but have everlasting life," John iii. 16.

THE RELIGIOUS TRACT SOCIETY: INSTITUTED 1799.