addressed to Dr. Jannetaz, Sécrétaire-général, rue des Grands Augustins, 7, Paris, France; and all moneys sent to Dr. Bioche, at the same address.

THE MODERN TELESCOPE

THE gain to astronomy from the discovery of the telescope has been twofold. We have first, the gain to physical astronomy from the magnification of objects, and secondly, the gain to astronomy of position from the magnification, so to speak, of *space*, which enables minute portions of it to be most accurately quantified.

Looking back, nothing is more curious in the history of astronomy than the rooted objection which Hevel and others showed to apply the telescope to the pointers and pinnules of the instruments used in their day; but doubtless we must look for the explanation of this not only in the accuracy to which observers had attained by the old method, but in the rude nature of the telescope itself in the early times, before the introduction of the micrometer; the modern accuracy has been arrived at step by step.

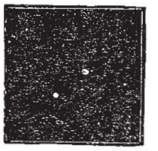

FIG. 1.—A portion of the constellation Gemini seen with the naked eye.

Let us see what the telescope does for us in the domain of that grand physical astronomy which deals with the number and appearances of the various bodies which people space.

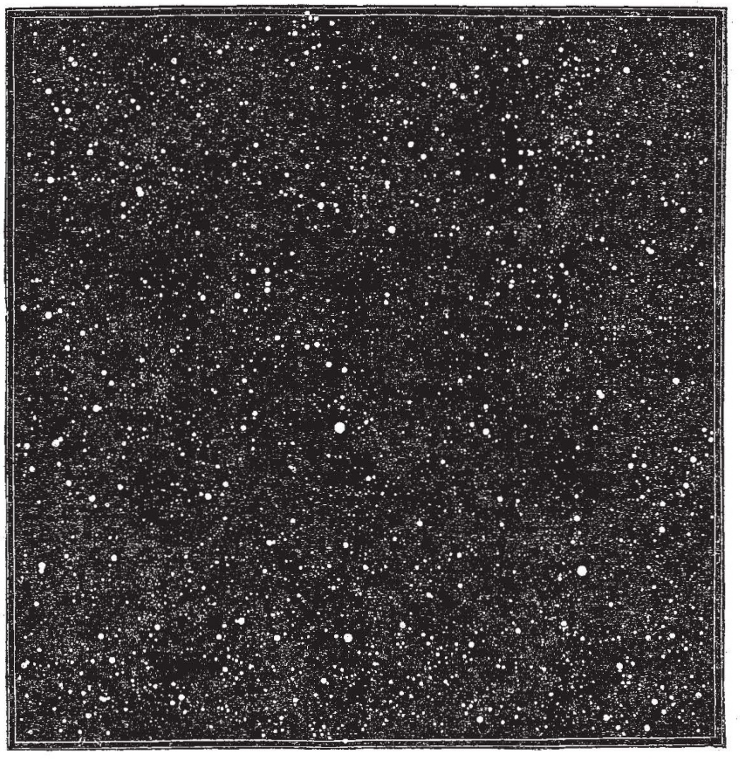

FIG. 2.—The same region, as seen through a large telescope.

Let us, to begin with, try to see how the telescope helps us in the matter of observations of the sun. The sun is about 90,000,000 of miles away; suppose, therefore, by means of a telescope reflecting or refracting, whichever we like, we use an eyepiece which will magnify say 900 times, we obviously bring the sun within 100,000 miles of us; that is to say, by means of this telescope, we can observe the sun with the naked eye as if it were within 100,000 miles of us. One may say, this is something, but not too much; it is only about half as far as the moon is from us. But when we recollect the enormous size of the sun, and that if the centre of the sun occupied the centre of our earth the circumference of the sun would extend considerably beyond the orbit of the moon, then one must acknowledge we have done something to bring the sun within half the distance of the moon. Suppose for looking at the moon we use on a telescope a power of 1,000, that is a power which magnifies 1,000 times, we shall bring the moon within 240 miles of us, and we shall be able to see the moon with a telescope of that magnifying power pretty much as if the moon were situated somewhere in Lancashire—Lancaster being about 240 miles from London.

It might appear at first sight possible in the case of all bodies to magnify the image formed by the object-glass to an unlimited extent by using a sufficiently powerful eyepiece. This, however, is not the case, for as an object is magnified it is spread over a larger portion of the retina than before; the brightness, therefore, becomes diminished as the area increases, and this takes place at a rate equal to the square of the increase in diameter. If, therefore, we require an object to be largely magnified we must produce an image sufficiently bright to bear such magnification; this means that we must use an object-glass or speculum of large diameter. Again, in observing a very faint object, such as a nebula or comet, we cannot, by decreasing the power of the eye-piece, increase the brightness to an unlimited extent, for as the power decreases, the focal length of the eye-piece also increases, and the eye-piece has to be larger, the emergent pencil is then larger than the pupil of the eye and consequently a portion of the rays of the cone from each point of the object is wasted.

We get an immense gain to physical astronomy by the

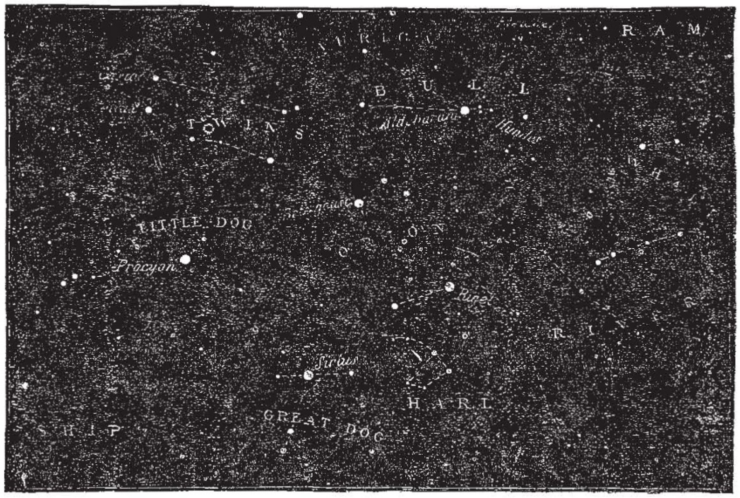

FIG. 3.—Orion and the neighbouring constellations.

revelations of the fainter objects which, without the telescope, would have remained invisible to us; but, as we know, as each large telescope has exceeded preceding ones in illuminating power, the former bounds of the visible creation have been gradually extended, though even now we cannot be said to have got beyond certain small limits, for there are others beyond the region which the most powerful telescope reveals to us; though we have got only into the surface we have increased the 3,000 or 6,000 stars visible to the naked eye to something like twenty millions. This space-penetrating power of the telescope, as it is called, depends on the principle that whenever the image formed on the retina is less than sufficient to appear of an appreciable size the light is apparently spread out by a purely physiological action until the image, say of a star, appears of an appreciable diameter, and the effect on the retina of such small points of light is simply proportionate to the amount of light received, whether the eye be assisted by the telescope or not; the stars always, except when sufficiently bright to form diffraction rings, appearing of the same size. It therefore happens that as the apertures of telescopes

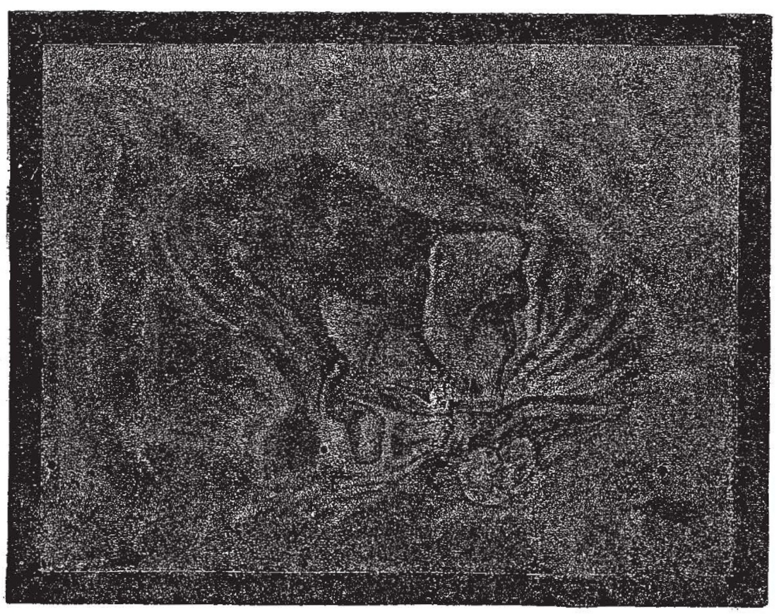

FIG. 4.—The Nebula of Orion, reduced from Lord Rosse's Drawing.

increase, and with them the amount of light (the eye-pieces being sufficiently powerful to cause all the light to enter the eye), smaller and smaller stars become visible, while the larger stars appear to get brighter and brighter without increasing in size, the image of the brightest star with the highest power, if we neglect rays and diffraction rings, being really much smaller than the apparent size due to physiological effects, and of this latter size every star must appear.

The accompanying woodcuts of a region in the constellation of Gemini as seen with the naked eye and with a powerful telescope will give a better idea than mere language can do of the effect of this so-called space-penetrating power.

With nebulæ and comets matters are different, for these, even with small telescopes and low powers, often occupy an appreciable space on the retina. On increasing the aperture we must also increase the power of the eye-piece, in order that the more divergent cones of light from each point of the image shall enter the pupil, and therefore increase the area on the retina, over which the increased amount of light, due to greater aperture, is spread; the brightness, therefore, is not increased, unless indeed we were at the first using an unnecessary high power. On the other hand, if we lengthen the focus of the object-glass and increase its aperture the divergence of the cones of light is not increased and the eye-piece need not be altered, but the image at the focus of the object-glass is increased in size by the increase of focal length, and the image on the retina also increases as in the last case. We may therefore conclude that no comet or nebula of appreciable diameter, as seen through a telescope having an eye-piece of just such a focal length as to admit all the rays to the eye, can be made brighter by any increase of power, although it may easily be made to appear larger.

Very beautiful drawings of the nebula of Orion and of other nebulæ, as seen by Lord Rosse in his 6-foot reflector, and by the American astronomers with their 26-inch refractor, have been given to the world.

The magnificent nebula of Orion is scarcely visible to the naked eye; one can just see it glimmering on a fine night; but when a powerful telescope is used it is by far the most glorious object of its class in the northern hemisphere, and surpassed only by that surrounding the variable star η Argûs in the southern. And although, of course, the beauty and vastness of this stupendous and remote object increase with the increased power of the instrument brought to bear upon it, a large aperture is not needed to render it a most impressive and awe-inspiring object to the beholder. In an ordinary 5-foot achromatic many of its details are to be seen under favourable atmospheric conditions.

Those who are desirous of studying its appearance, as seen in the most powerful telescopes, are referred to the plate in Sir John Herschel's "Results of Astronomical Observations at the Cape of Good Hope," in which all its features are admirably delineated, and the positions of 150 stars which surround θ in the area occupied by the nebula laid down. In Fig. 4 it is represented in great detail, as seen with the included small stars, all of which have been mapped with reference to their positions and brightness. This, then, comes from that power of the telescope which simply makes it a sort of large eye. We may measure the illuminating power of the telescope by a reference to the size of our own eye. If one takes the pupil of an ordinary eye to be something like the fifth of an inch in diameter, which in some cases is an extreme estimate we shall find that its area would be roughly about one-thirtieth part of an inch. If we take Lord Rosse's speculum of six feet in diameter the area will be something like 4,000 inches; and if we multiply the two together we shall find, if we lose no light, we should get 120,000 times more light from Lord Rosse's telescope than we do from our unaided eye, everything supposed perfect.

Let us consider for a moment what this means; let us take a case in point. Suppose that owing to imperfections in reflection and other matters two-thirds of the light is lost so that the eye receives 40,000 times the amount given by the unaided vision, then a sixth magnitude star—a star just visible to the naked eye—would have 40,000 times more light, and it might be removed to a distance 200 times as great as it at present is and still be visible in the field of the telescope just as it at present is to the unaided eye. Can we judge how far off the stars are that are only just visible with Lord Rosse's instrument? Light travels at the rate of 185,000 miles a second, and from the nearest star it takes some $3\frac{1}{2}$ years for light to reach us, and we shall be within bounds when we say that it will take light 300 years to reach us from many a sixth magnitude star.

But we may remove this star 200 times further away and yet see it with the telescope, so that we can probably see stars so far off that light takes 60,000 years to reach us, and when we gaze at the heavens at night we are viewing the stars not as they are at that moment, but as they were years or even hundreds of years ago, and when we call to our assistance the telescope the years become thousands and tens of thousands—expressed in miles these distances become too great for the imagination to grasp; yet we actually look into this vast abyss of space and see the laws of gravitation holding good there, and calculate the orbit of one star about another.

J. NORMAN LOCKYER

(To be continued.)

ZOOLOGICAL GARDENS [1]

THE lists and reports of the various zoological gardens now before us show that much progress has lately been made by these as by other institutions connected with natural history. For though zoological gardens are looked upon by many as a simple form of amusement there can be no question that, when rightly conducted, they are not only instructive in the highest degree, but also tend materially to advance the interests of the higher branches of natural science. All persons, therefore, who take an interest in the progress of science will be glad to see the number of zoological gardens increasing among the dependencies of this country and in other States.

Of the first of the five works on our list we need say but little. The Gardens of the Zoological Society of London, in the Regent's Park, are too well known to most of our readers to require a lengthened notice. The chief additions to their unrivalled menagerie are recorded every week in our columns. The volume now before us contains a catalogue of all the species of vertebrated animals, of which examples have been exhibited during the past fifteen years, arranged in systematic order. The various specimens are distinguished by letters, and the date and mode of acquisition of each individual are added. Thirty-five woodcuts, most of which have originally appeared in the Society's *Proceedings*, illustrate some of the more remarkable forms. The result shows that from the commencement of the year 1861 to the close of 1875, there have been obtained for the collection in the Regent's Park, examples of no less than 2,143 species of vertebrated animals. Of these 570 were mammals, 1,224 birds, 227 reptiles, 39 batrachians, and 83 fishes.

The catalogue of the animals in the newly-established Zoological Gardens at Calcutta, concerning the foundation and progress of which we have written at full length not long since,[2] is next upon our list. It is drawn up after

[1] (1) List of Vertebrated Animals now or lately living in the Gardens of the Zoological Society of London. Sixth Edition. 1877. (London: Longmans).
(2) List of Vertebrated Animals living in the Zoological Gardens, Calcutta, April, 1877. Printed at the Bengal Secretarial Press. 1877. 8vo.
(3) A Guide to the People's Park, Madras, with a description of the Zoological Collection contained therein. (Madras: Higginbotham and Co., 1876.)
(4) The Fifth Annual Report of the Board of Directors of the Zoological Society of Philadelphia. Read at the Annual Meeting of the Members and Loanholders of the Society, April 26, 1877. 8vo. (Philadelphia, 1877.)
(5) Report of the Director of the Central Park Menagerie, Department of Public Parks, City of New York, for year 1876. (New York, 1877: B. M. Lees, Printer, 210, Fulton Street.)

[2] NATURE, vol. xvi. p. 28.