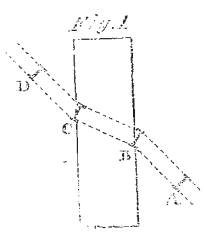
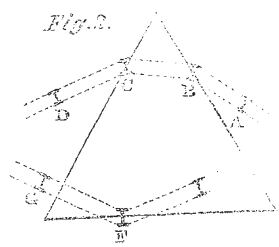
College of Science, and similar institutions in other districts, all who are in any way connected with our arts and manufactures may be trained to work on a method so really scientific that Britain shall in this, as she certainly is in some other respects, be foremost among the nations.

REFRACTION OF LIGHT MECHANICALLY ILLUSTRATED

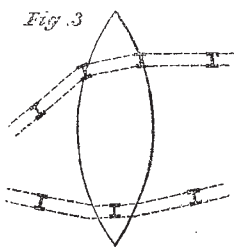
IN preparing an elementary lecture on Light, intended to be given at the Taunton College School, I have had to consider how best to explain the somewhat abstruse principle of optical refraction. It is true that Sir John Herschel, in the sixth of his "Familiar Lectures on Scientific Subjects," giving the explanation of refraction on the undulatory theory, describes it as being "exceedingly simple." The fact is, however, that it involves conceptions of wave-motion, difficult for any but advanced students, and even they feel grateful to the eminent physicist for the help afforded by a familiar illustration with which he follows it. He desires his readers to imagine a line of soldiers marching across a tract of country divided at a straight boundary into two regions, the one level ground suited for marching, the other rough and difficult to walk over. Now if the line of soldiers march with their line of front oblique to the boundary, the men on the side just engaged in the heavy ground

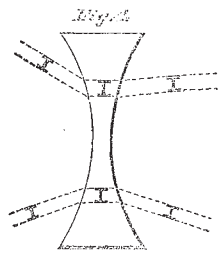




will be retarded as soon as they cross into it, so that if the line be kept unbroken, the consequence must be a change of front, which will leave the whole body of men marching across the heavy ground in a new direction—in a word, their direction of march will have been refracted. Now the light-waves emitted from a radiant point being compared to the circles spreading from a stone thrown into a pond, it is easily understood how a sensibly straight portion of such a light-wave, passing obliquely from one medium to another of different resistance, will be refracted in a new direction. This simple conception of change of front is at once apprehended by the learner, to whom refraction thenceforth ceases to be a molecular mystery, and becomes an intelligible mechanical act dependent on the resistance of the two media and the form of their limiting surface. Probably no point in all Herschel's lectures has fixed itself in the memory of so many intelligent readers.

In following up the train of thought started by Sir John Herschel's comparison, it occurred to me that an instrument made to perform refraction mechanically would be useful in teaching optics, and that such a contrivance would only require a pair of wheels running on a table, into and out of a resisting medium. After a number of trials, made with the help of Mr. R. Knight, a simple arrangement has been completed, which answers satisfactorily in showing the behaviour of a ray of light under the various circumstances of ordinary refraction. Pieces of a thick-piled velvety plush known as "imitation sealskin" are cut out to represent the sections of a thick plate, a prism, a convex and a concave lens, and glued on to smooth boards. The runner consists of a pair of boxwood wheels mounted loosely on a stout iron axle, and is trundled across the board, or still better, the board itself

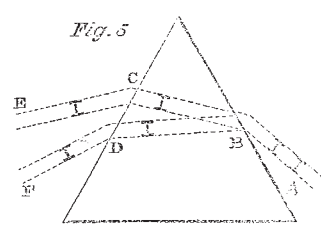




is tilted up, and the runner let go in the proper starting direction. The following figures show the path of the wheels, always from right to left of the page.

In Fig. 1, the runner starting from A, enters the rectangle of velvet at B, where its left wheel being first retarded, it shifts round into the direction BC, till it reaches C, where the left wheel first emerging gains on the right, so as to bring back the runner to the ultimate direction CD. This illustrates the refraction of a ray of light in entering and quitting parallel plane surfaces of a resisting medium, such as a plate of glass. When the runner enters at right angles to the boundary, its direction is of course unchanged, as with the ray of light.

Fig. 2 shows the path ABCD of the runner across a triangle, corresponding with the course of a ray traversing a prism. Also, by causing the runner to enter at about a right angle near E, a direction is given to it which, if the surface of the board and the triangle were similar as to resistance, would make it emerge near F, at a small angle



to the side. But the left wheel passing on to the smooth surface gains so much on the right wheel still in the velvet, that the axle slews round, the left wheel re-enters th velvet, and the runner goes off in the direction FG, thus illustrating the total reflexion which takes place when a ray of light is directed to emerge very obliquely from a more into a less resisting medium, as from a glass prism or a surface of water into air.

The action of the double-convex lens in causing parallel or divergent rays to converge is shown by the path of the runner in Fig. 3, which requires no further explanation, nor does that corresponding to the divergent action of the double-concave lens, Fig. 4. By starting two runners

at once from the right-hand side of the board, so as to traverse the upper and lower parts of the convex lens, they are made to run into one another, thus illustrating the meeting of rays in a focus.

Lastly, by using two runners with wheels of different diameters, as the refraction depends on the resistance to the wheels by the velvet, the apparatus may be so inclined as to show plainly their consequent difference of refractive angles. The courses of the two are seen in Fig. 5. This experiment, however, requires some nicety of arrangement

Now the separation of rays of different refrangibilities by a prism being due to a like cause, this experiment serves to illustrate mechanically the decomposition of white light. Let the large-wheeled runner represent the red ray, and the small-wheeled runner the violet ray, the principle of the prismatic spectrum becomes at once evident.

For the information of any who may wish to reproduce this simple apparatus, I may state the dimensions I have found convenient. The wheels may be 1¾ in. and 2 in., with rounded edges, mounted on a nearly half-inch iron axle, turned down to ⅜ in. at the ends. The boards may be 2 ft. 6 in. by 1 ft. 6 in., with velvet on each side. It is convenient to place the velvet nearer to one end of the board to leave room at the other for starting the runner; and care must be taken to cut the velvet so as to present a good resisting surface, as this varies with the direction of the pile. In using the apparatus for teaching, care in manipulation is required to neutralise the defects of the texture. Some kinds of "Utrecht velvet," to be had from the upholsterers, are more uniform than the "imitation seal-skin," and thus work more equally, but their effect is not so striking. Wet sand will answer equally well with the velvet, if metal wheels be used.

EDWARD B. TYLOR

THE FRESHWATER FISH OF INDIA AND BURMAH

Report on the Freshwater Fish and Fisheries of India and Burmah. By Surgeon-Major Francis Day, F.L.S. and F.Z.S., Inspector-General of Fisheries in India. 8vo. (Calcutta, 1873.)

IN the introductory part the author states that the present report is the result of investigations commenced by him in the year 1868, into whether a wasteful destruction of the freshwater fisheries is or is not occurring in India and Burmah. He comes to the conclusion that a wasteful destruction of fish is going on to a very great extent, that these fisheries are more and more deteriorating, and that immediate legislation is called for, to prevent the entire failure of a most important article of food.

The steps taken by the Inspector-General to ascertain the facts on which he bases his report were twofold. He personally inspected districts of various parts of the Indian Empire, and supplemented his own observations by collecting the opinions of European and Native officials, to whom he addressed a series of questions bearing upon the subject. Accordingly the book before us is divided into two parts :—(1) The report proper, pp. 1-118; and (2) A *résumé* of the answers returned, with marginal notes by the reporter, pp. i.-ccxxxvi. An article on "Fish as Food, or the reputed Origin of Disease," an Enumeration of the Indian freshwater fishes, and Notes on preserving specimens of fish, conclude the volume.

Europeans who have formed favourable ideas respecting Indian rivers and their abundance of fishes from the accounts which so frequently enliven the sporting papers of the day, will find them rudely dispelled by this report. It is true that not a few of the resident officials deny the decrease of fishes, and deprecate legislative interference altogether. Thus, for instance, the Commissioner of the Agra Division writes that there is no reason to apprehend that any wholesale destruction of fish goes on in these parts. A close-time might no doubt be introduced by law for the protection of fish during the breeding season, but it does not appear to him that it would be easy to carry out such a measure, or that there is any compensating object to be gained; that "it is a useful maxim—*de minimis non curat lex*—minute legislation is unbefitting our position in this country, and more likely to expose our Government to ridicule than to any results of important benefits to the people;" "it is in the highest degree undesirable that the public mind should be disturbed by gratuitous interference on the part of an alien administration, enforced by not very trustworthy agency." On the other hand, the Inspector adduces such incontrovertible evidence in favour of the conclusion he has arrived at, that we can but agree with him that in numerous districts the freshwater fisheries are in danger of being utterly destroyed, and this must appear to call for speedy interference by the Government all the more, as those districts are among the most populous, in which this article of food can be least spared.

Naturally one looks first for the causes by which the Indian fisheries are said to have been thus reduced; and it is not very flattering to be told by the author that this disastrous effect has been caused by the change from the Native to the British rule. He states that, under the former rule, fisheries formed royalties mostly let out to contractors, who alone in the district possessed the right to sell fish, and that they permitted the people, on payment, to capture fish for their own consumption; that the men who followed the occupation of fishing formed distinct crafts or castes, exercising their calling with certain restrictions and regulations. Under British rule the renting system was abolished; with the most philanthropic intentions, the British gave to the people liberty to fish when and where they pleased; where everybody could fish, fishing ceased to be a distinct calling; breedingfish were captured without regard to season; and when the supply of larger fish commenced to fail, it became the practice to catch undersized fish and fry. Add to this, that a number of irrigation weirs and dams were erected, preventing the fish from resorting to suitable spawning-beds, that fixed engines for the capture of fish are now used, where previously they were never permitted, and the natural result is the lamentable state as represented by the Inspector.

We need not enter at present into the remedial measures provisionally proposed by Mr. Day. His proposals, as well as the opinions of his opponents, will no doubt find due consideration on the part of the Indian Government. But I will not conclude this notice, without