

IN A RECENT NUMBER of *The Forum*, Mr. Lester F. Ward has an article on 'What shall the Public Schools Teach?' In this article Mr. Ward maintains that in refining upon the blessings of education we forget altogether what knowledge is for. His definition of civilization being that it consists in 'the utilization of the materials and forces of nature,' he holds that so far as the improvement of man's estate is concerned we know only in order to do, that knowledge unapplied is sterile, and is only fruitful when it makes two blades of grass grow where only one grew before, when it converts 'raw material' into useful objects, or when it directs into some useful channel the forces of nature which were previously running to waste or doing injury to man. Mr. Ward believes that nowadays all inventions are in the nature of 'improvements' upon pre-existing inventions, and are chiefly made by the mechanics or artisans of the higher grades, who are constantly using the original devices, and who, through an intimate acquaintance with these, eventually perceive how they may be improved; that as artisans become more intelligent this class of inventions will increase, and that nothing but the stolid ignorance of the working-classes in the past has prevented this from having always been the chief mode of advancing the useful arts; and the hope is expressed that in the near future the artisan as well as the engineer may not only receive a good education in the hitherto accepted sense of the term, but may also have such a training of the eye and the hand as will enable him to perceive and to effect all possible reforms in his chosen field of labor. Everywhere we see the lack of thought directed to the improvement of our material surroundings. If this is because the importance of improving those surroundings forms no part of the education which is given to the youth of the country, there is reason to believe that any system of education which will tend to develop the human powers of dealing with materials and forces will tend to raise the plane of civilization as defined. Mr. Ward even looks forward to the day when the need for the use of the human animal for the lowest forms of unthinking labor will be done away with, which would simply mean that there would be less opportunity for life among those of low intelligence, and that the 'average man' would be on a higher plane than at present.

This tendency to educate youth so that man may be the better able to deal with his material surroundings is doubtless wise, but brings forth a remonstrance occasionally from those versed in the old ways, who hasten to point out the other sides to a man's nature which come in contact with other conditions which he should be equally ready to contend with, or perhaps better to appreciate. The recently published life of the most illustrious and most amiable man of science of this scientific age has suggested to many readers doubts of the all-sufficiency of science to build up, not theories, but men. Mr. Darwin's admirably candid avowal of the gradual extinction in his mind of the æsthetic and religious elements has proved startling to a generation which, even when it is ready to abandon religion, would be direfully distressed to lose the pleasures afforded by art and nature, poetry and music. Instead of lifting the scientific vocation to the skies (as was probably anticipated), this epoch-making biography seems to Miss Frances Power Cobbe, writing of 'The Scientific Spirit of the Age,' in the *Contemporary Review*, to have gone far "to throw a sort of dam across the stream, and to have arrested not a few science-worshippers with the query," as Darwin wrote: "What shall it profit a man if he find the origin of species and know exactly how earth-worms and sun-dews conduct themselves, if all the while he grow blind to the loveliness of nature, deaf to music, insensible to poetry, and as unable to lift his soul to the divine and eternal as were the primeval apes from whom he has descended? Is this all that science can do for her devotee? Must he be shorn of the glory of humanity when he is ordained her priest? Does he find his loftiest faculties atrophied when he has become a 'machine for grinding general laws out of large collections of facts'?"

THE COAST AND GEODETIC SURVEY EXHIBIT AT CINCINNATI.

THE exhibit of the United States Coast and Geodetic Survey at the Cincinnati Exposition shows the principal instruments used in the geodetic, astronomical, topographical, hydrographic, and magnetic work of the Survey, with illustrations of the results of their use, as shown by a series of the annual reports, a number of the principal charts published, a collection of the more important scientific papers or works printed by the Survey, a model of an observing tripod as used in geodetic work, and models showing the basins of the Gulf of Mexico and of the western Atlantic, or 'Bay of North America,' constructed from the data furnished by the elaborate hydrographic surveys of those waters. The collection further includes an exhibit from the United States Bureau of Weights and Measures, which is under the care and direction of the Superintendent of the Coast and Geodetic Survey.

The Exposition occurs at a period of the year when many of the best instruments of the Survey, containing the latest improvements in their several departments of use, are in the hands of field parties and cannot be exhibited. To aid those interested in the exhibit, a pamphlet has been issued by the Survey explaining the instruments shown and their uses.

The great end and chief object of the Survey is, and has been, for a period of half a century, to furnish good and reliable charts of the coasts of the United States, and of its harbors and navigable rivers. These require in their construction a combination of skilful labor, differing greatly in means, appliances, and methods.

First in order is the reconnaissance and triangulation. Next comes the topographical survey of all that portion of the earth's surface which lies above the water. It includes all accidents of ground, all natural or artificial developments of surface, and every thing useful for purposes of commerce or defence.

Third in the chronological order of conducting a survey, but equal in its usefulness, is the development upon the chart of all that portion of the earth's surface which lies beneath the water. This important work is carried on by officers and enlisted men of the navy of the United States. There are 67 officers and 280 petty officers and seamen now engaged upon this duty. The instruments used in the work are only partly shown.

Although one of the minor branches of the operations of the Survey, the study and the application of the results of terrestrial magnetism from a practical point of view are of great importance, not only to the surveyor, but also to the mariner, to whom they are indeed indispensable.

This will be readily understood by simply referring to the extended use surveyors have made of the magnetic needle for the demarcation of land and the consequent frequent necessity of re-tracing old lines so laid out and recorded.

With reference to the use of the compass at sea, the charts of the Survey require the impress of the compass, they record the variation of the needle, and state the annual change so as to render the sailing directions applicable for other years than that of the issue of the chart. With reference to the adjustment of the compass on board ship, and the construction of deviation tables to answer for different directions, inclinations, and positions of the ship, a knowledge of the magnetic dip and the intensity is demanded. The labors of the Survey and their results may best be shown by a short historical review.

In the early years of the Survey under its first superintendent, the magnetic declination (the scientific term equivalent to the mariner's 'variation') was supplied to the charts as found by the ordinary nautical instrumental means then in vogue. In the Transactions of the American Philosophical Society (Philadelphia, 1825), he proposed to measure relative magnetic intensity by means of oscillations of a needle. The magnetic work of the Survey, however, may be said to have commenced in its three-fold aspects, the declination, the dip, and the intensity, with his successor in office in 1843. Professor Bache had previously made a magnetic survey of Pennsylvania, which, although a scanty beginning, was not followed until in quite recent years by the magnetic survey of Missouri. He imported new instruments suitable for more refined measures of the declination than could be secured by the older in-

struments, and at the same time capable of exact determinations of the intensity in absolute measure; he also procured dip circles, and availing himself of the additional temporary aid of Dr. Locke of Cincinnati and of Professor Renwick of Columbia College, the observational work was fairly started, and has since been prosecuted uninterruptedly by various assistants of the Survey. In consequence of the dual or polar character of the magnetic force, it resisted for a long time all attempts of measure expressible in the usual units, but in 1833 Gauss showed how this could be done, and after the invention, in 1836, of the portable magnetometer his method for the absolute measure of magnetic intensity came into general use.

Those who are acquainted with magnetic observations, which also include certain astronomical operations, know the delicacy and refinement of its operations when great accuracy is demanded, and it should also be remembered that in those early days of the development of practical methods there were none of those facilities we now possess in the number of trained observers, in the home manufacture of instruments, and in the many treatises for instruction now at hand. Apace with the field work the office work of computation and discussion was prosecuted, and the results were published from time to time in the annual reports.

At first the observations were confined to the vicinity of the sea-coast, but it was soon found that the charts could not satisfactorily be supplied with the values for the variation of the compass unless the observations were extended sufficiently inland to give proper direction to the magnetic lines, or isogonics as they are called, which curves determine the angular difference between the astronomical and magnetic meridian for a certain epoch. Meanwhile, surveyors from all parts of the country applied for information, not only for the present value of the declination, but what was far more difficult to answer, for the value at some earlier period. To satisfy this inquiry, and to provide for a better knowledge of the annual change of the declination needed for the charts, a more systematic general collection of all magnetic observations taken within the limits of the United States from the earliest to the present time was undertaken, and has been kept up since 1878, at which time the field of activity of the Survey was enlarged by the change of Coast into Coast and Geodetic Survey. This collection arranged by States and Territories now comprises several thousand observations of declination, dip, and relative and total intensities, and together with the direct survey work, which in July last comprised 731 stations (many of them occupied several times at definite intervals), constitutes the material from which most of the deductions were derived, and which mark the advancement of our knowledge in this department of research contributed by the Survey.

The first permanent magnetic observatories in North America were established at Toronto by the British Government about 1840 (which observatory is still in operation under the auspices of the Canadian Government), and about the same time at Philadelphia, 1840-45, at Girard College. The latter was directed by Professor Bache, who, after taking charge of the Coast Survey, took advantage of the newly invented application of photography to automatic registration, procured one of Brooke's magnetographs, and caused it to be set up and to record continuously the variations of the declination and of the horizontal and vertical intensities at Key West, Fla., between 1860 and 1866. After the lapse of half a sun spot cycle, which is the minimum duration for which it is profitable to keep up continuous observation at any one place, the instruments were transported to Madison, Wis., where between 1876 and 1880 a second series of observations was procured. When the support and co-operation of the Survey was asked for the two international expeditions fitted out by the United States for polar research, the needed magnetic instruments, both absolute and differential, so far as the Survey could supply them, were furnished and the observers were trained during the short time permitting.

The magnetic records of the second year (1882-83) at Point Barrow, Alaska, by the party in charge of Lieutenant Ray, were made by the Brooke magnetometers, which had in the mean time been altered for direct or eye-observations.

A superior self-recording magnetic apparatus, known as the Adie magnetograph, after the Kew pattern, and likewise working by means of photography, arrived here during the late war, but for

want of funds was not set up until 1882. This superior instrument was located at Los Angeles, Cal., and continues to give excellent results. It is intended to terminate this series towards the beginning of the next year, and then remount the instrument, either in Washington Territory near Puget Sound, or in southern Texas, in order to cover as much as possible of the space for which, heretofore, our knowledge of the laws of terrestrial magnetism was most incomplete.

The first isogonic chart published by the Survey, entitled 'Lines of Equal Magnetic Declination,' will be found in the annual report for 1855, the last one in three sheets appeared in the annual report for 1882: a comparison between these charts will show in the most conspicuous manner the progress made in our knowledge in this direction during the interval. The index to scientific papers in the annual report for 1881 under the heading of 'Terrestrial Magnetism,' enumerates no less than sixty-six titles up to the close of 1880; this will give some idea of the activity of the Survey in this department. Several important investigations have appeared in the later annual reports; in the report for 1882 we have an appendix discussing the distribution of the magnetic declination in the United States for the year 1885; the results are based on observations at more than 2,300 stations. In the report for 1885 we have an investigation of the magnetic dip and intensity, with their secular variations and their geographical distribution in the United States. This appendix, 145 quarto pages, involved much labor for its preparation: it is accompanied by three finely executed charts, besides the illustrations in the text, and discusses no less than 2,000 dip observations and more than 1,500 observations for intensity. The results for secular change of dip and intensity are new. In the report for 1886 (not yet issued) we have in type the sixth edition of an investigation much sought after, namely, 'The Secular Variation of the Magnetic Declination in the United States and at some Foreign Stations.' From a small beginning in 1859 this paper has grown to be a complete depository of magnetic results available for the study of the secular change within our territory, and the author discusses most thoroughly the laws governing this mysterious movement, the cause of which is as yet entirely unknown, though in its nature it must be cosmical, since we cannot think of any adequate cause within the earth to produce, so far as we can judge, with the utmost regularity, the observed angular motion of the needle during centuries.

The deductions rest on 1,071 observations made at ninety-four stations. The earliest observations on our western coast date from the sixteenth century (Sir Francis Drake), the earliest records on the eastern coast dating from the beginning of the next century (Hudson and Champlain). In this branch of research the Survey profited by the use of the valuable collection of declinations and dips, the earliest on record, made by Prof. E. Loomis (now of Yale College), who published them in *Silliman's Journal* in 1838 and 1840, and without which our results would not possess the degree of reliability they now have. In this sixth edition, which spreads over 116 quarto pages, we have minute references to observations, together with their critical examination. The resulting secular change, illustrated by several diagrams, is expressed analytically and is also given in tabular form. The laws which so far appeared to govern this motion are stated, and embrace the whole of the area of the United States (inclusive of Alaska), and are given sufficient expansion to facilitate their connection with similar relations referring to Europe, South America, and eastern Asia.

The magnetic records brought home by the polar expeditions in command of Lieutenants Ray and Greely were placed in care of the Coast and Geodetic Survey: this material was subjected to computation and discussion, and arranged for the press. The Point Barrow work (1881-83) forms part VI. of the official publication of Lieutenant Ray's expedition (published in 1885), and the work done at Fort Conger (1881-83) under Lieutenant Greely will form Appendix No. 139 of Vol. II. of the official publication now passing through the press.

The reduction, analysis, and discussion of the automatically registered material at the magnetic observatories still await sufficient computing force to bring out the many laws and complex relations due to the ceaseless changes of the magnetic force.

The annual expenditure on account of terrestrial magnetism is

small, being only about one two-hundredth part of the whole appropriation for the Survey.

Another of the subordinate branches of the Coast Survey work is the determination of the earth's density. The pendulum, being an instrument which will swing faster or slower according as the force of gravity is stronger or weaker, can be employed to measure this force. All forms of pendulums will determine variations of gravity, but different shapes are given it, depending upon the particular object in view. That approaching nearest the ideal mathematical pendulum would be a heavy ball suspended by a fine string. This form was used by Borda, and a modification of it by Bessel consisted of swinging the ball with strings of different lengths. Kater employed a form known as the invariable one,—meaning by the term 'invariable' that none of the parts of the pendulum are interchangeable, and that the instrument remains identical for experiments made at different stations. Kater's pattern is generally preferred when the object is simply a determination of the differences of the force of gravity for different places. The reversible pendulum is one having two points of suspension, which are so placed that the times of oscillation are equal, or nearly so, whether the instrument is hung in the direct or reversed position. This form is used when the object is the determination of the actual force of gravity, or in other words, how far a body will actually fall towards the earth in a given time. As the distance between the two points of suspension is equal to the length of a simple pendulum which would oscillate in the same time, the determination of the force of gravity by this method becomes a comparatively simple matter as far as theory and principle are concerned. In the practical execution of the work there are difficulties that make it one of the highest precision, and at the same time one demanding the greatest care and attention to details.

In all pendulum experiments for the determination of gravity, whether relative or absolute, it is evident that the pendulum must swing under precisely the same circumstances, or the observations must be reduced to what they would have been had they been made under the same circumstances. The principal influences bearing on the duration of an oscillation, and those which vary most from one station to another, are the changes in the rate of the time-keeper, those resulting from differences in amplitude of the oscillations, and those dependent on the temperature of the pendulum and the pressure of the surrounding atmosphere.

The first two are readily disposed of, as one is independent of the pendulum and the other is a question of simple geometrical relations. The influence of the temperature may be determined either by swinging in great ranges of temperature and noting the changes in the period of oscillation for the two conditions, or by measuring the increase of length of the pendulum for a given increase of temperature and resorting to computation for the effect of this increase of length on the time of an oscillation. The pressure correction, or at least as much of it as is dependent on the buoyancy of the atmosphere, may likewise have two independent determinations. A part of this correction comes from the influence of the air that is set in motion, and depends on its viscosity. But the whole atmospheric effect may be eliminated from the length obtained for the seconds pendulum by using a reversible pendulum whose external form is symmetrical with reference to the centre of figure. The Coast and Geodetic Survey pendulums devised by Assistant C. S. Peirce are so made. Two different lengths are also used, one yard and several metre pendulums having been made at the Coast Survey Office in 1881. These instruments have been swung in many parts of the United States, from Boston in the east to San Francisco in the west, and from Albany in the north to Key West in the south. Besides these experiments, which were nearly all made near the sea-level, comparatively speaking, many determinations have been made at higher elevations in order to study the effect of distance from the earth's centre, and the attractions of mountains and table lands lying between the station and the sea-level.

In order to connect our series of pendulum observations with similar work done in Europe and other parts of the world, several of the principal pendulum stations in Europe were occupied with a Repsold reversible pendulum, and the same was swung also at some home stations. Also the Kater invariable pendulums,

brought to this country by Captain Herschel, and which had been swung in different parts of the world, were swung at several of our stations as well as in New Zealand, Australia, the Malayan Peninsula, and Japan. The Coast and Geodetic Survey has thus secured an intimate connection with pendulum research the world over.

Outside our own country the Peirce pendulums have been sent to Lady Franklin Bay with the Greely expedition in 1882, to the South Pacific Ocean with the solar eclipse expedition of 1883, and to the Hawaiian Islands at the request of their government in 1887. In this last voyage both a yard and metre pendulum were swung at an elevation of ten thousand feet, and also at two stations at the sea-level. All this foreign work was done either by an officer of the Survey or by a trained observer following the most approved home methods.

The swaying of the stand on which the pendulum rests necessitates another correction to the time of oscillation in the case of absolute determinations. This source of error has been investigated mathematically by Professor Peirce. The English have used a small inverted pendulum attached to the stand for determining this correction.

The determination of the figure of the earth is one of the objects of pendulum observations. The force with which bodies attract each other depends on the quantity of matter in them and their distance apart. Places on the earth, therefore, which have an excess of matter, either from the material being of greater volume, or of greater density, will show a corresponding increase of the force of gravity; and places near the pole, from their being nearer the centre of the earth, would be expected to show a variation in the force of gravity in the same direction. Hence gravity determinations made at different points, starting from the equator and going towards the poles, will show the relative distances from the centre, and from this, with the aid of Clairaut's theorem, the shape of the earth. This would give a general figure for the sphere. Besides this, the pendulum will determine irregularities in this figure. In general, the result of pendulum observations thus far seems to indicate that gravity is in excess at island stations and coast-lines, and in defect on mountain tops; but this last may be partially due to the sea-level being raised in the neighborhood of continents by the attraction of the land, and the former is certainly influenced by the attraction of the surrounding sea-water. At any rate mountain observations point towards the conclusion that there may be either immense subterranean caverns beneath, or that the mass may be composed of lighter material than the earth's crust generally; and it may likewise be inferred that the stratum forming the bottom of the ocean is composed of comparatively heavy matter.

There are shown in this exhibit two reversible pendulums which have been used in the observations above described. One is a Peirce reversible metre pendulum swung in the heavy wooden frame devised for it by Professor Peirce, who has found it necessary to discard metallic stands. The other is the Repsold reversible metre pendulum referred to above. It is mounted now as it was when used, except that certain parts not necessary for showing the pendulum oscillations are omitted.

ENGLISH RAILROAD SPEEDS.

IN a recent letter from Manchester, England, to the *Railroad Gazette* of this city, Mr. W. H. Booth says that so important have been the changes made in the passenger traffic of all the great English companies, and also so numerous, that 'Bradshaw,' guide to all British lines, did not appear until the 3d of July. The alterations, of course, as usual, date from July 1, and call for special notice. 'Bradshaw' is studied with especial zeal just now by old established travellers, for the numerous changes have quite overthrown their knowledge. All the three companies which conduct a traffic between London and Scotland have added new expresses or increased the speed of existing trains, and the train service between the large towns has also been greatly improved and accelerated. For some time past American superintendents of motive power, and master mechanics, have been priding themselves upon running a good second to their English colleagues, and even ven-