Morgan's remark is easily verified by turning to Potts's Note on Euc. i. 10 (p. 49). Turning again to Boole ("L. of T.," p. 91), it would seem that the logician does not completely detach himself from the notion of infinity: he has to interpret 1 : 0 as well as 0 : 0.[1]

Bacon differs from Plato, who considered forms as absolutely abstracted from matter, and not as confined and determined by it, and agrees with Aristotle in saying that words are the images of thoughts;[2] so that the agreement of the views of Bacon with those of Prof. Max Müller would seem to be tolerably close. It is easy to find cases in which a doubtful meaning of a word may give rise to disagreement on matters of substance. Boole ("L. of T.," pp. 407, 408) observes that the term "necessary" may be applied either to the observed constancy of nature or to the logical connection of propositions. He expresses no decided preference for either meaning. The meanings should be kept carefully apart. If an axiom be a necessary truth, in the strictest sense, then Newton's laws of motion are laws *a priori*, viz. giving Kant's meaning to the term ("Prol.," p. 103); they are known independently of all experience. But Laplace ("Méc. Cél.," pp. 14–18[3]) treats them as results of experience. Moreover, he treats (pp. 65–69) the laws of motion under all the relations mathematically possible between force and velocity. Newton, in fact, usually speaks of "law," and gives the term "axiom" Bacon's meaning.

Boole's chapter xx. ("L. of T.," pp. 320–75) relates to problems on causes, but his use of the word "cause" has given rise to much discussion. He proposed a question on causes in 1851, which was answered by Prof. Cayley in 1853. The solution was criticized by Boole in 1854, who arrived at a different result, and in 1854, Mr. H. Wilbraham examined both solutions. Prof. Cayley returned to the subject in 1862, and Boole thereupon admitted that it would have been better, in stating his problem, not to have employed the word "cause" at all.[4] One mode of stating the nature of the relation between "cause" and "effect" may be this, viz. when a certain (antecedent) change is immediately and invariably followed by a certain other (subsequent) change, then the relation in which the antecedent stands to the subsequent (which may now be called the consequent) change is that of cause and effect. This is, in substance, if not in form, a view common to Algazel, Glanvil,[5] Hume,[6] Brown,[7] Kant, and, as I believe, Reid; for the question seems to be one about words. It differs but slightly from the view (C. T., vol. x., part 2, p. 300) of De Morgan. Perhaps "unvarying" might be a better word than "invariable," for one instant of time is the immediate and invariable antecedent of its consecutive instant; but the idea of "cause" does not seem to arise. When "cause" is used in the above sense, the solutions of Boole and Prof. Cayley agree. Boole's question has been dealt with in our Proceedings (vol. xi. p. 118) by Mr. McColl.

The import of the word "principle" is not the same when we speak of the principle of contradiction or of excluded middle, as when we speak of the principle of the permanence of equivalent forms, or of the sufficient reason, or of continuity. That of sufficient reason has been assailed by Brown ("C. and E.," sect. iv. pp. 222, misnumbered 322, to 306), and by De Morgan (C. T., x., part 2, pp. 290–304). Clifford (*op. cit.*, p. xl.) was prepared to sacrifice the principle of continuity, even in the case of space, and the author of anonymous "Strictures" on Peacock's "Algebra" (Camb., 1837), who was (so at least I was told many years ago by Davies) Hind, concludes (p. 21) that number is perfectly abstract, that it is the only thing which is so, that it is not rightly denominated a species of quantity, being equally connected with every species. An instance of a striking failure of the principle of the permanence of equivalent forms is given by Dr. J. W. L. Glaisher in the *Messenger of Mathematics*, N. S., vol. ii. (1872) p 95. Again, take another word—viz "disparity." Supposing it to be said that there are two persons in a room, whose united ages are twenty-one years, and between whose ages there is the greatest disparity possible. This is intelligible if one be a new-born or nascent infant, and the other a person aged twenty-one. But suppose the same statement made of three persons; the proficient in language might have to inquire of the mathematician what meaning, if any, the statement bears. Or, again, the mathematician might be asked what, or whether any, numerically definite meaning can be attached to the words, "triangle of maximum scalenity."

Prof. Newman ("Logic," 1838, p. 52) says that the truths of arithmetic are verbal. Perhaps this, and the corresponding statements of Dugald Stewart, would not now be insisted on. They are opposed to the views of Kant, Clifford, and De Morgan (C. T., xi., part 1, p. 160). The identities $3^2 + 4^2 = 5^2$, and $3^3 + 4^3 + 5^3 = 6^3$, seem to be something very different from definitions of words. Kant considers $7 + 5 = 12$ to be a synthetical judgment ("Proleg.," pp. 22, 23).

Metaphysics and mathematics are consorts in the East as well as in the West. Bhascara says that the analytical art is merely sagacity exercised, and is independent of symbols, which do not constitute the art.[1] If De Morgan[2] be right in placing Diophantus as late as the beginning of the seventh century, Aryabhatta was earlier, by two centuries, than Diophantus. The name certainly seems to have been a very common one. Josephus[3] relates that Alexander (a son of Herod the Great) said that Diophantus the scribe had imitated his hand. But Mr. Heath's work[4] renders it scarcely possible to sustain De Morgan's contention.

[1] See the last footnote but one.

[2] Bacon, "Advancement of Learning," p. 143; *conf.* pp. 130, 140. See also pp. 192, 209.

[3] My pagings refer to the 2nd ed. of the "Mécanique Céleste," vol. i. (Paris, 1829).

[4] Boole, *C. and D. M. J.*, vol. vi. p. 286; "L. of T.," pp 321–26; *Phil. Mag.*, S. 4, vol. vii. pp. 29–32; vol. xxiii., pp. 361–63; Wilbraham, *Phil. Mag.*, S. 4. vol. vii. pp. 465–76; Cayley, *Phil. Mag.*, S. 4, vol vi. p. 259; S. 4, vol. xxiii. pp. 352–65, and 470. A short letter by Boole (*Phil. Mag.*, S. 4, vol xxiv. (1862), p. 80, concludes the discussion.

[5] Glanvil (Joseph), "Scepsis Scientifica," &c. (Lond., 1665, 4to); Lond., 1885, 8vo. On Causation, I have only mentioned comparatively recent authors. But, going further back, we find Thales (with his elemental analysis), Xenophanes (with his one cosmic substance), and Pythagoras (with his arithmetical and geometrical combinations), all recognizing invariable sequences in nature; and Socrates admitted a class of phenomena wherein the connection of antecedent and consequent was invariable and ascertainable by human study (Grote, "History of Greece," vol. i., 1846, pp. 495–98). Socrates applied similar scientific reasonings to moral and social phenomena (*ib.*, p. 504).

[6] David Hume, "A Treatise of Human Nature," &c. (Lond., vols. i. and ii., 1739; vol. iii., 1740: his name does not appear on the title-pages). "Philosophical Essays concerning Human Understanding" (2nd ed., Lond., 1750). "An Inquiry concerning Human Understanding" (Lond., 1861) marks the issue to which I refer.

[7] Thomas Brown, "Inquiry into the Relation of Cause and Effect" (3rd ed., Edinburgh, 1818). Draper does not admit the construction put upon Algazel's words by Whewell ("Hist. Ind. Sc.," Lond., 1837, i. p. 251). A facsimile reprint of Glanvil has been published within the last few years. Buckle pronounced Brown's to be one of the best books ever written.

[1] Colebroke, "Algebra," &c. (London, 1817), p. xix.

[2] De Morgan, "Arithmetical Books" (London, 1847), p. 47.

[3] Josephus, "Antiquities of the Jews" (Burder's Translation, vol. i. pp. 616, 617). Burder's preface is dated London, October 1, 1811.

[4] T. L. Heath. "Diophantos of Alexandria: a Study in the History of Greek Algebra" (Cambridge University Press, 1885).

EXHIBITION OF METEOROLOGICAL INSTRUMENTS.

THE Royal Meteorological Society's tenth annual Exhibition of Instruments was held in the rooms of the Institution of Civil Engineers, 25 Great George Street, Westminster, from the 19th to the 22nd instant. This Society's Exhibitions are always interesting and instructive, as each one is devoted to some special class of instruments: this year the instruments consisted principally of actinometers and solar radiation apparatus. Specimens of most of the various forms of these instruments were exhibited; but when it was not possible to obtain an instrument itself, a photograph or drawing of it was shown, so that the visitors to the Exhibition could readily see what instruments have actually been made.

Several specimens were exhibited of Sir John Herschel's actinometer, for ascertaining the absolute heating effect of the solar rays, in which time is considered one of the elements of observation. This consists of a large cylindrical thermometer bulb, with a special open scale, so that minute changes may be easily seen. The bulb is of transparent glass filled with a deep blue liquid, which is expanded when the rays of the sun fall on the bulb. When taking an observation, the actinometer is shaded for one minute and read off; it is then exposed for one minute to sunshine, and its indication recorded; it is finally shaded again, and its reading again noted. The mean of the two readings in the shade, subtracted from that in the sun, indicates the expansion of the liquid produced by the sun's rays in one minute of time.

The Kew Committee exhibited Hodgkinson's actinometer, the principle of which is the same as that of Sir J. Herschel's, and also Pouillet's direct pyrheliometer, which consists of a cylindrical box of steel filled with mercury, into which the bulb of a thermometer is introduced, the stem being protected by a piece of brass tubing. As the surface on which the sun's rays fall and the quantity of mercury in the cylinder are both known, the effect of the sun's heat upon a given area can be expressed by stating that it is competent in five minutes to raise so much mercury so many degrees in temperature. The Rev. F. W. Stow showed an improved form of Pouillet's pyrheliometer, in which the instrument is placed in a silvered tube to shield it from wind and from all solar rays, except when the tube is turned directly towards the sun. Mr. Casella exhibited Secchi's solar intensity apparatus, in which two thermometers are kept immersed in a liquid at any convenient temperature, and a third, of which the stem passes through the same liquid and the bulb is outside it, is exposed to the rays of the sun shining down the hollow cylinder. The increase of temperature thus obtained is found to be the same, independent of the temperature of the liquid which surrounds the thermometer.

The British Association Solar Radiation Committee showed Prof. Balfour Stewart's actinometer; and Dr. Angström, of Stockholm, sent one of his pyrheliometers and a photograph of another pattern.

Luvini's dietheroscope for observing the changes of atmospheric refraction optically, and Bellani's lucimeter, as arranged by Prof. G. Cantoni for use at the Italian meteorological stations, were exhibited by the Meteorological Council; and Mr. Hicks showed some of Crookes's radiometers.

Dr. A. Downes illustrated his method of slow actinometry by oxalic acid, in which a definite quantity of a standard solution of oxalic acid is exposed to the action of light for a definite period; subsequently it is used to bleach a standard solution of permanganate of potash. The quantity of oxidized oxalic acid solution, compared with the quantity originally required to produce the same effect, is a measure of the intensity of the light.

Engravings illustrating Violle's, Crova's, and Frölich's actinometers were also exhibited.

The solar radiation thermometer consists of an ordinary maximum thermometer, with the bulb and about one inch of the stem coated with lamp-black, inclosed in a glass shield exhausted of air. Various specimens of this instrument were exhibited, with arrangements for testing the degree of exhaustion. Hicks's black bulb maximum thermometer *in vacuo* is supplied with platinum wires and a battery for testing the vacuum, while Negretti and Zambra's has a mercurial test gauge. Mr. Hicks also showed one of these instruments which had at the end of the outer jacket a second chamber in which is mounted one of Crookes's radiometers for testing the vacuum.

The Royal Meteorological Society showed a pair of black-bulb and bright-bulb maximum thermometers *in vacuo* as recommended for use at the Society's stations; while Messrs. Negretti and Zambra exhibited a similar pair of thermometers mounted in an upright position with the bulbs uppermost, as used at the Montsouris Observatory, Paris.

Mr. Casella showed Southall's helio-pyrometer for testing the accumulated heat of the sun in a confined blackened space, under glass. A black-bulb maximum thermometer is fixed on a cushion at the bottom of a box, the sides of which are also cushioned, and a thick piece of plate-glass is laid upon the top to prevent currents of air carrying off the heat. The box is placed in such a position that the sun's rays may strike as nearly as possible perpendicularly on the glass, when water contained in a small vessel will boil violently in the box.

The practical working of sunshine recorders may be said to date from 1854, when Mr. J. F. Campbell mounted a hollow glass sphere filled with acidulated water in the centre of a bowl of mahogany so arranged that the sun's rays were focussed on the interior of the bowl and burned it. The lines of burning therefore indicated the existence of sunshine. Solid glass spheres were substituted for the hollow ones in 1857, and in 1875 cards in metal frames were substituted for the wood. The Meteorological Council exhibited a number of wooden bowls showing the effect of sunshine by burning in the years 1855–56, 1883–84, and 1887–88; and the Astronomer-Royal sent the sunshine recorder with a hemispherical metal bowl which was in use at the Royal Observatory, Greenwich, from 1876–86. Specimens of the Campbell sunshine recorder with the improved Stokes's zodiacal frame for a fixed latitude, were shown by the Meteorological Council; a recorder with adjustments for use in any latitude, by Messrs. Negretti and Zambra; and the Whipple-Casella sunshine recorder, by Mr. Casella.

Mr. Jordan exhibited an experimental instrument for recording the intensity of daylight, the results being obtained by revolving a disk of sensitized paper behind a screen with a rectangular aperture. Messrs. Negretti and Zambra showed the various patterns of Jordan's photographic sunshine recorder, which consists of a cylindrical box, on the inside of which is placed a slip of cyanotype paper. Sunlight being admitted into this chamber by three small apertures, is received on the paper, and travelling over it by reason of the earth's rotation, leaves a distinct trace of chemical action. In the second pattern of this instrument two apertures are used instead of three; while in the new pattern two semi-cylindrical boxes are employed, one to contain the morning and the other the afternoon record. Prof. McLeod's photographic sunshine recorder was exhibited by Mr. Hicks. This consists of a glass sphere silvered inside and placed before the lens of a camera, the axis of the instrument being placed parallel to the polar axis of the earth. The light from the sun is reflected from the sphere, and some of it passing through the lens forms an image on a piece of sensitized paper within the camera.

Mr. A. S. Marriott showed two patterns of his instrument for comparing the active value of light at different stations; and the Kew Committee sent the chemical photometer devised by Sir Henry Roscoe.

Among the new instruments exhibited were Fineman's and Galton's nephoscopes for observing the direction of motion of clouds; Davis's improved air meters; Negretti and Zambra's recording hygrometer; Casella's Boylean-Mariotte barometer; and de Normanville's self-compensating sympiesometer. Mr. Murday showed in action his apparatus for obtaining readings of an aneroid placed at a distance by means of electric currents. An instrument, called the stephanome, which is used at the Ben Nevis Observatory for measuring the angular size of halos, fog-bows, glories, &c., was also exhibited.

Mr. Clayden showed a very ingenious and instructive working model illustrating the generation of ocean currents, which was a great attraction to all the visitors at the Exhibition. This model shows how the prevalent winds over the Atlantic are the chief cause of the circulation of the waters. A number of tubes are so arranged that when an attached blower is worked the circulation of air produced resembles that of the atmosphere; the imitation winds thus set up react upon the surface of the water, creating a system of currents which reproduces the main features observed in the Atlantic. Special attention was drawn to the Gulf Stream issuing from the Gulf of Mexico, and to the return current flowing eastwards between the equatorial currents. Mr. Clayden also showed some lantern slides illustrating the spiral circulation of the wind in both a cyclone and an anticyclone.

One of the chief features of last year's Exhibition was the large collection of photographs of flashes of lightning which had been gathered together by the Royal Meteorological Society from all parts of the world; this year the Society exhibited a number of similar photographs which have been received since May 1888. Near to these were placed a number of photographs of the electric spark taken by Mr. Wimshurst when the sensitive plate was rotating 2500 times per minute. These flashes are quite sharp and distinct, and show no sign of the movement of the plate.

A very interesting and valuable collection of sixteen photographs taken on the summit of Ben Nevis during the last eleven months were exhibited by the Directors of the Observatory, of which the following were of special interest: (1) cirrus cloud at the northern horizon, taken at midnight at the time of the summer solstice when the clouds are seen brightly illuminated; (2) St. Elmo's fire, at 11 p.m., on the top of the stove-pipe; and (3) views of the Observatory after continued fog and strong wind, but no fall of snow, when everything is covered with long crystals of ice formed out of the fog.

Mr. Bromhead exhibited two large photographs showing the thick rime on trees at Lincoln on January 7 last; and Mr. H. P. Curtis showed a photograph taken by moonlight.

Photographs of clouds were exhibited by Captain Wilson-Barker, Mr. Shepherd, and Captain Maclear.

The Exhibition also included a number of photographs and drawings of instruments, &c., as well as some models of hailstones, 7 inches in circumference, which fell near Montereau, France, on August 15, 1888.

William Marriott.