quite independent of the bombardment. The reports from numerous observers showed that as the showers moved along over the earth's surface those in front of it reported that the noise of the exploding dynamite occurred just before the shower; those in the wake of the shower reported that the shower came before the explosion, while those in the midst of the shower, of course, heard the explosion while it was raining. There was no evidence that the explosion had any effect on the clouds. Careful observations in Washington, D.C., during the whole of this first experiment, and during subsequent experiments with explosives, warranted the conclusion that no rainfall was produced by bombardment.

About that time a "rain wizard" commenced operating in Ohio. His method consisted in locking himself in a barn, house, luggage van or other room, wherein he made a fire and burned or evaporated certain chemicals, the smoke of which rose through the roof out of some impromptu chimney or stove-pipe and dissipated itself in the thin air. Of course it was claimed that the chemicals exerted a great influence on the atmosphere and forced rain to come. Occasionally rain did come after one, two, or three days of a chemical performance, but equally often it did not come. The Weather Bureau was often importuned for advice as to when the wizard should be called to any given town, and whether the inhabitants would be justified in paying him his fee of several hundred dollars. Eventually, a prominent railway company rigged up a car for his use, and during the years 1892–4 made it convenient for all the citizens on its lines to invoke the aid of "the rain producer." Of course there were numerous cases in which the operations were followed by rain; those who studied the Daily Weather Map could see at a glance that these rains accorded with the general weather conditions and had nothing to do with the rain-making operations. So long as frequent rains occurred, although they were natural and were predicted by the Weather Bureau on the basis of the weather map from day to day, yet the farmers of Iowa, Kansas and Nebraska, ignoring this fact, were sure to accredit all success to the wizard.

During the last great drought in California, 1898–1899, the citizens of one city authorised an extensive and expensive system of experiments by gases and by cannon, but were fortunately saved the necessity of actually wasting their money by the fact that an abundant rain fell naturally just before they were ready to begin their own operations.

Occasionally we still receive newspaper items reviving the old story that floods of rain were broken up by cannonading at Rome, or that rain was produced by cannonading in Italy, or that hailstorms were averted from a special vineyard that was protected by lightning rods while neighbouring vineyards suffered. These are all repetitions of the same old myths, or repetitions of useless experiments, and the intelligent reader may dismiss them as having no foundation. No matter how severely his land may be suffering from drought or flood, he should seek some other mode of relief and not waste his time and money in efforts to change the nature of the clouds or the atmosphere.

ON THE STATISTICAL DYNAMICS OF GAS THEORY AS ILLUSTRATED BY METEOR SWARMS AND OPTICAL RAYS.[1]

IMAGINE a cloud of meteors pursuing an orbit in space under outside attraction—in fact, in any conservative field of force. Let us consider a group of the meteors around a given central one. As they keep together their velocities are nearly the same. When the central meteor has passed into another part of the orbit, the surrounding region containing these same meteors will have altered in shape; it will in fact usually have become much elongated. If we merely count large and small meteors alike, we can define the density of their distribution in space in the neighbourhood of this group; it will be inversely as the volume occupied by them. Now consider their deviations from a mean velocity, say that of the central meteor of the group; we can draw from an origin a vector representing the velocity of each meteor, and the ends of these vectors will mark out a region in the velocity diagram whose shape and volume will represent the character and range of deviation. It results from a very general proposition in dynamics that as the central meteor moves along its path the region occupied by the group of its neighbours multiplied by the corresponding region in their velocity diagram remains constant. Or we may say that the density at the group considered, estimated by mere numbers, not by size, varies during its motion proportionally to the extent of the region on the velocity diagram which corresponds to it.

This is true whether mutual attractions of the meteors are sensibly effective or not; in fact, the generalised form of this proposition, together with a set of similar ones relating to the various partial groups of coordinates and velocity components, forms an equivalent of the fundamental principle of Action which is the unique basis of dynamical theory.

Now, suppose that the mutual attractions are insensible, and that W is the potential of the conservative field: then for a single meteor of mass m and velocity v we have the energy $\frac{1}{2}mv^2 + m\mathrm{W}$ conserved: hence if δv_1 be the range of velocity at any point in the initial position, and δv_2 that at the corresponding point in any subsequent position of the group, we have $v_1\delta v_1 = v_2\delta v_2$, these positions remaining unvaried and the variation being due to different meteors passing through them. But if $\delta\omega_1$ and $\delta\omega_2$ are the initial and final conical angles of divergence of the velocity vectors, corresponding regions in the velocity diagram are of extents $\delta v_1 . v_1^2\delta\omega_1$ and $\delta v_2 . v_2^2\delta\omega_2$: these quantities are, therefore, in all cases proportional to the densities at the group in its two positions. In our present case of mutual attractions insensible, the volume density is thus proportional to $v\delta\omega$, because $v\delta v$ remains constant. Now the number of meteors that cross per unit time per unit area of a plane at right angles to the path of the central meteor is equal to this density multiplied by v: thus here it remains proportional to $v^2\delta\omega$, as the central meteor moves on. In the corpuscular formulation of geometrical optics this result carries the general law that the concentration in cross-section of a beam of light at different points of its path is proportional to the solid angular divergence of the rays multiplied by the square of the refractive index, which is also directly necessitated by thermodynamic principles; as a special case it limits the possible brightness of images in the well-known way.

In the moving stream of particles we have thus a quantity that is conserved in each group—namely, the ratio of the density at a group to the extent of the region or domain on the velocity diagram which corresponds to it; but this ratio may vary in any way from group to group along the stream, while there is no restriction on the velocities of the various groups. If two streams cross or interpenetrate each other, or interfere in other ways, all this will be upset owing to the collisions. Can we assign a statistical law of distribution of velocities that will remain permanent when streams, which can be thus arranged into nearly homogeneous groups, are crossing each other in all directions, so that we pass to a model of a gas? Maxwell showed that if the number of particles each of which has a total energy E is proportional to $e^{-\mathrm{hE}}$, where h is some constant (which defines the temperature), while the particles in each group range uniformly, except as regards this factor, with respect to distribution in position and velocity jointly, as above, then this will be the case. In fact, the chance of an encounter for particles of energies E and E′ will involve the product $e^{-\mathrm{hE}}e^{-\mathrm{hE}'}$ or $e^{-\mathrm{h}(\mathrm{E}+\mathrm{E}')}$, and an encounter does not alter this total energy $\mathrm{E}+\mathrm{E}'$; while the domains or extents of range of two colliding groups each nearly homogeneous and estimated, as above, by deviation from a central particle in position and velocity jointly, will have the same product after the encounter as before by virtue of the Action principle. It follows that the statistical chances of encounter, which depend on this joint product, will be the same in the actual motion as are those of reversed encounter in the same motion statistically reversed. But if the motion of a swarm with velocities fortuitously directed can be thus statistically reversed, recovering its previous statistics, its molecular statistics must have become steady; in fact, we have in such a system just the same distribution of encountering groups in one direction as in the reverse direction: thus we have here one steady state. The same argument, indeed, shows that a distribution, such that the number per unit volume, of particles whose velocity deviations correspond to a given region in the velocity diagram, is proportional to the extent of that region without this factor $e^{-\mathrm{hE}}$, will also be a steady one. This is the case of equable distribution in each group as regards only the position and velocity diagrams conjointly; but in this case each value of the resultant velocity would occur with a frequency

[1] A paper read by Dr. J. Larmor, F.R.S., before Section A of the British Association at Bradford, September, 1900.

proportional to its square, and a factor such as e^{-hE} is required to keep down very high values. The generalisations by Boltzmann and Maxwell to internal degrees of freedom would lead us too far, the aim here proposed being merely concrete illustration of the very general but purely analytical argument that is fully set forth in the treatises of Watson, Burbury and Boltzmann.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Mr. H. Herbert Smith has been appointed Gilbey lecturer in agriculture for the next three years. Prof. Macalister and Dr. Habershon have been appointed additional examiners for medical degrees.

The Walsingham Gold Medal in biology has been awarded to Mr. H. Dale of Trinity College, and the Bronze Medal to Mr. R. C. Punnett of Caius College.

The University of New Brunswick has been affiliated to the University of Cambridge.

The researches submitted to the Board for physics by Mr. J. B. B. Burke, Mr. W. C. Henderson and Mr. A. H. Peake, advanced students, have been approved as qualifying for the B.A. degree.

Dr. Anningson, Dr. Collingridge, Prof. Sims Woodhead and Dr. Tatham have been appointed examiners in sanitary science.

The proposal for enabling the examiners to award a first class to candidates for the Natural Sciences Tripos, Part II., who show a sufficient knowledge of two subjects, but do not quite attain the first class standard in either, has been rejected by the Senate.

THE Childhood Society offers prizes of two guineas and one guinea for the two best essays on some prescribed subjects referring to the mental and physical characteristics of children. Information can be obtained from the Hon. Secretary of the Society, 72 St. Margaret Street, London, W.

GLANCING through the Calendar of the University College at Nottingham, we notice the announcement that the Board of Education is prepared to pay three-fourths of the laboratory fees at the College of Government teachers engaged in science teaching who wish to become familiar with practical methods. This rule applies to other University Colleges.

SCIENTIFIC SERIALS.

American Journal of Science, November.—Elaboration of the fossil cycads in the Yale Museum, by L. F. Ward. The collection contains twenty-nine different species of cycads from the Black Hills, represented by nearly eight hundred specimens. A number of new species are described, and termed respectively Cycadeoidea superba, rhombica, heliochorea, utopiensis, reticulata, minima, and protea.—Chemical composition of turquoise, by S. L. Penfield. Turquoise is so uniform in its chemical constitution that it can hardly be considered an accidental mixture of an aluminium phosphate and a copper phosphate. Copper and iron must be regarded as constituents rather than impurities. The author derives it from ortho-phosphoric acid, in accordance with the formula

$$[Al(OH)_2,Fe(OH)_2,Cu(OH),H]_3PO_4.$$

—Quartz-muscovite rock from Belmont, Nevada, by J. E. Spurr. The rock described occurs in a large dyke just east of Belmont. It occurs in large masses, changing gradually and irregularly into alaskite or muscovite-biotite granite. It is identical with the "beresite" occurring in the Urals in association with veins of auriferous quartz.—Volumetric estimation of copper as the oxalate, with separation from cadmium, arsenic, tin and zinc, by C. A. Peters. The precipitation of copper oxalate from solutions containing at least 0·0128 grammes of the oxide and saturated with oxalic acid is practically complete. Moderate amounts of copper may be determined quantitatively as the oxalate by precipitation with oxalic acid and titration of the precipitate by potassium permanganate. Copper may also be separated from other metals in the presence of nitric acid by the addition of considerable amounts of oxalic acid.—Synopsis of the collections of invertebrate fossils made by the Princeton expedition to Southern Patagonia, by A. E. Ortmann. Thirty-six new species are described, mostly gastropoda.—The kathode stream and X-light, by W. Rollins. The author advances two arguments against the supposition that the kathode stream particles are always of the same size, move with the same speed, and carry the same charge. Mercury particles appear too heavy to generate X-rays, and the loss of material from kathodes of different metals is not the same.

Bollettino della Società Sismologica Italiana, vol. vi., 1900–1901, No. 4.—The great earthquake of June 12, 1897, by R. D. Oldham. A summary of the author's report on the great Indian earthquake, and of his memoir on the propagation of earthquake motion to great distances (*Phil. Trans.*, 1900A, pp. 135–174).—A new protographic seismic pendulum, by G. Costanzi. A description of an apparatus for recording only the first part of the earthquake-motion, the surface on which the record is made being withdrawn from the moving pendulum.—Principal eruptive phenomena in Sicily and the adjacent islands during the year 1899, by S. Arcidiacono.—Notices of earthquakes recorded in Italy (June 5 to August 4, 1899), by A. Cancani, the most important being the Tuscan earthquake of June 27, the Latian earthquake of July 19, and distant earthquakes on June 5, 14, 17, July 7, 11, 12 and 14.

SOCIETIES AND ACADEMIES.

LONDON.

Linnean Society, November 15.—Mr. C. B. Clarke, Vice-President, in the chair.—Mr. W. B. Hemsley, F.R.S., F.L.S., exhibited a number of specimens and drawings of Fitchia (Hook. f. in *Lond. Journ. Bot.* iv. p. 640, pls. 23, 24), including a new species from the island of Raratonga in the Cook Archipelago, discovered by Mr. T. F. Cheeseman. The genus was described from specimens thought to have been procured on Elizabeth Island, a remote coral island in the Eastern Pacific; but Mr. Hemsley gave reasons for believing that the locality of the plant described by Sir Joseph Hooker was Tubnai Island in the same latitude, but 20° further to the west: an island of volcanic origin and mountainous, and, therefore, more likely than a coral island to be the habitat of such a plant, especially as it was originally discovered by Banks and Solander in Tahiti. Only three or four species are known: they are small resiniferous shrubs of tree-like habit, with rather thick branches, opposite simple leaves borne on slender stalks, and terminal, usually solitary flower-heads. Mr. Hemsley next exhibited an abnormal cluster of fruits of the edible chestnut found by Mr. Charles Read of Sway in the New Forest, and forwarded to Kew by the Rev. J. E. Kelsall. Usually there are two or three, rarely four in a cluster; but in the specimen exhibited there were at least fifteen, the largest nuts measuring about an inch in their greatest diameter. He also exhibited a curious flask-shaped bird's nest, which had been sent to Kew by Mr. J. H. Hart, Director of the Botanic Garden, Trinidad, but without any information concerning the bird which built it. It was constructed almost entirely of the soft plumose seeds of a species of Tillandsia (Bromeliaceæ). It measured a foot in length and between four and five inches in its greatest diameter, and had the entrance at the base, the receptacle for the eggs being near the top of the inside. Mr. J. E. Harting, in reply to a question from the chairman, said that without seeing a specimen of the bird which had built the nest in question, it was not easy to name the species with certainty; but that it was doubtless the nest of an Icterus, and probably of *Icterus leucopteryx*, commonly known in the West Indies as the Banana-bird.—Mr. James Groves, on behalf of Mr. Cecil R. P. Andrews, exhibited specimens of a Sea Lavender new to the Channel Islands, *Statice lychnidifolia*, Girard, discovered by Mr. Andrews in August of the present year growing sparingly on low rocks by the sea in Alderney in company with *S. occidentalis*, the most nearly allied British species. Mr. Groves pointed out that the interest of the record consisted, not so much in the fact of the plant occurring in Alderney (being a native of the adjacent French coast, and the Channel Islands being geographically more French than British), as in the fact that a species should be added to the flora of one of our possessions so near home.—Mr. W. C. Worsdell read a paper entitled "Further Observations on the Cycadaceæ," intended to throw additional light on the problem as to the phylogenetic origin and relationships of this group of plants.—On behalf of Miss Alice L. Embleton a paper was read by Prof. G. B. Howes on