may be mentioned his determination of the conducting powers of metals for heat by a method which appears to possess special advantages, and his investigation of the effect of extremely great pressures on thermometers, undertaken with a view to deducing correct results for the temperatures at great depths in the ocean from the observations made in the *Challenger* expedition. This latter subject has led him to investigate the behaviour, as to compressibility and development of heat, of liquids and solids under enormous pressures, a subject in which he is still engaged. Before concluding, I must mention his elaborate papers on systems of knots, recently printed in the *Transactions* of the Royal Society of Edinburgh.

The other Royal Medal has been awarded to our Fellow, Mr. Francis Galton, for his statistical inquiries into biological phenomena.

Mr. Galton is well known as an explorer and geographer, and his mind is singularly fertile in the devising of ingenious instruments for various objects. Many years ago he brought before us some remarkable experiments instituted with a view to test a particular biological theory, in which rabbits of a pure variety were so connected with others of a different variety that the same blood circulated through both individuals, and the point to determine was whether this blood-relationship, in the most literal sense of the term, had any effect on the offspring. Contrary to what the theory in question led us to regard as the more probable, the result proved to be negative. It is, however, in accordance with the rules for the award of the Royal Medals, more especially the later investigations of Mr. Galton, in relation to vital statistics, that have been taken as the ground of the award. He has shown that by taking the average of a number of individuals having some condition in common, individual peculiarities apart from that condition are eliminated in the mean, and results are obtained which may be regarded as typical of that condition. One way of doing this is by his method of compound photographs. Thus we may obtain typical features of criminals of a particular kind, of consumptive persons, and so forth. By adhering to the method of averages, he has even succeeded in obtaining a mathematical expression, very closely verified in observation, connecting the mean deviation of some condition (such for example as stature) in a series of individuals, from the general mean of the same condition, with the mean deviations of the same condition in the relatives of those same individuals of different kinds, such as fathers, brothers, &c. Nor is the statistical method applicable to bodily characteristics alone. Mr. Galton has even extended it with remarkable ingenuity and originality to mental phenomena also.

The Rumford Medal has been awarded to Prof. Samuel P. Langley, for his researches on the spectrum by means of the bolometer.

A better knowledge of the ultra-red region of the spectrum, which includes the larger part of the energy of solar radiation, had long been a desideratum when Prof. Langley commenced his work upon this subject. Finding the thermopile insufficiently sensitive for his purpose, he contrived the "bolometer." This instrument depends upon the effect of temperature upon the electrical resistance of metals, a quantity susceptible of very accurate measurement; and, with its aid, Prof. Langley has been able to explore a part of the spectrum previously almost inaccessible to observation.

A result of Prof. Langley's work, very important from the point of view of optical theory and of the ultimate constitution of matter, relates to the law of dispersion, or the dependence of refrangibility on wave-length. Cauchy's formula, which corresponds well with observation over most of the visible spectrum, is found to break down entirely when applied to the extreme ultra-red.

Prof. Langley has given much attention to the important question of the influence of the atmosphere on solar radiation. The expedition to Mount Whitney, successfully conducted by him in face of many difficulties, has given results of the utmost value, pointing to conclusions of great interest and novelty.

The Davy Medal has been awarded to our Foreign Member, M. Jean Charles Galissard de Marignac, for his researches on atomic weights.

M. Marignac's numerous researches on atomic weights, which have been continued for a great number of years, have played an exceedingly important part in establishing and consolidating that ground-work of chemistry. They are remarkable for originality in devising methods appropriate to the respective cases, the most conscientious care in discovering errors which occurred in the respective operations, and indefatigable perseverance in finding means to eliminate the disturbing influences. His labours are all the more valuable because he chose for their field chiefly those elements which are most generally used in chemistry, and are most important to chemists, and on which the determination of new atomic weights is most generally made to depend.

TEN YEARS' PROGRESS IN ASTRONOMY[1]

III.

COMETS.—During the past ten years we have been favoured with an extraordinary number of comets, and while perhaps no single great step has been made, yet it is certain, I think, that our knowledge of these mysterious objects has gained a real and considerable advance.

In 1876, curiously enough, not a single comet appeared; but in 1877 there were 6; in 1878, 3; in 1879, 5; in 1880, 5; in 1881, 8; in 1882, 3; in 1883, 2; in 1884, 3; and in 1885, 6; and so far this year, 3. Forty-four comets in all have been observed during the ten years, six of which were conspicuous objects to the naked eye, and two of them, the great comet of 1881, and the still greater one of 1882, were very remarkable ones.

The first of these will always be memorable as the first comet ever photographed. Dr. Henry Draper photographed both the comet itself and its spectrum; Janssen obtained a picture of the comet, and Huggins of its spectrum.

A number of excellent photographs were obtained of the great comet of 1882, especially by Gill, at the Cape. And it is worth mentioning that in May 1882 a little comet (not included in the preceding list, because no observations were obtained of it) was caught upon the photographs of the Egyptian eclipse.

Two of the bright comets, Wells's comet of 1881 and the great comet of 1882, approached very close to the sun, and their spectra, as a consequence, became very complex and interesting. A great number of bright lines made their appearance. Sodium was readily and certainly recognised; iron and calcium probably, but not so surely. The evidence as to the nature of the sun's corona, derived from the swift passage of the 1881 comet through the coronal regions, has already been alluded to.

The Pons-Brooks comet of 1883-84 is extremely interesting as presenting the first instance (excepting Halley's comet, of course) of one of the Neptunian family of comets returning to perihelion. There are six of these bodies with periods ranging from sixty-eight to seventy years. Halley's comet, the only large one of the group, has made many returns, and is due in 1910. Pons's comet, first observed in 1812, has now returned; Olbers's comet of 1815 is due in 1889, and the three others, all of them small, in 1919-20 and 1922.

I have spoken of them as Neptunian comets, *i.e.* their presence in our system is known to be due in some way to this planet. The now generally received theory is that they have had their orbits changed from parabolas into their present shape by the disturbing action of Neptune. Mr. Proctor has pointed out certain unquestionable, though, I think, inconclusive, objections to this view, and he proposes, as an alternative, the startling and apparently improbable hypothesis, that they have been *ejected* from the planet at some past time by something like volcanic action.

On the whole, however, the most important work relating to comets has been that of the Russian astronomer Bredichin. He has brought the mechanical and mathematical portion of the theory of comet's tails to a high degree of perfection; following out the lines laid down by Bessel, but improving and correcting Bessel's formulæ, and determining their constants by a most thorough discussion of all the accurate observations available.

It is hardly possible to doubt any longer that all the facts can be represented on the hypothesis that the tails are composed of minute particles of matter, first driven off by the comet, and then repelled by the sun. Bredichin's most interesting result, arrived at in 1878, is that the tails appear to be of three, and only three, distinct types—the long straight streamers which are due to a repulsive acceleration about twelve times as great as the sun's attraction; the second and most ordinary class of broad-curved tails for which the repulsive force ranges between one and two and a half times that of the attraction; and, finally, the short,

[1] "Ten Years' Progress in Astronomy, 1876-86," by Prof. C. A. Young. Read May 17, 1886, before the New York Academy of Sciences. Continued from p. 98.

stubby brushes which are found in a few cases, and correspond to a repulsive force not more than one-fourth the sun's attraction. Supposing, as he does, that the *real* repulsion is the same for each atom, the *apparent* repulsion, or repulsive *acceleration*, would be greater for the lighter atoms, and nearly inversely proportional to their molecular weights; and so he concludes that probably tails of the first type are composed of hydrogen, those of the second type of hydrocarbons, like coal-gas, and those of the third of iron, and its kindred metals. As to the second type, the spectroscope speaks distinctly in confirmation. Tails of the first and third types are not common, and are usually faint, and since Bredichin's result was announced there has been no opportunity for spectroscopic verification in their case.

I said his investigations had given a mathematical and mechanical explanation of comets' tails; but the *physical* question, as to the nature of the force which causes the observed repulsion, remains unsettled, though I think there is no doubt that general opinion is crystallising into a settled belief that it is electrical; that the sun is not at the same electric potential as surrounding space, and that, in consequence, semi-conducting masses of pulverulent matter, such as comets seem to be, are subject to powerful electric forces as they approach and recede from the central body. At the same time there are those—Mr. Ranyard, for instance—who forcibly urge that the direct action of the solar *heat* might produce a similar repulsive effect by causing rapid evaporation from the front surface of minute particles, charged with gases and vapours, *frozen* by the cold of outer space.

I ought not to dismiss the subject of comets without at least alluding to the numerous unprecedented and interesting phenomena presented by the great comet of 1882: first, its unquestionable relation to, but distinctness from, its predecessors of 1880, 1843, and 1668, the three belonging to one brotherhood, of common origin, and all following nearly the same path around the sun. I call special attention to this point, because Miss Clerke, in her new and admirable "History of Astronomy in the Nineteenth Century" (which I hope every one interested in astronomy will read as soon as may be), has, I think, made a mistake regarding it, assigning to the difference between the computed periods of these comets much too great an importance.

The strange elongation of the nucleus of this comet into a string of luminous pearls; the faint straight-edged beam of light that enveloped and accompanied the comet for some time; and the several detached wisps of attendant nebulosity that were seen by several observers, are all important and novel items of cometary history.

Meteors.—Time will not allow any full discussion of the progress of meteoric astronomy. It must suffice to say that the whole course of things has been to give increased certainty to our newly-acquired knowledge of the connection between meteor-swarms and comets, and to make it more than probable that a meteor-swarm is the result of the disintegration and breaking-up of a comet. This seems to be the special lesson of the Bielids, the re-appearance of which, as a brilliant star-shower last November, attracted so much attention. In an important paper read before the National Academy of Sciences, last April, Prof. Newton pointed out how all the facts connected with the division into two of Biela's comet forty years ago, its subsequent movements and disappearance, and the meteoric showers of 1872 and 1885, and especially the peculiar features of this last shower, all conspire to enforce this doctrine.

I mention, doubtfully, in this same connection the recent supposed discovery by Denning of what are generally alluded to as "long radiants": systems of meteors, *i.e.*, which for weeks, and even months, together, seem nightly to emanate from the same point in the sky. One of these radiants, for instance, the first of half a dozen described by Mr. Denning, is about $1\frac{1}{2}^\circ$ north of β Trianguli, and the shower appears to last from July to November, at the rate of perhaps one or two an hour.

If the fact is *real*, it follows inevitably that, disseminated through all the space in which the earth is moving, and has been moving for several years—not less than 1,000,000,000 miles—there are countless meteoroids moving in parallel lines, and with a velocity so great that the earth's orbital motion of 19 miles a second is absolutely insignificant as compared with theirs. Their speed must be many hundreds of miles per second. This may be true, but I own I am not ready to accept it yet. The observations indicate directly no extraordinary swiftness. Mr. Proctor, whose mind appears at present to be chiefly occupied by the idea that suns and planets are continually bombarding their neighbours (or at least do so at some stage of their existence), ascribes such meteors to the projectile energies of some of the "great" stars. But there is not time to discuss his notion, and it is hardly necessary, until it has begun to receive somewhat more extensive acceptance. I am not aware that, so far, he has any converts to his theory of comets and meteors.

Stars.—Want of time will also prevent any adequate treatment of the recent progress of stellar astronomy.

Two great works in the determination of star places must, however, be mentioned. One is the nearly completed catalogue of all the northern stars, down to the ninth magnitude, begun almost twenty years ago, under the auspices of the Astronomische Gesellschaft, by the co-operation of some fifteen different observatories. The observations are now nearly finished, and several of the observatories have already reduced and published their work. A very few years more ought to bring the undertaking to a successful end.

Another similar work, almost, though not quite, as extensive, is the great catalogue of southern stars, made at the Observatory of Cordova by our own Dr. Gould and his assistants. He himself, with his own eyes, observed every star of the whole number—nearly 80,000—his assistants reading the circle and making the records; and the whole has been reduced, printed, and published within the space of twelve years—a veritable labour of Hercules, for which, most justly, our National Academy has awarded him the Watson Medal. He had already, some years ago, received the gold medal of the English Royal Astronomical Society, for the "Uranometria Argentina," an enumeration of all the naked-eye stars of the southern hemisphere, with their approximate positions and estimated magnitudes. This, however, was only a sort of preliminary by-play, to pass the time while waiting for the completion of his observatory and meridian-circle.

We must mention also the remarkable star-charts made by Dr. Peters, of Hamilton College, of which he has already published and distributed at his own expense about twenty, and more are soon to follow.

But the old-fashioned way of cataloguing and charting the stars is obviously inadequate to the present needs of astronomy, and a new era has begun. While, hereafter, as hitherto, the principal stars, several hundred of them, will be observed even more assiduously and carefully than ever before, with the meridian-circle or similar instruments, the photographic plate will supersede the eye for all the rest. It is now easily possible to photograph stars down to the thirteenth or fourteenth magnitude, and to cover a space of $2\frac{1}{2}^\circ$ square on a single plate. The remarkable thirteen-and-a-half-inch instrument constructed by the Henry Brothers, for the Paris Observatory, and first brought into use last August, does this perfectly. Instruments very similar, but smaller, lately set up at Harvard College, at the Cape of Good Hope, and at Liverpool, while they do not reach so faint stars, cover more ground at a time.

Negotiations are already under way to secure the co-operation of a number of observatories for a photographic survey of the heavens; and it is probable that, after some preliminary consultation and before very long, it will be actually in progress. According to Struve's estimates, it could be accomplished in about ten or twelve years, even on the Paris scale, by the combined efforts of fourteen or fifteen establishments. Orders have already been given to the Henry Brothers, by Dom Pedro, of Brazil, and Mr. Common, of England, for instruments precisely like the one at Paris. Americans, and New Yorkers especially, may well take a peculiar interest in astronomical photography, since it was at Cambridge, in 1861, that the first star-photographs were ever made, and here, in New York, Rutherfurd and Draper were among the earliest and most successful workers: in the observatory above us is now mounted the very instrument with which Rutherfurd made his unrivalled pictures of the moon and his plates of the Pleiades, more than twenty years ago.

During the past ten years, stellar photometry has become almost a new science. Its foundations, indeed, were laid by J. Herschel, Seidel, Wolff, and Zöllner, before 1870, and the magnitudes of some two hundred stars had been measured, and the law of atmospheric absorption determined. But the great work of Pickering, at Harvard, in the invention and perfecting of new instruments, and his "Harvard Photometry," which gives us a careful measurement of the brightness of all the naked-eye stars of the northern hemisphere, marks an epoch. And he is pushing on, and has already well under way the measurement of the 300,000 stars of Argelander's "Durchmusterung." Nor must we omit to mention Pritchard, of England, whose name has just been joined with Pickering's by the Royal Astronomical Society, in the bestowal of their gold medal for his wedge-photometer and

the photometric work done with it. The "Harvard Photometry," and the "Uranometria Oxoniensis" together will carry down to all time the record of the present brightness of the stars. They will be especially valuable as data for determining changes in stellar brilliancy.

During the past ten years the number of variable stars has risen from about 100 to nearly 150; and our knowledge of their periods and light-curves has been greatly improved. In America, Chandler and Sawyer, of Boston, and Parkhurst, of this city, have done especially faithful work. During the ten years we have had two remarkable "temporary stars," as they are called—first the one which, in November 1876, in the constellation of Cygnus, blazed up from the ninth magnitude to the second, and then slowly faded back to its former brightness, but to a *nebulous* condition, as shown by its spectrum; then also the one which, last autumn, appeared in the heart of the nebula of Andromeda as of the sixth magnitude (where no star had ever been seen before), slowly dwindled away, and is now beyond the reach of any existing telescope. Perhaps, too, we ought to mention another little ninth-magnitude star in Orion's club, which last December rose to the sixth magnitude, and is now fading; it seems likely, however, from its spectrum, that this is only a new variable of long period.

As to star-spectra, a good deal of work has been done in their investigation with the ordinary stellar spectroscopes by the Greenwich Observatory, by Vogel at Potsdam, and by a number of other observers,—work well deserving extended notice if time permitted. But the application of photography to their study, first by Henry Draper in this city, and by Huggins in England, is the important new step. By the liberality of Mrs. Draper, and as a memorial of her husband, his work is to be carried on with the new photographic instrument and method just introduced by Prof. Pickering at Cambridge. He is able to obtain on a single plate the spectra of all the stars down to the eighth magnitude in the group of the Hyades, each spectrum showing under the microscope the characteristic lines quite sufficiently for classification. A different instrument is also to be built with the Draper Fund, which will give single star-spectra on a much larger scale and in fuller detail.

During the decade, the stellar parallax has been worked at by a number of observers. Old results have been confirmed or corrected, and the number of stars whose parallax is fairly determined has been more than doubled. The work of Brunnow and Ball in Ireland, of Gill and Elkins at the Cape of Good Hope, and of Hall, at Washington, deserves especial mention. A new heliometer of seven inches aperture has been ordered for the Cape Observatory, and when it is received, a vigorous attack is planned by co-operation between that observatory and that of Yale College, which possesses the only heliometer in America.

During the ten years, our knowledge of double stars has been greatly extended; several observers, and most eminent among them Burnham, of Chicago, have spent much time as hunters of these objects, and have bagged between one and two thousand of them. Several others, especially Doberck in England, and Flammarion in France, have devoted attention to the calculation of the orbits of the binaries, so that we have now probably about seventy-five fairly well defined.

In the study of the nebulæ, less has been done. Stephan at Marseilles and Swift at Rochester have discovered many new ones, mostly faint, and Dreyer, of Dublin, has published a supplementary catalogue, which brings Sir J. Herschel's invaluable catalogue pretty well down to date. The studies of Holden upon the great Orion nebula and the so-called "trifid nebula" deserve special mention, as securely establishing the fact that these objects are by no means changeless, even for so short a time as twenty or thirty years; also the discovery of a new nebula in the Pleiades by means of photography.

Observatories.—During the ten years, a considerable number of new observatories have been founded. Abroad, we mention as most important the observatories for astronomical physics at Potsdam, in Prussia, and at Meudon, in France, also the Bischoffsheim Observatory at Nice and its succursal in Algiers. The great observatory at Strasburg can hardly be said to have been founded within the period indicated, but the new buildings and new intruments and new efficiency date since 1880. We ought not to pass unnoticed the smaller observatory at Natal, in South Africa, and the private establishments of von Konkoly at O-Gyalla, of Gothard at Hereny (both in Hungary), and of the unpronounceable gentleman Jedrzejewicz at Plonsk, in Poland, and the observatory at Mount Etna, from which, however, we have no results as yet.

In the United States, we have the public observatories at Madison, Wis., at Rochester, N.Y., and at the University of Virginia, and the, as yet, unfinished Lick Observatory in California: also a host of minor observatories connected with institutions of learning, and mainly designed for purposes of instruction; such establishments have been founded within ten years at Princeton, at Northfield, Minn., at South Hadley, Ms., at Beloit, at Marietta, at Depauw, at Nashville, and at St. Louis, also at Franklin and Marshall College, and at Doane College, in Nebraska, at Columbia College, Ann Arbor, and Madison, Wis., and at one or two other institutions which escape me for the moment. Several others are also at this moment in process of erection. Every one of them has a telescope from six to thirteen inches aperture, with accessory apparatus sufficient, in the hands of an astronomer, for useful scientific work.

Instruments.—A large number of new instruments of great power have been constructed. We mention the great thirty-inch refractor of Pulkowa, the twenty-six-inch of Charlottesville, and the twenty-three inch at Princeton, for all which the lenses were made by our own Clark. We add the great Vienna twenty-seven-inch telescope by Grubb, and the twenty-nine-inch object-glass by the Henrys, made for the Nice Observatory, but not yet mounted; also the nineteen-inch telescope at Strasburg by Merz. Grubb has also at present a twenty-eight-inch object-glass under way for the Greenwich Observatory, and Clark has nearly completed the monstrous thirty-six-inch lens for the Lick Observatory. There never was a decade before when such an advance in optical power has been made.

Great *reflectors* have been scarce, the only ones of much importance constructed during the time being the twenty-inch instrument at Algiers, and Mr. Common's exquisite three-foot telescope, which he has lately sold to Mr. Crossley in order to make way for one of five feet diameter, now, I believe, under construction. The old three-foot and six-foot instruments of Lord Rosse have been improved in various ways, and are still in use,—especially in work upon lunar heat. Among newly-*invented* instruments, we mention the meridian-photometer of Pickering, the wedge-photometer of Pritchard, the almucantar of Chandler, the concave diffraction-grating of Rowland, and the bolometer of Langley—all, but one, American. Repsold's improvements in the micrometer, in the heliometer, and in the mounting of equatorials should also be mentioned here.

As to new astronomical methods, enough has been already said about photometry and astronomical photography. It is plain that we are entering upon a new era.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

THE examination for the Sheridan Muspratt Chemical Scholarship at University College, Liverpool, will begin on December 9. The Scholarship is of the value of 50*l.* per annum, tenable for two years. Candidates should apply to the Registrar before December 6.

SOCIETIES AND ACADEMIES

PARIS

Academy of Sciences, November 22.—M. Jurien de la Gravière, President, in the chair.—On the life and work of L. R. Tulasne, by M. Ed. Bornet. The paper contains a somewhat detailed account of the labours of this eminent botanist, who was born at Azay-le-Rideau (Indre-et-Loire) on September 12, 1815, and died on December 2, 1885. Appended is a list of the scientific publications of MM. Louis-René and Charles Tulasne.—On ammoniaco-magnesian phosphate, by M. Berthelot. In continuation of his previous researches on the colloidal and crystallised states of the earthy phosphates, and especially of the phosphate of magnesia, the author here studies the double ammoniaco-magnesian phosphate, determining the conditions of formation of this compound in chemical analysis.—The Montgaudier Cave, by M. Albert Gaudry. The author describes a visit he recently paid to this cave, which is situated in the Charente district, and which has revealed several objects of an artistic character, dating from the close of the Quaternary epoch, when the large fauna of extinct species had already mostly disappeared. But some remains,