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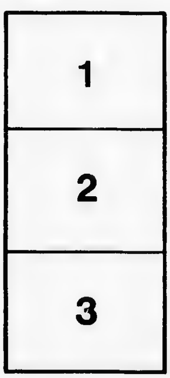
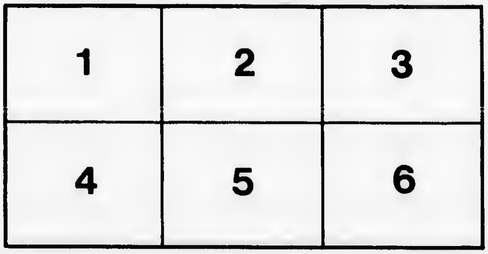




ASTRONOMY

IN INFANCY, YOUTH AND MATURITY.

ASTRONOMY, IN INFANCY, YOUTH AND MATURITY.

[*Address delivered before the Astronomical and Physical Society of Toronto in the Lecture Hall of the Canadian Institute, January 23rd, 1900, by the retiring President, Mr. Arthur Harvey, F.R.S.C.*]

The President, Mr. Geo. E. Lumsden, F.R.A.S., occupied the chair

I have found it as difficult to choose a title for my farewell address as to condense it into reasonable compass. I wish to treat, first, of the earliest stage of the development of our science; next, of the time and manner in which it threw off its swaddling clothes; and lastly, of some of its latest achievements. Mr. Lindsay, our editor, suggested as a caption, "The Growth of Astronomy," which will do very well, but I do not intend to attempt a consecutive history.

To be orderly, this paper should begin with the enquiry how old our civilization is.

Plato makes his Kritias tell a curious tale. He brings him to our notice as an old man, who, when a boy, heard from his grandfather the story Solon brought from Egypt. A priest at Sais told the Athenian student that the present Greeks were children, ignorant of their own history; they had really occupied Hellas 8,000 years before,* and had waged successful war with the Atlantides, who, coming from a great island just outside the Pillars of Hercules, had subjugated Europe and Africa, as far as the Tyrrhenian sea on the north, and Egypt on the south shore of the Mediterranean. Suddenly, however, great earthquakes and floods occurred, as indeed in the history of the human race they often had before: the island of Atlantis was submerged, and the Greek hosts were also swallowed up. In these floods the cities suffered destruction, and none but the hill folk escaped, so that Hellenic civilization had to recommence. Egypt, however, had always been free from earthquakes and torrential rain, having only the usual regulated flood of the Nile, wherefore it had preserved the records which traced back its history to the foundation of the kingdom—9,000 years before. The description given of the Atlantic island is minute, and it has ever

* In the Timæus the figures are thus given, in the Kritias a thousand more years are added.

been a debated question whether Plato's account is altogether mythical or not. I incline, with Grote, and against Jowett, to think it had a foundation in some recorded facts, though there is little to favour the contention of an American writer that the ancients had a regular communication with Mexico and Peru by galleys which rendezvoused near Ceylon and proceeded to the west coast of both North and South America.

Saint Augustine, in his great work *De Civitate Dei*,* refers to a letter written by Alexander the Great to his mother Olympias. After the conquest of Persia, Alexander turned his arms to Egypt, which had for a short time been most unwillingly subject to the Shah. He was received rather as a protector and liberator than as an enemy, and as he professed respect for their great past, for their monuments and their religion, he was favoured by the priests, who were the depositories of historical and scientific lore. One of these supplied him with information from the sacred books to the effect that even the Assyrian kingdom was 5,000 years old, though the Greek histories, which began it with the same king, Belus, assigned to it only 3,500 years. He gave as the duration ot the Persian and the Macedonian empires more than 8,000 years, though the Greeks allowed but 580 for the growth of Macedon, and but 233 for the Persian rule. Yet, said he, these high numbers must be trebly multiplied to reach the antiquity of Egypt! St. Augustine died in A.D. 430, when authentic copies of Alexander's letter may have been still extant. In an endeavour to minimize the length of time, he says the Egyptian year had been one of four months only, but Diodorus expressly states that it consisted of three hundred and sixty-five days six hours, and he gives to Egypt an antiquity of more than 20,000 years. Callisthenes, who was in Alexander's retinue, informed Aristotle that the Babylonians reckoned their city to be at least 1,903 years old when Alexander entered it. And Manetho, who was keeper of the Egyptian archives under Ptolemy Philadelphus, gave 5,300 years as the recorded length of the Egyptian dynasties.

We now have evidence from papyri, monuments and tablets to check these figures, for we have learned to read Egyptian and Assyrian almost as well as our own language, and have spaded up whole libraries of information. The Prisse d'Avennes papyrus is claimed to be the oldest writing in the world, and of the third dynasty 5,318 B.C. It is in a bold, clear, firmly set handwriting, which tells of a civilization old

* Book XII. chap. 10.

even then. Mr. J. C. Conder * says the Babylonians of the sixth century B.C. believed the first Chaldæan empire was established more than 3,200 years before their time, and it was certainly founded by men of Mongol race, whose language, called Akkadian, is found on the oldest records. Scholars have not yet come into thorough accord; one Dr. Hilprecht assigns 3,000 B.C. as the date of an inscription in cuneiform writing, which displaced Hittite hieroglyphics when Semitic races became powerful around Babylon, while a Dr. Oppert thinks it a thousand years later. However, the earliest Assyrian and Egyptian records come fairly close together, and there seems no prospect of tracing either further back than six or seven thousand years.†

The origin of astronomical studies is coëval with reason and observation, and a singular record of them appears to be found in the pyramids of Egypt. They seem to have had openings from which a passage led to the interior, so built that on a certain day the Sun or a given star could be seen from the recesses of the monument, as if shining down a tube. To such stars these pyramids are said to be "oriented." The most recent investigation of this interesting subject is to be found in the *Proceedings* of the Royal Society for last November, where Dr. E. A. Wallis Budge discourses on the Pyramid fields of the Soudan, which are especially important because while in northern Egypt the pyramids are oriented east and west, in southern Egypt and the Soudan, star worship is indicated. These tombs had on the south-east side a shrine or chapel, "into the innermost part of which the light from the celestial body to which it was oriented could enter. * * They consisted of two and sometimes three chambers with narrow doorways which served, like the various sights and sections of a telescope, to direct the rays of light from the celestial body to a given spot—that spot in the case of a pyramid being the centre of the shrine, where a figure of the deceased was placed." Now in these Soudan cemeteries, the star chiefly used as a "warning star" is Alpha Centauri, and it was so used from the XIIth dynasty, about 2,700 before Christ. As, owing to the precession of the equinoxes, the place of a star must change, the later tombs would have an orientation

* Scottish Review, October, 1899.

† The Chinese records do not much differ, for they state that the first Emperor Fohi reigned 2,952 years before Christ, and he, too, composed astronomical tables. The first King of the Indies is said to have lived 3,553 years before our era, and the astronomical epoch of the Brahmins is supposed to begin in 3,101 B.C.

somewhat different from the earlier ones, and Dr. Budge says the theory is strengthened by the fact that "archaeological considerations indicate that the pyramids which have different orientations belong to different periods."

Prof. C. Piazzi Smyth, as you probably all know, wrote a book on "Our Inheritance in the Great Pyramid," in which he insisted that it was a measure of the polar diameter of the Earth, and was intended as a standard of weights and measures. It seems, however, thoroughly established that it is so oriented that the passage points due north, at an angle which Col. Howard Vyse measured as 26° 41′. Sir John Herschel calculated that in 2,121 B.C. the star α Draconis was the Pole star, and that its lower culmination was then 26° 15′ 45″. As the annual precession in north polar distance in that part of the sky is 18″, the date of the orientation, supposing Col. Vyse's measure to be exact, was 83 years before, or 2,204 B.C.

According to Dr. F. C. Penrose, Greek temples were similarly oriented, and in the same number of the *Proceedings* of the Royal Society he gives several new instances. Three of the temples he has thus surveyed are oriented to α Arietis, rising; two to Spica rising; one each to α Pegasi setting and α Leonis rising. To illustrate the method of investigation I transcribe one :—

Name of Temple.	Orientation Angle.		Stellar Elements.	Solar Elements.	Name of Star.
The new Erechtheum.	265° 9′	A. Amplitude of star or Sun.	+ 6° 30′ E	+ 7° 20′ E	α Arietis rising
		B. Corresponding altitude..	4° 0′	3° 25′	
		C. Declination	+ 10° 35′	+ 7° 34′	
		D. Hour angles	6h. 13m.	7h. 26m.	
		E. Depression of Sun when star heliacal	......	12°	
		F. R. A.....................	23h. 58m.	1h. 11m.	
		G. Approximate date	445 B.C.	April 9	

In the case of temples the star would shine through some opening in the wall into the adytum at the date of the festival with which the temple was connected.

The Greeks took lessons in astronomy from the Egyptians, and perhaps from the Assyrians, and in due course became the teachers of the

Roman world. Lucretius, the poet of science, gives them that credit in some noble verses,* which suffer grievously in my translation :—

Of old, when Human life lay crushed to earth
By onerous creeds, each claiming heavenly birth,
Which showed their horrid forms in dreadful guise,
The Greeks first dared to lift their questioning eyes.
No tales about the gods, no lightning dire,
No growling thunder, threatening heaven's ire,
Cowed their free minds or stopped their opening wide
The gates of nature, theretofore untried.
And thus the living forces of the soul
Began to contemplate one glorious whole,
Outreached the luminous boundaries of Earth,
Made the great universe a field of worth
For mental culture, and correctly taught
The lawful bounds of profitable thought.

In his "Republic,"† Plato considers of the sciences to be studied. First, he mentions arithmetic, and then geometry, "which draws the soul towards truth and creates the spirit of philosophy." Next, he names astronomy, "For every one, as I think, must feel that astronomy compels the soul to look upwards and leads us from this world to another." "The spangled heavens," he urges, "should be used as a pattern, and with a view to that higher knowledge." And he insists that they should be studied with love "since knowledge acquired under compulsion has no hold upon the mind."

These old philosophers had some fair conceptions of the mechanism of the heavens. A paper by Mr. W. B. Musson, in our *Transactions* for last year, gives an excellent account of the theories of motion held by various Greeks, and Vince's "Complete system of astronomy," which we possess, gives a good summary of the history of the science among eastern nations. It seems clear to me that Plato spoke of the Earth as "revolving" around its pole, though the word used may have another meaning. Nor could Anaxagoras have explained the way in which the Moon is illuminated unless he had understood its motion with reference to both Earth and Sun. He was imprisoned for so doing; the world often maltreats its benefactors. The Aristotelians reasoned out the necessary rotundity of celestial bodies, and the Pythagoreans seem to have held a proper theory of the revolution of the wandering stars. One can see in

* De naturâ rerum, Lib. I., vv. 63-67.

† Book VII.

the Atlantean myth that the ancients appreciated the effect upon our globe of seismic forces and of heavy storms. But though they prepared the way for such men as Tycho Brahé and Copernicus, we must honour Galileo Galilei as the man who launched the barque of astronomical science upon its great modern career. All before him I call the childhood of astronomy. With him its vigorous youth began.

Our Librarian has placed us in possession of a copy of Galileo's works, printed at Bologne in 1655, only thirteen years after his death. It seems to me that we get nearer to the great men of past centuries through the perusal of these old editions, and he must be dull indeed who does not feel a thrill of unusual interest when he sees the *Syderius Nuncius* in something like its original dress.

After the dedication to Cosmo, of the Medici, dated in March, 1610, and the license to print, declaring that the work contains nothing contrary to the Holy Catholic Faith, the State, or approved custom, the second and fuller title of this celebrated tract appears, "*The Astronomical Messenger*, being an account of recent observations with the new Perspicillum on the surface of the Moon, the Milky Way and the nebulous stars; also of the innumerable fixed stars and of four planets named the stars of Cosmo, never before seen." (In the dedication they are called "Medicean stars.")

"About ten months ago," says Galileo, "there came a rumour to our ears that a certain Belgian had made a lens by the aid of which visible objects, though far from the eye, could be distinctly seen, as if they were near, * * which some believed and others not. A few days afterwards the fact was confirmed in a letter I had from Paris, which caused me to turn my thoughts to the reason for the effect, and to preparing an instrument that should produce the same result. I studied the subject of refraction, and, having made myself a leaden tube, I fixed glass lenses in the ends of it, plane on one side and spherical on the other—one convex and the other concave. On placing my eye to the concave glass, I looked at some objects of fair size and at a short distance, which I found three times as close and nine times as large as when looked at with natural sight. I then made another instrument which magnified sixty times. Finally, sparing neither time nor money, I made one so excellent that things seen by it were almost a thousand times enlarged, and appeared more than thirty times as close as when viewed by unaided vision."

The revolutionary and epoch-making narrative of two months' observations follows.

First as to the Moon. "It is of consequence," he says, "to know that the surface is not smooth and highly polished, as formerly supposed, and of exact spherical shape, as the great cohort of philosophers have thought it and other celestial bodies to be, but, on the contrary, accidented and rough, covered with swellings and cavities, and furrowed like the Earth with mountain ridges and deep valleys." He likens the spots to the eyes on a peacock's tail and to the marks on the surface of chilled glass. He applauds the Pythagoreans, who said the Moon was like another Earth, and thinks the Earth, seen from afar, would resemble her, especially in mountainous parts like Bohemia. Alluding to the features we call *maria*, as well as to the more frequent but smaller craters, and the differing phenomena of sunrise and sunset thereon, he opines that lunar hills are much loftier than ours.

As to the fixed stars, he thinks it strange they do not appear so much increased in brilliancy as the power of the telescope would seem to call for, since with a magnifying power of a hundred, stars of the fifth and sixth magnitude show no brighter than those of the first do to the naked eye. While the planets look like spheres or little moons, no disc can be noticed to the fixed stars, which are surrounded with rays, like lightnings, but in addition to the stars of the fifth and sixth magnitude the lens reveals an incredible number of smaller ones. His pamphlet gives several engravings of the Moon, and diagrams of the belt and sword of Orion, also of the Pleiades, in which he shows 36 stars instead of the six which are usually visible to the naked eye. He proceeds to rejoice in setting the world free from the disputes, which for so many centuries had engaged philosophers, as to the essence or material of the Milky Way, which is seen in his telescope to be merely a collection of innumerable stars, and, passing to nebulæ, he gives an engraving of one in the head of Orion; also of the Præsepe. In the former he figures 21 stars, and the latter, so far from being a single object, is an assemblage of more than 50. Lastly, and with more interest still, he describes the four secondary planets he has discovered, circling around Jupiter. On the seventh of the preceding January (1610), in the second hour of the night, he was looking at the stars with his newest telescope, when Jupiter became visible, and he saw three small but bright stars near the planet, which he supposed to be fixed, but admired because they were in a straight line, parallel to the ecliptic. Two were to the east of Jupiter, one to the west. Eight days thereafter, by a chance he cannot explain, he looked again, and saw quite a different situation: all three were west of the great planet. His work gives 65 diagrams of their positions, with an occasional fixed star as a point of comparison, and explains that the four satellites revolve around Jupiter as the Moon does around the Earth.

The whole of these announcements—title, dedication, figures and all—are contained in a pamphlet of 41 pages, and, at the end, the "candid reader" is told he may expect more soon, a promise which was fulfilled in the *Continuation of the Sidereal Messenger*, issued in 1611.

Galileo having found in his survey of the heavens something he did not wish to publish at the time, announced it to Kepler in the following jumble of 37 letters:—

Smaismrmilmepoetaleumibvneuvgttaviras.

Kepler tried to put this "pie" into intelligible words, but failed, so on November 13th, 1610, Galileo wrote to him from Florence, whither he had moved from Padua, and gave him the answer to the enigma:—

altissimum planetam tergeminum observari.

(I have seen the farthest planet divided into three, or, consisting of three parts.)

Another such jumble concealed until 1st January, 1610, the discovery of the phases of Venus. The *Continuation* announced also, though with some uncertainty, the gibbosity of Mars. No wonder Kepler said that Galileo used his lens like a ladder, with which to scale the furthest and loftiest ramparts of the world!

But all was not done yet. Our volume contains the long and famous treatise *Delle macchie Solari* (on sun-spots), the equally famous *Saggiatore*, and the four dialogues in which Salviate, Sagredo and Simplicio, discuss the causes of coherence and the method of finding centres of gravity. An appendix gives an account of the new discovery that projectiles have a parabolic course, and of one of Galileo's first observations. that the pendulum swings in equal times whatever be the arc it describes—a discovery which was fatal to all previous time-keeping appliances, orientations of public monuments, sun-dials, clepsydras, and hour-glasses.

Those who feel that they have added something to the sum of human knowledge can understand the sentiment of Horace, "*Non omnis moriar.*" It was not mere vanity that inspired Archimedes, as, leaping from his bath, he cried "Eureka!" when the principle of specific gravity flashed upon him. It was not an ignoble impulse that animated Bacon, who said, "We build the foundation of the sciences deeper and more securely and begin investigation earlier than man has done before," nor should we irreverently listen to his prayer "that the Father who gave visible light as the first fruits of creation, and at the completion of His work inspired the countenance of man with the light of understanding, would vouchsafe to endow the human race through his hands with gifts of knowledge." When Newton discovered the law of gravitation he was so ecstatic that he had perforce to employ hired service to complete his calculations about meaner subjects. Franklin's chief honours were given him because with his key and kite string he first drew lightning from the clouds. *Fulmen eripuit cœlo* is a juster title to honour than the *Sceptrumque tyrannis* which completes the inscription on his celebrated medal, and none can have felt more justly sure of the so-called immortality of fame than Galileo, when he opened a glorious new vista in the sky. He accomplished for the heavens what Columbus had recently been doing for the Earth. He loosened the clasps of a new volume of nature's records and spread open many of the most beautifully illuminated pages of a missal which, before his time, had been all but closed. From Prometheus to Darwin there is hardly a nobler name. Yet in his lifetime he was not happy, and even now there are some who grudge him his posthumous glories.

It was, of course, time for his discoveries. Leonardo da Vinci made drawings of a combination of lenses for seeing distant things enlarged, long before the Belgian Lippershey produced his telescope, and had not the inspiration come to Galileo to point the magic tube towards the heavenly spheres, it would soon have been done by others, for the

May-time of the modern world was drawing forth the long slumbering energies of mankind. But Leonardo did not put to use the telescope he designed. He locked up in all but undecypherable notes his proofs that the Sun is central and the Earth revolves around it. He was of a procrastinating disposition, and, though divinely gifted in Art, has left all too few exemplars to an admiring world. Therefore Copernicus can justly claim the honour of unlocking the riddle of planetary motions, and Galileo that of bringing the heavens closer to the Earth. There are often more discoverers than one of important facts, quite independent in their work, but the world recognizes him who first makes known his claim and carries on a successful fight for its establishment.

The *Saggiatore* is in this light an instructive document. The title is singular. It means "the assay scales," most delicate of balances, and is in great part a reply to the *Libra Astronomica* of Lotario Sarsi. It leads off with a complaint that the author's desire to serve the world by publishing his discoveries was met with enmity, detraction and fraud. Galileo was angered by the self-sufficient folks who cheapened the value of his work. "Why," he cries, "what a field for admirable speculation was afforded by my letter about solar spots, yet many disbelieved or thought little of it, doubted the correctness of my observations and theories, or imputed to me ridiculous or impossible opinions. One person has even claimed priority in the discovery." He was especially irritated because one Simon Marius, who had in earlier years stolen the idea of his geometrical compass, now claimed to have seen the satellites of Jupiter before him, and published a book, the *Mondo Gioviale*, to say so. The *Saggiatore* was printed in 1623. Later, in 1638, in dedicating his dialogues to the Count de Noailles, Galileo says he had been so confused and stupefied by the bad success of his other works that he once resolved not to print again, but to leave his manuscripts in some public places. His troubles with the Inquisition had, moreover, been followed by partial deafness and total blindness, and it was when thus afflicted that our Milton visited him.* *Paradise Lost* seems to bear evidences of the meeting. In it he dreams of—

—"A spot, like which, perhaps,
Astronomer in the Sun's lucent orb
Through his glazed optic tube yet never saw."

* "There it was that I found and visited the famous Galileo, grown old, a prisoner to the Inquisition, for thinking in astronomy otherwise than the Franciscan and Dominican licencers thought."—Milton's *Areopagitica*.

And, with the poetic instinct, always prophetic, he speaks of the lordly Sun's

—"Magnetic beam, that gently warms
The universe, and to each inward part
With gentle penetration, though unseen,
Shoots invisible virtue, even to the deep."

Milton, himself sightless, remembered Galileo when he cried:

"Seasons return, but not to me returns
Day, or the sweet approach of even or morn,
Or sight of vernal bloom, or summer's rose,
Or flocks or herds, or human face divine—
But cloud instead, and ever-during dark
Surrounds me."

Even in his blindness, however, the great Italian must have found some consolation, as Milton did, in knowing that he had done much to enlighten the world, and posterity has done him justice. The whole Earth has made the assay, and weighed the button of gold correctly, and found Galileo's work entitled to the hall-mark. One would like, did time permit, to dilate on the almost parallel experience of Columbus. But it will be enough to say that when one had found the way across the Atlantic and the other had bridged the sky, they had hosts of followers who enlarged their discoveries. For each in his chosen way stood at the dividing line between the childhood and the youth of knowledge. Each in his sphere broke the leading strings with which the world had been guided, for the time for guidance at the hands of antiquity had passed, new methods and new instruments were needed, new aims animated a re-born world; but while we recognize the fact, and so far from regretting it, are endeavouring as our chief object in this Society to help the progress of the new sciences, we must not forget the respect due to the ancients, who nourished them in infancy.

Let us now issue a new *Sidereal Messenger* and take up the subjects treated in the old tract. We have in our library the first plates of the great Lunar Atlas, the work of Messrs. Loewy and Puiseux, at the Meudon Observatory near Paris. The Society is having them photographed and adapted to lantern slides, believing that in this way we can here extend the liberality of the French Government. Galileo would stand long in wonder if he could see them! He would have to be told of the achromatic telescopes we now can make, with equatorial mounting, moved by clock work, so perfected as to follow the complex apparent motions of the Moon to the smallest fraction of a second in both latitude and longitude. He would have to hear the story of the photographic plate, undreamed of in his time. When he had mastered the elements of the new science of geology, he would perceive he could no longer agree with the Pythagoreans who thought the Moon was like the Earth. For, however carefully we scan these grand lunar maps, we can see no trace of any Neptunian action, no effect that can be referred to the influence of air or water, nothing that resembles the terrestrial layers of limestones, slates or clays. The Moon looks like an aggregation of primitive rocks, and if there have been inundations, they have been those of lava, stiffening quickly in the intense cold of space. The authors of these maps think they see evidence of five successive lava-flows. The lunar mountains, higher in proportion yet not quite so elevated as those of Earth, have been measured as well as mapped, and we are watching with the greatest care for some little change in the stony face, which we think will be noticed, if at all, in connection with the small secondary craters of which there are so many, and will be traceable by comparing later photographs with these, for without air or water there can be no smoke or other of the phenomena usual in terrestrial convulsions. The *maria*, which Galileo thought were places covered by stationary clouds, are now known to be low-lying plains, without mists of any kind, though why they are darker than the hilly regions we do not yet know. How he would enjoy looking at our twin planet with the various forms of telescope invented since his day, though he would find none of them fitted with the combination he employed, which has been relegated to the opera glass alone. It would be news to him to hear of the discovery of planets beyond Saturn, but not surprising to learn that there are moons for all the large planets outside the Earth, for he thought it likely. He knew nothing of the hundreds of Asteroids.

Would it not be delightful for Galileo to discourse with us of light? He devotes a page in his first dialogue to a suggestion for measuring its velocity. He wished to have a lamp put on a distant hill in charge of a confederate, and to place a similar one beside himself. This he intended to suddenly cover up, and when its extinction was noticed afar off, the other observer was to cover his. He tried this method, but only at the distance of a short mile, and he was "unable to decide whether light expanded instantaneously or not, but if not, it was extremely rapid." He says he thought light somewhat resembled sound in its way of moving, but added that he saw difficulties in the way of its traversing a vacuum across the infinite, across the indivisible, across instantaneous motions, and there were other matters to be reasoned out in this connection. Here was the infinite so bounded by numbers as to become unity ; from the indivisible must be born infinite divisibility, a vacuum must become a plenum, and finally the circumference of a circle must be considered as an infinitely long straight line. How gratified he would feel to learn that his own Medicean stars gave the first measure of the velocity of light by the difference of time in the occurrence of their eclipses, when Jupiter was in opposition and conjunction. It is not a little singular that Foucault's experiment, which first measured the velocity of light across terrestrial distances, was really based on his suggested method. Astronomical and physical science has certainly progressed far when we can correctly measure the wave-lengths of variously coloured light with a two foot rule, as our Mr. Chant did in our presence, at a recent meeting of this Society. Now that we have the spectroscope, to combine with the telescope and the photographic film, the science seems to have reached maturity, and is in the plenitude of its powers. Perhaps we may carry on the simile and say that Newton, who first produced the sunlight spectrum in a scientific way, and discovered in gravity the bond which holds all worlds together, married astronomy to physics, so that Urania no longer sits on a solitary eminence. The union has been fruitful, and while some of the intimates of the pair prefer one, and some the other as a friend, all respect them both, and even we, in the very name of our Society, profess to be admirers of the happy conjunction.

Our new *Sidereal Messenger* cannot indeed say that the stars have a perceptible disc, but we know the distances of many of them, we know that they are in rapid motion, that they are of many kinds, in various stages of growth or decay, that they are not all luminous, that some are revolving around each other. We know several of the substances present in their glowing atmospheres and we are engaged in measuring not only the light they emit but the heat we receive from them, and such is the perfection of our instruments, that at the Yerkes Observatory, Mr. Nichols has a radiometer so sensitive that the heat of a candle, 28 kilometres or $17\frac{1}{2}$ miles away, will make it deviate a millimetre. Arcturus gives us no more heat than a common candle 8 or 9 kilometres or 5 miles distant. Yet we can measure it ! What would

Galileo think of the photographic examination of Omega Centauri, in the southern hemisphere, where over 7,000 stars are seen in a luminous patch resembling a faint cloud, and smaller than the Moon, of which we know that 120 are variable?

Galileo was fortunately wrong in thinking he had settled all questions about the Milky Way; it is the subject of more lively interest now than ever. It seems to be the rim of the stellar aggregation of which our Sun forms part, and may be likened to the equator on the globe. Most stars of the first magnitude appear to be disposed in another great belt in a way resembling the ecliptic. The stars of different constitutions seem to be sorted out in layers or streaks, insomuch that a great difference is noted between the actinic and visual light of stars of different galactic latitudes. The most earnest attention of astronomers is now being given to stellar spectroscopy, the precise work being three-fold—the classification of stars according to the type of spectrum they show, the measurement of the wave-lengths of their bright and dark spectral lines, to identify the substances in their atmospheres, and the measurement of the displacement of such spectral lines from the normal, by which the velocity of the stellar motion in the line of sight can be determined. For this, the giant telescopes are used, also for the measurement of close double stars, the spectroscopic and photographic examination of nebulæ and the discovery of new planetary satellites. They are not employed in the work formerly done by smaller instruments, but in that which until their advent could not be done at all, so that the smaller observatories still have their hands full, and there is room even for the ordinary instrument of the amateur. To place this question on its lowest plane, 'tis clear there is no telescope so small that its use will not give a better conception than the unaided eye of the features of the Sun, Moon and stars, and enable its possessor to read with increased interest the works of astronomical writers.

One of the most interesting discussions of the present day is as to the age of our system, and especially of our own planet, which is distinct from the question of the time when man first developed upon it, and equally natural and appropriate at the close of a century. Between the physicists and the students of the natural sciences, the battle rages hotly. At the head of the former stands the illustrious Lord Kelvin, who announced his opinion in 1862, when he was Prof. William Thompson.* From the rate of increase of heat as the miner goes down-

* *Transactions* Royal Society Edinburgh, vol. xxiii.

ward, he reasoned out the rate of secular cooling, and declared that our Earth must be more than twenty but less than four hundred millions of years old. This argument has been reinforced by one depending on the retardation of the Earth's rotation by tidal friction, and another on the limitation of the age of the Sun. Lord Kelvin has, therefore, reduced his maximum to "not much more than twenty millions." The contest is by no means new. In the Atlantean myth are clear traces that the geologists of pre-Christian days required great lapses of time between deluge and deluge. That great geologist Hugh Miller, though a cataclysmist, a believer in the sudden destruction of whole races of living beings by terrestrial catastrophes, in beautiful and forcible English almost unequalled in our literature, proved the existence of life during incalculable æons. It is, therefore, historically right that the geologists of to-day, under the banner of Sir Archibald Geikie, should have taken up the gage of battle against Lord Kelvin, for themselves as well as the biologists. Nor is the subject unimportant, for if the sciences are true, they must be concordant, and it is needful, in the warfare of true knowledge against superstition, which is surviving ignorance, that divergences should be removed, as removed they cannot fail to be. The whole of Sir Archibald's address to the British Association, 1899, ought to be read by all interested in the subject; but I will quote a few sentences now.

"Even in the most ancient of the sedimentary registers of the Earth's history, not only is there no evidence of colossal floods, tides and denudation, but there is incontrovertible proof of continuous orderly deposition, such as may be witnessed to-day in any quarter of the globe. * * The conclusions drawn from the nature and arrangement of the sediments are corroborated and much extended by the structure and manner of entombment of the enclosed organic remains. * * Undoubtedly, most impressive of all the palæontological data is the testimony borne by the grand succession of organic remains among the stratified rocks as to the vast duration of time required for their evolution. * * So far as I have been able to form an opinion, one hundred millions of years would suffice for that portion of the history which is registered in the stratified rocks of the crust. But if the palæontologists find such a period too narrow for their requirements, I can see no reason on the geological side why they should not be at liberty to enlarge it as far as they may find needful for the evolution of organized existence on the globe."

Sir Archibald proceeds to regret the absence of numerical data, to form a satisfactory basis to compute the rate of denudation, and asks for the aid of all who can furnish any, as to the wearing away of coasts, the decay of buildings, and even of tombstones. I feel called upon to respond to his request with a new rule for measurement.

Our West Algoma is a severely glaciated region, in which none but archæan rocks remain, and many gold-bearing reefs have been exposed. Since the ice-cap left, the surface has been decaying, and the greater part of the aluminous and siliceous constituents of the rocks has been removed by water and wind. But the particles of gold, which are not destructible and are of too high a specific gravity to be blown away or carried off by trickling rain, have, in favourable places, been left, and I had a number of assays made last summer from one such spot. The gold contents of the reef, when "the solid" was reached, were about $3.50 to the ton, but the thin surface soil assayed $100, and, for several inches down, the fine particles of the precious metal had "crawled" into the crevices, enriching this surface rock to about $12. Averaging the gold contents of half a foot in depth at $25 to the ton, there must have been an erosion of nearly eight feet, to yield the values. Now, in 1875, I raised a large gneiss boulder to the surface of my grounds in Toronto, since which there has been a noticeable decay, but it cannot exceed the twentieth part of an inch. If the Algoma rocks have been disintegrated at this rate, it would have taken 6,000 years to wear away a foot, and nearly 50,000 years to erode the eight feet in question. I once measured the amount of detritus carried away by the creek which ran below the plateau where I live, by taking given quantities of its turbid water in times of freshet and measuring the sediment. Assuming continuity of conditions, I found it must have taken 70,000 years to excavate the valley of that Rosedale brook, and I argued that if the geological theory were true and the removal of a glacier-dam at the foot of Lake Ontario had caused the fall of its water-level, this was the time that had elapsed since the ice age here. As the ice must have left this latitude and elevation before it left Algoma, the calculations tally fairly, which may indeed be fortuitous, but it is only by averaging reasonable calculations that a safe estimate can be reached. I do not think the time given for the decay of a foot of granite should cause incredulity. I have seen the Pont du Gard, in France, built about 1,700 years ago, and the great stones there have not decayed three inches. The climate there is perhaps the less severe, but I think the material is limestone, which can scarcely be so durable as granite. But do rocks, covered lightly by the product of their own decay and by vegetation, take longer to wear away than those uncovered, and does much interior decay proceed along with exterior weathering? An affirmative answer to both these questions would perhaps not much change the result obtained; but, until they and many others can be answered, much doubt will envelop the subject, and the limits of possible error will have an enormous superior range.

But as no marked biological changes have been noted in that portion of the quaternary period which is subsequent to the ice age here, the disappearance of the ice-cap must be geologically very recent. A hundred times as much would be all too short for the evolution of present forms of life from its first beginnings in early stratified rocks, below which we have tens of thousands of feet more of strata in which no traces of life are visible. I myself measured 30,000 feet of the early Cambrian black slates exposed on the north-west of Lake Superior, and searched for many weeks for traces of life therein, without finding any. Only after these do we come to the archæan formations, of unknown thickness! It does seem, fain though I am to take sides with the physicists, that there is some error in their computations, of omission or assumption, and that this world is almost from everlasting, while almost to everlasting it must go on, as indeed they themselves prove.

Lord Kelvin's argument, however, like everything emanating from him, is beautifully simple. He adopts Fourier's analysis of the following problem:—Given, an infinite plane dividing an infinitely large solid mass, with different constant temperatures on each side of the plane (at the beginning of an epoch). What will be the rate of variation from point to point, and the actual temperature at any point? He shows that in the case of a globe 8,000 miles through, the surface may be considered as such a plane, and the depth infinite, without sensible error for more than a thousand millions of years. We thus have an equation into which there enter as elements the initial temperatures, the time, the distance of any point from the given plane and the temperature of that point at the time, also the conductivity of the solid. A tyro in differentials can follow the "mathematical poem" throughout. Assuming time to be a hundred million years, the conductivity, in relation to specific heat, the same as that of Edinburgh rocks; and the temperature 7,000° hotter than the present surface, the rate of increase works out one fifty-first part of a degree per foot for the first hundred thousand feet or so, such rate then rapidly decreasing. The chief variation allowable is in the function of the conductivity, and this, diminished by half or increased by one-half, gives the superior and inferior limits first alluded to by Sir Arch. Geikie. What new fact has induced Lord Kelvin to reduce his estimate I do not yet know. The effective temperature of the Sun is stated in the *Astrophysical* Journal for August, 1899, as 11,300° Centigrade, which equals 20,340° Fahr., and if the Earth had at the first a heat approaching this, and the cooled surface did not sink, as Lord Kelvin assumes it did, until by convection the temperature was so much reduced that the Earth became practically a solid—if, moreover, the protection given by its atmosphere of many miles introduces a neglected element into the Fourier problem—it may be that even Lord Kelvin's estimate will be again revised and meet biological requirements. The extension of our thermometrical range by Dewar's apparatus in London, and Moissan's electric furnace in Paris, has made it possible to study the behaviour of substances under conditions of cold and heat respectively, which could not be produced until now. In our immediate neighbourhood are great factories of carbides of calcium and silicon. It is possible that much of our world's original carbon is in the shape of carbides down below. Some of their known qualities may determine the position of active volcanoes which are all near oceans, and otherwise influence miners' experiences as to increasing heat.

Some progress has been made in the enquiry into the synchronism between magnetic storms on the Earth and changes in the luminosity of comets, and this being a discovery of my own, first announced to this Society, I venture to descant upon it here.

If a magnetised bar be suspended at right angles to the magnetic meridian, one force with which it strains towards its normal position, parallel with that meridian, is called the Horizontal Force, while if it be so pivoted as to oscillate up and down, the strain with which it dips towards the magnetic pole is called the Vertical Force. The third element, Declination, involving the angle between the geographical and magnetic meridians, is possibly of little importance in this connection. These forces vary, like the wind, from hour to hour, and when the variation is rapid and continuous and considerable, we have what is called a magnetic storm. Some years the magnets are stolidly quiescent, in others they show frequent and striking signs of great agitation. and it has been found that the measure of annual disturbance in the Sun, obtained from records of the areas of its spots, corresponds with the measure of the disturbance of our magnets. This was first noted by Sir Edward Sabine, when, in 1851, he was discussing the magnetic observations at Toronto and Hobarton from 1843 to 1848, and found in both a progressive increase of disturbance. Schwabe had just then published his tables of sun-spot frequency, which showed an increase of spot areas during those very years. Mr. Ellis has published diagrams in the *Proceedings* of the Royal Society which establish this concordance to the present date.

The delusion that sun-spots are the causes of magnetic disturbance must be dispelled. Many of our magnetic storms can be traced on the records as in process of preparation for months before the appearance of a sun-spot, appearing as slighter but very evident disturbances at previous periods, measured by the length of the Sun's synodical rotation. Thus the sun-spots can only be an effect of some cause which also makes the magnets tremble. The frequently coincident appearance of great sun-spots and magnetic disturbances shows indeed that there is a bond of relationship between them, but no rule obtains as to the position of the spot on the solar disc. At the crisis of the storm, the spot may or may not have reached or passed centrality.

Other phenomena are associated with these disturbances. The auroral curve is intimately connected with those of Magnetic Forces. The number of thunder-storms is said to be influenced by them too. In the *Comptes Rendus* of June 26th, is a table of the number of earthquakes in Greece, from 1893 to 1898, which follow fairly well the descending curve of sun-spots, for that period. In the *Monthly Weather Review* for April, the eruptions of Mauna Loa are reported to coincide approximately with sun-spot minima, and the same thing has been said about the eruptions of Ætna, though further statistics are needed in both cases. I do not find any agreement in the case of the Philipine islands' volcanoes. Mr. C. Parkinson, writing in a recent *Cornhill* of phosphorescence in the ocean, says that "on certain nights the entire marine fauna pulsates with a mysterious incandescent force suggestive of some connection with the magnetic currents of the universe."

If now we can sustain the assertion that comets feel this influence at the same time that Sun and Earth do, we locate the origin of the disturbances in the Sun—not in the region of cosmic space through which the system is passing.

In Prof. Barnard's account of the breaking up of Brooke's comet of 1893, October 22nd and following days, he says it seemed as if the body was passing through some resisting medium in space. On turning to the magnetic records I found a great disturbance from the 23rd to the 25th, and that was the most disturbed period of a year of great disturbances, just before a sun-spot maximum, and I thought solar influence might be found to explain the change in the comet more plausibly than floating cosmic matter. Additional researches gave colour to this view, and in our *Transactions* for last year, page 136, are some confirmatory notes, especially respecting Eucke's comet in 1871, just after a solar spot-maximum, and Donati's in 1858, when a maximum was close at hand. Mr. Elvins subsequently drew my attention to Swift's comet, 1892, I; as described by him in the Canadian Magazine. April 6th the comet seemed very bright and on the 7th the tail was torn up. There was a magnetic disturbance from the 5th to the 7th, not very severe, but the sun-spot maximum was close at hand. I then wrote to Prof. H. Krentz, the Director of the Astronomical Central Record Office at Kiel, who had the kind civility to reply at length, stating that the idea was new, but referring me to a paper of Prof. Berberich's in the *Astronomische Nachrichten* for 1888, in which that distinguished astronomer had treated of a relation between the brilliancy of Encke's comet at its successive visits and the number of sun-spots existing at these times. He had the further goodness to send me three recorded instances of sudden changes in comets, and enquired how they fitted in with the theory advanced. They were comet Pons-Brooks, 1884, I, which showed a sudden change in brightness on September 21st, 23rd, 1883; comet 1888, I, which changed its appearance suddenly, May 20th-21st; and comet 1892, III, Holmes, in which "from a simple mass of nebulous matter without a nucleus, there suddenly developed on January 16th, 1893, a bright nucleus surrounded by nebulous matter, which after some time disappeared." I find with respect to the Pons-Brooks comet that the observations, of which we have a full account in the pamphlets of our late Honorary member, Father Terby, of Louvain, were very imperfect, owing to continuous bad weather. The comet seems to have been very variable, and the magnetic weather was most variable too. There was a very great storm from the 15th to the 27th September, the greatest violence being however, before and after the date given for the cometic change. Comet

1888, I, gives a much more distinct confirmation of my views, for on the 20th May, the day mentioned by Prof. Kreutz, the greatest depression of the year occurred in the curve of Horizontal Force, and one of the most remarkable magnetic storms known was accompanied by one of the most brilliant auroræ all over the world. Though it was at a sun-spot minimum, there was a large regular spot on the Sun followed by many others in an irregular stream, the whole in a state of constant change. The spotted areas for May and the two months preceding and following, were:—

1888	March	April	May	June	July
Umbræ.....	5	4	37	5	3
Whole spots..	34	26	206	36	25

The principal spot, first seen on May 11th and last observed on the 23rd, was 37° past the central solar meridian by noon on the 20th, Greenwich civil time.

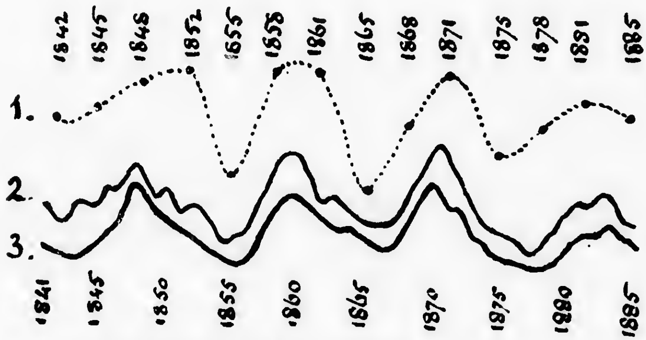
It only needs a few more of such striking coincidences to establish my theory beyond a shadow of doubt.

It must be admitted that no marked depression occurred on January 16th, 1893, the date given for a change in the comet Holmes;* there was indeed an increase of Horizontal Force on the previous day. But a great variability in the comet is recorded, as well as a much disturbed magnetic curve in November and December, 1892, the S S. maximum then fast approaching. As meteoric stones are known to vary in composition, so comets perhaps vary too, and all may not be equally susceptible to the particular solar influence which produces the brightening or dispersion of their appendages.

As showing the effect of this influence on another body than the Earth, I must refer to Leo Brenner's observation of Mercury on May 18th, 1896, when he was astonished to see the dark side of the planet surrounded by a beautiful aureole. To make sure it was not an illusion, he called Madame Manola to the telescope. That day was the crisis of a magnetic storm upon the Earth. He has promised to send me a list of the days when he has seen aureoles around the dark side of Venus, a much more frequent phenomenon, that I may see if they are coincident with magnetic disturbances.

* In the *Transactions Royal Society* for March, 1893, page 332, the accounts given of this comet for January and February do not agree with those of the *Nachrichten.* The only sign of a tail alluded to is on January 27th and February 4th, when there were depressions in the Horizontal Force curve.

Berberich's paper on Encke's comet gives data as to its brightness from 1786 to 1885. The intensity it ought to show is given by the formula $I = \frac{1}{r^2 D^2}$ where r is the distance of the comet from the Sun and D its distance from the Earth. After carefully reading the accounts he gives of its observed brightness, I have assigned to them numerical values from 1 to 10, placing a concordance with the average between 5 and 6, and have constructed a curve therefrom, which agrees remarkably with the Ellis curves of magnetic Horizontal Force and of sun-spot areas. Berberich thinks a higher power of r should be used to bring calculated intensity into accord with what we see when the comet is bright. I suggest adding instead another factor, connected with magnetic stresses, and I hope to find what it should be. I do not doubt that other periodical comets are most luminous at times of great magnetic disturbance, or that more comets can be observed in such seasons. That is, however, a different phenomenon from what I have noted, viz., the immediate effect upon some comets of particular magnetic storms.



No. 1 is the curve for brillancy of Encke's Comet.
No. 2 is the curve of Hor. Magnetic Force.
No. 3 is the curve of sun-spot areas.

The second and third from Mr. Ellis paper; the first prepared from Berberich's descriptions by the author.

Last year was not an *annus mirabilis* for observational astronomy. The Sun was almost clear of spots. The planets were not in very favourable positions. No large new stars blazed out. Comets were few and small. Even the November meteors were disappointing. Here it was generally cloudy and I saw through the drifting clouds but one, which was not a Leonid, as it came from Cancer and crossed the barely visible sickle in Leo. It is a beautiful sight to see a large shooting star through a haze or mist. Dr. Larratt Smith observed one such, in January last, which shot upwards from a radiant below the horizon, and Mr. Gordon Mowat reports seeing one through a cloud which shut other stars from view. The observatory at Meudon collected Leonid notes from Delhi in India to San Francisco, and observers all reported a paucity of meteors. The calculation of Leverrier was thus verified, that after the fine display of 1866, the Leonid ring would pass near enough to Jupiter and Saturn to have its orbit changed, and no confocal stream supplied its place, which seems to prove that the meteor-roadway of the ortho-Leonids is comparatively narrow. It is thought the star-shower will be more brilliant in November next. Remarkable observations were, however, made from balloons, two of which were sent up from Paris and three from other places to see the Leonids from above the clouds. Miss Klumpke, an *attachée* of Meudon, was one of the aeronants. Balloon observations afford several advantages. The stars shine brighter when seen from above the mists of Earth. Notwithstanding the light of the nearly full Moon, all the stars in Leo Minor could be well seen, and the colours of the meteors were far better marked. Only minutes were noted, as no chronometer was taken up, but in future ascents, when the omission will be made good, comparisons both as to colour and brilliancy can be made with observations from *terra firma*. The course of such balloons, ascertained by compass, can be checked by dropping weighted cards. The Perseid stream, of August, as important in its bearing on meteoric astronomy as the Leonid ring, was well observed in Europe, the average number of meteors during five days being about 100 an hour; and from a simple calculation we can obtain a very fair idea of the celestial spaces involved in the display. The Earth is 8,000 miles through, and rushes across the meteor-stream with a front we may estimate as equal to a plane of fifty million of miles in area. Supposing an observer can see 35 miles in every direction, he covers about 5,000 square miles, so that ten thousand stations would be needed to see all the meteors that fell. Now a hundred an hour, at ten thousand stations, for five days, means a hundred and twenty million meteorites. Again, the orbit traversed by the Earth in a year is about six hundred millions of miles long, so that in five days, the Earth would have crossed eight millions of miles, which is the breadth of the thickly starred part of the Perseid stream—the only necessary allowance being for the angle at which the orbits of the Earth and of the meteors intersect. Further, the Earth travels its own diameter-length in about seven minutes, so that the plane of fifty million miles with its ten thousand stations met within the space traversed in that time 120,000 meteors, and each one must have been flying along over thirty miles, on the average, from its neighbours.

Though experienced star-gazers may remember more splendid transitory sights than those of last year, observers who are young, either from years or from newly kindled interest (and of such there is a fresh crop every season) have had enough to stimulate them. They have enjoyed what some of us have long since lost; the exquisite luxury of vivid first impressions. The bright diamonds which attend on Jupiter can be seen every year with quite small telescopes; so, too, can the wonderful Saturnian microcosm. Double stars and nebulæ are always with us, I was about to say unchanged, but that is not the case; companion stars circle about each other, while changes in the form and relative brightness of parts of some nebulæ are thought to be noticeable also. The Moon is only inconstant in a Shakespearean sense, she is an object of transcendent loveliness of which old astronomers never tire; I know not whether she is more beautiful when the lace-like edge of the cresent shows like a fringe between the glare of her sunrise and the darkness of her half-month-long night—when she shines full upon us, a silvery, shadowless sphere—or when, the veil of eclipse thrown over her, she is coloured with the lovely bronze and blue tints of diffracted light.

Though passing shows have been few, there has been no pause in the progress of our science. Wonderful news reaches us from the mountain tops, where the clearest seeing is. The observatories there are in an astronomical fairy land, where the visible stars are brighter than below, and doubles shine with colours like "combinations of garnets and sapphires, topazes and rubies."

Schaeberle, at the Lick telescope, has seen, of a dull purple, the massive companion to Procyon, previously only known to exist by inference, like many other so-called dark stars. The companion to

Sirius is calculated to be of great size and weight, and it is very obscure. It was first seen by Alvan G. Clark in 1862, and has lately been almost in line with its principal, but now emerges. Its orbit is described in 52·20 years. The chief companion to Algol goes round in less than three days.*

Prof. See suggests that dark stars seem to be so because they shine with vibrations our optic nerves cannot respond to—say of the ultra-violet type. They may in such case be hereafter caught on a well focussed photographic plate, which is sensitive to vibrations the eye cannot perceive. Phœbe, the new ninth satellite of Saturn, was so found, and has not yet been distinguished by direct vision. It is the most distant of his family, just within the limit of permanent attraction, and quite small, showing only as a 15·5 magnitude starlet.

More asteroids have been "located." The first, Ceres, was discovered on the first of January, 1801, by Piazzi, at Palermo. The eccentric Eros, first known as D. Q. (No. 433), was introduced to his elders in 1898, and now we have E.W., which means that thirty have been found since then. The family group is now so large that when new members are caught, they are turned loose again, unless their orbits present some noticeable peculiarity.

Spectroscopists have scored another triumph in the discovery of a layer of carbon in the Sun. Prof. G. E. Hale and Mr. F. Ellerman, of the Yerkes Observatory, announce that they have found it at the base of the chromosphere, a very thin envelope, but unmistakeable. Only instruments of the highest power have revealed its existence. Non-telescopic spectroscopists rejoice in the discovery of vanadium in almost all stony meteorites, while it is absent from siderites, which they consider proves diversity in their origin.

Physicists are to the fore with an explanation of transparency, based, if I understand Mr. Sarzac aright, on the arrangement of the particles in the medium and on its elasticity. Light-waves, striking the surface of glass, water, or the like, force back its particles and communicate successive vibrations, which, if the thickness be not sufficient to absorb

*It is interesting to compare these periods with those of bodies such as one of the components of the double-double ϵ Lyræ, which takes 900 years to revolve, or the comet of 1811 which is calculated to have an elliptical orbit with a period of nearly 2,000 years.

the impulses, are transmitted by the second surface to the ether on the other side. Transparency, and the index of refraction, depend on the arrangement of the particles in such a method as to propagate wave motion harmoniously. The communication has recently been made to the French Academy.

In Radiography we now speak of Russel rays and Becquerel rays in addition to those of Roentgen. It is suspected indeed that all matter, including the human body, emits influences which will affect a sensitized plate, if kept in darkness for a sufficient time. Until last year uranium was thought to be the substance whose emanations most rapidly affected the film; it was displaced by radium, but Madame Curie's discovery of polonium gives us a metal which has four hundred times as much energy, and that without apparent exciting cause or perceptible diminution. Radium is even more energetic, with this remarkable difference, that its influence is affected by an electro-magnetic field, whereas the radiations of polonium seem not to be deflected thereby. This new science has already many applications, the latest being a proposal of Dr. Kolle's, in the *Electrical Engineer*, to supersede some of the processes of typography.

I do not know under what head to class the announcement by Mr. Chas. Honoré, of Montevideo, that the body of the sun, interior to the photosphere, rotates somewhat more rapidly than the visible exterior, and on an axis inclined to that we see evidence of. He promised proof, and thinks that periodicites in the phenomena of temperature and earthquake can be referred to this helio-thermic year.

We have had some very interesting records from the Toronto seismograph. The instrument is of the Milne type, only intended to show the time at which shocks occur, to aid in studying the rapidity of the transmission of tremors, and thus learning something more about the effective rigidity of the Earth. It is not meant to show the character of the oscillations, but it does to some extent show their violence. In 1898 it gave us notes of 28 earthquakes, and in 1899 of 37, the excess being probably due to its improved setting. Of these no less than 29 were in September last. It seems by the tracings that for several days the Earth was constantly shivering until on September 10th at 17h. 11′ 56″ Greenwich mean time a great throe began. The record from Victoria, B.C., miscarried in the mails, so we lack the most interesting comparison, but at Kew the first tremor was 3 minutes 7 seconds later. The maximum was noted here at 20h. 42′ 14″ Greenwich mean time, and at Kew 24 minutes 42 seconds later. Another great shake began at 20h. 42′ 14″ Greenwich mean time, with a maximum at 22h. 3′ 6″. Mr. Stupart, the director of our observatory, has kindly given me the tracings, and I show you that of the last great shock. The whole disturbance lasted for nine hours, though it was some days before absolute quiet reigned. The centre of disturbance was near Mount St. Elias, in North-western Canada, but as the Americans own the Pacific coast-line there, we shall hereafter read of it as the great Alaska earthquake. The local effects were terrifying and the region affected by the shocks was 4,000 miles or more in diameter. The contour of the coast-line was permanently changed, parts of islands being swallowed up and well-known land-marks having disappeared. Tidal waves rushed in from the ocean, the waters on submerged reefs were violently agitated and shaken into foam, the waters of inland lakes were let loose, and the sparse Indian inhabitants of the region were greatly frightened. The Rev. S. Jackson, Superintendent of Education of Alaska, was at Yakutat Bay, to which some panic-stricken people fled, and we may expect the full details next summer. Dawson City was badly shaken too. The most extraordinary effect seems to have been the changing of the face of every glacier on the coast, the Muir glacier with the rest, the ice having been fractured for a mile or more from the sea and having slid or been cast into it.

In the immediate future we are looking forward to the sun-eclipse of May 28th next. Expeditions are being organized on the other side of the Atlantic for its thorough observation, especially in Algiers, while on this side, observers will favour Georgia and Alabama, where at that time the least interference from clouds is to be expected, and the chance of a clear sky is seven or eight to one. The corona will not be widely extended, the carmine prominences will probably be small and few, but both, as well as other usual phenomena of total eclipses, will be as interesting as they are rare, including the onrush of the Moon's shadow over the Earth, the mysterious grandeur of which is alone worth going South to see.

I must not close without alluding to the progress of time reform, in which this Society has always taken a deep interest. "One of the great reforms of the last twenty years," says the *Weather Review* of Washington, "has been silently advancing. * * This amounts really to an international agreement that longitude and time shall be as far as practicable referred to the Greenwich meridian. * * Thus, in the Atlantic States, we use seventy-fifth meridian time, but in the Mississippi river water-shed, ninetieth meridian time, except, perhaps, in the western portion, where the one hundred and fifth is adopted," as it is on the Pacific. The same is the case in Canada, and the system is spreading on the other hemisphere. We have not yet succeeded in having the twenty-four hour notation commonly used, or in having astronomical and civil time brought together, the former still beginning its day at noon. The French *Annuaire du Bureau des Longitudes* has, however, this year adopted mean civil time, from 0h. to 24h., and astronomers there will have to fall into line. But a still more important change is perhaps being accomplished, as I speak, viz., the adoption in Russia of the Gregorian reform of the calendar, which dates from 1582. Ten days were omitted from the year when first the reform was instituted at Rome, eleven when England adopted it, in 1752, and the Russians will now have to omit thirteen. Reports being as yet contradictory, we are not yet sure. Some say the difficulties in connection with regulating church festivals are insuperable. It seems curious that time reckoning, which is strictly a matter of astronomy, should be made a matter of religion. It is however proposed that on January 1st, 1901 all Christendom shall date its letters on the same day and month. Then, on to Cosmic time, when every clock will be set to the same hour and minute! The greatest feature of the past century has been the general acknowledgment that one law, one common nature, one evolutionary system pervades not only this world but all others, and surely one law as to weights and measures, especially that of time, ought to be observed among men.

And now, in the last year of the century, in the last year of the Society's first decade, with my last words as your President, I think I ought to express the satisfaction we must feel in looking back over our own particular little day. From being peripatetic wanderers, we have become a settled institution, having comfortable quarters under the roof of the Canadian Institute. Our special room is decently furnished. Our library is fast growing into value, our volumes are properly bound, well arranged and catalogued, and I do hope the Society will continue the assiduous care of this department, for though the heavens are our chief books, written in pandemic language, and their suzerainty is ever preferable to that of the printed page, we need many others as commentaries upon them. Our *Transactions* have been regularly issued and have been well received at home and abroad. We are free from debt. Our organization has worked smoothly, our officers have been earnest and faithful, and our future seems as bright as we can reasonably wish. I received my trust from a model President, I surrender it to a capable and respected member. In the hands of Mr. G. E. Lumsden, F.R.A.S., the dignity of the position will not be impaired, and he will repay you for the honour conferred upon him with no less loving service than his predecessors.