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744TH ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL WESTMINSTER, S.W.1, ON MONDAY, MARCH 16TH, 1931,

AT 4.30 P.M.

LIEUT.-COL. T. C. SKINNER, F.R.Met.Soc. (LATE R.E.), IN THE CHAIR.

The Minutes of the previous Meeting were read, confirmed, and signed, and the HON. SECRETARY announced the election of the following:—As Associates: The Rev. Russell B. White, M.A., James Payne, Esq., and B. W. Leefe, Esq.

The CHAIRMAN, explaining with regret the author's inability to be present owing to distance, invited Lieut.-Col. J. H. Murray, R.E. (ret.), to read Colonel Molesworth's paper on "The History of Practical Astronomy."

HISTORY OF PRACTICAL ASTRONOMY.

By COLONEL F. C. MOLESWORTH (LATE R.E.), F.R.A.S.

THE object of this lecture is to recite briefly how the modern practical uses of astronomy grew out of the observations of the ancients.

I think one may say with tolerable certainty that man's first deliberate astronomical observation was that of the sun, in order to ascertain how the day was passing. This is obvious enough; the hunter wanted to know whether it was time to set out for a distant hunting-ground; the cultivator wanted to know whether it was time to cease work and start for home; the servant "earnestly desired the shadow." One and all would make use of the shadows of natural objects—trees or distant hills.

But in featureless countries, some artificial arrangement would be found necessary, and so the first sun-dial would be invented. With it would come the desirability of dividing the day into equal parts. When and by whom this was first effected is now difficult to say. In Old Testament times, the only subdivision of the day or night is the "watch," at first a third, and then a fourth, of the twelve hours. The expression "hour" in the book of Daniel is a translation of the Chaldean *sha'ah*, meaning an instant of time.

The Babylonians had, however, a subdivision known as *kasbu*, a twelfth of a solar day, or two hours. Whether they were the originators of this measurement cannot be said, but by the first century A.D., a reckoning in hours as we know them had spread over the then civilized world. "Are there not twelve hours in the day?"

The first portable sun-dial, as distinct from the gnomon, is said to have been invented by Berosus, the Babylonian astronomer, about 340 B.C. It would take too long to trace the history of the sun-dial, even briefly; it was early confronted by serious rivals, such as the water-clock; it could not tell the time at night, or on a cloudy day. It took no account of the "equation of time" and so might be as much as 16 minutes out in its reckoning. So, naturally, the invention of modern clocks and watches relegated it to the toy department. In its time, however, it served a useful purpose.

Turning now to man's first lunar observations, it is commonly supposed that the lunar calendar preceded the solar. In the nomadic and pastoral stages of his existence, the changes of the moon would make a greater impression on man's senses than the much slower changes in the altitude of the sun and the variation in its heat. Full moon facilitated his hunting operations, the nocturnal movement of his flocks and herds, the guarding of his camp, and so on. Particularly would this be the case in lower latitudes, where the difference in the seasons is not so marked as in the North. Primitive peoples still talk of an event having happened so many moons ago.

The month began, by general though not universal consent, with the first appearance of the crescent moon in the evening sky, as it does in Mussulman countries to this day. The inconvenience of this arrangement is obvious. To take an example, Ramadhan, the month of fasting, ends with the appearance of the new moon of the following month. It cannot be predicted with absolute accuracy on which of two successive evenings this will occur. The day following the appearance of the moon is a holiday. It cannot therefore be foretold until late the previous evening, which day will be a holiday. Imagine similar uncertainty regarding the date of our August Bank Holiday! The custom is, however, based on the Qur'an, and so is not likely to alter.

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The technical expression for the period occupied by the moon in undergoing its changes is known as a "lunation."

Bad weather conditions, even in better climates than our own, may defer the appearance of a new moon until it is two or three days old, with further inconvenience to the calendar. Thus, we read of a total eclipse of the sun taking place at Babylon on the 26th day of Sivan; in other words, the new moon that month could not have been visible until it was three days old. The eclipse has been identified with that of July 31st, 1053 B.C.

The actual sighting of the new moon became, therefore, an observation of great importance. In Babylonia it was associated with moon-worship. In Israel it was a day of festival.

The Sanhedrim used to sit in the Hall of Polished Stones to receive the evidence of credible witnesses that they had seen the new moon. They then decided whether the month just ended was to be of 30 days or "perfect," or of 29 days and "imperfect."

The Assyrians, long before this time, had an ingenious arrangement by which they predicted, from the relative positions of the sun and moon, when the next new moon would be visible.

In Muhammadan countries, the new moon at the end of Ramadhan is eagerly looked for by amateur astronomers on every hillock, roof, or minaret. The telegraph has, of course, made this a work of supererogation, since the moon's appearance in one place is wired all over the country, and the devout Mussulman is nowhere enjoined that his observation need be personal.

The month and the day are not commensurable; the average duration of a lunation is 29 days 12 hours 44 minutes and 3 seconds and a fraction. If therefore the months were made alternately 29 and 30 days in length, a working arrangement could be made which need not depend on actual observations; such an arrangement could persist for a generation without being seriously in conflict with theory. The Romans had an arrangement of this kind, and it is from this that our calendar, with its varying number of days in a month, is derived.

Some subdivision of the month must very soon have been seen to be necessary, and it is commonly, but I think erroneously, supposed that the week was the result of dividing the month into quarters. Four weeks of seven days each still leave more than a day and a half to be accounted for, and, as far back as records go, there is no trace of an intercalary day or days in the month.

The Romans divided the month in a way which seems curiously unpractical for such a practical race ; about the beginning of the Christian era they adopted the week of seven days, an institution of Hebrew, and most of us will agree, of Divine origin. It is noteworthy, however, that the expression "week," where first used in the Authorised Version of the English Bible, refers to a period of seven years (Gen. xxix, 27), although the collective "seven days" occurs frequently before that passage.

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It is not to be assumed that the year is not also a very ancient measure of time. We find the year in use as a measure as far back as records go ; the ages of the patriarchs in Gen. v, are given in years, and the juxtaposition of the terms year, month, and day, with approximately their relative values, in the Biblical account of the Flood, to which we shall refer later, precludes us from regarding them as anything other than what we regard them as now. In this connection it is noteworthy that Josephus (*Ant.* I, i, 3) states that "those that lived then noted down with great accuracy both the births and deaths of illustrious men."

It must have been discovered very early in history that the month and the year were not commensurable ; about $12\frac{1}{3}$ months go to the year. This incommensurability has given rise to the principal calendars in use, *viz.*, the solar, luni-solar, and lunar.

The measurement of time by lunar years, still in force in Mussulman countries, suffers from the disadvantage that it is impossible to use it as a guide for the sowing of crops and other agricultural and pastoral activities. Each year begins ten days earlier in the season than its predecessor. Agricultural nations, if they ever used it, soon gave it up for a solar year.

Here it may be mentioned that in some Muhammadan countries—Persia, for example—a solar calendar lies submerged beneath a lunar one. The *Nau Ruz*, or New Year's day, occurs there at the vernal equinox, whatever the month or day of the month may be.

In a luni-solar calendar the lunation and the solar year are both in use, an intercalary month at different periods effecting adjustment. A thirteenth month to the year becomes necessary every third year or so. The Jews adopted an intercalary month Ve-Adar.

The narrative of the Flood throws considerable light on the calendar in use in early times. A very remarkable series of dates occurs in Gen. vii and viii :—

vii, 11. 600th year, 2nd month, 17th day. Flood begins.
vii, 12. 40 days rain.
vii, 24 (included in 150 days flood).
viii, 4. 7th month, 17th day. Ark rests.
viii, 5. 10th month, 1st day. Tops of mountains seen.
viii, 6. 40 days. Raven and dove sent out.
viii, 10. 7 days. Dove sent out.
viii, 12. 7 days. Dove sent out for last time.
viii, 13. 601st year, 1st month, 1st day. Waters dried up.
viii, 14. 601st year, 2nd month, 27th day. Earth dried up.

There are certain noticeable points in the above : Firstly, it is almost impossible to resist the conclusion that Noah kept a log. Five specific dates are mentioned, as well as five periods of time varying from seven days to 150 days. Such exact dating does not again recur in the Bible for over 1,000 years, until the Exodus. Secondly, the period of 150 days is mentioned as equivalent to five months. It is not therefore to be assumed that the month was then fixed at thirty days ; with stormy skies dead reckoning would no doubt be employed, and the month calculated irrespective of the appearance of the new moon. Thirdly, the total duration of the Flood is 365 days, or a solar year, but whether this is anything more than coincidence is doubtful. Fourthly, the months had not yet been named, or, if named, the system of recognition by ordinals was in more common use. But if, with Josephus, we assume that the months of the years of Noah's life coincided with those of the calendar year, the date of the stranding of the Ark would have been the 17th of Nisan, consequently very close to our Easter day.

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The Jewish calendar year was 355 days in length, with a leap year of 385 days every third year. At what period in Jewish history this calendar was adopted is uncertain but the calendar in use at the Exodus persists to this day, with the one alteration that the first month, originally Nisan (Exod. xii, 2) was changed in the second century A.D. to Tishri, formerly the seventh month of the year. With such an arrangement it would be found in a short time that a leap year every third year was slightly inaccurate, and that seven leap years in every nineteen was a better guide.

The question would always arise as to when to insert the intercalary year. The Hebrews solved the question by watching the progress of the growing grain. To quote Maunder (*Astronomy of the Bible*, p. 307): "If at one new moon in spring time it appeared clear that some of the barley would be ready in a fortnight for the offering of the green ears at the feast of unleavened bread, then it was taken as beginning the new year. If it appeared doubtful if it would be ready, or certain that it would not be, then the next new moon was waited for."

Among the Babylonians, another method of fixing the beginning of the year was in use, the simplicity as well as the accuracy of which we cannot fail to admire. The heliacal rising of certain stars was observed, that is to say, the first time in the year that a star was visible in the brightening twilight. In clear skies this would give a very exact method of determining the length of the solar year. Such observations naturally associated certain constellations with the weather. Thus the Pleiades became associated with rain. The heliacal rising of the Pleiades at the time when the constellations were designed took place in April, and it has been suggested that the "sweet influences" referred to in Job typified the return of spring. In our own country we talk of the dog-days, *i.e.* the period in July and August when the dog-star, Sirius, rises and sets with the sun.

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In a solar calendar the month loses its connection with a lunation and becomes an arbitrary division of time. The Egyptians seem to have been the first to invent a purely solar calendar. They abandoned the use of the moon as a time measurer, and fixed the length of the year at 365 days, divided into twelve months of thirty days each plus five holidays. There was no arrangement for accounting for the six odd hours by which the solar year exceeds 365 days. Consequently, the beginning of the year worked backwards through the seasons, until, after the lapse of 1,460 years, it returned to its original starting-point. We know that this occurred in A.D. 139, and it is assumed that this date represented the conclusion of the second, or it may have been of the third, cycle, since the invention of that calendar. This would place the latter event in 2781, or it might be in 4241 B.C.

In the second century B.C., Hipparchus placed the length of the solar year at 365 days, 5 hours, and 55 minutes. Considering that he was, of course, entirely without optical aid, his discovery is of remarkable accuracy. It was on this figure that Julius Cæsar based his calendar reform, adopting the leap-year, the suggestion of one Sosigenes. With one modification due to Pope Gregory VII, this calendar has persisted to the present day. Pope Gregory's arrangement of omitting leap-years at the close of all centuries, except those where the first two figures of the year are divisible by four, will hold good up to the year 3200, which, to be as accurate as possible, should also be a leap-year ; but we need not worry about that now.

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We owe to the Babylonians the discovery of the periodicity of eclipses ; they found out that eclipses recurred at intervals of 18 years and 11 days (a period known as the Saros). This discovery implies a long record of carefully recorded observations. The Babylonians were at first, at any rate, far from deducing the actual cause of an eclipse, much less from finding a reason for their periodicity ; but the discovery of the Saros marked a milestone in human history, for the terror which a total solar eclipse caused would give way to different feelings once it was found to be a periodic and predictable phenomenon.

In giving credit to the Babylonians for this discovery, it should be mentioned that it is quite possible that the Chinese had long anticipated them. At any rate, in the third millennium B.C., an imperial edict ordered that "whether the instant of the occurrence of any celestial phenomenon was erroneously assigned, or the phenomenon itself not seen and predicted, either negligence should be punishable with death." The occasion of this sanguinary law is said to have been the total eclipse of the sun of 2127 B.C., when the two court astronomers, Ho and Hi.

were found to be drunk and incapable at the time, and were put to death. Since then, as a distinguished astronomer has said, astronomers have made a point of being sober on occasions of eclipses.

The Greeks learned of the periodic law of eclipses from Babylon. Thales foretold the eclipse of 585 B.C. At what period it was discovered that it was the moon which caused a solar eclipse is doubtful. It would, one would think, be discovered very early in a country where a lunar calendar was in force, that solar eclipses occurred only just before the new moon appeared, yet comparatively late in Babylonian history there is a table showing omens to be drawn from the appearance of a solar eclipse on every day of the month, from the first to the thirtieth.

We have seen that the gnomon was probably the first astronomical instrument; it was put to other uses than that of measuring time. It was found that the length of the shadow of a gnomon at the same hour on the same day of the year varied in different places. Pytheas, in the fourth century B.C., was the first to try to measure latitudes in this way, though without much success; he calculated that Marseilles and Byzantium were on the same parallel of latitude, although in reality they are 2¼ degrees apart.

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To digress somewhat, it is usually assumed that the sphericity of the earth was deduced comparatively late in history; in fact, I have seen it asserted that the great objection on the part of the fathers of the Church to Columbus's enterprise was that he would suddenly find himself on the edge. The truth is far otherwise. A traveller moving north would notice the Pole Star, or what passed as the Pole Star, rising higher and higher each night. This could only happen, he would reflect, if the surface on which he were moving were curved. If it were curved in a north and south direction, it was reasonable to assume that it was curved east and west too, and hence a spherical, or approximately spherical, world would be deduced. I have laboured the point at some length, because it is often assumed that in talking of "the circle of the earth," Isaiah was referring to knowledge gained directly by Divine revelation. The probability is that man had, long before that time, found out that the earth was round. Assumptions of this kind discredit both religion and science.

Eratosthenes, 276 to 194 B.C., was more successful than Pytheas. He discovered that at Aswan in Egypt on Midsummer Day the sun at noon cast a vertical shadow. He also found that at Alexandria, 5,000 stadia almost due north, the sun cast a shadow approximately one-ninth of the height of the object, at the same time of day on the same date. He argued that the angle subtended at the earth's centre by the arc must therefore be equal to this angle, which for the sake of simplicity we may call 7° 12′. The circumference of the globe must therefore be $360/7\frac{1}{5}$ times 5,000 or, say, 250,000 stadia. Taking the value of the stadion as 582 feet, we obtain the value of the earth's circumference as 27,750 miles, a remarkably good approximation considering the means employed. Eratosthenes might have applied, but apparently did not apply, his latitudes to the making of maps, for a tolerably accurate map can be constructed from the data he gives. Maps had, of course, been invented before his time, but the credit for using latitudes as fixed points on a map must apparently be given to Strabo, who used the latitudes and longitudes worked out by Eratosthenes and Hipparchus.

Latitude finding by altitudes of the sun is, as you know, one of the methods of finding latitudes at the present day. Elaboration of methods has, of course, resulted in greater accuracy, and now it is possible to fix the co-ordinates of an observatory within a fraction of a section of arc. Stellar observations give rather more accurate results than solar; man goes to the stars, billions of miles away, to measure the length of a tiny piece of his minute world.

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Another use made of the stars in very early times was for direction finding. The name given by the Greeks to the Pole Star was Cynosura, or the dog's tail. From the metaphorical use they made of the term, which has descended to us in the form "cynosure," we infer that they treated it as the Pole Star, although it was, in their time, distant some degrees from the Pole. With the recognition of this began the fearless navigation of the seas, instead of cautious voyages never out of sight of land.

In the Great Pyramid and in Stonehenge and other stone circles scattered about Celtic countries, we find undoubted use made of the sun and stars for orientation, at an epoch preceding by at least two millennia that of Greek science. Unfortunately, no record has come down to us as to why certain stars were selected, although conjectures are numerous. No doubt the position of a heavenly body at a particular time would be noted and fixed by templates, which would be replaced by permanent structures which would be available for the ceremony, whatever it was, on the corresponding day of the following year.

A development of this must have been the use of the sun and stars for direction finding. Every scout knows how to use the sun as a compass. The use of the stars for the same purpose is more intricate. No star stays in the same position long enough for us to use it as a direction post for more than a few minutes. Even the Pole Star describes a small circle round the true pole. If we were to start this evening on a twenty-mile march, using the Pole Star as a guide, we would deviate nearly 1,300 yards from our course. With other stars the error would be greatly exaggerated. In marching by the stars, it is necessary to halt every few minutes to realign oneself on a fresh star.

From these beginnings develops the use of the sun and stars for determining azimuths, *i.e.* the true bearings of distant objects.

Having found out the size and shape of the earth, man naturally began to attempt the problem of the distances of the moon and sun. The Greeks devoted time and trouble to the problem. Hipparchus came to the conclusion that the moon was distant from the earth not less than 67 nor more than 78 semi-diameters of the earth. As a matter of fact, the distance varies between 56 and 64 semi-diameters of the earth, so that Hipparchus was very near the truth. The problem of the sun's distance presented greater difficulties, but a result of about one-third of its actual value, which is what was obtained, must be considered very creditable with the instruments then extant.

I do not mean to infer that the Greeks had that in their minds when they began to calculate the distance of the moon. But the great genius of the Greeks lay in their pursuit of knowledge for its own sake. Theirs was the patient collection and recording of observations of which subsequent generations were to make use. It is true that they often made guesses which were not warranted by the extent of the data they possessed, but we are all liable to do that.

At a certain period in their history, however, the Greek mind seemed to tire. Aristotle wrote down all he knew, and most of his successors seemed to think that that was all there was to know. Ptolemy stereotyped the astronomy of the day, and in doing so sinned against the light, for he taught an immovable earth and a fixed heaven, though Aristarchus, centuries before, had taught the opposite. The doctrines of Aristotle and Ptolemy became, unfortunately, an article of belief in the Christian Church.

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The Greek mind deteriorated and plunged into astrology, a blind alley which leads nowhere. It is usually thought that astrology was the forerunner of astronomy; the reverse is probably the case. To quote Maunder again (*Astronomy of the Bible*, pp. 139, 140): "There is a widespread notion that early astronomy, whether among the Hebrews or elsewhere, took the form of astrology; that the fortune-telling came first, and the legitimate science grew out of it. Indeed, a claim is not infrequently made that no small honour is due to the early astrologers, since from their efforts the most majestic of all the sciences is said to have arisen.

"These ideas are the exact contrary of the truth. Mathematical, or perhaps as we might better call it, planetary, astrology as we have it to-day, concerns itself with the apparent movements of the planets in the sense that it uses them as its material; just as a child playing in a library might use the books as building blocks, piling, it may be, a book of sermons on a history, and a novel on a mathematical treatise. Astrology does not contribute, has not contributed, a single observation, a single demonstration to astronomy. It owes to astronomy all that it knows of mathematical processes and planetary positions."

The Romans, as the intellectual as well as the political heirs of the Greeks, were above all practical people, and made practical use of the astronomy they borrowed from Greece, taking, for instance, and probably developing, the art of fixing seasons for sowing, etc., by the heliacal rising of certain stars. But, as practical people, they had no use for recondite theories, which seemed to lead nowhere.

On the downfall of the Roman Empire, science slumbered until the Arabian revival, centred round Baghdad, about 1000 A.D. Then came another sleep, until the Renaissance, which brought to light the forgotten Greek knowledge. Thus scientifically we are the heirs, through the Greeks, of the Egyptians and Babylonians, and no doubt, to a very slight extent, of other countries. The Chinese, Mexicans and other ancient peoples no doubt knew a lot, but their knowledge died with them, and they have left no intellectual descendants.

One of the most important adaptations of modern science, already alluded to, is the forecasting of the tides. This is, almost entirely, a modern development, although the connection between the moon and the tides was known in classical times. The culmination of modern research in this direction may be said to be the tide-predicting machine of Sir W. Thomson, afterwards Lord Kelvin. The height of the tide for the place for which the machine is designed can be predicted for any hour of any day years ahead.

There are only a few recorded observations of sun-spots before the days of Galileo, but a great deal of time and labour is now spent by astronomers on their observation. At certain periods spots are almost entirely absent from the solar surface; at others, spots will cover a considerable portion, sometimes as much as 1·5 per cent. of the visible hemisphere. Such maxima occur fairly regularly at intervals of about 11·3 years, minima preceding such maxima by rather less than half this interval, *i.e.* rises to activity are rapid and declines slower.

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It is natural to try and connect such activity with our terrestrial weather; perhaps the wish was father to the thought. At any rate, about 1850 there was a general agreement that minimum spot years were wet and stormy and maximum years dry. The records of Indian monsoons were examined, and it was supposed that an 11-year fluctuation in the price of food grains had been discovered.

The accumulation of further data, both astronomical and meteorological, led to this theory, at any rate in its obvious form, being discarded. But a remarkable agreement has been traced between sun-spots and magnetic storms. Spencer Jones, in *General Astronomy*, p. 126, says: "When sun-spots are numerous, magnetic storms are relatively frequent; when sun-spots are few in number, the storms are rare. The connection between them was pointed out by Maunder, who examined nineteen magnetic storms between 1875 and 1903. These storms, in general, showed a sudden commencement, and in every case there was a large spot near the central meridian of the sun. Further, Maunder showed that magnetic storms frequently recur after an interval of about 27·3 days, and this is the period of the sun's synodic revolution. If a spot is on the central meridian at a certain date, it will again be on that meridian after the lapse of 27·3 days, and will then be in a position to cause another storm. It must be emphasized, however, that the presence of a large spot on the sun is not necessarily an indication that a magnetic storm will ensue."

Whether magnetic storms have an effect on our terrestrial weather is a point on which meteorologists are better qualified to speak. The following extract from the *Meteorological Glossary* has been given me by a member of the Institute : " The amplitude of the regular diurnal changes in terrestrial magnetism, even on quiet days free from magnetic storms, is increased at the epochs of high sun-spot numbers . . . One of the most striking relations is the correlation between the sun-spot number and the variation of level of the water in Lake Victoria at Port Florence. In this case the correlation coefficient is +·8."

The cause of the periodicity of sun-spots is unknown ; serious attempts have been made to connect the actual appearance of spots with the configurations of the planets. It has been stated that the conjunction of two planets, with regard to the sun, is the trigger effect which produces the actual spots. Should these assumptions prove correct, we should have a direct connection between the movements of the planets and our weather, presuming that it is possible to disentangle the solar effect from the much greater terrestrial effects.

The patient, laborious and careful collection of astronomical data, often in utter ignorance of whither they lead, has often led to the most unexpected but most practical results. As Sir James Jeans has put it : " In astronomy nothing succeeds so ill as the frontal attack." Such indirect results go a long way toward recompensing astronomers for the drudgery of recording and tabulating observations, made, not in the hope of immediate gain, but with the object of adding to the sum of human knowledge.

DISCUSSION.

The CHAIRMAN (Lieut.-Col. Skinner) said : A friend who had attended a meeting of the Victoria Institute and had read a number of our papers asked me recently why it was that so many colonels seemed always to take part in the discussions? The only reply I could make on the spur of the moment was that we were all retired and had nothing else to do!

Well, that sufficed for the moment; but, having heard Colonel Molesworth's paper, I think you will agree with me that, not indeed out of any enforced idleness, but out of his rich treasury of the mind, he has brought to us things new and old, a fine contribution, bearing even in the simplicity of its diction a hall-mark of genius.

I trust, therefore, that the rest of us, be we colonels or non-combatants, will take heart of grace, and give Colonel Molesworth's paper the discussion that it merits and himself the thanks he deserves. I will confine my own remarks to a few comments and an illustration of one of Colonel Molesworth's points.

At the foot of p. 160 is cited Isaiah's allusion to "the circle of the earth" and the assumption of some that he had gained his knowledge of the earth's sphericity by Divine revelation. While I agree with the author in thinking it probable that the sphericity was at least suspected long before Isaiah's day, I think we should be slow to affirm that Isaiah may not have had even a fact of science disclosed to him by revelation. Does not God speak often to man in a dream, in a vision of the night? Else how should we explain the marvellous panorama of Creation in the first chapter of Genesis in so near accord with the sequence disclosed by modern science? But an even simpler explanation offers, it seems to me, in the fact that wherever man goes, whether on land or on sea, he is surrounded by the wide circle of the horizon. Need any one, therefore, strain the allusion beyond that point? On p. 163 we are informed that *Astrology* was never the parent of *Astronomy*, but rather a parasite growth. I thank the author for bringing out that important point so clearly.

Now for an illustration. Emerson has advised us to "hitch our wagon to a star," but as a matter of fact, each of us, even the most unlearned, may really be more of a practical astronomer than he or she ever suspects. A soldier's yarn will serve to illustrate my point. It was in France during the War. The scene was set in a small, untidy French village at the edge of a darksome wood. The roads were quagmires, with mud and slush everywhere. Billets were in the roughest of barns and outhouses, illumined by about one tallow dip per platoon. Into this scene of desolation was shot one night a "reinforcement," to wit, one solitary old fellow who had never been out of England in his life before, and home-sickness was paramount. Faithful to his devoted wife at home, he penned a loving epistle, and this is what passed the censor—in the midst of a dismal lament this one gem of practical astronomy—"If it wasn't for the blinkin' old moon, Martha, I wouldn't know it was the same blinkin' earth." His adjective was a little more rugged than my translation of the same, but he had got his bearings all right, and his wagon was hitched.

We have listened to a most interesting paper, have we not? and one that, I feel sure, you will support me in saying, is of permanent value. Join with me, therefore, in the expression of a hope that it may be but the first of many papers from Colonel Molesworth, and signify appreciation by your hearty response.

The usual vote of thanks was heartily accorded.

Dr. NORMAN S. DENHAM said: In thanking Colonel Molesworth for his very able summary of a vast subject, I cordially agree that the prime value of astronomy for practical purposes is for the measurement of time. Astronomers are aware that the day, week, month and year are incommensurate. The search for solar and lunar cycles to correlate these measures has occupied mankind from the dawn of history. The problem has found no solution with respect to a permanent solar or luni-solar calendar because of the inevitable epacts.

It is extraordinary, in view of Gen. v, 5, that no one has attempted to suggest how Adam, correctly recording his days, could so total them as to afford posterity the precise total of the years of his life—a total, if we accept implicitly the Divine record, we take as scientifically accurate. Are we entitled to regard these years as "lunar," "solar," or "sidereal," as to their ultimate value, on no greater authority than conjecture?

I would ask Colonel Molesworth if he is justified, on p. 156, in asserting that the Exodus Calendar persists to this day. If reference be made to Rev. S. B. Burnaby's standard work on *The Elements of the Jewish Calendar*, it will be seen that the present Jewish Calendar differs greatly in its incidence from that which orthodoxy deems to have been used in Biblical times. The fact is, that little or no knowledge of the Exodus Calendar, let alone Adam's Calendar, exists, save that the months were lunar.

In the same paragraph the lecturer states that there is no historical "trace of an intercalary day or days in the month." When examining this problem, by following the hint given by the late Dr. Martin Anstey at p. 252 of his *Romance of Bible Chronology*, I deduced that the expression "in process of time" (rather "at the end of days") of Gen. iv, 3, indicated either the intercalary month or the close of a regular three-year intercalary cycle, which itself was identical with the three-year tithing period (Deut. xxvi, 12). We have three other occurrences in the Pentateuch, namely, Gen. xiv, 20 (A.H. 2091); Gen. xli, 1 (A.H. 2289); and Exod. ii, 23 (A.H. 2511). All these were the third years of a regular sequence of three-year cycles from Adam's first year, A.H. 1.

We may reverently consider whether Adam was divinely instructed from the outset as to the proper method of intercalation. Assuming his months and years were normally lunar, he could not have continued a consistent three-year intercalation for 930 years, and have kept true solar time. The embolismic month must have varied spasmodically from time to time. In such case, it is hopeless for us to attempt to check the patriarchal years. But were those years necessarily solar? I think not. At Exod. xii, 40, we read that 430 years after Abram's exodus from Haran, "on the *self-same day* all the hosts of the LORD went out from the land of Egypt." As accepted by all the best authorities, including Archbishop Ussher, Abram was 75 in A.H. 2083 (Gen. xii, 4). The Exodus year, 430 years inclusive from 2083, was A.H. 2512, the seventh month of which became the first month of A.H. 2513. "Self-same" means "anniversary" or "repetition," so we may infer that Israel left Egypt on the same day of the week and month as Abram left Haran. A *fixed calendar* at once suggests itself. Self-same dating in two years 39 years apart was discovered earlier in connection with the wanderings, so that the cycle of 39 was indicated. When 2083 and 2512 are divided by 39, the remainder in each case is the same, namely, 16. Immediately an amazingly simple but profoundly significant coincidence appears. Israel left Egypt on Wednesday, 14th Nisan, on *the self-same calendar day* of the age-long 39-year cycle in which Abram had left Haran eleven cycles before; and it may be added that on that *self-same* Wednesday, 14th Nisan, long years after, our adorable Lord and Master suffered His Exodus upon the Cross (*cp.* Luke ix, 31—" decease " means *exodus*).

If we examine the 39 years, taking them as sidereal, not solar years, we find that they total almost precisely 14,245 days. The total is exactly divisible by 7. Thus this cycle affords perfect commensuration for the passage of days, weeks and years, together with a unique basis for a fixed calendar, founded on basic time, for solar time is not really basic, but a mean only. A solar cycle of 39 years does not afford this exactitude and is useless for calendrical purposes. A lunar calendar based on this cycle would remain good for nearly 18,000 years without gaining one day on basic time.

One other point emerges. Rev. F. A. Jones, writing in 1909 on "The Dates of Genesis," shows that the ancient Egyptian year reckoning was sidereal, and he made the significant statement that " we have yet to learn the testimony of the stars to the chronology of the world." This prophecy receives confirmation by facts relative to the Great Pyramid at Ghizeh. Taking the measurements of Professor Sir Flinders Petrie, we find that its base structural circuit measures 36525·64 pyramid inches. This measurement, on the scale of 100 pyramid inches to a day, represents a good value of the sidereal year, and is actually only 8·6 seconds of time longer than the value for the present period. If the Egyptians had, in about 2170 B.C., embodied this knowledge in their imperishable monument, it is but a normal inference that such knowledge was even then ancient.

It is more than conceivable, it seems to me probable, that Adam was instructed by God Himself as to the simple intercalation of his lunar calendar at the close of every three years, to accord with sidereal time. Adam was thus enabled to keep perfect time records apart from any elaborate series of observations which might enable him at length to decide, even if he were competent, on the nicety of those " mean times " which are only now accepted as the basis of chronological computation.

Mr. G. WILSON HEATH wrote: The paper emphasizes the difficulty which I raised in the paper read to us by Colonel A. C. H. Kenney-Herbert last year as to the fixing of the 14th Nisan by astronomical observations, and especially by observing the time and date when the thin crescent of the new moon first became visible above the horizon. Atmospheric conditions would altogether mar the accuracy of such calculations, as I stated, and as the paper we have just listened to again and again indicates.

One can easily imagine that a sundial, in some crude form or other, would be the earliest mechanical method of measuring time. But a more elaborate and really wonderful instrument, and one which in its developed form was in use until quite recent years, was "The Astrolabe" or "The Planispheric Astrolabe." This instrument in its conception and initial stages was worked out by Appolonius of Perga in 240 B.C., and put to serious use by Hipparchus in 150 B.C.

Professor Jenkins, of Oxford, declared quite recently that it was "a useful educational scientific instrument with a history of 2,000 years, and the oldest scientific instrument known." It certainly has played an important rôle in the history of civilization. The most useful form of this instrument consisted of an evenly balanced disc of metal or wood, hung by a ring at the top, and provided with a diametral Rule with Sights, turning within a circle of degrees, and used thus for measuring the altitude of the sun or stars.

Only in the middle of the eighteenth century was the "Astrolabe and Cross Staff" superseded, in navigation by the sun and the stars, by Hadley's Quadrant. The story is entrancing, far too long for a discussion. I think it is well to be reminded that our earth is after all a very humble member of a great community; only the fifth largest planet belonging to one of the *lesser stars*. So insignificant are we that almost anywhere up yonder we must, in the midst of the grandeur of the universe, practically pass *unnoticed*.

The lecturer, on p. 160, makes reference to the old-world interpretation of the "circle of the earth." May I suggest that *hūg*, the word translated "circle" in Isa. xl, 22, and "compass" or "vault" in Job xxii, 14, and the same in Prov. viii, 27, in each case refers to the *vault* of the *heavens* bounded by the horizon, and not to the earth at all?

Eratosthenes, in 250 B.C., was the first to measure and determine that, as a traveller proceeded northwards one degree of latitude, the altitude of the Pole Star increased by one degree. Pythagoras and Aristotle used many arguments in order to prove the earth was spherical, some of which are used to-day, but as a fact all that was said was a speculation until explorers had actually sailed around the earth and discovered a set of stars in the south which they had never seen before in the north—a condition which would not have arisen if the earth had been a flat plane. The ancients had much to learn, and I feel sure that we with our extended knowledge have very much more to learn than they, but "a wise man will hear, and will increase in learning, and a man of understanding shall attain unto wise counsels" (Prov. i, 5).

Lecturer's Reply.

While thanking the Chairman and the others who have taken part in the discussion for their very kind remarks, I will confine my comments to the two points where I seem to be at variance with Dr. Denham.

Dr. Denham states that "the present Jewish Calendar differs greatly in its incidence from that which orthodoxy deems to have been used in Biblical times. The fact is, that little or no knowledge of the Exodus Calendar . . . exists, save that its months were lunar."

There are, however, the following other points of similarity :—

An intercalary month is in use in both.

The names of nearly all the months in the present Jewish Calendar are derived from Biblical originals.

In fact, there seems to be as much similarity between the two as between our calendar and that of Julius Cæsar.

The other point is that of an intercalary day or days in the month. Dr. Denham, in taking up this point, refers to intercalary months in the year—a very different matter ; my point was that, if the week of seven days had been originally a quarter of the month, the difference of more than a day between four weeks and a lunation would have had to be made up by intercalary days in the month, *i.e.* there would have been four weeks of seven days and then an extra day or days to make up the month. But of this there is no trace, however far we go back in history.