fellowships. Although there may be cause for criticism of the method of administration of the fund placed in the hands of the committee of the Privy Council, there is no doubt that, if wisely administered, it will have very far-reaching results, not only in developing our scientific industries, but in stimulating research in our universities and levelling up the standard of scientific attainment among the whole body of our science students.

## INSTITUTION OF MECHANICAL ENGINEERS.

THE annual report of the council of the Institution of Mechanical Engineers for the year 1915 shows that the fund raised in conjunction with other institutions to establish a memorial to the late Sir W. H. White, K.C.B., amounted to more than 3000*l.* After providing for a medallion portrait, to be placed in the Institution of Civil Engineers, and a donation to the Westminster Hospital, the bulk of the fund, together with any further contributions, is being devoted to the establishment of a research scholarship in naval architecture, to be administered by the Institution of Naval Architects. The report also states that the Thomas Hawksley medal for 1916 has been awarded to Prof. H. L. Callendar, for his paper "On the Steady Flow of Steam through a Nozzle or Throttle," and premiums of 5*l.* each have been awarded to Prof. A. H. Gibson and Mr. W. J. Walker, for their paper on "The Distribution of Heat in the Cylinder of a Gas Engine." A grant of 15*l.* has been made from the Bryan Donkin Fund, for original research in mechanical engineering, to Mr. A. H. Barker, in aid of his research at University College, London, "to investigate a new method of determining the radiant temperature and air temperature in a room." The balance of the third triennial award has been devoted to aiding the steam-nozzles and hardness tests researches of the institution.

The report contains particulars of the work done during the year by the various research committees of the institution. The work of the Alloys Research Committee, on the alloys of aluminium with zinc and copper, has been continued at the National Physical Laboratory. The importance of light alloys in connection with aeronautics has led to a Government grant for the erection and working of an experimental rolling-mill capable of dealing with ingots and billets. Further progress has been made with other branches of the work, including the study of the constitution of the alloys and the "disintegration" research. The series of researches relating to the double carbides of iron, under the direction of Profs. J. O. Arnold and A. A. Read, has been completed. The results of the studies on the carbides of cobalt and of molybdenum have been embodied in papers on "The Chemical and Mechanical Relations of Iron, Cobalt, and Carbon" and "The Chemical and Mechanical Relations of Iron, Molybdenum, and Carbon," both printed in the Proceedings of the Institution. A report was also submitted by Sir Robert Hadfield describing the effects of molybdenum upon iron, up to 18 per cent. of Mo. The Steam-Nozzles Research Committee has held three meetings and is engaged on the design of apparatus for conducting experiments relating to the action of steam passing through nozzles and steam-turbines. The British Westinghouse Electric and Manufacturing Company has offered to lend two large condensers to the committee, and substantial progress has been made with the design of nozzle-testing apparatus. The Hardness Tests Research Committee has been considering the design of a machine to determine rate of wear as a measure of hardness. An existing machine at the National Physical Laboratory was adapted as a preliminary procedure, but the results obtained from this machine and modifications thereof have not yet been satisfactory. The work of the Refrigeration Research Committee has been suspended, Prof. C. Frewen Jenkin, the reporter, being on active service.

Interesting particulars of the war work undertaken by members of the institution are contained in the report. The engineer unit of the Royal Naval Division, which was principally recruited from the members of the Institutions of the Civil, the Mechanical, and the Electrical Engineers, was on active service in Gallipoli. In the early stages of the war, a list was compiled of the engineering and other qualifications of members desiring to obtain commissions in the Army, and copies were forwarded to quarters where they were likely to be of use. The names of selected members have been put forward as candidates for commissions in the 12th King's Own (Yorkshire Light Infantry), Pioneer Companies, the Mechanical Transport branch of the Army Service Corps, and other engineering branches of the Army. Particulars of the engineering training and other qualifications of 159 members who expressed a desire to undertake engineering work in connection with the war have been forwarded to the Ministry of Munitions and other Government departments from time to time throughout the year. In response to an application from the Ministry of Munitions for the nomination of engineers for employment in connection with contracts for the manufacture of munitions, the council appointed a small committee to select possible candidates. The qualifications of sixty-seven members and others were considered, and the names of twenty-seven were submitted to the Ministry. In August last a list of 543 members on active service in the Army was compiled for transmission to the War Office. During the year 661 members had been on active service. Several designs for a mechanical bomb-thrower have been received from members and submitted to the War Office. Designs have also been submitted of apparatus for destroying barbed-wire entanglements, for clearing mines from the products of the explosion of the mine, and for non-slip chains for rubber tyres of motor-wagons. At the request of the Director of Fortifications and Works, a list was compiled of the names of mechanical engineers with whom the War Office might communicate in connection with problems arising out of the war.

## THE ORIGIN OF ENGLISH MEASURES OF LENGTH.[1]

ALTHOUGH there is considerable variety in the measures of length used by the different nations of the world, there can be no doubt that they are, for the most part, derived from a common origin, and that their ancestors, if the expression may be used, existed in times so remote that the date of their invention has been completely lost.

For the sake of clearness, it is convenient to divide the measures of length into four categories which are, to a certain extent, independent of one another, and may be defined as follows:—

(1) The shorter measures of length, used for building and manufacturing purposes, of which the more important in ancient times were the cubit, the palm, and the digit, or finger breadth, and the English representatives are the yard, the foot, and the inch.

[1] Abridged from a paper in the Journal of the Royal Society of Arts, December 31, 1915, by Sir Charles M. Watson, K.C.M.G., C.B.

(2) The shorter measures of distance, such as the foot, the yard, and the pace. (3) The longer measures of distance, including the stadium, the mile, the parasang, the schoenos, the league, the hour's march, and the day's march. (4) Measures of length used in connection with the calculation of land areas, of which the English representatives are the perch, the chain, and the furlong.

As regards the first of these classes of measures, it is generally accepted that they were, from the earliest times, based on the proportions of the human body, so that every man had his own scale to which he could work.

The palm is the width across the open hand at the base of the fingers; the cubit is the length of the arm from the elbow to the end of the middle finger; and the fathom the length of the outstretched arms. There is no fixed relationship between these units.

There is no record as to when an attempt was first made to combine the measures in a standard scale, but it was probably at an early period, as it must have been found inconvenient for workers on the same building, for example, to use different lengths of palms and cubits, and, when a standard was fixed, it may have been some such scale as the following :—

| | | | |
|---|---|---|---|
| | 1 digit = | 0·7375 | English inch |
| 4 digits = | 1 palm = | 2·95 | „ inches |
| 6 palms = | 1 cubit = | 17·70 | „ „ |

The cubit of this scale may be called the "cubit of a man," to distinguish it from other cubits, which will be described hereafter.

There is nothing to show when the foot was added to the units of the mechanic's scale, but when this was done it was assumed to be equal to four palms, or two-thirds of a cubit.

The third class of measures of length is the most important, and the history of these is of particular interest, as they appear to have started in a state of perfection, and to have been first used by a people who possessed a high degree of astronomical and mathematical knowledge, who were acquainted with the form of the earth, and were able to carry out geodetical measurements. There can be no doubt that they are based on the angular division of the circle, and on the application of this division to terrestrial measurements.

The unit of angular measurement is the angle of an equilateral triangle, and this angle was divided by the ancient geometricians, for purposes of calculation, into 60°, the best number possible, as $60 = 3 \times 4 \times 5$. Following the same principle, each degree was divided into 60 minutes, and each minute into 60 seconds. As the circle contains six times the angle of an equilateral triangle the circle was divided into 360°. This division of the circle, although so ancient that its origin is unknown, has never been improved upon, and is still in use by all nations. An attempt on the part of certain French mathematicians to substitute a division of the circle into 400°, on account of the supposed advantages of the decimal system, has proved a failure.

The manner in which the division of the circle into 360° was used by the ancients to determine the unit for terrestrial measures of distance was as follows. If a circle be described cutting the equator of the earth at right angles, and passing through the north and south poles, its circumference in angular measurement is equal to $360° \times 60' = 21,600'$, and the length of 1 minute, measured on the surface of the globe, was taken as the unit, which is called a geographical mile at the present time. If the earth was a perfect sphere, every geographical mile would be of the same length, but, as the polar diameter is less than the equatorial diameter in the proportion of 7900 to 7926, the length of the geographical mile, measured on the meridian, is not the same in all latitudes, but increases in length from 6046 English feet at the equator to 6108 English feet at the poles. Whether the ancient astronomers were acquainted with this irregularity in the figure of the earth it is not possible to say, but it is certain that the value at which they fixed it must have been close to the actual mean value as determined by modern astronomers, which may be taken as about 6075 English feet. The Greek stadion (the same as the Roman stadium), which was one-tenth of the geographical mile, was 600 Greek feet in length, and the Greek foot was about 12·15 of our present English inches.

The next step taken appears to have been with the view of assimilating the subdivisions of the geographical mile with the cubit, and it was not easy to do this, as the cubit of a man has no necessary connection with a geographical mile. The difficulty appears to have been solved by the invention of two new cubits, of which the smaller was very nearly equal to the cubit of a man, and was contained 4000 times in the geographical mile. This, for the sake of distinction, may be called the geographical cubit. The second cubit, afterwards known as the Babylonian Royal cubit, was longer, and was contained 3600 times in the geographical mile. According to Herodotus, this second cubit was three digits longer than the other cubit. On these two cubits there appear to have been based two different divisions of the geographical mile, one in accordance with a decimal, and the other with a sexagesimal system of calculation, but there is, so far as I know, no ancient record of these scales, and the following attempt to compose them is founded on inferences, drawn from the Babylonian, Greek, and Roman measures, all of which, there can be little doubt, came from the same origin.

The first based on the geographical cubit, which was rather longer than the average cubit of a man, is as follows :—

| | | | |
|---|---|---|---|
| | 1 digit = | 0·729 | English inch |
| 25 digits = | 1 geographical cubit = | 18·225 | „ inches |
| 100 „ = | 1 fathom = | 6·075 | „ feet |
| 100 fathoms = | 1 stadion = | 607·5 | „ „ |
| 10 stadia = | 1 geographical mile = | 6075 | „ „ |

The second, or sexagesimal scale, based on the Babylonian Royal cubit, appears to have been as follows :—

| | | | |
|---|---|---|---|
| | 1 digit = | 0·723 | English inch |
| 28 digits = | 1 Royal cubit = | 20·25 | „ inches |
| 60 cubits = | 1 plethron = | 101·25 | „ feet |
| 60 plethra = | 1 geographical mile = | 6075 | „ „ |

The ancient Egyptian measures of length, although evidently derived from the same origin as the Babylonian, differ from these in some respects. The most important smaller unit was a cubit usually known as the Egyptian Royal cubit, which was divided into seven palms, each palm of four digits. The approximate length of the Egyptian Royal cubit is well known, as a number of cubit scales have been found which give a mean length of 20·65 English inches, and an examination of the monuments of Egypt shows that this cubit was used for building purposes from ancient times.

It is matter of controversy from whence the Greeks derived their measures of length, whether from Egypt or Babylonia; but the latter appears more probable, as their principal measure of distance, the stadion, was equal to one-tenth of a geographical mile of 6075 English feet, and this was divided into 6 plethra, each of 100 Greek feet. The Greek scale appears to have been as follows :—

| | | | |
|---|---|---|---|
| | 1 Greek foot | = 12·15 | English inches |
| 1½ Greek ft. | = 1 cubit | = 18·225 | „ „ |
| 10 „ „ | = 1 reed | = 10·125 | „ feet |
| 10 reeds | = 1 plethron | = 101·25 | „ „ |
| 6 plethra | = 1 stadion | = 607·50 | „ „ |
| 10 stadia | = 1 geographical mile | = 6075 | „ „ |

There was another foot used in Greece, of which Petrie gives a number of instances, derived from old buildings, varying from 11·43 to 11·74, with a mean value of 11·60 English inches. This would appear to be a foot of 16 digits, used for building and manufactures, but not connected with measures of distance.

The Roman system of measures was based on the Greek, but while adopting the stadion—called by them stadium—as the fundamental measure of distance, they used the shorter Greek foot, and introduced another measure, the double pace. They also made the land mile to consist of 8 instead of 10 stadia, while retaining the geographical mile of 10 stadia for use at sea. As they had an affection for a duodecimal system of calculation, they also divided the foot into 12 inches, in addition to the old division into 16 digits. The Roman scale, which showed considerable ingenuity in assimilating a number of different measures which had no real relationship to one another, appears to have been as follows:—

| | | | |
|---|---|---|---|
| | 1 digit | = 0·729 | English inch |
| | 1 inch | = 0·972 | „ „ |
| 4 digits or 3 inches | = 1 palm | = 2·916 | „ inches |
| 4 palms | = 1 foot | = 11·664 | „ „ |
| 6 „ | = 1 cubit | = 17·496 | „ „ |
| 5 feet | = 1 pace | = 4·86 | „ feet |
| 125 paces | = 1 stadion | = 607·5 | „ „ |
| 8 stadia | = 1 land mile | = 4860 | „ „ |
| 10 „ | = 1 geographical, or sea mile | = 6075 | „ „ |

The above remarks deal with the measures of distance used by the principal nations of antiquity up to and including the geographical mile, upon which they seem to have been based, but in addition to these there are certain longer measures of distance which must be referred to, such as the parasang, the schoenos, and the league. The fundamental idea of these measures was that they represented the distance which could be marched in a given time, such as one hour, and as the rate of marching naturally varied with the nature of the country, it was not easy to have a fixed length, and when there was made a theoretical unit it did not always agree with the actual distance.

An important application of measures of distance from the earliest times was for the calculation of areas of land, but there is considerable doubt as to what was the original unit, and whether this was a square, or in the form of a rectangle one stadium in length and one-tenth of a stadium in width. In the latter case there would have been ten measures in a square stadium, and 1000 measures in a square geographical mile, and such a measure would seem quite in accord with the ancient system of measures of distance. Its area would have been 40×400 geographical cubits (36×360 Babylonian Royal cubits). There is a very widely distributed type of land measures based on a rectangle of this form, of which the English acre is an instance, as it measures 44×440 English cubits.

The Egyptian unit of land area appears to have been the "set," which was a square having a side of 100 Egyptian Royal cubits. A cubit of land was the 1/100 part of this, and was the area of a rectangle 1×100 cubits.

In the Greek system the unit of area was the square of a plethron or 100 Greek feet, of which there were 36 in a square stadion and 3600 in a square geographical mile.

The Roman unit of land area, called the "jugerum," was a rectangle, 120×240 Roman feet, which was subdivided duodecimally, the uncia of land being the twelfth part of a jugerum, or the area of a rectangle measuring 10×240 Roman feet.

It will be seen from the above descriptions that from the earliest times the shorter measures of length were based on the proportions of the human body, and the longer on the geographical mile, and that at some remote period an attempt was made to combine them into a continuous scale, from the digit to the geographical mile.

The modern measures of the civilised world are, with few exceptions, based on the ancient units, of which they may be regarded as the direct descendants. Of these exceptions the most important are the measures of the metric system, which were designed with the object of breaking away from the records of the past by the adoption of a new geographical mile, equal to 54/100 of the true geographical mile.

The English measures of length are a good example of the modern representatives of the old units, and are worthy of study from this point of view. How the measures originally came to England it is not easy to say, but there can be no doubt that they were in use before the Roman invasion, having possibly been introduced by Phœnician traders, and were afterwards modified by the Romans, the Saxons, the Scandinavians, and the Normans, each of whom had measures, based on the old units, but altered in course of time. It was not until the thirteenth century that they were moulded by law into one uniform system.

The English scale, as authorised by statute, may be summarised as follows:—

| | |
|---|---|
| | 1 inch |
| 12 inches | = 1 foot |
| 3 feet | = 1 yard |
| 5½ yards | = 1 rod, pole, or perch |
| 4 perches | = 1 chain |
| 10 chains | = 1 furlong |
| 8 furlongs | = 1 English statute mile |

Of these units the inch is derived from the Roman system, being one-twelfth of the foot, but the foot, on the other hand, is equal approximately to the Greek foot, while the yard, which is simply a double cubit, comes from the Babylonian system, being approximately a double geographical cubit. The perch is the English representative of the Babylonian gar, and the furlong occupies a similar place to the stadium, while the mile is composed of eight stadia, apparently in imitation of the division of the Roman mile. For use at sea, however, the geographical mile, divided into ten stadia, or, as we call them, cable lengths, has been retained, as no other mile can be used for purposes of navigation.

In order fully to understand the connection between the English measures and the ancient measures of length, it is necessary to write the scale in a somewhat different manner, and to introduce some other units which are no longer used. The revised scale is as follows:—

| | |
|---|---|
| | 1 barleycorn |
| 3 barleycorns | = 1 inch |
| 3 inches | = 1 palm |
| 4 palms | = 1 foot |
| 6 „ | = 1 cubit |
| 12 „ | = 1 double cubit or yard |
| 11 cubits | = 1 perch |
| 05 „ | = 1 cable's length |
| 4 perches | = 1 acre's breadth or chain |
| 10 chains | = 1 acre's length or furlong |
| 8 furlongs | = 1 English mile |
| 10 cables | = 1 geographical, or sea mile |

The English inch is equal in length to 3 barleycorns set end to end. The barleycorn, as a measure, is forgotten, but on a shoemaker's tape the sizes of boots and shoes increase by a barleycorn, or $\frac{1}{3}$ inch, for every size. For example: size No. 8 of a man's boot measures 11 inches; size No. 9, $11\frac{1}{3}$ inches; size No. 10, $11\frac{2}{3}$ inches, and so on. One would have thought that the sizes would increase by one quarter of an inch at a time, but the barleycorn has held its place to the present day.

The palm, which was originally composed of 4 digits or finger breadths, and, since the time of the Romans, of 3 inches or thumb breadths, is no longer used in England, and its place has to a certain extent been taken by a measure called the hand, composed of 4 inches and employed in measuring the height of horses.

Prior to the thirteenth century, the length of the foot in England was uncertain; but, by the ordinance known as the Statute for Measuring Land, enacted in the reign of King Henry III., the relations of the inch, the foot, and the cubit to one another were definitely fixed, and have never since been altered. The cubit of this statute is the double cubit, afterwards called the yard. A translation of the Latin words of the statute, describing the different measures, is as follows:—

"It is ordained that 3 grains of barley, dry and round, make an inch; 12 inches make a foot; 3 feet make a cubit; $5\frac{1}{2}$ cubits make a perch; 40 perches in length and 4 perches in breadth make an acre.

"And it is to be remembered that the iron cubit of our Lord the King contains 3 feet and no more; and the foot must contain 12 inches, measured by the correct measure of this kind of cubit; that is to say, one thirty-sixth part of the said cubit makes one inch, neither more nor less. And $5\frac{1}{2}$ cubits, or $16\frac{1}{2}$ feet, make one perch, in accordance with the above-described iron cubit of our Lord the King."

It is interesting that, in this statute, the double cubit, thus accurately described, should have been called the cubit of the King, just as the longer cubits of Babylon and of Egypt were called Royal cubits to distinguish them from the shorter cubits of those countries. In the Latin original of the ordinance the word used is "ulna," the usual word for cubit. The word "yard," to signify the English double cubit, occurs for the first time in the laws of England in a statute of 1483, which is written in French.

The two measures, the acre's breadth, afterwards called the chain, and the acre's length or furlong, have also been used from a very early period. The former is equal to 44 single cubits, 22 yards, or 66 English feet, while the latter is exactly ten times this, 440 cubits, 220 yards, or 660 feet. The furlong is the modern representative in our system of the ancient stadium, which had a length of 600 Greek feet, or 607·5 English feet, but the reason for its being longer than the stadium has, so far as I know, not been satisfactorily explained. But the change may have been due to the fact that other measures of distance were in use in England prior to the present statute mile, which varied in different parts of the country, and the mean of these was approximately equal to the Gallic league of 12 stadia or 7,290 English feet. One-eleventh of this, 663 English feet, is approximately equal to the English furlong, and eight of these measures, following the Roman system, were combined to form the English statute mile.

But whether this is the origin or not, there appears little doubt that the mile, furlong, and chain, or acre's breadth, were in use in England in Anglo-Saxon times, as there is a law of King Athelstane, who reigned A.D. 925–940, in which it is enacted:—

"Thus far shall be the King's grith from his burgh gate where he is dwelling, on its four sides; that is three miles, and three furlongs, and three acres' breadths, and nine feet, and nine palms, and nine barleycorns."

The length of the measure called the King's grith, or King's peace, was the distance from his house within which peace was to be maintained, and it is evident that in this law an attempt was made to express the distance in terms of ordinary measures.

The terms acre's length and rood are no longer used, and this measure is now known as the furlong, while the acre's breadth has been called the chain since the beginning of the seventeenth century, when it was divided into 100 links instead of 66 feet. The chain, which was the invention of Prof. Gunter, has proved very convenient for the measurement of land acres, and is now always used.

Since the introduction of the chain, the perch or rod has been less employed in connection with land measures, but is still used by builders for the measurement of brickwork. The common English stock brick is half a cubit in length, one-quarter of a cubit in width, and one-sixth of a cubit in thickness, or rather less than these dimensions, to allow for the thickness of the mortar joints, while a rod of brickwork, which one rod or 22 bricks in length, one rod or 66 bricks in height, and three bricks in thickness. The perch or rod of brickwork contains 4356 bricks.

The English sea mile is exactly the same as the geographical mile of the Babylonian system, and its tenth part, the cable length, is identical with the stadium. In these measures there has been no change, and the only difference is that the cable length is 405 English cubits, whereas the stadium was 400 original cubits.

## UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The next combined examination for entrance scholarships and exhibitions, at Pembroke, Gonville and Caius, Jesus, Christ's, St. John's, and Emmanuel Colleges, will be held on Tuesday, December 5, and following days. Mathematics and natural sciences will be subjects of examination at all the above-mentioned colleges. Most of the colleges allow candidates who intend to study mechanical science to compete for scholarships and exhibitions by taking the papers set in mathematics and natural sciences. A candidate for a scholarship or exhibition must not be more than nineteen years of age on October 1, 1916. Forms of application for admission to the examination at the respective colleges may be obtained from the masters of the several colleges.

Mr. S. W. Cole, of Trinity College, has been appointed University lecturer in medical chemistry, and Mr. C. S. Gibson, of Sidney Sussex College, has been appointed assistant to the professor of chemistry; both appointments are for five years.

The Smith's prizes are awarded to H. M. Garner, St. John's College, for two papers on orbital oscillations about the equilateral triangular configuration in the problem of three bodies, and to G. P. Thomson, Corpus Christi College, for four papers on aeroplane problems. A Rayleigh prize is awarded to W. M. Smart, Trinity College, for an essay on the libration of the Trojan planets.

The General Board of Studies does not propose to appoint a lecturer in animal embryology to succeed the late Dr. R. Assheton, and advises that the balance of the benefaction to the lectureship should be used for the completion and publication of the embryological work upon which Dr. Assheton was engaged.