

one and a half feet deep; the lowest that I examined was in the gravel twenty-two feet. Many of the bundles found either fell apart or have since been unwrapped, and so it has been possible to determine the sex of the person inclosed. From the observations thus made, I have found the graves of twenty-two males to average little less than six feet deep, while twenty-five graves containing females average a little less than six feet. Additional data might of course change these figures.

The grave is generally circular and about four feet in diameter. A few graves have been found, however, square or nearly so. These graves invariably had the appearance of being very old.

About twenty-five per cent. of the graves were covered with a roof. These generally consist of four or five rough sticks of algaroba, which served as rafters and were placed parallel over the graves at a depth of one to two feet. Over these and resting on them was a mat of reeds bound together by rope. Often there were two mats, one placed transversely over the other. The more elaborate roofs were covered with a thin, compact layer of clay or of bromeliaceous plants, or of both. These roofs were sometimes in such a good state of preservation that they had withstood the weight of the sand above and had not caved in; consequently there was found a hollow, undisturbed chamber beneath. The roofs were always larger than the graves, and were square, averaging about six and a half feet. Besides the roofs proper, the bundles were often immediately covered with a well-made mat of rushes. Of forty-six graves, not one male was covered with a roof or mat, while eight females had well made roofs and nine more were covered with a matting of rushes.

After the roof had been removed and the grave cleared of the sand which had fallen in, the bundle was found at the south side of the grave, and arranged around it were the vessels of food, work baskets or whatever the occupant owned in life. From these objects we are able to reconstruct much of a past civilization.

On examining the bundles, we find that no two were prepared for burial exactly alike. Generally the bodies were placed in a sitting posture, with the knees drawn against the breast and the hands folded over the face. Frequently the bodies so doubled up were buried lying on their backs. This was almost invariably the practice in the case of children. Only three bodies were found buried at full length.

It is interesting to note that all three were buried with the face downward and that they were poorly wrapped. Spindles were found with two of them. One body was found in a very peculiar position, in a half sitting and a half reclining posture, with the feet bent back under the body. The wrappings were very scant and nothing else was found in the grave.

Looking now more especially at the wrappings of the body, we find infinite variety, from the child wrapped in a single piece of cloth to bundles swelled to enormous size by the numerous garments and coverings of plants. A typical well-wrapped body would reveal the following coverings: A false head, bright colored poncho, finely woven mat of rushes, large pieces of cloth, and a two-inch layer of plants and leaves, several thicknesses of cloth and a layer of raw cotton still containing the seeds are found over the face and breast. The plants just mentioned apparently played a very important part in the preparation of the body for burial. They were used not only for enveloping the body, but for building up the shoulders even with the top of the head, so that it is not always possible to detect the location of the head from any outward indication. Thirty-seven per cent. of the graves contained bodies which were wrapped in plants, while over ten per cent. were provided with small bags or sacks of plants, which were either sown fast to the bundle or suspended from the false head.

The object of the false head or maskoid is a matter of conjecture. They have not been studied sufficiently as yet nor has enough attention been paid to their resemblance to the maskoids of the north. In forty-six graves seven bodies were so decorated, and five of these were women. They all differ in shape nor are any two quite alike in construction.

In general it may be said that they are about four inches wide and six inches long, and are simply constructed of cloth and straw and resemble a small cushion. The eyes are of shell, the nose of wood, and the mouth of yarn. Those found on women were further decorated with ear ornaments made of tiny reeds arranged in the shape of a star, and held in position with ribbon-like bands of the outer covering of large reeds or leaves of corn. The face is often painted red or yellow.

Over the top of the maskoid found with the men was often placed a woven band of straw and at the back was a feather plume. These plumes were carefully made, each quill of the feather being bound separately with thread and the whole then made fast to a piece of wood. When the maskoid is further provided with false hair the effect is very striking.

Many of the more delicate objects were found inside the wrappings, and include spindles, beautifully decorated gourds, pots, fine nets, bags, straw bands, knitted caps, garments, slings, etc. Inside of the wrappings and around the neck of the women were often necklaces of shell or colored beads. The art of tattooing was well known and was practiced on both sexes. The hands, arms, and breast were covered with small triangular-shaped figures in parallel rows. In one case, that of a man, the whole breast was tattooed with an intricate design which cannot now be clearly distinguished.

The objects found in the grave around the bundle vary considerably. The most common objects are calabashes and earthenware vessels containing food, or were found covered, and probably contained a beverage of some sort. The pottery is not remarkable either for its shape or for its decoration. The most common form is that of the plain, unadorned round-bottom cooking pot, with the outside still covered with soot. The decoration when present is generally in the form of small relief figures or simple geometric designs in black and white.

The foods found include ears of corn and parched corn and meal, peanuts, dried fish, sea crabs, guinea pigs, yucca, pecay, and some other fruits the names of which I have not been able to ascertain. The leaves

of the coca are found in almost every grave and with both sexes.

The remaining objects from the grave I shall mention as they occur with the man or woman. With the man only are found agricultural implements, war clubs, canes, slings, tweezers of copper and silver, flags, fish nets, pottery-making implements, straw bands and tablets. The agricultural implements are not numerous, and are only sharp pointed, wedge-shaped sticks. The war clubs consist of a heavy five-pointed, star-shaped head of stone mounted on a stick of wood an inch in diameter and four feet long. In one case the head of the stick was decorated with a bunch of coarse hair. The canes resemble the rough walking sticks of to-day, but are always over four feet long. Slings are still used to a great extent in the interior for driving llamas or killing birds or game. Those found in the graves do not differ materially from the modern ones. They are generally made of llama's wool, braided and often beautifully colored and decorated with tassels.

None of the bodies found had any trace of hair on the face. This fact explains the use of the tweezers so often found wrapped up in the bundles. They are generally of copper and are cylindrical in shape. In two of the graves a flag or banner was found. They are both alike and are twelve inches wide and sixteen long. The ground color is crimson, with a symbol like a Greek sigma worked in black and orange. Both were mounted on poles about five feet long, and they were placed at the right of the bundle. Probably the objects least understood and of the greatest significance from the graves are the tablets found leaning against the bundle. They are made of a piece of white cotton cloth stretched over a framework of reeds from six to ten inches square, fastened at the back and bound to a round stick of wood painted in black and red bands. The stick is about two feet long, and is thrust into the sand near the bundle. The face of the tablet is painted in black and red figures, generally rude and of a conventionalized human form. It is a curious fact that always an even number of tablets are found in the same grave, never less than two or more than six.

Fish formed an important article of food at Ancon then, as it does now, and they were caught in about the same manner—in nets and seines. Over thirty per cent. of the men found in the graves were provided with nets. Only one fish hook and line was found, a rather singular fact, as various forms of the hook and line are found below Ancon on the coast. The line mentioned is small and perfectly made, the hook is of copper, very small, semicircular in shape and sharp at both ends, and is not provided with a barb of any sort. In the same grave were found several incomplete straw bands, together with several bunches of the splints, which the owner was probably using at death. The male occupant of another grave was accompanied by a well-preserved yellow dog. The remains of llamas and parrots are often encountered.

As the male bundle has its peculiar decoration, the tablet, so that of the female was decorated peculiarly also. On the outside of the bundle and leaning against it were frequently numbers of small reeds, two feet long, and bound into bundles of three each, by colored yarns so placed as to form successive bands, or arranged in spiral figures one overlapping the other. These wand-like reeds have no use that I know of and were probably symbolical in their nature.

A more interesting article of the grave of the woman is the work basket, with its contents, which furnish us many valuable data. Two kinds of baskets are found, one made of reeds two feet long, ten inches deep and ten wide. The other is woven of straw and is about half the size of the one made of reeds. In the baskets are found spindles, hand looms, cotton, wools, yarn, ear ornaments, tubes of paint, leaves of coca, fruit, etc.

The spindles are of different kinds. The most common form is made up of a reed four inches long and less than one half inch in diameter, which forms the whorl. Into each end of this is thrust a round piece of hard wood, sharp at both ends. This form of spindle is rarely decorated. In the other form the whorl is of terra cotta, copper, or a short reed mounted on a perfectly rounded wooden shaft. In one grave I found a bundle of seventy spindles of this latter kind, and all beautifully decorated and exquisitely made. Many spindles contain a half-finished spool of yarn, which is still attached to the bunch of wool or cotton. The wools include llama, alpaca, and vicuña. The dyeing was done before spinning. The looms are very simple, consisting of three round and three flat sticks, but with those the most delicate work was accomplished. Some of the fabrics are remarkable both for texture and design. Small garments woven in the same manner as Gobelin tapestry are not uncommon, while they also embroidered and did drawn work most skillfully and tastefully.

In fact the degree of perfection and skill to which these people attained in textiles is wonderful, and has always been the glory of ancient Peru. The other objects found in the graves of the women do not differ from those found in the graves of the men, and of those I have already spoken. The tubes of paint mentioned as found in the work baskets are interesting, for they contained the paint which the lady of Ancon used on her face. We find the two colors white and red, but she applied them differently from the manner in which they are used in these degenerate days. She put the white on her cheeks and the red on her forehead. She also wore ear ornaments already described and silver bands on her wrists.

The contents of the children's graves consist of such objects as we might expect to find, small pots of food and little clay images, and in a few cases wooden tops. One fact alone is worthy of attention—several children have been found wrapped in the skin of a dog or of a llama, a covering which is never found with the adult.

I have spoken of the desert of Ancon and said it never rains on the coast of Peru and that the nearest ruins are nine miles distant. Where then did these people come from and how did they live? These questions have often been asked and never yet, I believe, satisfactorily answered.

In many places at Ancon I have found kitchen refuse at a depth of four feet—bones, rags, corn, shells, potsherds, reeds, and canes promiscuously mixed. This one is sufficient to prove that the plain has been inhabited for a great period of time.

Further, I believe, they buried their dead under

their houses or near them, and that their houses were built of canes plastered over with mud, just as the cathedral of Lima is built and all the houses on the coast of Peru—light and flexible, so as to withstand the earthquake shocks. Further I have traced the ruins of an ancient azequia or an irrigating canal round through the hills to the river Chillón, distant twelve miles, and I believe the present barren waste of Ancon was once a great fertile field dotted with patches of corn and beans, alive with an industrious people.

Even within modern times great azequias have been destroyed in civil revolutions, and now exists a great dry sandy plain where a few years ago was a sugar hacienda. Peru, with all her unbounded resources, does not advance as she ought. On the contrary, each year marks the destruction of a reservoir, an azequia, or a road of a people we know must have been in many respects highly civilized and enlightened now in a state of utter degradation and decay.

ENGINEERING PROBLEMS IN THE CONSTRUCTION OF LARGE REFRACTING TELESCOPES.*

By WORCESTER R. WARNER.

THE continued and growing demand of astronomers for larger and more far-reaching telescopes has presented an entirely new series of problems, for the solution of which the best talents of the engineer are brought into play.

Size and penetrating power, while most important, are not the only requisites of the great telescopes of to-day; for they must be specially designed and arranged for spectroscopic and photographic as well as for micrometric and visual work. This combination of uses greatly increases the complexity of the problems and the difficulty of their solution. The suggestion has been made periodically for the last fifty years that the proper system of construction for large telescopes is to place the optical axis of the instrument in a horizontal and permanent position on the ground, pointing due south, and to reflect the images of the heavenly bodies into it by means of mirrors. This would at first sight seem a happy solution of the engineering problems, were it not for the fact that in large instruments it introduces optical difficulties well-nigh insurmountable; for the mirrors must be much larger than the objectives into which they reflect the light, and to give good results their surfaces must be optically perfect, and must be mounted so as to be free from deflection in all positions. These conditions are so difficult to obtain that, for large telescopes, this system is practically ruled out, while for small or medium sized instruments the ordinary construction with a movable tube is much more convenient.

Prof. Langley has, however, recently erected at the Smithsonian Institution a 12 in. horizontal refracting telescope, having an 18 in. plane mirror, which is said to be very perfect and successful in its operation. It is the form known as the siderostat.

Again, much study has been given to a form of telescope known as the equatorial coude, in which the optical axis of the telescope is parallel to the axis of the earth, and the light of the star is reflected into it by two mirrors. This is very convenient for the astronomer, who can sit in his chair and observe the stars as easily as he can use his microscope; but the loss of light and definition by the double reflection, as well as the deflection of the mirrors, and the varying temperatures to which the different parts of the instrument are subjected, render this construction far from perfect; so the problems incident to mounting the largest telescopes with movable tubes still confront us.

The three largest telescopes in this country, viz., the new 26 in. equatorial of the Naval Observatory at Washington, the 36 in. Lick telescope at Mt. Hamilton and the 40 in. Yerkes telescope, just completed for the University of Chicago, and now erected in the Manufactures and Liberal Arts building at the World's Columbian Exposition, may serve to illustrate some of the modern methods of solving these problems and form the subject of this paper. As the last mentioned and largest is the most available for examination, we will confine the discussion to it.

In designing a large telescope, the first element to which the engineer naturally gives his attention is the tube; for, while its office is a very simple one, being merely to hold the objective and the eyepiece in their proper relation to each other and to enable the astronomer to direct the optical axis to the star, it is an extremely important factor.

The two most essential points in the tube are lightness and rigidity, the former for ease of motion and the latter to reduce flexure to a minimum. The material best calculated to give these two qualities seems at the present time to be sheet steel. Some material having aluminum as a base has been sought for, but thus far none has been found giving the requisite rigidity.

The form of the tube has much to do with its rigidity, a slight increase in diameter at the center serving to stiffen it to a great degree, and causing thinner material to suffice. No form of internal bracing seems so effective as the same amount of material used in the shell itself. In the tubes of the three large telescopes named there is, therefore, no bracing whatever, all the strains, both in tension and compression, being taken by the sheet steel forming the tube.

The tube for the 40 in. Yerkes telescope is 42 in. in diameter at the objective end, 52 in. at the center, and 38 in. at the eye end. The sheet steel forming the tube varies from 7.32 in. in thickness at the center to 1.8 in. at the ends. The total weight of the tube is 6 tons.

The declination axis carrying the tube is of forged steel, 12 in. in diameter and 12 ft. long, its weight being 1½ tons. This runs in segmental babbitt bearings in the declination sleeve, which weighs 4 tons. The polar axis carrying the whole system is of hard forged steel, 15 in. in diameter at the upper bearing and 12 in. at the lower bearing, and weighs 3½ tons.

Just above its upper bearing it carries the main driving gear, weighing one ton and having 330 teeth, by which the movement of the driving clock is communicated to the polar axis.

The great weight of the bearings of these axes is at

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most wholly relieved, and the resistance changed from sliding to rolling friction by means of three bracelets or live rings of steel rolls. One of these encircles the declination axis near the tube and one is placed above each bearing on the polar axis. These anti-friction live rings run in steel yokes, and are pressed against the axes by means of adjustable spring levers.

The live ring of rolls which is on the declination axis near the tube is the center of gravity of the system comprising the tube and the declination axis with their attachments, this one series of rolls serving to take the weight off both bearings of the declination axis, and so nearly eliminating friction that less than one pound of direct pressure on the tube is required for each ton of weight moved. This live ring is composed of 16 in. rolls, 5 in. long and 3 in. in diameter, and carries a total weight of 8 tons.

The live ring at the upper end of the polar axis is composed of 16 rolls, 6 in. long and 4 in. in diameter. This sustains a weight of nearly 20 tons. The end-thrust of all this great weight, due to the angle at which the axis is placed, is taken on a double series of 40 one in. hardened steel balls.

The methods of balancing the movable parts of the Yerkes telescope have been a special study, with results which seem all that can be desired.

The heaviest accessory to be used with the telescope is the solar spectroscope. With this in position, the tube is accurately balanced. Weights are then placed on the extension of the declination sleeve until the whole system is in balance. When the solar spectroscope is to be removed, sufficient supplementary weights are placed at the side of the eye end of the tube, so the balance is not disturbed.

The equatorial head and its bearings supporting the polar axis and the entire movable part of the telescope is cast in one piece, its base conforming to the rectangular shape of the column.

The column is 11 ft. \times 5 ft. at the base, tapering to 10 ft. \times 5 ft. at the head. It is cast in five sections, having internal flanges for securely bolting it together. In the upper section is placed the driving clock. A spiral staircase at the south side of the column gives easy access to the driving clock, and also to the balcony surrounding the head.

The driving clock is governed by a double conical pendulum, mounted isochronously, and making 60 revolutions per minute.

A driving weight, considerably in excess of the amount required to drive the telescope, is used with this clock, the surplus of power being taken by a friction ring placed just above the pendulum. The arms of the pendulum are so arranged that in operation they always take their natural and theoretical positions, not being swerved therefrom by the action of the power on the friction ring above mentioned. When the clock is unclamped from the polar axis, all the power required to move the telescope is instantly transferred to the friction ring, and the pendulum maintains its theoretical position and normal rate. An electric motor is provided for automatically winding the clock.

All clamps and slow motions, both in declination and right ascension, are operated by handles at the eye end within easy reach of the observer, while the assistant on the balcony can also set the telescope in any position and read the circles. In addition, electric motors are provided for operating all quick and slow motions and clamps.

These various motions and clamps being operated by the astronomer at the eye end of the tube either by hand or by means of the electric motors, and also by the assistant on the balcony, are so arranged that any one method of working them is not interfered with by either of the others. Each motion is therefore always ready for action and no conflict is possible.

Incident to the construction of large telescopes, problems are presented in providing domes to cover them, and elevating floors by means of which their use is made more convenient.

These problems have been very satisfactorily solved, for the domes of the best construction will revolve by a direct power of two pounds per ton of weight moved.

Elevating floors of nearly the diameter of the domes are in successful use with the 36 in. Lick telescope and also with the 26 in. telescope at the new Naval Observatory at Washington. Both these elevating floors are operated by hydraulic power, the simple movement of a lever sufficing to raise or lower them.

Such is the solution of some of the problems incident to the construction of large telescopes and their equipment to-day. What improvements the morrow may bring forth it were hazardous to predict.

THE CONSTITUTION OF THE STARS.*

By EDWARD C. PICKERING.

OUR only knowledge of the constitution of the stars is derived from a study of their spectra. This has been done at the Harvard College Observatory as a portion of the work of the Henry Draper Memorial. Photographs have been taken of the spectra of the brighter stars on a large scale, some of them being as much as six inches in length. To photograph the fainter stars, a smaller dispersion is employed, and in this way the spectra of stars as faint as the ninth or even the tenth magnitude may be obtained. To study the stars too far south to be visible in Cambridge, expeditions have been sent to South America, and a permanent observing station has been established near Arequipa, Peru, at an altitude of about eight thousand feet. There the southern stars are photographed with instruments similar to those used in Cambridge for the northern stars. A few spectra have been photographed with plates stained with erythrosin, which renders them sensitive to the yellow rays. A portion of the visual spectrum not shown on an ordinary plate is thus photographed. Images of the sodium line "D," in which the two components are clearly visible, have been obtained for several stars. In all, many thousand photographs have been collected, including stars in all parts of the sky, from the north to the south pole. The spectra of all the bright stars have been photographed as described above, with a large dispersion, and the spectra of a

large portion of the faint stars with a small dispersion. A careful study has been made by Mrs. M. Fleming of the fainter stars, and of the brighter stars by Miss A. C. Maury. From this it appears that while at first sight many spectra seem to be unlike, nearly all of them can be arranged according to a simple system. It is not proposed in the present paper to consider the cause of these differences. For purposes of description, it will be convenient to treat them as if due to differences in composition only, although there is evidence that the actual variation is rather in the order of growth. The spectra of ninety-nine one-hundredths of the stars could be imitated by combining in different proportions four sets of lines. These are first hydrogen; secondly, a substance presumably calcium in such a condition that it gives the broad lines "H" and "K," which are the most marked features in photographs of the solar spectrum; thirdly, the substance, or substances, which give the lines characteristic of many of the bright stars in Orion; fourthly, the lines of the solar spectrum omitting those due to hydrogen and calcium. These four classes of lines may be described as hydrogen, calcium, Orion, and solar lines. We may now arrange nearly all the visible stars in a sequence such that the spectra change insensibly from each one to the next. At one end of this sequence are such stars as α Virginis, α Eridani, and β Canis Majoris. In them, the Orion lines and hydrogen lines are well marked. The principal Orion lines have wave lengths 382, 402, and 453, and are sometimes nearly as intense as the hydrogen lines. These spectra are designated by the letter B in the provisional classification adopted in the Draper catalogue. In the next stars of the sequence the Orion lines have become fainter and the hydrogen lines stronger, while the calcium and solar lines are faintly seen. This gives the large class of stars called A in the Draper catalogue, of which the Milky Way is mainly formed. The stars α Canis Majoris and γ Lyrae are examples of this class. The hydrogen lines here so greatly exceed all the others in intensity that in faint spectra they are the only lines visible. The line "H," due to hydrogen, has a slightly greater wave length than the corresponding line due to calcium. When these lines are well defined and about equally intense the H line appears double. This is well shown in such stars as α Cygni, in which the hydrogen lines are narrow, but is also distinctly seen in good spectra of α Lyrae and other normal first type stars. In some stars, such as α Aquilæ, the hydrogen and other lines are broad and ill defined, as if the spectra were out of focus. It is possible that this is due to a rapid revolution of the stars around their axes, by which the portion near one edge would be receding while that near the opposite edge is approaching. But the velocity required, about a hundred miles a second in the case of α Aquilæ, is so great that such a hypothesis must be accepted with caution. The calcium and solar lines now gradually increase, and the Orion lines diminish in intensity, until they disappear; the hydrogen lines, "G" and "h," also diminish. This class of spectrum is called F in the Draper catalogue. The K line is as intense as the H line and the h and G lines are distinctly fainter. The stars α Argus (Canopus) and β Cassiopeiæ are examples of this class. The solar lines now steadily increase in intensity and the hydrogen lines diminish until the latter are no more intense than some of the solar lines. The typical second type stars are here reached and are represented by α Aurigæ, α Centauri, and α Ursæ Minoris. They are called G in the Draper catalogue or E if so faint that only the principal lines are visible. Before reaching this point we may have the hydrogen and solar systems of lines both strong, as in α Canis Minoris. It is, therefore, difficult to decide whether both substances are combined in a single star or whether the star is a close double, one component having a spectrum of the first, the other of the second type. This combination often occurs in double stars. In fact it has long been noticed that in the case of double stars, the brighter component is frequently of a reddish, the fainter of a bluish tint. The spectrum of the first star is then often of the second, while that of the second star is of the first type.

The photographs of the prismatic spectra so far described have a uniform density from the F to the H lines, that is from wave length 397 to 486. As we progress in the series the density of the portion of the spectrum of greater wave length increases as compared with the other portion. With sufficient dispersion the spectrum is seen to undergo a sudden diminution in density as the wave length diminishes at the point whose wave length is 430. The difference in brightness becomes more marked as the dispersion diminishes, so that when the dispersion is small very faint stars of this class may be recognized by their short spectra, the portion whose wave length is less than 430 not being visible. Probably the classification of spectra may be carried to fainter stars by means of this property than by any other. The letters H, I, and K are used in the Draper catalogue to designate such stars. Their spectra may be regarded as forming a second division of the second type. The sun and α Bootis are striking examples of this class, and α Tauri is a star still further advanced in the series. As we progress in the sequence, a second sudden change in intensity takes place at the point whose wave length is 476. Unlike the other change, the intensity of the portion of shorter wave length here exceeds that of greater wave length. This may be regarded as the distinctive feature of the photographic spectra of stars of the third type. The brightest star of this class is α Orionis. The letter M is used to designate spectra of the third type in the Draper catalogue. These stars may be further subdivided into four classes, of which the first is that just described. The second is represented by α Herculis, in which the spectrum is distinctly banded, each band having its edge of greater wave length bright. The third class is not represented by any bright star. Many of the variable stars of long period have this spectrum when they are not near their maxima. Variable stars of long period, when near maxima, constitute the fourth division, which differs from the third only in having one or more of the hydrogen lines bright.

Two classes of spectra must now be considered which are not provided for in the above classification. The first of these consists of the spectra of gaseous nebulae, the second that of the stars whose spectra consist mainly of bright lines. The wave lengths of

the lines in both of these classes of spectra appear to coincide with those of the Orion and hydrogen lines. They therefore appear to precede the Orion stars in the sequence described above, but the lines are bright instead of dark. While an ordinary star may be regarded as having a bright nucleus giving a continuous spectrum surrounded by an absorbing medium, the bright nucleus in these objects is wanting, and the spectrum appears to be directly due to the incandescent gas. The reversal in brightness may thus be explained. The gaseous nebulae can be divided into at least two classes and the bright line stars into at least three. A few other stars have one or more bright lines in their spectra; for instance, such stars as γ Cassiopeiæ and ϕ Persei, in which the F line is bright. They generally belong to the Orion class, and probably so much hydrogen is present in their atmospheres that the absorption is overbalanced by the direct light of the gases.

One other class of spectra remains, that of stars of the fourth type. Their spectra appear to be identical with that of carbon. Almost sixty of these objects are known. They are intensely red, and therefore difficult to study photographically. No connection has as yet been established between them and the sequence of spectra described above.

A few peculiar stars like Nova Aurigæ remain, but their number is so small that for the present each may be considered by itself.

The classification of the stars according to their spectra is so far reaching that it should be applied to each of their other properties. For instance, of the variable stars it appears that all known Algol stars have spectra of the first type, while long period variables in general are of the third type, and have the hydrogen lines bright when near their maxima, as stated above. This property has led to the discovery of more than twenty objects of this class, and no exception has been found of a star having this spectrum whose light does not really vary. Of the variables of long period which have been discovered visually, the hydrogen lines have been photographed as bright in forty-one, the greater portion of the others being too faint or too red to be studied with our present means. A few variable stars like U Hydrae, R Sculptoris, and B.D. + 62° 596 are of the fourth type. Their variation is small and their red color renders their visual observation uncertain. Variable stars of short period generally have spectra of the second type, but some like β Lyrae present special peculiarities.

The motion of the sun in space, as derived from stars of each class of spectrum, is a problem of especial importance. The plan of the Henry Draper Memorial provides for the study of each of these and similar problems.

In general, it may be stated that with a few exceptions, all the stars may be arranged in a sequence, beginning with the planetary nebulae, passing through the bright line stars to the Orion stars, thence to the first type stars and by insensible changes to the second and third type stars. The evidence that the same plan governs the construction of all parts of the visible universe is thus conclusive.

Harvard College Observatory, Cambridge, Mass., August 5, 1893.

MANURING SUGAR BEETS.

THE manufacturers of sugar from sugar beet in Germany, at their recent congress, had before them the report of Dr. Hellriegel, of the Bernburg Agricultural Station, on the manurial requirements of the sugar beet. This report was published in the *Sucrerie Belge*, and contained an account of a number of interesting experiments, of which we have prepared the following summary:

Dr. Hellriegel, taking as his starting point the principle that the aim of the agricultural chemist is to determine for each plant the minimum quantity of each fertilizing material which is necessary for its normal vegetation, has made a series of experiments on sugar beets grown in a specially prepared soil, each beet being kept separate, and given as much soil as it would generally have when grown in a field, while the conditions of growth, moisture, etc., were kept as close as possible to those prevailing on the large scale. It was found in the sterilized soil employed that beets could not be grown, though they were free from disease of any kind. Healthy and normal beets, however, were obtained when a sufficiency of lime, magnesia and sulphuric acid was added to the soil, and also a mixture of 2'940 grammes of nitrate, 2'840 grains of phosphoric acid soluble in water, and 6'594 grammes of potash (as phosphate or chloride) per head of beet. The beetroots thus obtained developed normally, and attained a total weight of 813 grammes.

Experiments were then made diminishing gradually and successively the three last-named elements. Naturally the plants in time began to deteriorate, and it was found that the plants suffered quicker when the nitrogen was reduced than when potash and phosphoric acid were wanting; the falling off in the case of the two latter being about equal, while a lack of these ingredients causes the plants to be poor. An excess does not do much good either, the experiments recorded for each element showing that at a certain point, about midway between what was found to be an excess and what was too little, the most satisfactory results were obtained.

The deduction which follows from an examination of the tabulated results of the experiments is that, to obtain a normal beet of about 800 grammes weight, there are required:

2.9	grammes of nitrogen.
1.2	" phosphoric acid.
1.7	" potash.

It will be seen that these results differ much from what is actually done in practice, but it must be borne in mind that when manure is applied on a large scale, one does not have to supply all the fertilizing materials the plant requires, but only such ingredients as the soil is short of. Consequently, as soils are usually poorer in phosphoric acid than nitrogen and potash, it often happens that the addition of a phosphatic manure is found to produce excellent results. It may be added, however, that of late years the addition of phosphoric acid has been carried to excess in the oppo-

* Read at the Congress of Astronomy and Astro-Physics, Chicago, August, 1893.