obliged in very dry seasons to drive their stock several miles daily to water. A belt of country north of this, and stretching from Lake Huron in a southwest direction quite across the State to Lake Michigan, is covered with the most beautiful little lakes of pure and sparkling water—lakes which never become stagnant and never dry up.

Farther north again, toward the northern part of the State, are found extensive pine barrens, where again there are but few rivers and streams; but I have seen wells driven there from 6 to 10 ft. only to an abundant supply of water. The little lakes I have referred to are replenished from the exposed outcroppings of gravel beds, and while they are often linked together so as to constitute the sources of considerable streams, the water from most of these lakes seems to sink away slowly again and to flow underground in broad sheets toward the great lakes. Nearly everywhere in this State water in abundance can be found by driven wells, and I am told that in the regions where the early settlers suffered so much from swamps and mud in winter and drought in summer, surface drains and tube wells have created an entirely new condition of things favorable to the farmer.

An objection has been frequently urged against the use of water from these shallow sub-surface deposits that there is danger from pollution or contamination of the water by sewage and surface drainage, the drainage from cemeteries, etc.

While it would obviously be undesirable to establish a driven well plant within the limits of a populous city, it may be said that the necessity for so doing is never likely to occur. Moreover, the purifying influence of the soil by infiltration is known to be very effective; the well-known processes of sewage disposal by irrigation and downward filtration are based upon this property of the ordinary porous soils.

A microscopic analysis of the effluent water from the irrigation fields of Paris showed that the number of microbes in the sewage was reduced from 20,000 per cubic centimeter to 12 per cubic centimeter, and that the effluent water from the irrigation fields contained fewer microbes than the water supplied to Paris for domestic uses. (See Gray's Report to the City Council of Providence.)

The water being drawn from considerable depths, usually the purifying effect of the slow downward filtration from the surface would probably be much more complete than is produced by any artificial filtration.

It should be a source of public congratulation that while our rivers and streams must become polluted by a growing population, nature furnishes another source of water supply so abundant and widespread, so pure and easily procurable.

Explorations and investigations having in view the more thorough study of this underground water supply deserve and should receive at the hands of the public the most earnest appreciation and encouragement.

THE APPLICATIONS OF PHOTOGRAPHY IN ASTRONOMY.

By DAVID GILL, LL.D., F.R.S., Her Majesty's Astronomer at the Cape of Good Hope.

So remarkable has been the progress of the miscellaneous application of photography to astronomy within the past year, that some account of it is essential to bring the history of the subject up to date. For example, we have the recent work of Professor Pritchard, of Oxford.

He has applied photography during the past year to the most refined and difficult problem of practical astronomy, viz., the determination of the annual parallax (*i. e.*, the distance) of the fixed stars. He has selected for experiment the interesting double star 61 Cygni. One of the original negatives of the series is now on the screen. This star, as is well known, was selected by Bessel, on account of its large proper motion, as the most suitable star for his first experiment. It was probable, because its large apparent motion among the stars was so great, its real distance from us would be less than that of stars of less apparent motion. Bessel's observations with the Königsberg heliometer proved this to be the case, and his discussion of these observations first convinced astronomers that the measurement of interstellar spaces was a problem not entirely beyond their reach.

Professor Pritchard has now photographed the star during a whole year, and within a few days he promises that we shall have the results of his measurement of the plates. It will be of great interest to compare his results with previous independent determinations of the parallax of the same star made by other astronomers with different means, but it will be still more interesting for the future of astronomy to compare the amount of accuracy which the photographic method affords as compared with the older existing methods. From preliminary results published by Professor Pritchard, we are led to expect a very high accuracy from the new process.

So far, however, as present experience goes, we shall not be able to apply this new method to the measurement of the parallax of very bright stars, because, when the plates have been exposed long enough to obtain pictures of the faint comparison stars, the disks of the brighter stars become too large and ill defined for exact measurement. It may be that this obstacle will yet be overcome, but at present it has still to be faced.

On the question of the comparative merits of refractors and reflectors as the proper instruments for photographic use, very elaborate comparison has been instituted, and much discussion has been held.

From the simple facts that the best work yet done has been done in stellar photography by refractors, and that they are in many ways more convenient and simple in use than reflecting telescopes, the Paris congress unanimously adopted the refractor as the instrument to be adopted for the international star charts. But here is a very remarkable picture taken with the Oxford reflector, which shows star disk very sharp and very round over a very large field of view, viz., eighty minutes of radius.

In the photography of special objects, such as star clusters and nebulae, much has been done.

Common's exquisite photograph of the great nebula of Orion you have seen before in this theater, and for exquisite beauty of detail it has never been excelled. But of this we may be sure: that if Mr. Common is

spared in health and strength to complete the great reflector of five feet aperture upon which he is now engaged, that photograph, beautiful as it is, will be far surpassed. Here is another photograph of the same object, by Mr. Roberts. So short is the focus of his telescope, so sensitive are the plates he has employed, that the detail of the brighter parts has been completely burnt out, but a great deal of new-found detail is brought to light.

Here is another photograph of the same object by Professor Pickering, taken with a four lens objective, of eight inches aperture and very short focus, and including a field of five degrees square. Exposure, 82 min. This shows what can be done with such a combination.

In 1885 the Brothers Henry, photographing the Pleiades on November 16, discovered a new nebula near the bright star Maia in the group. Here on the screen is a copy of the original negative by which the discovery was made. You observe the nebula like a filmy projection from one of the stars.

After the nebula had been discovered by photography it was found to be visible in the great telescope of thirty inches aperture at Pulkowa. But to discover is one thing, to see after discovery is another.

Strangely enough, this new nebula was really photographed a fortnight before its discovery at Paris, by Professor Pickering, at Cambridge, in America. In exhibiting the photograph to the National Academy of Sciences five days before Henry's discovery, Professor Pickering pointed out the "wing" attached to the star, but there was only one plate shown. The impression was that the mark was due to a defect in the gelatine film.

Here, however, is another picture of the Pleiades taken at Cambridge with the same instrument, and an exposure of eighty-two minutes, which shows nebulosity about more than one star of the group.

And here is a copy of a negative by Mr. Roberts, of Liverpool, with an exposure of three hours. The star disks are of course large and ill defined; but the quantity of nebula, invisible to the eye in the largest telescopes, is quite surprising.

These photographs appear to prove conclusively that the nebula and the stars in this group are one system. The doctrine of chances renders it almost an impossibility to suppose that such a symmetrical arrangement of nebula matter with respect to the stars could exist by chance, if the stars were projected in front of a far distant background of nebulous matter.

Here is a photograph of the stars surrounding the celebrated variable star η Argus, taken at the Cape with the telescope of nine inches aperture, generously presented to me for such work by Mr. James Nasmyth. The nebula surrounding this star is very faint compared with the Orion nebula, and it seems to be deficient in actinic rays, and, besides, the telescope is intended for stellar photography by its long focal length, and not for nebulae, which require a shorter proportional focus—*i. e.*, more intrinsically brilliant image.

Still there is the nebula, and I believe this is the only existing photograph of the object. The exposure was $2\frac{3}{4}$ hours, and yet, although the original negative has been enlarged four diameters, the star disks remain well defined. The corresponding region of the sky is less than the moon's apparent diameter, and of the many thousands of stars visible on the photograph not a single one is visible to the naked eye. The star η Argus was in 1843 nearly the brightest star in the heavens—in fact, second only to Sirius. It is now between the seventh and eighth magnitude.

Here is a star cluster in Argus. The star disks are not so sharply defined, but the original negative has been much magnified to bring out the star disks.

Here is a photograph, also taken at the Cape, of the wonderful star cluster ω Centauri. It is the finest globular cluster in the heavens, and I do not know that I have ever seen the separation of the central stars so distinctly with the eye as they are shown in this photograph. Perhaps, by photographing, we shall learn what motions occur in each cluster. This negative has been enlarged four diameters from the original.

Here is a photograph of the well known cluster in Hercules, taken by Mr. Roberts, of Liverpool, and a still more wonderful one by the Henrys, of Paris. They must be magnified more highly to give any idea of their quality.

When the objects are bright, such as bright double stars, or planets, or the moon, we can enlarge the image produced by the telescope by aid of a secondary magnifier.

Because of the greater size of the original pictures thus produced, the granulation of the photographic film interferes to a less extent with the detail of the picture. Of course, this advantage is purchased at the cost of a longer exposure, because the same amount of light is spread over a larger area of the sensitive plate, and consequently the same area of the film receives less intense light. With very bright objects, such as the sun, moon, and planets, this is of little consequence, and may be an advantage, as permitting more accurate regulation of the exposure.

Here is a picture of the sun photographed by M. Janssen at Meudon, near Paris. The exposure is less than one thousandth of a second of time. And here is an enlarged photograph of the same spot, showing an amount of detail which no artist could convey by hand and eye, nor could he emulate the absolute accuracy of the photograph. Here are some photographs of the planet Jupiter, taken at Paris, the original image being magnified eighteen times. Here is another showing the remarkable red spot—you even have before your eyes evidence of the rotation of Jupiter on its axis by the change in the position of the spot during the same evening. This spot appeared in 1878, and measured about 30,000 miles in length by 7,000 miles in breadth. It became of a deep red color in 1879, and for the three following years was a most striking feature in the planet. It almost faded entirely in 1883, but has again become nearly as bright as it was in 1882.

Miss Clerk tells the story most admirably and suggestively in the last edition of her "History of Astronomy," to which work I would refer those of my hearers in whom these beautiful photographs may excite a sufficient interest.

To enter fully into the matter would demand a lecture to itself—and the minute hand of that inexorable clock warns me that I must move on.

Here are some photographs of Saturn which illustrate the remarkable progress of celestial photography.

Here are some photographs of double stars. One of these, a photograph of γ Virginis, taken at Greenwich, is probably the finest photograph of a double star in existence. The star disks measure less than 1" in diameter.

Last of all I come to the most recent revelations of the power of photography as an aid to astronomy. Dr. Henry Draper, in 1872, was the first to photograph the lines in the spectrum of a star, but his admirable investigations were interrupted by death in 1882. In 1886, his widow placed in the hands of Professor Pickering, of Harvard College Observatory, in America, not only an ample sum of money for the purchase of costly apparatus, but also made a liberal provision for carrying on the work of photographic spectroscopy as a memorial to her husband. So noble a gift, and the execution of so pious a purpose, could not have been placed in abler or more active hands.

Within the past few weeks we have received the first fruits of Henry Draper Memorial Fund. When I began preparation of this lecture, I cabled to Professor Pickering for some glass copies of his original negatives. He kindly complied, and they arrived this morning. Time only permits me to show them rapidly, but those who remember Dr. Huggins' lectures on stellar spectra in this theater will recognize the enormous importance of such pictures as these. The ingenuity of the adopted methods, the extraordinary success attained, the promise of rich harvest, exceeding our highest expectations, which the results afford, are themes upon which one could dilate for hours.

Here we have the spectra of the distant stars whose actual disks we can never hope to see, registering in these rhythmic lines the story of their constitution and temperature, with an accuracy and precision which not many years ago we should have been glad to obtain in the records of the spectrum of our own sun. And this is not all. Not only have we such results for a few stars, but we are promised that "the complete work will include a catalogue of the spectra of all the stars of the sixth magnitude and brighter, a more extensive catalogue of spectra of stars brighter than the eighth magnitude, and a detailed study of the spectra of the bright stars." These are Professor Pickering's own words.

What Professor Pickering promises, we know from long experience that he will perform. We may also well say with him that "a field of work and promise is open, and there seems to be an opportunity to erect to the name of Dr. Henry Draper a memorial such as heretofore no astronomer has received."

There is in England wealth enough and to spare. Many a rich man dies puzzled how to dispose of his money; and there is many a living man who would gladly give for such an object if he knew how to do so. There is field enough in astronomy, and there are men enough in England to do the work. Let us hope they will receive aid such as Professor Pickering has received; and having done so, they will give an equally good account of their stewardship.

The miscellaneous applications of photography to astronomy offer a field so full of promise, so certain of immediate reward to those who are possessed of the necessary originality and the means to carry out their ideas, that there is more hope of private enterprise in that direction than in the more routine work of star charting.

But tempting as these fields are, brilliant and interesting as are the discoveries to be found in them, there is in the work instituted by the Paris congress an element that cannot be overlooked, and which compels attention; it is this: the question of the lapse of time. Every year which passes after that work has been carried out, increases its value and importance. Every year that we neglect in doing it will be a reproach to the astronomers of the day. Into all the great problems which that work is destined to solve, the element of time enters; and time lost now in such work can never be recalled.

Of the congress itself I would say a few last words. Its proceedings were characterized by an earnest spirit of work and entire absence of international jealousy. Our reception by the French was cordial and hospitable in the highest degree, the decisions of the congress were almost unanimous, and were marked by a moderation and judgment which must render them acceptable to the responsible authorities of the various governments.

Lastly, I would add that the good will which pervaded the meetings, the general success of the congress as a whole, were in no small degree due to the genial influence of the single-hearted, earnest-minded man who convened it—Admiral Monchez.

[INDIAN AGRICULTURIST.]

THE CLOVE TREE.

THE clove tree (*Caryophyllus aromaticus*), says Rumphius, "appears to me the most beautiful, the most elegant, and the most precious of all known trees." In form it commonly resembles the laurel, and sometimes the beech. Generally of the height of an ordinary cherry tree, its trunk is straight, and rises to four or five feet before it throws out branches. The bark is smooth, thin, and adheres closely to the wood, which is hard and strong, but of an ugly gray color, and, therefore, not suited for cabinet work. In the commencement of the wet season, which is the month of May in the native country of the clove, the tree throws out a profusion of new leaves. Soon after, the germs of the fruit are discovered at the extremities of the young shoots, and in the four following months the cloves are completely formed. The fruit, at first of a green color, assumes in time a pale yellow, and then becomes of a blood red color, if of the most ordinary variety. It is at this period that the clove is fit to be used as a spice, and of course this is the period of the clove harvest. It is not, however, the period of the full maturity of the fruit, which requires three weeks longer to perfect itself and serve for the purposes of propagation. In this short period the fruit swells to an extraordinary size, loses much of its spicy quality, and contains a hard nucleus like the seed of the bay. This state of the fruit is what Europeans call the mother clove, and the natives *paleng*.

There appear to be five varieties of the clove, viz., the ordinary cultivated clove, the clove called the