EDWARD EMERSON BARNARD

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[EDITOR'S NOTE.—The article given below was prepared by Dr. McGill in 1922 and published in three instalments in the *Vanderbilt Alumnus* of that year. Dr. Barnard went over this article in person and made such corrections and additions as to make it the most complete and authoritative account of his life and work to be found at that time.]

There is nothing more encouraging to young persons who are struggling in adverse circumstances to equip themselves for a useful and honorable career than to have set before them the example of one from their own community who has risen to the highest honors out of circumstances not more favorable than their own. So thinks our instructor in astronomy who has the habit of reading in the observatory to his class every year an excellent sketch of Edward Emerson Barnard written by Mrs. Janie McTyeire Baskervill, which was published in the Nashville *Christian Advocate* in the issue of November 8, 1900.

No alumnus of the University—not even excepting anyone of those who have won fame on the football field—is more widely known among the alumni than Dr. Barnard; not because of personal popularity or fraternal, alumnal, or University activities, but on account of his splendid achievements in astronomy, which have won for him the award of the highest honors that several of the most learned scientific bodies in the United States, France, and England could bestow.

Dr. Barnard's astronomical work is comprised in four periods: from 1879 to 1883 in Nashville at Poole's photographic gallery and his home, with his own 5-inch telescope; from 1883 to 1887 at Vanderbilt University; from 1887 to 1895 at the Lick Observatory, Mt. Hamilton, California, with the 36 and 12-inch refractors and a Willard portrait lens; and since 1895 at the Yerkes Observatory of the University of Chicago, with the 40-inch refractor and the 10-inch Bruce photographic telescope. His activities have embraced nearly every field of astronomical work, including the planetary system of our sun, comets, the fixed stars, nebulæ, meteors, occultations, eclipses and celestial phenomena, such as the aurora and the "gegenschein." It is not possible to follow these in detail in a limited article for a journal. Readers of the *Vanderbilt Alumnus* will be interested rather in an account of his life in Nashville and at the University, supplemented with a mention of his most notable discoveries at the Lick and Yerkes Observatories, his contributions to astronomical literature and the testimonials of astronomers and learned societies to the value of his work.

In speaking of his life in Nashville and at the University, I think I may venture to be more specific in the mention of persons, places, and incidents than would be appropriate in an ordinary record, yet admissible in this case because of the special interest

which we in Nashville have in one who spent the first thirty years of his life here and, going out from among us, has advanced to the foremost rank of those who in the study of celestial bodies and phenomena are solving the mysteries of the universe.

HIS FIRST EMPLOYMENT

In the year 1866, in the house at the southeast corner of Union and Cherry Streets (now Fourth Avenue), upstairs, where Calvert Brothers now are, Mr. Van Stavoren, a photographer, had his gallery. Mr. Van Stavoren was also a portrait painter; and, in order to throw upon the canvas a large-sized image, he used an immense solar camera located on a platform built above the roof of the house. Not having a heliostat, he employed boys to turn the lens constantly so as to keep the rays of the sun centered upon the camera. But no boy, it seemed, could stay awake long in this soporific employment. Incidentally mentioning this fact to his friend, Mrs. Elizabeth Barnard, she told him that her son Edward could do this and not go to sleep.

This employment led him to a discovery. He noticed that a shadow mark that indicated noon according to the ringing of the Catholic church bell changed its position slightly from day to day. That is, he found that solar time and clocktime do not exactly agree. This variation expressed in astronomical books by the "equation of time" was so small when represented by the change in the position of the noon shadow mark, that its discovery required close observation and seems as remarkable, under the circumstances for one of his age at that time, as the discovery of a comet by him ten or twelve years later. From his occupation on the roof he was promoted after a time to the position of printer in the photographic gallery; and there in a few years he became proficient in all the departments of the work.

So it came about that the subject of this sketch very early in life became interested in astronomy and the telescope through an employment that led him to the observation of the apparent variation in the motion of the sun and the effect of lenses on the rays of light, and, through the study and practice of photography, unknowingly prepared himself for the application of this art to the highest development of astronomical research.

FIRST TELESCOPE

In 1870 a Scotchman, Mr. J. W. Braid, an instrument maker and photographer, came to Nashville, and became the operator in the Van Stavoren gallery. One day as he was on the way to the Federal barracks in North Nashville, he picked up in the road a lens which had been used in a spyglass. Knowing young Barnard's interest in lenses, he fitted it into one end of a pasteboard tube and put some sort of an eyepiece in the other end and gave it to him. This was Barnard's first telescope.

His second telescope was made out of a brass spyglass tube bought of Charles Schott, an instrument maker,—afterwards for many years *factotum* for Chancellor Garland in the School of Physics at Vanderbilt University—a 2¼-inch lens ordered from Queen and Company, of Philadelphia, and two small lenses from an old microscope as an eyepiece. This was mounted on a tripod that had been used in the gallery as a camera stand. The exercise of a little mechanical ingenuity added a vertical movement to the instrument—and the telescope was complete. His desire for a telescope and to study the moon and the stars had been increased by the reading of Dr. Thomas Dick's "Practical Astronomy," a book left in his room as collateral for a loan of $2.00. This book, besides picturing very graphically the wonders of the heavens, described the construction of a telescope, and was thus of considerable assistance to young Barnard and his friend Braid in making a telescope. Barnard took the 2¼-inch telescope to his observatory, the open roof of the building, and was delighted to find how distinctly it brought out the diversified surface of the moon, the crescent of Venus and the disc of the planets.

In 1876, through Mr. Braid's relatives in New York, he heard of John Byrne, an optician and manufacturer of refracting telescopes. From Byrne he purchased one of his 5-inch telescopes complete, with eye-pieces, simple equatorial mounting but without driving clock or circles. When he went to California, being in pressing need of money after being there some time, he sold his 5-inch telescope to the University of Southern California, where it is at the present time.

ROOF LEVEES

There was no telescope in Nashville comparable to Barnard's before the 6-inch refractor was installed at the Vanderbilt Observatory. He was elated at its celestial revelations and was delighted to have his friends share his pleasure. At times the roof of the building at the corner of Fourth and Union was so crowded with guests that he was solicitous lest his treasure might be knocked off. After the friends departed he would begin his quiet work, and often the early morning would find him sweeping the heavens with his telescope. Fortunately in the day time it was no longer his duty to make the big solar lens follow the sun; Mr. Van Stavoren had sold out to Mr. R. Poole.

ELECTRIC "FANS"

Incidentally it may be mentioned that Mr. Braid, who had fitted up a small shop in a back room of the Poole gallery for electrical experiments and making instruments for this purpose, had become almost as deeply interested in telephony as Mr. Barnard was in telescopy. He and his friend, James Ross, used all their spare time in constructing telephones and testing them by means of wires strung between Poole's gallery and Ross's office and elsewhere. When a gentleman one day came into the gallery and greeted Mr. Poole

with "Well, how is business?" he ruefully replied, "With an operator crazy about electricity and a printer crazy about astronomy, I'm afraid my business is going to the devil."

NEWCOMB'S ADMONITION

In September of 1877 the American Association for the Advancement of Science held its annual meeting in Nashville at the Capitol. Mr. Barnard joined the Association and, at the request of several members, his telescope was taken to the Capitol for inspection. Simon Newcomb, president of the Association, the distinguished astronomer of the U. S. Naval Observatory to whom he was introduced, was interested and astonished to find one so poorly equipped educationally in possession of so fine an instrument, and told him that the mere observation of various interesting heavenly bodies was a waste of time and that he could accomplish nothing of value in astronomical work without a better education—especially in mathematics. Realizing his lack of education and seeing no opportunity of repairing the deficiency, Barnard was greatly depressed and discouraged by this frank admonition. But on reflection he became convinced that Professor Newcomb had given him sound advice and he determined to profit by it. With strict economy he managed to save enough out of his monthly earnings to employ a tutor, and began to spend his evenings in the study of mathematics instead of in the more pleasant occupation of looking at the heavens through his new telescope.

JUPITER THROUGH THE FIVE-INCH

When he resumed astronomical work it was with the intention of entering upon a careful study of a single body or class of bodies. He selected the planet Jupiter. "What particularly attracted my attention to the planet," he says, "was the great Red Spot which was first seen by me in the early morning of August 3, 1879. I had heard nothing of it, but found afterwards that it had been seen by Professor Pritchett, of Glasgow, Missouri, as early as July, 1878, and probably at intervals before that time." He continued this work assiduously through 1880 and at intervals up to May, 1882, making drawings of the planet during each observation. The drawings showing the changes in the red spot, white spot, belts and other markings during this period, and the notes and discussions accompanying them, form an important contribution to the literature of the planet Jupiter. From time to time he reported these observations to the *English Mechanic,* and *The Sidereal Messenger,* and other journals.

In 1889 he published an article on the planet Jupiter in the *Publications of the Astronomical Society of the Pacific,* containing 42 photo-lithographic reproductions of these drawings made before and after he went to Vanderbilt University. These were accompanied by tables of the numerous observations of the great red spot that he had made with his 5-inch telescope.

His Marriage

In 1875 Mr. P. R. Calvert, who had come from Yorkshire, England, to Nashville, a few years before this time, opened an art studio in connection with Poole's photographic gallery. He was joined later by his brother, E. Calvert. These artists soon became interested in young Barnard, and their friendship and association were very helpful to him at this period of his life. In January, 1881, he married their sister, Miss Rhoda Calvert, who for forty years thereafter was his constant and loving companion.

She died at Williams Bay, Wisconsin, May 25, 1921, and was buried beside Mr. Barnard's mother in the Mt. Olivet Cemetery at Nashville. On learning of her death Dr. Max Wolf, Director of the astronomical observatory at Heidelberg, Germany, paid a beautiful and appropriate tribute to her memory by naming a minor planet recently discovered by him after her, which will henceforth be known as *Rhoda*.

Discovers First Comet

The year of his marriage Mr. Barnard lived on Patterson Street, No. 1919, and in 1882 and the first half of 1883 on Belmont Avenue. During this time Mr. Barnard's astronomical observations with his 5-inch telescope were made in the yard at his home. From these standpoints he discovered two comets—the first, September 17, 1881, known in astronomical works as Comet VI, and the second September 13, 1882, called Comet 1882 III.

Enters Vanderbilt University

The connection of Mr. Barnard with Vanderbilt University dates from the spring of 1883. He came to the University at the request of Bishop McTyeire and Chancellor Garland to take charge of the observatory and assist Chancellor Garland in practical astronomy, and at the same time to enter as a student and equip himself better educationally for astronomical work. He lived during his connection with the University in the frame residence just west of the observatory.

With the exception of two months in the public schools of the city he had never been to school. Having to support an invalid mother he could not take time to attend school. His preparation for college was limited to what his excellent mother had taught him at home, what he could pick up at odd times when the work was not pushing, and the instruction which he had received in mathematics from a private tutor. He had always been so eager for an education and so ready to seize every opportunity for reading and study, that though painfully conscious of his lack of educational training, he was by no means noticeably deficient in this respect. He had acquired from his mother's teachings the love for good literature and was fond of Shakespeare and had read many of the best English novels. He however was not prepared to enter Vanderbilt University as a regular student, but he was allowed to take work the first

year in mathematics and physics, as these were most needed in his astronomical work. Later on he made a specialty of modern languages and studied also English and chemistry.

While pursuing his studies in the University and giving instruction in practical astronomy, he still found time to continue his astronomical observations as is shown by the number of comets he discovered here.

THE GEGENSCHEIN

In the fall of 1883 he discovered independently the *gegenschein,* a feeble but large spot of light which has a motion eastward among the stars corresponding to that of the sun. Originally it was discovered by Brerson in Germany and independently by the English astronomer, Backhouse. Dr. Barnard has made a special study of it from 1883 up to the present time. In an article in *Popular Astronomy,* February, 1919, Vol. 27, he states as an inference from many observations that the *gegenschein* lies on the ecliptic and is always exactly opposite the sun. He discusses several theories in regard to its nature and gives it as his opinion that the *gegenschein* is simply an illumination of our atmosphere by the sun's light through refraction and dispersion.

BETA CAPRICORNI

The discovery November 5, 1883, of the duplicity of the companion of Beta Capricorni is best described by the eminent astronomer, Professor S. W. Burnham, the discoverer of a greater number of double stars than any other man. Mr. Burnham says of this discovery that it is unique and illustrates Mr. Barnard's remarkable skill as an observer and ability to detect and interpret unsuspected phenomena. "Barnard was observing an occultation of the well-known star Beta Capricorni by the moon. (When the moon passes between the observer and a fixed star, the instant the lunar surface touches the line joining the eye of the observer and the star, the latter instantly vanishes from sight, because the star appears only as a point and the moon has no atmosphere.) When the moon passed in front of the star referred to the observer noticed that instead of disappearing instantly the process was gradual. The interval between the diminution and the complete extinction of the light occupied only a few tenths of a second, but it was long enough to put the expert observer upon inquiry, and was evidently a matter requiring explanation. Mr. Barnard called attention to this curious phenomenon in one of the astronomical journals, and suggested that the most probable explanation was that the star, always heretofore known as one of the ordinary type, was really composed of two stars so extremely close together that in the ordinary telescope they appeared as one star. It was also inferred that one of the stars must be considerably brighter than the other, from the fact that at the beginning of this fraction of a second the change in brightness was less than at the end. Subsequent examination of the star with

the 6-inch telescope with which the occultation was observed failed to show any peculiarity in it under the highest powers, and therefore the attention of astronomers with more powerful telescopes was called to the matter. The 18½-inch equatorial of the Dearborn Observatory at Chicago was subsequently turned on this object by Mr. Burnham and it was seen to be a close and unequal double star, and one which taxed the powers of that splendid instrument to show even to a trained eye." Dr. Barnard has to his credit now the discovery of thirty-six double stars, I believe; but doubtless he thinks more of the discovery of this one than of the other thirty-five altogether.

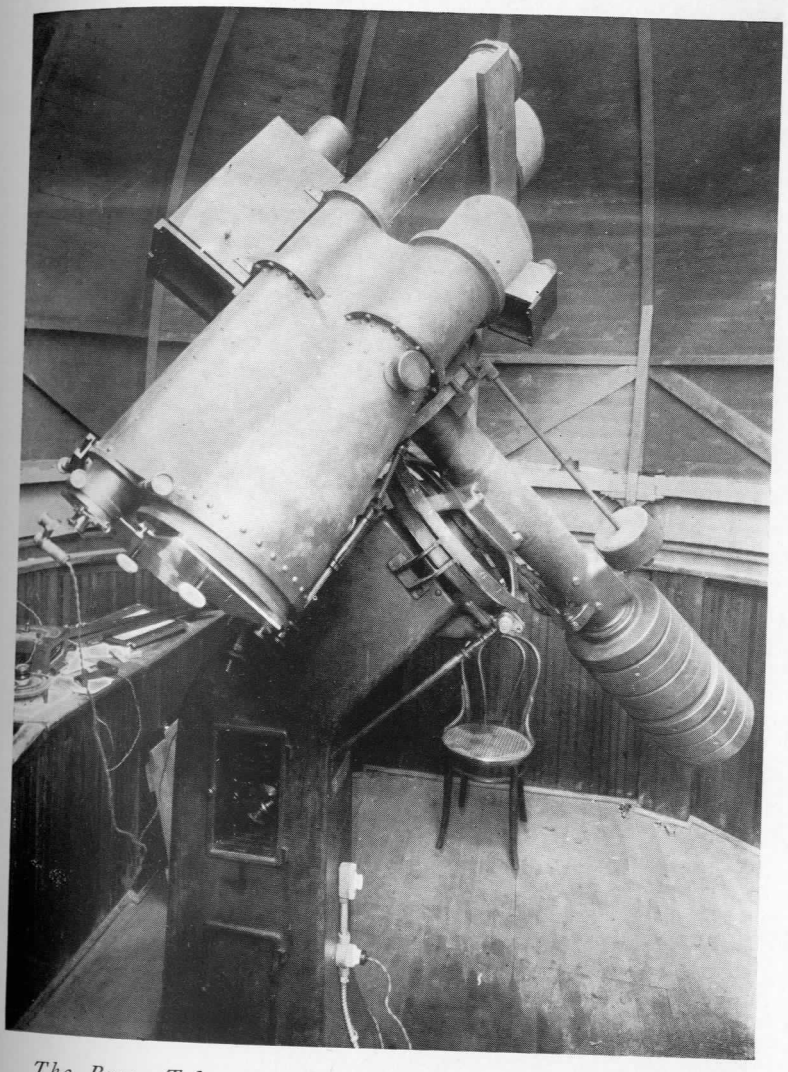
COMETS

During the four years Mr. Barnard was at Vanderbilt he discovered many nebulæ and seven comets. The dates of the discovery of these comets were as follows: 1884, July 16; 1885, July 7; 1885, December 3; 1886, October 4; 1887, January 23; 1887, February 15; 1887, May 12. He also discovered another comet on December 27, 1885, but it had been seen by another observer on December 26. The discovery of these comets not only brought the Vanderbilt Observatory into notice and increased the reputation of the young astronomer, but they also were of considerable value to him pecuniarily because of the fact that about the time Barnard came to the University Mr. Warner of Rochester, New York, offered a prize of $200 for each new comet first announced by the discoverer to the Warner Observatory.

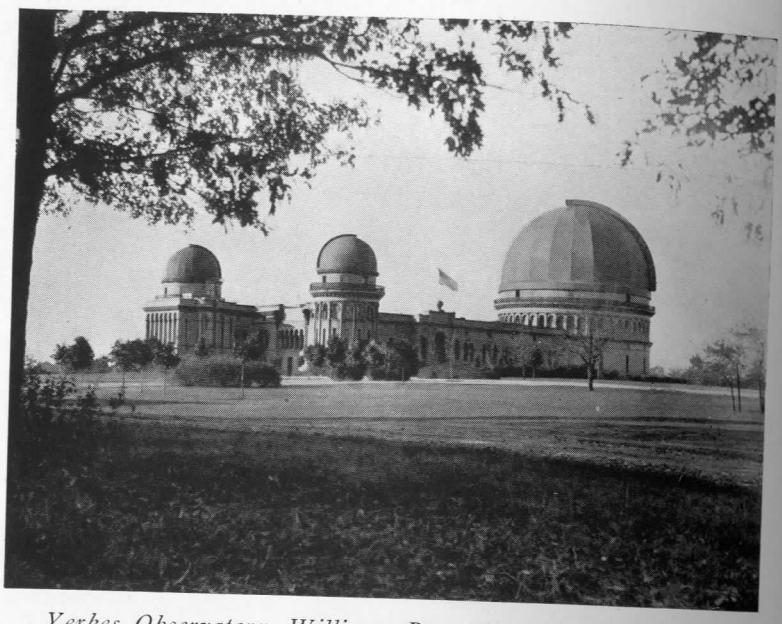
The comet discovered at the Vanderbilt University Observatory on 1886, October 4, became visible to the naked eye with a tail 20° or 30° long as it swept below the southern horizon in December of that year. The comets which he found from 1886, October 4, to 1887, May 12, were a record for rapidity of discovery.

In 1887 Mr. Barnard was offered a position in the Lick Observatory at Mt. Hamilton, California, then about to be opened, with the largest refracting telescope in the world. He accepted the offer, feeling that his pleasant associations at Vanderbilt should not outweigh the superior facilities at Mt. Hamilton for astronomical work and discovery.

Dr. Barnard has always evinced a strong affection for Vanderbilt University, his Alma Mater, and for Nashville, his native city. From the fascinating and absorbing interest of his work, he has, whenever possible during the full of the moon, stolen away to pay a visit to his old home. Many will recall his visit here in 1894 when he delivered two most entertaining and instructive lectures to crowded houses at the Vendome Theatre and received on one of these evenings at the hands of the beloved and venerable Chancellor Garland the diploma conferring upon him "all the rights, privileges, etc." of the degree of Doctor of Science, and again his visit in the year 1900 on the occasion of the celebration of the 25th Anniversary of the University, when as the representative of the alumni he delivered an address before a great assembly at the Ryman Auditorium.



The Bruce Telescope with which Barnard made most of his photographs of the Milky Way. It was presented to Yerkes Observatory by Miss Katherine Bruce of New York, and was specially designed for Barnard's photographic work.



Yerkes Observatory, Williams Bay, Wisconsin, where Barnard was Professor of Practical Astronomy in the University of Chicago, from 1895-1923.

Barnard's residence, overlooking Lake Geneva, near Yerkes Observatory

He came again on the occasion of the 20th anniversary of his class to the Commencement of 1907, and delivered the alumni address at the banquet. Last summer he visited Nashville at the invitation of the Tennessee Academy of Science and delivered two lectures before the Academy and the faculty and students of the George Peabody College.

Nashville's appreciation of the services of one of its distinguished sons, as well as that of the State of Tennessee, has recently been shown by the action of the Nashville Automobile Club in co-operation with the Tennessee Historical Committee, which is putting up markers throughout the state in commemoration of notable historical events, in placing a marker at 1919 Patterson Street, Nashville, in honor of Dr. Barnard. The marker reads:

"Edward Emerson Barnard, b. Nashville, 1857: Discoverer fifth satellite Jupiter, 16 comets, many nebulæ and double stars, pre-eminent in celestial photography. Awarded Lalande, Arago, Janssen gold medals, French Academy Sciences; Janssen prize, French Astronomical Society; gold medal, Royal Astronomical Society, Great Britain; Bruce gold medal, Astronomical Society of the Pacific. Discovered his first comet with his own telescope here, September 17, 1881."

Dr. Barnard's work at the Lick Observatory from 1887 to 1895 embraced a wide range of subjects, including planets and their satellites, occultations and eclipses, comets, double stars, nebulæ, and star clusters. He made several brilliant discoveries and a record of numerous observations which Professor Burnham says will have a greater value a century hence than they have today. The same may be said of his work since 1895 at the Yerkes Observatory of the University of Chicago. In these observatories he was usually engaged in several kinds of astronomical work in the course of a month or a week or even in a single night, the nature of his observations depending upon such contingencies as which one of the telescopes was at his service, the state of the atmosphere, and the character of celestial phenomena of special interest at the time. So that it seems best from now on in this paper to discuss his work classified under several heads rather than arranged in the order of time.

ECLIPSE OF JAPETUS

While he was at the Lick Observatory much of his time was spent in the study of the planets and their satellites. In November, 1889, he observed the eclipse of Japetus, the eighth satellite of Saturn, in the shadow of the ring system of that planet. The phenomenon is of very rare occurrence and this was the first time it had been seen. No other astronomer observed it on this occasion nor has it been observed since. The last opportunity to observe it was on December 9, 1918, but clouds prevented observations of it apparently everywhere. Barnard's special purpose was to determine the nature and density of the so-called dark, or crepe ring. His

observations strengthened the theory that the ring system is composed of minute particles of matter that encircle the planet like a dense swarm of satellites (since proved spectroscopically by Keeler) and reflect a sufficient amount of light to render the rings visible in a telescope, and established the fact, long suspected but not definitely proved, that the mysterious crepe ring is transparent, for the sunlight shone through it and illuminated the satellite far beyond.

The Belts of Jupiter

At the Lick Observatory he continued to give special attention to the planet Jupiter, not only taking notes of changes in position, form and color of the markings, but making accurate measurements of them with the 12-inch telescope. In 1891 he wrote an article in which he stated that a careful study for twelve years of the markings of the planet had led him to the discovery that their age is indicated by their color—any spot or marking (other than white spots) always turning after some time from dark or black to red. He also expressed the opinion that the supposition of a plastic or pasty condition for the surface of Jupiter, the belts and markings being merely discolorations in this due to internal eruptions, would be more consistent with the observed phenomena, than the theory generally accepted that the visible surface of Jupiter is a cloud surface. Possibly one might combine the two theories, he added, and account for any shortcomings in the plastic theory by supposing local clouds of steam near or on the surface.

Double Transit of a Satellite

While studying the markings of Jupiter he observed also transits of its satellites across the planet's disc. On one occasion in September, 1890, the first satellite appeared to be double. To be sure that he was not seeing double he asked Professor Burnham to look at it. Burnham, whose specialty in astronomy was double stars, said it appeared distinctly double to him. From subsequent observations Barnard showed that the phenomenon was due to a white belt around the equator of the satellite. The parts of the white belt having the bright surface of Jupiter as a background would become invisible from lack of contrast and the satellite would appear as two dark spots or like a double moon. None of the other bright satellites has such an equatorial belt.

Discovery of the Fifth Satellite of Jupiter

The discovery of the fifth satellite of Jupiter is thus described by Professor Burnham. "In July, 1892, Barnard commenced to use regularly the large telescope one night each week, and naturally began systematic observations of the great planet. In due course of mail the writer received at Chicago a letter from Professor Barnard written on Saturday morning, September 10, stating that on the previous evening, Friday, at about midnight he had observed an

extremely faint speck of light very close to Jupiter; that it seemed to be moving with the planet; and that he strongly suspected it was a new satellite. He said that it was so difficult with the large telescope that he was unable to see it except by shutting out the light of the planet. The suspected star was found by the observations of the following night to be a new satellite, and on Monday morning the whole astronomical world was electrified by the announcement that Jupiter, observed more than any other planet for the past three hundred years, had a fifth moon revolving about it in less than twelve hours at a distance from the surface of the planet of about 70,000 miles."

Due recognition of the importance of this discovery was accorded to Barnard by learned societies—especially in France and England. The French Academy of Sciences awarded to him the Lalande gold medal in 1892, the Arago gold medal in 1893 and the Janssen gold medal in 1900. The Lalande and Janssen medals are awarded for the discovery or work contributing most to the progress of astronomy. The Arago medal was established by the French Academy in honor of the noted French physicist and astronomer, Arago; and is awarded from time to time for a discovery, work, or service which appears to the Academy worthy of this token of its high esteem.

In 1897 Professor Barnard was awarded the gold medal of the Royal Astronomical Society for the discovery of the fifth satellite of Jupiter, his celestial photographs and other astronomical work. Dr. Common, the president of the society, said in presenting the medal that "the discovery of the fifth satellite of Jupiter was certainly the most important discovery of the last twenty years."

NEWCOMB'S REMINISCENCE

Of interest in this connection is a reference to this discovery found in Professor Simon Newcomb's *Reminiscences of an Astronomer*, published in 1904, followed by an account which he gives of an incident in the life of Professor Barnard which has been already mentioned in this paper.

"In 1892, only four years after the mounting of the telescope, came the surprising announcement that the work of Galileo on Jupiter had been continued by the discovery of a fifth satellite to that planet. This is the most difficult object in the solar system, only one or two observers besides Barnard having commanded the means of seeing it. The incident of my first acquaintance with the discoverer is not flattering to my pride, but may be worth recalling.

"In 1877 I was president of the American Association for the Advancement of Science at the meeting held in Nashville. There I was told of a young man, a little over twenty years of age, a photographer by profession, who was interested in astronomy, and who desired to see me. I was, of course, very glad to make his acquaintance. I found that with his scanty earnings, he had managed either to purchase or get together the materials for making a

small telescope. He was desirous of doing something with it that might be useful in astronomy and wished to know what suggestion I could make in that line. I did not for a moment suppose that there was a reasonable probability of the young man's doing anything better than amuse himself. At the same time, feeling it a duty to encourage him, I suggested that there was only one thing open to an astronomical observer situated as he was, and that was the discovery of comets. I had never even looked for a comet myself, and knew little about the methods of exploring the heavens for one, except what had been told me by H. P. Tuttle. But I gave him the best directions I could, and we parted. It is now rather humiliating that I did not inquire more thoroughly into the case. It would have taken more prescience than I was gifted with to expect that I should live to see the bashful youth awarded the gold medal of the Royal Astronomical Society for his work."

Newcomb had received this medal in 1877. The Bruce gold medal of the Astronomical Society of the Pacific awarded to Newcomb in 1898, was awarded to Barnard in 1918. The young man who approached this distinguished astronomer in 1877 with trepidation, entertained him with great pleasure as a guest in his home twenty years later, at the dedication of the Yerkes Observatory.

Size of the Fifth Satellite of Jupiter

What is known of the satellite is mainly from Barnard's observations. Immediately after its discovery, he worked out the period of its revolution about the planet and the elements of its orbit, and again in 1898, 1899, 1903 and 1904 from observations at the Yerkes Observatory with the 40-inch telescope. An object 115 miles in diameter at the mean distance of Jupiter would subtend an angle of 0.05 of a second, which is somewhat below the limit of measurement of this telescope. But the fifth satellite of Jupiter appears only as a speck with no apparent disc when seen with this instrument. Dr. Barnard reckons the satellite to be less than 100 miles in diameter.

Determination of the Diameters of the Planets and Asteroids

During the years 1894 and 1895 Barnard measured with the filar micrometer of the 36-inch telescope of the Lick Observatory the diameters of every planet, satellite and asteroid that was measureable, the rings of Saturn included. This work, he himself says, considering the difficulties attending the measurements, required a great deal of patience and labor. Waiting for moments of steadiness of the image at times when the wind was causing the tube of the great telescope to vibrate was extremely trying on the time and the nerves of the observer.

Previous to this investigation Neptune had been considered larger than Uranus and Vesta, because of its superior brightness, larger than Ceres. Barnard found the mean diameter of Uranus to be

34,900 and of Neptune 32,900 miles and the mean diameters of the asteroids, Ceres, Pallas, Juno and Vesta to be respectively 485, 304, 118 and 243 miles. His measures showed that this greater brightness of Vesta was due to its more highly reflective surface. The discs of these asteroids had never before been so accurately measured and consequently the diameters determined by Barnard were generally accepted. In the case of Juno, readings of the micrometer were taken as small as 0.11 of a second. At the Yerkes Observatory observations and measurements of the satellite of Neptune, the satellites of Uranus and the rings and satellites of Saturn were resumed in 1897 and have been continued at intervals to the present time. Barnard's measurements of the satellite of Neptune were used by Professor A. Hall for the determination of its orbit and by Professor Newcomb in an investigation of its motion.

COMETS DISCOVERED AT THE LICK OBSERVATORY

During the first four years Barnard was at the Lick Observatory he discovered seven comets. In 1889 Mr. J. Donohue, of San Francisco, established the comet medal of the Astronomical Society of the Pacific. Soon thereafter Barnard was the first to discover a comet that appeared, but it was found to be a return of D'Arrest's periodic comet. Barnard was entitled to the medal but refused it and asked that the wording of the award be changed so as to exclude the rediscovery of periodic comets, where the position of such an object in the sky could be predicted beforehand. In the next two years he won three of the medals. He discovered every comet of the year 1891. He then decided to give up the search for comets and devote his time to work which he considered more important. However, on October 12, 1892, he noticed that one of these mysterious visitors to the solar system had called to see him and left his streak, or card, on a photographic plate. He looked him up through the 12-inch telescope and found him at the address given. *This was the first comet ever discovered by photography.*

Barnard at this time was second only to Pons in the number of comets discovered. Brooks was third. When Barnard stopped, Brooks soon passed him. Pons died in 1831 and Brooks recently; so thirty years after ceasing to look for comets, Barnard is first of living astronomers in the number of comets to his credit as a discoverer.

CELESTIAL PHOTOGRAPHY

Dr. Barnard's most notable work in astronomy, outside of several brilliant discoveries, is in the field of celestial photography. About the time he went to the Lick Observatory, recent improvements in photographic processes and the success of Pickering, Wolf and others in photographing certain portions of the heavens led him to believe that the photographic plate was going to become a very important accessory to the telescope in astronomical discovery. His long experience in a photographic gallery had prepared him for work

of this kind, so when the Lick Observatory secured from a second-hand dealer in San Francisco an ordinary Willard portrait lens six inches in diameter, he strapped it to an equatorial telescope and began experiments. The equatorial, by means of its driving clock, enabled him to follow the motion of the stars in the field of view and keep the plate exposed continuously for several hours.

THE MILKY WAY

He made a number of photographs of the Milky Way and sent prints of them to astronomical journals. *These photographs were the first ever made to show the star clouds of the Milky Way.* Their beauty and excellence excited the astonishment of astronomers wherever they were seen. By what mysterious means, they asked, did this small lens and a photographic plate reveal the wonderful cloud structure of the Milky Way and also bring into clear view stars, nebulæ, and star clusters dimly seen or even invisible in telescopes of the highest power?

These effects were soon accounted for: The wide field of view of the portrait lens, compared with the small area of the heavens visible at one time through the telescope, accounts for the first. For no true conception of the whole outline of an object can be formed from looking at a small magnified portion. Certain properties of the photographic plate explained the second. In the first place, the rays of light to which the eye is least sensitive—those toward the blue-violet end of the spectrum or beyond—are the ones that most strongly affect the photographic plate. Nebulæ and star clouds, rich in such rays, that with the eye "are seen as through a glass darkly," may appear on the photographic plate as more or less brilliant objects. In the second place, the eye becomes wearied with steady gazing at a celestial object and the impression weakens and fades with prolonged seeing, but the impression on the photographic plate becomes more intense with the lengthening of the time of exposure. "With the eye there is no cumulative effect; on the contrary the longer one looks the less one sees. With the plate there is no fatigue. The longer it looks, the more it sees." So the dimly seen may grow brighter and the telescopic unseen may become visible on the photographic plate.

NEBULÆ

Dr. Barnard has discovered many nebulæ. Among the most important are the curved nebula in Orion and the great nebula in the region of Rho Ophiuchi. The former he discovered with a simple magic lantern lens of 1½ inches aperture. He learned afterwards that it had been photographed by Pickering at an earlier date. In regard to the discovery of the other nebula he said in 1897: "For many years this part of the sky troubled me every time I swept over it in my comet seeking. Though there seemed to be scarcely any stars here, there yet appeared a dullness of the field as if the sky were covered with a thin veiling of dust, that took away the rich

blackness peculiar to many vacant regions of the heavens. This was fifteen years ago at Nashville, Tennessee, when I searched for comets with a five-inch refractor. In 1890, at the Lick Observatory, I still noticed this peculiarity of that part of the sky, and finally found that two small stars north of Antares were involved in nebulosity. In 1895 this part of the sky coming within the sphere of my work in photographing the Milky Way, on March 23, I made a photograph of it with 2 hours 20 minutes exposure. The resulting negative showed a vast and magnificent nebula, intricate in form and apparently connected with many of the bright stars of that region, including Antares and Sigma Scorpii."

During the next eight years Barnard took many photographs of this interesting region at the Lick Observatory with the Willard lens and a number with the 10-inch photographic telescope after it was mounted in 1904. "In 1905, through the courtesy and deep interest of Professor George E. Hale, Director of the Solar Observatory of the Carnegie Institution, this telescope was transported to Mount Wilson, California, and set up there temporarily at an altitude of 6,000 feet, and Professor Barnard, by invitation, went there for the special purpose of investigating these and other regions of the Milky Way. While there he made a thorough study of what he calls "dark markings on the sky."

DARK MARKINGS ON THE SKY

Photographs of the sky show dark markings comparable in size to nebulæ scattered here and there over the heavens. They are especially noticeable in the Milky Way. For a long time they were generally assumed to be holes or vacant places in the sky. Among the first to suggest that these dark places might be real matter was Mr. A. C. Ranyard, an astronomer and editor of *Knowledge*. Speaking in 1894 of certain dark areas seen in a photograph of the region about Theta Ophiuchi by Professor Barnard, he said, "They seem to me to be undoubtedly dark structures, or obscuring masses in space which cut out the light from the nebulous or stellar region behind them." Barnard did not at first accept this view, but later became convinced from a study of his own photographs of the Milky Way that some of the markings are of this character. The hypothesis is that the nebulæ, like the stars, may in time cease to give out light and become dark bodies, or some of the nebulæ may never have been luminous. He holds now that he has proved this to be true. Others, he still believes, are real vacancies or places where the stars are thinned out.

DARK NEBULÆ

The assumption of dark nebulæ is not unreasonable, he says. As there are admittedly many dark stars, there are probably also dark nebulæ; and as there are stars of various degrees of luminosity between the extremes of brightness and darkness, the

same may be true of nebulæ. As these dark nebulæ, or obscuring masses, cut out the light from the starry or nebulous region behind them, they are themselves at the same time outlined and rendered visible by this brighter background. Some of these masses that appear dark on the background of the Milky Way are in some degree luminous and would shine with a feeble light in a less bright region. But there are numerous examples of objects, Barnard says, which are not in the Milky Way and are entirely devoid of light. It would seem that such bodies would be lost in the blackness of space, but they are visible against space itself. That is, *space itself is luminous*. This hypothesis which Barnard brought forward in 1916, he upholds in an article published in the *Astrophysical Journal* in 1919, in which he gives a catalog of 182 of these dark markings shown in his photographs of the sky.

Professor George E. Hale, Director of the Mount Wilson Observatory, in his report for the year 1919, states that "observations with the 100-inch reflector support the hypothesis that light from the most distant objects along the galactic plane may be obstructed by dark nebulous matter."

COMETS

Although Barnard—as has been stated—gave up the search for comets in 1892, he has continued to observe and study them whenever they have appeared; and in 1921 he was the first to discover the return of the Pons-Winneke comet.

One of the important and interesting observations made by him was the discovery in August, 1889, of several companions to Brooks' comet of that year (1889 V). Two of these companion comets, each with a nucleus and tail, remained under observation for several months and then suddenly melted away into space. He has also found that several comets while under observation were double or multiple, showing that this is not an uncommon condition of some comets. An earlier record of this kind was Biela's comet, which became double in 1845.

As the light of comets, like that of nebulæ, is largely actinic, it is advantageous to study them by means of the photographic telescope. Barnard in 1892 made a number of photographs at the Lick Observatory of Swift's comet, showing the changes in its structure and appearance and the division of the tail into several distinct streams of cometic matter, invisible except on the photographic plate. Professor Burnham, speaking of these photographs in 1893, said they were the most successful ever taken of a comet. Agnes M. Clarke, of London, England, uses two of them as illustrations in her *Popular History of Astronomy during the Nineteenth Century*.

Among the comets of unusual interest that Barnard has studied since that time are Brook's 1893 IV, Borrelly's 1903 IV, Daniel's 1907 IV, Morehouse's 1908 III, Halley's 1910 II, Brook's 1911 V, and Gale's 1912.

BARNARD MEDALS (Obverse)

(Approx. 2.4 times size of illustration.)

From the French Academy of Sciences:

The Lalande Gold Medal, 1892
The Arago Gold Medal, 1893
The Janssen Gold Medal, 1900

From the Astronomical Society of France:

The Janssen Prize in 1906

BARNARD MEDALS (Reverse)

(Approx. 2.4 times size of illustration.)

From the Royal Astronomical Society:
The Gold Medal, 1897

From the Astronomical Society of the Pacific:
The Bruce Gold Medal, 1917

At the Astronomical Congress in September, 1904, St. Louis, Mo., he exhibited a lantern slide made by super-imposing two original negatives, star for star, made of Brook's comet of 1893 on successive nights, the effect being the same as if two instantaneous exposures had been made at the two dates on the same plate. The change in position and shape of the tail in twenty-four hours was thus shown in a new and striking way.

Swift's Comet of 1892, Brook's of 1893, and Borrelly's of 1903 showed in photographs some characteristics which, Barnard said, the general theory of a comet's tail failed to explain. The numerous tails shown in the photograph of Swift's comet and some others are produced he believes by jets or streams of matter shot out from different centers of activity in the nucleus. When there is a sudden change in the direction of the emission of matter, as in Borrelly's comet, a new tail is formed and grows to its normal length, while the first tail separates from the comet and drifts out into space. In the case of Brook's comet of 1893 the tail which one day was in a normal condition was on the next day disturbed and broken. On another occasion it was disjointed in places and near the end was abruptly bent at nearly a right angle. Barnard expresses the opinion that this comet's tail encountered for several days some resisting or disturbing medium, and he regards the observed phenomena as evidence supporting the theory which he advanced as early as March, 1899, that "comets in traversing the solar system sometimes encounter swarms or streams of meteors or possibly some cosmical matter yet unknown that affect the form of their tails as they sweep through space."

Morehouse's comet of 1908, seen with the telescope alone, was an object of little interest; but pictured with the photographic camera, it proved a very remarkable comet. Barnard made 239 photographs of it on forty-seven nights. So strongly actinic was the light of this comet that when it was only faintly visible in the telescope it could be photographed in relatively a few minutes, and a longer exposure brought out features that never could have been suspected visually. The photographs indicate that the nucleus was very active. So rapidly was the comet changing on September 30th that it underwent a complete transformation in the course of a few hours. The photographs taken at intervals as brief as practicable, were really composites. This suggests the possible use of the kinetoscope when photographs indicate rapid changes.

Halley's Comet, which in 1835 was a fairly conspicuous celestial object, yet to millions of people a mysterious and terrifying spectacle, returned as predicted in 1910. Because of the prediction that the earth would pass through its tail and the statement in many newspapers that a very poisonous gas had been shown to exist in the tails of some comets, many persons apprehended its coming in 1910 as a visitation. The earth did probably pass through the tail of the comet on May 18 or 19, 1910, but our atmosphere was not noticeably affected.

The very meager description which Barnard was able to find of the appearance of this comet in 1835 suggested to him the importance of preparing a better description of its appearance in 1910 for observers on its return in 1985. He therefore put on record a careful description of its appearance at frequent observations during the period of its visibility as seen by the naked eye—supplemented when necessary with a pair of old-fashioned field glasses—and through the 5-inch guiding telescope of the Bruce photographic instrument. The comet was visible to the naked eye from April 29, 1910, to June 11, 1910; through the 5-inch telescope from April 11, 1910, to June 27, 1910; and through the 40-inch refractor from September 15, 1909, to May 23, 1911.

METEORS

The modern dry plate is so sensitive and so rapid in its action that it is affected by the flash of a meteor. On a number of Barnard's plates are long streaks which represent the trails of meteors. The portrait lens is of great value in the study of these objects. The wide field of the small lens shows the whole trail, even when the trail is long, or at least a greater part of it. Photographing a meteor locates it with greater accuracy than can be attained in any other way, and makes a permanent record. By taking photographs of a meteor simultaneously from different stations, its parallax can be obtained and from this the height of the meteor above the earth can be calculated. In 1891, discussing meteors, Barnard remarked that apparently the drift of meteor trails was eastward, and he recommended that when meteors are observed the direction of the drift of the trail be recorded for the purpose of increasing the data useful in the study of currents in the atmosphere at great elevations.

THE AURORA

Since 1896 Barnard has kept a record of all auroras that have been visible at Williams Bay. "These observations of the aurora," he says, "have been made with the hope that they might some day be valuable, although my interests have lain in other directions altogether." The record of these auroras is in great detail, and the phenomena of the more important ones from beginning to end have been described with the clearness and accuracy characteristic of a conscientious and expert observer. Writing in 1910, he says that with the exception of the great aurora of October 18, 1909, none that has been seen at the Yerkes Observatory in the previous ten or twelve years has displayed any such striking colors as were seen at Nashville, Tennessee, in the great aurora of April 16, 1882.

The above-mentioned record as far as through 1909, together with remarks on the observations has been published by the author in the *Astrophysical Journal*. These observations have been kept up to the present time.

VARIABLE STARS AND NOVÆ

Barnard has discovered a number of variable stars. One of the most interesting of these, because of its long period of variation, was discovered in 1919 on a photographic plate. On plates made from the year 1895 on, it appeared for the first time in 1909. On Harvard plates made from 1891 on, it was not seen before 1910. Its light-range was found to be about six magnitudes and its period of variation is reckoned at upwards of fifty years. This remarkable star was discovered by Dr. Max Wolf, in Germany, a year before Barnard found it, but it was not known in this country at that time on account of the war.

Of the novæ, Barnard has given most attention to Nova Persei of 1901 which he has had under observation more or less closely since its appearance in 1901, especially during the last three or four years. In 1916 he discovered (visually) a nebulosity closely preceding and involving the star. The presence of this nebulosity has been verified at the observatory on Mount Wilson. The fact that it surrounds the star symmetrically, giving it the appearance of a planetary nebula with a nova as a nucleus, has excited much interest among astronomers. A portion of this nebulosity is slowly receding from the star and changing its form.

Nova Aquilæ III, one of the most remarkable of the novæ, was discovered by Barnard independently on June 8, 1918. He first noticed it on his way back to Green River, Wyoming, from a point in that vicinity, where, with a party of astronomers, he had been observing the total eclipse of the sun that day. It had been seen earlier in the evening, however, by several astronomers further east in this country and in Europe who had the advantage of several hours in the nightfall. Looking up its history, Barnard found the star on fifty-four of his photographic plates. Since 1888 until recently it had been a small star, somewhat variable and of the 10th or 11th magnitude. June 3, 1918, it was in its normal condition. June 7th, it had risen in brightness to the sixth magnitude, probably faintly visible to the naked eye. It had become a star of the first magnitude on June 8th, and at its maximum on June 9th, it was the brightest star, with the exception of Sirius and possibly Canopus in the entire heavens. Gradually and irregularly waning from that time on, it was of about the fourth magnitude on July 20th. It is not now visible to the naked eye. It was at its maximum about 50,000 times, or more, brighter than in its normal state. This wonderful outburst which flashed even with the speed of light did not become visible here until centuries after it occurred, some astronomers imagine was caused by the entrance of the star into a mass of inflammable gas which it ignited, others think that the conflagration resulted from its collision with an unseen world, others that the star exploded; but it is indeed just one of the numerous awe-inspiring mysteries of the universe.

THE RUNAWAY STAR

The star, 1830 Groombridge, was long known as the "runaway star" because its proper motion per annum, 7.05″ (seconds of arc) was the greatest known for any of the fixed stars. In 1916 Barnard discovered a star in Ophiuchus that had a proper motion 10.3″ seconds per annum. The method of its discovery illustrates one way in which a historical photographic record of the position of celestial bodies can be used in astronomical research. On comparing two of his star plates, one made in 1894, the other in 1916, Barnard found on the latter a star which apparently had left no trace on the plate of 1894. Further investigation showed that this star was on his own plates of 1907, 1904 and 1894 and on Harvard Observatory plates of 1890 and 1888, but had been changing its position, moving in a northerly direction at the rate of 10.3″ per annum. The whole change of position in twenty-two years is about ⅛ the diameter of the moon as it is projected on the sky. The star is invisible to the naked eye, being of the tenth magnitude, is 6.3 light years distant from the earth, being the nearest fixed star known with the exception of Alpha Centauri, and *has the greatest apparent stellar motion known*, 10.3″ per annum. Though this great apparent motion is the largest known, it is mainly due to its nearness to us, for there are other stars that exceed it in actual velocity. This remarkable star is *the smallest sun that we know of*. Its diameter has been determined to be only 155 thousand miles. If the extreme outer edge of the ring of Saturn were a thin band, this tiny sun could be placed in it with nine thousand miles to spare all around.

STAR CLUSTERS

For more than twenty years Barnard has been giving considerable attention to star clusters. In the year 1900 he called attention to the fact that certain stars in the cluster M 13 (Hercules) which were unusually faint, were relatively bright on a photograph taken with the Potsdam astrographic refractor. From this he inferred that such stars are bluer than the average stars of the cluster and that stars of all spectral types exist in the cluster. Extending his observations to other clusters in the ensuing years, he published the results of the investigation in the *Astrophysical Journal* in 1912. The correctness of his views has been confirmed by a similar investigation taken up since that time at Mount Wilson, California, with the 60-inch reflector there and a slit-spectograph and through these superior facilities the knowledge of the nature of the stars comprising some of the great clusters has been much enlarged.

Another branch of work in the study of star clusters is accurate micrometric measurements to show the exact locations of the stars of the cluster in the heavens and their positions relative to one another. This can be done only with a large telescope. Of late years Barnard has devoted a considerable portion of the time allotted him with the 40-inch refractor of the Yerkes Observatory to this

important work. Such measurements made by astronomers indicate a drift of the Pleiades cluster of about 7″ per century. This is less than 1-250th of the apparent diameter of the moon. There must be a motion with respect to one another which may be determined by comparison of measurements made at long intervals of time. So far, no motion of this kind has been detected in the globular clusters.

TRANSITS OF MERCURY AND VENUS

The two most conspicuous bodies in the heavens, the sun and the moon, are the ones to which Barnard has given the least study. At the outset of his career when he had the use of only a very small telescope, the magnified surface of the moon was, of course, very interesting. But he soon found out that everything he saw had been fully described, and, as he said to Professor Newcomb at the meeting in Nashville of the Association for the Advancement of Science, he wished to find out something not already known about the heavenly bodies. Soon after this he saw a statement that a transit of Mercury across the sun would occur on a certain day. So on that day he took his 5-inch telescope to the Capitol, observed the transit and made notes of what he saw. These notes were among the first, if not the first, of his own that were ever printed. When the transit of Venus of 1882 occurred, he took his telescope to the Vanderbilt Observatory and observed this phenomenon at the same time that Professor Olin Landreth was observing it with the 6-inch equatorial there.

SOLAR ECLIPSES

It has been the custom of a number of observatories to send out parties to favorable localities to observe total eclipses of the sun. As photography is of especial value in catching and preserving interesting phenomena of eclipses, Barnard's known experience and skill in this art naturally brought his services into requisition for the eclipse of 1889 which was total in California. He was chosen by Professor Holden, Director of the Lick Observatory, to take charge of the photographic work of the party equipped by the University of California. The excellence of Barnard's photographs of the corona in this eclipse, together with his demonstration soon afterwards of the adequacy of a portrait lens for photographing certain regions of the sky, led to the erection and equipment of the Crocker dome on Mount Hamilton for celestial photography. In the year 1900 he was a member of an expedition from the Yerkes Observatory to Wadesboro, North Carolina, to observe the total solar eclipse. He used there a 61½-foot horizontal cœlostat in photographing the corona. By invitation, he joined the expedition sent out by the United States Naval Observatory in 1901 to Sumatra to observe the solar eclipse of that year and had charge of the same instrument he had used at the eclipse of 1900. In 1918 he was a member of the Yerkes Observatory party which observed the solar eclipse at Green River, Wyoming, a point selected as the most

favorable by Professor Frost, Director of the Yerkes Observatory, and himself, on a trip of inspection previously made to that region. At this eclipse he did the photographic work with the cœlostat and the 12-inch telescope assisted by his niece, Miss Mary R. Calvert, of Nashville, who made the exposures with the cœlostat.

EYESIGHT

I have been told that Barnard has rather avoided astronomical work requiring observation of bright objects such as the sun and the moon in order that he might preserve the sensitiveness of his eyes to very faint light. The keenness of his eyesight has often been spoken of by astronomers. Sir Robert Bell, an eminent Irish astronomer, says that "Barnard probably has the keenest eye that ever looked through a telescope with the possible exception of Sir William Herschel." Whether the following experiment which was made by Barnard to illustrate the distinction between the visibility of a black spot and a black line also indicates great keenness of sight, I do not know. He says, "A small wire whose diameter was 0.009 of an inch suspended against a bright sky was distinctly seen with the unaided eye at a distance of 356 feet. At this distance it subtends an angle of 0.44″ of arc." It may perhaps render the conception of this clear, to state that, approximately the same angle would be subtended by a cord one-tenth of an inch in diameter at 7½ miles away. However, on account of atmospheric effects and perhaps for other reasons, it is not likely that these objects could be seen with the unaided eye at such distances.

But I think that one, in valuing the qualities of an astronomer that have contributed to his success, may easily unduly appreciate the possession of keen eyesight. Keen eyesight does not make an astronomer. Like a telescope it is only an instrument which he uses.

CHARACTERISTICS

Barnard's success is mainly due to his aptitude for astronomical work, enthusiasm, industry and perseverance. Perhaps no astronomer during the last thirty-five years has utilized a greater percentage of nights available for observations. It is never too cold for observing when the night is clear. When the temperature of the dome is far below zero on nights that the great Yerkes telescope was assigned to him, he has gone on with his observations. While photographing at Mount Hamilton he would sometimes be so charged with electricity in his arctic fur insulated suit and rubber overshoes, that before looking through the telescope, he had to touch it with his hand in order to prevent an annoying discharge of electric sparks from his eye to the eyepiece. He chooses the time of full moon for lectures and other engagements that take him from the observatory. Professor S. A. Mitchell, Director of the Leander McCormick Observatory, of the University of Virginia, who was for some time with him at the Yerkes Observatory, says: "I have learned in observing him what enthusiasm and hard work could accomplish.

Barnard is a splendid, careful and painstaking observer. He has never been anxious to rush into print, but is always ready to wait until he is abundantly sure of his observations. He has therefore won a reputation for thoroughness and honesty. So carefully and thoroughly has his work been done that no one, so far as I have ever been able to learn, has ever questioned a single one of his observations." Professor Newcomb said, "When men like Burnham and Barnard say they have seen a thing, one may be perfectly sure that it is there." Not only can Barnard be relied on to be sure of the correctness of his own work, but to be fair and generous in giving credit to other astronomers for their work in the same field.

Further, in regard to his personal characteristics, I quote only a few sentences from two of his friends who have known him well. Mitchell says: "Barnard is always ready to help others, perhaps realizing from his own early life, that help from others is essential. He is consequently a staunch friend that sees only the best in people." Mrs. Baskervill, who was his nearest neighbor on the Vanderbilt campus, writing in the year 1900, said: "Personally, notwithstanding all the honors that have come to him, the man is simple, unassuming, free from all self-assertion and undue self-esteem, with a disposition so kindly and lovable that the charming simplicity of his character, his unselfishness, his modesty, and his genial nature are most thoroughly appreciated by those who know him best." Contact with the world and recognition by others of the value of his astronomical work have, to a large extent, taken away the timidity and lack of confidence in himself, characteristic of him at that time, but have left untouched the unassuming demeanor, frank sincerity, and friendliness of the man.

MEMBERSHIP IN SOCIETIES; DEGREES

Dr. Barnard is a member of the following scientific societies: The National Academy of Sciences, American Association for the Advancement of Science—fellow, vice-president in 1898; American Astronomical Society; Astronomical Society of the Pacific; American Academy of Arts and Sciences—associate fellow; American Philosophical Society; Royal Astronomical Society of Canada—honorary member; Royal Astronomical Society—foreign associate and fellow; Astronomical Society of France. The degree of A.M. was conferred on him by the University of the Pacific in 1889, the degree of D.Sc. by Vanderbilt University in 1893, and the degree of LL.D. by Queen's University (Canada) in 1909. The medals and prizes awarded him have already been mentioned.

CONTRIBUTIONS TO LITERATURE; LECTURES

Barnard's contributions to astronomical literature have been very numerous. For many years he has been a regular contributor to the following journals:

Monthly Notices of the Royal Astronomical Society, England.
Astronomische Nachrichten, Kiel, Germany.
The *Astrophysical Journal*, Chicago.

Publications of the Astronomical Society of the Pacific, California.

Popular Astronomy, Northfield, Minn.

The *Astronomical Journal*, Albany, N. Y., of which he is an associate editor.

He is also a trustee of the Gould Fund of the National Academy of Sciences.

Forty or fifty reprints from some of these journals are the sources of most of the information used by the writer in the preparation of this article, exclusive of an article by Professor S. W. Burnham, in the *Harper's New Monthly Magazine*, September, 1893, one by P. R. Calvert, in *The Young Peoples' Leader*, one by Mrs. Janie McTyeire Baskervill, in the Nashville *Christian Advocate*, November 8, 1900, and an address by Dr. A. A. Common, president of the Royal Astronomical Society on presenting the Gold Medal of the Society to Professor E. E. Barnard, published in *Popular Astronomy*, No. 41, 1897.

He has also occasionally written popular articles on astronomical subjects for current periodicals and delivered popular lectures in many parts of the United States and several in England and France. Most of his lectures are illustrated with lantern slides from his own photographs of which he has a great number available for a variety of astronomical subjects.

Books

Volume XI of the Publications of the Lick Observatory, which was issued in 1913, is composed entirely of photographs of the Milky Way and of comets made with the 6-inch Willard lens of the Crocker telescope during the years 1892 to 1895 by Barnard, together with forty-six pages of introductory matter and a description of the plates by the author. The volume is printed in quarto and contains 124 plates. A similar volume to be published by the Carnegie Institution is in course of preparation. The photographic prints have already been made and are at the Yerkes Observatory. There will be an edition of 700 copies with 51 plates each.

Dr. Barnard would hold me very remiss, I am sure, if I should fail to mention the assistance which his niece, Miss Mary Calvert, for the last fifteen years his computer and assistant, has given him in the preparation of these volumes, as well as in the computation and tabulation necessary for many of his other publications.

At the Present

Since 1895 Barnard has been at Williams Bay, Wisconsin, with the title of Professor of Practical Astronomy in the University of Chicago and Astronomer in the Yerkes Observatory. His residence is near the observatory and facing Lake Geneva. His employment at the Yerkes Observatory is divided between observations with the 40-inch refractor and work with the Bruce photographic telescope.

With the former he is observing comets, planets, double stars, variable stars, novæ or new stars, satellites of the various planets, and making micrometrical triangulations in many of the great globular star clusters; with the latter he is photographing the sky, especially the Milky Way and comets. He is at work on the book referred to above, getting it ready for publication by the Carnegie Institution.

Barnard's work in astronomy has covered an unusually wide range of subjects. His standing among astronomers of the whole world is high. In two departments of astronomy, at the least, he is considered, I believe, the highest authority: Comets and the Milky Way, as to the latter, especially its dark markings. *He has made the most complete set of photographs of comets in the world.*

SUPPLEMENTARY NOTE

Since Dr. Barnard's death, February 6, 1923, many articles concerning him have appeared in journals and newspapers. Articles that have been reprinted and distributed may be found in—

Popular Astronomy, Vol. XXXI, No. 3, March, 1923, by Philip Fox.

The University Record, Vol. IX, No. 2, April, 1923, by Edwin B. Frost.

The Journal of the Royal Astronomical Society of Canada, Vol. XVII, No. 3, April, 1923, by J. A. Parkhurst.

The Astrophysical Journal, No. 1, July, 1923, by Edwin B. Frost.

Professor Barnard bequeathed to the University of Chicago his home, as a memorial to his wife, and to the Observatory his scientific books and the medals and awards he had received in recognition of his notable services to science. Dr. Edwin B. Frost, Director of the Yerkes Observatory, has made a collection of his writings, which, though yet incomplete, contains, under 377 titles, not less than 900 items. At the annual meeting of the National Academy of Science in 1924 Dr. Frost presented a *Biographical Memoir Edward Emerson Barnard* which was published in the

Memoirs of the National Academy, Vol. XXI, 1926.

This is the best account of the life and work of Professor Barnard that has been written; and it includes a bibliography of his principal scientific papers prepared by Miss Mary R. Calvert.

The titles of the books listed in this bibliography are:

Photographs of the Milky Way and of Comets. Publications of the Lick Observatory, Vol. XI.

Atlas of Selected Regions of the Milky Way (illustrated by fifty prints taken with the Bruce photographic telescope). Published in two volumes by the Carnegie Institution, Washington, D. C., 1927.

Micrometer Measurements in Some of the Globular Star Clusters. To appear in the publications of the Yerkes Observatory.

The articles written by Dr. Barnard are so numerous that Miss Calvert has arranged them topically, without giving the exact titles except in papers of special importance. The topics, ninety-nine in number, are classified under nineteen headings as follows:

Double Stars, Clusters, Variable Stars, Proper Motion Stars, Novæ, Nebulæ, Celestial Photography, Milky Way, The Sun, The Moon, The Planets, Asteroids, Comets, Meteors, The Aurora, The Gegenschein, Miscellaneous, and Reviews.