washed by seas of a greenish hue. Bright white spots are seen about the poles, which are no doubt occasioned by the reflection of the sun's light from the snow and ice collected there. It is observed that as each pole is turned towards the sun the spots about it diminish in size, owing to the melting of the snow by the solar heat.

991. THE ASTEROIDS.—The Asteroids are so small that, with the exception of one or two which have been seen without a telescope, they are invisible to the naked eye. Their diameters have not yet been accurately determined; some exceed 100 miles, and others probably fall somewhat under that mark. A number of them are provided with extensive atmospheres. The Asteroids are supposed by some to be the wreck of one large planet, which they believe to have originally revolved between Mars and Jupiter, and by some tremendous catastrophe to have burst into fragments. Many similar bodies probably remain to be discovered in this region.

The Asteroids are comparatively so diminutive that the force of gravity on their surfaces must be very small. A man placed on one of them would spring with ease 60 feet high, and sustain no greater shock in his descent than he does on the earth from leaping a yard. On such planets giants may exist; and those enormous animals which here require the buoyant power of water to counteract their weight, may there inhabit the land.

992. JUPITER (♃).—Next to the asteroids is Jupiter, the largest of the planets, which exceeds the Earth in bulk nearly 1,300 times. Its revolution round the Sun is performed in about 12 years, and that around its axis in less than 10 hours. Jupiter is attended by four satellites, which revolve about it from west to east.

All of these satellites but one exceed our Moon in size. The largest would sometimes be visible to the naked eye as a very faint star, were it not lost in the superior brightness of its planet. Three of them are totally eclipsed during every revolution by the long shadow which the planet casts, and the fourth is very often eclipsed. The relation between their orbits and motions is such that for many years to come Jupiter will never be deprived of the light of all four at the same time.

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poles? By what are they supposed to be caused? 991. Are the Asteroids visible to the naked eye? What is the length of their diameters? What are the Asteroids thought by many to be? What is stated with respect to the force of gravity on their surface? 992. How does Jupiter rank in size? How does it compare in bulk with the Earth? What is the length of its year? Its day? By what is it attended?

So large is Jupiter, and so short a time is it in revolving on its axis, that every point on its equator must turn at the rate of 450 miles a minute. The result is an immense excess of centrifugal force at the equator; and this is seen to have operated before the mass of the planet became hard, by flattening it very much at the poles.—Jupiter's disk is always crossed with a number of dark parallel belts, as shown in Fig. 331. They vary in breadth and situation, but are always parallel to the equator of the planet; hence they appear to be connected with its rotation on its axis, and are no doubt produced by disturbances in its atmosphere.

992. SATURN (♄).—Saturn, which is next to Jupiter in distance from the Sun, is also next to it in size, having a diameter of 76,791 miles, and consequently a bulk nearly 1,000 times that of the Earth. Its day is not half so long as ours; but it is 29½ of our years in making one complete revolution in its orbit.

Saturn has eight moons, seven of which were known for sixty years before the eighth was discovered. The largest of them has a diameter about half as large again as our Moon. Saturn's disk, like Jupiter's, is frequently diversified with belts; spots are of rare occurrence. An atmosphere of considerable density is supposed to surround the planet.

Saturn has a remarkable appendage, consisting of three bright, flat, and exceedingly thin rings, encircling its equator, and revolving with it around its axis in about the same time in which the planet itself revolves. The whole breadth of these rings is 27,000 miles, while their thickness does not exceed 100 miles. They are supposed to consist of a mixture of gases and vapors, sufficiently substantial to cast a shadow. The three rings are detached from each other, and lie in the same plane very close together, while the inner one is 19,000 miles from the surface of the planet. They are prevented from falling in upon the planet by the centrifugal force generated by their rapid revolution.

993. URANUS (♅).—Uranus, the next planet to Saturn, revolves about the Sun in 84 of our years. There being no spots on its surface, we are unable to fix the period of its revolution on its axis. It is attended by six moons, which move from east to west (unlike the satellites of the other

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What is the size of the largest of these moons? What relation subsists between their orbits and motions? What is the shape of Jupiter? What has caused the flattening at the poles? With what is Jupiter's disk crossed? To what are these belts to be attributed? 992. What is the next planet to Jupiter? What is Saturn's diameter? How does its bulk compare with the Earth's? Its day? Its year? How many moons has Saturn? How is its disk diversified? What remarkable appendage has Saturn? Describe its rings. 993. What is the next planet to Saturn? What is the length of the year of Uranus? Its day? By what is it attended? How do its light

planets) in orbits nearly perpendicular to that of the planet. The solar heat and light of Uranus are only $\frac{1}{360}$ of ours.

994. Neptune (♆).—Neptune, the most remote planet of the solar system, is invisible to the naked eye. Seen through the telescope, it looks like a star of the eighth magnitude. The diameter of Neptune is 39,800 miles, which is 4,500 more than that of Uranus. Its revolution around the Sun is performed in about 165 of our years. Neptune has at least one moon, distant from it about as far as ours is from us.

The discovery of Neptune is one of the greatest triumphs of which science can boast. Comparing observations on Uranus, while it was still thought to be the most distant member of the solar system, astronomers found certain *perturbations* or irregularities, in its motions, which could be accounted for only on the supposition that there was some unknown planet beyond it by whose attraction it was affected. Le Verrier thoroughly investigated the subject, and even went so far as to compute the size and distance of the suspected planet, and to predict in what part of the heavens it would be found at a given date. A letter from the French astronomer, embracing the results of his calculations, reached Berlin, September 13, 1846; and that very evening, sweeping the heavens with his powerful telescope, according to Le Verrier's instructions, Dr. Galle discovered what was apparently a star of the eighth magnitude not laid down on his chart, but was proved by its change of place on the following evening to be a planet.—It is just to add that Adams, an English astronomer, had, about the same time with Le Verrier, made similar calculations, and with nearly the same result.

995. Real and Apparent Position of the Heavenly Bodies.—We seldom see the heavenly bodies in their real position. This is owing to two causes,—Refraction and Parallax.

996. *Effect of Refraction.*—Refraction, which has been explained in the chapter on Optics, bends rays of light entering our atmosphere from a rarer medium, and causes the body from which they proceed to appear higher than it really is. The Sun is thus made visible a few moments before he actually rises and after he sets. The effect of refraction is greatest when a body is on the horizon, and diminishes as it ascends towards the zenith, at which point it entirely disappears.

and heat compare with ours? 994. What is the most remote planet of the solar system? How does Neptune look, when seen through the telescope? What is its diameter? What is the period of its revolution? How many moons has Neptune? Give an account of the circumstances under which Neptune was discovered. 995. Why do we not see the heavenly bodies in their real position? 996. What is the effect of refraction?

997. *Effect of Parallax.*—A planet seen from different points of the Earth's surface appears to lie in different positions. This is evident from Fig. 335.

The planet C to an observer at A seems to lie at F; to one at B it appears to lie at D. To avoid the inconsistencies which would otherwise exist in observations made at different places, the centre of the earth is taken as a standard point; and the true position of a heavenly body is that point of the celestial arch which would be cut by a line connecting the centre of the Earth with the centre of the body in question, infinitely produced.

Fig. 335.

Parallax is the angle made by a line from a heavenly body to the Earth's centre and another line from the same body to the eye of an observer.

It is evident that, the nearer a heavenly body is, the greater is its parallax The fixed stars are so remote that they have no appreciable parallax. The Earth, if visible to them, would be nothing more than a minute point of light. —The parallax of a heavenly body is greatest when it is on the horizon. At the zenith it would be nothing, because from that point the lines to the observer's eye and the centre of the Earth would coincide.

998. Eclipses.—By an Eclipse of the Sun or Moon is meant its temporary obscuration by the interposition of some other body. An eclipse is called Total, when the whole disk is obscured; and Partial, when only a portion is darkened.

999. An eclipse of the Sun is caused by the Moon's getting between it and the Earth, and intercepting its rays. This can happen only at new Moon, because, when between us and the Sun, the Moon must present to us her unenlightened side.

fraction? 997. How does a planet seem to lie, when observed from different parts of the Earth's surface? Illustrate this with Fig. 335. What is the true position of a heavenly body? What is Parallax? What is said of the parallax of the fixed stars? What would be the effect of refraction and parallax on the apparent position of a body in our zenith? 998. What is an Eclipse? When is an eclipse called Total, and when Partial? 999. What causes an eclipse of the Sun? When alone can this hap-

If the Moon's orbit lay in the same plane as the Earth's, she would eclipse the Sun every time she became new; but, as her orbit is inclined to the ecliptic at an angle of more than 5 degrees, her shadow may fall above or below the Earth at the time of her change.

When the Moon intervenes between the Sun and the Earth at such a distance from the latter as to make her apparent diameter less than the Sun's, a singular phenomenon is exhibited. The whole disk of the Sun is obscured, except a narrow ring around the outside encircling the darkened centre. This is called an Annular Eclipse, from the Latin *annulus*, a ring.

1000. An eclipse of the Moon is caused by the Earth's getting between it and the Sun. This can take place only at full Moon, because when the Earth is between the Sun and the Moon the latter must present her enlightened side to the Earth.

Non-luminous itself, when cut off from the solar rays, the Moon must become invisible. There is this difference between an eclipse of the Sun and the Moon. In the former, the Sun shines the same as ever, and its brightness is undiminished to those who are out of the Moon's shadow. When the Moon is eclipsed, on the other hand, she diffuses no light, and is dark to all within whose range of vision she is situated.—Solar eclipses occur more frequently than lunar. The greatest number of both that can take place in a year, is seven; the smallest number, two; the usual number, four.

1001. When the Sun is totally eclipsed, the heavens are shrouded in darkness, the stars make their appearance, the birds go to roost, the animals by their uneasiness testify their alarm, and all nature seems to feel the unnatural deprivation of the light of day. It is not surprising that, when the cause of the phenomenon was unknown, it filled the minds of men with consternation. Even at the present day barbarous nations regard eclipses as indications of the displeasure of their gods. Columbus, on one occasion, when wrecked on the coast of Jamaica, and in imminent danger both of starvation and an attack from the Indians, saved himself and his men by taking advantage of this superstitious feeling. From his acquaintance with astronomy, he knew that an eclipse of the Moon was about to take place; and on the morning of the day, summoning the natives around him, he informed them that the Great Spirit was displeased because they had not treated the Spaniards better, and would shroud his face from them that night. When the Moon became dark, the Indians, convinced of the truth of his words, hastened to him with plentiful supplies, praying that he would beseech the Great Spirit to receive them again into favor.

pen? Why is not the Sun eclipsed every time the Moon becomes new? What is an Annular Eclipse? 1000. By what is an eclipse of the Moon caused? When can this take place? What difference is mentioned between an eclipse of the Sun and the Moon? Which occurs more frequently? What is the usual number in a year? 1001. Describe the appearance of things during a total eclipse of the Sun. How do barbarous nations regard eclipses? How did Columbus once save himself and his

1002. Comets.—*Comet* is derived from a Greek word meaning *hair;* and the term is applied to a singular class of bodies belonging to the solar system, from which long trains of light, called *tails,* spread out like hair streaming on the wind. They differ very much in appearance; but, for the most part, they consist of a *nucleus*, which is a very bright spot, apparently denser than the other portions; an *envelope*, which is a luminous fog-like cover surrounding the nucleus; and a *tail*, which appears to be an expansion of the envelope produced by solar heat.

The tails of different comets differ greatly in shape and extent. In some this appendage is entirely wanting; in others it has been found to extend 120,000,000 miles. Several tails have been exhibited at the same time; the comet of 1744 threw out no less than six, like an enormous fan, over the heavens. Even in the same comet the tail keeps changing, being largest when near the Sun and diminishing as it recedes from that body.—The tail lies on the opposite side of the nucleus from the Sun,—behind it, when approaching its perihelion, and preceding it when retiring from that point.

1003. *Constitution.*—The matter of which comets are composed must be an exceedingly thin gas or vapor.

The nucleus is always bright, no matter what position in relation to the Earth it may occupy; no phases are presented, as in the case of the planets; this proves the nucleus to be so rare that the solar light (which alone renders it visible) can penetrate it and be seen on the side opposite to that which it strikes. Again, comets have on different occasions passed very near the planets, yet have never been found to cause any irregularities in their motions, while their own motions have been materially affected. The tail, in particular, must be exceedingly rare, perhaps not weighing more than a few ounces, even when most extensive.

1004. *Orbits, Velocity.*—The orbits of the comets are either ellipses, parabolas, or hyperbolas.

If ellipses, they generally deviate very much from a circle, being lengthened out an immense distance in proportion to their breadth. Comets that move in elliptical orbits return after a series of years; those that move in parabolas or hyperbolas never reappear, but after wheeling about the Sun dash off into the remote regions of space, perhaps to visit other systems.

Some comets at their perihelion pass very close to the Sun. The one that

men? 1002. What are Comets? Of what do they consist? What is said of the tails of different comets? In the case of the same comet, what change takes place in the tail? How does the tail lie? 1003. Of what kind of matter must comets be composed? How is it proved that the matter of comets must be exceedingly rare? 1004. What shape are the orbits of comets? In what case will the comet return?

appeared in 1843 almost grazed its surface, approaching so near it that the solar disk must have appeared 47,000 times larger than it looks to us, and the heat received must have been twenty-five times greater than that required to melt rock-crystal.

1005. When near the Sun, comets move with incredible velocity,—sometimes at the rate of over a million miles an hour.

1006. *Number.*—The exact number of comets can not be determined. Over seven hundred have been seen and enumerated. Multitudes have visited our system without being seen from the Earth, in consequence of reaching their perihelion in the day-time, or when the heavens were obscured by mists and clouds. Arago estimated the number that have appeared or will appear within the orbit of Uranus at 7,000,000; the same calculation extended to Neptune's orbit would make the number 28,000,000.

1007. Comets were formerly regarded with superstitious terror as precursors of war, famine, and other misfortunes. In more modern times the fear of a collision made them formidable objects. This fear, however, has been dispelled by the discovery of their great rarity. A collision, however fatal it might be to the comet, would probably do little injury to a solid body like the Earth.

The Fixed Stars.

1008. The Fixed Stars are so called in contradistinction to the planets, because they maintain the same position relatively to each other, not because they are absolutely at rest. They all move about some fixed point in immense orbits, which it will take millions of years for them to complete. Shining by their own light and not by reflection, they are suns, and are probably each the centre of a system of its own.

1009. *Magnitudes.*—Varying in size and situated at different distances from us, the stars are not all of the same brilliancy. They are divided into about twenty classes according to their brightness, and distinguished as stars

How near did the comet of 1843 pass to the Sun? 1005. What is the velocity of comets, when near the Sun? 1006. What is the number of the comets? What prevents us from seeing many that visit our system? What was Arago's estimate? 1007. How were comets formerly regarded? How are they now looked upon? 1008. Why are the Fixed Stars so called? 1009. How are the fixed stars classified? What are Telescopic Stars? How many stars are there of the first magnitude? Of the second? Of the third? 1010. How are the fixed stars divided? How many constellations were laid off by the ancients? How many have been added in modern times? How are the stars in each constellation distinguished? 1011. What is the distance of the fixed stars? What is the distance of Sirius? Of the North Star? 1012. What are Periodical Stars? What are Binary Stars? What relation seems to subsist between the brighter and fainter star? Into what are some stars resolved? With what are

of the First, Second, &c., Magnitude. The stars of the first six magnitudes are visible to the naked eye; the rest are called Telescopic Stars, because seen only with the telescope. There are about 24 stars of the first magnitude, 50 of the second, and 200 of the third; but the number in the lower classes increases so rapidly as to be almost beyond enumeration.

1010. *Constellations.*—For convenience of reference, the stars are divided into constellations, or groups, named after animals and other objects to which their outline bears some fancied resemblance. The twelve constellations of the zodiac have been already named; there were thirty-six more laid off by the ancients in other parts of the heavens. The whole number has been increased in modern times to ninety-three. The stars in each constellation are distinguished, according to their magnitude, first by the letters of the Greek alphabet, then by those of the Roman, and when both are exhausted, by figures.

1011. *Distance.*—The distance of the fixed stars is absolutely incredible. None of them can be less than 19,200,000,000,000 miles from the Earth, while the greater part are far more remote.

The recent improvements in telescopes have enabled astronomers to compute the distance of nine of the nearest stars. Sirius, the brightest of them, is found to be so far off that light, with a velocity of 192,000 miles a second, is fourteen years in reaching us; from the North Star it is over 48 years. The mind is lost in trying to comprehend such mighty distances; and yet it will be remembered these are among the nearest stars.

1012. Several remarkable facts are worthy of note in connection with the fixed stars. Some of them wane for a time, so as to be classed in a lower magnitude, and then resume their former brilliancy. Others, after vanishing entirely for a season, suddenly reappear; these are called Periodical Stars.

Many stars (at least several thousand), when viewed through a powerful telescope, are resolved into two stars, one of which is generally much fainter than the other. These are known as Binary or Double Stars. In some cases the faint one may only appear to be near the bright one from lying in the same direction, and really be millions of miles behind it; but there is generally reason for supposing that the fainter luminary revolves about the brighter one in obedience to that same great law of gravitation which prevails in our own system.—Some stars, apparently single, are resolved into three, four, and even six, by the telescope.

Many of the binary stars are tinged with complementary colors. The larger one is orange-colored, the smaller blue; or the one is red, and the

other green. Some of the single stars look blood-red; but there are none that exhibit deep tinges of blue or green.

The size of several of the fixed stars has been calculated approximately. Their diameters are found to be enormous,—in one case not less than 200,000,000 miles. Sirius, "the dog-star", if set in the place of our Sun, would look 125 times as large as he, and give us 125 times as much light. Trillions of miles away, as it is, it dazzles the eye when seen through a powerful telescope.

1013. The Galaxy.—The Galaxy, or Milky Way, is a broad zone of light which stretches across the sky from horizon to horizon, encircling the whole sphere and maintaining the same position relatively to the stars. Examined through a powerful telescope, it is found to consist entirely of stars, scattered by millions, like glittering dust, on the black ground of the heavens.

1014. Nebulæ.—Nebulæ are clusters of stars so distant that they look like faint patches of cloud hardly discernible in the sky. They vary in shape, and are seen in different quarters of the heavens.

Lord Rosse's great telescope resolves some of the nebulæ into individual stars; it makes others appear bright, but not sufficiently so to be separated into the stars that compose them; and it calls up from the depths of space others which appear as faint even to its mighty magnifying power as those which it resolves appear to the unaided eye. The milky way is itself one of these nebulæ, more distinct than the others because nearer to us.

From the facts set forth we may conclude that the universe consists of a vast number of distinct clusters of worlds, separated from each other by immense intervals; that the fixed stars, the milky way, our Sun and its system, form one of these clusters; that the various nebulæ constitute other clusters, fainter or brighter according to their distance from us,—each composed of many different systems,—and having its members separated as widely as our Sun is from the brother suns about him.

How can the mind take in such mighty thoughts! How can the heart refuse its homage to the great Creator of all these worlds!

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many of the binary stars tinged? What has been found with respect to the diameters of some of the fixed stars? How would Sirius look, if set in the place of our Sun? 1013. What is the Galaxy? How does it look through a powerful telescope? 1014. What are Nebulæ? How do nebulæ look through Lord Rosse's telescope? What may we conclude from the facts set forth?

CHAPTER XIX.

METEOROLOGY.

1015. Meteorology is the science which treats of the phenomena of the atmosphere. Among these are winds, clouds, fog, dew, rain, snow, and hail.

Some of the phenomena of the atmosphere have been already described and explained in connection with the various subjects that have engaged our attention.

1016. Wind.—Wind is air put in motion.

The motion of the air is the result of changes constantly going on in the earth's temperature, in consequence of the alternation of day and night and the succession of the seasons. Those portions of the atmosphere that rest on the hotter regions of the earth become heated and rarefied, and rising leave a vacuum which is immediately filled by a rush of cooler air from the surrounding parts. Currents are thus produced, which we call *winds*.

The direction of the wind is determined by various local causes, modified by the revolution of the earth on its axis. The latter, operating alone, would make it appear to blow uniformly from the east; but the various projections on the earth's surface, and the unequal distribution of land and water (the latter of which is incapable of being heated to the same degree as the former), —these and other agencies constantly at work combine to give the wind different directions at different places, and to make it vary at the same place.

1017. *Velocity.*—The velocity of the wind is measured with an instrument called the An-e-mom'-e-ter.

There are several kinds of anemometers. One of the best consists of a small windmill, with an index attached for recording the number of revolutions made in a second.

It is found with the anemometer that a wind so slight as hardly to stir the leaves travels at the rate of 1 mile an hour; a gentle wind, 5 miles in the same time; a brisk gale, 15 miles; a high wind, 30; a storm, 50; a hurricane, 80; a violent hurricane, 100.

1018. *Kinds.*—There are three kinds of winds; Constant, Periodical, and Variable.

1015. What is Meteorology? Mention some of the phenomena of the atmosphere. 1016. What is Wind? What puts the air in motion? By what is the direction of the wind determined? 1017. How is the velocity of the wind measured? What is one of the best forms of the anemometer? How fast does a scarcely perceptible wind travel? A gentle wind? A brisk gale? A storm? A hurricane? 1018. How many