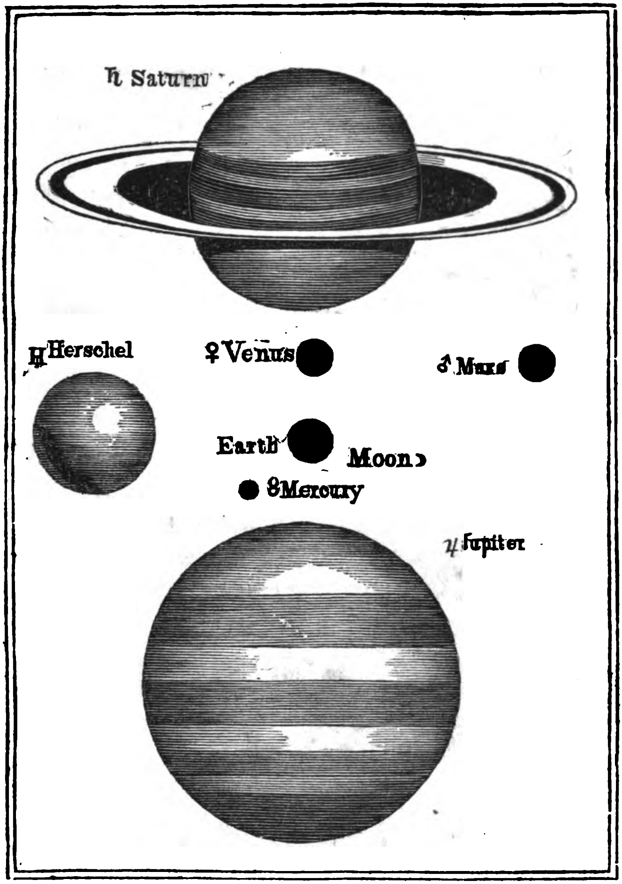
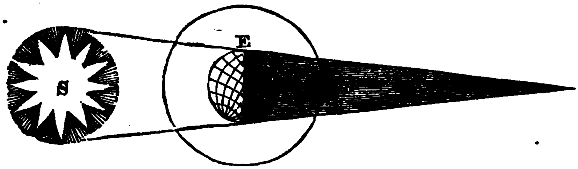


♄ Saturn
♅ Herschel
♀ Venus
♂ Mars
Earth
Moon ☽
☿ Mercury
♃ Jupiter

YOUTH'S BOOK

OF

ASTRONOMY.



BY J. L. COMSTOCK, M. D.

Author of Elements of Mineralogy, Elements of Chemistry, System of Natural Philosophy, Introduction to Botany, Outlines of Geology, &c.

HARTFORD:

PUBLISHED BY REED AND BARBER,

1838.

HARTFORD:
Hudson & Skinner, Printers.

ADVERTISEMENT.

This is the second number of the series of "BOOKS ON THE SCIENCES, FOR YOUTH," undertaken by the Author.

It is true that several small books on the same science, "designed for beginners," are already before the public. But the Author of this, has seen none which he thought brought the subjects down to the capacity of youth, and explained them in the plainest possible manner.

This volume begins with the Moon, which is obviously the most familiar and interesting celestial object, which youth can examine without astronomical apparatus.

It is also that part of astronomy which is most easily explained to the comprehension of the young mind, and therefore the best calculated to fix his attention to the subject.

After the Moon, the Earth is treated of as a planet, and her relations to astronomy as a celestial orb, when viewed from the moon and other planets, are described and illustrated.

After these, follow descriptions of the other planets in their order, as is done in other books.

If the author has not made the different subjects connected with this science more easily comprehended, and therefore better adapted to the capacities of youth than others, he has failed in one of the principal objects of this little volume; but of this the public must now judge.

Hartford, Conn. Feb. 1838.

CONTENTS.

YOUTH'S ASTRONOMY.

The word Astronomy comes from the Greek *Aster*, a star, and *Nomos*, a law, and signifies the science by which we are taught the motions, magnitudes, and distances of the heavenly bodies.

Astronomy is undoubtedly the most ancient, and certainly the most perfect of all the sciences.

From the very earliest times, the view of the heavens must have fixed the attention of mankind. At first, curiosity alone was probably the motive which led to the examination of the motions and changes which the heavenly bodies are constantly undergoing. But it was not curiosity alone which led men to the continued pursuit

What is the meaning of the term Astronomy?
What is said of the antiquity and perfection of this science?
What motive first led to the examination of the stars?

of this subject, and to bring it to its present degree of perfection; for it was long since discovered that astronomical calculations could be made highly useful to the inhabitants of the planet on which we live, and accordingly we find, that its uses have extended in proportion as the science has become more and more perfect.

To this science, navigation and the commerce of the world is indebted for its safety and extension, and by the same means civilization and the Christian religion have been planted in the uttermost parts of the earth.

We must therefore consider Astronomy as one of the most useful, as it certainly is the most sublime and interesting of all the sciences. No subject is so calculated to elevate the mind above the sordid affairs of this world, and produce a firm conviction of the wisdom, power and constant superintendence of an Almighty Being, as this. When the eye surveys the vault of the heavens, studded with millions of brilliant points, and the mind reflects that these are suns like our own, and around which myriads of planets like our earth are perpetually circulating, and that each is probably inhabited by millions of reasonable beings like ourselves, the conviction is inevitable, that there must exist a Being, who is both

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What object led to the continued pursuit and perfection of this science?

What is said of astronomy in regard to the commerce and civilization of the world?

In a moral sense, what convictions is astronomy calculated to produce?

omniscient and omnipresent, and whose Wisdom is equal to his Power and Glory. And when we remember that each inhabitant of this, and all other worlds, is under the especial notice and care of this Almighty Being, and that he is the source whence we derive all the means and the pleasures of existence, we cannot but conclude that his *goodness* is equal to his wisdom, power and glory.

THE MOON.

We shall make the subject of Astronomy as plain and easy for our young friends as possible, and for this purpose shall begin with the Moon, because, of all astronomical objects, this is the one with which they are best acquainted, and consequently with which, at first, they will be most interested.

The Moon, to the inhabitants of this earth, with the exception of the sun, is the most important and interesting of all the heavenly bodies.

The sun is too brilliant to be examined without glasses, and even when thus examined, he presents nothing very interesting to the young astronomer, since from month to month, and year to year, he undergoes but little change in appearance. But the Moon can be viewed

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Why does the author begin his astronomy with an account of the moon?

Why is the moon more easily examined than the sun?

by the unprotected or naked eye; and as she is constantly changing her appearance—as she gives us light by night—as she is the cause of the tides, and is supposed to have some influence on the weather,—she has been the object of constant and universal observation ever since man became an inhabitant of this earth.

Astronomers, also, have made more observations on this, than on any of the other planets, and as she is nearer the earth than any other celestial body, our knowledge concerning her motions, appearances and effects, is supposed to be more certain and accurate than it is of any other planet.

DISTANCE OF THE MOON.

The distance of the Moon from the earth is 240,000 miles, being about 400 times nearer than the sun, which is 95 millions of miles from us.

The manner in which the distance of the Moon, and the other planets, has been ascertained, cannot be explained here, as this would require a knowledge of arithmetic above the years of those for whose use this book is intended. We can therefore only state, that hundreds of astronomers who have made this science their only study for many years, have calculated the distance of

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Why has the moon always been an object of universal observation?
What is the distance of the moon from the earth?
How many times further from us is the sun than the moon?

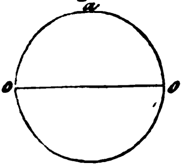
this planet, and that they all agree, either exactly or within a few miles. There is consequently no more reason to believe the existence of any considerable error with respect to the distance of the Moon from the earth, than there is with respect to the earth's diameter, or the distance of one place from another on its surface.

SIZE OF THE MOON.

The diameter of the moon is 2180 miles.

Now the *diameter* of a body is the distance from one side to the other, through the centre, as from *o* to *o*, in fig. 1. The Moon being round like a ball, as we shall see directly, has nearly the same diameter in all directions. The *circumference* of a ball is a little more than three times its diameter, and is the distance around the outside.

Fig. 1.



Thus in fig. 1, the distance from *o* to *o* again, is the circumference. The circumference of the Moon, therefore, is about 6500 miles, being more than one quarter that of the earth, which is nearly 24,000 miles in cir-

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What reason is there to believe that the true distance of the moon is known?
What is the diameter of the moon?
What is meant by the diameter of a body?
How is the circumference of a body found?
How many times the diameter make the circumference of a body?
How much greater is the bulk of the earth than that of the moon?

cumference. But the earth in bulk is full 48 times larger than the moon ; that is, if the earth and Moon are composed of the same kind of matter, the former would just balance 48 of the latter.

This would hardly be suspected when we have stated that the earth is only four times the circumference of the Moon. But the quantity of matter which balls or globes contain, is as the cubes of their diameter. Thus the diameter of the Moon being 2180, and that of the earth 7924 miles, the difference in their quantities of matter is as the difference of the cubes of these two sums. Now the cube of the earth's diameter, divided by the cube of the Moon's diameter, will show that the former is about 48 times the size of the latter. By the same rule, the difference between the solid contents of all the other planets may be known from their diameters.

The most simple, though not the most accurate method of determining the apparent diameter of the planet is, to place between it and the eye, a thin plate of metal, with a small circular aperture through it, and at such a distance from the eye that the entire face of the planet shall appear to exactly fill the aperture as represented by fig. 2. Then by measuring the diameter of the aperture and its distance from the eye, to determine by mathemat-

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What is the proportionate quantity of matter in globes?
By what method is it found that the earth is 48 times as large as the moon?
What is said to be the most simple method of determining the diameter of a planet?

Fig. 2.

ical calculations, the angle subtended by the diameter of the aperture, and by inference the diameter of the planet.

Another method by which comparative diameters are determined, is to cast the picture of a planet through a telescope on a sheet of white paper in a dark room, and to compare the diameter of this, with the picture of the sun or Moon projected in the same manner.

SHAPE OF THE MOON.

The shape or form, of the Moon is that of a globe or sphere. This is proved not only by looking at her when she is full, but also by the shadow she casts upon the sun, when she passes between the earth and that great luminary, which happens when the sun is eclipsed. Now

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What is the shape of the moon?
How is it proved that the form of the moon is globular?

Fig. 3.

we know that the shadow of a body is of the same shape as the body itself. When, therefore, the shadow of the Moon is seen on the face of the sun, in form of the dark half circle represented by fig. 3, it is proof that her form is globular, or like that of a ball.

The figure shows the appearance of the sun when partially eclipsed, the other half of the moon being unseen; because when she eclipses the sun, her dark side is always towards the earth, and therefore invisible.

LIGHT OF THE MOON.

The Moon is a dark solid globe, probably composed of earth and rocks, like the planet on which we live. She therefore can have no light of her own, but borrows all that which she throws upon us from the sun.

All objects, except those which are perfectly black, will reflect more or less of the light which is thrown upon them, but white objects reflect most of all. If a candle be so placed as not to shine into an adjoining room, with the door open, the objects in the enlightened room will throw more or less light into the dark one; and if a sheet of white paper be held near the candle, with its surface

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Whence does the moon obtain the light with which she shines upon us?

How is it known that the moon does not shine with her own light, but reflects that which she borrows of the sun?

towards the dark room, the quantity of light which it throws in will be quite apparent. It is therefore easy to conceive that the moon, though her surface may not be white, may still shine with considerable brilliancy when her full face, on which the sun shines, is turned towards us.

Besides, did the Moon shine with her own light, she would appear to us as a small sun, and would never be invisible except when she is below the horizon. But now she appears only in the night, and then only when that side on which the sun shines is turned towards us, either fully or in part.

SURFACE OF THE MOON.

Were the surface of this planet smooth like that of a mass of ice, or even like a sheet of still water, the image of the sun would sometimes be reflected from her to us, in the form of a small star, or brilliant point, which never happens. This circumstance alone would be sufficient to show that the surface of the moon is not so smooth as to reflect the unbroken light of the sun. But in addition to this, her surface, as it appears to the naked eye, is spotted with light and shade, clearly showing that it is rough and uneven. This appearance, when examined through a telescope, is greatly increased, the surface then

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If the surface of the moon was smooth like ice, in what manner would the light of the sun be reflected from her?

presenting itself almost everywhere surprisingly broken, and often highly precipitous. The cause of these appearances is supposed to be volcanoes, which threw up and shattered her mountains.

In some places, dark spots are seen, of considerable extent, which are on the opposite side to the sun, while on the side next him there is an illuminated patch. These spots are apparent, especially when the moon is old, and her illuminated face not fully seen. Hence astronomers infer that these spots are caused by hills or mountains, which project shadows when the rays of the sun fall obliquely upon them: in the same manner that the earth presents patches of light and shade in the morning or towards evening, when the sun shines on one side of a mountain and causes it to throw the other side into the shade. When the Moon is full, many of these spots disappear, because then the light of the sun falls directly upon her face, and reaches both sides of the hills, and into the valleys, in the same manner that the whole surface of the earth is illuminated at noon-day.

But at full Moon, there are still patches of light and shade on her surface, which are distinct to the naked eye, but the difference is greatly increased when seen through a telescope. These spots, some of which are of

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Besides the absence of an unbroken reflection of the sun, what are the other proofs that the surface of the moon is uneven?

When the moon is full, why do many of the spots on her surface disappear?

great size, were formerly supposed to be seas, and lakes of water, but with the assistance of more powerful telescopes, and repeated observations, these are now supposed to be deep cavities, or valleys, around which arise high mountains. These patches, when the Moon is in the same position with respect to the earth, are always exactly the same, no change either in form or extent having ever been noticed. Hence some astronomers have concluded that there are neither seas, lakes, atmosphere, clouds or rain at the moon, and consequently no vegetation.

Were the moon surrounded by an atmosphere like our own, in which clouds, mists and vapors are constantly floating, it is reasonable to conclude that her face would present dark patches, perpetually changing in place, figure and dimensions, as these clouds happened to prevent the light of the sun from shining on her surface. But we have seen that no such changes ever occur. We might also suppose, that, were the Moon inhabited, and the people destined to obtain their bread by the sweat of the face, as we terrestrials are obliged to do, there would in the course of years be visible changes produced on the surface by the cultivation of the earth, and the clearing of forests, and especially that there would be an obvious

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What is supposed to occasion the spots on her surface at the full moon?
Why is it supposed that there are no seas or lakes in the moon?
What reason is there to believe that the moon has no atmosphere?
What are the reasons for supposing that the moon is not inhabited?

difference between the seasons of summer and winter, did these changes take place as they do on our earth. It is very certain that if any considerable portion of her surface was ever covered with snow, a great difference in her appearance, and in the quantity of light which she sends us, would be the consequence.

From these and other considerations, many astronomers have concluded that the moon neither contains moisture nor inhabitants, but that she was created for the use of this earth.

On the contrary, it may be said, that no instance has come to the knowledge of man, where the Creator has left any considerable space unoccupied by some kind of inhabitants, and that for aught we know, the Moon could perform all its offices towards the earth, and still give residence and enjoyment to thousands of reasonable beings. Reasoning therefore from our limited knowledge of the works of nature, we ought to conclude that every planet and satellite is the residence of living, responsible beings, who are fitted by the wisdom and kindness of Providence, both naturally and morally, for the climates and stations they occupy.

It is true, that according to our experience, no animal can live without an atmosphere, and few without water and vegetation; but it is by no means certain that the

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Do we know of any instance where the Creator has left any considerable space unoccupied by living creatures?
Why ought we to conclude that every planet is inhabited?

moon does not contain all these, though we can discover no signs of either; and even could we ascertain the absence of these and of every other element which we consider necessary to animal existence, who even then would dare to say that the Creator could not, and has not, adapted animals, who are far above us in intellect, to the perfect enjoyment of life without the presence of a single article or circumstance, on which our lives and happiness depend?

REVOLUTIONS OF THE MOON.

The Moon revolves around the earth once in 27 days and 7 hours; and it is in consequence of this revolution, together with the motions of the earth, that she is constantly changing her appearance; gradually increasing from new Moon to full, and then as slowly diminishing until she entirely disappears, but only to appear again in the form of a new Moon as before; and so on continually.

The Moon not only passes around the earth, but also has a revolution on her own axis; that is, while she moves forward in her monthly journey, she turns over

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Is it certain that the moon does not contain the elements necessary for such existences as ours?

Even if it does not, what follows?

In what period does the moon make a single revolution around the earth?

What causes the moon to be constantly changing her appearance to us?

like the wheel of a carriage, only that she touches nothing.

The *axis* of a planet is a line passing through its centre, and about which it turns. If a stick be pushed through an apple, the stick becomes the axis on which the apple may be turned. The difference is, that the axes of the planets are imaginary lines, and are therefore without substance.

The moon turns once on her axis in about the same period that she performs a journey around the earth, and it is owing to this circumstance that she always presents the same side towards the earth.

Did the moon turn on her axis once in a day, or once in a week, we should observe different spots on her surface; but instead of this, as already stated, she always presents, when full, exactly the same appearance. Hence, in order to keep the same side towards us, she must turn as fast as she goes forward, and no faster, thus making one simultaneous revolution on her axis, while she makes another around the earth.

The motions of the Moon are readily illustrated in the following manner. Set a lighted candle on a table and carry around it the apple with the stick through it, but giving it no motion on its axis, and it will be seen that

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What other revolution has the moon besides that around the earth?
What is the axis of a planet?
How often does the moon turn on her axis?
Why does the moon always present the same side towards the earth?

the apple will, in succession, present its whole surface to the light, so that an eye placed near the candle will see every side of it. Hence, if the moon passed round us without any motion on her axis, she would in her journey present, in succession, every part of her surface towards the earth. If now the apple be turned many times on its axis while it is passing around the candle, it will then also be seen to present every part, in succession, to the eye; and for the same reason, did the moon turn rapidly on her axis, she would every day present us with a new face during her journey. Lastly, let the apple be carried around the light, turning it slowly on the axis so as to keep the same side illuminated, and it will be seen that while it makes one revolution around the candle, it will have made another on its own axis, thus illustrating the manner in which the Moon revolves around the earth.

Since this planet turns on its axis only once in a month, her inhabitants have only one day and one night during that period, each day and night being about two weeks long.

CLIMATE OF THE MOON.

We have seen that the moon has no clouds, nor indeed any indications of an atmosphere. Were it surrounded by an atmosphere like our own, it could not fail to be in-

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If the moon turned on her axis once in a day or week, in what respect would her appearance be changed?

dicated by the refraction of the light of the stars at the moment of their occultations. It would also be discovered did it exist, during the phenomena of solar eclipses.

The climate of the Moon must therefore be a mere alternation between unmitigated sunshine, much fiercer than that of the hottest parts of the earth, for a fortnight, and then a degree of cold, far exceeding that of our polar winters, for the same length of time, or during the night.

Under such circumstances, if the Moon contains any moisture on its surface, it must be transferred by distillation in a vacuum, from that portion of the surface under the sun, towards the opposite surface, where it must become solid ice; and thus one half the lunar day, (which is nearly thirty of our days,) would possess a temperature sufficiently high to distil water, while the other half would be colder than the regions of our north pole.

It is possible, however, that evaporation on the one hand, and condensation on the other, may mitigate the temperatures of each, and render the climate tolerable.

The lunar seasons consist of these alternate changes, the summer being about fourteen days long, with a temperature nearly equal to boiling water, immediately succeeded by a winter, probably so cold as instantly to freeze mercury. Still it is most probable that the wisdom and

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Had the moon an atmosphere how would it be discovered?
What is the climate of the moon?
What is said of the lunar seasons?

goodness of the Creator has adapted reasonable and responsible beings to such a climate.

PHASES OF THE MOON.

The monthly changes which the Moon undergoes, and in consequence of which she presents us so many different forms, from *new* to *full*, are called her *phases.*

These changes are exceedingly interesting to us, because we wish to understand the reason, or causes of things which we have noticed all our lives, and because many people believe that the inhabitants of this earth are more or less affected by these changes.

The phases of the Moon are easily explained, and we hope will be as readily understood by the young astronomer.

To make this explanation clear, it must in the first place be remembered, that the sun always, both night and day, shines upon one half the moon, and that when her entire illuminated face is turned towards us, we call it *full* Moon; but when her darkened side is towards us, she becomes invisible, and then she is undergoing what we call her *change*, that is, she is about to become visible in the form of a *new* moon.

What is meant by the phases of the moon?
Why are the changes of the moon interesting to the people of this earth?
On what proportion of the moon does the sun always shine?
What is understood by full moon?

When this planet, in the course of her revolutions, comes between the earth and the sun, then it is plain that her enlightened side is turned from us towards the sun, and her dark side towards us, and consequently she becomes invisible. This is the position she is in during her change. But as she progresses towards the east, about four days after her disappearance, she again becomes visible in the west, a little after sunset, in the form of a beautiful crescent which we call *new* Moon. This is occasioned merely by such a change in her position as to show us only a small part of her surface on which the sun shines. From this time, a little more of her illuminated surface is every evening seen, and her position becomes higher in the horizon, or she advances more and more towards the east, until her whole enlightened surface is turned towards us, the Moon being in the east while the sun is in the west, and thus she becomes what we call a *full* Moon.

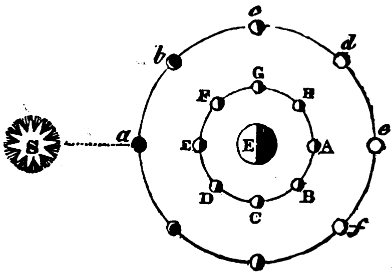
She now displays, on a cloudless night, a spectacle, which, to every terrestrial eye is both delightful and magnificent; but as if intended to be to us a perpetual emblem of the instability of human affairs, she soon loses a portion of her glory—her face becomes mutilated—

What is meant by the *change* of the moon?
In what position is the moon with respect to the earth and sun during her change?
What causes the new moon?
A full moon, what are the relative positions of the sun, moon and earth?

her light gradually diminishes, and in a few days she again becomes invisible. These changes she undergoes perpetually.

The phases of the Moon are illustrated by fig. 4, where let S be the sun, E the earth, and A B C, &c. the Moon in the different parts of her orbit, as she passes around the earth.

Fig. 4.



Now it will be seen, by the inner circle, that the sun shines on one half of the moon in every position; but a spectator on the earth would not see any of her enlightened surface, when her place is between him and the sun, as at E, because then her dark side only is towards him, as seen at *a*, in the outer circle. During this time she is in her change, and is said to be in *conjunction* with the sun; that is, the sun and moon are in the same direction as seen from the earth. When she passes to F, a small portion of her illuminated surface becomes visible, and she appears as at *b*, in the outer circle; that is, in the form of a new

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After full moon, what change does she undergo?
When is the moon said to be in *conjunction* with the sun; and when in opposition to him?

moon. When she comes to G, one half of her bright face is seen; when at F, still more is visible; and when she arrives at A, her whole surface on which the sun shines is turned towards us, and she becomes a full Moon, as represented in the outer circle at *e*. She is now in *opposition* to the sun; that is, when the sun sets in the west, the full moon is seen rising in the east.

From this time she begins to losė her splendor, and from being a full orb, becomes mutilated by the loss of a section of one side, as shown at *f*. She now continues every night to show less of her enlightened side, and to proceed westward until she comes to E, when she goes into conjunction, and again becomes invisible, and so on continually.

DESIGN AND USE OF THE MOON WITH RESPECT TO US.

The most obvious practical use of the Moon, so far as mankind are concerned, is the supply of light which she affords during the absence of the sun. But she herself, is sometimes below the horizon, when we think her light is most wanted. On the whole, however, we shall see that the wisdom of Providence has so directed her mutations that when she does shine upon us, it is at those seasons and times, when her light is most beneficial to us.

What is the most obvious use of the moon to us?

Sometimes the Moon gives no light, when she is above the horizon, and at such times, it matters little to us where she hides herself, whether above, or below us. But it is of much importance to our race, that she should be above the horizon when she gives out any considerable light. The sailor, the traveller, and the husbandman —the millions of our race, and even the beasts of the field, find convenience, or enjoyment in her light, during the otherwise profound darkness of many a long winter's night. Even when the atmosphere is full of clouds, or during storms and fogs, her light, when full, is sufficient to enable the sailor to see his land marks; the traveller to discern his road, and the husbandman to fold his herds.

Now from the relative positions of the sun, Moon and earth, and the motions of the two latter, it so happens that when the light of the Moon is considerable, and therefore useful to us, that her place is always above our horizon.

The quantity of light which the Moon reflects, is greatest, when she is at the greatest distance from the sun, or when they are in opposition to each other. At these periods, the Moon is said to be *full*, that is, her entire illuminated face is turned towards the earth, the Moon being in the east, and the sun in the west.

Does the moon always give light when above the horizon?
Where is the place of the Moon when her light would be useful to us?
What position is the moon with respect to the sun when she gives us most light?

The period of her greatest light will always bring her on the meridian near midnight, and hence at these times, she ascends above the horizon only a little after sun set, so that during the whole night she continues to illuminate the earth.

HARVEST MOON.

As the Moon follows, or rather attends the earth in its annual revolution around the sun, the motions of the Moon in her orbit are exceedingly complicated, and therefore cannot be explained to the comprehension of those for whom this little book is designed. But it is owing to these very irregularities that we have the advantage of what is called the *harvest* Moon, in the fall of the year.

During most of her course, the rising of the Moon is about fifty minutes later on each successive day, and if she moved in a regular orbit this would continue to be the ease through the year. But near the approach of the vernal equinox, that is, in September, she is retarded in her course, and instead of being later by about fifty minutes, as usual, on each day, she now rises for four or five successive evenings, about sun set. And as this happens near the close of harvest time, in northern latitudes, and when the husbandman thus has an opportuni-

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During her greatest light at what time is she on the meridian?
What is meant by the harvest moon?

ty of carrying on his work after sun set, it has obtained the name of the *harvest moon.*

HOW THE EARTH LOOKS TO THE PEOPLE OF THE MOON.

Having described the appearances of the Moon to us, we will now notice some of the phenomena which our earth presents at the Moon.

The earth, as seen by the lunarians, or inhabitants of the Moon, exhibits the same changes to them as the Moon does to us, but in a contrary order; for when the Moon is in conjunction, and consequently invisible to us, the earth appears full to them, and when the Moon is full to us, the earth is invisible to the lunarians.

This will be understood by fig. 5, which represents the sun, S, the earth, E, and moon, *a*, *b*, the latter being both in opposition and conjunction. Now when the Moon is in conjunction with the sun at *a*, with her dark side towards the earth, the illuminated side of the earth is towards the moon, so that while she is invisible to us, our earth appears fully enlightened to the people of the moon. On the contrary, when the moon is at *b*, and full

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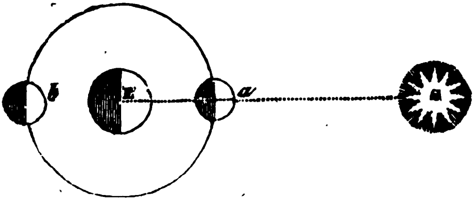
What changes does the earth undergo, as seen by the inhabitants of the moon?
When the moon is invisible to us, how does the earth appear at the moon?
When the moon is full, how does the earth appear to the lunarians?
Explain fig. 5, and show why these changes are reversed?

to us, then the dark side of the earth is towards her, and consequently invisible to the lunarians.

Fig. 5.



We have already stated that one side of the Moon is never turned towards the earth, consequently to the lunarians who live on the side nearest us the earth is always visible, except when the moon is in opposition, but those who live on the opposite side of the moon and always stay at home, never see the earth at all, because that side is never turned towards us. A lunar astronomer who happens to live on the side directly opposite to us would have to travel a quarter of the circumference of his planet to see the earth at all, that is about 1500 miles; and if he would see our orb in its greatest magnificence, he must go 3000 miles, or to the middle of the part next to us, where indeed he would behold a spectacle which any terrestrial astronomer would be happy to enjoy at

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When is the earth visible to the lunarians who live on the side next us?
How far is it said a lunar astronomer would have to travel to see the earth?
How large is it said the earth appears to the lunarians?

such an expense, namely, a Moon always directly over his head, thirteen times as large as the full moon appears to us, and turning on its axis, so that he could examine every part of it in twenty-four hours.

PROOF THAT THE EARTH SHINES UPON THE MOON.

That the earth shines upon the Moon in the same manner that she does upon us, is not only inferred from the known fact, that all the planets reflect the light of the sun, but is proved directly by the appearance of the Moon herself. For, at new Moon, when only an illuminated crescent is to be seen, and when, therefore, nearly the whole surface, being turned towards us, cannot be enlightened by the sun, we still can discern an outline of the entire orb, faint indeed, but often quite obvious even to the naked eye. Especially when the moon is two or three days old, and the sky is clear, this appearance is common, and can only be attributed to the light which the earth reflects from the sun to the moon, by which her broad face is so enlightened as to be seen from the earth. This appearance has been called "the old moon in the new moon's arms."

THE EARTH.

The Earth on which we live is a globular or spherical planet, having the form of all the other bodies which re-

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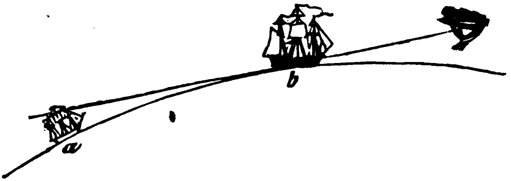
How is it proved that the earth throws light upon the moon?

volve about the sun. That this is the figure of the Earth, is proved by its shadow on the moon during eclipses; by the convexity or roundness of its surface, and by its having many times been circumnavigated.

The roundness of the Earth, including the sea, is shown by our seeing the masts and upper sails of a distant ship before the hull comes in sight. Every one who has been at sea, or who has stood on the shore and seen vessels at a distance, will remember this circumstance. Now were the ocean an exact plane, we should see the upper and lower parts of the vessel at the same time, provided they are of the same size; but instead of this, the hull is the last part of an approaching ship which comes in sight. To make this plain, we will suppose an eye placed, as in fig. 6, and that a ship is approaching the spectator from the ocean. At first he sees only the topsails, as shown by the straight line from the eye to the vessel *a*; but as she comes nearer, he will gradually dis-

Fig. 6.



What is the earth called in astronomy?
What is the figure of the earth?
How is it proved that the earth is globular?

cern more and more of her rigging, until she arrives at *b*, when the hull and whole ship will be visible. Now there is no reason except the Earth's convexity why the whole ship should not be seen at *a* as well as at *b*.

We know, for the same reason, that when a man is approaching us from the opposite side of a hill, that his head comes in view before his feet, and that in passing over a hill, we see the tops of the trees before we do the ground on which they stand.

MOTIONS OF THE EARTH.

The Earth, like the moon and the other planets, has two distinct motions; namely, one in her orbit around the sun, which is called her *annual* motion, and the other on her own axis, and called her *diurnal*, or daily motion.

The annual, or yearly revolution of the Earth, is completed in one year, or 365 days and about 5 hours, and her diurnal revolution in one day and night, or in precisely 24 hours.

The *orbit* of a planet is the line or path in which it revolves around the sun. Suppose S, fig. 7, to be the sun,

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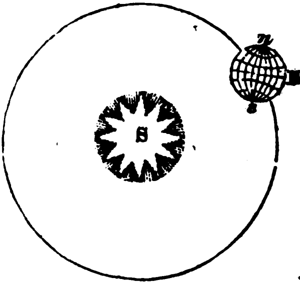
How many distinct motions has the earth?
What is meant by the annual revolution of the earth?
In what time does the earth perform her annual revolutions?
What is meant by the diurnal revolution?
What is the axis of the earth?
What is the orbit of a planet?

Fig. 7.



and E the Earth, then the circle in which the Earth moves around the sun to perform her annual revolutions, is the Earth's orbit.

The *axis* of the Earth, *n s*, as before explained, is a line drawn through her centre, from north to south, and around which she performs her daily revolutions. The axes of the planets, as well as their orbits are imaginary, that is, no such lines actually exist in nature,

VELOCITY OF THE EARTH.

The velocity of the Earth's motion along her orbit, is at the rate of 68,000 miles an hour, being about 1100 miles per minute. This is nearly a hundred times swifter than the motion of a cannon ball, and many hundred times faster than any bird can fly through the air. And yet all the houses, trees, men, and every other thing on this earth move around the sun at this amazing velocity, and have done so ever since the creation of living beings. Without the most positive proof, no one would believe, or in truth ought to believe, that this immense ball of Earth, containing so many millions of people, with their

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At what rate does the earth move in her orbit?

dwellings, towers and steeples, could be perpetually moving at this rate, without injury, and without our perception; but this motion being common to all things belonging to the Earth, and being perfectly uniform in its kind, their relative motions and situations are precisely the same that they would be if the whole only moved no faster than a sailing ship, or stood entirely still. Even in a mass no larger than a steam-boat, were there no noise or trembling, we should hardly be sensible of any motion, unless we noticed the land or some fixed object by which we passed.

Every one, on a little reflection, will be convinced that the Earth has another motion besides that of turning on her axis, which occasions the succession of day and night; for no one is so unobserving as not to notice the different positions of the sun, with respect to the Earth, in summer and winter. In summer, at noon, the sun's place in the heavens is almost vertical, or nearly over our heads; while in winter, at the same hour, he is seen far south, his rays falling upon us in an oblique, instead of a vertical direction. This difference may be well observed in a window facing the south. In summer the sun's rays are so nearly perpendicular with the Earth, as at noon to barely reach the floor of the room, or at most, if the win-

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Why are we insensible to the motions of the earth?
How is the annual motion of the earth proved by the positions of the sun with respect to the earth?
How does a south window show the difference between the height of the sun in summer and winter?

dow is high, to reach a foot or two from it; while in winter, from the same window, his rays extend at least half way across the room. This difference, as will be explained in another place, is caused by the different positions which the Earth takes with regard to the sun, during her annual revolution.

HOW THE EARTH'S VELOCITY IS KNOWN.

The method of ascertaining the rate at which the Earth moves is easily understood. In the first place, we know the distance of the sun from us, and consequently the diameter of the Earth's orbit; for it will be seen by fig. 7, that twice the distance of the sun must be this diameter. Having found the diameter, the circumference of the Earth's orbit is also known, and may readily be reduced to miles.

Now we know also that the Earth completes a revolution in her orbit in a year, or in 365 days and a few hours, therefore having found the number of miles over which she has travelled during a year, we may readily find her rate of motion, or how many miles she passes through in a day, an hour, or a minute.

Thus it is seen, that there is no more difficulty in ascertaining the rate at which the Earth moves, than there

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How do we know the diameter and circumference of the earth's orbit by knowing the sun's distance from us?
In what manner is the annual velocity of the earth ascertained?

is in finding how far a man goes in a minute, who rides 15 miles an hour.

While the Earth is performing one revolution around the sun, she makes 365 rotations on her axis, each of which forms a day and a night. This, as we have seen, is called her diurnal, or daily motion.

WHY THE SUN SEEMS TO MOVE FROM EAST TO WEST.

It is the revolution of the Earth from west to east that gives the Sun, stars and planets the appearance of moving around us, from east to west.

Before the science of astronomy was understood, it was believed that the Earth was the centre of the universe, and that all the heavenly bodies did in reality, as they appear to do, move around us once in every 24 hours. But astronomers have long since proved that this motion is only apparent and deceptive, and that the rising and setting of the Sun and stars is caused by the real motion of the earth from west to east, the Sun and stars never changing their places.

HOW WE KNOW THAT THE SUN STANDS STILL, WHILE THE EARTH REVOLVES.

To the inquiry how we " know that the Earth revolves, when our senses teach us that she stands still, while the

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How many diurnal revolutions does the earth make during one annual revolution?

Why do the sun and stars seem to move around us from east to west?

Sun and stars move around her;" we reply: *First*, that all the planets with which astronomers are acquainted revolve on their axes, and the Earth being a planet, there would be every reason to believe, without further inquiry, that she had a similar motion. *Second*, the revolution of each planet on its axis, gives the Sun and stars an apparent revolution around it, so that the inhabitants of each and all the other planets have the same reason to believe that their planet is the centre of the universe, as we have to think ours is so. *Third*, all astronomers of the present age agree, that the apparent motions of the celestial bodies can only be accounted for, by supposing that the Earth revolves on her axis once in 24 hours. *Fourth*, did the Sun make the circuit of our planet every 24 hours, as he seems to do, he would make the same revolution around all the other planets in the same time, so that the days and nights at all would be of the same length. But this is known not to be the case, since a day and night at Jupiter is only 10 hours long, that is, Jupiter turns on his axis once in 10 hours. *Fifth*, if the Sun makes the circuit of the heavens every 24 hours, as he appears to do, his distance being 95 millions of miles, he must move at the rate of nearly 400,000 miles in a minute, which is about 260,000 times as swift

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What is the first reason assigned for believing that the earth turns on her axis, and thus makes the apparent motion of the sun?
What is the second reason? What the third? What the fourth?
If the sun makes the circuit of the heavens in 24 hours, at what rate must he move?

as a cannon ball flies. But this motion, though a thousand times swifter than any body is known to move, is gradual and sluggish when compared with that of the stars, which, if the Earth stands still, must also pass around her in the same time with the Sun. Now the stars are calculated to be at least 400,000 times as far beyond the Sun, as the Sun is from us; if, therefore, they revolve around the earth, their velocities must be 400,000 times 400,000 miles in a minute, which is several millions of times swifter than any cannon ball ever flies, and which is indeed a degree of velocity of which no finite mind can have the least conception.

THE EARTH REVOLVES FROM WEST TO EAST.

Now all these difficulties, and even impossibilities, disappear at once, if we believe that the Earth has a daily revolution; and with respect to our senses, the appearance would be precisely the same that it now is. It is therefore the universal belief, of all who are capable of understanding this subject, that the apparent motion of the stars from east to west, and the rising and setting of the Sun, is caused by the real motion of the earth from west to east. This agrees perfectly with our experience, for every one knows that when he is moving rapidly in

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How much greater is this velocity than that of a cannon ball?
If the earth stands still, at what rate must the stars move?
With respect to our senses, what difference does it make whether the earth or sun revolves?

one direction, surrounding objects to be moving at the same rate in the opposite direction.

But let us examine this subject a little more at length, and see what difference it will make with respect to our senses, whether the earth rotates on her axis, or we stand still, and the sun revolves around us.

It is quite obvious that a spectator on any part of the Earth would be unconsciously carried around with it; and the reason why he would be insensible to the motion, is, that he has the same objects in view, and his vision is bounded by the same horizon. He will have the same landmarks before him, and individual objects will bear the same distances to each other, and himself, during the entire revolution. The perfect equality and smoothness of the motion, in which every thing he sees, like himself participates, conspire also to render the spectator unconscious of any motion.

We see therefore, that so far as terrestrial objects are concerned, there is not the most distant probability that we should be able to ascertain whether the Earth stood still, or whether she revolved on her axis, or whether the heavens revolved around us.

But when we examine celestial objects, we are certain, either that the Earth has a revolving motion, or that the heavens pass around us from east to west.

Why are we insensible to the motion of the Earth around its axis, by a view of terrestrial objects?

How do we become certain either that the earth or the heavens are in motion?

PHENOMENA OF CELESTIAL REVOLUTIONS.

Suppose the reader, says Sir John Herschel, to station himself on a clear evening, just after sunset, when the stars begin to appear, in some open situation, whence a good general view of the heavens can be obtained. He will then perceive, above, and around him, as it were, a vast concave hemispherical vault, beset with stars of various magnitudes, of which the brightest only will first catch his attention in the twilight; and more and more will appear as darkness increases, till the whole sky is overspangled with them. When he has a while admired the calm magnificence of this glorious spectacle, the theme of so much song, and of so much thought—a spectacle which no one can view without emotion, and without longing to know something of its nature and purport—let him fix his attention more particularly on a few of the most brilliant stars, such as he cannot fail to recognize again without mistake, after looking away from them for some time, and let him refer their apparent situations to some surrounding objects, as buildings, or trees, selecting purposely such as are in different quarters of the horizon. On comparing them *again* with their respective points of reference, after a moderate interval, as the night advances, he will find that they have changed their places, and advanced as by a general movement, in a westward direction; those towards the eastern quarter appearing to rise, or recede from the horizon, while those which lie towards the west will be seen to approach it; and if watched long enough, will, for the most part, finally sink beneath it, and disappear; while others, in the eastern quarter, will be seen to rise as if out of the earth, and joining in the general procession, will take their course with the rest towards the opposite quarter.

If the observer persists for a considerable time in watching their motions, on the same, or on different evenings, he will perceive that each star appears to describe, as far as its course lies above the horizon, a circle in the sky;—that the circles so described are not of the same magnitude for all the stars; that those described by different stars differ greatly in respect to the parts of them which lie above the horizon, some which lie towards the south, only remain for a short time above it, and disappear, after describing in sight only the small upper segment of their diurnal circle; others which rise between the south and east, describe larger segments of their circles above the horizon; remain proportionally longer in sight, and set precisely as far to the westward of south, as they rose to the eastward; while those which rise exactly in the east, remain just twelve hours visible, describe a semicircle, and set exactly in the west.

With those, again, which rise between the east and north, the same law obtains; at least as far as regards the time of their remaining above the horizon, and the proportion of the visible segment of their diurnal circles to their whole circumferences. Both go on increasing; they remain in view more than twelve hours, and their visible diurnal segments are more than semicircles. But the magnitudes of the circles themselves diminish, as we go from east towards the north; the greatest of all the circles the stars appear to make, being described by those rising due east.

Carrying his eye farther towards the north, the spectator will at length notice stars, which in their diurnal motion, just graze the horizon, at its north point, or only dip below it for a few moments; while others never reach the horizon at all, but continue always above it, revolving in entire circles round one point, called the *pole*, or *north polar star*, and which appears to be the common centre of motion, of all the stars in that direction, and which in the whole heavens, appears to the casual observer, to be the only immovable point.

But although the north star appears to be a fixed point in the heavens, yet on close examination, it is found to describe a small circle around an imaginary centre.

This star is mistaken by those who have not examined the subject, for the common centre about which revolves a constellation of stars called by astronomers the Great Bear, and by others the *northern winters*. But the imaginary point about which the polar star revolves is also the centre of the revolution of this constellation.

Does the north polar star have any motion of its own or not? Around what does this star revolve?

Any one may readily satisfy himself that the north star revolves, by fixing a tube in a position through which the star may be seen, and leaving it there for a short time, when on looking again, it will be found that the star has moved so as to be no longer visible through the tube.

It must not be understood from the above account of the polar star, that it has a real motion, any more than the other fixed stars, it being the revolution of our earth, which gives it this appearance, and the reason why it seems to revolve around so small a circuit, is owing to our northern position, and the vast distance of the star, in consequence of which, as we are carried round on the Earth, this star suffers little change of position with respect to us. Were the observer situated at the north pole, and did the axis of the earth's motion correspond with the polar star, the star would then cease to revolve, because the observer himself would cease to do so.

TO AN OBSERVER NORTH OR SOUTH OF THE EQUATOR, SOME STARS NEVER SET, WHILE OTHERS NEVER RISE.

We have seen that as we approach the north pole, some stars only just sink below the horizon, while others,

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How may one satisfy himself that the north polar star revolves?
Is the motion of the polar star real or only apparent?
Why does this star seem to circulate in so small a space?
Would this star have any motion to one at the north pole?

as the polar star and the constellation *Great Bear*, *never set*, but are always visible on every clear night.

Now to an observer thus situated, there is a corresponding portion of the southern hemisphere, where the stars, to him, *never rise*. To obtain a view of these stars, the spectator must change his position, and travel south, or towards the equator, which having passed, the southern pole will become visible, while the northern, will sink below his horizon. And here new constellations of stars, or such as he had never seen at the north, will rise to his view. Thus as he approaches the southern pole, these stars, which at his original station in the north, never set, now never rise, while those in the corresponding portion of the south, never set.

ALL PARTS OF THE HEAVENS VISIBLE AT THE EQUATOR.

If now the spectator returns back to the equator, which is equally distant from the two poles, he will find that all his old acquaintances among the constellations, both north and south will become visible. It makes no difference on what part of the equator the observer places himself; as the earth revolves, the same phenomena, the same stars will in succession pass in view before him.

Where must a person be situated to whose vision some stars never set, while others never rise?
Where are all parts of the heavens successively in view?
Will the phenomena of the heavens be the same in every part of the equator or not?

In this position the diurnal rotation of the heavens will appear to him to be performed about a horizontal axis, every star appearing to describe one half its revolution above, and one half below the horizon, being visible twelve hours, and invisible for the same period, owing to the superior light of the sun.

THE APPARENT REVOLUTION OF THE HEAVENS IS CAUSED BY THE DAILY ROTATION OF THE EARTH.

In addition to the reasons formerly stated, which make it nearly demonstrable that the revolving phenomena of the heavens, are caused by the diurnal rotation of the Earth, we shall only add, 1st, that the form of the Earth clearly proves such a motion. The Earth is not an exact ball, but is flattened at the poles, and protuberant at the equator, which is the very figure a ball of soft clay will take, if made to revolve rapidly on a spindle: and 2d, the simplicity and economy of this revolution, when compared with that of the sun and stars around the Earth.

We find every where that the designs of Deity are executed by the most simple, direct, and economical means, and since we see that all the phenomena of the heavens and Earth would be produced by the revolution of the

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How does the form of the Earth prove its daily revolutions?
What is said of simplicity and economy as proving that the Earth revolves?

latter, it is certain from all we have said that this is the case.

DAY AND NIGHT.

We have seen that the sun constantly shines on one half of the Earth, and that the earth revolves on her axis once in 24 hours. Every part of her surface, therefore, is successively coming into the light, or passing into darkness. This occasions alternate light and darkness, or *day* and *night*, in every part of the earth.

At certain seasons of the year the days are longer than the nights, and at others, the nights are longer than the days. This inequality between light and darkness is caused by the obliquity, or leaning of the earth's axis, with respect to the plane of her orbit.

Were the axis of the earth perpendicular to the plane of her orbit, the days and nights would be of equal length all over the earth, and at all seasons of the year.

To make this understood, suppose S, fig. 8, to be the sun, and E the Earth, standing with her poles or axis *n s* perpendicular to the line *h*, which we will consider a horizontal line; then, as the sun shines on one half of the earth from *n* to *s*, that is, from the north to the south pole, it is plain that if she revolves in this position, one

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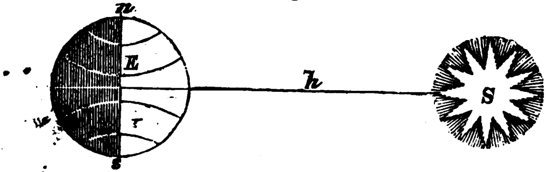
What is the cause of day and night?
Why are not the days and nights of equal length, at all seasons?
If the axis of the earth was perpendicular to the plane of her orbit, what consequence would follow with respect to the days and nights?

Fig. 8.



half of her surface would constantly be in the light and the other half in darkness, and thus that the days and nights would everywhere be equal at all seasons, each being twelve hours in length. A mere inspection of the figure shows that this would be the case.

Now instead of the position represented by fig. 8, the axis of the earth is inclined to her orbit in the manner seen by fig. 9, *n* being the north and *s* the south pole.

Fig. 9.

Consequently, as the Earth passes around the sun, she is at different seasons enlightened unequally; at one time the north pole and its vicinity being exposed for months to the solar rays, while the south pole is in darkness, as

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When the north pole is enlightened, is the south pole in darkness or in the light?

When the sun shines on the south pole, what is the state of the north pole with respect to the light?

seen by the figure; and at another time the south polar region being enlightened while the north is in darkness. It is this obliquity, as already stated, which causes the difference in the length of the days and nights, at the same place, in different seasons of the year. This will be understood by the diagram illustrating the changes of the seasons.

A DAY LOST OR GAINED IN PASSING AROUND THE EARTH.

Suppose a traveller or sailor to set out from any station, and constantly proceed westward until he makes the circuit of the globe, and returns again to the point whence he started, then he will have lost just one day in his reckoning of time. He will, for instance, enter the day of his arrival home, in his diary as Monday, when in fact it is Tuesday.

The reason of this will be obvious, after a little consideration; for days and nights are caused by the rotation of the earth on her axis, by which the sun and stars alternately appear and disappear. In the course of the year, the earth makes 365 diurnal revolutions, and hence at a fixed point on her surface, there are of course this number of days and nights.

But if the traveller passes once around the globe in the direction of its motion, he will have made one more

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How is it, that if a traveller proceeds westward until he performs the circuit of the earth, he will lose a day in his reckoning?

turn around its axis than the earth itself has made, and hence he will have *gained* a day as really as if the earth had made one additional turn around her centre.

On the contrary, if he travels to the east, or against the motion of the earth, he will have *gained* a day when he arrives to the same meridian from which he set out. In the former case, all his days will be longer than natural, because he goes forward with the earth's motion. If a boy runs after a passing waggon, though the carriage may go ten times as fast as he does, he will keep it in sight longer than if he stood still. And for the same reason, as the traveller proceeds west, he keeps the sun in sight longer than if he stood still, and thus lengthens the day.

On the other hand, it is plain that if the traveller goes towards the east, his days will be shorter than if he was stationary, for the sun will set earlier to him, in proportion to the length of his day's journey from the point where he sinks below the horizon.

These circumstances have actually happened to circumnavigators. Hence also, it must necessarily happen that distant settlements on the same meridian, will differ a day, in the usual reckoning of time, according as they have been colonized by settlers arriving from an eastern or western direction, a circumstance which may produce strange confusion into their calender, when they come to

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Explain the reason why a traveller would gain a day in passing around the earth towards the east.

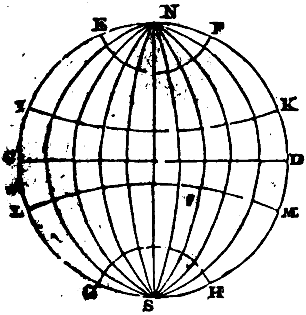
communicate with each other. The only mode of reconciling such a discrepancy, consists in having recourse to the equinoctial date, which can never be ambiguous.

DIVISIONS AND CIRCLES OF THE EARTH.

The pupil will do well to retain in his memory the following definitions of the circles and divisions of the Earth, as well as their directions.

The diameter of the Earth is 7924 miles, and is represented by the globe or sphere, fig. 10. Its figure, however, is not precisely that of a globe, being about thirty miles shorter through its axis, from pole to pole, than it is through the equator. The straight line through its centre, from N to S, is its axis, the extremities of which, N and S, are the north and south poles. The line C D, crossing the axis, is called the *equinoctial* line, or the *equator*, and divides the earth into two equal parts, called the *northern* and *southern hemispheres*.

Fig. 10.



The small circles, which include the two poles, and are marked E F and G H, are called the north and south *polar circles*, or the

What is the diameter of the earth?
How much does the earth differ from a true globe?
What is the axis of the earth? What are the poles?
What is the equinoctial line? What are the hemispheres?

arctic and *antarctic* circles. Between these there is, on each side of the equator, another circle, which marks the extent of the tropics on each side of that line. That to the north of the equator, marked I K, is called the *tropic of Cancer*, and that to the south, L M, the *tropic of Capricorn.* The lines crossing those already described, and meeting at the poles, are called *meridian*, or *mid-day* lines, for when the sun is on the meridian of any place, is the middle of the day at that place; and as these lines extend from north to south, the sun shines on their whole length at the same time, so that it is twelve o'clock at the same instant, through ths whole length of the same meridian.

The spaces on the Earth, between the lines passing around the earth from east to west, are called *zones.* That which lies between the tropics, from M to K and from I to L, is the *torrid zone*, being the hottest part of the earth. The portions which extend from the tropics, north and south, to the polar circles, are called the *temperate zones*, because the climate is temperate, and neither scorched with heat like the tropics, nor chilled with cold like the frigid zones. Those portions of the earth which are included within the polar circles, are called the

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What are the arctic and antarctic circles?
Where is the tropic of Cancer?
Where is the tropic of Capricorn?
What are meridian lines?
Where is the torrid zone?
Where are the temperate zones?
Why are they called temperate?

north and south *frigid* zones. These are the cold parts of the Earth.

These lines, it must be understood, are artificial, or imaginary, there being no such divisions marked by nature on the earth. They are, however, necessary in order to distinguish one part from another.

SEASONS OF THE YEAR.

In addition to the inclination of the Earth's axis, the vicissitudes of the seasons are caused by the revolution of the earth around the sun. These two causes operate jointly to produce the effect in question.

It is proper to explain here, that the orbit of the Earth is not a perfect circle as usually represented, but that it is an oval or ellipse, the place of the sun being towards one end; so that the earth, in her annual revolution, passes the sun at various distances during the different seasons of the year, being about three millions of miles nearer him in winter than in summer, as already stated.

This variation is, however, so small, when compared to the whole distance of the sun, as to make no perceptible difference with respect to his influence on the earth,

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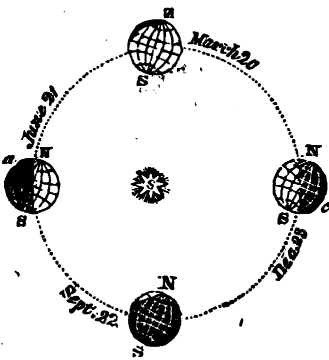
Where are the frigid zones?
Where are the coldest, and where the hottest parts of the earth?
Are these lines imaginary, or real?
What two causes produce the vicissitudes of the seasons?

Fig. 11.



and is not, therefore, estimated in explaining the causes of the seasons.

Fig. 11 exhibits the earth in four different parts of her orbit, representing the four seasons of the year, and showing also the inclination of the Earth's axis to the plane of her orbit, together with the parts of the earth on which the sun shines at the different seasons. On the 21st of June, the north pole, N, has the greatest apparent inclination towards the sun, and, as represented, the whole arctic or northern circle is illuminated. The real inclination of the axis is always the same in every position of the Earth; her apparent inclination in June being caused by her position with respect to the sun during our summer. At this season, the diurnal revolution of the Earth

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What is the form of the earth's orbit?
How much nearer is the earth to the sun at one season, than at another?
When is the earth nearest the sun?
Is this variation of the distance supposed to affect the heat of the earth, or not?
At what season of the year is the arctic circle illuminated?
Does the inclination of the earth's orbit vary during her annual revolution?
At what season is it constant day at the north pole?

causes no succession of day and night at the north pole, since the whole frigid zone is within the reach of the sun's rays.

The inhabitants who live within the arctic circle, therefore, enjoy perpetual day for the six summer months, since, during this period, the sun to them never sets. But for the same period, exactly the same proportion of the Earth that is enlightened in the northern hemisphere, is in total darkness in the opposite region of the southern hemisphere; so that while the people of the north enjoy constant day, those of the south are enveloped in total darkness, the sun never rising upon them for six months.

It will be seen by the figure that the line of darkness reaches as far beyond the south pole S, as that of light does beyond the north pole, N. In this position of the Earth, therefore, the line of light and shade crosses her in an oblique direction, producing summer in the northern and winter in the southern hemisphere.

As the Earth proceeds in her annual journey around the sun, the line which divides the darkness and the light gradually approaches both poles, until having performed one quarter of her journey from the point *a*, she comes to *b* about the 22d of September. At this time, the boundary of light and darkness passes through both poles, dividing the earth equally from east to west; and

While the people of the north are basking in constant day, what is the state of those at the south?

thus, as the sun always shines on one half of the earth, her daily revolution causes the nights and days everywhere to be of equal length, the sun being twelve hours above and twelve hours below the horizon.

During the progress of the Earth from *b* to *c*, the light of the sun gradually advances towards the south pole. The days, therefore, in the northern hemisphere, grow shorter at every diurnal revolution, until about the 23d of December, when the north pole and the whole arctic circle become involved in total darkness. And now the same regions which enjoyed constant day in the June before, are involved in a dreary night of the same length.

At this season, to those who live in the northern hemisphere, the winter nights are just as long as were the summer days, while the days are of the same length as were the summer nights.

When the Earth has performed another quarter of her annual journey, and has arrived at the point of her orbit opposite to where she was on the 23d of September, which happens about the 20th of March, the dividing line of light and darkness again passes through the poles, and again the length of the days and nights becomes equal in all parts of the world.

From this period, as the Earth advances, the northern

At what season with us, are the days and nights of equal length?
Why do our days grow shorter and our nights longer from September to December?
At what two seasons of the year are the days and nights of equal length in all parts of the earth?

hemisphere enjoys more and more light, while the southern polar regions gradually fall into darkness ; for it must not be forgotten that the sun never shines on more than one half of the globe at the same time ; consequently, as the light advances on one part, darkness follows on the other. From March to June, the days in the northern hemisphere are constantly increasing, and the nights diminishing in length, until the 21st of the last month, when the sun is the longest time above, and the shortest below the horizon, our days being of the length of December nights, and our nights of the length of December days.

Thus have we followed the Earth through one of her annual revolutions, and described the causes which make the vicissitudes of the seasons. And now can any person of the least reflection contemplate this subject without the conviction, that none but Almighty Power could have set this immense globe in motion ; and when in motion, can any one believe that the perfect order of its revolutions with respect to time, would go on from age to age without the perpetual superintendence of the same Power which created and threw it into open space. And since this whole arrangement has been constituted with express reference to the comfort and happiness of man, what reasonable being can withhold from this Almighty

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At what period, in the northern hemisphere, do the days increase and the nights diminish in length?

What is said of that Power which created and set our earth in motion?

Builder, his perpetual adoration and thanks, for the pleasure of living in a world so perfectly fitted to his temporal enjoyments; and especially for His gratuitous mercy, in having offered our whole race everlasting life, although we had fallen under the condemnation of his broken law?

It will be observed, that as the Earth moves round the sun, the inclination of the poles is alternately turned from and towards him. During our winter, as we live in the northern hemisphere, the north polar region is thrown beyond his rays, and at the same time a corresponding portion of the southern hemisphere enjoys his light, while during the summer this is reversed, as already explained. Thus in the north and south polar regions there is alternately six months of darkness and winter, and six months of light and summer.

At the equator, half way between the poles, these vicissitudes do not happen. On that part of the Earth the sun not only always shines, but there are two summers and no winter during the year, the days and nights being always equal, the sun being alternately twelve hours above, and twelve hours below the horizon. This ac-

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What do we owe Him who hath not only provided for us so many temporal enjoyments, but has also offered us the means of everlasting life?

During our winter, which pole of the earth is turned towards the sun?

In what parts of the earth, are there alternately six months of sunshine and summer, and six months of night and winter?

On what part of the earth are the days and nights equal?

counts for the reason why, in our climate, the heat of the summer is greater than it is towards the equator. In the northern temperate hemisphere, in which we live, the sun, during a part of the summer, shines fifteen hours on the earth and is absent only nine hours, while at the equator the days are never more than twelve hours long. Thus for more than two months, in the summer, we have the heating rays of the sun for nearly three hours per day longer than it shines at the equator. This is sufficient to account for the intense degrees of heat which we sometimes experience, so that strangers who come among us from equatorial regions are often oppressed by the excessive warmth of our summers.

HEAT AND COLD OF THE SEASONS.

From the difference we experience in the northern hemisphere, between the temperature of summer and winter, we should naturally be led to suppose that the Sun approached us during the former season, and withdrew himself during the latter. But, as we have already stated, the Earth is actually nearer the Sun in winter than in summer, by about three million of miles. This is only a little more than a thirtieth part of the Sun's distance from us, and therefore is not supposed to make

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How is the great heat of our summers to be accounted for, when compared with the heat of tropical climates?

What effect is the nearness of the sun in winter supposed to have on the earth?

any material difference in the effects of his heat upon the Earth. Perhaps the difference may in some degree soften the cold of a northern winter.

The difference of the temperature of the seasons does not, therefore, depend on the distance of the Sun, but on the direction in which his rays fall upon the Earth, together with the time of his continuance above the horizon.

In summer the sun is so high in the vault of the heavens, as at mid-day to throw his rays upon us in nearly a vertical direction, and at this season the disproportion between the length of the days and nights is so great, that the Earth does not part with all the heat during the night which she absorbs during the day, and hence the heat accumulates while these conditions continue. This accounts for the reason why the warmest part of summer is not at the time when the days are longest, which is about the middle of June, but some time after, as in July and August. In the winter, on the contrary, the Sun, instead of being nearly vertical at noon, only rises about half the distance between the horizon and the zenith, and hence his rays fall upon the Earth in an oblique direction, as we have before noticed, and being spread over a large surface, produce comparatively little warmth. The shortness of the days and the great length of the

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On what does the temperature of the seasons depend?
Why is not the heat of the season greatest when the sun is longest above the horizon?
Why does not the heat accumulate on the earth during the winter?

nights at this season, also prevent any accumulation of heat; that which came from the sun during the day being more than dissipated during the night. This accounts for the reason why the coldest season is not when the rays of the Sun are most oblique and the days the shortest, as about the middle of December, but sometime afterwards, for the Earth at this period constantly parts with more heat than she accumulates.

Any one may satisfy himself by a very simple experiment, of the difference between the heating powers of the direct and oblique rays of the sun. If one piece of board be placed so as to face the sun, and another piece so as to receive his rays in a slanting direction along its surface, it hardly need be said that the first will become the warmest in the same length of time.

Again, a small convex lens, or burning glass, will set wood on fire when the glass and wood are held parallel to each other, so that the figure of the focus is circular; but if the wood be placed so that the focus spreads along its surface, it is plain that no such effect will be produced.

In the application of such simple experiments to illustrate the heating effects of the Sun in summer and win-

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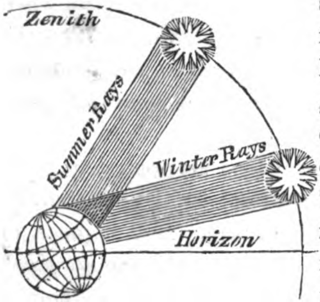
Why is not the coldest season when the rays are most oblique and the nights longest?
How may one satisfy himself of the difference between direct and oblique rays by two pieces of board?
How are the effects of the oblique direction of the rays illustrated by means of a burning glass?

ter, we have only to consider, that if a given number of rays would produce a certain degree of heat, then the same number of rays, if spread over twice the surface, would produce only half the effect. The diagram, fig. 12, shows this difference during the different seasons of the year. The number of rays coming from the Sun, in summer and winter, are supposed to be the same; but it will be observed that the winter rays, owing to the oblique direction in which they come, are spread over nearly twice as much surface as those of summer.

Fig. 12.



OF LATITUDE AND LONGITUDE.

Definitions. All circles surrounding the earth are divided into 360 equal parts called *degrees;* each degree is divided into 60 equal parts called *minutes*, and each minute into 60 parts called *seconds.* The signs by which these are indicated are 360° degrees, 60′ minutes, and 30″ seconds. These circles or lines, of course are imaginary, that is, they have no real existence, but were in-

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How are these simple truths applied in illustrating the effects of the summer and winter rays?
How are the circles of the earth divided?

vented for the purpose of conveying definite ideas of the distances of places from each other. Thus if we take a ball, as an artificial globe, and divide its circumference into 360 equal parts, and then with a pair of dividers measure off a certain number of these parts, we know, in a moment what proportion of the whole circle we have thus measured; and if we know the length of the circumference in miles, we know by the same means the distance of one place or point from another.

The *Latitude* of any place is its distance from the equator in degrees and minutes, either north or south.

Longitude is the distance, either east or west from any fixed station, or meridian.

Meridian lines are imaginary circles passing around the earth and meeting at the two poles, and thus dividing the earth from east to west. They cross the equator at right angles, and are the lines on which the degrees of latitude are marked. They are as numerous as the places through which they pass.

These lines as they apply to the earth, are called *terrestrial* meridians. When extended to the sphere of the heavens, they are called *celestial* meridians.

The *degrees* of latitude amount to 90 only, because

What is latitude?
What is longitude?
What are meridian lines?
How numerous are the meridian lines?
What are terrestrial, and what celestial meridians?
How many degrees of latitude and longitude are there?

they extend from the equator to the pole, either north or south, thus including one quarter of the great circle of 360 degrees.

The *degrees* of longitude amount to 180, since they extend from any meridian, either east or west, to the distance of one half the great circle of the earth.

HOW LATITUDE IS FOUND.

Latitude is reckoned from the equator, either north or south. When north of the equator, it is called *north* latitude; when south of the same circle, it is *south* latitude.

The principles on which latitude is determined, are easily understood, for if we can ascertain the distance where we stand from the equator, our latitude is found. Now the change which takes place in the apparent altitude or height of a celestial body, as a star, or the sun, either north or south of the equator, is equal to the variations of latitude.

The distance of a heavenly body from the equator, either north or south, is called its *declination.* When south of the equator it is called its south, or southern declination; when north, its northern declination. The amount of the sun's declination during the year, both

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Where do the degrees of latitude begin?
What is the altitude of a celestial body, either north or south of the equator, equal to?
What is the declination of a celestial body?

north and south, is about 23 degrees, that is, from one tropic to the other.

In finding latitude, the declination of the heavenly body is taken into account, as we shall see directly.

As the earth is a ball or globe, it is obvious that a heavenly body situated near the equator, will seem to rise or fall, as we approach or recede from it; and for the same reason, a body situated north or south of the poles of the earth, will appear to rise as we pass around the rotundity of the earth towards it, or sink, when we move in a contrary direction. Thus in our latitude, the north polar star never sets, that is, never to us falls below the horizon, because we are situated so far north that the daily revolutions of the earth do not hide it from us. Now as we approach the north pole, this star rises higher and higher, until having reached the pole itself, it will appear directly over our heads; and so on the contrary, if we travel south beyond the equator, this star will sink below our horizon, and not be seen at all.

The same happens with respect to the sun, for if we approach the north or south polar regions, he does not rise and set with the diurnal revolutions of the earth, but for months, is hid entirely from the observer.

Now it is by ascertaining the altitude of a heavenly body, by means of proper instruments, that the latitude

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Why does a heavenly body seem to rise or fall, as we approach or recede from it?
Why does the polar star never set in our latitude?

of any place is found, and this is done, sometimes by making observations on the sun, and sometimes on particular stars, the positions of which, with respect to the earth are known.

METHOD OF FINDING LATITUDE BY THE SUN.

Suppose we take the altitude of the sun, which is ascertained by means of an astronomical instrument called a *quadrant*, and find that at twelve o'clock, this is 40 degrees above the horizon, then as there are 90 degrees of latitude from the equator to the pole, if we subtract this from 90, we shall have 50, for our latitude.

If the sun is in the equinox, that is, directly over the equator, this is all that is necessary, but when this is not the case it is required that allowance be made for the sun's declination, either north or south.

Suppose therefore, that standing in latitude 50 degrees, we take another observation at a different season of the year, when the sun's northern declination is 10 degrees, then because he is 10 degrees north of the equator, his apparent altitude would be 60, instead of 50 degrees, and this therefore, (his declination,) must be subtracted from 60, which gives the latitude 50, as before. If on the contrary, the sun's declination

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What are the celestial objects by which latitude is found?
How is the altitude of the sun found?
Suppose the sun to be in the equinox, what is required to find the latitude of a place?

be south instead of north, and the observer be north of the equinoctial line, then the declination must be added to the sun's altitude. Thus, standing in latitude 50, and finding the sun's altitude to be 40, when his declination is 10 degrees south, we must add this to his apparent altitude, which brings the latitude 50 as before.

For common purposes this method is sufficiently accurate, and is that chiefly used for nautical purposes, but when much accuracy with respect to the latitude of a place is required, other methods are employed, and the altitude of a fixed star is found, instead of that of the sun.

SOLAR AND SIDERIAL TIME.

Before proceeding to point out the methods of finding longitude, it is necessary that the student in Astronomy should be informed that there is a difference between the length of a day, when measured by the revolution of a fixed star, and of the sun, and also, that he should understand the subject of Equation, or average time.

The length of a day and a night, or one diurnal revolution of the earth, when measured by a star, is 23 hours, 56 minutes and 4 seconds, while the sun appears to perform the same revolution in exactly 24 hours.

When the sun has a declination north or south, how is latitude found?

What is the length of a day when measured by a star?

A *tropical* or *solar* year, that is, a year measured by the sun, consists of 365 days, 5 hours, and nearly 49 minutes; while a year measured by any star, which is called a *siderial* year, has 365 days, 6 hours, and about 9 minutes.

No astronomical instruments are necessary to observe and establish these facts. The young student may satisfy himself that the siderial, is longer than the solar day, as well as the oldest astronomer. For this purpose, let the observer station himself on the north side of some vertical object, as a building, and placing his eye in a particular spot, observe the moment when a star, which he had previously selected, passes the angle of the building. A still more accurate method is to make a small hole through a plate of thin metal, as a piece of tin plate, and having nailed it to an immoveable support, notice the instant when a star disappears through the aperture, the eye being fixed at a particular spot.

By the same method, having the eye protected by a piece of smoked glass, the sun may be observed at any time in his passage through the heavens.

It makes no difference at what hour of the day or night these observations are made, since the object is to ascertain the exact time it takes the sun or a star, to make a complete diurnal revolution.

In what time does the sun appear to perform the same revolution?
What is a tropical or solar year?
What is the length of a siderial, and what of a tropical year?
By what may the moment of the passage of a star be ascertained?

The moment must be noted by a good time piece, when the celestial body passed the place of observation. This is one of the simplest and best methods of regulating the rate of a clock or watch.

EXPLANATION OF THE DIFFERENCE.

To explain the difference between a solar and siderial day, it must be considered that while the earth revolves on her axis, making day and night, she also advances in her orbit, in the performance of her annual revolution, and therefore, that at twelve o'clock yesterday, she was not in the precise position with respect to the sun, that she is at twelve o'clock to-day, or will be to-morrow.

But the fixed stars are at such immense distances from us, that the orbit of our earth, with respect to them, is merely a point, and therefore as the earth's annual period with respect to time, is perfectly uniform, she revolves from any given star to the same star again, in exactly the same period of absolute time.

But the sun, as seen from the earth, appears to arrive at the equator a little before it comes to the same star with which it coincided the year before, and thus it happens that there is a difference between a solar and siderial year.

Explain the difference between solar and siderial time, and the cause of this difference?

EQUATION OF TIME.

Were the orbit of the earth a perfect circle, to the plane of which her axis was perpendicular, the days and nights throughout the year would be of uniform length, in all parts of the earth, and the motion of the earth in every part of its orbit, would be equal. But the earth's orbit, instead of being a circle, is an elipse, or oval, so that she is sometimes nearer the sun, by several millions of miles, than at others. Hence the attraction of the sun is at one time increased, and at another diminished, and consequently the earth moves faster in one part of her orbit, than in another. Consequently, the solar time is unequal, a true time piece, and a sun dial, or noon mark, agreeing with each other only a few times in the year.

A chronometer or clock, which does not vary, when tested by a star, is said to keep *mean time*, or average time, and with respect to such an instrument, the sun is sometimes too fast, and sometimes too slow, the greatest difference between them during the year, being 16½ minutes, which happens about the first of November.

Suppose the earth's orbit a circle, how would the days and nights differ from what they now are?
Why does the earth move faster in some parts of her orbit than in others?
What effect does this unequal movement have on the apparent motion of the sun?

Apparent time is that which is indicated by the sun. Thus it may be twelve o'clock to-day by a meridian line, or noon mark, when by a clock which keeps true, or mean time, it may be ten minutes after, or before twelve. The difference between apparent, solar, and mean time, is called *Equation of time.*

PERIODS AT WHICH MEAN AND SOLAR TIME AGREE.

We have stated above, that the sun and a true clock coincide only a few times in the year. This agreement takes place on the 15th of April; the 1st of September; the 15th of June, and the 24th of December. On these days, and no other, is the sun exactly on the meridian of any place, when a true clock indicates the hour of twelve o'clock.

METHOD OF FINDING LONGITUDE.

Having made the above explanations with respect to time, it is hoped that the pupil is now prepared to understand in what manner the longitude of a place may be determined.

Although it is the daily revolution of the earth, from west to east, which gives the sun and stars an apparent

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What is apparent time?
When do the clock and sun agree?

motion from east to west, yet in the calculation of longitude, reference is only had to this apparent motion.

HOURLY MOTION OF THE SUN.

We have seen that all circles are divided into 360 equal parts, called degrees, and that the degrees of longitude are 180 east, and 180 west from any given meridian.

Now the sun, on each solar day, in passing from any meridian, to the same meridian again, may be said to describe 360 degrees of longitude, having passed the entire circle of the earth. As therefore, the sun occupies 24 hours in making this circuit, the whole number of degrees divided by the number of hours, will give the number of degrees which he passes in each and every hour, which is 15.

The meridian from which most astronomers reckon longitude, is that of the Royal Observatory, at Greenwich, near London.

Suppose then, the sun is on the meridian of Greenwich, or that it is twelve o'clock there, solar time, then since the sun travels at the rate of fifteen degrees per hour, it will be twelve o'clock fifteen degrees west of

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Is longitude calculated by the apparent, or real motion of the sun?
How many degrees of longitude are there?
How is it known at what rate the sun passes around the earth?
How many degrees of longitude does the sun pass per hour?
What is the meridian from which longitude is usually reckoned?

Greenwich, one hour after it was twelve at Greenwich. In two hours it will be twelve o'clock thirty degrees west of Greenwich, and in six, and twelve hours from the time when it was twelve at Greenwich, it will be twelve o'clock at places situated severally at ninety and 180 degrees west of the same place.

At Greenwich, of course, the corresponding hours will be one o'clock P. M., two o'clock, six o'clock, and twelve at midnight.

Now if at any place, we can ascertain precisely, at the hour of twelve at noon, what time it is at a given place at the east of us, we can find our longitude, for as the sun passes at the rate of fifteen degrees per hour, we have only to multiply the difference between the time of the two places by fifteen, to find the number of degrees of longitude between them.

CHRONOMETER.

The difference of time between two places, as the meridian of Greenwich, and the place of which the longitude is required, is ascertained by means of a time keeper, called a *Chronometer.* These instruments, in the form of a watch, are so nicely constructed and regulated, as not to vary more than a few seconds in a

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When it is twelve o'clock at Greenwich, what o'clock is it fifteen degrees west of that place?

By what instrument is the difference of time between two places found?

year, and are now in general use for the purpose in question.

Suppose then, that two chronometers, regulated so as to keep exact time, are set at twelve o'clock, by the meridian line of Greenwich, and that one of them remains there, while the other is taken to sea; and suppose the captain of the vessel, sailing towards the east, desires to ascertain his longitude, and finds by an observation on the sun, that it is twelve o'clock where he is, and that by his chronometer it is nine o'clock. Then because the time is earlier where he is, than at Greenwich, he knows that he is in east longitude, and because the difference between the time where he is, and that of Greenwich, is three hours, he knows his longitude is 45 degrees, that is, as the sun travels at the rate of fifteen degrees per hour, this multiplied by three, the difference of time between the two places is 45.

But suppose the captain with his chronometer on board, sails westward from Greenwich, towards America, and having been several days at sea, finds by the Greenwich time, that it is three o'clock, when it is twelve o'clock at the place of observation; then because it is noon at the place of observation, after it is noon at Greenwich, he knows his longitude to be west, and by multi-

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Suppose the captain finds by his chronometer that it is twelve o'clock where he is, before it is twelve at Greenwich, will he then be in east or west longitude?

Suppose the captain finds that it is three, Greenwich time, when it is twelve at the place of observation, what longitude will he be in?

plying the hourly motion of the sun, by the number of hours which his time differs from that of Greenwich, his longitude is found to be 45 degrees west.

There are other methods of finding longitude, but this is the most simple and easily understood.

ECLIPSES.

It has been shown that the sun constantly illuminates one half of the surface of the earth, moon and other planets, both night and day, and that night with us is caused merely by our passing into the earth's shadow, as she revolves on her axis. This shadow of the earth is projected into open space to a vast distance, in the contrary direction from the sun. The moon in like manner casts a shade into open space, but being much smaller than the earth, the length of her shadow is less in proportion.

Now when it so happens that the moon, in the course of her revolutions around the earth, falls into the shadow of the earth, the light of the sun is hidden from her, and she is said to be *eclipsed.* In other words, the earth passes between the sun and moon, intercepting the light from the latter. This can happen only when the moon is full and in opposition to the sun.

What is the cause of night on our planet?
What causes an eclipse of the moon?
In what position is the moon with respect to the sun when she is eclipsed?

On the contrary, when the earth falls into the shadow of the moon, that is, when the moon passes between the earth and sun, then an eclipse of the sun happens. This occurs only during the moon's change, and when the sun and moon are in conjunction.

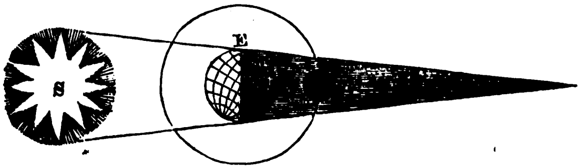
LUNAR ECLIPSE.

When the moon passes through only a part of the earth's shadow, so that a portion of her face still reflects the light, then there happens a *partial* lunar eclipse; but when the entire face of the moon is obscured, the eclipse is said to be *total*.

As the shadow of the earth is several times wider than the moon's diameter, lunar eclipses sometimes continue for several hours; and it is by estimating the moon's distance from the earth, together with the breadth of the earth's shadow at that distance, that astronomers are able to foretell the precise duration of an eclipse.

A total eclipse of the moon is represented by fig. 13,

Fig. 13.



What causes an eclipse of the sun?
When is an eclipse said to be partial?
When is an eclipse total?
How do astronomers foretell the duration of a lunar eclipse?

where it will be observed that she is entirely immersed in the earth's shadow, which is two or three times her diameter. This, therefore, represents a total eclipse.

A partial eclipse is only visible on certain parts of the earth, but a total one can be seen from the whole hemisphere at the same time, or from every part of the earth which is turned towards the moon.

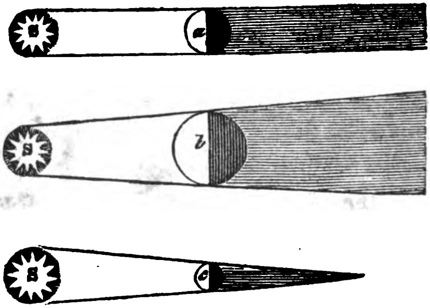
SOLAR ECLIPSE.

A *solar* eclipse happens whenever the moon passes between the earth and sun. Total eclipses of the sun are not of uncommon occurrence, but these are seldom seen as such from the earth, and never on any considerable proportion of her surface at the same time. The moon being a very diminutive body, when compared with the sun, never casts a dark shadow on the earth of more than 200 miles in diameter.

If the sun were of the same size with the moon, this shadow would be cylindrical, and being bounded on every side by parallel lines, would extend of the same size to an indefinite distance, as represented at *a*, fig. 14.

What is said of the extent to which a partial lunar eclipse is seen?
How extensive is a total lunar eclipse visible?
Are total solar eclipses common, or not?
Are such eclipses often visible from the earth, or not?
How wide a shadow does the moon ever cast upon the earth?
If the sun and moon were of the same size, what would be the form of the moon's shadow?

Fig. 14.



Were the moon larger than the sun, his rays would pass to it in a divergent state, and the shadow would increase indefinitely in diameter, as seen at *b*.

But since the moon is many thousand times smaller than the sun, the rays of light pass to it in a state of convergence, and the shadow constantly diminishes in size until it comes to a point, as shown at *c*.

This accounts for the reason why solar eclipses are seen on so small a part of the earth, the dark conical shadow being so diminished, when it reaches us, as to cover but comparatively a small extent.

The motion of the moon in her orbit, gives the shadow of the eclipse a corresponding motion across the earth,

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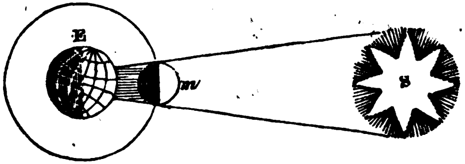
Were the moon larger than the sun, what then would be the form?
What is the real form of the moon's shadow?
How does this account for the small space in which a total eclipse of the sun is seen?

which is rapid in proportion to the nearness of the moon to the sun. Sometimes this motion is 2000 miles per hour.

When the entire face of the sun is obscured, the eclipse is total. In this case, the moon passes exactly over the face of the sun, so that their centres correspond. This phenomenon is highly interesting, not only because it is of rare occurrence, but because, although we know before what is to happen, still there is a thrilling sensation, perhaps of dread, in seeing the sun blotted out, and the darkness of night approaching us at noon day. Perhaps nothing which occurs on our earth excites so universal and intense an interest among every class of people, as a total eclipse of the sun.

A total eclipse of the sun is represented by fig. 15, by

Fig. 15.



which it will be observed how small a portion of the earth its shadow covers. To those who live within the range of this shadow across the earth, the darkness will be

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What is said of the motion of an eclipse across the earth?
What is said of the interest universally felt in a total eclipse of the sun?

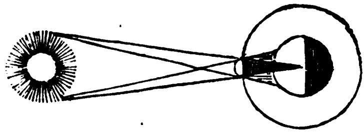
total, while to those who live without, or beyond the dark shadow, the obscurity will be only partial, and more or less so in proportion to the distance from the line of total darkness. This dark shadow is called the *umbra* of an eclipse.

PENUMBRA.

The *penumbra* of an eclipse is a faint shadow surrounding that of total darkness, and reaching to a great distance from it on all sides. This is occasioned by the crossing of the rays of light from opposite sides of the sun, being the effect of the great size of that luminary, when compared with the moon.

The penumbra, as distinguished from the umbra, is shown by fig. 16, the first being the light shade spreading wider as it approaches the earth, and in the midst of which is the umbra, or dark shadow, formed by the direct interposition of the moon, and diminishing in the direction in which the penumbra increases.

Fig. 16.



The penumbra sometimes covers a space of 3000 or 4000 miles on the earth, within the limits of which the

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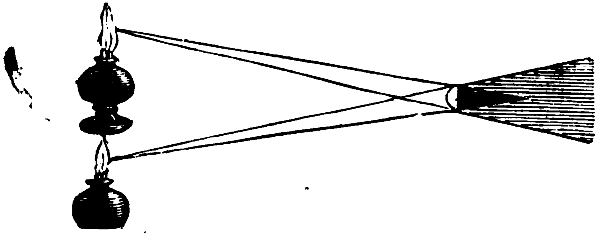
What is the umbra, and what the penumbra of an eclipse?
How large a space on the earth does the penumbra of a solar eclipse sometimes cover?

sun appears partially eclipsed. Hence a partial eclipse may be seen by the inhabitants of an entire hemisphere, while comparatively few will see it total.

The umbra and penumbra may be represented by placing two lighted candles at a little distance apart on a table, and holding any object, as a ball, ruler, or book, in

Fig. 17.



front, but so as to range between them, as represented by fig. 17. The shadow being received on a sheet of paper laid on the table, will show a dark conical umbra in the centre, with the lighter penumbra on each side of it.

ANNULAR ECLIPSE.

When the moon is at the greatest distance from the earth, and consequently nearest the sun, the umbra sometimes comes to a point in the air, and before it reaches the earth. In this case, an observer standing directly under the point of termination, will see the sun

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How may the umbra and penumbra be illustrated by fig. 17?
What is meant by an annular eclipse?

Fig. 18.

darkened, with the exception of a bright ring around the circumference of the moon, forming an uncommon and most striking spectacle. This is called an *annular* eclipse, from *annulus*, a ring, and is represented by fig. 18.

DIGITS.

For the purpose of description, the faces or diameters of the sun and moon, are divided into twelve equal parts, called *digits*, which mark the degrees of obscuration during eclipses. Thus when the moon covers one half of the sun's face, six digits of the sun's disk are said to be obscured.

Having thus given such an astronomical account of the moon and earth as the plan of this little book will allow, we will now proceed to describe the other bodies composing the solar system, together with the stars and comets.

SOLAR SYSTEM.

The solar system consists of the Sun, and all the planets, with their moons or satellites, which revolve around him, together with the comets which occasionally

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What is meant by digits of the heavenly bodies ?
What forms the solar system ?

make us a visit. The word *solar* comes from the Latin *sol*, which signifies the Sun. It is the system of the Sun.

The Sun is the centre of his own system, and around him all the planets perform unceasing revolutions, in the manner of the earth and moon already described.

The planets are distinguished into two kinds, called *primary* and *secondary*. The primary planets are all such as revolve immediately around the Sun, as the Earth and Venus. Secondary planets, or moons, are such as revolve around their primaries, as our moon.

The number of primary planets is eleven. Their names, beginning with that nearest the Sun, are Mercury, Venus, Earth, Mars, Saturn, Vesta, Juno, Ceres, Pallas, Jupiter and Herschel. The little planets, Vesta, Juno, Ceres and Pallas, are called *asteroids*, or star-like planets, on account of their diminutive sizes.

Mercury and Venus are called *interior* planets, because their orbits are within that of the earth, or nearest the Sun. The other planets are called *exterior*, their orbits being without, or beyond that of the Earth.

What does solar mean?
What is the centre of the solar system?
How are the planets distinguished into kinds?
What are the names of the primary planets, and what is their number?
Which is nearest, and which at the greatest distance from the sun?
What planets are called asteroids?
Which are the interior planets?
Why are they called interior?
Why are the others called exterior?

Five of the primaries may at different times be seen with the naked eye. These are Mercury, Venus, Mars, Jupiter and Saturn. All the satellites, with the exception of our moon, are invisible to the naked eye, and require the use of the telescope to be seen.

The satellites are 18 in number, of which our Earth has one, Jupiter four, Saturn seven, and Herschel six.

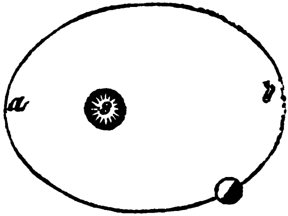
All the planets move around the Sun from west to east, and in the same direction do their satellites revolve about their primaries, with the exception of those of Herschel, which appear to revolve in a contrary direction.

The periods in which all the planets complete their annual revolutions have been ascertained to minutes and seconds; but as their diurnal revolutions can only be known by the spots on their surfaces, the times of these revolutions have been ascertained only in part. It is not even known that all the planets have diurnal rotations, though in every instance this has been found to be the case where spots on their surfaces can be seen. It is therefore inferred from analogy, that every planet, both primary and secondary, have daily as well as yearly revolutions.

Which of the planets may be seen with the naked eye?
What satellites are visible to the naked eye?
What is the whole number of satellites?
In what direction do the planets and satellites move?
Are the annual periodic times of all the planets known?
What is said of our knowledge of the diurnal motions of the planets?
What reason is there to believe that all the planets have daily motions?

The orbits of all the planets, as formerly noticed, are not perfect circles, but ovals, or ellipses, and therefore these bodies, as they pass around the sun, are at one time nearer him than at another. Fig. 19 represents such an orbit. When the planet is in that part nearest the sun, as at *a*, it is said to be in its *perihelion*, and when most distant from the sun, at *b*, it is said to be in its *aphelion*.

Fig. 19.



THE SUN.

There is no other source of heat and light belonging to the solar system but the Sun. His rays, therefore, warm and enlighten all the planets and their satellites which revolve around him. The light of the Sun on the earth has been calculated to be equal to that of 6500 candles, at the distance of one foot.

The distance of the Sun from the earth is ninety-five millions of miles. His diameter is 880,000 miles, being, so far as we know, the largest mass in the universe. His globe would nearly twice include the whole orbit of the moon.

When is a planet in its aphelion, and when in its perihelion?
Whence do all the planets derive their light and heat?
What is the distance of the sun from the earth?
What is the diameter of the sun?

Our earth, being 8000 miles in diameter, we should consider this a ball of vast magnitude; but when we come to compare it with the Sun, it dwindles to a mere foot-ball, for the Sun, in his dimensions, is *thirteen hundred thousand* times as large as the earth; that is, were the Sun composed of the same kind of matter, it would take thirteen hundred thousand such earths as ours to balance him in the scale. We shall see, however, that the sun is lighter, bulk for bulk, than the earth.

"If," says Dr. Dick, "it would require 18,000 years to traverse every square mile on the earth's surface, at the rate of thirty miles a day, it would take more than *two thousand millions of years* to pass over every part of the sun's surface at the same rate."

"Of a body so vast in dimensions," he continues, "the human mind with all its efforts, can form no adequate conception. It appears an extensive universe in itself; and although no other body existed within the range of infinite space, this globe alone would afford a powerful demonstration of the omnipotence of the Creator."

SPOTS ON THE SUN.

The Sun, although it does not circulate in an orbit, like the planets, is not, however, without motion, having

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How many miles in diameter is the earth?
How much larger is the sun than the earth?
If it would require 18,000 years to traverse every part of the earth's surface, how long would it take to do the same with respect to the sun?

a revolution on its own axis once in 25 days and 10 hours. This has been ascertained by the spots on his surface. These spots differ at different times, both in number and shape, and also in magnitude. Sometimes, or in some years, not a spot is visible on his disk, while at another time forty or fifty may be counted. These appear of all dimensions, from mere specks to several times the size of the earth, or even much larger.

The astronomer Mayer saw a spot on the sun, which was 45,000 miles long, and if the calculations of some other astronomers are true, much larger ones than this have been observed.

Sometimes these black spots break in pieces, or divide into several parts in a manner so rapid as to induce the belief that they consist of nothing more than clouds, floating in the sun's atmosphere.

In some cases they disappear entirely, while others appear in places where none existed before, and all this often takes place in the course of a few hours.

In the vicinity of large spots, or extensive groups of them, large spaces of the sun's surface may often be observed through the telescope, to be covered with strongly marked, luminous and dark streaks, and among these,

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What motion has the sun ?
How is it known that the sun is in motion ?
Are the spots on the sun always the same, or not ?
What is said of the size of the spots on the sun, and of their permanency ?

black spots may be seen suddenly to appear, and then as quickly to vanish.

WHAT ARE THESE SPOTS ?

Many theories have been proposed, to account for these dark spots. Some have supposed that they consisted merely of dense clouds floating over the sun's surface, while others believe that they are the dark, solid body of the sun, exposed to our view, by those immense fluctuations in the luminous regions of its atmosphere, to which it appears to be subject.

Respecting the manner in which the luminous matter surrounding the sun divides, to discover to us his dark body, various conjectures have been offered. Lalande suggests that these spots are mountains on the sun's body, which are laid bare by the fluctuations of the luminous ocean by which it is surrounded.

Sir W. Herschel considers the luminous strata of the sun's atmosphere to be sustained far above the level of his solid body by a transparent medium, or atmosphere, which is elastic, and which carries on its upper surface a cloudy stratum, which being illuminated from above, reflects light to our eyes, and forms a penumbra, while the solid body, shaded by the clouds, reflects none.

How is it believed these spots are made ?

INFLUENCE OF THE SUN ON THE EARTH.

The sun's rays are the ultimate source of almost every motion which takes place on the surface of the earth. By its heat are produced all winds, and those disturbances in the electric equilibrium of the atmosphere, which give rise to the phenomena of terrestrial magnetism. By their vivifying action, vegetables are elaborated from inorganic matter, and become, in their turn, the support of animals, and of man. By his rays the waters of the sea are taken up, and made to circulate in vapor through the air, whence they fall in the form of rain, to irrigate the earth. By them are produced the chemical decompositions, which then, by the same power give rise to new products.

HOW ARE THE HEAT AND LIGHT OF THE SUN SUPPORTED?

But to us, the greatest mystery about the sun, is how such degrees of heat and light are perpetually maintained for thousands of years, without diminution or variation.

If it be a conflagration, and consequent consumption of combustible matter, our finite conceptions cannot even approximate an estimation of the quantity con-

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What is said of the influence of the sun's rays on the earth?

sumed for a single day, or even hour, when we consider the intensity of light and heat which comes to us at the distance of 95,000,000 of miles. At the distance of Herschel, which is more than 1800 millions of miles from the sun, his light is still sufficient to be reflected back to our earth, from that planet, and his heat undoubtedly sufficient for the comfort of animal life.

It is most probable, however, that the light and heat of the Sun is not caused by conflagration, but by some chemical, or electrical action, by which an infinite generation of heat is produced. Possibly continual currents of electric matter may be in circulation in the vicinity of the sun's body. Herschel, the elder, insisted on the probable analogy between the light of the sun and that of the aurora borealis. Still it must be confessed that we know nothing with certainty on this subject.

MATTER OF THE SUN.

With respect to the kind of matter of which the Sun is composed, we must, it is obvious, be entirely ignorant, nor are there grounds even for a reasonable conjecture on this subject. Perhaps it may be composed in part of the same kind of ingredients as our globe, as rocks, metals, salt and earth; but for aught we know, it may

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What are the conjectures with respect to the cause of the heat and light of the sun?
What is said of the kind of matter which composes the sun?

be composed of substances of which we have no conception.

The quantity of solid matter which the Sun contains, in comparison to that of the earth, is nearly in the proportion of 355,000 to 1. It is, therefore, lighter, or less dense than the earth or even than water ; for had it the density of the earth, their weights would be in the proportion of their magnitudes, which we have seen is as 1,300,000 to 1. The Sun, however, contains a quantity of matter about 500 times greater than all the planets and their satellites put together. Its attraction is equal to 355,000 of our earths.

Dr. Herschel, the celebrated English astronomer, made a great number of observations on the sun, with the most powerful telescope ever constructed. From these observations he was led to believe that the Sun might be a solid, and opake body, like the earth, but surrounded with luminous or fiery clouds at the distance of many hundred miles from its surface. These clouds he supposed to emit the light and heat by which the whole solar system is illuminated and warmed. Hence the body of the Sun, instead of being a vast ball of fire as he appears to us, may be a habitable globe, and may contain myriads of intelligent, and responsible beings, whose powers of body and mind are in proportion to the magnitude of the globe they inhabit.

What is Dr. Herschel's conjecture with respect to the sun's heat? Is it certain that the sun is not a habitable globe?

MERCURY.

Mercury is the nearest planet to the sun, being distant from him, only 37 millions of miles. The annual period of this planet is about 87 of our days, and his diurnal revolution occupies 24 hours. His hourly motion is nearly 100,000 miles. Diameter about 3000 miles.

The heat of the Sun at Mercury is seven times greater than at the earth, so that, were our globe placed in the same position, all the water on the surface, even the sea itself, would soon begin to boil and be converted into steam. Not only this effect would be produced, but if we suppose the heat at Mercury to be seven times greater than the hottest parts of our earth in the summer season, some of our metals, as tin, lead, zinc and bismuth would be constantly in the state of fluids, or in perpetual fusion; while all our wood, whether in the form of trees or houses, would soon be burned to ashes and every animal would perish; for all these consequences would be produced in a temperature equal to 700 degrees of heat by the common thermometer. All this shows, not only that our earth was not intended to occupy the place of Mercury, but also proves intelligence and design in the adaptation of the beings, both animate and inanimate, belonging to

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What is the situation of Mercury with respect to the sun?
What is his distance from the sun?
What are the periods of his annual and diurnal revolutions?
How many times greater is the heat at Mercury than at the earth?
What would be the consequences, were the earth to take the place of Mercury?

each planet to its situation with respect to the Sun; for had the arrangement of the universe been a work of chance, as some have pretended to believe, no reason can be given why the earth should not have happened to occupy the place of Mercury, instead of its present situation.

Notwithstanding the great heat of Mercury, there is reason to believe it is occupied with living, and probably intelligent beings, nor need this idea excite surprise, since no more wisdom or power is required in the Creator, to adapt animals to such a climate as that of Mercury, than to the earth which we inhabit.

Mercury, when examined through the telescope, exhibits the different changes, or phases, which our moon undergoes.

This planet may sometimes be seen with the naked eye, beforet he rising and after the setting sun.

VENUS.

Next to Mercury comes Venus, that bright and beautiful planet, which every child knows under the name of the *evening star.*

What is said of design in the situation of the planets with respect to the sun?
Had chance directed the situation of the planets, why did not the Earth occupy the place of Mercury?
What is said of the Wisdom and Power required to adapt animals to the climate of Mercury?
Is this planet ever seen with the naked eye?
What planet comes next to Mercury?

This planet performs her revolutions around the sun in 224 days, at the distance of 68 millions of miles from him. Her daily rotation is completed in 23 hours, so that a day at Venus is nearly of the same length as ours. Her hourly motion in her orbit is about 80,000 miles. The diameter of this planet is 7624 miles, being somewhat less than the earth.

The orbit of Venus is exceedingly elliptical, so that her distance from the sun is at one time more than six times greater than at another. When nearest us, her distance from the earth is only 27 millions of miles, and when most remote, 168 millions of miles. When nearest the earth, only part of her illuminated face is turned towards us. Did she appear full at such times, she would exhibit about twenty-five times more light than she now does, and have the appearance of an exceedingly brilliant little moon; but when nearest, her dark side is chiefly towards us, so that she is hardly visible at all. When brightest, only one fourth of her disk is visible, though to the naked eye she appears full.

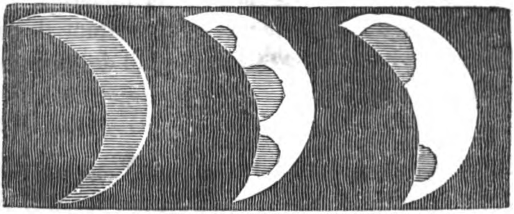
Venus, when examined through a telescope, is found to

What periods do the annual and diurnal revolutions of Venus occupy?
What is the size of Venus?
What is said of Venus's orbit?
How near the earth is Venus at one time, and how distant at another?
Do we ever see the fully illuminated face of Venus?
If her full face was towards us when nearest, how much more light would she give us than she now does?

undergo all the changes or phases of our moon; sometimes being crescent-shaped, or horned, and sometimes gibbous, as represented by fig. 20.

Sometimes dark spots are seen on her surface, of various shapes and extent, the nature, or occasion of which, is not known.

Fig. 20.



The exceeding brightness of Venus is supposed to arise from her dense atmosphere in consequence of which, she reflects a large quantity of the sun's light. The atmosphere of the moon, (if she has any,) is on the contrary very rare, which accounts for the little light she sends us.

The most distinct and beautiful views of Venus, are said to be obtained in the day-time, by means of a telescope prepared for the purpose.

The mountains of Venus, according to the calculations of some astronomers, are of great height, some of

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What is said of the phases of Venus?
What is the cause of Venus's brightness?
What is said of the mountains in Venus?

them being ten or twelve, and one, even twenty miles high.

This planet sometimes passes across the sun's disk in the same manner that the moon does to form a solar eclipse. But being so distant from us, and so near the sun, this *transit* of Venus, as it is termed, appears at the earth only in the form of a dark round spot, slowly passing through the blaze of that great luminary.

The earth is the next planet in order from the sun; but of this we have already given a full description, as also of the moon.

MARS.

Next to the earth comes Mars. This, with the others to be described, are called *exterior* planets, because their orbits are exterior to, or on the outside of the earth's orbit.

Mars completes his annual revolution in one year and ten months, or, in 867 of our days, at the distance of 145 millions of miles from the sun. His diameter is about 4,200 miles, and his hourly motion in his orbit 45,000 miles.

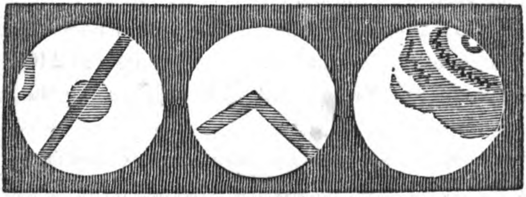
The daily rotation of this planet is completed in 24 hours and 40 minutes.

What is meant by the transit of Venus?
What planet is situated between Mars and Venus?
What is the period of Mars' annual revolution?
What is the diameter of this planet?
What is the hourly motion of Mars?
How long is a day at Mars?

Although the average distance of Mars from the sun is as above stated, still the form of his orbit is so eccentric as to make a vast difference in his distance in the course of his yearly revolution. At his nearest approach to the earth, his distance is only 50 millions of miles, while another portion of his orbit is so remote, as to carry him 240 millions of miles from us, making a difference of 190 millions of miles in his distance from the earth during his yearly revolution. Hence Mars appears to us many times larger at one period, than at another; sometimes being a brilliant star to the naked eye, and then again hardly to be distinguished without a good telescope.

The telescopic face of Mars appears curiously spotted, or sometimes striped, or clouded, these appearances being liable to change both in shape and color, so as at different times to present a great variety of aspects, some of which are represented by fig. 21.

Fig. 21.



What is the distance of Mars when nearest the earth?
What is his distauce when most remote from the earth?
What appearance in Mars does this difference account for?

The cause of these phenomena are supposed to be clouds, or mists, floating in the dense atmosphere of the planet.

The heat and light at Mars are less than one half of that which the earth enjoys.

To the inhabitants of this planet, our earth appears alternately, the morning and evening star, as Venus does to us.

The next four planets in order, are called *Asteroids*, or sometimes *new planets*, because they have been lately discovered. They are the smallest revolving bodies belonging to the solar system, and are situated between Mars and Jupiter. Their names are *Vesta*, *Juno*, *Pallas* and *Ceres*.

VESTA.

This planet was discovered in 1810, by Dr. Olbers, of Bremen. It appears like a small star, and sometimes may be seen with the naked eye. Its distance from the sun is 225 millions of miles, and around which she performs her annual revolution once in 3 years and 240 days. The diameter of Vesta is only 269 miles, being the most

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How is the spotted appearance of this planet accounted for ?
What proportion of light is there at Mars ?
How does the earth appear at Mars ?
What are the next four planets called ?
What are their names ?
How far is Vesta from the sun ?
What is the period of her revolution ?

diminutive celestial body known. From her intense white light, it is supposed that Vesta has a very dense atmosphere.

JUNO.

Juno was discovered by Mr. Harding of Bremen in 1804. Its mean distance from the sun is 254 millions of miles, and the period of its annual revolution 4 years and 130 days. Its diameter 1393 miles, and it is distinguished by the eccentricity of its orbit, in consequence of which its least distance from the sun is 189 millions of miles, while its greatest distance is 316 millions of miles.

PALLAS.

This asteroid was discovered in 1802 by Dr. Olbers. Its distance from the sun is 264 millions of miles, and around which she performs her revolution in 4 years and 7 months. Her diameter is 2000 miles, and it appears to have an atmosphere about 400 miles high.

CERES.

Ceres was discovered in 1801, by M. Piazzi, of Palermo, in Sicily. This planet cannot be seen by the naked

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What is the distance of Juno from the sun, and what the period of her revolution?

What are the diameters of these two planets?

What is the distance of Pallas from the sun, and what the period of its revolution?

eye, but through the telescope, appears like a small star of a reddish color. Its revolution is performed in 4 years and 7 months, at the distance of 263 millions of miles from the sun. Its diameter is 1582 miles, and it appears to be surrounded by a dense atmosphere.

The daily revolutions of the asteroids are not known, their immense distances, and small dimensions, preventing the discovery of any spots on their surfaces.

The hourly motions of these little planets are each about forty thousand miles.

From various circumstances, which astronomers have discovered with respect to these planets, it was imagined that they are the fragments of a large celestial body which once revolved between Mars and Jupiter, and which had been burst asunder by some tremendous force. It is true, that no proof of this theory can be given, but several able philosophers have agreed that such a supposition will satisfactorily account for many unusual phenomena which these little planets present.

JUPITER.

The mean distance of Jupiter from the sun is 495 millions of miles, being 400 millions of miles, or more

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What is the periodic time of Ceres?
What is the diameter of Ceres?
What is said of the daily revolutions of the asteroids?
What is the hourly motion of the asteroids?
What is said of the origin of the asteroids?
What is the mean distance of Jupiter from the sun?

than five times more remote from the source of heat and light than the earth.

At this distance, he performs his annual revolutions, in a little less than twelve of our years, moving in his orbit at the rate of nearly thirty thousand miles per hour.

Jupiter is the largest planet in our system, being eighty-six thousand miles in diameter, which is fourteen hundred times the magnitude of the earth.

His diurnal revolution is completed in nine hours and fifty-six minutes, which gives a velocity to the surface of his equator of twenty-eight thousand miles in an hour. This is about twenty-seven times more rapid than the motion of our equator. Did the earth revolve with such velocity, all the houses, rocks and trees, together with every inhabitant existing between the tropics, would leave the surface of the earth, and even portions of the earth itself, would be thrown off in straight lines, in the same manner, and for the same reason, that water flies away from a rapidly whirling grindstone. At Jupiter, therefore, there must be some law of nature of which we have no experience here. We may however suppose, that as all bodies attract each other in proportion to the quanti-

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What is the annual period of Jupiter?
What is the rate of motion through his orbit?
What is the diameter of this planet?
How much larger is Jupiter than the earth?
How long is a day at Jupiter?
What would be the consequence, if our earth revolved with the rapidity of Jupiter?

ties of matter they contain, and as the weight of the same body would be increased, or diminished, if transported to a larger or smaller planet, therefore the immense magnitude of Jupiter, so increases the weight of things on his surface, as to prevent their being thrown off by the rate of motion that would produce such an effect on the earth.

The figure of Jupiter is like that of the earth, being about 6000 miles shorter in the direction of the poles, than through the equator.

This planet, next to Venus, is the most brilliant primary in the solar system. This is probably owing to his vast size, for the light and heat he receives is nearly twenty-five times less than that of the earth.

Were our earth transported to the region of Jupiter, the cold which Capt. Parry experienced in the north polar regions, would be scorching oven-heat, when compared with that which reigns at such a distance from the sun. Our sea would there soon become a solid mass of ice, and it is not improbable that our atmosphere itself would assume the solid form, so that every living creature would perish, and each, retaining its figure, would be-

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On what principle is it possible that the velocity of Jupiter may not produce the effects which such a motion of the earth would do ?
What is the figure of Jupiter ?
What is said of the brilliancy of this planet ?
What proportion of light and heat does this planet receive ?
What is it supposed would be the consequence were the earth transported to Jupiter ?

come fixed and impenetrable like statues of marble. Thus instead of life and activity, all things would be motionless, and universal silence and death would prevail. Still it is most probable that this planet contains millions of living beings, fitted, like ourselves, for the climate and stations they occupy.

Fig. 22.

Jupiter is distinguished by dark colored stripes, or bands, called *belts*, which extend across his disk. These are quite irregular in number and appearance. Sometimes their edges are defined as represented by fig. 22, but at others, they appear more like clouds, their edges terminating in a manner, gradual and undefined. In some instances only a single belt is seen, while at others, their number is six or eight. Even during the time of an observation, several of them have been known to change their forms, or to vanish entirely. Sometimes their number and aspect remain the same for months, and then again new belts will form in an hour or two.

Of the nature of such phenomena, nothing certain, of course, can be known to us. It is most probable, however, that they are occasioned by clouds, or mists floating in the atmosphere of the planet, and perhaps are under

What distinguishes Jupiter?
Are these belts permanent in form and number, or not?
What is said concerning the nature of these belts?

the regulation of some law of nature of which we are entirely ignorant.

Jupiter has four moons which revolve around him in the same manner that our moon does around the earth. These complete their revolutions in various periods, the shortest being less than two, and the longest in seventeen days.

The nearest moon to the planet is two hundred and thirty thousand miles distant from his centre. This performs a journey around him in forty-two hours and a half, and appears to the people about four times as large as our moon does to us. To the people of this moon, Jupiter appears at least, a thousand times as large as our moon does to us, and goes through all the changes which our moon does, from the crescent to the full moon, every forty-two hours. What a grand and imposing spectacle these phases would present to a terrestrial astronomer!

ECLIPSES OF JUPITER'S SATELLITES.

Each of Jupiter's satellites, like our moon, is liable to be eclipsed by passing through the shadow of their primary.

Knowing the situation of Jupiter with respect to the Sun, which gives the direction of its shadow, and also

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How many moons has Jupiter?
In what periods of time do Jupiter's moons complete their revolutions?
What is the distance of Jupiter's nearest moon from him?
What is the appearance of Jupiter from this moon?

knowing the movements of the satellite, we may readily calculate the eclipse of that satellite.

Tables of all the eclipses of these satellites, are published every year, for the use of astronomers and navigators.

These eclipses are of great value in determining the longitudes of places, as we shall explain hereafter. The grand discovery of the rate at which light travels, was also made by means of the eclipses of Jupiter's moons.

In making observations on the fixed stars, Dr. Bradley found that light does not pass instantaneously from one place to another, but progressively, though with the immense velocity of 200,000 miles in a second of time. This was determined by observing, that when the earth was between the Sun and Jupiter, in which case the earth is nearest Jupiter, that the eclipses of his satellites appear to take place *sooner* by about eight minutes and a quarter, than they should appear according to the calculations as stated in the tables; whereas, when the earth is at the greatest distance from Jupiter, or the planet is beyond the Sun, then the eclipses of the satellites appear to take place about eight minutes and a quarter *later* than they ought to appear by the same calculations.

Now as the difference between the two distances of Jupiter from the earth, in the situations in which the

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What circumstances must be known to calculate the eclipses of Jupiter's satellites?
What is the velocity of light?

above observations were made, is equal to the diameter of the earth's orbit, which is twice the distance of the Sun from us, or 190,000,000 of miles, that of the Sun being 95,000,000 of miles; therefore, light passes across the diameter of the earth's orbit in sixteen minutes and a half, which is nearly 200,000 miles in a second.

SATURN.

The orbit of Saturn is next exterior to that of Jupiter. The distance of this planet from the Sun is 908,000,000 of miles, and his annual revolutions are performed once in about thirty years. The diameter of Saturn is eighty-two thousand miles, his bulk being nearly equal to one thousand of the earth on which we live. But notwithstanding his immense size, this planet turns on his axis once in ten hours, making 25,000 diurnal revolutions during one annual revolution, or 25,000 days in a year.

The shape of this planet, like all the other celestial bodies, is not an exact sphere, being flattened, so that the polar is about 6000 miles less than the equatorial diameter.

On account of his remoteness from the Sun, Saturn receives only one ninetieth part of the heat and light,

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How has the velocity of light been determined?
What is the distance of Saturn from the sun?
What is the diameter of Saturn?
How much larger is Saturn than the earth?
What is his annual period?
How many days compose Saturn's year?

which falls upon the earth. But the wisdom and benevolence of the almighty Architect of the universe, who is ever careful of the comfort and happiness of his creatures, has supplied Saturn with seven moons, which circulate around him at various periods from one to eighty days; and besides these, this planet has an immense appendage called Saturn's Ring, which, as well as the moons, reflects the sun's light, and possibly also some degree of heat upon his surface. The quantity of light which Saturn receives, is therefore undoubtedly sufficient for all useful purposes, both by day and night.

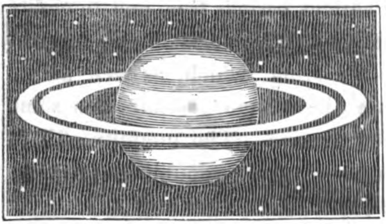
SATURN'S RING.

Saturn is distinguished from all the other planets by his ring, which is a vast and extraordinary circle of apparently white light, surrounding the body of the planet, but so far as can be discovered, no where touching it, being at the distance of 30,000 miles. This moves along with the planet in its revolutions around the sun, and with it, performs daily rotations in the same manner as if they were only one body.

How is the wisdom and care of Providence shown with respect to Saturn?
How many moons has Saturn?
What are the times of their revolutions?
What distinguishes Saturn from all other planets?
How far is this ring from the body of the planet?
Does there appear to be any connection between Saturn and his ring?
Does the ring revolve with the planet or not?

There are indeed two rings, one included within the other, with a space of 2,800 miles between them, nor can any connection be observed from one to the other.

Fig. 23.



It appears from the observations of Dr. Herschel, that the outer diameter of the smaller ring is about 184,000 miles, and that the same diameter of the larger is 205,000 miles. The breadth of the inner ring, is 19,000 miles, and that of the outer 7,000 miles. Thus the breadth of the two rings, with the dark space between them, is about 30,000 miles. Fig. 23 represents Saturn as he appears through a telescope, the ring being seen obliquely, so that it appears of an oval form, though its real form is nearly that of a circle.

The stripes across the body of this planet often change their appearance, and hence are supposed to be clouds, or mists, and perhaps arranged in his atmosphere by some natural law, of which on our little earth, we know nothing.

What is the diameter of Saturn's inner ring?
What the diameter of his outer ring?
What is the breadth of the two rings?
What is the form of Saturn's ring?
What is said of the stripes across the body of this planet?

The rings cast a dark shadow on the body of the planet, and hence Dr. Herschel concludes that they do not consist of clouds, or luminous matter, but of a solid substance, like that of the planet itself.

With respect to the uses of this enormous appendage, of which no other planet presents an example, one is undoubtedly that of reflecting the sun's light on the body which it surrounds. From appearances at different times, and when the planet is in various positions with respect to the sun, it is ascertained that this is one of its effects. This we may believe would be a most important and comfortable addition to our world, did we receive only a ninetieth part of the light we now enjoy, which is about the proportion which Saturn receives. This is however probably not its only use, since the planet Herschel, which is still more remote, has no such apparatus. Probably, as already suggested, it may throw the sun's heat as well as light on the body of the planet.

As Saturn revolves around the Sun once in thirty years, so his poles are alternately enlightened and in darkness, for the term of fifteen years, for the same reason that the corresponding parts of the earth successively have six months of day, and the same term of night.

Why is it supposed that this ring is solid matter?
What is supposed to be the use of Saturn's ring?
What is the difference with respect to the number of days at the equator and poles of Saturn?
What is said of the darkness during these fifteen years of night?

Thus while at the equator of Saturn there are 25,000 days during the year, at his poles there is only one day and one night, in the same period.

During these long seasons of the sun's absence, the ring of this planet, and his seven moons, most probably give the inhabitants such quantities of light as they require; for so far as we know, the Creator has never placed any race of animals in a situation, which is not adapted to their wants. Whether the animal is adapted to its situation, or the situation to the animal, is of course not essential. It is sufficient, that they are adapted to each other.

Of this planet Dr. Herschel says, "There is not perhaps another object in the heavens that presents us with such a variety of extraordinary phenomena as the planet Saturn; a magnificent globe, encompassed by a stupendous double ring; attended by seven satellites; ornamented with equatorial belts: compressed at the poles; turning on its axis; mutually eclipsing its rings and satellites; all parts of the system of Saturn occasionally reflecting light to each other; the rings and the moons illuminating the nights of the Saturnian; the globe and the satellites enlightening the dark parts of the rings, and the planet and rings throwing back the sun's beams upon the moons, when they are deprived of them, at the line of their conjunction."

What is said of the adaptation of animals to their situations?

The velocity of Saturn in his orbit is only 22,000 miles an hour, but the diurnal velocity of the circumference of his outer ring is more than 60,000 miles per hour. This motion is at least sixty times more rapid than that of the earth at the equator, a degree of velocity which would break the most solid parts of our globe into fragments, and perhaps throw some of its remains to the moon. We must infer, therefore, that either the matter of Saturn, or the laws of motion and force, by which it is governed, are widely different from any with which we terrestrials are acquainted.

HERSCHEL, OR URANUS.

This planet, the remotest in the solar system, was discovered by Dr. Herschel, in the year 1781. Its distance from the sun is 1827 millions of miles, being nearly twenty times more distant from the source of heat and light, than the earth. This distance is so great that a cannon ball, moving at the rate of five hundred miles an hour, would not reach it from the earth in less than four hundred years. And yet our system is so minute a part

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What is the hourly velocity of Saturn in his orbit?
What is the hourly diurnal velocity of Saturn?
What would probably be the consequences did our earth revolve with the velocity of Saturn?
When and by whom was Herschel discovered?
What is the distance of Herschel from the sun?
How long would a cannon ball be in going, at the rate of 500 miles the hour, to Herschel?

of the visible creation, that were the whole struck out of existence, it would leave a chasm, no greater in comparison, than the annihilation of a single star would do to the eye of an astronomer. Now when we consider that the entire universe is under the care of only ONE *superintendent*, who guides and directs the whole machinery, who is every instant so essentially in every place, that even a *sparrow* cannot fall to the ground without *his* knowledge and notice, what finite being can conceive of such Power and Omnipotence, and who will dare to disobey his just commands?

The diameter of Herschel is thirty-five thousand miles, which is about eighty times larger than the earth. His annual revolution is completed in eighty-three of our years, his motion being at the rate of fifteen thousand miles per hour, which is slower by more than six thousand miles per hour than the movement of any other planet. The great distance of this planet has prevented the discovery of his daily period.

The light and heat at Herschel, is about three hundred and sixty times less than that of the earth, and yet by calculation this light is equal to that of two hundred and forty-eight of our full moon's.

What is said of the minuteness of the solar system when compared with the visible universe?
What is the diameter of Herschel?
What is the period of his annual revolution?
What is his rate of motion?
What is the relative quantity of heat and light at Herschel?

When compared with our light, it is true that our neighbors at Herschel are in darkness; and yet even with our eyes, here would be no difficulty, after a little experience, in transacting all the business of this earth with such a light. The eye of man is formed with such exquisite skill as to accommodate itself to almost any quantity of light. Thus prisoners confined in nearly total darkness, will, after a time, be able to read the finest print. Besides, in compensation for this paucity of light, Herschel has six moons, which revolve around him at various periods, and of which, it is probable, more than one, every night enliven that remote planet with their reflected rays.

We have stated that Herschel is twenty times more distant from the Sun, than the earth is, and that the proportion of light and heat he receives, is three hundred and sixty times less than that of the earth. Now the ratio of light, is as the square of the distance from the luminous body. Thus the distance of Mercury from the Sun is thirty-seven millions of miles, that of the earth is ninety-five millions of miles. Without the millions, which are unnecessary in the calculation, the square of 37 is 1369, and the square of 95 is 9025, which being divided by the former sum, gives nearly 7.

Is it probable that the transactions of this earth could be done by such a quantity of light as the sun sends to Herschel?
How is the ratio of light and heat determined?
What example is given?

By the same rule the relative quantities of the heat and light of all the planets may be estimated, and by this method it is found that the proportions at Herschel, are as above stated.

RECAPITULATION.

Having given such an account of each of the planets and satellites, which form the system of the sun, as the plan of this little work will allow, we will here assist the memories of our young friends, by throwing together some of the principal things contained in the foregoing pages.

The number of bodies belonging to the solar system is twenty-nine; of which eleven are Primary, and eighteen are Secondary Planets.

The Primaries are Mercury, Venùs, Earth, Mars, Saturn, Vesta, Juno, Ceres, Pallas, Jupiter, and Herschel.

Of the Secondary planets, or moons, the Earth has one, Jupiter fóur, Saturn seven, and Herschel six.

The primaries have a double motion, by one of which they perform their annual revolutions around the sun,

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What is the number of bodies belonging to the solar system?
What are the primaries?
What is the whole number of moons, and to what primaries do they belong?
How many motions have the primaries?

and by the other, their daily rotations, producing day and night. The secondaries have triple motions. They revolve around their primaries, attend them in their annual journey about the sun, and at the same time rotate on their own axes.

TRUE DIAMETERS AND DISTANCES OF THE PLANETS.

Where the sums are great, we have not thought it necessary that the young pupil should remember the exact numbers, and therefore with respect to the diameters and distances of the planets, have generally given the nearest round numbers, in thousands or millions. It is however proper that the student should have it in his power to know the precise distances and diameters of these bodies, and also their hourly motions, and we therefore insert the following table of these elements. They are taken from a larger table of the elements of the solar system, calculated by Mr. E. H. Burritt, from data contained in the Report of the Council of Astronomers, which met in London in 1830.

What motions have the secondaries?
What proportion does there appear to be between the velocities of the planets and their distances from the sun?

Names.	Mean dist. from the Sun in miles.	Diameters in miles.	Hourly motion in miles.
SUN,		887,681	
MERCURY,	36.880,000	2,984	109,757
VENUS,	68,914,000	7,621	80,293
EARTH,	95,273.000	7,924	68,288
MARS,	145,168,000	4,222	55,322
VESTA,	225,016,000	269	44,435
JUNO,	254,287,000	1,393	44,799
CERES,	263,646,000	1,582	41,051
PALLAS,	264,183,000	2,025	41,009
JUPITER,	495,533,000	86.255	29,943
SATURN,	908.717,000	81,954	22,111
HERSCHEL,	1,827,580,000	34,363	15,593

By reference to the numbers expressing the hourly motions of each planet, it will be observed that their velocities in their orbits diminish in proportion as their distances from the sun increase. Thus the hourly motion of Mercury the nearest planet to the sun, is more than one hundred thousand miles, while that of Herschel, the most distant, is little more than fifteen thousand, during the same time. The cause of this will be explained under *Attraction of Gravitation.*

RELATIVE SIZES OF THE PLANETS.

[*See Frontispiece*]

The Frontispiece presents the student with a diagram in which the relative diameters of the planets are shown

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How much less is the diameter of Vesta, than that of Jupiter ?

as nearly as can be done on so small a scale. The asteroids are omitted, being too diminutive to be visible, if reduced to their relative proportions with the others. The diameter of Vesta being only 269 miles, would require to be reduced more than 300 times in order to represent its true proportion with that of Jupiter, the diameter of which is more than eighty-six thousand miles. To convey to the mind of the pupil a general impression of the relative magnitudes of the planets, "Choose," says Sir John F. W. Herschel, "any well levelled field or bowling green. On it place a globe, two feet in diameter; this will represent the sun; Mercury will be represented by a grain of *mustard seed*, on the circumference of a circle 164 feet in diameter for its orbit; Venus a *pea* on a circle 284 feet in diameter; the Earth also a *pea*, on a circle of 430 feet; Juno, Ceres, Vesta, and Pallas, *grains of sand*, in orbits from 1000 to 1200 feet in diameter; Jupiter a *moderate sized orange*, in a circle nearly half a mile across; Saturn a *small orange*, in a circle of four fifths of a mile; and Uranus (Herschel) a *full sized cherry*, or small plumb, upon the circumference of a circle more than a mile and a half in diameter."

To imitate the motions of the planets, in the above

Suppose the sun be represented by a ball of two feet in diameter, what would be the comparative size of Mercury?
What the size of Venus? of the Earth? of the Asteroids?
Of Jupiter? of Saturn? of Herschel?

mentioned orbits, Mercury must describe his own diameter, that is, must move through a space in his orbit, equal to his diameter, which is nearly 3000 miles, in 41 seconds; Venus must describe her diameter, which is 7621 miles, in 4 minutes 14 seconds; the Earth in 7 minutes; Mars in 44 minutes 48 seconds; Jupiter in 2 hours 56 minutes; Saturn in 3 hours 13 minutes, and Herschel in 2 hours 16 minutes.

The characters prefixed to the figure of each planet in the frontispiece, are those by which they are generally distinguished.

ATTRACTION OF GRAVITATION.

Before the pupil will be able to understand the cause of planetary motion, or why these celestial orbs perform unceasing revolutions around the sun, or around each other, he must comprehend what is meant by the *attraction of gravitation*, this being the basis on which these explanations are founded.

The attraction of gravitation is that power by which all bodies, having no peculiar properties, mutually tend towards each other. By *peculiar properties* we mean those belonging to some substances, but not to others, as

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How long is Mercury in moving the distance of his own diameter in his orbit?

How long is Venus in describing her diameter?

In what time does the earth and the remaining planets describe their diameters?

magnetism, and chemical attraction. By these properties bodies attract each other independently of gravitation. But the attraction of gravitation belongs to every form of matter with which we are acquainted, whether it has peculiar properties or not, and is the universal cause of what is commonly called *weight.*

If I throw a ball into the air, it soon returns again to the earth, because the earth and ball mutually attract each other. Now the cause which makes the ball return, or gives it weight or gravity, is the attraction of gravitation.

That common things attract each other, may be seen by placing several pieces of cork, or any other substance, on the surface of a dish of water. If placed near the centre, they will mutually approach each other, increasing their rate of motion, until they come into contact; but if placed near the side of the dish, they will not meet, being more strongly attracted by the matter of the vessel, to the sides of which they will soon be drawn. It is the gravitating attraction which makes these pieces of cork move towards each other, or towards the vessel's side.

This attraction constantly diminishes in proportion as bodies are removed at a distance from each other; and

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What is meant by attraction of gravitation?
What is the attraction of gravitation the universal cause of?
Why does a stone, when thrown into the air, return to the earth?
How is the attraction of bodies shown by means of a dish of water, and some pieces of cork?

increases as they approach each other. Hence the weight of all bodies increase when brought near the earth, and diminish in proportion to the distance they are carried from it. Hence a mass of lead weighing ten pounds on the earth's surface, would weigh less by some ounces, if carried a thousand feet into the air, and still less if carried higher.

Now it is the force of gravitating attraction, which keeps the planets in motion around the sun, and the moons in motion around the planets.

There are two forces which regulate the motions of the heavenly bodies. One is called the *centrifugal*, or centre-flying force, by which they tend to fly off in straight lines. The other is the *centripetal*, or centre-seeking force, by which they tend to leave their circular orbits, and approach the bodies around which they revolve. The latter force is the immediate effect of gravitation, while the other is the continuance of that motion which was given the planet when originally projected from the hand of the Creator. These two forces mutually balance and counteract each other. The centripetal force would draw the earth to the sun, upon which it would fall in a short period, did not the other force con-

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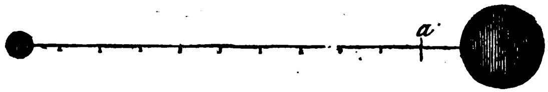
What effect does increasing or diminishing the distances of bodies have upon their attraction?
Why would a mass of lead weigh more at the surface of the earth, than at a distance from it?
What are the two forces which regulate the motions of the planets?
In what direction does the centripetal force tend to draw the planet?

stantly tend to carry it off in a straight line, by which such a catastrophe is ever prevented. On the contrary, the centrifugal force would impel the earth forward into open space, did not the attraction of the sun continually prevent it. Now the action of these two forces being continual, causes all the planets to circulate around their centres.

The sun, being the common centre of all the primaries, is retained in his place by their attractive forces, which operate in different, and opposite directions at the same time, while these are kept in their orbits by the attractive power of the sun. Thus the attractive influence of all the celestial bodies is reciprocal, and just sufficient to exactly balance, and retain each other forever in their places.

Fig. 24.



The motions or velocities of bodies towards each other, by the force of attraction, are inversely as their quantities of matter. That is, if two bodies approach each

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By what force is the sun retained in his place?
In what proportions do bodies approach each other by the force of attraction?
Suppose one body weighing ten, and another one pound should be placed a hundred feet apart, where would they meet by attraction?

other, the one weighing ten, and the other one pound, then the small body will move ten times as fast as the large one, and will pass through ten times as much space. Thus the two balls, fig. 24, being in the proportion of ten to one, by weight, would meet by their attractive forces at *a*, which is ten times as far from the small body, as from the large one.

The sun is many times larger than all the planets and satellites of the solar system together. In dimensions, he is equal to *fourteen hundred thousand* such earths as that on which we live. Hence, according to the law of motion, by the force of gravity, as above illustrated, the movement of the earth towards the sun would be nearly three hundred miles, while the sun would move towards the earth only a single foot. Thus, although the sun moves towards the earth, more or less, according to her distance from him, during her annual revolutions, still his motion is too small to be perceptible to us. For the same reason, the earth's motion towards the moon is too small to be appreciated.

ELLIPTICAL ORBITS OF THE PLANETS.

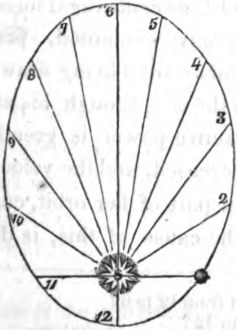
We have already stated that the orbits of all the planets are not true circles, as they are commonly represented, but ovals, or ellipses, as represented by fig. 19.

What is the size of the sun when compared with all the planets?
How much larger is the sun, than the earth?
In what proportion of distance will the earth and sun approach each other by attraction?

Now an ellipse has two foci, or centres, in one of which, called the *lower* focus, the sun is situated. Hence the planets, being nearer the sun, in some parts of their orbits, than in others, are, according to the preceding doctrine, more or less strongly attracted, and therefore must move with greater or less velocity in proportion. The effect of this arrangement on the earth is to make her move more rapidly through her orbit, at one season of the year, than at another, her motion being sometimes retarded, and then accelerated by the sun's attraction.

But whatever may be the earth's velocity, if her elliptical orbit be divided into unequal triangles, the acute angles of which centre in the sun, with the line of the orbit for their bases, the planet will pass through each of these unequal bases in equal times.

Fig. 25.



This will be understood by the diagram, fig. 25, which represents the form of a planetary orbit with the sun in the lower focus, and the area divided into triangular spaces in order to illustrate the principles just stated. The triangular spaces, 1, 2, 3, &c. though of different shapes, each and all of them contain the same quantity of

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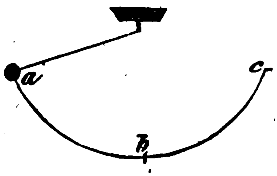
Where is the sun situated with respect to the ellipticity of the earth's orbit? Does the earth move with the same velocity through all parts of her orbit? What does fig. 25 represent?

surface, or are of equal dimensions. It will be seen that the earth in one part of her orbit, is much nearer the sun, than in another, and consequently in what parts her velocity is increased or diminished. Thus in passing from 1 to 2, and from 2 to 3, her motion must be retarded by the direct attraction of the sun, and she consequently moves with a diminished velocity until she arrives at 6, the remotest part of her orbit. Having passed that point, the sun's attraction coincides with the direction of the orbit, and because the force of attraction is perpetually increased by the approximation of the two bodies, the velocity of the earth is continually accelerated, so that she passes through the spaces from 9 to 12, respectively, in the same time that she did from 6 to 8.

Fig. 26.



When the earth comes to 12, its centrifugal force, already explained, prevents it from being drawn to the sun, though his attractive power is greatly increased, and the velocity she had acquired in the opposite part of her orbit, carries her through 1, 2, 3 to 6. The cause of this, is the

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Why is the motion of the earth retarded from 12 to 6?
Why is her motion accelerated from 7 to 12?
What prevents the earth from approaching the sun when his attraction is strongest, as when she is at 12?

same as that, which makes a pendulum sweep through a semicircle. If the weight, fig. 26, be lifted to *a*, and let fall, it does not stop at *b*, but rises, by the velocity it had acquired, against the gravitating force of the earth, up to *c*. If it be lifted higher, the velocity it would acquire in falling, would carry it in the same proportion, higher, on the opposite side.

In this experiment, it is plain to the eye, that the velocity of the pendulum weight, increases from *a* to *b*, and diminishes from *b* to *c*, and the causes of the difference are the same which increase and diminish the velocity of the earth in the different parts of her orbit.

When the earth arrives at 7, its motion is again increased by the sun's attraction, and it again acquires a velocity which carries it through the opposite part of its orbit, and so on continually.

WHY THE VELOCITIES OF DISTANT PLANETS ARE DIMINISHED.

If, as we have supposed, it is the attraction of the sun which retains the planets in their orbits, then the stronger this attraction, the greater must be the centrifugal force, otherwise the smaller revolving body, would be drawn towards, and finally would fall upon the larger. If, for

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How is the movement of a planet illustrated by the motion of a pendulum?

If the attraction be increased, why must the centrifugal force be increased also?

the same reason, the centrifugal force be increased, the attractive power must also be increased, otherwise the smaller body would leave the larger, and fly off in a straight line.

These principles are illustrated by the common sling for throwing stones. The whirling motion of the stone creates the centrifugal force, while the string answers to the centripetal or attractive power; and every one knows that when the motion of the stone is slow, a weak string will retain it, but that when it is intended to throw the stone to a great distance, the most rapid centrifugal motion is given it, and that then a strong cord is required to keep it from flying off in a straight line.

Now the motions of the celestial bodies, being caused by the joint action of these two forces, it is plain that if they are *both* increased, the velocity of the revolving body must be increased in proportion; and hence, other circumstances being equal, the nearer the planet is to the sun, the greater will be its velocity.

This accounts, in the most satisfactory manner, for the reason why the hourly velocity of each planet diminishes, as its distance from the sun increases, as shown by the table inserted at p. 118.

What would be the consequence of increasing the centrifugal force, without increasing the attraction?

How does the motion of the sling illustrate the movements of the planets?

How do you account for the diminished velocity of the remote planets?

THE ZODIAC AND ECLIPTIC.

The solar system, we have seen, consists of only twenty-nine planetary bodies, of which we can see at most only four or five at the same time, with the naked eye. All the other luminous points which are visible, on looking into the vault of the heavens, are fixed stars. Now the *zodiac* is an imaginary belt, or broad circle passing quite around the heavens among these stars.

In the centre or middle of the zodiac is the *ecliptic*, another imaginary circle, or line, through which the sun makes his apparent annual revolution. The zodiac extends to the distance of eight degrees on each side of the ecliptic, so that the zodiac is sixteen degrees broad, no space being allowed for the ecliptic, which is merely a line dividing the zodiac into two equal circles.

The whole circle of the heavens is divided into 360 equal parts called *degrees*. This division is made for the purpose of designating in descriptions, any portion of celestial space. Such divisions, of course, are imaginary with respect to any natural marks in the heavens.

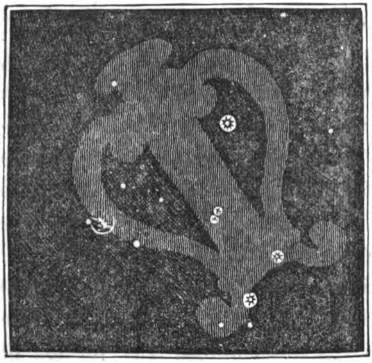
What are the brilliant points which we see in the vault of the heavens?
What is the zodiac?
What is the ecliptic?
How wide is the zodiac?
How wide is the ecliptic?
Into how many degrees is the circle of the heavens divided?

Each degree is subdivided into sixty equal parts, called minutes, and each minute into sixty seconds.

The zodiac is divided into twelve equal parts, called the *Signs of the Zodiac*, eaeh sign containing thirty degrees, and it is through the middle of these, that the sun makes his great apparent yearly circle.

These signs are called Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, and Pisces.—The common names, or meaning of these words, are, in the same order, the Ram, the Bull, the Twins, the Crab, the Lion, the Virgin, the Scales, the Scorpion, the Archer, the Goat, the Waterer, and the Fishes.

Fig. 27.



The division of the heavens into signs is of very ancient date, the stars in each sign being supposed to repre-

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Into how many parts are the degrees divided?
Into how many parts is the zodiac divided?
What are these divisions called?
How many degrees are there in a sign?
What are the names of the signs?
Do the signs present the figures of animals as their names suppose?
Is the division of the stars into signs a convenient method, or not?

sent, in their arrangement, the figure of some animal or thing after which the constellation was named. This is however entirely imaginary, for it is hardly necessary to say that no such figures are in reality represented by the stars, as the adjoining fig. 27 of Lyra will show. Still, this is undoubtedly the most convenient method of designating any particular star at the present day. If, for instance, we know where the constellation of Aries is situated, and are acquainted with the relative positions of the principal stars it contains, we at once understand which is meant by a star of the first magnitude in the neck, leg, or any other part of Aries.

As the motion of the earth around the sun, gives him an apparent motion along the ecliptic, and through all the signs of the zodiac, every year, his place in the heavens is often denoted by the name of the sign through which he is passing. Thus the sun enters Aries on the 21st of March; Taurus on the 19th of April; Gemini, May 20th; Cancer, June 21st; Leo, July 22; Virgo, August 22; Libra, September 23; Scorpio, October 23; Sagittarius, November 22; Capricorn, December 21; Aquarius, January 20; and Pisces, February 19.

APPARENT ANNUAL MOTION OF THE SUN.

The reason why the sun appears to move through the ecliptic, when the earth only circulates through

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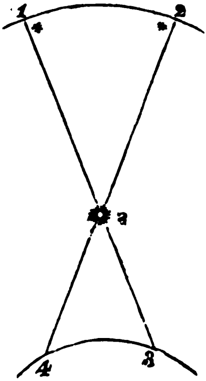
Through how many signs does the sun appear to move every year?

her orbit, is readily explained, and as easily understood.

Fig. 28.



Suppose that S, fig. 28, is the sun, 1, 2, a part of ecliptic, and 3, 4, a portion of the earth's orbit. Now a spectator on the earth, standing at 4, will see the sun in the vault of the heavens, say near a certain star, marked 2; but when the earth has passed along her orbit to 3, then the sun will appear contiguous to another certain star, marked 1. Thus the revolution of the earth through her orbit from west to east, gives the sun an apparent annual revolution in the contrary direction.

ORIGIN OF THE ZODIACAL SIGNS.

The zodiac, as already stated, was divided into twelve signs, as they are now known, at a very early period. Writers on the History of Astronomy, attribute this invention to a nation which inhabited the northern temperate zone, probably that part now called Tartary, at a

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What is the reason that the sun appears to move through the ecliptic when he is really stationary?
Explain fig. 28.
By what nation is it supposed that the signs of the zodiac were invented?

remote period. The Chinese, Indians, Babylonians, Arabians, Egyptians, and Greeks, who were, from time immemorial, acquainted with the zodiacal signs, are supposed to have derived their knowledge from this nation.

The zodiac, found in the temple of Dendera, in Upper Egypt, and which it is proved was placed there several centuries before the Christian era, has the animals representing the twelve signs, figured as they are at the present day, though differently arranged.

Even as far back as the days of Job, the heavens were divided into constellations, as is proved by his reference to Orion, Arcturus, and Pleiades. "Canst thou restrain the sweet influence of the Pleiades, or loosen the bonds of Orion?" was one of his sublime expostulations.

It is probable that the shepherds, "who watched their flocks by night," and who were, from their employment, the first students in Astronomy, began in the remotest age of man to name clusters of stars. This indeed, must have been the only method by which one part of the heavens could be distinguished from another, or what was of more importance to the shepherds, the time of night ascertained by the rising or setting of particular stars, or constellations.

The figures by which at least many of the signs are denoted, were anciently Egyptian hieroglyphics, or em-

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What is said of the zodiac, found at the temple of Dendera?
What reference is made by Job, with respect to the constellations?
What class of people is it supposed first studied Astronomy?

blems, and the earliest catalogue of them was made by Ptolemy, the Egyptian astronomer.

These signs undoubtedly had reference to the seasons of the year, or their productions.

Thus Aries, Taurus, and Gemini are the signs for the three spring months. The first two are most important animals to the farmer, and the last may have reference to the productiveness of these animals towards the close of spring.

Cancer, the fourth sign, may have reference to the retrograde motion of the sun at that season, not unaptly represented by the backward motion of the crab. Some however suppose that the disposition of the stars in this sign, resemble the figure of a crab.

Leo, the Lion, denotes the fifth month, July. This sign, probably, refers merely to the heat of summer, as the lion only inhabits the hottest countries.

Virgo, the sixth sign, is represented by a maid, holding an ear of corn in her hand. The time, being August, is very properly denoted by an emblem of the harvest season.

Libra, or the balance, is the seventh sign of the zodiac. It is a par of scales equally balanced, because in September comes the autumnal equinox, when the days and nights are of equal length.

We shall leave it to the discretion of the teacher, to ask such questions on the signs as he thinks best?

Scorpio, the eighth sign, denotes that, when the sun arrives to that part of the heavens where this constellation is placed, fevers and sickness, the diseases of autumn would begin their deadly progress. Or, perhaps it refers to the time of year when that deadly insect, the scorpion, was most numerous in Egypt.

Sagittarius, the Archer, is represented as a monster, half horse and half man, in the act of shooting an arrow from his bow. This is emblematical of the hunting season, bows and arrows being once the only weapons used for shooting game.

Capricornus, the Goat, denotes December, the season when this wild animal retired to the mountains for food, and where it was pursued by the huntsman.

Aquarius, the Waterer, is represented by the figure of a man, pouring water from a vessel on the ground. This is emblematical of the rainy month of January, in the country where the signs originated.

Pisces, the twelfth, and last sign, is the figure of two Fishes tied together. It appears to denote that during the month, February, the rivers and seas will afford provision for man, though that of the past season may have been exhausted.

The ancients, besides the signs of the Zodiac, had names for thirty-six constellations, in different parts of

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How many constellations, besides those of the zodiac, were known to the ancients?

the heavens, making in the whole forty-eight clusters of stars, known by distinct names.

Modern astronomers have added forty-four to these, so that the whole number of constellations now enumerated in complete catalogues is ninety-two. Of these twelve are in the zodiac ; forty-five in the southern hemisphere, and thirty-five in the northern hemisphere.

COMETS.

Besides the twenty-nine planetary orbs which we have described, there belongs to the solar system an unknown number of bodies called *comets*, which also revolve around the sun.

We are entirely ignorant of the origin, or number of these "wandering stars," or of their uses in the system of the world. But from the evident marks of benevolence and design exhibited in every part of creation, within our reach, we may conclude, by analogy, that these bodies form a part of the same beneficent system, and that possibly they are the abodes of millions of reasonable beings whose organization fits them for the vicissitudes through which they pass.

How many have modern astronomers added ?
What is the whole number of constellations at present ?
What is known concerning the number and uses of comets ?
From what we know of the works of creation, what may be inferred with respect to the comets ?

NUMBER OF COMETS.

The number of comets which have been observed, and the times of their appearance recorded, are about 700. "And when we consider," says Sir J. F. W. Herschel, "that in the earlier ages of astronomy, and indeed in more recent times, before the invention of the telescope, only large and conspicuous ones were noticed; and that since due attention has been paid to the subject, scarcely a year has passed, without the observation of one or two of these bodies, and that sometimes two and even three have appeared at once; it will be easily supposed that their actual number may be at least many thousands."

Besides the number seen, there are many that pass through those parts of our heavens, which are only visible in the day time; and hence, as they have not sufficient light to be seen when the sun shines, and never come within our view at night, are not seen at all. Such comets only become visible when there happens a total eclipse of the sun, a coincidence so rare, that thousands may visit us without their presence being known. Seneca relates that such a coincidence did happen about sixty

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How many comets have been observed?
On what grounds does Herschel conclude the number of the comets may be many thousands?
What is said of such comets as pass only through those parts of the heavens which are visible in the day time?
On what occasion can these be seen?

years before the Christian era, when, during a total eclipse, a large comet was discovered near the sun.

Instances are however recorded, where they have been so luminous as to be seen in the day time, and even at noon, when the sun was unclouded. Such were those of 1402 and 1532.

SUPPOSED DIREFUL MESSENGERS.

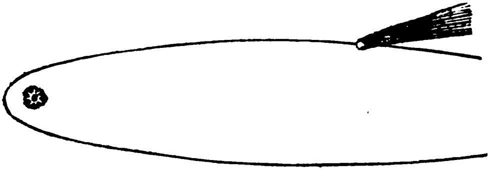
It was formerly believed, that these *blazing stars*, as they were called, merely passed by our world in their journeys from one unknown region of indefinite space to another, and that they never again returned. Nor was their appearance witnessed with unconcern, for it was generally believed that they were sent as direful messengers, to warn our world of the approach of war, pestilence, or famine, or the deaths of princes. One which appeared just before the assassination of Julius Cæsar, was supposed to have predicted his death.

But these dreadful apprehensions began to subside, after Sir Isaac Newton demonstrated that comets pass around the sun in regular orbits like those of the planets, only that these orbits are very extended, or eccentric ellipses, the sun being placed in one extremity.

Are comets ever so bright as to be visible in the day time?
For what purpose was it formerly supposed comets were sent among us?
What did Sir Isaac Newton demonstrate with respect to the orbits of comets?

FORM OF THEIR ORBITS.

Fig. 29.



The form of a comet's orbit is represented by fig. 29, by which it will be seen that these bodies move in gradually curved lines which approach each other at the two extremities, and that having passed around the sun, they retire again, in a similar direction whence they came.

TIME THEY ARE VISIBLE.

The length of time comets remain visible is exceedingly various; some are only in sight for a few days, while others have been visible for six months. These periods depend on the size of the comet, on the velocity of its motion, and the direction of its orbit with respect to the sun and earth.

Of those recorded, which have been longest in sight, one appeared in A. D. 64, in the reign of Nero; another

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What is the form of a comet's orbit?
What is said of the length of time comets are visible?
On what circumstances does the time of their appearance depend?

in 603, in the days of Mahomet, and another in 1240, during the time of Tamerlane's irruption. These were all visible for six months. A fourth came in sight in 1729, and was visible from July to January.

FORMS AND APPEARANCES OF COMETS.

Comets, for the most part consist of a splendid, but ill-defined mass of light called the *head*, which is brightest towards the centre, where it sometimes has the appearance of a brilliant star. From the head, in the direction *from*, or *opposite* to the sun, there diverge streams of light which grow broader as they extend from the head, and at the same time grow more and more faint, resembling the trains left by some meteors, as they dart through the sky. This part is called the *train*, or *tail*, and is sometimes of such immense length as nearly to equal the diameter of the whole solar system.

The tail, though a common, is not an invariable appendage to comets. In many instances, this part is so short and thin, as barely to be visible through the best glasses, and in a few, it is entirely wanting. This was the case of the comets of 1585, and 1763, and that of 1682 is described as being as round, and as brilliant as Jupiter.

What instances are recorded of their being visible for six months?
What are the general forms and appearances of comets?
What is said of the immense length to which the trains of comets extend?
Are these trains necessary appendages to comets or not?

MATTER OR SUBSTANCE OF COMETS.

The head, or nucleus, which most comets present, was formerly considered a solid mass of some kind of matter, while the tail was supposed to consist of vapor, steam, or electricity proceeding from this. As this part commonly increases in length, as the comet approaches the sun, some astronomers have also supposed that it might consist of inflammable matter in a state of combustion by the sun's heat. But more recent observations seem to prove that even the most solid parts of these bodies are of a substance so thin, or transparent, as to permit light to pass freely through them. Herschel says that "stars of the smallest magnitude remain distinctly visible, though covered by what appears to be the densest portion of their substance; although the same stars would be completely obliterated by a moderate fog extending only a few yards from the earth."

Were these luminous wanderers composed of solid masses of heavy matter, they would, in their voyages through the solar system, materially derange the regular motions of the planets, by their attractive coercion. But although they have often passed among the moons of

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What has it been supposed that the trains of comets consist of?
What is said of stars being seen through the densest parts of comets?
Were comets composed of solid matter like the earth, what effect would they have on the planets of our system?

Jupiter, no such effect has taken place. The comets themselves have, by the attraction of the planets, been occasionally drawn completely out of their orbits, while the planets have pursued their paths, as if nothing had happened.

It is certain, therefore, from the phenomena which comets present, that the matter of which they are chiefly composed, of whatever kind it may be, is so far from being of a dense, or solid nature, as to consist of some rare substance which would probably float in our atmosphere. The luminous parts at least, appear to have no more substance than our fogs or clouds.

Hence the danger which some astronomers have apprehended for the members of the solar system, and especially the earth, from the concussions of comets, appears to be without foundation. For, independently of the fact that these bodies move in regular orbits, and are, equally with the planets, under the care of HIM who superintends the mechanism of the universe, it is by no means probable, that in case of an impact between one of these bodies and the earth, or any other planet, that the mischief would be such as to throw the latter out of

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What effect has the mutual attraction of the comets and planets had on each other?
What is the conclusion concerning the substance of which comets are composed?
Ought there to be any apprehension that our earth, or any of the planets, will suffer from the stroke of a comet?
Why are such apprehensions groundless?

their orbits, but on the contrary that it would be slight and local.

PERIODICAL RETURN OF COMETS.

Although the comets which visit the solar system probably amount to several thousands, the periodical returns of only a very few have been ascertained with any degree of certainty.

Dr. Halley predicted the return of one in about 1759, which had appeared seventy-five years before. So extraordinary a prediction, (the first it is believed which any astronomer had ventured to make with respect to these periods,) excited much attention among astronomers, as the predicted time approached. One of the most interesting points to be ascertained was, how far the attraction of the distant planets would delay the return of this comet to that part of our horizon where it was expected to become visible, or to its perihelion.

Such a piece of calculation, to those who know little of the laws of gravity, or the refinements of mathematics, would seem absolutely impossible, and to those who have studied these subjects, it could not but present difficulties which only a few men in any age would be capable of surmounting.

Who first predicted the return of a comet?
What was the most interesting point to be known with respect to the return of this comet?

The calculations were however undertaken by the celebrated French astronomer, Clairaut, and accomplished, in a manner which the event proved to be equally profound and accurate.

Clairaut showed that the action of Saturn on this comet, would retard its return by 100 days; and that the attraction of Jupiter would hinder its progress by 518 days, so that its return would happen 618 days later than Dr. Halley, who had made no allowance for this circumstance, had predicted. It accordingly made its appearance nearly at the time it was expected, namely, in March, 1759. According to recent calculations, this comet may again be expected in November, 1835.

Two other comets are known to have several times made their appearance at the times predicted by astronomers. The first of these is called *Encke's* comet, so called from Professor Encke of Berlin, who first ascertained its periodical return. This has a period of 1207 days, or about three years and a half, and is known to have kept its time of return very exactly since 1819. Its next appearance will be in 1835. The other has also a short period, and is called *Biela's* comet, so named from M. Biela, of Josephstadt, who was the first to find its period. This has a periodical revolution around the

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For how long a period did the attraction of Saturn and Jupiter retard the return of a comet?
What is said of Encke's comet?
When may this comet again be expected?

sun once in 6¾ years ; and as it appeared according to prediction, in 1832, it may again be expected in 1838. The periods of comets are calculated from one perihelion, or nearest approach to the sun, to another, and hence a comet may be several weeks in sight before its period or perihelion is completed.

A great comet, which appeared in 1780, and on which Sir Isaac Newton made many profound observations, is supposed to have a period of 500 years, and therefore cannot be expected until the year 2225. Before that time nearly fourteen generations of our race will have been turned to dust, and if astronomy advances to that period, as it has done during the preceding, not only the exact predictions of hundreds of returning comets will be verified, but even the census of the moon will probably be calculated.

DIMENSIONS OF COMETS.

By calculating the elements of a comet's orbit, its real distance from the earth, at any time after it is visible, may be known, and when its distance is ascertained, there is little difficulty in calculating the diameter of its head, and the length and breadth of its tail.

What is the period of Biela's comet?
When may it be expected again to visit us?
From what position with respect to the sun are the periodic times of comets calculated?
What is supposed to be the period of the comet of 1780?

By such inquiries it is found that the comets are by far the largest bodies in our system, not even excepting the sun.

The tail of the great comet of 1780, already mentioned, was found by Newton, immediately after its perihelion, to be no less than fifty millions of miles in length. It afterwards, as the comet retired from the sun, increased to the amazing length of 123 millions of miles, thus exceeding the distance from the earth to the sun, by twenty-eight millions of miles. This comet when nearest the sun, moved at the amazing velocity of 880,000 miles an hour. The tail of another comet, which appeared in 1769, extended forty-eight millions of miles, and that of one which appeared in 1811, was 118 millions of miles long.

FIXED STARS.

The fixed stars are incomparably the most numerous of visible celestial objects.

Besides the planets, of which we seldom can see more than five or six with the naked eye, and the comets,

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What previous calculations are necessary, before a comet's size can be known?
What is said of the size of comets, compared with other members of the solar system?
How far did the great comet of 1780 extend?
How much does this exceed the distance from the earth to the sun?
What are far the most numerous of celestial objects?

which are rarely visible, all the other brilliant points, which we can see in the vault of the heavens during the absence of the sun, are fixed stars. They are called *fixed*, because they do not materially change their positions with respect to each other.

These luminaries are at such immeasurable distances from us, that according to the best calculations which astronomers have been able to make, the nearest, which is Sirius, or the Dog Star, cannot be less than 192,000,000,000,000 or 192 trillions of miles from the earth. This space is so vast, that light, which darts forward with a velocity equal to 200,000 miles in a second of time, would not pass through it, in less than three years.

Hence, were this star to be annihilated or covered from our view, it would continue to shine as it does now, for three years to come, since the light it has already emitted would not cease to reach us until the end of that time.

The stars are distinguished from the planets by their scintillations, or twinkling. The former appear to suffer instantaneous changes in the quantity of their light,

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Why are the stars called *fixed*?
What is the nearest star?
What is the distance of Sirius, the nearest star, from the earth?
How long would light be in passing from this star to us?
Were this star struck out of existence, how long would it appear as it does now? Why?
How are the stars distinguished from the planets by the eye?

owing to some cause not well ascertained, while the planets shine steadily, and without interruption. On a clear night, any eye may distinguish the two classes by this difference.

To a casual, or inattentive observer, the number of stars appears innumerable, and to such it will seem incredible, that on the clearest winter's night, not more than a thousand are visible to the naked eye at any one time. This deception with respect to numbers arises from the confused, and hasty manner in which observations are commonly made, and the momentary impression which each star leaves on the seat of vision, so that a faint image remains after the eye is withdrawn, in the same manner that the image of a candle, or the sun, remains for a moment. We see the stars and these images at the same time, and thus is the number multiplied. If the eye be kept fixed on a definite spot, say of a yard or two square, and the stars counted within its limits, their number will be found much less than their first appearance indicates.

The whole number of stars which the naked eye can distinguish in the entire vault of the heavens, from evening to morning, does not exceed 2000; and of these not more than about one half are visible at the same

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How many stars can be seen at once with the naked eye?
How is this deception accounted for?
What number of stars can the naked eye distinguish from evening till morning?

time, because, as the earth rotates on her axis, some are constantly setting, while others are rising.

For the purpose of discrimination, as well as of description, astronomers have divided the stars into orders, according to their apparent sizes. The largest are called stars of the *first magnitude*, the second in size, stars of the *second magnitude*, and so on to the sixth magnitude, which are the smallest that can be distinguished with the naked eye. Those still smaller, and which cannot be seen without glasses, are called *telescopic* stars; because they are visible only by the assistance of the telescope. These are classed to the tenth magnitude, making in the whole sixteen magnitudes of stars.

The number of telescopic stars appear to be indefinite, and, so far as we know, infinite, since the greater the power of the telescope, the greater is the number seen, and no doubt, their visible numbers would be increased a hundred, or a thousand fold, could we increase the power of our glasses in this proportion. In the constellation Pleiades, or *seven stars*, the eye can discern at most only eight stars, but with a telescope, of even moderate power, nearly two hundred can be seen. And in the constellation of Orion, where the naked eye can discern only seventy, or eighty, a good telescope discovers 2000. In

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Why cannot the whole number be seen at the same time?
Into how many different sizes or magnitudes are the stars divided?
What are telescopic stars?
What is said of the number of telescopic stars?

all the other constellations a similar proportion exists between the number of stars visible to the naked eye, and those discovered by the use of glasses.

The *galaxy*, *via lactea*, or *milky way*, undoubtedly consists of many hundred thousands of stars, which might be counted by such glasses as we now possess. Dr. Herschel, with his great telescope, had reason to believe that he saw 50,000, in a twelfth part of the milky way, and which passed over the field of his view in the course of a single hour.

In many parts of the heavens there are whitish or clouded spots which are permanent, but in which no distinct stars are visible. The milky way, to a considerable extent, presents this appearance. These spots are called *nebulæ*, and with a telescope are found to consist of clusters of stars, some of them containing hundreds, or even thousands, apparently arranged in lines behind each other. The galaxy, is almost one continued nebulæ, extending around the whole circle of the heavens.

Astronomers, from long and numerous observations, have ascertained that occasional changes take place among these brilliant points. Some stars described by ancient astronomers are not now to be seen, their places being vacant, while others have appeared in places where

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What is said of the galaxy, and the number of stars Dr. Herschel discovered in a small portion of it?
What are nebulæ?
Have any of the stars disappeared?
Are there instances of the appearance of new stars?

none formerly existed. Some have increased, while others have diminished in lustre ; and in a few instances they have undergone a gradual diminution, until they became, to appearance, entirely extinct, and then again have revived, slowly gaining their former brightness. These changes, in a number of instances, take place at regular periods of time, forming what astronomers call *periodical* stars.

A star called *Algol*, is one of the most remarkable of this kind. When brightest it is a star of the second magnitude, and such it continues for two days and fourteen hours, when it suddenly begins to diminish in lustre, and in about three hours and thirty minutes, is reduced to the fourth magnitude. It then begins to increase, and in about three hours and a half more, is restored to its usual brightness, thus passing through these changes in two days, twenty hours, and forty-eight minutes.

It is most probable that Algol is a sun, with planets revolving around him, and that one of them in the course of its periodic revolution hides a part of his light from us. This supposition accounts for the phenomenon in a satisfactory manner.

Sir J. F. W. Herschel has given a list of sixteen periodical stars, which have been discovered by various as-

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What is meant by periodical stars?
What changes does the star Algol appear to undergo, and how long are its periods?
How are the changes of this star accounted for?
How many periodical stars have been observed?

tronomers from the year 1600 to 1826. The times occupied in performing their periodical changes differ from about three days, to eighteen years.

Several of these, when brightest, appear as stars of the second and third magnitudes, and then gradually diminish to those of the fourth, fifth, or sixth magnitudes, while others disappear entirely, to reappear in a given time.

Possibly in some instances, the waxing and waning may be owing to dark spots on one side of the star, the increase and decrease of light, being caused by the period of its rotation on its own axis. Our sun, owing to spots on his surface, sometimes gives us less heat and light than at others.

With respect to the design and use of the stars, we may consider it quite certain that they serve more important purposes than to garnish the vault of the heavens for the delight of earthly existences. A single additional moon would give us a hundred times more light, than the whole firmament of stars. Besides, it is well known that there are thousands, and most probably millions, which the naked eye never sees, and which therefore do not answer the purpose intended, if they were designed

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How do they differ with respect to the lengths of their periods?
What reason is there to suppose that the periodical changes of some of the stars, is owing to the dark spots on their surfaces?
Is it probable that the stars were made for our use, or for other purposes?
What reason is there to believe that they were not made for our use?

for our use; and to believe that infinite Wisdom and Power ever formed a design, without a corresponding effect, would be equally unreasonable and impious.

We cannot therefore suppose that the creation of such myriads of celestial bodies, some of which are probably two or three times the size of our sun, had any reference to this little earth or its inhabitants. They are destined by the Sovereign of the universe to serve higher and much more magnificent purposes, being undoubtedly suns to other systems, and shedding light and heat on other revolving planets, as our sun does upon us.

From the distances at which the stars are placed, our sun would appear no larger than these do to us. Dr. Wollaston, by direct experiment, has shown that the light of Sirius, the nearest star, as received by us, is in proportion to the light of the sun, as 1 to 2000 millions, that is, it would take 2000 millions such stars, to give the light of our sun. According to the known laws of the diminution of light as the distance increases, our sun would require to be removed to 141,400 times its actual distance from us, in order to give the small light of Sirius. But the distance of Sirius is more than 200,000 times that of the sun. "Hence," says Herschel, Jr., "it fol-

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What great purposes is it nearly certain the stars answer?
How would our sun appear at the distance of Sirius?
What proportions do the light of the sun and that of Sirius bear to each other as seen by us?
How much more distant is Sirius from us than the sun?

lows that upon the lowest possible computation, the light really thrown out by Sirius cannot be so little as double that emitted by the sun; or that Sirius must in point of intrinsic splendor, be at least equal to two suns, and is in all probability vastly greater." We may add, that Dr. Wollaston makes this star equal in splendor, to nearly fourteen of our suns.

These circumstances prove in the clearest possible manner of which such a subject will admit, that the stars shine, like our sun, with their own intrinsic light, for we cannot for a moment suppose that a borrowed light, like that of the moon, even if reflected from a surface of the diameter of Herschel's orbit, could be seen at the distance of the stars.

The vast numbers of the stars and their apparent nearness to each other, argues nothing against their being suns to other worlds, since each may be as distant from the other, as our sun is from Sirius, and still appear to us as they now do.

To the inhabitants of these systems, it is most probable that our sun is a fixed star, in the vault of the heavens, and that it is no more conspicuous than those by which it is surrounded; nor would its annihilation be any great-

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How much larger is Sirius supposed to be than the sun?
What makes it certain that the stars shine with their own light like our sun?
Are the stars near, or at great distances from each other?
What is said of our sun being a fixed star?

er loss, in the system of the universe, than that of any other fixed star.

We have already shown, that according to the most accurate computations, light would not reach us from Sirius in less than three years. This star is one of the most splendid in the celestial sphere, and were it removed twenty times its present distance from us, would probably still be visible to the naked eye. What then, can we say of the distance of telescopic stars of the sixteenth magnitude!

According to some estimates on this subject, made by Herschel the son, if we suppose that the light of a star of each magnitude, to be equal to half that of the magnitude next above it, as seen by us, then it will follow, that a star of the first magnitude must be removed to 362 times its present distance, to appear no larger than one of the sixteenth magnitude, which is the smallest that can be distinctly seen through a good telescope.

Now taking Sirius as a star of the first magnitude, and taking its distance to be 192,000,000,000,000 miles, or 192 trillions of miles, then 362 times this number will show the estimated distance of a star of the 16th magnitude. This sum amounts to 69,504,000,000,000,000,

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Is it probable that our sun would be a greater loss in the system of the universe than any one of the stars?

What is said of Sirius, were it removed twenty times its present distance from us?

How far beyond its present distance must a star of the first magnitude be placed, to appear as one of the sixteenth magnitude?

or 69 quadrillions, 504 trillions of miles, a sum so enormous that the imagination can only consider the space it indicates as infinite and unbounded.

If light, passing at the rate of 200 thousand miles per second, would occupy three years in coming from Sirius to the earth, it would not, at the same velocity, reach us from a star of the sixteenth magnitude, under 1086 years.

We have already stated that the number of stars actually discovered is bounded only by the power of the telescope employed, and that were this instrument increased an hundred, or a thousand fold in power, it is most probable that the number seen would be in proportion.

Now notwithstanding that the countless number of stars which our best telescopes can discover would seem to form an infinite number of worlds, still for aught we know, our system is on the very outskirts of creation, and it is a conjecture, neither bold, nor improbable, that from a distance which it would take light a thousand years to come down to us, there still remains sun beyond sun, and system beyond system, and that from such a distance we should remain as ignorant of the boundaries of the creation as we now are.

How long does it take light to pass to us from a star of the sixteenth magnitude?

Is it probable, that from a star of the sixteenth magnitude, we should be any nearer gaining a knowledge of the boundaries of creation than we are now?

It may even be the case, that there are stars whose light has not yet had time to reach us since the creation, and that those which astronomers have discovered where none existed before, and called *new* stars, are among those whose light just arrived at the earth.

How small a part then, is our system, our earth, and especially ourselves, of the boundless universe, which was called into existence by the word of Almighty Power. And when we consider that the whole has but ONE Superintendent, and when with the whole we compare ourselves as individuals, may we not wonder that we are not overlooked, and lost, and may we not truly exclaim with the pious Psalmist, "Lord, what is man that thou art mindful of him, or the son of man that thou visitest him!"

NEBULÆ, OR CLUSTERS OF STARS.

The number of fixed stars to be seen in the heavens appear to be bounded only by the power of the telescope employed. With the naked eye, as has already been stated, we can see but about one thousand stars at any one time. With a telescope of moderate power, this number is doubled, or trebled, or quadrupled, according to the assistance it affords our vision. But with an in-

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What is said of stars whose light has not yet reached us?
What ought we to think of ourselves when compared with the boundless works of creation?
What is said of the number of fixed stars?

strument which magnifies thousands of times, like that employed by Sir William Herschel, every portion of the heavens appears either to be studded with brilliant points, in the form of distinct stars, or else their numbers are so great, that their light is blended so as to form whitish spots without distinction of individuals. Such spots, or clusters of stars, are called *nebulæ.*

The more powerful the telescope, the greater is the number of distinct stars, and nebulæ to be seen; and it is most probable that had we instruments an hundred, or a thousand times the power of any yet made, our discoveries with respect to the number of these heavenly bodies would be in proportion. No doubt can therefore exist, but that there is still an infinity of suns, and of revolving worlds, which remain, and always will remain, beyond the view of any telescopic instrument which man has, or ever will invent.

Either nebulæ, that is, distinct white patches, or nebulous appearances, are scattered in every part of the heavens, but that belt known under the name of the Milky-way, appears to be one continued cluster of stars. This can be seen by the naked eye, and may serve as an example of those phenomena. In many of its parts no distinct star can be seen by the unassisted eye, but with

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What are nebulæ?
What are these whitish spots found to be, when examined by the telescope?
What is said of the Milky-way?

a telescope, such parts present individual stars which can be so separated from each other, as to be counted.

Sir William Herschel with the most powerful telescope ever constructed, saw, according to his calculation, no less than one hundred and sixteen thousand stars in the Milky-way, which passed the field, or view of his instrument in about fifteen minutes.

Many stars which appear to be single to the naked eye, are found to be double, or treble, through the telescope. Of these, Dr. Herschel formed a catalogue of 269, and of which 227 had not been observed by any other astronomer. On observing these closely, he found that many of them, changed their situations with respect to each other; that some of them performed revolutions periodically around the other, and that others appeared to have a motion in a direct line away from the rest.

Dr. Herschel says that nebulæ are arranged into strata, and sometimes extend to great lengths, and that it is not improbable they surround the whole starry heavens, not unlike the Milky-way, which is undoubtedly nothing more than a stratum of fixed stars; and as this latter immense starry bed is not of an equal breadth or lustre, in every part, but is curved, and even divided into two

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What number of stars were distinguished in the Milky-way in a given time?
What is said of double stars?
Do any of the stars change their places?
What is said of the extent of nebulæ?

streams, along a very considerable portion of its length, so we may likewise expect a great variety in the forms and appearances of other nebulæ.

The forms of some nebulæ are oval, others round; while others have no particular shapes, but appear in patches with ragged edges.

But while in many, if not in most of these, a powerful telescope discovers stars, as above stated, there are other nebulous phenomena which do not seem to arise from starry clusters. These are stars surrounded with a faint, *luminous and extensive atmosphere.* This atmosphere, Dr. Herschel supposes to be the true nebulous matter, collected around a central point of attraction, and which he has not been able, with the highest magnifying power of his glasses to resolve into stars.

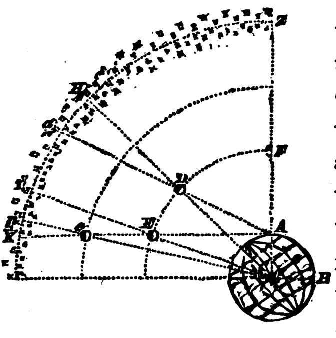
It is possible that the curiosity and invention of man may yet construct instruments, by the power of which, more may be known concerning these celestial phenomena, but at present we can only suppose that these stars shine by their own light, and therefore that they are suns—suns to other worlds, and that they shine upon the inhabitants of planets revolving around them, as our sun does upon us. How vast must be the extent of that Power and Wisdom which created, and watches over such an infinity of worlds!

What are their forms?
Are stars discovered in all nebulæ?
What is said of a luminous atmosphere surrounding some stars?

PARALLAX OF THE CELESTIAL BODIES.

Parallax is the difference between the true, and apparent place of a heavenly body. The *apparent* place is that in which it seems to be when viewed from the surface of the earth. The *true* place is that in which it would be, if seen from the earth's centre.

Fig. 30.



This will be readily understood by fig. 30, where it will be obvious that a spectator placed at G, the centre of the earth, would see the moon E, among the stars at I, while, without changing the position of the moon, it would appear at K, were the spectator on the surface of the earth, at A. Now, I is the *true*, and K, the *apparent* place of the moon, the space between them being the moon's *paral-*

What is meant by parallax?
Where is the true place of a heavenly body?
What is meant by the apparent place of a planet?
Will a spectator at the centre, and surface of the earth, see the moon in the same place?
What would be the difference?

lax. Parallax, therefore, makes the heavenly bodies appear less elevated than they really are.

The parallax of any celestial body is greatest when it is on the horizon, or when it is just rising so as to be seen, and constantly diminishes as it ascends to the zenith, or highest point in the heavens. Thus it will be seen by the figure, that the parallax of the moon is less, when at D, than it was at E, and that when it arrives at the zenith, or highest point in the heavens, Z, its position is the same, whether seen from the centre, or surface of the earth, and consequently that its parallax ceases entirely.

The greater the distance of the heavenly body, the less is its parallax. Thus were the moon at *e*, instead of at E, her parallax would only be equal to *n* K, instead of I K. Hence the moon, being the nearest celestial body, has the greatest parallax, the difference in its place among the stars, when seen from the centre and surface of the earth, being a distance of 4000 miles, is very considerable. The stars are at such immense distances, that the difference of station between the centre and surface of the earth makes no perceptible change in their places, and hence they have no parallax.

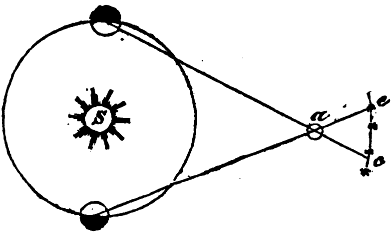
The above description applies only to what is termed

Does parallax elevate, or depress the object?
When is parallax greatest?
When does it cease entirely?
What effect does distance have on parallax?
Why have the stars no parallax?
What is meant by diurnal parallax?

diurnal parallax, or that which takes place every, day. The moon, as we have seen, has a parallax when she first rises, but as the earth revolves, or the moon ascends it diminishes, and ceases entirely at the zenith. The same is the case with the sun, and all the planets which have sensible parallaxes.

Besides this, there is an *annual* parallax, which is the difference in the apparent places of the celestial bodies, as seen from the earth at the opposite points of the orbit, and through which she passes in her yearly revolutions.

Fig. 31.



Suppose *a*, fig. 31, to be a stationary celestial object, then, as the earth makes her annual revolution around the sun, this object at one time will appear among the stars at *e*, but six months after, when the earth comes to the opposite point on her orbit, the same object will appear at *c*, the space from *e* to *c* being the annual parallax of the object *a*.

The vast distance of the fixed stars is proved by their having no sensible parallax. The diameter of the earth's

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What makes the annual parallax of a celestial body?
How does the want of parallax show the great distance of the fixed stars?

orbit is 190 millions of miles, being twice the distance from the earth to the sun. But this distance is so minute when compared with that of the stars, that they always appear in exactly the same places during the whole year, that is, they have no parallax even when the eye is assisted by the most powerful instruments; and yet, we should be able to detect a difference between the true, and apparent places of these objects, by annual parallax, were they not more than 200 thousand times more distant from us than we are from the sun. That is, were the stars within the distance of 19,000,000,000,000, or 19 trillions of miles, their distances could be ascertained by their parallaxes. But their distances, as we have seen, are much greater than this.

REFRACTION.

Parallax, as we have shown, makes the heavenly bodies appear less elevated than they really are, but *refraction*, as will be seen directly, makes these bodies seem higher than their true places.. Refraction is caused by the *atmosphere*, with which the earth is everywhere surrounded, and a portion of which we take into our lungs at every breath.

It is said if the stars were within a certain distance, their annual parallax could be detected; what is this distance?
What effect does refraction have on the place of a celestial body?
What causes refraction?

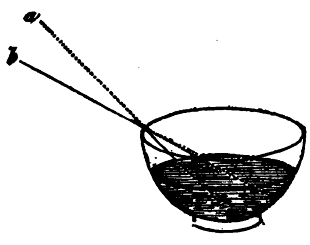
To make the subject of refraction understood, we must advert to one or two simple principles, belonging to the science of optics.

A *medium* is any transparent substance, or one through which light passes, as air, water, glass. Some media are more dense, or compact than others, thus water is more dense than air, and glass is more dense than water.

When light passes obliquely out of a rarer into a denser medium, it is refracted, or bent out of its former straight direction. When it passes from a denser into a rarer medium, it is also refracted but in the opposite direction from before.

A very simple experiment will illustrate the first kind of refraction, which is all that is required for our present purpose.

Fig. 32.



Place a small object as a penny, fig. 32, in a tea cup, and let another person fix his eye at *b*, so that he cannot see the money, but a little spot on the side of the cup above it. If now water be poured into the cup, the penny will

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When light passes from one medium into another of a different density how is it affected?
What is the experiment with the cup and penny?

seem to be elevated, so that it becomes visible with the eye still at *b*, while without the water the eye must have been raised to *a* in order to see it.

This apparent difference in the place of the coin, is caused by the refraction of the ray of light coming from it, which is bent downwards in its passage out of the water into the air; and as we see objects in the direction from which the light, causing its image, meets the eye, it appears in a direct line from *b*, though its true place is in the line from *a*.

In the application of this principle to the subject of atmospheric refraction, it will be plain from the above example, that if light pass through several media decreasing in density upwards, the refraction will be increased in proportion; or if the medium be uniformly increased in density downwards, instead of being made up of several distinct media, the same effect will be produced.

Now the atmosphere which surrounds the earth, and in which we live, is such a medium. Its density is greatest at the earth's surface, decreasing gradually and uniformly upwards to the height of forty or fifty miles. Hence the rays of light, from the rising or setting sun, or moon, as they enter this medium obliquely, form curved

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What is the cause of the apparent elevation of the penny?
In what direction does the atmosphere increase in density?
Why does the atmosphere, as a refracting medium, bend the rays of light downwards?
How high does the atmosphere reach above the earth?

lines in consequence of their refraction, and by which they are bent downwards, and made to take the form of the earth. We do not distinguish this curvature, because all objects appear to us, in the direction of the rays which form their images in the eye, as already explained.

As the rays are bent downwards, by atmospheric refraction, the effect is, to elevate the heavenly body above its real place, so that the sun and moon are seen before they actually rise above the horizon, and also some time after they sink below a straight line to the eye. Hence we see the sun and moon every clear morning and evening several minutes before they rise, and as many minutes after they set. From this cause, about six minutes are added, on an average to each day in the year.

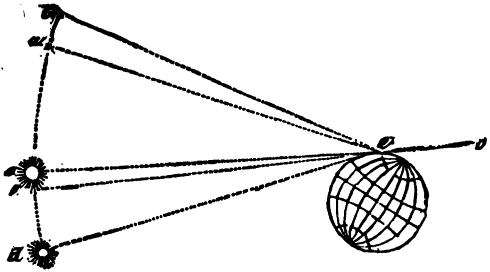
As the atmosphere diminishes in density upwards, and as the light from the heavenly bodies fall upon it obliquely until they attain a vertical position, we never see any of them in their true places, until they reach the zenith, at which time refraction ceases entirely, because then the light passes to us, through the atmosphere, in a direct line, and consequently no refraction is produced.

Why do we not distinguish the curvature which refraction makes in the rays of light?

What is the effect of atmospheric refraction on the place of the sun or moon?

How much are the days prolonged by this cause?

Fig. 33.



This will be made clear by fig. 33, where *o o*, is the real, or as it is termed, the *sensible* horizon, to a person situated on the earth at *e*. Now when the sun is actually below the horizon at *d*, and consequently not risen, it will be elevated by refraction above the horizontal line, and will appear at *c*, to the person situated at *e*. The same phenomena takes place with respect to the stars, that which appears at *b* being really situated at *a*.

The effect of atmospheric refraction is greatest when the atmosphere is most dense, and consequently increases in winter and diminishes in summer. From this cause, it is greater in high latitudes, or near the poles than at any other parts of the earth. Hence the people

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At what point only in the heavens do we see the heavenly bodies in their true places?
Why is there no refraction when the object is at the zenith?
When is the effect of refraction the greatest?
In what parts of the world is it greatest of all?

of Greenland sometimes see the sun when it is several hours below the horizon; a very providential, and comfortable circumstance in a climate, where his rays in winter are so little felt, and so much needed.

OVAL FORM OF THE SUN AND MOON.

Probably almost all of our readers have observed that the sun and moon at the moment of rising and setting, assume an oval form. This is another effect of atmospheric refraction.

We have seen above that the greater the density of the medium through which light passes, the greater will be the refraction.

Now the greatest density of the atmosphere, is of course nearest the earth, and from whence it diminishes gradually upwards in proportion to the height ascended.

The apparent diameter of the sun when viewed from the earth, is thirty-two minutes of a degree, but when on, or near the horizon, its vertical diameter varies from this, at least four minutes of a degree, and often much more, being shortened to this amount. Its horizontal diameter is not sensibly affected, because the density of the atmosphere does not vary in this direction. But the

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What occasions the apparent oval form of the sun and moon at the moment of their rising and setting?

What is the apparent difference between the vertical and horizontal diameters of the setting sun?

density being diminished upwards, the rays of light coming from the upper limb, or highest point of the sun's diameter, are refracted four minutes of a degree less than those coming from his lower limb, owing to the increased density of the atmosphere downwards. Consequently the apparent diameter of the sun in this direction will be only twenty-eight, while its horizontal diameter continues to be thirty-two, and thus the sun assumes an oval form.

The same observations will apply to the moon, under similar circumstances. But it will be remembered that the numbers above employed are rather for illustration, than for invariable truth, since the amount of refraction, and consequently the greater, or less oval form of these bodies will depend on the greater or less density of the atmosphere, which is greater in winter than in summer, but often varies greatly from one observation to another, though made on successive days. As the sun rises, the oval form diminishes, and is not apparent at the height of a few degrees above the horizon. The reason of this is, that the difference in the refractive power of the atmosphere, above and below the sun's disk, has no perceptible effect when far above the horizon, and continually diminishes to the zenith, when it ceases entirely,

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What is said of the amount of atmospheric refraction at different times?

Why does the oval form of the sun and moon diminish as they rise above the horizon?

because the rays of light pass directly, and not obliquely through the atmosphere.

WHY OBJECTS APPEAR DIM WHEN NEAR THE HORIZON.

When a ray of light passes through any medium, however transparent, a portion of it is absorbed, and consequently the whole is never transmitted. Thus we never experience the entire, original brilliancy of the sun's light, even at noon day, and when the sky is in appearance perfectly transparent, there being a portion absorbed by the forty-five miles of atmosphere through which it passes.

The more dense, and the less transparent the medium is, the less will be the quantity of light transmitted. The distance also, which the light has to pass through, it is obvious, will conspire to the same effect. Now a ray of light proceeding from a body, on, or near the horizon, passes through a much larger space of the atmosphere, than one from a body near the zenith. Besides this, the density of the atmosphere, as we have seen, is greatest on the horizon, and is always more or less obscured by exhalations of moisture from the earth, and of smoke arising from burning fuel.

Why do we not experience the full brilliancy of the sun on the earth?

What effect does a dense and obscure atmosphere have on the transmission of light?

From all these circumstances combined, the quantity of light flowing from the sun, or moon, is absorbed in much larger quantities when on, or near the horizon, than in the higher atmosphere; and it is from these causes that the heavenly bodies, as well as other objects, appear dim and obscure, when seen near the horizon.

ATMOSPHERIC REFLECTION.

The effect of atmospheric refraction as we have seen, is to shorten the duration of night, by prolonging the light of the sun on the earth.

But even after the refracted rays have ceased to illuminate us, by their direct influence, the light of the sun does not entirely cease, but is continued for a time by *reflection* from the vapors of the atmosphere, and perhaps also from minute, solid particles, floating in it.

To make this understood, we must remember that it is not only by the *direct* light of a luminous body, that we are enabled to see, but by that also which is diffused through the air, and reflected from surrounding objects.

That the atmosphere always contains floating particles, capable of reflecting light, may be proved by admitting a small ray of the sun through a window shutter into a darkened room, where it will appear as a bright line through the room, and in which millions of minute

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Why do objects appear dim when near the horizon?
How is the light continued after the sun sets?
How is it shown that the air contains particles of dust?

particles will be seen to float, and from which by reflection, the whole room will be more or less illuminated, in consequence of the light thus diffused.

The luminous lines, says Dr. Herschel, occasionally seen in the air, in a sky full of broken clouds, which the vulgar term "the sun drawing water," are similarly caused. They are sun-beams, through apertures in clouds, partially intercepted, and reflected on the dust and vapors of the air below.

Thus it is with those solar rays, which after the sun itself is concealed by the convexity of the earth, continue to traverse the higher regions of the atmosphere, and pass through and out of it, without striking on the earth at all.

TWILIGHT.

The diffusion of light in the atmosphere, by the sun's rays, and its reflection to the earth, form what is usually termed *twilight*, and in consequence, we continue to see, even distant objects, for some time after the sun has set.

Were it not for this reflecting and dispersing power of the atmosphere, no objects would be visible to us out of the direct sunshine; every shadow of a passing cloud, which intercepted the sun's rays, would produce pitchy

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How do you explain what is called the sun's drawing water?
What is twilight?
Did not the atmosphere reflect light, what would be the consequence in respect to objects out of the sun's rays?

darkness; the stars would be visible during the whole day; and every apartment into which the sun did not shine, would be involved in nocturnal obscurity.

This diffusive action of the atmosphere, on the solar rays, is much increased by the irregular currents of air, caused by different degrees of heat and cold on the earth's surface, and by which the light is variously reflected and refracted, instead of passing in straight lines, as it would do, were not these currents in the atmosphere.

TIDES.

The sea flows for six hours from east to west, and as it flows, the water rises, and finding its way into the harbors and bays along its shore, overflows their flats and banks, which before were naked. Having reached a certain height, which is varied by different causes, the water stands still for a time, and then begins to retire, or run back again from west to east, for six hours more. This alternate flowing and ebbing of the sea, constitutes the *tides*.

The cause of the tides, is the attraction of the sun and moon on the waters of the ocean, but chiefly that of the moon.

Under the article "Attraction of Gravitation," we have shown that this property is inherent in every form

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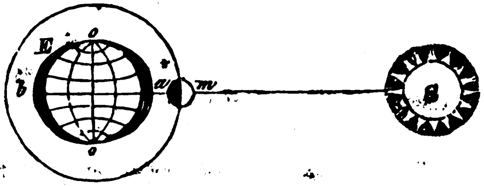
What constitute the tides?
What is the cause of the tides?

of matter, and that it extends from one planet to another. Thus the earth attracts the sun, moon and other planets, and these reciprocally attract the earth. But the earth is kept in her orbit by her centripetal force, and therefore is not drawn away towards the planets; but the waters of the ocean being free to move, obey the power of attraction, and the moon being nearest the earth, her attraction causes the waters to rise, or accumulate where this influence is strongest. It is therefore, always high tide nearly under the moon, over whatever part of the earth she may happen to be.

Fig. 34.



To illustrate this by a diagram, let S, fig. 34, be the sun, *m*, the moon, and E the earth, surrounded by water. The sun and moon are represented in conjunction, so that their united attractive forces are exerted on the earth. The elevation of the water at *a*, represented in the cut, is the immediate effect of this influence.

At the same time that the waters are raised by this at-

Where is it high tide with respect to the moon ?
What does fig. 34 represent ?

tractive force on that side of the earth nearest the sun and moon, they are elevated on the opposite side of the earth by another cause. This cause is the absence of the moon's attractive force on that side, together with the revolution of the earth on her axis, by which the water is accumulated on the part of the earth most distant from the moon. Thus it is high water on the two opposite sides of the earth at the same time.

Now in consequence of the elevation of the sea on the two opposite sides of the earth at the same time, the water is drawn away, and consequently depressed, on the two other opposite sides *o o*, so that while it is high water at the equator, it is low water at the poles, as represented by the figure. Thus when it is high tide at *a b*, it will be low tide at *o o*, and as the water is always elevated under the moon, and as the earth revolves once in twenty-four hours, there will be an alternate ebbing and flowing of the waters at every place around the globe, once in six hours.

The attraction of the sun alone does not raise the tides, but when added to that of the moon, as when they are in conjunction, there happens a greater elevation of the water than ordinary. These are called *spring* tides.

Where the influence of the moon causes a tide on one side of the earth, from what cause is there a tide on the opposite side at the same time?

When the sun and moon are in conjunction, what is the consequence on the tides?

When the sun and moon are in opposition, that is, when the sun is on one side of the earth, and the moon on the other, then, owing to the two attractive forces being in opposite directions, the influence of both on the waters are counteracted, and consequently the tides become smaller than usual. These are called *neap* tides.

The chief cause, however, of the differences in the height of tides, is the local situation of the shore. In some places, the tidal waves running up a channel which is constantly diminishing in capacity, causes the water to rise to a great height. At Annapolis, for instance, in the Bay of Fundy, such a situation of the land and water, it is said, causes the tide sometimes to rise one hundred and twenty feet. At Bristol, in England, the difference between the highest and lowest tide is fifty feet. In most places, however, and under ordinary circumstances, the difference between high and low water, is only from two to five or six feet.

In lakes there are no tides, because in small bodies of water, the influence of the sun and moon are not sufficient to cause such an effect.

The attractive influence of these bodies on the atmosphere which surrounds the earth, is sufficient to produce

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What are neap tides?
What causes the highest tides in different parts of the earth?
At what place is it said tides rise one hundred and twenty feet?
Why are there no tides on lakes?
What is said of atmospheric tides?

slight tides in the air, and which delicate observations have rendered sensible, and measurable.

USES OF THE TIDES.

The tides of the ocean are of great consequence, both in respect to the purity of the water, and to navigation. In obedience to the attractive forces of the sun and moon, the waters of the ocean are kept perpetually in motion around the whole earth, and are thus kept from stagnation, and consequent fermentation, by which they would become unwholesome. The shores are also washed by this process, twice a day, and are thus kept free from accumulations of animal and vegetable substances, which would otherwise ferment and cause pestilence.

The tides are also often of the greatest use to seamen in the navigation of shoal waters, where if the vessel strikes the sand during the ebb tide, the mariner has only to wait patiently, until the water rises, in order to get off in safety.

In convenient situations, tide-mills, and docks for the use of ships, are made by means of dams and gates, by which the water is admitted, and confined, or let out at pleasure.

What are the uses of the tides?

GENERAL VIEW OF THE SOLAR SYSTEM AND OF THE UNIVERSE.

Having in the preceding pages given an account of the sun, and all the planets which revolve around him, let us now direct our attention to the arrangement of the solar system, and its relation to the stars.

That vast globe the sun, which we have seen, is much larger than all the planets and their satellites together, has a revolution on its axis, once in nearly twenty-five and a half of our days. Its surface appears to be covered with an ocean of luminous matter, which is often in motion, and sometimes seems to divide so as to discover to us, the dark body of the sun itself. This however, may be a deception, since these dark spots may arise from other causes, and of which we terrestrials know nothing. It is certain that the face of the sun occasionally presents immense patches of a color nearly black, and that they suddenly change their forms, and even vanish entirely, while others appear, where none were to be seen before, but from what causes these phenomena proceed, nothing but conjecture can be offered.

Above, or around the sun, there exists an immense space in which the planets move with their moons, in orbits nearly circular, and in planes little inclined to the ecliptic.

Besides the planets, which we may here call regular, and orderly members of the solar system, there is an unknown company of eccentric bodies called *comets*, which also belong to our system. These visit us occasionally, the times of most of their returns being unknown. They, however, have regular and fixed periods, like the planets, but astronomy is not yet old enough to have discovered these periods, except in a few instances, where they return at short intervals.

The sun acts upon these bodies, and compels them to return, though some of them are supposed to fly off in a direction from him continually, for the space of two hundred and fifty years, the periodic times of such being five hundred years.

From this, we may perhaps have some faint idea of the vast distance to which the attraction of the sun extends, and also the distances of the fixed stars from our system, for did the comets extend their excursions beyond the sun's attractive influence, they would never again return to our system, but would approach the nearest attractive body, around which they would continue their revolutions. But since some comets have returned, after an absence of five hundred years, it is certain that they continued nearer our system than any other, as the mere fact of their return abundantly proves.

It is certain, therefore, that the sun keeps these eccentric bodies within his own attractive influence.

All the heat and light which the planets enjoy, from the melting temperature of Mercury, to the frozen regions of Herschel, they derive exclusively from the sun, and since we know that this influence is the cause of vegetation, and the great source on which depend the lives and comfort of all living existences on the earth, we have reason to believe, by analogy, that the same, or similar effects, are produced by the same cause, on the other planets. We know that Jupiter revolves on his axis, and consequently that there is there, a succession of day and night, as well as here, and so far as is known, this is the case with all the planets; they turn their surfaces in succession towards the sun. Now in the instance of the earth, we are certain that this diurnal revolution was expressly designed to give all its parts the advantage of heat and light; and since the same motion exists in the other planets, there is every reason to believe that it answers the same purpose. Hence we may justly infer that the planets are inhabited by reasonable, and if so, by responsible beings, but what their physical endowments may be, by which they are enabled severally to exist in a climate like that of Mercury, where lead would probably be in a state of constant fusion, or in that of Herschel, where possibly our atmosphere would become solid by freezing, we must of course remain in ignorance.

Man is formed for the temperature he enjoys on earth, nor would his habits, or his physical organization allow him to live comfortably in the climate of any of the other planets. But the same Power which adapted man to his residence on the earth, could as easily adapt the organizations of intelligent beings to the temperatures and climates of each and every other planet, as to ours. And as this adaptation must apply to all orders of animals, and even to plants, as well as to intellectual beings, how different, and how wonderful must be the productions of the other planets, when compared with ours. But on this subject even our imaginations are useless, however active.

But however arbitrary the systems peculiar to each planet may be, and however different we may imagine the productions of one from the other, still there exists several remarkable coincidences, and relations between them. Thus all these bodies move round the sun from west to east, and nearly in the same plane, and all the satellites move round their primaries in the same direction, and nearly in the same plane with the planets. All the planets also, and their satellites, so far as has been discovered, have a revolution on their own axes, and lastly, the sun has a rotation, in common with, and in the same direction as all the other members of the solar system.

A phenomenon so extraordinary, and at the same time, without knowing the facts, so unexpected, cannot for a moment be attributed to the effect of chance. It indicates an universal, intelligent, and all wise cause, which gave the planets their motions, and established the order and directions of their movements by invariable and eternal laws.

OF THE STARS.

If now we look beyond the solar system, we behold innumerable suns, in the form of minute brilliant points, with which the dark vault of the celestial sphere is every where studded.

These are undoubtedly the centres around which systems of planets revolve, as our sun is the focus of a similar system.

That the fixed stars are vast globes of fire, and that they shine by their own light, like our sun, and not by a borrowed light, like our moon, there can be no doubt. Their distances are so immense, as to preclude the least probability that their light, unless fully as brilliant as that of the sun, would reach us. Did they shine by a reflected light, their existences therefore, would never have been known to us.

No one can believe that the stars were created with any reference to the solar system, or at least to the inhabitants of this earth. Without the assistance of astronomical instruments, only a very small number of them ever appear to our eyes, and therefore to the ancients, who knew nothing of such instruments, only this number were ever seen, and the existence of others were unknown and unsuspected.

The little light which comes down to us from the stars, would have been much more than compensated by one additional moon, and as we have every reason to believe, that, not only nothing was made in vain, but that every act of creation was destined to answer the purpose designed, and no more, so we cannot believe that the hosts of heaven, visible and invisible, could ever have been designed merely for the purposes which they subserve to our world.

Some stars have been observed to undergo periodical variations, both in color and brilliancy. Others have suddenly appeared where none existed before, and after shining for a time, have as suddenly disappeared, and so far as is known, never again made their appearances. Some of the stars shine with a small degree of light, which gradually increases for a certain period, when it again diminishes for the same length of time, and thus continues waxing and waning perpetually.

The distances of some of the stars are so immense, that a cannon ball flying at the usual rate, would not probably have passed from them to us during the period since the creation of the world. Even light which passes at the rate of two thousand miles per second, would not have reached us from the nearest star, to the present time, though it had began its journey at the period when Columbus first discovered America. Other stars are known to be so distant that it would occupy light more than a thousand years to travel from them down to us; and it is not impossible but others may be so distant that their light has not yet reached us since the creation.

The relative distances of the stars which form each group, or nebula, are supposed to be at least a hundred thousand times greater from each other, than the sun is from us. Thus some idea may be formed of the vast extent of these groups, by the number of stars they contain, which, especially in some parts of the Milky-way, amount to thousands in a few yards square. But the imagination is lost, in the contemplation of such boundless space, and we can only say "Lord what is man that thou art mindful of him!"

STABILITY OF THE SOLAR SYSTEM.

It has been thought by some former astronomers, that the motions of several of the planets were becoming gradually slower than formerly, so that the actual times of their periodic revolutions were shorter than they were centuries ago; and that this depreciation of velocity, though so gradual as hardly to be detected for a short period, was yet sufficient so to derange the stability of the solar system, as finally to bring it to an end, at some future period.

Recent observations, however, have shown that these changes are periodical, and that as a whole, the mechanism of the system remains without the least appreciable derangement. But for the purpose of showing this, we must go into explanations of some length.

If each planet were to revolve round the sun without being affected by the other planets, there would be a certain degree of regularity in its motions, and for aught we can see, this regularity would continue forever. But it appears, by the discovery of the law of universal gravitation, that the planets do not execute their movements in this insulated and independent manner. On the contrary, each planet is acted upon by the attraction of all the rest. The Earth is constantly drawn by Venus, by Mars, and by Jupiter, bodies of various magnitudes, perpetually changing their distances, and their positions with regard to the Earth; the Earth in return is perpetually acting upon, and drawing these bodies with a force proportionate to their quantities of matter. Now the inquiry arises, what in the course of time will be the result of these mutual attractions?

All the planets are of diminutive size when compared with the sun, and therefore, as the sun holds them all, as it were in subjection, the derangement which they produce in the motion of any one of their number must be very small in the course of a single revolution. But this gives us no security that the derangement will not become great and material, in the course of many revolutions. The cause acts perpetually, and has perpetual time to work in. Is it not conceivable then, that in the lapse of ages, the derangements of the motions of the planets may accumulate; their orbits change their forms, and their mutual distances become so increased or diminished, as to produce great irregularities; and finally, is it not possible that these disorders may go on without limit, and result in the complete subversion and destruction of the solar system?

If for instance, the result of this mutual attraction should be to greatly increase the eccentricity of the earth's orbit, or in other words, to make its oval form greater and greater, or to make the moon approach perpetually, nearer and nearer to the earth at every revolution, then if no compensating power exists, the moon would finally fall upon the earth, or the earth, from year to year, receding to a greater distance from the sun, would fall upon that planet whose gravitating power was strongest.

If the motions of the other planets should in like manner become deranged, which of course would be the case, then some of them might approach so near us as to hasten our catastrophe, and we should have the premonitions of years of unequal length, and seasons of uncommon temperature, while we should behold planets and moons of portentous size and aspect, glaring upon us at uncertain intervals—tides rising like deluges, and sweeping our continents, and finally, a total derangement of all natural order, in regard to times, seasons, and climate.

Now an ordinary examination of the facts, with respect to the changes which have been taking place in the solar system, would tend to show that there is a tendency to indefinite derangement among its members. From the first dawn of science, to the present time, it has been known that changes have been progressively going on, in the motions of some of the heavenly bodies. Thus the eccentricity of the earth's orbit has been diminishing from the time of the earliest observations; and the moon has moved with a constantly increasing velocity, from the date of the first eclipses, and is now in advance, by about four times her own breadth, of what her place would have been, had her motion not been accelerated. The obliquity of the ecliptic also, is in a state of diminution, and is now about two fifths of a degree less than it was two thousand years ago.

Now one can hardly avoid asking the question,—will these changes go on without reaction and without limit? If so, it is plain that our system is tending towards dissolution, and the termination of the present order of things must finally be the result.

But is this so, is the order of nature which from the beginning has given us times and seasons, and days and years, with so much regularity to fail, and that beautiful symmetry which was established on Nature's law, at the creation, to be deranged, and finally to become extinct?

To show how far the perturbations at present existing among the heavenly bodies will progress, and still these bodies be within the government and control of those natural laws by which all their movements are graduated, is a mathematical question of no easy solution.

The question amounts to this—having the velocities and directions of about thirty bodies, all attracting each other, given, to find their places and directions and velocities, after any given length of time.

This, it must be seen, is a problem of extreme complexity, especially when it is considered that any new arrangement, or change of motion in one of the bodies, will, by its action, give a new direction to all the others. The mathematical investigation of such a question was by far too difficult for the earlier periods of physical astronomy. Its decision required a great number of preparatory steps, which only the most refined mathematics could solve, and it is only within a recent period, that a sufficient degree of knowledge, together with instruments of sufficient power and accuracy, have been in the possession of astronomers, to enable them to undertake the solution of this question with any hope of success.

It is, however, now understood by astronomers, that the two French mathematicians, Lagrange and Laplace, have demonstrated the stability of the solar system, beyond all doubt. They have shown that in long periods, the orbits of the planets remain unchanged, and that the slight changes which take place during short periods, never transgress certain bounds. Each orbit suffers deviations, in one direction or another, almost constantly, but these are never very considerable, and there appears to exist a conservative power, which corrects such eccentricities, and preserves on the whole, an average velocity, and an average period of revolution.

The planets produce constant perturbations in each other's motions, but these are not indefinitely progressive, being allowed to reach only a certain limit, after which such irregularities diminish, and the original boundaries are again preserved. The periods of time during which these derangements are in progress, amount to centuries, and even thousands of years, and similar periods are required for their restoration. But the order in the sequel, is as complete as the derangement, and the disturbance is never such as to produce effects, which can be detected without nice astronomical observations, and therefore, never such as to endanger the stability of the system.

There exists, therefore, in the solar system, a compensation, or provision for the slight irregularities which the planets undergo in their motions, and this provision is such, as to ensure the permanent, and for aught we can see, the eternal stability of the system.

Now is it probable that the conditions on which the stability of this system depends, can, under any possible view of the case, be the product of chance? Is it possible that nearly thirty bodies, moving in open space, all of different sizes, and all moving at different rates, and in orbits of unlike forms, and no two of them having the same annual, or diurnal periods, should have happened by chance, to have so exactly balanced each other by their mutual attractions, that their motions should never suffer any material variations, but become perpetual, and unceasing, even for thousands of years? He who does not see the doings of an Almighty hand, and the effects of Infinite Wisdom in the fact, that these vast bodies have moved around each other, through void space, for so many years, and with such perfect order, must indeed be either blind or mad.

THE AIR BALLOON.

The subject of balloons, though not closely connected with Astronomy, yet involves several points with respect to the atmosphere, with which young persons should be acquainted; and as the subject is of considerable interest in itself, the author has thought proper here to give such an account of the invention, and of the subject generally, as is sufficient for common inquirers.

The circumstances under which a body immersed in a fluid, will rise towards the surface, or sink to the bottom, are easily comprehended. If the body immersed, has greater weight than the same bulk of the fluid, it will sink, if it has less weight, it will rise. Thus a quantity of quicksilver, of the size of a leaden bullet, (no matter what the size may be,) is heavier than the lead, and therefore, such a bullet, or any other piece of lead, will rise to the surface of a dish of quicksilver. On the contrary, any given bulk of the metal called platina, is heavier than the same bulk of quicksilver, and therefore a piece of platina will sink in a vessel of quicksilver.

To apply this principle to the rise of balloons in the atmosphere, it is only necessary that the bulk of the balloon should be lighter than the same bulk of air. It will make no difference of what material the balloon is composed, provided it has this single property.

If for instance, we take a bag of some material that is impervious to air, and of such dimensions and lightness, that when distended its bulk will displace a quantity of the atmosphere, which will weigh more than the actual weight of the material of which it is composed, and fill this with heated air, we shall form a balloon which will rise to a certain height, through the atmosphere.

Thus a soap bubble, though of small dimensions, is composed of so thin and light a material, that the warm breath with which it is blown up, will at first cause it to rise, especially in cold weather, when the weight of the atmosphere is great, and therefore, when there is a considerable difference between the heat of the air in the bubble, and that by which it is surrounded.

Soap bubbles filled with the gas called *hydrogen*, at any common temperature, will rise rapidly, and to a considerable height in the air. This is the gas, as we shall see in the sequel, with which balloons are filled at the present day.

It does not appear that the ancients ever attempted the construction of a balloon, or that any one conceived, until a comparatively recent date, the possibility of rising in the air, by any means similar to that now employed for this purpose.

The method it appears, which first suggested itself, for this purpose, was to exhaust an air tight vessel of its air, and thus forming a vacuum in its interior, to produce such a difference between the weight of the vessel and the atmosphere, as to induce it to rise. The vessel of course, must be of such stability as to remain distended under the pressure of the atmosphere, and of considerable bulk, otherwise there could be no probability of its displacing such a quantity of the atmosphere as to compensate for its weight of material.

This was the method adopted by the first experimenter, in his attempt to construct such a machine. A Jesuit named Francis Lana, about the middle of the seventeenth century, caused to be constructed, with great labor, four hollow balls of copper, each twenty feet in diameter, and so thin that the total weight of the copper composing them, was less than that of the bulk of the atmosphere, which they would displace, if kept fully distended.

He proposed to attach these globes to a boat furnished with a sail, and by such means he hoped to navigate the air, and traverse the clouds.

But it is hardly necessary to inform, even the youngest pupil of the present day, that the pressure of the atmosphere, being fifteen pounds to the inch, would instantly crush such a ball, on removing the air from the interior. Indeed, had Lana's globes been an inch in thickness, or double that of a steam boiler, they would not have withstood the pressure of the atmosphere for a single instant. (See Youth's Book of Philosophy, article Pneumatics.)

We may state generally, that no substance with which we are acquainted, possesses sufficient strength to sustain the pressure of the atmosphere from without, when this is not balanced by a corresponding pressure within, unless its thickness, and consequently weight, be such as far to exceed that of the bulk of air which it displaces.

In order therefore, to give buoyancy to a large hollow body, and at the same time to secure it from the effects of atmospheric pressure, it must be filled with some elastic fluid, which by its elasticity will counteract, or balance the effect of external pressure. In this case, since the two forces, that is, the force of interior resistance, and of external pressure, must be nearly equal, no considerable strength is required in the material of which such a vessel is made.

If it be impervious, or nearly so, to a slight pressure of air from the inside, this is all that is required. Even the buoyancy of a volume of heated air, if prevented from expanding, and thus diffusing itself in the atmosphere, will carry up a weight with it, in proportion to its bulk, as already stated.

Next to the experiment with the copper globes, this indeed seems to have been the first method by which an attempt was made to rise in the air, and its success prepared the way for the more perfect method now employed.

In the year 1782, two brothers, Stephen and Joseph Montgolfier, paper makers by trade, and natives of France, constructed a bag of silk, in the form of a square box, containing about forty cubic feet when distended, and having an aperture on the lower side. Under the aperture they placed burning paper, which caused it to ascend to the height of nearly one hundred feet. The same experiment was immediately tried on a larger scale, and a balloon constructed in a similar manner, but containing about six hundred square feet, ascended to the height of six hundred feet.

Encouraged by this success, the brothers now resolved to try the experiment on a more extended and decisive scale, and accordingly, a machine was prepared of linen, lined with paper, which was one hundred and seventeen feet in circumference, and of a globular form. It weighed four hundred and fifty pounds, and carried upwards of four hundred pounds of ballast. This they sent up on the 5th of June, 1783, from their town, Annona, and had the high satisfaction of seeing rise, in about ten minutes, to the height of six thousand feet, or about one mile.

The means by which they caused it to ascend, was to kindle a straw fire, on a platform under the aperture, into which they from time to time, threw handfuls of chopped wool. But though the desired effect was produced, it does not appear that they, or others, at that time, had any correct ideas of the cause. The ascent was not attributed to the heat, and consequent rarefaction of the air, but to the agency of the peculiar air or gas, which they supposed to be developed by the burning of the straw and wool; nor was this error discovered, until shown by the experiments of a later date.

These experiments attracted the attention of the philosophers and professors of Paris, and it immediately occurred to some of them, that the same effect might be produced by means of *hydrogen*, a gas much lighter than atmospheric air, and which is obtained by dissolving zinc, or iron filings, in sulphuric acid. Accordingly, M. Charles, professor of Natural Philosophy, filled a bag, of silk fabric, coated with gum elastic varnish, and twelve feet in diameter, with hydrogen. The apparatus weighed twenty-five pounds, and rose upwards of three thousand feet, in about two minutes, and disappeared among the clouds. After an absence of three quarters of an hour, it again descended to the earth, at the distance of fifteen miles from Paris.

Thus the curious were gratified with two kinds of balloons, one to be raised by means of heated air, and the other by hydrogen gas.

Hitherto, the experiments had extended no further than to ascertain the possibility of ascending in the atmosphere, no animal, except perhaps some luckless dog, having undertaken an aerial voyage. But in 1783, Montgolfier having gone to Paris, found an assistant in M. Rozier, the superintendent of the Royal Museum. They completed together a balloon, which was seventy-four feet high, and forty-eight in diameter. Its shape was elliptical, with an aperture at the bottom, below which was suspended an iron grate, within reach of the hand of the aeronaut. A fire being made on the grate, the machine rose, and M. Rozier with it, to the height of from fifty to one hundred feet; and thus it was ascertained, for the first time, that a machine could be constructed, by means of which a man could ride through the air.

This experiment produced great interest and excitement, in the city of Paris, and the construction of another balloon, of larger dimensions, was immediately commenced, to be raised by means of fire, in the same manner, though M. Charles had previously shown that hydrogen, without the danger of flame, would produce the same effect.

An aerial voyage was now determined on, and every thing being prepared, M. de Rozier, and the Marquis de

Arlandes, ascended from the castle la Mulette, near Paris, in the presence of an innumerable multitude. The balloon having attained the height of about three thousand feet, floated off with the wind, and came down in twenty-five minutes, at the distance of nearly five miles from the place of ascent. But the aeronauts were exposed to great danger. The balloon was several times violently agitated by the wind, and took fire in several places. Finally, at the moment of their reaching the earth, the whole fell into the flame and was consumed, M. Rozier escaping with difficulty, and this appears to have been the only ascent to any considerable height, in a fire balloon.

Meantime, M. Charles and M. Robert, informed the citizens of Paris, that they would ascend in a balloon charged with hydrogen gas, and a subscription was accordingly opened, to defray the expense. Their balloon was formed of silk, made impervious by gum elastic varnish; of a globular form, and twenty-five feet in diameter. The car for the aeronauts, was attached by cords to a netting, drawn over the top of the balloon, and thus suspended under it. A valve was constructed at the upper part, to which was attached a string leading to the car, so that on rising where the atmosphere was less dense than at the surface of the earth, the gas might be allowed to escape. This was a necessary precaution, for as the atmosphere grows more rare the higher we ascend, the pressure becomes diminished in proportion, and without such a provision, the expansion of the gas in the balloon, under such diminished pressure, would have burst the silk. This valve also served the purpose of allowing the gas to escape, in order to bring the balloon to the earth.

The filling of the balloon with the gas, occupied several days, at the end of which, the ascent was made from the garden of the Tuileries, in the midst of a vast concourse of spectators, M. Rozier and M. Robert being in the car.

It rose with great rapidity to the height of 1800 feet, when it was lost from the sight of the spectators, being hid in a cloud, but it soon came down, a few miles from Paris, and M. Robert stepping out of the car, and the balloon thus being lightened of one hundred and thirty pounds, instantly rose again, and ascended to the height of 9000 feet, or nearly two miles. At this elevation, the gas expanded with such force, that had not M. Charles had the presence of mind to open the valve, the silk must inevitably have been torn, and the aerial voyager been precipitated to the earth, but after attaining an elevation in which no mortal before had reached, he came down in safety, about three miles from the place of his second ascent.

After this success, many balloons were constructed in different parts of the world, and many daring aerial voyages were performed. Among these, that of M. Blanchard, and Dr. Jefferies, an American, are among the most noted. These gentlemen made the bold proposition of crossing the British channel, between England and France, the width of which is twenty-three miles, in a gas balloon, and in this they succeeded without accident. Leaving the English coast, at one o'clock, with a fair wind, they landed on the French side, at half past two.

In 1785, two Frenchmen, M. Rozier, formerly mentioned as the first aeronaut, and M. Romain, proposed to pass from the French to the English side of the same channel; but in this they were unsuccessful, and their attempt was the occasion of a sad and memorable catastrophe.

It was the proposition of M. Rozier, to combine the two kinds of balloons, in the proposed voyage. The gas balloon, fitted up in the usual manner, was placed over another to be raised by fire, in the manner already described. The reason for this combination was, that at that time the gas balloon was not supposed to have sufficient elevating power, and besides, if this balloon came to the ground there was no possibility of raising it again, without an additional supply of gas, which it would take a day or two to procure. Whereas, by the fire balloon, Rozier supposed he could rise and sink at pleasure, by kindling more or less fire, while the gas balloon above would serve as a means of safety, in case of any accident.

But this experiment caused the death of both these individuals, for soon after the two balloons rose, the lower one caught fire, and was consumed in the air, while the gas of the upper one was exploded by the flame, and the two adventurers suffered instant death, probably by the explosion, and before they reached the ground.

Since the time of Rozier, bags of sand or other ballast, has been employed, so that when the balloon is found to be sinking too rapidly, it is made to rise again, or maintain its elevation by throwing out a small weight at a time, as circumstances require.

PARACHUTE.

The principal cause of danger attending aerial voyages, in the more perfect balloons now employed, arises from the accidental escape of the gas, either from the bursting of the fabric, imperfection of the valve, or some other unforeseen cause. Consequently, soon after the invention of balloons, it became a subject of inquiry whether some remedy or security could not be provided, in case of such accidents; and with this view, M. Blanchard contrived the apparatus called the *parachute*. This is little more than a large umbrella, which spreads above the car, with its concave side downwards. The effect of this, when fully spread, is to act against the air, and prevent a rapid descent. It rather floats, than falls with increasing rapidity, like a solid body, so that there is little danger from concussion against the ground, and therefore, if the person descends on land, his safety is nearly insured.

The subjects of the first experiments with the parachute were inferior animals. M. Blanchard, the inventor, having ascended to the height of six thousand feet in a balloon, dropped a dog suspended to a parachute, from this elevation. In its descent, the parachute was struck by a whirlwind, which carried it above the clouds, but soon after the two voyagers met, when the poor dog recognized his fellow traveller, and showed great solicitude either at his own situation, or that of his master; but another current separating them, the dog was carried out of sight, and did not reach the ground until after his master, which they both did in safety.

Sometime afterwards M. Garnerin made several experiments with the parachute. Having placed it half expanded above him, and between himself and the balloon, he had the intrepidity to cut the connection between himself and the balloon, at the height of two thousand feet from the ground. He descended slowly, the parachute gradually unfolding and finally reached the ground in safety.

The same daring aeronaut repeated similar experiments many times, and from various heights, in one instance descending, suspended to his parachute, from the elevation of eight thousand feet, or nearly a mile and a half.

As the balloon derives its power of ascending from the weight and pressure of the atmosphere, so the parachute in like manner, derives its properties from the same source. An apple will swim on the water, a leaden bullet will swim on the surface of quicksilver, and a gas balloon will float in the atmosphere, because in each case the floating body is lighter, bulk for bulk, than that in which it floats. But in addition to this, the parachute derives an additional power from the circumstance of its covering a large extent of surface, when compared with its actual weight; and also from its form, by which the air is made to rush from the circumference towards the centre, where its concentration and increased density offers a strong impediment to the rapid fall of the whole.

Another cause of the slow descent of the parachute, not often taken into account in explaining the fact, is the constantly increasing density of the atmosphere from above, downwards, so that it every instant meets with an additional resistance, as it approaches the earth. In consequence of these causes, the parachute descends in a regular and uniform manner, and not with a constantly increasing velocity, like that of a falling solid. Of course, the fall will be slow in proportion as the parachute is large, and the weight of the car and its contents is small.

As the gas by which the balloon is inflated, is lighter than the atmosphere, the valve provided for its escape, when the voyager wishes to descend, must be placed towards the top of the balloon. If it were placed in the lower part, even though it were open, the gas would not escape, at least not in any considerable quantity, nor with any degree of certainty. The superior weight and pressure of the atmosphere, compared with the levity of the gas, would prevent the latter from flowing downwards. A cup filled with hydrogen, with the mouth kept downwards, will retain its contents for a considerable time, and until it is gradually dissipated by mixing with the atmosphere, which presses against its under surface, but if the mouth of the vessel be turned upwards, the gas escapes instantly. It is plain, therefore, that the valve would be nearly useless unless placed in the upper part of the balloon.

The car which bears the person and ballast, is supported by a network of strong twine, which extends over the balloon, and from which it is suspended beneath, by means of ropes. In case of a violent wind, this part is often shaken and tossed to and fro, in a manner not a little appalling to the new voyager in the upper regions.

The total impracticability of guiding or governing balloons, in their course through the air, has hitherto prevented them from being applied to purposes of extensive utility. Nor does it appear probable that any means will be invented to remedy this radical defect; since the weight of any machinery of sufficient power to propel so large a body against the wind, would be too great to be sustained by atmospheric pressure. Besides, were it possible by wings, or other means, to do this near the surface, yet on descending, it is often found that the current of air is in a contrary direction, and still in some other direction on reaching another stratum of the atmosphere, so that to keep the same course, the active force of the balloon must be constantly changing.

Scientific men have attempted to throw light on various natural phenomena and agents, as temperature, electricity, magnetism, and atmospheric pressure, by means of the balloon. In 1804, two French philosophers, Gay Lussac, and Biot, made an ascent from Paris, furnished with various meteorological instruments, with the view of making scientific observations in the air. They ascended to the height of 13,000 feet, and afterwards Gay Lussuc alone, reached the enormous altitude of 23,000 feet above Paris; but it does not appear that the observations made during these voyages have resulted in any useful improvements to the sciences.

After the balloon had been so long in use as to show by experiment, that there was no considerable danger in making aerial voyages, exhibitions of the kind became quite common from all the large cities in Europe, so that an ascent under ordinary circumstances, attracted but comparatively little notice. It therefore became necessary for those who would attract public notice, to rise under some conditions of novelty or danger. Thus M. Garnerin, probably the most experienced and daring of aeronauts, made an ascent from London, and when at an immense height, and in sight of an innumerable multitude, he cut the connection between himself and the balloon, and came down in his parachute.

At first, and before the parachute unfolded, he fell with amazing velocity, being at a height where the atmosphere afforded little resistance to his descent. When however, the parachute opened, he came down gradually, though not without several severe bruises on reaching the ground.

During this descent, the parachute, cord, and basket containing M. Garnerin, vibrated like the extended pendulum of a clock, the man acting as the weight; and so great were these vibrations, that more than once the basket and parachute were nearly or quite on a horizontal level. Had these vibrations continued, it is easy to see what would have been the probable fate of M. Garnerin, but they nearly ceased as he approached the ground.

Besides the aerial excursions which M. Garnerin made from Paris and London, which were many, he performed upwards of seventy such voyages, in different parts of Russia, chiefly from Moscow and St. Petersburgh.

Not contented with aerial excursions by day, this veteran aeronaut performed several such voyages by night. On the 4th of August, 1807, he ascended from the vicinity of Paris, at eleven o'clock at night, his balloon being illuminated by twenty lamps, placed at such a distance as to obviate all danger from communicating with the hydrogen gas. He ascended to the height of 15,000 feet above the level of the earth, and after remaining in the air seven and a half hours, came down at the distance of 125 miles from the place of ascent, without accident.

But in a subsequent nocturnal excursion, M. Garnerin was placed in a situation at once the most perilous and awful, from which any human being ever escaped; nor indeed was any other man, ever placed in a similar predicament.

On the 21st of September, he made an ascent from the vicinity of Paris, at ten o'clock at night. He refused to be accompanied by any person, though solicited to do so, on account of the appearance of an approaching storm, being unwilling that any life but his own should be hazarded. He therefore took his departure alone, and was carried up with astonishing rapidity to a great height above the clouds which were gathering for a storm. M. Garnerin now found that his balloon was distended to an alarming degree, and that it was in imminent danger of bursting, unless some of the gas was set at liberty. But having been prevented by the turbulence of the mob, from regulating certain parts of his machinery, by which the gas could be allowed to escape, without coming into contact with the flame of the lamps, he now to his dismay, found that the gas which is extremely inflammable, could not be let off without the utmost danger of taking fire from some of the lamps, in which case it would inevitably explode the whole contents of the balloon, the very idea of which, being 15,000 or 20,000 feet from the earth, would be sufficient to distract and bewilder a mind less cool and deliberate, than that of Garnerin. In this awful situation, the balloon constantly ascending, and therefore the danger of bursting increasing, he had no alternative left, but with his knife in one hand, to make an opening into the side of the balloon, and with the other to extinguish all the lamps within his reach. Being thus relieved from the immediate danger of bursting, or an explosion, he was still without a valve by which he could regulate his descent, and indeed seemed only to have escaped one peril to fall into another, if possible, still more appalling; for, in the mean time the storm approached, and he was tossed to and fro by the wind, while the thunder and lightning could not but occasion the most fearful apprehensions.

Sometimes the cloud was far below him, and the flashes could be seen without dread, but for some time his balloon was enveloped in the cloud, and floated along with it, in which situation, as the lightning was frequent, there could hardly be expected any other event, than that the gas in the balloon would be inflamed, and M. Garnerin dashed to the ground from the height of nearly five miles, to which he supposed he attained. But the storm gradually subsided, and the balloon gradually settled down towards the earth, where this intrepid voyager arrived in safety, after spending many hours in the situation we have described.

In some instances the velocity of the wind at a distance above the earth, while there is little at the surface, is astonishing. In proof of this, on the 30th of June, 1802, the wind being strong, but not tempestuous, M. Garnerin and another gentleman, ascended with an inflammable gas balloon, from Ranelagh gardens, on the southwest of London, between the hours of four and five in the afternoon, and in exactly three quarters of an hour, they descended near the sea, at the distance of four miles from Colchester. The distance of that place from Ranelagh is sixty miles, therefore they travelled at the rate of *eighty miles* an hour. And in the instance above described, of M. Garnerin's nocturnal voyage, he was carried by the storm in the course of eight hours, to the distance of three hundred miles, making on an average of nearly forty miles an hour.

Several of the phenomena which occur in aerial voyages are worth relating.

The effects produced by the great rarefaction of the atmosphere at high elevations, are sensibly manifested by the difficulty of respiration, and the hurried manner in which it is performed. This arises from the thinness of the air, which does not fill and distend the lungs in the usual manner, and therefore there is a constant desire for more, and hence the hurried manner of breathing. Meantime the pulse becomes more rapid, the face swells, and the mouth is parched. The intense cold at great heights, also produces much inconvenience, being attended with numbness of the hands, general torpidity of the system, and almost an irresistible propensity to sleep.

The balloon has been the means of ascertaining that storms and currents in the atmosphere are local, and that while one stratum or portion is thus agitated, another portion above or below, is entirely at rest, so that by rising or falling, the aeronaut may transfer himself from wind to stillness, from a storm to a calm, or from one current of air to another in a different direction. We have seen that the velocity with which balloons sometimes move, is at the rate of eighty miles an hour.

The appearance of the clouds, seen from a great height above them, is said to resemble a plain of snow, or a sea of native cotton wool. Clouds which are charged with electricity, differ in appearance from others; they resemble the smoke of cannon.

Clouds containing hail or snow, are often encountered, and the car becomes well stored with these substances, when no signs of them are seen on the earth.

When birds are carried up and set free at great heights, they at first fall down almost perpendicularly, the thin atmosphere having not sufficient body or substance, to resist the motion of their wings.

Attempts have been made to bring the balloon into use as an instrument of war, and by its means to watch the movements of the enemy, from a sufficient height, thus gaining an advantage. During the French revolution, when the chief object of man was to seek out the best means to destroy his fellow, Napoleon founded an aeronautic academy at Meudon, near Paris, for the purpose of instructing a corps of young men in the management of the balloon, as a means of reconnoitering his enemies. But it does not appear that he ever obtained any considerable advantage from its use, and the project was soon laid aside.

CALENDAR.

By this term is meant the distribution of time into days and months, or other periods, throughout the year. It also signifies the register of these divisions.

At present, wherever the Christian religion prevails, time is divided into days, weeks, months, and years. It might perhaps be supposed, that the *week*, since it is connected with no natural period, would be a division of time only where the Scriptures are known, and yet this seems to have been one of the most ancient, and is now one of the most universal divisions of time. This period was used by the Egyptians, and is still observed by the Brahmins, of India; by the Chinese, and by the Arabians, to all of which nations it appears to have been known from time immemorial. Indeed, so universal is this division among the people of the old world, that the celebrated missionary Wolfe, undoubtedly the greatest traveller now living, informed the writer, that he had not visited a single nation or tribe, where the division of time into periods of seven days was unknown.

The year being an unequal number of days, hours and minutes, its exact division into smaller parts, so that a given day should correspond precisely, year after year, with the same periods of absolute time, was a work requiring an intimate knowledge of several sciences, together with long experience and close observation. And hence we find that the calendars of the older nations were very imperfect.

The most obvious natural divisions of the year, are undoubtedly those which are indicated by the changes of the moon, and accordingly the year was so divided. But it must soon have been found that this was a very imperfect method, since these changes do not correspond with the days of the year.

The Greeks were the first who attempted to make the courses of the sun and moon correspond, or to adjust lunar to solar time. For this purpose they reckoned twelve and a half revolutions of the moon, for one solar year, and to avoid the fractions of a month they made the year consist of twelve and thirteen months, alternately. Solon, the Athenian lawgiver, perceiving the imperfection of the arrangement, ordered that the number of days in a month should be twenty-nine and a half, and that the months should consist alternately of twenty-nine and thirty days. Still, these months did not correspond to the length of the year, and it was found after a time, that the same month did not correspond to the same season of the year, and consequently various plans for the reformation of the calendar were devised, but without any permanent success.

The calendar among the Romans was for a long period in no better state than that of the Greeks.

Romulus, the first king of Rome, made the year consist of ten months or divisions, of which four, namely, March, May, July and October, contained thirty-one days, while the other six, namely, April, June, August, September, November, and December, had only thirty days. But soon finding that this mode was imperfect, and that his months did not complete the year by more than sixty days, he inserted from time to time, as many days as were necessary, to bring the old year up to the beginning of the new.

The successor of Romulus, Numa Pompilius, finding the calendar in great disorder, undertook its reformation. With this view, he abolished the method of Romulus, and substituted the following in its stead. He added fifty days to the year; took one day from each of the six months containing thirty days, because even numbers were reckoned unlucky, and adding these together, making fifty-six days, he formed of them two new months, of twenty-eight days each, which he called January and February. Thus the year consisted of twelve months, six of which had twenty-nine days, four, thirty-one days, and two, twenty-eight days, in all making three hundred and fifty days.

To make this year agree with the course of the sun, additional, or what are termed *intercalary* days were used; and notwithstanding the great defects of this calendar, it was used to the end of the Roman constitution.

In their attempts to improve their calendar, by designating particular days by name, and by the necessary intercalations, they made it singularly complex and arbitrary.

They gave particular names to three days in the month; these were the *calends*, the *nones*, and the *ides*.

The first day in each month were the calends. In the four months of March, May, July, and October, the seventh days were called the nones, and the fifteenth, the ides. In the other months, the fifth were called the nones, and the thirteenth the ides. The other days were distinguished in the following manner—they counted from the above mentioned days backwards, observing also to reckon the day from which they began. Thus the third of March, according to the Romans, would be the fifth day before the *nones*, which in that month falls on the seventh. The eighth of January, in which month the *nones* happen on the fifth, and the *ides* on the thirteenth, was called the sixth before the ides of January.

To express any day after the *ides*, they reckoned in a similar manner from the calends of the following month. From the inaccuracy of the Roman method of computing time, it appears that in the days of Cicero, the seasons had gone back about two months, for the vernal equinox which ought to happen about the 21st of March, did not take place until the end of May.

Now as at the time of the equinoxes, the days and nights are of equal length, all over the world, and which, if the calendar be true with the sun, occur on the 21st of March, and the 21st of September, if the days and nights are equal on the 21st of May, instead of on the 21st of March, it shows an error in the reckoning of about sixty days.

The calendar of Numa had been used by the Romans for upwards of six hundred years, when Julius Cæsar, in the year 45 before Christ, undertook its reformation. For this purpose he invited the celebrated Greek astronomer, Sosigenes, to Rome, and with his assistance invented that mode of reckoning called the *Julian* calendar.

This improvement consisted in bringing the equinox up to its proper place in March, by inserting two months for that year between those of November and December, and enacting that the previous year should consist of four hundred and fifty-five days. On this account, that year ever afterwards was distinguished as *the year of confusion.*

The year now for the first time, began on the 1st of January, being the day of the new moon, immediately following the winter solstice of the year before, and to prevent the recurrence of such disorders in future, it was ordained that the year should consist, for the first three years in succession, of three hundred and sixty-five days, and that every fourth year, a day should be added, making it contain three hundred and sixty-six days. Thus the average length of the year was three hundred and sixty-five days and a quarter, or three hundred and sixty-five days and six hours.

The mode of adding the day every fourth year, was to reckon the 24th of February twice, and thus this year was made to consist of three hundred and sixty-six days, and is what is called a *leap year*, or *bissextile*.

The origin of the latter term, is as follows. The 24th of February, the day which was twice reckoned, was called by the Romans *sexto calendas Martii*, that is, the sixth of the calends of March, and the additional or intercalary day, was called *bis sexto calendas Martii*, or the second sixth of the calends of March, and hence, *bissextile*, or second sixth.

The length of the Julian year on an average, being three hundred and sixty-five days and six hours, while the length of the solar year is three hundred and sixty-five days, five hours and forty-eight minutes, and some seconds, the Julian, is longer than the solar year, by about eleven minutes, so that for every Julian year, the equinoxes were too late by eleven minutes, making a day in about one hundred and thirty years.

In consequence of this, in about the middle of the 16th century, the vernal equinox had changed its place in the calendar from the 21st to the 10th of March, that is, it really took place on the 10th, while it ought not to have happened until the 21st.

About this period several propositions were made to reform the calendar, and among others a plan was proposed by a physician of Verona, in Italy, named Lilius, which after his death, was presented by his brother, to Pope Gregory XIII. The basis of this plan forms the Gregorian calendar, which is that used by all Christian nations, except Russia, at the present day.

In 1582, Gregory issued a brief, abolishing the Julian calendar, in all Catholic countries, and introducing in its stead, the *Gregorian or reformed* calendar, or as it was called, the *new style*, in distinction from the Julian, which was termed the *old style*.

The amendment was as follows: ten days were suppressed after the 4th of October, 1582, so that the next day after the 4th, was the 15th of October. Every hundredth year, which by the old style was to have been a leap year, was now to be considered a common year, the fourth excepted, that is, 1600 was to remain a leap year, but 1700, 1800, and 1900 to be of common length, and 2000 to be a leap year again. In this calendar the length of the year was taken to be three hundred and sixty-five days, five hours and forty-nine minutes. The more recent observations of Lalande and others, have, however, shown that the tropical year is about twenty-seven seconds less than this reckoning. But this error amounts to less than a day in three thousand years.

The Gregorian rule is as follows: every year whose number is not divisible by four without remainder, consists of three hundred and sixty-five days; every year which *is* so divisible, but is not divisible by one hundred without remainder, to consist of three hundred and sixty-six days; every year divisible by one hundred, and not by four hundred without remainder, again to consist of three hundred and sixty-five days, and every year divisible by four hundred without remainder, again to be of three hundred and sixty-six days. For examples, the year 1833, not being divisible by four without remainder, has three hundred and sixty-five days; 1836, being divisible by four without remainder, has three hundred and sixty-six days; 1800 and 1900, of three hundred and sixty-five, and 2000, of three hundred and sixty-six days.

In order to see how near the truth this rule will bring us, let us see what number of days 10,000 Gregorian years will contain, beginning with the year 1.

In 10,000 the numbers not divisible by four are three fourths of 10,000, or 7500; the years divisible by one hundred and not by four hundred, without remainder, will in like manner be three fourths of one hundred or seventy-five, so that in the 10,000 years in question, there will be 7575 years consisting of three hundred and sixty-six days, and the remaining 2425 of three hundred and sixty-five days, producing in all 3,652,425 days, which would give for an average of each year, 365 days and 2425 decimals.

The actual length of the tropical year reduced to its decimal value is 365.24224, so that the error of the Gregorian rule, in 10,000 tropical years amounts only to 2.6, or in actual time to two days, fourteen hours and twenty-four minutes, which is less than a day in 3000 years.

This certainly is sufficiently near for all human purposes, astronomy excepted, which however, is in no danger of being led into error by this cause.

ATMOSPHERICAL PHENOMENA.

The air, or atmosphere which surrounds, and a portion of which we take into our lungs at every breath, is supposed to extend the height of about forty-five miles over every part of the earth and sea. Its weight is very considerable, being equal to that of about thirty-three feet of water, or thirty inches of quicksilver. The pressure of these fluids amount to fifteen pounds on every square inch of surface, and the reason why we do not feel this pressure on our bodies is, that its force is in all directions, upwards, downwards and sideways.

The composition of the atmosphere is 20 parts of oxygen, and 80 of nitrogen, to the one hundred. The oxygen is that portion which supports flame and the lives of animals, while the nitrogen serves to dilute the oxygen, which otherwise would be too stimulating for animals to breathe, and would cause too fierce a heat and flame, in all burning bodies.

Indeed, if we had an atmosphere of pure oxygen, all animals would have their blood too much heated, and a fever would be the consequence, which would soon destroy them. Many substances also, which are now incombustible, would be burned up, as iron and steel, in thin pieces, for these being heated, burn with intense brilliancy, in pure oxygen gas. Thus we should be unable to use thin iron stoves, as the heat of the fuel would be so increased, that it would set them on fire, and they would soon be consumed. The composition of the atmosphere is therefore the most perfect that could have been devised for our use.

The atmosphere near the surface of the earth, contains many other gases, besides oxygen and nitrogen, these being the products of the burning of the various kinds of fuel, as wood and coal, and the different sorts of manufactures which are constantly carried on in every part of the earth. These impurities are many of them absorbed by water, and some of them are taken up by growing vegetables. Were it not for this provision, they undoubtedly would produce serious effects on the health of populous places, and especially on that of large manufacturing towns.

The air has the power of taking up large quantities of moisture, and of transporting it from one place to another. This is done by a process called *absorption*, and by which the particles of air adhere to those of the water so as to suspend, and carry them away. Thus if a vessel of water is left open, especially if it be a shallow one, the fluid evaporates, that is, it is absorbed, and carried off by the particles of the atmosphere.

The atmosphere has a much greater capacity for moisture when it is warm or hot, than when it is cold, and hence it is well known that water evaporates much more rapidly in hot weather than in cold. But even in the coldest season absorption still goes on, nor does the freezing of the water entirely suspend the process, since ice is gradually carried away, when exposed to the action of the air.

When the air is warm, it retains its moisture, or continues to hold in solution a much larger quantity, than it does when cooled. Hence it is, that when a tumbler is filled with cold water in the summer, the outside of the glass is soon covered with moisture. This, some people call the *sweating* of the tumbler, and suppose the water comes through the pores of the glass, believing it, at the same time to be a sign of rain. Now the truth is, the moisture on the outside of the tumbler is owing to the cooling of the air in contact with it, in consequence of which, it cannot hold so much moisture as before, and therefore it throws down, or deposites a portion, on the glass. It makes no difference in the effect, whether the tumbler contains water or not, provided it is cold. An empty bottle taken from a cellar into the open air, on a hot day, exhibits the same phenomenon.

RAIN.

We have seen above, that heat promotes evaporation, and that the air is capable of retaining more water when warm than when it is cooled. But these facts do not explain all the phenomena attending rain, for although the simple cooling of the air may satisfactorily account for a shower, yet we frequently find from our own feelings, that it often grows warm instead of cold, before the commencement of rain, or during its fall. The cause of rain, therefore, cannot be explained by the mere cooling of the atmosphere, but it appears to be the result of the intermixture of two or more clouds, of different temperatures.

It has been ascertained that different clouds vary greatly with respect to their temperatures, though floating at similar elevations. Now suppose the heat of one such cloud to be considerably above that of another; that they are both full of moisture, and come into contact, or mix together, the consequence would be, that the heat of one would be raised, while that of the other would be diminished; or in other words, the heat of the mixed clouds would become an average of the heat of the two, before their mixture. Now both clouds being saturated, that is, full of vapor, it is clear that the cloud of the highest temperature must deposit a part of its moisture, in consequence of cooling.

This appears to be the true theory of rain, and if we are not mistaken, will account for the phenomena attending it, under all circumstances.

Preparatory to rain, and while it is falling, clouds are often seen to fly in various directions, and to mix with each other. But while they are carried by the wind in the same direction, in the lower atmosphere, they may be flying in a contrary direction in the higher, as we have already seen under the article Balloon.

QUANTITY OF RAIN.

The quantity of rain which falls in different latitudes, and in different situations, under the same latitude, is exceedingly various. In general, however, there is the greatest quantity in the hottest climates, there being a gradual diminution of the average number of inches, from the equator towards the poles of the earth.

Thus, at Bombay, a small island on the coast of Hindoostan, and within the tropics, the average quantity of rain which fell for ten years, was seventy-eight inches per year. In some years a much larger quantity than this falls. In the year 1822, there was one hundred and thirteen inches. In Brazil, in 1821, it is stated there fell two hundred and eighty inches of rain, and that at Cayenne, an island on the coast of South America, in four degrees, north latitude, there fell one hundred and sixty inches of rain in the month of February only.

From accurate records of the quantities of rain which fell in various places in England and France, it is found that the average depth for a series of years, does not exceed fifty-four inches in any place,—in most places it was not over thirty-six, and in some only nineteen inches. At London, the average quantity for forty years was only a little more than twenty inches per year. At Paris, for the term of fifteen years, it was on the average less than nineteen inches per year.

With respect to the quantity which falls in different parts of this country, we can give no accurate account, there having been, we regret to say, little attention paid to the subject. In Florida, latitude about 24 degrees, the quantity for the years 1834 and 1835, was severally nearly thirty-six and thirty inches.

The quantity of rain which falls, is ascertained by means of a *rain guage*. This is a vessel, which may be made of tin, eight or ten inches in diameter, and a foot and a half or two feet high, with a funnel in the top to prevent evaporation, and a graduated rod running through the mouth of the funnel, attached to a float, the rising of which, shows the quantity of water which falls. Or, the quantity of water may be told by a graduated glass tube attached to the outside, but communicating with the inside, by being let into the spigot, from which the water is discharged at the bottom of the vessel. The quantity which falls each month being recorded, that which remains may be discharged, so that each month may begin with an empty vessel. The guage should be painted inside and out. White is the best color for the outside, because it does not become heated by the sun, and thus increase the evaporation.

In the vicinity of high mountains, especially if they are capped with snow, it is found that there is a greater quantity of rain, other circumstances being equal, than in level countries. This arises from the cooling effects of the mountain on the passing clouds, in consequence of which they deposite their moisture, in conformity to the theory we have above explained. But under ordinary circumstances, it is found that the quantity of rain at a small distance above the earth, is considerably less than at the surface. Thus one rain guage placed on the top of a high tower or house, indicates a less quantity than another near the ground.

From some experiments made at Westminster Abbey, near London, it was found that the quantity at different heights, was as follows:

The upper rain guage, situated on the top of the Abbey, in a year, gave 12,099 inches. Middle guage, on the top of a house close by, 18,139 inches. Lower guage, on the ground, 22,608 inches.

This is certainly a much greater difference than could have been expected, and goes to prove that the vapor which the air contains, continues to be condensed, or concentrated into rain, near the surface of the earth, as well as in the higher region.

The quantity of rain which falls in hot climates, as we have already seen, is much greater than that of temperate, or northern ones. But it is found that the number of rainy days increase in some proportion to the latitude. Within the tropics, the rain at certain seasons, pours down in a perpetual torrent, the quantity falling in a day or two, being equal to that which falls in as many of the most rainy months, in temperate climates.

METEORS.

In all ages of the world, balls of fire have suddenly made their appearance in the atmosphere, and as suddenly vanished. These are called *meteors.* In general, they pass with amazing velocity through the air, sometimes giving a light nearly equal to that of the sun, and occasionally making a whizzing noise, and at the instant when the light vanishes, giving a report like that of a cannon, or several reports, like those of musketry.

In some instances, these phenomena are seen over a wide extent of country, and in others they appear to fall only from a small height, and are noticed only by a single person.

In the year 1783, a meteor passed over a considerable portion of Europe. It appears to have commenced over the Northern ocean, and passed near Edinburgh, and traversing the whole extent of the United Kingdom of Great Britain, crossed the straits of Dover, and was seen at Brussels, and Paris, and Rome. It appeared only for the space of half a minute, and during that time was estimated to have passed over a distance of one thousand miles.

The color of meteors differs considerably. Sometimes they are described as white, with a tinge of blue, and sometimes red. Their brightness is said in some instances, to be so intense as to be seen in broad day light, and even during full sun shine. Their duration is rarely more than half a minute, but more frequently their light appears only for an instant, and even before the beholder can turn to ascertain whence the light comes, the meteor itself has vanished.

In hot climates, these apparitions are of very frequent occurrence, sometimes many being seen on the same evening.

METEORLITES.

Meteorlites, or meteoric stones, are stony bodies which have fallen from the atmosphere.

From the remotest records of history, we have accounts of the fall of solid substances from the air; but because such facts contradicted all the theories, and preconceived opinions of philosophers, these accounts were considered fabulous, and unworthy any serious examination. It was deemed an impossibility that the atmosphere could sustain solid, heavy bodies, and hence, after it was ascertained beyond all doubt, that such bodies did fall from the air, it was attempted to be shown, that they were thrown from volcanoes.

At present, no fact in natural history, is better substantiated than that solid, stony bodies fall from the upper regions, and this too at such distances from any volcanic region, as to make it impossible that they should have had such an origin. Their appearance, and composition also, being unlike any volcanic product, proves still more clearly that they do not belong to that class of substances.

The phenomena which take place at the moment of their fall, are those which we have already described as attending meteors, and as an example of such phenomena, we give the following description of what was seen and heard on such an occasion at Weston, not far from Middletown, in this state. The facts were gathered by Professor Silliman, of New Haven, and published in his Journal at the time.

"About half past six o'clock, in the morning of the 14th of December, 1807, the people to the north of

Weston, observed a fire-ball issuing from a very dark cloud. Its apparent diameter was equal to that of the half, or two thirds of the full moon; its light was vivid and sparkling, like that of incandescent iron, and it left behind it a pale, luminous and waving train, of a conical form, and ten or twelve times as long as the diameter of its body, but which was soon extinguished. This meteor, of which the apparent motion was less rapid than that of most others, continued visible for half a minute, during which it exhibited three successive bounds, with a diminution of its lustre.

"About thirty or forty seconds after its extinction, there were heard, during three seconds, three very loud reports like the firing of a four pounder, at a little distance; and these were succeeded by a more prolonged and rolling noise. With the successive explosions, stones were darted into the environs of Weston, and even into the town itself. These stones were found in six different places, nearly in the line of the meteor's path, and from six to ten miles distant from each other. They fell in the presence of many witnesses, some of them plunging into soft soil, and others breaking into fragments against rocks, on which they happened to impinge.

"The most entire specimen weighed thirty-five pounds, but a much larger one was dashed in pieces against a rock of mica-slate, and from the amount of fragments collected, it was estimated to have weighed two hundred pounds.

"At the moment of their fall, these stones were hot and friable, (that is, easily ground to powder;) but they gradually became hard by exposure to the air. They had the black external crust of other meteorlites, and the usual gray cinerous (ash-colored) aspect within, with whitish gray particles of a rounded form, impacted in the mass, and a granular texture, in which were observed—1st. Globules of the same nature with the stone, but presenting a more compact structure, a more even fracture, and under a strong light, indications of a lamellar texture, with the appearance of felspar. 2d. Grains of oxide of iron, of rust color, and 3d. Shining yellow sulphuret of iron, disseminated in very minute grains.

"These stones were composed of about one third *iron*, somewhat more than another third of *silica*, or *flint*, the remainder being *magnesia*, *sulphur*, *lime*, the metal called *chrome*, and two or three other ingredients, in small quantity."

Meteoric stones of similar composition.—It is a singular and curious fact, and one which involves an equal mystery with the origin of these stony compounds, that they all have a similar composition. The knowledge of this is due to Mr. Howard, of England, who collected specimens from many different parts of the world, and found on analysis, that they were almost invariably composed of the same materials, and often in very similar proportions, in whatever age, or in whatever part of the world they fell.

It is also remarkable, though perhaps not unexpected, that these stones not only differ entirely in their composition, from any minerals which occur in the neighborhood where they are found, but also from all known substances which have hitherto been discovered on, or under the earth.

They are all covered with a thin crust of a black color; they are without gloss, and their surfaces are roughened with small asperities. Internally they are greyish, and of a granulated texture, more or less fine.

In all the instances in which these stones have been known to fall from the clouds, and of which any perfect account has been given, the appearance of a luminous meteor, exploding with a loud noise, has immediately preceded the fall, and hence has been considered as the cause. The stones likewise have been more or less hot, when found immediately after their supposed fall.

With respect to the origin of these substances, nothing but conjecture, nor even a plausible one can be offered. At first, they were supposed to be sent from volcanoes, as already stated. Others thought they came from the Moon; while others suggested that they might be bodies wandering through space, and which happened to come within the attraction of our planet. The last supposition is the most probable, but still there is a total want of facts to render it even plausible. In the present state of knowledge, therefore, it may be said, that we have no grounds even for a conjecture, where, or in what manner these bodies originated.

The list of the fall of meteoric stones, collected by Mr. Howard, consists of several hundred cases, which have occurred from the remotest historic period, and in nearly every part of the world. The first on the list is "The thunderstone of Crete," which fell in the year 1478, before Christ, and from that time, down nearly to the present, instances have occurred in some parts of the world, once in a few years.

In some instances, these stones were of considerable size, and in others, their number were several hundred.

In 1492, A. C., a stone fell at Alsace, weighing two hundred and sixty pounds. In 1668, two stones fell near Verona, in Italy, one of which weighed two hundred, and the other three hundred pounds.

In 1790, a great shower of stones fell near Bordeaux, one of which killed a man, and another a cow.

In 1510, there fell a shower of about twelve hundred stones, in a field near the river Abdua.

We might fill many pages with similar accounts, but these are sufficient for our present purpose.

Masses of iron which have fallen from the clouds.— Besides the compound stoney substances, above described, there are well authenticated accounts of the fall of masses of iron from the air. These are not so numerous as the meteorlites, but in some instances they are of immense size, and in all cases, of a peculiar shape and appearance, differing entirely from any thing found in the earth.

These masses of meteoric iron, always contain a portion of the metal called *nickel*, by which their composition is distinguished from other iron, and it is a singular fact that nearly every specimen of meteoric stone that has been analyzed, contains more or less of this metal.

The largest mass of meteoric iron known is that found in the province of Bahia, in Brazil. This is seven feet long, four feet wide, and two feet thick, and weighs about six tons. Other masses weighing two or three thousand pounds, have been found in different parts of the world.

WIND.

Wind is a perceptible motion of some portion of the atmosphere, either on, or above the surface of the earth.

The cause of wind appears to be a greater degree of heat, at one place than at another, and in consequence of which, the air passes from the colder towards the warmer region.

During the burning of a building, on a calm night, the wind blows from every direction towards the fire.

When the air is heated it rises, while that which is colder, sinks down and passes along to take its place, which in its turn becomes heated and ascends. When air is confined in a heated room, the coldest portion is always next the floor, while the warmest is next the ceiling. Thus, if a door is opened from a warm, into a cold room, and one lighted candle be held at the upper, and another at the lower portion of the door way, the upper blaze will point out of, and the lower into the room, showing that while the hot air passes out at the upper part, the cold passes in below, to take its place, and thus there are two currents in contrary directions.

The wind blows constantly towards the equator, or warmest portion of the earth, from the colder regions of the north and south. When the current arrives at these warm regions, the heat makes it ascend into the higher atmosphere, where it forms a current in a contrary direction, or towards the north and south. Thus there is a continual circulation of the air, from the north and south, at the surface of the earth, and in the opposite directions, from the equator, in the higher regions.

Islands situated in the oceans of hot climates, enjoy almost constant breezes, though in contrary directions, from the natural tendency of the air to pass from colder towards warmer places. Thus during the day, when the sun, acting upon the land, makes it warmer than the sea, there is a motion of the air in all directions from the sea, towards the land, in the same manner, and for the same reason that a burning building creates a wind towards itself. This is called the *sea breeze.* It begins about eight or nine o'clock in the morning, is strongest at two or three in the afternoon, and subsides towards evening.

Towards evening the wind changes its direction, and blows from the land towards the water, because the land, as the influence of the sun diminishes, parting with its heat more rapidly than the water, becomes cold, while the water retains its heat during the night. Thus, the land being warmest during the day, and the water warmest at night, there happens a diurnal change in the direction of the wind, from and towards every part of the island. Were it not for the cooling effects of these breezes, some islands situated in hot climates, now comfortable residences, would hardly be habitable.

HURRICANES.

Although as we have seen above, there is a natural cause why the wind blows from the colder towards the warmer place, and in cases where we know such a cause exists, the effect is readily explained; still there are many phenomena with respect to wind, which are not so readily accounted for, and which indeed, are unaccountable by any of the known laws of nature or philosophy. Such are the *hurricanes*, which occur both in hot and temperate climates, and the occasional hot winds which take place in various countries; also the *tornadoes*, to which many countries are subject, and the *whirlwinds* which happen with more or less violence in most parts of the earth.

Hurricanes are much the most common in hot climates, though every such climate is not obnoxious to them. The West India Islands are peculiarly liable to be visited by these calamities, which sometimes utterly destroy houses, villages and plantations, and indeed, except the solid rocks, every thing which projects above the earth's surface. They begin with the wind from the northern quarter, which gradually changes its direction to the west, and then into the south, when the violence usually ceases. In 1830, a hurricane which commenced in the West Indies, crossed the sea to the coast of Florida, and to the Carolinas, and thence to the banks of Newfoundland, a distance of 3000 miles, which was passed over by the storm in six days. It thus moved at the rate of five hundred miles per day. The width of the tract exposed to its influence, was from three hundred to six hundred miles, and its greatest duration at any one place was from twelve to twenty-four hours, its greatest violence being felt during the six and twelve first hours.

The *Harmattan* is an easterly wind of great dryness, which visits the western coast of Africa, and is probably produced by some interruption of the trade wind. It is attended with the most oppressive sensation of heat, and is said to be the forerunner of a hurricane.

In no country are the effects of wind more to be dreaded than in the deserts of Africa. During the storms that often rage in the great desert Sahara, the sand is raised into clouds, that entirely obscure the horizon, or by whirlwinds, it is formed into pillars of the most portentous and striking appearance. In passing through the eastern part of this desert, the celebrated traveller Bruce, witnessed one of these sand storms, which he describes as follows:

"At one o'clock we alighted among some acacia trees, having gone twenty-one miles. We were here at once surprised and terrified by a sight, surely one of the most magnificent in the world. In that vast expanse of desert, from west to north west of us, we saw a number of prodigious pillars of sand at different distances, at times moving with velocity, at others stalking with majestic slowness. At intervals, we thought they were coming in a very few minutes to overwhelm us, and small quantities of sand did actually more than once reach us; again they would retreat, so as to be almost out of sight, their tops reaching the very clouds; then the tops often separated from the bodies, and these once disjointed, dispersed in air, and did not more appear; sometimes they were broken in the middle, as if they were struck with a cannon ball.

"At noon they began to advance with considerable swiftness upon us, the wind being very strong at the north.

"Eleven of these pillars arranged themselves at the distance of about three miles from us; the greatest diameter of the largest appeared to me at that distance to be about ten feet. They retired from us with a wind at the south-east, leaving an impression on my mind to which I can give no name, though surely one ingredient in it was fear, with a considerable deal of wonder and astonishment.

"It was in vain to think of flying; the swiftest horse here would be of no use to carry us out of this danger, and the full conviction of this riveted me to the spot."

Sand-wind. The overpowering effects of a *sand-wind*, in the same desert, sometimes destroys a whole caravan. The effect of this wind is to raise the sand with which the air becomes filled. It does not throw it into pillars, like those described by Mr. Bruce, which undoubtedly is the effect of whirlwinds.

Mr. Denham, the African traveller, encountered one of these sand-storms, in the desert, of which he says, "The wind raised the fine sand so as to fill the atmosphere, and render the immense space before us, impenetrable to the eye, beyond a few yards. The sun and clouds were entirely obscured, and a suffocating and oppressive weight accompanied the masses of sand, which I had almost said, we had to penetrate at every step. At times we completely lost sight of the camels, though only a few yards before us. The horses hung their tongues out of their mouths, and refused to face the clouds of sand. A parching thirst oppressed us, which nothing could alleviate.

MONSOONS.

The *Monsoons* are periodical winds of tropical climates, which blow one half of the year in one direction, and the other half in a contrary direction.

These winds are attended with tremendous storms of rain, attended with thunder and lightning, at their commencement, which continue for several days and nights. After these deluges, there falls little or no rain, in the climates where the monsoons prevail, for several months. The monsoons pass over the southern parts of India, a part of Africa, the Malay peninsula, and other countries in that range.

AURORA BOREALIS.

Among atmospheric phenomena, the *aurora borealis* is often among the most curious and interesting. This appearance, usually called *northern light*, takes place most commonly in the winter season, and generally begins before midnight, but sometimes soon after sunset.

Its appearance at first sight, is like that of a burning building, at a great distance to the north, and for which it is not unfrequently mistaken. The light however, generally extends too far to the east and west, to closely resemble an ordinary conflagration.

The appearance of an aurora is that of a broad arch of light, the origin of which seems to be below the horizon, and its height at first, only a few degrees above it. From this arch there ascend columns or patches of variously colored light, as white, purple, and red, which dart upwards, sometimes with a rapid motion to the zenith. Sometimes the color of the whole celestial sphere is orange, with occasional patches of purple and red, in the north, east and west, giving the heavens a most splendid appearance.

In high northern latitudes, these phenomena are described as exceedingly brilliant and imposing, and it is said they are sometimes attended with a hissing, and crackling sound, like that of fire-works.

In our climate, northern lights are frequently seen, and within a few years, several very brilliant and striking ones have occurred.

Of the cause of this spectacle, there are various opinions, some supposing it to arise from the reflection of the sun's light from the snow and ice of the northern regions; others, that it is in some way connected with the atmosphere of the sun, and others again, that it is an electrical phenomenon, and which is now considered by men of science, as the most probable conjecture.

HISTORY OF ASTRONOMY.

The science which treats of the sun, moon, earth, planets, and other heavenly bodies, showing their magnitudes, order, and distances from each other, measuring and marking their risings, settings, motions, appearances, the times and quantities of their eclipses, &c. It comprehends what was anciently called the doctrine of the sphere, and is a mixed mathematical science.

Of all the sciences which have engaged the attention of mankind, none appears to have been cultivated so early as that of astronomy, which treats of the noblest and most interesting objects of contemplation. Josephus informs us that Seth, the son of Adam, is said to have laid the foundations of this science, and that his posterity, understanding from a prediction of Adam that there would be a general destruction of all things, once by the rage of fire and once by the violence and multitude of waters, made two pillars, one of brick and the other of stone, and engraved their inventions on each, that if the pillar of brick happened to be overthrown by the flood, that of stone might remain; which latter pillar, Josephus adds, was to be seen in his day. He also ascribes to the antediluvians a knowledge of the astronomical cycle of 600 years, but upon what authority we are not informed.

The account is, however, not improbable; for historians generally agree in assigning the origin of astronomy to the Chaldeans soon after the deluge, when, for the purpose of making their astrological* predictions, to which they were much addicted, as also for that of advancing the science of astronomy, they devoted themselves to the study of the heavenly bodies. The Chaldeans were in fact a tribe of Babylonians, who constituted the priests, philosophers, astronomers, astrologers, and soothsayers of this people, whence a Chaldean and a soothsayer became synonymous terms. These Chaldeans discovered the motions of the heavenly bodies; and, from their supposed influences on human affairs, pretended to predict what was to come. The planets they called their interpreters, ascribing to Saturn the highest rank; the next in eminence was Sol, the sun; then Mars, Venus, Mercury, and Jupiter. By the motions and aspects of all these they foretold storms of wind and of rain, or excessive droughts, as also the appearance of comets, eclipses of the sun and moon, and other phenomena. They also marked out thirty-six constellations, twelve of which they placed in the zodiac, assigning to each a month in the year, and thus dividing the zodiac into twelve signs, through which they taught that the several planets performed their revolutions. They appear not to have had much idea of the immense distance of some of the planets from the sun, but ac-

* From astrology, the art of foretelling by the stars.

counted for the time they took in performing their revolutions by the slowness of their motions. They, however, held that the moon completed her course the soonest of any, not because of her extraordinary velocity, but because her orbit, as it would now be called, was less than that of any of the heavenly bodies. They taught that she shone with a light not her own, and that when eclipsed she was immersed in the shadow of the earth. Of the eclipses of the sun they appear to have had no just idea, nor could they fix the time when they should happen. Their ideas of the earth as a celestial body were also crude and imperfect.

Astronomy was cultivated in Egypt nearly about the same time as among the Chaldeans; and, according to the opinions of some, the honor of the invention is due to them: but the most probable conclusion is, that as these two nations were coeval, and both addicted to the arts and sciences, they cultivated astronomy at the same time. The Egyptians had at a very early period their college of priests, who were all accurate observers of the stars, and kept, as Diodorus observes, registers of their observations for an incredible number of years. It is said, that in the monument of Osymandyas there was a golden circle of 365 cubits in circumference and one cubit thick, divided into 365 parts, answering to the days of the year, &c. The Egyptians discovered that the stars had an annual motion of 50″, 9‴, 45⁗ in the year; and Macrobius asserts that they made the planets revolve about the sun in the same order as we do. From Chaldea and Egypt astronomy passed into Phœnicia, where it was applied by that trading people to the purposes of navigation. The Arabians also, one of the most ancient nations in the world, cultivated astronomy as far as was needful to answer the ends of their pastoral life, by observing the stars, their position, and influence on the weather. In travelling through the desert, we are informed that, at a very early period, they used to direct their course by the Great and Little Bear, as is done at sea to this day. They also gave names to the stars, mostly in allusion to their flocks and herds; and they were so nice in this matter that no language abounds with so many names of stars and asterisms as the Arabic.

As to the Indians and Chinese there is no doubt but that they cultivated astronomy at a very early period, and that the Brahmins of the former people, being altogether devoted to speculative sciences, made advances in that of astronomy equal to any of the nations of antiquity. M. Bailly informs us, in his history, that he examined and compared four different sets of astronomical tables of the Indian philosophers, namely, that of the Siamese explained by M. Cassini in 1689; that brought from India by M. le Gentil, of the Academy of Sciences, and two other manuscript tables, found among the papers of the late M. de Lisle; all of which he found to accord with one another, referring to the meridian of Benares. It appears that the Indians date their astronomy from a remarkable conjunction of the sun and moon which took place at the distance of 302 years before Christ; and M. Bouilly concludes that, from our most accurate astronomical tables, such a conjunction did take place. The Indians calculate eclipses by the mean motions of the sun and moon, commencing at a period five thousand years distant; but, without giving them credit for an antiquity which is at variance with all historical documents, sacred and profane, it suffices here to observe that they have adopted the cycle of nineteen years, and that their astronomy agrees with modern discoveries in many particulars, as to the obliquity of the ecliptic, and an acceleration of the motion of the equinoctial points. They also assign inequalities to the motions of the planets, answering very well to the annual parallax, and the equation of the centre.

The Greeks, without doubt, derived their astronomical knowledge from the Egyptians and Phœnicians by means of several of their countrymen, particularly Thales the Milesian, who, about 640 years before Christ, travelled into Egypt, and brought from thence the chief principles of the science. He was the first among the Greeks who observed the stars, the solstices, the eclipses of the sun and moon, and proceeded so far as to predict an eclipse of the sun. It appears, however, that, before his time, many of the constellations were known, for we find mention of them in Hesiod and Homer, two of their earliest writers. After Thales, Anaximander, Anaximenes, Anaxagoras, but above all, Pythagoras, distinguished themselves among the number of those who cultivated astronomy. The latter, after having resided a long time in Egypt and other foreign parts, established a sect of philosophers in his own country, known by the name of Pythagoreans. He taught, among other things, that the sun was in the centre of the universe and immoveable; that the earth was round, and the inhabitants were antipodes to each other; that the moon reflected the rays of the sun, and was inhabited like the earth; that comets were wandering stars; that the milky way was an assemblage of stars, which derived its white color from the brightness of their light; besides a number of other particulars, some of which are admitted in the present day. Philolaus, a Pythagorean, maintained the doctrine of the earth's motion round the sun, 450 years before Christ, and Hicetus, a Syracusan, taught, a hundred years after, the diurnal motion of the earth on its own axis; also Meton, the inventor of the Metonic cycle, and Euctemon, observed the summer solstice 432 years before Christ, besides the risings and settings of the stars, and what seasons they answered to. The same subject was treated of at large by Aratus in his poem entitled Phœnomena. Eratosthenes, a Cyrenean, who was born in 271 B. C. measured the circumference of the earth; and, being invited to the court of Ptolemy Evergetes at Alexandria, he was made keeper of the royal library, and set up there the armillary spheres which Hipparchus and Ptolemy afterwards used so effectually. He also determined the distance between the tropics to be 11-83 of the whole meridian circle, which makes the obliquity of the ecliptic in his time to be 23 degrees, 51 minutes and one-third. Archimedes is said to have constructed a planetarium to represent the phenomena and motions of the heavenly bodies ; and many others added to the stock of astronomical knowledge, but none so much as Hipparchus, who flourished about 140 years B. C. and surpassed all that had gone before him in the extent of his researches. He showed that the orbits of the planets were eccentric, and that the moon moved slower in her apogee than in her perigee. He constructed tables of the motions of the sun and moon ; collected accounts of eclipses that had been computed by the Chaldeans and Egyptians ; and calculated such as would happen for six hundred years to come ; besides correcting the errors of Eratosthenes in his measurement of the earth's circumference, and computing the sun's distance more accurately. He is, however, most distinguished by his catalogue of the fixed stars to the number of a thousand and twenty-two, with their latitudes and longitudes, and apparent magnitudes. These and most other of his observations are preserved by his illustrious successor Ptolemy.

From the time of Hipparchus to that of Ptolemy, an interval of upwards of two centuries, few or no advances were made in astronomy. Claudius Ptolemy, who was born at Pelusium in Egypt, in the first century of the Christian era, is well known as the author of a great work on astronomy, entitled his Almagest, which contains a complete system of astronomy drawn from the observations of all preceding astronomers in union with his own. He maintained the generally received opinion of the sun's motion, which continued to be universally held until the time of Copernicus. The work of Ptolemy being preserved from the grievous conflagration that consumed the Alexandrian library during the ravages of the Saracens, was translated out of the Greek into the Arabic, A. D. 827; and, by the help of this translation, the Arabians, who now addicted themselves to the study of astronomy, cultivated it with great advantage under the patronage of the caliphs, particularly Al Mamon, who was himself an astronomer, and made many accurate observations by the help of instruments, which he himself constructed. He determined the obliquity of the ecliptic in his time to be 23 degrees, 35 minutes. Among the Arabian authors of this period was Alfragan, who wrote his Elements of Astronomy, and Albetegnius, who flourished about 880. This latter compared his own observations with those of Ptolemy, and computed the motion of the sun's apogee from Ptolemy's time to his own. He also composed tables for the meridian of Arabia, which were much esteemed by his countrymen. After this, Ebn Younis, astronomer to the caliph of Egypt, observed some eclipses, by means of which the quantity of the moon's acceleration since that time has been determined; also Arzechel, a Moor of Spain, observed the obliquity of the ecliptic; and Alhazen, his contemporary, wrote on the twilight, the height of the clouds, and the phenomena of the horizontal moon. He likewise first employed the optical science in astronomical observations, and showed the importance of the theory of refraction in astronomy.

In the thirteenth century, astronomy, as well as other arts and sciences, began to revive in Europe, particularly under the auspices of the emperor Frederick II.; who, besides restoring some decayed universities, founded a new one, and in 1230 caused the works of Aristotle, and the Almagest of Ptolemy, to be translated into Latin. Two years after this, John de Sacro Bosco, or John of Halifax, published his work De Sphæra, a compendium of astronomy drawn from the works of Ptolemy, Alfragan, Albetegnius, and others. This was held in high estimation for some centuries, and was honored with a commentary from the pen of Clavius and other learned men. In 1240, Alphonsus, king of Castile, a great astronomer himself, and an encourager of astronomers, corrected with their assistance, the tables of Ptolemy, which, from him, were called the Alphonsine tables. About the same time Roger Bacon published his tracts on astronomy, and shortly after Vitellio, a Polander, in his treatise on optics, showed, in accordance with Alhazen, the use of refraction in astronomy. Nearly two centuries elapsed from this period before any farther progress was made in the science, when Purbach composed new tables of sines for every ten minutes, constructed spheres and globes, wrote commentaries on Ptolemy's Almagest, corrected the tables of the planets and the Alphonsine tables, determined the obliquity of the ecliptic at 23 degrees, 33 minutes and a half, and begun, at his death, a new series of tables for computing eclipses. He was succeeded by John Muller, commonly called Regiomontanus, Bernard Walther, John Werner, and others. John Werner showed that the motion of the fixed stars, since called the precession of the equinoxes, was about 1 degree, 10 minutes, in a hundred years. The celebrated Copernicus came next in order, who distinguished himself by calling in question the Ptolemaic system of the universe, and reviving that of Pythagoras. After making a series of observations, and forming new tables, he completed in 1530 his work, first published under the title of De Revolutionibus Cœlestium Orbium, and afterwards under that of Astronomia Instaurata, in which he set forth the system since known by the name of the solar system, in which all the planets are considered as revolving round the sun as their immoveable centre.

The science of astronomy henceforth continued to receive regular accessions and improvements by a series of writers, as Schoner, Nonnius, Appian, Gemma Frisius, Byrgius, &c. Besides, William IV., landgrave of

Hesse Cassel, applying himself to the study, formed, by the help of the best instruments then to be procured, a catalogue of four hundred stars, with their latitudes and longitudes adapted to the beginning of the year 1593. About this time the Copernican system found a strenuous though unsuccessful opponent in Tycho Brahe, a Danish nobleman, who, to obviate the objections against the Ptolemaic system, advanced an hypothesis of his own, which added less to his reputation than the accurate observations which he made by the help of improved instruments in a new observatory built for him by order of the king of Denmark. His friend Kepler, who enjoyed the title of mathematician to the emperor, finished his tables after his death, and published them under the title of Rhodolphine tables. This latter astronomer discovered that all the planets revolve round the sun, not in circular but in elliptical orbits; that their motions are not equable, but quicker and slower as they are nearer to the sun or farther from him ; besides a number of other observations on the motions and distances of the planets. He also concluded, from his observations on the comets, that they are freely carried about among the orbits of the planets in paths that are nearly rectilinear. To the astronomers of this age may be added Bayer, who, in his Uranometria, has given a representation of all the constellations, with the stars marked on them, and accompanied with the Greek letters for the convenience of reference.

The seventeenth century added many great names to the list of astronomers, as Galileo, Huygens, Cassini, Hevelius, Newton, and Flamstead, &c. As the Copernican system had met with an opponent in one that ranked high in the science, it found a defender in Galileo, an Italian nobleman, who in his Dialogi, in 1632, drew a comparison between the Ptolemaic and Copernican system, much to the advantage of the latter, for which he incurred the censures of the church, as the doctrine of the sun's immobility was looked upon as directly opposed to the express language of Scripture. Although Galileo professed to recant in order to obtain his liberation from prison, yet the system daily gained ground, and became at length established. Galileo besides made many accurate observations in astronomy, and was one of the first who, by improving the new invention of the telescope, was enabled to employ them in advancing his favorite science. By this means he is said to have discovered inequalities in the moon's surface, Jupiter's satellites, and the ring of Saturn; so likewise spots in the surface of the sun, by which he found out the revolution of that luminary on its own axis. He also ascertained what Pythagoras had conjectured, that the milky way and the nebulæ consisted of innumerable small stars. Harriot made similar discoveries in England at the same time, if not earlier. Hevelius, by means of his observations, formed a catalogue of fixed stars much more complete than that of Tycho's. Huygens and Casini discovered the satellites of Saturn, and Sir Isaac Newton demonstrated, from physical considerations, the laws which regulated the motions of the heavenly bodies, and set bounds to the planetary orbs, determining their excursions from the sun, and their nearest approaches to him; he also explained the principle which occasioned that constant and regular proportion, observed both by the primary and secondary planets in their revolutions round their central bodies, and their distances compared with their periods. His theory of the moon, grounded on the laws of gravity and mechanics, has also been found to account for all her irregularities. Mr. Flamstead filled the office of Astronomer Royal at Greenwich, from 1675 until his death in 1729, during which time he was constantly employed in making observations on the phenomena of the heavens. As the result of his labors he published a catalogue of three thousand stars, with their places to the year 1689; also new solar tables, and a theory of the moon according to Horrox. On his tables was constructed Newton's theory of the moon, as also the tables of Dr. Halley, who succeeded him in his office in 1729. Besides composing tables of the sun, moon, and planets, Dr. Halley added to the list of astronomical discoveries, being the first who discovered the acceleration of the moon's mean motion. He also contrived a method for finding her parallax by three observed places of a solar eclipse, and showed the use that might be made of the approaching transit of Venus in 1761, in determining the distance of the sun from the earth, and recommended the method of determining the longitude by the moon's distance from the sun and certain fixed stars, which was afterwards successfully adopted by Dr. Maskelyne, Astronomer Royal.

It was about this period that the question respecting the figure of the earth appears to have been satisfactorily decided, and in favor of Newton's theory. M. Casini concluded, from the measurement of M. Picard, that it was an oblong spheroid, but Sir Isaac Newton, from a consideration of the laws of gravity, and the diurnal motion of the earth, had determined its figure to be that of an oblate spheroid flattened at the poles, and protuberant at the equator. To determine this point, Louis XV. ordered two degrees of the meridian to be measured, one under or near the equator, the other as near as possible to the poles ; the expedition to the north being intrusted to Messrs. Maupertuis and Clairaut, that to the south to Messrs. Condamine, Bouguer, and Don Ulloa. Among the many observations made by those who went on this expedition, it was found by those who went to the south that the attraction of the mountain of Peru had a sensible effect on the plumb lines of their large instruments, which is supposed to afford an experimental proof of the Newtonian doctrine of gravitation. A similar observation has since been made by Dr. Maskelyne on the mountain Schehallien in Scotland.

The eighteenth century was marked by the discoveries of Dr. Bradley, the successor to Dr. Halley as Astronomer Royal, and Dr. Herschel, who also filled the same post so honorably to himself. Dr. Bradley discovered the aberration of light, and the mutation of the earth's axis, besides having formed new and accurate tables of the motions of Jupiter's satellites, and the most correct table of refractions that is extant: also with a large transit instrument, and a new mural quadrant of eight feet radius, he made observations for determining the places of all the stars in the British catalogue, and likewise nearly a hundred and fifty places of the moon. Dr. Herschel, by augmenting the powers of the telescope beyond any thing existing before, or even thought of, succeeded in discovering a new planet, which he named the Georgium Sidus; he also discovered two additional satellites to Saturn, besides those of his own planet. Among those who cultivated the higher branches of the science, and distinguished themselves by their researches, Dr. Maskelyne, the predecessor of Dr. Herschel, ranks the foremost, having been the originator of the Nautical Almanac, and brought into use the lunar method of determining the longitude, &c. besides making the requisite tables. The theoretical part of the science was indebted to Clairaut, Euler, Simpson, de la Caille, Kiel, Gregory, Leadbetter, for many correct observations and elucidations. The practical part acquired a systematic form and many improvements from the pens of Lalande, Ferguson, Emerson, Bonnycastle, Vince, &c. The historians of the science are Weilder, in his History of Astronomy; Baillie, in his History of Ancient and Modern Astronomy; Montuccla, in his Histoire des Mathematiques; and Lalande, in the first volume of his Astronomy.

The nineteenth century was commenced with the discovery of several new planets, namely one in 1801 by M. Piazzi, of Palermo, named Ceres, between Mars and Jupiter; another, named Pallas, discovered March 28, 1802, by Dr. Olbers, of Bremen; a third, named Juno, by Mr. Harding, at the observatory at Lilienthal, near Bremen, Sept. 1, 1804; and a fourth, named Vesta, by Dr. Olbers, March 29, 1807. These three last have also been observed to revolve between Mars and Jupiter.