ELEMENTARY ASTRONOMY:

ACCOMPANIED BY

SIXTEEN COLORED MAPS,

EACH 3 BY 3½ FEET,

DESIGNED TO ILLUSTRATE THE

MECHANISM OF THE HEAVENS,

AND FOR THE USE OF

PUBLIC LECTURERS, PRIVATE LEARNERS, ACADEMIES AND SCHOOLS.

BY H. MATTISON.

NEW-YORK:
HUNTINGTON AND SAVAGE.
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LEAVITT, TROW & CO., PRINTERS,
33 Ann-street, N. Y.

PUBLISHERS' NOTICE.

As this book may fall into the hands of some who have not seen the Maps by which its lessons are illustrated, it is proper to say that the *size* of the maps is such as to admit of their being studied to good advantage at the distance of from twenty to forty feet. Hence one set of maps is sufficient for a hundred scholars, and they may all study them at the same time, without touching the maps, or saying a word to each other. The book will furnish all the necessary explanations.

Their *number* is such as to warrant the belief that the subject may be well illustrated by them. They contain, respectively, from ten to fifty distinct figures each; and being executed in white relief upon a black groundwork, they not only answer to the appearance of the heavens in the night, but admit of being tinted so as to correspond with every hue observable in the heavenly bodies, and with every sentiment or principle to be illustrated.

The *style* and *execution* of the maps is worthy of the subject. Though mostly original, and designed by the author from actual telescopic observations, they are drawn and engraved by the best artists in the country. They are not mere outline sketches, rough and unfinished in their appearance, but large and well executed engravings, beautifully colored. No pains or cost have been spared to make them rich and handsome, as well as adapted to use. Aside therefore from their scientific merits, they are decidedly beautiful; and would be a cheap and tasteful ornament for the private mansion, as well as for Public Halls, Libraries, Lyceums, &c.

Every set of the maps will be accompanied by a neat *case,* in which they will be put up, with a cover hung upon hinges; and a hook, or lock and key, to secure them from dust and exposure while not in use, and from injury in transportation. Each map will have its number where it can be seen when it is rolled up; to obviate the necessity for unrolling them to find any particular one that may be wanted.

They will be put up in two different styles, to accommodate purchasers. The *best* will be put up with cloth backs, and mounted on rollers; the price of these, including the case and one copy of the book, will be $20 00.

The second style will be printed on strong paper, colored the same as the first, with light slats or rollers at the top and bottom; and the edges bound with tape or ribbon. This quality will be sold at $15 00, and will be equal to the first, excepting the cloth backs.

During the early part of the enterprise the Publishers entertained the hope that the work might be afforded at prices even lower than these; but, such has been the expense of its publication, beyond what was anticipated, that it is found impossible to retail it lower than as above stated, and make the usual discounts to agents and other dealers.

Wherever the maps are purchased and it is found difficult to obtain a supply of books in the vicinity, either request some Bookseller or Merchant to procure a supply for the district, or send an order, containing the cash, direct to the Publishers, 216 Pearl-street, New-York. The order should specify *how* the package is to be sent—by Express or otherwise—and *to whom* it should be directed; and whenever Trustees or Teachers are obliged to take this course to supply their schools, the books will be sold to them, even in small quantities, at the wholesale price.

New-York, February, 1847.

PREFACE.

The object of the following pages, and the accompanying maps, is the introduction of the sublime study of Astronomy into the Domestic Circle, the Lyceum, the Lecture Room, and the Primary Schools of the country. That this laudable work has already been attempted by others, and with a measure of success, is freely admitted; but at the same time it cannot be denied that, comparatively speaking, very little has been effected. While it is almost universally acknowledged, on the one hand, that no department of science is so well calculated to arouse and expand the intellect, enlarge the field of thought, awaken a thirst for knowledge, and improve the heart; it may be affirmed without hesitancy, on the other hand, that no important branch of study is so generally neglected in primary education, as is that of Astronomy. For this there must be somewhere a sufficient reason—an adequate cause.

Of the practical advantages of this noble science, there can be no rational doubt. It is of immense utility in *Geography*, in *Navigation*, in *Agriculture*, in *Chronology*, in the propagation of *Religion*, and in the dissipation of *Superstitious Notions*. It unfolds to us the most striking displays of the perfections of Deity; it exhibits the grandeur and extent of God's universal empire; its disclosures afford subjects of the most sublime contemplation, and thus tend to elevate the soul above vicious passions and grovelling pursuits; it tends to moderate the pride of man, and thus to prepare the soul for the employment of a future state. Such, then, is the obvious practical importance of this study, that it must sooner or later be regarded as an essential branch of popular education ; and we apprehend the time has already come when an attempt to introduce it generally into the Primary Schools of the land, will receive the hearty co-operation of every friend of Youth.

The *method* adopted by the author is the one in general use in other departments of science. Black-boards, diagrams, outline maps, and visible illustrations, are now considered indispensible in the school-room. "Whenever instruction can be conveyed through the eye," says Professor Smith, "that one of the external senses through which the impressions conveyed to the mind are the most vivid and permanent, it must surely be best to employ it." "The eye" says another distinguished teacher, "is the only medium of permanent impression." These doctrines are constantly verified by experiment. In his successful career in this country, as a scientific lecturer, Dr. Lardner constantly depended upon diagrams to illustrate his public discourses. Especially were they found necessary in the department of Astronomy, his favorite study.

As a further testimonial in regard to the value of maps and diagrams, take the following from Professor Olmsted's Treatise on Astronomy:

"Diagrams for public Recitations.—As many of the figures of this work are too complicated to be drawn on a black-board at each recitation, we have found it very convenient to provide a set of permanent cards of paste-board, on which the diagrams are inscribed on so large a scale, as to be distinctly visible in all parts of the lecture room. The letters may be made with a pen, or better, procured of the printer, and pasted on. The cards are made by the book-binder, and consist of a thick paper board about 18 by 14 inches, on each side of which a white sheet is pasted, with a neat finish around the edges. A loop attacked to the top is convenient for hanging the card on a nail. Cards of this description, containing diagrams for the whole course of mathematical and philosophical recitations, [including Astronomy of course] have been provided in Yale

College, and are found a valuable part of our apparatus of instruction."

These cards, it will be seen, are only one sixth as large as the maps accompanying this work, and yet they are considered a valuable part of the apparatus of Yale College. But their value is estimated by their *utility*, and not by their *cost*.

In regard to the *claims* of the Elementary Astronomy and the accompanying maps, it is the opinion of the author, of course, that they possess decided advantages over all other works upon this subject now before the public. Nor is this said to disparage or make war upon them. By no means. Many of them are doing good service, and we rejoice in their labors. But as we have adopted a new method, it is neither censorious nor immodest to consider it one of superior utility.

But it may be due to the reader to state frankly what those distinguishing features are, relying upon which, we venture to put forth another elementary work upon this subject:

1. As already intimated we have the most abundant and striking illustrations, presented in an attractive form, and upon a scale sufficiently ample to be visible in every part of the largest school-room, by day or by night. Sixteen maps each three by three and a half feet, and containing respectively from ten to fifty distinct figures, all devoted to the illustration of one general subject, afford scope sufficient to do it good justice. Besides, many of these drawings are *entirely original*, and in the opinion of competent judges, better calculated to convey a correct and permanent idea to the mind, than any that have heretofore appeared.

2. The plan of the book, and consequently the order of the maps, is also original. It not only gives the *facts* of the science, but it gives them in a manner admitting of illustration; and in such *order* and *connection* as that they can hardly fail to be understood and remembered, when once read and illustrated. "Science," says Lord Brougham, "is knowledge systematically arranged, so as to be

conveniently taught, easily learned, and readily applied." If this definition be correct, (and we certainly think it is,) it follows that it is not every book that is filled with facts upon a particular subject, that should be considered scientific. Quite as much depends upon the arrangement as upon the style of the author, or the facts themselves. With a view to convenience in teaching, facility in learning, and tenacity in remembering, the matter of this Treatise has been arranged upon an entirely new plan; and one, in the opinion of the author, more in accordance with the demands of philosophical classification, than some methods heretofore pursued. The student begins his inquiries at home, or with the Solar System, and ends them in the more distant heavens. The Earth is considered where she properly belongs, namely, among the Primary Planets, and the Moon where she belongs, or among the Secondaries. Eclipses and Tides are afterwards considered in distinct chapters, as phenomena not necessarily connected with a description of either the primary or secondary planets.

3. Each class of facts respecting the heavenly bodies, —their names, distances, magnitudes, periodic times, density, &c.—is drawn out in brief and succinct tables, and arranged in Lessons in a manner well calculated to aid the memory, to encourage the pupil onward, and to present, within narrow limits, a comprehensive view of the whole subject. The work is written for beginners, or as a Text Book of Astronomy for Common Schools and Academies; and the author has aimed less at the production of a profound and elaborate work, than at *consiseness* and *practical utility*. It is believed that with this Treatise in his hands, and the maps spread out before him, a pupil may possess himself of all the leading facts of the science even without the aid of an instructor. It is intended to be, as its title imports, an "*Elementary Astronomy*," adapted to the present state of the science in this country, and to the wants of the public at large. Such a work, it is thought, has not heretofore been published. "It is seldom," says a

late writer, "that men who have arrived at great distinction in their favorite pursuit, have condescended to write a plain and simple treatise, suited to the wants of those who have just passed the threshold of science." Men who are conscious of superior abilities are sometimes fond of appearing learned in their productions; and moreover, as Bakewell observes, "he who attempts to make a scientific subject familiar, runs the risk of being decried as superficial: a plentiful share of dullness, combined with a certain degree of technical precision, is regarded as essential proof of profundity."

4. This work is the only one before the public that contains any thing respecting the two *New Planets*, namely *Astrea*, and *Leverrier;* or that embodies the recent discoveries of Lord Ross, respecting the Nebulæ.

5. The Book is a *concise* and *cheap* work, and consequently adapted to general circulation. The Maps can be purchased for schools with public moneys, so that the purchase of one of these Keys, costing the individual learner but a few shillings, opens the whole field, as well to the children of the poor, as to the more favored offspring of the rich.

Such are some of the improvements upon which we base our claims to public patronage, in sending forth a new elementary work upon the subject of Astronomy. In its preparation for the press, the author has availed himself of all the helps within his reach. He has consulted all the books upon the subject that were available in this country, as well as many practical teachers, and gentlemen of acknowledged scientific abilities. But while on the one hand he has used books as writers generally use them, namely, as sources of knowledge, and has advised with men of learning and experience in regard to many particulars, the author feels bound, in justice to himself, to claim for his work a good degree of originality; and to say that whether good or bad it is his own, and not the work of another.

It is only necessary to add that the statistics in the tables are generally given in round numbers, and according to what was considered the highest authorities.

Should any errors be discovered that have escaped notice, they will be promptly corrected in future editions; and should the work be found wanting in adaptation in any respect, either for city or country schools, it will at once undergo the requisite modifications, as we are determined to furnish a work of the greatest possible utility, at the least possible expense.

New-York, February, 1847.

From the Oswego Palladium.

It is but too true that the study of Astronomy has been too much neglected by all classes, and especially by the youth in our common schools, into which the subject has rarely ever been introduced: owing, doubtless, in a great measure, to a mistaken notion (arising from the want of an appropriate text-book) that the subject is intricate, and a knowledge of it difficult to be acquired. A well digested and properly arranged treatise on the science, therefore (such as we presume the one in question to be), one which will so simplify the subject as to render it easy of comprehension by youthful minds, will be a desideratum of no trifling importance; and the publication of such a work, and its introduction into our common schools as a text-book, are objects deserving of encouragement and success; and he who engages in the undertaking, will render a real service to the cause of education.

We have had the pleasure of a hasty examination of the Maps which are to accompany this work; and, so far as we are enabled to judge, they are admirably adapted to the purpose which they are intended to subserve.

From the Northern Christian Advocate.

* * * * * The facts of the science are classified in a manner altogether original, and in our opinion well calculated to facilitate their acquisition, and to fasten them permanently in the mind. * * After an examination of the work above described, we are decidedly of opinion that it must go into very general use, where districts and academies will feel themselves able to purchase it. And yet, considering its extent and execution, the price is by no means disproportionate to its real worth. Though it is hardly yet from the press, it has already been adopted in several counties, and commended by impartial and competent judges.

From the Rochester Daily Advertiser.

These Maps, with the accompanying work, seem admirably calculated to make the study of Astronomy not only an agreeable but an easy one. Every school and academy in the country should be provided with them.

RECOMMENDATIONS.

From the Hon. Ira Mayhew, *Superintendent of Public Instruction for the State of Michigan.*

Monroe, Jan. 16, 1847.

Rev. H. Mattison;

Dear Sir,—The first seventy-two pages of your forthcoming "Elementary Astronomy," has been received and read. Although I have not seen the Maps, nor any portion of the Second Part of the work, yet I think it cannot fail to be eminently useful.

Your plan is, so far as I have the means of knowing it, good and well executed. The manner in which you treat of the laws that govern the Solar Bodies seems better calculated to arrest the attentian and inform the mind of the student than any other treatise on that subject with which I am acquainted.

Hoping to see the entire work soon, and wishing you success in the prosecution of your noble undertaking, I remain, Dear Sir,

Yours truly

IRA MAYHEW.

Extract of a Letter from Prof. Smith, *of the Wesleyan University.*

Dr. Olin and Prof. Johnson have both expressed themselves favorably in reference to the utility of the series of maps which you propose publishing. * * * Of the plan you have in view I cannot doubt the efficiency. Whenever instruction can be conveyed through the eye, that one of the external senses through which the impressions conveyed to the mind are the most vivid and permanent, it must surely be best to employ it. By the series of maps you propose, many notions will be conveyed to the young mind which could hardly be communicated in any other way, and far more correct ones on almost all the points capable of visible illustration. Such a series I must therefore regard as exceedingly useful.

From Rev. E. E. E. Bragdon, A. M., *Principal of the Mexico Academy, Mexico, N. Y.*

Messrs. Huntington & Savage:—Having hastily examined a part of the work entitled "Elementary Astronomy," which is now being issued from your press, I take pleasure in stating that I am much pleased with the design and execution of the work. Astronomy is confessedly a very important science, and must be regarded as constituting an essential part of every good educational system. Any work, which is calculated to elicit a more general interest in this interesting department of nature, and, at the same time, bring the study of it within the reach of all classes of community, must be considered highly beneficial to the cause of sound education. Such we regard the "Elementary Astronomy," by Rev. H. Mattison. It is Astronomy simplified and made plain—well adapted to the capacities of the young. The author, having omitted the long and tedious mathematical demonstrations and formulas, which are essential for those to understand who may wish to push their investigations into the more recondite and difficult parts of the science, has seized upon the most interesting and important parts, and beautifully illustrated them by means of sixteen large and elegant maps, bringing the whole panorama of the heavens before the learner, and rendering the sublime study of Astronomy pleasing pastime. We think the work eminently adapted to the uses of our public schools and academies, and doubt not that it will secure that amount of favor from a discerning public which its merits may seem to demand.

E. E. E. BRAGDON.

*Mexico, Nov.*17, 1846.

I fully concur in the above recommendation.

JOHN SAWYER,
Pastor of the M. E. Church, Mexico, N. Y.

From the Faculty of Union Academy, Red Creek, N. Y.

UNION ACADEMY, RED CREEK, Nov. 17, 1846.

Rev. H. MATTISON:

DEAR SIR,—Having witnessed, last evening, an exhibition of your Astronomical Maps, we are fully persuaded that they are calculated to create a new and lively interest in the sublime study of Astronomy. They will supply a desideratum which has long been felt, in communicating, clearly and intelligibly, knowledge on some of the intricate subjects connected with this important study.

Their introduction into our institutions of learning will greatly relieve the teacher, by affording important illustrations, without which no student can acquire a thorough understanding of the science.

Please send to this Institution twenty-five copies of your "Elementary Astronomy," and one set of your best Maps.

HUGH B. JOLLEY, A. M.,
Principal, and Prof. of Mathematics and Astronomy.
JOHN W. PRATT, A. M.,
Prof. of Languages.

Report adopted by the Teachers' Institute of Orleans County, N.Y., Oct. 1846.

The committee, to whom was submitted for examination the Astronomical Charts of Rev. H. Mattison, ask leave to offer the following report:

In point of fitness for the popular wants on this subject, they are second to none within our knowledge. Among other excellencies, they possess the advantage over every other work of the kind, of combining strict accuracy with a plainness of arrangement easily comprehended by those least familiar with the subject; and we do most confidently and cordially recommend them to the attention of the Trustees and Teachers of the different districts in our county, as worthy of introduction into every school.

Any teacher, however unacquainted he may be with the interesting science of Astronomy, need feel no hesitancy in attempting to instruct a class of pupils from these Charts. Each successive step prepares the way for the next, in so plain and obvious a manner, as cannot fail to be both interesting and instructive. They have our decided approbation.

ALONZO BEEBE, *Co. Sup't.*,
JAMES C. CROSS,
CORNELL MOREY,
WILLIAM ORTON,
WM. M. MILLER,
Committee.

Resolutions of the Tompkins County Teachers' Institute, held at Ithaca, N. Y., Oct. 1846.

The undersigned, a committee appointed by the Teachers' Institute of the County of Tompkins, for the examination of Mr. Mattison's Astronomical Maps, &c., do report as follows:

Having examined said Maps, we consider them well calculated for the promotion of the science of Astronomy, inasmuch as they are adapted to the capacity of the youthful mind, and present to the understanding a familiar and well-arranged series of illustrations that can hardly fail to combine interest with instruction.

S. D. CARR,
Principal of Ithaca Academy.
L. WETHRELL,
Prof. of Chemistry and Mathematics.
E. A. TOMPKINS,
DANIEL WELLER,
J. S. McCREA,
J. D. THATCHER.

Ithaca, Oct. 23, 1846.

The above report was unanimously adopted by the Institute.

S. ROBERTSON, *Co. Sup't.*

Resolutions of the Greene County Teachers' Institute for 1846.

At the Fall Session of the Greene County Teachers' Institute held in the village of Cairo, N. Y., 1846, on motion of WM. F. TERHUNE, County Superintendent, seconded by ALBERT D. WRIGHT, Principal, the following resolutions were unanimously adopted:

Resolved, That the grateful thanks of the members of this Institute are due, and are sincerely tendered, to the Rev. H. Mattison, for his instructive illustrations and explanations of the Astronomical Maps of which he is the author; that we regard those Maps as a valuable accession to the cause of science; and that we heartily wish him entire success in the laudable efforts he is now making to introduce the study of the sublime science of Astronomy more extensively in our common schools.

Resolved, That we regard the study of Astronomy, by the advanced scholars of our district schools, as being conducive to the improvement, expansion, and elevation of their minds, enabling them to comprehend the stupendous machinery of nature, and impressing them with awe and reverence for nature's Great Architect.

WM. F. TERHUNE, *Pres't.*

From Prof. S. R. SWEET, *and others, members of the Temporary Normal School, Redfield, N. Y.*

At a public meeting of the citizens of Redfield, and the members of the Temporary Normal School, convened for the purpose of hearing a lecture on Astronomy from the Rev. H. Mattison, the following resolutions were unanimously adopted:

Resolved, That the thanks of the citizens, and the members of the Institute, be tendered to the Rev. H. Mattison, for his remarkably interesting and instructive lecture on the science of Astronomy.

Resolved, That the ingeniously conceived and admirably executed plan of presenting the more important principles and facts of Astronomy to the eye, by means of outline maps, merits our warmest approbation and encouragement; and as an evidence of our sincerity, we hereby order a set of the Maps at once, for the public school in this village, and pay for them in advance.

S. R. SWEET, *Prin. Tem. N. School.*
S. BROOKS, *Town Sup.*

From the Delaware Express.

On the whole, after examining the plan of the author, and the Maps in particular, we do not hesitate to pronounce them of a superior order, splendidly got up, and certainly *very* reasonable in price. We hope to hear of their introduction into the schools of our county.

From ALEXANDER M. BAKER, Esq., *County Superintendent of Oswego County.*

I have examined with much care Mr. Mattison's "ELEMENTARY ASTRONOMY," with the accompanying MAPS, and hail them as one of the greatest improvements of the day. Every practical school teacher has *seen* and *felt* the want of some elementary treatise on this subject, that should be adapted to the capacities of children and youth; and this, I think, is just THE work that has long been needed; and one which I hope ere long to see introduced into all our Schools and Academies.

A. M. BAKER.

Sandy Creek, Nov. 9, 1846.

From H. A. BREWSTER, Esq., *Chairman of the Library Committee of the Board of Education of the City of Rochester.*

ROCHESTER, Oct. 30, 1846.

Rev. H. MATTISON:

DEAR SIR,—I have examined your Astronomical Maps and method of teaching Astronomy, with a great degree of interest, and am decidedly of the opinion that it is the best method yet adopted for giving a correct impression upon that subject to the mind of the young.

The manner in which you introduce it is so simple and plain, that it will be easily apprehended by the smallest pupil; and yet, pursuing the illustrations by the system you have adopted, he is carried regularly forward, with great facility, to a complete knowledge of the whole science.

I think the Maps should be placed in all our schools and seminaries of learning, and that no better use can be made of the funds appropriated by the State to educate the rising generation, than by applying a sufficient sum to place a set in every school-house in the land. With great respect, your obedient servant,

H. A. BREWSTER.

From the Roman Citizen.

We had the pleasure of learning from Mr. Mattison, while in Rome, something of the character of this publication, and would bespeak for it in advance the favorable attention of the friends of education. To public lecturers, academies, schools, and in the family circle, we are confident it will prove a valuable acquisition. This sublime and truly ennobling study is too much neglected. We hope to see Mr. Mattison's work generally introduced into our schools, being persuaded that it will do much towards rendering the study of Astronomy attractive and easy.

From Rev. Elias Bowen, D. D., *of Ithaca, N. Y.*

To Messrs. Huntington & Savage, *Publishers, New-York :*

From a partial examination of the work of Rev. H. Mattison, entitled "Elementary Astronomy," &c., with the accompanying Maps, and designed for common schools, I am clearly of opinion that it will supply a desideratum which is beginning very sensibly to be felt in that department of our great educational system. Passing over the mathematical demonstrations, or the process by which the truths of the science are discovered, it adapts itself to the juvenile mind with great readiness, by a very natural and clear embodiment of facts, which fall as much within the comprehension of the incipient scholar as those of common Geography. The very interesting and useful method of teaching by illustration is here employed, in a series of Maps explanatory of the phenomena of the science, with the happiest effect.

ELIAS BOWEN.

Ithaca, Oct. 22, 1846.

From the Rome Sentinel.

This work is eminently original, and from its utility in studying the science of Astronomy, we believe it will meet the approbation of every student, teacher, and public lecturer in the country. Mr. Mattison, the author, is learned in the science of Astronomy, and has for a long time applied himself with great industry in getting up this work.

The plan he has adopted will furnish facilities for a thorough acquaintance with this science in the common schools of our country, where it has never been taught to any extent or with much profit and improvement to the learner. We hope to see it introduced into our common schools, academies, and higher institutions of learning.

From the Genesee Evangelist.

After giving the title of the work, the editor says:

We have had the pleasure of examining the greater part of the Maps which are to accompany this work, and for correctness of design, boldness of appearance, and simplicity and harmony of arrangement, we have never seen them excelled. They are admirably adapted in giving a clear and ready view of the science that they are designed to explain and teach. Astronomy has ever been an intricate study, requiring long and patient investigation. But the mode pursued by Rev. Mr. Mattison in teaching it, will render it interesting, beautiful, and inviting, and will throw a charm on every ascending step, exciting the mind to loftier flight, till the whole field is surveyed. The author has certainly rendered an essential service to science, and will no doubt be amply remunerated in the ready sale which will attend his work, and the new interest which will be imparted in investigating the variety, extent, and position of the heavenly bodies.

SUGGESTIONS TO TEACHERS.

1. It is recommended that Teachers who are not familiar with the subject of Astronomy, should review this branch, in connection with the Maps. This may be done in a short time, by taking the book, and a map or two home with them every night. Indeed a teacher who has never studied Astronomy to any great extent, can in this way keep ahead of his school, and qualify himself in the most effectual manner to interest them, as they follow on and explore the ground over which he has so recently travelled.

2. It is not expected that more than from fifteen to twenty minutes each day can be devoted to this subject; and the best time will probably be near the close of the school, as the exercise will be a sort of relaxation from severer studies.

3. It is deemed of the first importance that when the time for studying Astronomy arrives each day, the whole school should join in the exercise at the same time. When one or more of the maps are hung up to view, and especially when the questions and answers upon the lessons begin, it will be found difficult to confine a scholar to any other study in the same room. Let every thing else then be laid aside for a short time each day, and let the whole school advance together through the successive lessons. Even small scholars, or those who are only tolerable readers, may thus get a general knowledge of *Astronomy*, without in the least interfering with their *Reading*, *Writing*, *Arithmetic*, *Geography*, or *Grammar*.

4. Instead of one book only in the school, as a key to the Maps, and that in the teachers hands, it is indispensably necessary that every scholar pursuing the study, should have a copy of the book. It was in view of this necessity, that the subject was compressed within narrow limits, and the book got up in the cheapest possible form.

5. When the time for studying Astronomy arrives, the school will lay aside all other studies and take their books upon that subject. The Teacher will inquire what Maps are necessary to illustrate the lesson, to which the school will answer by naming the *number* referred to at the head of the lesson. The map, will then be hung up. Let the pupil understand that the left hand side of the map is East, the right West, the top North, and the bottom South. When, therefore, they can be hung in the south part of the school-

room, the pupil will refer every thing to the right point of compass, without the aid of the imagination.

6. The Map being hung up, the school will devote some ten or fifteen minutes to studying the lesson, occasionally looking at the map for illustration, as the thing to be learned is there pictured out. The oral exercise will then begin. If the lesson contains an important table, or list of names like lessons VII., VIII., XIV., XVIII., XXI., &c., such table or list should be recited in concert. If it be of less moment, and withall somewhat extended, it may be passed by being carefully studied over, and then reviewed orally, according to its character, and at the discretion of the Teacher. In many other cases where the lessons are like those from I. to VI. inclusive, they should only be *studied*, without committing to memory ; and the Teacher should ascertain the knowledge thus acquired by extemporaneous questions, at the same time illustrating what may still appear obscure to any pupil, and correcting any mistakes into which individuals have fallen.

7. After all, much will depend upon the judgment and ingenuity of the Teacher, and the interest he takes in the subject. Sound learning can never be acquired, by any mode of teaching, without thought and attention. Neither can any particular course be struck out that will be adapted to all kinds of schools, and to every part of the country. It will be inexpedient for the learner to pursue this branch at home, or in his room, except those parts of the work that require no illustration, or those lessons that do not refer to maps. In some cases, the whole subject may be presented orally by the teacher, in a series of evening lectures, following the course of the book ; but this should rather be in *addition* to the regular study during school hours, than a substitute for it.

With these suggestions the work is committed to the hands of Teachers, at the same time bespeaking their co-operation in rendering it useful to the rising generation ; in detecting any errors that may exist ; and in making any improvements of which it may yet be susceptible.

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INTRODUCTION.

LESSON I.

ASTRONOMY is that science which treats of the names, distances, magnitudes, and motions of the heavenly bodies—the Sun, Moon, Planets, Comets, and Fixed Stars—and the laws by which they are governed.

The oldest records of astronomical science are found in the Holy Scriptures. We there read of the creation of the sun, moon and stars, and the commencement of their revolutions. In the Book of Job, which was written fifteen hundred years before Christ, we read of "*Arcturus*, *Orion*, and *Pleiades*," and also of "*Mazzaroth*," supposed to mean the Zodiac. It is here said, likewise, that the Almighty "stretcheth out the north over the empty place, and hangeth the earth upon nothing."

The prophet Amos speaks of the "seven stars and Orion," seven hundred and thirty-three years before Christ, and of the phenomena of day and night.

The Greek philosopher, *Pythagoras*, taught astronomy five hundred years before Christ, and the Egyptian philosopher, *Ptolemy*, three hundred years before the Christian era. His was the first regular system of astronomy.

LESSON II.

THE PTOLEMAIC THEORY.

(Map 1.)

The Ptolemaic System, so called from Ptolemy, its author, is the subject of Map No. 1. It represents the earth as located in the centre of the universe; as being perfectly at rest; as a plane instead of a globe; and as inhabited only on one of its sides. Some supposed the earth to float upon an abyss of waters. Ptolemy taught, also, that the sun, moon, planets and stars revolved around the earth, from east to west, as they appear to do, every twenty-four hours. To account for their passing over the earth without falling down upon its surface, it was supposed that the heavenly bodies were supported by vast *arches*, or *hollow spheres*, in which they were firmly set like a diamond in a ring.

But as the sun, moon, planets and stars, were not all at the same distance from the earth, it was supposed that there were several of these spheres placed one above another—that the Moon was in the first, Mercury in the second, Venus in the third, the Sun in the fourth, Mars in the fifth, Jupiter in the sixth, Saturn in the seventh, and the Fixed Stars in the eighth. The ancients had no knowledge of Herschel.

Mercury, Venus, and the Moon, were placed in the three lower spheres, because they were sometimes seen to pass between the earth and the sun. But Mercury and Venus sometimes go before the sun, and sometimes follow after him. To account for this, it was supposed that besides the great circle of the heavens around which they passed daily, they had other smaller circles within their respective spheres, in which they revolved at the same time. These the ancients called *epicycles*. They may be seen on the Map, in the second or sphere of Mercury.

To account for the rapid westward motion of these ponderous spheres, it was believed that the necessary moving power was applied in some way to the upper sphere, above the fixed stars; and that this sphere communicated its motion to the one immediately beneath or within it, and so on down to the lower sphere. This, it was thought, moved slower than the rest, as the moon constantly fell back of the sun. To allow the light of the stars to pass down to the earth, it was supposed that the several concentric spheres rising one above another, were made of the finest *crystal*, and were perfectly transparent. The space above the fixed stars was designated as the blissful abode of departed spirits.

On the map, the spaces *between* the white circles represent the several crystaline spheres. The sun and moon are represented as going down in the west, the moon having fallen a little behind the sun, as when we first see the new moon; Mercury and Venus are near the sun, as they always are, and Jupiter, Saturn, and Herschel, on the left. On the right is seen a *comet* passing down towards the sun.

Such is the *Ptolemaic Theory* of the structure of the universe.

LESSON III.

DIFFICULTIES OF THE PTOLEMAIC THEORY.

(Map 1.)

Besides the clumsiness of the machinery, it was attended by numerous difficulties which its supporters could never explain or obviate.

1. It could never determine what upheld the earth. Rocks and mountains could not float upon water; and if they could, what upheld the water? Some imagined that the earth was upheld by a huge *serpent*, resting upon the back of a *tortoise*, as represented in the map. But what upheld the tortoise?

2. It represented many very large bodies, as the sun and some of the planets are now known to be, as revolving around the earth, a comparatively small one.

3. It adopted the most difficult and unreasonable plan for lighting and warming the earth, and producing

day and night. Taking the sun around the earth every twenty-four hours, was like carrying a fire around a person who was cold and wished to be warmed, instead of his turning himself to the fire as he pleased.

4. The Ptolemaic theory would require a motion inconceivably rapid in all the heavenly bodies. As the sun is ninety-five millions of miles from the earth, the entire diameter of his sphere would be one hundred and ninety millions of miles, and its circumference about six hundred millions. Divide this distance by twenty-four, the number of hours in a day, and it gives twenty-five million miles an hour, or sixty-nine thousand four hundred and forty-four miles per second, as the velocity of the sun!

This theory gives a still more rapid motion to Mars, Jupiter, Saturn, and the fixed stars. It would require the nearest of the latter to move at the rate of near fourteen thousand millions of miles per second, or seventy thousand times as swift as light, in order to accomplish its daily course.

But with all these difficulties in its way, the Ptolemaic theory was generally believed till about the middle of the sixteenth century, or three hundred years ago.

LESSON IV.

THE COPERNICAN SYSTEM.

(Map 2.)

About the year 1510 *Nicholaus Copernicus*, of Prussia, taking some hint perhaps from the writings of *Pythagoras*, discovered what is now generally received as the true theory of astronomy, and called after its author the *Copernican System.*

The Copernican System attributes the apparent daily motion of the sun, moon, and stars from east to west, to the actual motion of the earth on its axis from west to east. Though the heavenly bodies *seem* to move, yet we often transfer our own motion, in imagination, to other bodies that are at rest; especially when we are carried rapidly along without effort, as in a carriage, steamboat, or railway car. It places the sun in the centre of a system of worlds, of which the earth is one; gives them a revolution around their common centre, by which the seasons are produced; and another upon their axes, producing day and night. It accounts for all the motions of the heavenly bodies, and harmonizes the whole system of nature.

The *Copernican System* is represented in Map 2. In the centre is seen the sun, in a state of rest. Around him, at unequal distances, are the planets and fixed stars, the former revolving about him from west to east, or in the direction of the arrows. The white circles represent the *orbits*, or paths, in which the planets move around the sun. On the right is seen a *comet* plunging down into the system around the sun, and then departing. This is the *Copernican Theory* of the solar system.

> "O how unlike the complex works of man,
> Heaven's easy, artless, unencumber'd plan."

The truth of the Copernican theory is established by the most conclusive and satisfactory evidence. Eclipses of the sun and moon are calculated upon this theory, and astronomers are able to predict thereby their commencement, duration, &c., to a minute; even hundreds of years before they occur. We shall, therefore, assume the truth of this system, without further proof; and proceed accordingly to the study of the heavenly bodies.

LESSON V.

THE SOLAR SYSTEM AND SIDEREAL HEAVENS.

(Map 2.)

The material universe may be divided into two parts: the Solar System and the Sidereal Heavens.

The *Solar System* consists of the sun and all the planets and comets that revolve around him.

The *Sidereal Heavens* embrace all those bodies that lie around and beyond the solar system, in the region of the fixed stars.

The relation of the one to the other may be partially understood by carefully observing Map 2. The sun and his attendant worlds are there seen *within* the fixed stars, which occupy the corners of the map, and the spaces without in every direction. If the observer were placed at a distance beyond the solar system, in any direction, he would see vast numbers of the fixed stars between it and him, as if they were scattered between the eye of the learner and every part of the map. To us the solar system seems to be in the centre of the universe.

In considering the general subject of astronomy, we shall divide it into two parts; treating first of the SOLAR SYSTEM, and secondly of the SIDEREAL HEAVENS.

PART I.

OF THE SOLAR SYSTEM.

CHAPTER I.

CLASSIFICATION OF THE SOLAR BODIES.

LESSON VI.

(Map 2.)

THE Solar System derives its name from the Latin word *Sol*, the sun. It includes that great luminary, and all the worlds that revolve around him. To distinguish these attendant bodies from others in the heavens, they will be denominated *Solar Bodies*.

The bodies of the Solar System are divided into several distinct classes.

I. The SUN is the fixed centre of the system, around which all the solar bodies revolve; and from which they receive their light and heat.

II. The PLANETS are those bodies that revolve around the sun, and receive their light and heat from him. The term *planet* signifies a *wanderer*, and was applied to the solar bodies because they seemed to move or wander about among the stars. In this sense comets are planets; but for the sake of distinction the term is not applied to them in astronomy.

1. The planets are divided into *Primary* and *Secondary* planets.

The *primary planets* are those larger bodies of the system which revolve around the sun only, as their centre of motion. They may be distinguished in the map by their size, and also by their being in their orbits, or on the white circles.

The *secondary planets* revolve not only around the sun, but also around the primary planets, as their attendants or moons. They may easily be distinguished on the map.

2. The planets are again divided into *Interior* and *Exterior* planets.

The *interior* planets are those whose orbits lie *within* the orbit of the earth; or between it and the sun.

The *exterior* planets are those whose orbits lie *without* the orbit of the earth.

3. Five of the smaller primary planets are called *Asteroids*. They may be seen on the map near together, just above the sun.

4. *Comets* are a singular class of bodies belonging to the solar system, distinguished by their long flaunting trains of light, and also by the elongated form of their orbits, as shown in the map.

CHAPTER II.

OF THE PRIMARY PLANETS.

LESSON VII.

NAMES OF THE PRIMARY PLANETS.

(Map 2.)

The *Primary Planets* are twelve in number. They are distinguished in astronomical books by certain characters, which are used to represent their respective planets. The names of the planets and their symbols or signs are as follows:

Mercury,	☿	Ceres,	⚳
Venus,	♀	Pallas,	⚴
Earth,	⊕	Astræa,	*
Mars,	♂	Jupiter,	♃
Vesta,	⚶	Saturn,	♄
Juno,	⚵	Herschel,	♅

With the exception of the *Earth*, *Astræa*, and *Herschel*, they are all named after Heathen gods or goddesses. The five enclosed in brackets are the *Asteroids;* Mercury and Venus are the *interior* planets; and Astræa is the *new planet*, or one recently discovered. These planets should now be looked out upon the map, and their comparative size, distances from the sun, and appearances carefully noticed.

Mercury is seen close to the sun, and directly under him. *Venus* is also near the sun, and a little above him on the left. The *Earth* is next in order, above the sun, and a little to the right. The *Moon* and her orbit will be seen near the earth. *Mars* is on the right of the sun, and beyond the orbit of the earth. He is the first of the *exterior* planets. Above the earth are seen the five planets called *Asteroids*, viz.: *Vesta*, *Juno*, *Ceres*, *Pallas*, and *Astræa*. *Jupiter* is the large planet below the sun on the left. His surface is striped with curious *belts*, and he is attended by four secondary planets or moons. Above the Asteroids on the right is seen the beautiful planet *Saturn*. He is attended by seven moons, and surrounded by two magnificent and wonderful *rings*. *Herschel* and his six moons are placed on the left, near the upper corner of the map.

LESSON VIII.

DISTANCES OF THE PLANETS.

(Map 2.)

Map 1 shows all the planets at their relative distances from the sun. The scale is one hundred millions of miles to an inch. The distances of the planets in miles are as follows:

Mercury,	37	millions.	Ceres,	263	millions.
Venus,	69	"	Pallas,	263	"
Earth,	95	"	Astræa,	253	"
Mars,	145	"	Jupiter,	495	"
Vesta,	225	"	Saturn,	900	"
Juno,	254	"	Herschel,	1800	"

It is almost impossible to conceive of these vast distances. They may perhaps be better understood by considering the time it would require for even a rapid body to visit them from the sun.

Were a body to move at the rate of five hundred miles an hour, without intermission, it would require near eight and a half years for it to pass from the sun to the nearest of these planets. To visit the earth would require over twenty-one years; and to reach Herschel over four hundred years!

Railroad cars travel at the rate of thirty miles an hour, or a mile every two minutes. Now if there was a railroad from the sun to the orbit of Herschel, and the orbits of the other planets were stopping places on the route, the train would reach

Mercury,	in	152	years.
Venus,	"	264	"

Earth,	"	361	years.
Mars,	"	554	"
Jupiter,	"	1884	"
Saturn,	"	3493	"
Herschel,	"	6933	"

Such a journey would be equal to riding four hundred and fifty thousand times over Whitney's railroad, from Boston to Oregon.

It is now about 5850 years since the creation of the world. Had a train of cars started from the sun at that time to visit the orbit of Herschel, and travelled day and night ever since, at the rate of thirty miles per hour, they would still have 284 millions of miles to travel before they could reach their journey's end. To finish the passage would require 1083 years longer; the whole of time past and a thousand years to come!

Such is the vast area embraced within the orbits of the planets, and the spaces over which the sunlight travels, to warm and enlighten its attendant worlds.

LESSON IX.

DEGREES, MINUTES AND SECONDS EXPLAINED.

(Map 3.)

In astronomy, the distances and magnitude of bodies are often given in degrees, minutes, and seconds. It will be necessary, therefore to show what these mean.

A *circle* is represented on the right in Fig. 1.

A *quadrant* is the fourth part of a circle.

A *sextant* is the sixth part of a circle.

A *sign* is the twelfth part of a circle.

A *degree* is the thirtieth part of a sign, or one three hundred and sixtieth part of a circle.

A *minute* is a sixtieth part of a degree; and

A *second* is the sixtieth part of a minute.

On the map the circle is divided off into parts of ten degrees each, and numbered in figures every thirty degrees, or oftener. It will be seen that one-fourth of a circle contains just three *signs*, or ninety degrees; and half a circle six signs, or one hundred and eighty degrees.

All circles, whether great or small have the same number of degrees, namely, three hundred and sixty. But one hundred and eighty marks the greatest possible angle, as a pair of compasses can be opened no farther than to bring the legs in a straight line. These degrees, &c., are used to represent the angle which any two lines form, coming from different points, and meeting at the eye in the centre.

In the figure the lines passing from the stars on the left to the eye, are found by the measurement on the circle to be ten degrees apart. If the dotted line was perpendicular to the lower or plain one, they would be ninety degrees apart, &c.

Degrees, minutes and seconds are denoted by certain characters as follows: $^\circ$ denotes degrees, $'$ denotes minutes, and $''$ denotes seconds. Thus, $10^\circ\ 15'\ 20''$ is read ten degrees, fifteen minutes, and twenty seconds. These characters will often be used hereafter as we proceed.

Measurement by degrees, minutes, and seconds, is called *angular measurement.*

LESSON X.

ANGULAR DISTANCES, MAGNITUDES, &c.

(Map 3.)

In Fig. 1, the observer is represented as seeing two stars on the left side of the map. By looking at the divided circle it will be seen that the angle which these two stars make at the eye is 10°; the stars are therefore said to be 10° apart. If a globe filled the same angle, or number of degrees, as shown on the map, we should say it was 10° in diameter. If the space between the foot of a mountain and its top filled the same angle, we should say it was 10° high; and if a body passed through the same angle, in one hour, in the direction of the arrow, we should say its velocity was 10° an hour.

All circles, whether large or small, have the same number of degrees; but the angle which an object makes at the eye will be great or small, according as it is near to or distant from the observer. This is illustrated by fig. 2. On the left is the object. To the observer in the centre the globe is 20° in diameter; but to the one on the right its diameter is but 10°. To a third observer, at twice the distance of the last, it would appear but 5° in diameter, &c. This shows why objects grow smaller in appearance as we recede from them, and larger as we advance towards them. Their apparent magnitude is increased or diminished *in proportion to the distance from which they are viewed.*

LESSON XI.

THE SUN AS SEEN FROM THE DIFFERENT PLANETS.

(Map 3.)

By the table of distances, (Lesson VIII.) and also by Map 2, it will be seen that the Sun is about twice as near to Mercury as he is to Venus. Of course, then, according to the principle illustrated in Fig. 2, his apparent diameter must be twice as great when viewed from Mercury as when viewed from Venus. From the Earth it is still smaller, and so on till we view him from the distant orbit of Herschel, from which he will appear but a small glimmering point in the heavens. From the fixed star Sirius, he would appear smaller than Sirius appears to us.

The relative apparent magnitude of the Sun, as seen from the different planets, is represented by Fig. 3. His angular diameter, in minutes of a degree, would be,

From Mercury .	$82\frac{1}{2}'$	From Ceres .	$11\frac{1}{2}'$
" Venus . .	$44\frac{1}{4}'$	" Pallas .	$11\frac{1}{2}'$
" Earth . . .	$32'$	" Astræa	$12'$
" Mars . . .	$21'$	" Jupiter .	$6'$
" Vesta . . .	$13\frac{1}{2}'$	" Saturn .	$3\frac{1}{8}'$
" Juno . . .	$12'$	" Herschel	$1\frac{2}{3}'$

From Mercury it is supposed that the spots on the Sun would be visible to the naked eye, as seen on the map; and from Herschel the Sun himself would appear but as a large and brilliant star. Let the pupil imagine himself as approaching the sun till it has four times his present apparent diameter, and his spots stand out in full view to the naked eye; and then let him recede from the sun, pass the earth and the orbits of Jupiter and Saturn, and retire away into space, till the sun appears but a glimmering star, and he will have some faint conception of the almost inconceivable distances of the solar bodies.

LESSON XII.

PHILOSOPHY OF THE DIFFUSION OF LIGHT.

(Map 3.)

Light always moves in straight lines, unless turned out of its course by reflection or refraction. This is represented by fig. 4 on the map; where the light is seen passing to the right, from the sun on the left. From this law it follows that the squares A B and C in the diagram would receive equal quantities of light; but as B has four times, and C nine times the surface of A, a single square of B equal to A, would receive only one-fourth as much light as A; and a square of C, equal to A, would receive only one-ninth as much. This difference in the amount of light received is caused by the unequal *distances* of the several squares from the miniature sun on the left. The distances are marked on the upper line of light by the figures 1, 2, 3.

The rule for determining the relative amount of light received by several bodies, respectively, placed at unequal distances from their luminary, is, that *their light is inversely, as the squares of their distances.* This rule, also, is illustrated by the figure. The square of 1 is 1; the square of 2 is 4; and the square of 3 is 9. Hence 1, $\frac{1}{4}$, and $\frac{1}{9}$, will represent their relative light, as already shown. The checks are designed to illustrate this rule.

LESSON XIII.

LIGHT AND HEAT OF THE SEVERAL PLANETS.

(Map 3.)

By applying the foregoing rule to the *planets*, at their respective distances from the sun, we are enabled to ascertain the relative amount of light received by each; and on the supposition that their heat is proportionate to their light, we can easily determine their average temperature. At the bottom of the map the planets are placed at their relative distances from the sun, commencing with Mercury on the left, and ending with Herschel on the right. Immediately over each planet respectively, and near the upper line of the diagram, is marked the proportionate light and heat of each, the earth being one. They are as follows:

Mercury	$6\frac{1}{2}$	Juno and Astræa	$\frac{1}{7}$
Venus	2	Ceres and Pallas	$\frac{1}{9}$
Earth	1	Jupiter	$\frac{1}{27}$
Mars	$\frac{1}{2}$	Saturn	$\frac{1}{90}$
Vesta	$\frac{1}{6}$	Herschel	$\frac{1}{368}$

It appears, therefore, that Mercury has $6\frac{1}{2}$ times as much light and heat as our globe; and Herschel only $\frac{1}{368}$ as much. Now if the average temperature of the earth is 50 degrees, the average temperature of Mercury would be 325 degrees; and as water boils at 212, the temperature of Mercury must be 113 degrees above that of boiling water. Venus would have an average temperature of 100 degrees, which would be twice that of the earth. On the other hand, Jupiter, Saturn and Herschel seem doomed to the rigors of perpetual winter. Think of a region 27, 90, or 368 times colder than the average temperature of our globe. And can such worlds be inhabited? If so, it must be by beings adapted to their abode as we are to ours.

> "Who there inhabit must have other powers,
> Juices, and veins, and sense, and life, than ours:
> One moment's cold, like theirs, would pierce the bone,
> Freeze the heart's blood, and turn us all to stone!"

LESSON XIV.

MAGNITUDE OF THE PLANETS.

(Map 2.)

In Map 2 the planets are drawn on a scale of 40,000 miles of diameter to an inch. The sun is represented as but a point, because he could not be placed in the map, of a size proportionate to the planets.

The diameters of the several planets are as follows:

Mercury,	3,000	miles.	Ceres,	1,600	miles.
Venus,	7,800	"	Pallas,	2,100	"
Earth,	8,000	"	Astræa, unknown.		
Mars,	4,200	"	Jupiter,	90,000	"
Vesta,	270	"	Saturn,	80,000	"
Juno,	1,400	"	Herschel,	35,000	"

By carefully observing each planet as laid down on the map, it will be seen that their relative magnitudes correspond with their relative diameters as here stated.

LESSON XV.

RELATIVE MAGNITUDE OF THE SUN AND PLANETS.

(Map 4.)

The relative magnitude of the sun and planets is represented in Map 4, Fig. 1. They are all drawn on the same scale, as in No. 2, namely 40,000 miles of diameter to an inch. As the sun is 886,000 miles in diameter, he is drawn $22\frac{1}{6}$ inches across, to show his true magnitude as compared with the planets. These may be seen on the right side of the map, commencing with Mercury at the top, and passing downward to Herschel.

The secondary planets will be seen around their primaries.

The magnitudes of the primary planets as compared with the earth, are as follows, viz.:

Mercury,	$\frac{1}{15}$	Ceres,	$\frac{1}{135}$
Venus,	$\frac{9}{10}$	Pallas,	$\frac{1}{55}$
Earth,	1	Astræa,	unknown.
Mars,	$\frac{1}{6}$	Jupiter,	1,400
Vesta,	$\frac{1}{28000}$	Saturn,	1,000
Juno,	$\frac{1}{186}$	Herschel,	90

The *sun* is 1,400,000 times larger than the earth, and 500 times larger than all the other bodies of the solar system put together. It would take one hundred and twelve such globes as our earth, if laid side by side, to reach across his vast diameter.

The moon's orbit is two hundred and forty thousand miles from the earth. Now, if the sun was placed where the earth is, he would fill all the orbit of the moon, and extend more than two hundred thousand miles beyond it on every side! What is a globe like ours compared with such a vast and ponderous body as the sun?

LESSON XVI.

COMPARATIVE DENSITY OF THE PLANETS.

By *density* is meant *compactness* or *closeness of parts*. Hence we say cork is less dense than iron, and stone is more dense than common earth. In like manner the planets differ from each other in density, or in the compactness of the substances of which they are composed.

The comparative density of the several planets, and the substances with which they most nearly agree in weight, will be shown by the following table, in which the earth is taken as the standard of comparison.

Mercury, . .	3—lead.	Jupiter, . .	$\frac{1}{4}$—water.
Venus, . . .	$\frac{9}{10}$—earth.	Saturn, . .	$\frac{1}{10}$—cork.
Earth, . . .	1	Herschel, .	$\frac{1}{4}$—water.
Mars, . . .	$\frac{9}{10}$—earth.	Sun, . . .	$\frac{1}{4}$—water.

This table is one of considerable importance, and should be committed to memory. Its uses will be more clearly seen in the next lesson.

LESSON XVII.

ATTRACTION OF THE PLANETS.

Attraction or *gravitation* is the tendency of bodies towards each other. By this influence substances fall to the earth, when raised from it and left without support. The *force* of attraction is what constitutes the *weight* of bodies; and its amount depends upon the quantity of matter in the bodies attracting, and their distances from each other.

From the above law of attraction it follows that large bodies attract much more strongly than small ones, provided their densities are equal, and their distances the same; and as the force of attraction constitutes the *weight* of a body, it follows that a body weighing a given number of pounds on the Earth would weigh much more on Jupiter or Saturn; and much less on Mercury or the Asteroids.

The following table shows the relative attractive force of the Sun and Planets. A body weighing one pound on the Earth would weigh,

	lbs.	oz.
On Mercury, . .	0	9½
" Venus, . . .	0	15
" Mars, . . .	0	8
" Jupiter, . . .	2	8
" Saturn, . . .	1	5½
" Herschel, . . .	0	12½
" The Sun, . .	28	5¾

A person weighing 150 lbs. on the earth, would consequently weigh 375 lbs. on Jupiter; 4,250 lbs. on the sun; and only 75 lbs. on Mars. The attractive force of the Asteroids is so slight that if a man of ordinary muscular strength, were transported to one of them, he might probably lift a hogshead of lead from its surface without difficulty.

But the learner will notice that the attractive force, as shown in the above table, is not in strict proportion to the *bulk* of the planets respectively. This difference will be accounted for by again referring to Lesson XVI., where the subject of *density* is considered. From the principles there laid down it will be seen at once that though one planet be as large again as another, still, if it were but half as dense, it would contain no more matter than the smaller one; and their attractive force would be equal. If Jupiter, for instance, were as dense as the earth, his attractive force would be four times what it now is; and if the density of all the solar bodies was precisely the same, their attractive force, or the weight of bodies on their surfaces, would be in exact proportion to their bulk.

LESSON XVIII.

PERIODIC REVOLUTIONS OF THE PLANETS.

(Map 2.)

It has already been stated (Lessons IV. and VI.) that the planets revolve around the sun. Their direction is from west to east, or towards that part of the heavens in which the sun rises. The passage of a planet from any particular point in its orbit, around to the same point again, is called its *periodic revolution;* and the time occupied in making such revolution is called its *periodic time.*

The periodic times of the planets are as follows:

Mercury, . . .	0	years,	88	days.
Venus, . . .	0	"	225	"
Earth, . . .	1	"		
Mars, . . .	1	"	322	"
Vesta, . . .	3	"	230	"
Juno, . . .	4	"	131	"
Ceres, . . .	4	"	222	"
Pallas, . . .	4	"	222	"
Astræa, . . .	4	"	105	"
Jupiter, . . .	11	"	317	"
Saturn, . . .	29	"	175	"
Herschel, . . .	84	"		

The periodic time of a planet may very properly be called its *year;* hence, one of Herschel's years would equal 84 of ours; and a year of Saturn is equal to about 30 of ours.

But this difference in the length of the years of the several planets, is not owing solely to the difference in the extent of their orbits: there is an actual difference in their velocities, as will be shown in the next lesson.

LESSON XIX.

HOURLY MOTION OF THE PLANETS IN THEIR ORBITS.

(Map 2.)

Mercury, . . .	95,000 miles.
Venus, ...	75,000 "
Earth, . . .	68,000 "
Mars, ...	55,000 "
Vesta, . . .	44,000 "
Juno, ...	42,000 "
Ceres, . . .	41,000 "
Pallas, ...	41,000 "
Astræa, . . .	42,000 "
Jupiter, ...	30,000 "
Saturn, . . .	22,000 "
Herschel, . . .	15,000 "

Here, instead of finding the swiftest planets performing the longest periodic journeys, this order is reversed, and they are found revolving in the smallest orbits. The nearer a planet is to the sun, the more rapid its motion, and the shorter its periodic time. The reasons for this difference in the velocities and periodic times of the planets, will appear in the next lesson.

LESSON XX.

CENTRIPETAL AND CENTRIFUGAL FORCES.

(Map 2.)

The tendency of the planets towards the sun, or in other words, the mutual attractive force of the sun and planets, is called the *centripetal* force ; and the projectile force, or that which impels the planets onward in their orbits, is called the *centrifugal* force. If the centripetal, or force of attraction, was suspended, the planets would fly off in straight lines beyond their present orbits, and leave the solar system forever ; and if the centrifugal force was suspended, the planets would yield to the centripetal force, and fall to the surface of the sun.

It has already been stated, in Lesson XVII., that the force of attraction depended somewhat upon the distances of the attracting bodies ; those nearest together being mutually attracted most. It follows, therefore, that Mercury has the strongest tendency towards the sun, Venus next, the Earth next, &c., till we get through to Herschel ; and as the centrifugal force, which is to balance the centripetal, is created by the velocity or projectile force of the planets, that velocity must needs be in proportion to their distances respectively, from the sun ; the nearest revolving the most rapidly. This we find to be the actual state of things in the Solar System. And what wisdom and skill are displayed in so adjusting these great forces as that the planets neither fall to the sun on the one hand, or fly off beyond the reach of his beams on the other. As it is, they remain balanced in their orbits ; and steadily revolve at stated periods from age to age. "O Lord, how manifold are thy works ! in wisdom hast thou made them all."

LESSON XXI.

DIURNAL REVOLUTIONS OF THE PLANETS.

(Map 8.)

In addition to the motion of the planets in their orbits around the sun, they have another motion around their respective axes, producing the vicissitudes of day and night. So far as is known, the time of these revolutions, or the length of their days, respectively, is as follows :

Mercury, ...	24 hours.
Venus, ...	23½ "
Earth, ...	24 "

Mars, ...		$24\frac{1}{2}$ hours.
Jupiter, . . .		10 "
Saturn, ...		$10\frac{1}{4}$ "
Herschel, . .	1 day	18 "
Sun, . .	25 "	14 "

The learner will not fail to observe the striking similarity in the length of the days of the first four of the planets; much less the very rapid motion of Jupiter and Saturn upon their respective axes. As their days are only about five hours long, the sun must seem to mount very rapidly up the heavens, and to decline as rapidly downward to the western horizon. His progress must be apparent to the inhabitants of those planets.

From the rapid rotation of Jupiter and Saturn it follows that they must have about 875 of their days in one of our years; and as Jupiter's year is about 12 times, and Saturn's about 30 times as long as ours, it follows that the former will have about 10,500 days in his year; and the latter about 26,200.

The fact that the planets revolve upon their respective axes is ascertained by observing the motion and direction of spots on their surfaces; or in other words, of their continents and seas. For instance, in observing the sun I discover one of his spots on his eastern limb or edge, and by watching it find that it passes over his disc and disappears from his western limb in about 12 days and 19 hours. From this I infer that it would pass around and reappear where it was first seen, in 12 days and 19 hours longer; making the time of the entire revolution 25 days and 14 hours. It is in this way that the time of the revolution of the planets upon their axes is determined. The *effect* of the rotation of the planets in modifying their forms, will be shown in the next lesson.

LESSON XXII.

TRUE FIGURE OF THE PLANETS.

The spherical form of the planets is proof of the supreme wisdom of the great Creator. Were they cubes, for instance, instead of spheres, their temperature would be far less regular than it now is; the sun would rise suddenly upon a whole side at once, and as suddenly disappear at night; and the blessings of twilight, and the gradual succession of day and night, as they now transpire, would be unknown.

On the maps the planets are represented as exactly round, or spherical; but this is not their precise form. Their rapid motion around their respective axes has a tendency to depress or flatten them at their poles; and extend or widen them at their equators. Hence their equatorial diameter is considerably greater than their polar diameter; the true figures of the planets being that of *oblate spheroids.*

The difference between the polar and equatorial diameter of the planets respectively, so far as known, is as follows:

Earth, . .	36 miles.	Jupiter, .	6,000 miles.
Mars, . .	250 "	Saturn, . .	7,500 "

LESSON XXIII.

THE ECLIPTIC.

(Map 5.)

The *Ecliptic* is the plane or level of the earth's orbit, indefinitely extended. Fig. 1 represents the earth in her orbit, as she would appear to a beholder placed at a distance, and elevated above the plane of the ecliptic. She is represented in perspective as appearing smaller as she grows more distant; as keeping her poles towards the same points in the heavens; and as exhibiting the phases of the moon according as we see more or less of her enlightened side. She is colored green, as she usually is through the series, to represent her verdure. The arrows set in her orbit show her direction.

If the pupil has any difficulty in getting a correct idea respecting the ecliptic, let him suppose the orbit of the earth to be a hoop of small wire laid upon a table: the surface of the table both within and without the hoop would then represent the plane of the ecliptic.

From the above definition and description it will be seen that the ecliptic passes through the centre of the earth, and the centre of the sun; consequently the ecliptic and the apparent path of the sun through the heavens are in the same plane. It will be easy, therefore, to ascertain the true position of the ecliptic in the heavens; and to imagine its course among the stars on the other side of the globe.

LESSON XXIV.

THE POLES OF THE ECLIPTIC.

(Map 6.)

The poles of the earth are the extremities of her axis. The poles of the ecliptic are the extremities of the imaginary line or axis upon which the *ecliptic* seems to turn. The ends of a rod or pointer run through the map at the centre of the sun would exactly represent the poles of the ecliptic.

As the ecliptic and equator are not in the same planes, their poles do not coincide, or are not in the same points in the heavens.

LESSON XXV.

OBLIQUITY OF THE ECLIPTIC.

(Map 8.)

It has already been stated that the sun as well as the earth is always in the plane of the ecliptic. But he is north of the equator for six months, and south six months. It follows, therefore, that one-half the ecliptic is south of the plane of the earth's equator, and the other half north of it.

As the axis of the earth is inclined to the ecliptic 23° 28′, her equator must make the same angle to the ecliptic in the opposite direction; and the ecliptic must cross the plane of the equator obliquely. The angle of 23° 28′ thus made is what constitutes *the obliquity of the ecliptic.*

This subject will be better understood by examining the figure of the earth, and the position of her equator, as represented on the map.

LESSON XXVI.

THE ZODIAC.

(Map 5.)

The *Zodiac* is a belt 16° wide, namely, 8° on each side of the ecliptic, and extending from west to east quite around the heavens. It is represented on the map by the plain circles above and below the ecliptic. In the heavens the Zodiac includes the sun's apparent path, and a space of eight degrees south and eight degrees north of it.

LESSON XXVII.

SIGNS OF THE ZODIAC.

(Map 5.)

The great circle of the Zodiac is divided into twelve equal parts called *signs*. These divisions are shown on the map by the spaces between the perpendicular lines that cross the Zodiac. The ancients imagined the stars of each sign to represent some animal or object, and gave them names accordingly.

The names, characters and order of the twelve signs of the Zodiac, are as follows:

Aries, or the Ram, .	♈	Libra, the Balance, .	♎
Taurus, the Bull, . .	♉	Scorpio, the Scorpion, .	♏
Gemini, the Twins, .	♊	Saggitarius, the Archer,	♐
Cancer, the Crab, . .	♋	Capricornus, the Goat,	♑
Leo, the Lion, . .	♌	Aquarius, the Waterman,	♒
Virgo, the Virgin, . .	♍	Pisces, the Fishes, . . .	♓

The ancient astrologists supposed that each of these signs governed some particular part of the human body;

and to this day people often consult the frontispiece of their almanacs, to see whether the sign is "in the head," or "in the heart;" or to attend to certain important affairs "when the sign is right." The idea seems to be that the word "*sign*" signifies an *omen* or *prognostication;* and that the signs of the Zodiac have some mysterious control over the destiny of man. But this fragment of heathen astrology is fast falling into disrepute; and it is hoped will soon be utterly banished from every civilized country.

LESSON XXVIII.

NODES—ASCENDING AND DESCENDING.

(Map 5.)

Fig. 1 represents an interior planet as revolving in an orbit inclined to the ecliptic at an angle of about 45°; and as both planets revolve around the same centre of attraction, the interior planet must pass through the plane of the ecliptic twice at every revolution: once in ascending, and once in descending. These two points, where the orbit of a planet passes through the plane of the ecliptic, are called the *nodes* of its orbit. One is called the *ascending*, and the other the *descending* node. On the map A. N. is the ascending node, and D. N. the descending node.

A line drawn from one node to the other is called the *line of the nodes*, and may be seen on the map, marked L. N.

In the figure the ascending node is represented as being in the middle of Libra, and the descending node in the middle of Taurus. The design is merely to illustrate the subject, without representing the actual line of the nodes of any one of the planets.

LESSON XXIX.

TRANSITS.

(Map 5.)

By consulting Fig. 1 it will be seen that if an interior planet were at her ascending node, and the earth on the *line* of the nodes, on the same side of the ecliptic, the planet would seem to pass over the body of the sun, as shown in the figure. This passage of a planet over the sun's disc, or between the earth and the sun, is called a *transit.*

Mercury and Venus are the only planets that can make a transit visible to us; as all the rest are exterior to the earth's orbit, and consequently can never come between the earth and the sun. But the earth may make transits visible from Mars, the Asteroids and Jupiter; and they in turn may make transits for the inhabitants of all exterior worlds. The principle is, that each interior planet may make transits from all those that are exterior.

But transits can never occur except when the interior planet and the earth, or planet from which the transit is seen, are both on the line of the nodes. The sun and both the planets will then be in a line, and the one nearest the sun will seem to pass, like a dark round spot, over the sun's face.

If the orbits of Mercury and Venus lay in the plane of the ecliptic (see Lesson XXIII.), they would make transits whenever they were in conjunction with the sun. Even with their present inclination the same phenomenon would take place twice in every revolution, if Venus and the earth, for instance, were to start together from the line of Venus' nodes, and revolve in the same periodic time. Venus would then always make a transit in passing her nodes.

To calculate transits at any one node we have only to find what number of revolutions of the interior planet are exactly equal to one, or any number of revolutions of the earth; or in other words, when the earth and the planet will again meet on the line of the planet's nodes.

In the case of Mercury this ratio is as 87.969 is to 365.256; from which we ascertain that

7	periodical	revolutions	of	the Earth	are equal to	29	of Mercury;
13	"	"	"	"	"	54	"
33	"	"	"	"	"	137	"
46	"	"	"	"	"	191	"

Therefore transits of Mercury, *at the same node*, may happen at intervals of 7, 13, 33, 46, &c. years.

All transits and eclipses are calculated upon these principles.

LESSON XXX.

TRANSITS OF MERCURY.

(Map 5.)

The following is a list of all the transits of Mercury from the time the first was observed, November 6, 1631, to the end of the present century.

1631—November 6.	1776—November 2.
1644—November 6.	1782—November 12.
1651—November 2.	1786—May 3.
1661—May 3.	1789—November 5.
1664—November 4.	1799—May 7.
1674—May 6.	1802—November 8.
1677—November 7.	1815—November 11.
1690—November 9.	1822—November 4.
1697—November 2.	1832—May 5.
1707—May 5.	1835—November 7.
1710—November 6.	1845—May 8.
1723—November 9.	1848—November 9.
1736—November 10.	1861—November 11.
1740—November 2.	1868—November 4.
1743—November 4.	1878—May 6.
1753—May 5.	1881—November 7.
1756—November 6.	1891—May 9.
1769—November 9.	1894—November 10.

By carefully examining the above table it will be seen that the transits of Mercury all occur in the months of May and November. The reason for this is, that his ascending node is in the 16th degree of Taurus, and his descending in the 16th degree of Scorpio; the first of which points the earth always passes in November, and the other in May.

All the transits, therefore, that happen in November, are when Mercury is at his ascending node, and the residue are when he is at his descending node.

Again: If we take the transits in their order, as laid down in the table, they will be found not to occur at intervals of 7, 13, 33, 46, &c. years, as previously stated; but if we take those only that occur *at the same node,* we shall find them regulated according to the ratio prescribed. For example: from 1631 to 1644 is 13 years; from 1644 to 1651 is 7 years; from 1651 to 1664 is 13 years; from 1664 to 1677 is 13 years; from 1677 to 1690 is 13 years; from 1690 to 1697 is 7 years, &c. Thus far their intervals are 7 and 13 years; but they may happen at the other periods.

If we take those occurring in May we shall find them conforming to the same ratio; that is, the one previously laid down.

LESSON XXXI.

TRANSITS OF VENUS.

(Map 5.)

8	periodical	revolutions	of the	Earth	are equal to	13	of Venus;
235	"	"	"	"	"	382	"
243	"	"	"	"	"	346	"
251	"	"	"	".	"	408	"
291	"	"	"	"	"	475	"

The line of Venus' nodes lies in the middle of Gemini and Saggitarius; which points are passed by the earth in December and June. It follows, therefore, that transits of Venus must always happen in one or the other of these months.

The following is a list of all the transits of Venus from 1639 (the time the first was observed) to A. D. 2012.

1639—December 4.	1822—December 6.
1761—June 5.	2004—June 7.
1769—June 3.	2012—June 5.
1874—December 8.	

LESSON XXXII.

INCLINATION OF THE ORBITS OF THE PLANETS TO THE PLANE OF THE ECLIPTIC.

(Map 5.)

Fig. 1 represents the orbit of a planet as making an angle with the ecliptic of about 45°. But none of the planets have so great an inclination; the main object here being to illustrate the subject of nodes.

The inclination of the orbits of the several planets, to the plane of the ecliptic, is shown in Fig. 2. In the centre is seen the sun. The dotted line running horizontally across the map, and through the sun's centre, represents the *plane* of the ecliptic. On the right and left are seen arcs of a circle, divided off, and numbered every ten degrees. The plain lines, inclined more or less, and passing through the centre of the sun, represent the plane of the orbits of the planets respectively. On the left, outside the graduated circle, the names of the planets are given; and just within the circle the amount of the inclination of their orbits. This inclination is as follows:

Mercury	7°	Ceres	$10\frac{1}{2}$°
Venus	$3\frac{1}{2}$°	Pallas	$34\frac{1}{2}$°
Earth	°	Astræa	$7\frac{3}{4}$°
Mars	2°	Jupiter	$1\frac{1}{4}$°
Vesta	7°	Saturn	$2\frac{1}{2}$°
Juno	13°	Herschel . . .	$\frac{3}{4}$°

The wide colored portion of the graduated circle shows the limits of the Zodiac, extending 8° each side of the ecliptic.

It will be seen that the orbits of most of the planets lie within the limits of the Zodiac ; but Juno, Ceres and Pallas go beyond its bounds. They are therefore sometimes called the *ultra zodiacal* planets.

Near the middle of Fig. 2 are seen two *comets* in their orbits ; one coming down from the heights *North* of the ecliptic, passing around the sun and then reascending ; and the other coming up from the depths *South* of the ecliptic. The design is to illustrate the fact that the comets do not revolve in the plane of the ecliptic, or as nearly so as do the planets ; but that they approach the sun from all directions, or from every point in the heavens.

LESSON XXXIII.

CELESTIAL LATITUDE.

It will be understood by Lesson XXV., that the *ecliptic* and *equinoctial* are two different planes, intercepting each other at an angle of $23\frac{1}{2}°$. Now although terrestrial latitude is distance north or south of the earth's equator, yet celestial latitude is not reckoned from the celestial *equator*, or *equinoctial*, but from the *ecliptic*. Celestial latitude is, therefore, *distance north or south of the ecliptic*, and as one half of the ecliptic is *south* of the earth's equator (Lesson XXV.), it follows that a star may be in *north celestial latitude*, which is, nevertheless, *south of the equinoctial.*

LESSON XXXIV.

CELESTIAL LONGITUDE.

(Map 6.)

Longitude on the earth is distance east or west from any given point. On all English charts and globes, it is reckoned from Greenwich Observatory near London ; but on those of American origin, it is usually reckoned from the meridian of Washington City.

Longitude in the heavens is reckoned from the vernal equinox, or the first degree of Aries, eastward, around the *ecliptic* to the same point again. The map is a vertical view of the *Zodiac*, and when suspended to the south of the learner, gives a pretty correct idea of its position in the heavens.

Beginning at the first point of Aries, and passing around the ecliptic eastward, the longitude is marked off on the map, and numbered every ten degrees. The entire circle, like all other circles, has 360 degrees; which bring us to the point from which we started.

From what has been said, it will be obvious that if the sign Aries, for instance, were directly over head, or on the meridian at any given time, Libra would be in the opposite part of the Zodiac, or in the heavens beyond the other side of the earth. In using longitude to show the position of stars or other objects in the Zodiac, we should say the Twins were between the 70th and 80th degrees; the Lion between 130 and 140; the Balance between 190 and 200; the Goat between 280 and 290, &c. The pupil can trace them out for himself, and mark their longitude.

LESSON XXXV.

LONGITUDE OF THE ASCENDING NODES OF THE PLANETS.

(Maps 5 and 6.)

On Map 5, Fig. 1, the line of the nodes of the interior planet enters the middle of Aries, and the middle of Libra. It was stated in Lesson XXX. that the ascending node of Mercury was in the middle of Taurus, and his descending node in the middle of Scorpio. This will be fully illustrated by Map 6, where the line of his nodes is shown, and their longitude marked. The map represents the plane of the ecliptic. This side, or *north* of the map, is called *above* the ecliptic, and the other side *below* the ecliptic. To pass the plane of the ecliptic, therefore, from south to north, is to ascend; and to return from north to south is to descend. The arrows nearest the sun show not only the direction of Mercury, as he moves in his orbit, but also his relative distance from the sun, and the position of his nodes in the ecliptic. The entire line of Venus' nodes is also laid down on the map, together with her distance from the sun and direction, shown by the arrows crossing the line.

In astronomical tables, the longitude of the ascending node only is given ; for when this is ascertained, that of the descending node is easily inferred from it. Take for instance, the ascending node of Mercury. It is laid down on the map as in longitude 46°. Of course, then, his descending node is in the opposite side of the ecliptic, or just 180° distant. Add 180 to 46, and we have 226, the actual longitude of his descending node, as shown by the map. So by adding 180 to 75, the longitude of Venus' ascending node, we have 255, the longitude of her descending node. I have therefore given only the longitude of the ascending nodes of the planets, and one half the line of their nodes ; leaving the longitude of the descending nodes to be ascertained in the manner already explained.

The longitude of the ascending nodes of the planets respectively, is as follows :

Mercury . . .	46°	Ceres	80°
Venus	75°	Pallas . .	173°
Earth		Astræa	120°
Mars	48°	Jupiter	98°
Vesta	103°	Saturn	112°
Juno	171°	Herschel . . .	72°

This subject should be well understood before the learner dismisses it, to enter upon the next lesson.

LESSON XXXVI.

CONSTELLATIONS OF THE ZODIAC.

(Map 6.)

By this time the reader is no doubt anxious to know the meaning of the strange looking figures that are placed around this map, in the signs of the Zodiac. It must not be forgotten that a sign is merely *the twelfth part of a circle*. The largest circle on the map is divided into signs, as well as into degrees. In each sign, and outside of the circle, is placed a picture of some kind—a *bull*, a *lion*, a *lady* with wings, a *goat*, or some other figure. The reason for this we will now explain.

Outside the divided circle on the map, and around the different figures or pictures, may be seen numerous stars. Some are larger than others, and they seem to be scattered about at random. Such is the natural appearance of the heavens generally, in a clear night, as well that belt stretching over from west to east called the *Zodiac*, as any other portion. Now the ancients imagined that the stars were thrown together in clusters resembling different objects; and they consequently named the different groups after the objects which they supposed them to resemble. These clusters, when thus marked out by the figure of some animal, person, or thing, and named accordingly, were called *Constellations*.

As every part of the Zodiac is filled with stars, each sign has one or more of these ancient constellations. It is on this account that the figure supposed to be represented by the constellation of each sign is still retained; and the signs bear the names of their respective constellations.

The pupil will now more clearly discover the folly of the idea that each sign or constellation of the Zodiac "governs" a particular portion of the human body, as stated in some almanacs. How preposterous the notion that a cluster of stars, millions of miles from our globe, govern a man's head, his arms, or his feet! And yet some still think the "signs" should be consulted in reference to many important matters.

The names of the signs have already been given in Lesson XXVII., to which the learner may again turn, to refresh his memory, in connection with the map now before him.

LESSON XXXVII.

THE SUN'S APPARENT MOTION IN THE ECLIPTIC.

(Maps 5 and 6.)

In Map 5, Fig. 1, the earth is seen performing her annual journey around the sun. Now when the earth is in the sign ♎ the sun will appear to be in ♈; and as the earth moves on to ♏, the sun will appear to pass around to ♉. Hence, as the earth passes around in her orbit every year, from west to east, it is obvious that the sun will *appear* to make the circuit of the heavens in the same time, and in the same direction.

All the constellations of the Zodiac seem to overtake and pass by the sun westward once a year; or in other words, the sun appears to meet and pass through them all eastward, in regular order, every 365 days.

Map 6 may illustrate this subject still more clearly. The sun is seen in the centre. Around the sun the earth is seen in her orbit, the arrows showing her direction. Now when the earth is in ♉, in November, the sun must seem to be in ♏, on the opposite side of the ecliptic. So when the earth is in ♊, the sun will seem to be in ♐, &c.

On the 20th of March the earth is in longitude 180, or in the first degree of ♎; at which time we say the *sun* enters ♈.

The time of the sun's entrance into the different signs is as follows:

♈, March 20th.	♎, September 23d.
♉, April 20th.	♏, October 23d.
♊, May 21st.	♐, November 22d.
♋, June 21st.	♑, December 21st.
♌, July 23d.	♒, January 20th.
♍, August 23d.	♓, February 19th.

It must not be forgotten that this motion of the sun eastward around the Zodiac, is merely apparent; and is caused altogether by the revolution of the earth around the sun. By following the earth in her orbit from March

20th, around to the same point again, the sun will seem to enter all the signs, in the order, and at the times specified in the foregoing table.

As we have our spring while the sun is passing through ♈, ♉, and ♊, these are called the *spring* signs; ♋, ♌, and ♍, are the *summer* signs; ♎, ♏, and ♐, are the *autumnal* signs; and ♑, ♒, and ♓, the *winter* signs.

This subject will be still further illustrated in the next lesson.

LESSON XXXVIII.

SUCCESSIVE APPEARANCE OF THE CONSTELLATIONS IN THE NOCTURNAL HEAVENS.

(Map 6.)

We are very apt to suppose that because we see no stars in the daytime, there are none in the heavens above us. This is an erroneous conclusion. Were it not for the light of the sun, the stars would shine out as brightly during what we now call the daytime, as they ever do in the night; but instead of seeing the same constellations that we see in the night, at any given time, we should see those only that were visible in the night six months before; and would be above the horizon again six months afterwards.

The fixed stars surround the solar system in every direction; and the fact that we cannot see the stars beyond the sun, or in that half of the Zodiac in which he appears, on account of his superior light, is no proof that such stars do not exist and shine. When the sun is totally eclipsed the stars appear in the day time; and if we look through a long tube or descend into a deep well, so as to shut the strong light of the sun from the eye, the stars may be seen even at noon in the heat of summer.

Let this subject be illustrated by the map.

Suppose a person to be observing the constellations of the Zodiac on the 21st of June. At midnight all the constellations from ♎ around to ♈ would be in sight; but at twelve o'clock the next day, when the other half of the

Zodiac would be above the horizon, the sun would be between the observer and the signs ♊ and ♋, and would shed so strong a light over the whole visible heavens, as to eclipse or obscure all the stars.

But as the earth passes on in her orbit, and the sun seems to pass the signs eastward in regular order, the constellations will arise earlier and earlier every night; so that all of them will seem to pass over from east to west *in the night* in the course of a year.

This map may be used to show what constellations will be on the meridian at twelve o'clock, or at any other hour of the night, during every month in the year. In December they will be ♊ and ♋; in March ♍ and ♎; in June ♐ and ♑, &c., as the earth advances eastward in her orbit, and turns from west to east upon her axis.

LESSON XXXIX.

DISAGREEMENT BETWEEN THE MONTHS AND SIGNS.

(Map 6.)

The names of the months are marked around on the map from west to east, to show at what time the earth occupies any particular place in her orbit; and also when the sun enters the opposite sign. But the months and the signs do not exactly agree in longitude. The earth reaches long. 180°, and the sun enters ♈ on the 20th of March; so that there are eleven days of March left after the earth has passed into ♎, and the sun has entered ♈. Of course, then, all the months in the year are a little more tardy, so to speak, than the signs; and are represented, in the map, as jutting by them eastward about ten degrees of longitude.

LESSON XL.

THE EQUINOXES.

(Map 6.)

The great circle of the Zodiac is divided into four parts, by imaginary lines running through the centre of the sun, and at right angles with each other. On the map they are *dotted*, to distinguish them from others, one running perpendicularly, and the other horizontally. The earth is represented as being at the points where these lines cross her orbit.

Two of these points, namely, the upper and lower, are called the *equinoctial points*. They are so called because when the earth is at either of them the sun shines perpendicularly on the equator, and consequently to each pole; and the *days and nights are equal* all over the world.

The plane of the equinoctial passes through the earth's equator; or, in other words, it is the equator of the earth extending off into the heavens in every direction.

The earth passes the equinoctial points on the 20th of March and the 23d of September; the first of which is called the *vernal*, and the latter the *autumnal* equinox. These points being in opposite portions of the heavens, are, of course, 180° apart, as appears by the map.

LESSON XLI.

THE SOLSTICES.

(Map 6.)

The dotted line running horizontally across the map is the line of the solstices; and the points where this line crosses the earth's orbit are called the *solstitial points*.

At the time of the autumnal equinox, September 23d, the sun is directly over the earth's equator, and his light extends to both poles, as shown on the map. From this time to December 21st, the sun declines south, till it is perpendicular over the tropic of *Capricorn* (so called from the sign which the sun enters on that day), when its southern declination is stayed or ceases. Hence the name *solstice*.

From December 21st to March 20th the sun approaches the equinox, which it reaches at the latter period, when he begins to decline northward, till on the 21st of June he reaches the tropic of *Cancer*. He is then at the *summer solstice*. From June 21st to September 23d the sun again approaches the equator or equinox, at which time he begins again to decline south, &c.

This declination of the sun north and south, and his apparent passage through the plane of the equinoctial, twice a year, are caused by the inclination of the axis of the earth to the plane of the ecliptic, and her revolution around the sun. What we have here said will serve more fully to illustrate Lesson XXV., where the obliquity of the ecliptic is considered.

LESSON XLII.

THE COLURES.

(Map 6.)

The *Colures* are two great circles crossing at the *poles of the ecliptic* (see Lesson XXIV.), and passing through the ecliptic at right angles. One passes through the equinoxes, and is thence called the *Equinoctial Colure*; the other passes through the solstices, and is called the *Solstitial Colure*. They are to the heavens what four meridians, each 90° apart, would be to the earth. They divide the celestial sphere into four parts, like quartering an apple. Two hoops of wire, crossing between the eye of the learner and the sun, and also directly beyond the sun on the other side of the map, would represent the colures; provided one passed through the map at the solstitial, and the other at the equinoctial points. When once the place of the colures is clearly ascertained, they are very convenient in finding particular stars or constellations either north or south of the ecliptic.

LESSON XLIII.

ELLIPTICITY OF THE PLANETS' ORBITS.

(Map 7.)

Thus far we have proceeded upon the supposition that the orbits of the planets were exact circles, and that consequently the several planets were always at the same distance from the sun. It is time now to state more definitely the true figure of their orbits.

Fig. 1 represents the earth as revolving in an *ellipse*, or *oval-shaped* orbit. This is its true figure; and indeed, to a great extent, the figure of all the planetary orbits. But some are more elliptical than others, and the orbits of the comets, as shown in Maps 2 and 5, are more elliptical than those of any of the planets.

Not only are the orbits of the planets elliptical, but the sun is always found one side of the centre, or nearer one end of the ellipse than the other, as shown on the map. The point where the sun is placed is called one of the *foci* of the ellipse.

LESSON XLIV.

PERIHELION AND APHELION.

(Map 7.)

When a planet or comet is in that part of its orbit nearest to the sun, it is said to be at its *perihelion;* and when at the point most distant, at its *aphelion.* So of the moon; *perigee* and *apogee* are the points of her orbit nearest to and most distant from the earth.

On the map the earth is seen at her perihelion on the left, and at her aphelion on the right; the two points being at very unequal distances from the sun. In stating the distances of the solar bodies, we sometimes give their *perihelion* and *aphelion*, as well as their *mean* or average distances; but in Lesson VIII. the mean distances only are given. The following table will exhibit the *longitude* of their *perihelions*, respectively.

Mercury . . .	74°	21′	46″
Venus . . .	128	43	53
Earth . . .	99	30	5
Mars . . .	332	23	56
Vesta . . .	249	33	24
Juno . . .	53	33	46

Ceres . . .	147°	7′	31″
Pallas . . .	121	7	4
Astræa . . .	135	27	54
Jupiter . . .	11	8	35
Saturn . . .	89	9	30
Herschel . . .	167	31	16

LESSON XLV.

ECCENTRICITY OF THE PLANETS' ORBITS.

(Map 7.)

The *eccentricity* of a planet's orbit is the *distance of its centre from the centre of the sun.* It is just half as great as the *difference* between the aphelion and perihelion distances.

These principles will appear obvious by a careful ex-examination of Fig. 1. Place the pointer in the centre of the ellipse, and the sun will be found about two inches to the left. Of course, then, the other focus is about two inches to the right, or the two foci are about four inches apart. The difference between the earth's distance on the left, at her perihelion, and her distance on the right, at her aphelion, must therefore be four inches on the map; while her eccentricity is but two inches, or just half that amount.

The eccentricity of the orbits of the different planets, is as follows:

Mercury . . .	7,000,000	miles.
Venus . . .	492,000	"
Earth	1,618,000	"
Mars	13,500,000	"
Vesta	21,000,000	"
Juno	64,000,000	"
Ceres	21,000,000	"
Pallas	64,250,000	"
Astræa	Unknown.	
Jupiter . . .	24,000,000	"
Saturn	49,000,000	"
Herschel . . .	85,000,000	"

From the above table it appears that the orbits of Juno and Pallas are the most elliptical, while that of Venus is almost a circle.

LESSON XLVI.

THE SEASONS.

(Map 7.)

It has already been stated that the axis of the earth is inclined to the ecliptic 23° 28′. This is illustrated in Fig. 1; and also the fact that in consequence of the revolution of the earth around the sun, and the inclination of her axis to the plane of her orbit, her poles are alternately in the light six months, and in darkness six months. At the time of the equinoxes the light of the sun is seen to extend to both poles alike. On the 21st of June, the time of the summer solstice, the sun shines only to the *south* polar circle, and 23° 28′ beyond the north pole. It is then summer in the northern hemisphere. At the time of the winter solstice this order is reversed. The sun has passed from over the northern tropic, across the equinoctial, to the southern tropic; and now shines only to the north polar circle, and 23° 28′ beyond the south pole. Thus we have the regular succession of *the Seasons*.

But the map shows that we have winter in the northern hemisphere, when the earth is nearest to the sun. This may seem very strange to the learner, but it must be remembered that cold and heat in different latitudes do not depend so much upon the *distance* of the earth from the sun, as upon the manner in which the sun's rays strike her surface. Those parts of the earth upon which the rays of light fall *perpendicularly*, are always warmest; while those portions upon which his beams fall *obliquely*, are comparatively cold. It is easy to see, therefore, that when the north pole is turned *from* the sun on the 21st of December, and the rays of light fall obliquely on the northern hemisphere, it will be cold, even though the earth may be at her perihelion; but when the north pole is turned *towards* the sun, on the 21st of June, the light falls more directly upon the northern hemisphere, and we have our summer, though the earth is at her aphelion.

The only effect of the eccentricity of the earth's orbit upon her temperature is, that she has probably a greater degree of heat during summer in the southern hemisphere, when the earth is at her perihelion, than we ever have at the north in the same latitude. But this difference must be very slight, if indeed it is at all perceptible.

The subject of this lesson will be alluded to again when we come to consider the seasons of the other planets.

LESSON XLVII.

THE SUN'S DECLINATION.

(Map 7.)

The apparent distance of the sun north or south of the equator is called its *declination.*

From the 20th of March to the 23d of September he has *northern declination* ; and the rest of the year *southern declination.* His declination is nothing at the time of the equinoxes ; but from that time it increases till the time of the solstices, when it amounts to $23\frac{1}{2}°$. From the time of the solstices the sun gradually returns again towards the equator, and his declination constantly decreases till he passes the equinoctial, when it again begins to increase, though in another hemisphere.

The subject of this lesson is illustrated by Fig. 2 and 3. Fig. 2 shows the position of the sun at the time of the equinoxes and solstices ; the manner in which his light strikes the earth at these times ; the *zones* of the earth ; the extent of the sun's declination, &c.

Fig. 3 is still more full and explicit. In addition to what is contained in Fig. 2, it shows the place or declination of the sun for every month in the year, and the manner in which his beams strike the middle of both the temperate zones during every successive month. Take, for instance, the north temperate zone, at the 45th degree of latitude. On the 21st of December, when the sun has the greatest southern declination, and, as shown in Fig. 2, shines vertically on the tropic of Capricorn, he would seem to be quite low down in the south, even at noon ; and his rays would strike the north temperate zone quite obliquely, as shown in the figures. From December 21st to June 21st the sun advances towards the north, and the obliquity of his rays constantly diminishes. On the 21st of June the light falls quite obliquely on the southern hemisphere, where it is then winter. The two lines running off from the earth's surface to the letter Z, are designed to show the perpendicular and *zenith* of the 45th degree of latitude; and also how much the sun lacks of being directly over head at these points, at the time of the solstices.

It will be easy to see from these figures that *declination is to the heavens what latitude is to the earth.* They may be used, also, to show the use of a quadrant, and the manner of determining latitude by the sun's meridian altitude, and his declination.

LESSON XLVIII.

RIGHT ASCENSION.

(Map 6.)

Right Ascension is distance east of the vernal equinox, measured on the *equinoctial.*

In Lessons XXXIII. and XXXIV., it was shown that celestial latitude and longitude answered to terrestrial, except that in the former case we reckoned from and on the *ecliptic,* instead of the *equinoctial.*

On the other hand, right ascension and declination refer directly to the equinoctial ; and consequently answer to longitude and latitude on the earth.

The learner may here start the inquiry, Why were not declination and right ascension called celestial latitude and longitude, seeing that they refer to the celestial equator, instead of measurements from and on the *ecliptic ?* Such a question is not easily answered. The interchange of terms, as it may be called, is rather unfavorable to a ready and clear understanding of these topics. Even at this late period it might be a service to the science in the end, to call declination and right ascension celestial latitude and longitude.

Right ascension is reckoned around on the equinoctial to 360°, answering to 360° of celestial longitude, only that one is reckoned on the *equinoctial,* and the other on the *ecliptic*.

LESSON XLIX.

INCLINATION OF THE AXES OF THE PLANETS TO THE PLANE OF THEIR RESPECTIVE ORBITS.

(Map 8.)

That the pupil may fully understand this lesson, it may be well to recapitulate some things already learned.

1st. The *Ecliptic* is described Lesson XXIII.

2d. The *Orbits* of the planets are described Lessons IV., XLIII., and XLV.

3d. The inclination of the *orbits* to the plane of the *ecliptic* is the subject of Lesson XXXII.

We now call attention to the inclination of the *axes* of the several planets to the plane of their *orbits*.

This is a lesson of great interest and importance; and although so far as the earth is concerned it has already been anticipated, in our remarks on the seasons, declination, &c., still it opens a rich field of inquiry before the student, and should receive a good degree of attention.

On the map the dotted horizontal lines represent portions of the orbits of the planets, with the exception of the sun, in which case they represent the plane of the *ecliptic*. The *axis* of each planet is seen inclined to a section of its *orbit* at its true angle. The *equators* are shown by the double lines crossing the axes at right angles. The *zones* are distinguished by curved boundary lines, and by the different colors—the torrid zones being *red*, the temperate *green*, and the frigid *white*.

It will readily be seen that the extent of the torrid zone of a planet depends altogether upon the amount of its polar inclination. If its axis be much inclined, as in the case of Venus, it will have a wide torrid zone; but if its axis is but little inclined, like that of Jupiter, it will have a narrow torrid zone.

The sun's declination north and south of the equator of each planet must be just equal to its polar inclination; and as its torrid zone includes both its northern and southern declination, it follows that it must be twice as wide as the amount of its polar inclination.

These principles will be more clearly seen by the following table, in which the polar inclination, greatest declination, and width of torrid zone, are compared:

	Inc. of axis.		Declination.		Torrid zone.	
Venus . . .	75°	00′	75°	00′	150°	00′
Earth . . .	23	28	23	28	46	56
Mars . . .	28	40	28	40	57	20
Jupiter . .	3	5	3	5	6	10
Saturn . .	30	00	30	00	60	00
The Sun . .	7	20				

Only the first part of this table need be committed to memory; but the whole should be studied and compared with the map until its *principles* are fully understood.

Of Mercury, the Asteroids, and Herschel, nothing definite is known respecting their polar inclination; consequently we have no knowledge of the extent of their zones, or the character of their seasons.

LESSON L.

SEASONS OF THE DIFFERENT PLANETS.

(Map 8.)

The general philosophy of the seasons, together with the seasons of the earth, are already explained in Lesson XLVI. The same subject will now be resumed, as it relates to the rest of the planets.

The seasons of the planets depend upon two causes: the inclination of their axes to their respective orbits, and their periodic revolutions around the sun. The former determines the *extent* of their *zones*, and the latter the *length* of their *seasons*.

The effects of polar inclination are seen in the contrast presented by Venus and Jupiter. Venus, with a polar inclination of 75°, has a torrid zone 150° wide; while Jupiter, whose axis is inclined but 3° 5′ has a torrid zone only 6° 10′ wide. After the statement of these general principles, we shall proceed briefly to notice the seasons of the several planets.

LESSON LI.

SEASONS OF VENUS.

(Map 8.)

The tropics of Venus are 75° from her equator, and within 15° of her poles; and she has no frigid zone, or polar circles. Her periodic time being only 225 days (Lesson XVIII.), the sun passes in that short time from her northern solstice through her equinox to her southern solstice, and back to the point from which he started. So great is the sun's declination on Venus, that when over one of her tropics, it is winter not only at the other tropic, but also at her equator; and as the sun passes over from tropic to tropic and back again every 225 days, making spring at the equator as he approaches it, summer as he passes over it, autumn as he declines from it, and winter when he reaches the tropic; it follows that at her equator Venus has *eight seasons* in one of her years; or in 225 of our days. Her seasons, therefore, at her equator, consist of only about four weeks of our time, or $28\frac{1}{8}$ days; and from the heat of summer to the cold of winter can be only about 56 days. At her tropics she has only four seasons of 56 days each.

At first view it might appear to the reader that such an arrangement must be fatal to all vegetable life, especially at Venus's equator; but it should be remembered that He who inclined the axis of Venus to her orbit, and prescribed her periodic time, could as easily clothe her with vegetation of a month's growth, as with that requiring the lifetime of the oak or the cypress to bring it to maturity.

LESSON LII.

SEASONS OF THE EARTH.

(Map 8.)

It might be well here for the student to turn back to Lesson XLVI., and review it in connection with this map. Especially let him examine the figure of the earth and her zones with a view to the *obliquity of the ecliptic*, explained in Lesson XXV. Call to mind also the subject of the sun's declination, Lesson XLVII., and the difference between referring to the *ecliptic*, as in celestial latitude and longitude, or to the *equinoctial*, as in right ascension and declination. See Lessons XXXIII., XXXIV., XLVII., and XLVIII.

LESSON LIII.

SEASONS OF MARS.

(Map 8.)

The polar inclination and zones of Mars are very similar to those of the earth; but owing to the difference of his periodic time, his seasons are very different from ours. His year of 687 days is divided into four seasons of about 172 days each, or nearly twice the length of the seasons of the earth.

His polar inclination is 5° 12′ greater than that of the earth; making his torrid zone wider, and his polar circles greater than ours; while his temperate zones are somewhat narrower.

LESSON LIV.

SEASONS OF JUPITER.

(Map 8.)

So slight is the inclination of Jupiter's axis to his orbit, that it affords him but a very narrow torrid zone. The inclination of his orbit to the ecliptic is but 1° 15′, and his axis is inclined to his orbit but 3° 5′; so that his axis is nearly perpendicular to the ecliptic. The sun never departs more than 3° 5′ from his equator, and still, as his periodic time is about 12 years (Lesson XVIII.), he has alternately six years of northern and six of southern declination. His narrow torrid zone and small polar circles leave very extensive temperate zones. In passing from his equator to his poles, we meet every variety of climate, from the warmest to the coldest, with but slight variations in any latitude, from age to age. His days and nights are always nearly of the same length, as the sun is always near his equinoctial. His poles have, alternately, six years day and six years night.

In connection with the above facts, it may be well to associate the amount of *light* received by this planet; his *magnitude*; his *oblate figure*; his *rapid rotation* upon his axis; and his *distance* from the sun. The pupil cannot too often call up the facts already learned, as he advances from lesson to lesson. In this way he will soon be able to state the most interesting particulars respecting each of the solar bodies.

LESSON LV.

SEASONS OF SATURN.

(Map 8.)

The polar inclination and zones of Saturn differ but little from those of Mars; but his seasons are greatly modified by the length of his periodic time. This being about 30 years, his four seasons must each be about 7½ years long; and his polar regions must have, alternately, 15 years day, and 15 years night.

The rings of Saturn, which lie in the plane of his equator, and revolve every $10\frac{1}{4}$ hours, are crossed by the sun when he crosses the equinoctial of the planet. During the southern declination of the sun, which lasts fifteen years, the south side of the rings is enlightened, and has its summer. It has also its day and night, by revolving in a portion of the planet's shadow.

When the sun is at the southern tropic, it is midsummer on the south side of the rings; as the rays of light then fall most directly upon them. As the sun approaches the equator, the temperature decreases, till he crosses the equinoctial, and the long winter of fifteen years begins. At the same time the north side of the rings begins to have its spring; summer ensues, and in turn it has fifteen years of light and heat.

Of the seasons of Saturn, and the structure, dimensions, and uses of his wonderful rings, we shall remark further hereafter in a distinct lesson, in connection with Map 11.

Before dismissing the subject of the Seasons, we wish to add a remark or two applying the facts we have just been considering, to an argument which is sometimes met with in the pulpit, and in theological works. The extremes of cold and heat in different zones on the earth are cited as proofs of the Divine displeasure, and consequently of the natural depravity of man. A scientific text-book is no place to obtrude private theological views upon the public, hence we have no opinion to express here respecting the doctrine referred to; but it must be obvious to the reader that there are greater extremes of cold and heat on some other worlds than on our own; consequently whatever is inferred from such a state of things on our globe, respecting the moral condition of her inhabitants, should be inferred respecting every other planet whose seasons are known. But if we are not prepared to say that all the planetary worlds are inhabited by *fallen* and *guilty* beings, we must conclude that however true the doctrine of natural depravity may be, the above argument is fallacious; and ought never to be advanced in its support. True science and religion always go hand in hand; and a bad argument is always injurious to a good cause.

LESSON LVI.

CONJUNCTIONS AND OPPOSITION OF PLANETS.

(Map 9)

When any two or more of the solar bodies are found *in the same longitude*, they are said to be in *conjunction*. Fig. 1 represents the Sun in the centre, and Venus, the Earth, and Mars, at different points in their orbits. If the Earth was at D, and Venus at I or S, she would be in conjunction with the Sun, both appearing to be in the point between ♉ and ♊, or according to Map 6, in the 60th degree of longitude.

The *interior* planets have two conjunctions; the *inferior conjunction*, when between the earth and the sun, as at I; and the *superior conjunction*, when beyond the sun, as at S. At the superior conjunction the enlightened side of the planet is towards the earth; and at her inferior, the dark side.

When at her superior conjunction, Venus is 154 millions of miles from the earth; but when at her inferior conjunction, she is only 26 millions of miles distant. The reason for this great difference will be seen by a glance at the map; which shows her the whole diameter of her orbit farther off when at S than at I.

The *exterior* planets have a *superior* conjunction, as Mars at N; but they can never get between the earth and the sun to form an *inferior* conjunction. When, therefore, a planet gets in the same longitude as the earth, like Mars at F, it is said to be in *opposition*.

A planet in conjunction rises and sets nearly with the sun; but one in opposition rises when he sets, and sets when he rises.

Lesson XXXII. shows the orbit of Venus to be inclined to that of the earth in an angle of $3\frac{1}{2}°$; hence as one half of her orbit is above the ecliptic, and the other half below, she will always appear either above or below the sun when in conjunction, except when she is at one of her nodes; in which case she will appear to pass over the sun's disc, as represented in the figure. See Lesson XXXI.

LESSON LVII.

SIDEREAL AND SYNODIC REVOLUTIONS.

(Map 9.)

The sidereal or periodic revolution of a planet is its passage from any particular point in its orbit, around to the same point again.

A *synodic revolution* is one extending from either an inferior or superior conjunction to the same conjunction again. It is therefore considerably more than one complete revolution around the sun.

For example: were the earth stationary at D, the superior conjunction of Venus would happen $112\frac{1}{2}$ days after her inferior conjunction; or in just half her periodic time; but as both are in motion in the same direction, one revolving in 365 days, and the other in 225, it is obvious than when Venus reaches the point I, the earth will be far behind; and when the earth reaches D, Venus will have advanced to M in her second round; and will then have to overtake the earth before an inferior conjunction can be effected. This will occur when the earth reaches the point L in her second round.

From one inferior conjunction to another is 594 days; requiring about $2\frac{2}{3}$ revolutions of Venus, and nearly $1\frac{2}{3}$ revolutions of the earth.

The periodic times of the planets were given in Lesson XVIII.; but for the sake of a better understanding of the subject, the sidereal and synodic periods will here be given in connection. They are as follows:

	Sidereal.	Synodic.
Mercury . .	88 days. .	115 days.
Venus . .	225 " .	584 "
Earth . .	365 " .	365 "

Mars .	1 year—322 days. .	780 days.
Vesta .	3 " 230 " .	503 "
Juno .	4 " 131 " .	474 "
Ceres .	4 " 222 " .	466 "
Pallas .	4 " 222 " .	466 "
Astræa .	4 " 105 " .	476 "
Jupiter .	11 " 317 " .	399 "
Saturn .	29 " 175 " .	378 "
Herschel	84 " —— " .	369½ "

This is an interesting table, and may be studied for some time by the more advanced student to great advantage. He may imagine Mercury hurrying round to his starting point in 88 days, and in 27 more overtaking the earth, even before she has performed one-third of her annual journey.

The periodic time of Mars being nearly double that of the earth, her synodic period is but little over two years. By subtracting the earth's period from the synodic period of the rest of the planets, the remainder will show how long the earth is in overtaking the exterior planets respectively, after she has completed one revolution. Thus, the synodic time of Vesta is 503 days. In 365 days the earth completes one revolution, and reaches the point from which she set out. Vesta is then 365 days *ahead* of the earth, but moving at a four years' pace; so that in 138 days the earth overtakes her, and they are again in conjunction. In the cases of Jupiter, Saturn, and Herschel, it requires still less time. Their periods are long, and they move slowly in longitude; so that when the earth has completed a period, they are but a short distance in advance, or to the east of her, and she soon overtakes them. By subtracting, it will be seen that the time required is, for Jupiter, 34 days; for Saturn, 13 days; and for Herschel only 4½ days. Map 2 might be serviceable in illustrating this subject, so far as relates to the exterior planets.

The learner must not forget that the exterior planets have but one conjunction, while the interior have two; and that in the preceding table the time is given from one conjunction to another *of the same kind.* The opposite conjunction occurs in just half the synodic period.

LESSON LVIII.

ELONGATIONS OF A PLANET.

(Map 9.)

The elongation of an interior planet is its angular distance east or west of the sun, according as it follows or precedes him. The greatest elongation of Venus is 48°, and that of Mercury only 29°.

But these alternate elongations east and west are not always the same. Those of Mercury vary from 16° 12′ to 28° 48′; while those of Venus vary much less. E and W mark the positions of Venus at the time of her greatest elongation.

From the above facts several other important facts are deduced. The first is, that the orbits of Mercury and Venus are *within* that of the earth. If it were not so, they would depart farther from the sun, and sometimes appear in opposition to that luminary. In the second place, they show that the orbit of Mercury is within that of Venus; otherwise his elongation would exceed that of Venus. Thirdly, they show the ellipticity of the orbits of Mercury and Venus. If their orbits were complete circles their greatest elongation would always be the same; but as it varies, it proves that they are not always at the same actual distance from the sun, or, in other words, that their orbits are more or less elliptical.

LESSON LIX.

WHEN PLANETS ARE SAID TO BE STATIONARY.

(Map 9.)

For a short time, while at or near their greatest elongation, the interior planets seem neither to recede from, or approach towards, the sun. They are then said to be *stationary*. These periods are just before and just after an inferior conjunction. They are represented, in Fig. 1 at E and W. At E the planet would be coming towards the earth, and at W going from it.

LESSON LX.

DIRECT AND RETROGRADE MOTIONS.

(Map 9.)

It was stated in Lesson XVIII., that the planets revolved in their orbits from west to east, or in the order of the signs. But they do not always *appear* to maintain this order. At times they advance regularly through the signs, and again retrace their course. Hence the distinction of *direct* and *retrograde* motions. Direct motion is from west to east; retrograde is from east to west.

The general course of the planets is eastward, their retrogression being but for a short time, when the direct course is again resumed.

The cause of this seeming irregularity will appear by again consulting Fig. 1. The signs will be seen marked ♈, ♉, ♊, &c., on the right and left sides of the map, and may be imagined around the whole figure. When Venus is at W, she would seem, to an observer on the earth, to be in ♓, in the signs of the upper figure. As she passed on in the direction of the arrows, from W to E, her motion would be direct, and she would seem to pass through ♈, ♉ ♊, ♋, and into ♌; but in passing from E to W she would seem to fall back through ♋, ♊, &c. These are her direct and retrograde motions.

But the amount of apparent retrogression is greatly reduced by the motion of the earth in the same direction; as for instance, if the earth advances only from D to the lower hand (☞), during a revolution of Venus, she would not retrograde beyond the beginning of ♋.

The above principles are as applicable to Mercury as to Venus.

LESSON LXI.

RETROGRADE MOTIONS OF THE EXTERIOR PLANETS.

(Map 9.)

The apparent retrogression of the exterior planets is effected in a manner somewhat different from that of the interior planets.

Suppose the earth at A, and Mars at B; he would be seen among the stars at C. As the earth gains upon Mars, and reaches the point D, Mars, being at F, would be seen at G, or west of where he was first seen. When the earth reaches H, and Mars is only at J, he will be seen at K; or some 15° back, or west, of his first apparent position.

The part of the great circle of the heavens through which a planet seems to retrograde, is called its *arc of retrogradation.* In the figure it is the arc of the circle between C and K.

The following table will show the arc of retrograde motion, and also the time of retrogression in days.

	Arc.	Days.
Mercury	$13\frac{1}{2}$°	23
Venus	16	42
Earth		
Mars	16	73
Vesta	13	83
Juno	12	99
Ceres	12	99
Pallas	12	99
Astræa	12	99
Jupiter	10	121
Saturn	6	139
Herschel	4	151

Here it may be interesting to observe, that the more distant the exterior planet the less its *arc* of retrogradation, and the longer its *time.* The reason for this may be illustrated by the map, Fig. 1. Suppose Mars at F to represent Herschel. Now as his year consists of eighty-four of our years, it follows that the earth would pass him eighty-three times during one of his revolutions; and that during a revolution of the earth he would pass through only $\frac{1}{84}$ part of his orbit; or about $8\frac{1}{4}°$. The planet F would thence seem to retrograde slowly on the ecliptic nearly half the year; or while the earth was passing from A to H on the map.

Another result which may be seen in the table is, that the more distant the planet is from the earth's orbit, the smaller the angle which will be necessary to include that orbit; and the less the arc of retrogradation described by the planet on the concave of the heavens. But I must not explain and illustrate too much, lest the learner find no chance to think for himself.

LESSON LXII.

VENUS AS MORNING AND EVENING STAR.

(Map 9.)

"Next Mercury, Venus runs her larger round,
With softer beams and milder glory crown'd;
Friend to mankind, she glitters from afar,
Now the bright *evening*, now the *morning* star.
From realms remote she darts her pleasing ray,
Now leading on, now closing up the day;
Term'd *Phosphor* when her *morning* beams she yields,
And *Hesp'rus* when her ray the *evening* gilds.

It has been seen that in making her revolutions, Venus is sometimes east and sometimes west of the sun. From her inferior to her superior conjunction she is *west* of the sun; and from her superior to her inferior conjunction *east* of him. Now it is obvious that when she is west of the sun she will go down before him, and cannot be seen in the west after sunset; but if she sets before the sun she will rise before him, and can be seen in the east before sunrise. When, therefore, Venus is west of the sun she is *morning star*. When she is east of the sun she rises after the sun, and may be seen above the horizon in the west, after the sun is set. She is then *evening star*.

The ancients supposed these were two different stars, calling the first *Phosphor*, and the other *Hesperus*. Venus is alternately one or the other about 292 days. For 146 after her inferior conjunction she lingers farther and farther behind the sun, in the west, till she reaches her greatest *eastern* elongation. She then seems to approach the sun again for 146 days, when she passes her inferior conjunction, and becomes morning star. After this she rises more and more in advance of the sun for 146 days, when, having reached her greatest *western* elongation, she begins to fall back again towards the sun, and in 146 days is at her superior conjunction. This passed, she is again evening star.

Fig. 2 is designed fully to illustrate all that may yet seem obscure to the learner. From W to E will represent her *direct* motion, in the order of the signs. From E around to W again shows her *retrograde* motion. S and I mark her superior and inferior conjunctions; and the appearance of a *transit* is represented on the sun's disc.

By imagining the sun and Venus, as represented in the figure, to rise in the east and pass over to the west, the student will see that if Venus were at W she would be morning star, and at her greatest elongation; but if at E she would be evening star, &c. It would be a useful exercise to observe the exact position of Venus in the heavens, at the time of studying these lessons, and then point out that position on the map.

LESSON LXIII.

PHASES OF MERCURY AND VENUS.

(Map 9.)

As Mercury and Venus are opaque bodies, like our earth, only those portions of their surface appear bright which are enlightened by the sun; and as their enlightened sides are turned towards us, little by little, they present, when seen through a telescope, all the different appearances or phases of the moon.

Fig. 2 represents Venus in her orbit, and exhibiting all her different phases, in the course of her revolution. At I, her inferior conjunction, her dark side is towards us, and her enlightened side invisible. As she passes from I to W, and so on round to S, we see more and more of her enlightened side, till her whole illuminated disc is in view. From her superior to her inferior conjunction she continues to wane, till her dark side is again turned directly towards the earth.

Although when at S, her whole enlightened hemisphere is towards the earth, still she is less brilliant than when at E and W; owing to her increased distance from us, and her being, apparently, in the neighborhood of the sun.

It will be seen that Venus is the whole diameter of her orbit nearer to us, at her inferior conjunction, than at her superior; and as her mean distance from the sun is 69 millions of miles, her distance from the earth must vary to the extent of twice that amount, or the whole diameter of her orbit, which is 138 millions of miles. It is not strange, therefore, that her apparent magnitude undergoes sensible variations between her conjunctions.

LESSON LXIV.

TELESCOPIC VIEWS OF THE PLANETS.

(Map 10.)

Although in the preceding lessons we have frequently alluded to the appearance of some of the planets, when seen through a telescope, it is thought important to describe those appearances more in detail; and to illustrate the descriptions by appropriate engravings. This is the object of Map 10.

Before any particular planet is noticed, it may be well to state a few general facts respecting these primary bodies.

1. They all have the same general *figure*, namely, that of spheres or spheroids.

2. They all seem to be surrounded by an *atmosphere*, of greater or less density and extent.

3. The spots or belts seen upon their surfaces from time to time, by different observers, seem to be in the main permanent, and indicative of large divisions of land and water, like our continents and seas.

With these preliminaries, they will now be taken up and considered in order.

MERCURY.

"Of MERCURY," says Dr. Herschel, "we can see little more than that it is round, and exhibits phases. It is too small, and too much lost in the neighborhood of the sun, to allow us to make out more of its character." But this is not the opinion of every observer. Mr. Schroeter, an eminent German astronomer, assures us that he has not only seen *spots* on the surface of Mercury, but also *mountains*, the height of two of which he actually measured. They were situated in the southern hemisphere of the planet, and the highest was found to be nearly eleven miles in height.

Numbers 1 and 2 on the map, are representations of Mercury. The spots supposed to have been seen by Schroeter, are represented on his disc, and he has a faint bluish tint as when seen through a telescope. As elsewhere stated he exhibits the different phases of the moon during his synodic journey around the sun.

VENUS.

The figures from 3 to 12 inclusive, are telescopic views of *Venus*. As a whole they represent her various *phases*, as already explained in Lesson LXIII. ; and illustrated by the lower figures of Map 9. Figures 3, 4, 11 and 12, show her horned, as when near her inferior conjunction. Figures 5 and 10 show her as she appears when at her greatest elongation ; 6 and 9 as *gibbous*, between her greatest elongation and superior conjunction ; and 7 and 8 as she appears at her superior conjunction.

But these ten views present a great variety as it respects the *spots* that appear upon the surface of the planet. They seem not only to vary in *form* but also in their *number*. It may be proper, therefore, to state that these views were not all enjoyed by any one person, or during the same period of time.

Fig. 3	is a view by	*Schroeter*,	in	1791.
Fig. 4	"	*Bianchini*,	in	1726.
Fig. 5	"	*Cassini*,	in	1667.
Fig. 6	"	"	in	1666.

Figures 7 and 8 represent the face of the planet, as it is supposed she would have appeared, at the time of some of the other views, had her whole hemisphere been enlightened. It will be seen that each of these figures combine two other views.

Fig. 9 is a view by Schroeter, in 1790.

Fig. 10 is a view often had by the celebrated Dr. Dick.

Figures 11 and 12 are repetitions of former views, with the crescent inverted, in order to illustrate the subject of Venus's phases.

The *surface* of Venus is variegated with *mountains*, some of which are estimated to be over twenty miles in height. Three elevations have been estimated at $10\frac{3}{4}$, $11\frac{1}{2}$ and 19 miles, respectively.

The *atmosphere* of Venus is supposed to surround her to the depth of only about three miles; but it is supposed to be very *dense*.

The *color* of Venus is a *silvery white*. When at her greatest elongation, she is sufficiently bright to cause a perceptible shadow if her light is intercepted.

THE EARTH.

That the learner may know the grounds of the inferences drawn from the telescopic appearances of the planets, in regard to their geography, or their great natural divisions, as continents, seas, &c., we present him at No. 13 with a telescopic view of the planet *Earth*. Let him imagine himself to be placed upon *Mercury*, for instance with a good telescope, observing our planet. At the time of her opposition she would appear *full* from Mercury. The continents and islands would appear *brighter* than the rest of her disc; as they would reflect a stronger light than oceans, seas, and lakes. By watching these spots they would be found to cross the earth's disc in 12 hours, from which the observer would infer that our globe revolved on her axis in 24 hours, and from the *direction* of the spots he would deduce the *inclination* of her axis to the plane of her orbit, &c.

From the passage of *clouds* over her surface, and other phenomena, it would be inferred that the Earth had an *atmosphere*, and the different zones, and the changes of the seasons, might present a variety of *colors* to the celestial observer.

To a person on one of the *exterior* planets, the Earth would present all the phases of the Moon. The study of geography has no doubt made the learner familiar with the figures under consideration; but if he can divest himself for a moment of all particular knowledge of our globe, and contemplate her from a distance, as a *planet*, with what new interest does it invest her! She not only becomes one of a class, from which we may reason analogically respecting the physical constitutions and design of other worlds; but while we look with wonder upon the planetary orbs, and long to know more of their physical structure, we look upon the earth as the only orb which *we* are allowed to visit, and with whose history and peculiarities *we* may now become acquainted. And as the student looks upon the whole Western hemisphere, let him exclaim, "What is *man!*" What is a *city*, an *empire*, or a *world*, in the great universe of the Almighty?

MARS.

The figures from 14 to 23 inclusive are representations of *Mars*. The first two, namely 14 and 15, are views by Cassini, as long ago as 1610. They are copied from a volume of the Transactions of the Royal Society of London. Figures 16 and 17 represent views had by Maraldi, a celebrated French astronomer, in 1704. Figs.

18 and 19 represent the appearance of the spots on Mars, as seen by Dr. Hook in 1666, from a drawing made at the time by him. Figures 20 and 21 represent views by Sir William Herschel, previous to 1784. Fig. 22 is a view by Sir John Herschel, as copied by Nichol in his "Solar System," and by several other astronomical writers. Fig. 23 is a view by Dr. Dick, in 1832, and also in 1837. It is copied, as several of the above are, from his "Celestial Scenery."

It may seem impossible to the learner that all this variety in appearance could be produced by permanent objects on the surface of the planets; but let him remember that the map of Mars, which he is studying, is drawn upon a *sphere*; and that the revolutions of a planet would necessarily produce a constant change, not only in the general appearance, but also in the apparent form of the spots.

The bright spot on the upper end of Fig. 22, at the planet's north pole, is supposed to be the reflection of light from *snow* and *ice*. This supposition is rendered probable by the fact that the spot disappears as the north pole of the planet is turned towards the sun, and returns again with the departure of the direct rays of the sun, and the return of winter.

The *surface* of Mars is variegated with oceans, seas, and continents, with mountains and vales, like all the rest of the planetary bodies. "On this planet," says Dr. Herschel, "we discern, with perfect distinctness, the outlines of what may be continents and seas." The celebrated Mädler, of Berlin, constructed a complete map of the surface of Mars, with accurate delineations of its great natural divisions, as one would draw an outline map of the world from an artificial globe.

The *color* of Mars is *red*, owing, it is supposed, to the density of his atmosphere, which may color the whole scene, as clouds put on a gorg·ous crimson in the morning or evening sky. This color is not merely telescopic: it is the natural color of the planet as seen by the naked eye; and by it he may easily be distinguished from the fixed stars.

THE ASTEROIDS.

Of the *Asteroids* very little is known, on account of their distance and their diminutive size. A thin haze, or nebulous envelope, has been observed around Pallas, supposed to indicate an extensive atmosphere; but no spots or other phenomena have ever been detected. It is hoped that if ever Lord Rosse returns from examining the distant nebulæ, he will give us some new light respecting the bodies of the Solar System.

The Asteroids are never visible to the naked eye. Through a telescope they have a pale ash color, with the exception of Ceres, which in color resembles Mars.

JUPITER.

Fig. 24 is a representation of *Jupiter*, the prince of planets. His natural color is a palish *yellow*. His *belts* are seen where they are usually found, namely, on each side of his equator, or in his temperate zones. The map shows his *oblate form*, or the difference between his polar and equatorial diameter.

What the belts of Jupiter are is uncertain. "They are generally supposed to be nothing more than *atmospherical phenomena*, resulting from, or combined with, the rapid motion of the planet upon its axis." In *number* they vary from one to eight. Sometimes they continue without change for months, and at other times break up and change their forms in a few hours. Dark spots are also frequently seen in these belts, one of which was known to maintain the same position for upwards of forty years.

SATURN.

Fig. 25 is a telescopic view of Saturn with his *belts* and *rings*. The *belts* resemble those of Jupiter, already described. His *rings* will be noticed in a subsequent lesson, in connection with Map 11, to which the reader is referred. The body of Saturn is of a *lead color*—the rings a *silvery white*.

HERSCHEL.

Upon this distant orb no spots have ever yet been discovered. It is supposed (probably from analogy) to be surrounded by an atmosphere ; but even this is not certain. Through a telescope "we see nothing but a small, round, uniformly illuminated disc, without rings, belts, or discernible spots." It is of a pale ash color.

LESSON LXV.

OF THE DISCOVERY OF THE SEVERAL PLANETS.

Mercury, *Venus*, *Mars*, *Jupiter*, and *Saturn*, have been known from the earliest ages in which astronomy has been cultivated.

Ceres was discovered by Piazzi, at Palermo, Jan. 1st, 1801.

Pallas was discovered by Dr. Olbers, of Bremen, March 28th, 1802.

Juno was discovered by Mr. Harding, Sept. 1st, 1804.

Vesta was discovered by Dr. Olbers, March 29th, 1807.

Astræa was discovered by Mr. Henche, of Dresden, Dec. 15th, 1845.

Herschel was discovered by Sir William Herschel, March 13th, 1781.

Le Verrier's Planet.—Since the preceding lessons were written, a *New Planet* has been added to the list of those previously known, by the discovery of Dr. Galle, of Berlin. That our readers may the better appreciate this wonderful achievement of science, we copy the following letters from the *London Times*, in which this interesting subject is considered at length.

THE NEW PLANET.

Esh, near Durham, Oct. 8, 1846.

But a few months have elapsed since the discovery of the small planet Astræa, the companion of the small planets Juno, Ceres, Pallas, and Vesta, already known. The last few days have brought us the intelligence of the discovery of another new planet, under circumstances so unexampled, as to form the most brilliant achievement of theoretical and practical astronomy. Some of your readers may be interested in a familiar explanation of the steps which have led to this interesting discovery.

The motions of all the planets are affected by the gravitation of the planets to one another; and the places of the planets in the heavens are computed beforehand, so that the positions given by observation can be constantly compared with those previously calculated. Now the observed motions of the planet Uranus, the most distant hitherto known in our system, when thus compared, were found not to agree with the motions which the planet would have, after allowing for the influence of all the known planets, and when it was found that the deviations were far greater than any which could be ascribed to mere errors of observation, that they were of a regular character, and of such a nature as would arise from the action of a still more distant planet, the attention of astronomers was directed to ascertain whether the disturbances were such as to point out the position of the disturbing planet. As long ago as the year 1842, a communication took place between Sir John Herschel and the lamented German astronomer, Bessel, on this subject: and there is reason to suppose that some researches on the subject will be found among Bessel's papers; for, in a letter written Nov. 14, 1842, to Sir J. Herschel, Bessel says, "In reference to our conversation at Collingwood, I announce to you that Uranus is not forgotten." The question was, however, taken up by other astronomers. Le Verrier, in France, and Mr. Adams, of St. John's College, Cambridge, in England, each in ignorance of each other's labors, proceeded to investigate this most intricate question, and arrived independently at the same conclusion, that the probable place of the suspected planet was about 325° of heliocentric longitude. This was sufficient to point out, within certain limits, the part of the heavens at which the planet, if visible, would be seen; and, in consequence, Professor Challis, at Cambridge, for the last two months, was engaged in mapping the neighboring stars with a view of detecting the planet. Sir John Herschel alluded to the probability that the planet would be detected in the speech which he made on resigning the chair at the late meeting of the British Association. Having observed that the last twelvemonth has given another new planet to our system, he added, "It has done more. It has given us the probable prospect of the discovery of another. We see it as Columbus saw America from the shores of Spain. Its movements have been felt, trembling along the far-reaching line of our analysis, with a certainty hardly inferior to that of ocular demonstration."

The eloquent and glowing anticipation of the future was soon to receive its accomplishment. On the 31st of August, Le Verrier made public the following elements of the orbit of the supposed planet, deduced by most laborious calculations from the observed disturbances:

Semiaxis major . .	36,154
Eccentricity . .	0,10761
Longitude of Perihelion	284° 45′
Mean long. Jan. 1, 1847	318° 47′
Periodic time . .	217,387 sidereal years.
Mass	$\frac{1}{3900}$

He also announced that the planet would probably present a disc of about 3″ in magnitude. This announcement reached Dr. Galle, at Berlin, on the 23d of September, and on the same evening Dr. Galle, on comparing the stars in Dr. Bremiker's chart with the heavens, found a star of the eighth magnitude which was not marked upon the map. The place of this star was accurately observed, and on comparing this place with its position on the following night, its motion, amounting to about 4° in right ascension, and 30′ in declination, was detected; and the star was proved to be the expected new planet.

It ought to be noticed that the new investigations of Le Verrier, accompanied with a recommendation to astronomers to search for the planet by examining whether any star presented a sensible disc, did not reach Cambridge till September 29, and that Professor Challis, on that very evening, singled out one star, as seeming to have a disc, and that star was the planet. Thus the theory, derived by a most abstruse calculation, from long continued accurate observation, has been completely verified; and a triumph has been gained which will go down to posterity among the most brilliant of astronomical discoveries.

The known boundaries of our planetary system have thus been nearly doubled; a planet is added to it requiring more than 217 years to complete its revolution round the sun; and moving in regions so remote as to receive but $\frac{1}{1300}$th part of the light and heat which our earth enjoys.

It will remain to be discovered whether, as seems most probable, this planet is accompanied with a train of attendant satellites; whether its motions are in accordance with the known laws of gravitation; or whether it, in turn, is to serve as the means of a still further extension of the solar system.

There is one circumstance connected with this new planet which is too remarkable to be overlooked. It was long since noticed by Bode, that the distance of the planets from the sun follows a peculiar law, which may be thus stated—that if the distance of Mercury from the sun is assumed to be 4, the distance of Venus, the next planet, is 3 added to 4, or 7; that of the earth, which is next, *twice* 3 added to 4, or 10; and thus for the remaining planets, the distances from each other are *doubled* every time, as may be seen from the following table:

Name of Planet.	Dist. from the Sun.	Difference.
Mercury . . .	4	3
Venus	7	3
Earth . . .	10	6
Mars	16	12
Small Planets . .	28	24
Jupiter	52	48
Saturn . . .	100	96
Uranus . . .	196	192
New Planet . .	388	

The distance of the new planet then approximately satisfies this very remarkable law ; and the little stranger is at once recognized as bearing a strong family likeness to the other members of our system.

The new planet was observed at Durham observatory Oct. 3, and Oct. 6 ; and the following results obtained :

Greenwich mean time.		R. A.	Greenwich mean time.		H. D. D.
Oct. 3	8.48	21.52.31.07			
Oct. 6	11.88	.20.92	Oct. 6	11.25.6	103.28.55.1

TEMPLE CHEVALLIER.

Probable discovery of a ring to the new planet :

STARFIELD, Liverpool, Oct. 12.

On the 3d instant, whilst viewing this object with my large equatorial, during bright moonlight, and through a muddy and tremulous sky, I suspected the existence of a ring round the planet ; and on surveying it again for some time on Saturday evening last, in the absence of the moon, and under better, though still not very favorable atmospherical circumstances, my suspicion was so strongly confirmed of the reality of the ring, as well as of the existence of an accompanying satellite, that I am induced to request you, as early as possible, to put the observations before the public.

The telescope used is an equatorially mounted Newtonian reflector, of 20 feet focus, and 24 inches aperture, and the powers used were various, from 316 to 567. At about 8¾ hours, mean time, I observed the planet to have apparently a very obliquely situated ring, the major axis being seven or eight times the length of the minor, and having a direction nearly at right angles to a parallel of declination. At the distance of about three diameters of the disc of the planet, northwards, and not far from the plane of the ring, but a little following it, was situate a minute star, having every appearance of a satellite. I observed the planet again about two hours later, and noticed the same appearances, but the altitude had then declined so much that they were not so obvious. My impression certainly was that the supposed satellite had somewhat approached, but I cannot positively assert it.

With respect to the existence of the ring, I am not able absolutely to declare it, but I received so many impressions of it, always in the same form and direction, and with all the different magnifying powers, that I feel a very strong persuasion that nothing but a finer state of atmosphere is necessary to enable me to verify the discovery. Of the existence of the star, having every aspect of a satellite, there is not the shadow of a doubt.

Afterwards I turned the telescope to the Georgium Sidus, and remarked that the brightest two of his satellites were both obviously brighter than this small star accompanying Le Verrier's planet.

WM. LASSELL.

In the periodical from which we copy, this statement of Mr. Lassell is accompanied by a *drawing*, representing the appearance of the planet as above described.

From the calculation submitted in the foregoing accounts it appears that the Le Verrier planet must be nearly *four thousand millions of miles* from the sun! Verily, such a discovery is "enlarging the boundaries of the Solar System" most effectually. But what is this distance after all, when we consider that it would require more than 5000 such journeys to reach the nearest of the fixed stars?

LESSON LXVI.

TELESCOPIC VIEWS OF SATURN.

(Map 11.)

Before the invention of the Telescope, Saturn was known only as a distant planet, devoid of that special interest with which modern discoveries have invested him. But since the powers of that wonderful instrument have been brought to bear upon him, he has assumed new and resplendent glories, and now stands forth to view as one of the most interesting objects in the gorgeous heavens.

Though we have no room in this treatise to describe the different kinds of telescopes, or to detail their history, we propose, nevertheless, to give some idea of its *improvement*, by tracing the *successive steps* by which we have arrived at our present knowledge of the planet Saturn.

The objects arranged across the top of the map are representations of a variety of telescopic views of Saturn, by different observers, during the period of 45 years; or from 1610 to 1655. Though not arranged in the order we intended, each separate view may probably be identified by the learner, with proper care and attention. Let it be understood, then, that the figures 1, 2, 3, &c., over the top, refer to *two views each*, viz., the two immediately under and each side of them. In this manner I shall proceed to consider them.

But it may be well here to observe, that these different appearances of Saturn were owing almost solely to the imperfect state of the telescope at those early periods of its history.

The view presented at the *right* of Fig. 1, was had by *Galileo*, the inventor of the telescope, in 1610. The other, on the *left*, was by *Scheiner*, in 1614. The *right* figure, near No. 2, represents a view by *Riccioli* in 1640, and the *left* one a view by *Helvetius* in 1643. In 1649, the same observer saw Saturn as represented on the right of Fig. 3, and in 1650 as he is seen on the left. The latter was a very excellent view for that early period. In the same year, however, he had a still better view, as represented on the *right* of Fig. 4. On the *left*, near the same figure, is a view by *Riccioli* in 1651. The remaining four may be taken in the order in which they occur on the map. They were all had in 1655, the first by *Fontani*; the second by *Divini*; the third by *Riccioli*; and the fourth by *Gassendus*.

The real appearance of Saturn, as seen through a common and cheap telescope, is well represented at A or B, immediately under the above views, with the exception of the opening between the rings. We have often seen him as here represented,—and with the belts across his disc as shown in Map 10,—and that too with an ordinary refracting telescope; but in earlier periods in the history of the science, such views were denied even to the most wealthy, devoted, and profound astronomers.

But this wonderful planet does not present the same appearance at all times, even with the aid of the best glasses. Indeed, the better the instrument the more perceptible his variations. In the course of 30 years, the time of his periodic revolution, he presents all the different phases shown at Fig. 3, from A to H. At one time the rings are entirely invisible, except as a dark stripe across the body of the planet, as seen at A. About $3\frac{3}{4}$ years afterwards the rings appear slightly opened, as at B ; and in $3\frac{3}{4}$ years more they appear as at C, &c.

These different phases are all accounted for by Fig. 2. Here the sun is seen in his place in the centre, and the earth and Saturn in their orbits, as they may be supposed to appear to a beholder at a distance, and elevated somewhat above the plane of the ecliptic. This diagram may be used to illustrate a variety of principles.

1. It shows how the axis of Saturn (as well as that of the Earth, &c.) *preserves its parallelism* in all parts of its orbit, and from age to age.

2. It illustrates the subject of his *seasons*, as partially explained in Lesson LV. ; and shows how the sun must shine on one side of his rings 15 years, and on the other 15 years. At A the light falls directly on the *edge* of the rings ; but as soon as he passes that equinoctial point, the sun shines upon the *lower* or *southern* side of the rings, and continues to do so till the planet reaches its other equinox at E. Here the light crosses over to the *upper* or *north* side of the rings, upon which it continues for the next 15 years ; or till the planet passes round to A again.

3. It shows that *Equinoxes* and *Solstices* are by no means peculiar to the earth—they belong to all the planetary bodies. In the figure, A and E are the *equinoctial*, and C and G the *solstitial* points.

4. The learner should test himself by this figure to see if he fully understands the subject of the *sun's declination*, as explained in Lesson XLVII.

5. As before said, this view of Saturn in his orbit accounts for all his different phases during his periodic journey, as shown at Fig. 3. Let the student suppose himself on the earth, where he really is, and watching Sa-

turn in his course; and he will find that the rings must necessarily present all the variety in appearance which is seen in Fig. 3, as well as every intermediate degree of contraction and expansion.

Let this explanation be traced through. Take any particular position of Saturn, or take them in order, beginning at A, and it will be found that the view denoted by the corresponding letter in Fig. 3 must be the appearance *from the earth*, as she comes round between Saturn and the sun. At C the rings are thrown up, and hide the upper edge of the planet; while at G they seem inclined the other way, and the planet hides the upper edge of the rings, &c.

6. This diagram shows why we cannot see Saturn at all times in the year. Suppose him to be at C, for instance, on the first of January, and the earth on the same side of her orbit; of course he would be directly overhead, or rather on the meridian, at *midnight*, and might therefore easily be seen for six hours preceding, and six following that hour. In six months from that time, or by the first of July, the earth will have passed around to the point opposite G; but as Saturn has moved but a short distance apparently in his orbit, he will not only be above the horizon in the daytime, but he will be nearly in conjunction with the sun. He must therefore be invisible till the earth again gets around where Saturn will be comparatively in opposition, or on the dark side of the earth.

LESSON LXVII.

DIMENSIONS, STRUCTURES, AND USES OF SATURN'S RINGS.

(Map 11.)

Diameter of the planet . .	80,000	miles.
Distance to the interior ring . .	20,000	"
Width of the interior ring . .	20,000	"
Opening between the rings . .	2,000	"
Width of the exterior ring . .	10,000	"
External diameter of the outer ring	192,000	"
Thickness of the rings . .	100	"

Fig. 4 on the map is a *vertical* view of the rings of Saturn, or such as an observer would have if he were situated directly over either *pole* of the planet, and at a considerable distance from it. The opening between the rings, and between the planet and the rings would then be visible all around, and of uniform width. Through these openings the stars would be as distinct as in any other portion of the celestial sphere; hence we have so represented in the figure.

Fig. 5 is a view of the rings as they would appear to an observer situated upon the body of the planet itself, and about half way from his equator to his north pole. This is a *summer* view, of course, as the rings are enlightened; whereas during winter in the northern hemisphere the rings would look dark, like the dark part of a new moon.

Under this gorgeous arch may be seen a portion of the planet's surface. On the right is a *new moon*, and on the left a *full moon*, both in view at the same time, one in the west and the other in the east. On the left, and crossing the rings, may be seen the *shadow* of Saturn, gradually ascending the arch as the night advances, till it reaches the zenith at midnight, and disappears in the west at the approach of day.

Fig. 6 is a similar view from the body of Saturn, the observer being located at a distance from the equator, or near his pole. The arch would then appear low down in the south, and also more narrow and slender; and a much smaller portion of the rings would appear above the horizon. The following particulars may conclude this interesting lesson.

1. By observing the motion of certain spots or inequalities in the rings of Saturn, it has been ascertained that they *revolve* around the planet in $10\frac{1}{4}$ hours; or in the time of his diurnal revolution (Lesson XXI.).

2. That the rings are *solid matter*, like the body of Saturn, seems evident from the fact that they reflect the light of the sun very strongly, and cast a deep shadow upon the planet's surface.

3. Stars have sometimes been seen between the in-

ner and outer rings, which proves them to be actually separated.

4. Of the *uses* of these wonderful rings it is sufficient to say that they serve as so many *reflectors* to the planet; and being only about $\frac{1}{24}$ part as distant as our Moon, and of such vast magnitude, they must tend greatly to modify the *climate* of the planet, by contributing to the light and heat of his summer evenings. During the winter in each hemisphere, the rings *cast a shadow*, and increase the intensity of the cold.

CHAPTER III.

OF THE SECONDARY PLANETS.

LESSON LXVIII.

CHARACTER AND NUMBER OF THE SECONDARY PLANETS.

(Map 2.)

The *secondary planets* are those comparatively small bodies that accompany the primaries in their course, and revolve around them. As the primaries revolve around the sun, so the secondaries revolve around their primaries.

The number of secondary planets positively known to exist is *eighteen*. Of these, the Earth has *one*, Jupiter *four*, Saturn *seven*, and Herschel *six*. They may be seen on the map at their relative distances from their primaries. Their relative *magnitudes* are also represented.

Though the secondary planets have a compound motion, and revolve both around the sun and around their respective primaries, they are subject to the same general laws of gravitation—of centripetal and centrifugal force—by which their primaries are governed. Like them, they receive their light and heat from the sun, and revolve periodically in their orbits, and on their respective axes. In the economy of nature they seem to serve as so many *mirrors* to reflect the sun's light upon superior worlds, when their sides are turned away from a more direct illumination. The secondary planets are generally called *moons*, or *satellites*.

LESSON LXIX.

SUPPOSED SATELLITE OF VENUS.

Several astronomers have maintained that Venus is attended by a satellite. From the observations of Cassini, Mr. Short, Montaigne, and others, as quoted by Dr. Dick,* it seems highly probable that such a body exists. M. Lambert supposed its period to be 11 days, 5 hours, and 13 minutes; the inclination of its orbit to the ecliptic $63\frac{3}{4}°$; its distance from Venus about 260,000 miles; and its magnitude about $\frac{1}{7}$ that of Venus. It is to be hoped that this interesting question will ere long be fully settled, as it is one which numerous telescopes, both in this country and in Europe, have capacity to decide. It is a question worthy of the attention of Lord Rosse, and the powers of his colossal reflector.

LESSON LXX.

OF THE EARTH'S SATELLITE OR MOON.

(Map 12)

To ordinary observers of the heavens, the Moon is an object of great interest. Her nearness to the earth—her magnitude—her rapid angular motion eastward—her perpetual phases or changes, and the mottled appearance of her surface, even to the naked eye, all conspire to arrest the attention, and to awaken inquiry. Add to this her connection with *Eclipses*, and her influence in the production of *Tides* (of both of which we shall speak hereafter

* Celestial Scenery, pp. 84—89.

in distinct chapters), and she opens before us one of the most interesting fields of astronomical research.

The following table exhibits the principal statistics and facts respecting the Moon, and should be carefully studied or committed to memory.

Mean distance from the earth's centre	240,000 miles.
Sidereal revolution . . .	$27\frac{1}{3}$ days.
Synodic revolution . . .	$29\frac{1}{2}$ "
Periodic revolutions per year, nearly	13
Direction in orbit, from west to east.	
Hourly motion in orbit . . .	2,300 miles.
Mean angular motion per day	$13^\circ\ 10'\ 35''$
Diameter	2,160 miles.
Apparent angular diameter .	$31'\ 7''$
Bulk, as compared with the earth .	$\frac{1}{49}$
Bulk, " " " the sun .	$\frac{1}{70,000,000}$
Surface, as compared with the earth	$\frac{1}{13}$
Density, the earth being 1 . .	$\frac{2}{3}$
Inclination of orbit to the ecliptic .	$5^\circ\ 9'$
Excentricity of orbit . . .	13,333 miles.
Longitude of ascending node . .	variable.
Inclination of axis to orbit . . .	$1\frac{1}{2}^\circ$
Revolution upon axis	$29\frac{1}{2}$ days.
Light reflected by her, as compared with that of the sun	$\frac{1}{300,000}$

By comparing the *distance* of the Moon, as expressed in the foregoing table, with that of the Sun, (Lesson VIII.) it will be seen that the latter is four hundred times as far off as the former. It is for this reason that she generally appears as *large* as the Sun, when in fact he is seventy million times the largest. The Moon may therefore well be regarded as our near terrestrial neighbor.

It may also be interesting to compare the *angular magnitude* of the Moon as seen from the earth, with that of the Sun, as given in Lesson XI. They seem to differ but $53''$; or less than one minute of a degree. Thus the Sun, on account of his immense distance, looks no larger than the moon; when in fact he is equal in bulk to seventy millions of such bodies.

If the pupil does not fully understand the *cause* of this agreement in the apparent magnitude of the Sun and Moon, when they are in reality so disproportionate in bulk, let him turn back and review Lesson X., and the map and figure therein referred to.

LESSON LXXI.

CHANGES OR PHASES OF THE MOON.

(Map 12.)

The upper row of figures on the map represents the changes of the moon in passing from new to full moon, and around to new moon again. The first figure on the right represents the *new moon*, when, if visible at all, we see only her dark side. She is then at her *conjunction*, or in the same longitude with the sun, and to ordinary observers is invisible. As she advances eastward in her orbit, she falls behind the sun in his apparent daily course, and in a few days is seen in the west just after sundown, in the form of a slender crescent, as seen in the next view to the left. As she advances, we see more and more of her bright side, as represented on the map, till she reaches her *opposition*, when her enlightened hemisphere is towards us, and we see her as a *full moon*.

From this time onward the *west* side of the moon begins to be obscured, for want of the sun-light, and the crescent begins to be inverted. From the first quarter to the full, and from full moon to the last quarter, the moon is said to be *gibbous*.

The *cause* of these changes is further illustrated in Figure 2, where the Earth is shown in the centre, and the Moon at various points in her orbit. The sun is supposed to be on the right, as in Figure 3. The outside suit of moons shows that in fact just one half of the moon is always enlightened; while those on the inside show *how much* and *which part* of her enlightened side is *visible from the earth*. A is the new moon. B shows her when first visible. C is the first quarter; D gibbous; E full moon; F gibbous; G last quarter; H the crescent inverted; and A new moon again. This revolution of the moon around the earth, is called a *lunation.*

The points A and E, in the moon's orbit, are called her *syzygies;* C and G her *quadratures;* and B, D, F, and H, her *octants.*

LESSON LXXII.

THE MOON'S PATH AROUND THE SUN.

(Map 12.)

The Moon has two centres of motion viz., the Earth and the Sun. She may therefore be said to have a sort of compound orbit. Were the earth at rest, the moon's path around her would be comparatively uniform; but as it is she describes a variety of *epicycles*, in revolving monthly around the earth, and annually around the sun. These are represented in Fig. 3.

Suppose the moon to be at A, and the earth in her orbit between A and 19, of course it would then be *new moon.* The earth and moon start on eastward in their respective orbits, or in the direction of the arrows. In about 14 days the moon will reach B, when she will be in *opposition*, and persons on the dark side of the earth, or during the night, will see her as a *full moon.* In about 14 days longer, she passes around to C, when it will again be *new moon*, &c. Thus throughout the year the figure shows the earth's orbit and the moon's eccentric path, as well as the relative position of each, at each successive new and full moon.

But it will be seen that the twelve revolutions of the moon, and the one revolution of the earth *do not come out even;* or in other words, do not end at the same time. From the new moon at A, around to the new moon at D, are just twelve lunar months or revolutions; but at this time the earth wants 19° 20′ to reach her starting point at A, or to complete her year. The lunar year. therefore, consisting of twelve synodical revolutions of the moon, or 346 days, is 19 days shorter than the civil year.

LESSON LXXIII.

REVOLUTION OF THE MOON'S NODES AROUND THE ECLIPTIC.

(Map 12.)

By referring to Lessons XXX. and XXXI. it will be seen that the nodes of Mercury and Venus are permanent; that is that they are always at the same point in the ecliptic, or in the same longitude. But this is not the case with the Moon's nodes. Suppose the line passing down from A, Fig. 3, to represent the line of her nodes, at the commencement of a lunar year. After twelve lunations, and when she has passed round to the point D, she will have returned to the same node again, although she is 19° 20′ short of the point where that node was reached 346 days before. At this time the line passing down from D would represent the line of her nodes. In this manner the nodes of the moon's orbit fall back westward, or recede $19\frac{1}{3}$° every lunar year, till they complete a backward revolution quite around the ecliptic. To do this requires 18 years and 225 days; or 223 lunations; when the moon will reach the same node again at D, or in the same longitude.

This revolution of the moon's nodes will be noticed again in the chapter on *Eclipses*. The motion of the *apsides* will also be explained and illustrated in the chapter on *Tides* in connection with Map 14.

LESSON LXXIV.

SIDEREAL AND SYNODIC REVOLUTION OF THE MOON.

(Map 12.)

The difference between a *sidereal* and *synodic* revolution of the planets is explained in Lesson LVII. A *sidereal* revolution of the Moon is a revolution from a particular star, around to the same star again; or what would constitute a complete revolution if the earth were at rest. But as the earth is constantly advancing in her orbit, the moon, in passing from one full moon to another, has to perform *a little more* than a complete revolution to bring her again in opposition to the sun. This extended journey is called her *synodic* revolution.

The sidereal period is $27\frac{1}{3}$ days, and the synodic $29\frac{1}{2}$, as already stated, Lesson LXX.

LESSON LXXV.

REVOLUTION OF THE MOON UPON HER AXIS.

(Map 12.)

From the uniform appearance of the Moon's surface, even to the naked eye, it is obvious that she always presents nearly the same side to the earth. From this fact it is concluded that she makes but one revolution upon her axis during her synodic revolution—that her motion upon her axis is from west to east—that her day (including a lunar day and night) must be equal to $29\frac{1}{3}$ of our days; and that the earth is always invisible from one half of the moon's surface.

By consulting Fig. 2, it will easily be seen that to keep the same side towards the earth, the moon must necessarily revolve once on her axis during her synodic revolution; and also that if the side toward the earth at the full was towards us also at new moon, the side in darkness at full moon would be towards the sun, or enlightened at new moon. Observe, we are speaking of her *actual* light and shade, and not of her appearance from the earth.

LESSON LXXVI.

OF THE MOON'S LIBRATIONS.

(Map 12.)

Though the Moon always presents nearly the same hemisphere towards the earth, it is not always *precisely* the same. Owing to the ellipticity of her orbit, and the consequent inequality of her angular velocity, she appears to *roll* a little on her axis, first one way and then the other, thus alternately revealing and hiding new territory, as it were, on her eastern and western limbs. This rolling motion east and west is called her *libration in longitude.*

The inclination of her axis to the ecliptic gives her another similar apparent motion, alternately revealing and hiding her *poles.* This is called her *libration in latitude.* It may be illustrated by Map 4, Fig. 2, as explained in Chapter VI.

LESSON LXXVII.

SEASONS OF THE MOON.

The Moon's year consists of 29½ of our days; and as she revolves but once on her axis in that time, it follows that she has but *one day* and *one night* in her whole year. So slight is the deviation of her orbit from the plane of the ecliptic, and the inclination of her axis to the plane of her orbit, that the sun's declination upon her can never exceed 6° 40′. She must therefore have perpetual winter at her poles, while at her equator her long days are very warm, and her long nights very cold.

LESSON LXXVIII.

TELESCOPIC VIEWS OF THE MOON.

(Map 12.)

Fig. 4 is a telescopic view of the Moon, as she appears when about a week old. The ragged line dividing her illuminated from her dark hemisphere, and extending around the moon, is called the *circle of illumination;* and the portion of this circle towards the earth, as represented on the map, is called the *Terminator.* This line traverses the moon's disc from west to east in about 15 days, when it disappears from her eastern limb; and the other half of the circle of illumination immediately appears on her western border. In about 15 days longer it passes around to the eastern limb again, as represented at Fig. 6, and at the change of the moon entirely disappears.

The Figures 4, 5, and 6, are faithful representations of the moon, as she appears through a telescope of moderate power, at three different periods during a lunation.

LESSON LXXIX.

PHYSICAL CONSTITUTION OF THE MOON, MOUNTAINS, VOLCANOES, ATMOSPHERE, ETC.

(Map 12.)

Nothing is more obvious, from a telescopic view of the Moon, than that her surface is remarkably *rough* and *uneven*. The evidence of this is,

First, the crooked and ragged appearance of the *terminator*. Were the moon's surface level and smooth, this line would be uniform, and sharply defined.

In the second place, small bright spots appear from time to time, from new to full moon, *beyond* the terminator, in the dark portions of the moon's disc. These are never far from the terminator, and grow larger and larger as it approaches them. In the same manner these bright spots linger *after* the terminator, from full to new moon, and grow smaller and smaller till they disappear.

In the third place, after these spots fall fairly within the enlightened hemisphere of the moon, they project a *shadow* towards the terminator, or in a direction opposite to the sun. From new to full moon these shadows all point *eastward*, while from full to new moon again they all point *westward*.

Now nothing can be more certain, from all these phenomena, than that the moon is covered with *mountains*. Being elevated above the common level of the moon's surface, the sun's light would fall upon their summits before the surrounding valleys were rendered luminous or visible by reflected light. As the light advanced eastward it would enlarge the visible portions of the mountains; and finally, after the space around them, west, north, and south, was enlightened, they would still cast shadows eastward. Besides, these shadows are always darkest on the side towards the sun, or nearest the mountains.

By examining Figures 4 and 6, in connection with the foregoing remarks, the student can hardly fail to be satisfied that the Moon also has her Alps, her Andes, and her Pyrenees. Some of her mountains have been estimated to be five miles in height.

It has been ascertained also that many of the lunar mountains are of *volcanic formation*, like Etna and Vesuvius. Dr. Herschel states that he actually saw the light of the *fires* of several active volcanoes in the moon. The extravagant statement made by some authors, that *cities*, *fortifications*, and *roads* have been seen on the moon's disc, is worthy of little or no credit. It is much easier to *imagine* cities, &c. to exist on the moon's surface, than to actually *see* them even if they were there.

In regard to the existence of an *atmosphere* around the moon, astronomers are divided. From observations during eclipses of the sun, and other phenomena, it is thought that if the moon has any atmosphere at all, it must be very limited in extent, and far less dense than that of the earth.

LESSON LXXX.

GEOGRAPHY OF THE MOON, OR SELENOGRAPHY.

(Map 12.)

The great natural divisions of the Moon's disc have received appropriate names. The following is a list of some of the principal *mountains*, the number answering to their locality as designated on the map, Fig. 5. It may require a near view to discover the figures and letters.

1. Tycho,	6. Eratosthenes,
2. Kepler,	7. Plato,
3. Copernicus,	8. Archimedes,
4. Aristarchus,	9. Eudoxus,
5. Helicon,	10. Aristotle.

The dusky portions formerly supposed to be *seas*, are designated as follows:—

A. Mare Humorum,	E. Mare Tranquilitatis,
B. " Nubium,	F. " Serenitatis,
C. " Imbrium,	G. " Fecunditatis,
D. " Nectaris,	H. " Crisium.*

The subject of *Eclipses* and *Occultations* will be considered in Chapter IV.; and that of *Tides* in Chapter V.

LESSON LXXXI.

MOONS OF JUPITER.

(Map 2.)

Jupiter has four satellites, whose distances, magnitudes, and periodic times are as follows:—They are numbered in order, beginning with the one nearest to their primary.

	Diameter in miles.	Distance.	Periodic times.
1st	2,500 . .	259,000 . .	1 day 18 hours.
2d	2,068 . .	414,000 . .	3 " 12 "
3d	3,377 . .	647,000 . .	7 " 14 "
4th	2,890 . .	1,164,000 . .	17 " 0 "

By comparing the *magnitude* of Jupiter's satellites, with that of our moon, Lesson LXX., a striking resemblance will be discovered. Indeed the *size* and *distance* of the first answer almost exactly to the size and distance of the Moon. But when we come to the *periodic times*, we find a vast disproportion. So great is the mass and attractive force of Jupiter, that if even his most distant satellite had a periodic revolution of twenty-nine and a

* Olmsted's Introducton to Astronomy.

half days, its centripetal would overcome its centrifugal force, and it would fall to the body of the planet. To balance the great attractive force of the planet (Lesson XVII.) it is necessary that his secondaries should have a rapid projectile motion; hence, though the first is as large, and as distant from Jupiter as our moon is from the earth, it revolves more than *fifteen times* as rapidly as the Moon. For remarks on the centripetal and centrifugal forces, see Lesson XX.

The moons of Jupiter revolve nearly in the plane of his equator, and of course, nearly in the plane of his orbit and of the ecliptic. See XXXII. and XLIX. Their orbits, as stated by Dr. Herschel, are inclined to the plane of his equator, as follows:

1st . . .	3° 5′ 30″.
2d	Variable.
3d . . .	Variable.
4th	2° 58′ 48″.

The eccentricities of the 1st and 2d are not perceptible. That of the 3d and 4th is small, and variable, in consequence of mutual perturbations, caused by their mutual attraction. They all revolve from west to east, or in the direction of the revolution of their primary upon his axis.

The satellites of Jupiter may be seen with a telescope of very moderate magnifying power, or a common spy-glass; and one of them has even been seen with the naked eye. This noble planet with his retinue of moons is the solar system in miniature; and furnishes the most glorious confirmation of the truth of the Copernican theory.

For *eclipses* of Jupiter's satellites see the chapter on eclipses.

LESSON LXXXII.

SATELLITES OF SATURN.

(Map 2.)

The satellites of Saturn are seven in number, and are seen only with telescopes of considerable power. They revolve from west to east. The orbits of the six interior satellites are *neary circular*, and very nearly in the plane of the rings. That of the seventh is considerably inclined to the west, and approaches nearer to coincide with the ecliptic.

Their distances and periodic times are as follows:

	Dist. in miles.	Periodic times.
1st	123,000	0 days 22 hours.
2d	158,000	1 " 8 "
3d	196,000	1 " 21 "
4th	251,000	2 " 17 "
5th	351,000	4 " 12 "
6th	811,000	15 " 22 "
7th	2,366,000	79 " 7 "

Upon this subject an eminent astronomer remarks, that the satellites of Saturn have been much less studied than those of Jupiter. The most distant, is by far the largest, and is probably not much inferior to Mars in size. Its orbit is also materially inclined to the plane of the rings, with which those of all the rest nearly coincide. It is the only one of the number whose theory has been at all inquired into, further than suffices to verify Kepler's law of the periodic times, which holds good in this as in the system of Jupiter. It exhibits, like those of Jupiter, periodic defalcations of light, which prove its revolution on its axis in the time of a sidereal revolution about Saturn.

The next in order, proceeding inwards, is tolerably conspicuous; the three next very minute, and requiring pretty powerful telescopes to see them; while the two interior satellites, which just skirt the edge of the rings, and move exactly in their plane, have never been discovered but with the most powerful telescopes which human art has yet constructed, and then only under peculiar circumstances. At the time of the disappearance of the ring (to ordinary telescopes) they have been seen* threading like beads the almost infinitely thin

* By Sir William Herschel, in 1789, with a reflecting telescope of four feet in aperture.

fibre of light, to which it is then reduced, and for a short time advancing off it at either end, speeding to return, and hasting to their habitual concealment.*

LESSON LXXXIII.

SATELLITES OF HERSCHEL.

(Map 2.)

Herschel has *six* satellites, as shown on the map, which revolve around him at the distances here laid down, and in the following periodic times:

	Dist. in miles.	Periodic times.
1st	224,000	5 days 21 hours.
2d	296,000	8 " 17 "
3d	340,000	10 " 23 "
4th	390,000	13 " 11 "
5th	777,000	38 " 2 "
6th	1,556,000	117 " 17 "

The satellites of Herschel are distinguished by two very remarkable peculiarities. By Lesson XXXII. it will be seen that his *orbit* very nearly coincides with the *ecliptic*. Now the orbits of his satellites, instead of being down near the plane of the ecliptic, as is the case with those of Jupiter, are elevated so as to cross it at an angle of near 80°.

In the second place, while every other planet in the solar system, primaries as well as secondaries, revolve from west to east, the satellites of Herschel have a *retrograde* or *backward* revolution. This singular anomaly is indicated on the map by the direction of the arrows.

The *orbits* of Herschel's moons appear to be nearly circular.

LESSON LXXXIV.

SUPPOSED SATELLITE OF LEVERRIER'S PLANET.

From the observations of M. Lassell, as detailed on page 68, it is not improbable that this newly discovered

* Herschel's Treatise.

world is attended by one or more secondary bodies. Indeed we might almost infer this from analogy, especially when we consider the *magnitude* of the planet as answering pretty nearly to that of Herschel ; and his *immense distance* from the sun, upon which he also must depend for light and heat. This latter circumstance alone would seem to demand a profusion of moons to arrest the sunbeams in the surrounding space, and reflect them upon the cold and cheerless bosom of their primary. For the present, however, the learner must content himself with the little we are able to communicate upon this subject, in the hope that future observations may furnish us with a more satisfactory knowledge of the economy and peculiarities of this far distant orb.

The secondary planets are all supposed to revolve on their respective axes, in the time of their periodic revolutions, so as always to present the same hemispheres to their respective primaries. No smaller bodies have ever been discovered revolving around the *satellites*, as moons or satellites to them.

CHAPTER IV.

OF ECLIPSES.

LESSON LXXXV.

NATURE AND CAUSES OF ECLIPSES.

(Map 13.)

An *Eclipse* is the partial or total *obscuration* or *darkening* of either the Sun or Moon. An eclipse of the Sun is called a *Solar* eclipse, and that of the Moon a *Lunar* eclipse.

To understand the nature and philosophy of eclipses, it will be necessary to begin with what is called *the law of shadows*. The principles of this law are, as follows :—

1. A *shadow* is a portion of space deprived of light by the intervention of some dark or intransparent body.

2. The *length* and *form* of shadows depend not only on the form of the opaque body, by which the light is intercepted, but also upon its *magnitude* as compared with the luminous body; and its *distance from it.* At Fig. 1 the Sun is seen at S, on the right; the Earth at B, and the Moon at A and C. The shadows of the Earth and Moon are seen projecting to the left, and running to a point. They have this form because the earth and moon are *smaller* than the Sun; and as the earth is a *globe,* her shadow assumes the form of a *cone,* with its base towards the sun.

3. If the earth were *just as large* as the sun, her shadow would be in the form of a *cylinder;* and if *larger* than the sun it would spread out like a fan; or like the section of a cone with its base turned *from* the sun. These principles may be illustrated at leisure by a candle and several balls of different sizes.

4. When the opaque body is *smaller* than the luminous one, the *length* of its conical shadow will depend upon its distance from the source of light. Thus, if the earth were at E, Fig. 1, her shadow would be shorter than represented in the figure by one half.

5. The shadow cast by the earth is darker in some parts than in others. This is represented at O, and P P, Fig. 2. The deep conical shadow shown at O, and in all the other figures, is called the *Umbra;* and the faint shadow shown at P P, the *Penumbra.*

We are now prepared to state the *causes* of eclipses.

6. *An Eclipse of the Sun* is caused by the moon, passing between the earth and the sun; and casting her shadow upon the earth. This is represented at A, B, Fig. 1, where the moon is seen passing in her orbit around the earth, and hiding part of the sun's disc at S, from the observer at B; or, what is the same thing, casting her shadow upon the earth at B. As the Moon is moving eastward, or in the direction of the arrows, she covers the lower or *western* limb of the sun first, and advances to the east. By turning the right side of the map upper-

most for a moment, and placing it to the south of the learner, the figure can hardly fail to give him a correct and permanent idea.

7. *Eclipses of the Moon* are caused by her falling into the earth's shadow, as represented at C. These commence on the moon's *eastern* limb, as may be shown by turning the *left* side of the map uppermost.

8. In its natural position the map illustrates another fact: it shows why eclipses of the Sun always happen at *new* moon, and eclipses of the Moon at *full* moon. To an observer on the earth the moon must be *new* at A, and *full* at C.

LESSON LXXXVI.

EXTENT, DURATION, AND CHARACTER OF SOLAR ECLIPSES.

(Map 13.)

1. The first thing to be determined in regard to solar eclipses is the length of the moon's shadow. Let the reader now call to mind the fact that both the earth and moon move in elliptical orbits, as stated in Lessons XLIII. XLV. and LXX. Let him remember also, that the sun is in one of the foci of the earth's orbit, as represented in Fig. 2; and that the earth is in one of the foci of the *moon's* orbit, as shown at T and U. Now as the earth is farther from the sun at U, than at T, her shadow will be longer, and so with the moon. The shadows of both are much longer when the earth is at or near her *aphelion* as at U, than when near her *perihelion* as at T.

2. The length of the moon's shadow is also modified by her position in her orbit. As her mean distance from the earth's centre is 240,000 miles, she must be 480,000 miles nearer the sun at new moon than at her full. This difference in her distance must have its effect in lengthening or shortening her shadow. At T, Fig. 2, the earth is at her *perihelion*, and her shadow and that of her satellite are comparatively short. At U, the earth is at her most distant point from the sun; and the shadows of both the earth and the moon are proportionably elongated.

3. A *third* circumstance modifying the length of the moon's shadow, is the position of *her aphelion* and *perihelion* points, in respect to the sun. When the earth is at T, in her orbit, and the moon at her aphelion at M, which is then *towards* the sun, her shadow is the shortest possible; as she is then *nearer* the sun than at any other time; but when the earth is at her aphelion at U, and the moon comes to her aphelion when it is turned *from* the sun as at K, her shadow has its *greatest* possible length. Such is the variety of causes which conspire to affect the length of the shadows projected by the earth and moon.

4. When the earth is at U, and the moon at her perihelion, and in conjunction as at H, her shadow will extend 19,000 miles beyond the earth; and will be nearly 175 miles in diameter at the distance of the earth's surface. Consequently if her shadow fall *centrally* upon the earth, it will cover an area 175 miles in diameter, within which the sun will appear *totally* eclipsed. At this time the *penumbra* will cover an area 5000 miles in diameter, within which the eclipse will be only *partial*. If the shadow falls upon the *side* of the earth, it will of course cover a much larger space; and in either case, it will move from west to east over the earth's surface.

5. When the earth is at T, and the moon at M, the shadow of the moon will not reach the earth by 20,000 miles; and when the sun and moon are at their *mean* distances from the earth, the cone of the moon's shadow will terminate a little before it reaches the earth's surface.

6. The angular or apparent magnitude of a body depends much upon its distance from the observer (Lesson X.). When the sun and moon are at their mean distances, they appear nearly of a size; but when the earth is at U, and the moon at H, the moon appears larger than the sun, and if a central eclipse take place, it will be *total*; or, in other words, the moon will entirely cover or hide the sun's face. This is owing to the nearness of the moon to the earth, and the distance of the sun. A total eclipse may last 7 minutes and 58 seconds.

When the earth is at T, and the moon at M, the sun, being at his perihelion distance, will appear *unusually large;* and the moon being in apogee, will appear *unusually small.* Should a central eclipse happen at this time, the moon would not be large enough to hide the entire face of the sun, even when directly between us and him; consequently in the middle of the eclipse the moon will be seen covering the *centre* of the sun, and leaving a luminous ring unobscured, as represented at V on the map. This is called an *annular* eclipse, and the ring may last 12 minutes and 24 seconds.

7. For convenience in describing eclipses, the diameter of the sun and moon, respectively, is divided into twelve parts called *digits.* Thus at W, the sun would be described as about three digits eclipsed; at S, about four digits, &c.

The learner will now understand the difference between *partial* and *total, central* and *annular* eclipses. Both annular and total eclipses must be *central,* but the annular eclipse is not *total.* The ring or outer border of the sun is left unobscured.

"The following is a list of all the solar eclipses that will be visible in Europe and America during the remainder of the present century. To those which will be visible in New England the number of digits is annexed.

Year.	Month.	Day and Hour.	Digits.
1847,	Oct.	9 1 0 A. M.	
1848,	Mar.	5 7 50 A. M.	$6\frac{1}{6}$
1851,	July	28 7 48 A. M.	$3\frac{2}{3}$
1854,	May	26 4 26 P. M.	$11\frac{1}{3}$
1858,	Mar.	15 6 14 A. M.	$1\frac{2}{3}$
1859,	July	29 5 32 P. M.	$2\frac{1}{2}$
1860,	July	18 7 23 A. M.	$6\frac{1}{3}$
1861,	Dec.	31 7 30 A. M.	$4\frac{1}{2}$
1863,	May	17 1 0 P. M.	
1865,	Oct.	19 9 10 A. M.	$3\frac{3}{5}$

Year.	Month.	Day and Hour.	Digits.
1866,	Oct.	8 11 12 A. M.	0
1867,	Mar.	6 3 0 A. M.	
1868,	Feb.	23 10 0 A. M.	
1869,	Aug.	7 5 21 A. M.	10_4
1870,	Dec.	22 6 0 A. M.	
1873,	May	26 3 0 A. M.	
1874,	Oct.	10 4 0 A. M.	
1875,	Sept.	29 5 56 A. M.	$11\frac{1}{2}$
1876,	Mar.	25 4 11 P. M.	$3\frac{3}{8}$
1878,	July	29 4 56 P. M.	$7\frac{1}{3}$
1879,	July	19 2 0 A. M.	
1880,	Dec.	31 7 30 A. M.	$5\frac{1}{2}$
1882,	May	17 1 0 A. M.	
1885,	Mar.	16 0 35 A. M.	$6\frac{1}{2}$
1886,	Aug.	29 6 30 A. M.	$0\frac{1}{4}$
1887,	Aug.	18 10 0 P. M.	
1890,	June	17 3 0 A. M.	
1891,	June	6 0 0 Mer.	
1892,	Oct.	20 0 19 P. M.	$8\frac{1}{5}$
1895,	Mar.	26 4 0 A. M.	
1896,	Aug.	9 0 0 Mer.	
1897,	July	29 9 8 A. M.	$4\frac{1}{2}$
1899,	June	8 0 0 Mer.	
1900,	May	28 8 9 A. M.	11

The eclipses of 1854, 1869, 1875, and 1900, will be very large. In those of 1858, 1861, 1873, 1875, and 1880, the *Sun will rise eclipsed.*

Those of 1854, and 1875, will be *annular*. The scholar can continue this table, or extend it backwards, by adding or subtracting the Chaldean period of 18 years, 11 days, 7 hours, 54 minutes, and 31 seconds.*"

* Burritt.

LESSON LXXXVII.

OF ECLIPSES OF THE MOON.

(Map 13.)

1. The average *length* of the earth's shadow is 860,000 miles; or more than three times the moon's average distance from the earth. Its average *breadth* at the distance of 240,000 miles from the earth's centre, or where the moon passes it, is about 6,000 miles; or three times the moon's diameter. Now the *extent* and *duration* of a lunar eclipse must depend upon these three circumstances: (1.) The distance of the *earth* from the *sun*, and the consequent length of her shadow at the time. (2.) The distance of the *moon* from the *earth*, which determines the diameter of the earth's shadow where the moon passes it; and (3.) The *manner* in which she passes through the earth's shadow. If it be greatly elongated, it will be proportionably *larger* at the average distance of the moon's orbit; and if the moon is in perigee, and passes *centrally* through the earth's shadow, as at G and X, Fig. 2, the eclipse will be *total*, and *long continued.* On the other hand, if the moon is in apogee, she will pass the earth's shadow where it is comparatively slender as at K, and the eclipse will be of comparatively short duration. So if she pass through the *side* of the shadow, instead of its centre, the eclipse will be *partial* instead of total. An eclipse of the moon can never be annular, as she cannot get so far off that the earth's shadow would be insufficient, when centrally passed, to cover the moon's disc.

2. Before the moon enters the earth's shadow or *umbra,* as at O, the earth begins to intercept from her portions of the sun's light, or to cast a faint shadow upon her. This shadow, called the moon's *penumbra,* grows darker and darker as she advances, till she enters the conical and perfect shadow of the earth. Here the real eclipse begins. The umbra and penumbra may be seen at O, and P P, on the map.

LESSON LXXXVIII.

OF THE TIME AND FREQUENCY OF ECLIPSES.

(Map 13.)

1. If the Moon's orbit lay in the plane of the ecliptic, as represented at Fig. 1, there would be two central eclipses every month; viz., one of the Sun and one of the Moon. But as the Moon's orbit is inclined to the ecliptic in an angle of 5° 9′ (Lesson LXX.), it is evident that she may be either *above* or *below* the ecliptic at the time of her conjunction with the Sun; so that she will seem to pass either *above* or *below* him, and will not cause an eclipse. This will be understood by carefully observing the Moon's orbit at M and H, Fig. 2. At M, the side towards the Sun appears *thrown up*, or *above* the ecliptic; while at H it is *below* the plane of the Earth's orbit. Of course, then, the Moon's shadow will pass *below the Earth*, as represented at H, and though it be ever so long there will be no eclipse. For the same reason, the Moon may pass either above or below the Earth's shadow, at the time of her *opposition*, and no lunar eclipse occur.

2. It is only when the Moon is *at* or *near* one of her *nodes*, that either a solar or lunar eclipse can occur. On the Map, Fig. 2, the line L N represents the line of the nodes, as well as the plane of the ecliptic. The whole figure was intended to be in perspective. At A, the Moon is seen coming to her node, in the direction of the arrow, and casting her shadow upon the Earth. At the same time we see the eclipse advancing in the same direction, commencing upon the Sun's western limb at W. At G and X, in the same figure, we see the Moon totally eclipsed. If, therefore, the Earth and the Moon reach the line of the Moon's nodes at the same time, the eclipse will be central, whether it be of the Sun or Moon.

3. But it is not necessary that the Earth and Moon should be *precisely* on the line of the Moon's nodes, in order to produce an eclipse. "The distance of the

Moon from her node when she just touches the shadow of the Earth, in a lunar eclipse, is called the *Lunar Ecliptic Limit;* and her distance from the node in a solar eclipse, when the Moon just touches the solar disc, is called the *Solar Ecliptic Limit.* The Limits are respectively the farthest possible distances from the node at which eclipses can take place."*

The *Lunar Ecliptic Limit* is 11° 25′ 40″. This is the greatest distance from the Moon's node at which a lunar eclipse can take place; and in the event of its happening at such a distance from the node, it must be exceedingly small or slight.

The *Solar Ecliptic Limit* is 16° 59′. If at the moment of new moon her node be more than this distance from the Sun, no eclipse can happen.

This subject may be elucidated by contemplating the Moon as seen in her orbit at A, Fig. 2. As she approaches her node, it is evident that she will overlap or eclipse the Sun, as soon as she gets as near the ecliptic as the Sun's semi-diameter; as just one-half the Sun is above the ecliptic. That point, therefore, in the Moon's orbit which is only the semi-diameter of both the Sun and Moon from the ecliptic, is the *ecliptic limit* for solar eclipses.

4. The Moon's nodes constantly fall back westward on the ecliptic, at the rate of about 19° per year; so that she comes to the same node again, as from the line near A, Fig. 2, around to A again, in 19 days less than a year; or in 346 days. In just half this time, viz., 173 days she passes her other node in the opposite side of the ecliptic, as at N. It follows, therefore, that at whatever time of year we have eclipses at either node, we may be sure that in 173 days afterwards we shall have eclipses at the other node. And as for any given year eclipses commonly happen in two opposite months, as January and July, February and August, May and November, these opposite months, whichever they may be, are called for that year the *Node Months.*

* Olmsted.

5. There cannot be less than two nor more than seven eclipses in one year. If but two, they will both be of the Sun; but if seven, five will be of the Sun and two of the Moon. The usual number is two solar and two lunar.

LESSON LXXXIX.

ECLIPSES, OR OCCULTATIONS OF THE STARS.

An occultation of the stars is caused by the Moon passing between us and them, and concealing them from our view. Though a very simple and common phenomenon, it is, nevertheless, a very interesting one. At New Moon, especially, the star occulted may be traced to the very border of the Moon's eastern limb, when it suddenly goes out. From these stellar occultations, or eclipses of the stars, many important conclusions may be drawn. They teach us that the Moon is an opaque body, terminated by a real and sharply defined surface, intercepting light like a solid. They prove to us, also, that at those times when we cannot *see* the Moon, she really exists, and pursues her course; and that when we see her only as a crescent, however narrow, the whole globular body *is there*, filling up the deficient outline, though unseen. For occultations take place indifferently at the dark and bright, the visible and invisible outline, whichever happens to be towards the direction in which the Moon is moving; with this only difference, that a star *occulted* by the bright limb, if the phenomenon be watched with a telescope, gives notice, by its gradual approach to the visible edge, when to expect its disappearance; while, if occulted at the dark limb, if the Moon, at least, be more than a few days old, it is, as it were, extinguished in mid-air, without notice or visible cause for its disappearance, which, as it happens *instantaneously*, and without the slightest previous diminution of its light, is always surprising; and, if the star be a large and bright one, even startling from its suddenness.

The re-appearance of a star, too, when the Moon has passed over it, takes place, in those cases when the bright side of the Moon is foremost, not at the concave outline of the crescent, but at the invisible outline of the complete circle, and is scarcely less surprising from its suddenness, than its disappearance in the other case.*

LESSON XC.

ECLIPSES OF JUPITER'S MOONS.

Every planet in the Solar System, whether primary or secondary, casts its shadow in the direction opposite to the Sun. But none of the primaries can eclipse each other. In every case, however, where they are attended by satellites there may be eclipses.

Of the *number, distances, magnitudes, and motions* of Jupiter's moons, we have already spoken in Lesson LXXXI. It remains now to consider their *eclipses*. From the magnitude of Jupiter, and his distance from the Sun, it will be seen at once that he must cast a shadow of great dimensions, extending far into space towards the orbit of Saturn. But in order fully to understand the subject of his eclipses, it will be necessary to take into the account not only his distance, magnitude, &c., but the near coincidence of his *orbit* with the *ecliptic*, his *equator* with his *orbit*, and the *orbits* of his moons with his *equator*. All these points will be found duly noticed under their appropriate heads in the preceding lessons. Let it be remembered then—

1. That Jupiter casts a *broad* and *long* shadow in the direction opposite the Sun.

2. That the centre of this shadow lies in the plane of his orbit, which differs only $1\frac{1}{4}°$ from the plane of the ecliptic. (XXXII.)

3. That his axis is inclined to his orbit only 3° 5′, and of course the plane of his equator nearly coincides with that of his orbit. (XLIX.)

* Herschel's Astronomy.

4. Three of his moons revolve very nearly in the plane of his equator, and must consequently pass near the centre of his shadow at every revolution. They must, therefore, be totally eclipsed.

5. The most distant of his satellites has an orbit more inclined to the ecliptic, so that she sometimes but just grazes the border of the shadow in passing, and sometimes wholly escapes. But these instances are comparatively rare. As a general rule, it may be said that the satellites of Jupiter are *totally eclipsed* at *every revolution;* so that by determining the number of revolutions each makes in a month (Lesson LXXXI.), and adding them together, we find the number of eclipses in that period of time. They amount to about forty.

6. From the *nearness* of his satellites (LXXXI.) we infer that they must pass his shadow where its diameter must be nearly as great as that of Jupiter; hence the eclipses last for some time.

7. The shadows of the satellites, being much longer than those of our Moon, on account of their greater distance from the Sun, and some of them being much nearer Jupiter than our Moon is to the Earth, cast their shadows upon *him* at every revolution. They may be seen with good telescopes "like small round ink spots" traversing his disc.

8. The *entrance* of Jupiter's moons into his shadow is called their *immersion;* and their egress therefrom their *emersion*. Tables have been constructed showing the *precise time* when these shall take place, for a given longitude on the Earth, as for instance Greenwich Observatory, which tables are employed, in connection with a *chronometer* or accurate time-piece, for determining terrestrial longitude.

LESSON XCI.

ECLIPSES OF SATURN AND HERSCHEL.

Of the satellites of these two planets, too little is known to admit of any very positive statements in respect to their eclipses. Indeed very little is said upon this subject, even by the ablest practical astronomers. Of Saturn it is remarked by Dr. Herschel, that owing to the obliquity of his rings, and of the orbits of his satellites to the ecliptic, they suffer no eclipses, the interior ones excepted, until near the time when the rings are seen *edgewise*. (See Lesson LXVI. and Map.)

Of the eclipses of Herschel's moons, nothing whatever is known by observation, and very little by theory, as deduced from their distances, inclination of orbits, &c.

CHAPTER V.

PHILOSOPHY OF THE TIDES.

LESSON XCII.

OF THE NATURE AND CAUSES OF TIDES.

(Map 14.)

The alternate rising and falling of the waters of the ocean are called *Tides*. The rising of the waters is called *Flood* tide, and their falling *Ebb* tide. There are two flood and two ebb tides every day.

The *cause* of the tides is the attraction of the Sun and Moon upon the Earth and the waters surrounding it.

Fig. 1 represents the Earth surrounded by water in a state of rest, or as it would be were it not acted upon by the Sun and Moon.

Fig. 2 shows the Moon at a distance above the Earth, and attracting the waters of the ocean so as to produce a high tide at B. But as the Moon makes her apparent westward revolution around the Earth but once a day, the simple raising of a flood tide on the side of the Earth towards the Moon, would give us but one flood and one ebb tide in 24 hours; whereas it is known that we have two of each.

Fig. 3, therefore, is a more correct representation of the tide-wave, as it actually exists, except that its height, as compared with the magnitude of the Earth, is vastly too great. It is designed merely to illustrate the *principle* under consideration. While the Moon at A produces a high tide at B, we see a high tide at C, on the opposite side of the Earth. Of course, it is low tide, at this time, at D and E; and as these four tides traverse the globe, from east to west every day, it accounts for the rising and falling of the tides every twelve hours.

But the most difficult point remains yet to be elucidated. "The tides," says Dr. Herschel, "are a subject on which many persons find a strange difficulty of conception. That the Moon, by her attraction, should heap up the waters of the ocean under her, seems to most persons very natural—that the same cause should, at the same time, heap them up on the opposite side of the Earth, [as at C, Fig. 3,] seems to many palpably absurd. Yet nothing is more true, nor indeed more evident, when we consider that it is not by her *whole* attraction, but by the differences of her attractions at the two surfaces and at the centre, that the waters are raised."*

The law of gravitation (XVII.) is the same which prevails in the diffusion of light (XII.), namely, that *its force is, inversely, as the squares of the distances;* or, in other words, as the square of the distance is *diminished*, the force of attraction is *increased*, and *vice versa*. Let this rule be applied to the Earth and Moon, Fig. 3.

1. In the first place, nothing can be more evident than that the tide water at B is the whole diameter of the Earth, or 8000 miles nearer the Moon at A than the waters of the opposite side of the Earth at C. They must also be 4000 miles nearer than the *centre* of the earth, or the parts between D and E; while these parts, in turn, are 4000 miles nearer than the waters at C.

2. Now as the force of the Moon's attraction depends upon her *distance*, it must follow, in the second place, that the different parts of the Earth will be *unequally at-*

* Treatise, 315.

tracted. B will be attracted more than D E, and D E more than C.

3. This unequal attraction of the different parts of the Earth's surface will tend to *separate* these parts. As B is more strongly attracted than the body of the Earth, it will be drawn farther towards the Moon, so as to produce a high tide on that side of the Earth. The body, or solid parts of the Earth, being nearer to the Moon than the waters at C, will also recede from them towards the Moon, causing the waters to tend from D E towards C, and raising a high tide at that point.

4. This perturbation or swinging of the Earth one way and the other, in her orbit, is a constant result of the Moon's attraction. Though the Earth never deviates from her course more than the amount of her diameter, yet this is considered sufficient to account for the high tides opposite the Moon, when in conjunction with the Sun, upon the principles already explained.

LESSON XCIII.

LAGGING OF THE TIDE—EXCURSIONS IN LATITUDE.

(Map 14.)

1. The vertex, or highest point of the tide-wave, is generally about three hours behind the Moon in her passage westward. This is illustrated at Fig. 4, where the Moon is seen on the meridian at A, and the tide-wave hanging back to the east, with its vertex at B. The tide will be rising at C when the Moon passes the meridian ; and will continue to rise for three hours afterwards when it will begin to ebb again.

The *cause* of this delay of the tide-wave is a want of time for it to yield to the impulse given to the waters by the Moon's attraction. Besides, the Moon continues to act upon the waters east of her meridian, for some time after she has passed over them.

2. Not only does the tide lag behind the Moon, but the Moon lags behind her hour, so to speak, or rises

later and later every night, as she advances eastward *in her orbit;* so that high or low water is about fifty minutes later every day, in reaching any particular meridian, than on the day preceding.

3. The position of the Moon in regard to the *equinoctial* has also its effect in modifying the tides. This is illustrated at Fig. 5, where the Moon is seen at A, *south* of the equinoctial, and the vertex of the tide-wave at B, on the Tropic of Capricorn. Of course the vertex of the opposite wave would be at E, in the *northern* hemisphere. Were the Moon at C, or *north* of the equator, the vertices of the wave would be shifted from B and E to D and F. It is in this way that the *declination* of the Sun and Moon (XLVII.) materially affects the tides in any particular latitude. As the vertex of the tide-wave tends to place itself vertically under the luminary which produces it, when this vertical changes its point of incidence on the surface, the tide-wave must tend to shift accordingly; and thus, by monthly and annual periods, must tend to increase and diminish alternately the principal tides. The period of the Moon's nodes is thus introduced into this subject; her excursions in declination in one part of that period being 29°, and in another only 17°, on either side of the equator.*

It is on this account, that in high latitudes every alternate tide is higher than the intermediate ones, the evening tides in summer exceeding the morning tides, and the morning tides in winter exceeding those of the evening.

LESSON XCIV.

SPRING AND NEAP TIDES.

(Map 14.)

1. We have hitherto spoken chiefly of the Moon as instrumental in the production of the tides; but though she is the *principal*, she is not the *only* cause. The mass of the Sun is seventy millions of times greater than that

* Herschel's Treatise, 317, 318.

of the Moon (LXX.), but in consequence of his great *distance*, his attractive force upon the Earth is only about *one-third* as great as that of the Moon. Still it is amply sufficient to produce a perceptible tide-wave of itself, independently of the aid of the Moon. Now as the solar and lunar attractions are to each other as *one* to *three*, it is evident that when the two forces are combined they will produce tides *one-third greater* than usual; and when they counteract each other, the lunar tide-wave will prevail, but will be *one-third lower* than usual. These extraordinary variations are called the *Spring* and *Neap* tides. There are two of each every month; the spring, or highest tides, occurring at the *syzygies*, or at New and Full Moon, and the neap tides at her *quadratures*.

A, B, C, F, Fig. 6, are intended to illustrate these phenomena. At A, the Moon is seen *in conjunction*, as it is New Moon, so that they act together upon the waters of the ocean, and produce a *Spring tide*. The map shows the tide-wave as considerably higher than at F or B.

2. At B, the Moon has passed to her *first quarter*, so that her attraction is in a direction at right angles with that of the Sun. But as she exerts *three-fourths* of all the attractive force of the Sun and Moon both, she succeeds in producing a lunar tide *in spite of the Sun*, though he subtracts one-third from what would otherwise be its elevation. On these principles we account for the *Neap* tides.

3. At C, the Sun and Moon are seen in *opposition*, when the Earth exhibits *another spring tide*. But here the tide-wave opposite to each luminary respectively, cannot be materially augmented by the perturbations of the body of the Earth, as illustrated at Fig. 3, and explained at the beginning of this chapter; for as the Sun and Moon act in direct opposition to each other, they tend to keep the Earth from swinging towards either. But as the Moon has three times the force of the Sun, she will attract the Earth towards her, in spite of the Sun, so that she will thus contribute to the production of the

tide-wave on the side of the Earth towards C. On the hemisphere *towards* the Moon, she must raise her own tide, and that, too, with the whole force of the Sun's attraction acting against her. How, then, can there be a *spring* tide at this time on the side opposite the Sun? And yet such is the fact.

Here is a point which it must be acknowledged is not satisfactorily explained by the prevailing theory of the philosophy of tides. When the Sun and Moon are in *opposition*, they must necessarily *diminish* that perturbation of the Earth, which is assumed to be the cause of spring tides, and as the cause is reduced the effect also should be reduced. According to this theory, therefore, we ought to have a *neap* instead of a *spring* tide, when the Sun and Moon are in opposition. The Earth cannot swing in two opposite directions at the same time. Even Prof. Olmsted, whose abilities as an astronomer and mathematician are universally acknowledged, seems to be at a loss here. He says:—" At the time of New Moon, the Sun and Moon both being on the same side of the Earth [as represented at A and D], and acting upon it in the same line, their actions conspire, and the Sun may be considered as adding so much to the force of the Moon. We have already explained how the Moon contributes to raise a tide on the opposite side of the Earth. But the Sun, as well as the Moon, raises its own tide-wave, which, at New Moon, coincides with the lunar wave. At Full Moon, also, the two luminaries conspire in the same way to raise the tide; for we must recollect, that each body contributes to raise the tide on the opposite side of the Earth, as well as on the side nearest to it. At both the conjunctions and oppositions, therefore, that is, at the syzygies, we have unusually high tides."*

Here, it will be seen, that the learned author speaks of the *fact* of spring tide at Full Moon, and refers to the general principles upon which we account for spring tide at *New* Moon; but *how* the Sun and Moon, acting in *opposition*, can produce spring tides, remains to be explained.

* Introduction to Astronomy, 168.

4. At F, we see the Moon in the neighborhood of her *last quarter*, and the Earth exhibiting the *neap tides* again. We have thus passed through with one lunation, in which we have at A and C, *two spring tides*, and at B and F *two* neap tides.

5. The spring tides are not at their height at the moment of the syzygies, but about thirty-six hours afterwards.

PROFESSOR DAVIES' THEORY.

Since the foregoing was in type, the author accidentally met with Prof. Davies, formerly of West Point, who in view of the exceptions we had taken to the prevailing philosophy, on the preceding page, submitted the following theory. So far as we can discover, it is a philosophical one, and it is certainly more satisfactory upon some points than the prevailing doctrine, which we had previously ventured to call in question. In the correctness of his theory, Prof. D. expresses entire confidence; and by his consent it is here inserted for the benefit of the reader.

The principle upon which he accounts for the tides, is that of *hydrostatic pressure*. When fluids of different specific gravity are mingled together, the heavier will displace the lighter, and cause it to rise to the surface. If the waters of the ocean were not acted upon by the Sun or Moon, their specific gravity would be the same all over the world; and they would consequently balance each other, producing equilibrium, as represented at Fig. 1. But they do attract the waters of the ocean, and destroy their equilibrium. Take the Earth and Moon as represented at Fig. 3. While the Moon is at A, the tendency of her attraction is to diminish the specific gravity or weight of the waters at B, as she overcomes a portion of the Earth's gravitating force; so that these waters become *lighter* than they are wont to be. At the same time the Moon acts upon the waters at D E with a slightly diminished force; but the tendency at these points is in a *horizontal* direction, or from D E towards A, and not away from the Earth's centre. Of course, then, the specific gravity of the water is not lessened at D and E. But as the waters at B are rendered lighter by the Moon's attraction, the waters at D E, having retained their usual weight, will displace the former, thus causing the waters to rise at B and C. In a word, the difference in the *direction* of the Moon's attraction at B and D E, as respects a perpendicular to the Earth's centre, makes a difference in the *weight* of the waters at these two points; and the waters at D E, being *heaviest*, sink down till the lighter waters at B and C are enough higher to balance them; or till equilibrium is produced.

This theory applies as well to spring tides at Full Moon as to any other tides; and besides, it requires no sensible perturbations of the Earth as the result of the Moon's attraction. It may, however, be liable to this objection: that when the Sun and Moon are in opposition, they will counteract each other's influence in reducing the specific gravity of the waters on the side of the Earth opposite them respectively, and thus prevent rather than cause a spring tide.

LESSON XCV.

OTHER INEQUALITIES OF THE TIDES.

(Map 14.)

1. The tides vary in height, according to the *distances* of the Earth and Moon at the time when they occur. Take, for example, the spring tides at New Moon. If the Earth is at her aphelion distance from the Sun, and the Moon in apogee, as we see represented at A, Fig. 6, the attraction of both the Sun and Moon will be less than their average amount, so that there will be but a *moderate* spring tide; but if the Moon is in perigee, and the Earth at her perihelion, as seen at D, both the Sun and Moon, being at their nearest points to the Earth, and in conjunction, will exert their full attractive influence upon the Earth; and the spring tide will be unusually high, as shown on the map.

2. At E the earth is near her perihelion, and the Moon in opposition and in apogee. In such a case the Sun has his *greatest* agency in producing the tides and

the Moon her *least*. This will tend to equalize their forces.

3. The *height* of the tides in different parts of the world is exceedingly various, owing to their being crowded into narrow channels in some instances, and to various other local causes. In open seas the spring tides are about eleven, and the neap tides about seven feet. At London the spring tides rise to the height of nineteen feet; at the mouth of the Indus thirty feet; in the river Severn, England, forty feet; at St. Maloes, in France, forty-five feet; and at Cumberland, Bay of Fundy, seventy-one feet. This last is the highest tide in the world, and is caused by the meeting of the great northern and southern tide-waves of the Atlantic, which here come together in opposite directions.

The height of tides on different portions of the western continent has been given as follows:

Cumberland, Bay of Fundy, . . .	71	feet.
Boston, ...	11	"
New Haven, ...	8	"
New-York, ...	5	"
Charleston, S. C.	6	"

This table seems to accord well with the theory just named, in regard to the *cause* of the excessively high tides in the Bay of Fundy.

4. The lagging of the tide-wave behind the Moon (Lesson XCIII.) is greatly modified by local causes. Though the tides are usually highest about three hours after the Moon has passed the meridian, it is often retarded by shoals and channels, and by striking against capes and headlands, so that, as exceptions to the general rule, high tides happen at all distances of the Moon from the meridian.

5. Lakes and inland seas have no tides, in consequence of their inconsiderable magnitude, as compared with the waters of the ocean.

6. Dr. Herschel observes that the action of the Sun and Moon produces *tides in the atmosphere*, as well as in the water; and that delicate observations have rendered

them sensible and measurable. The pupil will find a remark concerning *tides on the Sun*, in Chapter VII., where the various theories of the solar spots are considered.

LESSON XCVI.

MOTION OF THE APSIDES OF THE MOON'S ORBIT.

(Map 14.)

At the close of Lesson LXXIII. we promised in this chapter to speak of the motion or revolution of the Moon's *apsides*. The *apsides* of the Moon's orbit are her perihelion and aphelion points; and the *line* of the apsides is a line drawn through those points, as shown in Fig. 6, wherever the Moon's orbit is represented. At A this line is marked M A.

Now the *motion of the apsides* is the revolution of these points around the ecliptic from west to east. The map shows this revolution as we trace the Moon around from A to F, in which place the line of the apsides, or the major axis of the ellipse, is at right angles with itself, as shown at A.

The apsides of the Moon's orbit make a complete revolution in about nine years. In four and a half years the line A M will shift ends, so that the perihelion point M will be towards the Sun; and in four and a half years more it will shift ends again, so that the Moon will reach her perigee again at M, or in the same part of the heavens. In this way the apsides constantly advance eastward, till, at the end of *nine years*, they finish a complete revolution.

It must not be supposed from what we have said above, that the apsides shift ends *suddenly*, or all at once. This is not the case. Their motion is gradual and uniform, as shown on the map.

As already stated in the chapter on that subject, the motion of the Moon's apsides must always be taken into the account in calculating Eclipses, as well as in the explanation of the Tides.

CHAPTER VI.

OF COMETS.

LESSON XCVII.

GENERAL DESCRIPTION OF COMETARY BODIES.

(Map 15.)

1. COMETS are the most singular class of bodies belonging to the Solar System. They derive their name from the Greek word *coma*, which signifies *bearded* or *hairy.*

2. A comet usually consists of three parts—the *Nucleus*, the *Envelop*, and the *Tail*. The *Nucleus* is what may be called the *body* or *head* of the comet, as seen at N, on the map. The *Envelop* is the nebulous or hairy covering that surrounds the nucleus. It may be seen around the nuclei of several of the specimens on the map, and especially that of 1585. The *Tail* of a comet is an expansion or elongation of the envelop.

3. Some comets have *no perceptible nucleus*, their entire structure being like that of a thin vapory cloud, passing rapidly through the heavens.

4. Many comets have simply the envelop, *without any tail* or elongation. Such were those that appeared in 1585 and 1763, the former of which will be found on the map.

5. Cassini describes the comet of 1682 as being *as round and as bright as Jupiter, without even an envelop.* But these are very rare exceptions to the general character of cometary bodies.

6. The tails of comets usually lie in a direction *opposite to the Sun* ; so that from perihelion to aphelion they *precede* their nuclei or heads ; or in other words, comets seem, after having passed their perihelion, to *back out* of the Solar System. See Map 2.

7. The comet of 1823 is said to have had *two tails*, one of which extended *towards* the Sun. This comet may be seen on the map, with a portion of its orbit. The Sun is supposed to be on the left, and the comet pass-

ing down towards its perihelion. Its nucleus and envelop are distinctly represented.

8. The tails of comets are usually *curved* more or less, being concave towards the region from whence they come. This is well shown in the comets of 1823, 1811, and 1680. That of 1689 is said to have been curved like a Turkish sabre, as shown on the map.

The *cause* of this curvature of the tails of comets is supposed to be a very rare ethereal substance, which pervades space, and offers a slight resistance to their progress. Of course it must be almost infinitely attenuated, as the tails themselves are a mere vapor, which could make no progress through the spaces of the heavens were they not very nearly a vacuum. They could no more pass a medium as dense as our atmosphere, than an ordinary cloud could pass through the waters of the sea.

9. Comets have been known to exhibit *several tails* at the same time. That of 1744, represented on the map, had no less than *six tails* spread out in the heavens like an enormous fan.

10. The tails of comets *do not continue of the same uniform length.* They *increase* both in length and breadth as they approach the Sun, and *contract* as they recede from him, until they often nearly disappear before the comet gets out of sight.

11. Instances have occurred in which tails of comets have been *suddenly expanded* or *elongated* to a great distance. This is said to have been the case with the great comet of 1811.

12. Of the *physical nature* of comets little is known. That they are in general very *light* and *vapory* bodies is evident from the fact that stars have sometimes been seen even through their densest portions, and are generally visible through their tails; and from the little attractive influence they exert upon the planets in causing perturbations. While Jupiter and Saturn often *retard* and delay comets for months in their periodic revolutions, comets have not power in turn to *hasten* the time of the planets for a single hour; showing conclusively that the

relative masses of the comets and planets are almost infinitely disproportionate. The comet of 1770 got entangled by attraction, among the moons of Jupiter, on its way to the Sun, and remained near them for four months; yet it did not sensibly affect Jupiter or his moons. In this way the *orbits* of comets are often entirely changed. That they are in themselves *opaque bodies*, and *shine only by reflected* light, is evident from their sometimes exhibiting distinct *phases*—from their increased brightness as they approach the Sun, and from the known difference in the properties of direct and reflected light.

LESSON XCVIII.

MAGNITUDES, VELOCITIES, TEMPERATURE, PERIODS, DISTANCES, NUMBERS, ETC. OF COMETS.

(Map 15.)

1. The heads or nuclei of comets are *comparatively small.* The following table shows the estimated diameter in five different instances.

The comet of	1778,	diameter of head	33	miles.
"	1805,	"	36	"
"	1799,	"	462	"
"	1807,	"	666	"
"	1811,	"	428	"

2. The *tails* of comets are often of enormous length and magnitude. That of 371 before Christ was 60° long, covering one third of the visible heavens. In 1618, a comet appeared which was 104° in length. Its tail had not all risen when its head reached the middle of the heavens. That of 1680 (see map) had a tail 70° long, so that though its head set soon after sundown, its tail continued visible all night.

The following table will show the length of the tails of some of the most remarkable comets, both in degrees and in miles. They will be identified only by the year when they appeared.

B. C.	371,	60°	. .	140,000,000 miles.
A. D.	1456,	60	. .	70,000,000 "
"	1618,	104	. .	65,000,000 "
"	1680,	70	. .	123,000,000 "
"	1680,	68	. .	100,000,000 "
"	1744,	30	. .	35,000,000 "
"	1769,	90	. .	48,000,000 "
"	1811,	23	. .	132,000,000 "
"	1843,	60	. .	130,000,000 "

As these estimates are the angles under which they were viewed *from the earth*, the length of their tails in miles would not be proportional to the angle merely, as their *distances* must also be taken into the account. So the comet of 1843, with an angular length of only 60° was longer in fact by 65,000,000 miles than the comet of 1618, with an angular length of 104°. At the time of measurement the latter was much nearer to the earth than the former when his dimensions were estimated.

The learner should look up the comets named in the above table, so far as laid down on the map.

3. The *velocity* with which comets often move, is truly wonderful. Their motions are accelerated as they approach, and retarded as they recede from the Sun; so that their velocity is greatest while passing their perihelions. The comet of 1472 described an arc of the heavens of 120° in extent in a single day! That of 1680 moved, when near its perihelion, 1,000,000 miles per hour.

4. The *temperature* of comets when nearest to the Sun must be very great. That of 1680 came within 130,000 miles of the Sun's surface, and must have received 28,000 times the light and heat which the Earth receives from the Sun—a heat more than 2,000 times greater than that of red-hot iron. What substance can a comet be composed of to endure the extremes of heat and cold to which it is subject? Some have supposed that their tails were caused by the Sun's light and heat rarefying and driving back the vapory substance composing the envelop.

5. The *periods* of but few comets are known. That of 1818, called "*Encke's Comet*," has a period of only $3\frac{1}{3}$ years. *Biela's Comet* has a period of $6\frac{3}{4}$ years. That of 1682 (then first noticed with care, and identified as the same that had appeared in 1456, 1531 and 1607) has a period of about 76 years. It is called *Halley's* Comet, after Dr. Halley, who determined its periodic time.

The great comet of 1680 has a periodic time of 570 years, so that its next return to our system will be in the year 2,250. Many are supposed to have periods of thousands of years, and some have their orbits so modified by the attraction of the planets as to pass off in parabolic curves, to return to our system no more.

Prof. Nichol is of opinion that the greater number visit our system but once; and then fly off in nearly straight lines till they pass the centre of attraction between the Solar System and the fixed stars, and go to revolve around other suns in the far distant heavens.* Sir John Herschel expresses the same sentiment.†

6. The *distances* to which those comets that return must go, to be so long absent, must be very great. Still their bounds are set by the great law of attraction, for were they to pass the point "where gravitation turns the other way," they would never return. But some, at least, *do* return, even from their "long travel of a thousand years." What a sublime conception this affords us of the almost infinite space between the Solar System and the fixed stars!

7. The *direction* of comets is as variable as their forms and magnitudes. They enter the Solar System from all points of the heavens. Some seem to come up from the immeasurable depths below the ecliptic, and, having doubled heaven's mighty cape, again plunge downward with their fiery trains, and are lost for ages in the ethereal void. Others appear to come down from the zenith of the universe, and having doubled their perihelion, reascend far above all human vision. Others,

* Solar System, p. 135.
† Treatise, American Ed. p. 289.

again are dashing through the Solar System, in all possible directions, apparently without any prescribed path, or any guide to direct them in their wanderings. Instead of revolving uniformly from east to west, like the planets, their motions are direct, retrograde, and in every conceivable direction.

8. The *number* of comets belonging to, or that visit, the Solar System is very great. It is supposed that not less than 700 have appeared at different times since the birth of Christ. The paths of only about 140 have been determined.

The *perihelion distances* of the various comets that have been noticed, and whose elements have been estimated by astronomers, are also exceedingly variable. While some pass very near the Sun, others are at an immense distance from him, even at their perihelion. Of 137 that have been particularly noticed,

30 passed between the Sun and the orbit of Mercury ;
44 between the orbits of Mercury and Venus ;
34 " " " Venus and the Earth ;
23 " " " the Earth and Mars ;
6 " " " Mars and Jupiter.

The extreme difficulty of observing comets whose nearest point is beyond the orbit of Mars, is supposed to account for the comparatively small number that have been seen without that limit ; and the proximate uniformity of the distribution of their orbits over the space included within the orbit of Mars, seems to justify the conclusion, that though seldom detected beyond his path, they are nevertheless equally distributed through all the spaces of the solar heavens. Reasoning upon this hypothesis, Prof. Arago concludes that there are probably *seven millions* of comets that belong to or visit the Solar System. *

9. Comets were formerly regarded as harbingers of famine, pestilence, war, and other dire calamities. In one or two instances they have excited serious apprehension that the day of judgment was at hand ; and that

* Arago and Lardner's Astronomy, p. 70.

they were the appointed messengers of Divine wrath, hasting apace to burn up the world. It may be well, therefore, to devote a paragraph to the question, *Are comets dangerous in the Solar System?* That they are not will be evident when we consider,

First, that there is scarcely the remotest probability of a *collision* between the earth and a comet. It has been determined, upon mathematical principles, and after the most mature and extended calculation, that of 281,000,000 of chances there is only *one* unfavorable, or that can produce a collision between the two bodies. The risk, therefore, to which the earth is exposed of being struck by a comet, is like the chance one would have in a lottery, where there were 281,000,000 black balls and but one white one, and where the white ball must be produced at the first drawing to secure a prize.

In the second place, if a comet were to come in direct collision with the earth, it is not probable that it would be able even to penetrate our atmosphere; much less to dash the world in pieces. Prof. Olmsted remarks, that in such an event not a particle of the comet would reach the earth—that the portions encountered by her would be arrested by the atmosphere, and probably inflamed; and that they would perhaps exhibit on a more magnificent scale than was ever before observed, the phenomena of shooting stars, or meteoric showers. * The idea, therefore, that comets are dangerous visitants to our system has more support from superstition than from reason or science.

I cannot better conclude this chapter than in the language of the lamented Burritt: "What regions these bodies visit, when they pass beyond the limits of our view; upon what errands they come, when they again revisit the central parts of our system; what is the difference between their physical constitution and that of the Sun and planets; and what important ends they are destined to accomplish in the economy of the universe, are inquiries which naturally arise in the mind,

* Introduction to Astronomy, p. 274.

but which surpass the limited powers of the human understanding at present to determine."

CHAPTER VII.

OF THE SUN.

LESSON XCIX.

GENERAL REMARKS RESPECTING THE SUN—ITS MAGNITUDE, ETC.

(Map 4.)

Although it has been found necessary to give many interesting facts respecting the Sun, in the preceding lessons, it is thought important to repeat them here, with others, in a more systematic order; and with opportunity for descriptions and explanations more in detail.

Of all the celestial objects with which we are acquainted, none make so strong and universal an impression upon our globe as does the *Sun*. He is the great centre of the Solar System—a vast and fiery orb, kindled by the Almighty on the morn of creation, to cheer the dark abyss, and to pour his radiance upon surrounding worlds. Compared with him, all the solar bodies are of inconsiderable dimensions; and without him, they are wrapped in the pall of interminable midnight.

The Sun is 886,000 miles in diameter. Were a tunnel opened through his centre, and a railway laid down, it would require, at the rate of thirty miles per hour, nearly three and a half years for a train of cars to pass through it. To traverse the whole *circumference* of the Sun, at the same speed, would require nearly eleven years. His diameter is 112 times that of the Earth, and his mass 1,400,000 times as great. He is 500 times larger than all the rest of the Solar System put together. The mean diameter of the Moon's orbit is 480,000 miles; and yet were the Sun to take the place of the Earth, he would fill the entire orbit of the Moon, and extend more than 200,000 miles beyond it on every side.

The *form* of the Sun is that of a *spheroid;* his equatorial being somewhat greater than his polar diameter. The map referred to exhibits the relative diameters of the Sun and Planets.

LESSON C.

SPOTS ON THE SUN'S SURFACE—THEIR NUMBER.

(Map 4.)

By the aid of telescopes a variety of *spots* are often discovered upon the Sun's disc. Their *number* is exceedingly variable at different times. From 1611 to 1629, a period of 18 years, the Sun was never found clear of spots, except for a few days in December, 1624. At other times twenty or thirty were frequently seen at once; and at one period, in 1825, upwards of fifty were to be seen. Prof. Olmsted states that over one hundred are sometimes visible. From 1650 to 1670, a period of 20 years, scarcely any spots were visible; and for eight years, from 1676 to 1684, no spots whatever were to be seen. For the last 46 years more or less spots have been visible every year. For several days, during the latter part of September, 1846, I could count sixteen which were distinctly visible, and most of them well defined; but on the 7th of October following, only six small spots were visible, though the same telescope was used, and circumstances were equally favorable.

LESSON CI.

REVOLUTION OF THE SUN UPON HIS AXIS.

(Map 4.)

The axis of the Sun is inclined to the ecliptic $7\frac{1}{2}°$, or more accurately $7° 20'$. This is but a slight deviation from what we may call a perpendicular, so that in relation to the Earth, he may be considered as standin up and revolving with one of his poles resting upon a point just half his diameter below the ecliptic. The *proof* of his revolution is the same as that by which we determine the revolution of the planets; namely, the passage of spots over his disc. The *time* occupied in a complete revolution is 25 days 10 hours.

LESSON CII.

MAGNITUDE OF THE SOLAR SPOTS.

(Map 4.)

The *magnitude* of the solar spots is as variable as their number. Upon this point the map will give a correct idea; as it is a pretty accurate representation of the Sun's disc, as seen on the 22d of September, 1846. In 1799, Dr. Herschel observed a spot nearly 30,000 miles in breadth; and he further states, that others have been observed whose diameter was upwards of 45,000 miles. Dr. Dick observes that he has several times seen spots which were not less than $\frac{1}{25}$ of the Sun's diameter, or 22,192 miles across.

It is stated, upon good authority, that solar spots have been seen by the naked eye—a fact, from which Dr. Dick concludes that such spots could not be less than 50,000 miles in diameter. The observations of the writer, as above referred to, and represented on the map, would go to confirm this deduction, and to assign a still greater magnitude to some of these curious and interesting phenomena.

LESSON CIII.

DIRECTION, MOTIONS, AND PHASES OF THE SOLAR SPOTS.

(Map 4.)

As the result of the Sun's motion upon his axis, his spots always appear first on his eastern limb, and pass off or disappear on the west. During one half of their passage across his disc, their apparent motion is *accelerated;* and during the remainder it is *retarded.*

This apparent irregularity in the motion of the spots upon the Sun's surface, is the necessary result of an equable motion upon the surface of a globe or sphere. When near the eastern limb, the spots are coming partly towards us, and their angular motion is but slight; but when near the centre, their angular and real motions are equal. So, also, as the spots pass on to the west, it is their angular motion only that is diminished, while the motion of the Sun upon his axis is perfectly uniform.

The figure of the Sun affects not only the apparent *velocity* of the spots, but also their *forms.* When first seen on the east they appear narrow and slender, as represented on the left of Fig. 1. As they advance westward, they continue to widen or enlarge till they reach the centre, where they appear largest, when they again begin to contract, and are constantly diminished till they disappear.

Another result of the figure of the Sun, together with his revolution upon an axis inclined to the ecliptic, and the revolution of the Earth around him, is, that when viewed from our movable observatory, the Earth, at different seasons of the year, the *direction* of the spots seems materially to vary. This fact is illustrated by Fig. 2. In June we have, so to speak, a side view of the Sun, his pole being inclined to the *left.* Of course, then, as he revolves, his spots will appear to ascend in a straight line. In September we have passed around in our orbit, to a point opposite the south pole of the Sun, and the spots seem to curve upward. In December we have another side view of the Sun, but we are opposite the point from which we had our first view, and on the other side of the ecliptic. The result is, that the poles of the Sun are now inclined to the *right;* and the spots, in passing over his disc, incline downward. In March, we reach a point opposite the *south* pole of the Sun, and the spots in revolving seem to curve downward. The polar inclination of the Sun, as given in the figure, is greater than it actually is in nature (see Lesson XLIX. and Map 8); the present design being merely to illustrate the principle upon which we account for the peculiar motion of the solar spots.

LESSON CIV.

SUPPOSED NATURE AND CAUSES OF THE SOLAR SPOTS.

(Map 4.)

The appearance of the spots is that of a dark *nucleus* surrounded by a border less deeply shaded, called a *penumbra.* These appearances are represented on the map.

When seen through a telescope, the Sun presents the appearance of a vast globe, wrapped in an ocean of flame, with the spots, like incombustible islands, floating in the fiery abyss. The principal facts by which we are to judge of their nature and causes are the following:

1. The Sun is often *entirely destitute* of spots.

2. When they are to be seen, the same spots do not regularly reappear on the east and pass around, with every successive revolution, to the west.

3. They are exceedingly variable as to *number* and *magnitude.*

4. They have been known to *break in pieces* and divide; and even finally to *disappear* altogether in a very short time.

5. They sometimes *break out* again, in the same places; and new ones often break out where none were perceptible before.

6. When they disappear, the central dark spot always contracts into a point, and vanishes before the penumbra or border disappears.

7. In the neighborhood of the large spots, the surface of the Sun is covered with strongly marked streaks or arms, more luminous than the rest, called *faculæ,* among which the spots often break out. The dark spots are sometimes called *maculæ.*

8. The spots are all found within 30° of the Sun's equator, or in a zone of 60° in width.

9. In a series of experiments conducted by Prof. Henry, of Princeton, by means of a thermo-electrical apparatus, applied to an image of the Sun thrown on a screen from a dark room, it was found that the spots were perceptibly colder than the surrounding light surface.

Concerning these wonderful spots a variety of opinions have prevailed, and many curious theories have been constructed. Lalande, as cited by Herschel, suggests that they are the tops of mountains on the Sun's surface, laid bare by fluctuations in his luminous atmosphere; and that the penumbræ are the shoaling declivities of the mountains, where the luminous fluid is less deep. Another gentleman, of some astronomical knowledge, supposes that the tops of the solar mountains are exposed by *tides* in the Sun's atmosphere, produced by planetary attraction.

To the theory of Lalande, Dr. Herschel objects that it is contradicted by the sharp termination of both the internal and external edges of the penumbræ; and advances as a more probable theory, that "they are the dark, or at least comparatively dark, solid body of the Sun itself, laid bare to our view by those immense fluctuations in the luminous regions of the atmosphere, to which it appears to be subject." Prof. Olmsted supports this theory by demonstrating that the spots must be "nearly or quite in contact with the body of the Sun."

In 1773, Prof. Wilson, of the University of Glasgow, ascertained by a series of observations that the spots were probably "*vast excavations* in the luminous matter of the Sun;" the nuclei being their bottom, and the umbræ their shelving sides.* This conclusion varies but little from that of Dr. Herschel, subsequently arrived at.†

* A valuable paper upon the subject of the solar spots, written by the lamented Ebenezer Porter Mason, may be found in his excellent Memoir, by Prof. Olmsted, page 238.

† Nichol's Solar System, pp. 122—126.

LESSON CV.

PHYSICAL CONSTITUTION OF THE SUN.

Concerning the physical organization of the Sun, very little is known. As before said, it appears when seen through a telescope, like a globe of fire, in a state of violent commotion or ebullition. La Place believed it to be in a state of actual combustion, the spots being immense caverns or craters, caused by eruptions or explosions of elastic fluids in the interior.

The most probable opinion is that the body of the sun is opaque, like one of the planets; that it is surrounded by an atmosphere of considerable depth; and that the light is sent off from a luminous stratum of clouds, floating above or outside the atmosphere. This theory accords best with his density, and with the phenomena of the solar spots.

Of the *temperature* of the Sun's surface, Dr. Herschel thinks that it must exceed that produced in furnaces, or even by chemical or galvanic processes. By the law relative to the diffusion of light (Lesson XII.) he shows that a body at the Sun's surface must receive 300,000 times the light and heat of our globe; and adds that a far less quantity of solar light is sufficient, when collected in the focus of a burning-glass, to dissipate gold and platina into vapor. And yet this theory of the high temperature at the Sun's surface, is thought by some philosophers to be no barrier in the way of its habitability.

It is supposed that the luminous matter is of less specific gravity than the vapor and clouds in the Sun's atmosphere; and that these, together with the atmosphere, form an effective screen against the excessive solar radiation.

After all, it must be confessed that but little is known as yet of the nature of this wonderful orb. For his *density* and *attractive force*, see Lessons XVI. and XVII.

LESSON CVI.

THE ZODIACAL LIGHT.

The *Zodiacal Light* is a faint nebulous light, resembling the tail of a comet, or the milky-way, which seems to be reflected from the regions about the Sun; and is distinguishable from ordinary twilight. Its form is that of a pyramid or cone, with its base towards the Sun, and inclined slightly to the ecliptic. It seems to surround the Sun on all sides, though at various depths, as it may be seen in the morning preceding the Sun, as well as in the evening following him; and the base of the cones where they meet at the Sun, must be much larger than his diameter.

The *form* of this substance surrounding the Sun, and which is sufficiently dense to reflect his light to the earth, seems to be that of a *lens;* or rather like a huge wheel, thickest at the centre, and thinned down to an edge at the outer extremities. Its being seen edgewise, and only one half at a time, gives it the appearance of two pyramids with their bases joined at the Sun.

Of the *nature* of this singular phenomenon very little is positively known. It was formerly thought to be the atmosphere of the Sun. Prof. Nichol says: "Of this at least we are certain—the Zodiacal Light is a phenomenon precisely similar in kind to the nebulous atmospheres of the distant stars," &c. Sir John Herschel remarks, that "it is manifestly of the nature of a thin lenticularly-formed atmosphere, surrounding the Sun, and extending at least beyond the orbit of Mercury, and even of Venus." He gives the apparent angular distance of its vertex from the Sun, at from 40° to 90°; and the breadth of its base from 8° to 30°. It sometimes extends 50° westward, and 70° eastward of the Sun at the same time.

In regard to its atmospheric character, Dr. Dick remarks that "this opinion now appears extremely dubious;" and Prof. Olmsted refers to La Place, as showing that the "solar atmosphere could never reach so far from the Sun as this light is seen to extend."

Another class of astronomers suppose this light, or rather the substance reflecting this light, to be some of the original matter of which the Sun and planets were composed—a thin nebulous substance in a state of condensation, and destined either to be consolidated into new planetary worlds, during the lapse of coming ages, or to settle down upon the Sun himself as a part of his legitimate substance. This theory may be noticed again when we come to speak of Nebulæ and Nebulous Stars, in the second part of this work.

Prof. Olmsted supposes the Zodiacal Light to be a nebulous body, or a thin vapory mass revolving around the Sun; and that the *Meteoric Showers*, which have occurred for several years, in the month of November, may be derived from this body. This is the opinion of Arago, Biot, and others.

The best time for observing the Zodiacal Light is on clear evenings, in the months of March and April. It may be seen, however, in October, November, and December, before sunrise; and also in the evening sky.

It is an interesting fact, stated by Prof. Nichol, that this light, or nebulous body, lies in the plane of the Sun's equator. A line drawn through its transverse diameter, or from one apex of the pyramids to the other, would cross the axis of the Sun at right angles. This fact would seem to indicate a revolution with that of the Sun upon his axis.

But, as already stated, the subject of the Zodiacal Light is in an unsettled state. After considering the various facts and theories stated, the learner must wait till future observations and discoveries shall furnish something upon this point more definite and satisfactory.

LESSON CVII.

MOTION OF THE SUN IN SPACE.

Although in general terms we speak of the Sun as the fixed centre of the Solar System, still the sublime and astonishing fact has been ascertained, that the Sun, and the whole Solar System, *have an actual motion in space.* Indeed the Sun may be said to have three distinct motions.

1. It has a revolution upon its own axis, once in 25 days $9\frac{1}{2}$ hours, as described in Lesson XXXVII.

2. "It has a periodical motion, in nearly a circular direction, around the common centre of all the planetary motions; never deviating from its position by more than twice its diameter." From the known laws of gravitation, it is certain that the Sun is affected in some measure by the attraction of the planets, especially when many of them are found on the same side of the ecliptic at the same time; but this would by no means account for so great a periodical motion.

3. It is found to be moving, with all its retinue of worlds, in a *vast orbit*, around some distant and unknown centre. This opinion was first advanced, I think, by Sir William Herschel; but the honor of actually determining this interesting fact belongs to Struve, who ascertained not only the *direction* of the Sun and Solar System, but als their *velocity.* The point of tendency is towards the °constellation of stars called Hercules, Right Ascension 259°, Declination 35°. See Lessons XLVII. XLVIII. The *velocity* of the Sun, &c., in space, is estimated at about 28,000 miles per hour, or nearly 8 miles per second!

With this wonderful fact in view, we may no longer consider the Sun as fixed and stationary, but rather as a vast and luminous *planet,* sustaining the same relation to some central orb, that the primary planets sustain to him, or that the secondaries sustain to their primaries. Nor is it necessary that the stupendous mechanism of nature should be restricted even to these sublime proportions. The Sun's central body may also have its orbit, and its centre of attraction and motion, and so on, till, as Dr. Dick observes, we come to the great centre of all—to the THRONE OF GOD.

The Sun will be further considered as a *Fixed Star*, in Part II.

CHAPTER VIII.

MISCELLANEOUS REMARKS UPON THE SOLAR SYSTEM.

LESSON CVIII.

NEBULAR THEORY OF THE ORIGIN OF THE SOLAR SYSTEM.

It is the opinion of La Place, a celebrated French astronomer, that the entire matter of the Solar System, which is now mostly found in a consolidated state, in the Sun and Planets, was once a vast *nebula*, or gaseous vapor, extending beyond the orbits of the most distant planets—that in the process of gradual condensation, by attraction, a *rotary motion* was engendered and imparted to the whole mass—that this motion caused the consolidating matter to assume the form of various concentric *rings*, like those of Saturn; and, finally, that these rings, collapsing, at their respective distances, and still retaining their motion, were gathered up into *planets*, as they are now found to exist. This opinion is supposed to be favored, not only by the fact of Saturn's revolving rings, but by the existence of the Zodiacal Light, or a resisting medium about the Sun (CVI.), and also by the character of irresolvable or planetary nebulæ, hereafter to be described.

On the other hand, the nebular theory is open to many very plausible objections. But we have not room in this treatise to enter at length upon its discussion. It is but justice, however, to say, that men eminent for learning and piety have advocated it, in the belief that it was perfectly consistent with the Mosaic account of the creation of the heavens and the earth. If the opinion of the writer is desired, he is frank to state, that while he acknowledges the force of some of the considerations urged in its support, he has not yet seen reason for adopting the nebular theory of the formation of the Solar System.

LESSON CIX.

LAWS OF PLANETARY MOTION.

There are three general principles which govern the motions of all the planets. These were first discovered by *Kepler*, a German astronomer, from whom they have since been called *Kepler's laws*. These laws or principles we have not time to explain in detail; nevertheless, they are inserted here for the benefit of advanced pupils, who may wish to make calculations upon them, when the easier lessons of the work are all fully mastered. They are as follows:

1. *The orbits of the Earth, and all the Planets, are ellipses, having the Sun in the common focus.*
2. *The radius vector, (or line drawn from the centre of the Sun to any Planet revolving around it,) describes equal areas in equal times.*
3. *The squares of the periodic times are as the cubes of the mean distances from the Sun.*

According to these laws, which are known to prevail in the Solar System, many of the facts of astronomy are deduced from other facts previously ascertained. They are, therefore, of great importance, and should be studied till they are, at least, thoroughly understood, if not committed to memory. The first is illustrated in several of the maps, and the ingenious teacher will readily illustrate the second by a simple diagram upon a slate or black-board. It would be a very useful exercise for the pupil to test the table in which the distances and periodic times are given, by this third law. See Lessons VIII. and XVIII.

LESSON CX.

MINIATURE REPRESENTATION OF THE SOLAR SYSTEM.

At the close of his remarks on the Primary Planets,* Sir John Herschel, has a most graphic and interesting description of the Solar System in miniature, which is here inserted for the perusal of the learner.

Choose 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 ; Mars a rather large pin's head, on a circle of 654 feet ; Vesta, Juno, Ceres, and Pallas, [also Astræa,] grains of sand, in orbits of 1000 to 1200 feet ; Jupiter a moderate sized orange, on a circle nearly half a mile across ; Saturn a small orange, on a circle of four-fifths of a mile ; and Herschel a full sized cherry, or small plum, upon a circumference of a circle more than a mile and a half in diameter. * * * * *

To imitate the *motions* of the planets, in the above mentioned orbits, Mercury must revolve in its orbit in 41 seconds ; Venus in 4 min. 14 sec. ; the Earth in 7 min. ; Mars in 4 min. 48 sec. ; Jupiter in 2 h. 56 min. ; Saturn in 3 h. 13 min. ; and Herschel in 2 h. 16 min.

So far as relative magnitude is concerned, it will be easy to discover the general accuracy of Maps 2 and 4, according to the representations of Dr. Herschel, as

* Treatise, p. 271.

above quoted. It is proper, however, to add, that the maps were calculated by the author without any reference to the foregoing, or any recollection of its existence.

LESSON CXI.

WERE THE ASTEROIDS ORIGINALLY ONE PLANET?

1. Some very curious speculations have been entertained by astronomers in regard to the origin of the Asteroids. As in the case of the recently discovered planet *Leverrier*, the existence of a large planet between the orbits of Mars and Jupiter was *suspected* before the Asteroids were known. This suspicion arose mainly from the seeming chasm that the absence of such a body would leave in the otherwise well-balanced Solar System.

2. The prediction that such a body would be discovered in the future, stimulated the search of astronomers, till, at length, instead of one *large* planet, *five small ones* were one after another discovered. For the time of their discovery, &c., see Lesson LXV.

3. From certain peculiarities of the Asteroids, it has been considered highly probable that they were originally one large planet, which had been burst asunder by some great convulsion or collision, and of which they are the fragments. The grounds of this opinion are as follows:

(1.) The Asteroids are *smaller* than any of the other primary planets. Lesson XIV.

(2.) Their *distances* from the Sun are nearly the same, as will be seen in Lesson VIII.

(3.) Their periodic revolutions are accomplished in nearly the same time, as appears by Lesson XVIII. The difference of their periodic times is not greater than might result from the supposed disruption, as the parts thrown *forward* would have their motion *accelerated*, while the other parts would be thrown *back* or *retarded*; thus changing the periodic times of both.

(4.) The great departure of the *orbits* of the Asteroids from the plane of the ecliptic is supposed to favor the hypothesis of their having been originally one planet.

(5.) Their orbits are *more eccentric* than those of the other primaries, as may be seen in Lesson XLV. Although the table shows the eccentricity of Herschel's orbit as greater in miles than that of even Juno or Pallas, yet when we consider the difference in the *magnitude* of their orbits, it will easily be seen that his orbit is less elliptical than theirs.

(6.) The orbits of Ceres and Pallas, at least, *cross each other*, as shown in Map 2. This, if we except the comets, is a perfect anomaly in the Solar System.

From all these circumstances, it has been concluded that the Asteroids are only the fragments of an exploded world, which have assumed their present forms since the disruption, in obedience to the general laws of gravitation. This theory of Dr. Olbers, is favored by Prof. Nichol, Dr. Brewster, Dr. Dick, and others; while Sir John Herschel observes that it may serve as a specimen of the *dreams* in which astronomers, like other speculators, occasionally and harmlessly indulge.* Dr. Dick remarks, that the breaking up of the exterior crust of the Earth, at the time of the general deluge, was a catastrophe as tremendous and astonishing as the bursting asunder of a large planet.†

The late General Root, of Delhi, was of opinion that the Asteroids were primarily *satellites of Mars*; which, as if dissatisfied with their low condition as mere attendants upon another, and one, too, not much larger than themselves, have wandered from their original spheres, and assumed the character of primaries. The *reasons* for this opinion, as stated to the author by Gen. Root, in the fall of 1846, are quite as satisfactory as the evidences by which the theory of Dr. Olbers is supported. But this is not endorsing either the one or the other. Indeed, in view of the *harmony* and *order* that reign throughout the planetary regions, directing the pathway and controlling the destiny of every world, it is hard to believe that any

* Treatise, p. 162. † Celestial Scenery, p. 140.

planet has either been broken to pieces by some mighty explosion or concussion, or wandered from its prescribed path into a new and vastly extended orbit.

LESSON CXII.

ARE THE PLANETS INHABITED BY RATIONAL BEINGS?

Upon this interesting question, it must be admitted, that we have no positive testimony. The argument in the affirmative is based upon analogies, and the conclusion is to be regarded only in the light of a legitimate inference. Still, it is remarkable that those who are best acquainted with the facts of astronomy are most confident that other worlds, as well as ours, are the abodes of intellectual life. Indeed, as Dr. Dick well remarks, it requires a minute knowledge of the whole scenery and circumstances connected with the planetary system, before this truth comes home to the understanding with full conviction.

It is not proposed, in this lesson, to discuss at length the question of a plurality of worlds, but merely to give the heads of the arguments by which this doctrine is supported, leaving the reader to amplify them by reflection, or to pursue the inquiry, at his leisure, in more elaborate works. Perhaps no writer has done better justice to this subject than Dr. Dick,* to whom we are indebted for many of the arguments with which this lesson is enriched.

1. The planets are all *solid bodies* resembling the Earth, and not mere clouds or vapors.

2. They all have a *spherical* or *spheroidal figure*, like our own planet.

3. The laws of gravitation, by which we are kept upon the surface of the Earth, prevail upon all the other planets, as if to bind races of material beings to their surfaces, and provide for the erection of habitations and other conveniences of life.

* Celestial Scenery, pp. 331–363.

4. The *magnitudes* of the planets are such as to afford ample scope for the abodes of myriads of inhabitants. It is estimated that the solar bodies, exclusive of the comets, contain an area of 78,000,000,000 of square miles; or 397 times the surface of our globe. According to the population of England, this vast area would afford a residence to 21,875,000,000,000 of inhabitants; or 27,000 times the population of our globe.

5. The planets have a *diurnal revolution* around their axes, thus affording the agreeable vicissitudes of day and night. Not only are they opaque bodies like our globe, receiving their light and heat from the Sun, but they also revolve so as to distribute the light and shade alternately over all their surfaces. There, too, the glorious Sun arises, to enlighten, warm, and cheer; and there "the sun-strown firmament" of the more distant heavens is rendered visible by the no less important blessing of a periodic night.

It is very remarkable, also, that those planets whose bulks are such as to indicate an insupportable attractive force, are not only less dense than our globe, but they have the most rapid daily revolution; as if by diminished density, and a strong centrifugal force combined, to reduce the attractive force, and render locomotion possible upon their surfaces.

6. All the planets have an *annual revolution* round the Sun; which, in connection with the inclination of their axes to their respective orbits, necessarily results in the production of *seasons*.

7. The planets, in all probability, are environed with *atmospheres*. That this is the case with many of them is certain; and the fact that a fixed star or any other orb is not rendered dim or distorted when it approaches their margin, is no evidence that the planets have no atmosphere. This appendage to the planets is known to vary in density; and in those cases where it is not detected by its intercepting or refracting the light, it may be too clear and rare to produce such phenomena.

8. The principal primary planets are provided with *moons* or *satellites*, to afford them light in the absence of

the Sun. It is not improbable that both Mars and Venus have each, at least, one moon; the Earth has one; and as the distances of the planets are increased, the number of moons seems to increase. The discovery of only six around Herschel is no evidence that others do not exist which have not yet been discovered.

9. The surfaces of all the planets, primaries as well as secondaries, seem to be variegated with *hill and dale*, with *mountain and plain*.

It is also argued, that as every part of the globe we inhabit is destined to the support of animated beings, it would be contrary to the analogy of nature, as displayed to us, to suppose that the other planets are empty and barren wastes, utterly devoid of animated being. The inquiry presses itself upon the mind with irresistible force, Why should this one small world be inhabited, and all the rest unoccupied? For what purpose were all these splendid and magnificent worlds fitted up if not to be inhabited? Why these days and years—this light and shade—these atmospheres, and seasons, and satellites, and hill and dale? The legitimate, and almost inevitable conclusion is, that our globe is only *one* of the many worlds which God has created to be inhabited, and which are now the abodes of his intelligent offspring. It is revolting to suppose that we of Earth are the only intelligent subjects of the "Great King," whose dominions border upon infinity.

PART II.

THE SIDEREAL HEAVENS.

CHAPTER I.

OF CONSTELLATIONS OF STARS.

LESSON CXIII.

DISTINGUISHING CHARACTERISTICS OF THE FIXED STARS.

The Sidereal Heavens embrace all those celestial bodies that lie around and beyond the Solar System, in the region of the Fixed Stars.

The Fixed Stars are distinguished from the Solar Bodies by the following characteristics:

1. They shine *by their own light*, like the Sun, and not by *reflection*.

2. To the naked eye they seem to *twinkle* or *scintillate;* while the planets appear tranquil and serene.

3. They maintain the same *general positions* with respect to each other, from age to age.

4. They are inconceivably *distant*, so that when viewed through a telescope they present no sensible disc, but appear only as shining points on the dark concave of the sky.

To these might be added several other peculiarities which will be noticed in the sequel, but they are not necessary to our present purpose.

LESSON CXIV.

CLASSIFICATION OF THE STARS.

(Map 16.)

For purposes of convenience in finding or referring to particular stars, recourse is had to a variety of artificial methods of classification, with which the pupil should here become acquainted.

1. The whole concave of the heavens is divided into sections of greater or less extent, called *Constellations.* For the origin of these most unnatural and arbitrary divisions consult Lesson XXXVI. A list of the constellations will be found in a subsequent chapter.

2. The stars are all classed according to their *magnitudes.* There are usually reckoned twelve different magnitudes, of which the first six only are visible to the naked eye, the rest being *telescopic stars.* This magnitude, of course, relates only to their apparent brightness, as the faintest star may appear dim solely on account of its immeasurable distance.

Fig. A on the map is a representation of the first eight magnitudes, the two smallest of which will be invisible to the pupil at a distance. "It must be observed," says Dr. Herschel, "that this classification into magnitudes is entirely arbitrary. Of a multitude of bright objects, differing, probably, intrinsically both in size and in splendor, and arranged at unequal distances from us, one must of necessity appear the brightest; the one next below it brighter still, and so on."

3. The next step is to classify the stars of *each constellation* according to their magnitude *in relation to each other*, and without reference to other constellations. In this classification the Greek alphabet is first used. For instance, the largest star in Taurus would be marked (α) Alpha; the next largest (β) Beta; the next (γ) Gamma, &c. When the Greek alphabet is exhausted, the Roman or English is taken up; and when these are all absorbed, recourse is finally had to figures.

4. To aid still further in finding particular stars, and especially in determining their numbers, and detecting changes, should any occur, astronomers have constructed *catalogues* of the stars, one of which is near 2000 years old.

5. Several of the principal stars have a specific name like the planets; as *Sirius*, *Aldebaran*, *Regulus*, &c.

6. Clusters of stars in a constellation sometimes re-

ceive a specific name, as the *Pleiades* and *Hyades* in Taurus.

7. The stars are still further distinguished into Double, Triple, and Quadruple stars; Binary System; Variable Stars; Periodic Stars; Nebulous Stars, &c.; all of which will be duly noticed as we proceed. But we must first consider the more general divisions of the starry heavens.

LESSON CXV.

NUMBER OF THE FIXED STARS.

The actual *number* of the stars is known only to Him who "telleth the number of the stars," and "calleth them all by their names." The powers of the human mind are barely sufficient to form a vague estimate of the number near enough to be seen by our best telescopes, and here our inquiries must end.

The number of stars down to the twelfth magnitude, has been estimated as follows:

Visible to the naked eye,	1st	magnitude,	18	
	2d	"	52	
	3d	"	177	
	4th	"	376	
	5th	"	1,000	
	6th	"	4,000	
				5,623
Visible only thro' tel'scopes,	7th	"	26,000	
	8th	"	170,000	
	9th	"	1,100,000	
	10th	"	7,000,000	
	11th	"	46,000,000	
	12th	"	300,000,000	
				354,296,000
			Total number,	354,301,623

Of these stars, Dr. Herschel remarks that from 15,000 to 20,000 of the first seven magnitudes are already *registered*, or noted down in catalogues; and Prof. Olmsted observes that Lalande has registered the positions of no less than 50,000.

LESSON CXVI.

DISTANCES OF THE STARS.

It has been demonstrated that the *nearest* of the fixed stars cannot be less than 20,000,000,000,000—*twenty billions* of miles distant! For light to travel over this space at the rate of 200,000 miles per second, would require 100,000,000 seconds, or upwards of three years.

What then must be the distances of the telescopic stars, of the 10th and 12th magnitudes? "If we admit," says Dr. Herschel, "that the light of a star of each magnitude is half that of the magnitude next above it, it will follow that a star of the first magnitude will require to be removed to 362 times its distance, to appear no larger than one of the twelfth magnitude. It follows, therefore, that among the countless multitude of such stars, visible in telescopes, there must be many whose light has taken at least a thousand years to reach us; and that when we observe their places, and note their changes, we are, in fact, reading only their history of a thousand years' date, thus wonderfully recorded."

Should such a star be struck out of existence now, its light would continue to stream upon us for a thousand years to come; and should a new star be created in those distant regions, a thousand years must pass away before its light could reach the Solar System, to apprise us of its existence.

LESSON CXVII.

MAGNITUDE OF THE STARS.

From what we have already said respecting the almost inconceivable distances of the fixed stars, it will readily be inferred that they must be bodies of great magnitude, in order to be visible to us upon the Earth. It is probable, however, that "one star differeth from another" in its intrinsic splendor or "glory," although we are not to infer that a star is comparatively small, because it appears small to us.

The prevailing opinion among astronomers is, that what we call the fixed stars are so many *Suns*, and centres of other systems. By a series of experiments upon the light received by us from Sirius, the nearest of the fixed stars, it is ascertained that if the Sun were removed 141,400 times his present distance from us, or thirteen billions of miles, his light would be no stronger than that of Sirius; and as Sirius is more than twenty billions of miles distant, he must, in intrinsic magnitude and splendor, be equal to two suns like ours. Dr. Wollaston, as cited by Dr. Herschel, concludes that this star must be equal in intrinsic light to nearly fourteen suns!

According to the measurements of Sir Wm. Herschel, the diameter of the star *Vega* in the Lyre, is 38 times that of the Sun, and its solid contents 54,872 times greater!

Sir John Herschel states that while making observations with his forty feet reflector, a star of the first magnitude was unintentionally brought into the field of view. "Sirius," says he, "announced his approach like the dawn of day;" and so great was his splendor when thus viewed, and so strong was his light, that the great astronomer was actually driven from the eye-piece of his telescope by it, as if the Sun himself had suddenly burst upon his view. He was obliged to employ a colored screen, as in the case of solar observations, to protect his eye from the strong and glowing radiance.

According to Sir Wm. Herschel, the relative light of the stars of the first six magnitudes is as follows:

Light of a star	of the	average	1st	magnitude	100
"	"	"	2d	"	25
"	"	"	3d	"	12
"	"	"	4th	"	6
"	"	"	5th	"	2
"	"	"	6th	"	1

LESSON CXVIII.

LIST OF THE CONSTELLATIONS.

Of the *nature* and *origin* of the constellations we have already spoken in Lesson XXXVI. Their formation has been the work of ages. Some of them were known at least 3000 years ago, and bore the very names by which they are known to this day. In the 9th chapter of Job we read of "Arcturus, Orion, and Pleiades, and the chambers of the south;" and in the 38th chapter of the same book, it is asked, "Canst thou bind the sweet influences of Pleiades, or loose the bands of Orion? Canst thou bring forth Mazzaroth in his season? or canst thou guide Arcturus with his sons?"

At first the number of constellations was few. Being found convenient in the study of the heavens, new ones were added to the list, composed of stars not yet made up into hydras and dragons, till there is now scarcely stars or room enough left to construct the smallest new constellation, in all the spacious heavens.

The constellations are divided into the *Zodiacal*, the *Northern*, and the *Southern*.

The *Zodiacal Constellations* are those which lie in the Sun's apparent path, or along the line of the Zodiac. See Lesson XXXVI. and the map.

The *Northern Constellations* are those which lie between the Zodiacal and the North Pole of the heavens.

The *Southern Constellations* lie between the Zodiacal and the South Pole of the heavens.

The constellations are also distinguished into *ancient* and *modern*. The following is a list of all the constellations, both ancient and modern, with the number of principal stars in each, according to Ptolemy's Catalogue, and also that of the Observatory Royal of Paris.

I.

ZODIACAL CONSTELLATIONS.

		Latin names.	English names.	Ptol's.	Ob. R.
1	♈	ARIES.	*The Ram.*	18	42
2	♉	TAURUS.	*The Bull.*	44	207
3	♊	GEMINI.	*The Twins.*	25	64
4	♋	CANCER.	*The Crab.*	33	85
5	♌	LEO.	*The Lion.*	35	93
6	♍	VIRGO.	*The Virgin.*	32	117
7	♎	LIBRA.	*The Scale.*	07	67
8	♏	SCORPIO.	*The Scorpion.*	27	60
9	♐	SAGITTARIUS.	*The Archer.*	31	94
19	♑	CAPRICORNUS.	*The Goat.*	28	64
11	♒	AQUARIUS.	*The Water-bearer.*	45	117
12	♓	PISCES.	*The Fishes.*	38	116

II.

NORTHERN CONSTELLATIONS.

ANCIENT.

13	URSA MINOR.	*The Little Bear.*	08	22
14	URSA MAJOR.	*The Great Bear.*	34	87
15	DRACO.	*The Dragon.*	31	85
16	CEPHEUS.	*Cepheus.*	13	58
17	BOOTES.	*Bootes.*	23	70
18	CORONA BOREALIS.	*The North'n Crown.*	08	33
19	HERCULES.	*Hercules.*	29	128
20	LYRA.	*The Harp.*	10	21

	Latin names.	English names.	Ptol's.	Ob. R.
21	CYGNUS.	*The Swan.*	10	85
22	CASSIOPEIA.	*Cassiopeia.*	13	60
23	PERSEUS.	*Perseus.*	29	65
24	AURIGA.	*The Charioteer.*	14	69
25	OPHIUCHUS.	*The Serpent-bearer.*	29	61
26	SAGITTA.	*The Arrow.*	05	18
27	AQUILA.	*The Eagle.*	15	26
28	DELPHINUS.	*The Dolphin.*	10	19
29	EQUULEUS.	*The Little Horse.*	04	10
30	PEGASUS.	*Pegasus.*	20	91
31	ANTINOUS.	*Antinous.*	15	28
32	ANDROMEDA.	*Andromeda.*	23	71
33	TRIANG. BOREALIS.	*The North. Triang.*	04	15
34	COMA BERENICES.	*Berenice's Hair.*	35	43

MODERN.

35	LEO MINOR.	*The Little Lion.*	—	55
36	CANES VENATICI.	*The Greyhounds.*	—	38
37	SEXTANS.	*The Sextant.*	—	54
38	CERBERUS.	*Cerberus.*	—	13
39	TAURUS PONIATOWSKI.	*Poniatowski's Bull.*	—	18
40	VELPECULA ET ANS.	*The Fox and Goose.*	—	35
41	LACERTA.	*The Lizard.*	—	12
42	TRIANGULA MINORA.	*The Little Triangle*	—	04
43	MUSCA BOREALIS.	*The Northern Fly.*	—	05
44	TARANDUS.	*The Rein Deer.*	—	12
45	CUSTOS MESSIUM.	*The Harvester.*	—	07
46	CAMELOPARDALUS.	*The Cameleopard.*	—	69
47	LINX.	*The Lynx.*	—	45

III.

SOUTHERN CONSTELLATIONS.

ANCIENT.

	Latin names.	English names.	Ptol's.	Ob. R.
48	CETUS.	*The Whale.*	22	102
49	ERIDANUS.	*The River Po.*	34	85
50	ORION.	*Orion.*	38	90
51	LEPUS.	*The Hare.*	12	20
52	CANIS MINOR.	*The Little Dog.*	02	17
53	CANIS MAJOR.	*The Great Dog.*	29	54
54	ARGO NAVIS.	*The Ship Argo.*	45	117
55	HYDRA.	*The Water Serpent.*	27	52
56	CRATER.	*The Cup.*	07	13
57	CORVUS.	*The Crow.*	07	10
58	CENTAURUS.	*The Centaur.*	37	48
59	LUPUS.	*The Wolf.*	19	34
60	ARA.	*The Altar.*	07	08
61	CORONA AUSTRALIS.	*The South'n Crown.*	13	12
62	PISCIS AUSTRALIS.	*The Southern Fish.*	18	24

MODERN.

63	FORNAX CHIMICA.	*The Chemic. Furn.*	—	39
64	RETICULIS RHOMB.	*The Rhomb'd Net.*	—	07
65	CELA SCULPTORIA.	*The Engrav's Tool.*	—	15
66	DORADO VEL XYPH.	*The Sword-fish.*	—	06
67	COLUMBA NOACHI.	*The Dove.*	—	02
68	EQUULEUS PICT.	*The P'nter's Easel.*	—	04
69	MONOCEROS.	*The Unicorn.*	—	31
70	PYXIS NAUTICA.	*The Marin's Comp.*	—	14

	Latin names.	English names.	Ptol's.	Ob. R.
71	Autlia Pneumat.	*The Air Pump.*	—	22
72	Avis Solit.	*The Solitary Bird.*	—	23
73	Crux Australis.	*The South'n Cross.*	—	06
74	Musca Australis.	*The Southern Fly.*	—	04
75	Chameleonis.	*The Chameleon.*	—	07
76	Piscis Volans.	*The Flying Fish.*	—	06
77	Telescopium.	*The Telescope.*	—	08
78	Horologium.	*The Pendulum, &c.*	—	23
79	Norma Euclidis.	*Euclid's Square.*	—	15
80	Circinus.	*The Compasses.*	—	02
81	Triang. Australis.	*The South. Triang.*	—	05
82	Ap. vel Av. Indica.	*The Bird of Parad.*	—	04
83	Mons Mensa.	*M'nt of Table Bay.*	—	06
84	Scutum Sobieski.	*Sobiesky's Shield.*	—	16
85	Indus.	*The Indian.*	—	04
86	Pavo.	*The Peacock.*	—	11
87	Octans.	*The Octant.*	—	07
88	Microscopium.	*The Microscope.*	—	08
89	Grus.	*The Crane.*	—	12
90	Touchana.	*The Amer. Goose.*	—	11
91	Hydrus.	*The Water Snake.*	—	08
92	Apparatus Sculp.	*The Sculpt's Studio.*	—	28
93	Phœnix.	*The Phœnix.*	—	11

RECAPITULATION.

Zodiacal Constellations,		12	Principal stars,		1125
Northern	"	35	"	"	1531
Southern	"	46	"	"	1050
	Total,	93		Total,	3706

LESSON CXIX.

DESCRIPTION OF SOME OF THE PRINCIPAL CONSTELLATIONS.

Although this work is designed particularly to illustrate the Mechanism of the Heavens, as displayed in the Solar System, we are desirous of furnishing the learner with a sufficient guide to enable him to extend his inquiries and investigations, not only to the different *classes* of bodies lying beyond the limits of the Solar System, in the far-off heavens, but also to the *Constellations* as such. For this purpose we shall here furnish a brief description of the principal constellations visible in the United States, or in north latitude, by the aid of which the student will be able to trace them with very little difficulty, upon that glorious celestial atlas which the Almighty has spread out before us.

These descriptions are partly original, and partly from the writings of Olmsted and Burritt.

ZODIACAL CONSTELLATIONS.

The Constellations of the Zodiac, succeeding each other in regular order eastward, and being more easily found on that account than others, should first be studied.

ARIES is a small constellation known by two bright stars, about 4° apart, which form the head. The brightest is the most northeasterly of the two.

TAURUS will be readily found by the seven stars or *Pleiades*, which lie in his neck. The largest star in Taurus is *Aldebaran*, in the Bull's eye, a star of the first magnitude, of a reddish color, somewhat resembling the planet Mars. Aldebaran, and four other stars in the face of Taurus, compose the *Hyades*. They are so placed as to form the letter V.

Gemini is known by two very bright stars, *Castor* and *Pollux*, about five degrees apart.

Cancer is less remarkable than any other constellation of the Zodiac. It has no stars larger than the third magnitude, and is distinguished for a group of small stars called the Nebula of Cancer, which is often mistaken for a comet. A common telescope resolves this nebula into a beautiful assemblage of bright stars.

Leo is a large and interesting constellation, containing an unusual number of very bright stars. Of these *Regulus* is of the first magnitude, and lies directly in the ecliptic. North of Regulus are several bright stars in the form of a sickle, of which Regulus is the handle. *Denebola* is a bright star of the second magnitude, in the Lion's tail. It is about 25° northeast of Regulus, and 35° west of Arcturus.

Virgo extends for some distance from west to east, but contains only a few bright stars. Of these, *Spica* in the ear of corn which the Virgin holds in her left hand, is a brilliant star of the first magnitude. The rest of her principal stars are of the third and fourth magnitudes.

Libra may be known by its four principal stars, forming a quadrilateral figure. The two brightest of these constitute the *beam* of the balance, and the smallest is in the top or handle.

Scorpio is one of the most interesting and splendid of the constellations. His head consists of five bright stars, forming the arc of a circle, and is crossed by the ecliptic near the brightest of the five. Nine degrees southeast is the star *Antares*, of a reddish color, and of the first magnitude. A number of small stars that curve around towards the east constitute the tail of Scorpio.

Sagittarius lies next to Scorpio, and may be known by three stars arranged in a curve, to represent the *bow* of the Archer, the central star being the brightest, and having a bright star directly west of it, forming the head of the *arrow*.

CAPRICORNUS lies northeast of Sagittarius, and may be known by two bright stars close together, which constitute the head.

AQUARIUS is represented by the figure of a man pouring water out of a vessel. Its four largest stars are of the third magnitude. Two of these, which lie in a line with the brightest stars in Capricornus, constitute the head of the figure.

PISCES, the last of the Zodiacal constellations, lies between Aquarius and Aries. The Southern Fish consists of 24 visible stars, of which one is of the first magnitude, two of the third, and five of the fourth. The remaining 16 are smaller. The largest star is situated in the mouth of the Fish, and is called *Fomalhaut*. The Northern Fish consists wholly of small stars, and is connected with the Southern by a series of stars forming a crooked line between them.

LESSON CXX.

NORTHERN CONSTELLATIONS.

The Constellations of the Zodiac being first well learned, so as to be readily recognized, will faciiitate the learning of others that lie *north* and *south* of them. Let us, therefore, review the principal *Northern Constellations*, beginning north of Aries and proceeding from west to east.

ANDROMEDA may be known by three stars of the second magnitude, situated in a straight line, and extending from east to west. The figure is that of a woman, with her arms extended, and chained by her wrists to a rock. The middle star, of the three just named, is situated in her *girdle*, and is called *Mirach*. The one west of Mirach is in the *head* of Andromeda, and the eastern one, called *Almaak*, is in her *left foot*. The star in her head is in the Equinoctial Coleur. The three largest stars in this constellation are of the second magnitude. Near Mirach are two stars of the third and fourth magnitudes, and the three in a row constitute the girdle.

The loose assemblage of small stars directly south of Mirach, are the Northern Fish, already described.

PERSEUS lies directly north of the Pleiades, and east of Andromeda. The figure is that of a man with a sword in his right hand, and the head of Medusa in his left. About 18° from the Pleiades is *Algol*, a star of the second magnitude, in the head of Medusa; and 9° northeast of Algol is *Algenib*, of the same magnitude, in the back of Perseus. It has, also, four stars of the third magnitude.

Algol will be mentioned again, under the head of Variable Stars.

AURIGA (*The Wagoner*) is the figure of a man in a declining posture, resting one foot upon the horn of Taurus. It is north of Taurus and Orion, and directly east of Perseus. *Capella*, the principal star in this constellation, is one of the most brilliant in the heavens. It is in the west shoulder of Auriga, and may be known by a small triangle near it, formed by three small stars.

The LYNX comes next in order, but presents nothing particularly interesting, as it contains no stars above the fourth magnitude, and even these are scattered over a large space north of Gemini, and between Auriga and Ursa Major.

LEO MINOR is composed of a few small stars lying between the sickle in Leo, and the Great Bear.

COMA BERENICES is a beautiful cluster of small stars, north of Denebolis, in the tail of the Lion, and of the head of Virgo. It has but one star as large as the fourth magnitude. *Cor Caroli*, or Charles's Heart, is a bright star about 12° directly north of Coma Berenices.

BOOTES is the figure of a man with a club in his right hand, with which he seems to be driving the Great Bear round the pole of the heavens. He is thence called the Bear Driver. ARCTURUS, situated near the left knee, is a star of the first magnitude, and of a reddish color. He is accompanied by three small stars (his "sons"*), which form a triangle a little to the southwest. A star of the second magnitude is in the head of the figure, and two bright stars of the third magnitude form the shoulders.

CORONA BOREALIS (*The Crown*) is situated between Bootes on the west, and Hercules on the east. It consists of six principal stars, in the form of a wreath or crown.

Alphacca, the largest star of the group, is of the third magnitude, and may be known by its position in the centre of the crown, as well as by its superior brightness.

HERCULES lies immediately east of the crown, and occupies a large space in the Northern hemisphere. The figure is that of a giant, with a large club in his right hand. The head is towards the south.

This constellation is thickly set with stars, the largest of which is called *Rasalgethi*, in the head of the figure, and is of the second magnitude. It has nine stars of the third magnitude, and nineteen of the fourth.

OPHIUCHUS (*The Serpent Bearer*) is situated directly south of Hercules, with its centre nearly over the equator, and nearly opposite to Orion. The figure is that of a venerable looking man, grasping a serpent in his hands, the *head* of which consists of three bright stars, situated

* Job 38 : 32.

a little south of the crown. The *folds* of the serpent may be traced by a succession of bright stars extending for some distance to the east.

The principal star in Ophiuchus is of the second magnitude, and is called *Ras Alhague.* It is situated in the *head* of the figure, and within 5° of Rasalgethi, in the head of Hercules.

AQUILA (*The Eagle*) is conspicuous for three bright stars in its neck, of which the central one, *Altair*, is a brilliant white star of the first magnitude. *Antinous* lies directly south of the Eagle, and north of the head of Capricornus.

DELPHINUS (*The Dolphin*) is a beautiful little cluster of stars, a little to the east of the Eagle. It may be known by four principal stars in the head, of the third magnitude, arranged in the figure of a diamond, and pointing northeast and southwest. A star of the same magnitude, about 5° south, makes the tail.

PEGASUS is a large constellation situated between the Dolphin and Eagle, on the west, and Andromeda and the Northern Fish, on the northeast. The figure is that of a winged horse, in an inverted posture. It may be known by four stars about 15° apart, forming a *square* called the square of Pegasus. They are of the second and third magnitudes, and one of them, viz. *Algenib*, has already been mentioned as belonging to Perseus.

The HORSE'S HEAD is a small cluster of stars, west of the head of Pegasus, and about half way to the Dolphin. It contains ten stars, of which the four principal are only of the fourth magnitude. They form a long irregular square, the two in the nose being 1° apart, and those in the eyes $2\frac{1}{2}$°. These four stars are about 1° southeast of the diamond in the head of the Dolphin.

We now come to notice the constellations around the North Pole, and which are always above the horizon in northern latitudes.

URSA MINOR (*The Little Bear*) is near the north pole of the heavens. It consists of the *Pole Star*, as it is called, which forms the extremity of the tail, and six other principal stars, three of the third, and four of the fourth magnitudes. The seven together are arranged in the form of a *dipper*, with the Pole Star in the end of the handle.

URSA MAJOR (*The Great Bear*) may be known by the figure of a larger *dipper*, which constitutes the hinder part of the animal. This dipper, also, is composed of seven stars. The first, in the end of the handle, is called *Benetnash*, and is of the second magnitude. The next is *Mizar*, known by a minute star almost touching it, called *Alcor*. This is a double star. The third in the handle is *Alioth*. The first star in the bowl of the dipper, at the junction of the handle, is *Megrez*. Passing to the bottom of the dipper we find *Phad*, and *Merak*, while *Dubhe* forms the rim opposite the handle. Merak and Dubhe are called the *Pointers*; because they always point towards the Pole Star.

The *head* of the Great Bear lies far to the west of the Pointers, and is composed of numerous small stars; while the *feet* are severally composed of two small stars, very near to each other.

DRACO (*The Dragon*) compasses a large circuit in the polar regions. He winds round between the Great and Little Bear, and commencing with the tail, between the Pointers and Pole Star, it is easily traced by a succession of bright stars extending from west to east; passing under Ursa Minor, it returns westward, and terminates in four stars which form the head, near the foot of Hercules. These four stars are 3°, 4° and 5° apart, so situated as to form an irregular square; the two upper ones being the brightest, and both of the second magnitude.

Cepheus lies east of the breast of Draco, but has no stars above the second magnitude. The figure is that of a king, crowned, and with a sceptre in his left hand, which is extended towards Cassiopeia.

Cassiopeia is a queen on a throne or chair, with her head and body in the Milky Way. The chair is composed of four stars, which form the legs, and two constituting the back. Five of these are of the third magnitude.

Lyra (*The Lyre*) is distinguished by one of the brightest stars in the northern hemisphere. It is situated east of Hercules, and between him and the Swan. Its largest star is *Vega*, or *Alpha Lyra*, and is of the first magnitude. It has two others of the second magnitude, and several of the fourth.

Cygnus (*The Swan*) is situated directly east of Lyra. Three bright stars, which lie along the Milky Way, form the *body* and *neck* of the Swan; and two others, in a line with the middle one of the three, constitute the *wings*. These five stars form a large *cross*.

Arided, in the body of the Swan, is a star of the first magnitude, and the remaining ones of the constellation are of the third and fourth magnitudes.

Camelopardalus (*The Cameleopard*) is a large and uninteresting field of small stars, scattered between Perseus, Auriga, the head of Ursa Major and the Pole Star. Its five largest stars are only of the fourth magnitude, the principal of which is in the thigh. The head of the animal is near the pole.

The Lynx also is composed of small stars, scattered over a large extent. It lies north of Gemini, and between Auriga and Ursa Major. Its three largest stars are of the third magnitude.

LESSON CXXI.

SOUTHERN CONSTELLATIONS.

The Southern Constellations are comparatively few in number, though some of them are very beautiful.

CETUS (*The Whale*) is the largest constellation in the heavens. It is situated below or south of Aries. It is represented with its head to the east, and extends 50° east and west, with an average breadth of 20°.

The *head* of Cetus may be known by five remarkable stars, 4° and 5° apart, and so situated as to form a regular pentagon, or five-sided figure. *Menkar*, of the second magnitude, in the nose of the Whale, is the largest star in the group, or in the constellation.

ORION lies south of Taurus, and is one of the most conspicuous and beautiful of the constellations. The figure is that of a man in the act of assaulting the Bull, with a sword in his belt, and a club in his right hand. It contains two stars of the first magnitude, four of the second, three of the third, and fifteen of the fourth. *Betelguese* forms the right, and *Bellatrix* the left shoulder. A cluster of small stars form the head. Three small stars, forming a straight line about 3° in length, constitute the *belt*, called by Job "the *Bands of Orion*." They are sometimes called the *Three Kings*, because they point out the Hyades and Pleiades on the one hand, and Sirius on the other. A row of very small stars runs down from the belt, forming the *sword*. These, with the stars of the belt, are sometimes called the *Ell and Yard*.

Mintika, the northernmost star in the belt, is less than $\frac{1}{2}$° south of the equinoctial.

Rigel, a bright star of the first magnitude, is in the left foot, 15° south of Bellatrix; and *Saiph*, of the third magnitude, is situated in the right knee, $8\frac{1}{2}$° east of Rigel.

Lepus (*The Hare*) is directly south of Orion. It may be known by four stars of the third magnitude, in the form of an irregular square. *Zeta*, of the fourth magnitude, is the first star, situated in the back, and about 5° south of Saiph in Orion. About the same distance below Zeta are the four principal stars, in the legs and feet.

Columba (*Noah's Dove*) lies about 16° south of Lepus. It contains but four stars, of which *Phaet* is the brightest. It lies on the right a little higher than *Beta*, the next brightest. This last may be known by a small star just east of it.

Eridanus (*The River Po*) is a large and irregular constellation, very difficult to trace. It is 130° in length, and is divided into the *Northern* and *Southern* streams. The former lies between Orion and Cetus, commencing near Rigel in the foot of Orion, and flowing out westerly in a serpentine course, near 40°, to the Whale.

Canis Major lies southeast of Orion, and may be readily found by the brilliancy of its principal star *Sirius*. This is the largest of the fixed stars, and is supposed to be the nearest to the Solar System.

Canis Minor is a small constellation situated between Canis Major and the Twins. It has but two principal stars, namely, *Procyon* of the first magnitude, and *Gomelza* of the second.

Monoceros (*The Unicorn*) lies between Canis Major and Canis Minor, with its centre directly south of Procyon. Its largest stars are of the fourth magnitude. Three of these are in the head, 3° and 4° apart.

Hydra has its head near Procyon, and consists of a number of stars of ordinary brightness. *Alphard*, in the heart, is a star of the second magnitude, about 15° southeast of the head. It is an extensive constellation, extending from east to west more than 100°.

Corvus (*The Crow*) is represented as standing upon the tail of Hydra, south of Coma Berenices. It contains but nine visible stars, only three of which are as large as the third magnitude.

Argo Navis (*The Ship Argo*) is a large and splendid constellation in the southern hemisphere, but so low down in the south that but little of it can be seen in the United States. It lies southeast of Canis Major, and may be known by the stars in the prow of the ship. *Markeb,* of the third magnitude, is 16° southeast of Sirius. *Naos* and *Gamma* are of the second magnitude, and *Canopus* and *Miaplacidus* of the first.

Centaurus is another large southern constellation, too low in the south to be traced by an observer in the United States.

Lupus (*The Wolf*) is next east of Centaurus, south of Libra, and is also invisible in northern latitudes.

Sextans (*The Sextant*) consists of a number of very small stars, situated between Leo on the north, and Hydra on the south. Its largest star is of the fourth magnitude, and is situated about 13° south of Regulus, near the equinoctial.

Crux (*The Cross*) is a brilliant little constellation, but too far south to be visible to us at the north. It consists of four principal stars, namely, one of the first, two of the second, and one of the third magnitude.

CHAPTER II.

OF DOUBLE, VARIABLE, AND TEMPORARY STARS, BINARY SYSTEMS, &c.

LESSON CXXII.

OF DOUBLE, TRIPLE, AND MULTIPLE STARS.

(Map 16.)

1. Many of the stars which, to the naked eye, appear single, are found, when examined by the aid of a telescope, to consist of two or more stars, in a state of near proximity to each other. These are called *double stars.* When three or more stars are found thus closely connected, they are called *triple* or *multiple* stars. They are also distinguished as *binary*, *ternary*, &c.

2. Double and triple stars are supposed to be constituted in two ways: first, by actual contiguity, and secondly, where they are only near the same line of vision, one of the component stars being far beyond the other. In the former case they are said to be *physically* double, while in the latter they are only *optically* double.

3. The figures from B to F on the map are specimens of double stars. B is a representation of the star *Mizar*, in the tail of the Great Bear. It may be seen double with a good spy-glass. C is a view of *Rigel* in Orion. D is the *Pole Star*, and E the star *Castor* in the Twins. Those under F are merely fancy specimens.

4. The number of double and multiple stars having one member as large as the eighth magnitude, and whose components are within 32″ of each other, is said to be about 6,000. This fact led astronomers to suspect a physical connection by the laws of gravitation, and also a *revolution* of star around star, as the planets revolve around the Sun.

LESSON CXXIII.

OF BINARY AND OTHER SYSTEMS.

(Map 16.)

1. By carefully noting the relative distances and angular positions of double and multiple stars, for a series of years, it has been found that many of them have their periodic revolutions around each other. These, it must be remembered, are the *double* and *multiple* stars, which appear single to the naked eye. Sir W. Herschel noticed about fifty instances of changes in the angular position of double stars, and the revolution of some *sixteen* of these is considered certain. Their periods are from 40 to 1600 years.

2. Fig. G on the map is a representation of one of these *Binary Systems*, namely, the star *Gamma*, in the Virgin. The largest star will be seen in the upper foci of the supposed orbit, and the arrows show the direction of the revolving star. At the first observation, by Bradley, in 1719, the smallest star was near the lower arrow, as represented. In 1756 it occupied a very different position, as the drawing shows, and so on to 1844, as represented on the map. The periodic time of this system is supposed to be 145 years.

3. Fig. H is another Binary System of a similar kind. In 1780 the smaller star was seen on the right, just above the lower arrow. In 1804 it was near that date on the map; in 1822, it was nearly opposite the first position, and so on to 1843. This system is found in the *Serpent Bearer*, and has a period of 93 years.

4. The learner should here be reminded that these are not systems of planets around suns, but of *sun around sun;* and that their component stars may not only be as far apart as our Sun and Sirius, but that they are probably each the centre of his own planetary system, like that which revolves around our central orb.

5. The double and multiple stars are of *various col-*

ors, beautifully contrasting with each other. The most common are *orange*, *blue*, *green*, *and red*. Some single stars are found of a crimson hue, even much redder than Aldebaran appears to the naked eye.

LESSON CXXIV.

VARIABLE OR PERIODICAL STARS.

1. Variable stars are those which undergo a regular periodical increase and diminution of lustre, involving, in one or two cases, a complete extinction and revival.

2. One of the most remarkable of these is the star *Omicron* in the Whale. It appears about twelve times in eleven years, remains at its greatest brightness about a fortnight, being then, on some occasions, equal to a large star of the second magnitude. It then decreases for about three months, when it disappears. In about five months it becomes visible again, and continues to increase during the remaining three months of its period.

3. Another remarkable periodic star is that called *Algol*, in the constellation Perseus. It is usually visible as a star of the second magnitude, and such it continues for the space of 2 days 14 hours, when it suddenly begins to diminish in splendor, and in about 3½ hours it is reduced to the fourth magnitude. It then begins again to increase, and in 3½ hours more is restored to its usual brightness, going through all its changes in 2 days 20 hours and 48 minutes, or thereabouts. There are several other variable stars, which we have not room here to mention.

4. The *cause* of these periodic variations in the brightness of some of the stars is not known. Some suppose them to be occasioned by opaque bodies revolving around them, and cutting off a portion of their light from us ; while others are of opinion that those distant suns emit less light from one of their sides than from the other, and by a revolution upon their axes present us alternately with their full and their diminished lustre.

LESSON CXXV.

TEMPORARY STARS.

1. Temporary stars are those which have appeared from time to time, in different parts of the heavens, blazing forth with extraordinary lustre, and after remaining for a while apparently immovable, have died away, and left no traces of their existence behind.

2. A star of this kind, which appeared in the year 125 B. C., led Hipparchus to draw up a catalogue of the stars, the earliest on record. In A. D. 389 a similar star appeared near the largest star in the Eagle, which, after remaining for three weeks as bright as Venus, disappeared entirely from view.

3. On the 11th of November, 1572, Tycho Brahe, a celebrated Danish astronomer, was returning in the evening from his laboratory to his dwelling-house, when he was surprised to find a group of country people gazing upon a star which he was sure did not exist half an hour before. It was then as bright as Sirius, and continued to increase till it surpassed Jupiter in brightness, and was visible at noon-day. In December of the same year it began to diminish, and in March, 1574, had entirely disappeared.

This remarkable star was in the constellation *Cassiopeia*, about 5° northeast of the star *Caph*. The place where it once shone is now a dark void!

4. "It is an extraordinary fact," says Dr. Goode, "that within the period of the last century, not less than *thirteen stars*, in different constellations, seem to have totally perished, and *ten new ones* to have been created. In many instances it is unquestionable, that the stars themselves, the supposed habitations of other kinds or orders of intelligent beings, together with the different planets by which it is probable they were surrounded, have utterly vanished; and the spots they occupied in the heavens have become blanks. What has befallen other systems, will assuredly befall our own. Of the

time and *manner* we know nothing, but the fact is incontrovertible; it is foretold by revelation; it is inscribed in the heavens; it is felt through the earth."

LESSON CXXVI.

FALLING OR SHOOTING STARS.

The subject of Shooting Stars is here introduced, not because it properly belongs here, by the laws of philosophical classification, but because the student will be more apt to look for it in this connection than in any other part of the work. We must say but little, however, as its full discussion falls not within the compass of our design.

1. Falling or Shooting Stars are not properly *stars*, of any kind, but *meteors*, within a short distance of the earth. A meteor is a fiery or luminous body flying through the atmosphere.

2. Although the number of shooting stars observable in a single night is usually small, there have been instances in which they fell in such numbers as to be denominated *Meteoric Showers*. One of these occurred November 13th, 1833. On that morning, says Professor Olmsted, from two o'clock until broad daylight, the sky being perfectly serene and cloudless, the whole heavens were lighted with a magnificent display of celestial fireworks. At times the air was filled with streaks of light, occasioned by fiery particles darting down so swiftly as to leave the impression of their light on the eye (like a match ignited and whirled before the face), and drifting to the northwest like flakes of snow driven by the wind; while, at short intervals, balls of fire, varying in size from minute points to bodies larger than Jupiter and Venus, and in a few instances as large as a full moon, descended more slowly along the arch of the sky, often leaving after them long trains of light, which were, in some instances, variegated with different prismatic colors.*

* Introduction to Astronomy, p. 282.

3. Of the *nature* of these meteors very little is known. They are supposed to descend from some point beyond the limits of our atmosphere, and to be ignited by their rapid motion, as they come in contact with it. They explode, and are resolved into small clouds, it is thought, at the height of about thirty miles above the earth.

Professor Olmsted thinks they are caused by some rare body like the tail of a comet, or the zodiacal light, falling in the way of the Earth in her annual journey around the Sun.

CHAPTER III.

OF CLUSTERS OF STARS, AND NEBULÆ.

LESSON CXXVII.

OF CLUSTERS OF STARS.

(Map 16.)

1. In surveying the concave of the heavens in a clear night, we observe here and there groups of stars, forming bright patches, as if drawn together by some cause other than casual distribution. Such are the *Pleiades* and *Hyades* in Taurus, the former of which may be seen at I, on the map. These are called *Clusters of Stars.* The constellation *Coma Berenices* is another such group, more diffused, and consisting of much larger stars. The luminous spot called the *Bee Hive*, in Cancer, is somewhat similar, but less definite, and requires a moderate telescope to resolve it into stars. In the sword-handle of Perseus, is another such spot or cluster, which requires a rather better telescope to resolve it into distinct stars.

2. There are a great number of these objects, which have been mistaken for comets, as through telescopes of

moderate power they appear like the comet of 1585, Map 15, or like small round, or oval, nebulous specks. Sir John Herschel observes that Messier has given a list of 103 objects of this sort, with which all who search for comets ought to be familiar, to avoid being misled by their similarity of appearance. That they are not comets, however, is evident from their fixedness in the heavens, and from the fact that when we come to examine them with instruments of great power, they are perceived to consist entirely of stars, crowded together so as to occupy almost a definite outline, and to run up to a blaze of light in the centre, where their condensation is usually the greatest.

3. Many of these clusters are of an exactly round figure, and convey the complete idea of a globular space filled full of stars, insulated in the heavens, and constituting in itself a family or society apart from the rest, and subject only to its own internal laws.

4. It would be a vain effort to attempt to count the stars in one of these globular clusters. They are not to be reckoned by hundreds; and on a rough calculation, grounded on the apparent intervals between them at the borders, and the angular diameter of the whole group, it would appear that many clusters of this description must contain at least from ten to twenty thousand stars, compacted and wedged together in a round space, whose angular diameter does not exceed eight or ten minutes, or an area equal to a tenth part of that covered by the Moon.

5. Some of these clusters are of an irregular figure, as may be seen at J, on the map. These are generally less rich in stars, and especially less condensed towards the centre. They are also less definite in point of outline. In some of them the stars are nearly all of a size, in others, extremely different. It is no uncommon thing to find a very red star, much brighter than the rest, occupying a conspicuous situation in them.

6. It is by no means improbable that the individual stars of these clusters are suns like our own, the centres of so many distinct systems; and that their mutual dis-

tances are equal to those which separate our Sun from the nearest fixed stars. Besides, the round figure of some of these groups seems to indicate the existence of some general bond of union in the nature of an attractive force.*

7. Figure J on the map, is a representation of the cluster in Coma Berenices already referred to ; and Figure K is a magnificent cluster in Capricornus, containing more than a thousand fixed stars.

LESSON CXXVIII.

OF NEBULÆ.

(Map 16.)

1. The term *Nebulæ* is applied to those clusters of stars that are so distant as to appear only like a faint cloud or haze of light. In this sense some of the clusters heretofore described may be classed as nebulæ, and indeed it may be said of all the various kinds of nebulæ, that it is impossible to say where one species ends and another begins.

2. *Resolvable Nebulæ* are those clusters the light of whose individual stars is blended together, when seen through a common telescope, but which, when viewed through glasses of sufficient power, can be resolved into distinct stars.

3. *Irresolvable Nebulæ* are those nebulous spots which were formerly supposed to consist of vast fields of matter in a high state of rarefication, and not of distinct stars. But it is exceedingly doubtful whether any nebulæ exist which could not be resolved into stars, had we telescopes of sufficient power. The following remarks, taken from a lecture recently delivered in Dublin, by Dr. Scoresby, in relation to the powers of Lord Rosse's mammoth telescope, will reflect light upon the subject under consideration. "About the close of last year, the Earl of Rosse

* Herschel's Treatise.

succeeded in getting his great telescope into complete operation, and during the first month of his observations on fifty of the unresolvable nebulæ, he succeeded in ascertaining that forty-three of them were already resolvable into masses of stars. Thus is confirmed the opinion, that we have only to increase the powers of the instrument to resolve all the nebulæ into stars, and the grand nebular hypothesis of La Place into a splendid astronomical dream."

Figure L on the map is a representation of the great nebulæ in Andromeda, generally considered as irresolvable. It resembles a comet, and may be seen under favorable circumstances by the naked eye, like a small faint cloud. The stars seen within its limits are supposed to be *beyond* it, and consequently seen through it.

4. Nebulæ are again distinguished as *Single* and *Double Nebulæ.* The former consist of one cluster standing alone, while in the latter case two or more seem to be united, or in a state of near proximity, as in Figure M. Of the Double Nebulæ there is almost every possible variety of form and proportionate magnitude. The specimen given is a representation of the double nebulæ in the Greyhound.

5. Figure N is a representation of what are called *Hollow Nebulæ.* This specimen may be found in the constellation Sagittarius.

6. *Stellar Nebulæ,* or *Nebulous Stars,* are such as present the appearance of a thin cloud with a bright star in or near the centre. They are round or oval shaped, and look like a star with a burr around it, or a candle shining through horn. Figures O and P on the map are specimens of this class. O is in Cancer, and P in Gemini.

7. The *Sun* is considered by astronomers as belonging to this class of nebulous stars, and the *Zodiacal Light,* of which we have spoken in Lesson CVI, has been regarded as of the nature of the gaseous matter with which the nebulous stars are surrounded. It is supposed that if we were as far from the Sun as we are from the Stellar Nebulæ, he would appear to us only as a small and nebulous star!

8. *Planetary Nebulæ*, says Dr. Herschel, are very extraordinary objects. They have, as their name imports, exactly the appearance of planets; round or slightly oval discs, in some instances quite sharply terminated, in others a little hazy at the borders, and of a light exactly equable or only a very little mottled, which, in some of them, approaches in vividness to that of the actual planets. Whatever be their nature, they must be of enormous magnitude. Granting these objects to be equally distant from us with the stars, their real dimensions must be such as would fill, on the lowest computation, the whole orbit of Herschel.

Figure Q on the Map, is intended as a specimen of Planetary Nebulæ, though, it must be confessed, it is not easy to get up a very striking resemblance.

9. *Annular Nebulæ* also exist, but are seldom to be met with. The most conspicuous of this class is to be found exactly half-way between *Beta* and *Gamma*, in the Lyre, and may be seen with a telescope of moderate power. It is small, and particularly well defined, so as in fact to have much more the appearance of a flat oval solid ring than of a nebula. The space within the ring is filled with a faint hazy light, uniformly spread over it, like a fine gauze stretched over a hoop.*

10. Figure R is a representation of a very remarkable nebula in the head of the Greyhound, about six degrees below *Mizar*, the middle star in the tail of the Great Bear. It consists of a large and bright globular nebula surrounded by a double ring, at a considerable distance from the globe, or rather a single ring divided through about two fifths of its circumference, and having one portion, as it were, turned up out of the plane of the rest. A faint nebulous atmosphere, and a small round nebula near it, like a satellite, completes the figure.

11. Figure S is another remarkable nebulæ in the constellation of the Fox. The two round spots about the foci of the ellipse or oval, exhibit but a faint and dusky light, while the portions about the ends of the transverse axis are remarkably bright and uniform.

* Sir J. Herschel.

12. Figure T represents a wonderful nebula in the Milky Way. Its form is fantastic, and it has several openings, through which, as through a window, we seem to get a glimpse of other heavens, and brighter regions beyond.

13. The *number* of nebulous bodies is unknown, perhaps we should say innumerable. They are especially abundant in the *Galaxy* or Milky Way. Sir W. Herschel arranged a catalogue showing the places of *two thousand* of these objects. They are of all shapes and sizes, and of all degrees of brightness, from the faintest milky appearance to the light of a fixed star.

14. *Star Dust* is a name given to those exceedingly faint nebulous patches that appear to be scattered about at random in the far distant heavens. They have no definite boundary, and are well represented by the *gray* portions of the map, *between* the various specimens of nebulæ. The map was printed light on purpose to furnish specimens of Star Dust, or of nebulæ so remote as to be barely visible through the best telescopes. This class of nebulous appearances seems to lie in the back ground, far beyond others that are more distinctly visible.

By placing the learner at a proper distance from the map, the idea we wish to convey will be readily understood.

15. This map may be used to very good advantage to illustrate the uses and powers of the telescope, in resolving nebulæ into stars. Place the pupil at the distance of from fifteen to twenty feet, according to the strength of the light, so that he will see the clusters J and K only as faint cloudy patches. Let him then make what he may call a telescope of low power, by rolling up a sheet of paper, and looking through the tube thus formed. Shutting the surrounding light from his eye will enable him to see the nebulous spots far more distinctly. Then, instead of a telescope of higher power, let him approach half way to the map, and look again through his paper tube. If the light is good, J and K will be mostly resolved into stars. By approaching still nearer, more stars will be seen where it appeared nebu-

lous before, and at length the *Star Dust* will be seen lying beyond the more distinct nebulæ, in remote regions of space.

It must not be supposed, however, that barely shutting the surrounding light from the eye is the principle upon which the telescope reveals objects otherwise invisible; the object in these exercises is merely to show that as the nearer we are to an object the more distinct the vision, so the better the telescope (an instrument which seems to bring objects towards us) the more perfect the view we have of the different kinds of nebulæ, and the more likely they are to be resolved into distinct stars.

16. The nebulæ, says Sir John Herschel, furnish in every point of view an inexhaustible field of speculation and conjecture. That by far a larger share of them consist of stars there can be little doubt; and in the interminable range of system upon system, and firmament upon firmament, which we thus catch a glimpse of, the imagination is bewildered and lost.

17. The *Milky Way* is generally regarded by astronomers as only a specimen of nebulæ, of which our Sun is one of the stars. This zone of small stars (for such it actually is) extends quite around the Solar System, as the nebulous circle of Figure R, on the map, extends around the large star in the centre. Like that circle, also, the Milky Way is divided through some part of its circuit, and has various branches and irregularities.

The vast apparent *extent* of the Galaxy, as compared with other nebulæ, is supposed to be justly attributable to its comparative *nearness*. Were we as far from the Solar System as we are from the nebulæ in the Lyre, Figure R, the Milky Way would doubtless appear as an *Annular Nebula* no longer than that. It may therefore with propriety be called "the Great Nebula of the Solar System."

But what an idea is here conveyed to the mind of the almost boundless extent of the Universe! Sir W. Herschel estimated that 50,000 stars passed the field of his telescope in the Milky Way in a single hour! And yet the space thus examined was hardly a point in this great zone in the "sun-strown firmament." The mutual distances of these innumerable orbs, are probably not less than the distance from our Sun to the nearest fixed stars, while they are each the centre of a distinct system of worlds to which they dispense light and heat.

Were the Universe limited to the Great Solar Nebula it would be impossible to conceive of its almost infinite dimensions; but when we reflect that this vast and glowing zone of suns is but one of thousands of such assemblages, which, from their remoteness, appear only as fleecy clouds hovering over the frontiers of space, we are absolutely overpowered and lost in the mighty abyss of being!

And here we leave the reader to his own reflections, barely reminding him that as productions of the GREAT CREATOR "these are but parts of his ways,"—the "workmanship of his fingers;"—that he upholds them all "by the word of his power," and that over all these worlds he presides in majesty as GREAT KING. And yet so perfect is his supervision in each, that the falling sparrow is noticed by his omniscient eye, and the very hairs of our head are numbered. While, then, we behold his Wisdom, Power, and Goodness so gloriously inscribed in the heavens—while they so loudly "declare his glory," and reveal him "in the firmament of his power," let us learn to be humble and obedient, to love and serve our Maker here, that we may be prepared for the more extended scenes of another life, and for the society of the wise and good in a world to come.

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