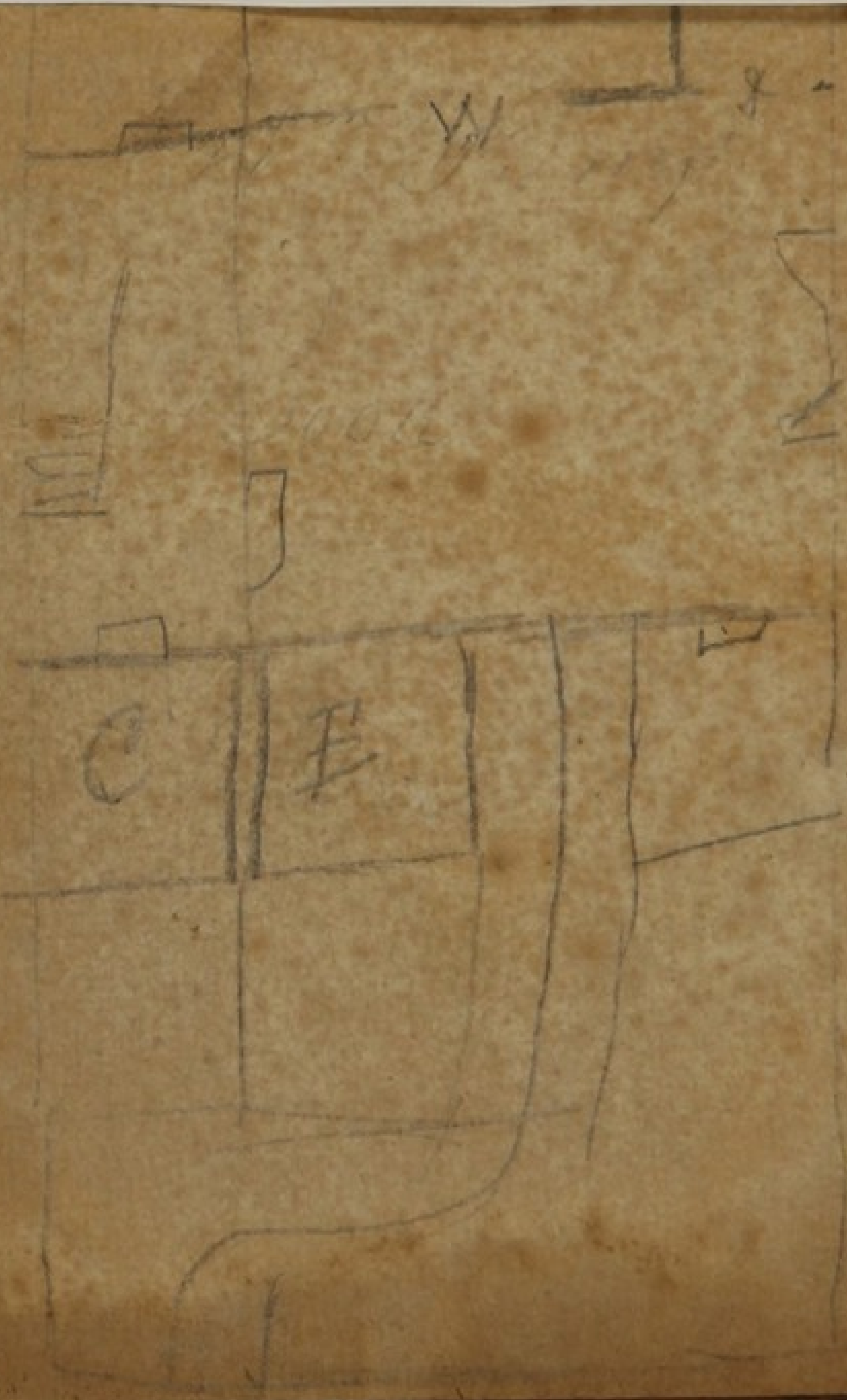
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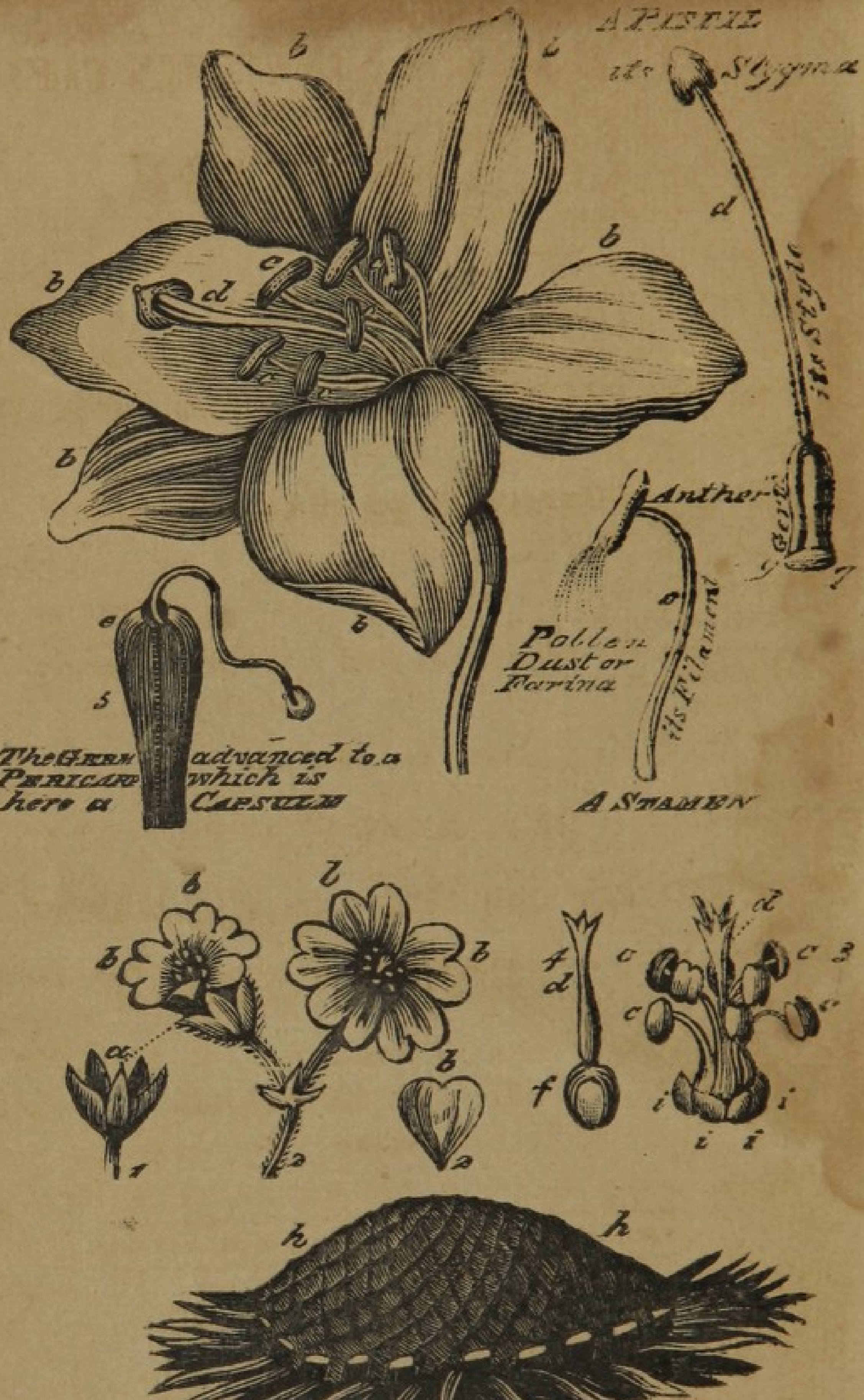
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LITERARY AND SCIENTIFIC
CLASS BOOK,

EMBRACING THE

LEADING FACTS AND PRINCIPLES OF SCIENCE.

Illustrated by Engravings,

WITH MANY DIFFICULT WORDS EXPLAINED AT THE HEADS OF THE LESSONS, AND QUESTIONS ANNEXED FOR EXAMINATION; DESIGNED AS EXERCISES FOR THE READING AND STUDY OF THE HIGHER CLASSES IN COMMON SCHOOLS.

SELECTED FROM THE

REV. JOHN PLATTS'

Literary and Scientific Class Book,

AND FROM VARIOUS OTHER SOURCES, AND ADAPTED TO THE WANTS AND CONDITION OF YOUTH IN THE UNITED STATES.

By LEVI W. LEONARD.

STEREOTYPED BY T. H. CARTER & CO. BOSTON.

Keene, N. H.

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1827.

ADVERTISEMENT.

THE following Extracts are introduced as recommendatory of the design of the Literary and Scientific Class Book.

In teaching the art of reading it is an obvious waste of the precious period, devoted to education, to confine the exercises in that art to mere combinations of words; or to compositions, the sole object of which is to prove the wit and genius of the writer;—to compositions which do not *teach* any thing, and which, after a volume of them has been perused and re-perused for years, leave the mind in a state of listless curiosity. In proof of the justice of this remark, we need only appeal to the feelings of those persons, who, while they were at school, read no other books than the selections published under the titles of Speakers, Readers, Extracts, and Beauties. As exercises in elocution, and as examples of elegant composition, such books cannot be sufficiently commended; but they are ill adapted to the more important objects of instruotion, and with regard to the purposes of general knowledge, they bear the same relation that gilding bears to gold, or pastime to useful labour.——Rev. D. Blair.

It is evident that want of time will prevent the great mass of mankind from pursuing a systematic course of education in all its details; a more summary and compendious method therefore must be pursued by them. The great majority must be content with never going beyond a certain point, and with reaching that point by the most expeditious route. A few, thus initiated in the truths of science, will no doubt push their attainments further; and for these the works in common use will suffice; but for the multitude it will be most essential that works should be prepared adapted to their circumstances...... It is not necessary that all who are taught or even a considerable proportion should go beyond the rudiments; but whoever feels within himself a desire and an aptitude to go further will do so,—and the chances of discovery, both in the arts and in science itself, will be thus indefinitely multiplied. Edinburgh Review, No. 81.

PREFACE.

THE Literary and Scientific Class Book, by the Rev. John Platts of Doncaster, England, was published in the beginning of the year 1821. "The grand object aimed at," he says in his Preface, "is, that while the pupil reads his daily lesson, he shall not only learn to pronounce words, but shall also treasure up a valuable stock of ideas, to enlarge his mind, to interest his heart, and to prepare him for his future scenes on the theatre of life."

The plan and leading title of the above-mentioned publication have been adopted in the present work, and many of the lessons have been retained either in full, or in an abridged and altered form. The notes, appendix, and engravings, have been added; and such materials have been selected from other sources as were judged best adapted to improve the hearts and enlarge the minds of youth in this country. Most of the lessons have been selected with a particular reference to the *instruction* which they contain on important branches of knowledge. Although the work is designed for the higher classes, yet it is believed that all young persons, who are able to read with facility, and are acquainted with the rudiments of arithmetic and geography, may use it with advantage.

The names of authors are given in many instances, but, in general, the quotations have been so much altered, or the same lesson taken from so many different sources, that it could not be done with convenience. The works consulted or from which extracts have been made, are noticed in the Appendix. A list of select books has been furnished for the use of those who wish to make further attainments.

Robinson's Catalogue of American Minerals, 8vo.
Locke's Outlines of Botany, 12mo.
Thornton's Elements of Botany, with 160 plates.
Eaton's Manual of Botany for the Northern and Middle States, 12mo.
Eaton's Botanical Exercises, including directions, rules, &c. 12mo.
Davy's Agricultural Chemistry, 12mo.
Brown's Compendium of Agriculture, 12mo.
Dean's New England Farmer, or Georgical Dictionary, 8vo.
Willich's Domestic Encyclopædia, edited by Dr. Cooper, 3 vols. 8vo.
Benjamin's Rudiments of Architecture, 8vo.
Cabinet Maker's Guide.
Gregory's Economy of Nature, 3 vols. 8vo.
Buffon's Natural History, 2 vols. 8vo.
Paley's Natural Theology, 12mo.
Harris' Natural History of the Bible, 8vo.
Harlan's Description of the Mammiferous Animals of North America, 8vo.
Bewick's Quadrupeds, 1 vol. 8vo.
Kirby and Spence's Introduction to Entomology, 2 vols. 8vo.
Worcester's Sketches of the Earth and its inhabitants, 2 vols. 12mo.
Malte-Brun's Universal Geography, or description of all parts of the world on a new Plan, 7 vols. 8vo.
Bingley's Useful Knowledge, 3 vols. 12mo.
Bigland's Letters on the Study of History, 8vo.
Tytler's Elements of History, Ancient and Modern, 12mo.
History of New England by Hannah Adams, 8vo.
History of England, abridged from Hume and Smollet, by J. Robinson, D. D.
Paley's Moral and Political Philosophy, 8vo.
Baker's Moral Philosophy, abridged from Paley, 18mo.
Parkhurst's Elements of Moral Philosophy, 12mo.
Smith's Wealth of Nations, 2 vols. 8vo.
The Federalist, by Madison, Jay, and Hamilton, 8vo.
Say's Treatise on Political Economy, 8vo.
The American Journal of Science and Arts. New-Haven.
The Boston Journal of Philosophy and the Arts.
New Edinburgh Encyclopædia, edited by Dr. Brewster.

CONTENTS.

THE

LITERARY AND SCIENTIFIC CLASS BOOK.

LESSON 1.

Intellectual Pleasures.

Evolv'ed, unfolded, unrolled, thrown out,
Transcen'dent, excellent, surpassing others.

WHEN we think of what man *is*, not in his faculties only, but in his intellectual acquisitions, and of what he must have been, on his entrance into the world, it is difficult for us to regard this knowledge and absolute ignorance as states of the same mind. It seems to us almost as if we had to consider a spiritual creation or transformation, as wondrous as if, in contemplating the material universe, we were to strive to think of the whole system of suns and planets, as evolved from a mere particle of matter, or rising from nothing, as when originally created. We believe that *they* were so created, and we know that *man*, comprehensive as his acquirements are, must have set out in his intellectual career from absolute ignorance; but how difficult is it for us to form any accurate conception of what we thus undoubtingly believe! The mind, which is enriched with as many sciences as there are classes of existing things in the universe, which our organs are able to discern—the mind, which is skilled in all the languages of all the civilized nations of the globe, and which has fixed and treasured in its own remembrance, the beauties of every work of transcendent genius, which age after age has added to the stores of antiquity—*this mind*, we know well, was once as ignorant as the dullest and feeblest of those minds, which scarcely know enough, even to wonder at its superiority.

That pleasure attends the sublime operations of intellect in the discovery of truth, or the splendid creations of fancy, or the various arts to which science and imagination are subservient, every one will readily admit, to whom these operations are familiar. But the great masters in science and art are few, and the pleasure which they feel in their noblest inventions, therefore, would be but a slight element in the sum of human happiness. The joy, however, is not confined to those, who have the pride of contemplating these great results as *their own.* It exists to all who have the humbler capacity of contemplating them merely as results of human genius. It is delightful to *learn,* though another may have been the discoverer; and perhaps the pleasure which a mind truly ardent for knowledge, feels in those early years, in which the new world of science is opened, as it were to its view, and every step, and almost every glance affords some new accession of admiration and power, may not be surpassed even by the pleasure which it is afterwards to feel, when it is not to be the receiver of the wisdom of others, but itself the enlightener of the wise.—Brown.

Call now to mind what high, capacious powers
Lie folded up in man; how far beyond
The praise of mortals, may the eternal growth
Of nature to perfection half divine,
Expand the blooming soul: what pity then
Should sloth's unkindly fogs depress to earth
Her tender blossom; choke the streams of life,
And blast her spring! far otherwise designed
Almighty wisdom; nature's happy cares
The obedient heart far otherwise incline.
Witness the sprightly joy when aught unknown
Strikes the quick sense, and wakes each active power
To brisker measures; witness the neglect
Of all familiar objects, though beheld
With transport once; the fond attentive gaze
Of young astonishment; the sober zeal
Of age, commenting on prodigious things.
For such the bounteous providence of heaven,
In every breast implanting this desire
Of objects new and strange, to urge us on
With unremitted labour to pursue
Those sacred stores that wait the ripening soul,
In truth's exhaustless bosom. Akenside.

LESSON 2.

Mental Improvement.

Par′aphrase, to explain in many words.
Di′agram, delineation of a geometrical figure.

No man is obliged to learn and know every thing, for it is utterly impossible; yet all persons are under some obligation to improve their own understanding. Universal ignorance or infinite errors will overspread the mind which is neglected, and lies without cultivation. Skill in the sciences is indeed the business and profession but of a small part of mankind; but there are many others placed in such a rank in the world, as allows them much leisure and large opportunities to cultivate their reason, and enrich their minds with various knowledge.

The common duties and benefits of society, which belong to every man living, and even our necessary relations to a family, a neighbourhood, or government, oblige all persons whatsoever to use their reasoning powers upon a thousand occasions; every hour of life calls for some regular exercise of our judgment as to times and things, persons and actions; without a prudent and discreet determination in matters before us, we shall be plunged into perpetual errors in our conduct. Now that which should always be practised, must at some time be learned.

Besides, every son and daughter of Adam has a most important concern in the affairs of a life to come, and therefore it is a matter of the highest moment for every one to understand, to judge, and to reason right about the things of religion. It is vain for any to say, we have no leisure or time for it. The daily intervals of time, and vacancies from necessary labour, together with the one day in seven in the Christian world, allow sufficient opportunity for this, if men would but apply themselves to it with half so much zeal and diligence as they do to the trifles and amusements of this life; and it would turn to infinitely better account.

There are five eminent means or methods whereby the mind is improved in the knowledge of things; and these are observation, reading, instruction by lectures, conversation, and meditation, which last, in a peculiar manner, is called study.

Observation is the notice that we take of all occurrences in human life, whether they are sensible or intellectual, whether relating to persons or things, to ourselves or others. It is this that furnishes us, even from our infancy, with a rich variety of ideas and propositions, words and phrases. All those things which we see, hear or feel, which we perceive by sense or consciousness, or which we know in a direct manner, with scarce any exercise of our reflecting faculties or our reasoning powers, may be included under the general name of observation. There is no time or place, no transactions, occurrences, or engagements in life, which exclude us from this method of improving the mind.

Reading is that means of knowledge, whereby we acquaint ourselves with the affairs, actions, and thoughts of the living and the dead, in the most remote nations, and most distant ages. By reading, we learn not only the actions and sentiments of different nations and ages, but transfer to ourselves the knowledge and improvements of the most learned men, the wisest and best of mankind. It is another advantage of reading, that we may review what we have read; we may consult the page again and again, and meditate on it at successive periods in our retired hours. Unless a reader has an uncommon and most retentive memory, there is scarcely any book or chapter worth reading once that is not worthy of second perusal.

Public or private lectures are such verbal instructions as are given by a teacher while the learners attend in silence. An instructer, when he paraphrases and explains other authors, can mark out the precise point of difficulty or controversy, and unfold it. When he teaches us natural philosophy, or most parts of mathematical learning, he can convey to our senses those notions, with which he would furnish our minds. He can make the experiments before our eyes. He can describe figures and diagrams, point to the lines and angles, and by sensible means make out the demonstration in a more intelligible manner.

Conversation is that method of improving our minds, wherein by mutual discourse and inquiry we learn the sentiments of others, as well as communicate our own. By friendly conference, not only the doubts which arise in the mind upon any subject of discourse are easily proposed and solved, but the very difficulties we meet with in books and in our private studies may find a relief. A man of vast reading, without conversation, is like a miser, who lives only to himself.

Meditation or study includes all those exercises of the mind, whereby we render all the former methods useful, for our increase in true knowledge and wisdom. By meditation we fix in our memory whatsoever we learn, and form our own judgment of the truth or falsehood, the strength or weakness of what others speak or write. Neither our own observation, nor reading the works of the learned, nor attendance on the best lectures of instruction, nor enjoying the brightest conversation, can ever make a man truly knowing and wise, without the labours of his own reason in surveying, examining, and judging, concerning all subjects upon the best evidence he can acquire.—Watts.

Questions.—1. What will be the state of the mind if uncultivated? 2. To what exercise do the common duties of society oblige all persons? 3. What is the most important subject on which every one should reason correctly? 4. What are the most suitable opportunities for this duty? 5. What are the five eminent means of knowledge? 6. What is observation? 7. Reading? 8. What are lectures? 9. What is included in meditation or study? 10. What are some of the advantages of each of these five means of knowledge?

LESSON 3.

Habit of Attentive Thought.

Grif′fin, a fabled animal.
Tal′isman, a magical character.

It is of great importance to your intellectual improvement that you should acquire the habit of attentive thought. The primary recommendation of science is its utility; and if you are really desirous of advancing in it, you will not regard the *occasional* ruggedness of a road, which is far from being *always* rugged. It may be allowed to him, who walks only for the pleasure of the moment to turn away from every path, in which he has not flowers and verdure beneath his feet, and beauty wherever he looks around. But in that knowledge which awaits your studies, in the various sciences to which your attention may be directed, you have a noble prize before you; and, therefore, you should not hesitate occasionally to put forth all the vigour of your attention, at the risk of a little temporary fatigue. It will facilitate your acquisition of a reward, which the listless exertions of the indolent can never obtain.

It is in science, or philosophy, as in many a fairy tale. The different obstacles which the hero encounters, are not progressively greater and greater; but his most difficult achievements are often at the very commencement of his career. He begins, perhaps, with attacking the castle of some enchanter, and has to force his way, unassisted, through the griffins and dragons that oppose his entrance. He finishes the adventure with the death of the magician—and strips him of some ring, or other talisman, which renders his subsequent adventures comparatively easy and secure. The habit of *attentive thought*, which the consideration of difficult subjects necessarily produces, in those who are not too indolent to give attention to them, or too indifferent to feel interest in them, is more truly valuable than any talisman, of which accident or force might deprive you. The *magic* with which this endows you, is not attached to a *ring*, or a gem, or any thing external; it lives, and lives for ever, in the very essence of your minds.—Brown.

LESSON 4.

Cultivation of Memory.

Super′fluous, unnecessary.
Cha′os, confusion. *ch* in words from the Greek sound like *k*.

Memory implies two things: first, a capacity of retaining knowledge; and, secondly, a power of recalling that knowledge to our thoughts when we have occasion to apply it to use. When we speak of a retentive memory, we use it in the former sense; when of a ready memory, in the latter. Without memory, there can be neither knowledge, arts, nor sciences; nor any improvement of mankind in virtue, or morals, or the practice of religion. Without memory, the soul of man would be but a poor, destitute, naked being, with an everlasting blank spread over it, except the fleeting ideas of the present moment.

There is one great and general direction, which belongs to the improvement of other powers as well as of the memory, and that is, to keep it always in due and proper exercise. Many acts by degrees form a habit, and thereby the capacity or power is strengthened and made more retentive and ready. Due attention and diligence to learn and know the things which we would commit to our remembrance, is a rule of great necessity. There are some persons, who complain they cannot remember what they hear, when in truth their thoughts are wandering half the time, or they hear with such coldness and indifference, and a trifling temper of spirit, that it is no wonder the things which are read or spoken make but a slight impression, and soon vanish and are lost. If we would retain a long remembrance of the things which we read or hear, we should engage our delight and pleasure in those subjects, and use proper methods to fix the attention. Sloth and idleness will no more bless the mind with intellectual riches, than they will fill the hand with gain, the field with corn, or the purse with treasure.

Some persons are conceited of their abilities, and trust so much to an acuteness of parts denominated genius, that they think it superfluous labour to make any provision beforehand, and they sit still, therefore, satisfied without endeavouring to store their understanding with knowledge. Such should remember that we are born ignorant of every thing. God has made the intellectual world harmonious and beautiful without us; but it will never come into our heads all at once; we must bring it home by degrees, and there set it up by our own industry, or we shall have nothing but darkness and chaos within, whatever order and light there may be in things without us.

Others, on the contrary, depress their own minds, despond at the first difficulty, and conclude that getting an insight in any of the sciences, or making any progress in knowledge, farther than serves their ordinary business, is above their capacities. The proper remedy here is to set the mind to work, and apply the thoughts vigorously to the business; for it holds in the struggles of the mind, as in those of war,—a persuasion that we shall overcome any difficulties that we may meet with in the sciences, seldom fails to carry us through them. Nobody knows the strength of his mind, and the force of steady and regular application, until he has tried.

All things are open to the searching eye
Of an *attentive* intellect, and bring
Their several treasures to it, and unfold
Their fabric to its scrutiny. All life,
And all inferior orders, in the waste
Of being spread before us, are to him,
Who lives in meditation, and the search
Of wisdom and of beauty, open books,
Wherein he reads the Godhead, and the ways
He works through his creation, and the links
That fasten us to all things, with a sense
Of fellowship and feeling, so that we
Look not upon a cloud, or falling leaf,
Or flower new blown, or human face divine,
But we have caught new life, and wider thrown
The door of reason open, and have stored
In memory's secret chamber, for dark years
Of age and weariness, the food of thought,
And thus extended mind, and made it young,
When the thin hair turns gray, and feeling dies.

PERCIVAL.

QUESTIONS.—1. What does memory imply? 2. What general direction is given for the improvement of memory? 3. What is a rule of great necessity? 4. What is said of those who are conceited of their abilities? 5. What is the proper remedy for those who despond at difficulties?

LESSON 5.

Plan of Reading.

Specula'tion, a train of thoughts formed by meditation.
Discrimina'tion, the act of distinguishing one from another.
Desidera'ta, pl. some desirable things which are wanted.
Lab'yrinth, a place formed with inextricable windings.

THE only method of putting our acquired knowledge on a level with our original speculations, is, after making ourselves acquainted with our author's ideas, to study the subject over again in our own way; to pause, from time to time, in the course of our reading, in order to consider what we have gained; to recollect what the propositions are, which the author wishes to establish, and to examine the different proofs which he employs to support them. Such reasonings, as we have occasion frequently to apply, either in the business of life, or in the course of our studies, it is of importance to us to commit to writing, in a language and in an order of our own; and if, at any time, we find it necessary to refresh our recollection on the subject, to have recourse to our own composition, in preference to that of any other author.

That the plan of reading, commonly followed, is very different from that which is here recommended, will not be disputed. Most people read merely to pass an idle hour, or to please themselves with the idea of employment, while their indolence prevents them from any active exertion; and a considerable number with a view to the display which they are afterwards to make of their literary acquisitions. From whichsoever of these motives a person is led to the perusal of books, it is hardly possible that he can derive from them any material advantage. If he reads merely from indolence, the ideas which pass through his mind will probably leave little or no impression; if he reads from vanity, he will be more anxious to select striking particulars in the matter or expression, than to seize the spirit and scope of the author's reasoning, or to examine how far he has made any additions to the stock of useful and solid knowledge.

A proper selection of the particulars to be remembered is necessary to enable us to profit by reading. When we first enter on any new literary pursuit, we commonly find our efforts of attention painful and unsatisfactory. We have no discrimination in our curiosity, and by grasping at every thing, we fail in making those moderate acquisitions which are suited to our limited faculties. As our knowledge extends, we learn to know what particulars are likely to be of use to us, and acquire a habit of directing our examinations to these, without distracting the attention with others. It is partly owing to a similar circumstance, that most readers complain of a defect of memory, when they first enter on the study of history. They cannot separate important from trifling facts, and they find themselves unable to retain any thing from their anxiety to secure the whole.

In order to give a proper direction to our attention to the course of our studies, it is useful before engaging in any particular pursuits to acquire as familiar an acquaintance as possible with the great outlines of the different branches of science; with the most important conclusions which have hitherto been formed in them, and with the most important desiderata which remain to be supplied. By such general views alone we can prevent ourselves from being lost amidst a labyrinth of particulars, or can engage in a course of extensive and various reading, with an enlightened and discriminating attention.—STEWART.

QUESTIONS.—1. By what method may our acquired knowledge be put on a level with our original speculations? 2. What reasonings is it important to commit to writing? 3. What plan of reading is commonly followed? 4. What are its disadvantages? 5. Why should a proper selection be made of the objects of knowledge? 6. What is useful before engaging in any particular pursuits? 7. What will an acquaintance with the great outlines of science prevent?

LESSON 6.

Hymn to Science.

Scho′liast, a writer of explanatory notes.
Soph′ist, a plausible but false reasoner.

SCIENCE! thou fair effusive ray
From the great source of mental day,
Free, gen'rous, and refined,
Descend with all thy treasures fraught,
Illumine each bewilder'd thought,
And bless my lab'ring mind.

But first with thy resistless light
Disperse those phantoms from my sight,
Those mimic shades of thee,
The scholiast's learning, sophist's cant,
The visionary bigot's rant,
The monk's philosophy.

Oh! let thy powerful charm impart
The patient head, the candid heart,
Devoted to thy sway;
Which no weak passions e'er mislead,
Which still with dauntless steps proceed
Where reason points the way.

Give me to learn each secret cause;
Let numbers, figures, motion's laws,
  Reveal'd before me stand;
Then to great nature's scenes apply,
And round the globe and through the sky
  Disclose her working hand.

Next to thy nobler search resign'd
The busy restless human mind
  Through ev'ry maze pursue;
Detect perception where it lies,
Catch the ideas as they rise,
  And all their changes view.

Her secret stores bid Mem'ry tell,
Bid Fancy quit her airy cell
  In all her treasures drest;
While, prompt her sallies to control,
Reason, the judge, recalls the soul
  To truth's severest test.

Say from what simple springs began
The vast ambitious thoughts of man,
  That range beyond control,
Which seek eternity to trace,
Drive through the infinity of space,
  And strain to grasp the whole?

Then range through being's wide extent,
Let the fair scale with just ascent
  And equal steps be trod,
Till, from the dead corporeal mass,
Through each progressive rank you pass
  To instinct, reason, God!

There, Science, veil thy daring eye,
Nor dive too deep, nor soar too high,
  In the divine abyss;
To faith content thy beams to lend,
Her hopes t' assure, her steps befriend,
  And light the way to bliss.

Then downward take thy flight again,
Mix with the policies of men,
  And social Nature's ties

The plan, the genius, of each state,
Its interest and its power relate,
  Its fortunes and its rise.

Through private life pursue thy course
Trace ev'ry action to its source,
  And means and motives weigh;
Put tempers, passions, in the scale,
Mark what degrees in each prevail,
  And fix the doubtful sway.

The last, best effort of thy skill,
To form the life, and rule the will,
  Propitious Pow'r! impart;
Teach me to cool my passions' fires,
Make me the judge of my desires,
  The master of my heart.

Raise me above the vulgar breath,
Pursuit of fortune, dread of death,
  And all in life that's mean:
Still true to reason be my plan,
And let my actions speak the man,
  Through ev'ry varying scene.

Hail, queen of manners! test of truth!
Hail, charm of age, and light of youth!
  Sweet refuge of distress!
E'en business you can make polite,
Can give retirement its delight,
  Prosperity its grace.

Of pow'r, wealth, freedom, thou the cause,
Foundress of order, cities, laws,
  Of arts inventress thou!
Without thee, what were human kind!
How vast their wants, their thoughts how blind!
  Their joys how mean, how few!

Sun of the soul! thy beams unveil!
Let others spread the daring sail
  On fortune's faithless sea:
While undeluded, happier I
From the vain tumult timely fly,
  And sit in peace with thee.

LESSON 7.

Usefulness of Mathematical Studies.

Ax′ioms, maxims, self-evident propositions.
Anal′ogy, resemblance—see Hedge's or Jamieson's Logic.
Phys′ics, natural philosophy, or the doctrine of natural bodies, their various appearances, affections, motions, operations, &c.

Of all the sciences which serve to call forth the spirit of enterprise and inquiry, there is none more eminently useful than mathematics. By an early attachment to these elegant and sublime studies we acquire a habit of reasoning, and an elevation of thought, which fixes the mind, and prepares it for every other pursuit. From a few simple axioms, and evident principles, we proceed gradually to the most general propositions, and remote analogies: deducing one truth from another in a chain of argument well connected and logically pursued; which brings us at last, in the most satisfactory manner, to the conclusion, and serves as a general direction in all our inquiries after truth.

Mathematical learning is likewise equally estimable for its practical utility. Almost all the works of art and devices of man, have a dependence upon its principles, and are indebted to it for their origin and perfection. The cultivation of these admirable sciences is therefore a thing of the utmost importance, and ought to be considered as a principal part of every well regulated plan of education. They are the guide of our youth, the perfection of our reason, and the foundation of every great and noble undertaking.

Mathematics are very properly recommended as the best remedy to cure an unsteady and volatile disposition. They teach us to reason in a clear and methodical manner. They give a manly vigour to our understanding, and free us from doubt and uncertainty on the one hand, and credulity and rash presumption on the other. These studies are calculated to teach exactness and perspicuity in definition, connexion and conclusiveness in argument, carefulness in observation, patience in meditation; and from no exercises can the scholar go better prepared and disciplined to the pursuit of the higher branches of knowledge. The benefit to be derived from them is thus stated by Mr. Locke: "I have mentioned mathematics as a way to settle in the mind a habit of reasoning closely, and in train; not that I think it necessary that all men should be deep mathematicians; but that having got the way of reasoning, to which that study necessarily brings the mind, they might be able to transfer it to other parts of knowledge, as they shall have occasion."

Mathematics, according to their proper definition, constitute the science of quantity, either as subject to measure or number. They are pure and mixed. The former consider quantity abstractedly, without any regard to matter or particular bodies; the latter treat of quantity as subsisting in bodies, and consequently they are intermixed with the consideration of physics, or experimental philosophy.

KETT'S Elements of General Knowledge.

QUESTIONS.—1. What habit does an early attention to mathematical studies produce? 2. What is said of their practical utility? 3. What are they calculated to teach? 4. How is the benefit to be derived from them stated by Mr. Locke? 5. Give a definition of mathematics. 6. How do pure mathematics consider quantity? 7. Mixed?

NOTE. *Pure* mathematics are arithmetic, algebra, geometry, and fluxions: *mixed* consist chiefly of mechanics, pneumatics, hydrostatics, optics, and astronomy.

LESSON 8.

Imagination.

WE do not merely perceive objects, and conceive or remember them simply as they *were*, but we have the power of combining them in various new assemblages,—of forming at our will, with a sort of delegated omnipotence, not a single universe merely, but a *new* and *varied* universe, with every succession of our thought. The materials of which we form them are, indeed, materials that exist in every mind; but they exist in every mind only as the stones exist shapelessly in the quarry, that require little more than mechanic labour to convert them into *common* dwellings, but that rise into *palaces* and *temples* only at the command of architectural genius. This power of combining our conceptions or remembrances in new assemblages is termed imagination.

The most sublime exertions of imagination are made by the poet. But we must not conceive, merely because they are sublime, that they comprehend the whole office of imagination, or even its most important uses. It is of far more importance to mankind, as it operates in the common offices of life,—in the familiar feelings of every hour. What are all those pictures of the future, which are ever before our eyes, in the successive hopes, and fears, and designs of life, but imaginations, in which circumstances are combined that never perhaps, in the same forms and proportions, have existed in reality, and which, very probably, are never to exist but in those very hopes and fears which we have formed? The writer of romance gives secret motions and passions to the characters which he invents, and adds incident to incident in the long series of complicated action which he developes. What he does, we, too, are doing every hour;—contriving events that never are to happen,—imagining motives and passions, and thinking our little romances, of which ourselves, perhaps, are the *primary heroes*, but in the *plot* of which there is a sufficient complication of adventures of those whom we love, and those whom we dislike. Our romances of real life, though founded upon facts, are, in their principal circumstances, fictions still; and, though the fancy which they display may not be as brilliant, it is still the same in kind with that which forms and fills the history of imaginary heroes and heroines.

It is well known, from experience, that the activity and consequent improvement of imagination, depend not a little upon the character of the objects with which it is first occupied. The great, the sublime, the beautiful, the new, and the uncommon, in external nature, are not only striking and agreeable in themselves, but, by association, these qualities powerfully awaken the sensibilities of the heart, and kindle the fires of youthful imagination. If the student permit objects which are mean, low, or sensual, to usurp possession of his mind; if the books which he reads, and the studies that he pursues, are contaminated with gross ideas, he has no right to expect that this omnipotent faculty shall ever draw from the polluted treasures of his memory, any thing noble, useful, or praiseworthy; or that his name shall ever be enrolled among those who have delighted, instructed, and honoured their native land and the world at large.

By an excessive indulgence in the pleasures of imagination, the taste may acquire a fastidious refinement unsuitable to the present situation of human nature; and those intellectual and moral habits, which ought to be formed by actual experience of the world, may be gradually so accommodated to the dreams of poetry and romance, as to disqualify us for the scenes in which we are destined to act. But a well-regulated imagination is the great spring of human activity, and the principal source of human improvement. As it delights in presenting to the mind scenes and characters more perfect than those with which we are acquainted, it prevents us from ever being completely satisfied with our present condition, or with our past attainments, and engages us continually in the pursuit of some untried enjoyment, or of some ideal excellence. Destroy this faculty, and the condition of man will become as stationary as that of the brutes.

QUESTIONS.—1. What is imagination? 2. By whom are its most sublime exertions made? 3. Illustrate its operation in the common offices of life. 4. On what do the activity and improvement of imagination greatly depend? 5. What may be the consequence of an excessive indulgence in the pleasures of imagination? 6. Why is a well-regulated imagination the great spring of human activity, and source of human improvement?

LESSON 9.

Beauty and Sublimity.

Emo'tions, vivid feelings arising immediately from the consideration of objects, perceived, remembered, or imagined.

Cartoon', a painting or drawing upon several sheets of large paper pasted on canvass. The most celebrated are the cartoons of Raphael. *See* Lesson on Painting.

OUR emotions of beauty are various; and, as they gradually rise, from object to object, a sort of regular progression may be traced from the faintest beauty to the vastest sublimity. These extremes may be considered as united, by a class of intermediate feelings, for which *grandeur* might, perhaps, be a suitable term, that have more of beauty, or more of sublimity, according to their place in the scale of emotion. Let us imagine that we see before us a stream gently gliding through fields, rich with all the luxuriance of summer, overshadowed at times by the foliage that hangs over it, from bank to bank, and then suddenly sparkling in the open sunshine, as if with a still brighter current than before. Let us trace it, till it widens to a *majestic river*, of which the waters are the boundary of two flourishing empires, conveying abundance equally to each, while city succeeds city, on its populous shores, almost with the same rapidity as grove formerly succeeded grove. Let us next behold it losing itself in the immensity of the ocean, which seems to be only an expansion of itself, when there is not an object to be seen but its own wide amplitude, between the banks which it leaves, and the sun that is setting, as if in another world, in the remote horizon;—in all this course, from the *brook* to the boundless waste of waters,—if we were to trace and contemplate the whole continued progress, we should have a series of emotions. The emotions which rose, when we regarded the *narrow stream*, would be those which we class as emotions of *beauty*. The emotions which rose when we considered that infinity of waters, in which it was ultimately lost, would be of the kind which we denominate *sublimity;* and the grandeur of the river, while it was still distinguishable from the ocean, to which it was proceeding, might be viewed with feelings, to which, on the same principle of distinction, some other name or names might be given.

The same progressive series of feelings, which may thus be traced as we contemplate works of nature, is not less evident in the contemplation of works of human art, whether that art has been employed in material things, or be purely intellectual. From the cottage to the cathedral—from the simplest ballad air, to the harmony of a choral anthem—from a pastoral to an epic poem or tragedy—from a landscape to a cartoon,—in each case there is a wide interval, and you may easily perceive, that, merely by adding what seemed degree after degree, you arrive at last at emotions which have little apparent resemblance to the emotions with which the scale began.

In the moral scene the progression is equally evident. Let us suppose, for example, that in the famine of an army, a soldier divides his scanty allowance with one of his comrades, whose health is sinking under the privation. We feel in the contemplation of this action, a pleasure, which is that of moral beauty. In proportion as we imagine the famine of longer duration, or the prospect of relief less probable, the action becomes more and more morally grand and heroic. Let us next imagine, that the comrade, to whose relief the soldier makes this generous sacrifice, is one whose enmity he has formerly experienced on some interesting occasion; and the action is not *heroic* merely, it is *sublime.*

It is in the moral conduct of our fellow men, that the species of sublimity is to be found, which we most gladly recognise, as the character of that glorious nature, which we have received from God,—a character which makes us more erect in mind, than we are in stature, and enables us not to *gaze* on the heavens merely, but to lift to them our very wishes, and to imitate in some faint degree, and to admire at least, where we cannot imitate, the gracious perfection that dwells there.—Brown.

Questions.—1. What illustration is given of the emotions of beauty and sublimity which arise from contemplating the works of nature? 2. The works of human art? 3. What is the example for illustrating moral beauty and sublimity?

LESSON 10.

Taste.

Fine Arts, the arts generally distinguished by the appellation fine, are poetry, music, painting, sculpture, and engraving, with their several branches. To these may be added architecture and gardening.

The word taste has two general significations: one literal or primitive relating to corporeal sensations; the other figurative, referring to mental discernment. This metaphor would not have been so general, had there not been a conformity between *mental taste*, and that *sensitive taste* which gives us a relish of every flavour. The subject of this lesson is mental or intellectual taste.

Without the emotions of beauty and sublimity, there would be no *taste* to discern the aptitude of certain means for producing these emotions. On the other hand, without the judgment, which discerns this order, in the relations of means and ends, there would be no voluntary adaptation of the great stores of forms and sounds, and colours, for producing them,—none of those fine arts which give as much happiness as embellishment to life. Reason and good sense have so extensive an influence on all the operations and decisions of taste, that a thorough good taste may well be considered as a power, compounded of natural sensibility to beauty, and of improved understanding. Frequent exercise and curious attention to its proper objects must greatly heighten its power. Nothing is more improveable than that part of taste, which is called an ear for music. At first, the simplest and plainest compositions only are relished. Our pleasure is extended by use and practice, which teach us to relish finer melody, and by degrees enable us to enter into the intricate and compound pleasures of harmony. An eye for the beauties of painting is never acquired all at once. It is gradually formed by being conversant among pictures, and studying the works of the best masters. It is the same with respect to the beauty of composition or discourse: attention to the most approved models, study of the best authors, comparisons of lower and higher degrees of the same beauties, operate towards the refinement of taste.

In no part of nature is the pure benevolence of heaven more strikingly conspicuous than in our susceptibility of the emotions of this class. In consequence of these emotions, it is scarcely possible for us to look around, without feeling either some happiness or some consolation. Sensual pleasures soon pall, even upon the profligate, who seeks them in vain in the means which were accustomed to produce them; weary, almost to disgust, of the very pleasures which he seeks, and yet astonished that he does not find them. The labours of severer intellect, if long continued, exhaust the energy which they employ; and we cease, for a time, to be capable of thinking accurately, from the very intentness and accuracy of our thought. The pleasures of taste, however, by their variety of easy delight, are safe from the languor which attends any monotonous or severe occupation, and, instead of palling on the mind, they produce in it, with the very delight which is present, a quicker sensibility to future pleasure. Enjoyment springs from enjoyment; and if we have not some deep wretchedness within, it is scarcely possible for us, with the delightful resources which nature and art present to us, *not* to be happy, as often as we *will* to be happy.

QUESTIONS.—1. What are the two significations of the word taste? 2. What does intellectual taste discern? 3. How may a thorough good taste be considered? 4. What effect have exercise and attention upon taste? 5. What examples of this are given? 6. What is said of sensual pleasures? 7. Of the pleasures of taste?

LESSON 11.

Poetry.

THE object of the philosopher is to inform and enlighten mankind; that of the orator, to acquire an ascendant over the will of others, by bending to his own purposes their judgments, their imaginations, and their passions: but the primary and the distinguishing aim of the poet is to *please;* and the principal resource which he possesses for this purpose, is by addressing the imagination.

In poetry, we perceive every where what Akenside calls

"The charm,
That searchless nature o'er the sense of man
Diffuses,—to behold, in lifeless things
The inexpressive semblance of himself,
Of thought and passion."

The zephyrs *laugh,*—the sky *smiles,*—the forest *frowns,* —the storm and the surge *contend together,*—the solitary place not merely blossoms like the rose, but it is *glad.* All nature becomes animated. The poetic genius, like that soul of the world, by which the early philosophers accounted for all earthly changes, breathes its own spirit into every thing surrounding it.

The world is full of poetry—the air
Is living with its spirit; and the waves
Dance to the music of its melodies,
And sparkle in its brightness—earth is veiled,
And mantled with its beauty; and the walls,
That close the universe, with crystal, in,
Are eloquent with voices, that proclaim
The unseen glories of immensity.

'Tis not the chime and flow of words, that move
In measured file, and metrical array;
'Tis not the union of returning sounds,
Nor all the pleasing artifice of rhyme,
And quantity, and accent, that can give
This all-pervading spirit to the ear,
Or blend it with the movings of the soul.
'Tis a mysterious feeling, which combines
Man with the world around him, in a chain
Woven of flowers, and dipped in sweetness, till
He taste the high communion of his thoughts,
With all existences, in earth and heaven,
That meet him in the charm of grace and power.
'Tis not the noisy babbler, who displays,
In studied phrase and ornate epithet,
And rounded period, poor and vapid thoughts,
Which peep from out the cumbrous ornaments,
That overload their littleness. Its words
Are few, but deep and solemn; and they break
Fresh from the fount of feeling, and are full
Of all that passion, which, on Carmel, fired
The holy prophet, when his lips were coals,
His language winged with terror, as when bolts
Leap from the brooding tempest, armed with wrath,
Commissioned to affright us, and destroy.—PERCIVAL.

QUESTIONS.—1. What is the object of the philosopher? 2. Of the orator? 3. Of the poet? 4. What is the principal resource of the poet? 5. To what is the poetic genius compared?

LESSON 12.

Advantages of studying History.

IF we consider the knowledge of history with regard to its application, we shall find that it is eminently useful to us in three respects, namely, as it appears in a *moral*, a *political*, and a *religious* point of view.

In a moral point of view, it is beneficial to mankind at large, as the guide of their conduct. In a political---as it suggests useful expedients to those who exercise the public offices of the state; or as it enables us to form, by comparison with those who have gone before them, a just estimate of their merits. In a religious—as it teaches us to regard the Supreme Being as the governor of the universe, and sovereign disposer of all events.

The faculties of the soul are improved by exercise; and nothing is more proper to enlarge, to quicken, and to refine them, than a survey of the conduct of mankind. History supplies us with a detail of facts, and submits them to examination before we are called into active life. By observation and reflection upon others we begin an early acquaintance with human nature, extend our views of the moral world, and are enabled to acquire such a habit of discernment, and correctness of judgment, as others obtain only by experience. By meditating on the lives of sages and heroes, we exercise our virtues in a review, and prepare them for approaching action. We learn the motives, the opinions, and the passions of the men who lived before us; and the fruit of that study is a more perfect knowledge of ourselves, and a correction of our failings by their examples.

Experience and the knowledge of history reflect mutual light, and afford mutual assistance. Without the former no one can act with address and dexterity. Without the latter no one can add to the natural resources of his own mind a knowledge of those precepts and examples, which have tended to form the character and promote the glory of eminent men. History contributes to divest us of many illiberal prejudices, by enlarging our acquaintance with the world. It sets us at liberty from that blind partiality to our native country, which is a sure mark of a contracted mind, when due merit is not allowed to any other. This study likewise tends to strengthen our abhorrence of vice; and creates a relish for true greatness and solid glory. We see the hero and the philosopher represented in their proper colours; and as magnanimity, honour, integrity, and generosity, when displayed in illustrious instances, naturally make a favourable impression on our minds, our attachment to them is gradually formed. The fire of enthusiasm and of virtuous emulation is lighted, and we long to practise what we have been instructed to approve.

The love of our country naturally awakens in us a spirit of curiosity to inquire into the conduct of our ancestors, and to learn the memorable events of their history. Nothing that happened to them can be a matter of indifference to us. We are their descendants, we reap the fruits of their public and private labours, and we not only share the inheritance of their property, but derive reputation from their noble actions.

History, considered with respect to the nature of its subjects, may be divided into *general* and *particular;* and with respect to time, into *ancient* and *modern*. Ancient history commences with the creation, and extends to the reign of Charlemagne, in the year of our Lord eight hundred. Modern history, beginning with that period, reaches down to the present times. General history relates to nations and public affairs, and may be subdivided into ecclesiastical and civil, or according to some writers, into sacred and profane. Biography, memoirs, and letters, constitute particular history. Statis'tics refer to the present condition of nations. Geography and chronology are important aids, and give order, regularity, and clearness to all. KETT.

QUESTIONS.—1. What is the advantage of history in a moral point of view? 2. In a political? 3. In a religious? 4. What are the uses of history in respect to the mental faculties and the conduct of life? 5. How does history divest us of illiberal prejudices? 6. How does it tend to strengthen our abhorrence of vice, and create a relish for true greatness? 7. What is said of the history of our ancestors? 8. How may history be divided? 9. subdivided?

LESSON 13.

Philosophy.

Proposi'tion, a sentence in which any thing is affirmed or denied.
Demonstra'tion, a process of reasoning in which we perceive it to be impossible that the conclusion should not follow from the premises, or antecedent propositions.

BY philosophy we mean the knowledge of the reasons of things, in opposition to history, which is the bare knowledge of facts; or to mathematics, which is the knowledge of the quantity of things, or their measures. These three kinds of knowledge ought to be joined as much as possible. History furnishes matter, principles, and practical examinations, and mathematics complete the evidence. All arts have their peculiar philosophy, which constitutes their theory. It is to be observed, that the bare intelligence and memory of philosophical proposi'tions, without an ability to demo'nstrate them, is not philosophy, but history only. Where such propositions, however, are determinate and true, they may be usefully applied in practice, even by those who are ignorant of their demonstrations.

Philosophy discovers and teaches those principles by means of which happiness may be acquired, preserved, and increased. Wisdom applies these principles to the benefit of individuals and of society. Knowledge which is applicable to no useful purpose cannot deserve the name of wisdom. The sources of that knowledge of truth which leads to the possession of happiness are reason and revelation. To instruct men in those truths which God hath communicated to mankind by revelation, is the province of theology. To teach them such truths, connected with their happiness, as are capable of being discovered by the powers of reason, is the province of philosophy.

The leading offices of philosophy may be easily deduced from the general idea of its object. As the permanent enjoyment of real good is the end to be attained, the business of philosophy, therefore, will be to cultivate the understanding, and direct its operations; to correct and improve the will and affections; to inquire out the causes of natural appearances, and hence arrive at the knowledge of the first cause, under those characters and relations that are most interesting to mankind; to conduct men to such an acquaintance with the properties of natural bodies, and their reciprocal actions, as shall enable them to apply the objects around them to their own convenience; and, finally, to assist them in investigating the principles of social virtue, and thus provide themselves with such rules of conduct as arise from mutual convenience and interest, from the natural sentiments of justice and humanity, and from the voluntary engagements of civil society.

QUESTIONS.—1. What is meant by philosophy? 2. What three kinds of knowledge should be joined as much as possible? 3. What is the distinction between philosophy and wisdom? 4. What is the province of theology? 5. Of philosophy? 6. What are the leading offices of philosophy? NOTE. The three great objects of philosophy are *God*, *man*, and the *universe*. Philosophy is sometimes divided into three parts, intellectual, moral, and physical, or natural.

LESSON 14

The Praise of Philosophy.

But now let other themes our care engage,
  For lo, with modest yet majestic grace,
To curb imagination's lawless rage,
  And from within the cherish'd heart to brace,
Philosophy appears. The gloomy race
  By Indolence and moping Fancy bred,
Fear, Discontent, Solicitude, give place,
  And Hope and Courage brighten in their stead,
  While on the kindling soul her vital beams are shed

Then waken from long lethargy to life
  The seeds of happiness and powers of thought;
Then jarring appetites forego their strife,
  A strife by ignorance to madness wrought.
Pleasure by savage man is dearly bought
  With fell revenge, lust that defies control,
With gluttony and death. The mind untaught
  Is a dark waste, where fiends and tempests howl;
  As Phœbus to the world, is science to the soul.

And Reason now through number, time, and space,
  Darts the keen lustre of her serious eye,
And learns, from facts compared, the laws to trace,
  Whose long progression leads to Deity.
Can mortal strength presume to soar so high!
  Can mortal sight, so oft bedimm'd with tears,
Such glory bear!—for lo, the shadows fly
  From Nature's face; confusion disappears,
  And order charms the eyes, and harmony the ears

In the deep windings of the grove, no more
  The hag obscene and grisly phantom dwell;
Nor in the fall of mountain-stream, or roar
  Of winds, is heard the angry spirit's yell;
  No wizard mutters the tremendous spell,
Nor sinks convulsive in prophetic swoon;
  Nor bids the noise of drums and trumpets swell,
To ease of fancied pangs the labouring moon,
  Or chase the shade that blots the blazing orb of noon.

Many a long-lingering year, in lonely isle,
  Stunn'd with th' eternal turbulence of waves,
Lo, with dim eyes, that never learn'd to smile,
  And trembling hands, the famish'd native craves
Of Heaven his wretched fare: shivering in caves,
  Or scorch'd on rocks, he pines from day to day:
But Science gives the word; and lo, he braves
  The surge and tempest, lighted by her ray,
  And to a happier land wafts merrily away.

And even where nature loads the teeming plains
  With the full pomp of vegetable store,
  Her bounty unimproved is deadly bane:
Dark woods, and rankling wilds, from shore to shore,
Stretch their enormous gloom; which to explore
  Even Fancy trembles in her sprightliest mood;
For there, each eye-ball gleams with lust of gore,
  Nestles each murderous and each monstrous brood,
  Plague lurks in every shade, and steams from every flood.

'Twas from Philosophy man learn'd to tame
  The soil by plenty to intemperance fed.
Lo, from the echoing axe, and thundering flame,
  Poison, and Plague, and yelling Rage are fled.
The waters bursting from their slimy bed,
  Bring health and melody to every vale:
And from the breezy main, and mountain's head,
  Ceres and Flora to the sunny dale,
  To fan their glowing charms, invite the flutt'ring gale.

What dire necessities on every hand
  Our art, our strength, our fortitude require!
Of foes intestine what a numerous band
  Against this little throb of life conspire!
Yet Science can elude their fatal ire
  Awhile, and turn aside death's levell'd dart,
Sooth the sharp pang, allay the fever's fire,
  And brace the nerves once more, and cheer the heart,
  And yet a few soft nights and balmy days impart.

Nor less to regulate man's moral frame
  Science exerts her all-composing sway.
Flutters thy breast with fear, or pants for fame,
  Or pines, to Indolence and Spleen a prey,

Or Avarice, a fiend more fierce than they?
Flee to the shade of Academus' grove;
Where Cares molest not, Discord melts away
In harmony, and the pure passions prove
How sweet the words of Truth breathed from the lips of Love.

What cannot Art and Industry perform,
When Science plans the progress of their toil!
They smile at penury, disease, and storm;
And oceans from their mighty mounds recoil.
When tyrants scourge, or demagogues embroil
A land, or when the rabble's headlong rage
Order transforms to anarchy and spoil,
Deep-versed in man, the philosophic sage
Prepares with lenient hand their frenzy to assuage.

'Tis he alone, whose comprehensive mind,
From situation, temper, soil, and clime
Explored, a nation's various powers can bind
And various orders, in one form sublime
Of polity, that midst the wrecks of time,
Secure shall lift its head on high, nor fear
Th' assault of foreign or domestic crime,
While public Faith, and public Love sincere,
And Industry and Law maintain their sway severe.

BEATTIE.

LESSON 15.

General Properties of Bodies.

Symmet'rical, proportionate, having parts well adapted to each other.
Cap'illary, a term applied to tubes of a very small bore, scarcely larger than to admit a hair, derived from *capillus*, the Latin word for *hair*.

WHEN we speak of bodies, we mean substances, of whatever nature, whether solid or fluid; and matter is the general term used to denote the substance of which the different bodies are composed. As we do not suppose any body to exist without certain properties, such as impenetrability, extension, figure, divisibility, inertness, and attraction, these, therefore, are called the general properties of bodies.

By *impenetrability*, is meant the property which bodies have of occupying a certain space, so that, where one body is, another cannot be, without displacing the former; for two bodies cannot exist in the same place at the same time. A liquid may be more easily removed than a solid body; yet it is not the less substantial, since it is as impossible for a liquid and a solid to occupy the same space at the same time, as for two solid bodies to do so. If some water be put into a tube closed at one end, and a piece of wood be inserted that accurately fits the inside of the tube, it will be impossible to force the wood to the bottom, unless the water is first taken away. The air is a fluid differing in its nature from liquids, but not less impenetrable. If you endeavour to fill a phial by immersing it in water, the air will rush out in bubbles in order to make way for the water; and if you reverse the phial, and plunge it perpendicularly into the water, so that the air will not be able to escape, the water will not fill it, though it will rise a little, because it compresses the air into a smaller space in the upper part of the glass.

A body which occupies a certain space must necessarily have *extension;* that is to say, length, breadth, and depth. These are called the dimensions of extension, and we cannot form an idea of any body without them. The limits of extension are called *figure* or shape. A body having length, breadth, and depth, cannot be without form, either symmetrical or irregular; and this property admits of almost an infinite variety. The natural form of mineral substances is that of crystals; many of them are very beautiful, and not less remarkable for their transparency and colour, than for their perfect regularity, as may be seen in the various museums and collections of natural history. The vegetable and animal creation appears less symmetrical, but is still more diversified in figure than the mineral kingdom. Manufactured substances assume the various arbitrary forms which the art of man designs for them.

Divisibility is that property of matter, by which its parts may be divided and separated from each other; and of this division there can be no end. We can never conceive of a particle of matter so small as not to have an upper and under surface, which might be separated, if we had instruments fine enough for the purpose. A grain of gold may be hammered by the gold-beaters to such a degree of fineness, that the two millionth part of it may be seen by the naked eye; and by the help of a microscope the fifty millionth part will be visible. There are animals, it is said, so small that a single grain of sand is larger than four millions of them. But the *natural* divisions of matter are still more wonderful. The fragrance of a body is a part of the body itself, and is produced by very minute particles or exhalations which escape from it. How inconceivably small must be the odoriferous particles of a carnation, which diffuse themselves through a whole garden, so that, in every part of it, its fragrance is perceptible!

The word *inertness* expresses the resistance which inactive matter makes to a change of state. It requires some external force to put a body which is at rest in motion; and an exertion of strength is also requisite to stop a body which is already in motion. If a ball were fired from a cannon with a certain velocity, and there were no resistance from the air, it would circulate round the earth perpetually, and never come to a state of rest. In this manner the moon goes round the earth.

By *attraction* is meant the tendency that bodies have to approach each other, whatever be the cause of such tendency. All bodies are composed of infinitely small particles of matter, each of which possesses the power of attracting or drawing towards itself any other particle, and of uniting with it, when sufficiently near to be within the influence of its attraction; but in minute particles this power extends to so very small a distance around them that its effect is not sensible, unless they are, or at least appear to be, in contact. It then makes them adhere together, and is hence called the *attraction of cohesion.* It is by this principle that bodies preserve their forms, and are prevented from falling to pieces. The cohesive attraction of solids is much greater than that of fluids; and in elastic fluids, such as air, there is no cohesive attraction among the particles, and the utmost efforts of human art have proved ineffectual in the attempt to compress them, so as to bring them within the sphere of each other's attraction, and make them cohere. If two polished plates of marble, or of brass be but together with a little oil between them to fill up the pores in their surfaces, they will cohere so powerfully as to require a very considerable force to separate them. Two globules of quicksilver, placed very near to each other, will run together, and drops of water will do the same. The ascent of water and other liquids in sugar, sponge, and all porous bodies is a species of this attraction, and is called *capillary attraction.*

Some bodies appear to possess a power which is the reverse of the attraction of cohesion. It is called *repulsion,* and is supposed to extend to a small distance around bodies, so as to prevent them from coming into actual contact. Water repels most bodies till they are wet. A small needle carefully placed on water will float. The drops of dew which appear in the morning on plants assume a globular form, from the mutual attraction between the particles of water; and upon examination it will be found that the drops do not touch the leaves, for they roll off in compact bodies, which would not be the case if there existed any degree of attraction between the water and the leaf. The repelling force between water and oil is so great that it is impossible to *mix* them in such a manner that they shall not separate again.

QUESTIONS.—1. What is matter? 2. What are the general properties of bodies? 3. What is impenetrability? 4. By what experiments is this property of matter illustrated? 5. Define extension and figure. 6. What is divisibility, and how illustrated? 7. Define inertness? 8. What is meant by attraction? 9. Attraction of cohesion? 10. What is said of the attraction of solids and fluids? 11. What experiments illustrate cohesive attraction? 12. What is capillary attraction? 13. What is repulsion, and by what experiments illustrated.

LESSON 16.

Attraction of Gravitation.

Rectilin'ear, consisting of right or straight lines.
Curvilin'ear, consisting of crooked, or curved lines.
Projec'tile, a body put in motion.
Evaga'tion, a wandering deviation.
Phenom'enon, (pl. phenomena) appearance, commonly expressive of some remarkable appearance in nature.

The attraction of gravitation is only a modification of the attraction of cohesion. The latter is not perceptible but in very minute particles, and at very small distances, the other acts on the largest bodies, and extends to immense distances.

> That very law which moulds a tear,
> And bids it trickle from its source,
> That law preserves the earth a sphere,
> And guides the planets in their course.—ROGERS.

The tendency which bodies have to fall is produced entirely by the attraction of the earth; for the earth is so much larger than any body, on its surface, that it forces every body, which is not supported, to fall upon it. The following simple incident led to the most extensive and complicated calculations, and was productive of the most noble and wonderful discoveries. Newton happening one day, in the year 1666, when only twenty-five years of age, to be sitting under an apple-tree, and an apple falling upon his head, it suggested a variety of reflections. The phenomena of falling bodies in particular engaged his attention; and, extending his researches to the heavens, he began to investigate the nature of motion in general. Because there is motion, he reasoned, there must be a force that produces it. But what is this force? That a body when left to itself, will fall to the ground, is known to the most ignorant; but if you ask them the reason of its thus falling, they will think you either an idiot or a madman. The circumstance is too common to excite their wonder, although it is so embarrassing to philosophers, that they think it almost inexplicable. It is the mark of a superior genius to find matter for wonder, observation, and research, in circumstances which to the ordinary mind appear trivial, because they are common, and with which they are satisfied, because they are natural, without reflecting that nature is our grand field of observation, that within it is contained our whole store of knowledge; in a word, that to study the works of nature, is to learn to appreciate and admire the wisdom of God.

In applying his reflections on the nature of falling bodies to the celestial motions, Newton soon perceived that the force of gravity was not confined to the surface of our globe; it being found to act alike at the bottom of the lowest valleys, and at the summit of the most lofty mountains. This led him to conjecture, that it might extend as far as the moon, and be the means of retaining her in her orbit. Imagine the moon, he reasoned, at the first moment of its creation, to have been projected forward, with a certain velocity, in a rectilinear direction; then, as soon as it began to move, gravity would act upon it, and impel it toward the centre of the earth. But as a body, impelled by two forces, will follow the direction of neither, the moon, so circumstanced, would neither proceed directly forward, nor fall directly downward, but keep a middle course, and move round the earth in a curvilinear orbit. This may be more fully illustrated, by attending to the motion of a shot, or any other projectile. A ball, shot from the mouth of a cannon, in a horizontal direction, does not fall to the ground till it has proceeded to a considerable distance; and if it be discharged from the top of a high mountain, it will fly still further before it comes to the earth. Increase the force and the height, and the distance will be augmented accordingly. And thus, in imagination at least, we can suppose the ball to be discharged with such velocity, that it will never come to the ground, but return to the place whence it set out, and circulate continually round the earth, in the manner of a little moon. Thus proceeding in his reflections, Newton discovered the admirable provision of the great Creator to prevent the evagation of the planets, and to retain them exactly within the bounds of their orbits. This he has demonstrated to be effected by gravity, and that gravity and motion completely solve all the phenomena of the planetary revolutions, both primary and secondary. By establishing this one principle in philosophy he has fully explained the system of the world, so far as it relates to this globe, and to all the rest of the planets that regard the sun as their centre. Such is the Newtonian system of universal gravitation or attraction. But what is this principle, which gives life and motion to inanimate beings, and how does it act? The effects are visible, but the agent that produces them is hidden from our senses. It eluded the search of Newton himself; he that soared to the utmost regions of space, and looked through nature with the eye of an eagle, was unable to discover it. This principle of gravitation, has been styled "The constant impression of Divine power;"—in every other sense the cause is likely to continue unexplored by man. It is, however, pretty generally agreed that the same principle of gravity, by which we see all bodies tend toward the centre of the earth, is a general law of nature, extended to all distances, and to every body, or substance, in the universe.

For this the moon thro' heaven's blue concave glides,
And into motion charms th' expanding tides,
While earth impetuous round her axle rolls,
Exalts her wat'ry zone, and sinks the poles.—FALCONER.

QUESTIONS.—1. What is the attraction of gravitation? 2. How is the tendency of bodies to fall produced? 3. What incident led Newton to the most wonderful discoveries? 4. How did he reason? 5. What is considered the mark of a superior genius? 6. What did Newton soon perceive respecting the force of gravity? 7. What did this lead him to conjecture? 8. How did he reason respecting the moon? 9. What has this principle of gravitation been styled? 10. What did Newton fully explain by it?

LESSON 17.

Centre of Gravity.

Perpendic'ularly, in the direction of a straight line up and down.
Pyr'amid, a pillar ending in a point.

THE centre of gravity of a body is that point about which all its parts, in any situation exactly balance each other, so that if a body be suspended or supported by this point, it will rest in any position. Whatever supports the centre of gravity bears the weight of the whole body; and while it is supported the body cannot fall. We may consider, therefore, the whole weight of a body as centered in this point. If a line is drawn from the centre of gravity of a body, perpendicularly to the horizon, it is called the *line of direction;* because it is the line which the centre of gravity would describe, if the body fell freely. The broader the base is upon which a body rests, the more difficult it will be to overturn it, as it must be moved the more to bring the line of direction beyond the base. A cask is easily rolled along, and so is a ball, but a box is moved with greater difficulty. When a box is longer than it is broad, it is much more easily turned on its side than set on its end. A building in the form of a pyramid is the most durable, because, as it becomes narrower and narrower as it ascends, each stone or brick is supported by those below. The pyramids of Egypt, both great and small, still remain, and without doubt will do so for thousands of years to come, while the vast temples are crumbling into ruin. In building, care is taken not to bring the upper rows of bricks beyond those below, and for this purpose a line and plummet are used. But it does not follow, because a building leans, that the centre of gravity does not fall within the base. There is a high tower at Pisa, a town in Italy, which leans fifteen feet out of a perpendicular direction; strangers tremble to pass by it, still it is found by experiment that the line of direction falls within the base, and therefore it will stand while its materials hold together.

The higher the centre of gravity is, the more easily may a body be overturned. Hence, a wagon or cart with a high load is more in danger of being overturned than one with a heavy load laid lower. This proves the injurious effect of rising in a coach or boat in danger of oversetting, the centre of gravity being thereby raised, and the line of direction thrown out of the base. In such circumstances the proper course is to lie down in the bottom, so as to bring the line of direction, and consequently the centre of gravity, within the base, and thus remove the danger of oversetting. Rope-dancers perform astonishing feats by the assistance of a long pole with very weighty pieces of lead at each end, by which they balance themselves and recover firm footing, if likely to fall on either side. In our ordinary actions we regulate the motions of our bodies, as if we were most correctly studying the nature and effects of the centre of gravity. If a man wishes to rise from a chair, he throws his body forward. If he is likely to fall on one side he leans to the other. A correct knowledge of the centre of gravity in bodies is of the utmost importance in the science of mechanics, as well as in many of the common actions of life.

QUESTIONS.—1 What is the centre of gravity? 2. The line of direction? 3. When does a body stand most firmly? 4. Why is a pyramid the most durable form of building? 5. What occasions a body to be easily overturned? 6. What is the proper course when a coach or boat is in danger of oversetting? 7. On what principle do we regulate our ordinary actions? 8. Show by fig. 12. the common centre of gravity of two bodies. 9. Illustrate by fig. 4. the overturning of a body, when the line of direction falls out of the base.

LESSON 18.

The Laws of Motion.

Momen'tum, (pl. momenta) the force acquired by different masses of matter moving with different velocities. A body, *twice* the weight of another, moving with *equal* velocity, will strike with *twice* the momentum,—with *twice* the velocity, with *four times* the momentum,—with *three times* the velocity, with *six times* the momentum, and so on.

A BODY is in motion whenever it is changing its situation with regard to a fixed point, and the cause which produces motion is called *force*. The causes of motion, or the motive powers are either muscular, as the action of men and other animals, or mechanical, as the force of wind, water, gravity, the pressure of the atmosphere or any elastic medium, and steam. The motion of a body acted upon by a single force is always in a straight line, in the direction in which it received the impulse; and the degree of quickness with which it moves, or the *velocity*, must be proportional to the force by which it is impelled. If a given force, therefore, will produce a given motion, a double force will produce the double of that motion. If a new force be impressed upon a body in motion, its motion will be increased proportionably to the new force impressed. The velocity with which a body moves is measured by the space passed over, divided by the time which it employs in that motion; for if you travel one hundred miles in twenty hours, your velocity is five miles in each hour. You may reverse this rule and say, that the time is equal to the space divided by the velocity, for one hundred divided by five gives twenty hours for the time; and you may say also that the space is equal to the velocity multiplied by the time, for twenty multiplied by five gives one hundred miles for the space.

Motion is uniform, accelerated, or retarded. *Uniform* motion is regular, and at an equal rate throughout. The hand of a watch is an example of uniform motion, for it passes over equal spaces in equal times. If neither gravity nor any other force opposed its motion, a ball thrown by the hand would proceed onwards in a right line, and with a uniform velocity for ever. Perpetual motion, however, cannot be produced by art, for gravity ultimately destroys all motion that human powers can produce. *Accelerated* motion takes place, when the motive power continues to act upon any body, so that its motion is continually increased. When a stone falls from a height, the impulse which it receives from gravity during the first instant of its fall, would be sufficient to bring it to the ground with a uniform velocity; but the stone is not acted upon by gravity merely at the first instant of its fall,—this power continues to impel it during the whole of its descent, and it is this continued impulse which accelerates its motion. It has been found by experiment that heavy bodies, descending from a height by the force of gravity, fall sixteen feet the first second of time, three times that distance in the next, five times in the third second, seven times in the fourth, and so on, regularly increasing their velocities according to the number of seconds during which the body has been falling. *Retarded* motion is that of a body which moves every moment slower and slower; and it is produced by some force acting upon a body in a direction opposite to that which first put it in motion, as when a stone is thrown upwards, its velocity is gradually diminished by the power of gravity.

The force, or power, with which a body in motion strikes against another body, is called its *momentum*. It is composed of its quantity of matter, multiplied by its quantity of motion; or in other words, its weight and its velocity. A small body may have a greater momentum than a large one, provided its velocity be sufficiently greater; the momentum of an arrow shot from a bow, for instance, must be greater than a stone thrown by the hand. The momentum of bodies is one of the most important points in mechanics; for you will find, that it is from opposing motion to matter, that machines derive their powers.

When a body in motion strikes against another body, it meets with resistance from it; and the resistance of the body at rest will be equal to the blow struck by the body in motion; or to express the same in philosophical language, *action* and *re-action* will be equal and in opposite directions. It appears, therefore, that one body acting upon another, loses as much motion as it communicates, and that the sum of the motions of any two bodies in the same line of direction, cannot be changed by their mutual action. From the action and re-action of bodies we may learn in what manner a bird, by the stroke of its wings, is able to support its weight in the air. If the force with which it strikes the air below it, is equal to the weight of its body, then the re-action of the air upwards is likewise equal to it, and the bird being acted upon by two equal forces in contrary directions, will rest between them. If the force of the stroke is greater than its weight, the bird will rise with the difference of these two forces; and if the stroke be less than its weight, then it will sink with the difference. In the act of rowing, the water is struck with the oars, in a direction opposite to that in which the boat is required to move; and the boat is driven along by the reaction of the water on the oars.

Questions.—1. When is a body in motion? 2. What is force? 3. What are the motive powers? 4. In what direction is the motion of a body acted upon by a single force? 5. What is velocity? 6. To what is the velocity of a moving body proportioned? 7. How do you calculate the velocity of a moving body? 8. What is uniform motion? 9. Accelerated? 10. Retarded? 11. Why cannot perpetual motion be produced by art? 12. When a stone falls from a height, how does gravity accelerate its motion? 13. What is said of the distances through which heavy bodies fall in successive seconds of time? 14. What is an instance of retarded motion? 15. What is the momentum of a body? 16. Of what composed? 17. Why is it so important with respect to mechanics? 18. What is meant by the term reaction? 19. To what is reaction equal? 20. Explain the manner in which birds support themselves in the air.

LESSON 19.

Compound Motion.

Projec'tile, impelled forward in a right line.
Horizon'tal, parallel to the horizon, on a level.
Oblique', not direct, not perpendicular, not parallel.

If a body be struck by two equal forces in opposite directions, it will not move at all; but if the forces, instead of acting on the body in opposition, strike it in two directions inclined to each other, it will follow the direction of neither of the forces, but will move in a line between them. There are many instances in nature, of motion produced by several powers acting at the same time. If a ship at sea sail before the wind directly east, and a current set from the north, it will be driven in a direction between the south and east.

A ball fired from a cannon is acted upon by two forces, the one is that occasioned by the powder, the other is the force of gravity.

Circular motion is the result of two forces on a body, by one of which it is projected forward in a right line, whilst by the other it is confined to a fixed point. When you whirl a ball, for instance, which is fastened to your hand with a string, the ball moves in a circular direction; because it is acted upon by two forces, that given it by yourself, which represents the force of projection, and that of the string which confines it to your hand. If during its motion the string were suddenly to break, the ball would fly off in a straight line; being released from confinement to the fixed point, it would be acted on but by one force, and motion produced by one force is always in a right line. The force which confines a body to a centre round which it moves, is called the *centrip'etal* force; and that force which impels a body to fly from the centre, is called the *centrif'ugal* force. In circular motion these two forces constantly balance each other, otherwise the revolving body would either approach the centre, or recede from it, according as the one or the other prevailed. If any cause should destroy the centripetal force, the centrifugal force would alone impel the body, and it would fly off in a right line in the direction in which it was moving, at the instant of its release. When a stone, whirled round in a sling, gets loose, it flies off in a right line, called a *tangent,* because it *touches* the circumference of the circle in which the stone was revolving.

It is by the laws of circular motion that the moon and all the planets revolve in their orbits. The moon, for instance, has a constant tendency to the earth, by the attraction of gravitation, and it has also a tendency to proceed in a right line, by that projectile force impressed upon it by the Creator; now, by the joint action of these two forces it describes a circular motion. If the projectile force were to cease, the moon must fall to the earth; and if the force of gravity were to cease acting upon the moon, it would fly off into infinite space.

When you throw a ball in a horizontal or oblique direction, it describes a curve line in falling, and is acted upon by three forces; the force of projection, which you communicated to it; the resistance of the air, which diminishes its velocity, without changing its direction; and the force of gravity, which finally brings it to the ground. The curve line which the ball describes is called in geometry a *parab'ola*.

A pendulum consists of a line, or rod, to one end of which a weight is attached, and it is suspended by the other to a fixed point, about which it is made to vibrate. Without being put in motion, a pendulum, like a plumb line, hangs perpendicularly to the general surface of the earth, by which it is attracted; but if you raise a pendulum, gravity will bring it back to its perpendicular position. It will, however, not remain stationary there, for the velocity it has received during its descent will impel it onwards, and it will rise on the opposite side to an equal height; from thence it is brought back by its gravity, and again driven by the impulse of its velocity. Were it possible to remove the obstacles occasioned by the resistance of the air, and by the friction of the part by which it is suspended, the motion of a pendulum would be perpetual, and its vibrations perfectly regular; being of equal distances, and performed in equal times. The metallic rods of pendulums are expanded by heat and contracted by cold; clocks therefore will go faster in winter, and slower in summer, for the longer a pendulum is, the slower are its vibrations. The common remedy for this inconvenience is raising or lowering the weight of the pendulum, by means of a screw, as occasion may require. Pendulums vibrate faster towards the poles, and slowest at the equator. This is accounted for by the earth's diameter being greater through the equator than through the poles. All bodies on the earth's surface are drawn to its centre by the force of gravity; and more powerfully as the square of their distance is less. Hence, if one portion of the earth's surface be farther from its centre than another, the force of gravity on a pendulum in one place must be less than in another; and consequently the pendulum will vibrate slower or faster according to its situation. And this is found to be actually the case.

It was from observing the difference in the vibrations of pendulums of the same length, that the difference of gravity was discovered, and the true figure of the earth ascertained. Pendulums vibrating seconds, at London, are thirty-nine inches and two-tenths in length; but at the equator about thirty-nine inches and one-tenth. Pendulums of the same length vibrate in the same time however different in weight.

QUESTIONS.—1. In what direction will a body move when impelled by two forces? 2. Describe the motion of a ship as impelled by the wind and a current. 3. What is circular motion? 4. The example? 5. Centripetal force? 6. Centrifugal? 7. What is said of these two forces? 8. What is a tangent? 9. What is said of the motion of the moon? 10. What is a parabola? 11. A pendulum? 12. Describe the manner in which a pendulum vibrates. 13. Why is not the motion of a pendulum perpetual? 14. Why do clocks go faster in winter than in summer? 15. Why do pendulums vibrate faster towards the poles than at the equator?

NOTE. The centrifugal force is stronger at the equator than at the poles; and as it tends to drive bodies from the centre, it is necessarily opposed to, and must lessen the power of gravity, which attracts them towards the centre. The equatorial diameter of the earth is stated by some to be 34 miles, and by others to be 26 miles longer than the polar diameter. 16. Illustrate by figure 1. the composition and resolution of motion.

LESSON 20.

Mechanical Powers.

Centre of motion is that *point* which remains at rest while all the other parts of a body move round it.
Axis of motion is the *line* about which a revolving body moves.
Equilib'rium, equipoise, equality of weight.

THE mechanical powers are simple instruments or machines in the hands of man, by which he is enabled to raise great weights, and overcome such resistances as his natural strength could never effect without them. They are six in number, the lever, the pulley, the wheel and axle, the inclined plane, the wedge, and the screw, one or more of which enters into the composition of every machine. In order to understand the power of a machine, four things are to be considered; the power that acts, which consists in the effort of men or horses, of weights, springs, running waters, wind, and steam; the resistance which is to be overcome by the power, which is generally a weight to be moved; the centre of motion, or, as it is termed in mechanics, the fulcrum, which is the point about which all the parts of a body move; and lastly, the respective velocities of the power, and of the resistance, which must depend upon their respective distances from the axis of motion. The power and weight are said to balance each other, or to be in equilibrium, when the effort of the one to produce motion in one direction, is equal to the effort of the other to produce it in the opposite direction. The power of a machine is calculated, when it is in a state of equilibrium, that is, when the power just balances the resistance opposed, and the momentum of each is equal.

The lever is any inflexible bar of iron, wood, or other material, which serves to raise weights, while it is supported at a point by a prop or fulcrum, on which, as the centre of motion, all the other parts turn. There are three different kinds of levers. The *first* kind has the fulcrum between the weight and the power, as in steelyards and scissors. It is the most common kind, and is chiefly used for loosening large rocks; or for raising great weights to small heights, in order to place ropes under them. Let it be required to raise a body which weighs ten hundred pounds, by the strength of a man equal to a hundred pounds weight. Now as the man's strength is only equal to the tenth part of the weight of the body to be raised, the arm of the lever, to which his strength is to be applied, must be ten times as long as the other, in order that the power and weight may be in equilibrium. A balance is a lever of this kind, with equal arms; but if one arm be four times the length of the other, then it is a lever which gains power in the proportion of four to one, and a single pound weight, put into the scale which is suspended from the long arm, will balance four pounds in the other. The *second* kind of lever is when the prop is at one end, the power at the other, and the weight between them. It explains why two men carrying a burden upon a pole, may bear unequal shares according to their strength, by placing it nearer to the one than the other. He, to whom the burden is five times the nearest, will have to bear five times as much weight as the other. In the case of two horses of unequal strength the beam may be so divided, that they shall draw in proportion to their respective ability. The *third* kind of lever is when the prop is at one end, the weight at the other, and the power applied between them. To this kind are generally referred the bones of a man's arm, for when he lifts a weight by the hand, the muscle that exerts its force to raise that weight, is fixed to the bone about one-tenth part as far below the elbow as the hand is. The elbow being the centre round which the lower part of the arm turns, the muscle, therefore, must exert a force ten times as great as the weight to be raised. At first view this may appear a disadvantage, but the loss of power is compensated by the gain of velocity, and by the beauty and compactness of the limb.

QUESTIONS.—1. What are mechanical powers? 2. What four things are necessary to be considered in order to understand the power of a machine? 3. When do the power and weight balance each other? 4. What is a lever? 3. Describe the lever of the first kind. 6. What are some instances of it, and to what purposes are they applicable? 7. What is said of a balance? 8. Describe the second kind of lever. 9. What does it explain? 10. What is the third kind of lever? 11. Show how the bones of a man's arm make a lever of this kind. 12. How is the loss of power compensated? 13. Give an illustration by fig. 7. of the first kind of lever. 14. Of the second kind, by figures 9 and 5. 15. Of the third kind, by figures 10 and 2.

LESSON 21.

The Pulley, Wheel and Axle, and Inclined Plane.

THE pulley is formed by a small wheel, made of wood or metal, with a groove in its circumference, which is placed in a frame and turns on an axis. The wheel is usually called a sheeve, and is so fixed in the frame, or block, as to move round a pin passing through its centre. Pullies are of two kinds; *fixed*, which do not move out of their places; and *moveable*, which rise and fall with the weight. A single fixed pulley gives no mechanical advantage, but it is of great importance in changing the direction of power, and is much used in buildings for drawing up small weights, for a man may raise a weight to any height without the fatigue of ascending a ladder. In the single moveable pulley, the advantage gained is as two to one; that is, a power exerted by the hand of ten pounds will balance a weight of twenty pounds. In a system of pullies, the power gained must be estimated, by doubling the number of pullies in the lower or moveable block. So that when the fixed block contains two pullies which only turn on their axes, and the lower block also contains two, which not only turn on their axes, but rise with the weight, the advantage gained is as four to one. In an example of this kind, you will perceive, that by raising the weight an inch, there are four ropes shortened each an inch, and therefore the hand must have passed through four inches of space in raising the weight a single inch; which establishes the maxim, that what is gained in power is lost in space.

The next mechanical power is the wheel and axle, which consists of a cylinder, and a wheel fastened to it, or of a cylinder with projecting spokes. The power being applied at the circumference of the wheel, the weight to be raised is fastened to a rope that coils round the axle. The advantage gained is in proportion as the diameter of the wheel exceeds that of the axle. Suppose a wheel to be twelve feet diameter, and the axle one foot, the power acting at the circumference of the wheel moves over twelve times the space which the circumference of the axle does. Hence, twelve hundred weight may be raised with the power of one hundred weight. The wheel and axle may be considered as a perpetual lever, the centre of the axle being the fulcrum, half the diameter of the wheel the long arm, and half the diameter of the axle the short arm. Now, from this it is evident, that the greater the diameter of the wheel, and the smaller the diameter of the axle, the stronger is the power of this machine; but then the weight must rise slower in proportion. A useful application of the wheel and axle is the crane used on wharfs for drawing goods up from a ship. A man sets a great wheel in motion by pressing on the spokes at the rim, and the rope to which the goods are attached is wound round the axle. The wheel is sometimes put in motion by a man in the inside, who is in an upright position, and keeps walking on the bars, as if ascending stairs, which keeps the wheel revolving.

The inclined plane is nothing more than a slope, or declivity, frequently used to facilitate the drawing up of weights. The increase of the power is in the proportion of the length of the plane to its height; that is, the more the plane is lengthened, or its height shortened, the less is the resistance to be overcome. If a plane be twenty feet long, and the perpendicular height be four feet, or one-fifth of the length, then five hundred pounds would be balanced on it by one hundred, because the plane is five times the length of the perpendicular height to which the weight is to be raised. If the height be two feet, or one-tenth of the length, then fifty pounds will balance the five hundred. It is much less laborious to ascend a hill by a winding gentle ascent than to climb up a steep declivity. In addition to there being a greater force required in ascending a hill, horses, that draw a load, are placed in a position in which they can exert but a small part of their usual strength. The principle of the inclined plane is applied to the construction of carriage-ways, for the conveyance of heavy loads up steep elevations. It is applied also in rail-ways, the use of which has been hitherto confined, almost exclusively, to coal-works, and other mines. Inventions, whose only recommendations are simplicity and usefulness, are often suffered to lie long in a state of public neglect, while others of more imposing aspect are readily adopted. It has been remarked with respect to Great Britain, that the time has at length arrived, when carriages moving on level surfaces, or on gently inclining planes, with little friction, and without obstructions, are fast spreading over the face of the country.

Questions.—1. How is the pulley formed? 2. What are the two kinds of pullies? 3. What is said of the single fixed pulley? 4. What advantage is gained in a single moveable pulley? 5. How is the power gained to be estimated in a system of pullies? 6. How is this explained and what maxim does it establish? 7. Describe the wheel and axle. 8. In what proportion is advantage gained in this mechanical power? 9. What is the example? 10. Why may the wheel and axle be considered as a perpetual lever? 11. What application is made of this power? 12. What is an inclined plane? 13. In what proportion is the increase of power? 14. What is the example for illustrating this? 15. What application is made of the principle of the inclined plane? 16. What has been remarked concerning the use of rail-ways? 17. With respect to Great Britain? 18. Explain the single moveable pulley by fig. 13.—system of pullies by fig. 15. 19. Illustrate the power of the wheel and axle by fig. 11. 20. Inclined plane by fig. 8.

LESSON 22.

The Wedge and Screw.

Percus'sion, the impression a body makes in falling or striking upon another, or the shock of two bodies in motion.
Sili'ceous, flinty; see Lesson 63.

The wedge may be considered as two equally inclined planes united at their bases. The advantage gained by it is in the proportion of the slant side to half the thickness of the back; so that if the back of a wedge be two inches thick, and the side twenty inches long, any weight pressing on the back will balance twenty times as much acting on the sides. But the great use of a wedge lies in its being urged, not by pressure, but usually by percussion, as by the blow of a hammer or mallet; for the momentum of the blow is greater, beyond comparison, than the application of any dead weight, or pressure, such as is employed in the other mechanical powers. Hence it is used in splitting wood and rocks, and even a large ship may be raised to a small height by driving a wedge below it. As all instruments, which slope off to an edge on one side only, may be explained by the principle of the inclined plane; so those that decline to an edge on both sides, may be referred to the principle of the wedge. A saw is a series of wedges, on which the motion is oblique to the resistance. A knife cuts best when it is drawn across the substance which it is to divide; and the reason is, that the edge of a knife is in reality a very fine saw, and therefore acts best when used like that instrument. It is usual in separating large mill-stones from the siliceous sand-rocks, in some parts of Derbyshire, in England, to bore horizontal holes under them in a circle, and fill these with wedges made of dry wood, which gradually swell as they imbibe moisture, and in a day or two lift up the mill-stone without breaking it.

The last mechanical power is the screw, which is a kind of perpetual inclined plane, the power of which is still farther assisted by the addition of a handle or lever, where the power acts; so that the advantage gained is in proportion as the circumference of the circle, made by the handle or lever, is greater than the distance between thread and thread in the screw. The screw may be conceived to be made by cutting a piece of paper into the form of an inclined plane, and then wrapping it round a cylinder. The edge of the paper will form a spiral line round the cylinder, which will answer to the thread of the screw. With the addition of the lever, the screw forms a very powerful machine, employed either for compressions, or to raise heavy weights. It is used by book-binders to press the leaves of books together; and is the principal machine used for coining money; for taking off copper-plate prints; and for printing in general.

All machines are composed of one or more of the six mechanical powers which we have examined. Their force is diminished in a considerable degree by friction, by which is meant the resistance with which bodies meet in rubbing against each other. There is no such thing as perfect smoothness or evenness in nature: polished metals, though they wear that appearance more than any other bodies, are far from possessing it in reality, and through a good magnifying-glass their inequalities may frequently be perceived. When the surfaces of two bodies, therefore, come into contact, the prominent parts of the one will often fall into the hollow parts of the other, and occasion more or less resistance to motion. Friction is usually computed to destroy one third of the power of the machine. The application of oil lessens friction, because it acts as a polish by filling up the cavities of the rubbing surfaces, and thus making them slide over each other the more easily. There are two kinds of friction, the one occasioned by the sliding of the flat surface of a body, and the other by the rolling of a circular body. The resistance resulting from the first is much the most considerable; whilst in the latter the rough parts roll over each other with comparative facility; hence it is that wheels are often used for the sole purpose of diminishing the resistance of friction. The power of a machine is considerably affected by the resistance of the air.

In all machines what is gained in power is lost in time. If a man can raise, by a single fixed pulley, a beam to the top of a house in two minutes, he will be able to raise six such beams in twelve minutes; but with six pullies, the three lower ones being moveable, he will raise six beams with the same ease at once; but he will be six times as long about it, that is, twelve minutes, because his hand will have six times as much space to pass over. One capital advantage in the mechanical powers is, that if the six beams were in one piece, it might be raised at once, though it would be impossible to move it by the unassisted strength of a single man.

Questions.—1. What is the wedge? 2. The advantage gained by it? 3. In what does its great use lie? 4. What is said of instruments? 5. A saw? 6. A knife? 7. How are mill-stones obtained in Derbyshire? 7. What is the screw? 8. What is the advantage gained by it? 9. How may the screw be conceived to be made? 10. For what uses is it employed? 11. What is friction? 12. What part of a machine's power does friction destroy? [Note. If 60 pounds are required to balance any weight with a mechanical power, 80 pounds will be wanted to put the machine in motion.] 13. How does oil lessen friction? 14. What are the two kinds of friction? 15. How does it appear that in the pulley what is gained in power is lost in time? 16. Explain the principle of the wedge by fig. 6. 17. Of the screw by fig. 3.

LESSON 23.

The Laws of Fluids.

Hydrostat'ics, a term formed of two Greek words, which signify *water*, and the science which considers the *weight* of *bodies*, viz. *statics*.
Gas, all kinds of air differing from the atmosphere are called gas.
Cu'bical, having six square and equal sides.
Or'ifice, any opening or perforation.

A FLUID is a body, the parts of which yield to any impression, and are easily moved among each other. Philosophers have generally imagined that the particles of which fluids are composed must be exceedingly small, because with their best glasses, they have never been able to discern them. And they contend that these particles must be round and smooth, since they are so easily moved among one another. This supposition will account for many circumstances which belong to them. If they are round, there must be vacant spaces between them. If a number of cannon balls were placed in a large vessel so as to fill it up even with the edge; though it would hold no more of these balls, yet a great number of smaller shot might be placed in the vacuities between them: and when the vessel would contain no more small shot, a great quantity of sand might be shaken in, and between the pores of these, water or other fluids would readily insinuate themselves. In a similar manner, a certain quantity of particles of sugar can be taken up in water without increasing the bulk, and when the water has dissolved the sugar, salt may be dissolved in it, and yet the bulk remain the same. And this is easily accounted for, if we admit the particles of water to be round.

Fluids are either non-elastic and incompressible, as water, oil, mercury, and others, or elastic and compressible, as air, steam, and the different gases. The science which treats of the nature, gravity, pressure, and motion of fluids, in general, and of the methods of weighing solids in them, is called hydrostatics. The non-elastic fluids are said to be incompressible, not because they are absolutely so, but because their compressibility is so very small as to make no sensible difference in calculations relative to their several properties. It has been found that water will find its way through the pores of gold, rather than suffer itself to be compressed into a smaller space. At Florence, a celebrated city in Italy, a globe made of gold was filled with water, and closed so accurately that none of it could escape. The globe was then put into a press, and a little flattened at the sides: the consequence of which was, that the water came through the fine pores of the golden globe, and stood upon its surface like drops of dew. It was concluded at that time that water was incompressible. Later experiments, however, have shown, that those fluids which were esteemed incompressible, are, in a very small degree, as, perhaps, one part in twenty thousand, capable of compression.

Fluids are subject to the same laws of gravity as solids; but their want of cohesion occasions some peculiarities. The parts of a solid are so connected as to form a whole, and their weight is concentrated in a single point, called the centre of gravity; but the atoms of a fluid gravitate independently of each other. It is on this account that water always finds its level; for when any particle accidentally finds itself elevated above the rest, it is attracted down to the level of the surface, and the readiness with which water yields to the slightest impression, will enable the particle by its weight to penetrate the surface and mix with it. The particles of a fluid acting thus independently, press against each other in every direction, not only downwards but upwards, and laterally or sideways, and in consequence of this equality of pressure, every particle remains at rest in the fluid. If you agitate the fluid you disturb this equality of pressure, and it will not rest till its equilibrium or level is restored. The pressure downwards is the effect of gravity, and if there were no lateral pressure, water would not run out of an opening on the side of a vessel. The lateral pressure proceeds entirely from the downward pressure, or the weight of the liquid above; and consequently the lower an orifice is made in a vessel, the greater will be the velocity of the water rushing out of it. In a cubical vessel the pressure downwards will be double the lateral pressure on one side; for every particle at the bottom of the vessel is pressed upon by a column of the whole depth of the fluid, whilst the lateral pressure diminishes from the bottom upwards to the surface, where the particles have no pressure. The upward pressure of fluids may be shown by a machine, called the hydrostatic bellows. It consists of two oval or round boards, covered with leather so as to rise and fall like the common bellows, but without valves. A long tube is fixed to the upper board and weights placed upon it. When the tube is supplied with water, it will, by its upward pressure, sustain and lift up the weights. The pressure of water and other fluids differs from the gravity or weight, in this respect; the *weight* is according to the *quantity;* but the *pressure* is according to the *perpendicular height.* Dr. Goldsmith relates that he once saw a strong hogshead split by the following experiment. A strong small tube, made of tin, about twenty feet long, was cemented into it, and then water was poured in to fill the cask; when it was full and the water had risen nearly to the top of the tube, the vessel burst with a prodigious force. This extraordinary power may be greatly increased by a forcing piston placed in the tube. A similar method has been adopted in forming a machine, called a hydrostatic press, by which hay or cotton may be brought into a compass twenty or thirty times less than it usually occupies.

Questions.—1. What is a fluid? 2. What have philosophers generally imagined respecting the particles of fluids? 3. What illustration is given respecting the vacant spaces between the particles of fluids? 4. What are the two kinds of fluids? 5. Define Hydrostatics. 6. Why are the non-elastic fluids said to be incompressible? 7. Describe the experiment made at Florence. 8. What was concluded at the time, and what have later experiments shown? 9. What is the difference between the gravity of fluids and solids? 10. Why does water always find its level? 11. What is said of the direction in which fluids press? 12. What is the cause of the downward and lateral pressure? 13. What is said of the lateral pressure in a cubical vessel? 14. How may the downward pressure be shown? 15. How does the pressure of a fluid differ from the weight? 16. What is related by Dr. Goldsmith? 17. What is said of the hydrostatic press? 18. Illustrate the pressure of fluids by figures 25. 24. and 23. 19 What is said of what is called the hydrostatical paradox?

LESSON 24.

Specific Gravity of Bodies.

By the specific gravities of bodies we mean the relative weights, which equal bulks of different bodies have to each other. And it is usual to compare them with that of water, as it is by weighing bodies in water that their specific gravities are found. A body immersed in a fluid will sink to the bottom, if it be heavier than its bulk of fluid; if it be suspended therein, it will lose as much of what it weighed in air, as its bulk of the fluid weighs. The instrument generally used for obtaining the specific gravities is called the hydrostatical balance; it does not differ much from the common balance. The general rule for finding the specific gravity of a solid, heavier than water, as a piece of metal, is this: weigh the body first in air, in the usual way, then weigh it when it is plunged in water, and observe how much it loses of its weight in this fluid, and dividing the former weight by the loss sustained, the quotient is the specific gravity of the body, compared with that of water. As an example, it is usual to take a guinea, which weighs in air one hundred and twenty-nine grains, and when suspended by means of a fine hair, and immersed in water, it is found to balance one hundred and twenty-one grains and three-quarters, losing of its weight seven grains and a quarter; now one hundred and twenty-nine divided by seven and a quarter, gives about seventeen for the quotient; that is, the specific gravity of a guinea compared with that of water, is as about seventeen to one. And thus, any piece of gold may be tried, by weighing it first in air, and then in water; and if, upon dividing the weight in air, by the loss in water, the quotient comes to be about seventeen, the gold is good; if the quotient be eighteen, or between eighteen and nineteen, the gold is very fine; but if it be less than seventeen, the gold is too much alloyed with some other metal. The same principle is universal. Hence we see the reason why boats or other vessels float on water; they sink just so low, that the weight of the vessel, with its contents, is equal to the quantity of water which it displaces. The method of ascertaining the specific gravities of bodies, was discovered by

Archimedes, in the following manner. Hiero, king of Syracuse, having given to a workman a quantity of pure gold, of which to make a crown, suspected that the artist had kept part of the gold, and adulterated the crown with a baser metal. The king applied to Archimedes to discover the fraud. The philosopher long studied it in vain, and at length accidentally hit upon a method of verifying the king's suspicion. Going one day into a bath, he took notice that the water rose in the bath, and immediately reflected that any body, of equal bulk with himself, would have raised the water just as much; though a body of equal weight, but not of equal bulk, would not raise it so much. From this idea he conceived a mode of finding out what he so much wished, and was so transported with joy, that he ran out of the bath, crying out in the Greek tongue, "I have found it, I have found it!"

Now, since gold was the heaviest of all metals known to Archimedes, it occurred to him that it must be of less bulk, according to its weight, than any other metal; and he, therefore, desired that a mass of pure gold, equally heavy with the crown when weighed in air, should be weighed against it in water, conjecturing that if the crown was not alloyed, it would counterpoise the mass of gold when they were both immersed in water, as well as it did when they were weighed in air. But upon making trial, it was found that the mass of gold weighed much heavier in water than the crown did: nor was this all—when the mass and crown were immersed separately in the same vessel of water, the crown raised the water much higher than the mass did; which showed it to be alloyed with some lighter metal that increased its bulk. And upon this principle is the doctrine of the specific gravities of bodies founded.

Questions.—1. What is meant by the specific gravities of bodies? 2. What is said of a body immersed in a fluid? 3. What is the general rule for finding the specific gravity of a solid heavier than water? 4. What example is given? 5. How may a piece of gold be tried? 6. Why do vessels float? 7. What incident led to the method of discovering the specific gravities of bodies? 8. Who made the discovery, and how? 9. Explain the method and the result. 10. Explain by fig. 14. the use of the hydrostatic balance. 11. Describe the hydrometer.

LESSON 25.

Hydraulics.

Intermit′tent, coming by fits, not constant.
Res′ervoir, a conservatory of water ; a store.
Vac′uum, a space unoccupied by matter.

THE science of Hydraulics teaches how to estimate the velocity and force of fluids in motion. Upon the principle of this science all machines worked by water are constructed, as engines, mills, pumps, and others. Water can be set in motion by its own gravity, as when it is allowed to descend from a higher to a lower level; and by an increased pressure of the air, or by removing the pressure of the atmosphere, it will rise above its natural level. In the former case it will seek the lowest situation, and in the latter, it may be forced to almost any height.

The *syphon* is a pipe used to draw off water, wine, or other fluids, from vessels which it would be inconvenient to move from the place in which they stand. It is made of tin or copper, and bent in such a manner that one limb may reach down through the hole in the top of the vessel to be emptied, to its very bottom; the other limb should be the longest, so that when filled it may contain a heavier body of fluid than that within the vessel. The pressure of the atmosphere being taken off from that part of the surface of the liquor within the tube, the liquor rises above its natural level, and flows through the longer limb, and the contents of the vessel are drawn off to the last. There are intermittent springs in various places of the world, which have been explained on the principle of the syphon. A passage for the water may have been formed in the soil, and when the internal cavity has been filled with water, so as to begin to run off by this passage, the pressure of the atmosphere will make the water flow till all is carried off. Of course the spring then ceases until the cavity is again filled with water, when the same phenomenon is repeated. Fluids may be conveyed over hills and valleys in bent pipes, to any height which is not greater than the level of the spring whence they flow. The Romans, either from their ignorance of the pressure of fluids, or from their love of magnificence, conveyed water across valleys by straight-lined aqueducts, which were supported by immense arches or columns.

The *common pump* consists of a large tube or pipe, called the barrel, whose lower end is immersed in the water which it is designed to raise. A kind of stopper, called a piston, is fitted to this tube, and is made to slide up and down by means of a metallic or wooden rod. In the piston, there is a valve, or little door, which opening upwards, admits the water to rise through it, but prevents its returning. A similar valve is fixed in the body of the pump. When the pump is in a state of inaction, the two valves are closed by their own weight; but when the piston is made to ascend, it raises a column of air which rested upon it, and produces a vacuum between itself and the lower valve; the air beneath this valve expands and forces its way through it; and the water, relieved from the pressure of air, ascends into the pump, being forced up by the weight of the surrounding atmosphere. When the piston now descends it is forced into the water, which, as it cannot repass through the lower valve, must rise through the valve of the moveable piston, by the ascent of which, it is lifted up and runs off at the spout. There must never be so great a distance as thirty-three feet from the level of the water in the well, to the valve in the piston, for in that case, the water would not rise through the valve, because the pressure of the atmosphere will not sustain a column of water above that height. But when the water has passed the valve in the moveable piston, it is not the pressure of the air on the reservoir which makes it ascend; it is raised by lifting it up, as you would raise it in a bucket, of which the piston formed the bottom.

The *forcing pump* is not only used to raise water from a well to the surface of the earth, but likewise to force it into reservoirs on the tops of buildings, from which pipes are laid to convey it to different parts as conveniency requires. It differs from the common pump by having the upper piston solid, and a pipe joined to the barrel just above the lower piston, through which the water passes into what is termed the air vessel. In the pipe which leads to the air vessel there is a fixed valve, which opens upwards and prevents the return of the water. Through the upper part of the air vessel a tube is inserted, which reaches nearly to its bottom. Now the air which is above the water in the vessel being confined, and condensed into a smaller bulk than its natural space, presses by its elasticity upon the surface of the water, and forces it violently up the tube in a continual stream. It is upon this principle that the engine for extinguishing fires is constructed.

QUESTIONS.—1. What does the science of hydraulics teach ? 2. What machines are constructed on the principles of this science? 3. What are the different ways in which water may be set in motion ? 4. What is the syphon ? 5. Describe the manner of its conveying fluids. 6. How are intermittent springs caused ? 7. Describe the common pump and show how it raises water. 8. How high can water be raised in a common pump ? 9. Describe the forcing pump. 10. What engine is constructed on the principle of the forcing pump ? 11. Describe the common pump by fig. 21. and show its action. 12. Forcing pump by fig. 22. and show how it acts in forcing up water.

LESSON 26.

The Diving Bell, and Steam Engine.

Ver′tically, in a direction perpendicular to the horizon.
Appara′tus, utensils and appendages belonging to a machine.

IF you take a glass tumbler, and plunge it in water with the mouth downwards, you will perceive that very little water will enter into it. The air which fills the glass prevents the entrance of the water ; but as air is compressible, it cannot entirely exclude the water, which, by its pressure, condenses the air in a slight degree. Upon this simple principle machines have been invented, by which people have been able to walk about at the bottom of the sea, with as much safety as upon the surface of the earth. The original instrument of this kind was much improved by Dr. Halley, more than a century ago. The machine was made of copper in the shape of a bell. The diameter of the bottom was five feet, that of the top three feet, and it was eight feet high. To make the vessel sink vertically in water, the bottom was loaded with a quantity of leaden balls. Light was let into the bell by means of strong spherical glasses fixed in the top. Barrels, filled with fresh air, were made sufficiently heavy, and sent down, from which a leathern pipe communicated with the inside of the bell, and a tube with a stop at the upper part let out the air which had become unfit for breathing. The divers are generally let down from a ship, and taking a rope with them, to which is fixed a bell in the vessel, they have only to pull the string, and the people in the ship draw them up; but if business requires it, they will stay several hours at the bottom of the sea without the smallest difficulty. By means of a strong globular cap with circular glasses in front to give light, it has been found practicable for a diver to go out of the engine to the distance of eighty or a hundred yards, the air being conveyed to him in a continued stream by small flexible pipes. Accidents, which through carelessness have sometimes occurred, may be readily prevented, by a proper degree of attention, and people may descend to very great depths without danger. The diving bell has often been used in bringing up the goods from a vessel which has sunk in deep water, and in blowing rocks which impeded navigation.

The Steam Engine is one of the most useful, curious, and important machines that have ever been invented. It consists of a large cylinder or barrel, in which is fitted a solid piston like that of the forcing pump. Steam is supplied from a large boiler, which in forcing up the piston, instantly opens a valve, through which cold water rushes, on the principle of the common pump. Other steam is then introduced above the piston, which forces it down, and drives the water out of the pipe. Steam raises the piston again, and again makes it fall, and thus produces an alternate motion, which is communicated, by an upright iron rod, to a large beam or lever, that is lifted up and pulled down with wonderful precision and force. This regular and powerful motion is easily applied by the mechanic to all kinds of machinery. The apparatus has been varied by different persons, and for different objects; but the principle remains the same.

By the admirable contrivances of Watt and Fulton, the steam-engine has become a thing stupendous alike for its force and flexibility,—for the prodigious power which it can exert, and the ease, and precision, and ductility with which it can be varied, distributed, and applied. The trunk of an elephant, that can pick up a pin or rend an oak, is nothing to it. It can engrave a seal, and crush masses of obdurate metal before it,—draw out, without breaking, a thread as fine as gossamer, and lift up a ship of war like a bauble in the air. It can embroider muslin and forge anchors,—cut steel into ribands, and impel loaded vessels against the fury of the winds and waves. It has armed the feeble hand of man, in short, with a power to which no limits can be assigned; completed the dominion of mind over the most refractory qualities of matter; and laid a sure foundation for all those future miracles of mechanic power which are to aid and reward the labour of after generations.

QUESTIONS.—1. What is the principle of the diving bell? 2. What were the dimensions of Dr. Halley's diving bell? 3. How was light let in? 4. Fresh air? 5. How do divers make known their wish to be drawn up? 6. Of what use is this invention? 7. Describe the steam-engine.

LESSON 27.

Nature and Properties of Air.

Den′sity, the degree of closeness and compactness of the particles of a body, the property directly opposite to rarity.
Ab′solutely, completely, without restriction, positively.
Hem′isphere, half a globe, or sphere.

THE science which treats of the mechanical properties of elastic or aëriform fluids, such as their weight, density, compressibility, and elasticity, is called Pneumatics. The air in which we live surrounds the earth to a considerable height, revolves with it in its diurnal and annual motion, and, together with the clouds and vapours that float in it, is called the atmosphere. The height to which the atmosphere extends has never been ascertained; but at a greater height than forty-five miles it ceases to reflect the rays of light from the sun. The air is invisible because it is perfectly transparent; but it may be felt on moving the hand in it, or when it moves and produces what we call wind. It is nearly nine hundred times lighter than water, but the whole atmosphere presses on all sides like other fluids, upon whatever is immersed in it, and in proportion to the depths. Its pressure upon a mountain is known to be less than in the plain or valley beneath. If a glass tumbler be completely filled with water, and covered with a piece of writing paper, so as to hold it tight, and accurately even, the water will not run out although the glass be inverted and the hand removed. The weight of the water is sustained by the upward pressure of the air upon the paper.

The most essential point in which air differs from other fluids, is by its spring or elasticity, that is to say, its power of increasing or diminishing in bulk, according as it is more or less compressed. The elasticity of air differs from that of bodies in general; for when solid bodies are compressed they have an elastic power, which causes them to resume the same figure they possessed before compression: but on removing the pressure on air, it will not only resume its first bulk, but expand to an indefinite extent. With regard to animal and vegetable bodies, the gravity of the air is destroyed by its elasticity. It is true, that the atmosphere presses with a weight of fifteen pounds upon every square inch of the earth's surface, when the air is heaviest, and that consequently a man's body, which contains nearly fifteen square feet, will sustain a weight equal to about fourteen tons and a half; but this pressure is so great that it would be absolutely insupportable, and even fatal to us, were it not equal in every part, and counterbalanced by the spring of that air which fills all the vesicles of the body, and reacts with an outward force equal to that with which the atmosphere presses inward.

By means of an air-pump, the air may be drawn out of a large glass vessel, or receiver, and a vacuum produced, in which a great number of curious experiments may be performed, showing at once the properties and usefulness of the air. We shall give a brief description of the air-pump, though a view of the machine itself will convey a much better idea of the important purposes to which it is applied, than any description can afford. Two brass cylinders are closely and firmly fastened down to the table or base of the machine, by means of what are called the head and the columns. The receiver is made to fit very accurately on a brass circular plate, which has a hole in the middle, through which the air passes from the receiver into a tube made of brass, that communicates with the cylinders. Near the bottom of each cylinder is a valve opening upwards, and above these valves are two others in pistons which are moved up and down by toothed rods that fall into a toothed wheel, to the axis of which a handle is fixed. On turning the handle one of the pistons is raised and the other depressed, consequently a rarefied space is formed between the upper and lower valve in one cylinder; then the air which is contained in the receiver rushes through the brass tube and by its elasticity forces up the lower valve and enters the cylinder; then the valve closes and prevents the air from returning into the receiver. When the motion is reversed, the other piston ascends, and the first is depressed; in its depression, the elasticity of the air contained between the two valves, forces open the uppermost valve, and it escapes into the upper part of the cylinder; then the valve closes and prevents its return. Whilst one piston, therefore, exhausts the air from the receiver, the other is discharging it from the top of the cylinder. Thus by continued exhaustion, the density of the air keeps decreasing in the receiver, till its elasticity is no longer able to force up the lower valves, which terminates the effect of the machine. The air is admitted into the receiver again by unscrewing a small nut which is so situated as to communicate with the air channel.

If the air be exhausted from a receiver, it will be held fast by the pressure of the external air. If a small receiver be placed under a larger, and both exhausted, the larger will be held fast, while the smaller will be easily moved. If a guinea and a feather be dropped from the top of the receiver, they will reach the bottom at the same instant, because there is then no resisting medium. Animals cannot live in an exhausted receiver, and the continuance of life varies according to the strength or size of the animal. A man requires a gallon of fresh air every minute. If a lighted candle be covered with a receiver containing a gallon of air, the candle will burn a minute; and then the flame, after having gradually decayed, will go out. A constant supply of fresh air, therefore, is as necessary to feed flame as to support life. If two brass hemispheres of three or four inches in diameter be put together, and the internal air exhausted, the pressure from without will require one hundred and fifty pounds to separate them; but if the external air be taken away, they will separate of themselves.

The Condensing Syringe has a solid piston, and a valve in the lower part of its barrel which opens downwards. By thrusting down the piston the air is forced through the valve, which is afterwards held close by the elasticity of the condensed air. When the piston is raised up a vacuum is produced, till it is raised above a small hole in the barrel, when the air rushes in, and is again discharged through the valve. An instrument of this kind is used to produce what is called the artificial fountain.

QUESTIONS.—1. What is Pneumatics? 2. What is the atmosphere? 3. What is said of its height? 4. What is wind? 5. What is said of the weight and pressure of the atmosphere? 6. What experiment illustrates the upward pressure of the atmosphere? 7. How does the elasticity of air differ from the elasticity of bodies in general? 8. What is the weight of the atmosphere upon a square inch? 9. Upon the surface of a man's body? 10. How is the pressure of the air upon the body counterbalanced? 11. Describe the air-pump. 12. Show the method by which the air is drawn from the receiver. 13. What are some of the experiments that may be performed by an air-pump? 14. Describe the condensing syringe, and its action. 15. Look at fig. 16. and describe the air-pump, and show its action. 16. Look at fig. 26. and describe the artificial fountain.

LESSON 28.

The Barometer.

Hermet'ically, a term applied to the closing of the orifice of a glass tube by fusion, so as to render it air-tight.

Respira'tion, the act of alternately *inspiring* air into the lungs, and *expiring* it from them.

THE Barometer is a very useful instrument for determining the variations of the weather. If a glass tube of about thirty-two or thirty-three inches long, hermetically sealed at one end, be filled with mercury, and then inverted in a basin or cup of the same fluid, the mercury in the tube will stand at an altitude above the surface of that in the basin between twenty-eight and thirty-one inches. The tube and the basin are fixed on a board, for the convenience of suspending it; the board is graduated for the purpose of ascertaining the height at which the mercury stands in the tube; and a small moveable metallic plate, called a vernier, an inch of which is divided into a hundred equal parts, serves to show that height with greater accuracy. The height at which the mercury will stand depends upon the weight of the atmosphere, which varies much according to the state of the weather. The air is heaviest in dry weather, for it is then that the mercury is found to rise in the tube and consequently the mercury in the cup must be most pressed by the air. It is true that in damp weather the air *feels* heaviest, but it is on account of its being less salubrious. The lungs under these circumstances do not play so freely, nor does the blood circulate so well; and thus obstructions are frequently occasioned in the smaller vessels, from which arise colds, asthmas, and fevers. The thinness of the air in elevated situations is sometimes oppressive from being insufficient for respiration; and the expansion which takes place in the more dense air contained within the body is often painful. It occasions distension, and sometimes causes the bursting of smaller blood-vessels.

The barometer has been used for the purpose of measuring the heights of mountains and towers, and of estimating the elevation of balloons. The weight of one hundred and three feet of air is equal to that of one tenth of an inch of mercury. If a barometer, therefore, be carried to any great eminence, the mercury will *descend* one tenth of an inch for every one hundred and three feet that the barometer *ascends*. When the surface of the mercury is convex, or stands higher in the middle than at the sides, it is a sign the mercury is then in a rising state; but if the surface be concave, or hollow in the middle, it is then sinking. In very hot weather, the falling of the mercury indicates thunder. In winter, the rising indicates frost, and in frosty weather if the mercury falls three or four divisions, there will be a thaw. But in a continued frost, if the mercury rises, it will snow. In wet weather, when the mercury rises much and high, and so continues for two or three days before the bad weather is entirely over, then a continuance of fair weather may be expected. In fair weather, when the mercury falls low, and thus continues for two or three days before the rain comes, then much wet weather may be expected and probably high winds. The unsettled motion of the mercury denotes unsettled weather. The words engraved on the scale are not so much to be attended to, as the rising and falling of the mercury. It always sinks lowest of all for great winds, though not accompanied with rain; but it falls more for wind and rain together than for either of them alone. Barometers are frequently made of a tube with a curved neck and bulb, being more commodious than the basin and tube. To make these tolerably exact, however, the circular area of the bulb should be at least thirty or forty times larger than that of the tube; so that the mass of mercury may be as little affected as possible whilst it rises and falls; for the height of the column is taken from the surface of the mercury in the bulb to its height in the tube.

QUESTIONS.—1. What is the construction of the barometer? 2. Upon what does the height of the mercury depend? 3. Why is the air heaviest in dry weather? 4. Why does it feel heaviest in damp weather? 5. How may the height of a mountain be ascertained by the barometer? 6. What is indicated by the convexity and concavity of the mercury? 7. Upon what other construction are barometers made than that first described?

LESSON 29.

Sound.

Humid'ity, moisture. The degrees of moisture in the air are measured by an instrument called a Hygrom'eter, of which there are various kinds; whatever contracts or expands by the moisture or dryness of the atmosphere is capable of being formed into one.

SOUND arises from a tremulous or vibrating motion in elastic bodies, which is caused by a stroke or collision, and is carried to the ear through the medium of the air. The production of sound therefore depends upon three circumstances, a sonorous body to give the impression, a medium to convey it, and the ear to receive it. Sonorous bodies, however, are merely the instruments by which a peculiar species of motion is communicated to the air. It is true that when you ring a bell, both the bell and the air are concerned in the production of sound: but sound, strictly speaking, is a perception excited in the mind by the motion of the air on the nerves of the ear; the air, therefore, as well as the sonorous bodies which put it in motion, is only the cause of sound,—the immediate effect is produced by the sense of hearing: for without this sense, there would be no sound. The vibrating air strikes the ear, and causes in the mind the perception of sound.

If you endeavour to ring a small bell, after you have suspended it under the receiver in an air-pump, from which the air has been exhausted, no sound will be produced. By exhausting the receiver, you cut off the communication between the air and bell; and the latter, therefore, cannot impart its motion to the air. It has been ascertained that liquids as well as air are capable of conveying the vibratory motion of a sonorous body to the organ of hearing; for sound can be heard under water. Dr. Franklin imagined, that with his ear under water, he heard the collision of stones in that medium, at the distance of a mile.

The vibration of a sonorous body gives a tremulous motion to the air around it, very similar to the motion communicated to smooth water when a stone is thrown into it. This first produces a small circular wave around the spot in which the stone falls; the wave spreads, and gradually communicates its motion to the adjacent waters, producing similar waves to a considerable extent. The same kind of waves are produced in the air by the motion of a sonorous body, but with this difference, that as air is an elastic fluid, the motion does not consist of regularly extending waves, but of vibrations, and are composed of a motion forwards and backwards, similar to those of a sonorous body. They differ also in the one taking place in a plane, the other in all directions: the aerial undulations being spherical. The first sphere of undulations which are produced immediately round the sonorous body, by pressing against the contiguous air, condenses it. The condensed air, though impelled forward by the pressure, reacts on the first set of undulations, driving them back again. The second set of undulations which have been put in motion, in their turn communicate their motion, and are themselves driven back by reaction. Thus there is a succession of waves in the air, corresponding with the succession of waves in the water.

The air is a fluid so much less dense than water, that motion is more easily communicated to it. The firing of a cannon produces vibrations of the air which extend to several miles around. Distant sound, however, takes some time to reach us, and we see the light of the flash long before we hear the report. The velocity of sound is commonly computed at the rate of eleven hundred and forty-two feet in a second. Its velocity varies according to the temperature, density, and humidity of the atmosphere. It is influenced also by the force and direction of the wind. The velocity of sound has been applied to the measurement of distances. If a ship at sea in distress fires a gun, the light of which is seen on shore twenty seconds before the report is heard, it is therefore known to be at the distance of twenty times eleven hundred and forty-two feet, or a little more than four miles and one third. By counting the number of seconds elapsed between the flash of lightning and the clap of thunder, you may ascertain how far distant you are from the cloud.

When the aerial vibrations meet with an obstacle, having a hard and regular surface, such as a wall or rock, they are reflected back to the ear, and produce the same sound a second time; but the sound will then appear to proceed from the object by which it is reflected. If the vibrations fall perpendicularly on the obstacle, they are reflected back in the same line; if obliquely, the sound returns obliquely in the same direction. This reflected sound is called an echo. At Rosneath, near Glasgow, there is an echo that repeats a tune, played with a trumpet, three times, completely and distinctly. At Brussels there is an echo that answers fifteen times; and in Italy, near Milan, the sound of a pistol is returned fifty-six times. Speaking trumpets, and those made to assist the hearing of deaf persons, depend on the reflection of sound from the sides of the trumpet, and also by its being confined and prevented from spreading in every direction.

QUESTIONS.—1. From what does sound arise? 2. Upon what three circumstances does the production of sound depend? 3. What is sound, strictly speaking? 4. How can it be shown that air is necessary to the production of sound? 5. Why cannot a bell be heard in an exhausted receiver? 6. What are conductors of sounds besides the atmosphere? (Ans. water, wood, flannel.) Tie a piece of iron or any metal to the middle of a strip of flannel, 2 or 3 ft. long. Press the ends of the flannel in your ears, and if the metal be struck against iron, you will hear a sound like that of a heavy church bell. 7. How is the tremulous motion of the air as produced by a sonorous body illustrated? 8. What is said of the velocity of sound? 9. Ship at sea? 10. Distance of lightning? 11. How is the sound of an echo produced? 12. Describe the speaking trumpet, fig. 20.

NOTE. The science which treats of sound in general is called acoustics.

LESSON 30.

Nature of Musical Sounds.

Ten′sion, act of stretching, state of being stretched.
Grav′ity, in music, the modification of any sound, by which it becomes deep or low in respect of some other sound.
Con′cert, many performers playing the same tune.
Line, a small French measure, containing the 12th part of an inch: geometricians conceive the line subdivided into six points.

If a sonorous body be struck in such a manner, that its vibrations are all performed in regular times, the vibrations of the air will correspond with them; and striking in the same regular manner on the drum of the ear, will produce the same uniform sensation on the auditory nerve and excite the same uniform idea in the mind; or, in other words, we shall hear one musical tone. But if the vibrations of the sonorous body are irregular, there will necessarily follow a confusion of aerial vibrations; for a second vibration may commence before the first is finished, meet it half way on its return, intercept it in its course, and produce harsh jarring sounds which are called discords. But each set of these irregular vibrations, if repeated at equal intervals, would produce a musical tone. It is only their irregular succession which makes them interfere, and occasions discord.

The quicker a sonorous body vibrates, the more acute, or sharp is the sound produced; and the vibrations of the same string, at the same degree of tension, are always of a similar duration. Striking the note in quick succession, produces a more frequent repetition of the tone, but does not increase the velocity of the vibrations of the string. The duration of the vibrations of the strings or chords depends upon their length, their thickness, or weight, and their degree of tension. The different length and size of the strings of musical instruments, therefore, serve to vary the duration of the vibrations, and consequently the acuteness or gravity of the notes.

Among the variety of tones, there are some which, sounded together, please the ear, producing what we call harmony or concord. This arises from the agreement of the vibrations of the two sonorous bodies; so that some of the vibrations of each strike upon the ear at the same time. If the vibrations of two strings, for instance, are performed in equal times, the same tone is produced by both, and they are said to be in unison. But concord is not confined to unison; for two different tones harmonize in a variety of cases. If one string or sonorous body vibrates in double the time of another, the second vibration of the latter will strike upon the ear at the same instant as the first vibration of the former; and this is the concord of an eighth or octave. If the vibrations of two strings are as two to three, the second vibration of the first corresponds with the third vibration of the latter, producing the harmony called a fifth. There are other tones which, though they cannot be struck together without producing discord, yet if struck successively, give us the pleasure which is called melody.

A sort of musical barometer has been invented in Switzerland, called the weather harp, which possesses the singuiar property of indicating changes of the weather by musical tones. In the year 1787, one was constructed in the following manner. Thirteen pieces of iron wire, each three hundred and twenty feet long, were extended across a garden, in a direction parallel to the meridian. They were placed about two inches apart; the largest were two lines in diameter, the smallest only one, and the others one and a half; they were on the side of the house, and made an angle of twenty or thirty degrees with the horizon; they were stretched and kept tight by wheels made for that purpose. Every time the weather changes, these wires make so much noise that it is impossible to continue concerts in the parlour, and the sound resembles that of a tea-urn when boiling, and sometimes that of a distant bell, or an organ.

QUESTIONS.—1. When do the vibrations of a sonorous body produce the same musical tone? 2. How are discords produced? 3. On what does the sharpness or acuteness of a musical sound depend? 4. On what does the duration of the vibrations of strings or chords depend? 5. How is harmony or concord produced? 6. How is an octave concord produced? 7. The harmony called a fifth? 8. Describe the musical barometer or weather harp. [NOTE. In the opinion of a celebrated chemist, this is an electro-magnetical phenomenon.] 9. Illustrate the vibrations of a musical string by figures 17, 18, and 19.

LESSON 31.

Optics.

Lu′minous, shining by its own light.
Transpa′rent, admitting rays of light to pass through.
Opaque′, stopping the rays of light.
Ze′nith, a point in the heavens directly over our heads, the pole of the horizon. Na′dir is a point diametrically opposite to the zenith, constituting the other pole of the horizon.

Optics is the science which treats of light, and of the instruments by which it is applied to useful purposes. It is one of the most interesting branches of natural philosophy, but not one of the easiest to understand; it will be necessary, therefore, that you give to it the whole of your attention.

Light, when emanated from the sun, or any other luminous body, is projected forwards in straight lines in every possible direction; so that the luminous body is not only the centre from whence all the rays proceed, but every point of it may be considered as a centre which radiates light in every direction. The particles of light are so extremely minute, that although they are projected in different directions, and cross each other, yet they are never known to interfere, and impede each other's course. It is still a disputed point, however, whether light be a substance composed of particles like other bodies. In some respects it is obedient to the laws which govern bodies; in others, it appears to be independent of them: thus, though its course is guided by the laws of motion, it does not seem to be influenced by the laws of gravity. It has never been discovered to have weight, though a variety of interesting experiments have been made with a view of ascertaining that point. Some suppose that the rays of light, instead of being particles, consist of the undulations of an elastic medium, which fills all space, and which produces the sensation of light to the eye, just as the vibrations of the air produce the sensation of sound to the ear. Most of the phenomena may be accounted for by either hypothesis, but that of their being particles applies more happily to some of the facts respecting the modifications of light by refraction and reflection.

When rays of light encounter an opaque body, part of them are absorbed, and part are reflected, and rebound just as an elastic ball which is struck against a wall. A ray of light striking perpendicularly upon a plane mirror, is reflected back in the same direction; but those rays which strike it obliquely, are reflected back in an opposite direction, but with the same obliquity; the angle of reflection, therefore, is exactly equal to the angle of incidence. If you stand directly before a looking-glass, you see your image reflected back to you. If you stand a little to the side, you cannot see yourself; but a person who stands just as far on the other side of it, can see your image in the glass, and you can see his. If you place a candle a little to one side, you must go as far on the other to see its image in the glass. This is the same rule which takes place in the collision of elastic bodies against any surface. If you strike an ivory ball or common marble perpendicularly against the wainscot, it returns to you; but if you make it strike sideways, it goes off at the same angle with which it came to the wainscot. So it is with rays of light; the incident ray, or the ray which falls upon a surface, makes an angle with a perpendicular line, drawn from the point where it strikes, equal to that which the reflected ray makes with it.

With respect to a looking-glass, it is the silvering on the glass which causes the reflection, otherwise the rays would pass through it without being stopped, and if they were not stopped they could not be reflected. No glass, however, is so transparent but it reflects some rays: if you put your hand near a window, you clearly see its image on the other side, and the nearer the hand is to the glass, the more evident is the image. Whatever suffers the rays of light to pass through it is called a medium, and the more transparent the body, the more perfect is the medium. But rays of light do not pass through a transparent medium, (unless they fall perpendicularly upon it) in precisely the same direction in which they were moving before they entered it. They are bent out of their former course, and this is called refraction. When they pass out of a rarer into a denser medium, as from air into water or glass, they are always refracted *towards* a perpendicular to the surface, and the refraction is, more or less, in proportion as the rays fall, more or less, obliquely on the refracting surface. But when they pass from a denser into a rarer medium, as from glass or water into air, they move in a direction *farther from* the perpendicular. If you put a piece of money into an empty basin, and stand at such a distance that it may not be visible; then let another person pour water into the basin, and the money will be seen; for the rays of light, in passing from a denser into a rarer medium, are bent *from* the perpendicular, and thus are directed to your eye. The following, therefore, may be established as a sort of axiom in optics: we see every thing in the *direction* of that line in which the rays approach us last. If you place a candle before a looking-glass, and stand before it, the image of the candle appears behind it; but if another looking-glass be so placed as to receive the reflected rays of the candle, and you stand before this second glass, the candle will appear behind that; because the mind imagines every object to be in the direction from which the rays come to the eye last. Hence, when the rays of light coming from the celestial bodies, arrive at our atmosphere, they are bent downward; and those bodies appear, when in the horizon, higher than they are. The effect of this refraction is about six minutes of time, but the higher they rise, the less are the rays refracted; and when they are in the zenith, they suffer no refraction. The sun is visible about three minutes before he rises, and about the same time after he sets; making in the course of a year about a day and a half. Twilight is occasioned partly by refraction, but chiefly by reflection of the sun's rays by the atmosphere, and it lasts till the sun is eighteen degrees below the horizon. Were there no atmosphere to reflect and refract the sun's rays, only that part of the heavens would be luminous in which the sun is placed; and if we could live without air, and should turn our backs to the sun, the whole heavens would appear as dark as in the night. In this case also, a sudden transition from the brightest sunshine to dark night would immediately take place upon the setting of the sun.

QUESTIONS.—1. What is said of optics? 2. In what manner is light projected from luminous bodies? 3. What is still a disputed point, and what is said of it? 4. How are rays of light reflected? 5. How is it shown that the angle of reflection is equal to the angle of incidence? 6. What is meant by the refraction of rays of light? 7. How are they refracted in passing from a rarer into a denser medium? 8. From a denser into a rarer? 9. What is the example for illustration? 10. What may be established as a sort of axiom in optics? 11. Give the illustration. 12. What is the effect of rays of light, coming from celestial bodies, being refracted by the atmosphere? 13. What occasions twilight? 14. How would the heavens appear if there were no atmosphere? 15. Illustrate the reflection of light by fig. 29. Engr. III. 16. Refraction of light by fig. 29. [NOTE. Fig. 31. is a vessel with a flower in water at the bottom, seen by the eye in the *direction* of the rays which enter it. This experiment, and many others, may be easily performed.]

LESSON 32.

Different kinds of Lenses.

Diverge', rays of light coming from a *point*, and continually separating as they proceed, are said to *diverge;* the point is called the *radiant point*.

Converge', rays which tend to a common point are said to *converge*.

A *Beam* of light is a body of parallel rays; a *Pencil* of rays is a body of diverging or converging rays.

Cam'era obscu'ra, a chamber darkened; an optical machine used in a darkened chamber.

A LENS is a glass ground into such a form as to collect or disperse the rays of light which pass through it. They are of different shapes, from which they take their names. If rays proceed from a radiant point distant as far as the sun, their divergency is so trifling that they may be considered as parallel. When parallel rays fall on a piece of glass having a double *convex* surface, that ray only, which falls in the direction of the axis of the lens, is perpendicular to the surface; the other rays falling obliquely, are refracted towards the axis, and they will meet beyond the lens at a point called its focus. The distance of the focus from the centre of the lens depends both upon the form of the lens, and upon the refractive power of the substance of which it is made; in a glass lens, both sides of which are equally convex, the focus is situated nearly at the centre of the sphere of which the surface of the lens forms a portion; it is at the distance, therefore, of half the diameter of the sphere. The property of a lens which has a double *concave* surface is to disperse the rays of light. Instead of converging towards the ray, which falls on the axis of the lens, they will be attracted towards its thick edges, both on entering and quitting it, and will, therefore, be made to diverge. Lenses which have one side flat and the other convex or concave are less powerful in their refractions, than those which have been described. They are called plano-convex and plano-concave. The focus of the former is at the distance of the diameter of a sphere, of which the convex surface of the lens forms a portion. The last kind of lens is called a mēnis′cus, being convex on one side and concave on the other, like the glass or crystal of a watch.

All the parallel rays of the sun which pass through a convex glass are collected in its focus, and the force of the heat there is to the common heat of the sun, as the surface of the glass is to the surface of the focus. If a lens four inches in diameter collect the sun's rays into a focus at the distance of twelve inches, the image will not be more than one tenth of an inch in diameter: the surface of this little circle is one thousand six hundred times less than the surface of the lens, and consequently the heat will be one thousand six hundred times greater at the focus than at the lens. A globular decanter of water acts as a double convex lens, and furniture has been set on fire by leaving one incautiously exposed to the rays of the sun. A gentleman of London formed a burning-glass three feet in diameter, and when fixed in its frame, it exposed a clear surface of more than two feet eight inches in diameter, and its focus, by means of another lens, was reduced to a diameter of half an inch. The heat produced by this was so great that iron plates were melted in a few seconds; tiles and slates became red-hot in a moment, and were vitrified, or changed into glass; sulphur, pitch, and other resinous bodies, were melted under water; gold was rendered fluid in a few seconds. But notwithstanding this intense heat at the focus, the finger might, without the smallest injury, be placed in the cone of rays within an inch of the focus. On bringing the finger nearer, a sensation was felt like that produced by a sharp lancet, and not at all similar to the pain occasioned by the heat of fire or a candle. Substances of a white colour were difficult to be acted upon. Pure water in a clear glass decanter will not be warmed by the most powerful lens, but a piece of wood placed in the water may be burned to a coal. If a cavity be made in a piece of charcoal, and the substance to be acted on be put in it, the effect produced by the lens will be much increased. Any metal thus enclosed melts in a moment; the fire sparkling like that of a forge to which the blast of a bellows is applied.

The image of an object when received through a convex lens will be inverted. If you cause the rays of light from the flame of a candle to pass through the glass of a common spectacle, and receive them on a sheet of paper, or dark skreen placed at a proper distance, you will see a complete inverted image of the candle on it. A convex lens placed in the hole of a window-shutter will exhibit, on a white sheet of paper situated in the focus of the glass, all the objects on the outside, as fields, trees, men, and houses, in an inverted order. The room should be quite dark, and the sun should shine upon the objects. A portable *camera obscura* may be made with a square box, in one side of which is to be fixed a tube, having a convex lens in it: within the box is a plane mirror, reclining backwards from the tube, in an angle of forty-five degrees. The picture is formed on a square of unpolished glass at the top of the box. If a piece of oiled paper be stretched on the glass, a landscape may be easily copied; or the outline may be sketched on the rough surface of the glass.

QUESTIONS.—1. What is a lens?—its axis?—focus? 2. Describe the five kinds of lenses. 3. What proportion is there between the common heat of the sun and the heat of the focus of a double convex lens? 4. Describe the burning glass formed at London. 5. What examples are given of images of objects being inverted by a convex lens? 6. How may a camera obscura be made? 7. Why is the mirror placed at an angle of 45 degrees exactly? Ans. To throw the image on the top, for incident rays, falling upon a surface declining 45 degrees, will be reflected at an equal angle of 45 degrees. 8. Describe figures 30. 36. 32. 33.

LESSON 33.

Mirrors.

Panoram'ic, exhibiting a succession of objects.
Opti'cian, a maker of optical instruments, one skilled in optics.

MIRRORS are made of glass, silvered on one side, or of some metal highly polished. There are three kinds of them, the plane, the convex, and the concave. Objects seen in convex mirrors are diminished. A globe of glass, silvered on the inside, is sometimes suspended from the ceiling of a room. It affords a sort of panoramic view of surrounding objects, though not all in natural proportion of size. When a convex mirror can be placed before a window, either with a good prospect, or where there are a number of persons passing and repassing in their different employments, the images reflected from it will be erect, and behind the surface; and a landscape or a busy scene delineated on one of them is always a beautiful object to the eye. Concave mirrors make objects appear larger, but distorted. If one be hung on the wall of a room, or fixed in a chair, a person beyond the focus sees his image inverted. As he puts forward his hand the image in the glass appears to do the same, as if to shake hands. As he tries to clasp the hand it vanishes from his view. Let the spectator hold out a knife in his hand, the image will appear to do the same; and so strong will be the impression on his mind, that he will feel a reluctance to run his hand forward against the apparent weapon. A concave mirror throws back the sun's rays into one point or focus, where paper or gunpowder may be set on fire. Mirrors are sometimes made of a cylindrical concave form; and as one of them is placed either upright or on its side, the image of the picture is distorted into a very long or a very broad image. Reflecting surfaces may be made of various shapes, and if a regular figure be placed before an irregular reflector, the image will be deformed; but if an object, as a picture, be painted deformed, according to certain rules, the image will appear regular. Such figures and reflectors are sold by opticians, and they serve to astonish those who are ignorant of these subjects.

Small convex reflectors are made for the use of travellers, who, when fatigued by stretching the eye to Alps towering on Alps, can by their mirror, bring these sublime objects into a narrow compass, and gratify the sight by pictures which the art of man in vain attempts to imitate.

Questions.—1. What are the three kinds of mirrors? 2. How do convex mirrors make objects appear?—concave? 3. What are some of the experiments that may be performed with them? 4. How do cylindrical concave mirrors make an image of a picture appear? [Note. A mirror is sometimes called a Spec'ulum, pl. Spec'ula.] 5. Describe fig. 27.

LESSON 34.

Colours.

Sem'icircle, a half round, part of a circle divided by the diameter.
Junct'ure, the line at which two things are joined together.
Prism, a solid piece of glass with three flat sides, and two equal and parallel triangular ends.

Sir Isaac Newton, to whom we are indebted for the most important discoveries respecting light and colours, was the first who divided a white ray of light, and found it to consist of an assemblage of coloured rays. This separation may be observed in the well known experiment of the prism. A ray being let into a darkened room, through a small round aperture in the shutter, and falling on a triangular glass prism, is, by the refraction of the prism, considerably dilated, and it will exhibit, on a skreen or on the opposite wall, an oblong image called a spectrum, variously coloured; the extremities of which are bounded by semicircles, and the sides are rectilinear. The colours are commonly divided into seven, which, however, have various shades gradually intermixing at their juncture. The following lines from Blackmore represent their order, beginning at the side of the refracting angle of the prism.

Of parent colours, first the flaming *red*
Sprung vivid forth; the tawny *orange*, next;
And next, delicious *yellow;* by whose side
Fell the kind beams of all-refreshing *green;*
Then the pure *blue*, that swells autumnal skies,
Ethereal played; and then, of sadder hue,
Emerged the deepened *indigo*, as when
The heavy skirted evening droops with frost,
While the last gleamings of refracted light
Died in the fainting *violet* away.

The union of these colours, in the proportions in which they appear in the spectrum, produce in us the idea of whiteness. If you paint a card in compartments with these seven colours, and whirl it rapidly on a pin, it will appear white. But a more decided proof of the composition of a white ray is afforded by uniting these coloured rays, and forming with them a ray of white light. This can be done by letting the coloured rays, which have been separated by a prism, fall upon a lens, which will converge them to a focus, and, being thus re-united, will appear white as they did before refraction.

Prisms are commonly made of solid glass, but those who do not possess one of this kind may easily make a substitute. Take three pieces of plate glass, each four or six inches long, and two or three inches wide; procure a tin frame, the two ends of which are in the exact shape of the three pieces of glass placed in the form of a triangle, with a strip of tin running from each angle of one end to the angles or corners of the other. These strips are bent so as to receive the two edges of the glass plates. The tin forming the ends is turned up so as to receive the plates, and one of the ends is furnished with a little tube to pour in water. When the frame and the glass plates are fastened together, and the crevices stopped, the prism is filled with clear water, and is ready for experiment.

When a spectrum is formed by the light which has passed through a prism upon a skreen, if a small hole be made through the skreen, and the rays of one colour only be permitted to pass through it, then whatever is viewed in that light, will appear of that particular colour. Thus if red light only has passed through the hole, then blood, or grass, or milk, viewed in that light behind the skreen, will appear red; excepting that the blood will appear of a stronger red colour than the grass or milk. If the blue light only has been transmitted through the hole, then the above mentioned substances will appear blue; and the like must be understood of the other colours. This proves that the colours, which seem to proceed from coloured bodies in general, do not belong to those bodies; but they are the component parts of the white light, in which those bodies are viewed, and that certain bodies have the property of absorbing some of those coloured rays of the white light which falls upon them, and of reflecting others. Thus, grass reflects the green rays and absorbs the rest; hence, the green rays coming to our eyes, render the appearance of grass green; thus blood absorbs every other coloured ray excepting the red, and so forth. Black bodies absorb all the seven coloured rays, and white bodies reflect them all. Providence appears to have decorated nature with the enchanting diversity of colours which we so much admire, for the purpose of beautifying the scene, and rendering it a source of pleasureable enjoyment. It is an ornament which embellishes nature wherever we behold her.

Questions.—1. Of what was Sir Isaac Newton the first discoverer? 2 How may a white ray of light be separated into the various colours of which it is composed? 3. How are the colours divided, and what are they called? 4. How is the idea of whiteness produced?—What is the proof of this? 5. How may a substitute for a solid glass prism be made? 6. How is it proved that the colours which seem to proceed from coloured bodies do not belong to those bodies? 7. What are colours? 8. What is a spectrum? 9. Describe fig. 37.

LESSON 35.

The Rainbow, Halo, and Parhelia.

Parhe′lia, (singular, Parhe′lion) a bright light appearing on one side of the sun.

When the rays of the sun strike upon drops of water falling from the clouds, and we are placed in such a direction that our back is towards the sun, and the clouds before us, we observe a peculiar phenomenon in the heavens, called a rainbow. We may consider the drops of rain as transparent globules upon which the rays fall, and are twice refracted and once reflected. Hence proceed the different colours of the rainbow. These colours appear the more vivid, as the clouds which are behind are darker, and the drops of rain fall closer. The drops continually forming produce a new rainbow every moment, and as each spectator observes it from a particular situation, it happens that scarcely two men, strictly speaking, see the same rainbow; and this appearance can only last whilst the drops which fall are succeeded by others.

Triumphal arch, that fill'st the sky
When storms prepare to part,
I ask not proud philosophy
To teach me what thou art—

Still seen, as to my childhood's sight,
A midway station given
For happy spirits to alight
Betwixt the earth and heaven.

Can all that optics teach, unfold
  Thy form to please me so,
As when I dreamt of gems and gold
  Hid in thy radiant bow.

When Science from Creation's face
  Enchantment's veil withdraws
What lovely visions yield their place
  To cold material laws.

And yet, fair bow, no fabling dreams,
  But words of the Most High,
Have told why first thy robe of beams
  Was woven in the sky.

When o'er the green undeluged earth
  Heaven's covenant thou didst shine,
How came the world's grey fathers forth
  To watch thy sacred sign!

And when its yellow lustre smiled
  O'er mountains yet untrod,
Each mother held aloft her child
  To bless the bow of God.

Methinks thy jubilee to keep,
  The first-made anthem rang
On earth delivered from the deep,
  And the first poet sang.

Nor ever shall the Muse's eye
  Unraptured greet thy beam:
Theme of primeval prophecy,
  Be still the poet's theme!

The earth to thee her incense yields,
  The lark thy welcome sings,
When glittering in the freshen'd fields
  The snowy mushroom springs.

How glorious is thy girdle cast
  O'er mountain, tower, and town,
Or mirror'd in the ocean vast,
  A thousand fathoms down.

As fresh in yon horizon dark,
As young thy beauties seem,
As when the eagle from the ark
First sported in thy beam.

For faithful to its sacred page,
Heaven still rebuilds thy span,
Nor lets the type grow pale with age,
That first spoke peace to man.

CAMPBELL.

In serene weather, we often observe a circular light, or luminous ring surrounding the moon; it is called a halo, or crown. Its outline sometimes faintly shows the colours of the rainbow. The moon is in the middle of this ring, and the intermediate space is generally darker than the rest of the sky. When the moon is at the full, and considerably elevated above the horizon, the ring appears most luminous. It is often very large. We are not right in supposing, that this circle really surrounds the moon; the true cause of such an appearance must be looked for in our atmosphere, the vapours of which make a refraction of the rays of light. False moons are sometimes seen near the real moon, and appear as large, but their light is paler. They are generally accompanied by circles, some of which have the same colours as the rainbow, whilst others are white, and others have long luminous tails. All these appearances are produced by refraction. The rays of light falling from the moon upon aqueous and sometimes frozen vapours, are refracted in various ways; the coloured rays are separated, and reaching the eye present a new image of the moon.

Parhelia or mock-suns are far more rarely seen, but their appearance is wonderfully curious. They generally appear about the size of the true sun, not quite so bright, though they are said sometimes to rival their parent luminary in splendour. When there are a number of them they are not equal to each other in brightness. Externally, they are tinged with colours like the rainbow. They are not always round, and have sometimes a long fiery tail opposite the sun, but are paler towards the extremity. They are formed by the reflection of the sun's beams on a cloud.

QUESTIONS.—1. Under what circumstances do we perceive the rainbow? 2. What is a halo? 3 What are parhelia, or mock-suns

LESSON 36.

Structure of the Eye.

Mem′branous, consisting of a web of several sorts of fibres interwoven together.
Op′tic, producing vision, subservient to vision.
Sclerot′ica, (pronounced sklē-rŏt′-i-ca,) derived from a Greek word signifying *hard.*

The body of the eye is of a spherical form. It has two membranous coverings; the external one is called the *sclerotica;* this has a projection in that part of the eye which is exposed to view, called the *cor′nea*, because, when dried, it has nearly the consistence of very fine horn, and is sufficiently transparent for the light to obtain free passage through it. The second membrane, which lines the cornea, and envelopes the eye, is called the *chōroid;* this has an opening in front just beneath the cornea, which forms the *pupil,* through which the rays of light pass into the eye. The pupil is surrounded by a circular border, which is a part of the choroid and called the *iris*, composed of a sort of network, which contracts or expands according to the force of the light in which it is placed. If a person sits looking towards a window, the pupils of his eyes appear very small, and the iris large. When he turns from the window, and covers his eyes with his hands, so as entirely to exclude the light for a few moments, the pupils will be enlarged and the iris diminished. This is the reason why the eyes suffer pain, when from darkness they suddenly come into a strong light; for the pupil being dilated, a quantity of rays must rush in before it has time to contract. And when we go from a strong light into obscurity, we at first imagine ourselves in total darkness; for a sufficient number of rays cannot gain admittance into the contracted pupil to enable us to distinguish objects: but in a few minutes it dilates, and we clearly perceive objects which were before invisible.

The choroid is imbued with a black liquor which serves to absorb all the rays that are irregularly reflected, and to convert the body of the eye into a more perfect camera obscura. Within these coverings of the eye-ball are contained three transparent substances, called humours. The first occupies the space immediately behind the cornea, and is called the *aqueous* humour, from its liquidity and resemblance to water. Beyond this is situated the *crystalline* humour, so called from its clearness and transparency; it has the form of a lens, and refracts the rays of light in a greater degree of perfection than any that have been constructed by art. The back part of the eye, between the crystalline humour and the retina, is filled by the *vitreous* humour, which derives its name from its supposed resemblance to glass. The most important part of the eye is the *retina;* for it is that which receives the impression of the objects of sight, and conveys it to the mind. It consists of an expansion of the optic nerve of the most perfect whiteness: it proceeds from the brain, enters the eye and is finally spread over the interior surface of the choroid. The refraction occasioned by the several humours unites the whole of a pencil of rays, proceeding from any one point of an object, to a corresponding point on the retina, and the image is thus rendered distinct and strong. The muscles of the eye are six, and by the excellence of their arrangement it is enabled to move in all directions.

All three of the humours of the eye have some effect in refracting the rays of light, but the crystalline is the most powerful: it is a complete double convex lens; and as every point of an object sends out rays in all directions, some rays from each point on the side next the eye will be converged and brought to as many points on the retina, and will form on it a distinct *inverted* picture of the object, which is seen *erect* by the habit of the mind. Although an image must be formed on the retina of each of our eyes, yet we do not see objects double; for when an object is seen distinctly with both eyes, the axis of each is directed to it, and the object appears single; but if the axes of both eyes are not directed to the object, it always appears double. If you look at any object, and then by pressing upon the under or upper side of one eye, remove it out of its natural place, you will see two objects, whose distance from each other will vary as the eye is more or less turned from its natural position.

It is well known that an object at a distance appears smaller than when it is near. The reason is, that the nearer any object can be brought to the eye, the larger will be the angle under which it appears; for the rays fall more *diver-*

gent upon the crystalline humour, and consequently include a greater angle, and thus the object is magnified. In objects placed at such distances as we are used to, we know, by experience, how much an increase of distance will diminish their apparent magnitude, and we instantly suppose them of the size they would appear if they were less remote; but this can only be done, where we are well acquainted with the real magnitude of the object; in all other cases we judge of magnitudes by the angle under which the object appears at the known, or supposed distance; that is, we infer the real magnitude from the apparent magnitude in comparison with the distance of the object. Sight, therefore, does not represent extension such as it is in itself; it often deceives us both in regard to the size and the distance of objects, and we should be led into continual errors if experience did not set us right. This is rendered strikingly manifest from the case of a young man who was blind from his infancy, and who recovered his sight at the age of fourteen, by the operation of couching. At first he had no idea either of the size or distance of objects, but imagined that every thing he saw touched his eyes; and it was not till after having repeatedly felt them and walked from one object to another, that he acquired an idea of their respective dimensions, their relative situations, and their distances.

Questions.—1. What is the external covering of the eye called?—Describe it. 2. Describe the cornea. 3. The choroid. 4. The pupil. 5. The iris. 6. What is said in order to illustrate the contraction and dilatation of the iris? 7. Of what use is the black liquor in the choroid? 8. Describe the three humours of the eye. 9. Of what does the retina consist, and what is its use? 10. How is the image on the retina rendered distinct? 11. How does it appear that the image on the retina will be inverted? 12. Having two eyes, why do we not see objects double? 13. Why does a distant object appear smaller than one that is near? 14. How do we judge of the real magnitudes of objects? 15. What case is related to show that experience is necessary to correct the errors of sight? 16. Look at fig. 28. and describe the eye. [Note. Let the instructer explain to his pupils *how* objects of equal magnitudes appear under a greater angle when near, than when at a distance.]

LESSON 37.

Optical Instruments.

Land′scape, the prospect of a country,—also a picture representing an extent of space with the various objects on it.

Glob′ule, a small particle of matter of a globular or spherical figure.

As the sight is the most noble and extensive of all our senses; as we make the most frequent use of our eyes in all the actions and concerns of life; that instrument which relieves the eyes when decayed, and supplies their defects, must be estimated as one of the greatest of advantages. Sight may be defective in various ways. Some eyes are too flat, others are too convex or round; in some, the humours lose a part of their transparency, and on that account, much of the light that enters the eye is stopped and lost in the passage, and every object appears dim. *Spectacles* are intended to collect the light and to bring it to a proper degree of convergency. The honour of their invention was claimed by Salvinus Armatus, a nobleman of Florence, who died in 1317, and the fact was inscribed on his tomb. When the eye is too flat, the rays proceeding from objects do not converge to a focus so soon as they reach the retina; in this case a convex glass is necessary, for it has the property of converging the rays, and of course, when suited to the eye, of bringing them to a focus, and forming an image on the retina. When the eye is too convex, the rays of light are converged to a focus before they reach the retina; to remedy this, a concave glass is used, which causes the rays to diverge, and prevents their coming to a focus too soon. Short-sighted persons bring objects close to their eyes; it has a similar effect to that produced by concave glasses; for the nearer an object is brought to the eye, the greater is the angle under which it is seen, that is, the extreme rays, and of course all the others, are made more divergent. But persons whose eyes are too flat, when examining an object, hold it at a distance, for the farther an object is held from their eyes, the less is the divergency of its rays, that is, the smaller is the angle under which it is seen: the focal distance is increased, and an image is properly formed on the retina. In considering vision as achieved by the means of an image formed at the bottom of the eye, we can never reflect, without wonder, upon the smallness, yet correctness of the picture, the subtilty of the touch, the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch diameter; yet the multitude of objects which it contains are all preserved; are all discriminated in their magnitudes, positions, figures, colours.

Microscopes are instruments for viewing small objects; and they apparently magnify them, because they enable us to see them nearer than with the naked eye, without affecting the distinctness of vision. The distance from the naked eye, at which most persons are supposed to see small objects best, is about seven inches; but by the help of convex glasses, we are enabled to view things clearly at a much shorter distance than this; for the nature of a convex lens is, to render an object distinctly visible to the eye at the distance of its focus. With a knowledge of this fact, we may easily determine the magnifying powers of glasses employed in *Single Microscopes*, which are small double convex lenses, having the object placed in the focus, and the eye at the same distance on the other side. If rays of light from an object are converged to a point at the distance of one inch from the centre of the glass, or, in other words, if the focal distance of the lens is one inch, an object may be seen through that lens at one inch distance from the eye, and it will appear, in its diameter,—since the natural sight is seven inches,—seven times larger than to the naked eye. But as the object is magnified every way equally, in length as well as breadth, we must square this diameter, to know really how much the object appears enlarged; and we shall thus find that its surface is magnified forty-nine times. If we suppose the focus of a convex lens to be at one-tenth of an inch distant from its centre, in seven inches there are seventy such tenths of an inch; and an object therefore may be seen through this lens seventy times nearer than it can, distinctly, by the naked eye. It will consequently appear seventy times longer and seventy times broader than it does to common sight; and as seventy multiplied by seventy makes four thousand nine hundred; so many times it really appears magnified. Those lenses, therefore, which have the shortest focus, will magnify the object most. Single microscopes of the greatest power may be made with a very small globule of glass, fixed in a thin plate of metal, so that the middle of it may be directly over the centre of an extremely small hole made in the plate.

The *compound microscope* consists of at least two lenses, by one of which an image is formed within the tube of the microscope; and this image is viewed through the eye-glass, instead of the object itself. The *solar microscope* is a kind of camera obscura, which, in a darkened chamber, throws the image on a wall or skreen. It consists of two lenses fixed opposite to a hole in a board or window-shutter. There is also a plane reflector or mirror placed without, which may be so regulated as to throw the sun's rays upon the outer lens. A *magic lantern* is constructed on the same principles. The light is supplied by a lamp instead of the sun, and it is used for magnifying paintings on glass, and throwing their images upon a white skreen in a darkened chamber.

QUESTIONS.—1. In what ways may sight be defective? 2. For what are spectacles intended? 3. How do they assist eyes that are too flat? 4. Too convex or round? 5. Why do some persons bring objects close to their eyes, and others hold them at a distance? 6. What are microscopes? 7. Single microscopes? 8. How is their magnifying power calculated? 9. Describe the compound microscope. 10. Solar microscope. 11. Magic lantern. 12. Look on fig. 35. and describe the single microscope. 13. On fig. 34. and describe the compound microscope.

LESSON 38.

Microscopic Discoveries.

Miniature, (pronounced min′ē-tūre,) representation in a small compass. Fil′ament, a slender thread.
Ped′icle, a footstalk. Animal′cule, a small animal.
Con′ical, consisting of a circular base or bottom and ending in a point.
Tissue, (pron. tish′ū,) a substance interwoven with threads, or variegated.

THE microscope has opened to us a new world of insects and vegetables; it has taught us that objects, invisible to the naked eye, exist, having figure, extension, and different parts; some examples of which we shall produce, that we may have more reasons for admiring and praising the wisdom and power of God. A grain of sand when examined by the eye appears round, but with the help of a glass we observe that each grain differs from the other, both in size and figure; some of them are perfectly round, others square, some conical, and the greater part of an irregular form. By microscopes which magnify objects millions of times, we can discover in the grains of sand a new animal world; for within their cavity dwell various insects. In the vegetable kingdom we are presented with a thick forest of trees and plants, bearing leaves, branches, flowers, and fruits. Mouldiness, when looked at by the naked eye, seems nothing but an irregular tissue of filaments; but the magnifying glass shows it to be a forest of small plants, which derive their nourishment from the moist substance which serves them as a base. The stems of these plants may be plainly distinguished, and sometimes their buds, some shut and some open. They have much similarity to mushrooms, which, it is well known, are the growth of a single night; but those in miniature, of which we are speaking, seem to come to perfection in a much less space of time; hence we account for the extraordinary progress which mouldiness makes in a few hours. A sort of dust, which covers some stones, has been found to consist of small mushrooms, raised on pedicles, the heads of which, round the middle, were turned up at the edges. Above their covering a multitude of small grains appear, shaped like cherries somewhat flattened; and among them several small red insects, which probably feed upon them. A small drop of the green surface of water, that has stood for some time, has been found to be altogether composed of animalcules of several shapes and magnitudes. The most remarkable were those that gave the water the green colour; they were oval creatures; they could contract and dilate themselves, tumble over many times together, and then shoot away like fishes.

If you slightly bruise some corns of pepper, and infuse them in water for a few days, and then expose a drop of it to the microscope, a number of animalcules will be visible, in continual motion, going backwards and forwards in all directions, turning aside when they meet each other, or when their passage is stopped by some obstacle. In other infusions, as in that of new hay, differently shaped animalcules will be found. When the drop in which they swim, and which to them is like a pond, becomes diminished by evaporation, they gradually retire towards the middle, where they accumulate, and at length, when entirely deprived of moisture, perish. Previously to this they appear in great distress, writhe their bodies, and endeavour to escape from that state of uneasiness which they evidently feel. If the smallest quantity of sulphuric acid be put into a drop of the infusion which swarms with these insects, they immediately throw themselves on their backs and expire.

Upon examining the edge of a very sharp lancet with a microscope, it will appear as broad as the back of a knife; rough, uneven, full of notches and furrows. An exceedingly small needle resembles a rough iron bar. But the sting of a bee, seen though the same instrument, exhibits every where a most beautiful polish, without the least flaw, blemish, or inequality, and it ends in a point too fine to be discerned. The threads of fine lawn seem coarser than the yarn with which ropes are made for anchors. But a silkworm's web appears perfectly smooth and shining, and every where equal. The smallest dot, that can be made with a pen, appears irregular and uneven. But the little specks on the wings or bodies of insects are found to be most accurately circular. The finest miniature paintings appear before the microscope rugged and uneven, entirely void of beauty, either in the drawing or colouring. The most even and beautiful varnishes will be found to be mere roughness. But the nearer we examine the works of God, even in the least of his productions, the more sensible shall we be of his wisdom and power. In the numberless species of insects, what proportion, exactness, uniformity, and symmetry do we perceive in all their organs! what a profusion of colouring! azure, green, and vermilion, gold, silver, pearls, rubies, and diamonds; fringe and embroidery on their bodies, wings, heads, and every other part! how high the finishing, how inimitable the polish we every where behold!

On the gay bosom of some fragrant flower
They, idly fluttering, live their little hour;
Their life all pleasure, and their task all play,
All spring their age, and sunshine all their day.
Not so the child of sorrow, wretched *man*,
His course with toil concludes, with pain began;
That his high destiny he might discern,
And in misfortune's school this lesson learn;

Pleasure 's the portion of th' inferior kind,
But glory, virtue, Heaven for MAN designed.

BARBAULD.

QUESTIONS.—1. What has the microscope done for us? 2. What is the appearance of grains of sand when examined by the eye, and by the microscope? 3. Mouldiness? 4. What is said of the green surface of standing water? 5. What is the appearance of animalcules in the infusions of pepper?—new hay? 6. What appearance has the edge of a lancet? 7. Sting of a bee? 8. Fine lawn? 9. Silk worm's web?

LESSON 39.

The Telescope and Telegraph.

Sat'ellite, a small planet revolving round a larger, a moon.
Octag'onal, having eight angles and sides.
O'ral, delivered verbally, not written.

No invention in the mechanic arts has ever proved more useful and entertaining than the production of the telescope; its utility both by sea and land is too well known to need observation; and without such assistance the science of astronomy must have been far short of its present state. A telescope is useful, not only for discovering those distant objects that are invisible to the naked eye, but for rendering more clear and distinct those that are discernible; it is constructed to act either by refraction or reflection. It is the sole business of all telescopes to enable the eye to see the object under a larger angle. For this purpose a new image of an object is produced by the object-glass of the telescope, and then this image is viewed by means of the eye-glasses. The first impression, conveyed to the mind by a telescope, is that of bringing the object nearer, which is only another mode of declaring that it is enlarged, or seen under a larger angle. To show objects in their natural posture, a telescope must have three eye-glasses. The two additional lenses simply give an erect position to objects. If you remove one of the eye-glasses from a common telescope, every thing will appear in an inverted position. The three eye-glasses have all their focal distances equal, and the magnifying power is found by dividing the focal distance of the object-glass by the focal distance of one of the eye-glasses. The two additional lenses are not necessary for astronomical telescopes; for no inconvenience arises from seeing the celestial bodies inverted.

When very great magnifying power is required, telescopes are constructed with concave mirrors, and called reflecting telescopes. Mirrors are used in order to bring the image nearer the eye; and a lens or eye-glass is for the same purpose as in the refracting telescope, that is, to magnify the image. The Newtonian reflecting telescope consists of a tube, towards the end of which a concave mirror is placed. The reflected converging rays, before they reach the focus, are made to fall upon a plane mirror placed at an angle of forty-five degrees, and thus are thrown upwards to the focus of a convex lens fixed in the upper side of the telescope, through which the eye looks down on the image. In the telescopes made by Dr. Herschel there is but one mirror, which is placed at the lower end of the tube, with such an inclination, that the rays are brought to a focus and the image formed near the edge of the upper end of the tube. The image, therefore, is formed by only *one reflection*, and its brightness, when viewed through the lens is, on this account, greater than that in the Newtonian telescope. The head of the observer, when a large aperture is wanted, may be placed entirely at one edge of the tube, so as not to intercept any of the rays at the time of making an observation; but as the eye looks down the tube, the back must be turned to the object. Dr. Herschel's grand telescope is nearly forty feet long, and four feet ten inches in diameter. The concave polished surface of the great mirror is forty-eight inches in diameter, and it magnifies six thousand times. This noble instrument was, in all its parts, constructed under the sole direction of Dr. Herschel: it was begun in the year 1785, and completed August 28th, 1789, on which day was discovered the sixth satellite of Saturn.

The telegraph is a machine for communicating intelligence at a considerable distance, by making various signals,—which have been previously agreed upon between two parties,—to represent letters, words, or ideas. No machine for making signals can with propriety be called a telegraph, unless it is adapted to express a sufficient number of letters or words to form a complete language, and which can be made, therefore, to communicate any information which can be expressed by oral or written language. Less perfect systems of signals which extend only so far as to communicate intelligence of events which have been foreseen, and the appropriate signals, previously arranged, are called signal flags, signal lanterns, and signal guns or fires. Telegraphs have been constructed in various ways. What is called the English telegraph consists of six octagonal boards, each of which is poised upon an axis in a frame, and worked by means of ropes in the manner of bell-ropes, so that it can either be placed vertically, and appear with its full size to the observer at the nearest station, or it becomes invisible to him by being placed horizontally, so that the narrow edge alone is exposed, which from a distance cannot be seen. Six boards make thirty-six changes, by the most plain and simple mode of working; and they will make many more, if more were necessary; but as the real superiority of the telegraph, over all other modes of making signals, consists in its making letters, it is not necessary that the changes should be more than the letters of the alphabet, and the arithmetical figures. Telegraphs of this description are set up on eminences at the distance of eight, ten, or twelve miles; and a line of them, by repeating each other's signals, conveys a message at the rate of a hundred miles in about five minutes. A telescope for the use of the observer is fixed in the watch-tower of each station.

QUESTIONS.—1. Of what advantage is the telescope? 2. Why does it seem to bring an object nearer? 3. What is said of the eye-glasses and the magnifying power of telescopes? 4. Why are mirrors used in reflecting telescopes? 5. Describe the Newtonian telescope. 6. Describe the telescope as made by Dr. Herschel. 7. His grand telescope. 8. What is a telegraph? 9. How is a proper telegraph distinguished from other machines for making signals? 10. Describe the English telegraph. 11. What is said of its number of changes? 12. At what rate will such telegraphs convey a message? 13. How may an idea of the Newtonian telescope be obtained by looking at fig. 27.

LESSON 40.

Astronomy.

Locomo'tive, having the power of removing, or changing place.

ASTRONOMY is the science which teaches the magnitudes and motions, distances, periods, and order of the celestial bodies. It is the boldest and most comprehensive of all our speculations. It is the science of the material universe considered as a whole. The wide-spreading firmament, while it lifts itself above all mortal things, exhibits to us that luminary, which is the light, and life, and glory of our world, and when this retires from our view, is lighted up with a thousand lesser fires, that never cease to burn, that never fail to take their accustomed places, and never rest from their slow, solemn, and noiseless march. Among the objects more immediately about us, all is vicissitude and change. Plants arise out of the earth, flourish awhile and decay, and their place is filled by others. Animals also have their periods of growth and decline. Even man is not exempt from the general law. Nations are like individuals, privileged only with a more protracted existence. The firm earth itself, the theatre of all this change, partakes in a degree of the common lot of its inhabitants, and the sea once heaved its waves where now rolls a tide of wealth and population. Situated as we are, in this fleeting, fluctuating state, it is consoling to be able to dwell upon an enduring scene, to contemplate laws that are immutable, an order that has never been interrupted, to fix, not the thoughts only, but the eye, upon objects that after the lapse of so many ages, and the fall of so many states, cities, human institutions, and monuments of art, continue to occupy the same places, to move with the same regularity, and to shine with the same pure, fresh, undiminished lustre.

Astronomy is the most improved of all the branches of knowledge, and that which does the greatest credit to the human understanding. We have in this obtained the object of our researches. We have solved the great problem proposed to us in the celestial motions; and our solution is as simple and as grand as the spectacle itself, and is in every respect worthy of so exalted a subject. It is not the astronomer only, who is thus satisfied, but the proof is of a nature to carry conviction to the most illiterate and skeptical. Our knowledge, extending to the principles and laws which the author of nature has chosen to impress upon his works, comprehends the future; it resembles that which has been regarded as the exclusive attribute of supreme intelligence. We are thus enabled, not only to explain those unusual appearances in the heavens, which were formerly the occasion of such unworthy fears, but to forewarn men of their occurrence; and by predicting the time, place, and circumstances of the phenomenon, to disarm it of its terror.

There is, however, nothing perhaps so surprising in this science, as that it makes us acquainted with methods, by which we can survey those bright fields on which it is employed, and apply our own familiar measures to the paths which are there traced, and to the bodies that trace them; that we can estimate the form, and dimensions, and inequalities of objects so immense, and so far removed from the little scene of our labours. What would be the astonishment of an inhabitant of one of those bodies, of Jupiter for instance, to find that, by means of instruments of a few feet in length, and certain figures and characters still smaller, all of our own invention, we had succeeded in determining the magnitude and weight of this great planet, the length of its days and nights, and the variety of its seasons, that we had watched the motions of its moons, calculated their eclipses, and applied them to important domestic purposes? What would be *our* astonishment to learn, that an insect, one of those for instance which serve sometimes to illuminate the waters of the ocean, though confined by the exercise of its proper organs and locomotive powers, to the sphere of a few inches, had, by artificial aids of its own contriving, been able to extend its sphere of observation to the huge monsters that move about it; that it had even attempted, not altogether without success, to fathom the depth of the abyss, in which it occupies so insignificant a place, and to number the beings it contains?

The first use of the telescope, about the commencement of the seventeenth century, opened a new and most brilliant era in the science of astronomy. The defect of the natural organ with respect to the objects of this science had never been recognised. We had gazed upon them without comprehending what we saw. We had cast a vacant eye over the splendid pages of this volume, as children amuse themselves with a book which they are unable to read. We had caught here and there a capital letter, or a picture, but we had failed to distinguish those smaller characters on which the sense of the whole depended. It is not the least of the advantages of this wonderful instrument, that it has taught us the importance of those means of improvement and enjoyment, which are placed within the reach of our own ingenuity and skill. No one surely would have dreamed of procuring such an aid to the natural sight, any more than of creating a new sense. It would have seemed like changing the law of our being, and the condition in which we are placed. We have, by means of this instrument, emerged, as it were, from a prison. The mind has effected its enlargement, as an insect bursts its little tenement, and flutters through the free air, and over the gay fields.

Another change in this science, of the first importance, was wrought by the genius of Kepler, who died in the year 1630. But the last and most important of all the revolutions that have taken place in it, is that achieved by Newton. There is no other instance of so signal a change in the opinions and pursuits of the philosophic world. It may be compared to those great and rapid conquests, by which new boundaries and new laws have been given to states and kingdoms, and new directions to the industry and active employments of men; with this difference, however, that these have been made by violence, and with the aid and co-operation of others, while the revolution in the sciences effected by Newton, was the silent, solitary work of an individual.

QUESTIONS.—1. What is astronomy ? 2. What is said of the improved state of this branch of knowledge ? 3. What may be regarded as most surprising in it ? 4. What is said of the first use and importance of the telescope ? 5. What is said of Kepler ? 6. Of Newton ? [NOTE. Newton died March 1727, aged 85.]

LESSON 41.

The Solar System.

Or′bit, the path in which a celestial body moves.
Car′dinal, one of the chief officers in the church of Rome.
Inquisi′tion, a court established for the detection of heresy.

THE true solar system consists of the sun and an unknown number of opaque bodies, which revolve round the sun, and some of which at the same time revolve round others. Those which revolve round the sun only, are called primary planets and comets. Those which revolve round a primary planet, at the same time they are revolving round the sun, are called secondary planets, moons, or satellites. The number of comets is unknown. The sun is the centre of the system, and the eleven primary planets, at different distances, and in different times, move round him, from west to east, in the following order, Mercury, Venus, the Earth, Mars, Vesta, Juno, Pallas, Ceres, Jupiter, Saturn, and Herschel or Uranus. The Earth has one moon, Jupiter four, Saturn seven, and Uranus six. Venus and Mercury being nearer to the sun than our earth, are called *inferior* planets, and all the rest, which are without the earth's orbit, are called *superior* planets; some astronomers distinguish them by the terms *interior* and *exterior*, which seem preferable. The planets are retained in their orbits by the united operation of the centripetal force, by which a body is attracted to the centre of gravity, and the centrifugal force, by which it endeavours to persevere in a straight line. These two powers, mutually balancing each other, compel them to make their respective revolutions. The time of performing their revolutions round the sun is called their *year*, and the time of performing their revolution on their axis, their *day*. The *axis* of a planet is an imaginary line conceived to be drawn through its centre, about which it revolves, and the extremities of this line, terminating on opposite points of the planet's surface, are called its *poles*.

The first material step in improving the science of astronomy was the establishment of the present arrangement of the sun and planets by Copernicus, who died in the year 1543. This doctrine, it is true, was held by Pythag′oras, but it was now presented in a new and stronger light, with its leading features more fully and distinctly unfolded. It is remarkable, that in so many instances, it should have exposed its authors and defenders to persecution. Pythagoras, we are told, made it known only to a select few; but one of his disciples, who had the courage to teach it publicly, was obliged to flee in order to escape the odium it excited. Copernicus meditated upon the subject for many years, before he undertook to give his thoughts to the world, and scarcely surviving the publication of his work, he left to others to receive the shock that awaited those who espoused it. Galileo could not resist the accumulated evidence, that presented itself to his enlarged and philosophic mind, in favour of this refined scheme, and was accordingly destined to bear the whole weight of indignation that was ready to burst upon the disturbers of a prejudice so old and so deeply rooted. He was arrested, and seven cardinals clothed with the authority of the church sat in judgment upon him, and sentenced him to the prison of the Inquisition for opinions, which they pronounced false in philosophy, heretical, and contrary to the word of God. After a year's confinement he was liberated, but continuing his discoveries, and apparently persevering in his opinions, he was imprisoned a second time. After being made to abjure what were deemed his errors, and to do penance for his offences, he was again restored to liberty. Indignant at the cruelty of this treatment, and the bigotry and blindness of his persecutors, he yet continued his pursuits; but in silence and fear. His excessive application, and the constant use of his telescope, together with frequent exposure to the air by night, had such an effect upon him, that he lost his sight. He died in 1642, at the age of seventy-eight.

QUESTIONS.—1. Of what does the solar system consist? 2. What are primary planets?—secondary planets? 3. What is the order in which the eleven primary planets move round the sun? 4. What planets have moons, and how many have each? 5. What are interior and exterior planets? 6. How are the planets retained in their orbits? 7. Define year, day, axis, poles. 8. What was the first material step in the progress of astronomy? 9. What is remarkable with respect to the true doctrine of the solar system? 10. What course did Copernicus adopt? 11. What is said of Galileo? 12. Explain Engr. IV.

LESSON 42.

The Sun.

Spher'oid, a body approaching to the form of a sphere, but not exactly round.

Ellip'tical, oval,—an ellipse is produced from the section of a cone by a plane cutting both its sides, but not parallel to the base. All the planets move round the sun in elliptical orbits, and the sun itself is situated in one of the foci of each ellipse: that focus is called the lower focus. See the Earth's orbit in fig. 40.

GREAT source of day! best image here below
Of thy Creator, ever pouring wide,
From world to world, the vital ocean round;

On nature, write with every beam, His praise.
Soul of surrounding worlds !—
'Tis by thy secret, strong, *attractive* force,
As with a chain indissolubly bound,
Thy system rolls entire; far from the bourn
Of utmost *Herschel*, wheeling wide his round
Of *eighty* years; to Mercury whose disk
Can scarce be caught by philosophic eye,
Lost in the near effulgence of thy blaze. THOMSON.

The sun is a fountain of light that illuminates the world; it is the cause of that heat which maintains the productive power of nature, and makes the earth a fit habitation for man. The figure of the sun is a spheroid, higher under the equator than about the poles; and his diameter is computed to be nearly nine hundred thousand miles. His solid bulk is more than a million of times larger than that of the earth. The sun has two motions; the one is a periodical motion, in an elliptical or very nearly circular direction, round the common centre of all the planetary motions; the other is a revolution upon its axis, which is completed in about twenty-six days. That the sun has a rotation round his axis is made evident by the spots seen on his surface. Some of these spots have made their first appearance near the edge or margin of the sun, and have been seen some time after on the opposite edge; whence, after a stay of more than thirteen days, they have re-appeared in their first place, and taken the same course over again. These spots were entirely unknown before the invention of telescopes, though they are sometimes of sufficient magnitude to be discerned by the naked eye. Some have been so large, as by computation to be capable of covering the continents of Asia and Africa, the whole surface of the earth, or even five times its surface. The sun has commonly been considered a globe of fire; but this has been doubted by modern astronomers. The celebrated Herschel considers the sun as a most magnificent *habitable* globe, surrounded by a very extensive atmosphere, which consists of elastic fluids that are more or less lucid and transparent; and of which the lucid ones furnish us with light. The appearances, called spots in the sun, he considers as real openings in the luminous clouds of the solar atmosphere.

The sun is accompanied by a phenomenon called the zodiacal light. It is a beam of light of a triangular form, visible a little after sunset and before sunrise, with the base towards the sun. It is most clear about the beginning of March in the evening, and in September in the morning, but in the torrid zone it is constantly seen. It is generally supposed to proceed from the sun's atmosphere.

QUESTIONS.—1. What is the figure of the sun? 2. Describe the motions of the sun. 3. How is it made evident that the sun has a rotation round his axis? 4. What is said of the spots that have been seen in the sun? 5. What does Dr. Herschel consider the sun to be? —The spots? 6. Describe the zodiacal light. 7. In what proportion do the planets receive light and heat from the sun? (*see Appendix.*) 8. What rule is given? 9. What is said of the attraction of bodies? 10. What is the rule for finding the distances of the planets from the sun? 11. What was ascertained by Kepler? 12. What is the rule for finding how many times one planet is greater than another? [NOTE. When any body, revolving round the sun, is nearest to him, it is said to be in its *perihe'lion;* and when it is most distant, in its *aphe'lion* (pron. ăf-ē'lē-un.) The common centre about which the sun revolves in its periodical motion is always found to be exceedingly near the sun, and most commonly within it: it may, therefore, without any material error, be regarded as the centre of the planetary system.]

LESSON 43.

Mercury and Venus.

Elonga'tion, a planet's elongation, or its angular distance from the sun, is an angle formed at the earth by two lines, one drawn from the earth to the sun, and one from the earth to the planet.
Disk, the face of the sun and moon, as it appears to us on the earth.

MERCURY is seldom visible to the inhabitants of the earth, for its greatest apparent distance from the sun, or its greatest elongation, is not more than twenty-eight degrees, and its reflected light is absorbed in the more powerful rays of the sun. He always appears on the same side of the heavens with the sun; of course, he can be seen in the east, only in the morning a little before sunrise, and in the west in the evening a little after sunset. When viewed with a telescope of high magnifying power, he exhibits nearly the same phases as the moon, and they are to be accounted for in the same manner. Mercury revolves round the sun at nearly the mean distance of thirty seven millions of miles, and completes his revolution in about three months. According to Sir Isaac Newton, the heat and light of the sun on the surface of Mercury, are almost seven times as intense as on the surface of the earth in the middle of summer; which, as he found by experiments made for that purpose with a thermometer, is sufficient to make water fly off in steam and vapour. Such a degree of heat, therefore, must render Mercury uninhabitable to creatures of our constitution; and if bodies on its surface be not inflamed and set on fire, it must be because their degree of density is proportionably greater than that of such bodies is with us. When Mercury passes over the sun's face, or is between us and the sun, this is called his transit, and the planet appears like a black spot in the sun's disk. The light emitted by Mercury is a very bright white.

Fair Venus next fulfils her larger round,
With softer beams, and milder glory crowned;
Friend to mankind, she glitters from afar,
Now the bright evening, now the morning star.

BAKER.

Venus is computed to be sixty-eight millions of miles from the sun, and completes her annual rotation in about seven and a half months, turning on her axis in a little less than twenty four hours. The light, which this planet reflects, is very brilliant, and often renders her visible to the naked eye in the day-time. When Venus is to the west of the sun, she rises before the sun, and is called the morning star; when she appears to the east of the sun, she shines in the evening, and is then called the evening star. She is in each situation alternately, for about two hundred and ninety days; and, during the whole of her revolution, she appears, through a telescope, to have all the various shapes and appearances of the moon. As the orbit of Venus is within that of the earth, like Mercury, she sometimes passes over the sun's face, and her transits have been applied to one of the most important problems in astronomy,—that of determining the true distances of the planets from the sun. The atmosphere of Venus has been calculated to be fifty miles high; this has been learned from observing her transits, when her atmosphere was seen to throw a shade on the sun's disk about five seconds before the more opaque part touched his edge. When the elongation of Venus is about forty degrees, her lustre far exceeds that of the moon, at the same apparent distance from the sun. For though the moon reflects more light to us than Venus does, yet this light is dull, and has none of the briskness which attends the beams of Venus. This difference is supposed to arise from the circumstance of Venus having an atmosphere far more dense than that of the moon.

Questions.—1. What is the appearance of Mercury? 2. What is the length of his year?—Distance from the sun? 3. Why is it seldom seen? 4. What is its greatest elongation? 5. What calculation did Newton make with respect to the light and heat of Mercury? 6. What must be the consequence of such a degree of heat? 7. What is called a transit of Mercury? 8. What is the distance of Venus from the sun?—Length of her year?—Day? 9. When is Venus evening and when morning star?—How long in each situation? 10. To what purpose have her transits been applied? 11. What is said of her atmosphere? 12. When is the lustre of Venus greatest, and to what is it attributed?

LESSON 44.

The Earth.

Merid'ian, a great circle passing through the poles of the world, and also through both zenith and nadir; it crosses the equator at right angles, and divides the sphere into two hemispheres, the eastern and the western; it has its poles at the east and west points of the horizon.

The planet which we inhabit is called the earth. It revolves about the sun at the mean distance of ninety-five, or, as some state, of ninety-three millions of miles. It completes this revolution in a year, and turns on its axis in a day, or twenty-four hours. If the earth were seen from the sun, it would appear to describe, while revolving in its orbit, a circle among the stars. But to us on the earth, the sun *appears* to describe precisely the same circle, only beginning at the opposite point. That imaginary great circle in the heavens, which the sun *appears* to describe in the course of the year, is called the *ecliptic*. The *apparent* diurnal, or *daily* motion of the sun is very different from the path which it appears to traverse in the course of a *year*. The *former* is observed by the most inattentive spectator; but the knowledge of the *latter* must be the result of patient observation.

The other primary planets, when seen from the sun, do not describe exactly the same circle among the stars, that the earth does; but are sometimes on one side of the ecliptic and sometimes on the other. But none of them, except Juno, Pallas, and Ceres, are ever farther distant from the ecliptic than eight degrees. So that within a zone or belt of sixteen degrees, that is, eight degrees on each side of the ecliptic, the planets, except those just named, are always to be found. This zone, or broad belt, is called the *Zodiac.* The ecliptic then is an imaginary circle in the heavens passing through the middle of the zodiac, and situated in the plane of the earth's orbit. A plane is an even level surface. If you suppose a smooth thin solid plane cutting the sun through the centre, extending out as far as the fixed stars, and terminating in a circle which passes through the middle of the zodiac; in this plane the earth would move in its revolution round the sun; it is therefore called the plane of the earth's orbit. The points, where the orbit of any heavenly body cuts the plane of the ecliptic, are called the *nodes* of that body. The point, where the body passes from the north side of the plane of the ecliptic to the south, is called its *descending node;* where it passes from the south to the north, its *ascending node.*

The ecliptic, as well as every other circle, great or small, is divided into three hundred and sixty degrees; but it has also another division into twelve signs, of thirty degrees each, called the twelve signs of the zodiac. These signs derive their names from clusters of stars, or constellations, which, as the ancients imagined, resembled certain animals. They are most commonly represented by characters, and the names given them should be made familiar; for the sun, as he *appears* to move round in the ecliptic, seems to enter these clusters of stars, and is therefore said to be in this or that sign.

If the axis of the earth be supposed to extend both ways to the starry heavens, its places or points among the stars are the *celestial* poles, one north and the other south, directly over or beyond the poles of the earth of the same name. If the plane of the earth's equator were extended every way to the starry heavens, the circle it would make among the stars is called the *celestial* equator. Now the celestial equator does not coincide with the ecliptic, but makes an angle with it of twenty-three degrees and twenty-eight minutes, that is, the axis of the earth is not perpendicular to the plane of the ecliptic, but is inclined twenty-three degrees and twenty-eight minutes. Thus we have two great circles, the ecliptic and equator, passing through the heavens eastwardly and westwardly, from either of which the latitude of the heavenly bodies might be estimated. But astronomers have selected the ecliptic for this purpose, and have supposed lines or circles to cross it at right angles, as the meridians do the equator ; which lines or circles are called *secondaries* to the ecliptic. The points where all the secondaries meet, are called the *poles of the ecliptic ;* which points are twenty-three degrees twenty-eight minutes from the celestial poles. Hence the latitude of a heavenly body is its distance from the ecliptic, measured on a secondary to the ecliptic ; and like latitude on the earth, it can never exceed ninety degrees. The longitude of a heavenly body is the distance of a secondary to the ecliptic, reckoned from some given uniform secondary, called the prime secondary. But the longitude of heavenly bodies, unlike longitude on the earth, is reckoned only *eastward;* it may extend, therefore, to three hundred and sixty degrees. It is usually stated in signs, degrees, minutes, and so forth ; and the prime secondary, from which it is reckoned, cuts the ecliptic in the beginning of the sign Aries, a point where the celestial equator crosses the ecliptic. If a secondary, for instance, passing through a heavenly body, cuts the ecliptic eighteen degrees in the sign Capricorn, then, since the first point of Capricorn is nine signs eastward from the first point of Aries, the longitude of that body is nine signs, eighteen degrees. But it is often important to know the distance of a heavenly body from the *celestial* equator, as well as from the *ecliptic*. This distance is its *declination*, and is reckoned on a meridian, as latitude is on the earth. Its distance from the beginning of Aries, reckoned on the equator, is its *right ascension ;* which, like celestial longitude, is reckoned through the whole circle, or three hundred and sixty degrees. Two planets are said to be in *conjunction* with each other, when they have the same longitude, or are in the same degree of the ecliptic on the same side of the heavens, though their latitude be different.

They are said to be in *opposition*, when their longitudes differ half a circle, or they are in opposite sides of the heavens.

Questions.—1. What is the ecliptic?—explain. 2. What is the zodiac?—explain. 3. What is meant by the plane of the earth's orbit? 4. What are nodes? 5. What are the divisions of the ecliptic? 6. What are the celestial poles? 7. What is the celestial equator? 8. How is the axis of the earth situated with regard to the plane of the ecliptic? 9. What are the poles of the ecliptic? 10. What is the latitude of a heavenly body? 11. The longitude? 12. How is the longitude of a heavenly body reckoned and stated? 13. What example is given? 14. What is the declination of a heavenly body. 15. Right ascension? 16. When are two planets said to be in conjunction? 17. In opposition? [Note. The points at which the ecliptic cuts the celestial equator are called the *equinoctial points*. Those two points of the ecliptic farthest from the equator are called *sol'stices*. *Ap'ogee*, that point of the orbit of the moon which is farthest from the earth. *Per'igee*, that point which is nearest to the earth.] 18. Look at fig. 40. and point out the ecliptic, zodiac, and signs of the zodiac.

LESSON 45.

Day and Night.

Ver'nal, belonging to the spring.
Intersect', to cut, to divide each other mutually.

By the diurnal motion of the earth, the same phenomena appear as if all the celestial bodies turned round it; so that in its rotation from west to east, when the sun or a star just appears on the eastern side of the horizon, it is said to be rising, and as the earth continues its revolution, it seems gradually to ascend till it has reached its meridian; here the object has its greatest elevation, and begins to decline till it set, or become invisible on the western side. In the same manner the sun *appears* to rise and run his course to the western horizon, where he disappears and night ensues, till he again illuminate the same part of the earth in another diurnal revolution. One half of the earth's surface is constantly illuminated, and by the regular motion of the earth on its axis, every place is successively brought into light and immersed in darkness. If the axis of the earth were always perpendicular to the plane of the ecliptic, the days would every where be of the same length, and just as long as the nights. For an inhabitant at the equator, and one on the same meridian towards the poles, would come into the light at the same time, and, on the other side, would immerge into darkness at the same time. And since the motion of the earth is uniform, they would remain in the dark hemisphere just as long as in the light; that is, their day and night would be *equal*;—the plane of the ecliptic would coincide with the plane of the equator. But as the ecliptic and equator make an angle with each other of twenty-three degrees and twenty-eight minutes, or in other words, as the axis of the earth has such an inclination to the plane of its orbit, it is manifest that, except the earth be in that part of its orbit where the ecliptic cuts the equator, an inhabitant at the equator and one on the same meridian towards the poles, will not come into the light at the same time, nor, on the other side, immerge into darkness at the same time. And since the axis of the earth always preserves the same inclination, they will,—except at the points where the two great circles intersect each other,—remain in the dark and light hemispheres different times; that is, their day and night will be *unequal*. The points where the equator cuts the ecliptic are at the beginning of the signs Libra and Aries. The earth is at these points of its orbit, or, as it is commonly said, the sun enters the sign Aries on the twentieth of March, and the sign Libra on the twenty-third of September. Hence at these periods, and at no others, the days and nights are equal all over the world; and on this account they are called equinoxes; the first the *vernal*, and the second the *autumnal* equinox. At these seasons, the sun rises exactly in the east at six o'clock, and sets exactly in the west at six o'clock; —the light of the sun is then terminated by the north and south poles, and as all parts of the earth turn round once in twenty-four hours, every place must receive the rays twelve hours, and be deprived of them for the same time. But at other seasons, when the rays of light are not terminated by the north and south poles, but extend over the one and do not reach the other, it must be manifest, from a moment's inspection of the circles drawn on globes, or common maps of the world, that day and night will be *unequal* in all places except those situated on the equator, where they will be always *equal*. At the poles there is but one day and one night in a year, each of six months. The sun can never shine beyond a pole farther than twenty-three degrees and twenty-eight minutes; for that is the extent of his declination; and when he has declination from the celestial equator either north or south, he must shine beyond one pole and not to the other; the days, therefore, will be longest in one hemisphere when they are shortest in the other.

The subject of this lesson may be illustrated, by hanging any round body above or below the level of a candle so as to correspond with the sun's declination. It will be seen, that the light shines over one pole and does not reach the other. If the ball be then turned round, it will be observed, that the circles performed by any parts of the surface are unequally divided by the light; that it will be constant day or night near the north pole, as the ball is depressed or elevated, and that all the phenomena will be reversed in the other, or lower hemisphere.

QUESTIONS.—1. What phenomena *appear* from the diurnal motion of the earth? 2. Under what circumstances would the days and nights be every where of the same length?—Why? 3. Why is not the day and night always equal to an inhabitant at the equator, and to one on the same meridian towards the poles? 4. At what points does the equator cut the ecliptic? 5. When is the earth at those points of its orbit?—and what happens at these periods? 6. At other seasons? 7. What is said of day and night at the poles? 8. How may the subject of this lesson be illustrated? 9. Look at fig. 40, and illustrate the variations in the lengths of the days and nights.

LESSON 46.

Changes of the Seasons.

Obliq'uity of the Ecliptic, the angle which the ecliptic makes with the equator.

LOOK nature through, 'tis revolution all;
All change, no death. Day follows night, and night
The dying day. Stars rise and set, and rise.
Earth takes th' example; see, the summer gay,
With her green chaplet and ambrosial flowers,
Droops into pallid Autumn. Winter gay,
Horrid with frost, and turbulent with storm,
Blows Autumn and his golden fruits away;
Then melts into the Spring. Soft Spring, with breath
Favonian, from warm chambers of the south,

Recals the first. All, to reflourish, fades;
As in a wheel, all sinks, to reascend:
Emblem of man, who passes, not expires.—THOMSON.

The orbit in which the earth revolves in his annual course round the sun is not a circle but an ellipse or oval; and we are more than three millions of miles nearer to the sun in December about the time of the winter solstice, than we are in June about the time of the summer solstice. Now as heat and light from the sun are greater as the distance is less, it is manifest that this circumstance would occasion a variation in the temperature of the air, like that of our seasons, if the equator always coincided with the ecliptic. But the seasons with us, in north latitude, are not in the least degree occasioned by this circumstance, but by the direction in which the sun's rays fall upon us. When they fall perpendicularly, or most nearly so, the season is warmest; and when they fall most obliquely, or in a slanting manner, the season is coldest. The cause of the difference in the obliquity of the sun's rays is the obliquity of the ecliptic. The effect of obliquity, in regard to rays will be evident, if a board be held perpendicularly before a fire. It will then receive a body of rays equal to its breadth. But if it be placed obliquely, at an angle of forty-five degrees, then only half the rays will fall on its surface, and the other half will pass over it; so it is with the surface of the earth in summer and winter. The circumstance also, that the days are longest, whether in north or south latitude, when the sun's rays fall in the greatest quantity and most directly at any place, contributes much to the warmth of summer and the cold of winter. In northern countries, where the days are eighteen or twenty hours long, or where the sun is above the horizon for any number of days together, the heat of summer is equal to that of any part of the world.

Since the degree of heat from the sun increases as the earth's distance diminishes, and this distance is least when it is summer in south latitude, and greatest when it is summer in north latitude, a greater degree of heat, therefore, must be received in summer in south latitude, than in summer in north latitude. But to compensate for a less degree of heat, the inhabitants in north latitude have longer summers than those in south latitude. For as the sun is not in the centre of an ellipse but in the focus, the earth must move farther in its orbit in one part of its revolution than in the other. It moves slower also as it is farther from the sun; and our summers are found to be eight days longer than the summers in south latitude; that is, between the vernal and autumnal equinoxes there are eight days more, than between the autumnal and vernal.

It is well known that the degree of heat is not greatest, when the days are longest. We have the warmest weather in the latter part of July, and in the first of August; and our coldest mouth is January. To account for this it has been stated, that a body once heated does not grow cold again instantaneously, but gradually; now as long as more heat comes from the sun in the day, than is lost in the night, the heat of the earth and air will be daily increasing, and this must evidently be the case for some weeks after the longest day, both on account of the number of rays which fall on a given space, and also from the perpendicular direction of those rays. It is for the same reason, that the warmest part of the day is not, when the sun is at the meridian, but about two or three o'clock in the afternoon.

Questions.—1. When are those who live in north latitude nearest the sun? 2. What would be the consequence if the equator coincided with the ecliptic? 3. What occasions the seasons with us? 4. How may the effect of obliquity in regard to the sun's rays be made evident? 5. What contributes much to the warmth of summer? 6. What is said of north and south latitudes as respects the degree of heat?—Explain. 7. Why is not the degree of heat greatest when the days are longest? 8. Look at fig. 40, and illustrate the diversity of the seasons.

LESSON 47.

The Moon.

Quad'rature, the first and last quarter of the moon.
Lu'nar, relating to the moon. Luna'tion, the revolution of the moon.

The moon is a secondary planet, revolving round the earth in about twenty-nine days and a half, and is carried with the earth round the sun once a year. Its distance from the earth is about two hundred and forty thousand miles; and it turns on its axis in the same time that it performs its revolution round the earth. The light of the sun illuminates one half of its surface, and leaves the other in darkness. Of this illumination we perceive different degrees, according to the various positions of the moon, with respect to the sun and the earth. We see one half of its body enlightened, or a full moon, when it is placed in opposition to the sun, or when the sun is in one part of the heavens, as west, and the moon in the opposite part, as east. When the moon is in conjunction with the sun, or in that part of its orbit which is between the earth and the sun, its enlightened surface is turned from us, which renders it invisible; this is the time of the new moon. When the moon appears in the intermediate part of its orbit, between the conjunction and opposition, it is in its quadratures, and about half of its illuminated surface is turned towards us.

As the moon illuminates the earth by light reflected from the sun, so she is reciprocally illuminated by the earth which reflects the sun's rays to the surface of the moon. As the surface of the earth is more than thirteen times greater than that of the moon, the earth must appear to the inhabitants of the moon thirteen times larger than the moon does to us, and it will exhibit the same phases, but in an opposite order. As the rotation of the moon on her axis is performed in the same time that she goes once round the earth,—which is evident from her always presenting the same face to us during the whole of her monthly revolution,—it is plain, that the inhabitants of one half of the lunar world are totally deprived of a sight of the earth, unless they travel to the opposite hemisphere.

The face of the moon appears to have shades of different colours. If viewed through an ordinary telescope, her surface will appear diversified with long tracts of mountains and cavities. It has been ascertained that these are mountains from the shadows which they cast, and some of them are supposed to be volcanic.

The difference between the rising of the moon on one day and the preceding is generally about fifty minutes. But in places of considerable latitude, there is a remarkable difference about the time of harvest, when at the season of full moon she rises for several nights together only about twenty minutes later on the one day than on that immediately preceding. By thus succeeding the sun before the twilight is ended, the moon prolongs the light, to the great benefit of those who are engaged in gathering in the fruits of the earth; and hence the full moon at this season is called the harvest moon. It is believed that this was observed by persons engaged in agriculture, at a much earlier period than it was noticed by astronomers. The phenomenon may be easily explained by the assistance of a globe; and it is occasioned by the moon's orbit lying sometimes more oblique to the horizon than at others.

The Harvest Moon.

All hail! thou lovely queen of night,
  Bright empress of the starry sky!
The meekness of thy silvery light
  Beams gladness on the gazer's eye,
While from thy peerless throne on high
  Thou shinest bright as cloudless noon,
And bidd'st the shades of darkness fly
  Before thy glory—Harvest moon!

In the deep stillness of the night,
  When weary labour is at rest,
How lovely is the scene!—how bright
  The wood—the lawn—the mountain's breast,
When thou fair moon of Harvest! hast
  Thy radiant glory all unfurled,
And sweetly smilest in the west,
  Far down upon the silent world.

Shine on, fair orb of light! and smile
  Till autumn months have passed away,
And labour hath forgot the toil
  He bore in summer's sultry ray;
And when the reapers end the day,
  Tired with the burning heat of noon,
They 'll come with spirits light and gay,
  And bless thee—lovely Harvest Moon!

W. MILLAR.

QUESTIONS.—1. In what time does the moon revolve round the earth? 2. At what distance is it from the earth? 3. In what time does it turn on its axis? 4. What is said of the illumination of the moon? 5. How does the earth appear as seen from the moon? 6. How does the face of the moon appear when viewed through a telescope? 7. What is the Harvest Moon? 8. By what is it occasioned?—9. Look at fig. 41, and illustrate the phases of the moon.

LESSON 48.

The Tides.

The sea is observed to flow for certain hours from the south towards the north. In this motion, which lasts about six hours, the sea gradually swells; so that entering the mouths of rivers, it drives back the waters towards their heads. After a continual flow of six hours, the sea seems to rest for about a quarter of an hour; it then begins to ebb, or retire back again from north to south for six hours more; and the rivers resume their natural course. Then, after a seeming pause of a quarter of an hour, the sea again begins to flow, as before, and thus alternately. This regular and alternate motion of the sea constitutes the *tides*. They are chiefly occasioned by the attraction of the moon, but are affected by that of the sun. There are two tides in about twenty-five hours; and the time of high or low water is every day fifty minutes later than on the preceding day. The moon is supposed to draw the earth towards itself, and to act upon the solid parts of it, in the same manner as if its whole weight were in a single point in or near the centre. Now the waters at any place over which the moon is passing, will be more attracted than the earth; and therefore will be heaped up under the moon. But the waters on the opposite side of the globe will be less attracted than the earth; consequently the earth is drawn away from them; and they are heaped up, or, in other words, it is high water there. When the waters are elevated at the side of the earth under the moon, and at the opposite side also, it is evident they must recede from the intermediate points, and thus the attraction of the moon will produce high water at two places and low water at two places on the earth at the same time. The tide is fifty minutes later every day, because it is twenty-four hours and fifty minutes before the same meridian on our globe returns beneath the moon. The earth revolves on its axis in about twenty-four hours; if the moon, therefore, were stationary, the same part of our globe would return beneath it, every twenty-four hours; but as during our daily revolution the moon advances in her orbit, the earth must make more than a complete revolution in order to bring the same meridian opposite the moon; we are fifty minutes in overtaking her, and the tides are retarded for the same reason that the moon rises later on one day than on the preceding.

The tides, though constant, are not equal; but are greatest when the moon is in conjunction with the sun or in opposition to it, or at the time of new and full moon; and least, when in quadrature to it. This increase and diminution constitute the *spring* and *neap* tides. The attraction of the sun does not raise tides; its only effect is to increase or diminish those of the moon. The tides are highest when both the luminaries are in the equator, and the moon at the least distance from the earth. This happens at the time of the equinoxes. The tide is at the greatest height, not when the moon is in the meridian, but some time afterwards, because the force by which the moon raises the tide continues to act after it has passed the meridian. The regular tides are greatly affected by strong winds. Continents also stop them in their course from east to west, and in narrow rivers they are frequently very high and sudden, from the resistance of the banks. The advantages arising from tides are great. By agitating the waters of the ocean they preserve them in a state of purity. Aided by their means, ships of the largest burden sail up rivers against their natural course, and convey into the interior of countries those productions which stimulate the industry and promote the happiness of nations.

QUESTIONS.—1. What are the tides? 2. How are they occasioned? 3. How does it appear that the moon produces high water in two places at the same time? 4. How do you account for the tide being fifty minutes later every day? 5. What are *spring* and *neap* tides? 6. What is the effect of the sun's attraction? 7. When are tides highest? 8. What produces irregularity in tides? 9. What advantages arise from tides? 10. Look at figures 42 and 43, and explain the tides.

LESSON 49.

Eclipses.

An′nular, having the form of a ring, from *annulus*, a Latin word for ring.

THE earth being an opaque body enlightened by the sun, necessarily projects a shadow into the regions of space in a contrary direction. When it so happens that the moon, in the course of her revolution about the earth, falls into this shadow, she loses the sun's light, and appears to us *eclipsed.* If we suppose two straight lines drawn from the opposite parts of the solar disk, touching the surface of the earth on opposite sides; these lines will represent the limits of the shadow, and as the sun is much larger than the earth, they will meet at a point and cross each other behind the earth, and the shadow will thus take the form of a cone. The moon can come within the shadow of the earth only when it is full, or in opposition to the sun. But the moon is not eclipsed every time it is full, because its orbit does not coincide with the plane of the earth's orbit, one half being about five degrees and a third above it, and the other half as much below it; and unless the full moon, therefore, happen in or near one of the nodes, that is, in or near the points in which the two orbits intersect each other, she will pass above or below the shadow of the earth, in which case there can be no eclipse. If the moon be within twelve degrees from the node, at the time when she is full, there will be a partial or total eclipse, according as a part, or the whole of her disk falls within the earth's shadow. As the shadow is considerably wider than the moon's diameter, an eclipse of the moon lasts sometimes three or four hours. It is by knowing exactly at what distance the moon is from the earth, and of course the width of the earth's shadow at that distance, that eclipses are calculated with the greatest accuracy, for many years before they happen. Lunar eclipses are visible over every part of the earth that has the moon at that time above the horizon; and the eclipse appears of the same magnitude to all from the beginning to the end. That faint reddish colour, which the moon exhibits in the midst of an eclipse, is supposed to proceed from the rays of light, which are refracted by the earth's atmosphere, and fall upon the surface of the moon.

An eclipse of the sun is caused by an interposition of the moon between the sun and the earth. This can happen only at the new moon, or when the moon at her conjunction is near one of her nodes; for unless the moon is in or near one of her nodes, she cannot appear in the same plane with the sun, or seem to pass over his disk. In every other part of her orbit she will appear above or below the sun. If the moon be *in* one of her nodes, she will, in most cases, cover the whole disk of the sun and produce a *total* eclipse ; if she be any where within about sixteen degrees of a node, a *partial* eclipse will be produced. When a bright luminous ring appears round the dark body of the moon during an eclipse of the sun, it is called an annular eclipse. This kind of eclipse is occasioned by the moon being at her greatest distance from the earth at the time of an eclipse; in which situation, the vertex or point of the cone of the moon's shadow does not reach the surface of the earth. A total eclipse of the sun is a very curious and uncommon spectacle; and total darkness cannot last more than three or four minutes. Of one that was observed in Portugal more than one hundred and fifty years ago, it is said that the darkness was greater than that of night;—that some of the largest stars made their appearance;—and that birds were so terrified that they fell to the ground. A very remarkable total eclipse took place in New England June 16, 1806. The day was clear; several stars were visible; the birds were greatly agitated; and a gloom spread over the landscape. The first gleam of light, contrasted with the previous darkness, seemed like the usual meridian day.

Questions.—1. What is an eclipse of the moon? 2. Describe the earth's shadow. 3 When does an eclipse of the moon happen? 4. Why is she not eclipsed at every full moon? 5. How near a node must she be in order to be eclipsed? 6. How long may an eclipse of the moon last? 7. From the knowledge of what circumstances are lunar eclipses calculated? 8. Over what part of the earth are they visible? 9. What is the cause of an eclipse of the sun? 10. When does an eclipse of the sun happen? 11. Why can it not happen at other times? 12. When will the moon produce a total eclipse of the sun? 13. Partial? 14. When is an eclipse of the sun called annular?—why? 15. What occasions this kind of eclipses? 16. How long may a total eclipse of the sun last? [Note. The diameters of the sun and moon are supposed to be divided into 12 equal parts, called *digits*. They are said to have as many digits eclipsed as 12th parts involved in darkness.] 17. Look at fig. 45. and illustrate an eclipse of the moon. 18. At fig. 44. and illustrate an eclipse of the sun.

LESSON 50.

Mars, Vesta, Juno, Pallas, and Ceres.

Eccen'tric, deviating from the centre.
Eccentriç'ity, the distance between the centre of an ellipse and the focus.

Mars, the first of the exterior planets, is distinguished from the rest by the redness of its colour, which has been attributed to the density of his atmosphere. He revolves round the sun in about two years, at the mean distance of one hundred and forty-four millions of miles, and turns on his axis in a little less than twenty-five hours. The time of his diurnal rotation was discovered by means of a large spot seen on his surface, when in that part of his orbit which is opposite to the sun and the earth. The telescopic appearance of Mars is exceedingly variable; but the predominant brightness of his polar regions, leads to the supposition, that, like those of the earth, they are covered with perpetual snow. The proportion of light and heat, received at Mars from the sun, is less than one half of that enjoyed by the earth.

The planet next to Mars in the solar system is Vesta. It shines with a pure and white light, and is visible in a clear evening without the aid of a telescope. It revolves round the sun, in about three years and eight months, at the mean distance of two hundred and twenty-three millions of miles. Vesta was first discovered by Dr. Olbers, of Bremen, in Lower Saxony, March 29, 1807.

Juno was discovered by Mr. Harding, near Bremen, September 1, 1804. It completes its revolution in about four years and four months, at a mean distance from the sun of about two hundred and fifty-three millions of miles. It is distinguished from all the other planets by the great eccentricity of its orbit; and the effect of this is such that it passes over one half of its orbit in half the time that it employs in describing the other half. From the same cause its greatest distance from the sun is double the least distance, the difference between the two distances being about one hundred and twenty-seven millions of miles.

Pallas was discovered by Dr. Olbers, March 28, 1802. It completes its revolution in about four years and seven months, and its orbit is nearly as eccentric as that of Juno. Its mean distance from the sun is two hundred and sixty-three millions of miles. Its atmosphere seems to be dense and cloudy.

The planet Ceres was discovered by Piazzi, at Palermo, in Sicily, January 1, 1801. It is apparently surrounded by a dense atmosphere, and is of a ruddy appearance. Its mean distance from the sun, and its revolution in its orbit is nearly the same as that of Pallas. These newly discovered planets exhibit various changes in appearance and size; so that their real magnitude has not been ascertained with certainty.

From some irregularities, observed in the motions of the old planets, some astronomers had been led to suppose, long before the discovery of the four new planets, that a planet existed between the orbits of Mars and Jupiter. Dr. Olbers, before he made his last discovery, conceived that these small celestial bodies were merely the fragments of a larger planet, which had been burst asunder by some internal convulsion, and that several more might be discovered. With the intention, therefore, of detecting other fragments of the supposed planet, he examined, thrice every year, the little stars in certain constellations, till his labours were crowned with success by the discovery of the new planet Vesta. The opinion, that these four small planets have been separated from one original planet, by some convulsion in nature, has been maintained by Dr. Brewster with much ingenuity and plausibility. He supposes, moreover, that the phenomena of the meteoric stones, which have fallen on the earth from the atmosphere, may have been occasioned by the bursting of this planet.

Questions.—1. By what is Mars distinguished from the rest of the planets? 2. In what time does Mars revolve round the sun? 3. At what mean distance? 4. What is the time of his diurnal rotation, and how was it discovered? 5. What is the telescopic appearance of Mars? 6. Proportion of light and heat? 7. What is the appearance of Vesta? 8. When, where, and by whom were each of the new planets discovered? 9. What is the distance of each from the sun? 10. By what is Juno distinguished from all the other planets? 11. What supposition did some astronomers make before the discovery of the new planets? 12. What was the conjecture of Dr. Olbers, and to what did it lead? 13. To what does Dr. Brewster think the phenomena of meteoric stones may be attributed?

LESSON 51.

Jupiter.

JUPITER is the largest of all the planets. His diameter is eighty-nine thousand miles. He revolves round the sun at the mean distance of four hundred and ninety millions of miles, completes a revolution in a little less than twelve years, and turns on his axis in the short interval of nine hours and fifty-six minutes. With the exception of Venus, Jupiter is the most brilliant of the planets, and, when viewed through a telescope, its surface is remarkable for being always covered with a number of belts or stripes of various shades. They are not regular or constant in their appearance, and their breadth is also variable, one belt growing narrower while another in its neighbourhood becomes broader, as if one had flowed into the other. Sometimes one or more spots are formed between the belts, which increase until the whole are united in one large dusky band. Bright spots also may be discovered on Jupiter's surface, which are more permanent than the belts, and re-appear after unequal intervals of time. For the cause of these appearances, we are referred by eminent philosophers, to his swift diurnal motion, to the changes in the density of his atmosphere, as occasioned by variations of temperature, and to other incidental agencies. The axis of Jupiter is perpendicular to the plane of his orbit; his inhabitants, therefore, will experience no change of seasons, nor difference in the length of their days and nights. At the equator there will be perpetual summer, and at the poles unceasing winter. The degree of light and heat is about twenty-five times less than at the earth.

The satellites of Jupiter are invisible to the naked eye, but through a telescope they make a beautiful appearance. As our moon turns round the earth, enlightening the nights by reflecting the rays of the sun, so these also enlighten the nights of Jupiter, and move round him in different periods of time, proportioned to their several distances. They often pass behind the body of the planet, and also into its shadow, and are eclipsed. These eclipses are of use for ascertaining the longitude of places. They have led to the discovery, that light is about eight minutes in coming from the sun to the earth; for an eclipse of one of these satellites appears to us to take place sixteen minutes sooner, when the earth is in the part of her orbit nearest Jupiter, than when in the part farthest from him. Hence light is sixteen minutes in crossing the earth's orbit, and of course eight minutes in coming from the sun. An observer on Jupiter, with eyes constructed like ours, could never see Mercury, Venus, the Earth, or Mars, for, on account of the immense distance, they are always immersed in the sun's rays.

QUESTIONS.—1. What is the diameter of Jupiter?—distance from the sun?—time of revolution round the sun?—diurnal rotation? 2. Describe the telescopic appearance of Jupiter. 3. What is the position of his axis, and the consequence of that position? 4. What is said of Jupiter's moons? 5. Of what use are their eclipses? 6. To what discovery have they led?—how?

LESSON 52.

Saturn and Uranus.

Anom'aly, irregularity, deviation from rule.
Hypoth'esis, a supposition, a system formed under some principle not proved.

SATURN though not so brilliant as Jupiter, is a very conspicuous planet. It shines with a pale light, and the degree of heat and light is eighty times less than at the earth. It revolves round the sun in little less than thirty years, at the mean distance of nine hundred millions of miles. It turns on its axis in little more than ten hours, and its diameter is seventy-nine thousand miles.

Saturn, as seen through a good telescope, is a beautiful object, having seven moons, a double ring, and appearances similar to the belts of Jupiter. The ring is one of the greatest anomalies in our system. It is a thin, broad, opaque, circular body, encompassing the planet without touching it, like the wooden horizon of an artificial globe. Although the phenomenon is usually termed the ring, yet it consists of two, entirely detached from each other and from the body of the planet, one exactly without or beyond the other. Stars have been seen through the vacancy between them, and also between the inner ring and the planet. Concerning the nature and uses of the ring there have been various hypotheses. Dr. Herschel thinks it not less solid than the body of Saturn itself, and it is observed to cast a strong shadow upon it. The light of the ring is generally brighter than that of the planet, which has been attributed to its situation above the region of mists and clouds. Both the planet and the ring perform their rotations about the same common axis, and in nearly the same time. The ring disappears twice in every revolution of the planet round the sun; that is, once in fifteen years, and Saturn appears quite circular for nine months together. Some have supposed that the use of the ring is to collect, refract, and transmit the rays of the sun to the body of the planet.

The planet Uranus, or Herschel, completes a revolution round the sun in about eighty-four years. On account of its distance from the earth, which is eighteen hundred millions of miles, its diurnal rotation has never been determined. Heat and light at Uranus are about three hundred and sixty times less than at the earth. It is scarcely visible to the naked eye, although its diameter is thirty-five thousand miles. Astronomers formerly considered it as a star, but on the 13th of March, 1781, Dr. Herschel discovered it to be a planet.

Questions.—1. How far is Saturn from the sun? 2. What degree of light and heat has it? 3. How often does it revolve round the sun? 4. On its own axis? 5. What is the appearance of Saturn as seen through a telescope? 6. Describe the ring. 7. What is said concerning the nature and uses of the ring. 8. In what time does Uranus complete a revolution? 9. At what distance from the sun? 10. What is the diameter of Uranus? 11. Degree of heat and light? 12. When and by whom discovered? [Note. Saturn's inner ring is distant from its body 21,100 miles. The breadth of the inner ring is 20,000 miles. The outer ring is distant from the inner ring 2,839 miles, and the breadth of the outer ring is 7,200 miles. Uranus is the name which has been given to the planet Herschel, or Georgium Sidus, on the continent of Europe.]

LESSON 53.

Comets.

Hast thou ne'er seen the comet's flaming flight?
Th' illustrious stranger passing, terror sheds

On gazing nations, from his fiery train
Of length enormous; takes his ample round
Through depths of ether; coasts unnumbered worlds
Of more than solar glory; doubles wide
Heaven's mighty cape, and then revisits earth,
From the long travel of a thousand years. YOUNG.

Besides the primary and secondary planets, there are other bodies which revolve round the sun, and consequently make a part of the solar system. These are called *comets*, and appear occasionally in every part of the heavens. They are solid, opaque bodies, generally distinguished by a lucid train or tail, issuing from that side which is turned away from the sun. Most of them move in very elliptical orbits; at one time coming very near the sun, even nearer than Mercury, and again receding to a distance far beyond the orbit of Uranus. The train is so transparent, that the fixed stars may be seen through it, and sometimes it extends to an immense distance in the heavens. The farther it reaches, the broader it seems to become, and at times it is divided into rays.

Viewed through a telescope, comets appear full of spots and inequalities, and a vapour frequently renders it impossible to observe their figure. In a clear sky, however, the solid body of a comet often reflects a splendid light. That part of astronomy relating to comets is still imperfect, for the opinion once prevailed, that they were only meteors generated in the air, like those we see in a clear night, vanishing in a few moments, and no care therefore was taken to observe or record their phenomena with accuracy.

The number of comets belonging to the solar system is unknown. More than five hundred have appeared since the commencement of the christian era. The orbits of ninety-eight comets, up to the year 1808, have been calculated; but of all the comets the periods of only three are known with any degree of certainty, being found to return at intervals of seventy-five, one hundred twenty-nine, and five hundred and seventy-five years; and of these that which appeared in 1680 is the most remarkable. This comet, which will not appear again till the year 2225, at its greatest distance, is about eleven thousand two hundred millions of miles from the sun, while its least distance from the centre of the sun is about four hundred ninety thousand miles. In that part of its orbit nearest the sun, it flies, according to Newton, with a velocity of eight hundred eighty thousand miles an hour; but according to calculations made since the days of Newton, its motion has been computed to be one million two hundred forty miles an hour.

The comet of 1758 was looked for with great interest by astronomers, because its return had been predicted. But it is worthy of remark, that what, in this century, excited only the curiosity of astronomers and mathematicians, had been regarded four revolutions before, in 1456, with feelings of horror. Its long train spread consternation over all Europe, already terrified at the success of the Turkish arms, which had just destroyed the great empire. Pope Callixtus, on this occasion, ordered a prayer, in which the comet and the Turks were included in the same anathema.

QUESTIONS.—1. What are comets? 2. How do they move? 3. What is said of the train of a comet? 4. How do comets appear through a telescope? 5. What is said of the number of comets? 6. What is known of the orbits of comets? 7. What is said of the comet of 1680? 8. What is worthy of remark with respect to the comet of 1758? [NOTE. The comet of 1758 is expected to return in 1834.]

LESSON 54.

The Fixed Stars.

Neb'ula, (plural, nebulæ,) a cloud of obscure light in the heavens; some nebulæ consist of clusters of telescopic stars, others appear as luminous spots of different forms. Sir'ius, the dog-star.

THOSE luminous bodies which always appear in the heavens at the same distance from each other, are called *fixed stars;* because, with the exception of a few, which, in a course of years, appear to change their places, it has not been discovered, that they have any proper motion of their own. When viewed through a telescope they appear as points of small magnitude; they must be at such an immense distance, therefore, as to be invisible to the naked eye, if they borrowed their light; as is the case with the satellites of Jupiter and Saturn, although they appear of very distinguishable magnitude through a telescope. The stars are probably suns, around each of which revolve primary and secondary planets, as about our sun. They are distinguishable from the planets by their twinkling.

The magnitudes of the fixed stars appear to be different from one another, which difference may arise either from a diversity in their real magnitudes, or distances; or from both these causes acting together. The difference in the apparent magnitude of the stars is such as to admit of their being divided into six classes, the largest being called stars of the first magnitude, and the least which are visible to the naked eye, stars of the sixth magnitude. Stars that cannot be seen without the help of glasses are called telescopic stars. The number of stars, visible at any one time to the naked eye, is about one thousand; but Dr. Herschel, by his skilful improvements of the reflecting telescope, has discovered that the whole number is great beyond all conception. Upon viewing the heavens during a clear night, we discover a pale irregular light, and a number of stars whose mingled rays form the luminous tract called the milky-way. The stars themselves are at too great a distance to be perceived by the naked eye; and among those which are visible with a telescope there are spaces apparently filled with others in immense numbers. Many whitish spots or tracts (called *nebulæ*) are visible in different parts of the heavens, which are supposed to be milky-ways at an inconceivable distance.

The distance of these remoter bodies is so vast and measureless, that we can hardly speak of it except in relation to the inconceivable swiftness of light. The rays by which they are now made visible to the eye of the astronomer, the rapid motion of which might circle the earth while one is pronouncing a syllable, have been darting forward for thousands and ten thousands of years to reach us. All the events and revolutions, which history records, have taken place during their progress. They commenced their career, it has been computed, at a period of such remote antiquity, that, compared with it, the date of that time, when God gave the earth to man for a habitation, is but of yesterday.

Dr. Herschel has calculated that the distance of the remotest nebulæ, exceeds that of the nearest fixed star at least three hundred thousand times. Upon this fact, he thus remarks; a telescope with a power of penetrating into space, like my forty feet one, has also, as it may be called, a power of penetrating into time past. To explain this we must consider that from the known velocity of light, it may be proved that when we look at the star called Sirius, the rays which enter the eye cannot have been less than six years and four months and a half coming from that star to the observer. Hence it follows that when we see an object at the calculated distance, at which one of these very remote nebulæ may still be perceived, the rays of light which convey its image to the eye, must have been more than nineteen hundred and ten thousand, that is, almost two millions of years on their way; and that, consequently, so many years ago, this object must already have had an existence in the sidereal heavens, in order to send out those rays by which we now perceive it.

But when we have reached the utmost distance to which the power of our instruments can penetrate, who will say, that we are approaching any limits of the creation? who will say, that if the disembodied spirit should travel forward through eternity, numberless systems would not be continually spreading before it? All that part of the universe which we are able to discern, is peopled by inhabitants, who have the common want of heat and light; who will say, that there are not other parts of the material universe inhabited by beings of different natures, to whom these wants are unknown? It is only some portion, we know not how small, of the material universe which is obvious to our senses; who will attempt to define the limits of the invisible world? who will attempt to set bounds to the works of infinite power and infinite goodness?

QUESTIONS.—1. What are fixed stars?—why so called? 2. How does it appear that they do not borrow their light? 3. What is said of the magnitude of the stars? 4. Number? 5. Describe the milky-way (or galaxy.) 6. What calculations did Dr. Herschel make? [NOTE. Many stars, single to the naked eye, appear double, triple, and even quadruple, through a telescope. Dr. Herschel found that in more than fifty double stars, a change of situation really takes place: it is concluded, therefore, that they describe orbits round a centre of gravity.]

LESSON 55.

The Constellations.

THE first people who paid much attention to the fixed stars were the shepherds in the beautiful plains of Egypt and Babylon. Endowed with a lively fancy, they divided the stars into different companies or constellations, each of which they supposed to represent the image of some animal, or other terrestrial object. Of these ancient constellations there were fifty, to which the moderns have added about thirty others. Twelve of these *constellations* are in the zodiac, bearing the same names with the *signs* of the zodiac or ecliptic. But these constellations and signs do not coincide, for the equinoctial points are not stationary, but move backward, and the sign Aries always begins at one of them, and all the other signs each succeed Aries in order; it follows therefore that all the signs of the ecliptic or zodiac move backward with the equinoxes. The distance which they move annually is about fifty seconds of a degree; so that with respect to the fixed stars the equinoctial points fall backwards thirty degrees, in about two thousand two hundred years, whence the stars will appear to have gone forward thirty degrees, with respect to the signs of the ecliptic, which are always reckoned from the equinoctial points. This shows the importance of distinguishing between the *signs* of the zodiac and the *constellations* of the zodiac; for stars, which are in one sign at one time, will be in the succeeding one at another. Thus, the stars which were formerly in Aries, are now in Taurus, and so on. When these names were given to the signs and constellations, it is supposed that each sign coincided with the constellation of the same name; but on account of this moving of the equinoctial points, or, as it is termed, the precession of the equinoxes, there is now about one sign or thirty degrees difference. The period will be completed in about twenty-six thousand years.

Among the northern constellations, none are more remarkable than that which is nearest to the north pole, and termed the little bear. The last star of its tail is but two degrees from the pole; hence it is called the polar star. It is easily distinguished from the neighbouring stars, because it scarcely appears to change its position, and is always in the same part of the heavens. By its fixed situation it becomes a guide to travellers, and particularly to mariners who are sailing on the open seas. Before the discovery of the compass sailors had no surer guide than the polar star; and even now, when the sky is serene, they repose in many cases with greater certainty upon the direction of this star, than upon the magnetic needle.

Hymn to the North Star.

The sad and solemn night
Has yet her multitude of cheerful fires;
The glorious host of light
Walk the dark hemisphere till she retires:
All through her silent watches gliding slow,
Her constellations come, and round the heavens, and go.

Day, too, hath many a star
To grace his gorgeous reign, as bright as they:
Through the blue fields afar,
Unseen, they follow in his flaming way.
Many a bright lingerer, as the eve grows dim,
Tells what a radiant troop arose and set with him.

And thou dost see them rise,
Star of the Pole! and thou dost see them set.
Alone in thy cold skies,
Thou keep'st thy old unmoving station yet,
Nor join'st the dances of that glittering train,
Nor dip'st thy virgin orb in the blue western main.

There, at morn's rosy birth,
Thou lookest meekly through the kindling air,
And eve, that round the earth
Chases the day, beholds thee watching there;
There noontide finds thee, and the hour that calls
The shapes of polar flame to scale heaven's azure walls.

On thy unaltering blaze
The half-wrecked mariner, his compass lost,
Fixes his steady gaze,
And steers, undoubting, to the friendly coast;
And they who stray in perilous wastes, by night,
Are glad when thou dost shine to guide their footsteps right.

And, therefore, bards of old,
Sages, and hermits of the solemn wood
Did in thy beams behold
A beauteous type of that unchanging good,

That bright eternal beacon, by whose ray
The voyager of time should shape his heedful way.
BRYANT.

QUESTIONS.—1. What is said of the first division of the stars into constellations? 2. Why do not the constellations and signs of the zodiac coincide? 3. What is the present difference between them? 4. At what rate does the change take place? 5. Describe tne situation of the polar star.

LESSON 56.

Forms and Divisions of Time.

As the form of the year is various among different nations, so is its beginning. The Jews, like most other nations of the East, had a civil year, which commenced with the new moon in September; and an ecclesiastical year, which commenced from the new moon in March. The Persians begin their year in the month answering to our June; the Chinese, and most of the inhabitants of India, begin it with the first moon in March; and the Greeks with the new moon that follows the longest day. In England and America, the civil or legal year formerly commenced on the twenty-fifth of March, and the historical year on the first of January. But since the alteration of the style, which took place in 1752, the civil year in both countries has likewise begun on the first of January.

The principal division of the year is into parts called *months*, which are either astronomical or civil. An astronomical or natural month is that which is measured exactly by the motion of the Earth or Moon, and is accordingly either *lunar* or *solar*. A lunar month is the time the moon takes to revolve round the earth, which she performs in twenty-seven days, seven hours, and forty-three minutes. A solar month is that space of time in which the earth runs through one of the signs of the zodiac; as the earth constantly travels through the twelve signs in three hundred and sixty-five days five hours and forty-nine minutes, each solar month is found by dividing this number by twelve, to contain thirty days, ten hours, and twenty-nine minutes.

Civil months are those which are framed to serve the uses of life, and approach nearly to the quantity of astronomical months either lunar or solar; being made, with the exception of February, to consist of thirty and thirty-one days. To the days of a week, the Pagans gave the names of the sun, moon, and planets; and for the first two days and last day of our weeks, those names are still retained.

A *natural* or *solar* day is the time which the sun takes in passing from the meridian of any place till it comes round to the same meridian again; or it is the time from noon to noon. A *sidereal* day is the time in which the earth revolves once about its axis. The rotation of the earth is the most equable and uniform motion in nature, and is completed in twenty-three hours, fifty-six minutes, and four seconds, for any meridian on the earth will revolve from a fixed star, to that star again in this time. Sidereal days, therefore, are all of the same length; but solar or natural days are not. The mean length of a solar day is twenty-four hours, but it is sometimes a little more, and sometimes less. The reason of the difference between the solar and sidereal day is, that as the earth advances almost a degree eastward in its orbit, in the same time that it turns eastward round its axis, it must make more than a complete rotation before it can come into the same position with the sun that it had the day before; in the same way, as when both the hands of a watch or clock set off together, as at twelve o'clock, for instance, the minute hand must travel more than a whole circle before it will overtake the hour hand, that is, before they will be in the same relative position again. It is on this account that the sidereal days are found to be, on an average, shorter than the solar ones by three minutes and fifty-six seconds.

As a clock is intended to measure exactly twenty-four hours, it is evident that, when a solar day consists of more than twenty-four hours, it will not be noon by the sun till it is past noon by the clock; in which case the sun is said to be slow of the clock. But when a solar day consists of less than twenty-four hours, it will be noon by the sun before it is noon by the clock; and the sun is then said to be fast of the clock. Time measured by a clock is called equal or *mean* time, and that measured by the apparent motion of the sun in the heavens, or by a sun-dial, is called *apparent* time. The adjustment of the difference of time, as shown by a well-regulated clock and a true sun-dial is called the *equation of time.*

Since the stars are found to gain three minutes and fifty-six seconds upon the sun every day, amounting in a year to one diurnal revolution, it follows that, in three hundred and sixty-five days as measured by the sun, there are three hundred and sixty-six days as measured by the stars. This regular return of the fixed stars to the meridian affords an easy method of determining whether our clocks and watches keep true time. For if through a small hole in a window-shutter, or in a thin plate of metal fixed for that purpose, it be observed at what time any star disappears behind a chimney or the corner of a building at a small distance; then if the star disappears the next night three minutes and fifty-six seconds sooner by the clock or watch than it did the night before, on the second night seven minutes fifty-two seconds sooner, and so on, it is a certain sign that the machine goes right; but if it does not observe this rule, it is evidently not accurate, and as the disappearing of a star is instantaneous, we may depend upon this information to half a second at most.

QUESTIONS.—1. What is said of the form and commencement of the year among different nations? 2. What is an astronomical month? 3. Lunar month? 4. Solar month? 5. Civil month? 6. Solar day? 7. Sidereal day? 8. How does it appear that sidereal days are all of the same length? 9. Why is there a difference between the lengths of a solar and sidereal day? 10. When is the sun said to be slow of the clock? 11. Fast of the clock? 12. What is mean time? 13. Apparent time? 14. Equation of time? 15. What follows in consequence of the stars gaining upon the sun? 16. What is an easy method of determining whether clocks and watches keep true time? [NOTE. The inequality of solar days, as caused by the eccentricity of the earth's orbit, and the obliquity of the ecliptic, is clearly illustrated in Wilkins' Elements of Astronomy: the work has been recommended as containing a judicious selection and concise statement of the leading facts and principles of the science.]

LESSON 57.

The Planetary System.

Fair star of eve, thy lucid ray
Directs my thoughts to realms on high;
Great is the theme, though weak the lay,
For my heart whispers 'God is nigh.'

The Sun, vicegerent of his power,
Shall rend the veil of parting night,
Salute the spheres, at early hour,
And pour a flood of life and light.

Seven circling planets I behold,
Their different orbits all describe;
Copernicus these wonders told,
And bade the laws of truth revive.

Mercury and Venus first appear,
Nearest the dazzling source of day;
Three months compose *his* hasty year,
In seven *she* treads the heav'nly way.

Next, Earth completes her yearly course;
The Moon as satellite attends;
Attraction is the hidden force,
On which creation's laws depend.

Then Mars is seen of fiery hue;
Jupiter's orb we next descry;
His atmospheric belts we view,
And four bright moons attract the eye.

Mars soon his revolution makes,
In twice twelve months the sun surrounds;
Jupiter, greater limit takes,
And twelve long years declare his bounds.

With ring of light, see Saturn slow,
Pursue his path in endless space;
By seven pale moons his course we know,
And thirty years that round shall trace.

The Georgium Sidus next appears,
By his amazing distance known;
The lapse of more than eighty years
In his account makes one alone.

Six moons are his, by Herschel shown,
Herschel of modern times the boast;
Discovery here is all his own,
Another planetary host!

And lo! by astronomic scan,
Three stranger planets track the skies,
Part of that high majestic plan,
Whence those successive worlds arise.

Next Mars, Piazzi's orb is seen,
Four years six months complete his round;
Science shall renovated beam,
And gild Palermo's favoured ground.

Daughters of telescopic ray,
Pallas and Juno, smaller spheres,
Are seen near Jove's imperial way,
Tracing the heavens in destined years.

Comets and fixed stars I see,
With native lustre ever shine;
How great! how good! how dreadful! He,
In whom life, light, and truth combine.

Oh! may I better know his will,
And more implicitly obey;
Be God my friend, my father still,
From finite—to eternal day. MANGNALL.

NOTE. The foregoing rhymes were made, probably, before Vesta was discovered, and some of the facts, relating to the other new planets, not so well ascertained as at present. Ceres is sometimes called Piazzi, after the discoverer.

LESSON 58.

Chemistry.

Chemistry is an instructive, interesting, and valuable science. Within the last sixty years its empire has been wonderfully extended. There is scarcely an art of human life which it is not fitted to subserve; scarcely a department of human inquiry or labour, either for health, pleasure, ornament, or profit, which it may not be made in its present improved state, eminently to promote. To the husbandman this science furnishes principles and agents of inestimable value. It teaches him the food of plants, the choice and use of manures, and the best means of promoting the vigour, growth, productiveness, and preservation of the various vegetable tribes. To the manufacturer chemistry has lately become equally fruitful of instruction and assistance. In the arts of brewing, tanning, dyeing, and bleaching, its doctrines are important guides. In making soap, glass, pottery, and all metallic wares, its principles are daily applied, and are capable of a still more useful application, as they become better understood. Indeed, every mechanic art, in the different processes of which heat, moisture, solution, mixture, or fermentation is necessary, must ever keep pace in improvement with this branch of philosophy. To the physician this science is of still greater value, and is daily growing in importance. He learns from it to compound his medicines, to disarm poisons of their force, to adjust remedies to diseases, and to adopt general means of preserving health.

To the student of natural history chemistry furnishes instruction at every step of his course. To the public economist it presents a treasure of useful information. By means of this science alone can he expect to attack with success the destroying pestilence, and to guard against other evils to which the state of the elements gives rise. And to the successful prosecution of numberless plans of the philanthropist, some acquaintance with the subject in question seems indispensably necessary. Finally, to the domestic economist this science abounds with pleasing and wholesome lessons. It enables him to make a proper choice of meats and drinks; it directs him to those measures with respect to food, clothing, and respiration, which have the best tendency to promote health, enjoyment, and cheapness of living; and it sets him on his guard against many unseen evils, to which those who are ignorant of its laws are continually exposed. In a word, from a speculative science, chemistry, since the middle of the eighteenth century, has become eminently and extensively a practical one. From an obscure, humble, and uninteresting place among the objects of study, it has risen to a high and dignified station; and instead of merely gratifying curiosity, or furnishing amusement, it promises a degree of utility, of which no one can calculate the consequences or see the end.

QUESTIONS.—1. What does chemistry do for the husbandman? 2. For the manufacturer? 3. For the mechanic arts? 4. For the physician? 5. For the student of natural history? 6. For the public economist? 7. For the philanthropist? 8. For the domestic economist?

LESSON 59.

General Principles of Chemistry.

THE object of chemistry is to ascertain the ingredients of which bodies are composed,—to examine the compounds formed by those ingredients,—and to investigate the nature of the power which produces these combinations. The science therefore naturally divides itself into three parts: a description of the component parts of bodies, or of *elementary* or simple substances as they are called,—a description of the compound bodies formed by the union of simple substances,—and an account of the nature of the power which produces these combinations. This power is known in chemistry by the name of *affinity*, or *chemical attraction.*

By simple substances is not meant what the ancient philosophers called elements of bodies, as fire, air, earth, and water, nor particles of matter incapable of farther diminution or division. They signify merely bodies that have never been decomposed, or formed by art. The simple substances of which a body is composed are called the *constituent* parts of that body; and, in decomposing it, we separate its constituent parts. If, on the contrary, we *divide* a body by cutting it to pieces, or even by grinding it to the finest powder, each of these small particles will consist of a portion of the several constituent parts of the whole body: these are called the *integrant* parts. *Compound* bodies are formed by the combination of two or more simple substances with each other.

Attraction is that unknown force which causes bodies to approach each other. Its most obvious instances are, the gravitation of bodies to the earth; that of the planets towards each other, and the attractions of electricity and magnetism. But that attraction, which comes under the more immediate cognizance of chemists, subsists between the particles of bodies; and when it operates between particles of the same species, it is called the attraction of *cohesion*, or the attraction of aggregation; but when between the particles of different substances, it is called the attraction of composition, chemical attraction, or chemical affinity. The attraction of cohesion, then, is the power which unites the *integrant* particles of a body: the attraction of composition that which combines the *constituent* particles. When particles are united by the attraction of cohesion, the result of such a union is a body of the same kind as the particles of which it is formed; but the attraction of composition, by combining particles of a dissimilar nature, produces compound bodies quite different from any of their constituents. If, for instance, you pour upon a piece of copper, placed in a glass vessel, some of the liquid called nitric acid (*aqua fortis*) for which it has a strong attraction, every particle of the copper will combine with a particle of acid, and together they will form a new body, totally different from either the copper or the nitric acid. If you wish to decompose the compound which you have thus formed, present to it a piece of iron, for which the acid has a stronger affinity than for copper; and the acid will quit the copper to combine with the iron, and the copper will be what the chemists call *precipitated*, that is to say, it will be thrown down in its separate state, and reappear in its simple form. In order to produce this effect, dip the blade of a knife into the fluid, and when you take it out you will observe that, instead of being wetted with a bluish liquid like that contained in the glass, it will be covered with a thin coat of copper.

The simple substances were said very lately to amount to more than fifty in number, but since the truly interesting and very important discoveries of Sir Humphrey Davy, and other eminent chemists, it is scarcely possible to say what substances are not compound bodies. But it will be most conducive to science to consider all those substances as simple, which no mode of decompounding has yet been discovered. Simple substances naturally divide themselves into two classes. Those which belong to the first class are of too subtile a nature to be confined in any of the vessels which we possess. They do not sensibly affect the most delicate balance, and they have received therefore the name of *imponderable* bodies. The second class of bodies may be confined in proper vessels, may be exhibited in a separate state, and their weight and other properties may be determined. They have received the name of *ponderable* bodies. The imponderable bodies at present supposed to exist are four, light, heat or caloric, electricity, and magnetism. The first three are intimately connected with chemistry, but magnetism has with it no known connexion.

QUESTIONS.—1. What is the object of chemistry? 2. How does the science divide itself? 3. What is meant by simple substances? 4. What is the difference between decomposition and division? 5. How are compound bodies formed? 6. What is attraction and its most obvious instances? 7. Define attraction of cohesion and attraction of composition. 8. What are the results of each of these kinds of attraction? 9. What example is given to illustrate chemical affinity or attraction? 10. How may you decompose the body thus formed? 11. Define the chemical term *precipitate*. 12. What is said of the number of simple substances? 13. Into what two classes are they divided? 14. What is stated as the ground of this division? 15. What are the four imponderable bodies?

LESSON 60.

Caloric.

Chem'ically, when a mere mixture of two or more substances is made, they are said to be *mechanically* united; but when each or either substance forms a component or constituent part of the product, the substances have formed a *chemical* union.

HEAT is a well known sensation which we perceive on touching any substance whose temperature is superior to that of the human body. Chemists have agreed to call the matter of heat *caloric*, in order to distinguish it from the sensation which this matter produces. Caloric has a tendency to diffuse itself equally among all substances that come in contact with it. If the hand be put upon a hot body, part of the caloric leaves the hot body, and enters the hand; this produces the sensation of *heat*. On the contrary if the hand be put upon a cold body, part of the caloric contained in the hand leaves the hand to unite with the cold body; this produces the sensation of *cold*. If you pour warm water into one basin, cold water into a second, and a mixture of hot and cold water into a third; then put the one hand into the cold water and the other into the warm, for two minutes, and after that put both hands into the luke-warm water, to the one hand it will feel cold and to the other hot. Persons ascending from the burning shores of Vera Cruz, on the road to the mountain land of Mexico, will feel the climate become colder, and will put on their great coats, and yet they will meet people descending complaining of the heat. Cold therefore is nothing but a negative quality, simply implying the absence of the usual quantity of caloric.

Caloric is uniform in its nature; but there exist in all bodies two portions, very distinct from each other. The one is called *sensible* heat, or free caloric; the other *latent* heat, or combined caloric. Sensible caloric is the matter of heat disengaged from other bodies, or, if united, not *chemically* united with them. *Latent* caloric is that portion of the matter of heat which makes no *sensible* addition to the temperature of the bodies in which it exists. Wrought iron, though quite cold, contains a large portion of *latent* caloric; and if it be briskly hammered for some time on an anvil, it will become red hot by the action of this species of caloric, which by the percussion of hammering is now evolved and forced out as *sensible* heat.

Caloric pervades all bodies; and this is not the case with any other substance with which we are acquainted. It combines with different substances, however, in very different proportions; and for this reason, one body is said to have a greater *capacity* for caloric than another. When gaseous substances become liquid, or liquid substances solid, by this change of state they lose in a great measure their capacity for caloric. During the slaking of quick-lime, the caloric which is evolved escapes from the water in consequence of its changing from a liquid to a solid form by its union with the lime. When solid bodies become liquid or gaseous, their capacity for caloric is proportionately increased. If you place a glass of water in a mixture of equal quantities of snow and salt, during their conversion to a liquid, the water will be frozen in consequence of parting with its caloric to supply the increased capacity of the mixture.

The portion of caloric necessary to raise a body to any given temperature is called its *specific* caloric. The instrument in common use for measuring the temperature of bodies is called a Thermometer. It consists of a glass tube containing a portion of mercury, with a graduated scale annexed to it. It is constructed in the following manner. A small bulb is blown on the end of the tube, and this bulb and a part of the tube are to be filled with mercury which is to be heated till it boils. This ebullition forces out the air and the tube is hermetically sealed while the mercury is boiling. The next object is to construct the scale. It is found by experiment, that melting snow or freezing water is always at the same temperature. If, therefore, a thermometer be immersed in the one or the other, the mercury will always stand at the same point. It has been observed, too, that water boils under the same pressure of the atmosphere at the same temperature. A thermometer, therefore, immersed in boiling water, will uniformly stand at the same point. Here, then, are two fixed points, from which a scale may be constructed, by dividing the intermediate space into equal parts, and carrying the same divisions as far above and below the two fixed points as may be wanted. When a thermometer is brought in contact with any substance, the mercury expands or contracts till it acquires the same temperature; and the height at which the mercury stands in the tube, indicates the exact temperature of the substance to which it has been applied. It will not show the absolute caloric in substances; for it cannot measure that portion which is latent, or chemically combined with any body.

Caloric is the cause of fluidity in all substances capable of becoming fluid, from the heaviest metal to the lightest gas. It insinuates itself among their particles and invariably separates them in some measure from each other. Thus ice is converted into water, and by a further portion of caloric, into steam. We have reason to believe that every solid substance on the face of the earth might be converted to a fluid, or even to a vapour or gas, were it submitted to the action of a very high temperature in peculiar circumstances. Some bodies give out their superabundant caloric much sooner than others. Iron is a quicker conductor of caloric than glass, and glass than wood. If you take a piece of iron in one hand, and a piece of wood in the other, the iron feels cold, the wood warmer, though the thermometer shows that their temperature is the same. Substances usually become more dense by the loss of caloric; but the freezing of water is a striking *exception* to this general law of nature, and is a memorable instance of the wisdom and provident care of the Almighty, when he established the laws of the universe.

QUESTIONS.—1. What is heat? 2. Why is the matter of heat called caloric? 3. How are sensations of heat and cold produced? 4. What is cold? 5. What is sensible caloric? 6. Latent caloric? 7. What experiment illustrates this? 8. Why is one body said to have a greater capacity for caloric than another? 9. How do bodies lose their capacity for caloric? 10. Why is caloric evolved during the slaking of quick-lime? 11. When is a capacity for caloric increased? 12. Describe the experiment. 13. What is specific caloric? 14. Of what use is a thermometer? 15. Of what does it consist? 16. How is it constructed? 17. How is caloric the cause of fluidity? 18. What is said of conductors of caloric? 19. To what general law of nature is the freezing of water an exception? 20. What are the different kinds of thermometers? (See Appendix.) 21. How is each graduated?

LESSON 61.

Atmospheric Air.

Gas. When solid substances are rendered *permanently* aëriform by heat, the air, thus produced, is called a gas. All the gases are compounds of solid matter and caloric. It is caloric which separates the particles, and gives to the whole a gaseous form. The permanency of the gases appears to be owing to the strength of the affinity existing between caloric and their bases, which affinity resists every reduction of temperature.

THE atmosphere, which was formerly supposed to be a simple fluid, is composed of two distinct substances, termed oxygen gas and nitrogen gas. It is not a chemical *compound*, but a mere *mixture* of those gaseous substances in the proportion of 21 of the former and 79 of the latter. It contains also about one part in every thousand of carbonic acid gas, a considerable portion of water in a state of elastic vapour, and several adventitious substances.

Oxygen is an element or simple substance generally diffused through nature, though like caloric it does not exist by itself. It takes its name from two Greek words, signifying that which produces or generates acids, because one of its general properties is to form acids by combining with different substances, which are called the bases of the several acids. Its different combinations are essential to animal life and combustion. Acted upon, or combined with caloric, it becomes oxygen gas, which is distinguished from all other gaseous matter by several important properties. Inflammable substances burn in it under the same circumstances as in common air, but with infinitely greater vividness. If a taper, the flame of which has been extinguished, the wick only remaining ignited, be plunged into a bottle filled with it, the flame will instantly be re-kindled, and will be very brilliant, and accompanied by a crackling noise. If a steel wire, or thin file, having a sharp point, armed with a bit of wood in a state of inflammation, be introduced into a jar filled with the gas, the steel will take fire, and its combustion will continue, producing a most brilliant phenomenon. Oxygen gas is a little heavier than atmospheric air, and from its being absolutely necessary to the support of animal life, it has been called *vital* air.

Nitrogen is a substance diffused through nature, and particularly in animal bodies. It is not to be found in a solid or liquid state; but combined with caloric, it forms nitrogen, or azotic gas, in which no animal can breathe, or any combustible burn. It is uninflammable and somewhat lighter than atmospheric air, and though, by itself, it is so noxious to animals, it answers an important end when mixed with oxygen gas in atmospheric air. Were it not for this large quantity of nitrogen in the atmosphere, the stimulating power of the oxygen would cause the blood to flow with too great rapidity through the vessels; the consequence of which would be, that the life of man would not be protracted to the length that it now is. The vermilion colour of the blood is owing to the inhalation of oxygen gas. When the dark purple blood of the veins arrives at the lungs, it imbibes the vital air of the atmosphere, which changes its dark colour to a brilliant red, rendering it the spur to the action of the heart and arteries, the source of animal heat, and the cause of sensibility, irritability, and motion. With regard to the nitrogen that is combined with atmospheric air, the greatest part of it is thrown out of the lungs at every respiration, and it rises above the head, that a fresh portion of air may be taken in, and that the same air may not be repeatedly breathed. The leaves of trees and other vegetables give out during the day a large portion of oxygen gas, which, uniting with the nitrogen thrown off by animal respiration, keeps up the equilibrium, and preserves the purity of the atmosphere. In the dark, plants absorb oxygen, but the proportion is small, compared to what they exhale by day.

Questions.—1. Of what is atmospheric air composed? 2. What is the proportion of each, and what other substances does it contain? 3. What is oxygen? 4. Why is it thus named? 5. How does it become oxygen gas? 6. What are some of its important properties? 7. Why has it been called vital air? 8. What is nitrogen, and how does it form nitrogen or azotic gas? 9. What are some of its properties? 10. What important end does it answer, and how? 11. How is the vermilion colour of the blood produced? 12. What becomes of the nitrogen that is thrown out of the lungs?—why? 13. What tends to preserve the purity of the atmosphere? [Note. Nitrogen (pronounced Nī'trō-jĕn,) is called azote by the French chemists on account of its being so destructive of life. Oxygen, (pronounced ox'ē-jĕn,) besides producing most of the acids, is necessary also to the production of the alkalies.]

LESSON 62.

Water.

Cal'cine, to burn in the fire to a calx;—calx is a substance easily reduced to powder. Efferves'cence, an intense motion which takes place in certain bodies, occasioned by the sudden escape of a gaseous substance.

Water was formerly considered as a simple substance, and chemical philosophers were for a long time unwilling to allow of its being otherwise. Its compound nature, however, has been fully proved. It is composed of eighty-eight parts by weight of oxygen, and twelve of hydrogen, in every hundred parts of the fluid. It is found in four states, namely, solid or ice; liquid or water; vapour or steam; and in a state of composition with other bodies. Its most simple state is that of ice, and the difference between liquid water or vapour and ice, is merely that water contains a larger portion of caloric than ice, and that vapour is combined with a still greater quantity than water. However long we boil a fluid in an open vessel, we cannot make it in the smallest degree hotter than its boiling point, for the vapour absorbs the caloric, and carries it off as fast as it is produced. It is owing to this, that all evaporation produces cold. An animal might be frozen to death in the midst of summer, by repeatedly sprinkling ether upon him, for its evaporation would shortly carry off the whole of his vital heat. Water thrown on burning bodies acts in the same way; it becomes, in an instant, converted into vapour, and by thus depriving them of a large portion of their caloric, the fire, as we term it, is extinguished. Vapour occupies a space eight hundred times greater than it does when in the form of water, and the expansive force of steam is found by experiment to be much greater than that of gunpowder. There is reason to believe that, in time, steam may be applied to many useful purposes of which at present we have no idea.

Hydrogen is the base of the gas which was formerly called inflammable air, and when in the aëriform state, it is the lightest of all ponderable things. If you put a quantity of filings of zinc into a vessel which has a glass tube adapted to it, and then pour upon them sulphuric acid (*oil of vitriŏl*) diluted with six or eight times its quantity of water; an effervescence will immediately take place, the oxygen of it will become united to the metal, and the hydrogen gas will be disengaged, and may be conveyed by the glass tube into any proper receiver. While it is rushing through the tube, it may be kindled with a taper, and it will burn with a long flame like a candle. In the burning of the gas, the hydrogen unites with the oxygen of the atmosphere, and the result of the combination is flame and water. It has been supposed that the torrents of rain, which generally accompany thunder storms, may arise from a sudden combustion of hydrogen and oxygen gases by means of lightning. Hydrogen gas is only one fourteenth of the weight of atmospheric air, and occupies a space fifteen hundred times greater than it possessed in its aqueous combination. It is continually emanating from vegetable and animal matters during their decay, and is evolved from various mines, volcanoes, and other natural sources. From its great levity it has generally been used to fill air-balloons.

Water is said to be in a state of *composition* with other bodies, because in many cases it becomes one of their *component* parts. It is combined in a state of solidity in marble, in crystals, in spars, in gems, and in many alkaline, earthy, and metallic salts, both natural and artificial, to all of which substances it imparts hardness, and to most of them transparency. Near the poles water is eternally solid; there it is similar to the hardest rocks, and may be formed by the chisel of the statuary, like stone. It becomes still more solid in the composition called mortar, and in cements, having parted with more of its caloric in that combination than it does in the act of freezing. If you take some ground plaster of Paris, fresh calcined, and mix it with a little water, the affinity of the plaster for the water is so great, that in a few minutes the whole will be converted to a solid.

Questions.—1. Of what is water composed? 2. In what four states is it found? 3. What is its most simple state? 4. What is the difference between liquid water or vapour and ice? 5. Why cannot water in an open vessel be made hotter than its boiling point? 6. How may an animal be frozen to death in the midst of summer? 7. Why would this happen? 8. Explain the extinguishing of fire by water. 9. What space does vapour occupy? 10. What is said of the expansive force of steam, and its probable application? 11. What is hydrogen, and how may hydrogen gas be obtained? 12. What is the result of kindling hydrogen gas on its rushing from the glass tube? 13. What is its weight and what space does it occupy? 14. In what substances is water combined in a state of solidity? 15. Why does water become solid in mortar and in cements? [Note. Hydrogen (pron. Hi′drō-jĕn,) takes its name from two Greek words signifying to produce water.]

LESSON 63.

The Earths and Alkalies.

The earths are silex, or silica, alumine, glucine, zircon, yttria, magnesia, barytes, strontites, and lime:—the four last mentioned are called alkaline earths.

Stra′ta (plural of stratum) beds, layers.

Earths are such incombustible substances as are not ductile, are mostly insoluble in water or oil, and preserve their constitution in a strong heat. Notwithstanding the varied appearance of the earth under our feet, and of the mountainous parts of the world, whose diversified strata present to our view substances of every texture and of every shade, the whole is composed of only nine primitive earths; and as three of these occur but seldom, the variety which is produced by the other six becomes the more remarkable. One of the most valuable earths with which we are acquainted is silex or pure flint. It is the most durable article in the state of gravel for the formation of roads; it is a necessary ingredient in earthenware, porcelain, and cements; it is the basis of glass, and of all vitreous substances. It is white, inodorous and insipid in its pure state, and the various colours, which it assumes in different substances, proceed from the different ingredients with which it is mixed. Alumine obtained its name from its being the base of the salt called alum. It is distributed over the earth in the form of clay, and on account of its aptitude for moulding into different forms, and its property of hardening in the fire, is employed for various useful purposes. In making earthenware, a due proportion both of silex and alumine are necessary; for if alumine alone were used, the ware could not be sufficiently burnt without shrinking too much, and even cracking; and a great excess of silex would lessen the tenacity and render the ware brittle. Lime is never found pure in nature; it is obtained by decomposing calcareous matters by the action of fire, which deprives them of their acid. In its pure state it is used in many of the arts. It is employed by the farmers as a manure; and by bleachers, tanners, iron-masters and others, in their several manufactories, and in medicine. The use of lime in agriculture may be attributed to its property of hastening the dissolution of all animal and vegetable matters, and of imparting to the soil a power of retaining a quantity of moisture necessary for the nourishment and vigorous growth of the plants. Magnesia, besides being the basis of several salts, is of great use in medicine; and is employed by the manufacturers of enamels and porcelain.

The alkalies are distinguished by an acrid and peculiar taste; they change the blue juices of vegetables to a green, and the yellow to a brown, and have the property of rendering oils miscible with water. They form various salts by combination with acids, act as powerful caustics when applied to the flesh of animals, and are soluble in water. Potash and soda have been called fixed alkalies, because they will endure a great heat without being volatilized: and yet in a very high temperature they are dissipated in vapour. They were formerly considered to be simple substances, but they are now found to be compounds of metallic substances, called potassium and sodium, with oxygen. They have various uses in surgery and medicine, and are employed in large quantities by the glass-maker, the dyer, the soap-maker, the colour-maker, and by many other manufacturers. Ammonia is so extremely *volatile* as to exhale at all known temperatures. When combined with carbonic acid, it takes a concrete form, and a beautiful white colour, and is known in commerce by the name of volatile salts. With muriatic acid it forms what is termed sal ammoniac, which is employed in many of our manufactories, particularly by dyers to give a brightness to certain colours. In tinning metals it is of use to cleanse the surfaces, and to prevent them from oxydizing by the heat which is given to them in the operation. Ammonia is furnished from all animal substances by decomposition. The horns of cattle, especially those of deer, yield it in abundance, and it is from this circumstance that a solution of ammonia in water has been called hartshorn.

QUESTIONS.—1. What are earths? 2. What the names of the nine earths? 3. What is said of silex? 4. Of alumine? 5. Of lime? 6. Of magnesia? 7. How are alkalies distinguished? 8. Why are potash and soda called fixed alkalies? 9. Of what are they compounds? 10. What is said of their uses? 11. From what is ammonia furnished? 12. What is said of its combinations and uses? [NOTE. Besides the nine earths, above enumerated, we have now *thorina*, which is a rare earthy substance lately discovered. A new alkali, called *lithia*, has recently been discovered, which, like potash and soda, is found to be a metallic oxyd: its base is called *lithium*. Three new vegetable alkalies have also been discovered, called morphia, picrotoxine, and vauqueline. Clay, as it exists in soils, is commonly called *argillaceous* earth; and lime in soils is called *calcareous* earth.]

LESSON 64.

Acids and Salts.

Acids which contain different quantities of oxygen are distinguished by their termination. The name of that which contains most oxygen ends in *ic*, the other in *ous*. Thus we say *sulphuric* acid, and *sulphurous* acid. All salts that are composed of acids ending in *ic*, take an ending in *ate* ; as sulphate of lime, a compound of lime with sulphuric acid. All salts composed of acids ending in *ous*, take an ending in *ite*, instead of *ate* ; as sulphite of lime. When there is an excess of acid, the preposition *super* is added ; and when an excess of the base, then *sub* is prefixed, as super-sulphate of potash, or sub-borate of soda, (*borax*.)

The name *acid*, in the language of chemists, has been given to all substances, whether liquids or solids, which produce that sensation on the tongue which we call sour. Most of the acids owe their origin to the combination of certain substances with oxygen ; and they have the property of changing the blue, green, and purple juices of vegetables to red, and of combining with alkalies, earths, or metallic oxyds, so as to compose those compounds termed *salts*. The acids were formerly divided into three classes, mineral, vegetable, and animal ; but the more useful and scientific way of dividing them is into two classes only. The undecomposable acids, and those which are formed with two principles, are comprised in the first class ; while those acids which are formed with more than two principles compose the second class.

Sulphuric acid is procured by burning sulphur, in contact with some substance containing oxygen ; by which process the sulphur combines with the oxygen, and becomes acidified. In commerce it is commonly called the oil of vitriol. That peculiar acid which is called muriatic is usually obtained from muriate of soda, which is the chemical name for common salt. Carbonic acid is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being so intimately combined in chalk, lime-stone, and other substances. If you pour some diluted sulphuric acid over pulverized chalk or marble contained in a glass vessel, which has a tube connected with it, an effervescence will take place, and carbonic acid gas will escape through the tube. This gas is more destructive of life than any other, and it extinguishes flame instantaneously. Water may be made by pressure to absorb three times its bulk of this gas; by which it acquires an acidulous and not unpleasant taste. Soda water, cider, and other fermented liquors owe their briskness and sparkling to the presence of this gas. Fatal accidents often happen from the burning of charcoal in chambers, for wherever charcoal is burned this gas is always formed. It so often occupies the bottoms of wells, that workmen ought not to venture into such places without previously letting down a lighted candle. If the candle burns they may enter it with safety; if not, a quantity of quick-lime should be let down in buckets, and gradually sprinkled with water. As the lime slakes, it will absorb the gas, and the workmen may afterwards descend in safety.

The number of acids that are well known amounts to more than forty, and their uses are so many and important that it is impossible to enumerate them. They are indispensable to various arts and manufactures; they are employed for culinary purposes, and for medicine; they act an important part in the great elaboratory of nature, and form a great proportion of many of the mountainous districts of the globe in their various combinations.

The precise number of the *salts* is not known, but they probably amount to more than two thousand. The different salts are known from each other by the peculiar figure of their crystals, by their taste, and other distinctive or specific characters. The separation of salts from the water in which they may be dissolved, is generally effected by evaporation and cooling. When a certain portion of the water of solution is evaporated, and the remainder left in a proper temperature at rest, the salts will shoot into crystals, and will be found dispersed through the water at the bottom and at the sides of the vessel, and sometimes also on the surface of the solution. Their crystallization is owing to the abstraction of the heat or water by which they were dissolved. Crystallized salts are liable to changes in their appearance by exposure to atmospheric air. Some have so great an affinity for water that they absorb it with avidity from the atmosphere, and thus becoming moist or liquid, they are said to deliquesce. Others, having less affinity for water than atmospheric air has, lose their water of crystallization by exposure, and readily fall into powder. Such salts are said to effloresce. Salts have not only the property of dissolving in water, but by exposure to great heat they will melt, and they require different degrees of heat to put them in a state of fusion, as well as different quantities of water for their solution.

Many of the salts are found native, and the carbonates, sulphates, and muriates are the most frequent. Chalk, limestone, and marble, are all included in the term carbonate of lime. Few salts are more copiously disseminated than the sulphate of lime, particularly in the vicinity of Paris, and hence its name Plaster of Paris. Of the native muriates, muriate of lime occurs with rock-salt, and muriate of magnesia is found in abundance in sea-water; and muriate of soda not only exists in immense quantities in the ocean, but vast mountains in different parts of the world are entirely formed of this salt. Nitrate of potash, known by the more familiar name of nitre or salt-petre, is collected in various parts of the globe. Phosphate of lime, which is the basis of all animal bones, exists native in Hungary, and composes several entire mountains in Spain. Mountains of salt were probably formed in very remote ages, and by processes of which we can form no idea. It may be supposed, however, that these changes have been slow and gradual, for several of the native salts exhibit marks of regularity and beauty in their crystallization, which cannot be imitated by art.

Questions.—1. To what substances is the name acid given? 2 To what do most acids owe their origin? 3. How do they form salts? 4. What is said of the division of acids? 5. How is sulphuric acid procured? 6. Muriatic acid? 7. What is carbonic acid? 8. How may you obtain carbonic acid gas? 9. What are some of the properties of this gas? 10. Why do fatal accidents often happen from the burning of charcoal? 11. How may it be destroyed at the bottom of wells? 12. What is said of the number and uses of the acids? 13. How are the different salts known from each other? 14. How may salts be separated from their water of solution? 15. To what changes are crystallized salts liable on exposure to atmospheric air? 16. What native salts are mentioned? 17. What is said of salt mountains?

LESSON 65.

Simple Combustibles.

E′thers, volatile liquids formed by the distillation of some of the acids with alcohol. Al′cohol, rectified spirit of wine. It is always the same from whatever kind of spirit it is distilled : it is the purely spirituous part of all liquors that have undergone the *vinous* fermentation.

The combinations of sulphur are denominated *sulphurets ;* of phosphorus, *phosphurets ;* of carbon, *carburets ;* of hydrogen, *hydrurets ;* the sulphuret of iron, for instance, is the union of sulphur with iron.

Most of the simple substances are combustible, or bear some relation to combustion. Light and caloric are evolved during combustion ; oxygen is the principal agent ; and hydrogen, sulphur, phosphorus, carbon, and the metals, are the subjects, or the true instruments of this process. Hydrogen gas may be combined with water, sulphur, phosphorus, or with carbon. When combined with phosphorus it forms phosphuretted hydrogen gas, which takes fire whenever it comes in contact with atmospheric air. The elastic substance, which is called carburetted hydrogen gas, is carbon dissolved in hydrogen ; it has likewise been called heavy inflammable air. It is this gaseous compound which has occasioned so many dreadful accidents to miners, who call it the fire-damp. This gas is procured from pit-coal by dry distillation ; and from its inflammability and brilliant flame, it has been used for lighting streets, shops, manufactories, and light-houses on the sea-coast. The rate at which it is procured is trifling compared to the expense of oil and tallow.

Phosphorus is a solid inflammable substance, which burns at a very low temperature, when in contact with oxygen gas or atmospheric air. Many amusing experiments may be performed with it, but it must be handled with extreme caution. If you fix a piece of solid phosphorus in a quill, and write with it upon paper, the writing, in a dark room, will be beautifully luminous. If the face or hands be rubbed with phosphuretted ether, they will appear, in a dark place, as though on fire, without danger or sensation of heat.

Pure carbon is known only in the diamond ; but carbon in the state of charcoal may be procured by heating to redness a piece of wood closely covered with sand in a crucible, so as to preserve it while in the fire, and afterwards, while cooling, from the action of the atmosphere. It is capable of forming various combinations, but charcoal is that with which we are most familiar. Carbon is not only a component part, but it forms nearly the whole of the solid basis of all vegetables, from the most delicate flower in the garden to the huge oak of the forest. It not only constitutes the basis of the woody fibre, but is a component part of sugar, and of all kinds of wax, oils, gums, and resins, and of these again, how great is the variety! It is imagined that most of the metals may be combined with carbon; but at present we know only of its combination with iron. In one proportion it forms cast iron; in another, steel; and in a third, plumbago, generally, though improperly, called black lead. There is no lead in its composition. Cast iron contains about one forty-fifth of its weight of carbon,—steel is combined with about one part of carbon in two hundred of iron,—and plumbago, or carburet of iron, has been found to consist of nearly nine parts of carbon to one of iron. Wrought iron differs from cast iron, in being deprived of its carbon and oxygen, by continued heat and repeated hammering, which render the metal malleable. Steel is made of wrought iron by various processes, whereby the metal resumes a small portion of the carbon, and acquires a capacity of receiving different degrees of hardness.

The metals are generally procured from beneath the surface of the earth, in a state of combination either with other metals, with sulphur, oxygen, or with acids; though a few of them have occasionally been found in a state of purity. Metals are the great agents by which we are enabled to examine the recesses of nature; and their uses are so multiplied, that they are become of the greatest importance in every occupation of life. They are the instruments of all our improvements, of civilization itself, and are even subservient to the progress of the human mind towards perfection. They differ so much from each other, that nature seems to have had in view all the necessities of man, in order that she might suit every possible purpose his ingenuity can invent, or his wants require. We not only receive this great variety from the hand of nature, but these metals are rendered infinitely valuable by various other properties they possess;—by their combustibility, their solubility in fluids, their combinations with various substances, and by their union with each other, whereby compounds or alloys are formed, extremely useful in a variety of arts, manufactures, and other requisites of life. By combining them with oxygen we can invest them with *new* properties, and are enabled to employ these to promote the progress of the fine arts, by imitating the master-pieces of creation in the production of artificial salts, gems, and crystals, of every colour and of every shade.

QUESTIONS.—1. What are the simple combustibles? 2. What is said of phosphorus combined with hydrogen gas? 3. What is carburetted hydrogen gas? 4. What do miners call it? 5. To what use may it be applied? 6. What is phosphorus? 7. What experiments may be performed with it? 8. How may carbon be obtained in the state of charcoal? 9. What is said of carbon with regard to vegetables, sugar, wax, &c. 10. What is said of its combinations with iron? 11. In what state are metals generally found? 12. What is said of the utility of metals? [NOTE. Chlorine (oxymuriatic acid,) boron and fluorine (the bases of the boric and fluoric acids,) and a substance of recent discovery, called iodine, have lately been added to the list of simple substances. (see Appendix.) Iodine and Chlorine are capable of forming distinct and peculiar acids by combination with Hydrogen. They form various other compounds, such as Iodides, Chlorides; Iodates, Chlorates; Iodurets, Chlorurets, &c.

LESSON 66.

Oxyds and Combustion.

As oxygen can combine in different proportions with the same simple substance, the products have been designated by the names of *protoxyd*, *deutoxyd*, or *tritoxyd*, according as the oxygen entered into it, in *one*, *two*, or *three* proportions; and that has been called *peroxyd*, which was most oxydated, or oxydized.
Retort′, see description of fig. 48, in Appendix.

ANY metal or combustible body which is combined with less oxygen than is sufficient to render it *acid,* is usually called an *oxyd.* Whenever a substance is converted into an oxyd, we say it is *oxydized;* but if it becomes an acid by its union with oxygen, we say it is *oxygenized.* The mineral, the animal, and the vegetable kingdoms, all furnish matters which are convertible into oxyds, by an union with oxygen. Metallic oxyds are formed in several ways, the chief of which are by the access of atmospheric air, by the decomposition of water, and by the decomposition of acids. Iron may be mentioned as a familiar example of a metal becoming oxydized by atmospheric air. It is well known that when this metal is exposed to air and moisture, it acquires rust, or in other words its surface is converted to an oxyd, in which state the metal will be found to have acquired an increase of weight. Common red lead, which is a true oxyd of lead, is made by melting that metal in ovens so constructed as to have a free access to atmospheric air. Gold, silver, and platina, cannot be oxydized, unless in a very high temperature; and with respect to other metals, they not only differ in their capacity for oxygen, but also in their attraction for it; so that one will often rob the other, thus reducing the first oxyd to its primitive metallic form. If you dissolve some quicksilver in nitric acid, and after dropping a little of the solution upon a bright piece of copper, gently rub it with a piece of cloth, the mercury will precipitate itself upon the copper, which will be completely silvered.

With regard to the oxyds of nitrogen; the first degree of oxydizement produces *nitrous* oxyd;—a further portion of oxygen nitric oxyd, and they are both in a state of gas. Nitrous oxyd gas bears the nearest resemblance of any other to atmospheric air. It will support combustion even better than common air; it is respirable for a short time, and it is absorbed by water. Persons who have inhaled this gas have felt sensations similar to those produced by intoxication. In some people it produces involuntary muscular motion and a propensity to leaping and running; in others, involuntary fits of laughter; and in all, high spirits, and the most exquisitely pleasurable sensations, without any subsequent feelings of debility. It is readily procured by exposing crystals of nitrate of ammonia, in a retort, to the heat of a lamp, by which means, the ammoniacal salt is decomposed, and this gas is evolved.

Combustion may be defined to be a process by which certain substances decompose oxygen gas, absorb its base, and suffer its caloric to escape in the state of sensible heat. The agency of oxygen in combustion is attributable to its affinity for combustible bodies. The combustible having a greater affinity to oxygen than oxygen has to caloric, the oxygen gas is decomposed, and its oxygen combines with the ignited body, while its caloric, becoming free, is diffused among the surrounding bodies. Whenever we burn a combustible body, a continued stream of atmospheric air flows towards the fire place, to occupy the vacancy left by the air that has undergone decomposition, and which, in its turn, becomes decomposed also. Hence a supply of caloric is furnished without intermission, till the whole of the combustible is saturated with oxygen. As the combustible burns, *light* is disengaged, and the more subtile parts, now converted by caloric into gas, are dissipated in that state. When the combustion is over, nothing remains but the earthy parts of the combustible, and that portion which is converted, by the process, into an oxyd, or an acid. The smoke which arises from a common fire is chiefly water in the state of vapour, with a mixture of carburetted hydrogen and bituminous substances; part of the water comes from the moisture of the fuel; the other part is formed during combustion, by the union of the hydrogen of the combustible with the oxygen of the atmosphere. The agency of oxygen in combustion may be demonstrated by placing a lighted candle under a glass vessel inverted upon a plate of water. It will be seen that the candle will go out as soon as it has consumed all the oxygen contained in the included air, and that the water will rise up in the vessel to fill the vacancy. In the decomposition of atmospheric air by combustion, it is natural to ask what becomes of the nitrogen gas? As the oxygen becomes fixed in the combustible body, its caloric is disengaged, a part of which combines with the nitrogen, and carries it off in the form of rarefied nitrogen gas. When bodies are burnt, none of their principles are destroyed. We have reason to think that every particle of matter is indestructible, and that the process of combustion merely decomposes the body, and sets its several component parts at liberty, to separate from each other, to form other new and varied combinations. It was said of old, that the Creator *weighed* the dust, and *measured* the water, when he made the world. The first quantity is here still; and though man can gather and scatter, move, mix, and unmix, yet he can destroy nothing: the dissolution of one thing is a preparation for the being, and the bloom, and the beauty of another. Something gathers up *all* the fragments, and nothing is lost.

QUESTIONS.—1. What is an oxyd? 2. What are the principal ways by which metallic oxyds are formed? 3. What is said of iron as an example? 4. What is red lead and how is it made? 5. What is said of the different capacity and attraction of metals for oxygen? 6. What experiment is given for illustration? 7. What is said of the properties of nitrous oxyd gas? 8. What effects does it produce on being inhaled? 9. How may it be procured? 10. How may combustion be defined? 11. How is the process of combustion explained? 12. What remains when the combustion is over? 13. What is smoke? 14. How may the agency of oxygen in combustion be demonstrated? 15. What becomes of the nitrogen gas? 16. What is said of the indestructibility of matter? 17. What is a retort? (see Appendix.) 18. How may chlorine be procured? 19. What is said of the attraction of chlorine for the metals? 20. How is combustion defined in the Appendix, and on what grounds is it so defined?

LESSON 67.

Electricity.

Elec'tric. The first electrical phenomena are supposed to have been observed in a mineral substance called amber, in Greek *elektron*, and hence the fluid or power has been denominated electric.

THE surface of the earth, and of all the bodies with which we are acquainted, is supposed to contain or possess a power of exciting or exhibiting a certain quantity of an exceedingly subtile agent, called the electric fluid or power. The quantity usually belonging to any surface, is called its natural share, and then it produces no sensible effects; but when any surface becomes possessed of more, or of less, than its natural quantity, it is electrified, and it then exhibits a variety of peculiar and surprising phenomena ascribed to the power called electric. If you take a stick of sealing-wax and rub it on the sleeve of your coat, it will have the power of attracting small pieces of paper, or other light substances, when held near them. If a clean and dry glass tube be briskly rubbed with the hand, or with a piece of flannel, and then presented to any small light substances, it will immediately attract and repel them alternately for a considerable time. The tube is then said to be excited. If an excited glass tube, in a dark room, be brought within about half an inch of the finger, a lucid spark will be seen between the finger and the tube, accompanied with a snapping noise, and a peculiar sensation of the finger. Dry flannel clothes, when handled in the dark, frequently exhibit a sparkling appearance, attended with the same kind of noise that is heard in the experiment of the glass tube.

All those bodies which transmit or conduct electricity from one surface to another, are called conductors, and those surfaces that will not transmit the electric power, are called electrics or non-conductors. The general class of conductors comprehends metals, ores, and fluids in their natural state, except air and oils. Vitrified and resinous substances, amber, sulphur, wax, silk, cotton, and feathers, are electrics or non-conductors. Many of these, such as glass, resin, and air, become conductors by being heated. When a surface is supposed to have more than its natural quantity of this fluid, it is said to be *positively* electrified; and when less than its natural share, to be *negatively* electrified. When any electrified conductor is wholly surrounded by non-conductors, so that the electric fluid cannot pass from it along conductors to the earth, it is said to be *insulated*. The human body is a good conductor of electricity; but if a person stand on a cake of resin, or on a stool supported by glass legs, the electric fluid cannot pass from him to the earth, and if he is touched by another person standing on the ground, the same sparkling appearance and noise, as mentioned above, will be exhibited. Two surfaces, both positively, or both negatively electrified, *repel* each other; and two substances, of which one is positively, and the other negatively electrified, *attract* each other. Opposite electricities always accompany each other, for if any surface become positive, the surface with which it is rubbed becomes negative; and if any surface be rendered positive, the *nearest* conducting surface will become negative. When one side of a *conductor* receives the electric fluid, its whole surface is instantly pervaded; but when an *electric* or *non-conductor* is presented to an electrified body, it becomes electrified on a small spot only. If to one side of a pane of glass, you communicate positive electricity, the opposite side will become negatively electrified, and the plate is then said to be *charged.* These electricities cannot come together, unless a communication, by means of conductors, is made between the sides of the glass; and if their union be made through the human body, it produces an affection of the nerves called an *electric shock.*

As the excitation which is produced by rubbing with the hand on a tube or plate of glass, is not only very laborious, but inadequate to the production of any material quantity of electric fluid, machines have been constructed of various forms for this purpose. The most common machine consists of a glass cylinder, supported by two glass pillars, and made to turn by a crank or handle. A rubber, or cushion, of leather, spread with an amalgam of mercury and zinc or tin is fastened to a spring, which proceeds from a socket cemented on the top of another glass pillar. A piece of black silk is fastened to the cushion and extended over the cylinder, nearly to the receiving points, to prevent the fluid from flying off. A fourth glass pillar supports what is called the prime conductor, which is made of hollow brass or tin plate, and, at the end towards the cylinder, has a collection of pointed wires, and at the other end, a single wire terminated by a brass ball. A small chain is fastened to the cushion, one end of which extends to the floor or table. It serves to conduct the fluid in passing from the earth to supply the machine. When the cylinder is turned swiftly, the electric fluid passes from the rubber to the glass, and is thence conveyed to the points of the prime conductor, which is thus positively electrified. While the electric fluid is collecting, it produces a crackling noise, and in a darkened room the flame will be seen spread on the surface of the cylinder. If a cylinder be made of resin, the electricity is the reverse of that which is produced by the smooth glass cylinder and rubber of the usual machines; for in this case the rubber partakes of the positive, and the cylinder, and prime conductor, is electrified with the negative. This difference between the resin and glass has given rise to what is called the double current, or vitreous and resinous electricity; but it is generally supposed that the difference arises more from the effect of the surfaces that act on each other, than from any peculiar qualities in the different bodies.

Some of the experiments which may be made with an electrical machine are necessary for illustrating the laws of electricity, and others are merely entertaining. If the inside of a glass tumbler be electrified by presenting it to a pointed wire extending from the prime conductor, and then placed over a few pith-balls laid upon a table, the balls will immediately begin to leap up along the sides of the glass, and then back to the table; they are attracted and repelled by the electrified inside surface of the glass, the electricity of which they gradually conduct to the table. If a person having long hair, not tied up, be placed upon an insulated stand, and, by means of a chain be connected with the prime conductor, when the machine is put in motion, the hairs on his head, by repelling each other, will stand out in a most surprising manner. A piece of sponge, filled with water, and hung to a conductor, when electrified in a dark room, exhibits a most beautiful appearance. If a piece of sealing-wax be fastened to a wire, and the wire be fixed into the end of the conductor, and the wax lighted, the moment the machine is worked, the wax will fly off in the finest threads imaginable. Take a two ounce phial, half full of olive-oil, pass a slender wire through the cork, and let the end of it be so bent as to touch the glass just below the surface of the oil; then place your thumb opposite the point of the wire in the phial, and if, in that position, you take a spark from the charged conductor, the spark, in order to reach your thumb, will actually perforate the glass. In this way holes may be made all round the phial.

QUESTIONS.—1. What parts of bodies contain the electric fluid? 2. When is a body said to be electrified? 3. What experiment may be made with sealing-wax? 4. When is a glass tube said to be excited? 5. What is said respecting an excited tube when in a dark room? 6. What are conductors of electricity? 7. Electrics, or non-conductors? 8. When is a surface positively, and when negatively electrified? 9. When is a conductor said to be insulated? 10. What is said of the human body as a conductor? 11. When do surfaces repel, and when attract each other? 12. What takes place when a conductor receives the electric fluid?—non-conductor? 13. When is a plate of glass said to be charged? 14. What is an electric shock? 15. Describe the electrical machine. 16. What are some of the experiments that may be made with it? (See Electrical Machine, fig. 49.) [NOTE. The earliest account of any known electrical effect is by the ancient naturalists, Thales and Theophrastus, who flourished, the first 600, and the latter 300 years before the present era.]

LESSON 68.

Electricity (*continued.*)

A queous, watery. Collapse′, to fall together.

The Leyden phial is a glass jar coated with tin foil on the inside and outside within about three inches of the top of its cylindrical part, and having a wire with a brass ball at its extremity. This wire passes through a cork or piece of wood, and at its lower extremity is a small chain, or wire, that touches the inside coating in several places, and serves as a conductor to charge the jar with electric fluid. On bringing the ball of the jar near the prime conductor, after a few turns of the machine, the jar will be charged. The discharging rod consists of two brass balls attached to the ends of a wire, bent in the form of a semicircle, and fixed to a glass handle. When one of the balls of the discharging rod is applied to the ball of the jar, and the other to the outside coating, a communication is made between the outside and inside of the jar, by which the equilibrium is instantly restored by the superabundant electricity passing from one side to the other, appearing in the form of a vivid flash, and accompanied with a loud report. Any number of persons may receive the shock together by laying hold of each other's hands, the person at one end touching the outside of the jar, and the person at the other end bringing his hand near the ball of the jar. If there were a hundred persons so situated, they would every one feel the shock at the same instant. The electric fluid may be thus conveyed many miles in a moment of time. When great force is required from the electric fluid, a number of jars of the above description are connected together by making a communication between all their outsides, and another between all their insides. In this manner any number of jars may be charged with the same facility as a single one, and from the powerful effect of the electric fluid, when it is thus collected, it is called an electrical battery.

The Leyden phial received its name from the birth-place of the discoverer, who was a native of Leyden in Holland. But the greatest discovery that was ever made in electricity was reserved for Dr. Franklin, in America. It had been imagined before his time that a similarity existed between lightning and the electric fluid; but Franklin brought this supposition to the test, and proved the truth of it by the simple means of a boy's kite covered with a silk handkerchief instead of paper, and some wire fastened in the upper part, which served to collect and conduct the fluid. When he had raised this machine into the atmosphere, he drew electric fluid from the passing clouds, which descended through the flaxen string of the kite as a conductor, and was afterwards drawn from an iron key which he tied to the line at a small distance from his hand. This important experiment immediately led to the formation of conductors to secure buildings from the effects of lightning.

When aqueous vapour is condensed, the clouds formed are usually more or less electrical, and the earth below them being brought into an opposite state, a discharge takes place when the clouds approach within a certain distance, constituting lightning; and the collapsing of the air, which is rarefied in the electrical circuit, is the cause of the thunder, which is more or less intense, and of longer or shorter duration, according to the quantity of the air acted upon, and the distance of the place where the report is heard from the point of the discharge.

In gloomy pomp, whilst awful midnight reigns,
And wide o'er earth her mournful mantle spreads,
Whilst deep-voiced Thunders threaten guilty heads,
And rushing torrents drown the frighted plains,
And quick-glanced Lightnings, to my dazzled sight,
Betray the double horrors of the night:

A solemn stillness creeps upon my soul,
And all its powers in deep attention die;
My heart forgets to beat; my steadfast eye
Catches the flying gleam; the distant roll,
Advancing gradual, swells upon my ear
With louder peals, more dreadful as more near.

Awake, my soul, from thy forgetful trance!
The storm calls loud, and meditation wakes;
How at the sound pale Superstition shakes,
Whilst all her train of frantic fears advance!

Children of darkness, hence! fly far from me!
And dwell with guilt and infidelity!

But come, with look composed, and sober pace,
Calm Contemplation, come! and hither lead
Devotion, that on earth disdains to tread;
Her inward flame illumes her glowing face,
Her upcast eye, and spreading wings, prepare
Her flight for heaven to find her treasure there.

She sees, enraptured through the thickest gloom,
Celestial beauty beam, and 'midst the howl
Of warring winds, sweet music charms her soul;
She sees while rifted oaks in flames consume,
A FATHER GOD, that o'er the storm presides,
Threatens, to save,—and loves, when most he chides.

CHAPONE.

QUESTIONS.—1. What is the description of the Leyden phial? 2. How is it charged?—how discharged? 3. What experiment may be made by it? 4. What is an electrical battery? 5. What great discovery did Dr. Franklin make,—and by what means? 6. To what did this experiment lead? 7. What is lightning?—thunder? (See Leyden phial, fig. 50.)

LESSON 69.

Falling Stars, Water Spouts, and Northern Lights.

Lam'bent, playing about, gliding over.
Glo'ry, a circle of rays which surrounds the heads of saints in pictures,—praise, celebrity, felicity of heaven.

IT is supposed to be owing to the electricity of the atmosphere, that we observe a number of curious and interesting phenomena, such as falling stars, water-spouts, and northern lights. What are called falling stars are seen chiefly in clear and calm weather: it is then that the electric fluid is probably not very strong, and passing through the air it becomes visible in particular parts of its passage, according to the conducting substances with which it may meet. One of the most striking of this kind is recorded by Beccaria, an Italian.—As he was sitting with a friend in the open air, an hour after sun-set, they saw a falling, or as it is sometimes called, a shooting star, directing its course towards them, growing apparently larger and larger, till it disappeared not far from them, and, disappearing, it left their faces, hands, and clothes, with the earth, and neighbouring objects, suddenly illuminated with a diffused and lambent light, attended with no noise at all. He concluded this to be the effect of electricity, because he had previously raised his kite, and found the air very much charged with the electric matter : sometimes he saw it advancing to his kite like a falling star ; and sometimes he saw a kind of glory round it, which followed it as it changed its place.

Water-spouts are often seen in calm weather ; and the sea seems to boil and send up smoke under them, rising in a sort of hill towards the spout. A rumbling noise is often heard at the time of their appearance, which happens generally in those months that are peculiarly subject to thunder-storms, and they are commonly accompanied or followed by lightning. When these approach a ship, the sailors present and brandish their swords to disperse them, which seems to favour the conclusion that they are electrical. The analogy between water-spouts and electricity may be made visible by hanging a drop of water to a wire, communicating with the prime conductor, and placing a vessel of water under it. In these circumstances, the drop assumes all the various appearances of a water-spout, in its rise, form, and mode of disappearing. It is inferred, therefore, that the immediate cause of this extraordinary phenomenon is the attraction of the lower part of the cloud for the surface of the water.

The northern light (*Aurora Borealis*) is an extraordinary meteor, or luminous appearance, showing itself in the night, in the northern part of the heavens ; and most frequently in frosty weather. It is usually of a reddish colour inclining to yellow, and sends out frequent coruscations of pale light, which seem to rise from the horizon in the form of a pyramid with undulating motion, and shoot with great velocity up to the zenith. This kind of meteor, which is more uncommon as we approach towards the equator, appears with the greatest lustre in the polar regions, and during the long winter is almost constant. In Sweden and Lapland, the northern lights are not only singularly beautiful in their appearance, but afford travellers by their almost constant effulgence a very beautiful light during the whole night. In

Hudson's bay, they diffuse a variegated splendour, which is said to equal that of the full moon. In the north eastern parts of Siberia, they have been described as beginning with single bright pillars, rising in the north, and almost at the same time in the north-east, which gradually increasing comprehend a large space of the heavens, rush about from place to place with incredible velocity, and finally almost cover the whole sky. The northern lights are supposed to be electrical phenomena, because electricians can readily imitate the appearance with their experiments. Dr. Franklin's idea is that they may arise from a discharge of electricity, accumulated in the atmosphere near the poles, into its rarer parts.

On the Northern Lights.

BY LOMONOSOV, A RUSSIAN POET—TRANSLATED BY J. BOWRING.

WHERE are thy secret laws, O nature, where?
Thy north lights dazzle in the wintry zone:
How dost thou light from ice thy torches there?
There has thy sun some sacred, secret throne?
See in yon frozen seas what glories have their birth;
Thence night leads forth the day to illumine the earth.

Come then, philosopher! whose privileged eye
Reads nature's hidden pages and decrees;
Come now, and tell us whence, and where, and why,
Earth's icy regions glow with lights like these,
That fill our souls with awe; profound inquirer, say;
For thou dost count the stars and trace the planets' way!

What fills with dazzling beams the illumined air?
What wakes the flames that light the firmament?
The lightning's flash? there is no thunder there—
And earth and heaven with fiery sheets are blent;
The winter night now gleams with brighter, lovelier ray
Than ever yet adorned the golden summer's day.

Is there some vast, some hidden magazine,
Where the gross darkness flames supplies?
Some phosphorus fabric, which the mountains screen,
Whose clouds of light above those mountains rise?
Where the winds rattle loud around the foaming sea,
And lift the waves to heaven in thundering revelry?

Thou knowest not! 'tis doubt, 'tis darkness all!
E'en here on earth our thoughts benighted stray,
And all is mystery through this worldly ball—
Who then can reach or read yon milky way?
Creation's heights and depths are all unknown, untrod;
Who then shall say how vast, how great, creation's God!

QUESTIONS.—1. Why is it supposed that those meteoric appearances called falling stars owe their origin to electricity? 2. How may the analogy between electricity and the water-spout be made visible? 3. Describe the northern light. 4. What is Dr. Franklin's idea of it? [NOTE. A similar light called aurora australis has been long since observed towards the south pole.]

LESSON 70.

Galvanism.

Mus'cle, the fleshy fibrous part of an animal body.

GALVANISM is another mode of exciting electricity. In electricity the effects are chiefly produced by mechanical action; but the effects of galvanism are produced by the chemical action of bodies upon each other. This branch of philosophy has been denominated galvanism, from Galvani, an Italian professor, whose experiments led to its discovery. In 1789, he was by accident led to the fact of electricity having the property of exciting contractions in the muscles of animals. After having observed that common electricity, even that of lightning, produced vivid convulsions in the limbs of recently killed animals, he ascertained that metallic substances, by mere contact, under particular circumstances, excited similar commotions. He found it to be essential that the forces of metals employed should be of different kinds. He applied one piece of metal to the nerve of the part, and the other to the muscle, and afterwards connected the metals, either by bringing them together, or by connecting them by an arch of a metallic substance; every time this connexion was formed, the convulsions took place. The greatest muscular contractions were found to be produced by zinc, silver, and gold. A person may be made sensible of this kind of electric action by the following experiments. If he place a piece of one metal, as a half crown above, and a piece of some other metal, as

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zinc, below his tongue, by bringing the outer edge of these pieces in contact, he will perceive a peculiar taste, and in the dark will see a flash of light. If he put a slip of tin-foil upon the bulb of one of his eyes, and a piece of silver in his mouth, by causing these pieces to communicate, in a dark place, a faint flash will appear before his eyes. Galvani supposed that the virtues of this new agent resided in the nerves of the animal, but Volta, who prosecuted this subject with much greater success, showed that the phenomena did not depend on the organs of the animal, but upon the electrical agency of the metals, which is excited by the moisture of the animal, whose organs were only a delicate test of the presence of electric influence. In exciting the electricity of the pieces of silver and zinc, the saliva of the mouth answers the same purpose as the moisture of the animal.

The conductors of the galvanic fluid are divided into the perfect and imperfect. The perfect conductors consist of metallic substances and charcoal: the imperfect are water and oxydated fluids, as the acids and all the substances that contain these fluids. To render the Galvanic, or more properly the Voltaic power sensible, the combination must consist of three conductors of the different classes. When two of the three conductors are of the first class, the combination is said to be of the first order; when otherwise, it is said to be of the second order. If a piece of zinc be laid upon a piece of copper, and upon the copper a piece of flannel, moistened with a solution of salt in water a *circle* of the first class is formed; and then if three other pieces be laid on these in the same order, and repeated several times, the whole will form a pile or *battery* of the first order. The effects may be increased to any degree, by a repetition of the same simple combination. The following is a cheap and easy method of constructing a Voltaic pile, for zinc is one of the cheapest of metals, and may be easily melted, like lead. Let a person cast twenty or thirty pieces of zinc, of the size of a cent, which may easily be done in moulds made of clay. Let him then take as many cents, and as many pieces of paper or woollen cloth cut in the same shape, and which he is to dip in a solution of salt and water. In building the pile, let him place a piece of zinc, wet paper, the superabundant water being pressed out, after which the copper; then zinc, paper, copper, and so on, until the whole be finished. The sides of the pile may be supported with rods of glass, or varnished wood, fixed in the board on which it is built. Having wet both hands, touch the lower part of the pile with one hand, and the upper part with the other, constant little shocks of electricity will be felt until one hand be removed. If the hand be brought back a similar repetition of shocks will be experienced. Hold a silver spoon in one hand, and touch with it the battery in the lower part, then touch the upper part with the tongue; the bitter taste is extreme. If the end of the spoon be put under the eyebrow, close to the ball of the eye, a sensation will be felt like the burning of red-hot iron, but which ceases the instant the spoon is removed. The plates will soon become oxydated, and require cleaning in order to make them act.

QUESTIONS.—1. What is galvanism? 2. Give an account of the origin of this branch of philosophy. 3. How may a person be made sensible of this kind of electric action? 4. What was the discovery of Volta? 5. What are perfect conductors of galvanic fluid?—imperfect? 6. What is necessary in order to render the galvanic or voltaic power sensible? 7. When is the combination said to be of the first order?—second order? 8. How may a pile or battery of the first order be formed? 9. What is a cheap and easy method of forming a voltaic pile? 10. What experiments may be formed with such a pile? 11. Why do the plates require cleaning? (See Voltaic pile, fig. 47.)

LESSON 71.

Galvanism (*continued.*)

Lab′oratory, a room fitted up with apparatus for the performance of chemical operations.

Def′lagrate, to burn rapidly: nitre thrown on hot coals deflagrates. When accompanied with a loud noise it is termed *det-o-na′tion*.

THE most convenient kind of galvanic battery consists of a trough made of baked wood, three inches broad, and about as deep; in the sides of the trough are grooves opposite to each other; into each pair of grooves is fixed by cement, a plate of zinc and silver soldered together, and in the order of silver and zinc; the cement must be filled in so as to prevent any communication between the different cells. The cells are to be filled with water and nitrous acid, and then if a communication be made between the first and last cell, by means of the hands, a strong shock will be felt, which will be repeated as often as the contact is renewed. Several persons, by joining hands, having first wetted them with water, may receive the shock.

The spark from a powerful galvanic battery acts upon and inflames gun-powder, charcoal, cotton, and other inflammable substances, melts all metals and disperses diamonds. Fill the battery, described above, with water and nitrous acid in the proportion of nine parts of water and one of acid, and wipe the edges of the plates very dry; then fasten two wires to pieces of copper, which are to be put into the outer cells, and in order to hold the wires they must be surrounded to a sufficient extent with little glass tubes. If the ends of the wires be brought together on a plate of glass, a spark will be perceived; and if gun-powder be laid on the glass between the points of the wires, it will be exploded.

The galvanic battery in the laboratory of the Royal Institution at London consists of two hundred instruments, connected together in regular order, each composed of ten double plates arranged in cells of porcelain, and containing in each plate thirty-two square inches; so that the whole number of double plates is two thousand, and the whole surface one hundred and twenty-eight thousand square inches. This battery, when the cells are filled with sixty parts of water, mixed with one part of nitric acid, and one part of sulphuric acid, affords a series of impressive and brilliant effects. When pieces of charcoal, about one inch long and one-sixth of an inch in diameter, are brought near each other, a bright spark is produced, and more than half the volume of charcoal becomes ignited to whiteness, and by withdrawing the points from each other, a constant discharge takes place through the heated air, in a space equal at least to four inches, producing a most brilliant ascending arch of light, broad and conical in form in the middle. When any substance is introduced into this arch, it instantly becomes ignited; platina melts as readily in it as wax in the flame of a common candle; fragments of diamond, and points of charcoal, and plumbago, rapidly disappear, and seem to evaporate in it. Such are the decomposing powers of electricity, that not even insoluble compounds are capable of resisting their energy; for glass, when moistened and placed in contact with electrified surfaces from the voltaic apparatus is slowly acted upon, and the alkaline, earthy, or acid matter carried to the poles in the common order. Not even the most solid aggregates, nor the firmest compounds, are capable of resisting this mode of attack; its operation is slow, but the results are certain; and sooner or later, by means of it, bodies are resolved into simpler forms of matter.

The effects of galvanism on metallic bodies are greatly increased by using plates of a large size; and on the contrary, the shock is increased by multiplying the pairs of plates. The shock of a battery containing eighty or a hundred pairs of plates, of three or four inches in diameter, is such as few persons would be willing to bear more than once. At the same time such a battery produces but feeble effects when passed through a metallic wire. On the contrary, if one or two pairs of plates containing the same extent of surface be used, the sensation it gives is hardly to be felt, while it will deflagrate a metallic wire of considerable size.

Professor Hare, of Philadelphia, has invented a new method of extricating the Voltaic influence, by so connecting the plates, that, in *effect*, only two great surfaces of the metals are presented to each other. By this arrangement, the galvanic action on different substances has presented some new phenomena, and the common theory of galvanism must undergo, it is thought, a radical change. The calorific principle is immensely increased, while the electric shock is hardly to be perceived. Charcoal exposed to the effects of this new deflagrator melts into globules resembling diamond, and the process is attended with a most intense light. If mercury be placed in the hand, and the back side of the hand be applied to the negative pole, and the positive pole be brought to the surface of the mercury, it will be inflamed, and the hand will be affected with no disagreeable sensation, till the mass of mercury becomes heated. The new view, which Professor Hare has been induced to offer, is, that galvanism is a compound of electricity and caloric, and this is thought to be confirmed by the action of his machine.

QUESTIONS.—1. What is the most convenient kind of galvanic battery? 2. What is the effect of a powerful galvanic battery upon inflammable substances? 3. Describe the battery at the Royal Institution in London. 4. What effect does it produce upon charcoal?—other substances? 5. What is said of the effects of galvanism by using plates of a large size?—by multiplying the pairs of plates? 6. What is the invention of Prof. Hare? 7. What experiments may be performed with it? 8. What new view of the subject has Prof. Hare offered? (See the galvanic or voltaic battery described at the beginning of this lesson, fig. 46.) [NOTE. Prof. Hare has named his new apparatus *Calorimotor*, or heat mover.]

LESSON 72.

Magnetism.

Polar'ity, that property of a magnet, by which, if left at liberty, it will point towards the poles of the earth, or nearly so: the same end always points to the same pole.

ALTHOUGH the phenomena of the magnet have, for many ages, engaged the attention of natural philosophers, not only by their singularity and importance, but also by the obscurity in which they are involved; yet very few additions have been made to the discoveries of the first inquiries into the subject. No hypothesis has hitherto been framed, that will account in an easy and satisfactory manner, for all the various properties of the magnet, nor have the links of the chain, which connect it with the other phenomena of the universe, ever been pointed out. It is certain, indeed, that both natural and artificial electricity will give polarity to needles, and even reverse a given polarity; and hence it may be inferred that there is a considerable affinity between the electric and magnetic powers, but in what manner electricity acts in producing magnetism, is still utterly unknown.

The ancients were acquainted with the attractive and repulsive powers of the magnet; but it does not appear that they knew of its tendency to the pole: this very fortunate discovery was made about the beginning of the fourteenth century, when the spirit of exploring distant regions was gradually forming in Europe. The use which might be made of it in directing navigation was immediately perceived, and that most valuable, but now familiar instrument, the mariner's compass, invented. When navigators found that they could, at all seasons, and in every place, discover the north and south with the greatest ease and accuracy, it became no longer necessary to depend, like the voyagers of former ages, merely on the light of the stars, and the observation of the sea-coast. They gradually abandoned their ancient timid and lingering course along the shore and ventured boldly into the ocean. Relying on this new guide, they could steer in the darkest night, and under the most cloudy sky, with a security and precision till then unknown. The compass may be said to have opened to man the dominion of the sea, and to have put him in full possession of the earth, by enabling him to visit every part of it.

Nearly half a century elapsed, from the time of this discovery, before navigators ventured into any seas which they had not been accustomed to frequent. But in the course of the fifteenth century, discoveries were made far beyond the conception of all former ages. In the first voyage of Columbus, the Spaniards were struck with an appearance, not less astonishing than new. They observed that the magnetic needle, in their compasses, did not point exactly to the polar star, but varied toward the west; and, as they proceeded, this variation increased. This appearance, which filled the companions of Columbus with terror, and which still remains one of the mysteries of nature, is that deviation from the meridian which is called the *variation of the needle*. It is different in different parts of the world; being west at some places, east at others, and in parts where the variation is of the same name, its quantity is very different. It is the same to all needles in the same place; and for a long time, it was thought to be invariably the same, at the same place, in all ages; but it was discovered, about the year 1625, that it was different at different times, in the same place. From subsequent observations, it appears, that this deviation was not a constant quantity, but that it gradually diminished; and at last, about the year 1660, it was found that the needle at London pointed exactly north. At present the declination at London is about twenty-four degrees west. For some years, it has been nearly stationary; but it is understood now to be returning in an easterly direction. Knowing the variation, or declination of the magnetic needle, that is, the angle which the magnetic meridian makes with the meridian of the place, mariners are able to sail by the compass with as much accuracy as if it pointed exactly north.

The inclination, or *dipping* of the magnetic needle, expresses the property which the magnet possesses of inclining one of its poles towards the horizon, and of elevating the other pole above it. This property was discovered in the year 1576. It is found to be always the same at the same place, but different in different places.

QUESTIONS.—1. When was the polarity of the magnet discovered? 2. What use was made of this property of the magnet? 3. When and by whom was the deviation of the needle from the meridian discovered? 4. What is said of this variation with respect to the same place?—to different places? 5. What is said of the declination of the needle at London? 6. What is the inclination or dipping of the magnetic needle?

LESSON 73.

Magnetical Experiments.

THE natural magnet, or loadstone, is found in the earth, generally in iron mines, in a hard and brittle state, and for the most part, more vigorous in proportion to the degree of hardness. Artificial magnets, which must be made of hard or highly tempered steel, are now generally used in preference to the natural magnet; not only, as they may be procured with greater ease, but because they are far superior to the natural magnet in strength, communicate the magnetic virtue more powerfully, and may be varied in their form more easily. In making artificial magnets, care should be taken to apply the north pole of the natural magnet or magnets to that extremity of the steel which is required to be made the south pole, and to apply the south pole of the magnet to the opposite extremity of the piece of steel. Very powerful magnets may be formed by first constructing several weak magnets, and then joining them together to form a compound one.

The north or south poles of two magnets *repel* each other; but the north pole of one *attracts* the south pole of another. The attraction between the magnet and iron is mutual, for the iron attracts the magnet as much as the magnet attracts the iron; since if they be placed on pieces of wood, so as to float upon the surface of the water, it will be found that the iron advances towards the magnet as well as the magnet towards the iron, or, if the iron be kept steady, then the magnet will move towards it.

Magnetic attraction will not be destroyed by interposing obstacles between the magnet and iron. If you lay a small needle on a piece of paper, and put a magnet under the paper, the needle may be moved backwards and forwards; and with a piece of glass or board the effect will be the same. This property of the magnet has afforded the means of several amusing deceptions. A small figure of a man has been made to spell a person's name. The hand, in which was a piece of iron, rested on a board, under which a person, concealed from view, with a powerful magnet, contrived to carry it from letter to letter, until the word was made up. If the figure of a fish, with a small magnet concealed in its mouth, be thrown into the water, and a baited hook be suspended near it, the magnet and iron by mutual attraction will bring the fish to the bait.

If you lay a sheet of paper, covered with iron filings upon a table, with a small magnet among them, and then shake the table a little, at the two ends or the poles, the particles of iron will form themselves into lines, a little sideways, which bend, and then form complete arches, reaching from some point in the northern half of the magnet to some other point in the southern half. If you shake some iron-filings through a gauze sieve upon a paper that covers a bar magnet, they will be arranged in beautiful curves.

Soft iron is attracted by the magnet more forcibly than steel, but it is not capable of preserving the magnetic property so long. The gradual addition of weight to a magnet kept in its proper situation, increases the magnetic power, but heat weakens it, and great heat destroys it. Bars of iron that have stood long in a perpendicular situation, are generally found to be magnetical; this circumstance, together with the phenomena of the compass and the dipping needle, leaves no room to doubt but that the *cause* exists within the earth.

Questions.—1. Where is the natural magnet found? 2. Why are artificial magnets used in preference to natural? 3. How may very powerful magnets be formed? 4. How do the poles of a magnet attract and repel each other? 5. How does it appear that the attraction between the magnet and iron is mutual? 6. How does it appear that magnetic attraction will not be destroyed by the interposition of bodies? 7. What amusing deceptions has the attractive property of the magnet afforded? 8. How may the magnetic power be weakened or destroyed? 9. From what is it concluded that the cause of magnetism exists in the earth?

LESSON 74.

Aërostation.

Wick'er, made of small sticks. A'eronaut, one who sails through the air.
Meteorolog'ical, relating to the phenomena of the atmosphere, such as the alterations of its weight and temperature, changes produced by evaporation and rain, its excessive agitations, its electricity, &c.

Aerostation, in the modern application of the term, signifies the art of navigating through the air, both in its principles and practice. Hence also the machines which are employed for this purpose, are called aërostats, or aërostatic machines; and on account of their round figure, air-balloons. Air-balloons are of two kinds, those filled with rarefied air, and those filled with hydrogen gas. The best forms for balloons are globular or oval. Large balloons, for hydrogen gas, must be made of silk, and varnished over so as to be air-tight. The car, or boat, is made of wicker-work, covered with leather, well varnished or painted, and is suspended by ropes proceeding from the net which goes over the balloon. The hydrogen gas for filling the balloon is procured by putting a quantity of iron-filings, or turnings, with some sulphuric acid diluted with water, into casks lined with lead. From the top of these casks tin tubes proceed, which unite into one that is connected with the silk tube of the balloon. Balloons of oiled silk cannot be made smaller than five or six feet in diameter, as the weight of the material is too great for the air to buoy it up.

In 1729, Bartholomew Gusman, a Jesuit of Lisbon, caused an aërostatic machine, in the form of a bird, to be constructed, and made it ascend, by means of a fire kindled under it, in the presence of the king, queen, and a great concourse of spectators. Unfortunately, in rising, it struck against a cornice, was torn, and fell to the ground. The inventor proposed renewing his experiment; but the people had denounced him to the inquisition as a sorcerer, and he withdrew into Spain, where he died in an hospital. In 1766, the Honourable Henry Cavendish discovered that hydrogen gas (then called inflammable air,) was at least seven times lighter than common air. It occurred soon afterwards to the celebrated Dr. Black, that if a thin bag were filled with this gaseous substance, it would, according to the established laws of specific gravity, rise in the common atmosphere; but he did not pursue the inquiry. The same idea was conceived by Mr. Cavallo, to whom is generally ascribed the honour of commencing the experiments on this subject. He had made but little progress, however, in these experiments, when the discovery of Stephen and John Montgolfier, paper-manufacturers of France, was announced in 1782, and engaged the attention of the philosophical world. Observing the natural ascent of smoke and clouds in the atmosphere, those artists were led to suppose that heated air, if enclosed in a suitable covering, would also prove buoyant. After several smaller experiments, by which this idea was fully confirmed, they inflated a large balloon with rarefied air, which immediately and rapidly rose to the height of six thousand feet, and answered their most sanguine expectations.

It was soon found that machines of this kind might be so contrived, as to convey small animals, and even human beings, through the air with ease. The first adventurer in this aerial navigation was Pilatre de Rozier, a daring Frenchman, who rose in a large balloon from a garden in the city of Paris, on the 15th of October, 1783, and remained a considerable time suspended in the air. He made several aerial voyages afterwards of greater extent, and in two of them was attended by other persons. In a short time, however, the use of rarefied air in aërostation was for the most part laid aside, as inconvenient and unsafe. On recurring once more to the discovery of Mr. Cavendish, the philosophers of Paris concluded that a balloon, inflated with hydrogen gas, would answer all the purposes of that contrived by the Montgolfiers, and would also possess several additional advantages. They made their first experiment in August, 1783, which was attended with complete success. Since that time, air-balloons filled with rarefied air have not been generally used.

The first aerial voyage in England was performed by Vincent Lunardi, a native of Italy. The diameter of his balloon was thirty-three feet. Soon after, Mr. Blanchard ascended, carrying up a pigeon, which flew away from the boat, laboured for some time with its wings to sustain itself in the air, and finally returned and rested on one side of the boat. He ascended so high as to experience great difficulty of breathing, but perceiving the sea before him, he descended near Ramsey, about seventy-five miles from London, having travelled at the rate of nearly twenty miles an hour.

The singular experiment of ascending into the atmosphere with a balloon, and of descending with a machine, called a parachute, in the form of a large umbrella, was performed by Mr. Garnerin in 1802. The weather was clear and pleasant, and the wind was gentle. In about eight minutes the balloon and parachute had ascended to an immense height, and Mr. Garnerin in the basket, could scarcely be perceived. While the spectators were contemplating the grand sight before them, Mr. Garnerin cut the rope, and in an instant he was separated from the balloon, trusting his safety to the parachute. Before the parachute opened, he fell with great velocity; but as soon as the parachute was expanded, which took place a few moments after, the descent became very gentle and gradual. It was observed that the parachute, with the appendage of cords and basket soon began to vibrate like the pendulum of a clock, and the vibrations were so great, that more than once the parachute, and the basket with Mr. Garnerin, seemed to be on the same level, or quite horizontal; the extent of the vibrations, however, diminished as he descended. On coming to the earth, he experienced some strong shocks, but soon recovered, and remained without any material injury.

The fate of Rozier, the first aerial navigator, and of his companion Romain, has been much lamented. They ascended with an intention of crossing the channel to England. Their machine consisted of a spherical balloon, filled with hydrogen gas, and under this balloon, a smaller one filled with rarefied air, designed to diminish the specific gravity of the whole apparatus. For the first twenty minutes they seemed to pursue the proper course; but the balloon appeared to be much inflated, and the aëronauts appeared anxious to descend. Soon, however, when they were at the height of three quarters of a mile, the whole apparatus was in flames, and the unfortunate adventurers fell to the ground, and were killed.

The invention of balloons cannot be considered as having added much to the comfort or utility of man. The only practical purposes which it has been made to subserve, are those of aiding meteorological inquiries, and of inspecting the fortifications and reconnoitring the camp of an enemy, which could not be approached by other means. The difficulties, under which this species of navigation labours, appear at present to be insurmountable; and the want of some means to control and regulate the movements of the aerial vessel is so essential, as to excite a fear that it cannot be supplied.

Questions.—1. What is aërostation? 2. What is the best form for a balloon? 3. What are the two kinds of balloons? 4. How is a balloon filled with hydrogen gas? 5. Who invented the first aërostatic machine, and what was the result? 6. What discovery did Cavendish make? (Hydrogen gas is 14 times lighter than common air,—see Lesson on water.) 7. What afterwards occurred to Dr. Black? 8. What idea did Cavallo conceive?—what is ascribed to him? 9. What discovery did the Montgolfiers make? 10. Who was the first aerial navigator? 11. What was the next discovery in this science? 12. What is said of the ascent of Mr. Blanchard? 13. Describe the experiment of Mr. Garnerin. 14. What was the fate of Rozier and Romain? 15. What is said of the advantages which have been derived from balloons? 16. Of the difficulties under which this species of navigation labours? [Note. Small balloons may be made of thin strips of bladder, or other membrane, glued together.]

LESSON 75.

Natural History.

Pellu'cid, clear, transparent, not opaque.

Those who with a philosophical eye have contemplated the productions of Nature, have all, by common consent, divided them into three great classes, called the Animal, the Vegetable, and the Mineral or Fossil kingdoms. These terms are still in general use, and the most superficial observer must be struck with their propriety. Animals have an organized structure which regularly unfolds itself, and is nourished and supported by air and food; they consequently possess life, and are subject to death; they are moreover endowed with sensation, and with spontaneous, as well as voluntary, motion. Vegetables are organized, supported by air and food, endowed with life, and subject to death as well as animals. They have in some instances spontaneous, though we know not that they have voluntary motion. They are sensible to the action of nourishment, air, and light, and either thrive or languish according to the wholesome or hurtful application of these stimulants. The spontaneous movements of plants are almost as readily to be observed as their living principle. The general direction of their branches, and especially of the upper surface of their leaves, though repeatedly disturbed, to the light, the unfolding and closing of their flowers at stated times, or according to favourable or unfavourable circumstances, with some still more curious particulars, are actions undoubtedly depending on their vital principle, and are performed with the greater facility in proportion as that principle is in its greatest vigour. Plants alone have a power of deriving nourishment, though not indeed exclusively, from inorganic matter, mere earths, salts, or airs, substances certainly incapable of serving as food for any animals, the latter only feeding on what is or has been organized matter, either of a vegetable or animal nature. So that it would seem to be the office of vegetable life alone to transform dead matter into organized living bodies.

The Mineral kingdom can never be confounded with the other two. Fossils are masses of mere dead unorganized matter, subject to the laws of chemistry alone ; growing indeed, or increasing by the mechanical addition of extraneous substances, or by the laws of chemical attraction, but not fed by nourishment taken into an organized structure. Their curious crystallization bears some resemblance to organization, but performs none of its offices, nor is any thing like a vital principle to be found in this department of nature. If it be asked what is this vital principle, so essential to animals and vegetables, but of which fossils are destitute, we must own our complete ignorance. We know it, as we know its omnipotent Author, by its effects. The infinitely small vessels of an almost invisible insect, the fine and pellucid tubes of a plant, all hold their destined fluids, conveying or changing them according to fixed laws, but never permitting them to run into confusion, so long as the vital principle animates their various forms. But no sooner does *death* happen, than, without any alteration of structure, any apparent change in their *material* configuration, all is reversed. The eye loses its form and brightness ; its membranes let go their contents, which mix in confusion, and thenceforth yield to the laws of chemistry alone. Just so it happens, sooner or later, to the other parts of the animal as well as vegetable frame. Chemical changes immediately follow the total privation of life, the importance of which becomes instantly evident when it is no more. If the human understanding can in any case flatter itself with obtaining, in the natural world, a glimpse of the *immediate agency* of the Deity, it is in the contemplation of this *vital principle*, which seems independent of material organization, and an impulse of his own divine energy.

The man who surveys the vast field of nature, and devotes a portion of his time to the study of the principles which influence, or govern, the motions of animated beings, however minute they may be, will not only derive pleasure from the pursuit, but he will gain the only means of discovering the object and utility of their creation. And as he journeys along from one gradation of knowledge to another, he will become more and more intimate with the designs of the great Creator of all. He will gain a more comprehensive view of that wonderful and illimitable power which hath organized the universe, for purposes with which, in the fulness of time, the wise and the virtuous will doubtless be made acquainted. But knowledge must ever be progressive; and he who makes the attempt to read the characters by which the wisdom, power, beneficence, and eternal nature of God is stamped upon every thing here below, will not do it in vain.

He suits to nature's reign th' inquiring eye,
Skill'd all her soft gradations to descry;
From Matter's mode through Instinct's narrow sway,
To Reason's gradual but unbounded way,
And sees through all the wonder-varied chain
No link omitted, no appendage vain,
But all supporting and supported, till
The whole is perfect as the AUTHOR's will.

Hence even the meanest points of *Nature's* care
Fix his attention—his attachment share:
The pebble, through pellucid waters shown,
The moss that clothes—the shrub that cleaves to stone,
The modest-tinted flowers that deck the glade,
The aged tree that spreads its awful shade,
The feathered race that wing the ethereal way,
The insect tribes that float upon the ray,

The herds that graze, the flocks that nip the plain,
And scaly natives of the watery reign.

These hold ten thousand wonders to the sight,
Which prompt inquiry and inspire delight;
Relations—properties—proportions—ends—
Burst into light as her research extends;
Until unnumbered sparks around him fall
From the Great Source of Light, and Life, and All!

DR. L. BROWN.

QUESTIONS—1. How are the productions of nature divided? 2. What is said of the organization of animals? 3. Of vegetables? 4. What are fossils or minerals? 5. What do we know of the vital principle?

LESSON 76.

Mineralogy.

An′alyze, to resolve a compound into its constituent parts, for the purpose of examination. Phys′ical, natural, relating to nature.

ALL the solid materials of which this globe of ours is composed have received the name of Minerals; and the science which makes us acquainted with the relations under which they present themselves to us, is distinguished by the title Mineralogy. These substances, without doubt, must have at all times attracted the attention of mankind; because from them alone are drawn the metals, stones, and other similar substances of indispensable use. But it is only very lately that the method of ascertaining the component parts of these substances was discovered, or that it was possible to describe them so as to be intelligible to others. From the ancients no information of any consequence on these topics is to be expected. The whole science of mineralogy has been created since the year 1770, and is at present advancing towards perfection with astonishing rapidity. New minerals are every day described and analyzed, collections are every where forming, and travels of discovery are succeeding each other without intermission. The fruit of these labours has been the discovery of several new earths and metals; besides a vast number of useful minerals which had been formerly unknown or disregarded.

Nothing at first sight appears easier than to describe a mineral, and yet in reality it is attended with a great deal of difficulty. It is obvious, that to distinguish a mineral from every other, we must either mention some peculiar property, or a collection of properties, which exist together in no other mineral. These properties must be described in terms rigidly accurate, which convey precise ideas of the very properties intended, and of no other properties. The smallest deviation from this would lead to confusion and uncertainty. Now it is impossible to describe minerals in this manner, unless there be a peculiar term for each of their properties, and unless this term be completely understood. Mineralogy, therefore, must have a language of its own; that is to say, it must have a *term* to denote every mineralogical property, and each of these terms must be accurately defined. The language of mineralogy was invented by the celebrated Werner, of Freyburg, and first made known to the world by the publication of his treatise on the *External Characters of Minerals*. The object of this philosopher was to invent a method of describing minerals with such precision, that every species could readily be recognised by those who were acquainted with the terms employed. For this purpose, it was necessary to make use of those properties only which presented themselves to our senses on inspecting the mineral. These accordingly were chosen, and called by Werner external characters; because they may be ascertained without destroying the mineral examined. These constitute the first division of the characters of minerals. To the second belong those which are derived from the chemical composition, or discovered by any chemical change which the mineral suffers; to the third are referred those properties which are afforded by certain physical characters, as electricity or magnetism; and to the fourth a few characters, derived from circumstances frequently observed with regard to a mineral, as the place where it is found, or the minerals by which it is usually accompanied.

QUESTIONS.—1. What are minerals? 2. What is mineralogy? 3. What is said of the knowledge which the ancients had of minerals? 4. What has been the state of this science since the year 1770? 5. How must minerals be described? 6. What was the object of Werner in inventing the language of mineralogy? 7. What was necessary for this purpose? 8. Why were they called external characters? 9. What are the three other divisions of the characters of minerals? 10. What are the *general* external characters of minerals? (See Appendix.) 11. *Particular* external characters? 12. What farther descriptions are given?

LESSON 77.

Classification of Minerals.

Lap'idary, one who deals in gems, or precious stones.
Ductil'ity, a quality of certain bodies, in consequence of which they may be drawn out to a certain length without fracture.
Malleabil'ity, that property of metals which gives them the capacity of being extènded and flattened by hammering.

MINERALS are usually arranged under four classes; earthy, saline, inflammable, and metallic. The *earthy* minerals contain all such as derive their qualities from the earths; and they are divided into genera, according to the particular earth which predominates in each, or more properly, into families, according to their resemblance in external characters, as the diamond family, the ruby family, talc family, and others. The diamond, of which there is only a single species, is the hardest and most beautiful of all the mineral productions. When heated to the temperature of melting copper, and exposed to a current of air, it is gradually but completely combustible. It is wholly converted into carbonic acid, and therefore consists of pure carbon, as we have already mentioned. By means of diamond powder, this substance can be cut and polished upon a wheel in the same way as any other gems are wrought by emery. It is manufactured by jewellers into brilliants and rose diamonds; and is employed by glaziers for cutting glass; by lapidaries for cutting and engraving on the hardest gems, and in the finer kinds of clock work. Before the discovery of the Brazilian mines, diamonds were much more rare, and of course dearer than they have been since. In the year 1730, eleven hundred and forty-six ounces were brought to Europe; in consequence of which, the price of this article immediately fell three-fourths, and to prevent a still further depreciation, the Portuguese government restricted the number of slaves allowed to be employed by those to whom leases of these mines had been granted. The ruby family of minerals is composed of seven species. They are all extremely hard, and several of them highly valued on account of their beauty.

The *saline* minerals comprehend all the combinations of alkalies with acids which exist in the mineral kingdom: such are salt-petre or nitrate of potash; common rock salt, or muriate of soda; and sal-ammoniac, or the muriate of ammonia. Common salt is found in immense masses under the earth's surface in many countries, particularly in Poland, Hungary, and England. The salt-springs in some parts of the United States owe their origin to beds of fossil salt. The rain-water, which penetrates to their surface, effects the solution of a certain portion of them with which it comes in contact, and thus becomes, in some cases, it is said, ten times salter than the water of the sea. The *inflammable* minerals comprehend all combustible bodies, except metals and the diamond; and include sulphur, resins, bitumens, and graphite. Among the bitumens are found the several varieties of mineral coal that are used for fuel, gas-lights, and other purposes. At Pittsburgh in Pennsylvania there are inexhaustible quantities of coal of a superior quality; it is found also in other parts of the state, in some parts of New-York, and in Rhode-Island. It not only enhances the value of the lands in which it is found, and through which it must pass, but is a source of national wealth. In England there are vast beds of coal which often lie at the depth of a hundred feet beneath the surface of the earth. Near White-haven there are some coal mines that extend half a mile under the sea.

The *metallic* minerals comprehend all the mineral bodies, that are composed either entirely of metals, or of which metals constitute the most considerable and important part. It is from the minerals belonging to this class that all metals are extracted; and for this reason they have been called ores. They are found in a native state, either simple, consisting only of one substance, or compound, when composed of two or more substances. We shall briefly describe a few of the most useful *metals*. The first is platina. This is the heaviest of metals, and is found among the gold ores of South America in the form of small grains or scales. Its colour is between steel-grey and silver-white, and its ductility and malleability are very great. From late improvements in the process of bringing it to a pure and malleable state, its price has been diminished, and its utility is becoming more generally acknowledged. Facts are continually brought to light by means of platina instruments, which, without it, might perhaps ever have escaped notice.

Questions.—1. What are the four classes of minerals? 2. What are earthy minerals and how are they divided? 3. What is said of the diamond? 4. What are saline minerals? 5. Inflammable? 6. Metallic? 7. To what do salt-springs owe their origin? 8. What is said of mineral coal? 9. What is said of platina? [Note. The United States possess abundant sources of some of the most useful minerals, and of the stones used in jewelry.]

LESSON 78.

Gold.

In′got, a mass of metal. Nitro-muriat′ic acid is formed by mixing one part of nitric and four parts of muriatic acid; it was known to the ancient alchymists, and called *aqua regia.*

Gold is never found in a mineralized state; but it occurs native in many parts of the world, generally alloyed with a little silver or copper, and commonly in the form of grains. Most of the gold of commerce is obtained at present from Africa and the continent of America. It is the heaviest of all metals except platina, and although its tenacity is such that a wire of one tenth of an inch in diameter will support a weight of five hundred pounds without breaking, yet it possesses less tenacity than iron, copper, platina, or silver. It is ductile and malleable beyond any known limits. The method of extending it used by gold-beaters, consists in hammering a number of thin rolled plates between skins or animal membranes, upon blocks of marble fixed in wooden frames. A grain of gold has been extended to more than forty-two square inches of leaf, and an ounce, which, in the form of a cube, is not half an inch either high, broad, or long, is beaten under the hammer into a surface of one hundred and forty-six and a half square feet. There are gold leaves not thicker in some parts than the three hundred and sixty-thousandth part of an inch; but on the wire used by the lace-makers it is still thinner. An ingot of silver, usually about thirty pounds weight, is rounded into a cylinder, an inch and a half in diameter, and twenty-two inches long. Two ounces of gold leaf are sufficient to cover this cylinder, and sometimes it is effected with a little more than one. The ingot is repeatedly drawn through the holes of several irons, each smaller than the other, till it be finer than a hair; and yet the gold covers it, and never leaves the minutest part of the silver bare, even to the microscope. It has been calculated, that it would take fourteen millions of films of gold, such as is on some fine gilt wire, to make up the thickness of one inch: whereas fourteen million leaves of common printing paper would occupy nearly three-fourths of a mile in thickness. The ductility of gold is such, that one ounce of it is sufficient to gild a silver wire more than thirteen hundred miles long.

Gold may be dissolved in nitro-muriatic acid; and it thus becomes muriate of gold, which is obtained in small crystals, and is very soluble in water. If white satin riband, or silk, be moistened with a diluted solution of gold, and, while moist, exposed to a current of hydrogen gas or sulphurous acid gas, the metal will immediately be reduced, and the silk become gilt with a regular coat of gold. The potters dissolve gold to be applied to the common kind of porcelain, and it is used in a state of solution for staining ivory and ornamental feathers. It gives a beautiful purple red, which cannot be effaced; even marble may be stained with it. Mercury and gold form a compound called the amalgam of gold, which is much used in gilding. The amalgam is spread upon the metal which is to be gilt; and then, by the application of a gentle and equal heat, the mercury is driven off, and the gold left adhering to the metallic surface.

Questions.—1. In what state is gold found? 2. What is said of its weight and tenacity? 3. How do gold-beaters extend it? 4. What surface may an ounce be made to cover? 5. How is silver wire gilt? 6. What calculation has been made respecting the films of gold on gilt wire? 7. What length of silver wire may be covered with an ounce of gold? 8. To what uses may muriate of gold be applied? 9. What is amalgam of gold, and how is it used in gilding?

LESSON 79.

Silver and Mercury.

Ful′minate, to explode with a loud report.

Silver is a heavy, sonorous, brilliant, white metal, only moderately hard, but exceedingly ductile, and of great malleability and tenacity. It is found in various parts of the world, particularly in Peru and Mexico, in a metallic state; also in the state of an alloy, of a sulphuret, of a salt, and in that of an oxyd. It is the most brilliant of metals, and nothing surpasses it in splendour except highly polished steel. It is chiefly used for ornamental work, for domestic utensils, and for current coin: but for these purposes it is generally alloyed with copper, without which it would not have sufficient hardness to sustain much wear. You may know when silver is pure by heating it in a common fire, or in the flame of a candle; if it be alloyed, it will become tarnished; but if it be pure silver, it will remain perfectly white. Of the salts of silver the nitrate is best known, and when melted and run in moulds, it forms the lunar caustic of the apothecary. A solution of it mixed with a little gum water, forms, in conjunction with an alkali, the indelible ink, used in marking linen.

Silvering may be performed on the same substances, and by similar methods with gilding. But as works of this kind are liable to tarnish, they are seldom used. Plating with silver is performed in the following manner: one of the surfaces of an ingot of copper is rendered smooth and clean, and is sprinkled over with a saturated solution of borax; upon this is laid a plate of fine silver, about one twelfth the weight of the copper, and the two are carefully bound together by wire. The mass is now exposed to a full red heat, and the silver adheres to the copper. The ingot is then passed through a rolling-press, and formed into a plate; both the silver and copper extending uniformly during the whole process, at the conclusion of which, the two metals are inseparably united.

Mercury or quicksilver has been known from the earliest ages of the world. In the temperature of our atmosphere, it is a white fluid metal, having the appearance and brilliancy of melted silver. When submitted to a sufficient degree of cold, it is similar in appearance to other metals, and may be beaten into plates. At the poles it would probably be always solid. It readily combines with several of the other metals, and forms with them what are called amalgams. Mercury is used in large quantities for separating gold and silver from their ores; for silvering mirrors, for water-gilding, for making barometers and thermometers; by the philosophical chemist for many purposes of the laboratory; and in the manufactory of vermilion. It has also various and important uses in medicine. By dissolving mercury in nitric acid, a fulminating powder is obtained, two or three grains of which, laid on an anvil and struck smartly with a hammer, will explode with a loud report. Four grains will occasion indentation in the hammer and anvil. By exposing mercury to cold of a proper degree of intensity, which may be easily accomplished by certain freezing mixtures, it becomes a solid metal. If a lump of this be dropped into a cup of warm water, the solid metal will immediately become fluid, and the fluid water in the same instant will become solid. If a glass be used for the experiment, it should be infolded within a cloth to prevent accidents; for sometimes it will be shivered in pieces by the rapidity of the action.

The quicksilver mine of Guanca Velica, in Peru, is 170 fathoms in circumference, and 480 deep. In this profound abyss are seen streets, squares, and a chapel. Thousands of flambeaux are continually burning to enlighten it. The mine generally affects those who work in it with convulsions. Notwithstanding this, the unfortunate victims of an insatiable avarice are crowded together, and plunged naked into these abysses. Tyranny has invented this refinement in cruelty, to render it impossible for any thing to escape its restless vigilance:—

For in the dark Peruvian mine confined,
Lost to the cheerful commerce of mankind,
The groaning captive wastes his life away,
For ever exiled from the realms of day;
While all forlorn and sad, he pines in vain
For scenes he never shall possess again. FALCONER.

QUESTIONS.—1. What is silver? 2. In what states is it found? 3. For what used? 4. How can you ascertain its purity? 5. What is said of nitrate of silver? 6. Of silvering? 7. Plating? 8. Describe mercury. 9. For what is it used? 10. What is said of fulminating powder? 11. Of mercury as a solid metal? 12. What is the description of the quicksilver mines in Peru? 13. How much must the temperature of mercury be reduced before it will become solid? (see Appendix.) 14. What is said of freezing mixtures?

LESSON 80.

Copper and Lead.

Concen'trated, usually applied to fluids which are rendered stronger by evaporating, by means of heat, a portion of the water they contain.

Heteroge'neous, dissimilar in nature. Homoge'neous, having the same nature or principles

Cu'linary, relating to the kitchen.

Copper is a brilliant metal, of a red colour, very hard, sonorous, and elastic; and the most ductile of all the metals, except gold. Its malleability is also so great, that it is hammered into leaves, and sold in thin paper books in imitation of leaf-gold. It will not burn so easily as iron; which is evident from its not striking fire by collision. On this and other accounts it has been substituted for iron in the machinery which is employed in gun-powder mills. The salts of copper are numerous, and much used in the arts connected with chemistry. Concentrated sulphuric acid dissolves copper by the aid of heat, and thus the sulphate of copper or blue vitriol is formed. Copper exposed to the vapour of vinegar or acetic acid becomes acetate of copper or verdigris. All the salts of copper are poisonous, therefore great care should be taken not to taste wantonly the solutions. The uses of this metal are too various to be enumerated. Besides its employment to make boilers and other vessels of capacity, and to sheathe the bottoms of ships, it enters as a component part into several of the most valuable alloys. The most important of these alloys is brass, which is formed by the union of copper and zinc, though brass is never made with pure zinc, but generally with calamine, which is a native oxyd, or rather carbonate of zinc. Bronze and gun-metal are formed by the union of copper and tin in the proportions of a hundred parts of the former to ten or twelve of the latter. Bell-metal is also an alloy of tin with copper, but this usually contains one fourth of its weight of tin. Oxyd of copper is used by the coloured-glass makers. It forms a beautiful green glass.

Lead is a metal of a bluish white colour, very brilliant when first cut with a knife, but it soon tarnishes by exposure to the air; it will mark writing-paper, though in a fainter manner than plumbago. It is malleable and ductile, but possesses very little tenacity. Lead may be mixed with gold and silver in a moderate heat, but when the heat is much increased, the lead rises to the surface, combined with all heterogeneous matters. Upon this property of lead is built the art of refining the precious metals. If melted lead be exposed to the atmosphere, a greyish-yellow powder begins to form upon the surface. By keeping it exposed for some time the powder becomes more yellow. In this state it is called massicot, or yellow oxyd of lead. By a second exposure this oxyd appears capable of combining with more oxygen. It gradually changes colour, and ultimately assumes a splendid red. In this state it is called minium or red lead. The process requires considerable management with regard to heat and the access of air. If the heat be too great or rapid, the lead becomes converted into a flaky substance, called litharge; and a still greater heat converts it into a clear, transparent yellow glass. Thin plates of lead, exposed to the fumes of vinegar at a certain temperature, are gradually corroded and converted into a heavy white powder, used as paint, and called white lead.

The ore of lead is so poisonous, that the steam arising from the furnaces where it is worked, infects the grass in all the neighbouring places, and kills the animals which feed on it. Culinary vessels, lined with a mixture of tin and lead, which is the usual tinning, are apt to communicate to acid foods pernicious qualities, and require to be used with great caution. The same may be said of liquors and other acid substances kept in glazed ware, and of wines adulterated with litharge, and such other preparations of lead as are sometimes used for the purpose of rendering them sweet.

QUESTIONS.—1. What is copper? 2 Why is it substituted for iron in some machinery? 3. What is said of the salts of copper? 4. What is brass? 5. What are bronze and gun-metal? 6. Bell-metal? 7. Describe lead? 8. Why is it used in refining metals? 9. How does lead become oxydized so as to form massicot, and minium? 10. What is litharge? 11. How is white lead formed? 12. What is said of the poisonous qualities of lead?

LESSON 81.

Iron and Tin.

Chalyb'eate, a term descriptive of those mineral-waters which are impregnated with iron.

Pyri'tes, a name given to certain ores, as of iron, copper, tin, &c. which contain a large quantity of sulphur, and have a metallic lustre.

If utility were made the standard of estimation, iron would hold the first place in the class of metals, and would be counted more valuable than gold, as it appears indispensably necessary to the carrying on of every manufacture. It appears to be one of the principal means of civilizing mankind. There has never been an instance of a nation, acquainted with the art of manufacturing iron, which did not in time attain to a degree of civilization infinitely beyond the inhabitants of those countries where this metal was wanting, or its use unknown. It is plentifully and universally diffused throughout nature, pervading almost every thing, and is the chief cause of colour in earths and stones. It may be detected in plants and in animal fluids. There is a great variety of iron ores, which have different names given them by the workmen, and are of very different qualities. They are chiefly composed of the oxyds of iron and clay. This metal is susceptible of two degrees of oxydizement:—the scales, which are detached from forged iron by a high degree of heat, are in the state of black oxyd, and the common rust of iron is the red oxyd. If a bar of iron be heated red-hot, and a stick of sulphur applied to it, a fluid substance will drop from its end, which is found to be a compound of sulphur and iron, and in chemistry is called sulphuret of iron. Iron-filings mixed with sulphur, and made into a paste with water, in a certain time become very hot, and even produce flame. This mixture is sometimes buried under the ground to produce an artificial volcano. In this experiment the water is decomposed, the oxygen unites with the iron to form an oxyd of iron, and with the sulphur to form sulphuric acid, while the hydrogen combines with another portion of the sulphur, and produces sulphuretted hydrogen gas, which occasions the flame. Green vitriol or copperas, which is of so much use in dyeing, in colouring hats, and in other manufactures, is a sulphate of iron. With the prussic acid, iron forms that beautiful paint, known in commerce and the arts by the name of prussian blue.

Tin must have been known very early, as it is mentioned by Homer, and also in the books of Moses. It is a white metal, of little elasticity, and small specific gravity. It is not very ductile, but so malleable that it may be beaten out into leaves thinner than paper. Tin-foil, as it is termed, is usually about one-thousandth part of an inch in thickness. Tin enters into combination with many of the metals, and forms alloys with them, some of which are of great importance. The amalgam of mercury with tin is used in silvering mirrors. Pewter, which was formerly much used, is an alloy of tin and lead. In tinning iron the plates are immersed in the melted tin, and are either moved about in the liquid metal, or are dipped several different times. They are then taken out, and rubbed to remove the impurities from the surface. Tin is consumed in large quantities by the dyers. It is employed to give a brightness to several articles used in forming reds and scarlets. Substances which produced to the ancients only faint and fleeting colours, give us such as are brilliant and durable, by the use of a solution of this metal.

Questions.—1. What is said of the utility of iron? 2. Of its abundance? 3. Of its oxyds? 4. Of its sulphuret? 5. How may an artificial volcano be produced? 5. How do you account for this? 7. What is green vitriol and prussian blue? 8. Describe tin. 9. What is said of the alloys of tin? 10. Of tinning iron plates? 11. Of the use of tin by dyers?

LESSON 82.

Zinc, Manganese, and Antimony.

Sublima'tion, a process whereby certain volatile substances are raised by heat, and again condensed by cold into a solid form: thus are obtained flowers of arsenic and flowers of sulphur.

Zinc is a very combustible metal, and when broken, appears of a shining bluish white. It is one of the most abundant metals in nature except iron, and in Wales its ore was employed till lately in mending the roads. It is used in

China for the current coin, and for that purpose is employed in the utmost purity. When zinc is heated it readily attracts oxygen ; and at a white heat, the absorption of oxygen is so rapid and violent, that the oxyd immediately sublimes, and for this reason it has acquired the name of flowers of zinc. It is frequently combined with copper or tin, in various proportions, and these mixtures constitute some of the most useful compound metals. It is used in medicine, is the base of white vitriol, and its carbonate or oxyd may be advantageously substituted for white lead in house-painting.

Manganese is a brilliant metal, of a darkish white colour, inclining to gray, of considerable hardness, and of difficult fusibility. When exposed to the air, it absorbs oxygen with rapidity and falls into powder. It abounds in this country ; but on account of its great affinity for oxygen, it has never been discovered in a metallic state. Its oxyd is easily procured ; but the pure metal can only be obtained by art, and in order to preserve specimens of it, it is necessary to varnish them, or to keep them immersed in oil, or ardent spirits. Its oxyds are used in preparing the bleaching liquor, in purifying glass, and in glazing black earthen ware. It is also employed, in some cases, to give colours to enamels in the manufacture of porcelain. The black oxyd is much used by chemists for producing oxygen gas, which, by the application of a red heat, it yields in great abundance.

Antimony is a brilliant, brittle metal, of a silvery white colour, which has not much tenacity, and is entirely destitute of ductility. It may be entirely volatilized by heat. It is also susceptible of vitrification, and produces a hyacinth-coloured glass. Antimony is combined with some other metals in making types for printers. Its oxyds are employed in medicine, and in colouring glass.

Arsenic is generally found in combination with sulphur, oxygen, and many of the metals. Its colour is bluish, or greenish white, becoming, on exposure to the air, dark, almost black ; it is extremely brittle, and at the same time the softest of all metals. It is one of the most active of mineral poisons.

Beautiful shades of various colours may be given to different substances by solutions of arsenic. So that the substance which is most injurious to the animal economy, appears to be endowed with properties for embellishing the works of creation, and by imparting colour to other bodies, is made to minister in various ways to our gratification. How diversified are the means which the Creator hath adopted for the promotion of his benevolent designs!

Who, not content
With every food of life to nourish man,
By kind illusions of the wondering sense,
Has made all nature beauty to his eye,
Or music to his ear. AKENSIDE.

QUESTIONS.—1. What is zinc and its uses? 2. Describe manganese. 3. For what are its oxyds used? 4. What is antimony and its uses? 5. Describe arsenic. 6. Give a general account of the seven classes of metals. (See Appendix to Lesson 65.) [NOTE. The description of the metals properly belongs to the subject of Chemistry, (see Lesson 65) but for the sake of a little more variety it was thought best to insert a brief account of the most important ones after Mineralogy.]

LESSON 83.

Study of Geology.

Crude, unconnected, not well digested.
Intersec'tion, the point where lines cross each other.

GEOLOGY has for its object the study of the earth in general, of its plains, hills, and mountains; and embraces the consideration of the materials of which it is composed, and the circumstances peculiar to its original formation, as well as the different states under which it has existed, and the various changes which it has undergone. Geology has now become an object of the attention and inquiries of many distinguished philosophers. The discoveries of chemists and mineralogists, and the observations of intelligent travellers, have all tended to facilitate these inquiries, and to render them more enlightened and satisfactory; and, although modern times have produced many visionary theories, and crude conjectures on this subject, they have also given birth to some important acquisitions, and much correct philosophy, which will be highly prized by all who study the history and structure of our globe. The science of *geology*, independently of the healthy employment it affords, is of great importance in a practical point of view. It very nearly concerns the miner, engineer, and drainer, and even the farmer and architect; and discloses a variety of indications highly useful in their respective pursuits: to the *miner*, the rocks containing metallic veins and coals; to the *engineer*, the association of hard rocks with soft; to the *drainer*, the intersection of a country by hard dykes, or veins impervious to water; to the *farmer*, the best places for finding lime-stone, marl, and clay; and to the *architect*, the most durable stones for buildings. The person who is attached to geological inquiries, can scarcely ever want objects of employment and of interest. The ground on which he treads —the country which surrounds him—and even the rocks and stones, removed from their natural position by *art*, are all capable of affording some degree of amusement. Every new mine or quarry that is opened, every new surface of the earth that is laid bare, and every new country that is discovered, offers to him novel sources of information. In *travelling*, he is interested in a pursuit which must constantly preserve the mind awake to the scenes presented to it; and the beauty, the majesty, and the sublimity of the great forms of nature, must necessarily be enhanced by the contemplation of their order, their mutual dependence, and their connexion as a whole.

QUESTIONS.—1. What is geology? 2. What is said of the discoveries of chemists and mineralogists? 3. Why is the science of geology important in a practical point of view? 4. What are the advantages of studying geology?

LESSON 84.

Geology.

Stratifica'tion, the division of a mass of rock into many parallel portions, whose length and breadth greatly exceed their thickness.

THE surface of the globe, considered with relation to its inequalities, is divided into highland, lowland, and the bottom of the sea. The highland comprises *alpine land*, composed of mountain groups or series of mountain chains; *mountain chains*, formed by a series of those still more simple inequalities, called *mountains:* in the former we consider their length, height, form, and connexion; the parts of the latter are the foot, the acclivity, and the summit. Lowland comprises those extensive flat tracts which are almost entirely destitute of small mountain groups. To the bottom of the sea belong the flat, the rocky bottom, shoals, reefs, and islands. It is only after a diligent study of the inequalities just pointed out, that we can with advantage undertake to explore the means employed by nature to produce them; and the first step is to proceed to the examination of the physical causes of the slow, but unceasing changes of the globe. Observation teaches us, that most of the elevations and hollows we meet with on the surface of the earth owe their origin to the action of the atmosphere, to that of the ocean, and to volcanic fire. These powerful agents may be considered with regard to their *destroying*, and, in consequence of this destruction, with regard to their *forming* effects.

All geologists are agreed that our present continents were once covered with water. This is proved by the remains of marine animals imbedded in the strata which lie on the summits of the highest mountains. The structure of the globe, as far as we are acquainted with it from the intersections made by rivers, by the action of the sea upon the coast, and by mining operations, consists of beds of different kinds of stone, which generally increase in thickness as we descend deeper. Stratification, in its simplest form, may easily be conceived, by placing a closed book with the back resting upon the table, and raising the opposite edges a little; the book may represent a thick mineral bed, and the leaves a series of strata. In nature we frequently find the strata much broken, and thrown out of the original position. Where any series of strata are wanting, a question naturally arises, have they been carried away by some sudden inundation, before the upper strata were deposited, or have they never extended to that place? In some instances it is certain that the strata have been carried away from particular situations, as in some of the excavations which have formed valleys, in which the strata that terminated on one side of the valley may be discovered again in the hills on the opposite side. The substances of which the strata are composed, are argillaceous, calcareous, or siliceous earth, which are generally more or less intermixed or combined. The strata of clay, or argillaceous strata, being water-tight, give rise to springs, as they arrest the water that runs through the porous strata, and convey it to other situations. The inclinations of the strata, with the breaks and inequalities, render the globe habitable, by distributing the waters over the surface.

The strata to a great depth are generally characterized by the remains of animals or vegetables, in what is called a petrified state, the organic structure being distinctly visible, although the animal or vegetable matter is almost entirely removed, and its place generally supplied by calcareous or siliceous earth. These organic remains are more abundant in the upper than the lower strata; and in the lowest beds of rock which have yet been explored, no traces of organic existence have been found. These remains make us acquainted with the great changes which must have taken place in the condition of our planet in remote ages. The uppermost stratum in England and in various parts of Europe, is formed of alluvial soil. In this soil, the remains of quadrupeds of vast size, such as the elephant, the rhinoceros, and mammoth or mastodon, are frequently found. Many of these are different from any existing species, and they prove that dry land existed in the vicinity, and that Europe was then inhabited by species of animals at present unknown.

The researches of modern geologists have given abundant confirmation to the sacred history, not only with respect to the general deluge, but also with regard to the age of the earth. Until very lately several geological phenomena were considered, by superficial inquirers, as indicating that the creation of the globe we inhabit was an event much more remote than the sacred history represents. This opinion was kept in countenance only as long as geology was in its infancy. Every successive step which has been lately taken in the improvement of this science has served to show its fallacy. The investigations of the latest and most accurate philosophers have afforded the strongest proofs, that the earth, in its present form, cannot have existed longer than appears from the Mosaic account.

QUESTIONS.—1. How is the surface of the globe divided? 2. What does the highland comprise?—lowland? bottom of the sea? 3. What does observation teach us? 4. In what are all geologists agreed? 5. How is this proved? 6. What is said of the structure of the globe? 7. How may stratification be conceived? 8. What are the substances of which the strata are composed? 9. What is said of organic remains? 10. What have modern geological researches confirmed?

LESSON 85.

Relative Situation of Rocks.

Pseu'do, a prefix, which, put before words, signifies false, counterfeit.

Lichen, (pronounced Lik'en) a cryptogamous plant, growing on rocks; in Ireland, a species of Lichen is prepared and used as food.

Presented to the cultured eye of taste,
No rock is barren, and no wild is waste.

Rocky masses, variously placed over each other, compose the whole crust of the earth, to the greatest depth that the industry of man has been able to penetrate. Now these rocks, with respect to each other, occupy a determinate situation, which holds invariably in every part of the earth. Thus limestone is no where found *under* granite, but always *above* it. Werner has chosen this relative situation as the basis of his classification of rocks. He divides them into five classes which are called formations; as primitive, transition, fletz, alluvial, and volcanic. The primitive formations are of course the lowest of all, and the alluvial constitute the very surface of the earth; for the volcanic, as is obvious, are confined to particular points. Not that the primitive are always at a great depth under the surface, very often they are at the surface and constitute mountains. In such cases the other classes of formations are wanting altogether. In like manner the transition and other formations may, each in its turn, occupy the surface, or constitute the mass of a mountain. In some cases all the subsequent formations which ought to cover them are wanting in that particular spot. Each of these grand classes of formations consists of a greater or smaller number of rocks, which occupy a determinate position with respect to each other, and which like the great formations may often be wanting in particular places.

The rocks which constitute the *primitive* formations are very numerous. They have been divided into several sets, such as granite, gniess, mica-slate, and others. It deserves attention, that the rocks constituting them are all chemical combinations, and generally crystallized; that they contain no petrifactions; and that the oldest formations contain no carbonaceous matter. *Transition* rocks are not so numerous. In these, petrifactions first make their appearance, and they usually consist of species of corals and zoophytes, which do not at present exist, and are therefore supposed to be extinct. *Fletz* rocks are disposed in flat or horizontal strata. They contain abundance of petrifactions; and these much more various in their nature than those which occur in the transition formations, consisting of shells, fish, and plants. The *alluvial* formations constitute the great mass of the earth's surface. They have been formed by the gradual action of rain and river water upon the other formations. They consist of the component parts of previously existing rocks, separated by the influence of air, moisture, and change of temperature, and deposited in beds. Sand, gravel, loam, and petrifactions of animals and vegetables, are often found in this class. *Volcanic* formations are pseudo-volcanic, or such minerals as are altered in consequence of the burning of beds of coal situated in their neighbourhood; and true volcanic, or such as are actually thrown from the crater of a volcano.

The expansion of water in the pores or fissures of rocks by heat, or congelation, is a physical cause of the separation of their parts. The solvent power of moisture exerted upon alkaline or calcareous matter, in rocks, is another cause of their decomposition. Electricity, which is shown, by experiments with the voltaic apparatus, to be a most powerful agent of decomposition, seems to assist in all these changes; electrical powers being almost constantly exhibited in the atmosphere. The production of a bed for *vegetation* is effected by the decomposition of rocks. As soon as the rock begins to be softened, the seeds of *lichens*, which are constantly floating in the air, make it their resting-place. Their generations occupy it, till a finely-divided earth is formed, which becomes capable of supporting mosses and heath: acted upon by light and heat, these plants imbibe the dew, and convert constituent parts of the air into nourishment. Their death and decay afford food for a more perfect species of vegetable; and, at length, a mould is formed, in which even the *trees of the forest* can fix their roots, and which is capable of rewarding the labours of the cultivator. The decomposition of rocks tends to the *renovation of soils*, as well as their cultivation. Finely-divided matter is carried by rivers from the higher districts to the low countries, and alluvial lands are usually extremely fertile. The quantity of habitable surface is constantly increased by these operations; precipitous cliffs are gradually made gentle slopes, lakes are filled up, and islands are formed at the mouths of great rivers. In these series of changes, connected with the beauty and fertility of the surface of the globe, small quantities of solid matter are carried into the sea; but this seems fully compensated for by the effects of vegetation in absorbing matter from the atmosphere, by the production of coral rocks and islands in the ocean, and by the operation of volcanic fires.

> What does not fade? the tower, that long had stood
> The crash of thunder, and the warring winds,
> Shook by the slow but sure destroyer, Time,
> Now hangs in doubtful ruins o'er its base;
> And flinty pyramids and walls of brass
> Descend: the Babylonian spires are sunk;
> Achaia, Rome, and Egypt, moulder down.
> Time shakes the stable tyranny of thrones,
> And tottering empires rush by their own weight.
> This huge rotundity we tread grows old,
> The sun himself shall die, and ancient night
> Again involve the desolate abyss. ARMSTRONG.

QUESTIONS.—1. What is the basis of Werner's classification of rocks? 2. Into what five classes does he divide them? 3. What is said of primitive rocks? 4. Transition? 5. Fletz? 6. Alluvial? 7. Volcanic? 8. How does the decomposition of rocks produce a bed for vegetation? 9. Tend to the renovation of soils? [NOTE. Some knowledge of geology is daily becoming more necessary, for without it, scarce a volume of travels or topography, a review or a journal, can be read with all the interest it demands. The structure of the country and the stratification of its mountains, are now as often and as minutely described, as the plants and the animals which are found upon their acclivities.]

LESSON 86.

Biographical Sketch of Linnæus.

CHARLES LINNÆUS, the founder of modern botany, was born in 1707, at a small village in Sweden, where his father resided as a clergyman. His father was attached to his garden, which he had stocked with some of the rarer plants in that climate, and it is to the delight with which this spot inspired Charles, from his earliest childhood, that he himself ascribes his botanical passion. He was not distinguished for his proficiency in the ordinary studies of a literary education; but he made a rapid progress in the knowledge of plants, which he ardently pursued, both by frequent excursions in the fields, and by the unwearied perusal of such books on the subject as he was able to procure. When his father, who designed him for his own profession, came to the seminary, at which he was placed, for the purpose of inquiring into his improvement, he was much mortified to find his son declared utterly unfit for a learned profession by the tutors, who advised that he should be put to some manual occupation. In this perplexity he applied to the physician, Rothman, who was also lecturer in natural philosophy. This person discovered in young Linnæus, talents, which, though not fitted to make him a theologian, were not ill adapted for another profession, and he proposed that of a physician. He took the youth gratuitously into his own house, gave him private instructions, and put him into a systematic method of studying botany.

In 1727, Linnæus entered the University of Lund. He lodged in the house of Stobœus, a physician, who possessed a good library, and a museum of natural history. He paid for his entertainment by various little services, and it was only by accident that his host came to know the extent of his studious ardour. The mother of Stobœus having observed that the candle in his chamber was burning at unseasonable hours, was induced, through fear of fire, to complain of it to her son. Stobœus, therefore, entered his chamber at a late hour, and found him diligently occupied with reading. Struck with this proof of his thirst after improvement, he gave Linnæus the free use of his library, and admission to his table. The advice of Rothman, however, caused him, in 1728, to quit Lund, and to remove to Upsal, for the sake of the superior advantages it afforded. His father advanced him the sum of about eight pounds sterling, which he was informed was all the paternal assistance he was to expect. Thus he was turned out upon the world while yet but a learner in the profession by which he was to obtain his bread. His little patrimony was soon exhausted, and he was reduced to depend upon chance for a meal. Unable to pay even for the mending of his shoes, he was obliged to patch them himself with folded paper.

At length, in the autumn of 1729, as he was intently examining some plants in the garden of the university, he was accosted by Celsius, professor of divinity, and an eminent naturalist, who was then engaged in preparing a work on the plants mentioned in the scripture. A little conversation soon apprised him of the extraordinary botanical acquisitions of the student, and perceiving his necessitous circumstances, he took him to live in his own house. It was in this year that Linnæus conceived the idea of a new systematic arrangement of plants. He drew up a treatise, which was shown to Celsius, and by him to the botanical professor, who had the liberality to bestow on it his warmest approbation. As the professor's advanced age made him desirous of an assistant in the office of lecturing, Linnæus was appointed. He was afterwards invited by the Academy of Sciences at Upsal, to explore the cold regions of Lapland, and the alacrity with which this proposal was accepted, and the faithfulness with which the objects of his journey were secured, were equally creditable to his zeal and perseverance. He visited Holland, and the most richly stored gardens of England and France. The great object of his wishes had always been the professorship of botany at Upsal, and through the kindness of an eminent Swedish statesman, he at length was chosen to that station, and he entered upon the duties of his office in the autumn of 1741. His increasing fame attracted students from every quarter, among whom were several, who imbibed, and diffused throughout the civilized world, a taste for the science over which Linnæus presided.

His father who had so often grieved at the perverseness of his son's disposition for hunting after plants and insects, fortunately lived to see him, not only professor of botany, but dean of the College of Physicians at Upsal, caressed by the noblemen of Sweden, and honoured by all the learned men of Europe. His opulence was such as to enable him to purchase an estate near Upsal, which was his chief summer residence during the last fifteen years of his life. His views of nature impressed him with the most devout sentiments towards its author, and a glow of unaffected piety is continually breaking forth throughout his writings. A general mourning took place at his death, in 1778, and his body was attended to the grave with every token of respect.

Questions.—1. To what circumstance does Linnæus ascribe his passion for botany? 2. What is said of his early proficiency? 3. How was his thirst for improvement discovered at the University of Lund? 4. What is said of his pecuniary means on his removal to Upsal? 5. In what manner did he come into notice at Upsal? 6. By what means was a taste for natural history diffused throughout the civilized world?

LESSON 87.

Study of Botany.

Botany is that branch of natural history which treats of the vegetable kingdom. The study of this science is not a trifling employment, undeserving the time and attention bestowed upon it. Can we for a moment conceive that the works of God are unworthy the attention of man?—that those productions which bear such evident marks of the wisdom and power of the Creator, are too contemptible for the examination of his creatures? Whoever has had the curiosity to crop the humblest flower of the field, and to observe the wonderful conformation of its parts, combining the united purposes of elegance and utility, will not hastily despise the study of nature. But when these observations are extended through the immense variety of productions which compose the vegetable kingdom; when the different offices of each particular part of the plant, every one essentially contributing towards its existence and propagation, are considered; when we advert to the variety of modes by which these ends are effected, and the infinite contrivance which is exhibited in their accomplishment, a wide field for instruction and admiration is opened before us.

We need not labour to prove how delightful and instructive it is to

"Look through nature up to nature's God;"

neither, surely, need we attempt to show, that if any judicious or improved use is to be made of the natural bodies around us, it must be expected from those who discriminate their kinds and study their properties. Of the benefits of natural science in the improvement of many arts, no one doubts. Our food, our medicine, our luxuries are improved by it. By the inquiries of the curious new acquisitions are made in remote countries, and our resources of various kinds are augmented. We find that gardening, the most elegant, and agriculture, the most useful of all arts, are improved only in those countries in which botany is made subservient to their advancement. And when a knowledge of this science is more generally diffused throughout our own country, we may expect to see it more frequently enriched with fields and adorned with gardens, which while they bestow honour on their possessors, shall prove a pleasant recreation to the old, and a useful study to the young. Nor should its influence on the moral character be disregarded. The late President Dwight was an eminent champion of the virtue which he practised. He often directed the attention of his pupils to Sweden, to point out the influence of natural history on the moral character of man. In that country botany is taught in the schools, and the habitation of her excellent children presents a cheering picture of domestic felicity. Their piety and their patriotism both flow from the same source; for while they examine the productions of their country, they become attached to its soil, and while they contemplate the works of their Maker, they are animated with the glowing spirit of devotion.

Botany deserves our highest regard as the source of mental improvement. Nothing so powerfully attracts the notice of the young observer, as the gay, though fleeting beauty of flowers; yet these interesting objects serve to produce an accuracy of discrimination, which is the foundation of correct taste and sound judgment. To those whose minds and understandings are already formed, this study may be recommended, independently of all other considerations, as a rich source of innocent pleasure. Some people are ever inquiring what is the use of any particular plant? They consider a botanist with respect, only as he may be able to teach them some profitable improvement, by which they may quickly grow rich, and be then perhaps no longer of any use to mankind or to themselves. They would permit their children to study botany, only because it might possibly lead to professorships, or other lucrative preferment. These views are not blameable, but they are not the sole end of human existence. Is it not desirable to call the soul from the feverish agitation of worldly pursuits, to the contemplation of divine wisdom in the beautiful economy of nature? Is it not desirable to walk with God in the garden of creation, and hold converse with his providence? If such elevated feelings do not lead to the study of nature, it cannot be far pursued without rewarding the student by exciting them. The more we study the works of the Creator, the more wisdom, beauty, and harmony become manifest; and while we admire, it is impossible not to adore.

"Soft roll your incense, herbs, and fruits, and flowers,
In mingled clouds, to *Him*, whose sun exalts,
Whose breath perfumes you, and whose pencil paints!"

Questions.—1. What is Botany? 2. Why is the study of this science not a trifling employment? 3. What renders it a field for instruction and admiration? 4. What may we expect when a knowledge of this science is more generally diffused? 5. Why did Dr. Dwight often direct the attention of his pupils to Sweden? 6. How is botany a source of mental improvement? 7. How do some people regard a botanist? 8. How are these views to be considered, and what reply is made to them?

LESSON 88.

Texture of Vegetables.

Longitu'dinally, running in the longest direction.
Concen'tric, having one common centre.

Every part of a living plant is covered with a skin or membrane called the *cuticle*. In the root and trunk it is coarse and hard, while in the leaves, flowers, and tender shoots, it is a fine, colourless, and transparent film, not thicker than a cobweb. It is porous and admits of the passage of fluids from within as well as from without, but in a due and definite proportion in every plant. It not only protects the young tree from external injury, but it preserves our choicest fruit from premature decay, and without it, the leaf would lose its verdure, the flower its fragrance, and their transitory beauty would become still more evanescent. To wheat, rye, and most kinds of grass, the cuticle is of the highest importance, for it supports their stalks and secures them from injuries. In these, and still more abundantly in some others, Sir Humphry Davy has discovered the existence of a flinty earth; and it is this which makes the ashes of burnt straw one of the best materials which can be employed in giving its finest polish to marble. The fruit of the peach and the leaf of the mullein have a cuticle covered with dense and rather harsh wool.

Immediately under the cuticle of leaves and young stems is found a substance called the *cellular integument*. It is of a pulpy texture and the seat of colour. No plants are destitute of it, for it is the seat of operations indispensably necessary to healthy vegetation. When the cellular integument is removed, the outer surface of the *bark* presents itself, which in plants or branches that are only one year old, consists of one simple layer; but in the older branches and trunks of trees, it consists of as many layers as they are years old. The bark contains a great number of woody fibres, running for the most part longitudinally, which give it tenacity, and in which it differs very essentially from the parts already described. In the bark, the peculiar virtues or qualities of particular plants chiefly reside. Here we find in appropriate vessels the resin of the Fir, the astringent principle of the Oak, the fine and valuable bitter of the Peruvian Bark, and the exquisitely aromatic oil of the Cinnamon. Immediately under the bark is situated the *wood*, which forms the great bulk of trees and shrubs. When cut across it is found to consist of numerous concentric layers. Linnæus and most writers believe that one of these circular layers is formed every year, the hard external part being caused by the cold of winter; consequently, that the exact age of a sound tree when felled may be known by counting these rings. That the bark produces wood seems to have been proved beyond dispute, for plates of tin-foil have been introduced under the barks of growing trees, the wounds carefully bound up, and after some years, on cutting them across, the layers of new wood have been found on the outside of the tin.

The centre or heart of the vegetable body, within the wood, contains the *pith*. Its texture is precisely similar to that of the cellular integument, being composed of cells which are seen to best advantage in the centre. These cells, which are unusually large in the Elder, are filled with fluids when young, but in old branches the fluids are gone and the cells are empty. Of its uses in the economy of vegetation, but little is known.

QUESTIONS.—1. What is the cuticle of a plant? 2. How is it described and what are its uses? 3. Describe the cellular integument. 4. The bark. 5. The wood. 6. The pith. 7. What chiefly resides in the bark of plants? 8. What is said of the circular layers of wood? 9. How has it been shown that the bark produces the wood?

LESSON 89.

Sap and Secretions.

Odorif'erous, fragrant, perfumed. Propul'sion, the act of driving forward. Es'culent, good for food, eatable.

THAT the whole vegetable body is an assemblage of tubes and vessels is evident to the most careless observer; and those who are conversant with the microscope and books relating to it, have frequent opportunities of observing how curiously these vessels are arranged, and how different species of plants, especially trees, differ from each other in the structure and disposition of them. It is familiar to every one that plants contain various substances, as sugar, gum, acids, odoriferous fluids, and others, to which their various flavours and qualities are owing; and a little reflection will satisfy us that such substances must each be lodged in proper cells and vessels to be kept distinct from each other. They are extracted, or secreted, from the common juice of the plant, and called its peculiar or secreted fluids. Various experiments and observations prove also that air exists in the vegetable body, and must likewise be contained in appropriate vessels. Besides these, we know that plants are nourished and invigorated by water, which they readily absorb, and which, by proper tubes or vessels, is quickly conveyed through their stalks and leaves. It is observed, moreover, that all plants, as far as any experiment has been made, contain a common fluid, which at certain seasons of the year is to be obtained in great quantity, and this is properly called the sap. It is really the blood of the plant, by which its whole body is nourished, and from which the peculiar secretions are made.

The great motion, called the *flowing* of the sap, which is to be detected principally in the spring, and slightly in the autumn, is totally different from that constant propulsion of it which is going on in every growing plant. Its facility to run is the first step towards the revival of vegetation from the torpor of winter. Its exciting cause is heat, and the effect of heat is in proportion to the degree of cold to which the plant has been accustomed. The same principle accounts for the occasional flowing of the sap in autumn after a slight frost. Such a premature cold increases the sensibility of the plant to any warmth that may follow, and produces, in a degree, the same state of its constitution as exists after the long and severer cold of winter.

The sap in its passage through the leaves and bark becomes quite a new fluid, possessing the peculiar flavour and qualities of the plant, and not only yielding woody matter for the increase of the vegetable body, but furnishing various secreted substances. These are chiefly found in the bark, and often in large and conspicuous vessels, as the turpentine-cells of the Fir tribe. In herbaceous plants, whose stems are only of annual duration, the perennial roots frequently contain these fluids in the most perfect state, nor are they, in such, confined to the bark, but deposited throughout the substance of the root, as in Rhubarb and Gentian. It may be useful to enumerate some of the most distinct secretions of vegetables. Gum or mucilage, a viscid substance of little flavour, exudes from many trees in the form of large drops or lumps, as in Plum, Cherry, and Peach trees. Resin is a substance soluble in spirits, and it differs according to the peculiar tree from which it is obtained. The more refined and volatile secretions of a resinous nature are called essential oils, and they are often highly aromatic and odoriferous. They exist in the highest perfection in the perfumed effluvia of flowers, some of which, capable of combination with spirituous fluids, are obtainable by distillation, as that of the Lavender and Rose. The bitter secretion of many plants does not seem exactly to accord with any of the foregoing. Some facts would seem to prove it of a resinous nature, but it is often perfectly soluble in water like gum or mucilage. Acid secretions are well known to be very general in plants. The astringent principle would seem to be a sort of acid, of which there are many different forms, or kinds, and among them the tanning principle of the Oak, Willow, and others. To the secretion of plants we owe the existence of sugar. In tropical countries it is commonly obtained from the expressed juice of the sugar-cane, but the Maple of the North yields it equally pure and scarcely less abundant. It exists also in the roots of some, and in the esculent fruit of many plants, communicating a sweet and usually an agreeable taste.

To the foregoing secretions of vegetables may be added those on which their various colours depend. We can but imperfectly account for the green so universal in their herbage, but we may gratefully acknowledge the beneficence of the Creator in clothing the earth with a colour the most pleasing and the least fatiguing to our eyes. We may be dazzled with the brilliancy of a flower-garden, but we repose at leisure on the verdure of a grove or meadow.

QUESTIONS.—1. What is said of the whole vegetable body? 2. What are called the peculiar or secreted fluids of plants? 3. What is said of the sap? 4. The *flowing* of the sap? 5. What are some of the most distinct secretions of vegetables? 6. What is said of those secretions on which the colours of vegetables depend?

LESSON 90.

Process of Vegetation.

Incip'ient, just beginning. Suc'culent, juicy, moist.

WHEN a seed is committed to the ground, it swells by the moisture which its vessels soon absorb, and which, in conjunction with some degree of heat, stimulates its vital principle. Atmospherical air is also necessary to incipient vegetation, for seeds in general will not grow under water, except those of aquatic plants, nor under an exhausted receiver. Seeds buried in the ground to a greater depth than is natural to them, do not vegetate, but they often retain the power of vegetation for an unlimited period. Earth taken from a considerable depth will, when exposed to the air, be soon covered with young plants, though no seeds have been allowed to have access to it. The young root is the first part of the infant plant that comes forth, and by an unerring law of nature, it is sent downwards, to seek out nourishment as well as to fix the plant to the ground. In sea-weeds, it seems merely to answer the latter purpose. In the Dodder, the original root lasts only till the stems have established themselves on some vegetable, on whose juices they feed by means of other roots or fibres, and then it withers away. When the young root has made some progress, the two lobes, commonly of a hemispherical figure, which compose the chief bulk of the seed, swell and expand, and are raised out of the ground by the ascending stem. These lobes are called the *Cotyle'dons*, and between them is seated the *Embryo*, or germ of the plant. The leaves of the germ being of a succulent nature, assist the plant by attracting from the atmosphere such particles as the tender vessels are fitted to convey. These particles, however, have not in their own nature a sufficiency of nutriment for the increasing plant. The substance or farina of the lobes becomes soft and sweet, being converted into sugar, and is conveyed as long as it lasts to the tender plant, by means of innumerable small vessels, which are spread through the lobes; and which, uniting into one common trunk, enter the body of the germ, and thus supply that balmy liquor, without which the plant must inevitably have perished; its root being then too small to absorb a sufficiency of food, and its body too weak to assimilate it into nourishment.

Such is the general course of vegetation in plants furnished with two lobes or cotyledons. But there is a very distinct tribe, which have but one lobe, and are called *monocotyle'dons*. These are the grass and grain tribe, and many others, in which the body of the seed does not ascend out of the ground. The preservation of the vital principle in seeds is one of those wonders of nature which pass unregarded, from being every day under our notice. Some may be sent round the world through every vicissitude of climate, or be buried for ages deep in the ground, and yet, in favourable circumstances, they will vegetate. Others in order to succeed must sow themselves, in their own way, and at their own time. Great degrees of heat, short of boiling, do not impair their vegetative power, nor do we know any degree of cold that has such an effect. Those who convey seeds from distant countries, should be instructed to keep them dry; for if they receive any damp sufficient to cause an attempt at vegetation, they necessarily die, because the process cannot, as they are situated, go on. It is usual with gardeners to keep melon and cucumber seeds for a few years, in order that the future plants may grow less luxuriantly, and be more abundant in blossoms and fruit. Dr. Darwin accounts for this from the damage which the lobes may receive from keeping, by which their power of nourishing the infant plant, at its first germination, is lessened, and it becomes stinted and dwarfish through its whole duration.

Questions.—1. What takes place when a seed is committed to the ground? 2. What is said of the young root? 3. Of sea-weeds? 4. Of Dodder? 5. What are the two lobes called? 6. The germ? 7. How do the leaves of the germ assist the plant? 8. To what use is the farina of the lobes applied? 9. What are plants called that have only one lobe? 10. What is said of the preservation of the vital principle in seeds? 11. Why do gardeners sometimes keep melon and cucumber seeds for a few years? 12. How does Dr. Darwin account for this?

LESSON 91.

Roots, Stems, Buds, and Leaves.

Rad′icle, the minute branch of a root.
Physiol′ogy, the doctrine of the constitution of the works of nature.
Perspire′, to give out moisture. Absorb′, to take in moisture.

The root of a plant consists of two parts, the body of the root, and the fibre. The latter only is essential, being the part which imbibes nourishment. Roots are either of annual, biennial, or perennial duration. The first belong to plants which live only one year, or rather one summer, as barley; the second to such as are produced one season, and, living through the ensuing winter, produce flowers and fruit the following summer, as winter-rye and wheat; and the third to those which live and blossom through many succeeding seasons to an indefinite period, as trees and many herbaceous plants. Botanists distinguish several different kinds of roots, which are necessary to be known, not only for botanical purposes, but as being of great importance in agriculture and gardening. Barren and thin soils are best suited to the wide spreading roots, which creep extensively on the surface; dry and sandy plains are adapted to those which penetrate deep for nourishment, and are supplied with bulbs for its preservation, or with downy radicles for its abundant absorption.

Linnæus enumerates seven kinds of trunks, stems, or stalks of vegetables. These are necessary to be known for botanical distinctions, though some are more important than others.

About midsummer the progress of vegetation seems to be suspended, and for several days the vital energies of the tree are exerted in the formation of buds. We no longer observe the vigorous growth of spring, but if we examine the young branches, we shall find the newly formed buds at the base of the leaf-stalk, immediately above the place of their insertion. After the fall of the leaves they are more conspicuous, and during the winter we may perceive a gradual enlargement, corresponding to the developement of the tender germs which they enclose. Plants, as is well known, may be propagated by buds, and in that sense each bud is a separate being, or a young plant in itself; but such propagation is only the *extension* of an individual, and not a *re-production* of the species, as by seed.

Leaves are eminently ornamental to plants from their pleasing colour, and the infinite variety as well as elegance of their forms. Their different situations, insertions, forms, and surfaces, which are of the greatest possible use in systematical botany, cannot here be described. A knowledge of their real use with regard to the plant is a curious branch of vegetable physiology. That leaves give out moisture, or are organs of insensible perspiration, is proved by the simple experiment of gathering the leafy branch of a tree, and immediately stopping the wound at its base with wax to prevent the effusion of moisture in that direction. In a very short time the leaves droop, wither, and are dried up. If the same branch, partly faded, though not dead, be placed in a very damp cellar, or immersed in water, the leaves revive, by which their power of absorption is also proved. A knowledge of the perspiring and absorbing power of leaves is often of great practical importance. It teaches us that plants droop, in consequence of the excess of the former, and are to be revived by diminishing their discharge, or increasing their absorption. The former is accomplished by confining the air around them, and the latter by sprinkling water over the leaves; and when plants have recently been removed, such management is frequently required.

Air is not less essential to the healthy existence of animals than of plants. One great use of leaves is to perform, in some measure, the same office for the support of vegetable life, that the lungs of animals do for the support of animal life. Light has a very powerful effect upon plants, and the green colour of leaves is so much owing to it, that plants raised in darkness are of a sickly white Light acts beneficially upon the upper surface of leaves, and hurtfully upon the under side; hence the former is always turned towards the light, in whatever situation the plant may be placed. A great number of leaves follow the sun in its course, and a familiar instance of this is a clover-field. The leaves of some plants, when the light is withdrawn, fold over each other, or droop as if dying; and this is called by Linnæus the sleep of plants. Some leaves display an extraordinary sensibility to the touch of any extraneous body, or to any sudden concussion, as those of the sensitive plant. An impression made, in the most gentle manner, upon one of its leaflets, is communicated in succession to all of them, evincing an exquisite irritability. The moving plant of India exhibits such powers as to excite the astonishment of every beholder. If its motion be impeded, no sooner does it regain its liberty than its operations are renewed with increased activity, as if it were necessary to redeem the time which it had lost. Its winged leaves seem to disdain to rest, and to exhibit a most astonishing example of industry.

QUESTIONS.—1. What are the two parts of the root of a plant? 2. How are roots divided with regard to their duration? 3. Give the examples. 4. What is said of buds? 5. How is it proved that leaves are organs of perspiration, and of absorption? 6. What office do leaves perform for plants? 7. What is the effect of light upon plants, and leaves? 8. What is said of the sensitive plant? 9. Of the moving plant of India? 10. Describe the several kinds of Roots, (see Appendix.) 11. What is said of the root of common herds grass? 12. What are the seven kinds of trunks or stems? 13. What are the several kinds of appendages to a plant? 14. What are the several kinds of Inflorescence?

LESSON 92.

Flower and Fruit.

Fil'iform, thread like, or very slender.
Ves'icle, a small cuticle, filled or inflated, or a little bladder.

Go, mark the matchless working of the Power
That shuts within the seed the future flower;
Bids these in elegance of form excel,
In colour these, and those delight the smell;
Sends nature forth, the daughter of the skies,
To dance on earth, and charm all human eyes.
COWPER.

LINNÆUS classed the flower and fruit together, and defined them to be a temporary part of vegetables, destined for the reproduction of the species, terminating the old individual and beginning the new. These constitute the reproductive organs, by which the species have been hitherto preserved from extinction, and by which alone they will be renewed, so long as seed time and harvest continue. There are seven of these organs, some of which are essential to the very nature of flower or fruit, others not so indispensably necessary, and therefore not universal. The student, who wishes to gain an adequate idea of these organs, should dissect different flowers, and bestow upon each part a separate examination. He will find externally the *cal'yx* or flower-cup, usually of a green colour, and often wanting; the *corol'la*, or as it is sometimes termed the blossom, assuming various shades of colour, exhibiting a more delicate texture than the preceding, and like it sometimes wanting; the *stamens*, which are filiform organs arranged interior to the corolla, and are never wanting; the *pistils*, arising from the centre of the flower, containing the rudiments of the fruit, and of course essential; the *seed-vessel*, of a pulpy, woody, or leathery texture, enclosing the seeds, but wanting in many plants; the *seed*, the perfecting of which is the sole end of all the other parts; and the *receptacle*, or base, which is the point of connexion, and must necessarily be present in some form or other.

The corolla constitutes the chief beauty of a flower, and includes two parts, the Pētal and the Nectary. The former is either *simple*, as in the primrose and bell shaped flowers, in which case the corolla is said to be monopet′alous; or *compound*, as in the rose, in which it is polypet′alous. The whole use and physiology of the corolla have not yet been fully explained. The nectary contains or secretes honey; and there can be no doubt that the sole use of the honey with respect to the plant is to tempt insects, who in procuring it fertilize the flower, by disturbing the dust of the stamens, and even carry that substance from the barren to the fertile blossoms. A stamen commonly consists of two parts, the Filament and Anther, the former being merely what supports the latter, which is the only essential part. The anther is generally of a membranous texture, consisting of two cells or cavities. It contains the *Pollen*, or Dust, which is thrown out chiefly in warm dry weather, when the coat of the anther contracts and bursts. The Pollen, though to the naked eye a fine powder, and light enough to be wafted along by the air, is so curiously formed, and so various in different plants, as to be an interesting and popular object for the microscope. Each grain of it is a round or angular, rough or smooth vesicle, which remains entire till it meets with any moisture, being contrary in this respect to the nature of the anther; then it bursts with great force, discharging a most subtile vapour.

The Pistil consists of three parts: the *Germen*, or rudiment of the young fruit and seed; the *style*, various in length and thickness, sometimes altogether wanting, and when present serving merely to elevate the third part, which is called the *Stigma*. This last is indispensable. It is very generally downy, and always more or less moist. The moisture is designed for the reception of the pollen, which explodes on meeting with it, and hence the seeds are fertilized and rendered capable of ripening, which they would not otherwise be, though in many plants fully formed.

The ways in which insects serve the purpose of perfecting the seeds in plants are innumerable. These active little beings are peculiarly busy about flowers in bright sunny weather, when every blossom is expanded, the pollen in perfection, and all the powers of vegetation in their greatest vigour. Then we see the rough sides and legs of the bee, laden with the golden dust which it shakes off, and collects anew, in its visits to the honeyed stores inviting it on every side. All nature is then alive, and a thousand wise ends are then accomplished by innumerable means that "seeing we perceive not;" for though in the abundance of the creation there seems to be a waste, yet in proportion as we understand the subject, we find the more reason to conclude that nothing is made in vain.

Questions. 1. How did Linnæus define the flower and fruit? 2. What do these constitute? 3. What is said of the number and importance of these organs? 4. Describe the several parts belonging to the flower and fruit. 5. What two parts does the corolla include? 6. When is the corolla termed monopetalous? 7. Polypetalous? 8. What is the use of the honey with regard to the plant? 9. What are the parts of a stamen termed? 10. Describe the anther. 11. The Pollen. 12. What are the parts of the Pistil? 13. Describe the stigma. 14. What are the seven kinds into which the calyx is divided? (see Appendix) 15. What are the seven kinds of seed vessels? 16. What are some of the parts of which the seed itself is composed? 17. Look at Engr. VII. and describe the parts of the flower and fruit of the Lily. (see the description in Appendix to Lesson 93.)

LESSON 93.

Classification of Vegetables.

Ge′nus, (plural gen′era) a set of plants, animals, or other things, comprehending many species.

Nomencla′ture, a term employed to denote the language peculiar to any particular science or art: a vocabulary.

All the known vegetable productions, upon the surface of the globe, have been reduced by naturalists to Classes, Orders, Genera, Species, and Varieties. The classes are composed of orders; the orders of genera; the genera of species; and the species of varieties. We may attain a clearer idea of them, by comparing them with the general divisions of the inhabitants of the earth. Vegetables resemble Man; Classes, nations of men; Orders, tribes, or divisions of nations; Genera, the families that compose the tribes; Species, individuals of which families consist; and Varieties, individuals under different appearances.

Linnæus, dissatisfied with every system invented before his time, undertook to form a new one. With an eye which could at a single glance discern the peculiar features of an object; with firmness to encounter, and with talents to overcome, the greatest difficulties, he planned and accomplished more than all his predecessors, and his works which remain at this day unrivalled, will probably long continue unequalled. The number, situation, and proportion of the stamens were the foundation of his primary divisions. These organs, so constant, so essential to the completion of the flower, so necessary for the preservation of the vegetable kingdom, were happily selected to furnish each of his *Classes* with an obvious immutable character. The *Orders* into which his classes are subdivided, are established on a basis equally constant, on the number and situation of the pistils, or on some other circumstance equally obvious and invariable. A *Genus* is a subdivision of an order, and includes such plants as agree with each other in the form and situation of their flowers and fruits. A *Species* consists of such as agree in these particulars, but differ in the form of their root, stem, leaves, and other parts.

A remark, which has sometimes been made to the prejudice of the study of Botany, is, that it is a mere nomenclature, tending only to burden the memory with an immense list of names, without imparting to the student any degree of real and useful knowledge. But is it a small gratification, or of small importance, to be enabled to distinguish, at first sight, the productions of the vegetable kingdom, and to refer them to their proper classes, families, and stations? The disadvantages resulting from the neglect of this study, are seldom more seriously felt than in the perusal of those narratives of voyages and travels, which are now so profusely published. In passing through countries which have seldom been visited, it is in the highest degree desirable, that the adventurer should be able to avail himself of the opportunities afforded him, so as to render his labours of substantial service to mankind: but how is this to be effected, unless he be previously furnished with sufficient knowledge to distinguish those natural productions which it may be thought important either to procure or describe? For want of this knowledge, which would enable him to acquaint us in two words with the name of any known plant, and to refer to its proper station every one which is unknown, we have endless descriptions of unknown and surprising vegetables, which either give us no precise idea, or by a long and circuitous track, enable us at length to recognise an old and familiar acquaintance. A striking instance of this may be found in the celebrated Kotzebue's narrative of his banishment to Siberia, in the course of which he discovered a plant which attracted in a high degree his admiration, and which he has described at great length, as one of the most beautiful flowers he had ever met with. A very moderate acquaintance with botanical science would however have informed him, that this plant was already known to most parts of Europe; and the only doubt which remains is, as to the particular species of the plant, a doubt which his description does not after all enable us to clear up.

The natural history of animals, though in many respects more interesting than botany to man as an animated being, and more striking in some of the phenomena which it displays, yet, in other points, is less pleasing to a tender and delicate mind. In botany all is elegance and delight. No painful experiments are to be made. Its pleasures spring up under our feet, and, as we pursue them, reward us with health and serene satisfaction. None but the most foolish or depraved could derive any thing from it but what is beautiful, or pollute its lovely scenery with unamiable or unhallowed images. Those who do so, either from corrupt taste or malicious design, can be compared only to the fiend entering into the garden of Eden.

QUESTIONS.—1. How have naturalists arranged vegetables? 2. Give the illustration. 3. What are the foundations of the Linnæan Classes?—Orders? 4. What does a genus include? 5. A Species? 6. What remark has been made to the prejudice of the study of botany? 7. What is said to obviate this objection? 8. What is related of Kotzebue? 9. What is said of botany as compared with the natural history of animals? 10. What are the names of the twenty-four classes? 11. Of the orders of the first thirteen classes? 12. Give an example of the divisions of classes, orders, &c. 13. How is the species of a plant distinguished? (For answers to the four last questions, see Appendix.) 14. Look at Engr. VII. and describe the parts of the flower and fruit of the geranium.

LESSON 94.

Flowers.

Carna'tion, a fine and fragrant flower whose varieties of colour and luxuriance are innumerable. Class Decandria, order Digynia, genus Dianthus.

The infinite variety of flowers is not less a subject of admiration than their regular succession, and equally evinces consummate wisdom and design. This diversity is not discernible only in the different families of flowers, but it is to be seen in the individuals. In a bed of tulips or carnations, there is scarcely a flower in which some difference may not be observed in its structure, size, or assemblage of colours; nor can any two flowers be found in which the shape and shades are exactly similar. Flowers have not only furnished the poets with inexhaustible description, but the philosophers in every age with a variety of moral sentiments. Those who have gathered a rose, know but too well how soon it withers; and the familiar application of its fate to that of human life and beauty is not more striking to the imagination than philosophically and literally true.

The following interesting account has been given by Sir John Hill of what appeared on examining a carnation. Its fragrance led me to enjoy it frequently and near; the sense of smelling was not the only one affected on these occasions; while that was satisfied with the powerful sweet, the ear was constantly attacked by an extremely soft but agreeable murmuring sound. It was easy to know that some animal within the covert, must be the musician, and that the little noise must come from some little creature suited to produce it. I instantly distended the lower part of the flower, and placing it in a full light, could discover troops of little insects frisking with wild jollity among the narrow pedestal that supported its leaves, and the little threads that occupied its centre. What a fragrant world for their habitation! What a perfect security from all annoyance, in the dusky husk that surrounded the scene of action! Adapting a microscope to take in at one view the whole base of the flower, I gave myself an opportunity of contemplating what they were about, and this for many days together, without giving them the least disturbance. Thus I could discover their economy, their passions, and their enjoyments. The microscope had given, on this occasion, what nature seemed to have denied to the objects of contemplation. The base of the flower extended itself under its influence to a vast plain; the slender stems of the leaves became trunks of so many stately cedars; the threads in the middle seemed columns of massy structure, supporting at the top their several ornaments; and the narrow spaces between were enlarged in walks, parterres, and terraces. On the polished bottoms of these, brighter than Parian marble, walked in pairs, alone, or in larger companies, the winged inhabitants; these from little dusky flies, for such only the naked eye would have shown them, were raised to glorious glittering animals, stained with living purple, and with a glossy gold that would have made all the labours of the loom contemptible in the comparison. I could at leisure, as they walked together, admire their elegant limbs, their velvet shoulders, and their silken wings; their backs vieing with the empyrean in its blue; and their eyes each formed of a thousand others, out-glittering the little planes on a brilliant; above description, and too great almost for admiration. I could observe them here singling out their mates, entertaining them with the music of their buzzing wings, with little songs formed for their little organs, leading them from walk to walk among the perfumed shades, and pointing out to their taste the drop of liquid nectar just bursting from some vein within the living trunk; here were the perfumed groves, the more than myrtle shades of the poet's fancy realized. Here in the triumph of their little hearts, they skipped from stem to stem among the painted trees; or winged their short flight to the close shadow of some broader leaf—

"All formed with proper faculties to share
The daily bounties of their Maker's care."

Note. The night-flowering cereus (*cactus grandiflorus*) is one of our most splendid hot-house plants, and is a native of Jamaica and some other of the West India Islands. Its stem is creeping, and thickly set with spines. The flower is white and very large, sometimes nearly a foot in diameter. The most remarkable circumstance with regard to the flower is the short time it takes to expand, and the rapidity with which it decays. It begins to open late in the evening, flourishes for an hour or two, then begins to droop, and before morning is completely dead.

LESSON 95.

Animal Kingdom.

Zo-ol′ogy, that branch of natural history which treats of animals.
Ver′tebre, (pronounced ver′te-bur,) a joint of the spine.

Few departments of knowledge are more interesting than the natural history of animals, and the attention given to it in the present age furnishes the best evidence that its claims to notice begin to be fully estimated. In our own country the inducements to its cultivation are peculiarly strong, for our immense lakes, forests, and mountains, have as yet been but imperfectly explored by naturalists, and the little that is known of their productions leads to the belief, that they contain abundance to encourage and reward the labours of science.

The study of Zoology is particularly advantageous to the young, from its direct tendency to cultivate one of the most useful habits of the mind, that of attentive observation of things of common and daily occurrence. Its objects are every where around us,—swimming in the waters, flying in the air, walking the earth, and burrowing beneath it. One set provides our food and clothing, another purloins and destroys them. Some attack, and others protect us. Their forms are continually before our eyes, and their voices always sounding in our ears.

In order to treat clearly of the animal kingdom, it is necessary to consider it according to some method of arrangement, by which those animals which most resemble one another are connected together for the convenience of description. This arrangement is founded upon their form and structure, and separates them into various divisions and subdivisions, according to their degree of similarity, and the points in which their structures correspond. Such a system of arrangement is called a classification of the animal kingdom; and an accurate acquaintance with the principles on which it is founded will be of great assistance to the student of natural history.

All animals are divided in the first place into two grand divisions, namely, into *vertebral*, embracing those that have a spine, or *vertebres*, and into *invertebral*, comprehending all those that are destitute of a spine, or vertebral column. The vertebral animals are subdivided into four *classes*, and the invertebral into five. (*See Appendix.*) Each of the classes is divided into a greater or less number of *orders*, distinguished by some important, clear, and remarkable peculiarities of conformation and structure, which are common to all the animals included under each of them. Orders are subdivided into *genera*. These comprehend animals that have a general external resemblance to each other, a kind of family likeness. Genera are made up of *species*. Each distinct kind of animal constitutes a species, and they are known from one another by their size, colour, form, and various other circumstances of external appearance.

Each kind of animal, then, constitutes a distinct *species;* a number of species taken together form a *genus;* those genera which have important and well defined points of resemblance in structure and conformation common to all, are placed together in an *order;* whilst upon a similar principle, but more extensive in its application, these orders are marshalled into separate *classes*.

QUESTIONS—1. What are the inducements to the study of Zoology in our own country? 2. Why is this study advantageous to the young? 3. Upon what is a classification of the animal kingdom founded? 4. What are the first two grand divisions? 5. How are these subdivided? 6. What are classes? 7. Orders? 8. Genera? 9. Species? 10. Give a general definition of species, genus, order, and class. 11. What are the nine classes of the animal kingdom? 12. How many and what are the classes according to Linnæus? [NOTE. In the exercise of reading, the words included in parentheses and italicized should be passed over. They are placed in the lessons that the attention of pupils may be particularly directed to them. Pupils should mention them in answering the questions.]

LESSON 96.

The first Class of Animals (Mammalia.)

THE animals of this class are distinguished for a more perfect bodily structure, for more varied faculties, more delicate sensations, a more elevated intelligence, and greater capability of improvement by imitation and education, than those of any other. It is to this class that man, considered as an object of natural history, properly belongs. He is arranged with the animals of this class, because he nearly resembles them in structure and organs, though raised in reality far above them by the possession of intellectual and moral powers almost infinitely superior.

The structure of an animal is always found to correspond to its character, mode of life, and food; and those, therefore, which have a similar structure, resemble one another to the same extent in other particulars. From the formation of the anterior extremities of an animal, we may judge of the degree of address of which he is capable, and of the kind of motions he is able to perform; and from the structure of his teeth, what is the nature of his food. Thus, the fore-feet of animals may be either enveloped in hoofs, or armed with claws, or furnished with slender nails; and the perfection of the sense of touch will be in proportion to the delicacy of these organs respectively. Thus too, there are three kinds of teeth; the incisive or cutting teeth, the canine or lacerating teeth, and the molar or grinding teeth; but all animals have not each of these kinds of teeth, nor are they of the same shape and formation in all animals.

It is principally from a regard to these parts, that naturalists have proceeded in the arrangement of this class of animals. The *orders* thus formed are nine in number. (*See Appendix.*) Of the first order (*Biman'a*) man is the only example. In point of adroitness, skill, and address, the structure of his body and the faculties of his mind give him great advantages over other animals. In consequence of his erect position, he has the free use of his hands, and his arms have unincumbered and various motions in every direction. There are several distinct races of mankind inhabiting different portions of the earth, which differ one from another more or less in form, in features, in complexion, and in character. The cause of these varieties has never been satisfactorily pointed out. They have been attributed to climate, to situation, and to manner of life, but none of these circumstances appear sufficient to produce them, and we therefore still remain in ignorance on the subject. But notwithstanding the differences in man, he maintains every where a decided rank, far above that of any other animal. He is the only one which has the power of communicating its thoughts and feelings by articulate speech; the only one which can properly be said to avail itself of the advantages of society; and the only one that, strictly speaking, educates its young. It is in consequence of these advantages, particularly that derived from association, that he has been enabled under all circumstances, to acquire and preserve a dominion over other animals, to protect himself against the severity of climates, and thus spread his species over every part of the earth. Naturally tender and defenceless, he could only exist in the most equable and temperate climates; but, aided by the inventions and discoveries of social life, he is enabled to brave the cold of the polar circle, as well as the overpowering heat of the regions on the equator.

The second order (*Quadruman'a, apes, baboons, &c.*) of this class of animals forms a numerous tribe, and comprehends a great variety of species. They maintain the erect position with difficulty; it is a constrained one. Their structure evidently fits them for climbing, and their usual places of habitation are trees, on the fruits of which they feed.

The third order is subdivided into several *tribes* or families, accordingly as they are more or less *carnivorous*. The *first* tribe is that of the Bats, distinguished by their wings, which are formed of a thin fold of skin, extending between the two limbs of the same side. By means of this apparatus, many of them are able to fly with a force and rapidity equal to that of birds; but in others it answers only the purpose of a parachute to break their fall from lofty places, or to enable them to perform great leaps in their passage from tree to tree. The *second* tribe includes a number of small animals, which feed principally upon insects, and are called *insectiv'orous*, as the shrew-mouse and the mole. The *third* tribe possesses the characteristics of carnivorous animals in the highest degree. They are endowed not only with an appetite for animal food and a structure adapted for its mastication and digestion, but with strength and courage for seizing and retaining it; as the wolf, fox, lion, panther, and others. A *fourth* tribe of this order comprehends the *amphibious* animals, as the Seal and the Morse. They live almost entirely in the sea, but they cannot remain constantly under water.

The fourth order (*Roden'tia, gnawers*) are remarkably qualified by the arrangement of their teeth for penetrating very solid substances; and they frequently feed upon woody fibres and the bark of roots and trees. Of this order, among others, are the beaver, the squirrel, and the various species of hare and rabbit. Beavers are aquatic animals, and they construct themselves habitations upon waters which are sufficiently deep never to be frozen to the bottom.

The fifth order (*Edenta'ta, toothless*) are remarkable for a great degree of torpor, listlessness, and indisposition to motion; but some more than others. The sloth, the ant-eater, and the armadillo are among them, and of each of these there are several species. The three-toed sloth is an animal whose very aspect is painful and disgusting. The expression of its countenance, and its whole attitude, indeed, convey to the beholder the impression, that its very existence is a burden.

Ruminating animals form the sixth order of this class, and examples may be found in the camel, antelope, deer, ox, and sheep. They have been more valuable to man than any others. Their flesh furnishes a large proportion of our animal food. They are mild, docile, and easily domesticated.

The seventh order (*Pachyder'mata, thick-skinned*) embraces all the animals with hoofs which do not ruminate, as the elephant, the tapir, the horse. The Hippopot'amus, or River-Horse, inhabits principally the rivers of the south of Africa. It walks with ease at the bottom of the water, though obliged, occcasionally, to rise to the surface for breath.

Animals of the whale kind, or *cetaceous* animals, form the eighth order. They are usually confounded with the class of fishes, which they resemble in many particulars of external appearance, as well as in the circumstance of residing always in the water. In point of structure, however, they clearly belong to the present class, since they breathe air by means of lungs, are warm-blooded, produce their young alive, and nourish them with milk.

The *Marsŭ'pial* animals, which form the ninth order, are distinguished from all others by the possession of a receptacle, formed by a duplicature of the skin, for the purpose of holding their young, or of receiving them on the approach of danger. Such are the Kanguroo and Opossum.

QUESTIONS.—1. By what are animals of the class Mammalia distinguished? 2. Why is man, as an object of natural history, arranged with this class? 3. From a regard to what parts of animals of this class have naturalists arranged them into orders? 4. Describe the first order of mammalia,—second, &c. 5. What are the orders of mammalia according to Linnæus? [NOTE. The distinctive characters of the Linnæan orders of mammalia, with the exception of the last, depend on the kind, position, and number of the teeth, and thus animals of very different habits were brought together, from a resemblance in one comparatively unimportant particular.]

LESSON 97.

Birds.

Ornithol'ogy, that branch of natural history which describes the structure, economy, habits, &c. of birds.
Vis'cid, glutinous, tenacious.

THE immense catalogue of the species of birds, and the variety and beauty of their external characters, have made them favourite objects of investigation with the natural historian. The extraordinary degree of instinct displayed in all their habits and economy, more especially in the construction of their nests, the care of their young, and the conduct of their migrations, have called forth the admiration of the philosopher and the lover of nature. The splendid colouring of their plumage, the powers of melody, and the liveliness and docility of many species, have given them value as objects of beauty and entertainment.

The class of birds is divided, according to their structure and habits of life, into six orders. Birds of prey, or *rapacious* birds (*accip'itres*) correspond, in many respects, with the carnivorous animals among quadrupeds. They are distinguished by their strong, hooked beaks, and their crooked and powerful talons. They are particularly remarkable for the very great distance at which they perceive their prey, and the accuracy with which they direct their flight towards it. Besides the upper and under eye-lids, all birds have a third which is semi-transparent, and serves the purpose of protecting the eye from the contact of external bodies, or from too powerful light, whilst at the same time it does not prevent them from distinguishing the objects around them. This membrane is situated at the inner angle of the eye, and is drawn over the globe of it, like a curtain, at will. It is by means of this protection, that the eagle is enabled to look steadily at the sun.

Sparrows (*Pas'seres*) form the most extensive and numerous order, embracing a great variety of species, which differ so much among themselves, as to be hardly capable of an intelligible description, common to them all. To this order belong those species which are most celebrated for the sweetness and harmony of their notes; and in general the organ of voice in them is larger and better formed, than in any others. Among them are the robin, the swallow, the linnet, the humming-bird, and the nightingale.

The third order (*Scanso'res, Climbers*) includes those birds that have the external toe upon each side turned backwards, which enables them to grasp substances more firmly, and affords them a more sure support, than other birds. Among them are the woodpecker, the cuckoo, and the parrot. Woodpeckers are furnished with a long and slender tongue, covered towards its tip with spines or bristles, which are turned backwards, and coated with a thick viscid secretion. They run in every direction around the trunks and branches of trees, striking them with their beaks, and thrusting their tongues into holes and clefts, for the purpose of drawing out their food.

The Gallinaceous birds (*Gallina'ceæ*) have short and weak wings, and, of course, they are not constructed for long and continued flight. Of this order are the peacock, the turkey, the pigeon and the common fowls. The pigeons form in some particulars an exception to the general characteristics of their order. They fly very well, live in pairs, and build their nests upon trees or in the clefts of rocks. The most remarkable species among them is the crowned pigeon of the Molucca islands, which is equal in size to a turkey. Its voice is exceedingly loud and harsh, and is said to have frightened sailors who landed on the islands which it inhabits, by its resemblance to the yells of the savage natives.

The Waders (*Gral'læ,*) otherwise called shore birds are distinguished by their very long and naked legs, which permit them to wade to a considerable depth in the water without wetting their feathers. All birds with this structure are not, properly speaking, waders in their habits, though they are ranked in this order. Among them are the heron, plover, oxeye, and ostrich. The ostrich is almost incapable of flight, but runs with immense rapidity. Its height varies from six to eight feet; it is the most lofty of birds and the swiftest of all animals.

The toes of Web-footed birds (*An'seres,*) are connected together by a membrane, which fits them for being used as oars. Their whole structure is such as to adapt them for swimming; their legs are situated far back upon their bodies, their feathers are thick, smooth and oily, and their skin beneath covered with a layer of close down, which effectually protects them from the contact of water. Most of them are capable of lofty and long continued flight, as the wild goose and duck; whilst others from the shortness of their wings can scarcely raise themselves into the air, but are principally confined to the surface of the water.

As quadrupeds cast their hair, so all birds every year obtain a new covering of feathers; this is what is termed moulting. During its continuance, they always appear sickly and disordered; no feeding can maintain their strength, for their nourishment is now consumed and absorbed in administering a supply to the growing plumage. It is worthy of observation, that of the vast number of birds which inhabit the globe, it has never been discovered that a single one is of a poisonous nature. They differ very much in being more or less salutary and palatable, as an article of diet; but none of them are pernicious. Sea-faring people and travellers eat every species of egg without the smallest hesitation.

QUESTIONS.—1 What renders birds objects of interest to the naturalist and philosopher? 2. Describe the first order of birds. 3. Second. 4. Third. 5. Fourth. 6. Fifth. 7. Sixth. 8. What is said of their moulting? 9. What is worthy of observation respecting them? 10. What are the Linnæan orders of birds? (see Appendix.)

LESSON 98.

Reptiles and Fishes.

Icthyol'ogy, that branch of natural history which treats of fishes.

REPTILES have less intelligence, fewer faculties, and less instinct, than either quadrupeds or birds. They are, in general, sluggish and indolent in their habits of life, and obtuse in their sensations. In cold countries they pass the greater part of the winter in a dormant state. They are arranged in four orders. The Tortoises (*Chelo'nia*) have a covering consisting of an upper and under shell, joined at their sides into one, which permits only their head and other extremities to be extended without it. They have no teeth but their jaws are armed with a tough horny substance which supplies their place. The order of Lizards (*Sau'ria*) includes a very considerable variety. The greater part of them have four feet, but a few are possessed of only two. They have nails and teeth, and their skin is covered with scales. Among them are the crocodile, the alligator, the chameleon, the true lizards and the dragons. The crocodile is the most celebrated. It is from twenty to thirty feet in length including the tail, and is covered with a coat of scales, which on the back form an armour proof against a bullet, and have an appearance like that of carved work. The Serpents (*Ophid'ia*) are distinguished by their long and slender bodies without limbs, and by the great extensibility of their jaws, mouth and throat. They are divided into the venomous and those that are not venomous. The number of the latter is the greatest and includes the largest animals. The venomous serpents are generally armed with fangs for the specific purpose of infusing poison into the wounds they inflict. When the tooth pierces the flesh of any animal, the poisonous fluid is injected into the opening. When broken or injured, these fangs are renewed, and when not employed, are hidden from the sight by a fold or projection of the gum. Serpents cast their skins annually, and the beauty and lustre of their colours are then highly augmented. The reptiles of the fourth order (*Batrach'ia*, *frog, salamander*, &c.) are principally remarkable for a transformation which takes place in their offspring after leaving the egg. When first hatched, they are strictly an aquatic animal, and capable of breathing and living only under water. In this state they are seen by thousands, of a dark colour, with round bodies, swimming about in brooks and small ponds. After a certain period, their form and structure are altered, and they become at once animals capable of breathing only in air.

Fishes being destined to inhabit only the water, are provided with organs and a structure adapted to the element in which they reside. Since they cannot breathe pure air, they have a peculiar modification of the organs of respiration and circulation. A current of water is constantly passed over the gills by the action of the mouth of the animal, and by means of the air it contains, exerts an influence over the blood circulating in them, and produces the same changes in it as are produced in the lungs of other animals by the air they breathe. A few fishes, one of which is called the torpedo, are possessed of a very remarkable means of defence, which consists in the power of inflicting upon whatever living creature comes in contact with them, a powerful electrical shock. These shocks are so powerful, that in South America, horses driven into the pools which some fishes of this kind inhabit, have sometimes been stunned and even killed. The shocks become weaker and weaker upon continued repetition, till the animal is exhausted, and loses for some time the power of producing any effect.

Questions.—1. What is said of reptiles? 2. Describe the first order. 3. The second. 4. The third. 5. The fourth. 6. Describe the organs of respiration and circulation in fishes. 7. What remarkable means of defence have some fishes? [Note. Fishes are divided into orders and genera, according to certain differences in the formation, structure, and situation of their mouth, gills, gill-coverings, fins, &c.:—and they are called *Apodes*, as eels; *Jugulares*, as cod; *Thoracici*, as perch; *Abdominales*, as pike and salmon.]

LESSON 99.

Structure and Transformation of Insects.

Fa′cet a little face or side of a body cut into a number of angles.
Hexag′onal, having six sides, or angles.
Lu′bricated, made smooth so as easily to glide over any part.
Entomol′ogy, that branch of natural history which treats of insects.

The animals of this class are remarkable for a greater variety of powers and a more wonderful display of instinct and intelligence, than any other of the invertebral animals. They are distinguished by many peculiarities of form. Instead of a heart, insects have a vessel or reservoir situated along the back, extending from one end of their bodies to the other, and filled with a transparent fluid, which is supposed to answer the purpose of blood, and to be conveyed, by absorption, to the various organs. They have no particular organ for respiration, but their bodies are penetrated in every direction by tubes, through which the air is transmitted to every part. These tubes communicate externally by openings called *spiracles.* To serve the purpose of a brain and nervous system, they are furnished with two knotted cords running the length of their bodies. They possess the senses of seeing, tasting, smelling, and feeling; but organs of hearing, if they exist, have not yet been discovered. They are provided with a hard external covering which differs in different species; in some it forms a complete case of a horny or shell-like substance; and in others it consists merely in a tough muscular coat, divided into rings which surround the body. Their heads are furnished with anten′næ or feelers, which are a kind of filaments composed of joints, designed probably as the organs of the sense of touch, or of sensations still more delicate and of a nature totally unknown to us.

The mouth of insects varies much in construction, according to the nature of their food. Some are armed with a sort of lancet, and others with a trunk or probos′cis, which in the butterflies is capable of being rolled up in a spiral form. Their eyes may be considered among the most surprising of nature's works. They differ much in form and colour in the different insects; but they are not, as might be at first supposed, mere hemispherical bodies of plane simple surfaces, for examination proves them to be composed of an immense assemblage of highly wrought hexagonal facets, each furnished with its proper optic nerve, retina, and other parts necessary for vision: the number of these facets differs in different species; eight thousand have been counted in the eye of the common fly, and twelve thousand in that of the dragon fly.

How sweet to muse upon His skill displayed!
Infinite skill! in all that he has made,
To trace in Nature's most minute design
The signature and stamp of Power Divine;
Contrivance exquisite expressed with ease,
Where unassisted sight no beauty sees;
The shapely *limb*, and lubricated *joint*
Within the small dimensions of a point;
Muscle and *nerve* miraculously spun,

His mighty work who speaks, and it is done.
Th' Invisible in things scarce seen revealed;
To whom an atom is an ample field. COWPER.

The greater part of insects are winged. Those which are not winged, continue, during their whole existence, of the same form and structure as at birth. Those which are winged undergo certain changes of form, which are called their *metamor'phoses.* They differ in number in different kinds of insects. For an example we may take the tribe of the Butterfly. From the egg of this insect is hatched an animal differing entirely from its parent. Its body is long and cylindrical, and divided into numerous rings. It is provided with a large number of very short legs, with jaws, and with several small eyes. It is familiarly known to us by the name of *caterpillar.* It lives in this state a considerable time, subsisting upon such food as is adapted to its nature. At length it casts off its skin, and appears in another form without limbs. It ceases to feed or to move. It seems to be totally without life. This is called the *chrys'alis.* After a while, by examining it closely, the imperfect shape of a butterfly may be distinguished through its surface; and finally the envelope is broken and the animal escapes. Its wings are at first short, weak, and moist, but they soon unfold to a greater size, and become strong; and the insect is in a state to fly. It has now six long legs, a spiral trunk, two antennæ, and eyes differing entirely from those of the caterpillar. In short, it is an animal totally different, delighting us by the beauty of its spots and the variety of its colours; and yet these wonderful changes are only the successive unfolding of parts contained one within another in the original em'bryo.

In the first state the animal is called the *larva;* in the second the *chrysalis* or *nympha;* and the third is called the *perfect state.* A considerable portion of the insect tribes pass through these three changes of existence. But many only undergo what is called a demi-metamorphosis. Their larva resembles the perfect insect, except that it has no wings. And the only change they experience is, that in the nymph state they have the rudiments of wings, which finally on casting their skins, are changed into complete ones. Such are grasshoppers and many others.

When about to pass into the chrysalis state, which is a state of imbecility, insects select the most proper places and modes of concealing themselves from their enemies. Some, as the silk-worm and others, spin silken webs round their bodies, by which the animal form is completely disguised. Others leave the plants upon which they formerly fed, and hide themselves in little cells which they make in the earth. Some fix themselves by a gluten, and spin a rope round their middle to prevent them from falling. Others attach themselves to walls, with their heads higher than their bodies, but in various inclinations. In this state many remain motionless and seemingly inanimate, during the whole winter.

Behold the insect race, ordained to keep
The lazy Sabbath of a half year's sleep;
Entombed, beneath the filmy web they lie,
And wait the influence of a kinder sky.
When vernal sun-beams pierce their dark retreat,
The heaving tomb distends with vital heat;
The full formed brood impatient of their cell,
Start from their trance and burst their silken shell;
Trembling, awhile they stand, and scarcely dare
To launch at once upon the untried air:
At length assured, they catch the favouring gale,
And leave their sordid spoils and high in ether sail.

BARBAULD.

QUESTIONS—1. For what are insects remarkable? 2. What have they instead of a heart? 3. What have they to answer the purpose of a respiratory organ? 4. Brain and nervous system? 5. What is said of their senses and external covering? 6. What are antennæ? 7. Describe the eyes of insects. 8. What are the changes called which winged insects undergo? 9. Give a description of these changes in the example of the butterfly. 10. What is the animal called in its first—second—third state? 11. Describe what is called demi-metamorphosis. 12. What are some of the artifices of insects when about to enter the chrysalis state? [NOTE. All insects have six legs, with the exception of the millepedes, (pronounced mil′le-pēdz, or mil-lep′ē-dēz) which have always more, and the number increases also with their age. *Aurelia* and *Chrysalis* are synonymous words, both alluding to the metallic or golden splendour of the case in which insects are enclosed during that state. This brilliancy however seems to be confined to the butterfly tribe. The name *Pupa* has lately been substituted for chrysalis and aurelia, because many insects in this state are thought to resemble an infant in swaddling clothes.

LESSON 100.

Orders of Insects.

Per'forator, a part of some insects with which they bore various substances in order to admit their eggs.
Farina'ceous, mealy, resembling the farina of flowers.

LINNÆUS divided insects into seven orders. His divisions are founded upon the presence or absence of wings, their number, their texture, their arrangement, and the nature of their surface. The *first* order (*coleop'tera*) has four wings. The upper pair consist of a hard, crustaceous or horny substance, and cover or defend the under pair, which are of a more soft and flexible texture, and are folded beneath them. This is the most numerous and best known kind of insects; and many of them are very remarkable for the singularity of their forms and the beauty of their colours. The various insects known under the name of beetles and winged bugs are included in this order.

The *second* order (*hemip'tera*) has likewise four wings; but the upper pair is not of so hard a texture as those of the beetle tribe. They are more like fine vellum, and, at their extremities, terminate with a membranous edge, which resembles the substance of the under pair. They cover the body horizontally, and do not meet in a straight line or ridge, as they do in the first order. Among them are found the grasshopper and the locust.

The *third* order (*lepidop'tera*) has four wings and comprehends the various kinds of moths and butterflies. Their wings are covered with a farinaceous powder, or rather with scales or feathers, disposed in regular rows, nearly in the same manner as tiles are laid upon the roofs of houses. The elegance, the beauty, the variety of colours, exhibited in their wings, are produced by the disposition and tincture of these minute feathers. When the feathers are rubbed off, the wings appear to be nothing more than a naked and often a transparent membrane.

The *fourth* order (*neurop'tera*) has four naked membranous wings, which are so interspersed with delicate veins, that they have the appearance of a beautiful net work. They have no sting. Of this order are the various species of dragon fly, large and well known insects that frequent lakes and pools of stagnant water; the Ephem'eral flies, which pass two or three years in the states of larva and chrysalis, but whose existence as winged and perfect insects is limited to a single day; and the Ant-lion and Ter'-mites, the former celebrated as the destroyer of the common ant, and the latter for the ravages they make in some tropical countries.

The *fifth* order (*hymenop'tera*) has four naked membranous wings, but destitute of that delicate, netted structure, which belongs to the last order. The females have either a perforator or a sting. In the domestic economy and mode of propagation of some of the species, there are circumstances which excite our admiration and astonishment. The ant, wasp, and bee belong to this order. They live in societies, greater or less in extent and number; and prepare habitations and nourishment for themselves and offspring, with a forethought and provident care, excelled only by man himself. In some of the tribes of this order, there is, beside the males and females, a third sort called neuters, as among the ants and bees.

The *sixth* order (*dip'tera*) has only two wings, but beneath them are two cylindrical projections, which seem as if they were the rudiments of another pair. These have been called balancers or poisers, from being supposed to aid them in preserving an equilibrium during their flight. Between them and the wings themselves are found small membranous scales, one upon each side, against which the balancer strikes with great rapidity, whilst the insect is in motion, and causes that buzzing which is then observed. To this order belong some of the most troublesome and annoying of the whole animal creation, such as the various species of gnat, and the common fly. They are found in almost every part of the globe.

The *seventh* and last order of insects (*ap'tera*) includes a great variety that are destitute of wings. It is true that in the preceding orders are arranged many sorts of insects that are destitute of wings, but they are so arranged because in their general structure and habits of life they resemble the other members of the order. The Aptera, however, have no such resemblance, and are therefore placed by themselves. Some animals of this order cover the surface of plants so completely as to produce the appearance of a discoloured change of structure.

The family of spiders (*ara'nea*) is not always arranged among insects, and strictly speaking their structure is different in some important particulars. They are distinguished from all other insects by the absence of the antennæ. They have generally eight legs, and are furnished with six or eight eyes, which enable them to see objects in several different directions at once. They are nourished generally by living prey, which they secure by means of a web, spun with much ingenuity. The threads, of which the web is composed, are produced from six little fleshy bunches, or muscular instruments, each of which contains about a thousand tubes, or outlets of threads, so extremely minute that many hundreds of them must be united before they form one of those visible ropes, of which the spider's web is composed. By means of their webs, many species of spiders, particularly when young, are able to transport themselves to a considerable distance through the air. In order to effect this, they ascend some eminence, and throw out a number of webs. These are raised up and carried along by the wind, and the animal being buoyed up by them is conveyed sometimes to a great height. In order to alight, they have only to disengage themselves from a part of their web, and suffer themselves to descend gradually to the ground. It is probable that they have recourse to this expedient, in part at least, for the purpose of catching insects for food. In autumn, the air is often full of the cobwebs which have been made use of for this singular mode of conveyance. This fine filmy substance is called *Gossamer;* and it is seen not only in the air, but is more observable in stubble fields, and upon furze and other low bushes. Those who have ascended eminences for the purpose of observing the phenomenon, have frequently seen spiders floating by in the air, supported in the manner which has been described.

To the Insect of the Gossamer:—By C. Smith.

Small, viewless aëronaut, that by the line
 Of Gossamer suspended, in mid air
 Float'st on a sunbeam. Living atom, where
Ends thy breeze-guided voyage? With what design
In ether dost thou launch thy form minute,

Mocking the eye? Alas! before the veil
Of denser clouds shall hide thee, the pursuit
Of the keen swift may end thy fairy sail.

Thus on the golden thread that fancy weaves
Buoyant, as Hope's illusive flattery breathes,
The young and visionary poet leaves
Life's dull realities, while seven-fold wreathes
Of rainbow light around his head revolve.
Ah! soon at Sorrow's touch the radiant dreams dissolve.

QUESTIONS.—1. Upon what is the division of insects into orders founded? 2. What are the characteristics of the first order? 3. Second? 4. Third? 5. Fourth? 6. Fifth? 7. Sixth? 8. Seventh? 9. Describe the wings of butterflies. 10. Describe ephemeral flies? 11. What is worthy of notice in ants, wasps, and bees? 12. How is the buzzing of flies produced? 13. How do aptera insects often appear on plants? 14. How are spiders distinguished from all other insects? 15. How is the web of the spider produced? 16. Describe the aerial excursions of spiders. 17. What is the gossamer, and where seen?

LESSON 101.

Crustaceous and Molluscous Animals.

Mu'cous, slimy, viscous or glutinous.

THE Crustaceous animals have been sometimes included in the class of insects, to which they have indeed many strong points of resemblance. They deserve, however, a separate consideration, both on account of their size and importance, and of some anatomical differences of structure. They have articulated limbs, antennæ, and jaws, similarly formed to those of insects. But they breathe by means of gills, and have a regular, double circulation; in which particulars they *differ* from insects. Among the most familiar examples of this class are the lobster, craw-fish, and what is usually called the horse-shoe. They are covered by a pretty thick, firm shell, which envelopes them completely. As this shell is incapable of growth, it is occasionally changed, to make room for the constant increase in size of the animal. It is thrown off, and their bodies remain for a time entirely naked, and exposed in a soft and defenceless state.

In this case, the animal generally retires to some place of concealment and security, and remains till the shell is restored by the deposition of calcareous matter on the external membrane of the skin, which becomes hard and firm, and finally takes the place of the old shell.

The Molluscous animals form a large and extensive class, but their structure, residence, and habits, are obscurely and imperfectly known. Among them are the cuttle-fish, oyster, clam, snail, and, in short, nearly all the testaceous animals, or shell-fish, as they are usually called, although they have no resemblance to fishes, and do not all inhabit the water. They are destitute of bones and articulated limbs. Their bodies are generally of a soft texture, and frequently, at first sight, appear to be little else than a simple mucous mass, without parts and almost without organization. In most instances they are completely enveloped in a fold or reflection of the skin, which is called their mantle. Sometimes there is only this simple membranous covering; but more frequently there is a hard external shell, which serves as a retreat into which the animal may withdraw itself, and which it can carry about in all its changes of place. These shells differ exceedingly in shape, colour, and texture, in different species, and among them are found some whose form, polish, and splendid tints place them among the most beautiful objects in nature.

QUESTIONS.—1. In what points do crustaceous animals resemble insects? 2. In what do they differ? 3. What are examples of this class? 4. What is said of the growth and casting of their shell? 5. What are examples of molluscous animals? 6. What description of them is given? 7. What is said of their shells? [NOTE. The study of those animals in the class mollusca which are characterized by a shell or calcareous covering has obtained the distinct scientific name of *Conchology*. The objects of conchology are separated into three divisions, namely, *multivalves*, or shells with many valves; *bivalves*, or shells with two valves; *univalves*, or shells with one valve.]

LESSON 102.

Vermes and Zoophytes.

Tentac'ula, often called feelers; organs supplying the place of hands and arms to some animals, and intended also for feeling. (Singular, Tentaculum.)

The term Ver'mes has been used with great vagueness in natural history, and employed to designate animals to which the name was not appropriate. It is now, however, more restricted in its application, and is made to include only a small class of animals. Their bodies are of a cylindrical, elongated shape, divided into a great number of rings. In some species, certain black points appear around the head, which have been supposed to be eyes, but this is doubtful. They are the only invertebral animals which have red blood. It circulates in a double system of vessels, but there is no distinct fleshy heart to give it motion. They breathe by means of gills, which are sometimes within and sometimes without their bodies. They have no limbs, but on each of the rings of which their bodies are composed, are little spines or bristly projections which answer in some sort the purpose of feet. All, except the earthworm, inhabit the water. Many of them bury themselves in the sand; some form themselves a sort of tube or habitation of sand, or other materials; and others exude from their surfaces a calcareous matter, which produces a shell around them. When cut through the middle, each portion becomes a distinct individual.

There are several species of the leech, of which the medicinal leech is the most valuable. It has three jaws or rather lancets, with which it pierces the skin of animals, in order to draw their blood. Its tail is furnished with a shallow cup, by which it is able to fix itself firmly to different objects, while obtaining its nourishment; and by means of the same organ it moves from place to place.

The class of Zo'ophytes is the last division of the animal kingdom, and the lowest in the scale of the animated creation. It includes an immense number of individuals but imperfectly known, and having but few points of resemblance and connexion with one another. In general, they have no nervous system, no complete vascular circulation, no distinct apparatus for respiration, and no sense but that of feeling and perhaps that of tasting. This is not true, however, without exception; for, in some instances, traces of a nervous system, of a circulation, and of respiratory organs, may be detected, as in the sea-urchin, the common star-fish, and the sea-egg. These Zoophytes are the most perfect in their structure, and are endowed with a curious set of organs for the purpose of motion. Their shells are pierced with a large number of holes, regularly arranged, through which project the feet of the animal, or rather the instruments answering the purpose of feet. These are little hollow cylinders, filled with a liquid, and terminating in a kind of knob, which is also hollow. By forcing the liquid into these cylinders, or by exhausting it from them, the animal can either lengthen or shorten them. The knob, when exhausted, is drawn into a cup-like form, and thus may be firmly fixed to whatever object it is applied, like a cupping-glass; and when the liquid is again thrown into it, it is again loosened.

Pol′ypes have a hollow, cylindrical, or conical body, with one extremity open which serves for their mouth, and is surrounded by a number of organs, (*tentacula*) by which they seize their prey. Many of them have been celebrated on account of the fact, that when one is divided into several pieces, each piece becomes a distinct animal, perfect in all its parts. The immense beds of coral and the different kinds of sponge, are nothing but the habitations of infinite numbers of these little animals, and are produced by their labour. Corals grow in such quantities, and to such heights in some seas, as to create islands. The Friendly Islands, in the Pacific Ocean, were thus raised by corals from the depth of that sea. Ships have often been lost by striking on coral-rocks.

QUESTIONS.—1. What is said of the former and present application of the term Vermes? 2. What is said of the structure of Vermes? 3. Of the circulation of their blood and of their respiration? 4. Of their instruments of motion, and their habitations? 5. Describe the medicinal Leech. 6. What is said of the *general* structure of Zoophytes? 7. Describe the organs of motion in the most perfect Zoophytes. 8. What is the structure of Polypes? 9. For what celebrated? 10. How are corals and sponge produced? 11. What is said of the growth of corals in some seas? [NOTE. To the class of Zoophytes belong Intestinal worms, sea-nettles, or sea-anem′ones, Medusæ, or sunfish, and

Animalcules, which have been called infusorial animals, (*Infusoria*,) because they are principally found in some animal and vegetable fluids and infusions.] 12. What are the orders of Vermes according to Linnæus? (see Appendix.) 13. In treating of a particular animal, how are naturalists accustomed to designate it? 14. Give examples.

LESSON 103.

Existence of the Deity.

God and the world which he has formed are our great objects. Every thing which we strive to place between these is *nothing*. We see the *universe*, and seeing it, we believe in its *Maker*. The universe exhibits indisputable marks of design: it is not, therefore, self-existing, but the work of a designing mind. From the great masses that roll through space, to the slightest atom that forms one of their imperceptible elements, every thing is conspiring for some *purpose*. I shall not speak of the relations of the planetary motions to each other,—of the mutual relations of the various parts of our globe,—of the different animals of the different elements, in the conformity of their structure to the qualities of the elements which they inhabit,—of man himself in all the nice adaptation of *his* organs :—to these *splendid* proofs, it is scarcely necessary to do more than to allude. But when we think of the feeblest and most insignificant of living things,—the minutest insect which it requires a microscope to discover, when we think of it as a creature, having *limbs* that move it from place to place,—nourished by little vessels, that bear to every fibre of its frame, some portion of the food which other organs have rendered fit for serving the purposes of nutrition;—having senses, as quick to discern the objects that bear to it any relative magnitude as ours,—and not merely existing as a living piece of most beautiful mechanism, but having the power, which no mere mechanism, however beautiful, ever had, of multiplying its own existence, by the production of living machines exactly resembling itself;—when we think of all the proofs of contrivance which are thus to be found in what seems to us a *single atom*, or less than a single atom, and when we think of the myriads and myriads of such atoms, which inhabit even the smallest portion of that earth, which is itself but almost an invisible atom, compared with the great system of the heavens,—what a combination of simplicity and grandeur do we perceive! It is one *universal design*, or an infinity of design;—nothing seems to us *little*, because nothing is *so* little as not to proclaim the omnipotence which made it;—and I may say too that nothing seems to us great in itself, because its very grandeur speaks to us of that immensity, before which all created greatness is scarcely to be perceived.

On particular arguments of this kind, however, that are as innumerable as the things which exist, it is not necessary to dwell. Those whom a single organized being, or even a single organ, such as the eye, the ear, the hand, does not convince of the being of a God,—who do not see him, not more in the social order of human society, than in a single instinct of animals, producing unconsciously, a result that is necessary for their continued existence, and yet a result which they cannot have foreknown—will not see him in all the innumerable instances that might be crowded together by philosophers and theologians.

The world, then, *was* made;—there is a designing Power which formed it—a Power whose own admirable nature explains whatever is admirable on earth, and leaves to us instead of the *wonder of ignorance*, that *wonder of knowledge* and *veneration* which is not astonishment, but love and awe.

BROWN.

LESSON 104.

Political Economy.

Tech′nical, belonging to arts; not in common or popular use.

THE language of science is frequently its most difficult part, but in political economy there are few technical terms, and those easily comprehended. It may be defined as the science which teaches us to investigate the causes of the wealth and prosperity of nations.

In a country of savages, you find a small number of inhabitants spread over a vast tract of land. Depending on the precarious subsistence afforded by fishing and hunting, they are frequently subject to dearths and famines, which cut them off in great numbers. As soon as they begin to apply themselves to pasturage, their means of subsistence are brought within narrower limits, requiring only that degree of wandering necessary to provide fresh pasturage for their cattle. Their flocks ensuring them a more easy subsistence, their families begin to increase; they lose in a great measure their ferocity, and a considerable improvement takes place in their character.

By degrees the art of tillage is discovered, a small tract of ground becomes capable of feeding a greater relative number of people; the necessity of wandering in search of food is superseded; families begin to settle in fixed habitations; and the arts of social life are introduced and cultivated.

In the savage state scarcely any form of government is established; the people seem to be under no control but that of their military chiefs in time of warfare. The possession of flocks and herds in the pastoral state introduces property, and laws are necessary for its security; the elders and leaders therefore of these wandering tribes begin to establish laws, to violate which is to commit a crime and to incur a punishment. This is the origin of social order; and when in the third state the people settle in fixed habitations, the laws gradually assume the more regular form of a monarchical or republican government. Every thing now wears a new aspect; industry flourishes, the arts are invented, the use of metals is discovered; labour is subdivided; every one applies himself more particularly to a distinct employment, in which he becomes skilful. Thus, by slow degrees, this people of savages, whose origin was so rude and miserable, become a civilized people, who occupy a highly cultivated country, crossed by fine roads, leading to wealthy and populous cities, and carrying on an extensive trade with other countries.

The whole business of political economy is to study the causes which have thus co-operated to enrich and civilize a nation. This science, therefore, is essentially founded upon history,—not the history of sovereigns, of wars, and of intrigues,—but the history of the arts, and of trade, of discoveries, and of civilization. We see some countries, like America, increase rapidly in wealth and prosperity, whilst others, like Egypt and Syria, are impoverished, depopulated, and falling to decay; when the causes which produce these various effects are well understood, some judgment may be formed of the measures which governments have adopted to contribute to the welfare of their people; whether certain branches of commerce should be encouraged in preference to others; whether it be proper to prohibit this or that kind of merchandise; whether any peculiar encouragement should be given to agriculture; whether it be right to establish by law the price of provisions or the price of labour, or whether they should be left without control; and whether many other measures, which influence the welfare of nations, should be adopted or rejected.

It is manifest, therefore, that political economy consists of two parts—theory and practice; the science and the art. The science comprehends a knowledge of the facts which have been enumerated; the art relates more particularly to legislation, and consists in doing whatever is requisite to contribute to the increase of national wealth, and avoiding whatever would be prejudicial to it. MRS. BRYAN.

QUESTIONS.—1. What is political economy? 2. What is the state of savage life? 3. What is the consequence of attending to pasturage? 4. What is the effect of discovering the art of tillage? 5. What introduces property? 6. What is the origin of social order? 7. What follows after the laws assume the regular form of a government? 8. On what is the science of political economy founded? 9. How may some judgment be formed of the measures of governments? 10. What does the science of political economy comprehend? 11. The art?

LESSON 105.

Property.

WHEN we consider the multitude who are in possession of means of enjoyment, that are to them the means only of selfish avarice or of profligate waste, and when, at the same time, we consider the multitudes, far more numerous, to whom a small share of that cumbrous and seemingly unprofitable wealth, would in an instant diffuse a comfort, that would make the heart of the indigent gay in his miserable hovel, and be like a dream of health itself to that pale cheek, which is slowly wasting on its wretched bed of straw, in cold and darkness, —it might almost seem to the inconsiderate, at least for a moment, that no expression of the social voice could be so beneficial, as that which should merely say, let there be no restraint of property, but let all the means of provision for the wants of mankind, be distributed according to the more or less imperious necessity of those wants, which all partake. It requires only the consideration of a moment, however, to perceive, that the very distribution, would, itself, be the most injurious boon that could be offered to indigence,—that soon, under such a system of supposed freedom from the usurpations of the wealthy, there would only be one general penury, without the possibility of relief; and an industry, that would be exercised, not in plundering the wealthy, for there could not then be wealth to admit of plunder, but in snatching from the weaker some scanty morsel of a wretched aliment, that would scarcely be sufficient to repay the labour of the struggle, to him who was too powerful not to prevail. There would be no palaces, indeed, in such a system of equal rapine,—and this might be considered as but a slight evil, from the small number of those who were stripped of them; but when the chambers of state had disappeared, where would be the cottage, or rather the whole hamlet of cottages, that might be expected to occupy its place? The simple dwellings of the unhappy peasant might be the last, indeed, to be invaded; but when the magnificent mansion had been stripped by the first band of plunderers, these too would soon find plunderers as rapacious. No elegant art could be exercised, no science cultivated, where the search of a precarious existence for the day, would afford us no leisure for studies or exercises beyond the supply of mere animal wants; and man, who, with property, is what we now behold him, and is to be, in his glorious progress even on earth, a being far nobler than we are capable, in our present circumstances, of divining,—would, without property, soon become, in the lowest depth of brutal ignorance and wretchedness, what it is almost as difficult for our imagination to picture to us, as it would be for it to picture what he may become on earth, after the many long ages of successive improvement.

The great inequality of property, strange as it may seem to be at any one moment, is only the effect of that security and absolute command of property, which allows the continual accumulation of it by continued industry. If all things had been common to all,—instead of that beautiful and populous earth which we behold,—where cities pour wealth on the fields, and the fields, in their turn, send plenty to the cities,—where all are conferring aid and receiving aid, and the most sensual and selfish cannot consume a single luxury, without giving, however unintentionally, some comfort, or the means of comfort to others,—instead of this noble dwelling-place of so many noble inhabitants, we should have had a waste or a wilderness, and a few miserable stragglers, half famished on that wide soil which now gives abundance to millions. BROWN.

QUESTION.—What reasons may be given for the institution of property?

LESSON 106.

Division of Labour.

Smelt'ing, the melting of ore in a furnace so as to extract the metal. In the more precious metals this is called *refining*.

THAT separation of employments, which, in political economy, is called the division of labour, can take place only in civilized countries. In the flourishing states of Europe and America we find men not only exclusively engaged in the exercise of one particular art, but that art subdivided into numerous branches, each of which forms a distinct occupation for the different workmen. Observe the accommodation of the most common artificer or day-labourer in a civilized and thriving country, and you will perceive that the number of people, of whose industry a part, though but a small part, has been employed in procuring him this accommodation, exceeds all computation. The woollen coat, for example, which covers the labourer, though it may appear coarse and rough, is the produce of the joint labour of a great number of workmen. The shepherds, the sorter of the wool, the carder, the dyer, the spinner, the weaver, the fuller, the dresser, with many others, must all join their different arts to complete even this ordinary production. How many merchants and carriers, besides, must have been employed in transporting the materials from some of those workmen to others who often live in a distant part of the country! How much commerce and navigation in particular, how many ship-builders, sailors, sail-makers, rope-makers, must have been employed, in order to bring together the different drugs made use of by the dyer, which often come from the remotest corners of the world! What a variety of labour too is necessary in order to produce the tools of those workmen! To say nothing of such complicated machines as the ship of the sailor, the mill of the fuller, or even the loom of the weaver, let us consider only what a variety of labour is requisite to form that very simple machine, the shears with which the shepherd clips the wool. The miner, the builder of the furnace for heating the ore, the burner of the charcoal to be made use of in the smelting house, the brick-maker, the brick-layer, the workmen who attend the furnace, the mill-wright, the forger, the smith, must all of them join their different arts in order to produce them. Were we to examine, in the same manner, all the different parts of his dress and household furniture, the different hands employed in preparing his food, the glass window which lets in the heat and the light, and keeps out the wind and the rain, with all the knowledge and art requisite for preparing that beautiful and happy invention, together with the tools of all the different workmen employed in producing those different conveniences; if we examine all these things, and consider what a variety of labour is employed about each of them, we shall be sensible, that without the assistance and co-operation of many thousands, the very humblest person in a civilized country could not be provided for, even according to what we falsely imagine the easy and simple manner in which he is commonly accommodated. Compared, indeed, with the more extravagant luxury of the great, his accommodation must no doubt appear extremely simple and easy; and yet it may be true, perhaps, that the accommodation of an European prince does not always so much exceed that of an industrious and frugal peasant, as the accommodation of the latter exceeds that of many an African king, the absolute master of the lives and liberties of ten thousand naked savages.

LESSON 107.

Agriculture.

Agriculture is the science which explains the means of making the earth produce, in plenty and perfection, those vegetables which are necessary to the convenience or subsistence of man. Its practice demands a considerable knowledge of the relations subsisting between the most important objects of nature. It is eminently conducive to the advantage of those engaged in it, by its tendency to promote their health, and to cherish in them a manly and ingenuous character. Every improvement made in the art must be considered as of high utility, as it facilitates the subsistence of a greater proportion of rational and moral agents; or if we suppose the number to be unincreased, furnishes them with greater opportunities than could be possessed before, of obtaining that intellectual and moral enjoyment, which is the most honourable characteristic of their nature. The strength of nations is in proportion to their skilful cultivation of the soil; and their independence is secured, and their patriotism animated, by obtaining from their native spot all the requisites for easy and vigorous subsistence. Not only to raise vegetables for the use of man, but for those animals also which are used as food, is obviously, therefore, part of the occupation of the husbandman; and to assist him in his operations, other animals are to be reared and fed by him, to relieve his labours by their strength and endurance of exertion. In cold, and comparatively infertile climates, the services of these creatures are particularly important, if not absolutely indispensable, and their health and multiplication become, therefore, objects of great and unremitted attention.

Since the errors of ancient husbandry have been corrected, and vulgar superstitious traditions exploded, agriculture has been gradually improving. A solid and rational system of the art has been founded upon clear and intelligible principles. The application of natural history and chemistry to it has greatly accelerated its improvements. Inquiries have been made into the causes of the fertility and barrenness of land, the food and nutriment of vegetables, the nature of soils, and the best modes of meliorating them with various manures. Foreign seeds have been introduced, and the methods of cultivation adopted from the nations whence they were borrowed. The intelligent farmer, profiting by the wider diffusion of knowledge, derives assistance from the philosopher, and is furnished with the useful principles of every art in the least degree conducive to the improvement and success of his occupations.

Questions.—1. What is agriculture? 2. What does the practice demand? 3. Why is it advantageous to those who engage in it? 4. Why must every improvement in the art be considered of high utility? 5. What is said of agriculture with regard to nations? 6. What belongs to the business of the husbandman besides the raising of vegetables? 7. What is said of modern improvements in agriculture?

LESSON 108.

Commerce and Manufactures.

Cap'ital, the fund or stock of a trading company, or corporation; the stock which a merchant or tradesman employs in business on his own account.

Commerce is the interchange of commodities, or the disposal of produce of any kind for other articles, or for some representative of value for which other articles can be procured, with a view of making a profit by the transaction. The term is usually restricted to the mercantile intercourse between different countries. The internal dealings between individuals of the same country, either for the supply of immediate consumption, or for carrying on manufactures, is more commonly denominated trade.

Those who engage their capitals in commerce or trade, act as agents between the producers and the consumers of the fruits of the earth; they purchase them of the former, and sell them to the latter, and it is by profits on the sale that capital so employed yields a revenue or income. Commerce or trade increases the wealth of a nation, not by raising produce, like agriculture, nor by working up raw materials like manufactures; but it gives an additional value to commodities by bringing them from places where they are plentiful to those where they are scarce; and by providing the means for their more extended distribution, both the agricultural and manufacturing classes are incited to greater industry. Agriculture never arrives at any considerable, much less at its highest, degree of perfection, where it is not connected with trade, that is, where the demand for the produce is not increased by the consumption of trading cities. But it should be remembered that agriculture is the immediate source of human provision; that trade conduces to the production of provision only as it promotes agriculture; and that the whole system of commerce, vast and various as it is, has no other public importance than its subserviency to this end.

Manufactures are the arts by which natural productions are brought into the state or form in which they are consumed or used. They require in general great expenses for their first establishment, costly machines for shortening manual labour, and money and credit for purchasing materials from distant countries. There is not a single manufacture of Great Britain which does not require, in some part of its process, productions from the different parts of the globe; it requires, therefore, ships and a friendly intercourse with foreign nations, to transport commodities and exchange productions. They would not be a manufacturing unless they were a commercial nation.

The two sciences which most assist the manufacturer, are mechanics and chemistry;—the one for building mills, working mines, and in general for constructing machines, either to shorten the labour of man by performing it in less time, or to perform what the strength of man alone could not accomplish; the other for fusing and working ores, for dyeing and bleaching, and extracting the virtues of various substances for particular occasions.

It is more common to see merchants and manufacturers accumulate large and rapid fortunes than farmers. They are a class who generally employ capital upon a much larger scale, hence their riches make a greater show. Yet, upon the whole, trade and manufactures do not yield greater profits than agriculture. It must be observed that though a farmer does not so frequently and rapidly amass wealth as a merchant, yet neither is he so often ruined The risks a man encounters in trade are much greater than in farming. The merchant is liable to severe losses arising from contingencies in trade; he must have therefore a chance of making proportionally greater profits. The chances of gain must balance the chances of loss. If he be so skilful or so fortunate as to make more than his average share of gains, he will accumulate wealth with greater rapidity than a farmer; but should either a deficiency of talents or of fortunate circumstances occasion an uncommon share of losses, he may become a bankrupt. The rate of profits, therefore, upon any employment of capital is proportioned to the risks with which it is attended; but if calculated during a sufficient period of time, and upon a sufficient number of instances to afford an average, these different modes of employing capital will be found to yield similar profits. It is thus that the distribution of capital to the several branches of agriculture, commerce, and manufactures, preserves a due equilibrium, which, though it may be accidentally disturbed, cannot, whilst allowed to pursue its natural course, be permanently deranged. A remarkably abundant harvest may occasionally raise the rate of agricultural profits, or a very bad season may reduce them below their level. The opening of a trade with a new country, or the breaking out of a war which impedes foreign commerce, will affect the profits of the merchant: but these accidents disturb the equal rate of profits, as the winds disturb the sea; and when they cease, it returns to its natural level.

Questions.—1. What is commerce? 2. Trade? 3. How does commerce or trade increase the wealth of a nation? 4. To what end is the whole system of commerce subservient? 5. What are manufactures? 6. What is said of the connexion of manufactures with trade? 7. How do the sciences of mechanics and chemistry assist the manufacturer? 8. What is said of the profits arising from agriculture, commerce, and manufactures?

LESSON 109.

Money.

Spe'cie, gold and silver coin, distinguished from paper money.

Gold and silver, when first introduced into commerce were probably bartered like other commodities, by bulk merely; but shortly, instead of being given loosely by bulk, every portion was weighed in scales, but weight was no security against mixing gold and silver with base metals. To prevent that fraud, pieces of gold and silver are impressed with a public stamp, vouching both the purity and the quantity; and such pieces are termed coin. This was an improvement in commerce, and at first, probably, deemed complete. It was not foreseen that these metals wear by much handling in the course of circulation, and consequently, that in time the public stamp is reduced to be a voucher of the purity only, not of the quantity. This embarrassment is remedied by the use of paper money; and paper money is attended with another advantage, that of preventing the loss of much gold and silver by wearing.

Before the invention of money, men were much at a loss how to estimate the value of their property. In order to express that value they were necessarily obliged to compare it to something else, and having no settled standard, they would naturally choose objects of known and established value. Accordingly we read both in Scripture and in the ancient poets, of a man's property being worth so many oxen and so many flocks and herds. We are informed that even at the present day the Calmuc Tartars reckon the value of a coat of mail from six to eight, and up to the value of fifty horses. In civilized countries every one estimates his capital by the quantity of money it is worth;—he does not really possess the sum in money, but his property, whatever be its nature or kind, is equivalent to such a sum of money.

It is common to imagine that the more money a country possesses, the more affluent is its condition. And that is usually the case. But the cause is often mistaken for the effect. A great quantity of money is necessary to circulate a great quantity of commodities. Rich flourishing countries require abundance of money, and possess the means of obtaining it; but this abundance is the *consequence*, not the *cause* of their wealth, which consists in the commodities circulated, rather than in the circulating medium. The increase of European comforts, of affluence, of luxury, is attributed to the influx of the treasures of the new world—and with reason; but those treasures are the sugar, the coffee, the indigo, and other articles, which America exports, to obtain which Europe must send her commodities that have been produced by the employment of their people. Gold and silver, though they have greatly excited their avarice and ambition, have eventually contributed but little to stimulate their industry. It has been remarked of Spain, that the gold and silver of America, instead of animating the country and promoting industry, instead of giving life and vigour to the whole community, by the increase of arts, of manufactures, and of commerce, had an opposite effect, and produced in the event weakness, poverty, and depopulation. The wealth which proceeds from industry resembles the copious yet tranquil stream, which passes silent, and almost invisible, enriches the whole extent of country through which it flows; but the treasures of the new world, like a swelling torrent, were seen, heard, felt, and admired; yet their first operation was to desolate and lay waste the spot on which they fell. The shock was sudden; the contrast was too great. Spain overflowed with specie, whilst other nations were comparatively poor in the extreme. The price of labour, of provisions, and of manufactures, bore proportion to the quantity of circulating cash. The consequence is obvious; in the poor countries industry advanced; in the more wealthy it declined.

Questions.—1. What is probable respecting gold and silver on their first introduction? 2. Why were gold and silver coined? 3. To what is the public stamp in time reduced? 4. What is the advantage of paper-money? 5. How did men estimate the value of their property before the invention of money? 6. How is capital estimated in civilized countries? 7. What is said of an abundance of money? 8. What has been remarked of Spain?

LESSON 110.

Ship-building and Navigation.

No art or profession has appeared more astonishing and marvellous than that of navigation, in the state in which it is at present. This cannot be made more evident than by taking a retrospective view of the tottering, inartificial craft to which navigation owes its origin: and by comparing them with the noble and majestic edifices now in use, containing a thousand men, with their provisions, drink, furniture, wearing-apparel, and other necessaries for many months, besides a hundred pieces of heavy ordnance, and carrying all this vast apparatus safely, on the wings of the wind, across immense seas.

These majestic floating structures are the result of the ingenuity and united labour of many hundred of hands, and are composed of a great number of well-proportioned pieces of timber, nicely fastened together by means of iron nails and bolts, and rendered so tight with tow and pitch, that no water can penetrate into any part.

To give motion to these enormous machines, lofty pieces of timber called masts, have been fixed upright in them; and sails of linen cloth are placed for the purpose of catching the wind, and receiving its propelling power. It has been requisite also to add vast quantities of cordage and tackling. Yet all these would be insufficient for the perfect government and direction of the vessel, if there were not fastened to the hinder part of it, by means of hinges and hooks, a moveable piece of wood called the rudder, very small in proportion to the whole machine, but the least inclination of which to either side is sufficient to give immediately a different direction to the enormous mass; so that two men may direct and govern this floating town, with the same or with greater ease than a single man can direct a boat.

Even the vaulted part of the fabric, together with its sharp termination underneath, is proportioned according to the nicest calculations; and the length, width, and strength of the sails and tackling, are all in due proportion to one another, according to certain rules founded upon the principles of the art of ship-building.

A large ship carries at least 2200 tons burden, that is, 4,500,000lb., and at the same time is steered and governed with as much ease as the smallest boat. And yet if such a ship sailed along the coast only, and, like the navigators of old, never lost sight of the shore, we might still look on navigation as an easy business. But to find the shortest way across an ocean from 4000 to 6000 miles in width, sailing by day or by night, in fair weather or in foul, as well when the sky is overcast, as when it is clear, with no other guide than the compass, or the height of the sun, the moon and stars, with exactness and precision, is the extraordinary and surprising task of him who is skilled in the science of navigation.

A violent storm of wind will make us tremble with fear in a well-built house, in the midst of a populous city; but the seaman, provided he has a good ship, rides with unshaken courage, amidst the enraged waves, when the whole surface of the ocean presents to the eye an awful scene of immense watery mountains and bottomless precipices.

LESSON 111.

Architecture.

AMONGST the various arts cultivated in society, some are only adapted to supply our natural wants or assist our infirmities; some are instruments of luxury merely, and calculated to flatter our pride, or gratify our desires: whilst others tend at once to secure, to accommodate, delight, and give consequence to the human species.—Architecture is of this latter kind; and when viewed in its full extent, may truly be said to have a very considerable part in almost every comfort or luxury of life. Houses are among the first steps towards civilization, and have great influence both on the body and mind. Secluded from each other, and inhabitants of woods, of caves, or of wretched huts, men are generally indolent, dull, and abject, with faculties benumbed, and views limited to the gratification of their most pressing necessities; but wherever societies are formed, and commodious dwellings are found, in which, well sheltered, they may breathe a temperate air, amid the summer's heat or winter's cold; sleep when nature calls, at ease and in security; study unmolested; converse and taste the sweets of social enjoyments; there they are spirited, active, ingenious, and enterprising; vigorous in body, speculative in mind; agriculture and arts improve; the necessaries, the conveniences, and soon even the luxuries of life become abundant.

The immediate and most obvious advantages of building are, employing many ingenious artificers, many industrious workmen, and labourers of various kinds; converting materials of little value into the most stately productions of human skill; beautifying the face of countries; and multiplying the comforts of life. But these, however great, are not the most considerable: that numerous train of arts and manufactures, contrived to furnish and adorn the works of architecture, which occupies thousands, and constitutes many lucrative branches of commerce; that certain concourse of strangers, to every country celebrated for stately structures, who extend your fame, and create a demand for your productions, are considerations of the highest consequence. Nor is architecture less useful in defending, than prosperous in adorning and enriching countries; she guards their coasts with ships of war, secures their boundaries, fortifies their cities, and by a variety of useful constructions, controls the ambition and frustrates the attempts of foreign powers; curbs the insolence, and averts the danger, and the horror of internal commotions.

Materials in architecture are like words in phraseology. They have separately but little power, but they may be so arranged, as to excite ridicule, disgust, or even contempt; yet when combined with skill, and expressed with energy, they actuate the mind with unbounded sway. An able writer can move even in common language, and the masterly disposition of a skilful artist, will dignify the meanest materials; while the weak efforts of the ignorant render the most costly materials despicable. To such the compliment of Apelles may justly be applied, who, on seeing the picture of a Venus magnificently attired, said to the operator, "Friend, though thou hast not been able to make her fair, thou hast certainly made her fine."

The five orders of architecture were successively invented in ancient Greece and Italy; they are called the Tuscan, the Doric, the Ionic, the Corinthian, and the Composite; and are to be found in all the principal buildings of the Christian world. The Saxons had a simple style of architecture, distinguished by semi-circular arches and massive plain columns. The Normans too invented a beautiful style of architecture, called the Gothic; distinguished by its lightness and profuse ornaments; by its pointed arches, and by its pillars, carved to imitate several conjoined. A knowledge of the several species of architecture may be conveyed more effectually by engravings, than by any verbal descriptions.

QUESTIONS.—1. To what objects are the arts adapted? 2. What is man in a state of seclusion? 3. Of society? 4. Describe the advantages of architecture. 5. Why are materials in architecture like words in phraseology? 6. What are the five orders of architecture?

LESSON 112.

Constitution of the United States.

As all the youth of America ought to be well acquainted with the constitution of the country in which they live, and to which they must be subject, it will be proper to exhibit its general outlines.

A strong sense of the value and blessings of union induced the people at a very early period to institute a federal government to preserve and perpetuate it. They formed it almost as soon as they had a political existence; (1778) nay, at a time when their habitations were in flames, when many of them were bleeding in the field, and when the progress of hostility and desolation left little room for those calm and mature inquiries and reflections which must ever precede the formation of a wise and well balanced government for a free people. It is not to be wondered at, that a government instituted in times so inauspicious, should, on experiment, have been found greatly deficient, and inadequate to the purpose it was intended to answer. The people perceived and regretted these defects. They observed the danger which threatened their union, and more remotely their liberty; and being persuaded that ample security for both could only be found in a national government more wisely framed, deputies from the several states met in convention at Philadelphia (1787,) to take the important subject into consideration. In the mild season of peace, with minds unoccupied with other subjects, they passed many months in cool uninterrupted and daily consultations; and finally, without having been awed by power, or influenced by any passion except love for their country, they presented and recommended to the people the constitution or form of government produced by their joint and very unanimous councils.

The government of the United States is called republican. It is a representative democracy. All power resides ultimately in the people; but they exercise it by means of their representatives, or persons chosen by them for that purpose. All the departments of the government are bound to conform to the provisions of the constitution, and the act of any one of them, even an act of Congress, if contrary thereto, is void.

The most fundamental article in every form of government is the *legislative* branch, which has the power of making all the laws and regulations to which the whole community must be subject. This, in the United States, consists of a senate and house of representatives, jointly called the *Congress*, which must be assembled at least once every year. The senate consists of two members from each of the separate states, chosen by the legislatures of each state to serve for six years. The seats of one third of the senators are vacated every two years. The senate tries all persons impeached by the house of representatives; but they can only punish by deprivation of office, or disqualification in future; and the conviction must be by the votes of two thirds of the members present at any trial. The Vice-president presides in the senate, but without a vote, except in case of an equal division of the votes of the other members. No person can be a senator who has not attained to the age of thirty years.

The members of the house of representatives must be twenty-five years of age, and they are chosen by the people at large every two years. The number of the representative body varies according to the number of the separate states, and the population of each state. For this purpose an enumeration of all the people must be made every ten years, and the number of representatives must never exceed one for every thirty thousand, but each state shall have at least one representative. The senators and representatives receive a compensation for their services, to be ascertained by law, and paid out of the treasury of the United States. All bills for raising revenue must originate in the house of representatives; but the senate may propose or concur with amendments as on other bills.

The *judicial* power is vested by the constitution in a supreme court, and such inferior courts as Congress shall from time to time appoint; and all the judges hold their office during good behaviour. Besides the ordinary exercise of its power of deciding controversies, it is incident to the judicial power of the United States to pass upon the acts of Congress and decide upon their constitutionality; a power essential to the rights of the people, but not known in any of the governments of Europe.

The *executive* power is vested in a President, who is chosen every fourth year by electors appointed in the methods prescribed by the constitutions or legislatures of the separate states. If no person have a majority of the votes of the electors, then from the persons having the highest numbers not exceeding three on the list of those voted for, the house of representatives shall choose the president by ballot. But in choosing the president, the votes must be taken by states, the representatives from each state having one vote. If no person have a majority of the votes of the whole number of electors for vice-president, then from the two highest numbers on the list, the senate shall choose the vice-president.

The president must be thirty-five years of age, and he may be re-elected as often as the people please. He is liable to be impeached and removed from office for misbehaviour. He is the commander in chief of the army and navy: and by and with the advice and consent of the senate, makes treaties, appoints judges, foreign ministers, and other officers. If the president disapprove of any bill presented to him, after having had the concurrence of both houses, he must give his objections to it; and if two thirds of each house still abide by their first vote, the bill passes into a law, notwithstanding his rejection of it.

Besides the general government, whose power for many purposes extends over the whole union, each state has a separate local government, whose jurisdiction is confined to the regulation of its own concerns. These separate governments are all republican, and consist generally of a governor, and two legislative branches, though the powers of the different departments are variously modelled in the several states.

QUESTIONS.—1. When did the people of the United States first form a government? 2. What served to render this government deficient? 3. When did a convention meet to form our present constitution? 4. Under what advantages did the members deliberate? 5. How do the people of the United States exercise their power? 6. What power has the legislative branch of government? 7. Of what does this consist in the United States? 8. Describe the senate. 9. House of representatives. 10. Where is the judicial power vested? 11. The executive? 12. Describe the manner of choosing the president and vice-president. 13. What are some of the powers which the constitution gives the president? 14. What is said of the governments of the separate states? [NOTE. The principal subordinate officers in the *executive* department, are the secretaries of state, of the treasury, of war, and of the navy.]

LESSON 113.

Excellence of our Republican Government

It is the just pride of the people of the United States, that they have attempted a mode of government which divests itself of all the support which is derived from the honest weaknesses and attachments of the human mind; which, disclaiming all alliance with reverence of ancient authority, or the deep-rooted habits of unthinking obedience, trusts itself, with no other attractions than its own moral worth and dignity, to the custody of our virtues. By subjecting legislative bodies to rule, and holding them under the restraints of those fundamental principles and enactments, which we call the constitution, we have given a new dignity and a higher duty to *law*, and realized the noble idea of a moral supremacy, clothed with power, to hold not only subjects of the government to a just performance of their various individual duties, but also the government itself, in all its departments, in its proper place and sphere.

In the brighter moments of our hopes for the future fortunes of our country, we may exclaim with Sir William Jones—

What constitutes a state?
Not high raised battlement or laboured mound,
Thick wall or moated gate;
Not cities proud, with spires and turrets crowned;
Not bays and broad armed ports,
Where laughing at the storm rich navies ride;
Not starred and spangled courts,
Where low browed baseness wafts perfume to pride.
No! Men, high minded men,
With powers as far above dull brutes endued,
In forest, brake, or den,
As beasts excel cold rocks and brambles rude;
Men, who their duties know,
But know their rights, and knowing, dare maintain,
Prevent the long aimed blow,
And crush the tyrant while they rend the chain:
These constitute a state;

And sovereign *law*, that state's collected will,
O'er thrones and globes elate,
Sits empress, crowning good, repressing ill.

We may be told that this is a vision of a perfect commonwealth; and so it is:—still the hopes of patriots and sages, amid discouragement and defeat, gather about and rest upon it, with something of that gladness of heart, which the tired traveller feels, when he first descries the sun light upon the distant towers of the happy valley.

Although the dangers of American liberty may arise and press upon us from every side, to chastise our hopes and our confidence, the duty of its friends is not doubtful. They must labour to augment that moral force, to which its very existence is committed. N. AM. REVIEW.

LESSON 114.

Intelligence of the People a means of safety to the Government.

IN a government like ours, where the supreme control depends on the opinion of the people, it is important certainly that this opinion should be enlightened. "There is no power on earth which sets up its throne in the spirit and souls of men, and in their hearts and imaginations, their assent also and belief, equal to learning and knowledge; and there is scarce one instance brought of a disastrous government, where learned men have been seated at the helm." Now the most certain mode of making learned rulers, is to extend as far as possible the influence of learning to the people from whom the rulers are taken. But intelligence not only makes good rulers, it makes peaceable citizens. It causes men to have just views of the nature, value, and relations of things, the purposes of life, the tendency of actions, to be guided by purer motives, to form nobler resolutions, and press forward to more desirable attainments. Laws will be obeyed, because they are understood and rightly estimated. Men will submit cheerfully to good government, and consult the peace of society, in proportion as they learn to respect themselves, and value their own character. These things are the fruit of knowledge. But ignorance is a soil which gives exuberant growth to discords, delusions, and the dark treacheries of faction. While the people are ignorant, they are perpetually subject to false alarms, and violent prejudices, ready to give a loose rein to the wild storms of their passions, and prepared to yield themselves willing victims to the seductions of every ambitious, turbulent, treacherous, and faithless spirit, who may choose to enlist them in his cause. Knowledge will work upon this charm with a potent efficacy, lay the hideous spectres which it calls up, and preserve the soundness and growing strength of the social and political fabric.

It should be considered the glory, and the duty of the government, to aid in establishing morals and religion. The first step in accomplishing this purpose is to fix the principles of virtue, and impress the importance of religious practice, by enlarging the sphere of mental light, touching the springs of curiosity, opening the channels of inquiry, and pouring into the mind new materials of thought and reflection. All branches of intellectual improvement will lead to moral goodness. The mind, which is taught to expatiate throughout the works of God, to ascend to the heavenly worlds and find him there, to go into the deep secrets of nature and find him there, to examine the wonders of its own structure, and look abroad into the moral constitution of things, and perceive the hand of an invisible, Almighty Being, giving laws to the whole, will be impressed with a sense of its own dependence, and feel something of the kindling flame of devotion. It is not in human nature to resist it. And so the man who begins to study the organization of society, the mutual relations and dependencies of its parts, its objects, and the duties it imposes on those who enjoy its benefits, will soon be made to respect its institutions, value its privileges, and practise the moral virtues, in which its very existence consists. The more extensively these inquiries are encouraged, and these principles inculcated, in the elements of education, the greater will be the certainty of moral elevation of character, and the brighter the prospects of a virtuous community. In regard to religion, ignorance is its deadliest bane. It gathers the clouds of prejudice from all the dark corners of the mind, and causes them to brood over the understanding, and too often the heart, with a dismal, chilling influence. It gives perpetuity to error, defies the weapons of argument and reason, and is impassive even to the keen sword of eternal truth. To bring into salutary action these two great instruments of human happiness, morals and religion, nothing is of so much importance, as to multiply the facilities of education, and quicken the spirit of enlightened inquiry.

Through the medium of education the government may give a stronger impulse to the arts, and help to build up the empire of the sciences. Before men can invent, or make profound discoveries, they must be taught to think. Savages never advance a step farther in inventions and discoveries, than they are compelled by their wants. The external comforts of civilized life depend on the useful arts, which an improved state of the intellect has brought to light. In the sciences, and in literature, we have a vast uncultivated field before us. In the arts of traffic, and the mysteries of gain, we may perhaps be contented with the skill we possess. But to be contented with our progress in the sciences and literature, and all those attainments, which chiefly dignify and adorn human nature, would argue an obtuseness and apathy altogether unworthy of a people, who are blessed with so many political, civil, and local advantages of various kinds, as the inhabitants of the United States.

North American Review.

Questions.—1. What are some of the advantages of knowledge with regard to rulers and the people? 2. What are some of the effects of ignorance? 3. How may government aid in establishing morals and religion? 4. How does intellectual improvement promote devotional feelings? 5. What will be the effect of studying the organization of society? 6. What is the effect of ignorance in regard to religion?

LESSON 115.

The Government of England.

The government of England, which has sometimes been called a mixed government, sometimes a limited monarchy, is formed by a combination of the three regular species of government; the *monarchy*, residing in the king; the *aristocracy* in the house of lords; and the *republic* being represented by the house of commons. The crown of the united kingdom of Great Britain and Ireland is hereditary, and its rightful inheritor is bound, by the conditions of his inheritance, to the discharge of certain duties, as well as vested with certain powers and privileges. By the oath administered to the sovereign at his coronation, he solemnly engages to govern according to law, to execute judgment in mercy, and to maintain the established religion. To the king belongs the sole power of sending and receiving ambassadors; and it is his prerogative also to enter into treaties, and to form alliances with foreign princes and states, to make war or peace, to raise and regulate fleets and armies, to erect fortifications, to coin money, to regulate commerce, and to establish courts of judicature. He is the fountain of honour, office, and privilege, and he can grant letters of nobility and erect corporations. The king has an absolute negative upon the acts of parliament, his person is sacred, and he is not accountable for misconduct. It is a principle of the constitutional law that "the king can do no wrong;" but it is provided, that for all his public acts, his ministers and advisers are responsible to the nation at large by the medium of the parliament, and other legally constituted assemblies.

The house of peers is composed of the lords spiritual and the lords temporal. The former consist of two archbishops, and twenty-four bishops, who are a kind of representatives of the clergy of England and Wales; and of four bishops, who are taken by rotation from the eighteen bishops of Ireland. With regard to England the number of temporal peers is unlimited. The Scotch peers are sixteen in number, and are elected by their own body for one parliament only. The lords temporal are divided into dukes, marquises, earls, viscounts, and barons, who hold their respective ranks in the foregoing order, by hereditary descent or by creation. In its aggregate capacity, the house of peers has a right to a negative upon all legislative proposals.

The representatives, who constitute the house of commons, or the lower house of parliament, are divided into two classes, knights of the shire, or representatives of counties; and citizens and burgesses, or representatives of cities and boroughs. The qualification for voting for county members, is the possession of a freehold of the value of forty shillings per annum or upwards. The right of election in boroughs is various, depending upon the charters or immemorial usage of each place, or upon decisions made by committees appointed by the house of commons. "There is nothing in the British constitution so remarkable," says Paley, "as the irregularity of the popular representation. If my estate be situated in one county of the kingdom, I possess the ten thousandth part of a single representative; if in another, the thousandth; if in a particular district, I may be one in twenty who choose two representatives; if in a still more favoured spot, I may enjoy the right of appointing two myself. To describe the state of national representation as it exists, in reality, it may be affirmed, I believe with truth, that about one half of the house of commons obtain their seats by the election of the people, the other half by purchase, or by the nomination of single proprietors of great estates." He acknowledges this to be a flagrant incongruity in the constitution; but he doubts whether any new scheme of representation would collect together more wisdom, or produce firmer integrity. The house of commons enjoys the privilege of a negative upon all the laws which may be proposed for its consideration, and exercises the right of originating all bills, which levy money upon the subject by way of taxes or assessments. The English regard this as the principal safeguard of their liberties, and the main barrier against the inordinate increase of the power of the crown, for the commons can at any time check measures of folly or guilt, by withholding the supplies, and without money the strength of the executive is paralyzed. The king, however, is invested with a power to dissolve the parliament, and thus, by submitting their conduct to the revision of their constituents, to appeal against them to the nation at large.

Questions.—1. How is the government of England formed? 2. What is the import of the oath which the king takes at his coronation? 3. What are some of the prerogatives of the king? 4. Describe the house of peers. 5. House of commons? 6. What are the remarks of Paley respecting the house of commons? 7. What do the English regard as the principal safeguard of their liberties?

LESSON 116.

America.

Here the free spirit of mankind at length
Throws its last fetters off; and who shall place
A limit to the giant's unchained strength,
Or curb his swiftness in the forward race.
For, like the comet's way through infinite space,
Stretches the long untravell'd path of light
Into the depths of ages: we may trace,
Afar, the brightening glory of its flight,
Till the receding rays are lost to human sight.

Europe is given a prey to sterner fates,
And writhes in shackles; strong the arms that chain
To earth her struggling multitude of states;
She too is strong, and might not chafe in vain
Against them, but shake off the vampyre train
That batten on her blood, and break their net.
Yes, she shall look on brighter days, and gain
The meed of worthier deeds; the moment set
To rescue and raise up, draws near—but is not yet.

But thou, my country, thou shalt never fall,
But with thy children—thy maternal care,
Thy lavish love, thy blessings shower'd on all—
These are thy fetters—seas and stormy air
Are the wide barrier of thy borders, where
Among thy gallant sons that guard thee well,
Thou laugh'st at enemies: who shall then declare
The date of thy deep-founded strength, or tell
How happy, in thy lap, the sons of men shall dwell.

Bryant

LESSON 117.

Structure of the Human Body.

Car′tilage, gristle. Ad′ipose, fatty.
Ten′dons, hard, insensible cords, by means of which muscular fibres are attached to bones.

Dr. Hunter gives the following beautiful representation of the structure of the human body, with reference to all the wants and requisites of such a being as man, in answer to a supposed objector, who asks why a more simple, less delicate, and less expansive frame had not been adopted. First, says he, the mind, the thinking, immaterial agent, must be provided with a place of immediate residence, which shall have all the requisites for the union of spirit and body; accordingly, she is provided with the *brain*, where she dwells as governor and superintendent of the whole fabric. In the next place, as she is to hold a correspondence with all the material beings around her, she must be supplied with organs fitted to receive the different kinds of impression which they will make. In fact, therefore, we see that she is provided with the organs of sense, as we call them; the eye is adapted to light; the ear to sound; the nose to smell; the mouth to taste; and the skin to touch. Further, she must be furnished with organs of communication between herself in the brain, and those organs of sense; to give her information of all the impressions that are made upon them; and she must have organs between herself in the brain, and every other part of the body fitted to convey her commands and influence over the whole. For these purposes the nerves are actually given. They are soft white chords which rise from the brain, the immediate residence of the mind, and disperse themselves, in branches, through all parts of the body. They convey all the different kinds of sensations to the mind in the brain; and likewise carry out of thence all her commands to the other parts of the body. They are intended to be occasional monitors against all such impressions as might endanger the well-being of the whole, or of any particular part; which vindicates the Creator of all things, in having actually subjected us to those many disagreeable and painful sensations which we are exposed to from a thousand accidents in life.

The mind, in this corporeal system, must be endued with the power of moving from place to place; that she may have intercourse with a variety of objects; that she may fly from such as are disagreeable, dangerous, or hurtful; and pursue such as are pleasant and useful to her. And accordingly she is furnished with limbs, with *muscles* and *tendons*, the instruments of motion, which are found in every part of the fabric where motion is necessary. But to support, to give firmness and shape to the fabric; to keep the softer parts in their proper places; to give fixed points for, and the proper directions to, its motions, as well as to protect some of the more important and tender organs from external injuries, there must be some firm prop-work interwoven through the whole. And, in fact, for such purposes the bones are given. The prop-work is not made with one rigid fabric, for that would prevent motion. Therefore there are a number of bones. These pieces must all be firmly bound together, to prevent their dislocation. And this end is perfectly well answered by the *ligaments*. The extremities of these bony pieces, where they move and rub one upon another, must have smooth and slippery surfaces for easy motion. This is most happily provided for, by the *cartilages* and *mucus* of the joints. The interstices of all these parts must be filled up with some soft and ductile matter, which shall keep them in their places, unite them, and at the same time allow them to move a little upon one another; these purposes are answered by the *cellular membrane*, or adipose substance. There must be an outward covering over the whole apparatus, both to give it compactness, and to defend it from a thousand injuries; which, in fact, are the very purposes of the skin and other integuments.

QUESTIONS.—1. How does the soul correspond with material beings? 2. What are the nerves, and their use? 3. Of what use are the bones? 4. The ligaments, cartilages, and mucus? 5. Cellular membrane? 6. Skin and other integuments?

LESSON 118.

Structure of the Human Body (continued.)

Secre'tion, the process by which various fluids are separated from the blood by means of the glands. Vas'cular, full of vessels.

The mind being formed for society and intercourse with beings of her own kind, she must be endued with powers of expressing and communicating her thoughts by some sensible marks or signs, which shall be both easy to herself, and admit of great variety; and accordingly she is provided with the organs and the faculty of speech, by which she can throw out signs with amazing facility, and vary them without end. Thus we have built up an animal body which would seem to be pretty complete; but as it is the nature of matter to be altered and worked upon by matter, so in a little time such a living creature must be destroyed, if there is no provision for repairing the injuries which she must commit on herself, and those to which she must be exposed from without. Therefore a treasure of blood is actually provided in the heart and vascular system, full of nutritious and healing particles, fluid enough to penetrate into the minutest parts of the animal; impelled by the heart, and conveyed by the arteries, it pervades every part, builds up what was broken down, and sweeps away the old and useless materials. Hence we see the necessity or advantage of the heart and arterial system. The heart consists of four cavities, from one of which, the blood is driven into the arteries through the body, by another, it is received back again by the veins: it then passes into the third, whence it is forced into the lungs. Having there been revivified by coming in contact with the air, it is carried back by a set of veins into the fourth cavity, and thence into that in which it began its course: it is then again forced into the arteries, brought back by the veins, and thus circulates till the end of life. Each cavity of the heart is generally called into action four thousand times every hour. The *arteries*, into which the blood is forced, branch in every direction through the body, like the roots, branches, and leaves of a tree, running through the substance of the bones, and every part of the animal, till they are lost in such fine tubes as to be wholly invisible. In this manner, they distribute nourishment, supply perspiration, and renew all the waste of the system; and by passing through glands in every part of the body, all the various animal secretions are elaborated. In the parts where the arteries are lost to the sight, the *veins* take their rise, and in their commencement are also imperceptible. The blood is then of a dark colour. In this discoloured state it has lost some of its vital power; but on being driven through the lungs its colour is restored. All this provision, however, would not be sufficient, for the store of blood would soon be consumed, and the fabric would break down, if there was not a provision for fresh supplies. And we actually find that on its passage from the lungs to the heart the blood receives a supply of a new fluid extracted from the food by myriads of fine tubes which carry it to a larger one, that empties itself into a large vein, and being mixed with the blood is conveyed to the heart. We see, therefore, by the very imperfect survey which we have been able to take of this subject, that the animal man must necessarily be complex in his corporeal system, and in its operations. He must have one great and general system, *the vascular*, branching through the whole circulation; another, the *nervous*, with its appendages the organs of sense, for every kind of feeling; and a third for the connexion and union of all these parts. Besides these primary and general systems, he requires others which may be more local or confined. One for strength, support, and protection; another for the requisite motion of the parts among themselves, as well as for moving from place to place, *the muscular system;* another to prepare nourishment for the daily recruit of the body, *the digestive organs;* and others for the various purposes of existence.

QUESTIONS.—1. What are the uses of the blood? 2. Describe the circulation of the blood. 3. Describe the arteries. 4. What changes does the blood undergo in the course of its circulation? 5. How is provision made for a fresh supply of blood? [NOTE. That cavity of the heart from which the blood is driven into the arteries is called the *left ventricle;* the next is called the *right auricle;* the third the *right ventricle;* and the fourth the *left auricle.*]

LESSON 119.

The Human Voice.

Epiglot'tis, a small and thin piece of cartilage, placed at the back of the tongue, and having the office of closing the glottis, when the food is passing.

THE parts employed in the production of the voice are three in number, the trachea, or wind-pipe, by which the air passes to and from the lungs; the larynx, which is a short cylindrical canal at the head of the trachea; and the glottis, which is a small oval opening between two semicircular membranes. The glottis being very narrow compared with the size of the trachea, the air can never pass through it without acquiring a considerable degree of velocity; so that the air thus compressed and forced on communicates, as it passes, a vibratory motion to the particles of the two lips of the glottis, which produces the sound. The sound thus produced is reverberated through the different parts of the mouth; and it is the mixture of different reverberations, well proportioned to one another, which produces in the human voice a harmony, which no instrument can equal.

The most wonderful part of the mechanism of the voice is the contraction and dilatation of the glottis. It is these changes which produce all the variety of tone. The diameter of the glottis never exceeds one tenth of an inch: now suppose a person capable of sounding twelve notes—to which the voice easily reaches,—there must be the difference of the hundred and twentieth part of an inch for each note. But if we consider the subdivision of notes of which the voice is capable, the motion of the sides of the glottis appears still more minute. Suppose that a voice can divide a note into one hundred parts; it will follow that the different openings of the glottis will be twelve hundred in one tenth of an inch, and it is known that each of these will produce sounds perceptibly different to a good ear. But the movement of each side of the glottis being equal, it is necessary to double this number, and the side of the glottis, therefore, actually divides the tenth of an inch into twenty-four hundred equal parts.

Speech is articulated voice, that is, voice modified by the action of the palate, teeth, tongue, and lips. All animals have a voice, but man alone speaks in the sense now alluded to. Some animals, it is true, have been taught to pronounce a few words; but they express no thoughts by these sounds. It is believed that no sufficient reason can be drawn from mere organization, why man invariably should possess, and animals invariably want the power of speech. If we consider speech simply as a medium of the reciprocal expressions of present feelings to the little society of citizens and friends of which we are a part, even in this limited view, of what inestimable value does it appear! To communicate to every one around us, in a single moment, the happiness which we feel ourselves,—to express the want, which we have full confidence, will be relieved as soon as it is known, —or to have the still greater privilege of being ourselves the ministers of comfort to wants, which otherwise could not have been relieved by us, because they could not have been discovered,—when the heart which we love is weighed down with imaginary grief, to have it in our power, by a few simple sounds, to convert anguish itself into rapture,—these are surely no slight advantages; and yet compared with the benefit which it affords to man as an *intellectual* being, even these are inconsiderable. By means of language, spoken or written, the opinions which are perishing in one mind, are rising in another; and often, perhaps, at the last fading ray of the flame of genius, that may have almost dazzled the world by excess of brilliancy, some star may be kindling, which is to shine upon the intellectual universe with equal light and glory.

QUESTIONS.—1. What are the parts employed in the production of the voice? 2. How is the sound produced? 3. What is the most wonderful part of the mechanism of the voice? 4. What is said of the divisions and subdivisions of the glottis in sounding twelve notes? 5. What is speech? 6. What is said of the voice of animals?

LESSON 120.

The Ear.

Trun′cated, divided. Sen′tient, perceiving.

THE ear is adapted in an eminent degree to the purposes it is designed to execute; and it offers an inviting subject to such as are disposed to investigate the minute mechanism of an organ, which contributes remarkably to some of our most exquisite and refined enjoyments. Though the rapid glance of the eye, and the immense distance to which it enables us to carry our perceptions have given rise to some of our most pleasurable and magnificent sensations, still the sense which we are now considering has contributed most efficiently to the daily happiness of life. It enables us to hold communication with our fellow creatures; to improve and exalt our understandings by the mutual interchange of ideas; and thus to increase the circle not only of our physical, but of our moral relations. The charms of eloquence and the pleasure resulting from the concord of sweet sounds are other sources of intellectual enjoyment, which contribute to place this sense among the most delightful as well as the most important we possess.

The organ of hearing, in its simplest form, consists of the expansion of a nerve, gifted with its peculiar sensitive qualities, over the surface of a delicate membrane. In man and the more perfect animals, there is an additional apparatus connected with this, the design of which is to collect and modify those pulses of the air which are finally to be impressed on the nervous membrane. In man this apparatus consists of a piece of cartilage, seated externally to the head, which contracts into a tube leading to the internal parts. The bottom of this tube is truncated obliquely, and its aperture closed by a firm membrane stretched across it, called the drum of the ear, which separates the external part from the succeeding, or middle portion of the organ. Beyond, or on the opposite side of this membrane, we meet with a small cavity, hollowed out in bone. Of the several openings into it, there is one more particularly demanding attention. It is the internal aperture of a tube, the other extremity of which opens behind and above the palate. By means of this communication, the external air is admitted into the cavity, and equipoises the weight of the atmosphere on the other side of the membrane. Across the cavity there is extended, though by no means in a straight line, a series of little bones, the exterior one of which is attached to the membrane we have just mentioned, the most internal set being firmly connected with another membrane, which, in conjunction with it, shuts up the entrance to a still more deepened cavity, called the labyrinth of the ear. This last hollow, excavated as it were in the solid bone, consists of a middle portion of irregular figure, and of different channels, which proceed from it in various directions, and, finally, return, with one exception to the same chamber. All these passages are lined by a membrane, on which the sentient extremity of the auditory nerve is expanded in different shapes; from these it is collected into one trunk and goes on to join a particular part of the brain, and thus completes the communication between the external agent and the sensorial organ.

QUESTIONS.—1. What is the organ of hearing in its simplest form? 2. What apparatus is connected with this in man? 3. Describe the tube and cavity beyond it. 4. What opening deserves particular attention? 5. What is the use of it? 6. What extends across the cavity? 7. Of what does the labyrinth consist? 8. On what is the auditory nerve expanded? and what does it join when collected into one trunk?

LESSON 121.

Music.

MUSIC is the art of combining tunable sounds in a manner agreeable to the ear. It is an expression of feeling, which, almost like verbal discourse, may be said to be a language, since it is the utterance of thought and emotion from heart to heart. But music has a voice, as independent of the mere arbitrary forms of speech, as the tears of gratitude, or the smiles of love, that may indeed, give eloquence to *words*, but require no *words* to render *them* eloquent. Though, when very strictly considered, even the pure and almost spiritual delight of music, may perhaps be counted only a pleasure of sense, yet it approaches, by so many striking analogies, to the nature of our intellectual enjoyments, that it may almost be said to belong to that class. In its relation to the general pleasures of common minds, it is not to be considered as a mere pastime or relaxation; it assumes a far higher character, and it may be said, at least, to be the *intellectual luxury* of those, who are incapable of any other luxury that deserves so honourable a name. And it is well, that there should be some such intermediate pleasure of this sort, to withdraw for a while the dull and the sensual, from the grosser existence in which they may be sunk, and to give them some glimpses, at least, of a state of purer enjoyment, than that which is to be derived from the sordid gains, and sordid luxuries of common life. Of the influence, which music has upon the general character, when cultivated to great refinement, there are different opinions. But of its *temporary* influence, as a source of tranquillizing delight, there can be no doubt.

Who ne'er has felt her hand assuasive steal
Along his heart—that heart will never feel.
'Tis hers to chain the passions, sooth the soul,
To snatch the dagger, and to dash the bowl
From Murder's hand; to smooth the couch of Care,
Extract the thorns, and scatter roses there.
To her, Religion owes her holiest flame:
Her eye looks heaven-ward, for from heaven she came.
And when Religion's mild and genial ray,
Around the frozen heart begins to play,
Music's soft breath falls on the quivering light;
The fire is kindled, and the flame is bright;
And that cold mass, by either power assail'd,
Is warm'd—made liquid—and to heaven exhal'd.

PIERPONT.

The phenomena of music, in addition to their general interest, are truly worthy of our astonishment, from that striking diversity of organic power in the perception of *melody* and still more of *harmony* which they exhibit in different individuals, in whom all other circumstances are apparently the same. This diversity has often attracted the attention of philosophers, and has led even those who have no great tendency to speculation of any kind, to wonder at least, which is the first step of all philosophizing. In the present instance, however unfortunately, this first step is the only step which philosophers have been able to take. If the want of a musical ear had involved either a general defect of hearing, or a general slowness of discrimination in other cases of nice diversity, the wonder would not have been great. But those who are without ear for music perceive as readily as others the faintest whisper;—they distinguish like them, the faintest shades of difference in the mere articulations of sound which constitute the varieties of language, nor the articulations only, but the differences also of the mere tones of affection or displeasure, grief or gayety, which are so strikingly analogous to the varied expression of musical feeling;—and their power of discrimination in every other case in which the judgment can be exercised, is not less perfect.

That the ear may be improved by cultivation, or in other words, by nice attention to the differences of musical sound, every one knows; and if this attention can enable us, even in mature life, to distinguish sounds as different in themselves, which, but for the habitual attention, we should have regarded as the same, it may well be supposed that continued inattention, from earliest infancy, may render us insensible of musical relations still more obvious and precise, than those which we have thus only learned to distinguish;—or, which is the same thing, that continued attention from infancy to slight musical differences of sound may render us capable of distinguishing tones as very dissimilar, the differences of which, however obvious at present, we should scarcely, but for such original attentive discrimination, have been able to detect.

QUESTIONS.—1. What is music? 2. What renders the phenomena of music worthy of astonishment? 3. What may be supposed to result from inattention to the differences of musical sounds? 4. Attention?

LESSON 122.

Painting.

Pen'cil, an instrument used by painters for laying on colours; the finer sorts are made of camels' hair, or sometimes of the down of swans.

The art of distributing lights and shades is called clair obscure, or chiaro-scuro.

THE art of painting gives the most direct and expressive representation of objects; and it was, doubtless, for this reason employed by many nations, before the art of writing was invented, to communicate their thoughts, and to convey intelligence to distant places. The pencil may be said to write a universal language; for every one can instantly understand the meaning of a painter, provided he be faithful to the rules of his art. His skill enables him to display the various scenes of nature at one view; and by his delineation of the striking effects of passion, he instantaneously affects the soul of the spectator. Silent and uniform as is the address which a good picture makes to us, yet it penetrates so deeply into our affections, as to appear to exceed the powers of eloquence.

Painting is the most imitative of all the arts. It gives to us the very forms of those, whose works of genius, or of virtue, have commanded or won our admiration, and transmits them from age to age, as if not life merely, but immortality flowed in the colours of the artist's pencil; or, to speak of its still happier use, it preserves to us the lineaments of those whom we love, when separated from us either by distance or the tomb. How many of the feelings, which we should most regret to lose, would be lost but for this delightful art, —feelings that ennoble, by giving us the wish to imitate what was noble in the moral hero or sage, on whom we gaze, or that comfort us, by the imaginary presence of those whose affection is the only thing dearer to us, than even our admiration of hĕr′oism and wisdom. The value of painting will, indeed, best be felt by those who have lost, by death, a parent or much-loved friend, and who feel that they should not have lost every thing, if some pictured memorial had still remained.

Paintings, in regard to their subjects, are called historical, landscape, or portrait; and in regard to the painters, they are divided into schools or countries; as the Italian, German, French, English, and other schools. Each of the schools has treated the practice of painting in its peculiar manner, and each with exquisite beauty and admirable effect. The great component parts of painting are, invention, or the power of conceiving the materials proper to be introduced into a picture; composition, or the power of arranging them; design, or the power of delineating them; the management of lights and shades; and the colouring. Invention consists principally in three things, the choice of a subject properly within the scope of the art; the seizure of the most striking and energetic moment of time for representation; and the discovery and selection of such objects, and such probable incidental circumstances, as, combined together, may best tend to develope the story, or augment the interest of the piece. In this part of the art, there is a cartoon of Raphael, which furnishes an example of genius and sagacity. It represents the inhabitants of Lystra about to offer sacrifice to Paul and Barnabas. It was necessary to let us into the cause of all the motion and hurry before us; accordingly, the cripple, whom they had miraculously healed, appears in the crowd: observe the means which the painter has used to dintinguish this object, and of course to open the subject of his piece. His crutches, now useless, are thrown to the ground; his attitude is that of one accustomed to such support, and still doubtful of his limbs; the eagerness, the impetuosity, with which he solicits his benefactors to accept the honours destined for them, point out his gratitude and the occasion of it. During the time that he is thus busied, an elderly citizen of some consequence, by his appearance, draws near, and lifting up the corner of his vest, surveys with astonishment the limb newly restored; whilst a man of middle age and a youth, looking over the shoulder of the cripple, are intent on the same object. The wit of man could not devise means more certain of the end proposed; such a chain of circumstances is equal to a narration.

In the cartoon of Paul preaching at Athens, the elevated situation, and energetic action of the apostle, instantly denote him the hero of the piece, whilst the attentive but astonished circle gathered around him, receive, as it were, light from him, their centre, and unequivocally declare him the resistless organ of divine truth.

QUESTIONS.—1. What are paintings in regard to their subjects? 2. To the painters? 3. What are the great component parts of painting? 4. In what three things does invention consist? 5. What cartoon of Raphael is an example in this part of the art? [NOTE. Engravings, taken *originally* from the cartoons of Raphael, are sometimes inserted in Bibles. That of Peter and John healing the cripple at the beautiful gate of the temple, and that of Paul preaching at Athens, are common.]

LESSON 123.

Sculpture.

Consist'ence, degree of density or rarity.

To ascertain when the art of sculpture was first practised, and by what nation, is beyond human research. We may safely conjecture, however, that it was almost one of the original propensities of man. This will still appear in the ardent and irresistible impulse of youth to make representations of objects in wood, and the attempts of savages to embody their conceptions of their idols. A command from the author of our being was necessary to prevent the ancient Israelites from making graven images; and the inhabitants of the rest of the earth possessed similar propensities. The descriptions in the Scriptures demonstrate that the art had been brought to great perfection at the period of which they treat.

It is necessary to make a distinction between carving and sculpture: the former belongs exclusively to wood, and the latter to stone or marble. It is probable that every essay at imitating animated objects was in each nation made originally in wood. But they soon discovered, doubtless, that wood was incapable of a durability commensurate with their wishes; they adopted, therefore, a close grained and beautiful granite, which not only required tools of iron, but those of the most perfectly tempered steel, to cut it; and with such they have left us at this very distant time vast numbers of excavated figures, as complete and as little injured as if executed within our own memory. The acknowledged masters of the sublime art of sculpture are the ancient Greeks, to whom every nation of the earth still pays a willing homage, and from whose matchless works each sculptor is happy to concentrate and improve his observations on the human figure, presented by them to his contemplation in its most graceful perfection. Such have been the excellence and correctness of their imitations of nature, and the refined elegance of their taste, that many of their works are mentioned, as efforts never to be exceeded or perhaps equalled.

Statuary is a branch of sculpture employed in the making of statues. The term is also used for the artificer himself Phidias was the greatest statuary among the ancients, and

Michael Angelo among the moderns. Statues are not only formed with the chisel from marble, and carved in wood, but they are cast in plaster of Paris, or other matter of the same nature, and in several metals, as lead, brass, silver, and gold. The process of casting in plaster of Paris is as follows: the plaster is mixed with water, and stirred until it attains a proper consistence; it is then poured on any figure, for instance, a human hand, or foot, previously oiled in the slightest manner possible, which will prevent the adhesion of the plaster: after a few minutes the plaster will dry to the hardness of soft stone, taking the exact impression of every part, even the minutest pores of the skin. This impression is called the mould. When taken from the figure that produced it, and slightly oiled, plaster, mixed with water as before, may be poured into it, and it must remain until it is hardened; if it be then taken from the mould, it will be an exact image of the original figure. When the figure is flat, having no deep hollows or high projections, it may be moulded in one piece, but when its surfaco is much varied, it must be moulded in many pieces fitted together, and held in one or more outside or containing pieces. This useful art supplies the painter and sculptor with exact representations from nature, and multiplies models of all kinds. It is practised in such perfection, that casts of the antique statues are made so precisely like the originals in proportion, outline, and surface, that no difference whatever is discoverable, excepting in colour and materials.

QUESTIONS.—1. What is said of the origin of sculpture? 2. How does sculpture differ from carving? 3. What is said of this art as it existed among the ancient Greeks? 4. Define the word statuary in both senses. 5. How are statues formed? 6. What is the process of casting in plaster of Paris? 7. Of what use is the art of casting to the painter and sculptor?

LESSON 124.

The Love of Nature.

WHEN the mind becomes animated with a love of nature, nothing is seen tha does not become an object for curiosity and inquiry. A person under the influence of this principle can converse with a picture, and find an agreeable companion in a statue. He meets with a secret refreshment in a description; and often feels a greater satisfaction in the prospect of fields and meadows, than another does in the possession. It gives him indeed a kind of property in every thing he sees; and makes the most rude uncultivated parts of nature administer to his pleasures; so that he looks upon the world, as it were, in another light, and discovers in it a multitude of charms, that conceal themselves from the generality of mankind. A river is traced to its fountain; a flower to its seed; and an oak to its acorn. If a marine fossil lies on the side of a mountain, the mind is employed in the endeavour to ascertain the cause of its position. If a tree is buried in the depths of a morass, the history of the world is traced to the deluge; and he who grafts, inoculates, and prunes, as well as he who plants and transplants, will derive an innocent pleasure in noting the habits of trees and their modes of culture; the soils in which they delight; the shapes into which they mould themselves; and will enjoy as great a satisfaction from the symmetry of an oak, as from the symmetry of an animal. Every tree that bends, and every flower that blushes, even a leafless copse, a barren plain, the cloudy firmament, and the rocky mountain, are objects for his attentive meditation. For,

To him who in the love of Nature holds
Communion with her visible forms, she speaks
A various language; for his gayer hours
She has a voice of gladness, and a smile
And eloquence of beauty, and she glides
Into his darker musings, with a mild
And gentle sympathy, that steals away
Their sharpness, ere he is aware. BRYANT.

LESSON 125.

The Importance of Natural Philosophy.

WITH thee, serene *Philosophy*, with thee,
And thy bright garland, let me crown my song:

Effusive source of evidence and truth !
Without thee, what were unenlightened man ?
A savage roaming through the woods and wilds,
In quest of prey ; and with the unfashioned fur
Rough clad : devoid of every finer art,
And elegance of life. Nor happiness
Domestic, mixed of tenderness and care,
Nor moral excellence, nor social bliss,
Nor guardian law were his ; nor various skill
To turn the furrow ; nor to guide the tool
Mechanic ; nor the heaven-conducted prow
Of navigation bold, that fearless braves
The burning line, or dares the wint'ry pole.

THOMSON.

What can be more gratifying than to become acquainted with the wonderful laws of matter and motion ; with the grand mechanical powers ; and the ingenious and admirable application of them to numberless purposes of human industry, convenience, and comfort ? What more pleasing than to know the nature and properties of the element in which we live ; to understand the laws on which the motion and pressure of fluids depend ; to be able to ascertain the specific gravities, or the relative weight of different bodies ; and to be made acquainted with those newly-discovered principles, by means of which the aspiring genius of man has dared to soar through the trackless regions of the air, and to explore, unhurt, the capacious bosom of the deep ? What can be more interesting or more delightful, than to accompany the rays of light in their rapid journey from the sun ; to observe the various effects of reflection and refraction ; to analyze distinctly the principle of light ; to grasp the fading colours of the rainbow ; to understand the laws of vision ; and to view the wonderful and happy application, which has been made of the grand principles of optics, to the promotion of physical and astronomical science ? What more astonishing than the exquisite nature of that most subtile, all-pervading fluid, which, when collected, produces such powerful effects upon the human frame, which sports in the northern lights, and flashes amidst the storm ; and which, by the penetrating genius and art of man, has even been rendered tractable and obedient to his will ? To be made acquainted with the surprising laws of magnetic bodies, with the polarity of the needle, and the amazing changes which a knowledge of this most remarkable property has effected in the widely-extended intercourse of different nations by means of improved navigation, are certainly objects of the greatest utility, and interesting and instructive in the highest degree. While you contemplate the admirable laws of the planetary system, you will, doubtless, be struck with reverence and awe at the great First Cause, which originally established, and which continually maintains them in order and in being.

> Curious to search what binds old Ocean's tides,
> What through the various year the seasons guides,
> What shadows darken the pale queen of night,
> Whence she renews her orb and spreads her light.

You will take a pleasing survey of those grand movements in the heavenly bodies, to which the sweet interchange of day and night, the grateful succession of the seasons, the occurrence of eclipses, and the regular flowing and ebbing of the tides, may be justly ascribed. With the mind's eye you will even cast a glance into that universe of worlds, which, orbit within orbit, system combined with system, the daring genius of philosophy has ventured to descry in the regions of infinite space; and while absorbed in these sublime speculations, you will be ready to exclaim with the inspired poet of Israel, "The heavens declare the glory of God, and the firmament proclaimeth his handy work:" or to break forth in the beautiful strains of Thomson—

> "These, as they change, Almighty Father, these
> Are but the varied God; the rolling year is full of Thee!"

LESSON 126.

Mythology.

Mythology comprehends all those fabulous details concerning the objects of worship, which were invented and propagated by men who lived in the early ages of the world, and transmitted to succeeding generations, either by oral traditions, or written records. *Fable* is a creature of the human imagination, and owes its birth to that love of the marvellous, by which man is so peculiarly distinguished. Many circumstances conspired to extend and establish the empire of fable. The legislature employed fiction as the most effectual means of civilizing a rude world; philosophers, poets, and musicians, made this a vehicle of instruction to the savage tribes. A fondness for fable, and her attendants allegory and personification, early characterized the *Orientals*. The boldness and the extravagance of their mythology are to be attributed, in a great measure, to the genial warmth of the climate, and to the fertility of the soil; to the face of nature perpetually blooming around them; and to the opportunity they had of contemplating the heaven ly bodies, continually shining under a cloudless sky. These were soon considered as the residence of Divine intelligence, and worshipped, together with the elements, as deities. The historians of antiquity were all poets. To immortalize the heroes, whose deeds they described, they elevated them to the skies, and bestowed on them the names of the celestial luminaries. The sculptor and the painter exercised all their skill to encourage this strange delusion. The use of hieroglyphics was another fertile source of error. The minutest animals and plants were worshipped as emblems of Deity.

QUESTIONS.—1. What does mythology comprehend? 2. What is Fable? 3. By whom, and for what ends, was fiction employed? 4. What characterized the Orientals, or eastern nations? 5. What occasioned their peculiar mythology? 6. Why did ancient historians encourage mythology? 7. To what other causes is this delusion to be attributed?

LESSON 127.

Account of the principal Heathen Gods.

BEFORE the birth of our Saviour, the Jews were the only nation of the world who worshipped the true God. All the other nations worshipped different imaginary beings, which existed only in their absurd and ridiculous fancies. Most of these false gods, however, have now become forgotten, together with the nations that believed in them; but it is necessary to preserve a knowledge of the gods and goddesses worshipped by the Greeks and Romans, as they are much spoken of in the finest writings of antiquity, and are still frequently mentioned both in poetry and in prose. The most ancient of their gods were Cha'os, and his son Er'e-bus; or confusion, and darkness. Saturn, one of their descendants, is the same as Time: his reign is called the Golden Age; and it is said, that the earth then produced corn and fruits without labour, and justice prevailed among all mankind. Saturn was deposed by his son Jupiter, called also Jove; who then divided his father's power between himself and his two brothers, Neptune and Pluto. Jupiter was to reign over heaven; and he was said to hold his court, or council of the gods, on the top of Olym'pus, a mountain in Thes'saly. He is called by the ancient poets, the king of gods and men; and the eagle is represented as being the bearer of his thunderbolts. Neptune, the god of the sea, is represented with a trident, or fork with three teeth in his hand instead of a sceptre. He was drawn in his chariot by sea-horses, with his son Triton blowing a trumpet made of a shell, and dolphins playing round him.

The dominions of Pluto, the god of the infernal regions, were divided into two parts, called Tar'tarus and Elys'ium. Tartarus was the place where the souls of the wicked were punished, and Elysium was the scene of perpetual happiness allotted to the good. The passage from the earth to these regions was across the river A'cheron, over which the departed spirits were conveyed by an old boatman, named Cha'ron; and the further bank was also guarded by a dog with three heads, named Cer'berus. There were two remarkable rivers of Tartarus: one named Styx, which the gods used to swear by when they intended to make their oath very solemn; and another named Le'the, which caused whoever bathed in it to forget every thing that was past. Mars, the son of Jupiter, was the god of war. Apol'lo, likewise the son of Jupiter, was the god of music, poetry, and medicine. He is also represented as driving the chariot of the sun, drawn by four horses abreast; or rather, he is the sun itself. As a mark of affection, he intrusted this chariot one day to his son Phaëton; who was killed by being thrown out of it, but not till after he had set a part of the earth on fire. Apollo is called also Phœbus, and Hype'rion; and is represented as a beautiful young man, without a beard, and with graceful hair. Mercury, a son of Jupiter, was the messenger of the gods; and is therefore represented with wings to his cap and his feet. He was said to be the inventor of letters, and hence he is the god of eloquence; and was the god of trade, and thence also of thieves. He was called also Her′mes; and is represented as carrying a wand, called cadu′ceus, with two serpents twisting round it. Vulcan, the god of fire and of smiths, was the artificer of heaven; and made the thunderbolts of Jupiter, and the armour and palaces of the gods. It is said that one of his principal forges was within Mount Etna. He is called also Mul′ciber.

The foregoing are the principal gods, but there were many of a second or still lower order. Bac′chus was the god of wine, and was crowned with leaves of the vine and the ivy. E′olus was the god of the winds: the north wind was called Bo′reas, the south wind Au′ster, the east wind Eu′rus, and the west wind Zeph′yrus. Mo′mus was the god of satire, and likewise of laughter and jokes. Plu′tus was the god of riches. Hy′men was the god of marriage: he is represented with the burning torch. Cu′pid was the god of love: he is represented as a beautiful child, but blind or hoodwinked, and carries a bow and arrows. Ja′nus, a god with two faces, looking forward and backward, had a temple which was open in time of war, and shut in peace. Escula′pius was an inferior god of medicine, below Apollo: he is represented as accompanied by a serpent, which was thought the most long-lived of all animals. Pan was the god of shepherds; and he is represented as having horns, and as carrying the musical instrument, now called Pan's pipes. There were other rural deities called Sat′yrs, Fauns, and Syl′vans: their figures were half man and half goat, and they dwelt chiefly in forests. Every river also was supposed to have its own god; who was drawn with a long beard, a crown of reeds, and leaning on an urn. There were likewise a great number of demi-gods, or half-gods; the principal one of these was Her′cules; who was accounted the god of strength, from his having performed some wonderful undertakings, called his Twelve Labours. He is represented leaning on a large club, and wearing a lion's skin.

LESSON 128.

Account of the principal Heathen Goddesses.

Ju′no was the wife of Ju′piter, and was of course the queen of heaven. She is represented as drawn by peacocks in a chariot of gold. Her favourite messenger was I′ris the goddess of the rainbow. Miner′va, a daughter of Jupiter, was the goddess of wisdom and of war. She was represented in complete armour, bearing a shield, called ægis, with a head on it, so terrible, that every one who looked on it was turned into stone. She was likewise the patroness of spinning, needle-work, and embroidery. She was called also Pal′las, and her principal emblem was the owl. Dian′a was the twin sister of Apollo; and as he drove the chariot of the sun, so she presided in that of the moon. She was the goddess of hunting; and is drawn as carrying a bow and arrows, with a half moon as an ornament on her forehead, and attended by several nymphs as her companions, and by her hounds. She is called also Phœbe; and Cyn′thia, from having been born on Mount Cynthus, and she had a very famous temple at Eph′esus, which is mentioned in the New Testament, in the 19th chapter of the Acts.

Venus was the goddess of beauty and of love; and the wife of Vulcan, and mother of Cupid; her chariot was drawn by doves, and the myrtle was sacred to her. She was said to have sprung from the sea, near the island of Cythe′ra; and her most celebrated temple was at the city of Pa′phos, in the island of Cyprus; hence she is called also Cythere′a; and the Pa′phian, or the Cyp′rian, goddess. Ves′ta was the goddess of the earth and of fire. In her temple at Rome, a perpetual fire was maintained, which was kindled from the rays of the sun, and was constantly watched by priestesses chosen from the most noble families. They were called vestal virgins, and had very great honours and privileges. Ce′res was the goddess of corn and of harvest. Cyb′ele was one of the most ancient of the goddesses, being the wife of Saturn; and in some respects represents the earth. She is displayed as crowned with towers, holding a key in her hand, and drawn in her chariot by lions. Pros′erpine was the wife of Pluto, and of course the queen of the infernal regions. She was the daughter of Ceres. Amphitri′te was the wife of Neptune. Her sister was The′tis, another sea-goddess; and hence, when the sun sets, she is said to sink into Thetis's lap. The foregoing are the principal goddesses.

Flo′ra was the goddess of flowers, and Pomo′na was the goddess of fruits. Bello′na was an inferior goddess of war. Auro′ra was the goddess of the morning, or rather of day-break. The′mis, the sister of Sa′turn, was the goddess of righteousness and justice: her daughter Astre′a also represents justice; she is sometimes called the Virgin, and in this character has a place among the stars, being denoted by the constellation Vir′go, or the Virgin. Hyge′ia was the goddess of health. He′be was the goddess of youth, and was cup-bearer to Jupiter. A′te was the goddess of mischief. The Muses were nine virgin-goddesses who presided over every kind of learning, and in that character attended on Apollo. They were sisters; the principal of them were Cli′o, who was the muse of history; Thali′a, of comedy, Melpom′ene, of tragedy; Terpsic′hore, of dancing; and Ura′nia, of mathematics and astronomy. They are sometimes called merely the Nine, in reference to their number.

Parnas′sus and Hel′icon were two mountains sacred to Apollo and the Muses; at the feet of which flowed two streams, whose waters were supposed to communicate the inspiration of prophecy, or of poetry. Peg′asus was a winged horse of the Muses. The Graces were three sisters, who were supposed to give its attractive charms to beauty of every kind, and to dispense the gift of pleasing. The Furies were three sisters of a very different character; they were the most deformed and horrible of all the deities. Instead of hair, they had snakes hanging from their heads. They carried chains, and whips with lashes of iron or of scorpions in one hand, and lighted torches in the other. They were the bearers of the vengeance of heaven. The Destinies or Fates, were also three sisters, of whom one was represented as holding a distaff; another drawing from it a thread, signifying the life of man; and the third with a pair of shears, ready to cut the thread whenever she should choose. The Dry′ads and Ham′adryads were rural goddesses, each having a single tree in her charge. The Na′iads were goddesses presiding over springs, wells, and fountains; each, in the same manner, having one under her care. The Ne'reids were inferior goddesses of the sea.

From BALDWIN'S PANTHEON.

LESSON 129.

Harmony of Science and Christianity.

AFTER all the attacks of infidelity, and of theoretical philosophy, the religion of Christ, when contemplated through the medium of science, has had a complete and victorious triumph. It has been often objected to Christianity, that it is unfavourable to the progress of knowledge; that it discourages scientific enterprises; that it is inimical to free inquiry, and has a tendency to keep the minds of men in blindness and thraldom. The history of Christianity, since the Reformation at least, demonstrates that the very reverse of what the objection states is the truth. *Christian nations* have been, of all others, most remarkable for favouring the advancement of liberal knowledge. In those countries in which religion has existed in its greatest *purity*, and has enjoyed the most general *prevalence*, literature and science have been most extensively and successfully cultivated. It is also worthy of remark, that, among all the professions denominated *learned*, the *clerical* profession may be considered as having furnished as many, if not more authors of distinction than any other. And if we join to the *clergy*, those lay authors who have been no less eminent as *Christians* than as scholars, the predominance of learning and talents on the side of religion will appear too great to admit of comparison. The discoveries made in mechanical and chemical philosophy have served to elucidate and confirm various parts of the Christian Scriptures. Every sober and well-directed inquiry into the natural history of man, and of the globe we inhabit, has been found to corroborate the Mosaic history, and the reports of voyagers and travellers have served to illustrate the sacred records, and to confirm the faith of Christians. Never was there a period in which so much light and evidence in favour of revelation were drawn from the inquiries of philosophy as in the present era; nor was it ever rendered so apparent, that the information and the doctrines contained in the sacred volume perfectly harmonize with the most authentic discoveries, and the soundest principles of science.

QUESTIONS.—1. For what have christian nations been remarkable? 2. What is said of the predominance of learning on the side of religion? 3. To what purpose have discoveries in philosophy been subservient? 4. What is the character of the present period?

LESSON 130.

The Influence of an early Taste for Reading.

THERE is, perhaps, nothing that has a greater tendency to decide favourably or unfavourably respecting a man's future intellect than the question, Whether or not he be impressed with an early taste for reading.

Books are the depository of every thing that is most honourable to man. He that loves reading has every thing within his reach. He has but to desire, and he may possess himself of every species of wisdom to judge, and power to reform.

The chief point of difference between the man of talent and the man without, consists in the different ways in which their minds are employed during the same interval: they are obliged, we will suppose, to walk from Temple-bar to Hyde-park Corner: the dull man goes straight forward, he has so many furlongs to traverse: he observes whether he meets any of his acquaintance; he inquires respecting their health and their family; he glances his eye, perhaps, at the shops as he passes; he admires, perchance, the fashion of a buckle, and the metal of a tea-urn. If he experience any flights of fancy, they are of a short extent; of the same nature as the flights of a forest bird clipped of his wings, and condemned to pass the rest of his life in a farm-yard.

On the other hand, the man of talent gives full scope to his imagination. Unindebted to the suggestions of surrounding objects, his whole soul is employed. He enters into nice calculations; he digests sagacious reasonings. In imagination he declaims, or describes, impressed with the deepest sympathy or elevated to the loftiest rapture. He makes a thousand new and admirable combinations. He passes through a thousand imaginary scenes, tries his courage, tasks his ingenuity, and thus becomes gradually prepared to meet almost any of the many-coloured events of human life. If he observes the passengers, he reads their countenances, conjectures their past history, and forms a superficial notion of their wisdom or folly, their virtue or vice, their satisfaction or misery. If he observes the scenes that occur, it is with the eye of an artist. Every object is capable of suggesting to him a volume of reflections.

The time of these two persons in one respect resembles; it has brought them both to Hyde-park Corner. In every other respect how dissimilar!

Probably nothing has contributed so much to generate these opposite habits of mind, as an early taste for reading. Books gratify and excite our curiosity in innumerable ways. They force us to reflect; they present direct ideas of various kinds, and they suggest indirect ones. In a well-written book we are presented with the maturest reflections, or the happiest flights of a mind of uncommon excellence; and it is impossible that we can be much accustomed to such companions, without attaining some resemblance of them.

GODWIN.

LESSON 131.

The Mechanical Wonders of a Feather.

Lam'ina (plural laminæ,) thin plate, one coat laid over another.

EVERY single feather is a mechanical wonder. If we look at the quill, we find properties not easily brought together, strength and lightness. I know few things more remarkable than the strength and lightness of the very pen with which I am now writing. If we cast our eyes towards the upper part of the stem, we see a material made for the purpose, used in no other class of animals, and in no other part of birds; tough, light, pliant, elastic. The pith, also, which feeds the feathers, is neither bone, flesh, membrane, nor tendon. But the most artificial part of a feather is the beard, or as it is sometimes called, the vane; which we usually strip off from one side or both when we make a pen. The separate pieces of which this is composed are called threads, filaments, or rays. Now, the first thing which an attentive observer will remark is, how much stronger the beard of the feather shows itself to be when pressed in a direction perpendicular to its plane, than when rubbed either up or down in the line of the stem; and he will soon discover, that the thread of which these beards are composed are flat, and placed with their flat sides towards each other; by which means, while they easily bend for the approaching of each other, as any one may perceive by drawing his finger ever so lightly upwards, they are much harder to bend out of their plane, which is the direction in which they have to encounter the impulse and pressure of the air, and in which their strength is wanted. It is also to be observed, that when two threads, separated by accident or force, are brought together again, they immediately reclasp. Draw your finger round the feather which is against the grain, and you break, probably, the junction of some of the contiguous threads; draw your finger up the feather, and you restore all things to their former state. It is no common mechanism by which this contrivance is effected! The threads or laminæ above mentioned are interlaced with one another; and the interlacing is performed by means of a vast number of fibres or teeth which the threads shoot forth on each side, and which hook and grapple together. Fifty of these fibres have been counted in one twentieth of an inch. They are crooked, but curved after a different manner: for those which proceed from the thread on the side towards the extremity of the feather are longer, more flexible, and bent downward; whereas those which proceed from the side toward the beginning or quill-end of the feather, are shorter, firmer, and turned upward. When two laminæ, therefore, are pressed together, the crooked parts of the long fibres fall into the cavity made by the crooked parts of the others; just as the latch which is fastened to a door, enters into the cavity of the catch fixed to the door-post, and there hooking itself fastens the door! DR. PALEY.

LESSON 132.*

Art of Making Pins.

Though pins are apparently simple, their manufacture is, however, not a little curious and complex. When the brass wire, of which the pins are formed, is first received at the manufactory, it is generally too thick for the purpose of being cut into pins. The first operation, therefore, is that of winding it off from one wheel to another with great velocity, and causing it to pass between the two, through a circle in a piece of iron of smaller diameter. The wire being thus reduced to its proper dimensions, is straightened by drawing it between iron pins, fixed in a board in a zigzag manner, but so as to leave a straight line between them; afterwards it is cut in lengths of three or four yards, and then into smaller ones, every length being sufficient to make six pins. Each end of these is ground to a point, which was performed, when I viewed the manufactory, by boys, who sat each with two small grinding-stones before him, turned by a wheel. Taking up a handful, he applies the ends to the coarsest of the two stones, being careful at the same time to keep each piece moving round between his fingers so that the points may not become flat: he then gives them a smoother and sharper point by applying them to the other stone, and by that means a lad of twelve or fourteen years of age, is able to point about sixteen thousand pins in an hour. When the wire is thus pointed, a pin is taken off at each end, and this is repeated till it is cut into six pieces. The next operation is that of forming the heads, or, as they term it, head-spinning, which is done by means of a spinning-wheel, one piece of wire being thus with astonishing rapidity wound round another, and the interior one being drawn out, leaves a hollow tube between the circumvolutions; it is then cut with shears, every two circumvolutions, or turns of the wire, forming one head; these are softened by throwing them into iron pans, and placing them in a furnace till they are red-hot. As soon as they are cold, they are distributed to children, who sit with hammers and anvils before them, which they work with their feet, by means of a lathe, and taking up one of the lengths, they thrust the blunt ends into a quantity of the heads which lie before them, and catching one at the extremity, they apply them immediately to the anvil and hammer, and by a motion or two of the foot, the top and the head are fixed together in much less time than it can be described, and with a dexterity only to be acquired by practice; the spectator being in continual apprehension for the safety of their fingers' ends. The pin is now finished as to its form, but still it is merely brass; it is therefore thrown into a copper containing a solution of tin and the lees of wine. Here it remains for some time, and when taken out assumes a white, though dull appearance: in order therefore to give it a polish, it is put into a tub containing a quantity of bran, which is set in motion by turning a shaft that runs through its centre, and thus by means of friction it becomes perfectly bright. The pin being complete, nothing remains but to separate it from the bran, which is perfectly similar to the winnowing of corn, the bran flying off, and leaving the pin behind it for immediate sale.

LESSON 133.

Clouds and Rain.

Conge'ries, a mass of small bodies heaped up together.

A CLOUD is a collection of vapour, suspended in the atmosphere. In other words, it is a congeries of watery particles raised from the waters, or watery parts of the earth, by the solar or electrical fire. These watery particles, in their first ascent, are too minute and too much separated by their mutual repulsion, to be perceived; but as they mount higher and higher, meeting with a greater degree of cold, losing their electricity, or by some process employed by Nature for this purpose, they are in a certain degree condensed, and rendered opaque, by the re-union of their parts, so as to reflect and absorb light, and become visible as clouds.

The lowest part of the air being pressed by the weight of the upper against the surface of the water, and continually rubbed upon it by its motion, attracts and dissolves those particles with which it is in contact, and separates them from the rest of the water. And since the cause of solution is the stronger attraction of the particles of water towards the air than towards each other, those that are already dissolved and taken up will be raised still higher, by the attraction of the dry air, which lies over them, and thus will diffuse themselves, rising gradually higher and higher, thereby leaving the lower air not so much saturated, but that it will still dissolve and take up fresh particles of water; which process is greatly promoted by the motion of the wind.

When the vapours are thus raised into the higher and colder parts of the atmosphere, some of them will coalesce into small particles, which, slightly attracting each other, and being intermixed with air, will form *clouds;* and these clouds will float at different heights, according to the quantity of vapour borne up, and to the degree of heat in the upper part of the atmosphere. The clouds, therefore, are generally higher in summer than in winter; in the former season they are from one mile to three miles high, and in the latter from a quarter of a mile to a mile.

When the clouds are much increased by a continual addition of vapours, and their particles are driven close together by the force of the winds, they will run into drops heavy enough to fall down in *rain*. If the clouds are frozen before their particles are gathered into drops, small pieces of them being condensed, and made heavier by the cold, they fall down in flakes of *snow*. If the particles are formed into drops before they are frozen, they become *hailstones*. When the air is replete with vapours, and a cold breeze springs up which checks the solution of them in the air, clouds are formed in the lower parts of the atmosphere, and these compose a *mist* or *fog:* this usually happens in a cold morning; but the mist is dispersed when the sun has warmed the air, and made it capable of dissolving the watery particles of which the mist is composed.

Southerly winds generally bring rain, because, being commonly warm, and replete with aqueous vapours, they are cooled by passing into a colder climate; and therefore part with some of them, and suffer them to precipitate in rain: northerly winds, on the contrary, being cold, and acquiring heat by coming into a warm climate, take up or dissolve more vapour than they before contained; and therefore are dry and parching, and usually attended with fair weather.

GREGORY.

QUESTIONS.—1. What is a cloud? 2. Describe the process by which the watery particles are supposed to become visible clouds. 3. What is the process by which other or fresh particles of water are taken up? 4. Why are clouds generally higher in summer than in winter? 5. When will clouds fall down in rain?—in flakes of snow? 6. When do they become hailstones? 7. How and when is mist or fog produced? 8. Why do southerly winds generally bring rain? 9. Why are north winds usually attended with fair weather.

LESSON 134.

Invention and Progress of Printing.

Glu'tinous, gluey, viscous, tenacious.

THE art of printing deserves to be considered with attention and respect. From the ingenuity of its contrivance, it has ever excited mechanical curiosity; from its intimate connexion with learning, it has justly claimed historical notice; and from its extensive influence on morality, politics, and religion, it is now become a very important speculation. Coining, and taking impressions in wax, are of great antiquity, and the principle is precisely that of printing. The application of this principle to the multiplication of books, constituted the discovery of the art of printing. The Chinese have for many ages printed with blocks, or whole pages engraved on wood; but the application of single letters or moveable types forms the merit of the European art.

The honour of giving rise to this method has been claimed by the cities of Harlem, Mentz, and Strasburg; and to each of these it may be ascribed in some degree, as printers resident in each made successive improvements in the art.

It is recorded by a reputable author, that Laurens Koster of Harlem, walking in a wood near that city, cut some letters upon the rind of a beech-tree, which for fancy's sake, being impressed upon paper, he printed one or two lines for his grand-children; and this having succeeded, he invented a more glutinous ink, because he found the common ink sunk and spread; and then formed whole pages of wood, with letters cut upon them, and (as nothing is complete in its first invention) the backsides of the pages were pasted together, that they might have the appearance of manuscripts written on both sides of the paper. These beechen letters he afterwards exchanged for leaden ones, and these again for a mixture of tin and lead, as a less flexible and more solid and durable substance. He died in 1440, and by some his first attempt is supposed to have been made about 1430, but by others as early as 1423.

From this period printing made a rapid progress in most of the principal towns of Europe, superseded the trade of copying, which, till that time, was very considerable, and was in many places considered as a species of magic. In 1490 it reached Constantinople, and was extended by the middle of the following century to Africa and America.

During the period since its invention, what has not the art of printing effected? It has blunted the edge of persecution's sword, laid open to man his own heart, struck the sceptre from the hand of tyranny, and awakened from its slumber a spirit of knowledge, cultivation, liberty. It has gone forth like an angel scattering blessings in its path, solacing the wounded mind, and silently pointing out the triumphs of mortality and the truths of revelation to the gaze of those whom the want of precept or good example had debased, and whom ignorance had made skeptical.

QUESTIONS.—1. The application of what principle to the multiplication of books constitutes the discovery of the art of printing? 2. What is said of Harlem, Mentz, and Strasburg? 3. What is related of Laurens Koster? 4. What is said of the progress of printing in the world? 5. Of its effects? [NOTE. The fourth Centennial Anniversary of the Invention of Printing was observed at Harlem in Holland on the 10th and 11th of July, 1823, with great rejoicing and a splendid festival.]

LESSON 135.

Hope.

THERE is no happiness which hope cannot promise,—no difficulty which it cannot surmount,—no grief which it cannot mitigate. It is the wealth of the indigent, the health of the sick, the freedom of the captive. As soon as we have learned what is agreeable, it delights us with the prospect of attaining it; as soon as we have lost it, it delights us with the prospect of its return. It is our flatterer and comforter in youth; it is our flatterer and comforter in years which need still more to be flattered and comforted. What it promises, indeed, is different in these different years; but the kindness and irresistible persuasion with which it makes the promise are still the same; and while we laugh, in advanced age, at the easy confidence of our youth in wishes which seem incapable of deceiving us now, we are still, as to other objects of desire, the same credulous, confiding beings, whom it was then so easy to make happy. Nor is it only over terrestrial things that it diffuses its delightful radiance. The power which attends us with consolation, and with more than consolation, through the anxieties and labours of our life, does not desert us at the close of that life which it has blessed or consoled. It is present with us in our last moment. We look to scenes which are opening on us above, and we look to those around us, with an expectation still stronger than the strongest hope, that, in the world which we are about to enter, we shall not have only *remembrances* of what we loved and revered on earth, but that the friendships from which it is so painful to part, even in parting to Heaven, will be restored to us there, to unite us again in affection more ardent, and in still purer adoration of that Great Being, whose perfections, as far as they were then dimly seen by us, it was our delight to contemplate together on earth, when it was only on earth that we could trace them, but on that earth which seemed holier, and lovelier, and more divine, when thus joined in our thought with the Excellence that made it.

BROWN.

APPENDIX.

EXPLANATION OF THE ENGRAVINGS.

LESSON 17.

Centre of Gravity. Engraving I.—If the centres of gravity of two bodies, A and B, *fig.* 12. be connected with the right line A B, then the common centre of gravity, C, will be as much nearer to A than to B, as the ball A is heavier than the ball B. If the ball A weigh 12 pounds, and the ball B only 4 pounds, and the length A B be 20 inches, then, because the ball A is three times heavier than the ball B, the distance A C will be three times less than the distance B C, that is, A C will be 5 inches and B C 15 inches; the point C, therefore, is the common centre of gravity of the two bodies A and B, and if supported by this point they will balance each other. As $12+4=16$ is to 20, so is 4 to 5, or so is 12 to 15.

The inclining body A B C D, *fig.* 4. whose centre of gravity is E, stands firmly, because the line of direction E F falls within the base. But if the body A B G H be placed upon it, the centre of gravity will be raised to L, and then the line of direction L D will fall out of the base towards I: the centre of gravity, therefore, is not supported, and the whole body must fall.

LESSON 19.

Compound Motion.—The body A, *fig.* 1. acted upon by a force in the direction A B, and at the same time by another force in the direction A C, will move in the direction A D. If the lines A B and A C be made in proportion to the forces, and C D and D B be drawn parallel to them, then A D, the diagonal, will represent the force with which the body will move; and this force will be as much greater than either of the two forces by which it was impelled as A D is longer than A C, or any other single side of the parallelogram. This is called the *composition and resolution of motion.* [Note. Several things in this Lesson may be obscure to some students: the teacher should explain and illustrate them by familiar "verbal instructions," and by such figures and diagrams as he may have in his possession, or may easily draw upon paper or a slate.]

LESSON 20.

Levers.—First kind, *fig.* 7. C E is the lever, and B the prop. A the stone to be raised = 1000 pounds, and the strength of a man at C = 100 pounds. Since the strength of the man is only one tenth the weight of the stone, that the power and weight may balance each other, the arm of the lever B C must be ten times as long as the arm B E. *Second* kind, *fig.* 9. If the hand C be nine times as far from A as the point X, then one pound at C will balance nine pounds at B. *Fig.* 5. a burden on a pole. Weight W three times nearer to *a* than to *b*, *a* then will bear three times as much of the weight as *b*. *Third* kind, *fig.* 10. Distance P F 3 inches; W F 12:—then 20 pounds at W will require the force of 80 at P in order to balance it, for 12 is four times 3. *Fig.* 2. man's arm,—D centre of motion,—the power is the muscle inserted at C,—A the weight:—now as the distance D C is one tenth part of C A, the muscle, therefore, must exert a power equal to 100 pounds in order to raise 10 pounds.

LESSON 21.

Pulley.—Fig. 13. *single* moveable,—in order to raise the weight W one inch, the power P must draw the strings B and C one inch each: the whole string, therefore, is shortened two inches, while the weight is raised only one. *Fig.* 15. *System* of pullies. While the weight W rises one inch, each of the four ropes must be shortened an inch, and P, therefore, must move four inches: 5 pounds at P will balance 20 at W. *Wheel and Axle, Fig.* 11. If the diameter of the wheel be 4 feet, and that of the axis only 8 inches, then the power P of 100 pounds will balance the weight W of 600 pounds; for 6×8=48 inches which make 4 feet, the diameter of the wheel. *Inclined Plane. Fig.* 8. If B C=

4 A C, then W will be supported by a power $= \frac{1}{4}$ of its weight. *Example.* If a wagon with its load weigh 40 cwt. and may be drawn on level ground by a force equal to 8 cwt., in drawing it to the top of a hill which rises 20 yds. in a 100, the horses will have to pull with an additional force $= \frac{1}{5}$ of 40 cwt., that is, 8 cwt. *more* than on level ground, or with double their former force.

LESSON 22.

The Wedge, fig. 6.—A B C D may be divided into two inclined planes, A D C and B D C, which may be used separately, and will gain advantage as such; therefore, when united at D C, the advantage gained will be in the same proportion as when they were used in different parts. *The Screw, fig.* 3. A must turn once round before the resistance can be moved from one spiral winding to another, as from x to z $= \frac{1}{2}$ an inch. If the lever A = 36 inches, then the circle described by its end *a* will be about 226 inches or 452 half inches; therefore one pound at *a* will balance a resistance of 452 pounds. [NOTE. Since the lever = 36 inches, the diameter of the circle will be 72 inches, and the circumference of a circle is 3.1416 times the diameter, therefore, $72 \times 3.1416 =$ the circumference = 226 inches or 452 half inches.]

LESSON 23.

Pressure of Fluids.—In the vessel A B, *fig.* 25. Engr. II. the bottom C B does not sustain a pressure equal to the quantity of the whole fluid, but only of a column, whose base is C B, and height C F. In the vessel F G, *fig.* 24. the bottom sustains a pressure equal to what it would if the vessel were as wide at the top as bottom. If to the wide vessel A B, *fig.* 23. a tube C D be attached, and water poured into either of them, it will stand at the same height in both; of course the small quantity in C D balances the large quantity in A B. This has been called the *hydrostatical paradox,* because any quantity, *however* small, may be made to counterpoise any quantity, *however* large, but it is no paradox, when we consider that the particles of a fluid press against each other in every direction, not only downwards, but upwards and sideways.

LESSON 24

Specific Gravity. Hydrostatic Balance, fig. 14. Engr. I. If a body *x*, suspended under the scale, be first counterpoised in air by weights in the opposite scale, and then immersed in water, the equilibrium will be destroyed, then if a weight be put into the scale from which the body hangs, to restore the equilibrium, that weight will be equal to the weight of water as large as the immersed body,—or it is what the body loses of its weight in the fluid.

The *Hydrometer* consists of a thin glass ball, with a graduated tube : a smaller ball is attached to the instrument below, containing a little mercury, for the purpose of making it remain upright in the liquid under trial. The specific gravity of the liquid is estimated by the depth to which the instrument sinks.

LESSON 25.

The Common Pump, fig. 21. Engr. II. A B the barrel. P the piston. R the rod. V the valve in the moveable piston. *y* a valve fixed in the body of the pump. S the spout. The *Forcing Pump, fig.* 22. A B the barrel. P a solid piston. D the pipe joined to the barrel. V a fixed valve. When P descends it shuts the valve *y*, and forces the water into D through V. When P is raised the valve *y* opens and the valve V shuts, and the water ascends through *y*. The forcing pump described in the Lesson differs a little from this figure. We may suppose an air vessel to be placed above V, and a pipe descending through it nearly to V, and the elastic pressure of the air upon the surface of the water, confined in the vessel, will force the water upwards through the pipe.

LESSON 27.

The Air Pump, fig. 16. D E the base or wooden frame. A A the two brass cylinders. B the head. C C the columns holding down the head. K the receiver. I a hole in the brass plate, through which the air passes in a brass tube to the cylinders. R R toothed rods. H handle or winch. N a nut, on turning which the air may be excluded from, or admitted to the receiver. M a quicksilver gage with a small receiver over it: this is designed to show the different densities of the air in the large receiver, when the machine is at work. There is a communication between this and the hole I by a brass pipe. This is not an essential part of an air pump, though it is convenient, as showing the degree of exhaustion: the more the air is exhausted the higher will the mercury rise in the gage.

Artificial Fountain, *fig*. 26. A is a strong copper vessel, having a tube that screws into the neck of it, so as to be air tight, and so long as nearly to reach to the bottom: *x* is the handle of a stop. Having poured some water into the vessel, and screwed in the tube, the condensing syringe is to be adapted, and the air condensed. The stop is to be shut while the syringe is unscrewed, then, on opening the stop, the air, by its great density acting upon the water in the vessel, will force it out in a jet to a considerable height.

LESSON 29.

Sound. *Speaking Trumpet*, *fig*. 20. The voice instead of being diffused in the open air, is confined within the trumpet, and the vibrations which spread and fall against the sides of the instrument, are reflected according to the angle of incidence, and fall into the direction of the vibrations which proceed straight forwards. The whole of the vibrations are thus collected into a focus, and if the ear be situated in or near the spot, the sound is prodigiously increased. The reflected rays are distinguished from those of incidence, by being dotted, and they are brought to a focus at F.

LESSON 30.

Musical Sounds.—The line A B, *fig*. 17. represents a musical string fastened at both ends. Drawn out in the situation A C B, and then let go, it will, in consequence of its elasticity, not only come back to its position A B, but go to the situation A D B, or nearly as far from A B as A C B was on the other side. All the motion one way is called one vibration; after this, the string will go again nearly as far as C, making a second vibration, then nearly as far as D, making a third vibration, and so on, diminishing the extent of its vibrations gradually, until it settles again in its original position A B. According to the laws of pendulums, those of equal length move in equal times, though they pass through different arcs, or portions of a circle. If the pendulums A B, fig. 18. and C D, fig. 19. be equal, the time of passing through E F is equal to that of passing through G H. Thus the vibration of the string A B, fig. 17. is considered as a double pendulum, vibrating from the points A and B, the respective vibrations of which, from the greatest to the least, are performed in the same time: this is the reason why a musical string has the same tone from the beginning of the vibrations to the end.

LESSON 31.

Optics. Reflection and Refraction of Light. If L G, *fig.* 29. Engr. III. be a reflecting surface, as a looking glass, then B C is the *incident* ray, and C E is the *reflected* ray. The line F C is a perpendicular to the reflecting surface L G. The *angle of incidence* is that which is contained between B C and C F, and the *angle* of reflection is that contained between E C and C F: and the angle of incidence is equal to the angle of reflection, that is, the angle B C F is equal to the angle E C F. (It is usual to call every angle by three letters, and that at the angular point must be always the middle letter of the three.)

Let B C, *fig.* 29. be a ray of light passing out of air into water or glass L G at the point C, the ray B C, instead of proceeding along C H, will be bent, or *refracted towards* the perpendicular C K, as along C I. But if C I be supposed to be a ray of light passing out of glass or water into air, that is, out of a denser into a *rarer* medium, it will not proceed in the direction of the line C *x*, but in the direction C B, *farther from* the perpendicular F C than C *x*. [Note. On the subject of optics the instructer should be particular in giving his pupils a correct idea of angles, parallel lines, &c.]

LESSON 32.

Lenses. Fig. 30. A is a plano-convex lens, B plano-concave, C double convex, D double concave, E a meniscus. F G is the axis of all the five lenses.

Fig. 36. A candle at C *diverges* rays of light towards *x*.

They are said to *converge* when considered as flowing from *x* towards C. And to be *parallel* as flowing from *x* towards *a* and *b*. C is the *focus* of the *converging* rays, and the *imaginary focus* of the *diverging* rays. The lens here being plano-convex, the *focus*, as is manifest, is at the distance of the diameter of the sphere, of which the convex surface of the lens forms a portion. The distance from the middle of the glass to the focus is called the *focal distance.*

Fig. 32. The *focal distance* of a double convex lens is situated at the centre of the sphere, of which the surface of the lens forms a portion;—of the lens A B, for instance, *f* is the focus, and the distance from *f* to the circumference of the circle is the focal distance, which is equal to half the diameter of the sphere. If another double convex lens F G be placed in the rays at the same distance from the focus, it will so refract the rays, that they shall go out of it parallel to one another. It is evident that all the rays except the middle one, cross each other in the focus *f;* of course the ray D A, which is uppermost in going in, is the lowest in going out, as G *c*.

Fig. 33. If the rays *a b c*, &c. pass through A B, and C be the centre of concavity, then the ray *a*, after passing through the glass, will go in the direction *k l*, as if it had come from C, and no glass in the way: the ray *b* will go on in the direction *m n*, and so on. The point C is called the *imaginary focus.*

LESSON 33.

In *fig*. 27. A B is a *concave mirror*, C is the centre of concavity. The rays, which proceed from any remote terrestrial object, as D E, will be converged at a little greater distance than half way between the mirror and C, and the image will be inverted with respect to the object, as *d e*. When the object is more remote than the centre of concavity, or C, the image is less than the object, and is between the object and the mirror, as *d e* between D E and B C. When the object is nearer than C, the image will be more remote and larger than the object, as D E. If the object be in C, the image and object will be equal and coincide.

LESSON 34.

Fig. 37. P is a *prism.* A is a ray of light, which is refracted on entering the prism, and also on leaving it. A B is the spectrum, on which are exhibited the variously coloured rays.

LESSON 36.

Structure of the Eye. Fig. 28. *a a a a a,* is called the *sclerotica: b b,* the *cornea: c c c,* the *choroid: d d,* the *pupil: e e,* the *iris: f f,* the *aqueous humour: g g,* the *crystalline* humour : *h h,* the *vitreous* humour : *i i,* the *retina;* which proceeds from the brain and enters the eye at *n.*

LESSON 37.

Single Microscope, fig. 35. E F is the object to be viewed : A B a double convex lens : *c* the pupil of the eye : D the crystalline humour : the rays are converged to a focus on the retina at R R. *Compound Microscope, fig.* 34. with which we do not see the object A B, but a magnified image of it *a b.* Two lenses are employed ; the one L M, for the purpose of magnifying the object, is called the object glass ; the other N O, acts on the principle of the single microscope, and is called the eye glass.

LESSON 39.

To obtain an idea of the Newtonian Telescope, look at *fig.* 27. and consider the concave mirror A B as placed at the end of a tube, and rays of light falling upon it from the object D E : then suppose a plane mirror placed a little below *e,* so that the rays, being reflected from it, shall pass out through a lens at *d,* where the eye of the observer looks down on the image.

LESSON 41.

Solar System. Engr. IV. *Fig.* 38 exhibits the order in which the planets move round the sun. *Fig.* 39 shows their comparative magnitudes. On the left hand side of the Engr. are represented the proportional distances of the planets from the sun.

LESSON 42.

Table of the distances, rotations, periods, &c. of the Sun and Planets.

	Distance in Millions.	Time of revolving round the sun.	Time of turning on their axis.	Diameter in miles.	The Earth being 1.			Greatest distance from the Ecliptic.	Hourly motion in miles.
					Bulk.	Heat and Light.	Density.		
Sun	—	—	25,5 d.	883217	1380000	—	1/4	—	—
Mercury	37	87,97 d.	24 h.	3123	1/15	6,68	2	7° 40′	110000
Venus	68	224,7 ..	23,36 h.	7702	8/9	1,91	1 1/4	3° 20′	84000
Earth	95	365,25 ..	24 h.	7916	1	1,	1	0	68000
Mars	144	687,00 ..	24,64 h.	4398	7/31	,43	7/10	1° 50′	54000
Vesta	223	1313,00 ..	unkn.	unkn.	unkn.	,18	unkn.	7° 9′	45000
Juno	253	1586,00 ..	* 27 h.	*1545	* 1/135	,14	unkn.	13°	42000
Pallas	263	1680,00 ..	unkn.	*2280	* 1/72	,13	unkn.	34° 30′	41000
Ceres	263	1980,00 ..	unkn.	*1761	1/90	,13	unkn.	10° 30′	41000
Jupiter	490	4332,60 ..	9,94 h.	89170	1400	,037	23/100	1° 19′	30000
Saturn	900	10759,0 ..	10,27 h.	79042	1000	,011	9/100	2° 29′	22000
Uranus	1800	30688,0 ..	unkn.	35100	90	,0027	1/5	0° 49′	15000

Those marked * are uncertain.

Note. The planets receive light and heat from the sun according to the square of their distances, that is, light and heat *decrease* as the square of the distance *increases*. If the distance of one planet be called 1, of another 2, and of a third 3, the heat and light received at the first is $1\times1=1$, at the second $2\times2=4$ times less, or $\frac{1}{4}$, at the third $3\times3=9$ times less, or $\frac{1}{9}$. The following rule may be given; as the square of the distance of any planet from the sun is to 1, which represents the light and heat received at the earth, so is the square of the earth's distance from the sun, to the degree of light and heat received at the planet in question.

The attraction of bodies *decreases* as the square of the distance *increases;* the attraction is mutual, and greater or less according to their solid contents.

The following is the rule for finding the distances of the planets from the sun:—as the square of the earth's period of revolution round the sun is to the cube of its distance, so is the square of any other planet's annual period of revolution to the cube of its distance; and the cube root of the number thus found will be the planet's distance from the sun. It was ascertained by Kepler and demonstrated by Newton, that from the combined forces of attraction and rectilinear motion, the *squares* of the periodical times or revolutions of the planets are, as the *cubes* of their distances. It was ascertained by Kepler also, that if a line were drawn from the sun to the earth, this line would, by the earth's motion, pass over equal spaces, or areas in equal times.

To such pupils as are sufficiently acquainted with Arithmetic, the instructer should explain at large the particulars mentioned in the above note. Questions may easily be proposed, and worked out by the above rules:—for instance, if the period of Mercury be 88 days, what is its distance from the sun?—If the heat and light at the earth be 1, what is the degree of heat and light at Mercury? and so of other planets.

To find how many times one planet is greater than another, the rule is, cube the diameter of each planet, and divide the greater number by the less, the quotient will give the proportional magnitudes, or the number of times the one is greater than the other.

LESSON 44.

Fig. 40. Engraving V. S represents the sun, and N S is the earth in different parts of its orbit. The white circle in the dark space represents the ecliptic. The dark circular space filled with stars extending eight degrees from each side of the ecliptic represents the zodiac. The names of the signs of the zodiac and the characters which represent

them are placed around the zodiac, as Aries, Taurus, &c. At March 20th, the earth as seen from the sun appears at the beginning of the sign *Libra;* but the sun as seen from the earth, at that time, appears at the beginning of the sign Aries. Some of the particulars mentioned in Lesson 44 should be illustrated by the instructer by means of globes, if access to them can be obtained, or by such sensible objects as he can prepare for the purpose.

LESSON 45.

Day and Night. Fig. 40. If the line N S, which represents the axis of the earth, were always in the circle that divides the light hemisphere from the dark one, the days and nights would be every where equal; for an inhabitant at the equator, and one on the same meridian towards the poles, would come into the light at the same time, and immerge into darkness at the same time. But the line N S is not in this circle, but has more or less of the positions as represented at the sign Cancer or Capricorn, that is, at Dec. 23d or June 21st. Here it is plain that an inhabitant at the equator does not come out of the dark hemisphere or immerge into it at the same time with an inhabitant on the same meridian towards the poles. But while the earth is at Capricorn, an inhabitant on the north side of the equator is in the light hemisphere longer than in the dark; that is, the day is longer than the night. But at Cancer, an inhabitant on the north side of the equator is in the dark hemisphere longer than in the light; that is, the night is longer than the day: whereas at the equator, in all situations of the earth, day and night are equal.

LESSON 46.

Changes of the Seasons. Fig. 40. The variety of the seasons depends (1,) upon the length of the days and nights; and (2,) upon the position of the earth with respect to the sun. In what manner the seasons are affected by the different lengths of the days and nights must be evident from what has been said above; and as to the other circumstance, it is manifest from a mere inspection of the figure, that in June the sun's rays will fall more perpendicularly upon an inhabitant on the north side of the equator than in Dec., for

N is turned towards the sun in June and from it in Dec.: it is warmer therefore at the former season than at the latter. But to render the subject more plain it may be proper to trace the annual motion of the earth in its orbit. About the 20th of March the earth is in Libra, and consequently to its inhabitants the sun will appear in Aries, and be vertical to, or over the equator. The equator and all its parallels are then equally divided between the light and the dark, and consequently the days and nights are equal all over the world. As the earth pursues its journey from March to June, its northern hemisphere comes more into light, and on the 21st of that month, the sun is vertical to the tropic of Cancer. All the circles parallel to the equator are then unequally divided; those in the northern half have their greater parts in the light, and those in the southern have their longer parts in darkness; it is summer therefore to the inhabitants of the northern hemisphere, and winter to the southern. Trace the earth now to September, and the sun is found vertical again to the equator, and, of course, the days and nights are again equal. And following the earth in its journey to December, or when it has arrived at Cancer, the sun appears in Capricorn; and it is vertical to that part of the earth called the tropic of Capricorn, and now the southern pole is enlightened, and all the circles in that hemisphere have their longer parts in the light, and, of course, it is summer to those parts, and winter to us in the northern hemisphere.

NOTE. Since it is summer to all those parts of the earth, where the sun is vertical, and we find the sun is vertical twice in the year to the equator, and every part of the globe between the equator and tropics, consequently there are two summers in a year to all those places; and in those parts near the equator, they have two harvests every year.

LESSON 48.

Figures 42 and 43. *The Tides.* S the sun, M the moon, E the earth, represented as covered with water. When the waters at *c* fig. 42, are under the moon, they will be heaped up at *c*, and recede from the intermediate points *a* and *b*, and being less attracted on the opposite side will be heaped up also at *d*. The sun tends to raise tides at *a* and *b*, but its only effect is to diminish those of the moon. In fig

43, both the moon and sun tend to raise tides at the same places as at *a* and *b*.

LESSON 49.

Eclipses, *figures* 44, and 45, Engr. VI. *Fig.* 45, represents an eclipse of the moon. A F and B G are two straigh lines drawn from the opposite parts of the solar disk, touching the surface of the earth at C and D. The moon *m* is seen passing through the earth's shadow in opposition to the sun. Besides the dark shadow of the earth, C F D G which would terminate in a point if continued far enough, there is another shadow C r s D, distinct from the former and called the *penumbra,* which is faint at the edges towards r and S but becomes darker towards F and G. The instant the moon enters the earth's shadow at *x*, it is deprived of the sun's light, and is eclipsed to all in the illuminated hemisphere of the earth. As the shadow of the earth is but a little darker than the region of the penumbra next it, it is difficult to determine the exact time when the moon passes from the penumbra into the shadow, and from the shadow into the penumbra, that is, when the eclipse begins and ends. *Fig.* 44, represents an eclipse of the sun. As the sun constantly illuminates half the earth's surface, and as the moon's shadow falls upon but a part of this illuminated hemisphere, the sun therefore appears eclipsed to but a part of those to whom he is visible. Sometimes when the moon is at its greatest distance, its shadow *o m* terminates before it reaches the earth, and then to an inhabitant directly under the point *o*, the eclipse will appear annular. The other shadow C r s D is the penumbra. Within the dark shadow, the sun is *totally* eclipsed, but within the penumbra, only a part of the sun's rays are intercepted, and the sun is *partially* eclipsed. The beginning and ending of a solar eclipse may be determined instantaneously. The penumbra, under the most favourable circumstances, falls upon but about half of the illuminated hemisphere of the earth. Note. The pupil should be taught to enlarge the above as well as other explanations of the figures.

LESSON 60. *Caloric.*

Different kinds of Thermometers. Fahrenheit's thermometer is universally used in Great Britain, and for the most part throughout the United States. In it, the range between the freezing and boiling points of water is divided into 180 degrees; and as the greatest possible degree of cold was then supposed to be that produced by mixing snow and common salt, it was made the zero, or commencement of the scale, hence the freezing point became 32° and the boiling point 212°. *Reaumer's* thermometer, which was formerly used in France, divides the space between the freezing and boiling of water into 80°, and places the zero at the freezing point. The *Centigrade* thermometer places the zero at the freezing point, and divides the range between it and the boiling point into 100°. This has long been used in Sweden under the title of Celsius's thermometer. *De Lisle's* thermometer is used in Russia. The graduation begins at the boiling point, and increases towards the freezing point. The boiling point is marked 0 and the freezing point 150.

LESSON 65.

Simple Combustibles. The following is an enumeration and classification of the simple bodies in general. I. Comprehending the imponderable agents, *Heat* or *Caloric*, *Light*, and *Electricity*. II. Comprehending agents capable of uniting with inflammable bodies, and in most instances of effecting their combustion,—*Oxygen*, *Chlorine*, and *Iodine*. Many learned chemists have doubted whether Chlorine and Iodine were supporters of combustion, any farther than they contain oxygen. They are classed among the simple bodies because they have not, as yet, been resolved into other ingredients. The name chlorine is simply expressive of its greenish colour, and iodine of its violet colour. III. Comprehending bodies capable of uniting with oxygen, and forming with it various compounds,—1. *Hydrogen*, forming water. 2. Bodies forming acids. *Nitrogen*, forming nitric acid. *Sulphur*, forming sulphuric acid. *Phosphorus*, forming phosphoric acid. *Carbon*, forming carbonic acid. *Boron*, forming boric acid. *Fluorine*, forming fluoric acid. 3. Metallic bodies, which have been divided into the seven following classes. 1st. The metals which combine with oxygen and form alkalies. These are *potassium*, *sodium*, and *lithium*. The volatile alkali ammonia has been found by Sir H. Davy to be a triple compound of nitrogen, hydrogen, and oxygen. 2d. Those metals which by combining with oxygen form the alkaline earths; viz. *calcium*, *magnesium*, *barium*, and *strontium*. Calcium is the base of lime, magnesium of magnesia, and so on. These metallic substances are of the colour of silver. 3d. Those metals which by combining with oxygen constitute the remainder of the earths. These are *silicum*, *alumium*, *zirconium*, *glucinum*, *yitrium*, and *thorinum*. These are *presumed* metals, for the earths, of which they are supposed to constitute the bases, have been as yet but partially decomposed: respecting some of them little is known. 4th. The metals which absorb oxygen and decompose water at a high temperature. These are *iron*, *tin*, *zinc*, *cadmium*, and *manganese*. 5th. Those metals which absorb oxygen at different temperatures, but do not decompose water at any temperature. This class is composed of twelve distinct metals, viz. *osmium*, *cerium*, *tellurium*, *titanium*, *uranium*, *nickel*, *cobalt*, *copper*, *lead*, *antimony*, *bismuth*, and *mercury*. 6th. Those metals which do not decompose water, but absorb oxygen, and are thereby converted into acids. These are *arsenic*, *molybdenum*, *tungsten*, *chromium*, *columbium*, and *selenium*. 7th. The metals which do not decompose water, nor absorb oxygen from the atmosphere at any temperature. These are *platina*, *gold*, *silver*, *palladium*, *rhodium*, and *iridium*.

LESSON 66.

A Retort, fig. 48, Engr. VI. A vessel in the shape of a pear, with its neck bent downwards, used in distillation. The extremity of the neck may be fitted into another glass vessel, called a receiver. Fig. 48, represents a *common* glass retort, an instrument much used in chemical laboratories for various purposes. A *tubulated* retort is an instrument like the latter, with a tube at the bend T, and with a ground glass stopper to fit it. This is the most useful kind of retort, as materials may be put in through the tube during the operation. The student may find engravings and descriptions of a chemical apparatus in Parkes' Rudiments of Chemistry.

NOTE. Chlorine may be procured by heating in a glass retort a mixture of equal weights of the black oxyd of manganese and common muriatic acid (spirit of salt.) The gas is soon liberated, and may be conveniently collected over warm water. The attraction of chlorine for the metals is in most instances extremely energetic: when copper leaf, or antimony, or arsenic in powder, are thrown into the gas, they immediately enter into vivid combustion and form binary compounds. Upon the French theory of combustion, oxygen is absolutely necessary to the phenomena, but here are instances of brilliant inflammation without the presence of that body (that is if chlorine be a simple substance, containing no oxygen.) Other cases might be adduced, such as the combustion which ensues when copper filings and sulphur are heated together in an exhausted vessel, or when potassium and arsenic are made to combine under similar circumstances. Combustion therefore is to be regarded as the general result of the exertion of powerful chemical attraction, and not as dependent upon any peculiar substance, or as resulting from the decomposition of any distinct form of matter. When phosphorus is introduced into chlorine, it spontaneously ignites and burns with a pale yellowish flame, producing a white volatile substance, composed of two proportions of chlorine and one of phosphorus.

LESSON 67.

Electrical Machine, fig. 49. A the glass cylinder.—B the prime conductor.—R the rubber, or cushion.—C the chain.

LESSON 68.

Leyden Phial, fig. 50. A a round brass ball at the extremity of a wire, which passes through a cork D. R is a discharging rod,—*a a* two brass knobs or balls attached to wires which are fastened to the handle at *x*.

LESSON 70.

Voltaic pile, fig. 47. The pieces of copper, zinc, and woollen cloth, are supported with three rods of glass, as ***a b***, ***a b***, ***a b***, and pieces of wood *x* and z.

LESSON 71.

Fig. 46. A B a trough made of baked wood.—*w w* are wires fastened to pieces of copper and put into the outer cells

—*a a* are little glass tubes to hold the wires by,—*v* is a glass plate on which the ends of the wires are to be brought together.

LESSON 76.

Mineralogy. Werner divides the external characters of minerals into two kinds, namely, *general* and *particular.* The general characters are the following: 1. Colour; 2. Cohesion; 3. Unctuosity; 4. Coldness; 5. Weight; 6. Smell; 7. Taste. The particular characters are the following: 1. Aspect of the surface; 2. Aspect of the fracture; 3. Aspect of the distinct concretions; 4. General aspect; 5. Hardness; 6. Tenacity; 7. Frangibility; 8. Flexibility; 9. Adhesion to the tongue; 10. The sound.

General Characters. I. The *colours* of minerals are extremely various. Werner conceives eight fundamental colours, and describes all the others as compounds of various proportions of these. The fundamental colours are, 1. Snow white. 2. Ash grey. 3. Velvet black. 4. Berlin or Prussian blue. 5. Emerald green. 6. Lemon yellow. 7. Carmine red. 8. Chestnut brown. II. With respect to *cohesion*, minerals are either *solid, friable*, or *fluid.* III. With respect to *unctuosity*, minerals are distinguished into *greasy*, and *meagre;* the first have a certain degree of greasiness in the feel; the second not. The other four general characters require no particular description.

Particular characters. I. In the *aspect* of the surface of a mineral, three things claim attention. 1. The *shape* of the mineral. 2. The kind of *surface.* 3. The *lustre* of the surface, which is either splendent, shining, glistening, glimmering, or dull. II. When a mineral is broken, the new surface exposed is called the fracture. Three things claim attention: 1. The *lustre* of the fracture. 2. The *kind* of fracture. 3. The *shape* of the fragments. III. *Distinct concretions* are distinct masses, which may be separated from each other, without breaking through the solid part of the mineral, by natural seams. Three particulars with respect to these are, 1. Their *shape.* 2. Their surface, 3. Their lustre. IV. Under the head of *general aspect*, three particulars are comprehended, 1. The *transparency.* 2. The streak. 3. The soiling, or the *stain* left when rubbed. V. Minerals are either, 1. *Hard*. 2. *Semihard*, or, 3. *Soft*. VI. With respect to *Tenacity*, minerals are, 1. *Brittle*, when on being cut with a knife the particles fly away with noise; 2. *Sectile*, when the particles do not fly off but remain; 3. *Ductile*, when the mineral can be cut into slices. VII. By *Frangibility* is meant the resistance which minerals make when we attempt to break them. The degrees are five, 1. *Very tough;* 2. *Tough;* 3. *Moderately tough;* 4. *Fragile;* 5. *Very fragile*. VIII. With respect to *Flexibility*, some are, 1. *Elastic;* others, 2. *Common;* others, 3. *Inflexible*. IX. Some minerals *adhere* to the tongue, 1. Very *strongly;* 2. others *moderately;* 3. others *slightly;* 4. and others *very slightly*. X. Some minerals give a *ringing* sound; others a *grating* sound; others a *creaking* sound, as tin.

With respect to *electricity*, some minerals become electric when *heated*, others when *rubbed*, others cannot be rendered electric. The electricity of some is *positive*, of others *negative*.

LESSON 79.

Silver and Mercury. Freezing mixtures. Salts dissolved in water, ice, or snow dissolved in nitric and muriatic acids, reduce the temperature of the mixtures a great number of degrees. Mercury has been frozen or rendered solid, even in summer, though it requires the temperature of 39° below zero at least to congeal that metal. Four parts of caustic potash, crystallized, and reduced to a fine powder, mixed with three parts of snow sinks the mercury in a thermometer from 32° above to 51° below zero. Two parts muriate of lime mixed with one of snow, sinks it from zero to 66° below zero. The cause is, that the mixture has a larger capacity for caloric than would be derived from blending the two capacities of the ingredients, and taking a mean proportional between them.

LESSON 91.

Roots, Stems, Buds and Leaves. The generality of roots may be arranged under the following heads. 1. A *Fibrous Root*, consisting only of fibres either branched or undivided. Many grasses and the greater part of annual herbs have this kind of root 2. A *Creeping Root*, as in Mint. 3. A *Spin-*

dle-shaped or *Tapering Root*, as the Carrot, Parsnip, and Red Clover. 4. An *Abrupt Root*, is naturally inclined to the last mentioned form, but from some decay or interruption in its descending point, it becomes abrupt, or as it were bitten off. It is found in many of our native Violets. 5. A *Tuberous* or *Knobbed Root*, is of many different kinds, as in the Potatoe and the Artichoke. Several of the Pea kind are furnished with them on a smaller scale. 6. A *Bulbous Root*, is either *solid*, as in the Crocus; *tunicate*, composed of concentric layers, as in the onion; or *scaly*, like that of the Lily. 7. A *Jointed* or *Granulated Root*, as in the Wood Sorrel and White Saxifrage. It is evident that fleshy roots, whether of a tuberous or bulbous nature, must at all times powerfully resist the drought. The common herdsgrass, or Timothy, when growing in pastures that are uniformly moist, has a fibrous root, but in dry situations, it acquires a bulbous one. This is an evident provision of nature to guard the plant against too sudden a privation of moisture from the soil.

The seven kinds of stems are as follows. 1. *Caulis*, a *stem* properly so called, which bears or elevates from the root, the leaves or flowers. The trunks and branches of all trees and shrubs come under this denomination, as well as of a greater proportion of herbaceous plants. 2. *Culmus*, a *straw* or *culm*, is the peculiar stem of grasses, rushes, and plants nearly allied to them. 3. *Scapus*, a *stalk*, springs from the root, and bears the flowers and fruit, but not the leaves, as in the Primrose and Cowslip. 4. *Pedunculus*, the *Flower-stalk*, springs from the stem, and bears the flowers and fruit, but not the leaves. 5. *Petiolus*, the *Foot-stalk*, or *Leaf-stalk*. This term is applied exclusively to the stalk of a leaf. 6. *Frons.* A *Frond.* In this the stem, leaf, flowers, and fruit are produced from the leaf itself as in the Fern tribe. 7. *Stipes*, *Stipe*, is the stem of a frond, which in ferns is commonly scaly.

Botanists enumerate above 100 distinctions of leaves, according to their position and form.

There are several kinds of *appendages* to a plant which were not mentioned in any of the Lessons on Botany. 1. *Stipula*, *Stipule*, a leafy appendage to the proper leaves or to their footstalks. They are usually found in pairs at the base of the petiole. In the common Pea they are round, and in other plants they assume other figures. In the natural order of Grasses it is solitary, forming a membranous scale, which arises from the summit of the sheath, and like it encloses the culm. 2. *Bractea*, The *Floral Leaf*, a leafy appendage to the flower or its stalk. It is of a variety of forms. 3. *Spina*, a *thorn*, which proceeds from the wood itself. 4. *Aculeus*, a *prickle*, arises from the bark only and comes off with it. 5. *Cirrus*, a *tendril*. This is intended solely to sustain weak and climbing stems upon more firm and sturdy ones. Tendrils or claspers when young are usually put forth in a straight direction; but they presently become spiral. 6. *Glandula*, a *gland*, a little tumour discharging a fluid. They occur in the substance of the leaves of the Myrtle, Lemon, and common St. John's Wort. 7. *Pilus*, a *hair*. This is an excretory duct of a bristle like form. In the Nettle it is tubular and pervious, having each a bag of poison at its base, like the fang of a serpent. But the hairs which clothe many plants are merely a protection against cold, heat, or insects.

The several kinds of Inflorescence, or modes of flowering are as follows. 1. The *Umbel*, a number of flower stalks issuing from a common centre, diverging like the rays of an umbrella, bearing their flowers on the summit, and raising them about the same height. The Carrot, Parsnip, and Hemlock are familiar examples, which, with all others like them in this respect, are called umbelliferous plants. 2. A *Cyme* has the general appearance of an umbel, and agrees with it so far that its common stalks all spring from one centre, but differs in having those stalks variously and alternately subdivided, as in the Elder and other species of Viburnum. 3. A *Corymb* is a spike whose partial flower stalks are gradually longer as they stand lower, so that all the flowers are nearly on a level. The flowers of Yarrow grow in this manner. 4. A *Fascicle* is an assemblage of flowers more densely arranged than in the Corymb, as in the Sweet-William. 5. A *Spike* is an assemblage of flowers arising from the sides of a common stem, as in the herdsgrass. The flowers are commonly all crowded close together, but sometimes they form separate groups, as in some Mints. 6. A *Raceme*, or cluster, as in the Currant. 7. A *Head*, or Tuft, (*capitulum*) is an assemblage of flowers upon the extremity of the branch or stem, and arranged in a globular, oval or cylindrical form, as in the Globe Amaranth, and in several species of Clover. 8. A *Whorl* (*Verticillus*) is an assemblage of flowers surrounding the stem or its branches, as in the Dead Nettle and Mint. 9. A *Panicle* bears the flowers in a sort of loose subdivided bunch or cluster, without any order, as in the Oat. 10. A *Thyrse* is a dense or close panicle, more or less of an ovate figure, of which the Lilac is an example.

LESSON 92.

Flower and Fruit. The *Calyx,* Flower-cup, or Empalement, as it is sometimes called, is divided into seven kinds. 1. A *Cup,* (*Perianthum*) properly so called, as in the five green leaves which encompass a Rose. 2. A *Fence,* (*Involucrum*) as in the Hemlock or Carrot. 3. A *Catkin* (*Amentum*) as in the Willow or Hazel. 4. A *Sheath,* (*Spatha*) as in the Snow-drop or Narcissus. The Spatha sometimes encloses a *Spadix,* or elongated receptacle, as in Dragon-root. In Indian corn, the spadix is enclosed by leaves or husks; in the Sweet Flag, it is naked. 5. A *Husk,* (*Gluma*) as in oats, wheat, or grasses. 6. A *Veil,* or *scaly sheath,* (*Perichaetium*) as in some mosses. 7. A *Cap,* or *Wrapper,* (*Volva*) as in mushrooms.

The seed-vessel (*Pericarpium*) is also divided into seven kinds. 1. A Capsule, as in the poppy. 2. A Pod, (*Siliqua*) as in wall-flower and honesty. 3. A Legume, or Shell, as in pea and broom. 4. Drupe, as in cherry and peach. 5. A Berry, (Bacca) as in elder and gooseberry. 6. A Pome, as in apple and pear. 7. A Cone, (*Strobilus*) as in fir and pine.

A *Seed* is composed of several parts. *Embryo,* or germ called by Linnæus *Corculum,* or little heart. The *Cotyledons* or seed-lobes, immediately attached to the embryo. *Albumen,* or the White, a farinaceous substance to nourish the germinating embryo. The *Yolk,* (*Vitellus*) less general than the other parts already mentioned, but absorbed, like the albumen, for the nourishment of the embryo. The *Skin* (*Testa*) contains all the parts of a seed above described, giving them their due shape. The *Scar,* (*Hilum*) the point by which the seed is attached to the seed-vessel, or receptacle. The *Pellicle,* closely adhering to the outside of some seeds, so as to conceal the proper colour and surface of their skin. The *Tunic*, (*arillus*), a complete or partial covering of a seed, fixed to its base only, and more or less loosely, or closely enveloping its other parts. The *Seed-down*, (*Pappus*,) the chaffy, feathery, or bristly crown of many seeds that have no Pericarp. Its use is to transport seeds from their native spot, as in the Thistle, and Dandelion. The *Tail*, (*Cauda*,) formed from the permanent style, and generally of a feathery, hairy appearance. *Beak*, (*Rostrum*,) an elongation of the seed-vessel, though applied to some naked seeds. A *Wing* (*Ala*) is a membranous appendage to seeds, or their capsules. The *Awn* is usually an appendage to the flower and seeds of grasses Seeds are occasionally furnished with spines, hooks, scales, &c., designed for their security while living, and for their subsequent dispersion.

LESSON 93.

Table of the 24 Classes.

1	Monandria.... 1	Stamen.	*Pigeon's foot and Star wort.*
2.	Diandria..... 2	stamens.	*Pennyroyal, Lilac.*
3.	Triandria.... 3	do.	*Blue flag, Herdsgrass.*
4.	Tetrandria... 4	do.	*Chequer berry, Witch hazel.*
5.	Pentandria... 5	do.	*Swamp Pink, Mullein, Violet.*
6.	Hexandria... 6	do.	*Barberry, Lily, Sweet Flag.*
7.	Heptandria .. 7	do.	*Horse chestnut.*
8.	Octandria... 8	do.	*Blue berry, Crane berry.*
9.	Enneandria.. 9	do.	*Sassafras, Fever bush.*
10.	Decandria... 10	do.	*Ground Laurel, Chickweed, Pink.*
11.	Dodecandria . 12	do.	*Purslane, Wild Ginger.*
12.	Icosandria... 20	do. or more, inserted into the Calyx.	*Rose.*
13.	Polyandria...	Many Stamens, inserted into the receptacle.	*Buttercups.*
14.	Didynamia...4	Stamens; 2 long and 2 short.	*Spearmint, Catmint.*
15.	Tetradynamia 6	do. 4 long and 2 short.	*Mustard.*
16.	Monadelphia .	Filaments united at bottom, but separate at top.	*Mallow.*
17.	Diadelphia ..	Filaments in two sets.	*Fumitory, Lupine.*
18.	Polyadelphia .	Filaments in many sets.	*St. John's Wort.*

19. Syngenesia . . Anthers united into a cylinder; flowers compound.
20. Gynandria. . . Stamens and pistils together. *Ladies' Slipper.*
21. Monœcia . . . . Stamens and pistils in separate flowers, upon the same plant. *Nettle.*
22. Diœcia. . . . . . Stamens and pistils in separate flowers, upon different plants. *Hop.*
23. Polygamia . . Variously situated.
24. Cryptogamia. Flowers inconspicuous.

The names of the classes, which at first sight appear difficult, are formed of Greek words, expressive of the characters of each class; and those of the first ten classes may be easily remembered, by considering the word *andria*, as meaning the same as *stamens*, and annexing it to the Greek numerals.

The names of the *orders*, like those of the classes, are formed from the Greek numerals, but with the addition of the word *gynia*, instead of *andria;* so that when there is but one pistil, the plant is said to be in the order monogynia; if there are two, *digynia*, &c.

Names of the Orders of first 13 *Classes.*

Monogynia	1	pistil.
Digynia	2	pistils.
Trigynia	3	do.
Tetragynia	4	do.
Pentagynia	5	do.
Hexagynia	6	do.
Heptagynia	7	do.
Octagynia	8	do.
Enneagynia	9	do.
Decagynia	10	do.
Dodecagynia	12	do.
Polygynia	Many pistils.	

The 14th class has only two orders; *gymnospermia*, in which the seeds are naked at the bottom of the calyx; and *angiospermia*, in which they are enclosed in a seed vessel. Examples of the first are spearmint, motherwort, and catmint, and of the second, cow-wheat, toad-flax, and beech-drops, The two orders of the 15th class are distinguished by the form of the fruit; the first, called *siliculosa*, has broad short pods, as in pepper-grass or wild-cress; and the second, called *siliquosa*, is known by its long pods, as in wild radish and common mustard. The orders of the 16th, 17th, and 18th classes, are characterized by the number of *stamens* in each flower, and the names of some of the *classes*, therefore, are used to distinguish them, as Triandria, Decandria, Polyandria, &c. The 19th class has five orders, 1st, *æqualis*, all the florets with stamens and pistils, and all fertile; as dandelion, burdock, and cotton thistle: 2d, *superflua*, florets of the disk, or surface with stamens and pistils, those of the margin with pistils only, all fertile, as common life-everlasting, white weed, and elecampane: 3d, *frustanea*, florets of the centre with stamens and pistils, fertile; those of the margin with pistils only, barren, as the sunflower: 4th, *necessaria*, florets of the centre with stamens and pistils, barren; those of the margin with pistils only, fertile, as what is called high water shrub, growing about the borders of salt marshes: 5th, *segregata*, comprehends such flowers as have tubular florets, all perfect, each floret having its own separate calyx, in addition to the general calyx, which includes all the florets, as the globe-thistle. The orders of the 20th, 21st, and 22d classes are distinguished by the number of *stamens*. The 23d class has three orders, 1st, *monœcia*, barren, fertile, and perfect flowers, found in one plant, as poke root, or American hellebore: 2d, *diœcia*, barren, fertile, and perfect flowers on different plants, as ginseng, swamp maple, rock maple, and white ash: 3d, *triœcia*, the same on three separate plants; of this, the figtree is supposed to be a solitary, though doubtful example. The 24th class has 5 orders, *Filices*, Ferns; *Musci*, Mosses; *Hepaticæ*, Liverwort; *Algæ*, Flags; *Fungi*, Mushrooms. The term, Algæ, was originally applied to marine plants, as sea-weeds, but it has been employed in a more extensive sense, and, among others, embraces the Lichens which cling to rocks. NOTE. The 21st, 22d, and 23d classes have been abolished by some writers.

The instructer should read and explain to his pupils the names of the classes and orders, and point out the circumstances on which their distinctions are founded, by the help of engravings, or real specimens.

It may be proper to give an example of the division of classes, orders, genera, and species. The geranium, from its having ten stamens united in one set, is in the *class* Monadelphia, and *order* Decandria: the whole family of the plant geranium constitutes a *genus* of the order above mentioned; and the different kinds, as ivy-leaved, rose-scented, spotted (*or Cranesbill,*) wood geranium, &c. are the different *species* of the genus.

To distinguish the species of a plant, botanists employ two words; the first which is called the *generic* name, is common to all the species of the same genus; and the second, termed the *specific* name, is confined to a single species. For example, *rosa damascena*, which is the botanic name for the damask rose, *rosa* is the *generic* name applicable to the whole genus or family of roses, and *damascena* is the *specific* name, used to distinguish the particular kind or species of rose. *Rosa alba*, or white rose, is another species. Sweet Briar is a species of rose, called *Rosa rubiginosa*. The genus *Rosa* is in the class Icosandria, having 20 or more stamens, inserted on the Calyx, and in the order Polygynia, having many pistils.

The Lily is represented in the upper part of Engr. VII. It belongs to the *class* Hexandria, *order* monogynia, having six stamens as *c c c c c c*, and one pistil as *d*. Its corolla is composed of six petals, as *b b b b b b*. The Lily has no calyx. Fig. 7 is an enlarged view of the pistil; *g* its receptacle or base, and *d* its style. Fig. 5 *e*, is the seed vessel or pericarpium, with its pistil represented as withered. There is an enlarged view also of a stamen with its filament, anther, and pollen.

Figures 1, 2, 3, 4, represent a Geranium with several of its parts separately sketched:—*a*, calyx five leaved, and 1, the same separated from the stem:—*b b b b*, the corolla, composed of five regular obcordate petals: the petals are called *obcordate*, because they are heart-shaped with the point inward or downward, as may be seen in *b* 2, which represents one of the petals apart from the rest.—The nectary in the spotted geranium consists of five glands, as *i i i i* on the base of the longer filaments, *c c c c*, four which only are represented in fig. 3.—*d* 4, a pistil, and *f* its seed or fruit.

The bottom fig. *h h* represents the base, or receptacle of the cotton thistle; it is cellular like a honeycomb,

LESSON 95. *Animal Kingdom.*

I. *Vertebral Animals.*

1. *Mammalia,* viviparous, and nourish their young with milk.
2. *Birds*, oviparous.
3. *Reptiles*, as frogs and serpents.
4. *Fishes.*

The two first of the above classes are warm blooded, and the two last cold blooded.

II. *Invertebral Animals.*

5. *Insects.*
6. *Crustacea,* as the lobster and crab.
7. *Mollusca*, as the oyster, clam, and cuttle fish.
8. *Vermes*, or worms, as the leech, earth worm, and hair worm.
9. *Zoophytes.* as the star fish, sponges, corals, and madrepores.

NOTE. According to the Linnæan arrangement, which will be found in most works that treat systematically of natural history, all animals are divided into six classes, 1. *Mammalia,* 2. Birds, 3. *Amphibia,* 4. Fishes, 5. Insects, 6. Worms.

LESSON 96. *Orders of Mammalia.*

1. The *Bimana* or *two handed* animals. Man is the only example. He has hands upon his superior extremities alone. He has nails of a thin and delicate texture, which give to his thumb and fingers a wonderful delicacy of touch.

2. The *Quadrumana* or *four handed* animals, comprising apes, monkeys, and baboons. They have hands upon all four of their extremities, but less perfect than those of man.

3. The *Carnivora* or *carnivorous* animals. These have no hands, but their feet are furnished with claws. NOTE. These three orders have all the three kinds of teeth, which differ however in shape and strength, according to the habits and food of the different species.

4. The *Rodentia* or *gnawers.* They have no canine teeth; and their claws are similar to those of the *carnivora.*

5. The *Edentata* or *toothless* animals; so called because they are deficient always in the incisive teeth, and sometimes have no teeth at all.

6. The *Ruminantia* or *ruminating* animals are those which chew the cud. They are cloven footed, and have moreover no incisive teeth in the upper jaw.

7. The *Pachydermata* or *thick skinned* animals. This order includes a considerable variety of other animals with hoofs, but which do not ruminate.

8. The *Cetacea,* or animals of the *whale* kind, distinguished by having no posterior extremities, and their anterior so constructed as to answer the purpose of fins, as whales, porpoises, and dolphins.

9. The *Marsupial* animals are distinguished from all others by the possession, in the female, of a bag or pouch (*marsupium*) on the outside of the abdomen, for the purpose of holding their young after birth. Note. Linnæus divided the class mammalia into seven orders; 1. *Primates,* of this order man was placed at the head, and next him, the ape, monkey, Oran-outang, and bat. 2. *Bruta,* as the elephant, sloth, and ant-eater. 3. *Feræ,* as the seal, dog, cat, and hedge-hog. 4. *Glires,* as beavers, mice, and hares. 5. *Pecora,* as oxen, sheep, goats, and others. 6. *Belluæ,* as the horse, hog, and the tapir. 7. *Cetæ,* as the whale tribes.

LESSON 97. *Birds.*

The orders of Birds according to Linnæus are, 1. *Accipitres.* 2. *Picæ,* or the pie kind, as parrots, ravens, crows, &c. 3. *Anseres,* or the duck kind. 4. *Grallæ,* or the crane kind. 5. *Gallinæ,* or the poultry kind. 6. *Passeres,* or the sparrow kind.

LESSON 98.

Linnæus divided his class *Amphibia* into four orders, 1. *Reptiles,* as the crocodile, tortoise, lizard, frog, &c. 2. *Serpents,* as the rattle-snake, viper, &c. 3. *Meantes,* as the siren. 4. *Nantes,* as torpedoes, sharks, &c.

LESSON 102. *Vermes.*

Linnæus divided Vermes or worms into five orders, 1. *Intestinal* worms, as tape worms, leeches, &c. 2. *Molluscous* worms, chiefly inhabiting the sea. 3. *Testaceous* worms, as muscles, oysters, snails, &c. 4. *Zoophytes.* 5. *Infusoria,* or animalcules.

NOTE. In treating of any particular animal, naturalists are accustomed to designate it by a name derived from its genus and species. This name is comprised of two words; the first being the name of its genus; and the second being altogether arbitrary, or else expressing some circumstance relating to the colour, size, or residence of the animal, which serves in a degree to distinguish it from others. The first is called its *generic*, the second its trivial or *specific* name. For example: in the class Mammalia, order carnivora, the *genus* Felis includes all those of the cat *kind* (Felis being the Latin word for cat) and these animals, although differing one from another very much in size and colour, have yet a very close resemblance in their general form, figure, character, and habits of life. The different *species* of the genus Felis are distinguished from one another in the following manner:—The Lion is called Felis leo; the Tiger, Felis tigris; the Leopard, Felis leopardus; the Lynx, Felis lynx, &c. In the genus Canis, the dog is called Canis domesticus; the wolf Canis lupus; the fox, Canis vulpes, &c. In the class of Birds, order accipitres, the genus Falco includes those of the eagle or hawk *kind*:—The fierce eagle is called Falco ferox, the common falcon, Falco communis, the American brown hawk, Falco fuscus, &c.

The Lessons on Zoology, in this Class Book, have been abstracted from Dr. John Ware's edition of Smellie's Philosophy of Natural History; chiefly from the Introduction, which was wholly prepared by Dr. W., whose system of classification is principally derived from Cuvier, a celebrated French naturalist. The class of insects, however, is arranged in orders according to the system of Linnæus. Besides the above, the following works have been consulted, and from many of them extracts made. Conversations on Natural Philosophy; Webster's Elements of Natural Philosophy; Blair's Grammar of Natural and Experimental

Philosophy; Blair's Universal Preceptor; Blair's Class Book; Joyce's Scientific Dialogues, 3 vols. 12mo. Wilkins' Elements of Astronomy; Parkes' Rudiments of Chemistry; Conversations on Chemistry; Thomson's System of Chemistry, 4 vols. 8vo.; Wakefield's Introduction to Botany; Smith's Introduction to Physiological and Systematical Botany; Sumner's Compendium of Physiological and Systematic Botany; Bigelow's Collection of Plants of Boston and its Vicinity; Conversations on Political Economy; Kett's Elements of General Knowledge; Paley's Natural Theology; Paley's Moral Philosophy; Brown's Lectures on the Philosophy of the Human Mind; Rees' Cyclopædia; Nicholson's Encyclopædia; North American Review; United States Literary Gazette.

THE END.

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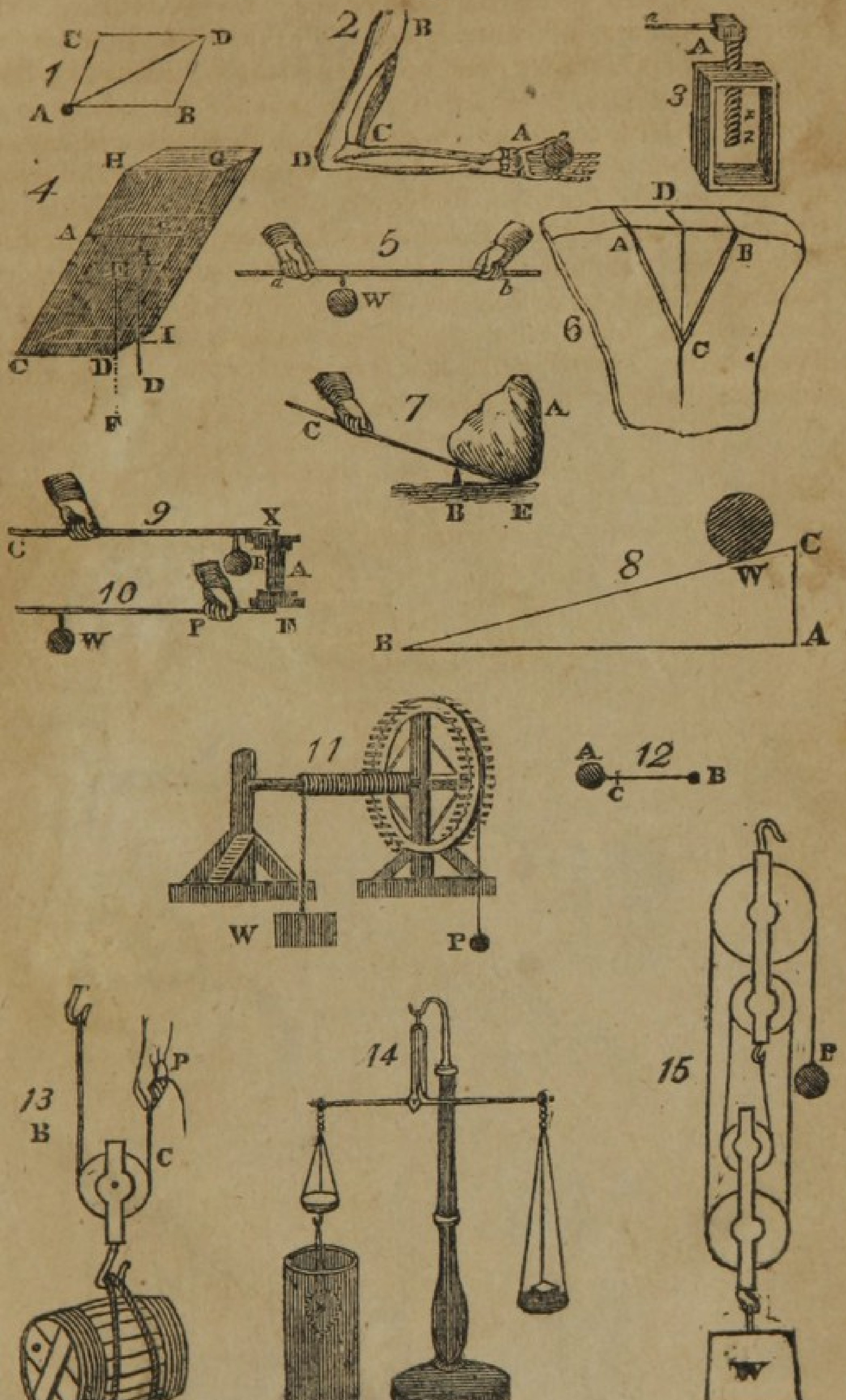
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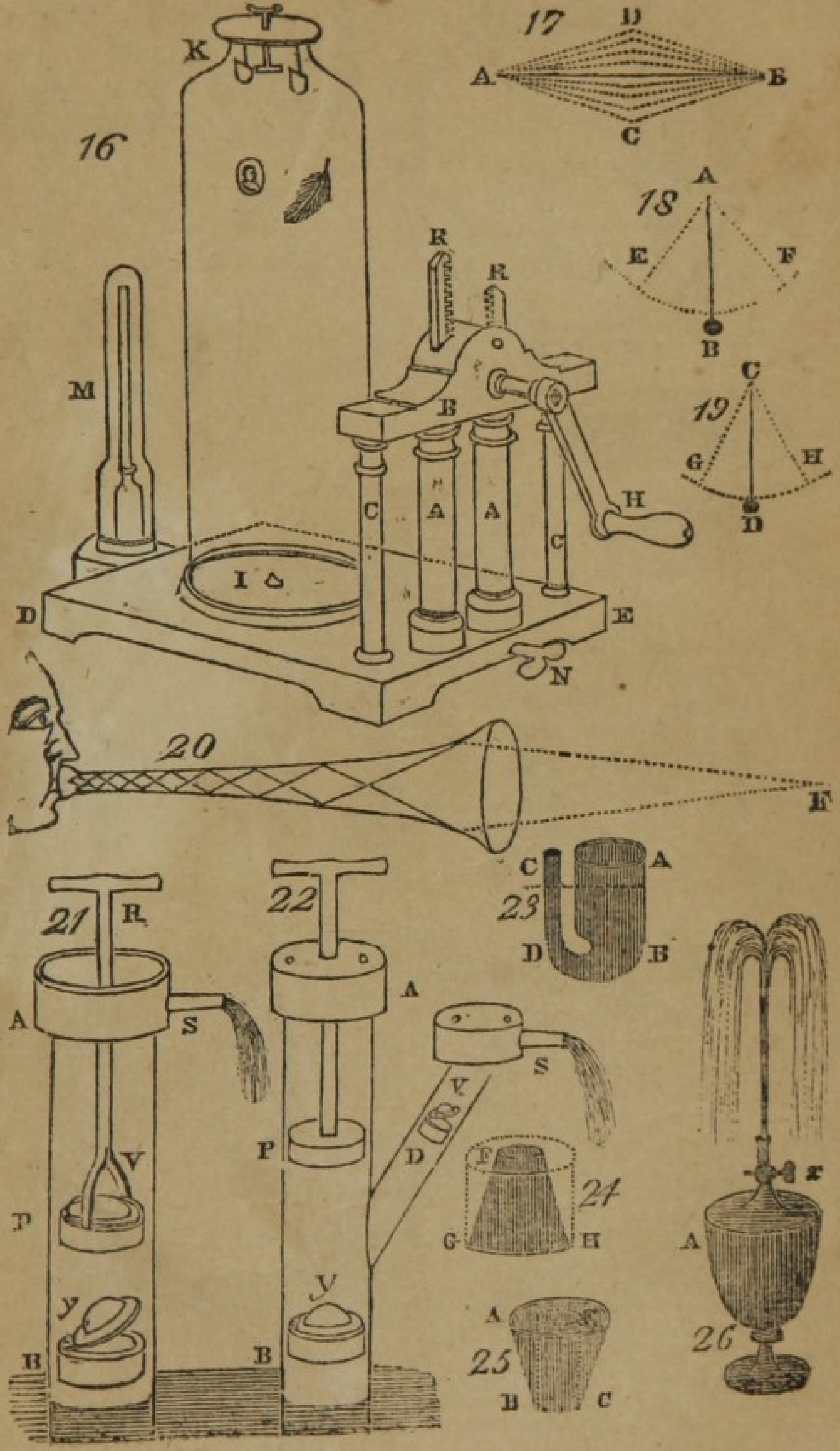

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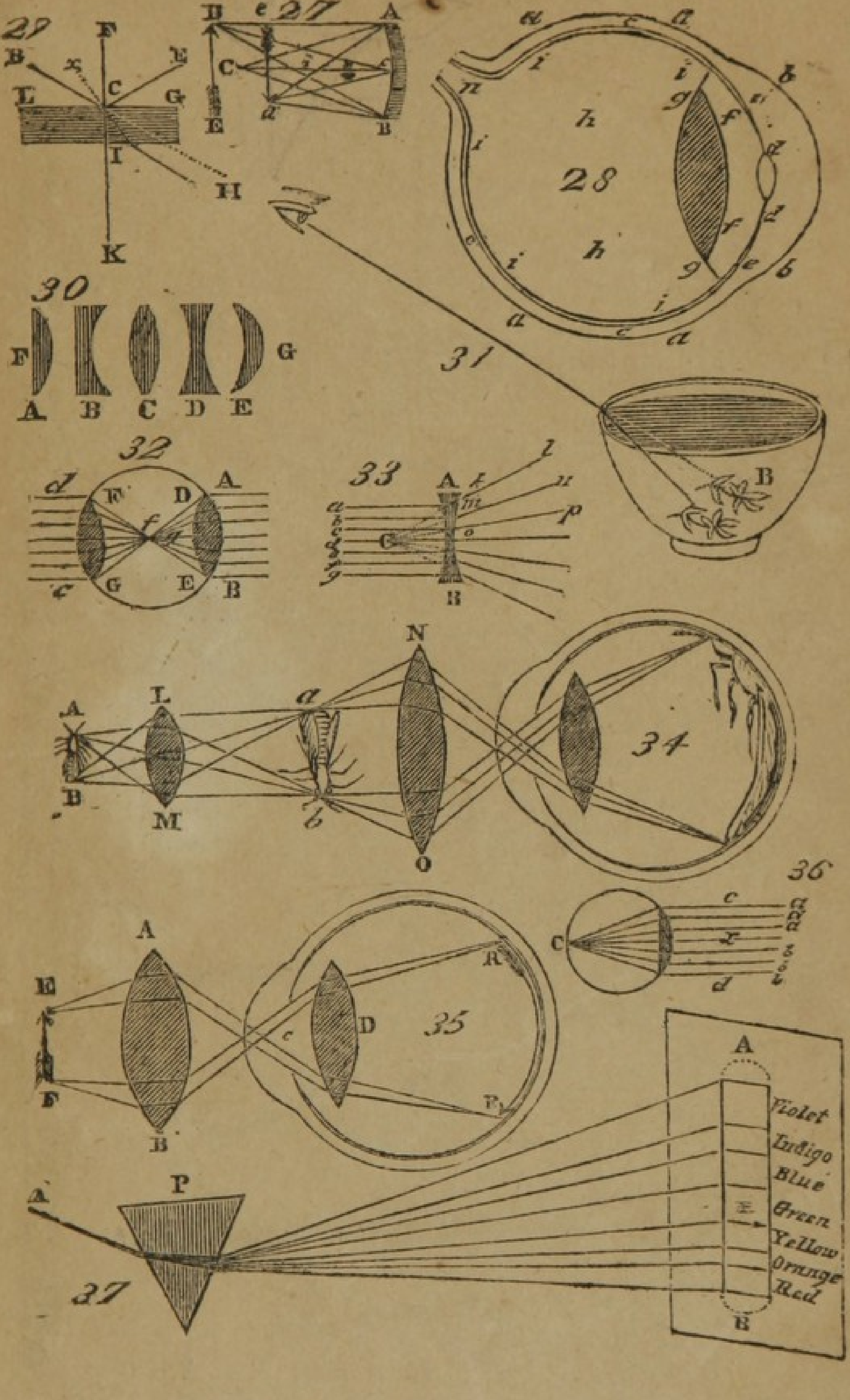
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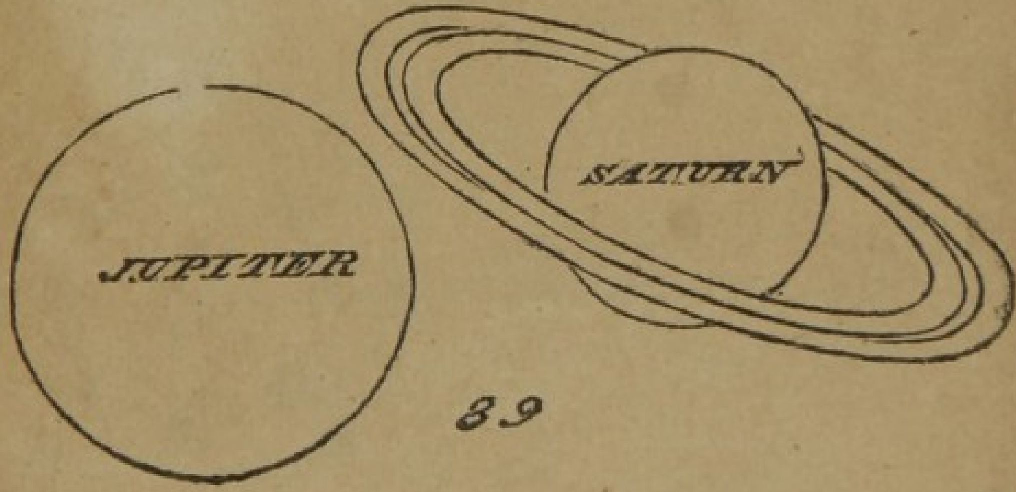
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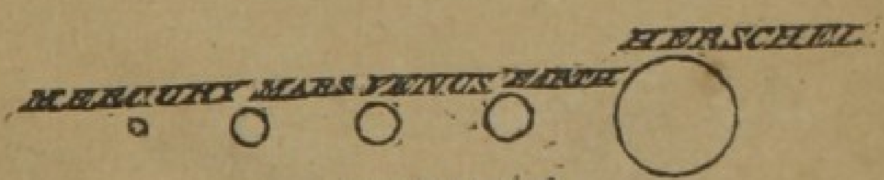
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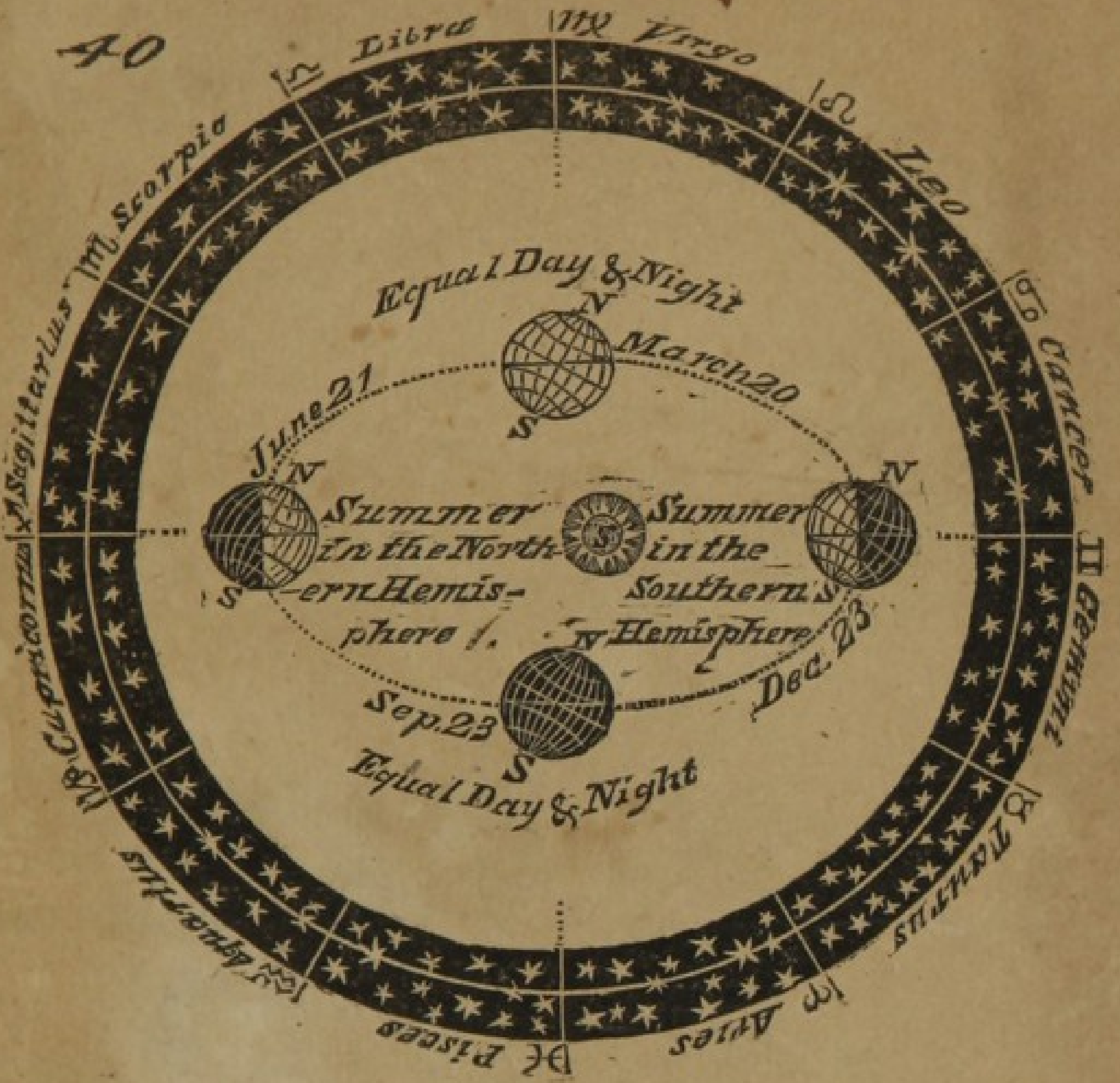
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Aquarius
Taurus
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Dec. 23
Sep. 23
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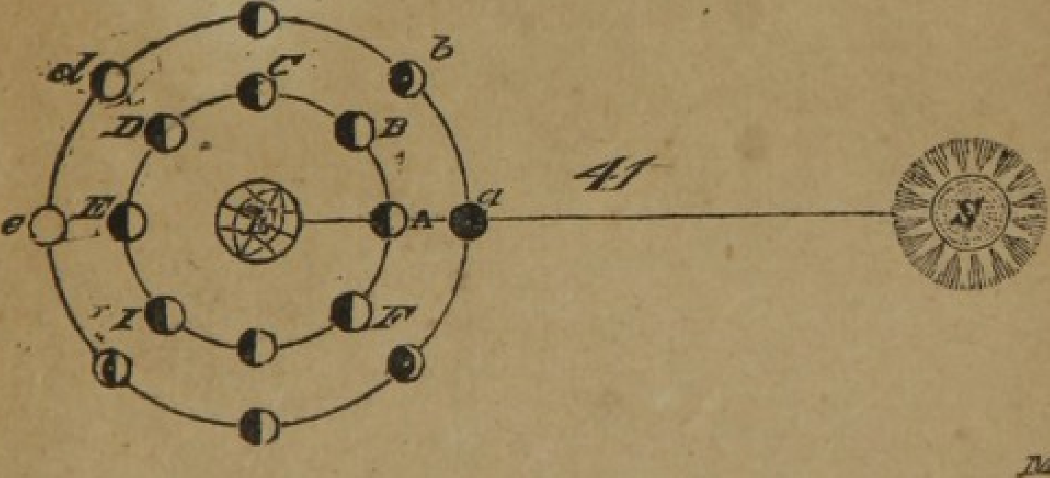

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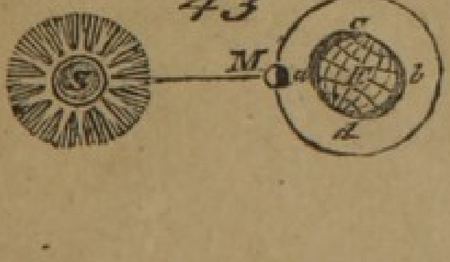

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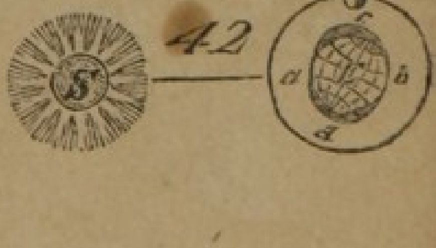

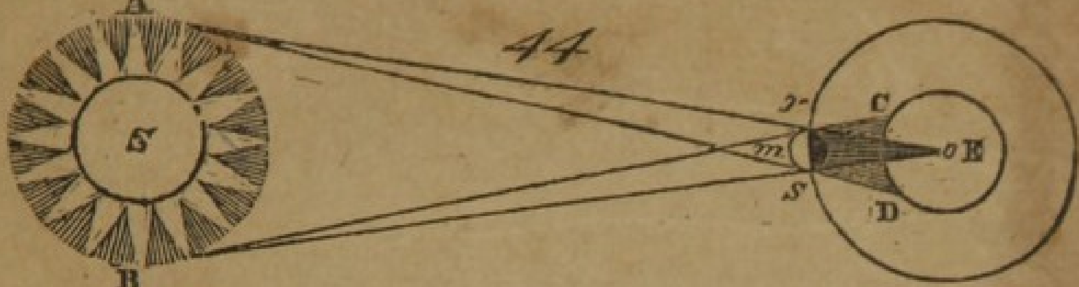

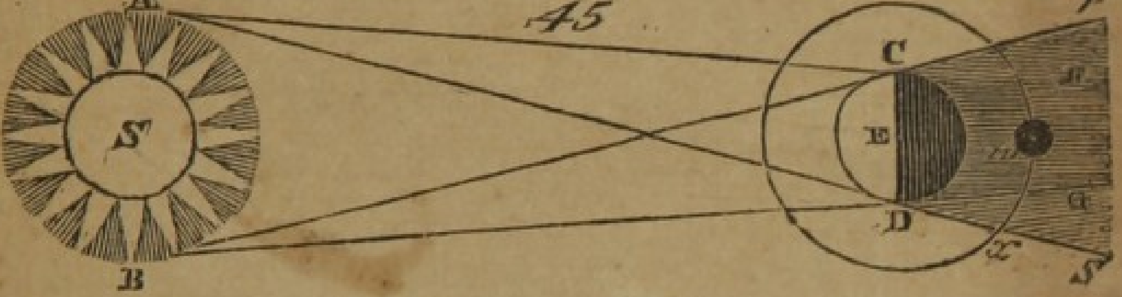

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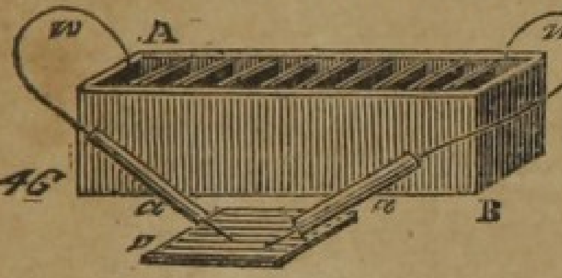
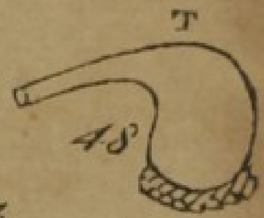
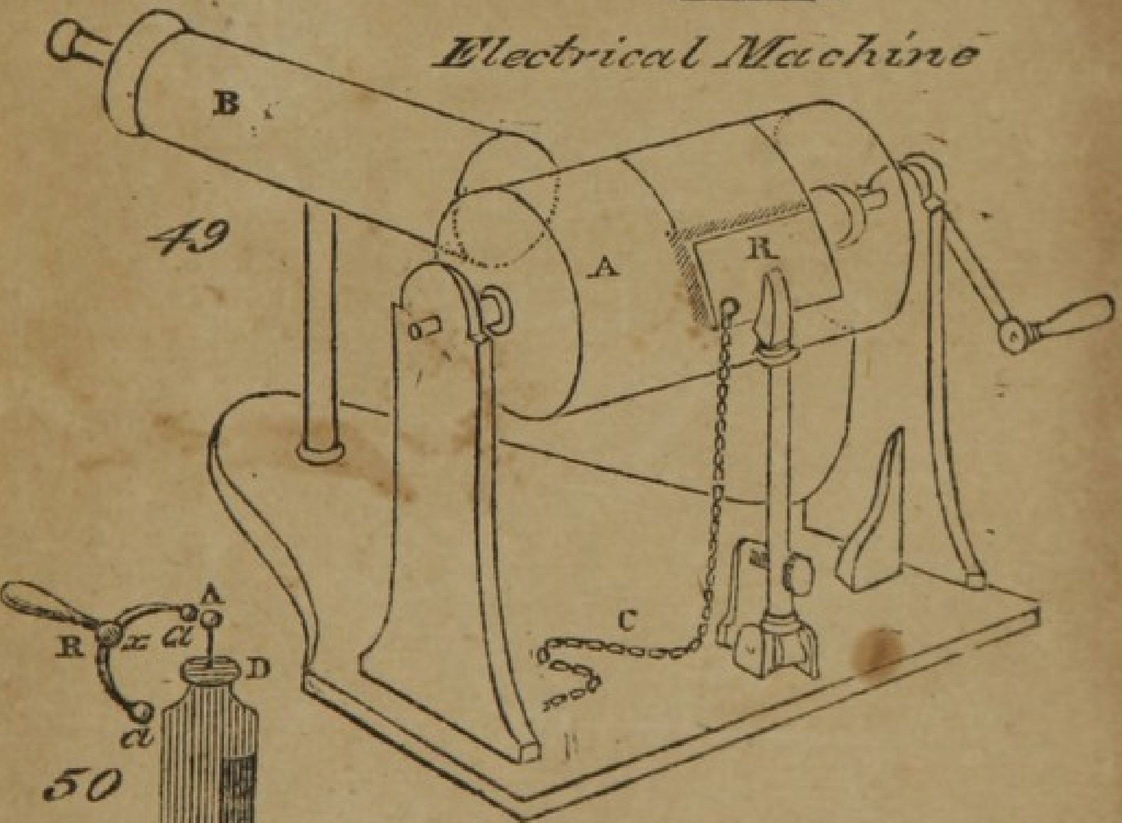
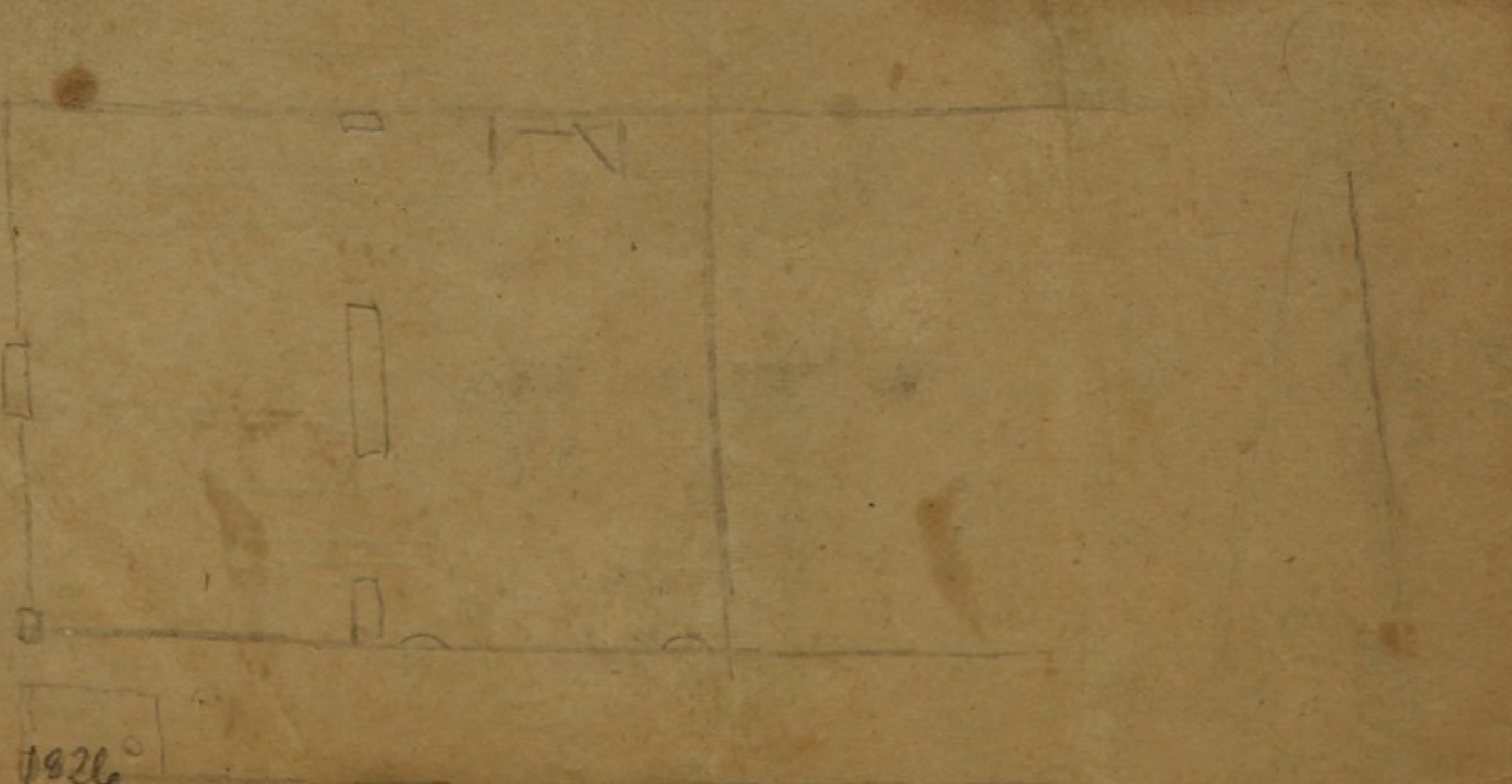




Electrical Machine





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