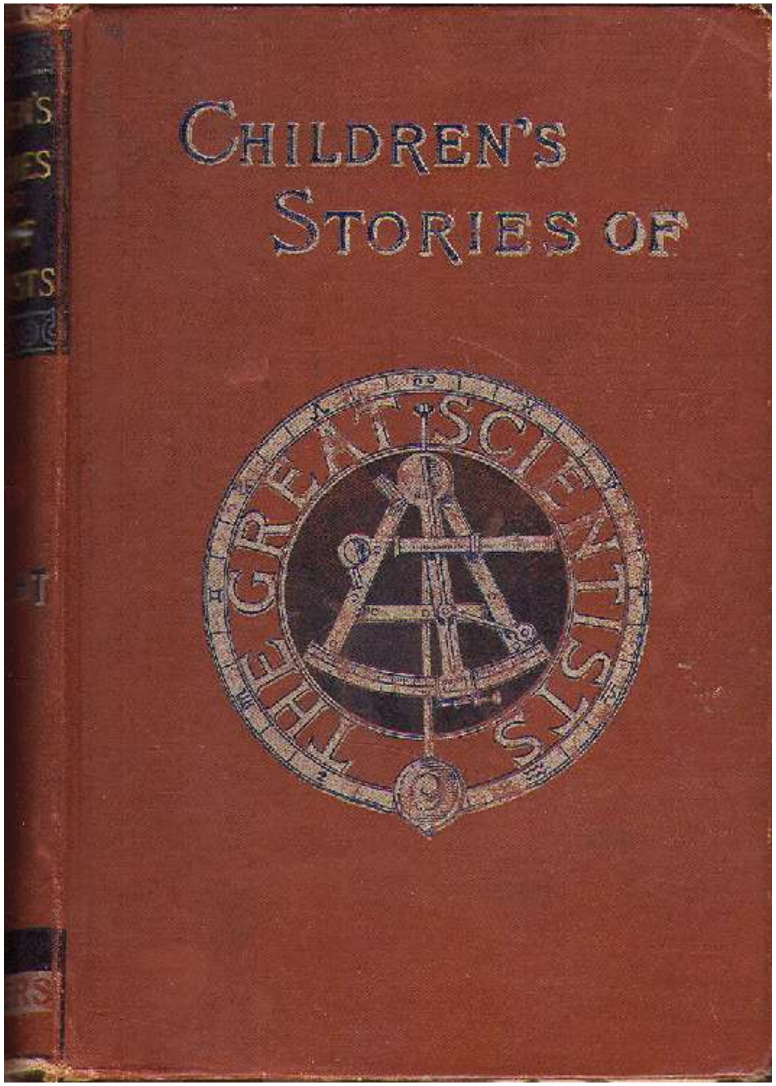


# CHILDREN'S STORIES

OF

# THE GREAT SCIENTISTS

BY

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"CHILDREN'S STORIES OF AMERICAN PROGRESS"

*With Portraits*

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# Table of Contents

## CHAPTER I

# GALILEO AND THE WONDERS OF THE TELESCOPE,

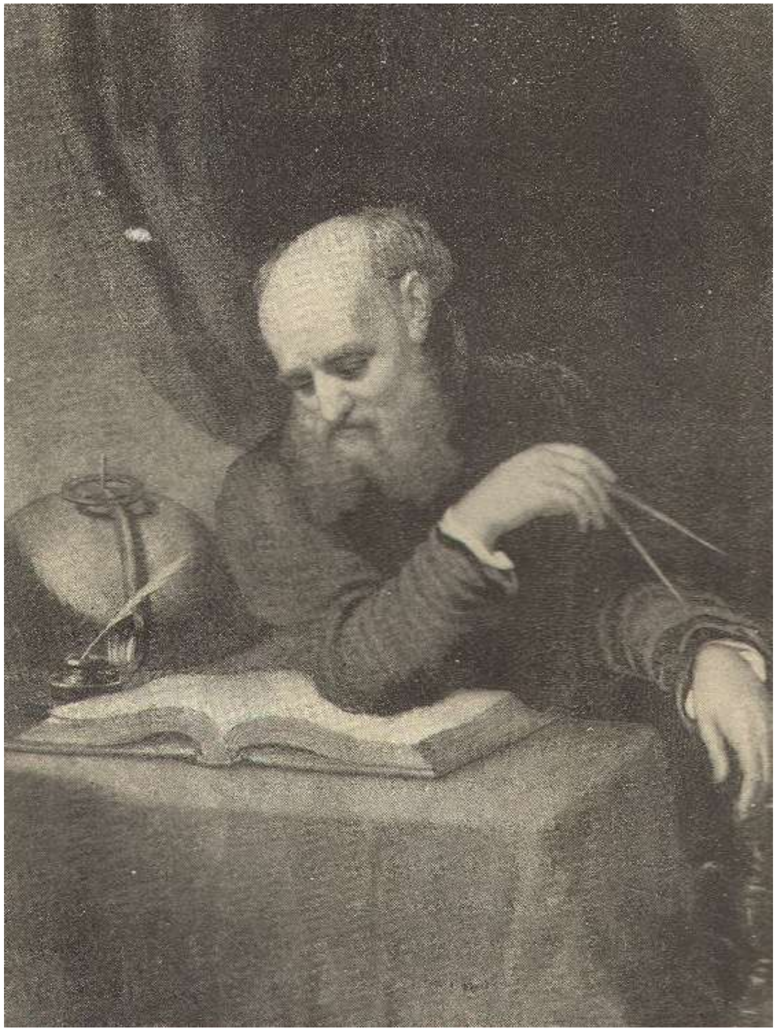
## 1564–1642

Ages ago, in the almost forgotten past, when the earth was peopled with the primitive races that knew scarcely anything of life outside of the thought of food for the day and shelter for the night, the laws of nature were quite uncomprehended, and all the interesting phenomena of the universe were either entirely unnoticed, or accepted with an ignorant awe that never thought of inquiring into their origin.

And later on, when great nations had been formed out of the tribes that once roamed in lawless and hostile bands, the wonders of nature were still regarded with the same awe, and it was even considered impious to question their cause or study their effect.

The wonderful succession of day and night, the recurrence of the seasons, the sun and moon, the stars and the winds and the tides, and all things else, were only a part of the great mystery of life, and all equally incomprehensible, from the flaming comet that illumined the heavens with unnatural brightness to the opening of the first bud or the fall of the first snowflake; and it was never dreamed that the time would come when man would look upon these things with any feeling but amazement.

And even when the world had grown wise in many ways, and there were great cities ruled and kept by powerful kings and mighty armies, and while poets and painters were making immortal poems and pictures, and man had learned to use the winds and the tides to guide him on his journeys, still the unexplained marvels of the universe were clothed in sacred mystery, and only the priests and astrologers dared to study and proclaim their laws.



GALILEO GALILEI

From time to time some philosopher, seeking earnestly after the truth, would assert that he had discovered some secret of nature that would lead to the better understanding and use of her laws, but the world seemed so enchanted with its own ignorance that the new discoveries were either received with unbelief, or the author accused of impiety and perhaps sentenced to death.

And so long centuries passed away while man seemed to gain knowledge of every other kind, but held the world of nature still in childish wonder, and was as much terror-stricken by the sight of a comet or the eclipse of the sun as had been his remote ancestors who dwelt in caves and went naked through the wilderness in search of food.

But there came an age at last when knowledge had so increased and was so widely diffused among people of every class, that the rulers and priests of a country could no longer prevent any new discovery from being made known.

Every city boasted of schools and universities, and in them were found not only the great scholars and philosophers, but students from every class, for ignorance was no longer considered desirable, and it was esteemed honorable to be able to talk of history and literature, the fine arts and philosophy. These universities were frequented by visitors from all parts of the civilized world, and thus it happened that any newly discovered scientific truth or theory was at once carried to remote places, and in this manner the systems taught in one city soon became known to the others, and knowledge greatly advanced by their mutual intercourse. About the middle of the sixteenth century the universities of Italy held a high rank among institutions of learning, and within their walls could be found some of the most earnest and enlightened thinkers of the world. Many of these gave their days and nights to the study of nature, and strove with untiring zeal to grasp the secrets that had eluded the wise of other ages.

Among these restless and inquiring spirits was Galileo Galilei, a youth of Pisa, who had entered the university of his native town at the age of nineteen as a student of medicine.

Although the father of Galileo was not wealthy, and a university education for his son would call for considerable denial on his part, still the effort was cheerfully made, and the rapid progress of the young student immediately proved the wisdom of the step.

From his earliest childhood Galileo had shown the greatest talent for mechanical invention, his wonderful toys and little models of machinery being the admiration and delight of his companions, and as he grew older this talent developed more and more, and led to some of the most important inventions in the history of mechanics.

Two years after his entrance at the university he noticed one day, while sitting in the cathedral, a lamp swinging from the roof, and keeping as it swung a regular and uniform motion. This circumstance, which would never have attracted the notice of the careless observer, at once held the attention of the young inventor, and he watched the lamp until he became convinced, by comparing its motion with the beating of his pulse, that its vibrations, whether great or small, recurred at regular and equal intervals. He immediately saw that this discovery might lead to some useful mechanical invention, and at once set about verifying it by different experiments; the results proved the truth of his supposition, and it then occurred to him that if he were able to reckon the vibrations of a swinging body from the beat of a normal pulse, he might be able to do the reverse and ascertain the pulse of a patient by comparing it with the same vibrations. He at once constructed a simple instrument to test this theory, and the experiment proved so satisfactory that the invention at once passed into common use by all the physicians of the day.

This first pendulum—which was called a pulsilogy, from the use it was put to—consisted simply of a weight attached to a string, and a graduated scale. The string was gathered up in the hand till the vibrations of the weight coincided with the beating of the pulse, and it was then reckoned from the scale whether the rate were normal or otherwise.

Although the pendulum was invented for the sole purpose of assisting in the practice of medicine, yet the discovery of its principle by Galileo led to important results; previous to this there had been many contrivances for the measurement of time, hour-glasses, sun-dials, water-dials, burning candles, and other expedients succeeding each other in turn, but none of these had been able to measure time so accurately as the pendulum, and its use in dividing the day, and in astronomical observations soon became indispensable. Its invariable regularity was of the greatest service to the astronomers, who, by means of the pendulum-clock which was invented some years later by Huygens, a Dutch astronomer, were able to make calculations more exactly and satisfactorily than ever before, and the same instrument in time led to the knowledge of the real form of the earth. Thus the first invention of Galileo not only served the practical needs of daily life but was the means of advancing scientific observation to a plane inaccessible before.

Although Galileo had entered the university as a student of medicine this subject gradually lost all charm for him, and he devoted himself more and more exclusively to mathematics and physics. This change was at first unwelcome to his father, but as time passed and he saw that his son was irresistibly carried on by his new pursuits, he no longer opposed him, and allowed him to devote his time to the study of natural philosophy.

An essay on physics brought Galileo to the notice of one of the leading mathematicians of Italy, and through his influence the young philosopher was appointed to the lectureship of mathematics at Pisa. This new position did not prevent his pursuing his studies with undiminished vigor, and his lectures attracted immediate attention. Almost from the beginning of his university career Galileo showed that boldness and originality of thought which distinguished him in after-life, and won the ill-will of several of the professors by his unwillingness to accept for truth many of the dogmas which they held sacred.

But, Galileo had been brought up under the influence of a father who was accustomed to give full and free discussion to any subject that occupied his mind, and this training, together with his own original genius, made it impossible for the son to follow easily in the beaten paths of university life, and thus thrown back upon himself, and with only the help and sympathy of one or two of his companions, he began to find out new lines of thought, and to follow paths that had hitherto been considered unlawful.

New ways of solving old questions presented themselves freely to his inquiring mind, and were tested, and, when found satisfactory, accepted with the same readiness that was accorded the old faiths, and this could not be forgiven by the professors, who considered it the most honorable thing in the world to receive the ancient philosophies without question or disparagement, and whose greatest ambition it was to discover or wring some new meaning out of the old texts that would apply to all doubts and settle all discussion. And thus from the beginning of his career Galileo was surrounded by the enemies of progress, and even his mechanical investigations were received with cold favor.

But this did not daunt him, and as he advanced in his studies he subjected all the propositions of the old philosophy to the severe test of free investigation, glad when he could find no flaw in the world-old wisdom, but gladder still when he discovered an error the righting of which would lead thought into wider and purer channels. And the responsibility of his position as a teacher made him the more anxious to sift out the good from the bad, while the opportunity thus offered of influencing a younger generation made him strive with renewed earnestness after the truth.

These efforts only served to increase the hostility that the professors had shown toward him in his student-days; but Galileo persisted in his investigations, and proved the folly of some of their most cherished beliefs, announcing the results of his experiments with a persistent determination and faith that won many adherents. But his enemies would not listen even when his arguments were followed by the most conclusive proofs; and on one occasion, when Galileo performed the experiment of letting two bodies of different weight, fall simultaneously from the leaning tower of Pisa, in order to prove that they would reach the ground at the same time, his angry opponents refused to believe the evidence of their own eyes, and quoted in reply the sentence from Aristotle which asserted that if two different weights were let fall from the same height the heavier one would reach the ground the sooner. Such obstinacy, combined with ill-will and distrust, rendered Galileo's position at Pisa so unpleasant that, when an opportunity offered for him to take the chair of mathematics at Padua, he did not hesitate, and left Pisa after having taught there only three years.

He now began to circulate his writings more freely, one essay following another with such rapidity, and all embodying such new and startling theories, that his name soon became familiar to the scientific world, and his opinions were listened to with a respect that roused the fiercest resentment of his enemies.

One of the most sacred beliefs of the day was the Plotemaic theory that the earth was the centre of the universe, and that the sun, moon, planets, and stars all revolved around it, outside of the atmospheres of air and fire which immediately surrounded it.

Many absurd reasons were given to prove the truth of this theory, and philosophers seemed willing to accept anything as fact, provided it coincided with this popular superstition, and even gravely acquiesced when it was asserted that the earth must be the centre of the universe because it was the only planet that had a moon. This theory took its name from Claudius Ptolemy, an old astronomer and geographer, who lived at Alexandria about the middle of the second century A.D. Ptolemy gave innumerable reasons for his belief, and said that it would be impossible and absurd to believe otherwise. About four hundred and fifty years B.C., Pythagoras, a Greek philosopher, who spent many years in studying in Egypt, and who was familiar with the astronomical theories of the Chaldeans and Egyptians, proclaimed to his disciples that the earth had a motion and revolved periodically around a great central fire, and this theory met with the warmest approbation of some other Greek philosophers, who also believed in two motions of the earth, an annual and daily, and claimed that the heavens only appeared to move because the earth turned on its axis with such rapidity.

But this belief was rejected with scorn by Ptolemy, who said that it was impossible to believe that the earth turned on its axis from west to east during twenty-four hours; for if it were true, then bodies lighter than the earth and suspended in the air, would have an opposite movement, and that it would thus be impossible for clouds or birds, or any object thrown in the air to go toward the east, as the earth would be constantly going before them and make it seem as if everything were going toward the west. And for two thousand years the world clung to the Ptolemaic theory, in part because it seemed reasonable and convincing, but chiefly because it had received the sanction of Aristotle, the greatest of the Greek philosophers, whose influence upon thought was so unlimited that even his most absurd theories of mechanics were received without question.

But in 1543 Nicholas Copernicus, a Prussian astronomer, published his great work "De Revolutionibus"—concerning the revolutions—in which he entirely refuted the Ptolemaic theory, and asserted that the earth was not the centre of the universe, and that it had a daily rotation on its axis and an annual revolution around the sun, which two motions accounted for all the other phenomena of the heavens, and satisfactorily explained all the hitherto unexplainable mysteries in regard to the motions of the heavenly bodies.

The opinions of Copernicus were received with disdain by the philosophers of the old school, and his work was derided as the wildest nonsense; but the more thoughtful minds gave his writings careful attention, and came gradually to accept his incontrovertible arguments, and among these was Galileo, who found it impossible to hold the Ptolemaic theory after becoming familiar with the works of Copernicus.

His conversion to the true theory was not, however, made publicly known at once, either because he felt that he had not yet sufficiently studied it, or because he feared that the opposition of his enemies might do the new system more harm than it would be in his power to overbalance.

But in 1604 the scientific world was startled by the sudden appearance of a new star, whose splendor at once attracted the attention of all astronomers. Night after night its brilliant light, changing from orange to yellow, purple, red, and white successively, illumined the heavens with new glory, and records were searched and old treatises pored over in order to see how often similar appearances had been noticed before.

Galileo studied the star with the greatest interest, and his lecture-rooms were crowded when it was announced that he would give a public explanation of the wonder; but the crowds who had come to agree with old theories or idly speculate over ancient astronomical history, were rudely startled by Galileo's original views, which swept away many of the fondest illusions of the age, and proclaimed clearly a new and unwelcome advance in the study of the heavens.

It was generally believed that the new star was a meteor having its origin in the atmosphere, and that it was nearer the earth than the moon; but Galileo claimed that this was impossible, and proved, by exact calculations from the situation and appearance, that the star must be placed among the most distant of the heavenly bodies, and that the belief in its motion around the earth was contrary to true theory of the earth's revolution around the sun.

This view was received with scorn by the followers of Aristotle, who held that the sky was unchangeable, and that the stars were carried in hollow crystalline spheres around the earth, thus making it impossible to account for the new star in this manner. They also declared their opposition to the theory of the motion of the earth, and Galileo was called upon to defend the Copernican system. He did this with such zeal that the university was at once divided into two parties, one agreeing with the Aristotelians, and the other following Galileo and accepting the new doctrines with delight. The dispute went on for some years, and Galileo omitted no chance to proclaim his belief in the Copernican system, and to add new proofs to strengthen its hold upon the minds of others; and in 1609 an event occurred which enabled him to completely vindicate the truth of his new belief, and to convince all but the most obstinate that it would be no longer possible to hold to the old theories. This was the invention of the telescope, the use of which revealed the most startling wonders in the heavens, and demonstrated the truth of Galileo's belief to the fullest extent.

Previous to this astronomers had been obliged to depend entirely upon the naked eye for making all observations; and although the world had advanced in almost every other way, in this respect' the Italian star-gazer of the sixteenth century had no advantage over the Chaldean shepherds who, ages before, had studied the mysteries of the heavens during their lonely night-watches. But the telescope changed all this, and revolutionized the study of astronomy. It brought to light unsuspected possibilities for research, and laid bare the secrets that had eluded man from the earliest times. Not only were the planets and stars that were already known brought nearer and rendered more familiar by closer observation, but even the most distant of the heavenly bodies shone with a new glory, that was not diminished by the discovery that, farther still beyond their circles, other stars even yet more beautiful swept through their limitless courses, and that what had before seemed only empty space was in reality filled with vast systems of worlds, which waited only the proper moment to reveal themselves in all their bewildering splendor.

It is claimed by some that Galileo's invention of the telescope was not strictly original, and that he only applied and improved upon an idea that had already been used to some extent in the manufacture of optical instruments.

But, however this may be, it is certain that the first telescope which Galileo made and pointed to the heavens created the greatest wonder in the scientific world, and was considered almost as much of a marvel as the discovery of a new world would have been.

This first telescope, which was called Galileo's tube, aroused public curiosity to the greatest height, and Galileo's house was thronged with visitors eager to satisfy their curiosity; the most extravagant and absurd stories were circulated, and all through Venice, where Galileo happened to be staying at the time, there was no talk of anything but the wonderful instrument which was thought to be possessed of almost magical powers. The news spread rapidly from place to place, and all the astronomers set themselves to making telescopes, though it was long before anyone could produce an instrument equal in excellence to those made by Galileo. And so great was the excitement over the new invention, that small telescopes were sold in the streets as curiosities, and the observatories were besieged with people who gave the astronomers no peace until they satisfied their incredulous wonder.

In the meantime Galileo ascended his tower night after night, and pointed his telescope toward the heavens which had so suddenly assumed such new and intense interest. And the results showed that, although he had given his whole life to the study, he had really only just begun to learn anything of the marvels of creation. One mystery after another was unfolded to his wondering gaze, and even the objects that had once seemed familiar to him now disclosed such new characteristics as to appear almost strange.

This was especially true of his observations on Jupiter, a planet which, from its great size and brilliant light, had always attracted the attention of astronomers. Regarded at first by mankind simply as a splendid star whose beauty added another glory to the sky, it was studied with unusual care, and even when later philosophers denied its stellar character, it was still an object of intense interest to astronomers, who looked upon it as a mysterious presence wandering among the familiar stars, awing them by its majesty, and yet as little understood as the flittings of the will-o'-the-wisp among the fire-flies in the meadow. And although its planetary character was fully established in the time of Galileo, the wonder in it had not yet ceased. Galileo brought it night after night under the range of the telescope, and was soon rewarded by the most startling discovery in astronomical science.

He noticed, at first, that there seemed to be three new stars situated very near to Jupiter, and further observation led to the discovery of a fourth. Careful study of that part of the heavens soon led to the astonishing disclosure that these small stars revolved around Jupiter, in the same way that the moon revolved around the earth; and Galileo, after verifying his theory by elaborate and continuous observations, announced the undreamed-of fact that Jupiter was attended by four moons.

This intelligence was received with undisguised amazement by all classes. The friends of Galileo and the advocates of the Copernican system, at once joyfully accepted this new proof of the harmonious motions of the heavenly bodies, while his opponents were equally bitter in their denunciation, refusing to look through the telescope for fear it would convince them of their error, and, as usual, bringing forth the most absurd arguments in favor of their own obstinacy.

Galileo had named the satellites the Medicaan stars in honor of his patron, Cosmo di Medici, and one antagonistic philosopher gravely denied the willingness of nature to give Jupiter four moons simply for the sake of immortalizing the name of Medici, and said that the whole thing was an idle dream.

Another declared solemnly that he did not more surely know that he had a soul in his body, than that the moons were caused entirely by reflected rays of light, and claimed that Galileo's "thirst for gold" had alone led him to such an announcement.

And still another astronomer seriously demonstrated that it was contrary to the law of nature to have more than seven planets, and that therefore more than seven could not exist. He argued that there were seven windows given to animals in the domicile of the head, to admit the air to the rest of the body to warm and nourish it, and that likewise, in the heavens there were two favorable stars, Venus and Jupiter; two unfavorable, Mars and Saturn; two luminaries, the sun and the moon; and Mercury alone undecided and indifferent. Also, that there were but seven metals, seven days in the week, and innumerable similar phenomena to prove that there could only be seven planets; summing up with the conclusion that the satellites were invisible to the naked eye, that they therefore could exercise no influence on the earth, that they were therefore useless, and therefore did not exist.

To this Galileo only replied that, however weighty the reasons might be that no more than seven planets could exist, they scarcely seemed sufficient to destroy the new ones when actually seen, and went on observing Jupiter.

His friends supported his theories as warmly as ever, and the controversy was kept up until the existence of the satellites was established beyond a doubt, when his enemies went to the other extreme and claimed that Galileo's observations were most imperfect, as there were really twelve satellites instead of four; and it was only when Jupiter moved to another part of the heavens, carrying his four moons with him, that they admitted that the original announcement was correct.

Galileo's observations of the moon also led to a fierce discussion, and philosophers again spent a great deal of time in arguing and denying, with the usual results.

From its nearness to the earth, and the interesting phenomena connected with the various changes that it passed through every month, the moon had from the earliest times been an object of the greatest interest to man, who attributed mysterious power to its influence, and placed it among the divinities. And it still held its subtle attraction long after the old religions had passed away, for with the exception of the sun, it alone of all the heavenly bodies exercised an important influence in the concerns of daily life. Filling the heavens with its wondrous beauty long after the great god of day had set, it seemed like a beneficent spirit sent by some protecting power to guard the lonely watches of the night; while to the traveller on desert or mountain or sea, its beams came with friendly assurance of help and companionship in braving the unseen perils of the darkness.

In the time of Galileo the popular belief concerning the moon was that it was a perfectly spherical body, with a surface as smooth and polished as a mirror, and that the dark parts of its surface were either the reflections of the forests and mountains of the earth, or caused by the interposition of opaque bodies floating between it and the sun, or, because of its nearness to the earth, the result of contact with certain terrestrial elements which marred its beauty and made it less pure than the bodies in the more remote heavens.

But Galileo's observations led him to the belief that the moon resembled the earth in structure, and that its dark portions were the shadows reflected from mountains and other inequalities in its surface; while he also claimed that it was probable that there were continents and oceans distributed over the surface similar to those on the earth, and that the faint shadow which was attached to the crescent moon, and filled out that part of the surface unlighted directly by the sun, was caused by the reflection of the earth's light, or earthshine. These theories were at once attacked by his opponents, who said that Galileo took delight in ruining the fairest works of nature, and utterly denied the existence of mountains on the moon, as their presence there would destroy its spherical shape.

Galileo replied that to conceive of the moon and the earth as perfectly spherical bodies would only detract from their use, in the plan of nature, for absolute smoothness and sphericity would make of the earth only a vast, unblessed desert, void of animals, of plants, and of men; the abode of silence and inaction; senseless, lifeless, soulless, and stripped of all those ornaments which made it so beautiful. But this argument was derided by his enemies, who re. plied that the moon's surface was really smooth and unalterable in spite of all that Galileo could say, and that the parts which appeared hollow or sunken were in reality filled up with a crystal substance perfectly imperceptible to the senses, but still serving the purpose of giving to the moon her true spherical shape.

Galileo agreed to accept the theory of a crystal substance filling all irregularities, provided the philosophers would allow him to raise crystal mountains ten times higher than those he had actually seen and measured, and this nonsense effectually put an end to the crystalline theory.

In regard to Galileo's theory of earthshine his critics averred that it was untenable, because the earth was not a planet and did not revolve around the sun, or shine like the other planets, and ascribed the shadow to Venus or the fixed stars, or the rays of the sun shining through the moon. And thus the endless dispute went on, and all of Galileo's wonderful discoveries were received with scorn and unbelief by the enemies of progress, who bent all the powers of their minds to the refutation of the Copernican theory. But Galileo went on with his observations undisturbed by this opposition, and constantly announced new wonders.

He examined the Milky Way, and was the first to prove that its nebulous appearance was caused by the presence of myriads of stars, whose light reached to infinite distances beyond the system of the earth; and although this theory was of course disputed, it was firmly established by repeated observation, and thus confirmed beyond a doubt the conjecture of Pythagoras that countless millions of stars circled continuously through their distant courses far beyond the vision of man.

Galileo subjected all of the planets in turn to his scrutinizing gaze, and one discovery followed another with astounding rapidity, so that there never ceased to be a new marvel to wonder at.

He detected the presence of Saturn's rings, although his glass was not strong enough to show him their real nature, and he supposed the planet to have two attendant stars; and a month later he announced the discovery of the phases of Venus, deducing from this fact another proof of the Copernican system. He also examined the fixed stars, and by careful comparison of their light with that of the planets decided that they did not receive their light from the sun, and he added still another argument to the doctrine of Copernicus by the discovery of the spots on the sun and their motion across its disc.

As early as 807 A.D. dark spots had been observed on the face of the sun, and for centuries after this phenomenon attracted the attention of astronomers. But all curiosity was satisfied by the supposition that the dark body was simply caused by the passage of Mercury or some other small object across the sun's surface.

But Galileo claimed that the spots were in actual contact with the sun, and that they had a common and regular motion with which they revolved around the sun, which turned upon his axis once a month.

Here was another argument for the Copernican theory, and in consequence the new explanation of sun spots was received with little favor by the followers of Aristotle.

And thus in the midst of opposition and discouragement Galileo kept on his way, continually adding to the sum of scientific knowledge, and unwearying in his efforts to place natural science upon a more reasonable and comprehensible plane than it had before reached.

His observations included not only the phenomena of the heavens, but also those connected more intimately with the earth, and his essays extended over a great variety of subjects which had hitherto been treated only with ignorance or indifferent success.

The results of his work were published from time to time, and in 1632 the labor of his life was given to the world in the form of a book entitled, "The Dialogue on the Ptolemaic and Copernican Systems," in which were incorporated all his views on natural science, and his arguments in favor of rejecting many of the old theories of the universe and accepting the new.

And now the unpopularity which had always followed him found a new object for its hatred.

The book was received with the most intense ill-will by Galileo's enemies, many of whom occupied high positions in philosophical circles, and possessed an unbounded influence with the dignitaries of Church and State, and the "Dialogue of the Systems" was made the means of bringing the quarrel between the old and new philosophies to an issue.

The hatred of years had at last found its opportunity, and Galileo was summoned to Rome to answer to the charge of heresy in teaching the doctrines of Copernicus, which were assumed by the Church to be in opposition to the revealed word of God.

Galileo was seventy years old, and his life had been spent in the reverent study of the works of nature, but the conclusions he arrived at differed from those accepted by the theologians of the day, and his long and faithful devotion to science, and all his splendid discoveries, were simply regarded by his enemies as the work of a man who had dared to dispute the holiest tenets of the Church, and to offer a scientific creed opposed to the sacred beliefs of the Aristotelian philosophers.

The Inquisition, which was then the judicial tribunal of the Roman Catholic Church, examined Galileo upon his religious and scientific views, and pronounced them impious and heretical, and called upon him to renounce and abjure the most cherished convictions of his soul, or suffer the penalty that attended any persistent opposition to the Holy Office.

The subject of Galileo's abjuration has always been a matter of dispute, some contending that it was extorted from him while undergoing torture at the hands of the officers of the Inquisition, and others claiming that the terms of abjuration were dictated by the inquisitors themselves, and are not to be considered as expressing the recantation of Galileo.

But, however that may be, it is certain that an abjuration, that was considered sufficiently condemning by his enemies, was sworn to by Galileo in the presence of the officers of the Inquisition, and that his recantation saved him from imprisonment, and perhaps death.

The well-known anecdote that when Galileo rose from his knees after signing the abjuration, he stamped on the ground and whispered to one of his friends—"It [the world] does move, though"—is without foundation. Although copies of his abjuration were immediately circulated throughout Italy, and were ordered to be read in the universities, the Copernican system still kept its hold upon the minds of all advanced thinkers, and Galileo was still regarded as its most powerful advocate.

The fact that his abjuration did not cost him the respect and admiration of his friends, is sufficient evidence that it was obtained under circumstances that reflect little credit on the supporters of the Church, and admits the probability that, even in this terrible crisis, Galileo maintained his character as an uncompromising advocate of the new school of thought; and his judges can only place his whole brave and consistent life against the questionable practices of the Inquisition, to give a balance largely in his favor.

Galileo died in 1642, having been blind for five years before his death.

The malice of his enemies followed him to the end, and he was denied the privilege of making a will, and of burial in consecrated ground.

But this petty spite could not interfere with the sentence passed upon him by all the unbiased thinkers of his own and succeeding ages, that his life was one of noble devotion to his work, and that through his influence scientific inquiry was first led into the pure ways of reasonable thought, and the world of nature more fully and clearly revealed, and endowed with new and unimagined beauty.

## CHAPTER II

## KEPLER AND THE PATHWAYS OF THE PLANETS

## 1571–1635

The invention of the telescope prepared all minds for new wonders, and made astronomy the leading science of the day. The heavenly bodies were observed with a new interest, and their motions studied more intently; for, while the Copernican system proved that the earth and other planets moved around the sun as a centre, it left many mysteries unexplained which could not be accounted for by the fact of the daily rotation of the earth or its annual revolution. And while Galileo was startling the world by his magnificent discoveries in the heavens, the German astronomer Kepler was revolving in his mind a theory of the universe which would explain some of these mysteries, and was destined to make his name as famous as that of his great contemporary.

The motions and nature of the heavenly bodies were questions that were puzzling the wisest heads, and many strange theories were advanced to account for the apparent irregularities in the movements of the planets and their relation to the fixed stars.

Tycho Brahe, the Danish astronomer, from his magnificent observatory, Uraniberg, had spent years in studying the order of planetary motion, and at his death left his observations recorded in a set of tables which he intrusted to the care of Kepler, his friend and pupil. Uraniberg, the city of the heavens, was built on the Island of Huen, in the Baltic, and under the patronage of the King of Denmark had become the resort of many of the most earnest scientific students, who gladly availed themselves of the teaching of Tycho Brahe. The observatory was furnished with the most complete set of astronomical instruments in the world, and was famous for its facilities for studying the heavens.

It was by means of these instruments, and by his great knowledge of mathematics, that Tycho Brahe was able to make those accurate observations which gave his tables a priceless value, and enabled Kepler to work out calculations that it would have been impossible to make without them.

Unlike many great scientists, Kepler had shown no special liking for any particular study when a child, and he was led to the study of astronomy only because he was appointed professor of that science in the university of Gratz. But while preparing his lectures, he became so deeply interested in the subject that before long it entirely occupied his mind, and nothing else seemed of any importance as compared with it.

Kepler possessed a very enthusiastic nature, and was always ready to listen to new theories, no matter how wild they might seem. He was among the first to rejoice over the splendid discoveries of Galileo, and was an ardent supporter of the Copernican system while it was yet being reviled by the authority of the Church and the disciples of Aristotle; and his originality and enthusiasm made him capable of turning the earnest work of Tycho Brahe to the very best account.

The Copernican theory had been steadily gaining ground in the estimation of astronomers, and, as one after another gave up the old system, they ceased to speculate about the apparent movements of the sun and stars around the earth, and began to study the planets from a new point of view.

The path which a planet takes in revolving around the sun is called its orbit, and astronomers now became interested in the question of the size of the orbits and the rate of motion.

The idea that there was always to be found a certain harmony throughout all the works of nature, swayed the minds of men as much in the sixteenth century as it had done in the dawn of scientific thought, and no sooner was a new theory advanced, or a new discovery made, than the question arose as to how it would harmonize with the truths already known, or how, by following out some suggestion it contained, still other discoveries might be made.

Kepler possessed more than any of his contemporaries the gift of intuition, or the power of grasping a truth that has not been demonstrated by any known law of nature, and it is to this insight that he owed his success. He believed that the entire universe was governed by one great law or principle, and that there was a subtle relation existing between things that seemed to be utterly disconnected. All the great discoveries of science, all the wonderful operations of nature, every expression of beauty in the animal or vegetable world, and every useful invention of man, seemed alike to him to be controlled by some great harmonious principles that might be applied with equal appropriateness to the turning of a water-wheel, or the rise of the tides, or the rushing of a comet through illimitable space.

With this idea ruling his mind every new fact was at once made a basis for calculations that might lead to the discovery of the great secret law of the universe, and no toil was considered irksome that could help him on his way, for he believed that the relation existing between the different forces of nature was so strong that the discovery of the law of one would be the master-key that would unlock the whole mystery of creation.

This belief, which had haunted the minds of philosophers of all ages, seemed to Kepler of infinitely more importance than anything else, and the discovery of a new planet in the heavens meant to him not only a new wonder to be admired and gazed at, but a new instance of the harmonious working of the order of creation.

Pythagoras had claimed, two thousand years before, that he had discovered the world-secret, and that harmony, or proportion, was the law of the universe. He taught that the planets revolved around a central fire, moving with an inconceivable swiftness that caused them to be accompanied by mighty rushing sounds, but that the different velocities were so beautifully proportioned that the result was not mere noise, but, the most exquisite music, which excelled in sweetness and power all earthly melodies. It was said that the reason that these harmonies were not heard by man was because they were unceasingly sounding in his ears from the moment of birth, and that they would therefore be unnoticed by him. This notion was also held by many of the philosophers of the Middle Ages, and even at a much later day the astrologers and seers claimed that the music of the spheres might be easily distinguished by the initiated.

However absurd these theories may seem, it is nevertheless a fact that the love and study of the marvellous have in many cases led to the knowledge of some great truth of nature, and had it not been for Kepler's belief in the possibility of finding the secret that had forever eluded mankind, he might never have been led on to the discoveries that made him famous.

Calculations whose length and intricacy would have disheartened anyone else were cheerfully carried on by him for months and years, to be as cheerfully abandoned if found incorrect, and the unwearied and painstaking labor of a life-time would have been counted as nothing in comparison to the discovery of some hitherto unknown truth.

The possession of Tycho Brahe's tables aided him greatly in the work, for so accurate had been the observations of the Danish astronomer, and so reliable his deductions, that Kepler was able to depend upon them almost absolutely, and to decide that in every case his theories must be rejected if they did not agree with the statements in the tables.

Having always in mind the discovery of the law of harmony that governed the universe, Kepler bent the whole energies of his mind to the study of the number of the planets, their motions, and the sizes of their orbits. It seemed to him that there must be some proportion between the sizes of the orbits, and he made many calculations to prove the truth of this conjecture. There were at that time but five planets known, and after having failed to prove any relation existing between the sizes of their orbits, Kepler imagined a new planet between Venus and Mercury, and another between Mars and Jupiter, and then made a new calculation to see if he could discover the proportion he was looking for; but he failed also here, and, after many months spent in fruitless toil, he was obliged to give up the work without having proved that there was any regular rate of increase between the orbits of the planets nearest the sun and those farthest from it.

In all his calculations Kepler started from the old theories of the relations which were supposed to exist between the different solid and plane figures, and when he began the study of the planets' orbits he pursued the same plan.

Up to this time the belief had always been that the motions of the heavenly bodies were described in circles. The circle, which was considered the most beautiful of all curves, had always had a mystic meaning for the old philosophers, and was always associated in some manner with their religious belief. It was the emblem of eternity, and was carved on the tombs of kings, and inscribed in sacred books, and many things in nature seemed to mark it with special significance. The arch of the heavens stretching from earth to earth again, the cycle of the seasons, the expansion of the moon, which was worshipped as a deity, from the crescent form, to the perfectly rounded figure, the circular disc of the sun, and many other things all enveloped the circle with a sacred meaning which had by no means lost its power when astronomy was invested with new interest by the genius of Copernicus.

And when it was conceded that the planets revolved around the sun it was at once assumed that their orbits were circular, for this shape alone would enable them to harmonize with the popular belief in regard to the mystic importance of the circle.

Kepler, starting with this idea, tried in vain to account for the irregularities of the planets' motions which had puzzled other astronomers. If the planets moved in circles about the sun, each always taking the same time for a revolution and moving at a perfectly regular rate, then, by knowing their positions at any one time and the rate at which they were moving, it would be easy for an astronomer to calculate where they would be at any other time.

But this was found not to be the case. Mars was the planet most convenient for making observations upon, and Kepler made this planet the subject of careful study for years, in order to determine the reason for its irregularity of motion. Mars, travelling round the sun in a circular orbit should reach a certain point on a certain date, and because this did not happen the astronomers were sorely puzzled and invented many ingenious reasons to account for it.

Kepler made nineteen different theories to explain the irregularity of the motion of the planets, but none of them could be considered entirely satisfactory. Each theory was made the subject of the most careful calculation, but all failed, and planetary motion remained as great a mystery as ever.

At last Kepler was forced to think that possibly the planets did not move in circular orbits, although the circle was the most beautiful of curves, and he began to imagine the orbits to be of a different shape than had hitherto been supposed. The careful study that he had made of the orbit of Mars seemed to show that it was of an oval form, and as the ellipse was the simplest form of oval; Kepler chose this curve as a basis for new calculations.

He had already become convinced, from his study of the earth's motion, that the planets did not move in their orbits at a regular rate of motion, but that they moved faster when they were nearer the sun and slower when farther from it; this in itself was a most important discovery.

On applying this rule to calculate the motion of Mars, Kepler found, to his surprise and delight, that when its orbit was taken to be an ellipse the planet would reach any point in its path just at the moment calculated, but that this would not be so if any other form of orbit were assumed. This was also found to be the case with the other planets.

These two great discoveries startled the world by their originality, and placed Kepler among the greatest astronomers of the day. Hitherto his theories had been regarded rather indifferently, as his contemporaries thought him always too eager to run after new ideas, and his method of starting a new hypothesis and making one intricate calculation after another to test it, did not correspond with their more sober way of proceeding.

But Kepler kept on in his own manner of working, and continued his study of the planets' orbits. He was still desirous of proving his old theory of some proportion existing between them, and after many months of unremitting toil he was at length rewarded by the discovery of a law which at once established a most beautiful harmony in the solar system; for, although he had failed to find any relation existing between the sizes of the orbits, he now found that there was a very direct and beautiful proportion between the times of the revolutions of the planets and their distances from the sun, and that one, knowing the distance of any one planet from the sun and the time it occupied in its revolution, could calculate the distance of any other planet whose period was given, or the period of any planet whose distance was known.

These three great discoveries—the shape of the planets' orbits, the rate of their motion, and the relation existing between their distances and periods of revolution—are called Kepler's Laws, and were the basis for all astronomical calculations from that time. Their discovery was of incalculable value to astronomers, and they contained, besides, the first proof of the ancient belief in the harmony that prevailed throughout the universe.

The thought of the old philosophers was found to be no dream, but a reality as beautiful as the conception that raised the walls of cities by the power of music or changed the loved of the gods to constellations, whose solemn motion through the heavens possessed infinite power over the destinies of mankind; and although the great discoverer of these laws lived a life of the greatest hardship and died in extreme poverty, he is yet to be envied as one who realized all the hopes of his life and saw his greatest wish brought to a satisfying completion.

## CHAPTER III

# NEWTON AND THE FINDING OF THE WORLD SECRET

## 1642–1727.

From the time that men first began to speculate about the earth, one of the principal questions was how it was held in its position in the universe, and the ancients had many curious theories regarding this subject.

One of the oldest beliefs was that the earth was supported by Atlas, the Titan, who had rebelled against the authority of the gods and was punished by being made to stand in the centre of the Western Ocean and bear the world on his shoulders.

Still another theory was that the earth rested on the back of an enormous tortoise; and a third belief, which was held by some of the Eastern nations, was that the world was carried by a large whale, whose sudden movements caused earthquakes and other such calamities. Another philosopher declared that the world floated in the ocean like an egg, the half that was above the water being the part that was inhabited.

But these different speculations failed to satisfy even the minds of the early students of nature, and as time passed and scientific knowledge increased, it was found necessary to account in some other way for the earth's support.

The establishment of the Copernican system made the problem all the more perplexing, as it was more difficult to imagine a support for a world that was whirling through space than for one at rest, and after the discovery of Kepler's laws the subject became more interesting than ever, and received a larger share of attention.

Kepler himself had suggested that the motion of the planets might be caused by spokes radiating from the sun and pushing the planets with them as they rotated. And absurd as this theory seems, Kepler spent considerable time in trying to verify it, and it was regarded as highly plausible by many other astronomers.

SIR ISAAC NEWTON

Descartes, the great French philosopher, invented the theory that all space was filled with air, in which there were innumerable whirl-pools and vortices. One great vortex was supposed to exist around the sun, which carried the planets around, and just as the centre of a whirlpool in a river revolves more rapidly than its outer circles, so those planets near the sun would be carried around faster than those farther away. This theory accounted for the movement of the moons around the planets by supposing that they were carried by smaller vortices around their individual centres, while the elliptical figure of the orbits was explained by imagining the planets pushing one another a little out of a circular path.

But although the name of Descartes was celebrated enough to cause his theory to be received with great respect, and although it was supported by some of the most eminent scientific men, it was never fully accepted, as it was thought impossible that nature, whose known laws were so simple and harmonious, should have so blundered in describing the orbits of the planets as to make it possible for them to push one another out of their paths.

Those philosophers who combined scientific experiment with a belief in astrology and the supernatural, still held the old belief of the crystal spheres in which the planets were borne around, and which had a mystic relation to the ten heavens and the atmospheres of air and fire; while a more common and simpler theory, which was admitted by some of the most learned men, was that each planet was carried through its orbit by an angel.

But the sixteenth century was a time of earnest thought, and of great men whose achievements had already made it famous in the history of science, and it was felt that whatever problem might vex the human mind would be solved at last, if painstaking labor and devotion to knowledge were of any avail.

The Copernican system had set the current of speculation in new directions, and on the day of the death of Galileo, its most famous supporter, there was born in Woolsthorp, Lincolnshire, England, a child whose name now stands as the greatest in the history of science, and whose work it was to perfect the great theory and prove its truth by means of the most splendid discovery that the world has ever known.

This was Isaac Newton, the descendant of a line of English farmers, who passed the uneventful years of his boyhood in a quiet country home, whose humdrum life gave no hint of the brilliant future in store for him.

A mile from his home was the little hamlet of Stoke, where he attended day school, and where he learned to read and write; and with his first knowledge of books, he displayed also that love of mechanics which showed even at that early age the bent of his mind. He was always making little models of machines, finding hints for them in his plays, and in the suggestions of the world of nature with which he was so early familiar; and the little water-clocks and sun-dials which he made served a still greater purpose than an hour's amusement, for they developed a sense of observation and accurate reasoning which were of the greatest service later on.

When he was twelve years old he entered the grammar school at Grantham, but attracted no attention for any especial talent, and had it not been for the books which he read at home, his school life might have passed without leaving any particular mark upon his character.

But it was during this period that Newton was attracted by some works on chemistry, alchemy, and magnetism, and the reading of these books made an impression upon his mind which was never lost, and which went far toward determining his career.

From this time a new world was opened to the thoughtful lad who, as he wandered over the meadows around his home, or through the pleasant English lanes, puzzled his head over the questions that had occupied the gravest thinkers of all ages, and wondered if ever the answers would be reached.

Newton entered Trinity College, Cambridge, in 1661, and almost immediately attracted the attention of his teachers by his extraordinary talent for mathematics. Subjects which his fellow-students found most difficult he grasped with apparent ease, and he soon became known as one from whom great achievements might be expected. And this expectation was not disappointed, for before leaving college Newton gave proof of the originality of his mind by making certain discoveries in mathematics which at once attracted the attention of scientific men, and promised a future of renown.

It was in the same year that he left college—1665—that Newton conceived the great idea that won him eternal fame, and, strange as it may seem, this idea was something quite apart from the studies in mathematics and light which had hitherto occupied his mind.

The great question of the motion of the earth was ever before men's minds, and Newton's experiments in light and his mathematical discoveries still left room for thoughts of the problem that had not yet been solved by ancient or modern philosophers, although from time to time some hint of the meaning had been given. The old Greeks had claimed that all motion in the universe was caused by the action of two forces which they called love and hate, and the alchemists had taught that all nature was pervaded by a subtle power which could not only change base metals to gold and give man an infinite existence on the earth, but also held sway over the remotest regions of space, and bound the stars and planets in its mystic rule.

Newton's early studies had made him familiar with the older theories, and also with the laws of chemistry, which demonstrated the close relation which existed between different forms of matter. Kepler's laws exactly described the motions of the heavenly bodies which Galileo's telescope had first proven, but the question still remained—what gave the planets their motion, and carried them around the sun—and Newton, in his twenty-fourth year, gave evidence of the masterly powers of his mind by offering an explanation so clear and yet so simple as to perfectly harmonize with the known laws of nature, and place its probability beyond a doubt.

Experiments had shown that magnetism, or the power of attraction, existed between certain bodies, but the nature and power of this force were quite unknown. The ancients were content to say that certain bodies had a breath, or life, which attracted other bodies, and so let the mysterious power alone; and in later times, while it was known that this power of attraction existed in a far greater degree than had formerly been supposed, it was still an almost unknown subject. Kepler and other astronomers even went so far as to say that the planets attracted one another, but how great this attraction was and what result it would have were not demonstrated.

Still the subject was one of intense interest to philosophers, and was ever present in their thoughts, and as the smallest incident often leads to great results, so in the case of Newton, the simple circumstance of an apple falling from a tree in the garden in which he was sitting, suggested a train of thought which finally led to the discovery of the great law which holds the planets in their courses and governs the remotest stars.

It was an accepted fact in philosophy, that all objects on the earth were held there by magnetism, or the force of attraction, and that in fact the earth was a great magnet which held all things upon it in their places, and kept them from flying off into space, just as surely as the loadstone attracted steel.

The fall of the apple from the tree led Newton to the thought that the magnetic power of the earth must also extend to things beyond its surface, and not in actual contact with it, and this suggested the still greater idea that, if the earth had any attractive power at all, this power must be felt to the farthest limit of the solar system, though in a much less degree. Newton at once perceived that if this were true the earth would exert an attraction over the moon, and he immediately undertook to see if this were so.

Ever since the establishment of the Copernican system, astronomers had been trying to find out what power kept the moon revolving around the earth; for it was evident that, according to the laws of motion, the moon would fly off into space were it not for the action of some powerful but unknown force.

Newton decided that whatever this power was, it must also exist between Jupiter and his moons in order to agree with the harmonious working of the universe, and he therefore made a calculation which proved that Jupiter's moons revolved around him and were kept in their orbits by the same power which the earth exerted over all objects on and near it, and that this power was greater or less according to the distance of the satellite from the planet; or that Jupiter exerted a certain power over the nearest moon, less power over the next in order, and so on. This being established, it was an easy matter to determine if the earth kept her moon in place in the same way. But the most accurate calculations failed to prove the truth of the theory, and Newton was obliged to own to himself that his reasoning had been at fault. He therefore said nothing of his hope or disappointment, resolving to keep both secret until time should have given better opportunities for a study of the problem.

Ten years afterward a French mathematician announced that the accepted theory of the moon's distance from the earth was incorrect, and that the moon was in reality farther from the earth than had been supposed. This discovery at once led Newton back to his old theory in regard to the attractive power of the earth, for, since the degree of attraction depended upon the distance, he saw that his former hope might still be realized. He therefore began another calculation based upon the new value of the moon's distance, and so great was his joy on finding that the numbers were coming out as he wished, that his excitement prevented him from finishing the calculation, and he had to ask the aid of a friend. This success was immediately followed up by calculations on the satellites of Saturn, and the same result was obtained. Newton then extended his observations to the revolution of the planets around the sun, and to the motion of comets; and finally, after innumerable experiments and calculations, gave to the world his great law of attraction, viz., that every particle of matter in the universe attracts every other particle with a force depending upon the weight and the distance—a body twice as heavy as another body exerting twice the force, and a body at twice the distance exerting one-fourth the force.

This law, which is generally known as the law of gravitation, is considered the greatest discovery ever made by the human mind.

Not only did it solve the question of the means by which the planets were carried around the sun, but it proved that the planets had this motion simply because of their mutual attraction, and the attraction of the sun; and that the whole universe was governed by the same law, which kept the planets in their orbits, governed the movement of comets, and controlled the entire mechanism of the heavens.

Newton also deduced from this law the correct figure of the earth, proving that gravitation, which caused the earth to rotate on its axis, would also give it a spheroidal shape, and not make it the perfect sphere which it had been supposed to be; the simple experiment of a circular elastic hoop made to rotate around a fixed axis being sufficient to prove that a rotating body always tends to assume a spheroidal form, and to be flattened at its poles in proportion to the rapidity of movement. And although at this time there was no means of finding out the figure of the earth by actual measurement, later on it was proven by conclusive experiment that Newton's theory in regard to it was so correct as to approach very nearly to the actual amount of oblateness.

Newton also proved that tides were caused by the attraction exerted by the sun and moon upon the earth, the moon exerting much more force than the sun, because of its nearness to the earth. When the sun and moon are both on the same side of the earth their force is united, and they draw the water away from the earth toward them, and the earth away from the water at the point directly opposite; and when the sun and moon are on opposite sides of the earth the same thing happens; so that at these times—at new and full moon—the highest tides occur; the lowest tides occurring when the sun and moon are at right angles, for then their forces do not act together, one drawing in one line and the other in a line perpendicular to it, so that much of the attraction is lost.

These and many other phenomena were explained by Newton as having their origin in the attraction of gravitation, and the results of his investigations, together with his work on other subjects, were finally summed up in his great work called the "Principia," which was published in 1687, the cost of the printing being born by Halley, the astronomer, as Newton himself could not afford the expense.

Although it might have been supposed that the grand, yet simple, principles laid down in the "Principia" would appeal to every scientific mind, yet such was not the case, and Newton had to suffer from that misapprehension and prejudice which fall to the lot of every original thinker. But few people were capable of understanding the new ways of reasoning which Newton introduced, and some of the most celebrated astronomers of the day derided the conclusions as absurd and false. Books were written to prove that the phenomena of the heavens could be explained on entirely different principles from those laid down in the "Principia," and it was even said that the Newtonian philosophy was simply another form of the old superstition of the ancients, who believed in the presence of mysterious agents, working in undiscoverable ways, and holding all the universe in their subtle power. But the new thought made its way surely, if slowly, and during the next century was accepted by the whole world of science.

The mystery which had baffled the ages was unfolded at last, and the old dreams of the "world-secret," the faith of Copernicus, the vision of Galileo, and the inspiration of Kepler, were triumphantly shown to have been, not idle play, but divine leadings toward the discovery of the greatest truth of nature that has ever been revealed to man.

What this mysterious power is which binds the universe together in one harmonious whole, we do not know. We can only see its workings, and define its results, and the rest is unknown.

Nature holds her grandest secrets close, and even Newton, her greatest interpreter, after a long life of research, could only sum up his experience in these significant words: "I have been but as a child playing on the sea-shore; now finding some pebble rather more polished, and now some shell more beautifully variegated than another, while the immense ocean of truth extended before me unexplored.

## CHAPTER IV

# FRANKLIN AND THE IDENTITY OF LIGHTNING AND ELECTRICITY

## 1706–1790.

Among all the subjects ever studied by scientific men none have been found more interesting than electricity, although for centuries almost nothing was known about it, and even now our knowledge of its nature and power is very limited.

But the very mystery that has always surrounded it has given it an enduring interest, and from time to time there have been certain philosophers whose experiments and discoveries in this subject alone would have been sufficient to place their names high on the roll of scientific fame.

Dr. Gilbert, an English physician, published a book in the year 1600, in which he gave all the facts that were then known about magnetism and electricity, and laid down some general laws in regard to them. Previous to this, amber, jet, and a few other substances were supposed to be the only bodies that would attract other bodies to them when rubbed, but Gilbert's investigations showed that this property was common to many other things, and gave a list of such substances as possessed it.

A half century later than this, the first electrical machine was made by Otto von Guericke, a German philosopher. This machine consisted of a sphere of sulphur—one of the substances which Gilbert described as having the power of attracting light bodies when rubbed; the sphere was made to rotate around an axle, and with this simple apparatus Guericke's experiments were carried on.

In using this machine Guericke first noticed the electric spark, which was so feeble, however, owing to the small power of the sulphur, that it could only be seen in the dark; also, by placing his ear quite close to the sulphur, he was able to hear the sound which always accompanies the spark. Guericke also noticed that the sulphur ball, when rubbed, would at first attract light substances and afterward repel them, although he did not know the reason of this.

BENJAMIN FRANKLIN.

Later on, Hawkesbee found that amber or glass rubbed with flannel would produce light, and that the same result would follow if two lumps of sugar were rubbed together; and that many other substances had the same property.

Afterward it was discovered that all electrical substances, i.e., bodies which attract light substances when rubbed, will also become luminous by friction. This was the first important general law discovered by experiments in electricity.

In the eighteenth century the English scientist, Stephen Gray, found that electricity would pass from one body to another, though the same experiments proved that this was not always the case, and that in fact certain bodies, called conductors, would receive electricity from other bodies, while other substances, called non-conductors, would not receive it. Gray also established the conducting power of fluids, and of the human body.

These were discoveries of vast importance, and showed, as nothing else could have done, the great advance in science from the days of the old Greeks, who thought that the only electrical bodies they knew owed their power to a breath, which could no more be transferred to another substance than the lily could give its perfume to the rose. Many of the practical uses of electricity, among them the electric telegraph, are based upon this discovery of Gray.

Du Fay, a French scientist who was induced to study the subject by becoming interested in Gray's writings, also made one of the greatest discoveries in electricity. Guericke's observation that electrical substances would at first attract and then repel light substances, was made a subject of experiment by Du Fay, who was finally led to the astonishing discovery that there were two kinds of electricity: one kind—such as is developed by rubbing glass with silk—which he called vitreous electricity, and the other—such as is developed by rubbing sealing-wax with flannel—which he called resinous electricity, and that the two kinds always attract each other; while, on the contrary, a body charged with vitreous electricity would repel another body charged also with that kind, and the same would be true of bodies charged with resinous electricity.

One of the most important discoveries in the history of the science followed soon after, namely, that the two kinds of electricity existed in all electrical bodies, and that the rubbing simply separated them, and that one kind was never produced without the other.

To this period also belongs the discovery of the Leyden jar, an electrical instrument in which large quantities of electricity may be stored up and kept; a metal coating on the inside of the jar being charged with one kind of electricity, which is kept from escaping by the attraction of the opposite electricity on the outer coating of the jar, the two being separated by the non-conducting jar itself. When the two coatings are connected by a conductor the electricities rush together and the jar is discharged. While experimenting with this instrument a Dutch scientist experienced the electric shock, a sensation which caused him considerable alarm, for although it had been known from the time of the ancients that the torpedo could transmit a powerful shock to the human body, it was supposed that the power belonged to that animal alone, and the discovery that this sensation could be produced by an electrical machine made a great impression on the public mind. The Dutch experimenter declared he would not undergo the experience again for the crown of France; but after the first fear had passed away and subsequent experiments had given the operator greater control over the machine, it became quite the fashion for people to take an electric shock, just for the novelty of the thing, and the Leyden jar became as popular a plaything as the first telescopes and microscopes had been.

Still another great discovery in electricity was made in the eighteenth century, by Benjamin Franklin, whose work for science is none the less interesting from the fact that he was distinguished in many other ways.

Franklin was born in Boston, in 1706, and was the tenth son of an English mechanic who had settled in America, and followed the business of a soap-boiler and tallow-chandler. The father was a man of worth and of strong religious principles, and from the old fashion of giving a tenth of everything to the church as tithes, intended to devote Benjamin to the ministry.

But poverty compelled him to give up this idea, and at ten years of age Benjamin was taken from school and made to assist his father in boiling soap and making candles. This business seemed tiresome to the boy, who was of an ambitious turn of mind, and besides had his head filled with romantic ideas about the glory and charm of a life at sea, and would have liked nothing better than to run away and become a pirate or buccaneer, had chance offered; but for all that, he did well the small duties that were assigned him, it being a part of his character always to do thoroughly what he set about; and after two years at soap-boiling he left his father's shop, and became an apprentice to an older brother who was a printer in the same town.

Here his work was more congenial, for he had an opportunity of reading more books than he had ever had access to before, and reading had always been one of his greatest pleasures; and being fond of books, the making of books seemed to him much more interesting than any other trade. He set himself to learning the printer's calling with a good will, and very soon became a very creditable apprentice. His young fellow-workmen took a kindly interest in the boy who was among the youngest of their number, and seeing his fondness for reading, lent him all the books they owned; and as Benjamin also in time made acquaintance with the various booksellers with whom his brother had dealings, he was able sometimes to borrow books from them, often sitting up all night to read a book which had to be returned in the morning. But yet his taste for reading did not entirely destroy his inclination toward a life of adventure, and his predilection for pirates was as great as ever, though by this time he had given up the idea of running away to sea in a ship which floated a black flag; and when it became noised about that Blackbeard, one of the most notorious pirates of the day, had been captured, Franklin's imagination was immediately excited by the event, and he at once set about the composition of a poem of which Blackbeard was the hero, and in which he gave his fancy great freedom, and mixed up bold metaphors and bad rhymes to an appalling degree. This production, together with another one celebrating a shipwreck which had just occurred, was printed and sold about the streets of Boston by the young author, who was immensely flattered at seeing his verses so eagerly seized by the public, and conceived the idea of leaving the printing office and turning poet. But on being assured by his father that poets were generally beggars, and being confirmed in this belief by his reading, he gave up the idea of distinguishing himself in poetry, and turned his attention to prose. And as was his fashion, he set himself to the matter with all the seriousness of his nature, taking for his model the works of the best English writers, and studying them with the greatest care, first reading the articles, then thinking them over till he had the subject well in his mind, and finally writing down his impressions and comparing them with the original. And although this work at the time seemed to his family but the pastime of a restless boy, yet it bore fruit long afterward, when the force and purity of Franklin's style, both in speaking and writing, were of incalculable value not only to himself but to his country.

This course of study, together with the advantage he received from the conversations that were carried on in his brother's shop, in which all the important questions of the day were discussed, led in time to another attempt at authorship, but this time Franklin acted in secret from fear of ridicule, and slipped his manuscript under the office door, where it was found the next morning by his brother, who read it aloud to his friends all unconscious that the author stood by trembling with suspense, lest his judgment should be unfavorable.

But the paper was well received, and printed in the newspaper which was published at the office, and from this time Franklin made several contributions to the same paper before the name of the author was found out.

At this time Franklin was about sixteen years of age, and considering that he had not been at school since he was ten, and that all his chance for study had to be taken out of his few leisure hours, he was a tolerably well-informed lad. He was of a very practical turn of mind, and listened to all the discussions on political topics with a keen interest and many a suggestive thought of the remedies that might be applied to existing evils. But his brother, who misunderstood the boy's nature, was not calculated to develop his young charge, and as he had always exercised over him a petty tyranny that was most aggravating to the younger brother, the time came at last when Franklin decided that it would be better for them to part.

He said nothing of his plans to anyone, knowing full well that he would only meet with opposition, but selling some of his books to obtain money, he took passage on a sloop that sailed between Boston and New York, whither he had determined to go. He left home in the night, secretly, and so really ran away at last, though only to become a harmless printer instead of the daring buccaneer he had once imagined himself.

But on reaching New York, which at that time contained only one printing-office, Franklin failed to obtain work, and so pushed on to Philadelphia, where after many ups and downs he finally succeeded in getting the promise of a printing-office of his own, and recommendations to people in England, where it was necessary for him to go to buy the needful outfit.

But Franklin found that the friend he had depended upon had failed him at the last moment, and he reached London without any letters of recommendation and with very little money, and found it necessary to work at his trade in order to get the means to return.

This experience, however, was not lost upon one who turned all the events in life to some use, and when after eighteen months in England Franklin returned to Philadelphia, he found himself possessed of the newest processes in printing, besides having picked up much other useful information.

Soon after his return to America Franklin started a debating society among his young friends, which was called the Junto, or Leather Apron Club, because every member was supposed to be a mechanic, and in this society the young printer soon occupied a leading position.

Here were discussed all the political questions of the day, and also various philosophical subjects, and the interest that was then awakened in such discussions led to the most important results; for much of the ease and straight-forwardness which distinguished Franklin as a political speaker later on, could be traced to the exciting and inspiring debates in the Junto Club, while many of the practical plans for the benefit of the public which were suggested by Franklin, owed their origin to the same source.

The first circulating library in America was started by the Junto Club, and began with fifty subscribers, and all of Franklin's plans for improving the condition of the city were laid before his fellow-workmen in the Junto before being made public.

These plans were so practical and of such undoubted value, that before long Franklin's name was associated with every movement connected with the public life of the city, and the citizens of Philadelphia came to have such a high regard for the man who had so often proved their benefactor, that it was sufficient for them to know that Franklin approved of any plan to give it their heartiest support.

In this way it came about that the public service was raised to such a degree that Philadelphia became a model city among the colonies.

The circulating library was followed by the establishment of a night patrol for the protection of the city, and which was supported by taxes on property; then came the organization of the first fire brigade, which met with such success that in a short time most of the prominent citizens became members of it, every member pledging himself to furnish a certain number of the bags, buckets, and baskets which constituted the working utensils of the company. Then came the founding of the American Philosophical Society in 1743, the headquarters of which were fixed in Philadelphia; and a few years later the Junto Club started a movement which immediately became popular through the exertions of Franklin, and which resulted in the founding of the University of Pennsylvania.

The first hospital built in Philadelphia was largely due to Franklin's influence, people refusing to subscribe to it until they heard that he considered it desirable. Franklin also first called attention to the streets of Philadelphia, which were at that time unpaved and generally in a filthy condition. He first succeeded in having a walk paved in one of the principal streets, and as it soon became splashed with mud from the road, suggested that the house-owners should each pay a small sum to have the pavement kept clean. But paving the streets, when once it was started, seemed so desirable a thing to the inhabitants, that in a very short time the whole city was rendered clean and comfortable by paved streets. Then some one suggested that the streets should also be lighted, and lamps were brought from London for that purpose, Franklin again showing his practical turn of mind by substituting square chimneys of four panes of glass for the original globes which became speedily dimmed by the smoke; and this care for details and interest in the small concerns of life was also shown by the invention of the Franklin stove, which was a great advance over the wide, open, draughty chimneys which had hitherto been used for all household purposes, and by some wise suggestions about a cure for smoky chimneys.

In fact, Franklin never considered that any matter which concerned the welfare and comfort of his fellow-men was unimportant, and would set himself just as readily toward abating some perplexing household annoyance, as to solving a question in philosophy, claiming always that the aim of all knowledge should be the practical serving of the human race.

In the troubles between the colonies and the mother-country which preceded the Revolution, Franklin showed the full powers of his mind, and was a tower of strength to the people. Never weary of planning, advising, and working, he was an example of firmness of purpose united to unceasing labor, and his courage and perseverance at this critical time were of inestimable value. He was among the first to claim and insist upon the rights of the colonies, and declared that justice must be maintained if every law of man should be broken in the attempt. But, notwithstanding his bold stand at this time, Franklin's wise and temperate judgment did not allow him to be carried away by any of the enthusiasms which were at that time popular among the more excitable class of colonists. He did not advocate separation from the mother-country if justice could be obtained without that step, and claimed that he was a loyal American only because he was a loyal Englishman. But when the crisis came, and England proposed to do as she pleased with her own, regardless of all principles of right and justice, and when the English Parliament voted money for forcing the colonies to submission at the point of the sword, then Franklin, who had been in England during the preliminary troubles, trying to arrange matters on a peaceful basis, at once declared that the time for entire independence had come, and that the question would never be settled until the American colonies had become a separate nation. And all through the dangerous and disheartening years of the Revolution, he was the firm friend and unwavering supporter of the struggling colonies. He was one of the signers of the Declaration of Independence, and a few months afterward was appointed Commissioner to the French court, where he remained during the war, and where his influence in behalf of his country proved of incalculable value. And when the struggle was over, and the United States took their place among the nations, the treaty of peace which acknowledged the independence of America, was signed by Franklin, who was the American representative.

Franklin, on his return to America, was made Governor of Pennsylvania, and in less than two years afterward was appointed to take part in drafting the Constitution; and although he was then an old man, he showed the same good judgment and vigor of thought which had always made him such a valuable adviser in public matters.

In his scientific career Franklin was not less illustrious than in his political life. The founding of the American Philosophical Society, which was in constant communication with the Royal Societies of London and Dublin, and of which he was the first secretary, led to a familiarity with the progress of science in Europe, and throughout his long and busy life he never failed to keep up his interest in the scientific pursuits which at that time received such an impetus.

The discoveries of Gray and Du Fay in electricity produced a great impression upon him, and his studies in the same department were followed with an absorbing interest. What this mysterious power called electricity was, became the question of the day, and scientific minds set resolutely to work to solve the question.

Franklin's experiments in electricity were confined to the problems of finding out, if possible, what electricity was, and its distribution throughout nature. Gray and Du Fay had shown that there were two kinds of electricity, which repelled and attracted each other mutually, and that the electric current could pass from one body to another. Franklin attempted to find out the reason for this attraction and repulsion, and to discover why there existed conductors and non-conductors, or why some bodies would allow the electricity to pass through them and others would not.

After many careful and interesting experiments, he was led to the belief that electricity was not created or produced, either by friction or any other process whatsoever, but that it was present everywhere, and that every body contained some quantity of this mysterious force, though what its nature was and how great its power might be, no one could decide. Franklin reasoned that as all bodies were equally supplied with electricity, there would be a state of equilibrium which would show no signs of its existence unless it were in some way disturbed, and that the electricity manifested itself only when something occurred to disturb the normal condition of the body, either by giving it more electricity or taking some away from it.

Instead of the theory of two kinds of electricity, Franklin claimed that all the phenomena connected with the subject could be explained by supposing a body to contain more or less of electricity, and introduced the words positive and negative to illustrate the condition of a body containing more or less than its normal quantity, and suggested that the terms vitreous and resinous be supplanted by the words positive and negative, a body being electrified positively when it receives an addition of electricity, and negatively when some is taken from it; and these are the expressions that are now generally used in speaking of the different conditions.

Franklin's greatest contribution to this department of science, however, was the discovery that electricity and lightning are the same thing. The thought that this might be true was not strictly original with Franklin, as Gray and others had hinted it before, but he was the first to make the experiment which proved their identity beyond a doubt.

This discovery, which was destined to make the name of Franklin famous in the history of science, resulted from the simple experiment of drawing the lightning from the clouds by means of a silk kite, to which was attached a pointed wire—Franklin having demonstrated before this the power of points to attract electricity. The experiment was tried in the open field during a heavy thunder-shower, Franklin and his son standing under an open shed which afforded them a shelter from the rain. Franklin at first noticed that the fibres of the kite string which he held in his hand were separating, as in the passage of the electric current, and by means of a small metal key attached to the cord he obtained the electric spark and the shock, and charged a Leyden jar, as well as performing other electrical experiments.

The experiment was thus a complete success and established the identity of electricity and lightning beyond the shadow of a doubt. And although, when Franklin's paper on the subject was read to the Royal Society of London, the learned members greeted it with sneers and laughter, yet the scientists throughout the rest of Europe accepted its views with alacrity, and French, German, and Italian translations were eagerly sought for, and the name of the discoverer of this new secret of nature was spoken of everywhere with admiring praise.

Franklin's practical mind could not rest until he had found some means of applying this great discovery to the benefit of mankind, and the lightning rods which were before long erected on many buildings were among the results which followed his famous experiments; and had it not been for the engrossing political cares which occupied his mind during the long period of his country's need, it is probable that he would have made other inventions which, if not anticipating those at present in use, would at least have proven of much practical benefit in applying the powers of electricity to the concerns of daily life.

Next to the discovery of the law of gravitation, the discovery of the identity of lightning and electricity and its universality throughout nature, was perhaps the greatest truth of nature that had yet been grasped, and Franklin's work for science, though forming only an episode in his brilliant political career, was of such lasting importance as to place his name high on the list of the world's great discoverers.

He died in Philadelphia on April 17, 1790.

# CHAPTER V

# CHARLES LINNAEUS AND THE STORY OF THE FLOWERS

## 1707–1778

In the days when all things in nature were symbols to man of some force for good or evil, trees and flowers played an important part in his belief, and the old poems of those times are full of allusions to certain plants which were supposed to typify some hidden power. And the effect of this belief was seen not only in the concerns of daily life, but in things that were held most solemn and sacred, and flowers were gathered and cherished not only for their beauty and fragrance, but because their presence was felt to be a bond between man and those strange secrets of nature which were to him such a great mystery.

All the nations of antiquity shared this belief alike, and we find that flowers and fruits were constantly used in all religious ceremonials and in the decoration of the temples. Solomon's temple had doors and pillars of fir and cedar and olive wood, while around the walls were carved opening flowers and drooping palms; the curving brim of its molten sea was wrought with lily-work, and the tops of the pillars were circled with golden pomegranates, while cherubim, carved of olive wood and covered with gold, stretched their mighty wings across the holy place until they met above the sacred ark; and during their solemn festivals the priests, clad in the sacred robes the hems of which were wrought in blue and purple and scarlet pomegranates, and hung with golden bells, passed to and fro before the altar, waving boughs of palm and boughs of willow and sheaves of grain, and offered the first-fruits of the harvest in thanksgiving.

On the pillars of temples in Chaldea and Egypt we find carved the lotos, the flower of the resurrection, and in the oldest religious song of the Hindoos we read that sheaves of grain were offered to the God above all gods, the Beautiful-winged, who upheld the spheres. In Persia, the king sat upon a golden throne under a canopy of grape-vines whose leaves were of gold and fruit of priceless gems, while the priests offered grain and fruits to Ormuzd, the Spiritual One, of whom Zoroaster—golden splendor—was the interpreter. In Greece the worship of nature was carried to a still greater extent. At the great religious festivals the altars were twined with roses, and every feast was deemed incomplete till the guests had been crowned with wreaths of flowers. In the spring there were special songs sung in honor of the awakening earth, and in the autumn, at the grape-harvest, a dirge was chanted for the falling leaves and dying flowers. And we find that the study of plants has interested mankind from the earliest times, and in the oldest histories are recorded the works of those who spent their lives in learning something of the beauty and mystery of the vegetable world.

Kings, philosophers, and priests alike devoted themselves to this study, and every country had its wise men, who sought good to the race and honor to the nation by the discovery of some secret of nature as shown in the laws of plant-life.

At first these researches were carried on chiefly as an aid to the study of medicine, which was practised principally by the priests, who mixed with their discoveries many crude theories of vegetable life, and the change of plants into animals. But later on, great attention was given to the subject by men who were interested in knowledge of all kinds, and the priestly caste ceased to be alone the interpreters of the mysteries of the vegetable world.

Aristotle, the greatest naturalist of antiquity, was familiar with the laws of plant-life, and his pupil, Theophrastus, wrote a history of plants in which he described five hundred kinds; and three hundred years later was born Pliny (23 A.D.), the great

Roman naturalist, who devoted seventeen books of his history to botany.

In these books Pliny gives an account of all the trees, shrubs, and plants that were then known, and describes their cultivation and their uses in medicine and the arts. The products of the East, incense, spices, gems, and perfumes, were all noted, and fruit-trees of all kinds, the sugar-cane, the vine and the different kinds of wine made from its purple clusters, flowers, herbs, vegetables, shrubs and trees of every kind, are described with great care, and their medicinal value noticed.

But although the study of botany thus received the attention of the wise of all ages, it was long before any successful attempt was made by which plants could be arranged into different classes, and until this was done botany could never take its proper place among the sciences.

Occasionally a naturalist would suggest some plan of classification, but it would be lacking in so many necessary particulars that it could only fail; to be followed by another that would also fail, and so on, until at last the great Swedish naturalist, Linnaeus, succeeded in solving the question which had perplexed the minds, of all preceding botanists, and offered a plan which, if not perfect, was at least complete enough to enable naturalists to follow their studies with much greater ease than had ever been possible before.

Linnaeus, so called from the Latinized form of the family name, Linne, was born at Rashult, in the Province of Smaland in Sweden, in the year 1707. His father was the pastor of the village, and had a fine taste for flowers, which he cultivated successfully, introducing so many rare exotics in his collection that the little garden soon became famous even far beyond the limits of the parish. All the Linne family were passionately fond of botany, taking their name, even, from the great linden-tree which towered far above the houses of their native village; and Carl, the minister's little son, was no exception to the rule, and the little garden sloping down to the lake, stocked with rare and beautiful plants, and visited by admiring friends who listened respectfully while the pastor talked learnedly about this flower or that, was one of the boy's first recollections.

Later on he had a garden of his own given him, and then, besides the collection from the home plot, all the neighboring country was laid under contribution, and wood and meadow and hillside had all to give up their treasures to the brown-eyed boy who sought them with such untiring zeal. Very strange things found their way into the little garden, the commonest wild-flowers and poisonous weeds being alike cherished with the roses and lilies, and, had it not been for the father's intervention, even colonies of wild bees and wasps would have been domiciled there; but, as these threatened the safety of the hive-bees, Carl was forced to allow them to depart to their wild haunts again.

The boy studied the secrets of bud and leaf and perfect flower with such eagerness that, before he was eight years old, all the four hundred different plants in his father's collection were perfectly familiar to him, and he could understand the interesting talks about their nature and properties; and the father took care that the knowledge thus gained should be of the most accurate and practical character; Carl had memory-exercises given him in which he was required to describe the composition and properties of certain plants, and this careful training of eye and ear was no doubt the foundation of that wonderful power of observation for which he was so celebrated later on.

At first this intelligent love for flowers brought only pleasure to his parents, who looked with pride upon a son so likely to keep up the traditions of the Linne family, but, as time passed, they became anxious that he should show an equal interest in other branches of knowledge.

But this Carl refused to do, and the first trouble of his life began with his school-days, when he was forced to learn weary lessons in arithmetic and grammar, instead of roaming through the woods and meadows of Stenbrohult gathering specimens for his herbarium and learning fresh secrets of the great world of nature around him.

But his father and mother were ambitious for Carl; they wished him to become a famous minister and succeed his father in the rectorship, or even perhaps be greater still and gain a name that would resound through Sweden. And so his dislike for his school-studies was frowned down by both parents, and, when the boy was ten years of age, it was decided that he should be sent to the Latin school at Wexio, to begin the usual course of study necessary for the training of a clergyman.

It cost some denial on the part of the pastor to furnish the money for the boy's outfit, but in time all things were ready, and, one pleasant spring morning, just as the Stenbrohult meadows were turning green again, and the buds were swelling with the rich life of the new year, Carl and his father started for Wexio, where great things were expected.

And to the boy the whole world seemed as full of promise as the opening year, and he did not doubt that at Wexio he should unravel all the mysteries that had ever puzzled him, and that all the secrets that had hitherto lain hidden in the hearts of his loved flowers would disclose themselves to his eyes, just as the lilies in his little garden unfolded their dazzling petals and showed their golden hearts when warmed by the June sun.

But great was the disappointment of the Linne family when it became known that Carl was not showing himself such a clever boy, after all, and that grammar and theology and Latin were still odious to him, and that he preferred a ramble through the country-lanes to all the books in the school-library, unless they were books on botany. Other boys were praised, and delighted their friends by winning honors in their classes, but Carl had only censure, and the highest honor he ever received was that of being called the "Little Botanist" by his good-natured companions; and so poor was his record at Wexio that, when he was seventeen, his father decided to apprentice him to a shoemaker; for he thought him a hopeless dunce, and that all his self-denying efforts to give him an education had been made in vain.

But, in spite of his stupidity in regard to Latin grammar, Carl had made one friend in Wexio in the person of Dr. Rothman, the principal physician of the town, who had been attracted to the boy by his love of botany, and who now offered to take Carl into his house while he finished his course at Wexio, provided he should be allowed to study medicine instead of theology.

The discouraged father readily agreed to this, and thus Carl was saved from being a shoemaker, a calling he would doubtless have disliked as much as the ministry, and happier days began at once, for he was allowed to follow his favorite pursuits without offending his father, and received encouragement and advice where before he had only met with disapproval or ridicule.

This was the decisive period in the boy's career, and it was while he was with this kind friend that his life-work was decided upon, for here he came across the writings of Tournefort, the greatest botanist of his time, and was so impressed by these works that he decided to devote his life to the study of botany. All his energies, therefore, were bent in this direction, and he studied to such good purpose that when he left Wexio, at the end of three years from the time he entered Dr. Rothman's house, he had already laid the foundations of that vast knowledge for which he afterward became famous.

But his studies in other directions had been so unsatisfactory to his teachers that, in place of the usual certificate from the school, he bore one which stated that he was regarded as an unpromising plant which had not flourished in Wexio but which might possibly blossom and bear fruit in some more congenial soil.

But notwithstanding this discouragement, Linnaeus entered the University of Upsala a year afterward, with his hopes higher than ever, for the magnificent library and fine botanic garden presented unusual advantages for his favorite study. But now began troublesome times for Linnaeus. He had entered Upsala with very little money, hoping to obtain private pupils, which would help him meet his expenses; but without influence or friends, what could be expected for a young student who scorned the regular course of study and threw his whole soul into the fascinating subject of natural history? His money rapidly disappeared, and no friend came to offer a helping hand. The professors in the university did not particularly notice the poorly dressed young man who plainly showed that he thought more of the commonest plant in the botanical garden than of all their learned lectures; and, had it not been for the society and encouragement of his friend Artedi, a fellow-student, who like him was poor and unknown, the brave heart of Linnaeus might have failed him at this critical period.

Artedi, like Linnaeus, was devoted to natural science, and was consequently very unpopular at Upsala, where the study of the classics was considered of more consequence than anything else, and the two friends were thus drawn together by something more than the ordinary bonds of friendship. And so the two unknown students joined their forces against poverty and unpopularity, and even then found the battle going against them.

They wore the poorest clothing, patched and darned with their own hands, and were hungry and cold many a time as they sat in their humble rooms, for which at last they could not even pay the rent. Linnaeus mended his shoes with paper, and Artedi picked berries for their breakfast when they went botanizing, and their only comfort lay in the hope that Celsius, a professor who was then absent, might return and take notice of them because of his own love for natural history.

But nearly two years passed before this hope was realized, and the friends suffered all the discomforts of poverty, and Linnaeus was just on the point of leaving Upsala in despair when Celsius did at last come back, and bring hope with him. Linnaeus saw him first in the same botanical garden which had been the means of bringing him into such disgrace with the professors, and from the first moment of their meeting a new life began for the poor and obscure young student. Celsius was surprised and delighted with his unusual knowledge of botany, and, finding out his poverty readily enough, took him into his own house to live.

And then Upsala awoke at last and found out that Linnaeus was there, for Celsius was one of the most celebrated men in Sweden, and did not hesitate to show his opinion of his protege's talents. He gave Linnaeus every possible opportunity for study, and it was while he was at Celsius' house, assisting him in preparing a work on the plants mentioned in the Bible, that the idea of his own great system first came into his mind.

The modern world had improved very little upon the plan of the old Greeks for the study of botany, and up to the time of Linnaeus no system had been successfully introduced by which new and strange plants could be classified. One naturalist offered a system based upon the nature of the fruit; another separated the whole vegetable world into flowering and flowerless plants; a third declared that the flower and the fruit must both be considered; and a fourth classified according to the form of the flower.

Each system had something to recommend it, and yet all were sadly deficient, and botanists were far from satisfied.

At the time of Linnaeus the system in vogue was that of Tournefort, who established his principles according to the form of the flower or blossom. But although this system was generally accepted throughout Europe as being as perfect as any that had been offered, it did not by any means fully satisfy the scientific world. New plants were being constantly brought from abroad, owing to the better travelling facilities, and many of these foreign specimens found no place in the system of Tournefort.

It seemed that the time had come when a new basis of classification must be found which would not only dispose more satisfactorily of the families of plants then known, but also include those strange blossoms that began to find their way from remote places in Asia, and from America and the islands of the sea.

And just at this time Linnaeus appeared with a theory that revolutionized botanical science, and was destined in a few years to make his name renowned over the civilized world.

At first it did not seem possible to the professors at Upsala that they had been mistaken in the abilities of the young student from Stenbrohult, whose poverty and lack of friends had kept him in the greatest obscurity, and whose stubborn pursuit of botany had offended them; but Celsius soon showed them their error, and Linnaeus proved worthy the faith of his good friend. He was but twenty-three years old when the idea which formed the basis of his new system flashed upon him, and his youth and obscurity might have stood greatly in his way but for the high opinion that Celsius held of his talents.

But, sure of the favor and appreciation of his new friend, Linnaeus went on developing his new thought and bringing it to perfection until it was perfectly clear and distinct in his own mind, and he was furnished with sufficient proofs to make it plain to others. Then he prepared a paper stating his views, which met with the warmest approval from Celsius. A public discussion was just then being carried on in the university, and Linnaeus took this opportunity of reading his paper and bringing his new theory into notice. Upsala was at first astounded, and then delighted, and before long all Sweden was ringing with the name of the young student whose talent was to confer immortal honor upon his country.

He was appointed Assistant Professor of Botany in the university, and his lectures at once became famous and attracted large numbers of students to Upsala, and thus, in less than three years from his entrance to the university, he had been advanced to a position and received honors that were undreamed of when he first entered its inhospitable walls.

The Linnaean system, which made such progress as to rapidly supersede all others, is founded upon the number, situation, and proportion of the stamens and pistils of flowers. It divides the vegetable world into twenty-four classes, distinguished by their stamens, and these classes are again divided into orders, which are generally marked by the number of pistils.

This system was the most perfect that had yet been offered, and the surprise and delight of naturalists who found classification thus easily simplified at once brought it into popular favor. It had, of course, many imperfections, which were regretted by none more than by Linnaeus himself, and he never spoke of it as a perfected system but always considered it only as a leading toward truer ways of classification.

The idea which Linnaeus made use of was not original with him, for it was hinted at by more than one old Greek, and had lain dormant in the minds of naturalists for centuries, but Linnaeus was the first to think of using it as a basis for a system of classification, and it must thus be forever associated with his name.

This system is called the artificial system, because it merely furnished a convenient method of finding the name and place of a plant, without regard to its relationship.

The natural system, which is based upon the relationship of one family of plants with another, in time superseded the Linnaean system, which owes its chief interest now to the fact that it was the first classification which made it possible to reduce the study of botany to a science, and that its establishment led to the development of the natural system, which Linnaeus himself declared to be the only true way of classifying, and which his system only embraced in part.

After his appointment as professor at = Upsala, other honors rapidly followed. The next year he was commissioned by the Royal Academy of Sciences to travel through Lapland and examine its natural curiosities and productions, and this trip was a source of great pleasure to him, though travelling was often dangerous in those remote regions, where rocks and marshes obstructed the way, and roads were almost unknown. It was while on this trip that he found a little unknown plant growing in shady places which he immortalized by giving it his own name, the *Linnaea borealis*, and which, he said, typified his own "neglected fate and early maturity."

The journey was a success, and raised him still higher in the estimation of Upsala, but his honors could not shield him from the jealousy of enemies who prevented his obtaining the position at the university that he expected to receive, and, disappointed in this, Linnaeus left Upsala and undertook a journey into Norway under a commission from the Governor of Dalecarlia; and with this trip he began those extensive travels which lasted through so many years and in which he gained the experience that enabled him to go on with his work and add more and more to his fame.

From Dalecarlia he proceeded to Holland, where he wished to obtain his degree, going by the way of Hamburg, whose honest burghers he insulted by revealing the fact that their wonderful hydra, or seven-headed serpent, was nothing more than a clever fraud, with its seven heads all made of the jaw-bones of weasels, and this made him so unpopular that some friends actually advised him to shorten his stay in the city.

He took his degree as Doctor of Medicine at Harderwyk (1735), and immediately after went to Leyden, where he formed the acquaintance of the celebrated naturalist Gronovius, who was so astonished when Linnaeus showed him his Systema Naturae that he offered to publish it at his own expense.

The publication of this work immediately brought Linnaeus to the notice of all the eminent naturalists of Europe, and procured for him great attention wherever he appeared; and during the three years he spent in Holland, France, and England he received the most distinguished favors.

All this, however, could not prevent a longing for home, whither he returned in 1738, and four years after was appointed Professor of Botany at Upsala, a position he had long desired.

And now life, at last, seemed only pleasant to him. Occupying the proud position of the first naturalist in Europe, and with means at his hand to command whatever resources he desired, he devoted his time more diligently than ever to study, and gained new honors year by year. The number of students in the university increased from five hundred to fifteen hundred, all attracted by the fame of Linnaeus, and the collection of plants in the botanical gardens soon became unrivalled.

Rare specimens were sent to him from the most distant places, and his pupils were soon scattered all over the globe, carrying his name and fame with them, and thinking themselves well repaid for all their trouble if they were able to bring some new or rare plant to their beloved master. Many important discoveries were made at this time by Linnacus, not the least interesting being that of the sleep of flowers, which was first brought to his notice by the closing of the petals of a lotos in the evening.

From this circumstance he formed the theory, and proved that flowers have regular periods of sleep, and he made a little calendar in which the hours of the day were marked off by the closing of the different blossoms.

In these congenial pursuits time passed pleasantly enough, and Linnaeus almost forgot the hardships and struggles of his early youth. Sweden, ever ready to do him honor, offered him one mark of distinction after another, until there seemed nothing left to offer. In 1761 the king made him a noble, and the family was thenceforth called Von Linne, an honor little dreamed of by its peasant-founder. And thus, with the years full of content, life went happily on, and when old age came to Linnaeus he could reflect on years that had been well spent and full of good to his fellow-men.

During the last years of his life he suffered much from disease and mental weakness, but still kept his serene and cheerful spirit, and never lost his keen interest in his beloved studies.

And when death came to him at last one day as he lay quietly sleeping, it seemed but as the folding of the perfect flower which closes its petals when its time of expansion is over, and becomes a fragrant memory, full of a sweetness and grace as enduring as the immortal beauty of which it was a part.

## CHAPTER VI

# HERSCHEL AND THE STORY OF THE STARS

## 1738–1822

The early state of society is sometimes called the childhood of the race, when none of the questions which vex the human mind had yet been asked and mankind accepted all things as a child does, without doubt or comment.

And as the child looks without wonder on all the marvels of creation, and fears nothing, knowing that the day-world, with all its beauty, will only fade away to be supplanted by the night-world, with its charm of star and moon and dream, so did the early races look with the same unquestioning eyes upon the succession of day and night, and starlight and sunlight were to them but two separate kingdoms, over which they had equal dominion .but of whose resources they had no knowledge.

The Chaldeans and Egyptians were the first nations who have left us records of their studies of the world of nature, and it is to them that we owe the faint beginnings of scientific thought. Believers in a fate or destiny which ruled all the affairs of men from the greatest to the smallest, they sought, in every manifestation of nature, a sign, or lesson, and their faith in the influence of the stars upon the lives of men gave to the study of the heavens a special value.

This superstition passed, with the progress of knowledge, into the minds of other nations, and among the Greeks there early arose a separate class of students called astronomers, from the word aster, a star, which had for its object the study of the stars, and it was from this desire to connect all the workings of nature with the affairs of daily life that the science of astronomy was born.

For ages the stars and planets, "the lamps of heaven," were regarded with a superstitious awe, and the old faith of the Chaldean priests could be found living in the breasts of the mystics of the Middle Ages, long after the race had outgrown its childhood, and astrology, the science which professed to foretell the fate of man from the constellation which ruled at his birth, still flourished when the advancement of thought had brought about a state of society in which science and the arts played an important part.

But modern thought finally freed itself from this intellectual bondage, and set about the study of the stars in the same practical manner that a seaman would undertake a voyage of discovery, and from that time astronomical knowledge made rapid progress.

Among the greatest of modern astronomers was William Herschel, who was born in the city of Hanover in 1738. His father was an oboeist in the Hanoverian Guards, and the child's first impressions were connected with the little musicales that were held every evening in the unpretentious family sitting-room. Money was scarce in this obscure little household, the father's salary hardly sufficing to bring needed comforts to the children, but there was not a happier family in the city, for all that. The father had all a musician's love for his art, and wanted nothing more, when his hours of duty and teaching were over, than to gather his children around him and improvise a family concert, training the little performers with earnest care, noticing their improvement with fatherly pride, and refreshing himself with the thought that he was supplying them with are source that, no matter how hard their lot might be, would always be a comfort and help to them in the future.

William was the second son, and very early was considered an important personage in the family group, showing an extraordinary taste for music, and developing a great talent for discussion; for, besides their musical bent, the family were much given to grave talks about everything that attracted their attention. As the children grew older the father adapted these conversations to subjects best suited to develop their minds, and art and philosophy were as eagerly discussed as music. Sometimes, before the evening was over, they would all go out of doors, and spend an hour in studying the constellations and listening to their father's remarks on astronomy, which seemed just as interesting to them as their lessons in music, although it was quite understood that all the sons were to be musicians, a calling that seemed the most honorable and enviable of any to the entire family.

With the idea of initiating them as early as possible into the mysteries of their chosen profession, the father allowed them from time to time to take part in public concerts, their talent being so unusual that even as children they were given solo parts to play, and thus, while yet a little boy, the future astronomer was made to assume certain responsibilities, and to look upon life seriously.

The Herschel boys attended the garrison school in Hanover, where they learned the ordinary branches, their father taking care that any deficiency in the course should be supplied at home, and letting them feel that in all their pursuits and enjoyments Ile wished to be their companion and friend. It was necessary, however, for the children to aid in the support of the family as soon as possible, and therefore the two oldest sons were yet lads when they entered the guards, William accepting the position of oboe-player. The family concerts, however, still continued, only interrupted by the making of musical instruments and all sorts of mechanical toys, for which the father and sons had a fancy, and the family discussions still formed an interesting part of their life, more than half the night often being passed in animated talk as to the merits of the different artists, philosophers, and naturalists who were then famous.

William remained in the army for four years, one year of which was spent in England, and at the age of nineteen left the guards on account of delicate health, and returned to England, with the hope of being able to earn his living there.

A less enterprising youth might have been dismayed at the prospect of being homeless and friendless in a foreign land, but Herschel did not consider his lot by any means hopeless. He could speak English well enough to make himself understood, could play on the oboe, violin, and organ with sufficient skill to assure him some kind of a living, and, above all, his wants were few and modest; and so his new life in England did not frighten him, and he began it with a brave heart.

Some years were spent by the young musician in wandering from one town to another, without having any permanent employment, but finally he came under the notice of Dr. Miller, a well-known organist of Durham, who was so delighted with Herschel's rendition of the works of his favorite composers that he invited him to come and live with him, promising to do all that he could to advance him in his profession. Herschel accepted this generous offer in the same good faith in which it was made, and from this time his success was assured.

Miller's influence procured him the place of first violin in the popular concerts at Durham, where he speedily became a favorite, and was soon offered as many pupils as he could take; and as his popularity spread he was offered one advantageous position after another, until he was finally appointed organist of the principal church in Bath, where the gay society and intelligent companionship of his new friends, together with increased means at his disposal and larger facilities for study, made up a life as pleasant as could be desired.

Herschel was at this time about twenty-eight years old, and had made such progress in music that he soon began to publish his compositions, and to have the satisfaction of seeing them favorably received by the public. At this time, although an earnest student and devoting every spare moment to study, he seems to have had no other ambition than to become a good musician; and in order to accomplish this, he began a careful study of harmony, using for his instruction a work on harmonics which then enjoyed considerable fame. The study of harmony is dependent upon a knowledge of mathematics, and this led to kindred subjects. The author of the "Harmonics" had also written a work on optics, which fascinated Herschel to such a degree that he pored over it every leisure moment of the day, and spent long hours of the night in studying it. His interest was turned in this way to astronomy, and so absorbed did he become in this subject that he had no rest until he had procured a telescope and looked out all the objects in the heavens which were described in the books. And when this point was reached, his true work in life first began. From the time that he first saw the magnificent spectacle of the heavens revealed to him in its hitherto unknown splendor, he devoted himself to its study with an ardor that made all his previous interests seem insignificant.

Pupils were dismissed in order to gain more time for study and observation, although he could not well spare the money, and his brother and sister, who now lived with him, were drawn off from their musical studies and pressed into the service of making telescopes and other instruments necessary for surveying the heavens.

The brother and sister gave themselves to the new work with the energy that characterized the family; and soon the house was turned into a huge workshop, and stands, tubes, and mirrors were turned out as fast as possible.

Herschel became so engrossed that he would not leave the workshop even for his meals, and his sister could only induce him to eat by standing by his side and putting the food into his mouth, while at the concerts and theatres where he led large orchestras, it was no uncommon thing for him to rush out between the acts and spend the time in snatching brief glimpses of the heavens. This industry was well rewarded, for Herschel was so successful in his experiments that he was able to produce telescopes far superior to any that had yet been made, and received quite an addition to his income by the sale therefrom; and the careful study of the heavens which he then began proved of infinite service to him later on.

Herschel's great object was to make a more thorough survey of the stars than had yet been attempted, and, in order to do this, he mapped out the heavens in sections, determining to study each part with the greatest care; and so earnestly did he carry out this plan that for years he never went to bed of a clear night while a star was visible, remaining winter and summer in the open air until the day dawned. While thus engaged Herschel noticed one night a star of different appearance and much larger than the small stars near it, and a careful observation for two or three nights showed him that the body did not remain stationary, and scintillate as the stars, but that it shone with a steady light and appeared to change its place. Herschel thereupon decided that he had found a new comet, and at once announced the discovery to the world. All the astronomers of Europe immediately turned their attention to this interesting object, and mathematicians at once began to observe its motions and calculate from them the size and shape of its orbit. All the comets that were known had been found to have orbits very elliptical in form, but, after many months of calculation, astronomers were forced to admit that the new comet could not move in an orbit similar to those of other comets, but that, on the contrary, it was travelling in a path only slightly elliptical, like that of the earth and other planets,

This conclusion at once led to the suggestion that perhaps the new object was not a comet, after all, but a planet, and, startling as this idea seemed, it was finally demonstrated by the French astronomer Laplace, that Herschel had really discovered a new planet.

The world of science was electrified by this discovery, which was not only the greatest that had been made by the telescope since the splendid revelations of Galileo, but the greatest that had ever been made. The other planets had been known as far back as the memory of man extended, and the finding of new stars, or of the satellites of the planets, seemed of much less importance than the discovery that there was still another member of the system of planets, like them bound by the mysterious influences that held them together, and performing its regular revolution around the sun, although its presence had been unknown and unsuspected through all the countless ages of the world.

Astronomy was invested with a new interest, and all eyes were turned with eager gaze to the starry fields of heaven, for who could tell what new wonder might not be found, far away in the dim recesses of space?

And in the meantime honors were showered upon the one who had read this new secret, and who had hitherto only been known to the world as a clever amateur astronomer who had spent the intervals between his musical studies in writing a theory on the height of the mountains of the moon, or in manufacturing telescopes.

Herschel wished to name the new planet after George III., King of England, but this was objected to by other astronomers, some of whom proposed to call it after its discoverer and others thinking it would be more in harmony with the traditions of science to give it the name of one of the old Greek deities. These last carried the day, and the planet was finally named Uranus, after the oldest of the gods.

Uranus was discovered on the 13th of March, 1781. It had been before this napped as a star, and, in order to connect the discovery of its planetary character with the name of Herschel, its sign in astronomical records is the letter H with a suspended orb.

It was now generally acknowledged that the labors of such a genius as Herschel should be devoted to science alone, and accordingly the king granted him a pension which enabled him to give up teaching. Some time after this the family moved to Slough, where there were better opportunities offered for study, and Herschel at once began the construction of an immense telescope which, when finished, greatly aided him in his survey of the heavens.

A new satellite of Saturn was discovered the day after the completion of the great telescope, and in 1787 it was found that Uranus was furnished with two moons. This discovery filled Herschel with delight, being an added proof of the harmony that extended throughout the universe. Before making it known, and in order to be absolutely sure that he had not been mistaken, Herschel prepared a sketch of Uranus and his revolving satellites as they would appear on a certain night, and great was his joy, when the moment came, to find that the position and appearance of the group exactly corresponded to his drawing.

This experiment seemed to give him a greater hold than ever upon the secret of the heavens, which he spoke of as a luxuriant garden filled with choice flowers, whose life might be watched from the bursting of the seed through all the successive stages of foliage, bloom, maturity, and decay, just as plants are studied from the time of the sowing of the seed to the fall of the last leaf in autumn.

Two thousand years before the time of Herschel a catalogue of the stars had been executed by Hipparchus, the Greek astronomer, who was led to the work by the appearance of a new star of unusual brilliancy which disappeared after a while from the heavens. And although from time to time after this, star-catalogues were prepared, it was reserved for Herschel to make the first thorough and systematic attempt to construct a catalogue in which the stars were classified according to their relative brightness. In the preparation of this catalogue the conclusion was reached by Herschel that there are certain stars which appear and disappear, and others whose light increases and diminishes for no known reason. Such stars are called variable stars, and it is of the utmost consequence in preparing a catalogue to take these into account. In catalogues, the stars are classed as of the first magnitude, second magnitude, and so on, according to their brightness. Stars of the sixth magnitude are visible to the naked eye, while the telescope even reveals those of the seventeenth magnitude; but these numbers do not signify the actual degrees of brightness, as a star of the first magnitude shines with one hundred times the brilliance of one of the sixth.

When viewed through a telescope, certain stars which appear only as brilliant points to the naked eye can be separated into one or more stars, and a careful study of these interesting bodies led Herschel to one of his grandest discoveries.

He observed these stars through several years, and at last came to the conclusion that in all cases of double stars one revolved around the other, just as the moon revolves around the earth.

Newton's system of gravitation bound the earth and planets to the sun, and made of the solar system a harmonious whole, but Herschel's discovery of the revolution of one star around another went even further than this, and extended the harmony to the farthest regions of space, and the grandeur of this discovery was alone sufficient to make the name of Herschel famous in the history of science.

In connection with his study of the stars, Herschel undertook to measure their distances from the earth, and to find out if their brightness depended upon their nearness to or remoteness from us. And after a long series of careful experiments, he determined that if stars of the first magnitude, like Sirius and Arcturus, were removed twelve times their actual distance, they would be just visible to the naked eye, while if stars which are only now to be seen through a telescope were to be brought nearer to the earth so as to be only one-tenth as far away as they now are, they would shine with the brightness of the largest and most brilliant stars. He concluded, therefore, that the brightness of the stars depended on their distance, and that the fainter stars were the more distant ones, and even devised a method based on this idea by which their relative distances could be ascertained.

It is now known that he was wrong in this view, for some of the faintest stars have been found to be among those nearest the earth; but the difficulties met in determining star-distances are so great that it was not till sixteen years after the death of Herschel, and when the instruments for making observations had been greatly improved, that the distance of a fixed star was actually measured. Herschel's investigations and experiments on the light of the stars and their distance led the way to some of the most valuable and wonderful results of modern astronomical research and have given him the position of a pioneer in the science.

In connection with these studies, Herschel also took up the subject of the nature of the sun and its place in the universe. The accepted theory of the sun's nature was that it was a solid, surrounded by a luminous atmosphere which gave it its brightness, and this theory, with some changes, was also held by Herschel. But his deductions in regard to the sun's place in the universe were of more importance. His discovery of the revolution of double stars could only lead to speculation with regard to all the objects of creation, and it was but natural to conclude that motion, which was a property of so many, should belong to all.

Observations extended from the time of the ancients had led to the conclusion that some of the largest stars of the first magnitude had changed their places within the historic period, and they were therefore supposed to have an individual motion, and from this fact Herschel argued a corresponding motion for the sun, which he decided was itself a small star. He therefore began a series of experiments, and finally came to the conclusion that the sun, with all his attendant company of planets and comets, was in reality moving through space at a marvellous rate of progress, and that, in accordance with the law of gravitation, he was passing through an orbit of inconceivable magnitude having for its centre one of the remote stars.

It has been thought that this great central fire whose mighty forces thus govern the mechanism of the solar system is the star Alcyone, in the Pleiades, but of this we cannot be sure. We only know that the sun, with his great retinue of revolving worlds, is moving toward some unknown point in the heavens, and that the stars, which were once thought to be brilliant globes firmly fixed in crystal spheres, are in reality probably the centres of attendant planets which they carry with them in their majestic progress through the boundless regions of space; and that, if it were possible to view the heavens as they really are, we should see an infinite number of such systems, with orbits crossing and recrossing, in the most intricate manner, but in place of the apparent confusion and entanglement there exist the most exquisite order and symmetry.

Herschel's study of the heavens also included observations on those cloud-like appearances called nebulae which are seen in various constellations, and of which the Milky Way is the greatest example.

From the earliest times this broad band of light had attracted the attention of mankind, and many quaint legends were connected with it. The Romans called it the Highway of the Gods, and in later times it was sometimes spoken of as Jacob's Ladder; but even among the ancients some true idea of its character existed, for Pythagoras declared that the Milky Way was only a great assemblage of stars, and Galileo's telescope had proved that in the main the theory of the old Greek was correct. At first Herschel was led to believe that all nebulae could be seen to be made up of stars, if viewed through a sufficiently powerful telescope. But later he changed his opinion, and came to the conclusion that there were two kinds of nebulae—the resolvable, which are made up of great star-clusters which have a cloudy appearance from their immense numbers and great distance, and the irresolvable, which are immense masses of self-luminous matter which gradually is condensing into solids like the sun and stars. This last idea was not new to Herschel, for Tycho Brahe and Kepler had both suggested that the "new stars" which appeared from time to time might be caused by the condensation of the ether which filled all space. And although all "new stars" are really believed now to belong to the temporary stars which appear and disappear with regularity, yet the thought that the universe had been evolved out of such matter shows in a marked degree the originality and boldness of Kepler's genius.

The French astronomer Laplace, a contemporary of Herschel, also held this theory of the nebulae, which he published in a work called the "Nebular Hypothesis."

Laplace conceived that the solar system consisted originally of matter in the form of gas or vapor of an enormously high temperature; that as it cooled unequal currents were formed, which gradually caused it to rotate; that its rate of motion increased until the outside, which was of a lower temperature than the centre, would become detached and break up into smaller parts; that these parts came together finally and formed spheroidal masses which revolved around the centre; that the sun was what was left of the original matter, and the planets and asteroids were the parts that had been thrown off. This theory, which had its foundation in the action of the law of gravitation, may apply not only to the solar system but to the entire universe, and Herschel's idea of the irresolvable nebulae, consisting of a shining fluid which was solidifying into stars, has been supported by later astronomers, for when the light from these nebulae has been analyzed it has given out the colors of matter in a state of gas, while an analysis of the light of the stars gives a very different result.

And thus Herschel's comparison of the heavens to a flower-garden may be seen to have a deeper significance than would at first appear; and if we consider the claims of the nebular hypothesis, we might say that the nebulae are the great seed-repositories of nature, from which are evolved all the stars and planets which, passing through the time of bloom and maturity, come at last to a state resembling that of the dead moons—the withered flowers of these celestial gardens—from which all life has passed away.

Herschel made many observations on light and heat in connection with his other studies, but he is chiefly remarkable for his exhaustive survey of the stars.

He died in 1822, at the age of eighty-four, preserving his great mental powers till the last, and claiming, with truth, that he had looked farther into space than any other eye had yet penetrated.

The nebular hypothesis which his researches helped to formulate is as yet but an unproved theory, and whether it' embodies the true secret of creation or not we cannot tell.

## CHAPTER VII

# RUMFORD AND THE RELATIONS OF MOTION AND HEAT

## 1753–1814

Benjamin thompson, known in the scientific world as Count Rumford, was born in North Woburn, Mass., in 1753. His family had been farmers for generations, and his relatives destined him for the same calling; but the boy showed such a distaste toward farming that this fact, in connection with some troubles in relation to the distribution of the property, led at last to the choice of another mode of life.

Up to his eleventh year young Thompson attended the village school, and learned reading, writing, and arithmetic for several hours in the day, devoting his play-hours to the more congenial employment of making drawings of his companions' faces, which he often caricatured unmercifully, constructing various mechanical toys, and in experimenting in a small way in natural philosophy.

These amusements did not meet the approval of his family, whose idea of life was quite different. The experiments and inventions showed a taste for something beyond the ordinary routine of a farmer's life, and Benjamin's fancy for exploring the unknown was not encouraged. Happily for him, he was sent in his eleventh year to an adjoining village in order to be under the care of a very excellent teacher, and as his interest in things outside of the usual line increased daily by contact with the mind of his teacher, it was decided by his friends to give up all hopes of making the boy a farmer, and apprentice him to some trade. When he was thirteen years old, therefore, he was sent to Salem to learn to be a merchant, and here he met friends who encouraged his love for knowledge, and aided him in the most substantial way. His duties as clerk were faithfully performed, but they only seemed to him to be the necessary means toward something higher. All his leisure time was spent either in boyish frolicking, or in studying subjects quite unconnected with the mercantile life, and both these circumstances often caused some of his friends to shake their heads gravely over his refusal to regard trade as the most serious and respectable business of life.

Their disapproval, however, did not in the least affect the spirits of Benjamin, who was always ready for fun, sometimes even enlivening his dull business by playing on the violin, and at others busily engaged over the question of making fireworks which he and his friends were to send off at the first possible opportunity. A little note-book which he kept at this time shows a curious mixture of caricatures, drawings of boats, bottles, tomahawks, human bones, bars of music, and pistols, interspersed with recipes for making rockets, stars, serpents, and other fireworks, illustrated with drawings in ink.

These pursuits, however, did not prevent attention to more serious subjects, and during the first years of his apprenticeship Benjamin made such good use of his time, and of his opportunity of studying with an older friend, that before he was fifteen he had a fair knowledge of algebra and geometry, and had made such progress in astronomy as to be able to calculate an eclipse so accurately that it occurred within a few seconds of the computed time.

Trade could not long hold the attention of such a mind, and when he was eighteen Benjamin left his master and began the study of medicine, supporting himself in the meantime by teaching school. He made considerable progress in his new business, and was so successful as a teacher that he was invited to take charge of a school at Concord, then called Rumford.

And it was here that events happened which entirely changed his life, and resulted in his devoting his great powers to science. Shortly after his arrival at Concord he married the daughter of one of the most prominent men of the place, coming by this means into the possession of a large estate; but hardly had he settled down to the business of managing his new property before he was compelled to leave the town as a fugitive. His marriage had taken place in October, 1774, and in November of the same year he was accused of sympathy with the English Government, and his life was threatened by his enraged townsmen, who were in the full tide of anger against the mother country.

Although at the trial afterward he was pronounced innocent of the charges laid against him, he never recovered the faith of his countrymen, and was always subject to their suspicions, which were perhaps not wholly unjust when it is considered that in 1776 he went to London and took service under the British Government.

He now began to make experiments in gun-powder, and on the making of cannon and the measurement of the velocities of bullets, and subsequently went on a cruise in order to give his theories a final test. He thus acquired a taste for military life, and after a short trip to America, he returned to Europe in 1783, hoping to serve in the Austrian campaign against the Turks. He was always so thoroughly in earnest that if Austria had begun the expected war it is probable that Thompson's career might have been wholly directed to military glory; but, fortunately for science, he met about this time an old lady, the wife of one of the Austrian generals, whose influence led him to take other views of life, and convinced him that a life devoted to the relief of mankind was of infinitely more value than any honor gained on the field of battle.

Soon after this he was invited to Munich by the Duke of Bavaria, who urged him to enter his service, and from this time his life was one of ceaseless activity. Munich, in common with other European cities, was at that time subjected to the most incompetent public service, and the state of affairs in the capital was common throughout the country.

Thompson was appointed colonel of a cavalry regiment, and aide-de-camp to the duke, who also gave him a palace to live in, and a military staff and corps of servants. But his magnificent style of living, and the honor paid him as the friend and adviser of the duke, did not in the least interfere with the plans he had formed for the improvement of Bavaria. Thriftlessness, abuse of power by the priesthood, discontent in the army, and neglect of the resources which might bring comfort and wealth were among the evils that Thompson set about finding remedies for, and his practical mind and great executive ability soon brought about the needed reformation.

The discontent of the army had its source in real grievances. The soldiers were taken from their homes and scattered all over the country, leaving the fields untilled and the manufacturing industries destroyed while they were serving in the army, which had such a demoralizing effect upon them as to unfit them for useful labor when their time of service had expired. Their pay was miserable, their quarters uncomfortable, and the comfort of their families entirely overlooked.

Thompson's remedy for this evil was radical and prompt. He had permanent garrisons made, so that the soldiers from the different districts might remain near their homes; he reformed the drill and discipline, giving the soldiers much more time at their own disposal, and this time could either be employed in the public works, or in manufacturing different articles from the raw material furnished them, or in the cultivation of the little gardens which were the property of every soldier, every one of the different occupations being a source of added income to the privates, who had hitherto been looked upon only as the slaves of the officers.

Besides this, the barracks were made clean within and without, the soldiers were better clothed and better fed, there were schools established for their children, and when it was absolutely necessary for the troops to be garrisoned at great distances from home, long furloughs were allowed, so that the men might attend to the agricultural and manufacturing interests that had sprung up. The effect of the new system was magical. Discontent disappeared from the army, and the soldier was transformed from an indolent, fault-finding, and dissatisfied attache of the officer, to a self-supporting and self-respecting citizen. Little gardens sprang up all over the country, where the soldier, clothed in the working suit furnished him by the State, might be seen planting seeds; and many vegetables, among them the potato, which had hitherto been almost unknown in Bavaria, from this time became staple articles of food. The reform of the army was followed by another improvement of equal value.

The evils of a standing army, the dearth of manufactures and the neglect of agriculture, had all combined to bring about a state of affairs among the working classes as demoralizing as the condition of the soldiers. The whole of Bavaria was overrun with people who had no trade, no home, no duties, and, worst of all, who considered that they had a right to demand a living of their more self-respecting and independent neighbors.

Beggars abounded everywhere, and society was divided into two factions, one representing the respectable element, and the other the disreputable hordes who roved about the country, feared on account of their numbers and defiant of all control. Not only did the natives take advantage of this condition, but beggars swarmed in from adjoining countries and found cordial welcome from the depraved vagabonds who had learned that numbers meant power.

Beggary was in fact but a kind of freebooting, and the beggars considered themselves members of a respectable and worthy fraternity whose rights must be maintained. And they found this an easy matter, as their crimes had made them a terror to the country, and the civil authorities had come to look upon the case as almost hopeless. The highways were lined with beggars who demanded alms from all travellers; stores, houses, workshops, and churches were entered and money extorted by threats; and the husbandman and merchant had alike learned to consider the beggar's portion as a necessary detail in the year's expenditures.

In the cities things were even worse. In Munich the whole city was divided off into districts, each being under the control of certain bands, which were governed by a code of unwritten but not the less stringent laws. This nuisance was attacked by Thompson in the same spirit which had actuated him in his work for the army. He declared that the government owed not only protection to the honest classes, but moral responsibilities to the beggars themselves, and he proposed to rid the country of begging by turning the offenders into self-supporting citizens. Such a proposal from one less practical and less powerful would have met with no response. But Thompson's regeneration of the army had proved his administrative powers, and the authorities of Munich gladly promised him all the aid he could desire.

He ordered the city to be divided into districts, and every dwelling, from palace to hovel, to be numbered. Each district was furnished with a priest, a physician, a surgeon, an apothecary, and one prominent citizen whose duties were to consist in looking after the respectable poor. Then a large building in one of the suburbs was fitted up with kitchen, refectory, workshops, and machines suitable to the wants of the various trades. Over these were put master carpenters, smiths, turners, spinners, weavers, dyers, and so on, who were furnished with the necessary raw material for carrying on their different vocations. These were the teachers in the institution, which was called the Military School, and had for its object the reclaiming of the lowest orders to respectable modes of life. Besides the workshops, the building was fitted up as attractively as possible, and was made thoroughly neat and comfortable.

As soon as the arrangements were completed, the work of reformation was begun. New Year's Day was the great annual holiday of the beggars, who paraded the streets from morning till night, demanding alms in the most offensive manner, and making the thoroughfares almost impassable for the respectable classes.

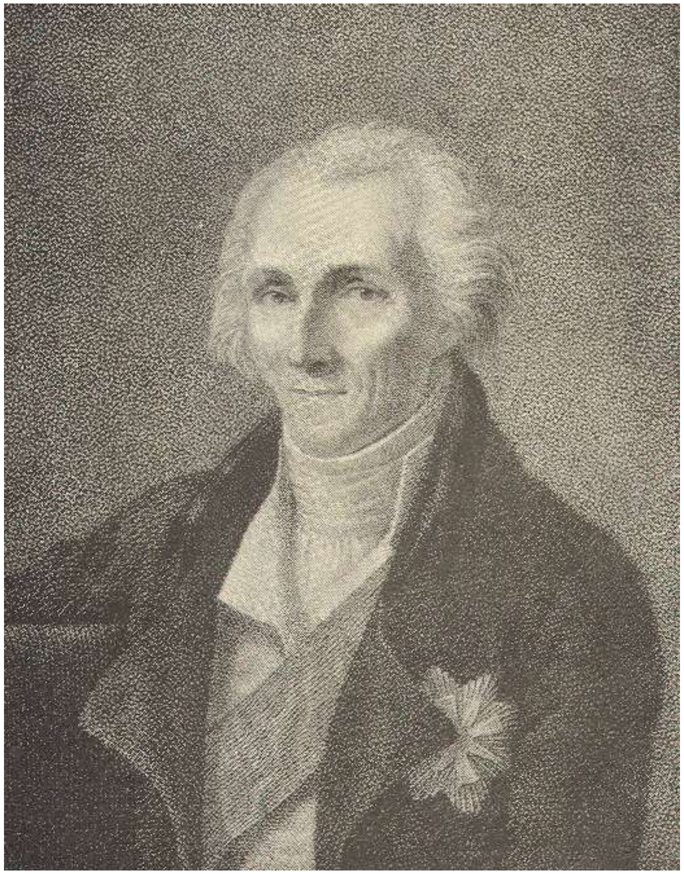
On the morning of this festival Thompson had soldiers stationed all over the city, and he, with the civil authorities, started out on the bold venture of capturing every beggar in the streets of Munich. They had hardly reached the street when a beggar approached Thompson and extended his hand for alms; the decisive moment had come, and with a firm but gentle denial, Thompson laid his hand on the man's shoulder and declared him under arrest. His example was immediately followed by his associates, and the raid was as thorough as unexpected. Every vagabond in the streets was carried to the townhall, and his name and residence taken, and orders given for him to appear next day at the Military School.

The beggars were astounded, but showed a better spirit than had been hoped for; the plan succeeded beyond the most sanguine expectations of its originator, and within a week twenty-six hundred beggars had presented themselves at the workhouse and had started on a career of useful labor. Nothing can better illustrate the esteem which their benefactor was held in than the fact that, some time afterward, when these reclaimed outcasts learned of the critical illness of Thompson, they assembled in large numbers and, forming in a procession of hundreds, marched to the cathedral and offered prayers for his recovery.

A year after the organization of the Military School, Thompson was made a Count of the Holy Roman Empire, in token of the inestimable services he had rendered to Bavaria; he took the name of Rumford, from the little village in Massachusetts where he said that fortune first smiled upon him.

Count Rumford was constantly employed with some scheme to alleviate the condition of mankind, and Bavaria, under his guidance, was transformed as if by magic from a state of disorder and shiftlessness to prosperity and peace. In the world of science Count Rumford occupies a distinguished position. He made many valuable contributions to physics, but is chiefly known by his discoveries in heat.

Various theories had been held as to the origin and nature of heat, and, the ancients had many curious ideas in regard to this subject.



BENJAMIN THOMPSON (COUNT RUMFORD)

Up to the end of the eighteenth century the most generally accepted theory of heat was that it was a kind of subtle fluid which could enter the pores of bodies, and then be squeezed out again by compression. This fluid was called caloric, and was supposed—by its capability of combining with certain substances—to explain by its actions all the phenomena of heat.

Count Rumford, in opposition to this theory, asserted that heat was a form of motion, and that all its phenomena could be accounted for on this supposition alone.

This belief, like many other scientific creeds, was partly arrived at by accident. While watching one day the boring of a large brass cannon in the arsenal, he was struck by the great quantity of heat that was produced by the pressure of the boring bar against the brass. He immediately began some simple experiments with the filings to see how the heat might be accounted for, and the results led him to the conjecture that the thing known as heat was really a form of motion.

He made a test-experiment in the presence of some of his friends, causing a brass cylinder to be placed inside a wooden machine which contained a quantity of water, and then having the cylinder revolve against a steel borer. At the end of two hours the spectators were astonished to see the water boil, although there was no fire near.

It had been known from the earliest times that friction would produce heat; but it was also generally supposed that the friction brought out the caloric that was latent or hidden in the bodies that were rubbed together. Rumford claimed, on the contrary, that if this were so there would be a limit to the amount of heat that could be obtained by the friction two bodies, just as it is impossible to squeeze more than a certain amount of water out of a sponge; and as he had shown by experiment that there was no limit to the amount of heat that could be obtained by friction, he concluded that heat was not a substance which bodies contain as a sponge holds water, but that it was itself simply a form of motion. According to this view a hot body differs from a cold one in that its particles are in more vigorous motion.

This is called the dynamic theory of heat, and it is this contribution to scientific discovery that has connected Count Rumford with other great physicists.

# Chapter VIII

# Cuvier and the Animals of the Past

## 1769–1832

The kingdom of science may be likened to a meadow full of children at play. One child plucks flowers, another gathers the pebbles that lie on the shores of the little brook, a third watches the waves bearing away the bits of moss from the woods beyond, and a fourth listens to the songs of the birds, or gazes at the clouds floating in the blue sky far above him.

If a child were asked why he plucked flowers instead of listening to the voices of the birds, he could not tell, and if his companion were ordered to throw away his pebbles and gather the drifting moss, he would only stare in wonder.

And so it is in the great world of nature when, instead of children at play, we find earnest men giving all their energies of mind a soul to some special calling.

To one it seems best to count the flowers of the field, to another to number the stars of heaven, a third studies the hidden forces of nature, and a fourth can find satisfaction only in the presence of that life which so closely resembles his own.

And if the botanist were asked why he did not choose astronomy as his calling, he could not tell, and if the physicist were compelled to turn zoologist it would seem to him as if study had lost its charm.

And the progress of science corresponds to these individual tastes and exertions. One age is distinguished for one thing, and another for another, and it would be as difficult to find a reason for this as to know why still another period will be marked by widely different characteristics.

Thus we find that in the beginning of the eighteenth century, scientists were engrossed by the study of the secret forces of nature—light, heat, electricity, and chemistry—and the mysterious laws of plant life; studies which in another hundred years were destined to bear a golden harvest for science.

By the latter part of the eighteenth century the point of view had shifted a little, and other subjects began to occupy scientists; the questions of the antiquity of the earth, its formation, and the connection between the past and the present began to be studied by one class of minds though another class was still working at the problems of the hidden forces of nature, and among the new subjects of study we find paleontology the study of the remains of the plants and animals which lived in remote ages; these remains are called fossils, and their study has thrown much light on the subject of the earth's formation, and the development of life.

Chief among the students of nature who gave themselves to this study we find George Leopold Chretien Frederic Dagobert Cuvier, who was born in the village of Montbeliard, in France, August 23, 1769.

Montbeliard is beautifully situated on the River Allar, with a background of wooded hills, and in the midst of sunny slopes covered with choice vineyards.

On the rocky heights above the village stand, the two ancient castles which were the pride of Montbeliard in the feudal days, and everywhere throughout the valley bloom the roses and wild flowers that give the place one of its brightest charms.

It is not strange that amid such congenial surroundings the little Cuvier early showed a great love for nature, and the influence of his mother, who was his first teacher, aided him in forming those habits of keen observation and diligent study which served him so well in after-life.

He was a delicate child, and much of his mother's time was given to the care of his health; but still the little lad had learned to read by the time he was four years old, and in his walks and excursions around Montbeliard he saw much that added to the small store of knowledge, which he gained daily at the little school he attended. When school-hours were over, and the outdoor exercise of the day had ended, then came little drawing-lessons from his mother, which trained his eye and strengthened his memory, and led him to notice accurately all things around him.

The shape of the clouds that hung over the low hills, the grouping of the shrubs in the home garden, the outlines of the old chateaux on the heights above, and the interlacing branches of the leafless trees in winter, all played their part in the training of the bright young eyes that looked so eagerly out on the world and found everything in it interesting.

Every new object was at once made a subject for drawing; and even this did not satisfy the child, who often cut out little pasteboard models of anything that pleased him, and delighted in reproducing whatever seemed difficult or mysterious to his companions.

This faculty was shown at a very early age, for when only six years old he astonished his friends by his explanation of the tricks of a juggler who was passing through the village, and whose various marvels of sleight of hand were easily understood by Cuvier, who reproduced them in pasteboard, and explained their mysteries away in the most satisfactory manner.

At ten years of age Cuvier entered the Gymnasium, or high school, of Montbeliard, where he soon became known as a diligent pupil in history and mathematics, never tiring of the latter and able, by means of his well-trained memory, to make even the driest facts of history easy learning.

Here his love for drawing still continued, and he delighted in making tiny maps of the places about which they were studying, and giving them to his companions, while the new subjects that were constantly being brought into his lessons all served to excite his imagination and develop still further his power of illustration.

At this time, too, his fondness for reading increased to such an extent that his mother had frequently to take his books away from him and force him to seek recreation. And although this always seemed hard at first, yet, a half-hour after he had been sent out, no one would have recognized the pale little student in the merry lad whose laugh and shout rang loudest and longest. For whatever came to the boy he put his whole soul into; whether it was learning long lists of the names of dead kings and statesmen, or training a company, of boys in military tactics, or rambling through the woods and fields in company with his mother, it was sure to engage his deepest attention at the time, and he would become so absorbed that it seemed impossible to imagine that he could ever be interested in anything else.

It was while a pupil at the Gymnasium that Cuvier first showed his great love for the study of nature. Wandering one day in the school-library, he came across a copy of the works of the Swedish physician Gesner, and from that moment a new world was open to the studious boy.

Nothing hereafter seemed of any importance as compared with the delights of natural history, and long hours were spent in poring over the fascinating pages; and as about the same time the works of the celebrated natural. ist Buffon fell into his hands, the first impression was deepened, and he became still more eager after the knowledge that had grown so interesting.

He read and reread the glowing descriptions, copying them out from the printed page, and coloring them with paint, or pieces of silk; and so diligent was he in studying, both from books and nature, that by the time he was twelve years old he was as familiar with birds and quadrupeds as any first-class naturalist.

Cuvier's fine scholarship at the Gymnasium could not fail to bring him into notice, and at fourteen he was appointed a student in the University of Stuttgart by Duke Charles of Wurtemberg, who had taken such a fancy to him that he offered to pay his expenses.

This offer was gratefully accepted, and soon after the young student set out for his new home; the journey was made in a carriage and occupied three days, which were rendered intolerable to Cuvier by his travelling companions, who spoke German incessantly, of which he understood not a word, and this circumstance, added to the homesickness which beset him, made such an impression upon him that he used to say in after-years that he could never think of the time without a shudder.

But life assumed a pleasanter aspect when he was once settled in the university, for his new teachers at once recognized his unusual talents and placed him in the classes that would best develop them.

And Cuvier's progress did not disappoint their faith. Before he had been at the university a year he took the prize for German, and his advancement in his other studies proved equally satisfactory.

Natural history still kept its old charm for him, and he found that his new home furnished rare advantages for the study of his favorite subject. In the libraries he found editions of the works of Linnaeus and other naturalists, which he read over and over again, comparing their descriptions with the world of nature around him, and frequently illustrating the printed page with his pencil.

But delightful as he found his favorite authors, there was a pleasure even greater in rambling over the surrounding country and discovering its resources, and, as usual, he turned these excursions to the most practical uses. Every leaf and flower held for him a deep meaning, and so ardent was he in making collections that his herbarium soon became famous through the university, his specimens of plants including many that had hitherto not been known to exist near Stuttgart. His drawings of insects and birds exceeded in number and excellence any that had ever been made before by the students, and he kept constantly in his room numbers of living insects, feeding them and watching their habits with the most patient interest, never tiring of the wonderful study, and learning daily new facts about their curious life that proved of great advantage to him later on.

And thus his student life at Stuttgart passed pleasantly and profitably for three years. Honors and prizes were showered upon him, and the foundations laid for the earnest and fruitful life-work that he was soon to undertake.

At the end of the third year it became necessary for Cuvier to earn his own living, and he accepted the position of tutor to the son of a gentleman living at Caen in Normandy. This step seemed a very unwise one to his university friends, who prophesied gloomily that the drudgery of teaching would soon crush out any higher aspirations, for Stuttgart was proud of her young prodigy and desirous of seeing him in some position that would enable him to continue his studies.

But circumstances and place made very little difference to the young naturalist, and Normandy furnished him with the same material for study that Wurtemberg had offered. The world of nature was still around him, and the sound of the waves dashing against the coast became as great an inspiration as had been the groves and fields around Stuttgart. He at once turned his attention to the study of marine animals, and had the necessary books been at hand his pursuit of this branch of natural history would soon have yielded the most satisfactory results; but away from libraries, and with no one to give him needed information, he was obliged to leave this study incomplete.

He consoled himself somewhat by making drawings of a magnificent collection of Mediterranean fishes owned by a gentleman of Caen, and although he was debarred from entering into an exhaustive study of fishes, and the absence of books proved a serious obstacle, yet it was while he was a tutor at Caen that Cuvier entered upon that particular branch of study that was destined to make him famous. Up to the latter part of the seventeenth century the attention of naturalists had been directed more particularly toward the study of plants, as these could be more easily procured, preserved with less expense, and needed smaller space for collections than any other object. Thus it happened that botany had profited more than any other branch of natural history by the works of illustrious naturalists, and was, comparatively speaking, far in advance of the others.

Linnaeus and other investigators had studied animals with much painstaking interest, but their conclusions were far from being satisfactory, and later naturalists found great difficulty in reconciling new specimens with their assigned places in the accepted systems.

Linnaeus and his followers divided the animal kingdom into six classes, founded principally upon the breathing and blood, the entire zoological arrangement resting upon observation alone.

But this method had so much in it that was objectionable, that from time to time new systems were dreamed of and naturalists were continually trying to solve the difficulty. But it was reserved for Cuvier to advance a new theory so startling, and yet so conclusive, that in a few years it commanded the admiration of the civilized world.

Examining one day some fossils that had been dug up near Fecamp, the thought came to him of comparing fossil with recent species, and this little circumstance led eventually to the establishment of that great system which was to supersede all others.

Filled with his new idea Cuvier at once proceeded to make anatomical studies of the mollusks, and careful comparisons proved to him that a system based upon the internal structure of animals would solve all the difficulties that had hitherto been considered insurmountable.

The results of his investigations were carefully written out, and although he apologized for his work by saying that it doubtless contained nothing that was not known to the naturalists of Paris who had the benefit of books and collections that were denied him, yet it was soon found that the manuscripts were full of new facts, and suggestions superior to any that had yet appeared.

It was the custom of Cuvier at this time to attend the meetings of a little society that had for its object the discussion of agricultural topics, and here he met M. Tessier, who had sought in Normandy safety from the horrors of the French Revolution. M. Tessier was an author on agricultural subjects, and displayed so much knowledge in his arguments that Cuvier recognized him, although he was living under an assumed name, and was supposed to be a surgeon in a regiment quartered near Caen. The fugitive was preparing to give himself up for lost upon his recognition; but Cm;ier assured him that he would, on the contrary, only be the object of the greatest solicitude, and thus a friendship was begun which brought the most lasting benefits to the young tutor.

M. Tessier was astonished at his learning, and familiarity with comparative anatomy, and it was through his influence that Cuvier first became known to the savants of France. He wrote to his friends that Cuvier was "a violet hid in the grass," and that nothing could redound more to their credit than to draw him from his retreat and give the world the benefit of his unusual talents. In consequence of this interest Cuvier's merits were at once recognized by some of the most learned men in Europe; his articles on the mollusks were published in the leading scientific journals, and he speedily became known as one of whom great things might be expected. His new friends did not allow their interest to flag, and in 1795 he was called to Paris and given a professorship.

He now devoted himself more eagerly than ever to his scientific pursuits, and carried the study of comparative anatomy far beyond any point that it had before reached, his work in this department never ceasing through, his entire life.

Many other branches of knowledge commanded his attention and were enriched by his toil, but everything was made subservient to the great principle which he hoped to establish by means of comparative anatomy. Fossils were brought to him from all parts of the world, and he gave his days and nights to the task of comparing them with the bones of recent animals, and giving them their place in the series of beings.

His general plan was to take the best known living species, examine their bones, describe the countries they inhabit and the number of kinds, and then compare them with the bones found in the fossil state.

Many interesting discoveries were made in this connection, and Cuvier's investigations destroyed many of thc, illusions that had always hung around the subject. From the most ancient times there had been a popular belief in the finding of the tombs of giants, and in many places there were kept collections of enormous bones that were said to belong to the human species; and even in the time of Cuvier this belief, strengthened by the ever-present love of the marvellous, still held sway over people's minds and often gave rise to the most absurd stories. Giants' bones were continually being discovered in all places, and many cities counted them among their most interesting treasures. In Switzerland they claimed to have found relics of enormous giants that lived before the deluge, and in France, a sepulchre thirty feet long was discovered inscribed with the name of one of the kings of the Cimbri. The city of Lucerne had stamped on its coat-of-arms the figures of some giants, nineteen feet long, that had been accidentally found, and exaggerated accounts of the discovery of similar bones elsewhere were received with the most credulous wonder.

But Cuvier visited England, Holland, Ger many, Italy, and other places where the supposed human fossils had been found, and proved beyond the shadow of a doubt that the bones belonged to the elephants that had wandered over those countries in the prehistoric ages. And although the wonder-lovers were loath to give up their giants, they were obliged to accept such strong proof as Cuvier offered, and turn their attention to something else. Then came marvellous stories of the monster beasts of the New World, which was as yet almost an unknown country to naturalists, and its vast plains and immense forests were speedily peopled with gigantic quadrupeds frightful in appearance and combining the worst features of the elephant and rhinoceros.

But again Cuvier came forward and demonstrated that the fossil remains of the American mammoth and mastodon proved conclusively that the conditions for their existence no longer remained, and that their presence would be as foreign to the new world as that of the hippopotamus or zebra. Many only listened curiously to these revelations, but the scientific world was delighted, and accepted with enthusiasm the words of the man who could thus recreate the ancient world and bring before their minds its mighty forests and endless plains, and bottomless marshes, with its gigantic inhabitants roving in peaceful bands, or fighting their fierce battles, unseen by human eye, and yet leaving such unimpeachable records behind that those long distant ages seemed almost as near as the days of some bygone summer.

And to one ignorant of such subjects the conclusions reached could only seem marvellous, for how stupendous seemed that knowledge of the laws of organization which could reconstruct an entire animal from the fragments of bones scattered through the layers of the earth, and assign to it its place in history; reproducing again its long-vanished home, and describing its habits and even its tastes, till the dim past was filled with a long procession of living figures, each distinct and interesting, and connected by indissoluble links with the present, from the mighty mammoth that tramped awkwardly through the wilderness, and the great winged birds that brooded in gigantic palms, or circled over sombre northern plains, to the fleet-footed quadrupeds that now dart in and out through the sunlit paths of the forest, or the robins that sing in the white blossoms of the cherry-trees in the springtime.

The publication of the work on fossils at once led to world-wide fame, and it was immediately seen that Cuvier held the key to the mystery that had puzzled so many. For although it had previously been tried to make use of fossils in the study of geology, yet to Cuvier alone belongs the credit of developing the idea to an extent undreamed of by the originators, and of applying the same principle to the study of animals, and by combining zoology and anatomy found a system of classification that would rest upon incontrovertible principles.

He abandoned the Linnaean system, and divided the animal kingdom into four classes—vertebrates, or back-boned animals, articulates, or jointed animals, mollusks, or soft bodied animals, and radiates, or star-shaped animals—claiming that there existed in nature only four principal forms or general plans, according to which all animals were moulded. The whole animal kingdom was reviewed in support of this theory, his anatomical studies embracing every variety of species known, and the results were embodied in his great works on "Fossil Remains" and on the "Distribution of the Animal Kingdom."

His conclusions showed such minute investigation, careful research, and wide knowledge, that there could be no hesitation about the acceptance of his theory by the scientific world, and in a short time it had gained such favor as to supersede all others. The materials for the founding of the new system naturally included a wide range of study, and Cuvier was the author of innumerable volumes embracing works on natural history.

He was, besides, appointed to various positions of honor in the Government from time to time, and was charged with many offices relating to educational matters, and held important places of trust during the unsettled years that followed the days of '93.

His early manhood was passed during the terrible struggle of the First Revolution; he lived under Louis XVI., the Directory, Napoleon, Louis XVIII., the Second Revolution, Charles X., and was made a peer of France by Louis Philippe, but through all these changes he kept the great purpose of his life steadily in view, and never wavered in his determination to place zoology upon a firmer foundation than he had found it.

That his efforts were deservedly crowned with success was the greatest satisfaction of his life, and he felt amply rewarded for all his unwearied toil by the assurance that he had brought to the world a gift by means of which science was brought to the threshold of a new epoch, more brilliant than any it had yet seen.

## CHAPTER IX

# HUMBOLDT AND NATURE IN THE NEW WORLD

## 1769–1859

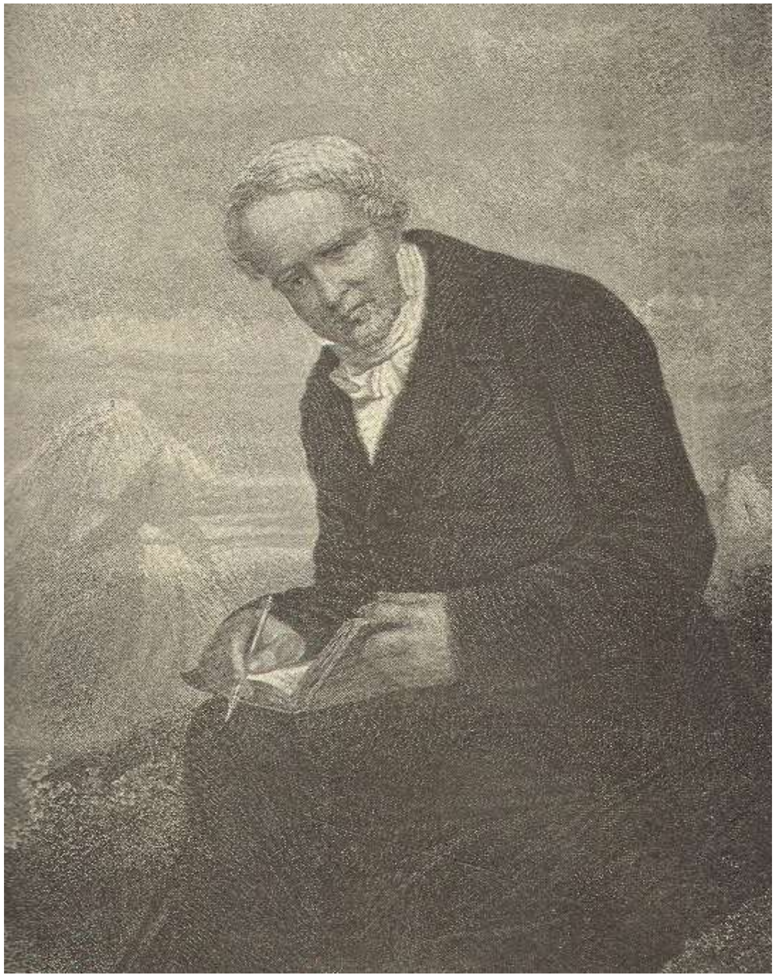
Alexander von Humboldt, the celebrated naturalist, was born in Berlin, September 14, 1769, one month after the birth of Cuvier. The von Humboldts were an ancient noble family of Germany, and at the time of Alexander's birth possessed large estates and occupied a prominent position, and the future scientist thus started in life with the prestige of wealth and influence, circumstances unusually fortunate for him since he was a very delicate child.

One of the family possessions was the ancient castle of Tegel, situated a short distance from Berlin, and at this place Alexander spent the greater part of his childhood and youth.

The castle enjoyed the distinction of having more than one interesting legend connected with its history, and the young Alexander and his elder brother William found great delight in weaving strange romances about the place which possessed such a mysterious charm.

The country about Tegel was extremely beautiful, and the castle commanded a view of gardens, lakes, promenades, forests, and towns in the distance, while near by were the picturesque fortress of Spandau, situated on the southern shore of Tegel Lake, and the fine grove reaching on the other side toward Berlin.

Major Humboldt, the father of the two boys, was renowned for his hospitality, and the castle was the scene of almost uninterrupted festivities, the visitors including princes, statesmen, and scholars in their number, and thus the Humboldt children were from their earliest years thrown into the society of some of the most distinguished men of the age.



ALEXANDER VON HUMBOLDT

When he was about ten years of age Alexander saw his father receive Goethe as a guest, the visitor little dreaming that the two fun-loving boys who shyly greeted him would one day become his chosen friends, equally esteemed for their nobility of character and their intellectual gifts; while the children themselves, to whom as yet no dreams of fame had come, thought only of the present moment, and associated their father's guest only with the wonderful stories of which he was the author, and which had so speedily won for him so great a renown.

But such opportunities for seeing the most learned men of the day could not fail to make an impression upon the minds of the brothers, and they early imbibed the idea that intellectual greatness and individual exertion took the precedence of wealth or rank in the opinion of the truly wise; and thus although a fortunate future might await them in view of their father's position, they early understood that higher distinction could only come from their own earnest effort.

This impression was deepened by the influence of the man whom their father had chosen for their teacher, Heinrich Campe, one of the foremost thinkers of the time.

Campe was a devoted advocate of the new methods of teaching then being introduced into Germany, and found his views warmly supported by Major Humboldt, who desired his children to have the benefit of the advanced school of thought. And it thus happened that the Humboldt brothers had from the beginning the advantage of superior instruction, and had nothing to unlearn when after-years decided their career.

Campe, following the new method, trained his pupils not only in the exercises which develop the memory, but led their minds into new channels, and awakened an interest in the world at large which only increased as the years went on. It was to him that the boys owed their first impressions of foreign countries, and thus from the beginning of their education they were led to take an interest in matters quite outside their own immediate sphere. Campe desired them to become students, not only of the dead languages and mathematics, but of men, manners, and the world in general, and this wish was ardently fulfilled by his pupils.

Although Campe only remained at Tegel two years, his influence was never lost, and extended over the whole lives of his pupils. He was the editor of an edition of "Robinson Crusoe," and made this fascinating volume the groundwork of an interest in foreign countries which only increased with time.

All the old legends which hung around the castle of Tegel failed to excite their imagination to the degree of wonder wrought by the marvellous history of the hero of the desert island; and the familiar fairies, spirits, and genii of their native forests lost their charm in the presence of the actual living Crusoe, whose bravery they might emulate and whose example they both determined to follow.

Thenceforth desert islands possessed a magical fascination, and Alexander avowed his intention of starting for the South Sea at the earliest opportunity. Books of travel were read with an interest never felt before, and the tales of the travellers who now and then visited the castle were listened to with absorbing attention; and the purpose excited by these events was clung to by Alexander with a tenacity that was the more remarkable considering that his delicate health seemed to forbid the possibility of his high hopes ever being realized.

When Campe left the castle to accept an important position elsewhere, he was succeeded by Christian Kunth, whose influence upon his pupils was as beneficial as that of his predecessor, and who remained their lifelong friend.

The plan of Campe to awaken a love for universal knowledge was also pursued by Kunth, and the Humboldts were thus able to continue their methods of study without any serious interruption. Kunth's interest for the welfare of the boys, and his influence over them, continued even when they came to receive instruction from special teachers; and thus when Alexander began taking lessons in botany at the age of fourteen, of an official who lived near Tegel, it was Kunth who led his mind to contemplate the study only as a part of the great system of nature, and kept before him the fact that botany was important not because of itself, but because it led to a better understanding of the universality of the laws of creation.

Thus the necessity of grasping the principle that underlies any collection of facts was early instilled in the mind of the future naturalist, and while learning the Linnaean system of classification he also learned that this knowledge was but a step toward the goal desired by the true seeker after wisdom.

During the years of Kunth's tutorship the Humboldts spent the time partly in Berlin and partly at Tegel, giving the strongest evidence, even in their boyhood, of the diversity of their tastes, William devoting himself principally to the classical studies, while Alexander experienced an ever-increasing love for natural history.

Great was the delight of the younger brother, therefore, when the choice of a university fell upon Gottingen, for there lived the celebrated Blumenbach, whose knowledge of the natural sciences would be of priceless value to the eager student, and it was at Gottingen also that Alexander formed an intimacy that proved of more than usual importance. This was his friendship with George Forster, a son-in-law of one of the teachers in the university, and a man of fine attainments and unusual originality.

Forster had been one of the companions of Captain Cook in his famous voyage around the world, and this fact at once made him an interesting personage in the eyes of Alexander. Forster was equally attracted toward his ardent young admirer, whose tastes were so congenial, and willingly gave him the benefit of his larger experience. All of Alexander's old enthusiasm for desert islands and foreign travel was aroused by the recital of his friend's wonderful adventures, and as Forster was a great student of natural history his story had the effect of rousing in the mind of his hearer an earnestness of purpose that was invaluable in its influence upon his character.

Hereafter a journey across the sea and into unknown lands was not only looked upon as an opportunity for personal excitement and adventure, but was viewed as a serious undertaking, containing possibilities for grave work in science, and, in fact, with his usual good fortune, Alexander had, on his arrival at Gottingen, fallen in with the very man who of all others could best serve him in his preparation for the serious business of life. From this time there was never any question in his mind as to the nature of his work.

His friendship with Forster but strengthened the already half-formed resolution to become a man of travel and science, and the succeeding years only made this purpose more definite. Works of travel, geography, languages, and natural science were hereafter studied with a view to his future work, and he ardently longed for the time when he might begin his life of travel.

The Humboldts left the university of Gottingen after a two years' course, and a few months later Alexander, being then in his twenty-third year, started with Forster on his first scientific journey. This was an expedition down the Rhine, through Holland, and over to England, and resulted in the publication of an original theory of the formation of the rocks of the Rhine. This journey was chiefly important because it roused in Humboldt a greater delight in mineralogical studies, and led to a decision to make mining his particular business.

He therefore went to Freiburg the following year to study the metallurgical sciences, and made such rapid progress that in less than two years he was appointed superintendent of the mines in Franconia, with the commission to remodel the plan of the working of the mines according to his own ideas.

While in this position Humboldt made many interesting experiments on the chemistry of metals, and also contributed toward the discussion that was then going on between geologists as to the formation of the earth. Although he was so young a man his views were received with attention by the older scientists, and were indeed so accurate as to be incorporated into his later works.

The plan for a great journey to America was all this time maturing in his mind. America was still almost a new world to Europeans as regarded the knowledge of its mineral re- sources, vegetation, and animal life, and it was Humboldt's desire to be the Columbus who should open this unknown territory to the scientific world. North America, with the exception of a narrow portion lying along the Atlantic coast, was still practically unknown even by the inhabitants of the oldest settlements, and South America was even chore a land of myths and ignorant wonder. The mines of Mexico and Peru, the vast profits of which had enriched the Spanish crown in the early days of American exploration, were still regarded as objects of interest whose reality could not be doubted, but the most indefinite and extraordinary accounts were in circulation as to the rest of the continent.

Cuvier, by his scientific analysis of American fossils, had exploded some of the more extravagant theories of the monstrous beasts and birds that were supposed to inhabit the tropical forests, but in other departments the greatest ignorance still prevailed. Marvellous stories were told of the forests, with their strange inhabitants, and of the great rivers, and plains, and the lofty mountain ranges, and volcanoes; but the exaggerated accounts brought by chance travellers to these regions were useless for scientific purposes, and Humboldt resolved to visit those remote countries, view their wonders with his own eyes, and then give to the world a faithful record of his travels, in the hope that such a contribution would be of value to the students of natural history.

Having this idea in his mind he made several short trips to the Alps, Poland, and Italy, which, were designed as a preparation for his great journey, and devoted his entire time to the accurate study of geological formations and similar scientific matters, in order that he might be able to compare his experiences in Europe with his explorations in America. He also devoted much care to the testing of instruments and other practical matters, with a view to making his outfit as complete as possible.

But many things hindered Humboldt in the carrying out of his plans, and years passed and 1799 found him still on European soil, detained by one thing and another, but principally by the war then waging, which resulted in the blockade of many ports, and made it almost impossible for a vessel to sail.

But finally the long-deferred hope was realized, and in June, 1799, he left Spain in a ship which was able to leave port in consequence of a severe storm which caused the blockading vessels to put out to sea, bearing with him the royal permission to explore all the Spanish possessions in America, without condition or hindrance.

They sailed first for the Canary Islands, and a few days after starting, Humboldt enjoyed the first surprise of the traveller, in the appearance of immense numbers of jelly-fish which covered the sea in all directions, their colors forming a striking contrast to the waters.

At Santa Cruz they landed and ascended the peak of Teneriffe, and here Humboldt made some observations on its geological formation, which were interesting as foreshadowing the nature of his work in tropical America. It was at this time that Humboldt was first led to observe that mountains and rocks resemble one another, though separated by oceans and seas, while on the contrary, the plants and animals of distant places vary with climate and position.

From the Canaries they proceeded toward the Cape Verd Islands, and thence westward, the usual route of the mariner, and in less than a month from the time of sailing Humboldt saw the Southern Cross blazing in the sky at night, and knew that he had indeed left Europe behind, and was entering those regions of romance and wonder that it had been the dream of his life to see.

The voyage across the Atlantic was uneventful, but not monotonous, as it was Humboldt's first experience as an ocean traveller, and the ever-changing aspect of the sea, the condition of the atmosphere, the direction and force of the winds, together with other phenomena, proved a fruitful source of interest.

In this connection he noticed the difference between the temperature of the air on the land and on the sea, in the same season and latitude, and made some very interesting observations on the blueness of the sky, using an instrument which measured the intensity of the color; his work in this regard possessing a peculiar value, as he was the first traveller who made scientific observations of the sky in the region of equal days and nights.

He also measured the color of the sea, finding that it often changed from blue to green or gray, when there was no apparent change in the atmosphere, and noticing that, contrary to the usually accepted belief, the sea did not reflect the sky, retaining its vivid azure tint often when the sky was entirely covered with white clouds.

Humboldt also made some observations on the attraction of the magnetic needle in those latitudes, and thus the voyage of forty-one days was made the beginning of his actual work.

He had intended going directly to the West Indies, but the breaking out of an epidemic on the ship induced him and his travelling companion, Bompland, to land on the coast of Venezuela, and led him to decide upon visiting the coasts of South America before proceed ing further.

They landed at Cumana, a port guarded by a fortress whose ramparts were formed of a thicket of prickly cactus, which was in turn surrounded by a moat in which living crocodiles served as an effective means of defence. This original fortification was a source of immense interest to Humboldt, as illustrating the ingenuity of the human mind in adapting to its uses the very things which were by their nature inimical to man; and as Cumana had been visited by an earthquake the year before, the traces of which still remained, Humboldt immediately upon landing found himself in a situation well calculated to enliven his scientific interest.

The neighborhood of Cumana was equally full of suggestion, and after making a study of the volcanic soil of the place, and of the history of the earthquakes, in order to find, if possible, some law which governed the recurrence of shocks, he started out on his first scientific excursion in the New World.

This was an expedition to the island of Araya, formerly famous for its pearl fisheries and slave trade, and was not remarkable except as the beginning of a series of small excursions around Cumana, which were fruitful in suggestion, and of much use in preparing the travellers for longer and more important South American journeys. The visit to Araya occurred in August, 1799, and from that time till the following November, Humboldt made Cumana the base of his operations.

During this time he visited many of the old Spanish missions, and was able to study something of the life of the Mission Indians, who lived in little huts surrounded by sugar-cane, maize, and fruit trees.

The impression that the rich tropical vegetation made upon Humboldt was most vivid, and made him realize, as nothing else could have done, that he was indeed in a strange land. He now saw growing in the greatest profusion the trees, shrubs, flowers, and fruits that could only be found in rare botanical collections in Europe, and he and Bompland immediately set about gathering specimens with a zeal that was astonishing to the monks at the Missions, who looked upon their dried plants and scientific instruments with a gentle wonder not entirely unmixed with a little disdain, that human beings should find interest in such unimportant things.

It was during his stay in this region that Humboldt visited some Indians who prophesied earthquake shocks in the near future, a prophecy which was fulfilled after his return to Cumana. For nearly a month before the earthquake occurred Humboldt was able to study the phenomena which preceded it. At first the sky was covered for a few minutes at night with a reddish mist, then the mist grew denser, the air became hotter and hotter, the sea breezes failed, and the sky grew flame-colored. The inhabitants grew nervous and fearful as these alarming signs succeeded one another, and on the day of the shock the feeling of dread extended even to the animal world. The birds uttered low cries of distress, the dogs howled, and the crocodiles left the beds of the rivers and fled with hideous noises into the forests.

When the shock came the inhabitants rushed into the streets, wild with terror, imploring the saints for aid, and a scene of confusion ensued almost as terrifying to the unfamiliar mind as the earthquake itself. Cumana suffered from several shocks at this time, and Humboldt and Bompland were surrounded by questioners who eagerly asked if their instruments could not foretell the duration of the trouble, or indicate fresh shocks.

The splendid sunset, and the banks of golden clouds tinged with rainbow colors which illuminated the west at the end of this eventful day, were not the least interesting among the strange experiences which Humboldt felt at this time.

In the latter part of November, Humboldt and Bompland left Cumana for Caracas, where they remained two months, charmed with the delightful climate, and interested in making collections of geological and botanical specimens. Caracas was one of the most important towns of South America, and the surrounding country was rich in plantations of citron, figs, coffee, and other tropical productions. The inhabitants were hospitable, and gave a friendly welcome to the travellers, who were glad to remain a while amid such pleasant scenes before starting out on the great undertaking which had detained them in South America.

This was to explore the Banos of the Orinoco and Amazon, and make a scientific survey of those almost unknown regions. After a preliminary excursion to various places of interest, such as the warm springs, the gold veins, the sugar and indigo plantations, which were to be found in the western part of Venezuela, they finally embarked on their journey on the Apure, intending to sail down this stream to its junction with the Orinoco, thence to the Rio Negro, and so on to the Amazon.

The journey was important, for from the moment of starting they travelled through regions hitherto almost unknown to the white man, and abounding in scenes of scientific interest. The river itself was crowded with fish, sea-cows, crocodiles, and turtles, its shores were the home of innumerable flocks of birds, and the woods were filled with monkeys, tapirs, jaguars, and other animals. In the daytime the voyaging was comparatively easy. The Indians who managed the boat were skilled oarsmen, and the constant variety of incident kept up a lively interest; but at night, when the boat was moored, and the travellers had lain down in the hammocks weary with the day's journey, another side of the picture presented itself.

The neighboring forests were filled with the shrieks and howls of the wild animals, many of whom pursued their prey at night, and the knowledge that among these was the jaguar, whose approach always carried dread with it, did not greatly reassure the alarmed travellers, who saw in the waving shadows cast by their camp fires the angry eyes of this terrible foe glaring at them through the darkness, and could discern above the voices of the other animals his hoarse scream, as he pursued his prey from tree to tree.

The journey on the Apure was largely occupied by Humboldt in adding to his collections of specimens and making drawings of every object of importance, and was thus very rich in scientific interest.

When they reached the Orinoco, whose broad expanse of waters stretched before them like a sea, they had still greater opportunities for studying the characteristics of South American scenery, and during their progress a remarkable rise in the river gave a fine chance for making observations on the water-levels.

While on this river they landed on an island owned by one of the Spanish missions, and found that they were considered as suspicious characters by the priests, who could not imagine that they had really left the comforts of home and undertaken the dangers of an unknown country merely for the sake of making botanical collections and measuring the land.

The great waterfalls in the Orinoco were a source of deep interest to Humboldt, who took the opportunity of measuring the height of the falls and comparing it with other celebrated cataracts; the noise of the falls was also made a subject of investigation, and as in the solitude of such a region the quiet of the day is never disturbed, Humboldt came to the conclusion that the increased loudness at night was due to the fact that the cold air conducted the sound more perfectly than the warm air of the day.

Humboldt stayed among the waterfalls five days, studying their physical characteristics, and then proceeded on his journey toward the Cassiquiare, which unites the Orinoco with the Rio Negro. He reached the latter stream in due time, but found the passage of it the most difficult in his journey, as the swarms of poisonous insects, and the impenetrable thickets which lined the shores, made both rowing and landing equally hard. They had to cut a landing place with their axes, while the dampness of the wood, owing to the great amount of sap, made it almost impossible for them to obtain a fire.

But at last the passage was over, and Humboldt felt amply rewarded for all the hardships he had endured when he found that he had actually traced the connection between the Orinoco and the Rio Negro. This event was of the greatest importance to the travellers, as it enabled them to solve the mystery that had hitherto hung over those almost inaccessible regions. The possibility of travelling by water from the Orinoco to the Amazon had been a matter of doubt to Europeans, and the voyage of Humboldt was of the greatest scientific interest, as it settled the question definitely. The drawings which Humboldt made were used to correct the old charts, and the societies of

Europe were loud in their praise of the man who had ventured on such a perilous journey for the sake of science.

At this place, also, Humboldt collected some valuable materials for illustrating the peculiar formation of the soil, and was able, from the experience gained, to hint at some general laws of nature in distributing the veins of water over the globe. Having accomplished the great object of his journey, Humboldt now left the region which had hitherto been regarded as almost mythical by Europeans, and returned to Cumana.

Humboldt now arranged to undertake a gigantic expedition, to include visits to Cuba, Mexico, the Philippine Islands, India, and Turkey, and as the first stage of the journey, sailed with Bompland for Cuba, reaching Havana a month after leaving Cumana.

They remained in Cuba several months, studying the soil, climate, and vegetation, making many valuable additions to their botanical collections, and observing the condition of the slaves. But the great journey that had been planned was never undertaken, as in Cuba Humboldt heard that a friend with whom he had promised to travel through Chili and Peru, had sailed from France for Buenos Ayres, and he at once determined to return to South America and join him. But on reaching Carthagena, they learned that the season was too far advanced for a voyage on the Pacific, and resolved to occupy their time during the necessary delay by a journey up the Magdalena, hoping to enrich his collections by some rare specimens.

In this he was not disappointed, for they found the botanical treasures of this region equal to those in the Orinoco valley, and in addition to this work, Humboldt was able to make a chart of the river district, another great gift to geographical science.

When this had been accomplished they left the Magdalena and proceeded overland to Quito, which they reached four months after leaving Carthagena.

The journey was difficult, as the way led through an almost pathless region, but Humboldt improved his time by studying the formation of the rocks and waterfalls, mines, remains of earthquakes, the soil, and the snow-covered volcanoes and mountain passes; and although they arrived at Quito in an almost exhausted condition, they considered this part of their experience in South American travel as invaluable. The delightful situation of Quito, with its agreeable climate and beautiful surroundings, soon brought back health and good spirits to the travellers.

The ranges of lofty, snow-capped mountains which bounded the horizon roused anew the love for scientific research, and preparations were made for the ascent of Chimborazo and Cotopaxi.

The volcano of Cotopaxi had always been noted for its terrific eruptions, and the visit of Humboldt to its crater was anticipated with unusual interest by the inhabitants of that region. Humboldt had already found the crater of Pichincha inflamed, and bare of the snow which had filled it so long, a circumstance which excited general alarm in Quito, as indicative of another eruption, and any appearance of danger in the neighborhood of Cotopaxi would have been regarded with even more dread. In 1738 the flames from this volcano had risen above the crater in a ring measuring nearly three thousand feet in circumference; two years later another eruption occurred, the noise of which was heard two hundred miles away; a still later outburst threw so many ashes in the air that it was dark for several hours, and the inhabitants of the villages near were obliged to go about with lanterns; but at the time of Humboldt's visit the snow still lay in gleaming masses on the summit, and as it was impossible to reach the brim of the crater he was unable to make the scientific experiments he had anticipated.

He was also unable to reach the extreme point of Chimborazo, as a bottomless chasm stretched directly across his path, but he reached an altitude never before attained by any human being, pushing on his way even after reaching a point where the mercury froze in the thermometer and the blood gushed from the nostrils of the adventurous travellers.

Humboldt now made various tours, fruitful in scientific interest, during which he examined the flora of the district, visited the remains of the great aqueduct of the Incas, and corrected the chart of the Amazon which had been made by a French astronomer, but which Humboldt found to be full of errors. Their travels finally brought them to Lima, where they were able to make some important observations on the climate and in astronomy, remaining there several months for that purpose.

From Lima they sailed for Mexico, and as they passed the snowy peaks of the Chimborazo group an ominous sound reached their ears. It was the roar of Cotopaxi, fifty miles distant, whose snow-capped summit had vanished in a single night, and whose thunderings reached them day and night when they were far away on their journey.

Humboldt carried away from South America a picture so vivid and startling that he said, in after-years, it was only necessary to close his eyes to shut out surrounding objects, to see again the foamy waves of the Orinoco, down which he glided, followed by the shrieks of the jaguars; or the treeless stretches of the llanos, where the moss-covered huts of the inhabitants lie miles apart, and the crocodile and boa, buried deep in the soil, sleep through the long season of drought—while the horses and cattle wander about roaring in agony, and the burnt grass falls in dust on the parched ground.

During his journey he had suffered from extremes of heat and cold unknown in the temperate zone; he had lived in solitudes where only plants and animals flourished, and where the foot of man had never trodden before; he had been exposed to ravenous beasts, and had found danger even in the trailing vines and beautiful flowers whose poisonous breath touched him as he passed, but through it all his courage never faltered, and his work for science still went on.

And seldom has it been the fortune of the traveller to open such a world of unexplored beauty to the eye of the untravelled.

South America, with its mighty rivers, lofty mountain-ranges, picturesque inland lakes, its llanos, varying from scenes of desolation to the luxuriant beauty of tropical vegetation; with its fabulous mineral wealth, its forests of mahogany and rosewood, its vast herds of horses and cattle roaming in undisturbed freedom over the immense plains; its flourishing cities, in strange contrast to the secluded missions that were scattered in places remote from the world, its ruins of old Peruvian towns, and remains of a dead civilization, were all calculated to inspire the mind of a traveller like Humboldt—and when to this was added the knowledge that all this beauty of city and plain lay at the mercy of the dreaded earthquake and volcano, which were liable at any time to destroy it forever, the interest could not fail to be increased.

In Mexico Humboldt's most important scientific work consisted in certain astronomical observations by which he arrived at the correct longitude of the city of Mexico, which, had until then been wrongly given on the maps. He also visited the celebrated mines of that country, devoting much time to the study of the ores, and made important observations on the formations of the volcanoes of the region; the antiquities of Mexico were also a source of great interest to the travellers, and much time was spent in examining them and transcribing descriptions to their journals.

At last the great American journey came to an end, and, after a short trip to the United States by the way of Havana, Humboldt sailed for France and reached Bordeaux in August, 1804, five years after his departure from European shores.

The knowledge that Humboldt, who had more than once been reported dead, had actually returned to his native land, bringing with him his valuable collections, created an immense excitement all over Europe, and his name soon became a household word.

For the first time Europeans had an accurate and life-like picture presented to them of the New World, which had always possessed such a mysterious charm, and as they read the fascinating descriptions of Humboldt, they followed him in imagination through all his wonderful journey. With him they sailed up the Orinoco, traversed the Banos, crossed the snow-fields of the Andes, and visited the tropical forests; and the popular fancy, not content with actualities, threw over the adventures of Humboldt even a more magic spell. It was said that in his western tour he had fought and conquered giants, visited the tombs of dead nations and learned their buried secrets, had his courage tested by encounters with races that were but half-human, and had learned of Nature in her great solitudes the secret which governed the life of man, and the wisdom of all the ages. And though this view of Humboldt was but the result of that love for the marvellous which is ever seeking something new, it did not lessen the fascination which was attached to his name, and he was regarded as a second Marco Polo, whose adventures were more romantic and exciting than any tale of the "Arabian Nights."

For many years after his return Humboldt spent his time in preparing the complete history of his travels in America, giving public lectures, and perfecting his great theory as to the nature and development of the plan of the universe.

But during this period of twenty-five years he had ever before his mind a great journey to Central Asia. With this in view he studied the languages, geography, and history of the East, as well as the existing descriptions of the physical formation of the country, and in 1829, having completed all his arrangements for an extensive tour, set out for India. Humboldt was accompanied by a number of scientists, and the expenses of the journey were to be defrayed by the Russian Government, which was desirous of obtaining accurate scientific reports of the mineral wealth of its dominions.

The expedition left St. Petersburg in May, 1829, and was absent eight months, during which time Humboldt's industry was indefatigable. During this time he explored the Ural formations, and gained an important insight into the gold and platinum deposits, besides discovering several new minerals; visited the Altai Mountains, and made an important expedition to the Caspian Sea for the purpose of analyzing its waters and obtaining specimens of fish, besides making many observations on the climate, soil, and geological formation of the mountains.

The journey was a most important one for science. Previous to this there existed only the vaguest ideas of the geography of Central Asia, the connection of the mountain-chains, and the productions of the soil; but Humboldt's accurate survey of the hitherto unknown territory put geographical knowledge on a firmer foundation, and gave to the world a clear idea of that interesting land which possessed a charm for all nations as being the supposed first home of the human race. Humboldt proved that Central Asia was neither a broad plateau nor an immense cluster of mountains, as had been supposed, but that it was crossed by the four mountain-systems which have exercised an immense influence on the migration of nations, and helped to form the history of the world.

Humboldt also made important observations on the boundary of eternal snow, and, in his study of the winds and tides and their relation to climate, and to the forms of the continents, deduced a theory of the different temperatures of places in the same latitude but at great distances from one another.

The entire result of Humboldt's travels and studies was incorporated in his great work called "Cosmos," which was compiled from his notes, and in the composition of which he was aided by Cuvier and other naturalists. "Cosmos" contains a theory of the formation of the universe, and embraces observations on the heavens, mountains, earthquakes, the sea, the earth's crust, the atmosphere, the geography of plants and animals, the races of men, the form, density, latent heat, and magnetic power of the earth, and the aurora borealis.

It is the most exhaustive work ever under taken by a single mind, and shows, as nothing else could have done, the extent and originality of Humboldt's powers. Besides the valuable contributions to geographical and geological knowledge, Humboldt's theories of the distribution of heat and magnetism were of special importance. His observations on the magnetic needle and the aurora borealis were of the greatest service to science, and it is largely due to him that observatories have been erected all over the world, from Canada to the Cape of Good Hope, and from Paris to Pekin, with special reference to the study of the earth's magnetism.

Humboldt also devoted much time to the study of the isothermal lines, or lines of equal temperature which connect different places, and likewise the sciences of climatology and geognosy may be said to date from his time,

## CHAPTER X

# DAVY, AND NATURE'S MAGICIANS

## 1778–1829

Davy was born in 1778 at Penzance, in Cornwall, where his family, who were of the middle class, had lived as farmers for over two hundred years. The country about Penzance is healthy and beautiful, diversified by hill and glen and stream, green fields and orchards, and bounded on one side by the sea, across whose waters shone the gray slopes of Mount Michael. And besides these advantages, the neighborhood possessed other attractions well calculated to charm the attention of an imaginative boy; for here were the great monuments of the Druids, the most famous in England, the massive piles seeming to hold old memories of an almost forgotten past, and here also were the not less interesting mining works, celebrated all over the world, and the source of all the wealth of Cornwall.

Such surroundings made an early impression on the mind of Davy, and, while he was yet a child, his love for the marvellous and his taste for natural history were visible in a marked degree. Penzance was then famous for its ghostly traditions of haunted houses, there being hardly a dwelling in the neighborhood that was not marked by some supernatural horror, while its proximity to the sea also made the place a popular resort for smugglers, and thus gave it an added fascination to a mind that had a leaning toward the adventurous, and it is thus not to be wondered at that the early years of the boy were filled with thoughts of the marvellous, and that life from the first was endowed with poetic and unusual interest.

All the old tales of the region were poured into his ears by his grandmother, a woman of fervid imagination, who thoroughly believed in ghosts, witches, and fairies, and when this fund failed, the Arabian Nights proved a still more fruitful source of pleasure; and when there were no more stories to be had in any way, then the boy turned story-teller himself, and, mounted on a cart, would thrill his young companions with exciting tales of sea and land, in which genii, ghosts, and smugglers played interesting parts, embellishing his narration by his own imagination, and earning a great local reputation by his dramatic representation of the events under consideration.

This taste for the marvellous, which was such a marked characteristic of his childhood, was still prominent in boyhood, and was the principal factor in his choice of a profession. The natural surrounding of his home, with its ever-changing sea and skies, the great variety of minerals produced from the mines and the various kinds of rocks that formed the outlying cliffs and headlands, all joined to awaken a keen sense of the marvels of nature and a desire to understand the laws which could produce such results. His school-days were not only devoted to the study of text-books, but were occupied with excursions, which had for their object the pursuit of natural history; mineralogical and geological specimens were eagerly sought after, and a collection of birds and fishes was also added to the young naturalist's stores.

When he was fifteen years of age, Davy was apprenticed to a physician, and from this time his studies assumed a more serious form, and he laid down a regular plan of reading, which included among other things works on botany, chemistry, and astronomy. For the next four years his time was fully occupied with these various duties. His reading included a copy of Lavoisier's "Elements of Chemistry," and almost immediately after his acquaintance with this work he began a set of experiments to prove the propositions contained in it; and although his apparatus was very simple, consisting of wine-cups, tobacco-pipes, glass bottles and earthen crucibles, his materials being the mineral acids and other articles in use in medicine, and he was obliged to work at the kitchen fire because he could not afford one in his own room, yet the quality of the work was so fine, and the experiments such a success, that he was encouraged to go on; and from this time he made such rapid progress in his scientific studies that before he was twenty years of age he had propounded certain theories of light and heat which brought him to the notice of other students of science, and which are now considered as embodying the true theory of heat as accepted by modern physicists.

In his twentieth year Davy was appointed superintendent of an institution in Bristol, which had for its object the treatment of disease by different gases. The institution was supported largely by scientific men who wished to find out the remedial qualities of gases, and was furnished with a hospital, laboratory, and lecture-room. And this appointment proved of the highest service to the young superintendent. Time and the best apparatus were at his disposal, and he could work in the consciousness that he had the intelligent sympathy of some of the first intellects of the day.

He began his work here by the publication of his theories on light and heat, and this was immediately followed by experiments in gases. His first experiment was with nitrous oxide, a gas which was supposed to be harmful to the animal system, and capable of destroying life if inhaled in large quantities. Davy, in the course of his experiments, proved that this view of nitrous oxide was a mistaken one, and found that he could breathe in six quarts of the supposed harmful gas without the least injury, and declared that instead of being a deadly poison, the gas could be used with great benefit by physicians who wished to render patients insensible to pain, nitrous oxide being the first anaesthetic ever employed by the medical faculty. The publication of his researches in gases which came out in 1800, excited considerable attention among scientific men, and resulted in his appointment as Professor of Chemistry to the Royal Institution in London, and in 1801, he delivered his first lecture there, which at once made him famous. His lectures were attended by the most celebrated people, and men of science did not more eagerly seek the lecture-room than did the noblemen, and leaders of fashion, who immediately opened their houses to receive such a distinguished guest, and vied with one an other in bestowing flattering attentions upon him.

But these things were of minor importance to the young chemist, who declared that his life was filled with his work, and that amusements seemed to him only like the dreams which came between his hours of waking. The fine laboratory now at his disposal would have amply compensated him for the loss of popular favor, and from this time his devotion to science was greater than ever, and the next few years were marked by a series of brilliant chemical discoveries, unequalled in the history of any other scientist. These discoveries related chiefly to the connection between chemistry and electricity.

The discovery by Galvani of galvanic electricity, and the investigations of Volta that had led to the construction of the voltaic battery, had given an immense impetus to electrical science; and subsequently the truth of Lavoisier's theory that water was composed of oxygen and hydrogen was proved by the use of the battery in decomposing water into its two elements.

Davy was from the first intensely interested in the subject of applying electricity to chemical experiments, and said that the Voltaic battery was an alarm bell to every scientist in Europe, calling them to new fields of action; and his own great fame rests chiefly upon his chemical researches in connection with electricity.

When water was decomposed by the electric current, it was noticed that the positive and negative poles of the current showed the presence of other substances than hydrogen and oxygen, and this phenomenon was for many years a great puzzle to scientists, who were forced to the conclusion, that, notwithstanding the fact that they could combine the two gases in such proportions as to make pure water, still there must, in reality, exist other elements in water than they had yet discovered.

Davy believed that the presence of the other substances at the poles of the current was due to impurities in the water, and, after a series of interesting experiments, proved to the entire satisfaction of the scientific world that chemically pure water consists of oxygen and hydrogen alone.

These experiments extended over many years, and were carried on under unusually favorable conditions, as Davy had at his command all the resources of the Royal Institution, which included the largest galvanic battery in the world, and a staff of assistants whose intelligence and fidelity aided greatly in the progress of the work.

The remarkable power of electricity to break up chemical combinations and apparently neutralize the most powerful chemical attractions, as was shown in the decomposition of potash and soda and separation of the metals potassium and sodium, led Davy to the conclusion that chemical affinity and electrical attraction both resulted from the same cause, acting in the one case on the particles of substances and in the other case on their masses.

This theory proved useful in his work, because it suggested a number of experimental inquiries that were fruitful of important results.

Davy also suggested that light, heat, electricity, chemical attraction, and gravitation might all be manifestations of the same power. But this speculation, interesting as it is, reaches out into a region in which darkness and obscurity still reign, in spite of the light of modern science. Yet there is now no doubt but that electricity and light are most intimately connected, and it is more than possible that electricity plays a part in all chemical actions.

In the progress of his work Davy made many experiments of a practical nature in order to put his discoveries to daily use. He visited tanyards to investigate the various processes used, and to try and aid this branch of industry by some suggestions of his own; he also paid great attention to agriculture, which he claimed could be carried on to much better advantage if farmers understood the principles of chemistry, and suggested that much of the sterility observable in mining districts was due to the presence of the poisonous productions from the mines, the refuse of which lay in heaps over the ground, impregnating the streams and making the atmosphere impure.

Davy discovered the metals sodium and potassium, and assisted other scientists in identifying other new elements. His discovery of sodium and potassium is considered his greatest contribution to chemistry, with the exception of his theory of the connection between electrical and chemical forces.

The wish of Davy to make all his discoveries serve some practical use to man, led him to make one of the most important inventions in the history of physics. From his earliest years he had been acquainted with the dangers and horrors which constantly beset the lives of miners, and his mind had always been drawn to the subject of some means of preventing those terrible explosions, which from time to time caused such sorrow and desolation in every mining district.

These explosions were caused by the inflammable gas, called fire damp, which always accumulates in great quantities in mines, and which is ignited by a lighted candle or lamp. Although fire damp is always present in mines, it is only dangerous when mixed with a certain proportion of common air, and the danger lies in the inability of the miner to detect this condition, in the power of the gas to issue in enormous quantities in a comparatively short space of time, and, in a great measure, in the carelessness which characterized that class of men, whom constant peril had rendered almost indifferent to danger.

In 1815, Davy began a series of chemical experiments to investigate the nature of fire damp, and arrived at these results: that it requires to be mixed with a very large quantity of common air before becoming dangerous, that it requires a greater amount of heat to ignite it than any other gas, that it produces little heat when burning, and has small power of expansion; he found also, that the mixture of fire damp and air necessary for explosion will not ignite in metal tubes, and that it can be made non-explosive by adding carbon or nitrogen to it.

Mining could not be carried on without the use of lamps, lamps could not burn without air, and air if mixed with fire damp would cause explosions; the problem, therefore, was to invent a lamp which could burn in safety in the presence of fire damp, and this Davy did. He surrounded the flame of the lamp with wire gauze which took the place of metal tubes, in lowering the heat; the gauze allowed the fire damp to rush in and surround the flame which ignited it, but although this happened inside of the wire, so much heat was carried off by the metallic surface, that the temperature outside was not raised to the explosive point before the miner had a chance to escape.

This safety lamp, which is always known by the name of its inventor, has been one of the greatest gifts of science to man, and it has been estimated that it has saved more lives than any other invention, having robbed one of the chief industries of the world of its greatest terror, and brought safety and comfort where before existed danger and ever-present alarm.

In the beginning of his career, while he was yet a boy, roaming about the hills and dells of Cornwall, he had sketched on the cover of a little book which contained his notes, the figure of a lamp encircled with an olive wreath, and this almost prophetic symbol may well illustrate the motive which prompted all the researches of this great man, that in all the discoveries and achievements of science, the student of nature should but aim at the revelation of truth and the peaceful advancement of the race.

Davy died in Italy in 1829, while travelling for his health. Although only fifty-nine years old he had accomplished as much as is often done in much longer lives, and he will ever be known as the chief of that illustrious band, whose work has marked their era as the golden age of chemistry.

## CHAPTER XI

# FARADAY AND THE PRODUCTION OF ELECTRICITY BY MAGNETISM

## 1791–1867

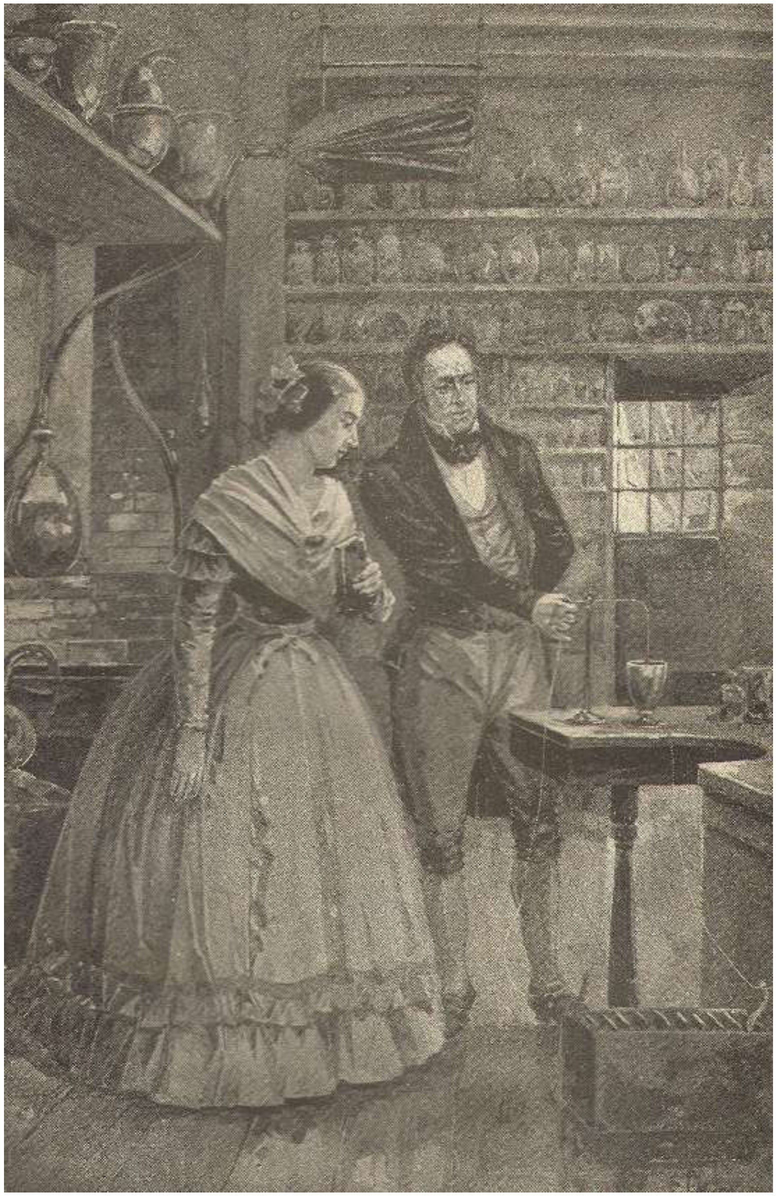
The year following the death of Franklin was marked by the birth of Michael Faraday, whose work in electricity brought that comparatively new science to a still more practical plane than had been reached by the American philosopher.

Faraday was born at Newington, South London, and was the son of a blacksmith, whose delicate health made it often impossible for him to earn a comfortable living for his family, and Michael's early years were spent in the manner usual to the poorer class of city children.

He played in the streets with the children of other mechanics, and took care of his younger sister while his mother was busy about household matters, and ran on errands to neighboring shops; and, in fact, had his life filled with that mixture of responsibility and duty which usually falls to the lot of the younger members of the families of city workmen, and which develops so early the shrewdness and self-reliance which characterize that class of children.

There was nothing in the surroundings of the boy to lead to the study of nature, and although the older members of the family had memories of a country home in Yorkshire, life to Michael meant only the crowded streets, and uninteresting sights and sounds which mark the poorer districts of a great city. But happily for him the very humbleness of his circumstances was made the opening for something better. The serious business of life begins early for the children of the poor, and when he was thirteen years of age Michael was placed as errand boy to a bookseller who lived near by. He had learned to read, write, and cipher, at a common day-school in the neighborhood, and this meagre education, supplemented however by good health, an honest purpose, and excellent home training, formed his capital in his venture with the world. It was his business, among other things, to deliver newspapers to his master's customers, and so well did he acquit himself of these duties that after a year in the shop the master received him as a regular apprentice in the bookbinding and stationery business, exempting him from the usual premium in consideration of his faithful services.

And, as in the case of Franklin, it was while he was an apprentice that his mind was first directed toward serious study. The handling of books was his daily work, and their contents could not fail to be of interest to the curious boy who had always been noted for his talent for asking questions about everything that came under his notice. And so he began to read, and learned straightway that the world was a very wonderful place. He had known before that if he left London and travelled through all the ways that civilized man has traversed, he should come across many strange things, and undergo many strange adventures, while becoming familiar with the different countries and races of the earth; this was an experience common to the lot of every traveller. But it was new to him to learn, from the pages of a popular work on chemistry, or the articles on electricity in the "Encyclopaedia Britannica," that there existed in the poor little neighborhood, where he made his home, wonders as great as any that had ever been seen by the most adventurous traveller; and that, in fact, he was not living in a dingy London court, but in a fairyland where the most marvellous events were constantly transpiring, and that water, and fire, and air, which he had only hitherto known as familiar agencies for supporting life, were in reality great magicians who held sway over mighty, secret forces, and most marvellous of all, that their secrets could be learned even by so humble a person as himself, provided he brought the necessary care and sincerity to the work.



FARADAY ANNOUNCING HIS DISCOVERY TO HIS WIFE ON CHRISTMAS MORNING, 1821.

Faraday stood astounded at the magnitude of this discovery, and immediately set about putting it to a practical test. His reading was followed by such simple experiments as could be carried on at a slight expense, and the results showed that he had read to good purpose, and that science stands ready to unlock her treasure house to her humblest follower, if he bring but an honest purpose with him.

The success of these little experiments encouraged Faraday to such a degree, and gave natural philosophy such a strong interest, that he was glad to accept the money from his brother to attend a course of lectures on the subject which were given at a private house, and he learned drawing in order that he might illustrate these lectures and preserve them for future use. And there is every reason to believe that his future career was decided at this time. Science had such a fascination for him that he longed for occupation more congenial than bookbinding, and declared that the humblest work of the laboratory would seem a delight if he could but enter upon it. Pushed on by this desire he wrote to the President of the Royal Society, in the hope that something advantageous might result from it, but in this he was disappointed, the president paying no heed to the solicitation of the unknown apprentice.

But notwithstanding this rebuff Faraday kept to his purpose, and his apprentice life was largely filled with experiments and theories in natural philosophy.

Since the time of Franklin various discoveries had been made in electricity, and as this subject interested Faraday peculiarly, some of his earliest experiments were based upon these discoveries.

In 1800, the Italian scientist, Volta, made an electric apparatus which possessed the wonderful power of constantly recovering the charge, thus forming a perpetual source of electricity. The apparatus was a very simple one, consisting only of alternate disks of copper and zinc, separated by pieces of paper or leather saturated with salt water. This combination formed a perfect electric machine and solved the question of preserving electricity indefinitely, and its invention is said to be the greatest effort of a single mind that the world has ever seen. This battery is called the Voltaic Pile, and one of Faraday's first experiments consisted in constructing one of these piles, and finding that it would decompose Epsom salts; afterward, with a larger pile he decomposed sulphate of copper, and made some experiments on the decomposition of water, and this pastime of his apprentice days eventually led to one of his greatest discoveries.

Very soon after his apprenticeship had expired Faraday wrote to Sir Humphry Davy, whose lectures he had attended, sending with his letter the notes he had taken of the lectures, and signifying his desire to enter upon some business of a scientific nature. This letter was favorably received by the great scientist, and an opportunity occurring soon after, Faraday was received by him as his assistant. A journey to the Continent was made in company with Davy, and here Faraday was brought in contact with the most celebrated scientists of the time and found his enthusiasm for his chosen calling increasing with every day. He made notes of the experiments that he saw, and on his return to England carried on his studies with greater vigor than ever.

His connection with Sir Humphry Davy was of the greatest service to him at this time, and was always warmly appreciated by Faraday, whose generous acknowledgment of benefits was no less a characteristic of his mind than his own great modesty about his achievements.

Three years after his entrance at the Royal Institution as Davy's assistant he delivered a course of lectures at the City Philosophical Society, on the general properties of matter, and the same year he published one of his experiments in the journal of Science, showing that his progress as a thinker and as a public man was very rapid; and his work for the five following years, devoted almost exclusively to experiments in chemistry, placed him among the first chemists of the day.

When he was thirty years old Faraday began his researches in electricity which resulted in the discoveries that made him famous. A few years before this Professor Oersted, of Copenhagen, while lecturing before his class, noticed that a magnetic needle that happened to be lying on the table before him was set in motion by the current of electricity from a Voltaic pile with which he was experimenting. Oersted immediately followed up the suggestion contained in this occurrence, and before long gave to the world his famous discovery that electricity will deflect the magnetic needle, or cause it to change its position, though the current may have to pass through a wire of considerable extent—a discovery which in time led to the invention of the telegraph.

Faraday conceived the idea that if electricity would affect the needle, and magnetize iron as Oersted had discovered, it might be possible to accomplish the reverse of this, and therefore at the beginning of his work in electricity set about finding the relation between it and magnetism, starting with the proposition that they were identical. For seven years he worked over this problem and at last his efforts were crowned with success, and he proved that a magnet would induce electricity in a coil of wire.

Oersted's discovery is called electro-magnetism, and Faraday's magneto-electricity, and both discoveries rank among the greatest in electrical research. Previous to this very little was known about magnetism. The lodestone had been shown to have the power of giving its attraction to a few other substances, such as steel, cobalt, and iron, but Faraday's experiments threw new light on this interesting subject. He proved that many other substances were susceptible of polarity—the peculiar property of the magnetic needle in pointing to the north and south, and having its attraction at the poles—and that certain other bodies were repelled by both poles of the magnet. He also discovered the magnetism of the air, and that nearly all substances are affected in one way or another by a powerful magnet.

His discovery of magneto-electricity, one of the results of which is the electric light, was hardly more important than the discovery that is known as voltaic induction, or the power of a current of electricity passing through a wire to develop a current in a parallel wire which does not touch it. This discovery led to the invention of the induction coil by Ruhmkorff, which has been the means of many later important discoveries in electricity.

Faraday's third great contribution to electrical science, which was preceded by the discovery of the identity of all kinds of electricity however produced, was the establishment of the law which governs the decomposition of bodies by electricity.

Besides the electric light, the practical results of Faraday's labors are shown in many ways, but even if his discoveries had been found impractical for the uses of daily life, his researches would have still been of the greatest value to science, where an isolated fact often leads to the most important consequences.

Faraday's genius was allied to that of the old philosophers who sought to find the secret of life, and he entertained the idea that gravitation, electricity, heat, light, and all the forces of nature might be identical, or different expressions of one governing power.

This fancy led to many of his most important discoveries, and contains a suggestion which may in time lead to the solution of the world-old problem; but, however that may be, his work for science will bear fruit to the latest day.

## CHAPTER XII

# CHARLES LYELL AND THE STORY OF THE ROCKS

## 1797–1875

The history of the natural sciences may be likened to a book which has been read a little from time to time, but of which no one has gained a full knowledge.

And this is especially true of geology, the science that treats of the history of the earth.

The Greeks, with their eager thirst for knowledge, and untiring zeal in its pursuit, had opened this wonder-book of nature, and read some of the secrets revealed in its fascinating pages, but, as was the case with many other branches of science, the knowledge thus gained consisted more of isolated facts than of any deep comprehension of the great laws which underlie the workings of nature.

Pythagoras, in his journeys through Egypt and Chaldea, noticed the different appearances of the land, and made some observations on the subject, taking for his starting-point the idea of continual change. "Nothing," said he, "perishes, but all things change their form," and it was to these constant changes that he claimed all the phenomena connected with the earth were due.

After Pythagoras, other Greek philosophers took up the story where he left off, and read a little further on; but the knowledge thus gained was not of a kind to explain any of the secrets that were hidden in the earth, and can only be likened to the pictures scattered through a volume, and which are understood only when one has read the printed page.

And then for many centuries the history of the earth was like a closed book, and even when astronomy, botany, electricity, and other subjects had received earnest study by the great men of science, geology was still an unexplored region.

Men had learned to count the stars of heaven, to number the flowers of the field, and to control some of the subtlest forces of nature long before any serious attempt was made to read the history of the earth, and all the wonders that lay before their eyes were only regarded as unexplained, and perhaps inexplainable mysteries.

In the old days the popular belief that the interior of the earth was inhabited by races of beings who performed all the miracles of nature, was esteemed a sufficient explanation, and all the vast mineral wealth that is stored away in the earth's great treasure chambers was supposed to be the work of the kind genii who bestowed their riches with lavish hands upon their human favorites.

But it was only in the dark ages of science that this belief could be held, and when nature's wonders ceased to be regarded with the unreasoning awe which is the general attendant of ignorance, and it was no longer considered irreligious to study the workings of the universe, then the old superstitions faded away, and man required a more intelligent answer to his questions as to the causes of the wonderful effects that were everywhere visible.

And although geology is one of the sciences that have been very lately developed, yet, when once aroused, the interest in it became so strong that it was pursued with an ardor that soon brought about great results. The earth suddenly ceased to be regarded simply as the abode of man, and interesting only because it produced the wherewithal to supply his needs.

It came to be looked upon instead as a thing in itself so wonderful and with a history of such antiquity, that man's experience seemed insignificant beside it, and geology was clothed with an interest as great as that attached to astronomy when the telescope suddenly revealed the existence of the great star-systems of the remote heavens which had been hitherto invisible to the human eye.

And then came study and research of the most absorbing nature, and in the new light thus given them, men saw even new and greater beauty. Before this the interior of the earth had been considered as a great treasure house, whose largess might be his who would seek it; but now it was found that the rich veins of gold and silver which streamed through the earth, like the rivers that flowed over its surface, the secret mines that held the priceless diamonds and rubies in their hidden chambers, and the great coal measures whose layers bore the impress of the lily and the palm that had perished in dim-forgotten ages, could all tell the magic story of their birth to one who had the gift of hearing their voices.

And the wise seekers after knowledge listened with reverent attention, and gathered what wisdom they could, and thus a little of the marvellous history of the earth was learned.

Chief among these earnest seekers was Charles Lyell, who was born at Kinnordy, Forfarshire, Scotland, November 14, 1797.

Although an intelligent and observing child, Lyell did not show any particular love for nature until his eleventh year, when ill-health made it necessary for him to leave school and go home for a few months.

Then the absence of playfellows, and the bent of his mind toward some absorbing occupation, first led him to notice the world of nature that he had hitherto neglected, and all the myriad forms of life that he saw were suddenly endowed with an unexpected interest.

His attention was thus directed toward the study of the animal kingdom, and he began to observe carefully, if not methodically, the habits and peculiarities of insects.

It happened that his father also had been interested in this branch of study, and the family library was furnished with some valuable volumes on entomology, the illustrations of which served to teach Lyell the names and localities of the butterflies, moths, and aquatic insects that he began to collect.

Although he was not conscious of it, his investigations were carried on in the true scientific spirit, including the study of the insects, particularly of the butterfly, from the hatching of the caterpillar, through the transformation of the chrysalis; while at the same time he learned to discriminate so nicely between the several hundred species that he soon became familiar with, that the names which he gave to certain tribes, such as "the fold-up moths," "the yellow underwings," etc., were afterward found by him to really indicate the natural families of classification.

This pursuit did not meet with the sympathy of the people at home, and young Lyell had to endure much bantering and ridicule in consequence of it, but this did not daunt his enthusiasm, and his persistence clearly indicated the spirit of the true seeker after wisdom who lets nothing turn him aside from the path he has chosen. Lyell's collection of insects made at this time was valuable, even though his methods of preserving the specimens were often unscientific and injurious, and he had the satisfaction in after years of knowing that the butterflies and moths which he captured and preserved with so much patience, finding inspiration and help in his work only from the printed pages of Linnaeus and other naturalists, was considered of sufficient value to be utilized by one of the first entomologists in England.

From this time Lyell's appreciation of nature never failed, and his usual boyish pursuits received new zest whenever they approached the region of living forms; and when he returned to school his ardor by no means decreased; the favorite amusement of birds'-nesting being turned by him to an advantage which resulted in a knowledge of the eggs of almost every bird in that region, which was particularly rich in varieties.

The love of one branch of natural science invariably leads to an interest in others, for in the world of nature all things are so closely allied that an interest in one presupposes an interest in all, and thus it happened that Lyell's taste for entomology eventually led to the selection of his life's work.

When he was seventeen he entered Oxford, and although he pursued the regular course with a fair amount of interest, he still showed a love for the works of nature which distinguished him from his companions.

He continued his studies of insects in his leisure hours, having at this time the assistance of an experienced naturalist, and it was during this period also that he became aware that there was such a science as geology, and that the history of the earth might be studied with the same exactness as distinguished the classification of animals and plants.

The knowledge that the earth, which he had hitherto regarded only as the abode of man, possessed an antiquity far exceeding the most remote history of the human race, excited his imagination to such a degree that he knew no rest until he undertook a course in geology. He was thus led to an interest in fossils, and at once began to form acquaintances among collectors, recognizing in one instance the house of a prominent naturalist by a large ammonite which he saw at the door.

From the time of his second year at Oxford geology occupied a prominent part in Lyell's mind, and the study of the earth became gradually of absorbing interest; and he was more and more amazed to find that, while science had progressed in every other department, the earth still remained almost as great a mystery as it had been in the first dawn of scientific thought.

The genius of Galileo and Herschel had read the secret of the heavens, and mapped out the star-system so that remote space had long since ceased to be regarded as an unknown region, and the astronomer could find the orb he sought with the same ease that one might walk into a garden and pluck a favorite flower.

Kepler and Newton had formulated the great laws of planetary motion, and the discoveries in electricity had revealed a subtle force which pervaded all nature to an extent that had not been dreamed of before. Linnaeus had demonstrated the order which harmonized the animal and vegetable worlds, and chemistry had brought to light the unsuspected resources of nature, but as yet no one had given a theory of the earth's history which would satisfactorily account for its present state, and place geology among the familiar sciences.

Besides the gold and gems, other things served to tell man of the wonders of the earth; the fossils found in Europe, in America, and in Asia showed that the earth had undergone changes as great as those which turn the nebulous masses of infinite space into great stars, whose light will shine on for countless ages after man has ceased to exist, or that which converts the sunshine and the dew into the flowers that spangle the meadows or brighten the wayside.

Leaf by leaf the great book of nature was turned, and the story found to be marvellous beyond any conception of poet or romancer. To the common eye the surface of the earth, with its wide diversity of mountain, valley, ocean, and plain seemed wonderful enough, but the geologist looked deeper and found still more enchanting scenes. Like a magician of old he bade the earth lay aside her green veil of mystery, and claimed her secrets for his own.

He examined the rocks and found that the white cliffs of England were the products of living animals, and that the tiny shells, pieces of coral, fragments of sponges, and other fossils found in limestone or chalk rocks, indicated clearly the sources of formation, and pointed to a time when myriads of animals swarmed in the seas where now stand the long ranges of hills that give beauty to the land.

He looked at the great coal measures of Europe and America, and read in their records even more wonderful accounts of the time when the continents were clothed in verdure to the shores of the Arctic seas; imprinted in the dark layers of coal he saw the plume of the fern, great tree-ferns that towered like palm-trees, resembling species now found in tropical regions; while other forms, such as large cone-bearing trees resembling the pines, and trees of a type that has now disappeared from the earth, having the whole surface of the bark covered with leaves thickly set like scales, gave greater evidence of the abundant vegetation which gave grace and beauty to those far-off ages.

Then the zoologist added his gifts of fossil animals, and it was found that the earth was full of the remains of ancient life, and that from the skeleton of the great mastodon, whose tread would trample down the trees of the forest, to the tiny leaf imprisoned in a crystal drop of amber, all could contribute to the story of the earth and make its meanings clearer.

But, while geologist and zoologist combined their powers for the accumulation of innumerable facts, there was yet no theory perfect enough to account for the earth's formation, and to give the order of its successive stages.

And it was in this respect that geology became especially important to Lyell. He studied the different strata, the fossils, and the rocks that contained no fossils, earthquakes, volcanoes, the courses of rivers and glaciers, the fall of avalanches, and in fact all the phenomena connected with the changes going on in the earth, and it seemed to him that, as nature always works harmoniously and according to fixed laws, it might be possible to learn how all the changes that have taken place came to pass, and to formulate some law that should explain the workings of nature in this regard. While yet a student at Oxford a hint of the great system that he was to build up came to Lyell, but as this was in direct opposition to the popular theory of the history of the earth, he refrained from making it known until his studies and experience should have made him better able to pronounce upon such an important matter. With this in view he began to travel, visiting France, Germany, and Italy, and making the most accurate observations on everything that came in his way.

He studied the rocks of the Jura, the Alps, and the Valley of Chamouni, the glaciers of the Rhone, and the floods of the Valois, and in his descriptions of these places showed remarkable power both as a botanist and geologist.

When he returned from his journey he began geologizing through England, examining chalk beds, crystallized rocks, alluvial marsh lands, and clay pits, and from his indefatigable industry soon became known to all the leading geologists, who were glad to give to his powers of observation and generalization the tribute which they justly deserved.

In 1823 he was elected a secretary of the Geological Society, being in his twenty-fourth year. In the same year he visited France again, and saw Cuvier and Humboldt, both of whom recognized in the young geologist a worthy student of science. For several years after this Lyell's time was spent, partly in England and partly on the Continent, studying volcanic and glacial action, and preparing his work on geology which appeared in 1830.

Up to this time there had been a wide diversity of opinion among geologists as to the causes of the changes in the earth's surface. About the middle of the seventeenth century, Steno, a Danish geologist, gave to the world his explanation of fossils, claiming that they were the mineralized remains of animals, and said that the animals now in existence could only be properly studied by comparing them with the fossil remains of other ages. This was a step far in advance of the time when it was claimed that the shells and fossils found in mountains remote from the sea were made by the stars, or produced by some trick of nature, and the suggestion to study the past from the present was made in the true scientific spirit.

A century later, Hutton, a Scottish geologist, whose love for chemistry had led to the study of geology, made some interesting observations on the changes which water will produce on the hardest rocks, and gave it as his belief that all the former changes in the earth's surface were due to the same agents that are now at work. He claimed that the strata which composed the earth at present were once under the sea, and said that the ruins of an older world were visible in the present structure of our planet, and that the same forces were now at work destroying the hardest rocks and carrying them to the sea, where they become again altered by volcanic heat, and that thus there was a constant change going on all the time in which nothing was lost, but everything gradually transformed.

At that time the popular theory of the changes in the earth's surface was quite opposed to the views of Hutton; nearly all scientists taught that all the changes that had taken place in the earth's crust had been caused by great and sudden convulsions, such as earthquakes, volcanic eruptions, floods, upheavals and depressions of the land and similar phenomena, which clearly indicated that nature acted spasmodically, and the earth had reached its present condition through the action of forces very different from those now in operation.

This view would, of course, preclude the idea that nature acted in a uniform or constant way, and supposed all her laws to be subject to violent changes.

Hutton's theory was received with little favor by the public, who saw in it a disposition to ignore the Biblical account of the creation, and the author received a storm of abuse from critics who thought that any inquiry into the origin of the universe was an act of impiety. But to all his opposers Hutton only replied that the laws of nature were immutable, and that the forces which governed the changes on the earth were as unalterable as those which kept the planets in their courses, and held the reins of life and death.

Hutton's theory was far in advance of his age, and was not generally accepted even by the most liberal men of science, but it is interesting to know that it became Lyell's work to elaborate the same idea, and to so strengthen it with indubitable proofs as to make its acceptance a necessity.

Contemporarily with Hutton lived the English geologist, William Smith, whose good fortune it was to carry geology a step farther than it had yet reached.

The different strata or layers found in rocks had heretofore attracted the attention of geologists very slightly, and the beds of different materials which lay one over the other in pits, and rock quarries were little regarded. They were known to exist, just as the beds, or strata of mud, gravel, and sand were known to alternate in the mouth of a river, but they were hardly recognized as of more importance than that given by the old botanists to the different colors of the rose, or the varied tints of the lily.

But Smith studied the strata of all the rocks that he saw, and was able, from his accurate observations and logical reasoning, to deduce a theory of the earth's formation in which the strata formed a prominent part.

Two important discoveries were made by this geologist: first, that there is a regular order of succession of the strata, or beds, which proves them to have been formed at different times, and that in every case the beds at the bottom are the oldest; also that this same order of succession may be found all over the world; and so sure was Smith of the truth of this theory that even at the time of its first conception he guessed correctly the nature of some hills he saw in a distance by their relative position in regard to certain rocks in the county through which he was passing. The second discovery was of equal importance, namely, that each stratum contained fossils differing from those found in other layers, and that knowing the fossils one could determine the strata from which they were taken. From these two discoveries Smith deduced a general law which he summed up as follows: The same strata are always found in the same order of succession, and contain the same peculiar fossils.

Lyell's "Principles of Geology," which was published nine years before the death of Smith, incorporated the views of all those geologists who had striven to prove that nature works in a uniform manner, and the author announced as the foundation of his theory the belief that the past could only be studied from the present.

Lyell's studies, travels, experiments, and observations had all led him to the same conclusion, that in nature there is no life or death, but only change; and that the same agents which produced the great changes on the earth's crust are at work now, although they work so slowly that the effects are almost imperceptible.

Murchison, a distinguished contemporary of Lyell, taught that the mountains, and hills, and valleys had been created by great and violent convulsions of nature. This was called the convulsionist theory and had many adherents, who explained every change by saying it was the result of some great catastrophe.

But Lyell had read the book of nature with a clearer eye, and his study had led him to a belief more in harmony with the known laws of the universe. He taught that those subtle alchemists, the rain, and the frost, and the snow, the rivers and the glaciers, carried on their silent work of transformation in the remote ages as surely and as steadily as they labor now; that the river which comes down from the mountain cutting its way slowly through the solid rock till the path has deepened into a trench, and the trench widened into a ravine, and the ravine become a valley, is but a type of the action of all the rivers that have flowed since time began; and that the rain and frost which splintered the mountain crest into peak and pinnacle, and carved out crag and cliff from its rocky sides are still carrying on the work begun when first the mountains were upheaved by the great forces working in the interior of the earth, and never to cease till all the ages of the future have passed away.

Lyell took the minerals and rocks of the earth and placed them one by one in their proper places till the great book of the earth's history could be read from beginning to end, and all its text and pictures rendered so clear that even the most ignorant could understand it, and know that the child who stands by the mountain rill watching the strong current sweep along the shining pebbles is reading the secret by which the great rocks were formed; and that the violet which drifts upon the surface of the meadow brook till it is caught and tangled among the debris at its outlet is but a type of those great deposits which it took thousands of years to harden into imperishable forms of beauty: while the tiny sea-shell which he picks up along the shore tells the same wonderful story of those bygone ages when all the teeming life of the animal and vegetable worlds had not yet turned to stone.

The fact that the different strata could be recognized by their fossils was made by Lyell the basis of the law of succession of life upon the globe, and from this time geologists began to speak of the different ages of the world in reference to the life of plants and animals upon it; those rocks in which few fossils are found belonging to one age, those which contain fossils resembling living species, another age, and so on, until the present was bound to the past with the strongest links, and the succession of life was proven with the same ease that one might demonstrate a law of mathematics.

Although the "Principles of Geology" met with severe criticism from those who fancied that they saw in it proof that the author wished to inculcate views different from those taught by the Church as to the origin of the world, it grew steadily in popular favor, and is the theory accepted at the present time. And Lyell's work later on showed the same spirit of progressive thought.

His travels in Europe and America only served to deepen his belief in his first impressions. Thirty years after the publication of the "Principles" he published his "Antiquity of Man," in which he claimed that the human race was many thousands of years older than had been supposed, a theory which later researches have all strengthened, while his observations on the great ice age have an equal value for later geologists.

## CHAPTER XIII

# AGASSIZ AND THE STORY OF THE ANIMAL KINGDOM

## 1807–1874

The records of civilized nations can hardly point to a time when man had not yet learned to tame and bend to his will the beasts which seemed only created for his use. And the great value of these four-footed slaves soon became so apparent that the entire wealth of families and tribes was often counted by the number of oxen, camels, sheep, horses and elephants which were owned; these animals were also used as the medium of trade, and in agricultural countries, where the inhabitants had few and simple wants, it often happened that gold and silver money was quite unknown, and wheat and barley were exchanged for sheep and oxen, just as now the same products are brought to market and sold for so much coin.

The animal kingdom thus occupied a very important place, and the chief who could count his camels and horses by the hundred was the one who received the greatest honors, and could hold easy dominion over his less wealthy neighbors.

Very early, too, we find that men learned to put a different and greater value on animals than that granted by the mere power of possession, for in many countries they were worshipped as gods, and received divine honors; and even those which were not actually regarded as deities, were in many cases held sacred, from the great reverence which was paid to life.

Thus many animals not used for food, such as cats, dogs, crocodiles, and serpents, were looked upon as sacred to certain divinities, and it was considered an ominous sign to kill one of these, even by accident, while he who should so disregard custom as to be willfully guilty of the death of one was regarded with the greatest horror.

LOUIS AGASSIZ

In Egypt this superstition arose largely from the popular belief that the soul of man after death entered the body of some animal as a punishment for the sins committed in life, and the study of medicine was hindered by the abhorrence attached to one who dared to aid his studies by the dissection of a dead animal; but in many cases, as in India to-day, the dislike to slay an animal, needlessly, arose from the awe and mystery which were attached to life, which the mystics of all European and Asiatic nations invested with the utmost sacredness.

For many centuries man was content to know that certain animals could be put to certain uses, and were called by certain names, and let his interest cease at that point.

But later, when Greek civilization and learning had combined to invest all knowledge with priceless value, the animal kingdom began to be looked upon as an interesting study, and Aristotle, whose genius left no branch of knowledge unimproved, may be said to have founded the science of zoology when he incorporated among his other works an account of all the animals known to the ancients, and made some attempt at classification and description.

In this work Aristotle sums up such a vast number of statements in regard to the resemblances and differences of animals, their anatomy and the functions of the various organs, that the modern naturalists have only had to follow the way he marked out to arrive at some of the most interesting discoveries in Zoology.

It is supposed that Aristotle was assisted in his zoological studies by the great number of strange animals that Alexander the Great had sent to him from Asia and Africa, for this monarch was justly proud of the genius of the famous philosopher, and took pleasure in affording him every opportunity for displaying it.

Aristotle placed the backboned animals first in his order of classification, and distinguished between these and the white-blooded animals, which have no backbone, and are divided into rings or segments.

Although the student who now reads the works of Aristotle will find many statements that are absurd and false, they do not detract from the genius of the man who first conceived the possibility of arranging the different families of the animal kingdom so that they might be intelligently studied, and it has been suggested by an eminent modern authority that the errors in Aristotle's treatise may have arisen from the fact that the students who listened to his lectures incorrectly reported his notes, and that it is these notes which form the greater part of what is now known as Aristotle's treatise on animals.

Hippocrates, who died ten years before the birth of Aristotle, had taught that the practice of medicine could not be properly followed without a knowledge of the structure of the human body, and his studies in zoology first led to the foundation of the art of healing upon scientific principles. Many of his descriptions of the symptoms and developments of fevers and other diseases are found accurate to-day, and although his theories have for the greater part fallen into disuse, he will ever be remembered as one of the world's most progressive thinkers, lose work it was to destroy the superstition that all disease resulted from the anger of some offended deity, and to found instead a belief based upon reason and experiment.

Aristotle's influence on thought was shown by the fact that when the great library of Alexandria was founded, there were gardens, menageries, and dissecting rooms especially devoted to the study of zoology; and if the results of that period of investigation had not been lost it it is probable that many of the modern discoveries in zoology would be but the finding again of well-known truths.

After the decline of the Greeks the Arabs became prominent as cultivators of literature, the arts and science. Taking for their motto: "He dies not who gives his life to science," these careful students stored up the priceless treasures of Greek learning, and at a time when the nations of Europe were sunk in ignorance and superstition, kept alive the spirit of scientific inquiry and preserved for posterity much of the wisdom of the ancient world.

About the middle of the sixteenth century the study of zoology received a fresh impetus from the works of Gesner, a Swiss physician and professor of Natural History at the University of Zurich.

Gesner published a valuable work on animals in which he reviewed the old authorities, contributed many important facts in regard to living species, and gave illustrations of many fossils.

The link between the past and present was formed by the work of Gesner, for modern zoology dates from that time; and although nearly a century passed before the appearance of another eminent naturalist, yet the work went slowly on, and the interest in zoology kept steadily increasing, so that by the end of the seventeenth century it was possible to indicate a very decided advance in that study.

Harvey had discovered the circulation of the blood, and given the world the benefit of his wonderful anatomical discoveries which revolutionized the study of medicine; Ray had published his classification of the animal kingdom, the scientific merit of which has won him immortal renown; and the use of the microscope had led to the knowledge of those minute forms of animal life which had hitherto escaped observation, and to an acquaintance with the anatomy of insects.

Thus the beginning of the eighteenth century found the world in a state of expectancy in regard to the natural sciences, and the work of Reaumur, who was born early in the century, gave evidence that the time was fruitful in original thinkers.

Reaumur's labors were confined almost entirely to zoology, though his experiments in chemistry, wherein he discovered the art of tinning iron, and made several contributions toward the manufacture of iron and steel and porcelain, were of great service in the mechanic's arts.

His work in zoology consisted of a most exhaustive study of insects. He describes their habits and anatomy, and was the first zoologist to bring their instincts into notice. The work was published in six volumes, and has been a valuable source of information to succeeding entomologists.

Linnaeus' work on zoology was of great value, as his method of classification enabled students to easily place any animal in its proper order and family, and Buffon, another zoologist of the eighteenth century, gave to the world a popular illustrated work on the animal kingdom which will ever be remembered as being the inspiration of more than one eminent naturalist.

Buffon's work was not distinguished for the careful exactness which belongs to other writers, but his glowing descriptions, and animated style gave his volumes a peculiar value. Zoology from that time ceased to be regarded as the province of the learned, for Buffon had shown that it could be a source of amusement and instruction to the most unscientific; and we have only to call up the picture of Linnaeus and Cuvier sitting in a college library and poring over the fascinating pages of this author to realize the important influence exercised by Buffon in the history of zoology.

Still another zoologist of the eighteenth century was Lamarck, a French author, who, although he did not begin the study of zoology until after he was fifty years old, is regarded as one of the greatest authorities by the student of to-day.

Lamarck's principal work was devoted to the study of intervertebrates, or animals which have no backbone, and he raised this branch of zoology to a very important place. He was the first master to insist upon a thorough acquaintance with the lower forms of life as a preliminary study to the higher forms, and so minute and exact were his studies of the lower animals that his works have become the text-books for all time.

Lamarck was among the few zoologists who taught that the lower animals were first formed, and that the vertebrates or back-boned animals are of much later origin, a view that has been confirmed by the discoveries in zoology, and by the greatest modern naturalists.

And thus the study of zoology was led on step by step, one naturalist making a discovery and another using it as a basis for a new ground-work of belief, until the nineteenth century found the scientific world possessed of a tolerably clear idea of the resources of the animal kingdom, and its history from the earliest times. And then the story was taken up again by others interested in the great wonder-book of nature, and thus we find that time cannot interrupt, but only make more complete, the work of those who give their lives to science. Among the worthy successors of Linnaeus, Lamarck, and Cuvier may be counted Louis Agassiz, whose name is familiar wherever the student of science is found.

Agassiz was born at Motier, in Switzerland, in 1807, exactly one hundred years after the birth of Linnaeus, and his early life very closely resembled that of the illustrious child of the North. Like Linnaeus, his childhood was passed in a quiet country parsonage, situated on the borders of a lake, and embracing a view of a region of such picturesque beauty, that it could not fail to impress itself upon the mind of the child.

The home-life of the parsonage was very simple, and the children of the family were early taught to regard only those things as valuable which were independent of wealth, and their childish pleasures were all such as could be found in any of the unpretentious little homes that surrounded them.

Unlike many of the great naturalists who only took up their special work late in life, Agassiz may be said to have begun his life-work in his early childhood, though he himself was unconscious of it.

For, like Linnaeus and Cuvier, his first impressions of nature were received from the games and employments of his country home; and in his boyish taste for collecting nests, eggs, birds, and other pet animals, and in the little aquarium, supplied with specimens from the lake, could be traced the small beginnings of his scientific career.

Thus the love of nature, and the finding out of her secrets, began with the boy's first consciousness, and in all his out-of-door sports he was laying up stores of valuable information. To him, as to all country children, the different seasons of the year brought each its offering of gifts and laid them at his feet; and from the first spring blossom to the fall of the snow all nature seemed a harmonious whole, and the wide earth but a treasure-house where one might gather largess at his will. And as the years passed, Agassiz learned more and more of the great forces which linked him with the world of nature around him, and began to understand the sympathy which the genuine naturalist feels for all forms of life.

Besides these lessons, learned in the fields and woods and by the shores of the lake, where nature herself was the teacher, Agassiz had a few simple tasks out of books, his father and mother being his teachers, and, up to his tenth year, he received no instruction outside of his home.

But a boy so intelligent and observing as Agassiz could not fail to learn many things not included in his daily hours of study, and the home-life of Motier, which was in many respects very primitive, furnished the boy many a self-imposed but not the less instructive task.

From the shoemaker who came twice a year to fit the family out with boots and shoes, the boy learned how to make a tiny pair of shoes for his sister's dolls, from the tailor, who was a guest in the house while making the spring and winter outfits, he learned to fashion a suit of clothes, and when the cooper arrived to put the barrels and hogsheads in order for the vintage, he found an apt pupil in the boy to whom nothing seemed uninteresting, and who gained, in these childish amusements, much of that training of the eye and hand which were invaluable to him later on when dexterity and delicacy of touch were so necessary to his scientific pursuits.

And the times of seed-sowing and harvest and vintage, when all the members of the family took an unusual interest in the farming affairs, were also made to contribute their share toward the education of the future naturalist, who learned many practical, useful lessons about growing plants at a time when the learning seemed only childish pastime.

The vintage was the great annual holiday season, when almost the entire population gave themselves up to the business of gathering the grapes and making the wine, and the merry-making attendant upon such a festival. Here all ages and classes met together, the very old and the very young being alike able to give their share of work and fun, and it was amid such scenes that Agassiz early learned to sympathize with the tastes and interests of everyday-life, and imbibed that generous love for humanity which was such a distinguishing trait of his character.

When he was ten years old Agassiz left home to attend school at Bienne, twenty miles away, where he remained five years, coming home only for the vacations.

They were years full of pleasure to the boy, who developed a great taste for study, and made a lasting impression upon his mind; for long before their close he had learned the great lesson for all scientists, to love knowledge for its own sake, and not merely as the means to an end.

During this time his taste for natural history was confirmed, and the little collections he had made at Motier gave place to others more in keeping with his ambitions. He did not have the benefit of a teacher in these pursuits, and the pages of manuscript filled with notes were written on a plan entirely his own. He made at first no attempt at classification, being content to give all the plants and animals for which he knew Latin names, with the design of extending the list gradually until it should include the entire animal and vegetable kingdoms.

Although this design may seem childish enough, it yet shows the birth of the true scientific spirit, which begins with inquiry into the familiar, and never ceases until the unknown has been explored as widely as possible.

And although Agassiz's attempts at studying natural history were at this time so desultory, and included only general observations on the appearance and habits of the specimens, they yet were fruitful in laying the foundations for those accurate studies from nature which distinguished the work of this naturalist.

Meadow, field, forest, and stream were haunted by the boy, who thought no living thing uninteresting, and his room was gradually turned into a small museum of natural history. Birds, insects, and fishes were collected with great care, and their modes of life so carefully studied that the knowledge thus gained became a store-house of useful facts when Agassiz became interested in the graver problems of natural history. He raised caterpillars from the eggs and studied with minute care the different kinds, describing their habits and differences of diet, and the length of time passed in the chrysalis state, and accurately noting the characteristics of the great variety of butterflies and moths, with which he soon became familiar.

The songs of the birds, their twitterings, scoldings, changes of position, habits, and instincts were all as well understood by the boy-naturalist as the voices of his friends; and in his autobiography he says that what he knew of the habits of the fresh-water fishes of Central Europe was almost entirely learned at that time, it being a matter of great surprise to him when he became acquainted with the works of the principal authorities on fishes, to find how little they knew of their habits and life, things which Agassiz himself had been familiar with since boyhood.

The parents of Agassiz had intended that he should leave school at fifteen, and enter commercial life, for they had never associated any serious meaning with the boy's love for natural history, and the years passed at Bienne seemed a sufficient preparation for a life to be spent at the desk of a man of business. But Agassiz's love for study had grown to such proportions by the time it became necessary for him to leave Bienne that he begged for two years more of student life, and although this called for some self-denial on the part of the parents, who had only a limited income to depend upon, the wish was cheerfully granted, and the boy was allowed to enter the college of Lausanne.

And this step, whose importance no one then conjectured, was in reality the turning-point of the boy's life. Here he heard his first lectures on zoology, based upon the teachings of Cuvier and Lamarck, and learned the great importance of system and classification, and that the greatest authorities could differ in regard to the name and place of the various classes. The views of Cuvier in the "Regne Animal," and of Lamarck in his work on the invertebrate animals, all showed conclusively the importance of anatomy in the study of zoology, as their conclusions were drawn chiefly from observations on the structure of the animals, and depended little on other points. Agassiz was thus led to see the great value of anatomy, and his interest in this subject was at once awakened.

Lausanne possessed the only collection of animals in that part of the country, and Agassiz's newly awakened interest was stimulated by the sight of so many specimens hitherto unknown to him; he visited the museum as often as possible, observing and comparing the different varieties with his usual intelligence, and, no longer content with this superficial way of study, ardently began to long to understand the internal structure, so that he might be led to the scientific way of classification.

In this respect he was fortunate in having an uncle at Lausanne, who was a physician, and who lent a willing ear to Agassiz's intelligent questioning. And it was through the influence of this relative that all thoughts of a commercial life for Agassiz were finally abandoned, and he was allowed, when seventeen years of age, to enter the University of Zurich as a student of medicine.

Here Agassiz's real scientific training began, as, for the first time, he came under the instruction of men who were studying nature from her own book, and did not depend utterly on the teachings of others; and this originality was of the greatest benefit to Agassiz at this time.

He entered upon his medical studies with the greatest zest, being delighted with the idea of taking a profession so closely allied to his favorite pursuit of natural history, and as his teachers lent their aid and encouragement, whenever it was possible, his life at Zurich promised to partake more of the nature of a holiday than of a serious working time. His anatomical studies were especially interesting, as in that department he felt that he was not only fitting himself for his work as a physician, but that he was put in the way of following out the suggestions contained in the works of Cuvier and Lamarck, and entering upon a wider field of scientific inquiry than he had been before able to work in.

The first lectures he heard in anatomy roused such an interest that he could think of nothing else, and in speaking of this time afterward he said that he could see nothing but skeletons, and could find no pleasure out of the dissecting-room. With his customary zeal he at once began to make a collection of bones and skulls, dissecting all the animals he could find, and, as was the case at Bienne, turning his rooms into a small menagerie.

A large pine-tree in the corner of the room became the home of scores of birds which flew about the head of the young naturalist while he was busy arranging his collections, and the streams and lakes furnished specimens for a new aquarium, while shells, minerals, and living pets of all kinds, showed that Agassiz had in nowise changed his tastes from those which distinguished him as a child.

A private library at Zurich, to which Agassiz had access, held some valuable works on natural history, and here the young student spent many an hour copying the text and illustrations in his note-books, as he could not afford to buy the necessary text-books. Two volumes of Lamarck's "Invertebrate Animals" were copied at this time, and although this plan of study might appear unnecessarily hard, yet it after all served a good purpose, as it made Agassiz depend less on text-books and more on observation and original research, a thing which could not fail to have a beneficial effect on one who was destined to become distinguished as an independent thinker.

During his two years' stay at Zurich, Agassiz was diligent in his application to the study of medicine, but the love of natural history was gaining greater sway over him year by year, and the books and reports of those naturalists who had enjoyed foreign travel took such hold of his fancy that he, too, became possessed of an ardent desire to travel and study the wonders of nature for himself.

It is not surprising, therefore, that at the end of two years, he persuaded himself and his friends that it was absolutely necessary for him to enter the University of Heidelberg for the purpose of pursuing his medical studies to the best advantage, for there he knew he should find some of the most distinguished naturalists of Europe.

The life at Heidelberg was but a continuation of that passed at Zurich, with the exception that soon after his arrival at his new quarters Agassiz made the acquaintance of a young man who was, like himself, very deeply interested in natural history, and who became his intimate friend almost from the first moment of meeting.

The two friends were together constantly, and studied zoology in the fields, woods, streams, fish-markets and museums, each benefiting the other by his experience and advice; for although Agassiz had by this time become familiar with a large part of the animal kingdom his friend Braun was the better botanist of the two, and thus they were able to derive mutual benefits from each other's company. When not abroad botanizing and zoologizing they spent much of the time in their rooms, where, while one prepared specimens, arranged collections, or dissected cats, dogs, fishes, and butterflies, the other read aloud from some work on anatomy or physiology. His intercourse with Braun proved of the greatest service to Agassiz, who, from that time, ceased to regard the study of living animals as of paramount importance, and began to take a wider view of the aims and ambitions of the naturalist.

The work of Cuvier, and other specialists on fossils, also attracted his attention about this time, and in fact the experience of Agassiz at Heidelberg served to so deepen his perception of his own peculiar powers as to make him dream more and more of becoming a naturalist to the exclusion of everything else.

After a year and a half spent at Heidelberg Braun determined to enter the University of Munich, and Agassiz accompanied him. Munich was rich in the presence of several teachers and travellers of distinction, and Agassiz at once felt the inspiration of the new influence. His medical studies grew irksome to him, and his studies in natural history occupied nearly his entire attention, while his visits to the rooms of two of his new friends who had travelled in Brazil, and brought home a fine collection of fishes, awoke anew that love of travel which is the ever-present impulse of the true naturalist.

But travel was impossible at this time, and Agassiz was somewhat comforted for the deprivation, by a proposition from one of his travelled friends to describe the fishes brought back from Brazil. This was work of a character highly suited to the wishes of the young student, and he set about it with enthusiasm, keeping it a secret from his parents as he wished to surprise them with an evidence that his taste for natural history and distaste for medicine might, after all, lead to some practical end.

Agassiz worked on the Brazilian fishes with an earnestness that well repaid the trust reposed in him, and the first volume appeared in the autumn of 1828, when the editor was in his twenty-second year. The work was well received by all European naturalists, who felt that it furnished a necessary link in ichthyological history, and Agassiz received from Cuvier a letter of warm appreciation of its merits, and the promise to incorporate it into his new edition of the "Regne Animal."

This success so encouraged him that he decided to undertake another work somewhat similar in character, and he therefore began his work on the fishes of Switzerland and Germany.

During his preparation of the "Brazilian Fishes," Agassiz was buoyed up by the hope that he might be included in the list of those who were about to start on scientific tours, hoping either to join Humboldt's expedition to Asia, or a similar excursion to South America under the direction of another naturalist.

He therefore undertook a regular course of training as a preparation for the journey, learning blacksmithing, carpentering, practising sword and sabre exercises, and taking long walks day after day, loaded down with bags of plants and minerals. This course, he thought, would fit him to endure the disadvantages of travel through uncivilized countries, and it was a bitter disappointment to him to find that he could obtain no place as assistant to any one contemplating foreign travel.

However, he still kept on the path he had marked out for himself, and as a fine opportunity presented itself for studying the collection of fossil fishes in the museum of Munich, he at once undertook the preparation of a work on that subject. It was a fine chance for the young naturalist to show what he could do, as fossil fishes had up to that time received little attention, and it was Agassiz's own originality and vigor of thought that suggested the choice of this topic.

He employed two artists to help him in the work which progressed rapidly in spite of the fact that the author was at the same time engaged on his Fresh-Water Fishes of Central Europe, and hard at work studying for his diploma.

In the spring of 1830, Agassiz received the degree of Doctor of Medicine, being in his twenty-third year, and at the end of the same year left Munich for Switzerland, where he remained for a year working on the fossil fishes and fresh-water fishes, and practising medicine as often as opportunity offered. But he was restless for the larger life to be found in the scientific circles of a great city, and in the autumn of 1831 started for Paris, though not without a certain dread of the future, as his financial prospects were anything but cheering.

But his scientific life in his new home was so inspiring that it repaid all the loss he suffered in personal deprivations. Humboldt and Cuvier received him with the greatest kindness, and the museum at Paris offered inexhaustible resources in the prosecution of his work on the fossil fishes. In this work Agassiz's aim was to determine to what geological period the different specimens belonged, and to trace the connection between the fishes of the past ages and those of the present time.

This was not an easy task, as in many cases it was impossible to obtain enough of the skeleton to distinguish the specimen without great difficulty. But Agassiz was undeterred by this circumstance. A tooth, a scale, or a spine served him as a guide into this wide field of research, and from these trifles his patient energy would reconstruct the entire skeleton, and bring back to life again, as it were, the dead animal which the long centuries had carved in stone. The importance of this work, which would serve the twofold purpose of explaining the development of the different classes of fishes, and the succession of the layers of rock, as told by their presence or absence, was well understood by Agassiz, and it was a matter of great seriousness to him that his limited means should stand in the way of carrying on his studies to the best advantage.

During the year he spent in Paris he received a generous loan from Humboldt, whose high appreciation of Agassiz's talent never diminished, but Agassiz felt more and more the impossibility of depending upon chance for a livelihood, and in 1832 accepted a professorship at Neuchatel. His work on fossil fishes occupied him ten years, during which time he visited England, Germany, and France, for the purpose of studying the fossils in the various museums.

The publication of the first volume in 1833 at once placed Agassiz among the greatest living naturalists, and was received with the most distinguished favor by all the scientific societies of Europe.

In this work Agassiz made the very important discovery that the natural succession of the different classes of fishes, as regarded their development, also corresponded with the succession of the geological epochs, as marked out by the recent studies in geology.

While this work was in progress Agassiz also made some very interesting studies on the nature of the action of glaciers. Up to this time the theory about those great fields of moving ice had been based upon the convulsionist theories of the older geologists, and the presence of vast ice fields, and great boulders, in places where there seemed no apparent reason for their existence, was explained by supposing that nature worked by fits and starts, and that there could be no other way of accounting for her actions.

But from the year 1836 to 1846 Agassiz visited all the glaciers of Europe, and studied them with the greatest care. In these excursions he was accompanied by other men of science, who gave him help in special ways, and he was thus able to make the most thorough study of glacial action. One member made a microscopic study of the red snow, and the animal life it contained, another studied the flowers, another the temperature of the interior of the glaciers, and another the deposits or debris left by this slow movement.

The geologists of all countries had long been puzzled over the presence of boulders, fossils, and the quantity of loose unstratified material called drift, which were scattered over various places, where their appearance did not correspond with the geological formation of the rocks, and Agassiz's bold theory of glacial action, which explained these phenomena on simple and reasonable grounds, was received with unmistakable satisfaction and admiration.

Agassiz laid aside the theory of sudden convulsions of nature, and claimed that the glacial phenomena could be explained upon principles more in harmony with the ordinary workings of nature; and his ten years' study of glaciers only confirmed a conclusion to which he had been led early in his investigations.

According to this theory, the whole of the northern continent was once covered with ice which extended from the North Pole to the boundaries of Central Europe and Asia. Before this ice period the whole of that region had been covered with a luxuriant vegetation and was inhabited by the great animals which are now found only in the torrid zone. Elephants, hippopotami, and enormous flesh-eating animals wandered through the vast forests, and the rivers which flowed into the Arctic Ocean were the haunts of fishes and waterfowl, now only to be found in the streams of the tropics.

This condition of things existed for long ages, during which the earth was covered with verdure from the equator to the uttermost north, and the teeming life of the tropics extended to the polar regions. Then, by degrees, the whole aspect of nature changed, and from some unknown source, cold succeeded heat, and death came to take the place of life. Lakes, seas and rivers were frozen, and the myriad living creatures they contained were changed to inanimate forms; over the vast plains stretched a great mantle of ice, which touched the flowers, shrubs, and trees, as if by magic, and turned them to stone, while the huge beasts, wandering through the forests, or basking in the sunlight of the northern shores, were overtaken by the same dreadful fate, which spread a shroud over the living face of nature and turned a scene of beauty to ruin and desolation.

Ages after this catastrophe, the sun's beams melted the ice and snow, which slowly began their retreat toward the north, and the ice-fields and glaciers of Central Europe alone remain to remind the student of nature that the story they tell was a living reality, and not the fanciful imagining of the poet or romancer.

The acceptance of this theory accounted for the presence in the Siberian rivers of those re- remains of gigantic animals whose counterparts are now to be found only in the tropics, and explained the appearance of fossils, boulders, and other deposits in places where their presence had been hitherto unexplainable. And although it was elaborated during the years when Agassiz was busy upon zoological studies of the gravest importance, it lacked nothing of that conciseness, vigor, and attention to detail which distinguished all the work of this master, who considered every part of creation of equal interest and found zoology and geology alike but the means of reading more clearly the great design of the universe.

In 1846 Agassiz came to the United States on a visit, having for its object the pursuit of his scientific studies. At this time, when his fame was world-wide, his theories were nowhere received with greater enthusiasm than in America, and it was a matter for no surprise that two years after his landing in the New World he was offered the chair of Natural History in Harvard University.

From that time his scientific work was confined to the continent and islands of America, and his many journeys, having for their object the study of zoology and geology, were all made in the interests of science in connection with those studies in the New World.

Agassiz's most important contribution to science after his settlement in America was his report upon the Florida Reefs, a strip of rocks fringing the southern coast of Florida, which had long puzzled the American naturalists, who had so far been unable to agree as to their geological formation. The Coast Survey of the United States was particularly anxious to have the question of their formation settled, both from a practical point of view in regard to navigation, and for scientific reasons, and

Agassiz was asked to make an exploration of that region in the interests of the Government.

Agassiz accepted the commission with great eagerness, and made an exhaustive study of the reefs, arriving at the conclusion that these fringes of rocks, which were separated by deep channels, were not a freak of nature, but that the whole peninsula of Florida had been formed by successive circles of these coral reefs, the everglades being only filled up channels, and that the soft soil, now so shifting and uncertain, would in time present the firm appearance indicated by the older portions.

The report was valuable to the Coast Survey, as it determined the nature of the soil, and indicated what localities might be available as offering stable foundations for light-houses, signal stations, and the like.

The life of Agassiz from the time of his coming to America was one of ceaseless activity, and his lectures at Cambridge and in Charleston, S. C., where he resided for some time, formed only a small part of his work. His contributions to science were of the greatest value, and during the first fifteen years of his residence in the United States his essays on the geographical and geological distribution of animals; on the natural history of the United States; on the glacial phenomena of Maine, and kindred subjects, served to advance in a marked degree the sciences of geology and zoology, which were still in a process of formation, while the establishment of several scientific schools, which have since attained to eminence, were likewise attributable to the same master-mind.

In 1865 Agassiz made a journey to Brazil, having the twofold object of obtaining a needed rest from his usual work, and of making collections for the Museum of Natural History; and this expedition was fruitful in scientific interest.

He remained in Brazil something over a year, and was able to make a most satisfactory collection of Brazilian fishes, bringing away with him two thousand specimens obtained from the Amazon and its tributary streams and lakes. It was also a great source of pleasure to Agassiz to find, in the Brazilian tropics, evidences of the great ice-period, which proved to him that the glaciers had once covered that region, where now the rays of the sun are so powerful as to endanger life.

In 1871 Agassiz started out on another expedition, having for its object the study of the animals of the sea, for which purpose it was proposed to dredge the coast-waters down the Atlantic and up the Pacific as far as San Francisco. This work was especially attractive to Agassiz, as he believed that the study of the deep-sea animals would reveal many of the missing links between the fossil world and living species; and, beside this, he also expected to find evidences that the glacial phenomena, familiar to the northern hemisphere, were also to be found in the southern, and thus add a stronger proof that his glacial theory was correct.

The active work of the expedition began as soon as the Gulf Stream was reached, with the study of the Sargassum, or fields of drifting sea-weed, which abound in those regions, and which was filled with minute forms of life. Agassiz was able to make a very satisfactory study of the Sargassum, and this good beginning was followed up by dredgings in the Barbadoes, which revealed some living sponges, so much like the fossils he had previously studied that Agassiz felt that his theories of deep-sea dredging were already bringing him a golden harvest.

On the coast of Montevideo Agassiz found strong evidences of glacial action, and on the coast of the Argentine Republic many interesting fossils were obtained from the huge boulders which were scattered everywhere; while the geological formation of the coast of the Straits of Magellan gave still further evidence of the truth of his favorite theory in regard to glaciers. Here he found a moraine composed of boulders, pebbles, and gravel, polished and grooved, and bearing all the signs of glacial action, while the ice- and snow-fields glittering upon the slopes of the mountains could only remind him of the glaciers of the Alps, thus proving to Agassiz that the ice period had extended over the southern as well as the northern continents, coming in both cases from the poles and retreating eventually in the same directions. Agassiz studied the glacier regions of the south for several weeks, and then the vessel proceeded on her way to new fields of investigation.

A trip was made to the Galapagos Islands, interesting to naturalists because of their recent origin and their peculiar varieties of plants and animals, some of which are different from any known in other parts of the world; and here Agassiz made some important studies on the formation of volcanic islands, of which this group formed an instance.

The voyage was then continued up the Pacific, the original plan to proceed to San Francisco being carried out by their reaching that city in August, 1872, having accomplished very nearly all that they set out to do. This was Agassiz's last scientific excursion; and, after his return to Cambridge, he busied himself with plans for a School of Natural History to be established somewhere on the coast of Massachusetts, and which was to be in operation in the summer, for the benefit of pupils and teachers from all over the country; an important plan, as it has resulted in the founding of various summer schools which have greatly advanced the study of science.

Lectures, essays, and study filled up another year, and in December, 1873, the work of the great student came to a close, and he passed away from earth leaving behind him the fruits of a well-spent life in which selfish aims and enjoyments had no share, and which was of in estimable value to science.

# CHAPTER XIV

# TYNDALL, AND DIAMAGNETISM AND RADIANT HEAT

## 1820–1893

The study of light and heat as a science may be said to have begun with Aristotle, who was the first great philosopher to inquire into their origin. Aristotle claimed that light and heat arose from the friction caused by the swift motion of the stars through the air, and further that it was the nature of all motion to produce heat.

This doctrine of Aristotle is interesting because modern science, calling to its aid all the multitudinous inventions that ingenuity can devise, has reached the conclusion that heat is a condition of motion of the particles of material bodies. Yet the resemblance between this result and the speculation of the old philosopher, though noticeable, is merely superficial, and no certain progress was made in the study of heat till philosophers learned to submit their guesses to the test of experiment.

The progress of science is not a steady advance, there are continual haltings by the way, and even temporary retreats; a long-period of stagnation may precede some brilliant discovery or powerful and far-reaching generalization that will at once rouse investigation and usher in a period of great progress; this was true in a marked degree of the study of light.

Early speculation taught that light was an emanation thrown out in straight lines from the luminous body. But during the seventeenth century the theory that light consisted of waves or undulations coming from the heated body was powerfully advocated by Huyghens. Newton, however, who made many interesting and important investigations in light, strongly advocated the emission theory, and the weight of his great authority turned the scale against the wave theory, in consequence of which it was in disrepute for nearly a hundred years, during which time very little progress was made in the knowledge of light.

During the life of Newton it had been established by Roemer, a Danish astronomer, that it took a certain time for light to pass from a heated body to the eye; for by calculations based on the times when the moons of the planet Jupiter were observed to be eclipsed, he had found that light travelled at the rate of 185,000 miles in a second.

Just at the beginning of the present century Thomas Young, an English scientist, brought forward new and convincing evidence of the truth of the wave theory, and showed how waves of light could be made to interfere with each other and produce darkness. This was the opening of a period of great progress. Immediately succeeding Young came Fresnel, the great French physicist, who contributed more than any one else to the development of the wave theory, and whose labors, together with those of such men as Arago and Foucault, at once brought the science of light almost to the position it occupies to-day.

But it is not true that all waves coming from a hot body are visible; even if it were not hot enough to give out waves of light it would send off waves which, though invisible, are capable of giving the sensation of warmth. These invisible waves, or heat radiations as they are sometimes called, have been made the subject of many careful investigations, and prominent among those who have devoted themselves to their study we find Professor John Tyndall, whose studies in radiant heat and diamagnetism have given him an honored place in the scientific world.

Tyndall was born in the village of Leighlin Bridge, Ireland, in 1820. His parents were poor, and this poverty brought with it the usual gifts in developing the mind and ingenuity of the little lad who was to owe all his success in life to his own individual efforts.

Like his little companions in the same condition of life, he played about the village streets, made excursions into the surrounding country, and found life a pleasant thing; for poverty to the country child brings with it none of that sordid wretchedness which so early leaves its blighting impress on the soul of the city child, to whom it comes without any grace or brightening charm.

Thus circumstanced, in spite of his parents' humble means, the boy's life passed, pleasantly enough; and the lessons which nature taught him in his wanderings around Leighlin Bridge were the most useful he could have learned. He grew up a part of the beautiful world around him, and the songs of the birds, the blossoming of the flowers, and the thousand experiences of life with which he was always familiar, seemed to belong to him as much as the coloring and perfume were a part of the wild flowers he gathered.

And, besides this love and appreciation of nature, the boy was fortunate in the books which he read as a child, and which left an indelible mark on his character. His father was a man of strong religious principle, and the volumes in the family library included, with the Bible, the principal works of the most celebrated writers on theology; and, although this subject would have ordinarily no charms for a child, yet the fervid imagination, the poetic feeling, and above all the high ideality which made the duties of common life seem a religious ceremony, could not fail to make a lasting impression on the mind of a sensitive and imaginative child; while the Bible, with its wonderful imagery and powerful descriptions of nature, together with its human interest, all tinged with the deepest religious inspiration, was no less a source of fruitful teaching to the child, who read and re-read the glowing pages until he knew the volume almost by heart, and the sublime style of the Hebrew prophets had grown as familiar to him as the voice of Nature in the outdoor world.

Thus, when at seven or eight his school-days began, young Tyndall started up the hill of learning with two priceless aids—a loving intimacy with nature, and a familiarity with the grandest literature that the world has ever known.

His school days reached to his nineteenth year, during which time he pursued the usual course of study, and showed no particular talent for anything, excepting perhaps mathematics, a taste for which developed itself during the last two years of his school life. He began the study of civil engineering after leaving school, intending to make it his profession, and for three years diligently studied the preparatory course, meeting with the most gratifying results.

But in 1842 he attended a course of lectures at a Mechanics' Institute, which, combined with a desire for larger study which had come to him the year before, opened wider fields of thought and gave him a deep interest in subjects unconnected with his special work.

But for five years longer he kept on in the way he had marked out for himself, completing his course of study and practising engineering with marked success. Then, in 1847, he was appointed teacher in Queenswood College, Hampshire, and during the year that he spent in this place he became so interested in chemistry and other branches of physical science, that he determined to leave England and take a course of scientific study at some German university.

Marburg, in Hesse-Cassel, was chosen as the place of study, and here, in company with the friend whose lectures in chemistry had first interested him in natural science, Tyndall spent two years engaged in absorbing study. His student life was of the simplest kind, as money was scarce, and the end he had in view, the acquiring of knowledge for its own sake, did not point to any large remuneration from a material stand-point in the future. He studied sometimes sixteen hours a day, and although his hopes of success were sometimes overclouded by the gloomy doubts which often visit the imaginative mind, his resolve never faltered; and if his life at Marburg had borne no other fruit, it yet would have been rich in the development of that loftiness of purpose and stern devotion to duty, which at this period became such marked characteristics of the young student.

But Marburg did bring other and great prizes to him. He was under the teaching of Bunsen, the celebrated chemist, whose lectures on electro-chemistry, or the chemical changes which occur through electricity, attracted Tyndall at once, and at the same time he attended an illustrated course of lectures on radiant heat, or heat which comes in rays from the heated body, in the same manner that the heat of the sun reaches the earth. These studies were in the direct line of experimental research, and Tyndall was thus easily led to a point where he began independent investigation.

Faraday's important discovery of diamagnetism, was then attracting great attention in the scientific world. Faraday had shown that all matter could be influenced by magnetism, and had divided bodies into magnetic and diamagnetic. A bar of a magnetic substance when suspended between the poles of a magnet would point in the direction of the line joining the two poles. But if the bar were diamagnetic, it would set itself cross-wise, so that its two ends were as far away as they could get from the poles of the magnet.

But further investigation had brought to light the fact that certain substances which were diamagnetic, ceased to be so when discovered in the form of crystals. Thus, a piece of bismuth suspended between the poles of a magnet would point across the line joining the two poles, showing that bismuth was a diamagnetic substance, but a crystal of bismuth when suspended did not follow this direction, and the same was found to be true of many other substances.

In 1849 Tyndall began the study of this interesting phenomenon, and for several years carried on experiments in magnetism and electricity with the hope of arriving at some satisfactory conclusion; and, by 1855, he may be said to have reached results which were so important as to place his name foremost in the ranks of those who have studied this subject.

Crystallization, or the mysterious force by which charcoal becomes a diamond, common clay a sapphire or ruby, and by which other transformations are effected, had been an interesting subject of study from the time that science had first revealed that the same substance might exist either in the crystalline or non-crystalline state, and it was in this field of thought that Tyndall labored in his experiments on diamagnetism.

He claimed that the apparently contradictory actions of some diamagnetic substances and their crystals, were due to the structure of the substance or crystal, or the peculiar ways in which the particles forming the body were joined together. This property or peculiarity he stated was not simply characteristic of certain substances, but that, as nature acted by general laws, it would be possible, by following out the suggestions contained in this fact, to arrive at the most important discoveries in relation to the structure of the earth, and its magnetic actions; and that just as the fall of an apple suggested to Newton the theory of gravitation, so the refusal of a crystal to act in accordance with the laws that governed the uncrystallized substance might point to a law of nature which, if discovered, would unravel many of the mysteries which puzzle the scientific mind.

Tyndall also demonstrated that polarity, or the power of a substance to attract one pole of a magnetic needle and repel the other, was also a property of diamagnetic substances, with the difference that, if placed under the same magnetizing influence, a bar of diamagnetic substance would show north polarity at that end which in a bar of iron or other magnetic substance would be a south pole. It was also shown that the attractive force of magnetism is infinitely greater than diamagnetism, the magnetism of iron exceeding the diamagnetism of bismuth two and a half million times.

In 1859 Tyndall began his researches in radiant heat, a subject of great interest, not only to scientists but to all who are desirous of understanding the relations which exist between the forces of nature and the laws of life.

The power of the atmosphere to absorb the heat of the sun was then attracting attention, as it is a question bearing directly upon human interests, as well as being a valuable subject for scientific inquiry.

The Italian physicist, Melloni, had made some very important researches in radiant heat, and had given special study to its passage through different substances.

A body which allows heat to pass through it is said to have the property of diathermancy, just as a body which allows light to pass through it is said to have the property of transparency. And Melloni, by a series of interesting experiments, established several laws in regard to the diathermancy of different substances.

Rock salt was found to possess great diathermancy, as it allowed nearly all the heat to pass through; glass, on the contrary, which was as transparent as rock salt, was found to have little power of transmitting heat; ice and alum, equally transparent, have slight diathermancy, while clear and smoky quartz, one as transparent as glass, and the other nearly opaque, alike transmit considerable heat.

Tyndall's experiments related chiefly to the diathermancy of gases, and proved that the heat in gases and vapors was absorbed and radiated with as great differences as those which marked its passage through liquids and solids, and that it was governed by certain laws which played an important part in the distribution of heat over the world.

He found that dry air permitted heat to pass freely, but that watery vapor was possessed of great power for absorbing the heat, and this conclusion was made the basis of a most interesting hypothesis in regard to the distribution of heat over the globe.

Countries distinguished by a moist climate, like England or Ireland, were thus particularly favored, as the watery vapor, which Tyndall likened to a blanket, absorbed the heat which would otherwise have passed off by radiation from the earth, and kept a sufficient warmth to protect vegetation, just as clothing protects the human frame; and Tyndall said that if this watery vapor were removed from the air for a single summer night, the sun would rise the next day upon an island held fast in the iron grip of frost, with every plant and flower dead.

The absence of watery vapor in the atmosphere would, in like manner, account for the terrible cold of dry climates, such as Central Asia, and the nights of the Sahara desert. This theory was of special importance to geology, as it explained the origin of the glacial era; for as the earth was passing through its cooling period, the oceans, as is now the case, would naturally be warmer than the land, owing to the presence of watery vapor over their surface which served as a blanket to keep in the heat; the dry air over the land would permit the heat to pass off rapidly into space, on the contrary; and thus the rapid cooling of the land turned the mountains into receivers of the condensing vapors, which formed into the great glaciers which once covered the earth.

Another very interesting study of radiant heat, made by Professor Tyndall, related to the separation of the invisible from the visible waves or rays of light.

The fact that the light of the sun as reflected from the moon has very little heating power in proportion to its illuminating effect, had suggested to Melloni the idea of a set of experiments which resulted in the separation of heat from light on a smaller scale, and Tyndall made some successful experiments showing that the reverse was also true. In these experiments he separated the visible from the invisible rays of the sun, the lime light, and electric light, allowing the dark rays, which have the principal heating power, to pass through the intercepting medium that he used, while at the same time not a ray of light was received. With these dark rays he produced fire, melted metals, and obtained the different-colored rays of light, thus proving that the invisible rays of the sun may carry on the mightiest operations of nature, just as surely as the flower may give forth its fragrance in the darkness.

In this connection Tyndall invented a respirator for the use of firemen. This instrument, which consisted of layers of moist wool, dry wool, charcoal fragments, and caustic lime, enclosed in a wire gauze, was found to be a great protection to firemen who were unable to carry on their duties in consequence of the smoke from the burning building. The respirator effectually destroyed the bad effects of the smoke, and allowed the firemen to breathe in a room filled with the densest smoke without discomfort.

In his researches on light Tyndall also gave his attention to sound, and its relation to heat. Seamen had often been puzzled by the fact that the signals used during fogs often failed to convey the warnings in fine weather, and that the guns, gongs, and powerful whistles heard miles away during the rain could not be distinguished sometimes at short distances when the sun was shining. Tyndall suggested that this was due to the presence of invisible clouds which formed a barrier to the waves of sound, just as a dark cloud shuts out the sunshine; and, pursuing this subject later on he found that certain vapors and gases possessed the power of conveying sound in the same order as their absorption of radiant heat.

Some of the experiments leading to this conclusion related to the conversion of light into sound. Starting from the fact that thin disks of metal would produce musical sounds when struck by an intermittent beam of light, Professor Tyndall carried on a number of experiments which proved to his satisfaction that such a beam of light striking a highly absorbent vapor would even produce a more intense sound than that produced by a solid. The test experiment consisted of an arrangement by which the light struck the vapor only at intervals, the sounds being caused by the alternate expansion and contraction of the vapor, it being found that vapors and gases which allowed the heat to pass through them would produce no sounds whatever. Chloride of methyl was found to give forth sounds which, when conveyed to the ear by a rubber tube, resembled the peal of an organ in intensity.

In his pursuit of science Tyndall has added the advantages of travel, and his study on the glaciers of the Alps and the Falls of Niagara have an especial interest from the fact that they were carried on in the midst of dangers that might well have deterred a less devoted seeker after truth.

Professor Tyndall possesses a remarkable faculty for making his subjects of study understood by the unscientific mind, and his lectures in England and America have done much to make the study of science and its high objects popular, while his uncompromising love of truth, and his unimpeachable honesty in its pursuit have won him distinction from his fellow-laborers in the fields of knowledge.

# CHAPTER XV

# KIRCHOFF, AND THE STORY TOLD BY SUNBEAM AND STARBEAM

## 1824–1887

Among the many discoveries that have made the nineteenth century famous, none have been more interesting than those which relate to the physical constitution of the universe, and which tell us of what the stars are made.

This subject has always been a fascinating one to mankind, and was much discussed by the old philosophers, who offered various theories to account for the formation of the universe, and wrote many long treatises to make the facts agree with their theories. Air, fire, and water, together or singly, were regarded by some as the primal substances from which all things were made, while others held a more elaborate and intellectual creed.

Plato, the great Greek philosopher, taught that the universe was an animal in the form of a sphere, the most perfect of figures, made of an imperishable material, and with a circular motion. To the universe was then given a soul, and within its boundaries were placed gods, mortals, and the animals of the air, the earth, and the sea. The gods were made of fire, were circular in form, and were scattered over the heavens among the stars. Each star had a soul, which at some time entered a human body, forming its immortal part, and after living a certain time on the earth might return to its home if the years had been righteously spent.

This theory, which was perhaps but an allegory veiling some belief that might have been considered impious by the vacillating Greeks, is important from the fact that it embodies the idea that had existed from the earliest times among the mystics, that there was a certain unity and identity among the various phenomena of nature, and that the universe should be considered as a whole made up of many diverse parts.

The discovery of the law of gravitation, and its application by Herschel to the star systems, established the harmony of the motions of the heavenly bodies, and brought the earth into relationship with the most distant stars. It was the first convincing proof that the earth was but a member of the one great system which is called the universe, and it brought with it a suggestion that was full of meaning to those who were interested in the question of the physical constitution of the universe.

The nebular hypothesis answered this question partly, but left a wide field for speculation, and it is to the German physicist, Kirchoff, that we are indebted for the discovery of a method by which the nature of the substances which compose the sun and stars may be determined.

To understand the work of Kirchoff we must start with Newton's discoveries as to the nature of light.

The beautiful colors displayed in the rain-bow, as well as in drops of dew, in glass prisms, precious stones, and other substances, had always been of great interest to philosophers, and many fanciful reasons were given for these appearances, but Newton was the first to explain the phenomena as due to the nature of light, and not to some quality in the substance through which the light passed or on which it rested.

Starting with the well-known fact that the white or colorless light from the sun would separate into rays of different colors corresponding to the hues of the rainbow when made to pass through a prism, he carried on a number of experiments which finally led to one of the most interesting discoveries in science. He found that the rays always arranged themselves in the same order—violet, indigo, blue, green, yellow, orange and red—no matter what substance they passed through, and from this he deduced the theory that white light consists of rays of different colors which are simply separated by the action of the prism. This theory, which would account for all the prismatic colors shown in various substances, was conclusively proved by Newton's collecting the different rays which had been separated and bringing them together again to a common focus by passing them through a lens, when a band of white light was produced.

From this discovery Newton claimed that all color arises from the arrangement of the particles of bodies in such a manner that certain rays of light will be reflected, and certain others absorbed by them.

Important as this discovery was it attracted little notice, and it was more than a hundred years afterward before the subject received any particular attention. But, in 1815, the German physicist, Fraunhofer, made a discovery in relation to the composition of white light which led to the most important results.

The band of rainbow colors which is produced by causing a ray of sunlight to pass through a prism, is called the solar spectrum. When the beam of sunlight that falls on the prism comes through a large opening the colors seen in the spectrum overlap each other, so that often the middle of the spectrum, where all the colors overlap, appears white, only the two ends showing colors, one end being red and yellow and the other end blue and violet. But when the opening through which the sunlight streams upon the prism is made narrower the colors overlap less, and if it is a very narrow slit there is scarcely any overlapping at all, so that there will be a continuous change in the color from one end to the other, each different ray having its own place. In this case if rays of any one color are absent the part of the spectrum which they would occupy if present will appear black. Fraunhofer made use of this arrangement and allowed a beam of sun-light that came through a very narrow crack or slit to fall on the prism, and on examining the spectrum with a telescope observed that the different colors were crossed transversely by a great number of fine dark lines. Fraunhofer counted over five hundred of these lines, but their number has since been raised to thousands.

By a series of careful experiments Fraunhofer came to the conclusion that these dark lines always occurred in the same order when the solar spectrum was shown, whether the light came directly from the sun or was reflected from the moon or planets; and another set of experiments proved that the light from the fixed stars gave a spectrum in which the dark lines were seen to differ in position and number from those in the solar spectrum, and from this he was led to believe that the dark lines were caused by some special property of the sun's light, which thus differed from the light of the stars. The attention of the scientific world was at once turned toward this new field of investigation, and the science of spectroscopy, or the study of the colored rays of light, was pursued with much eagerness.

Sunlight, direct and reflected, the light of the stars, the electric spark, the flame of a candle, and the colored flames produced by burning different metals, together with the light from gases and vapors, were all subjected to the most careful study. The results were marked in a set of tables which indicated the spectrum of each substance, and thus a knowledge of the spectra of many different metals and vapors was attained. The dark and bright lines which crossed the spectra of the different substances were also marked according to their number and position, and in this manner it became as easy to recognize a certain mineral by its spectrum as to distinguish a flower by its perfume.

It was found that the spectra of glowing hot solid or liquid bodies are continuous and show no trace of the fine black lines. The spectra of vapors and gases, on the other hand, showed simply a number of fine bright lines of different colors according to their position in the spectrum. Thus the spectrum of white-hot iron is simply a continuous colored band with no dark lines in it, and so does not differ from that given by any other hot solid or liquid substance. But the spectrum of the vapor of iron consists of an immense number of fine bright lines in all parts of the spectrum, which are seen on a dark background, while in the sun spectrum we see a series of dark lines on a colored ground. These spectra of vapors are highly characteristic.

Now the spectrum of sodium vapor consists of two fine yellow lines; it is also observed that in the sun spectrum there are two fine black lines in the yellow part of the spectrum that exactly match the two yellow lines of sodium. Kirchoff discovered that when the light from a glowing solid body which shows no dark lines in its spectrum is made to pass through the vapor of sodium it will then have two dark lines exactly like those in the solar spectrum. Further experiments established the fact that whenever light which had passed through the vapor of a substance was examined, dark lines were found in its spectrum corresponding to the bright lines which the vapor would give if it were itself the source of light.

On the basis of these splendid results Kirchoff built up his theory of the physical constitution of the sun.

Taking the bright lines in the spectra of iron, nickel, copper, zinc and many other metals, he found that they were identical with the dark lines in the solar spectrum, as regarded number and position, and he was therefore led to the conclusion that the sun was a glowing solid or liquid mass whose light passed through an atmosphere of luminous vapors, which contained many of the substances which compose the earth.

This theory, which seemed to be upheld by the most convincing proofs, was immediately perceived to be the most reasonable that had yet been offered as to the nature of the sun, and scientists at once set to work to see whether its acceptance might not lead to a true knowledge of the physical constitution of all the heavenly bodies.

The light of the stars was found to give a similar spectrum to that of the sun, as regarded the appearance of dark lines, and, after many interesting experiments, the conclusion was reached that many of the stars have nearly the same physical structure as the sun, and the dark lines in their spectra indicate that many of the metals that we are familiar with on the earth exist also in them.

Further study of the light of the stars has resulted in placing them in groups according to the appearance of their spectra. Thus the stars which shine with a white light, and give spectra crossed by a few broad dark bands form one group, to which belong the great star Sirius and many of the brightest stars in the heavens. The red-colored stars give different spectra and form another group. Those stars which shine with a yellow light, and whose spectra are crossed by many fine dark lines, form another group, and to this it is supposed that the sun belongs.

It was thought by many astronomers that nebulae would be seen to be merely groups of very fine stars, if our telescopes were only powerful enough to discover them; but the spectroscope has given a decisive answer to the idea. The spectra of nebulae are found to be made up of bright lines, showing that they are simply masses of glowing vapors or gases.

Spectrum analysis, or the study of the colored rays of light, has had an effect upon the study of the universe second only to that of the discovery of the law of gravitation, and it is impossible to foresee the great results it may lead to. Already it has brought a knowledge of the nature of the remotest stars and the scarcely discernible nebulae, and with the increased facilities which more delicate optical instruments may bring, we can hardly calculate the importance of its powers.

And it is the more remarkable that this wonderful agent may be of as much use in the mechanic arts as in solving the great problems of astronomy. The use of the spectroscope, in connection with the microscope, has led to the detection of certain substances in a drop of blood the size of the head of a pin which could never have been discovered by any other process, and the same subtle power has given to the world several new metals whose presence had never been suspected until the lines in the spectrum indicated their existence.

These metals have, for the most part, been named for the colors of the lines in the spectrum. Rubidium, which is found in many plants, as cocoa, tea, coffee, oak and others is shown by two dark-red lines; caesium gives two intense blue lines; indium is marked by two characteristic lines of an indigo blue; and thallium, which gives a vivid green color, is named from the Greek word which means a green branch.

Thus the spectroscope reveals the unseen and unsuspected in nature, and brings to light forces as subtle as those which paint the flowers and give music to the winds.

## CHAPTER XVI

# DARWIN AND HUXLEY

As, in the study of a flower, the botanist includes not only the color, form, and perfume, but the internal structure and the conditions which have produced a rose in one place and a lily in another, so it is in the study of all the natural sciences.

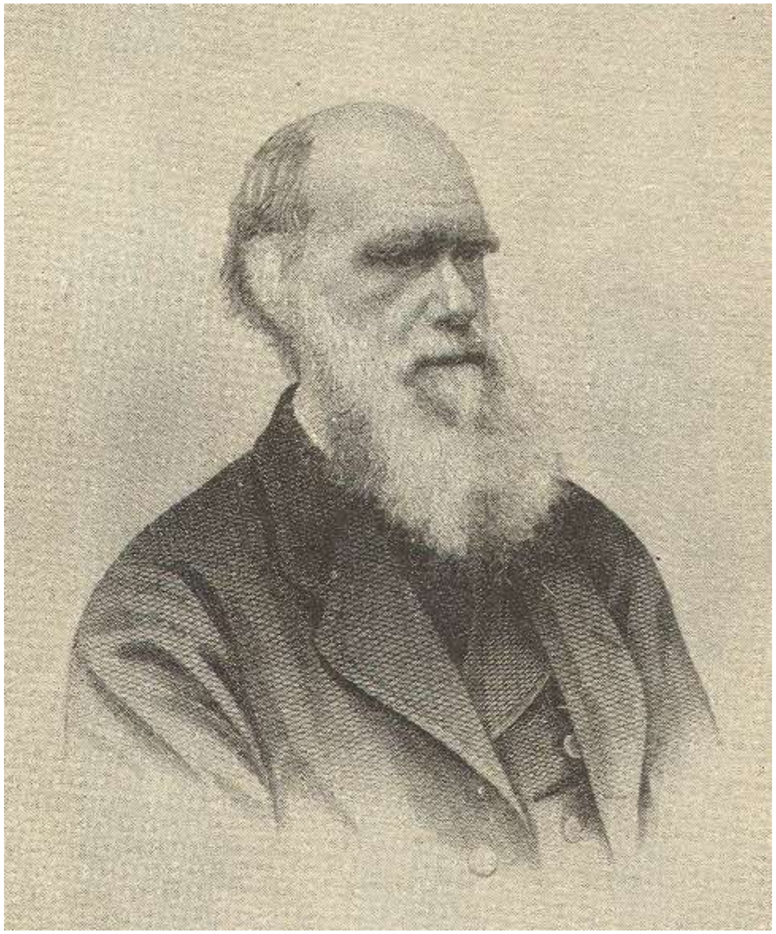
Behind the gem, or flower, or shell lies the force that produced it, and the flash of the diamond, the tint of the rose, and the pearly chambers that once held a living form all tell the story of the power, circumstance, and condition to which they owe their existence.

Thus, whether the naturalist studies the history of the sun, the earth, a leaf, or a drop of dew, he studies the forces which produced them; and it has been the aim of science to investigate these forces and to define their laws as clearly as possible.

Every branch of natural history records some facts that have been found out by certain special workers, and geology, botany, zoology, and physics are merely terms which express the sum of knowledge that has been gained concerning the history of the earth as related by the rocks, the laws of vegetation, of animal life, and of the hidden forces of nature as shown in electricity, chemistry, heat and other agents.

And of all these studies none have been found more interesting to naturalists than those of the forces which relate to and govern life, whether it be life as expressed in the animal or vegetable kingdoms.

The student has found that after he has counted the stamens and pistils of a flower and assigned it its place in the world, there still remains the mystery of its existence, the power that passed away from it with its separation from the stem, and allied it to the earth and stones and other dead matter around it.



CHARLES DARWIN

And the same is true of the animal kingdom. The bird that falls by the sportsman's gun, ere the echo of its song has died away is changed in a moment of time from a creature with will, and power, and voice, to an object as senseless as the withered flower. If the dead bird were examined all its organs would be found in their places, but the mysterious force called life would have departed—flown away as invisibly as the perfume steals from the flower.

The science which treats of the life-force—its laws, limitations, and capabilities—is called biology, and is one of the latest developed of all the sciences, though even in the early ages of the world some attempt was made to grasp the meaning of life and its strange negation, death.

But, for the most part, these attempts ended in definitions which left no new light on the subject. "Life is the breath of God," said the old sages, and any effort to find out the principles governing its development would have been deemed unphilosophical in an age where all experiment was ridiculed and all questions of natural science were answered by the reason alone.

The old belief in the possibility of finding the elixir of life which would confer immortality resulted, as has been seen, in a knowledge of laws of chemistry which might have been unrevealed for ages, but for this impelling motive.

And strange as it may appear, the old alchemists, who seemed to grope blindly in the dark, were after all on the true path, for it is to chemistry that we owe much of our knowledge of the laws that govern life, and the *ignis fatuus* of the Middle Ages has thus become the torch that has led modern science into the ways of truth.

In the eighteenth century Lamarck advanced some views in regard to the different forms of animal life which may be accepted as the definite beginning of modern biology.

Lamarck suggested that the varying species of animals were perhaps due to such influences as climate, soil, food, and other things, and that the appearance and instincts of animals might change just as much under special conditions as a plant may be changed at the will of a florist.

These changes would, of course, only occur at great intervals of time, as nature works slowly; and the study of fossils and their connection with living species would thus not only be useful to the biologist, but to the geologist, in determining the ages of the different strata of the earth.

Historical research, reaching back to he remotest times, can arrive at no period when wheat, the highest developed of all the cereals, was not found in its present form. And, as it is well-known that this grain must have been found originally in a wild state, whence it was rescued by the tribes that were exchanging barbarism for civilization, some idea of the length of time necessary to effect such a transformation may be obtained.

Thus the ears of wheat, sculptured on the tombs of the kings who ruled in those far-off ages, tell us that behind the nations called the oldest, stretch long vistas of time, and that Egyptian, Babylonian, and Hindoo civilization are but things of yesterday compared to the countless ages that went before.

And so the fossil found in the rock may tell its story; and, as its form differs from the living animal, we may judge of the long period of time that must have elapsed, and what vital difference of conditions must have occurred to bring about the change.

These views of Lamarck were also held in some degree by Buffon and other naturalists of the period, but they were never popularly accepted, and it remained for another generation to reap the harvest of the seed thus sown.

Chief among those who have made the subject prominent in the nineteenth century was Charles Darwin, who was born in Shrewsbury, England, in 18og. Darwin's early love for natural history was developed in a marked degree during his college life by his study of geology, which first led him to take an interest in the succession of life on the earth, and it was while he was pondering over the views of the opposing schools of geology that he began to seriously think of the great questions of the development of different forms of animal life.

His love for natural science brought him into notice; and, when he was but twenty-two years old, he was appointed naturalist of a government surveying party which intended visiting the coasts of South America and the islands of the Pacific.

This voyage occupied five years, and left Darwin with no choice of a profession, as his special work was from that time as much a necessity of his life as his love for it was deep and abiding. The Western World fascinated the young naturalist, and all the varying forms of tropical life, from the gigantic palms to the flowers which sprinkled the earth like stars, and from the huge fossils, which told of other ages, to the tiny lizards which gleamed like fire-flies in and out among the rank grass, were alike full of interest.

The collections made during this time were very important, including plants, insects, birds, reptiles, fish, fossils, and everything that could illustrate the flora and fauna of South America, Australia, and the Pacific islands, and the results of the voyage were given to the world in a book called the "Zoology of the Voyage of the Beagle," of which Darwin was the editor.

The cruise of the Beagle may be said to have formed the education of Darwin as a naturalist, an education wider and broader than any vouchsafed to so young a naturalist before, as it included a study of the forms of life in regions practically unknown, and occurred at a period of life when the young student was not yet hampered by the fixed ideas of those in authority.

It was during this voyage that Darwin first began to think of the origin of the different kinds of animals, and to wonder how far circumstances and special conditions went in changing one species to another almost entirely different.

And this question, which it was the aim of his life to settle, he studied patiently for the next twenty-one years. In the grounds around his house and in the conservatories, aquariums, and rooms for collections he studied the phenomena of plant and animal life from the earliest stages to the latest; comparing his conclusions with the views of all the great modern scientists, whose works found ready welcome to his library.

These studies were so exact and thorough that Darwin gained a reputation for accuracy which was of great service to him when he brought out the great theory which was destined to meet with such bitter opposition.

As the result of his years of labor he published in 1857 his great work on the "Origin of Species," which has done more to change the current of scientific thought than any other work of the century.

Although the great central thought of the book was not original with Darwin, it was to his untiring efforts and exhaustive studies that its acceptance by the scientific world was due. His wide experience and years of careful investigation gave his words a special value, while the generalization, or summing-up of the scattered facts, developed the hint of the older naturalists into the almost impregnable theory which Darwin sought to make it.

In "The Origin of Species" all the different varieties of animals are accounted for as due to changes in circumstances, on the theory that any organ of an animal which is not used will gradually become useless, and one that is much used, or put to uses for which it was not at first intended, will grow larger and stronger, and change its appearance to suit its new work.

Thus the fishes in the Mammoth Cave are blind because the darkness there has made the eyes useless for many preceding generations; on the contrary, the eyes of the eagle, whose mode of life necessitates great strength and clearness of vision, would grow stronger and stronger with each age; and if, by some accident, the fish or bird were transferred to an entirely new element, the organs of their descendants would be so modified to suit their new life that they would be entirely changed in appearance.

It must be remembered that these changes occur at great intervals of time, and that though any observing boy would be able at once to detect the difference between a wild and carrier pigeon, these differences are only the result of conditions which have existed for a comparatively short time, while ages would elapse before the winged reptile would develop into a bird.

This theory of the development of species, which will always be connected with Darwin's name, was also advanced by Alfred Wallace, a Welshman, who was born in 1824, and who arrived at the same conclusion as Darwin, although each naturalist was ignorant of the other's views until they were matured. In 1858, before the publication of Darwin's book, Wallace sent home from the Malay Archipelago a pamphlet containing a theory of the origin of species which was practically the same as Darwin's, and the ideas of both naturalists were made known to the scientists of London at a meeting of the Linnaean Society in the same year.

Thus to both belong equal honors, and that two men, working quite independently, should arrive at the same result, is another instance of the fact that the realm of science belongs to no nation or age or individual, but is the common heritage of all.

The publication of the "Origin of Species" produced an immense sensation, and resulted in the division of scientists into many sects, who arrayed themselves as bitterly against one another as did the disciples of Aristotle against the followers of Copernicus; and we must recall the persecution of Galileo by the Inquisition to find a parallel for the vindictive enmity which followed Darwin for the next few years.

But what the telescope did for the Copernican system, geology has done for Darwinism, and in the fossils of the far-off ages we read the same story that is written in the pages of Darwin.

Two years after the publication of the "Origin of Species," a fossil was found of a creature with the wings, feathers, feet, and breast of a bird, and the head, teeth, and tail of a lizard; an unmistakable proof of the former existence of a class of animals between reptiles and birds. And further study of the fossils has revealed other intermediate forms of life just as remarkable. Fossils of reptiles standing on hind legs like those of the kangaroo, and fossils of birds with teeth have been found, while the forms of extinct quadrupeds show that the horse, with its hoofed foot, is descended from a much smaller animal with five toes, and that cats, dogs, bears, and many other animals differ as much to-day from their remote ancestry as the butterfly differs from the caterpillar. And in the vegetable world the same thing has been found true, and the plants of to-day are connected in the same mysterious way with those of past ages, the form of fern and lily being but a repetition of the forest trees, and gigantic blossoms of the older world.

And while geology has been the guiding light illuminating the past, so that its records might be thus easily read, the living world, too, adds its proofs that the changes alluded to by Darwin are still going on, and that in this as in other things the past may be studied from the present.

The animals that inhabit islands, of the same species as those of the mainland, have their habits and organs altered by their changed conditions; the birds, lizards, and insects of the desert are all of the neutral tints which correspond with the prevailing color of their surroundings—because those are the conditions which best protect them against their enemies, who would be more easily attracted to them if their color were brilliant. The fur of the same species of animal is thicker in the north than in the south, and the same kind of shells differ in depth of color as they are found in deep or shallow water. And an infinite number of other instances might be shown to prove that the same forces which changed the scale-covered reptile to the bird furnished with wings and feathers are still at work.

And thus, just as Newton and Herschel connected the earth by a magnetic chain to every star of heaven, so Darwin joined all the visible forms of life, and proved that each plant and animal is a link in the same chain, bound together by a power as subtle as that which holds the stars.

Among the great thinkers who have helped to popularize the opinions of Darwin, Professor Huxley, born in 1825, must rank first. Huxley's investigations have followed the same lines as those which mark the labors of Darwin, and his independent researches and splendid work for science have done much to place the Darwinian theory on a firm basis. This is due, first, to the fact that Huxley's original work is of such merit as to make his opinions carry great weight, and, secondly, because he has the gift of the interpreter, and whether he speaks of his own communings with nature, or translates the words of another, he is equally powerful and convincing; and the work of Darwin, which to many might have remained a sealed book, has been by the genius of Huxley rendered comprehensible, just as the works of a great composer reach the multitude through the medium of the performer, and the written notes become exquisite melody.

Huxley's own works comprise studies in almost every department of zoology, and are remarkable for their originality and depth of thought, and will ever be considered as independent and valuable supports of the new school of thought.

The studies of the forms of animal life have led to a truer knowledge of the laws of development than the older naturalists thought it possible to attain, and the mystery of life has been invested with a new interest from the discovery of the close connection between the animal and vegetable worlds.

In his careful studies of organic life the naturalist has found it difficult often to tell where the one world leaves off and the other begins. Plants have been found so closely resembling animals as to make their place in the world of nature doubtful, as for instance the Sundew, which, by a singular arrangement of its organs, is able to capture insects and digest them by a process like that of animal digestion, and to feel the effect of anesthetics. On the other hand, certain organisms, as the sponge, which have been placed in the animal kingdom, are plant-like in their habits.

Chemistry, electricity and the microscope have been effective agents in the study of the development of the different forms of life, and the results have been such as to place biology among the leading sciences of the day.

Whether future study will reveal secrets that elude the biologist of to-day and discover yet closer relations between all forms of life is a question which carries its own answer with it, as the history of science has shown that the questions which one age asks the succeeding age answers, and that the progress of scientific thought is, on the whole, as sure as the growth of the oak from the acorn.

The science of the present day has made its most far-reaching generalization in the statement that no energy is ever lost, but only changes its form; the muscular force of man may, by the rubbing together of two pieces of wood, produce heat, and the heat light, and light is absorbed and transformed again into heat, or converted into chemical energy. Thus everywhere is seen one form of energy changing to another, and all gradually tending toward heat.

As the life of man is bound up with and dependent upon the mysterious forces of nature, his interest in them can never cease, and thus the last word for science can never be written while the race endures.