

Stories of Great Scientists

GREAT LIVES SERIES

SELECTED AUTHORS

Stories of Great Scientists

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Stories of Great Scientists

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Stories of Great Scientists

By Selected Authors

Archimedes

287 B.C-212 B.C.

Hiero, the king of Syracuse, had given his jeweler a certain weight of gold to be fashioned into a crown. When the crown was finished, the suspicion arose in Hiero's mind that his jeweler had stolen part of the gold and replaced it with an equal quantity of silver. Accordingly he commissioned his court scientist, Archimedes, to detect the fraud if possible.

After many days of fruitless research, Archimedes was about to abandon the task. But one morning, as he stepped into his tub at the public bathhouse of Syracuse, he noticed the overflow of the water. The sight of this overflow set his imagination aflame. Forgetting his naked condition, he leaped out of his bathtub and ran home through the streets of Syracuse crying, *"Eureka! Eureka!—I have found it! I have found it!"*

What he had found was a simple solution to his problem about Hiero's crown. He would procure two masses of metal, one of gold and one of silver, and each of equal weight with the crown. Then he would in turn submerge each of the three masses—the gold, the silver and the crown—in a vessel filled with water and measure the overflow of the water in each of the three cases.

As soon as possible he put this idea to the test and discovered that the amount of water displaced by the

crown was more than the amount of water displaced by the gold, and less than the amount of water displaced by the silver. And in this way he knew that the crown consisted neither entirely of gold nor entirely of silver, but that it was a mixture of both.

This simple method of comparing the weights of solids with the weights of equal quantities of water supplied Hiero with the solution to the mystery of the crown. But it supplied the rest of mankind with a far greater gift—the key to the solution of one of the profound mysteries of nature, the so-called "specific gravity" of the various substances which go into the making of the world. This law of specific gravity, known to the present day as the *Principle of Archimedes*, may be briefly stated as follows: "A body immersed in a fluid loses as much in weight as the weight of an equal volume of the fluid."

Thus it was in the simple process of bathing that Archimedes discovered one of the great secrets of nature. Yet bathing to Archimedes, it is interesting to note, was not an ordinary process. Rather it was an extraordinary event. So absorbed was he in his scientific experiments that, to quote Plutarch, "his servants with the greatest difficulty, and against his will, got him to the baths to wash and anoint him." And when finally they succeeded in luring him to the baths, continues Plutarch, "he would ever draw all sorts of geometrical figures with his fingers upon his naked body."

Geometry was his greatest passion. "Intoxicated and ravished with the sweet enticements of this siren, which as it were lay continually with him, he often forgot his meat and his drink." He lived in the springtime of the mathematical sciences—an era in which the manipulations of numbers and the measurements of triangles and circles were amongst the most exciting of adventures in the academies and the colleges of the Greek world. The magic of Euclid, the "Father of Geometry," still lay like a bloom over an enchanted age. This professor of mathematics at the University of Alexandria had transformed the earth and the heavens into a vast design of intricate configurations. And with the deft fingers of his amazing intellect he had taken this design apart and analyzed it into its simple components—points, lines, angles, curves, surfaces, solids—a map of the infinite translated into the finite language of elementary mathematics. Euclid made the impossible possible by the simplest of methods. When his fellow professors at Alexandria told him that there was no human way to measure the height of the Great Pyramid, he proceeded to measure it as follows: He waited for that hour of the day when the length of his shadow was exactly equal to the height of his person, and then he measured the length of the pyramid's shadow. "This, gentlemen," he said, "is the exact height of the Great Pyramid."

Though he simplified his geometry, Euclid insisted upon a thorough study of its principles in order that his

students might fully understand them. The story is told that Ptolemy, the king of Alexandria, once expressed his impatience at Euclid's elaborate manner of explaining his theorems. "Isn't there," asked the king, "a shorter way of learning geometry than through your method?"

"Sire," replied Euclid, "in the country there are two kinds of roads—the hard road for the common people and the easy road for the royal family. But in geometry all must go the same way. There is no royal road to learning."

As to the details of Euclid's life, very little is known about them. One legend has it that the last—and best—section of his famous *Elements of Geometry* was thrown into the fire by his wife in a fit of temper. If this story is true, the probability is that his wife lost her temper through no provocation on Euclid's part. For he was, the ancient writers tell us, "a gentle and kindly old man." His students idolized him. For he "guided them like a father." Yet on occasion he could tame the more impertinent of his "children" with the lash of a biting sarcasm. "Can you tell me," asked one of his students after he had learned the first theorem, "just what practical advantage there is in studying geometry?" Whereupon Euclid turned to his servant. "Grumio," he said, "give this gentleman a dollar; he can't learn without money."

Euclid himself, like most of the ancient Greek scholars, cared little for the "practical" values of his scientific investigations. He loved learning for learning's

sake. Shy, modest and aloof, he "lived peaceably in his habitation" and allowed the world of petty politics and of military glory to clatter by in its noisy and vulgar parade. "These things," he said, "shall pass. But the designs of the heavenly stars shall remain eternally fixed."

II

Quite different from this dispassionate life of quiet contemplation was the career of Archimedes, the "spiritual grandson" of Euclid. (Archimedes was the pupil of Conon, who was the pupil of Euclid.) As a young man he desired, like his great predecessor, to devote himself exclusively to mathematics. He continued the study of geometry from the point where Euclid had left off. He calculated the ratio of the circumference of a circle to its diameter; he devised a plan for counting the sand on the seashore; he formulated a method for measuring the areas and the volumes of circular and of spherical objects; and he discovered the relation between the volume of a cylinder and that of an inscribed ball. This last discovery was as simple as it was ingenious. He constructed a cylindrical cup whose height was equal to its diameter, and a sphere that fitted snugly into this cup. He then filled the cup with water, immersed the sphere in the water, and compared the amount of the overflow with the original amount of the water in the cylinder. He thus found that the volume of an inscribed sphere is equal to exactly two-

thirds of the volume of its enclosing cylinder. So proud was he of this discovery that he ordered the figure of a sphere within a cylinder to be carved upon his tombstone.

For Archimedes, like Euclid, was anxious to be remembered only as a philosophical mathematician. He wanted to be left alone to his geometrical studies. But the insistent demands of his environment compelled him to become an inventor as well as a philosopher. Archimedes thoroughly disliked his compulsory role as "a maker of the vile and beggarly and mercenary machines of commerce and war." But he was related to Hiero and therefore felt constrained by a double obligation—as a subject and as a kinsman—to obey the orders of the king.

Working under these orders, Archimedes produced no less than forty inventions—some of them for commercial use but most of them for military purposes. Perhaps the most interesting of his commercial inventions was the so-called *Screw of Archimedes*. This hollow corkscrew, placed upon an inclined surface with the lower end immersed in a pool of water and with the spirals turning constantly from left to right, scoops up the water at the bottom and spills it out at the top—thus compelling the water to perform the apparently impossible "miracle" of flowing uphill.

This commercial invention—employed even today for the draining of swampy areas in the Netherlands—was to the contemporaries of Archimedes an object of

profound amazement. But more amazing than his "utensils of peace" were his engines of war. His native city of Syracuse was besieged by the Romans, and King Hiero called upon Archimedes to devise weapons of defense against this siege. A Roman fleet, under the leadership of Marcellus, had set sail against Syracuse. "I believe I can destroy that fleet," said Archimedes.

"By what means?" asked Hiero.

"By means of burning mirrors."

Hiero said nothing, but shook his head. His poor kinsman had apparently lost his reason through overstudy.

Yet Archimedes made good his boast. For, "as soon as the ships of the enemy came within bowshot of Syracuse," he trained upon them the battery of his mirrors which he had constructed especially for the purpose. These mirrors were "huge concave plates of metal" so designed as to focus the blazing light of the sun upon the oncoming fleet.

In connection with this story it is interesting to note that Sir Isaac Newton, after a series of experiments with concave mirrors, expressed his opinion that such an invention on the part of Archimedes was not beyond the realm of scientific possibility. Most of the historians, however, reject the incident as fictitious, since no account of it is found either in Plutarch or in Polybius, the two leading authorities on the life of Archimedes.

But there seems to be little disagreement among the leading historians as to the authenticity of his other military inventions. When the blockade around Syracuse had become a serious threat to the further existence of the city, Hiero again called his kinsman to his aid. "Is it possible," he asked, "to remove the enemy's ships?"

"Yes," replied Archimedes. "It is possible even to remove the earth."

"Just what do you mean?"

"Merely this—that if I had a place in another world in which to plant my feet, I could wrench the earth out of its course." He then went on to explain his theory of levers and pulleys—a discovery of his own—by means of which he could move a maximum of weight with a minimum of effort.

When Hiero expressed his doubt as to the efficacy of this plan, Archimedes proceeded to put it to the test. He constructed a multiple pulley, attached the chain at one end of the pulley to a large and heavily laden Syracusan ship, and handed the rope at the other end of the pulley to Hiero. "Pull the rope, Sire, and see what happens."

The king pulled the rope, and a cry of astonishment escaped from his lips. For the feeble effort of his two small hands had lifted the ship as if by magic out of the water and dangled it into the air.

It was not long before Marcellus, too, was to marvel at the "magic" of Archimedes. The Roman commander had

arrived before the walls of Syracuse equipped with "a fleet of sixty vessels filled with all sorts of arms and missiles." Moreover, he had erected "an engine of artillery on a huge platform supported by eight galleys fastened together." But all this stupendous armada was merely a handful of toys in the enormous iron grappling hooks that were attached to the pulleys of Archimedes. Descending upon the Roman ships like birds of prey, these "iron claws" of Archimedes drew them "straight up into the air, and then plunged them stern foremost into the depths." At times, to vary his defensive strategy, Archimedes carried the enemy's galleys "high over the cliffs that jutted out beneath the walls of the city, and then whirled them around and around and finally dashed them with all their merchandise and men—a dreadful spectacle—upon the jagged rocks below."

When Marcellus saw the devastation visited upon his fleet, he is said to have exclaimed: "Let us stop fighting against this geometrical monster, who uses our ships like cups to ladle water from the sea, and has whipped our most efficient engines and driven them off in disgrace, and with the uncanny jugglery of his mind has outrivaled the exploits of the hundred-handed giants of mythology." Finally the Roman soldiers had become so fearful, observes Plutarch, that whenever they saw a bit of rope or a stick of timber projecting a little over the wall they cried, "Here comes Archimedes," and turned their backs and fled.

Realizing the impossibility of conquest by assault, Marcellus decided to overcome the Syracusans by means of a blockade. Yet in spite of this blockade the ingenuity of Archimedes held off the surrender of his city for three years. And even then it was only through the carelessness of the Syracusans that their city fell. It was on the night of the festival held in honor of Artemis, the goddess of the moon. The people of the beleaguered city had yielded themselves up too freely to their wine and their sport. Shortly before dawn, "when their senses were befuddled and their bodies worn out," a number of Roman soldiers succeeded in climbing over the walls and in opening the gates of the city from within. When the Syracusans awoke the next morning, they found their city in the hands of the enemy.

As Marcellus looked down upon the city from the heights just outside the walls, he is said "to have wept much in commiseration of its impending fate." For he knew that his soldiers, having been held so long at the leash, could not now be restrained from "their harvest of plunder." Indeed, even among his officers many were in favor of razing the city to the ground and putting all the inhabitants to the sword. To this riotous fury of revenge Marcellus vigorously objected. For he admired the courage of the Syracusans who had so long and so brilliantly held out against him. He especially admired his "geometrical" opponent. "Let no one," he commanded,

"dare to lay a violent hand upon Archimedes. This man shall be our personal guest."

III

As for Archimedes, he was sitting quietly in the market place drawing a circle in the sand and calculating some abstruse mathematical problem. So wrapped up was he in his thought that he was surprised to see a drunken Roman soldier rush upon him with his sword. "Before you kill me, my friend," said Archimedes, "pray let me finish my circle."

But the soldier paid no heed to him and transfixed him with his sword.

"Ah well," whispered the gentle old scientist as he lay dying upon the ground, "they've taken away my body, but I shall take away my mind."

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.

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 fireflies 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 Medicæan 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 replied 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.

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 Grätz. 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 lifetime 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.

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.

Descartes, the great French philosopher, invented the theory that all space was filled with air, in which there were innumerable whirlpools 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."

Charles Linnæus 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 lilywork, 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, Linnæus, 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.

Linnæus, so called from the Latinized form of the family name, Linné, was born at Râshult, in the Province of Smâland 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 Linné 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 hill-side 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 Linné 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 Linné 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, Linnæus 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 Linnæus. 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 Linnæus might have failed him at this critical period.

Artedi, like Linnæus, 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. Linnæus 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 Linnæus was just on the point of leaving Upsala in despair when Celsius did at last come back, and bring hope with him. Linnæus 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 Linnæus was there, for Celsius was one of the most celebrated men in Sweden, and did not hesitate to show his opinion of his protégé's talents. He gave Linnæus 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 Linnæus 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 Linnæus 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 Linnæus 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 Linnæus 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, Linnæus 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 Linnæus 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 Linnæan 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 Linnæus 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 Linnæus 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 Linnæus 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 Linnæan 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 Linnæus 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 *Linnœa 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, Linnæus 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 Linnæus showed him his Systema Naturæ that he offered to publish it at his own expense.

The publication of this work immediately brought Linnæus 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 Linnæus, 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 Linnæus, 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 Linnæus 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 Linné, 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 Linnæus 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.

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 a resource 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 he 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 mapped 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 *nebulæ* 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 nebulæ 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 nebulæ—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 Brahé 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 nebulæ, 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 nebulæ, consisting of a shining fluid which was solidifying into stars, has been supported by later astronomers, for when the light from these nebulæ 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 nebulæ 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.

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 gunpowder, 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 *attaché* 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 town-hall, 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 work-house 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.

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 of 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.

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 and 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 Léopold Chretien Frédéric Dagobert Cuvier, who was born in the village of Montbéliard, in France, August 23, 1769.

Montbéliard 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 Montbéliard 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 Montbéliard 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 out-door 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 Montbéliard, 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 naturalist 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 Würtemberg, 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 Linnæus 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 Würtemberg 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.

Linnæus 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.

Linnæus 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 Fécamp, 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 Cuvier 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 the 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, Germany, 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 pre-historic 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 Linnæan 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.

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 another 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.

John James Audubon
1785-1851

Have you ever happened to see a book that cost a thousand dollars?

A man who loved birds and knew a great deal about them drew pictures of all the kinds to be found in our country, calling these drawings, when they were colored and bound together *The Birds of North America*. It took four volumes to hold all these pictures, and each one of these books costs a thousand dollars. There were only seventy-five or eighty of these sets of bird books made, but you can see them in the Boston Public Library, the Lenox and Astor libraries in New York City, and at several colleges and private homes. Each one of these books is more than three feet long and a little over two feet wide, and is so heavy that it takes two strong men to lift it on to a rack when some one wants to look at the pictures. If you should look through all four books, you would see more than a thousand kinds of birds, all drawn as big as life, and each one colored like the bird itself.

You may be sure it took the maker of these books many, many years to travel all over the United States to find such a number of birds. The man's name was John James Audubon. He slept in woods, waded through marshes and swamps, tramped hundreds of miles, and

suffered many hardships before he could learn the colors and habits of so many birds. He always said his love for birds began when his pet parrot was killed.

It happened this way.

One morning when John James was about four years old and his nurse was giving him his breakfast, the little parrot Mignonne, who said a lot of words as plainly as a child, asked for some bread and milk. A tame monkey who was in the room happened to be angry and sulking over something. He sprang at Mignonne, who screamed for help. Little John James shouted too, and begged his nurse to save the bird, but before any one could stop the ugly monkey's blows, the parrot was dead.

The monkey was always kept chained after that, and John James buried his parrot in the garden and trimmed the grave with shrubs and flowering plants. But he missed his pet and so roamed through the woods adjoining his father's estate, watching the birds that flew through them. By and by he did not care for anything so much as trying to make pictures of these birds, listening to their songs, finding what kind of nests they built, and at what time of year they flew north or south.

John James lived in Nantes, France, when he was a small boy, although he was born in Louisiana. His father was a wealthy French gentleman, an officer in the French navy, and was much in America, so that John James was first in France and then in America until he was about

twenty-five, at which time he settled in his native country for good. Few men have loved these United States better than he.

John James did not care much for school. Figures tired his head. He loved music, drawing, and dancing. His father was away from home most of the time, and his pretty, young stepmother let the boy do quite as he pleased. She loved him dearly, and as he liked to roam through the country with boys of his age, she would pack luncheon baskets day after day for him, and when he came back at dusk, with the same baskets filled with birds' eggs, strange flowers, and all sorts of curiosities, she would sit down beside him and look them over, as interested as could be.

Some years later, when John James's father put him in charge of a large farm near Philadelphia, the young man bought some fine horses, some well-trained dogs, and spent long summer days in hunting and fishing. He also got many breeds of fowl. It is a wonder that with all the leisure hours he had, and the large amount of spending money his father allowed him, he did not get into bad habits, but young Audubon ate mostly fruit and vegetables, never touched liquor, and chose good companions. He did like fine clothes and about this time dressed rather like a fop. I expect the handsome fellow made a pretty picture as he dashed by on his spirited black horse, in his satin breeches, silk stockings and pumps, and the fine, ruffled shirts which he had sent over from France.

Anyway, a sweet young girl, Lucy Bakewell, lost her heart to him. Only as she was very young, her parents said she must not yet be married. And while he was waiting for her, he fixed over his house, and with a friend, Mr. Rozier, and a good-natured housekeeper, lived a simple, country life. You would have enjoyed a visit to him about this time. He turned the lower floor into a sort of museum. The walls were festooned with birds' eggs, which had been blown out and strung on thread. There were stuffed squirrels, opossums, and racoons; and paintings of gorgeous colored birds hung everywhere. Audubon had great skill in training animals and one dog, Zephyr, did wonderful tricks.

When Audubon and Lucy married, they went to Kentucky, where he and his friend Rozier opened a store. But Rozier did most of the store work, as Audubon was apt to wander off to the woods, for he had already decided to make this book about birds. His mind was not on his business, as you can see when I tell you that one day he mailed a letter with eight thousand dollars in it and never sealed it! The only part of the business he enjoyed were the trips to New York and Philadelphia to buy goods. These goods were carried on the backs of pack horses, and a good part of the journeys led through forests. He lost the horses for a whole day once, because he heard a song-bird that was new to him, and as he followed the sound of the bird so as to get a sight of it, he forgot all about the pack horses and the goods.

By and by his best friends said he acted like a crazy man. Only his wife and family stood by him. Finally when his money was gone, and there were two children growing up, things looked rather desperate. But Lucy, his wife, said: "You are a genius, and you know more about birds than any one living. I am sure all you need is time to show the world how clever you are. I will earn money while you study and paint!"

So Audubon traveled to seek out the haunts of still more birds, while Lucy went as governess in rich families, or opened private schools where she could teach her own two boys as well as others. She earned a great deal of money, and when he had made all his pictures and was ready to publish the books, she had nearly enough to pay the expense, and gave it to him.

"No," he said, "I am going to earn part of this myself. I will open a dancing class." He had danced beautifully ever since he was a child and could not understand how people could be so awkward and stupid as his class of sixty Kentuckians proved to be. In their first lesson he broke his bow and almost ruined his beautiful violin in his excitement and temper. "Why, watch me," he cried, and he danced to his own music so charmingly that the class clapped their hands and said they would do their best to copy him. By and by they did better, and before he left them, they quite satisfied him. And what was fortunate for him, they had paid him two thousand dollars. With this and Lucy's earnings, he went to England and had the

famous drawings published. When they were done, he exhibited them at the Royal Institute, charging admission, and earned many pounds more.

Audubon was a lovable, courteous man, never too poor to help others, very modest and gracious. He adored his wife, and as his books (he wrote many volumes of his travels, which I hope you will read some day) brought in quite a fortune, the two, with their sons, and their grandchildren, spent their last days in great comfort, on a fine estate on the Hudson River.

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 Linnæus 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. Linnæus 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 seashell 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.

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 wilfully guilty of the death of one was regarded with the greatest horror.

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, whose 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 Réaumur, who was born early in the century, gave evidence that the time was fruitful in original thinkers.

Réaumur'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.

Linnæus' 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 Linnæus 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 Linnæus, Lamarck, and Cuvier may be counted Louis Agassiz, whose name is familiar whenever the student of science is found.

Agassiz was born at Motier, in Switzerland, in 1807, exactly one hundred years after the birth of Linnæus, and his early life very closely resembled that of the illustrious child of the North. Like Linnæus, 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 Linnæus 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 merrymaking 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 storehouse 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 freshwater 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 "Régne 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 "Régne 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 Neuchâtel. 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 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 seaweed, 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 snowfields 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 inestimable value to science.

"No one can warp Nature to suit his own views. She brings us back to absolute truth as often as we wander."

Louis Agassiz.

A Swiss Boy and His Wanderings

One May, over a hundred years ago, there was born in a low cottage, in the Swiss village of Motier, a baby boy who was given the long name of Jean Louis Rudolphe Agassiz. This name did not burden the child, however. He was a lusty, rollicking baby, an out-of-doors boy from the very first; and, no doubt, he knew much better how to coo than how to cry. His parents, who spoke French, might have nicknamed him "Le soleil" or "Le Bonheur",—French names for sunshine and for happiness; but they called him simply Louis.

The manse where Louis lived, for his father was a clergyman, was very pleasant. There was a vineyard, an orchard, and a garden, and, behind the house, a great stone basin made Louis' first aquarium,—a home for fish. Very near, too, was the beautiful Lake Morat,—a swimming-pool in summer and a skating-rink in winter; and seemingly near was Mont Vully, vine-clad or snow-clad with the seasons' change.

Until Louis was ten years old, he had no other teachers but his parents, his own good little brain, and "Mother Nature." He had no special love for study; but he loved everything that was alive. He loved the blossoms that spangled the moist Swiss meadows,—the glistening buttercups, and crowding blue-bells, and scores of other

frail flowers blowing nameless in the valley. And yet, much as he loved flowers, he loved animals still more. He and his younger brother, Auguste, had all kinds of pets—"birds, field-mice, hares, rabbits, and guinea-pigs." He described his own room as a "little menagerie." He "searched the neighboring woods and meadows for birds," and raised caterpillars and "fresh beautiful butterflies." Besides this, there was the aquarium in the big stone basin. Like some other boys, Louis and Auguste needed nothing to catch fish with but their active hands, and they usually cornered their fish between the rocks while they were in bathing.

One might think from this story that these brothers had one unbroken life of play; but they were learning many useful things. It was a curious custom in Switzerland, at that time, for the cooper to come just before grape-gathering season, to fit up the wine-cellar with barrels and hogsheads; for the tailor to come to make clothes; and for the shoemaker to call three times a year at all the Swiss homes, and practically shoe the entire family. These visits were events in the home life, and Louis, with a child's instinct for imitation, made the most of them, watched closely, and then tried to do the same things,—till he could make a tiny barrel, perfectly water-tight, could tailor well, and could make a fine pair of shoes for his little sister's doll. And so he learned many things which he could not learn from books.

Naturally willing though he was to work with his small hands, Louis Agassiz, a Swiss boy in every fiber, had

breathed in from the Swiss mountains a love of freedom,—of the wisest kind of freedom,—which no cooper's or tailor's or shoemaker's bench could make him forget, and he was by no means easy to confine or to control. Growing up as he did, with an immense admiration for the daring Swiss guides, he probably dreamed, sometimes, that he himself would be a mountain-climber. He did not mind danger, and he did not mind cold. He felt almost as much at home on his skates as in his shoes;—and, one winter day, he gave his good mother a fright that she did not soon forget. That morning, Monsieur Agassiz, the boys' father, had gone to a fair, on the other side of Lake Morat, expecting to return home that afternoon. A little before noon, while Louis and Auguste were skating, Louis proposed that they should cross the lake, join their father at the fair, and have the fun of a ride back. In time for dinner, the other boys of the village came home and told Madam Agassiz where her two children were. A little worried, naturally, by the news of this scheme, the mother hurried upstairs to search the lake, and this picture greeted her:—lying on his stomach across a wide crack in the shining ice was Louis, making a kind of bridge of his young body for his little brother Auguste to crawl safely across. You may believe that Madam Agassiz lost no time in sending a workman, who was a "swift skater", after the boys; and they were overtaken just in the enthusiastic heat of their enterprise,

and ignominiously brought back, hungry and tired, with no fair, and no ride home with Father.

This is only one story of Louis and Auguste as playmates; but it is easy to imagine that, sharing as they did their pleasures and their disappointments, they were fast friends, and it was hard for both boys when, for the first time, they were separated. Twenty miles from Motier, at a town called Bienne, there was a "college for boys", and Louis was sent there alone when he was ten years old. A year later, though, Auguste joined him, and again the brothers worked and played together, and looked forward eagerly to each vacation, when they would *walk home*, starting on their long journey a good deal earlier than the sun started on his. We can imagine them jodeling in joyous Swiss fashion for a large part of the way and mingling their voices with the "rush of Mountain streams" and the goat-bells tinkling from the mist-wrapped hills.

Louis stayed at Bienne four years, till he was fourteen, and then for two years more went farther away still, to a more advanced school,—the college at Lausanne. During all this time, his interest had grown in the very things that interested him as a little boy; he had a passion for natural history. Though he studied all his books with considerable faithfulness, he only *loved* the books on science. In his room, some forty birds flew about, a pine-tree in the corner for their only home. In his heart was a kind of hunger to search, to experiment, and to discover, and there was a vague but persistent longing to write. His

practical father, however, gentle but firm, did not encourage him in this: Louis must fit himself for some definite, work that would insure him a steady income. Accordingly, after much thought, the boy decided to be a physician, and, with that aim, went first to a medical school at Zurich, then to the University of Heidelberg, and finally to Munich, where he won his degree of Doctor of Medicine.

I have called this story of Louis Agassiz' life "A Swiss Boy and His Wanderings" because, as Longfellow said, the Swiss boy "wandered away and away with Nature, the dear old Nurse", to many cities and to many lands; though his purpose was as fixed as the poles. To search and find the truth was, he believed, "the glory of Life" and, because nature is the source of truth, with nature he spent his youth and manhood, giving what he found to the world through his teaching and through his books.

When a boy goes to college, he has at least two things to consider: his parents' aims and his own; and very often he and his parents do not agree. This was true of Agassiz. He yearned to search the mysteries of nature; but he was constantly and necessarily reminded by letters from home, that the supply of money for his education was limited and that he must settle down to something practical. And so, Agassiz' student life gives us two separate pictures: the picture of the boy himself, away from home, and the picture of the people at home thinking about the boy.

If we had been with Agassiz at college, we should have found that, though he had infinite patience with a microscope,—so real a longing to understand the sciences that he was

"Content to spy a sullen egg for weeks,
The enigma of creation to surprise,"—

though he had this eagerness for knowledge, Agassiz' heart and body were almost as active as his head; he had kept his boyish love of fun and of adventure. At Heidelberg, he met a young man, named Alexander Braun, who loved plants as much as Agassiz loved animals; and a deep friendship sprang up between them, to last as long as they lived. He and Braun were room-mates at Heidelberg, and doubtless often went swimming together in the Neckar, after lectures. Carl Schimper, a special friend of Braun's, went with them on their long trips for specimens, and he and Braun taught Agassiz many things about botany, while Agassiz taught them zoology; for he could "recognize the birds from far off by their song, and could give a name to every fish in the sea."

It was delightful that these three friends, though they were separated for a little while after leaving Heidelberg, could join each other again at the University of Munich. Alexander Braun, in a letter to his father, gives us a little glimpse of their life: "Under Agassiz' new style of housekeeping, the coffee is made in a machine which is devoted during the day to the soaking of all sorts of

creatures for skeletons, and in the evening again to the brewing of our tea." Schimper and Braun shared Agassiz' studio, and "the couch, the seats, and the floor were covered with their specimens as well as his." A stranger coming in, could hardly have told who the fellows were, for they went by such nicknames as "Molluscus", "Cyprinus", and "Rhubarb." Their whole life here, notwithstanding their hard work, was full of happy informality, for, though men in brains, they were boys at heart. Once, on hearing some piece of good news, Agassiz actually "rolled himself in the snow for joy"; and, though such youthful capers were by no means usual, he always loved exercise of all kinds. He was a "powerful gymnast and an expert fencer." He despised the "closet student." To his natural robustness, his Swiss boyhood had added a fine store of vitality. He loved to walk and climb and did "not fear forced marches"; to get specimens for botany or geology he sometimes walked thirty or thirty-five miles a day "for eight days in succession", carrying on his back "a heavy bag loaded with plants and minerals." In his letter home, Agassiz described all this life vividly and honestly, for he knew that his parents were his best friends. He realized, however, that his course was long and expensive, and so he wrote also of the practical side: reminded them that he was doing his best to economize; that he had earned his own microscope by writing; and that soon a book on Brazilian fish would be out, written by their

"Louis", adding: would not that be "as good as to see his prescription at the apothecary's?"

Agassiz' father, though a clergyman, was not without a sense of humor. His "Louis"—most lovable of sons—seemed to him like a dreamer, with "a mania for rushing full-gallop into the future." "If it is absolutely essential to your happiness," wrote the father, "that you break the ice of the two poles in order to find the hairs of a mammoth, or that you should dry your shirt in the sun of the tropics, at least wait till your trunk is packed and your passports are signed." When, the course ended and the medical degree won, Louis finally wrote that he would come home to practise, bringing with him all his scientific instruments, an immense collection, and a *painter* to illustrate his books, the news threw the family into real consternation. Just at that time, there was excitement enough at home. Cecile Agassiz, for whose doll the little Louis had made shoes, was now grown up, and the next winter she was to be married. That summer, the house would be overrun "with a brigade of dressmakers, seamstresses, lace-makers, and milliners." Monsieur Agassiz said that he had put up a "big nail in the garret on which to hang his own bands and surplice." Where could Louis stow "his fossils, all his scientific outfit," and a *painter*? Yet, somehow, the family made room for him, painter and all, and for one year he practised medicine. Then, he wandered away again, to Paris this time, to continue his studies in natural history, for he was unable to give up his great life-plan.

In Paris, Agassiz knew that there was a man who could give him what he wanted or help him to get it for himself. While he was there, however, satisfied and absorbed, studying and receiving inspiration from the great Cuvier, letters came from home urging him to take up teaching as a profession. With this in view, he returned to Switzerland, to the beautiful town of Neuchâtel, and accepted a position as teacher of natural history. He was now a man, with a man's responsibilities; his student days ended nominally, but really ended only by his death. From then on, his large life seemed to divide itself, naturally, into three parts: his life as a traveler and student; his teaching life; and the life of his heart (or home and friends); and even then, to try to tell his story is almost like trying to carry the ocean in a pail. It included the widest wanderings: up many dangerous mountains to study glaciers; years spent in America lecturing at Harvard, and, with Mrs. Agassiz, teaching in a girls' school in Cambridge; three short visits to England to study fossil fish; a year of teaching in Charleston, South Carolina; summers by the sea in a pleasant vine-covered cottage at Nahant; a trip in the United States Coast Survey steamer to the Florida reefs; a long journey to Brazil for his health; a voyage in the *Hassler*, round South America to the Pacific, for deep-sea dredging; one summer more at home, spent mostly with his mother in the shady garden of the Swiss manse; and, at last, a summer—

"On the Isle of Penikese
Ringed about by sapphire seas."

And there was never a journey,—there was, perhaps, never a day,—in which the great scientist did not learn something new. He was always a boy at heart—nature was his big, beautiful book,—and he must read it as long as his eyes could see, for there would not be time to read it all.

Of the subjects in this book, he loved best glaciers and fish. Wherever he went, he found traces of moraines—"polished surfaces, furrows, and scratches", and all the other autographs which a world of ice leaves to be read by a world of men. As far as experiments went, however, no country offered him a better opportunity than his own Switzerland, and there he first worked among the white peaks that had encircled his childhood.

To discover how glaciers moved, he and one or two scientific friends, with wise, brave guides, built a rude hut on the Aar glacier. The projecting top and side of a huge boulder made a wall and roof, and a large blanket curtained off a sleeping-room big enough for six. In September 1841, they had bored holes in the ice in a straight line from one side of the glacier to the other, and in these they had planted a row of stakes, to find out which moved faster—the sides or the middle of this river of ice. The following July, when they returned to the old station, they found these stakes no longer in a straight line, but almost in the shape of a crescent, proving, for the first

time, that the glacier moved faster in the middle than on the sides.

This experiment, though it took almost a year for its result, was much less exciting than the one in which Agassiz studied the condition of the ice at the base of a crevasse; and I might here add, that in all his Alpine wanderings, his eyes having been strained by microscopic work, the glitter of the sun on the unbroken "white world" was terribly painful. He did not seem to notice pain, however, nor to falter in steep or slippery climbing; he was often, of course, tied to his friends for safety; his mountain tramps as a college lad had fitted him to bear fatigue; and the same daring that prompted him to bridge an ice-crack for Auguste, when they were boys, made him unhesitatingly attempt this new feat.

Over a glacial crevasse he had a strong tripod built, and "seated upon a board firmly attached by ropes, he was let down into the well, his friend Escher lying flat on the edge of a precipice to direct the descent and listen for any warning cry." Agassiz, absorbed in watching the "blue bands in the glittering walls", did not realize how deep he had gone till he felt his feet plunged into ice-cold water. Even then, at the signal of danger, it was no easy task for his friends to draw him up, one hundred and twenty-five feet, with pointed icicles on the sides threatening to spear his head.

All this time, interested as he was in the mountains and their glaciers, Agassiz never forgot the sea with its fish. Perhaps he was answering a thousand questions which had puzzled him as a boy, beside the old stone basin in Motier. At any rate, he was learning many new things. At the seashore at Nahant and Penikese, the best aquariums were the natural, still pools, regularly deepened by the tides and pleasantly shaded by the rocks. Here were whole families of starfish, crawling crabs, and scrambling lobsters, sea-urchins with their spines, and lovely clusters of anemones that made the pool a garden of pink and purple flowers. Agassiz often went out in his dory for large fish. When he was on the *Hassler* and the cruise of the United States Survey, the deck of the vessel was a fine laboratory. He learned more there "in a day than in months from books or dried specimens." No trip, however, seems to have given him more delight than the journey to Brazil. He went there worn out with overwork, and found himself rested by the romance and novelty of a tropical country. And when he left his Cambridge home, it was with a merry, rhymed send-off from his jovial friend, Dr. Oliver Wendell Holmes:

"Heaven keep him warm and hearty,
Both him and all his party!
From the sun that broils and smites,
From the centipede that bites,
From the hail-storm and the thunder,
From the vampire and the condor.

God bless the great Professor,
And the land his proud possessor,—
Bless him now and evermore!"

Agassiz encountered most of the dangers that Holmes prophesied,—and more, too; but they brought him interest rather than fear. He loved the tangled forest, the brilliant flowers, and fine fruits. For him black slaves sang and danced their fandangoes. He saw many lazy alligators lying still as logs in the "glassy waters", and heard the harsh cries of monkeys, that jump and swing in the trees. He and his party slept in hammocks in huts with mud floors and walls, rats scampering around and bats rustling overhead. Sometimes, several Indian children slept in the same room with Agassiz' gentle wife, and once a pig took breakfast with them in the morning. Mrs. Agassiz accepted everything very naturally, even to the snake which, after gliding by night from her husband's pocket, wriggled out of her shoe just as she was going to put it on. She enjoyed the trip, like the best of sports, and has published an interesting account of their travels. As they journeyed, they of course collected animals, both to "preserve" and to pet; and on the way down the Amazon, the deck held quite a menagerie: parrots, monkeys, deer, and one lazy little sloth, hanging as sloths do, upside down, and making every one laugh by his perpetual sleepiness.

Though the world will perhaps remember Agassiz best as an explorer and scientist, many of his dearest friends

will think of him as a teacher. Teaching was his business during those twenty-seven years, when his real home was in Cambridge, Massachusetts; and his teaching life meant much to him, for, with characteristic simplicity he signed his will "*Louis Agassiz—Teacher*" Whether his pupils were young or old, rich or poor, brilliant or stupid, he taught them freely and gladly—"His purse and knowledge all men's like the sea." He talked with farmers of their cattle, praised the fishermen's big fish, chummed it with the quarrymen and with the Indians of Brazil, gaining from all of them what they had learned just by living, and giving to all what he had learned by research. In the lecture-rooms at Harvard and in the school for young girls, his teaching was almost a chalk-talk. His attempts as a child to make small barrels and shoes, and his years of college practice in drawing, had fitted him to stand before his classes, and, with one sweep, draw a perfect egg, or, in a few lines, picture a starfish, or the beautiful mystery of resurrection from chrysalis to butterfly. Best of all, Agassiz *loved* to teach; "the things he spoke of never grew old to him"; and his lectures had added charm because, in spite of hours of practise, there was always a little touch of French in his good English. To the last, and to the delight of his hearers, he pronounced development—devil-ope-ment.

When he was in charge of laboratory-work, instead of giving his pupils help, he forced them to make their own discoveries from actual specimens. After fifteen years of teaching, he said: "My greatest success is that I have

educated five observers." One student, at least, who was closeted for hours alone with a dead, blear-eyed fish will hardly forget his "lesson in looking."

"Take this fish," said Agassiz, "and look at it; by and by I will ask you what you have seen." With that, he plunged his big hand to the bottom of a huge jar of fish preserved in alcohol and drew out a specimen, dripping and none too fragrant. "Keep your fish in the tray, and moisten it often with alcohol, but be sure to put back the stopper of the jar each time." He shot a kind glance down into the would-be scientist's disheartened face, turned his broad back, and was gone.

In about ten minutes the young student, to quote his own words, "had seen all that could be seen in that fish," and, ready for further enlightenment, set off in search of his teacher: but he had left the museum! Two hours and a half dragged by; still no professor. "Sloppy" and loathsome, the fish waited dumbly in its tray. In despair, the student "turned it over and around; looked it in the face,—ghastly: from behind, beneath, above, sideways, at a three quarters' view,—just as ghastly." Time did not sweeten its fragrance nor reveal its secrets; neither the glazed eyes nor settled jaw would tell anything of its creation. An early lunch offered relief. Back into the stale, yellow alcohol went the fish and out into the fresh air and sunlight went the boy. Being a boy, sick as he thought himself, he could still eat, and eat heartily.

When he returned, he found that Professor Agassiz had been there and gone and would not be back for several hours. "Slowly I drew forth that hideous fish," says the student, "and with a feeling of desperation again looked at it." Magnifying glasses and all other instruments were forbidden. "My two hands, my two eyes, and the fish; it seemed a most limited field. I pushed my finger down its throat to feel how sharp the teeth were. I began to count the scales in the different rows until I was convinced that that was nonsense. At last a happy thought struck me—I would draw the fish."

Just then Professor Agassiz beamed in: "That is right; a pencil is one of the best of eyes. I am glad to see that you keep your specimen wet and your bottle corked." Then, after a pause, "Well—what is it like?"

The young man began to recite his discoveries, describing the head, the lips, the eyes, the fins, the tail. He thought he had seen a good deal. But when he stopped he was met with eyes full of disappointment.

"You haven't looked very carefully. You haven't even seen one of the most conspicuous features of the animal, which is as plainly before your eyes as the fish itself. Look again, look again!" And once more the broad back disappeared.

For three days this search-training continued, Agassiz glancing in now and then, kind and wistful, but always patiently silent in the hope that the boy would make his

own discoveries. "Look, look, look!" he repeated again and again. But when, at last, the young student falteringly suggested "symmetrical sides and paired organs", the teacher's enthusiastic yes was well worth waiting for.

Of all Agassiz' dear schools, none was dearer to him than his out-of-doors school on the island of Penikese in Buzzard's Bay. The lecture-room was an old barn near the sea. The wide doors stood "broadly open to the blue sky and fresh fields"; and the swallows which had built in the old rafters flew in and out, making the "air glad with wings." We can imagine Agassiz standing there, big and genial and earnest, and, like Whittier, we almost hear him say:

"We have come in search of truth;
As with fingers of the blind,
We are groping here to find
What it is that hides beneath
Blight and bloom and birth and death."

Then the great scientist who had never lost his simple, childlike faith, but believed that, even by searching, men could not *alone* find out God, asked his pupils and teachers to join him in a short, silent prayer for God's companionship. And every one *felt* this prayer, though there was no sound on the island but the call of birds and the voice of the lapsing sea.

It is impossible to tell how his pupils loved him. He drew them all to him by his warmth, his sympathy, his

hearty love of fun. Lowell has beautifully said: "His magic was not far to seek,—he was so human!" When he gave up his girls' school in Cambridge, his pupils tried to show their love by giving him a purse of over four thousand dollars. He always had many birthday surprises: serenades in his own Swiss tongue; German student-songs to recall his happy days at Heidelberg; and, from friends, not students, one celebration that touched him deeply. It was at the Saturday Club, on his fiftieth birthday, and he was sitting, as usual, at the head of the table—

"Ample and ruddy
As he our fireside were, our light and heat."

There were fourteen at dinner, among them, Holmes, Lowell, Hawthorne, Emerson, Sumner,—and Longfellow,—who presided at the other end of the table. None of them ever forgot that night: how Longfellow rose, cheeks and eyes glowing, and face young in spite of its wreath of white hair, and read in his " modest, musical" voice "The Fiftieth Birthday of Agassiz"; and how, plunged as the great scientist was into a thousand memories of childhood, the tears rolled down his cheeks at the lines

"And the mother at home says, 'Hark!
For his voice I listen and yearn;
It is growing late and dark,
And my boy does not return!'"

Agassiz lived sixteen years after this happy birthday, loving and being loved. Even his faults seemed to endear him to us. He was hopelessly unbusinesslike—said he had "no time to make money"; but this trait came from a nature really too large and too earnest. He was wasteful of his health, turning abruptly from weeks of mountain-climbing, to months indoors with a microscope; but he forgot himself in love for his work. Like his family and friends, we excuse and forget these little faults, in memory of his great charm and nobility. His children will remember him as working in a corner, a pleasant smile on his face, while they entertained their guests with music and dancing; his friends will remember him as tall and broad-shouldered, with "the strong step of a mountaineer", "a boyish twinkle in his eye", a big contagious laugh, and a general air of joyousness. Longfellow came back from one of his trips to Europe loaded with messages like these: "Give my love to Agassiz. Give him the blessing of an old man"; "I have known a great many men that I like; but I love Agassiz"; and, "What a set of men you have in Cambridge...why, there is Agassiz,—he counts for three." The Cambridge people used to say that one had "less need of an overcoat in passing Agassiz' house."

Much as his friends loved and watched him, however, they could not keep him always; they could not save him from overwork. "Remember that work kills!" was Cuvier's

last warning; Humboldt wrote: "Take care of your eyes, they are *ours*."

And now, in 1869, at the first bad attack "affecting speech and motion", his doctors ordered him "not to think." "Nobody can ever know," Agassiz exclaimed, "the torture I endure in trying to stop thinking!" and again: "My museum! My museum! always uppermost, by day and by night, in health and in sickness, always—always!"

A second stroke of paralysis, the final break, came in 1873, the winter after Agassiz founded the school at Penikese. His friend, Lowell, far off in Florence, picked up the paper one December morning, and was carelessly scanning the news when, suddenly, three small words blurred his sight—"Agassiz is dead!" No one can tell how Lowell felt so well as he, himself, in his beautiful poem, "Agassiz,"—vivid in its picture of the two friends walking back from Boston to Cambridge arm in arm, stopping on Harvard Bridge, each to find his own message in the dark water, and at last ringing out their good-nights.

"'Good-night!' again; and now, with cheated ear
"I half hear his who mine shall never hear."

Agassiz is buried in Mount Auburn, where later were borne his friends Longfellow, Holmes, and Lowell. Pine-trees from the old home surround the Swiss boy's green grave, and keep the place fragrant and musical on windy days; and the stone, a big boulder from the Aar glacier, reminds us of the Swiss man who once built there his little

hut, tramped sturdily over the snow, and even danced and sang in the free air.

Charles Robert Darwin
1822-1882

On Wednesday, April 26, 1882, sitting in the North Transept of Westminster Abbey, I looked upon a sad and impressive scene. Under the dome stood an oaken coffin, quite covered with white wreaths; close by were seated the distinguished pall-bearers, Sir John Lubbock, Canon Farrar, the Duke of Argyle, Thomas H. Huxley, James Russell Lowell, and others. Representatives of many nations were present; the great scientists of France, Germany, Italy, Spain, and Russia.

Of the thousands who were gathered to honor the famous dead, every person wore black, as requested on the cards of admission to the abbey. Perhaps never in the history of England have so many noted men been assembled on an occasion like this. As the choir, in their white robes, stood about the open grave, singing the "Dead March from Saul," the strains seemed to come from a faroff country, producing an effect never to be forgotten. Darwin lies buried close to the graves of Sir Isaac Newton and Sir John Herschel.

At Shrewsbury, England, February 12, 1809, Charles Robert Darwin was born, in a square, redbrick house at the top of a terraced bank leading down to the Severn. The greenhouse with its varied plants, the ornamental shrubs

and trees in the grounds, became a delight as soon as the boy was old enough to observe them.

The mother, Susannah, the daughter of Josiah Wedgwood of Etruria, a woman with a sweet and happy face, died when Charles was eight years old, leaving five other children; Marianne, Caroline, Erasmus, Susan, and Catherine. Charles says of her in his autobiography, "It is odd that I can remember hardly anything about her except her death-bed, her black velvet gown, and her curiously constructed work-table." She evidently encouraged the boy's love for flowers, for he used to say, at school, that his mother had taught him "how, by looking at the inside of the blossom, the name of the plant could be discovered."

The father, Robert Waring Darwin, was a well known physician, a man of fine physique and courtly manner, who had amassed wealth by his skill and business ability. Charles's admiration of him was unbounded: "the wisest man I ever knew," he used often to say.

"His chief mental characteristics," said Darwin, "were his powers of observation and his sympathy, neither of which have I ever seen exceeded or even equalled. His sympathy was not only with the distresses of others, but in a greater degree with the pleasures of all around him. This led him to be always scheming to give pleasure to others, and, though hating extravagance, to perform many generous actions. For instance, Mr. B—, a small manufacturer in Shrewsbury, came to him one day, and

said he should be bankrupt unless he could at once borrow ten thousand pounds, but that he was unable to give any legal security. My father heard his reasons for believing that he could ultimately repay the money, and, from his intuitive perception of character, felt sure that he was to be trusted. So he advanced this sum, which was a very large one for him while young, and was after a time repaid.

"I suppose that it was his sympathy which gave him unbounded power of winning confidence, and as a consequence made him highly successful as a physician. He began to practise before he was twenty-one years old, and his fees during the first year paid for the keep of two horses and a servant. On the following year his practice was large, and so continued for about sixty years, when he ceased to attend on any one. His great success as a doctor was the more remarkable as he told me that he at first hated his profession so much that if he had been sure of the smallest pittance, or if his father had given him any choice, nothing should have induced him to follow it. To the end of his life, the thought of an operation almost sickened him, and he could scarcely endure to see a person bled—a horror which he has transmitted to me."

Charles went to the day-school in Shrewsbury, when he was eight years old. "By the time I went to this day-school," he says, "my taste for natural history, and more especially for collecting, was well developed. I tried to make out the names of plants, and collected all sorts of things, shells, seals, franks, coins, and minerals. The

passion for collecting, which leads a man to be a systematic naturalist, a virtuoso, or a miser, was very strong in me, and was clearly innate, as none of my sisters or brothers ever had this taste....

"I must have been a very simple little fellow when I first went to the school. A boy of the name of Garnett took me into a cake-shop one day, and bought some cakes, for which he did not pay, as the shopman trusted him. When he came out I asked him why he did not pay for them, and he instantly answered, 'Why, do you not know that my uncle left a great sum of money to the town on condition that every tradesman should give whatever was wanted without payment to any one who wore his old hat and moved it in a particular manner?' and he then showed me how it was moved. He then went into another shop where he was trusted, and asked for some small article, moving his hat in the proper manner, and of course obtained it without payment.

"When we came out, he said: 'Now, if you like to go by yourself into that cake-shop (how well I remember its exact position) I will lend you my hat, and you can get whatever you like if you move the hat on your head properly.' I gladly accepted the generous offer, and went in and asked for some cakes, moved the old hat and was walking out of the shop when the shopman made a rush at me, so I dropped the cakes and ran for dear life, and was astonished by being greeted with shouts of laughter by my false friend Garnett.

"In the summer of 1818, I went to Dr. Butler's great school in Shrewsbury, and remained there for seven years, till midsummer, 1825, when I was sixteen years old. I boarded at this school, so that I had the great advantage of living the life of a true schoolboy; but as the distance was hardly more than a mile to my home, I very often ran there in the longer intervals between the callings over, and before locking up at night. This, I think, was in many ways advantageous to me, by keeping up home affections and interests. I remember, in the early part of my school life, that I often had to run very quickly to be in time, and, from being a fleet runner, was generally successful; but when in doubt I prayed earnestly to God to help me, and I well remember that I attributed my success to the prayers and not to my quick running, and marvelled how generally I was aided.

"I have heard my father and elder sister say that I had, as a very young boy, a strong taste for long, solitary walks; but what I thought about I know not. I often became quite absorbed, and once, whilst returning to school on the summit of the old fortifications round Shrewsbury, which had been converted into a public footpath with no parapet on one side, I walked off and fell to the ground, but the height was only seven or eight feet. Nevertheless, the number of thoughts which passed through my mind during this very short but sudden and wholly unexpected fall was astonishing, and seem hardly compatible with

what physiologists have, I believe, proved about each thought requiring quite an appreciable amount of time."

As Dr. Butler's school was strictly classical, Darwin always felt that, for him, these years were nearly wasted. He read many authors, Shakspeare, Thomson's Seasons, Byron, and Scott, but later in life, he says, lost all taste for poetry. This he greatly regretted, and said, if he were to live his life over, he would read some poetry every day. The book that most influenced him was the "Wonders of the World," which gave him a desire to travel, which was finally realized in the voyage of the Beagle. He did not forget his zest in collecting, at first, however, taking only such insects as he found dead, for, after consulting his sister, he "concluded that it was not right to kill insects for the sake of making a collection. From reading White's 'Selborne,' I took much pleasure in watching the habits of birds, and even made notes on the subject. In my simplicity, I remember wondering why every gentleman did not become an ornithologist.

"Towards the close of my school-life, my brother worked hard at chemistry, and made a fair laboratory, with proper apparatus, in the tool-house in the garden, and I was allowed to aid him as a servant in most of his experiments. He made all the gases and many compounds, and I read with great care several books on chemistry, such as Henry and Parkes 'Chemical Catechism.' The subject interested me greatly, and we often used to go on working till rather late at night. This was the best part of my

education at school, for it showed me practically the meaning of experimental science. The fact that we worked at chemistry somehow got known at school, and, as it was an unprecedented fact, I was nicknamed 'Gas.'...

"When I left the school, I was for my age neither high nor low in it, and I believe that I was considered by all my masters and by my father as a very ordinary boy, rather below the common standard in intellect. To my deep mortification, my father once said to me: 'You care for nothing but shooting, dogs, and rat-catching, and you will be a disgrace to yourself and all your family.' But my father, who was the kindest man I ever knew, and whose memory I love with all my heart, must have been angry and somewhat unjust when he used such words."

Dr. Darwin now sent his two boys, Erasmus and Charles, to Edinburgh University. Here, Charles found the lectures "intolerably dull," all except those on chemistry by Hope. His father, evidently not being able to determine for what his son was best fitted in life, suggested his being a doctor. The youth attended the clinical wards in the hospital, but one day witnessing two operations, one upon a child, he rushed away. He says, "Nor did I attend again, for hardly any inducement would have been strong enough to make me do so; this being long before the blessed days of chloroform. The two cases fairly haunted me for many a long year."

While in Edinburgh, Charles became deeply interested in marine zoology, and read a paper before the Plinian Society, an association organized for the study of natural history. He also attended the meetings of the Wernerian Society, where he heard Audubon deliver some interesting lectures upon the habits of North American birds, and the Royal Society, where he saw Sir Walter Scott in the chair as president.

"I looked at him and at the whole scene," says Darwin, "with some awe and reverence, and I think it was owing to this visit during my youth, and to my having attended the Royal Medical Society, that I felt the honor of being elected, a few years ago, an honorary member of both these societies more than any other similar honor. If I had been told at that time that I should one day have been thus honored, I declare that I should have thought it as ridiculous and improbable as if I had been told that I should be elected King of England."

During this time, Charles met Sir James Mackintosh, "the best converser," he says, "I ever listened to. I heard afterwards, with a glow of pride, that he had said, 'There is something in that young man that interests me.'.... To hear of praise from an eminent person, though no doubt apt or certain to excite vanity, is, I think, good for a young man, as it helps to keep him in the right course."

After two years at Edinburgh, Dr. Darwin, seeing that Charles probably would never become a physician, sent

him to Cambridge University, that he might prepare for the Episcopal ministry.

Of this time he says, "The three years which I spent at Cambridge were wasted, as far as the academical studies were concerned, as completely as at Edinburgh and at school. I attempted mathematics, and even went during the summer of 1828 with a private tutor (a very dull man) to Barmouth, but I got on very slowly. The work was repugnant to me, chiefly from my not being able to see any meaning in the early steps in algebra." He found great delight in Paley's "Evidences of Christianity," and his "Moral Philosophy."

At Cambridge, like Humboldt, he formed a rare friendship, which helped towards his subsequent success. Professor Henslow was an ardent scholar, a devoted Christian, and a man of most winning manners and good temper. From his great knowledge of botany, entomology, chemistry, mineralogy, and geology, he became a most attractive person to young Darwin, whose especial passion seemed to be the collecting of beetles. Henslow soon became equally fond of Darwin, and the two took long walks together daily, Darwin being known as "the man who walks with Henslow."

Darwin said of this model teacher, years afterward, "He had a remarkable power of making the young feel completely at ease with him; though we were all awe-struck with the amount of his knowledge. Before I saw

him, I heard one young man sum up his attainments by simply saying that he knew everything. When I reflect how immediately we felt at ease with a man older, and in every way immensely our superior, I think it was as much owing to the transparent sincerity of his character as to his kindness of heart, and, perhaps, even still more to a highly remarkable absence in him of all self-consciousness. One perceived at once that he never thought of his own varied knowledge or clear intellect, but solely on the subject in hand.

"Another charm which must have struck every one was that his manner to old and distinguished persons and to the youngest student was exactly the same; and to all he showed the same winning courtesy. He would receive with interest the most trifling observation in any branch of natural history, and, however absurd a blunder one might make, he pointed it out so clearly and kindly that one left him no way disheartened, but only determined to be more accurate the next time.

''His lectures on botany were universally popular, and as clear as daylight. So popular were they that several of the older members of the University attended successive courses. Once every week he kept open house in the evening, and all who cared for natural history attended these parties, which, by thus favoring intercommunication, did the same good in Cambridge, in a very pleasant manner, as the scientific societies do in London.... This was no small advantage to some of the

young men, as it stimulated their mental activity and ambition....

"During the years when I associated so much with Professor Henslow, I never once saw his temper even ruffled. He never took an ill-natured view of any one's character, though very far from blind to the foibles of others. It always struck me that his mind could not be even touched by any paltry feeling of vanity, envy, or jealousy. With all this equability of temper and remarkable benevolence, there was no insipidity of character. A man must have been blind not to have perceived that beneath this placid exterior there was a vigorous and determined will. When principles came into play, no power on earth could have turned him one hair's breadth....

"Reflecting over his character with gratitude and reverence, his moral attributes rise, as they should do in the highest character, in preeminence over his intellect."

Through this noble friend, Darwin had the opportunity of taking a five years' voyage in the ship Beagle, as a naturalist. The bark, of two hundred and thirty-five tons, under command of Captain Fitz-Roy, was commissioned by government to survey Patagonia, Tierra del Fuego, the shores of Chili, Peru, and some islands in the Pacific, "and to carry a chain of chronometrical measurements round the world."

Professor Henslow knew the captain, and recommended his young friend for the position. Darwin

had read Humboldt's travels eagerly, and was delighted with the prospect of a journey like this.

Dr. Darwin was opposed at first, but finally said, "If you can find any man of common sense who advises you to go, I will give my consent." Young Darwin at once visited his uncle, Josiah Wedgwood, at Maer, who approved of the journey, and soon convinced Dr. Darwin of the wisdom of it.

The vessel sailed December 27, 1831. Though for a young man of an extremely affectionate nature the separation from family was painful, yet it was a glad day for Darwin. He had looked forward eagerly to it, saying, "My second life will then commence, and it shall be as a birthday for the rest of my life," and so it proved. He said, years afterward, "The voyage of the Beagle has been by far the most important event in my life, and has determined my whole career."

These years were busy, earnest ones, devoted to constant labor. To his father he wrote from Bahia, or San Salvador, the following spring: "No person could imagine anything so beautiful as the ancient town of Bahia; it is fairly embosomed in a luxuriant wood of beautiful trees, and situated on a steep bank, and overlooks the calm waters of the great Bay of All Saints. The houses are white and lofty, and, from the windows being narrow and long, have a very light and elegant appearance...But the exquisite, glorious pleasure of walking amongst such

flowers and such trees cannot be comprehended but by those who have experienced it....I will not rapturize again, but I give myself great credit in not being crazy out of pure delight. Give my love to every soul at home....I think one's affections, like other good things, flourish and increase in these tropical regions."

Again he writes from Rio de Janeiro: "Here (at Rio Macoa) I first saw a tropical forest in all its sublime grandeur—nothing but the reality can give any idea how wonderful, how magnificent the scene is....I never experienced such intense delight. I formerly admired Humboldt, I now almost adore him; he alone gives any notion of the feelings which are raised in the mind on first entering the Tropics. I am now collecting freshwater and land animals....I am at present redhot with spiders; they are very interesting, and, if I am not mistaken, I have already taken some new genera." Busy as he was, he was ever thinking of home, and anxious to receive letters. When they were received, he almost "cried for pleasure."

He writes to his sister: "If you knew the glowing, unspeakable delight which I felt at being certain that my father and all of you were well, only four months ago. You would not grudge the labor lost in keeping up the regular series of letters."

Later he writes: "It is too delightful to think that I shall see the leaves fall and hear the robin sing next autumn at Shrewsbury. My feelings are those of a schoolboy to the

smallest point; I doubt whether ever boy longed for his holidays as much as I do to see you all again."

To his "dear Henslow" he writes: "It is now some months since we have been at a civilized port; nearly all this time has been spent in the most southern part of Tierra del Fuego....The Fuegians are in a more miserable state of barbarism than I had expected ever to have seen a human being. In this inclement country they are absolutely naked, and their temporary houses are like what children make in summer with boughs of trees."

Captain Fitz-Roy, on a previous voyage, had carried several natives to England, and now brought them again to their own land. "They had become," says Darwin, "entirely European in their habits and wishes, so much so that the younger one had forgotten his own language, and their countrymen paid but very little attention to them. We built houses for them, and planted gardens, but by the time we return again on our passage round the Horn, I think it will be very doubtful how much of their property will be left unstolen."

At the Cape of Good Hope, Darwin met and dined with Sir John Herschel. For some time he lived at St. Helena, "within a stone's throw of Napoleon's tomb." He became so deeply interested in his geological investigations in South America, that he wrote his sister Susan: "I literally could hardly sleep at nighty for thinking over my day's work. The scenery was so new, and so

majestic; everything at an elevation of twelve thousand feet bears so different an aspect from that in a lower country."

To another sister he wrote: "I trust and believe that the time spent in this voyage, if thrown away for all other respects, will produce its full worth in Natural History; and it appears to me the doing what *little* we can to increase the general stock of knowledge is as respectable an object of life as one can in any likelihood pursue.... What fine opportunities for geology and for studying the infinite host of living beings! Is not this a prospect to keep up the most flagging spirit? If I was to throw it away, I don't think I should ever rest quiet in my grave."

Darwin says: "As far as I can judge of myself, I worked to the utmost during the voyage, from the mere pleasure of investigation, and from my strong desire to add a few facts to the great mass of facts in natural science. But I was also ambitious to take a fair place among scientific men." In studying the geology of St. Jago, "It then first dawned on me that I might perhaps write a book on the geology of the various countries visited, and this made me thrill with delight. That was a memorable hour to me, and how distinctly I can call to mind the low cliff of lava beneath which I rested, with the sun glaring hot, a few strange desert plants growing near, and with living corals in the tidal pools at my feet. Later in the voyage, Fitz-Roy asked me to read some of my journal, and declared it would be worth publishing, so here was a second book in prospect!"

Darwin, stirred by the right kind of ambition, had found his life-work. It would not be in the church, as his father had fondly hoped, but the world would be his audience.

On October 5, 1836, Darwin arrived at Shrewsbury, after five years' absence. He left home a high-spirited, warm-hearted youth, fond of athletic sports, and vigorous in body. He came back with a passionate love for science, "with the habit of energetic industry and of concentrated attention," but with health impaired, which made the whole of his after life a battle with suffering. Yet he conquered, and gave to his generation a wonderful example of the power of mind over body; of victory over obstacles.

During the voyage he was an almost constant sufferer from sea-sickness. He wrote home the last year: "It is a lucky thing for me that the voyage is drawing to its close, for I positively suffer more from sea-sickness now than three years ago."

"After perhaps an hour's work," says Admiral Stokes, "he would say to me, 'Old fellow, I must take the horizontal for it,' that being the best relief position from ship motion. A stretch out on one side of the table for some time would enable him to resume his labors for a while, when he had again to lie down. It was distressing to witness this early sacrifice of Mr. Darwin's health, who

ever afterwards seriously felt the ill effects of the Beagle's voyage."

Admiral Mellersh says: "I think he was the only man I ever knew against whom I never heard a word said; and as people, when shut up in a ship for five years, are apt to get cross with each other, that is saying a good deal." Says another: "He was never known to be out of temper, or to say one unkind or hasty word *of* or *to* any one."

This lovely spirit, which so endeared him to everybody, Darwin kept through life, a spirit which sheds a halo around every book he wrote, and makes him worthy the admiration and honor of every young man. Many persons have the gift of writing books, but comparatively few persons have the great gift of self-control.

After a brief visit with his family, Darwin hastened to Cambridge, to prepare his "Journal of Travels." He had learned on the Beagle that "a man who dares to waste one hour of time has not discovered the value of life." After three months of hard work, he went to London, where he finished the "Journal," and began working on his "Zoology of the Voyage of the Beagle," and his "Geological Observations." He said at this time: "I have nothing to wish for, excepting stronger health to go on with the subjects to which I have joyfully determined to devote my life."

For three years and eight months he worked untiringly. He wrote Henslow: "I fear the Geology will

take me a great deal of time; I was looking over one set of notes, and the quantity I found I had to read for that one place was frightful. If I live till I am eighty years old I shall not cease to marvel at finding myself an author. In the summer before I started, if any one had told me that I should have been an angel by this time, I should have thought it an equal impossibility. This marvellous transformation is all owing to you."

Darwin and Lyell now became very intimate friends. "I am coming into your way, of only working about two hours at a spell," he writes to Lyell; "I then go out and do my business in the streets, return and set to work again, and thus make two separate days out of one." Of Lyell he said: "One of his chief characteristics was his sympathy with the work of others....The science of geology is enormously indebted to Lyell—more so, as I believe, than to any other man who ever lived."

The "Journal" was published in 1839. January twenty-nine of this year, Mr. Darwin, now thirty years of age, was married to his cousin, Emma Wedgwood, daughter of Josiah Wedgwood of Maer, and granddaughter of the founder of the potteries of Etruria. The extreme happiness of his married life proved the wisdom of his choice. He said in after years, "No one can be too kind to my dear wife, who is worth her weight in gold many times over."

They lived at No. 12 Upper Gower Street, as he wrote a college mate, "a life of extreme quietness....We have

given up all parties, for they agree with neither of us; and if one is quiet in London, there is nothing like its quietness."

In 1842, his "Structure and Distribution of Coral Reefs" was published, a book which cost him, he says, "twenty months of hard work, as I had to read every work on the islands of the Pacific, and to consult many charts." Of this book, Professor Geikie says: "This well known treatise, the most original of all its author's geological memoirs, has become one of the classics of geological literature. The origin of those remarkable rings of coral-rock in mid-ocean has given rise to much speculation, but no satisfactory solution of the problem has been proposed. After visiting many of them, and examining also coral reefs that fringe islands and continents, he offered a theory which, for simplicity and grandeur, strikes every reader with astonishment....No more admirable example of scientific method was ever given to the world, and, even if he had written nothing else, this treatise alone would have placed Darwin in the very front of investigators of nature."

Lyell wrote to Darwin concerning this book: "It is all true, but do not flatter yourself that you will be believed till you are growing bald, like me, with hard work and vexation at the incredulity of the world."

Darwin's next work, on the "Volcanic Islands Visited during the Voyage of the Beagle," was published in 1844.

This book, he said, "cost me eighteen months." His third geological book, "Geological Observations on South America," was published in 1846.

Meantime, tired of smoky London, Darwin purchased a home in Down, a retired village five or six hundred feet above the sea. The house was a square brick building, of three stories, vine-covered, in the midst of eighteen acres. "Its chief merit," Darwin writes to a friend, "is its extreme rurality. I think I was never in a more perfectly quiet country." Here, for forty years, Darwin lived the isolated life of a student, producing the books that made him the most noted scientist of his century. Of these years, Mr. Darwin said: "Few persons can have lived a more retired life than we have done. Besides short visits to the houses of relations, and occasionally to the seaside or elsewhere, we have gone nowhere. During the first part of our residence we went a little into society, and received a few friends here; but my health almost always suffered from the excitement....I have, therefore, been compelled for many years to give up all dinner parties....From the same cause I have been able to invite here very few scientific acquaintances. My chief enjoyment and sole employment throughout life has been scientific work; and the excitement from such work makes me for the time forget, or drives quite away, my daily discomfort."

At Down, Darwin worked for eight years on two large volumes concerning cirripedia (barnacles), describing all the known living species; the extinct species, or fossil

cirripedes, were in two smaller volumes. The first books were published by the Ray Society, between 1851 and 1854; the others by the Palæontographical Society. About two years out of the eight were lost through illness. Sometimes he became half discouraged. He wrote a friend, "I have been so steadily going downhill, I cannot help doubting whether I can ever crawl a little uphill again. Unless I can, enough to work a little, I hope my life may be very short, for to lie on a sofa all day and do nothing but give trouble to the best and kindest of wives and good, dear children is dreadful."

Darwin doubted, in after life, "whether the work was worth the consumption of so much time," but Professor Huxley thinks he "never did a wiser thing than when he devoted himself to the years of patient toil which the cirriped-book cost him....The value of the cirriped monograph lies not merely in the fact that it is a very admirable piece of work, and constituted a great addition to positive knowledge, but still more in the circumstance that it was a piece of critical self-discipline, the effect of which manifested itself in everything he wrote afterwards, and saved him from endless errors of detail." Darwin's patient labor is shown by his working "for the last half-month, daily, in dissecting a little animal about the size of a pin's head, from the Chonos archipelago, and I could spend another month, and daily see more beautiful structure."

During these years from 1846 to 1854, death had twice disturbed the quiet life at Down. In 1849, Dr. Darwin died, and his son Charles was so ill that he could not attend the funeral. In 1851, Annie Darwin died, at the age of ten, after a brief illness. "She was," said Darwin, "my favorite child; her cordiality, openness, buoyant joyousness, and strong affections made her most lovable....When quite a baby, this [strong affection] showed itself in never being easy without touching her mother when in bed with her; and quite lately she would, when poorly, fondle for any length of time one of her mother's arms....She would at almost any time spend half an hour in arranging my hair, 'making it,' as she called it, 'beautiful,' or in smoothing, the poor, dear darling, my collar or cuffs—in short, in fondling me.... Her whole mind was pure and transparent. One felt one knew her thoroughly and could trust her. I always thought that, come what might, we should have had, in our old age, at least one loving soul which nothing could have changed.

"All her movements were vigorous, active, and usually graceful. When going round the Sandwalk with me, although I walked fast, yet she often used to go before, pirouetting in the most elegant way, her dear face bright all the time with the sweetest smiles. Occasionally she had a pretty coquettish manner towards me, the memory of which is charming....

"In the last short illness her conduct, in simple truth, was angelic. She never once complained; never became

fretful; was ever considerate of others, and was thankful in the most gentle, pathetic manner for everything done for her. When so exhausted that she could hardly speak, she praised everything that was given her, and said some tea 'was beautifully good.' When I gave her some water, she said, 'I quite thank you;' and these, I believe, were the last precious words ever addressed by her dear lips to me."

Such consideration and politeness she naturally inherited. Francis Darwin says in his delightful life of his father, "He always spoke to servants with politeness, using the expression, 'Would you be so good,' in asking for anything. In business matters he was equally courteous. His solicitor, who had never met him, said, 'Everything I did was right, and everything was profusely thanked for.'" Of the drawings made by his children, he would say, "Michael Angelo is nothing to it!" but he always looked carefully at the work and kindly pointed out mistakes.

"He received," says his son, "many letters from foolish, unscrupulous people, and all of these received replies. He used to say that if he did not answer them, he had it on his conscience afterwards, and, no doubt, it was in great measure the courtesy with which he answered every one which produced the universal and widespread sense of his kindness of nature which was so evident on his death."

In November, 1853, Darwin received the Royal Society's Medal. He was gratified, finding it "a pleasant little stimulus. When work goes badly, and one ruminates

that all is vanity, it is pleasant to have some tangible proof that others have thought something of one's labors."

November 24, 1859, when Darwin was fifty, his great work, "Origin of Species by means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life," was published. For twenty years he had been making experiments with plants and animals, and filling his note-books with facts. To his old classmate, Fox, he writes asking that the boys in his school gather lizards' eggs, as well as those of snakes. "My object is," he says, "to see whether such eggs will float on sea-water, and whether they will keep alive thus floating for a month or two in my cellar. I am trying experiments on transportation of all organic beings that I can; and lizards are found on every island, and therefore I am very anxious to see whether their eggs stand sea-water." Again he writes, asking Fox for ducklings and dorkings; "The chief point which I am and have been for years very curious about is to ascertain whether the young of our domestic breeds differ as much from each other as do their parents, and I have no faith in anything short of actual measurement and the Rule of Three....I have got my fan-tails and pouters in a grand cage and pigeon-house, and they are a decided amusement to me, and delight to H."

Of this book, Darwin himself says: "I worked on true Baconian principles, and without any theory—collected facts on a wholesale scale, more especially with respect to domesticated productions, by printed inquiries, by

conversation with skilful breeders and gardeners, and by extensive reading. When I see the list of books of all kinds which I read and abstracted, including whole series of Journals and Transactions, I am surprised at my industry. I soon perceived that selection was the keystone of man's success in making useful races of animals and plants....

"In October, 1838, that is, fifteen months after I had begun my systematic inquiry, I happened to read 'Malthus on Population,' and, being well prepared to appreciate the struggle for existence which everywhere goes on, from long continued observation of the habits of animals and plants, it at once struck me that under these circumstances favorable variations would tend to be preserved, and unfavorable ones to be destroyed. The result of this would be the formation of new species....But at that time I overlooked one problem of great importance....This problem is the tendency in organic beings descended from the same stock to diverge in character as they become modified. That they have diverged greatly is obvious from the manner in which species of all kinds can be classed under genera, genera under families, families under sub-orders, and so forth....The solution, as I believe, is that the modified offspring of all dominant and increasing forms tend to become adapted to many and highly diversified places in the economy of nature."

The book was written slowly, each chapter requiring at least three months. When the "Origin of Species"—which had reached its thirty-third thousand in 1888—was

published, it created the most profound sensation throughout the thinking world. Heretofore, most men of science had believed that each species had been separately created by the Almighty,—that species were immutable, unchanging.

Mr. Darwin, by twenty years of study, proved to his own mind, and now to most of the world, that there has been a gradual evolution, through unnumbered ages, of one form of animal life from another. He said, "Probably all the organic beings which have ever lived on the earth have descended from some one primordial form, into which life was first breathed."

The theory of evolution was not original with Darwin. Lamarck, in 1801, published his "Organization of Living Bodies," in which he stated his belief "that nature, in all the long ages during which the world has existed, may have produced the different kinds of plants and animals by gradually enlarging one part and diminishing another to suit the wants of each." Geoffrey Saint-Hilaire, Goethe, Dr. Erasmus Darwin, the grandfather of Charles, all believed that species are descended from other species, and in various ways improved.

Some of the reasons for the belief in evolution are so simply and clearly stated by Arabella B. Buckley, in her "Short History of Natural Science," that I quote her words:—

"All the Animals of each class are formed on the same plan....

"Why should the animals of one class (such as the vertebrate or back-boned class) be formed all on one plan, even to the most minute bones; so that the wing of a bat, the front leg of a horse, the hand of a man, and the flapper of a porpoise, are all made of the same bones, which have either grown together, or lengthened and spread apart, according to the purpose they serve? And, more curious still, why should some animals have parts which are of no use to them, but only seem to be there because other animals of the same class also have them? Thus the whale has teeth like the other mammalia, but they never pierce through the gum; and the boa-constrictor has the beginnings of hind legs, hidden under its skin, though they never grow out. Here, again, it seems extraordinary, if a boa-constrictor and a whale were created separately, that they should be made with organs which are quite useless; while, on the other hand, if they were descended from the same ancestor, as other reptiles and mammalia who have teeth and hind legs, they might be supposed to have inherited these organs....

"Embryos of animals alike in Structure.

"Another still more remarkable fact was that pointed out by Von Baer, that the higher animals, such as quadrupeds, before they are perfectly formed, cannot be distinguished from the embryos of other and lower

animals, such as fish and reptiles. If animals were created separately, why should a dog begin like a fish, a lizard, and a bird, and have at first parts which it loses as it grows into its own peculiar form?

"Living animals of a country agree with the fossil ones....

"We know that certain animals are only found in particular countries; kangaroos and pouched animals, for example, in Australia, and sloths and armadillos in South America. Now, it is remarkable that all the fossil quadrupeds in Australia are also pouched animals, though they are of different kinds and larger in size than those now living; and in the same way different species of sloth and armadillos are found fossil in South America; while in the rocks of Europe fossil mammalia are found, only slightly different from those which are living there now." It seems natural to conclude that the living have descended from the fossils.

The study of the rocks has produced other "missing links" in the succession of animal life. Professor Huxley, in some lectures given in New York in 1876, described the Hesperornis, found in the western rocks,—a huge bird, five or six feet in length, with teeth like a reptile. In England a fossil reptile has been found, the Archæopteryx, having a reptile-like tail, with a fringe of feathers on each side, and teeth, "occupying a midway place between a bird and a reptile." Flying reptiles have been found, and reptiles which walked on their hind legs. Those who have visited

Yale and Amherst Colleges must have seen the huge bird-tracks or reptile foot-prints taken from the rocks in the Connecticut valley.

Professor Huxley showed the probable descent of the horse with its hoofed foot from the extinct three-toed Hipparion of Europe, and that from the four-toed Orohippus of the Eocene formation. He declared it probable that a five-toed horse would be found, and Professor Marsh, in the West, has found the Eohippus, corresponding very nearly to Professor Huxley's description.

The question among naturalists was, "How can plants and animals have become thus changed?" Darwin showed how it was possible to effect most of these changes by "natural selection," or the choosing of the best to survive in the struggle for existence. As man by grafting secures the finest fruit, and by care in animal life the swiftest horses for speed as well as the strongest for labor, so nature selects her best for the higher development of the race.

Darwin says, "There is no exception to the rule that every organic being naturally increases at so high a rate that, if not destroyed, the earth would soon be covered by the progeny of a single pair. Even slow-breeding man has doubled in twenty-five years, and, at this rate, in less than a thousand years there would literally not be standing-room for his progeny.... The elephant is reckoned the

slowest breeder of all known animals; it will be safest to assume that it begins breeding when thirty years old, and goes on breeding till ninety years old, bringing forth six young in the interval, and surviving till one hundred years old; if this be so, after a period of from 740 to 750 years, there would be nearly nineteen million elephants alive, descended from the first pair."

In various ways the weakest are destroyed. Darwin, on a piece of ground three feet long and two wide, says, "I marked all the seedlings of our native weeds as they came up, and, out of 357, no less than 295 were destroyed, chiefly by slugs and insects."

He gives this interesting instance of the struggle for existence. "I find from experiments that humble-bees are almost indispensable to the fertilization of the heart's-ease, for other bees do not visit this flower....Humble-bees alone visit red clover, as other bees cannot reach the nectar...Hence we may infer as highly probable that, if the whole genus of humble-bees became extinct or very rare in England, the heart's-ease and red clover would become very rare, or wholly disappear. The number of humble-bees in any district depends in a great measure upon the number of field-mice, which destroy their combs and nests; the number of mice is largely dependent, as every one knows, on the number of cats." Hence, as Mr. Darwin shows, the frequency of certain flowers in a district may depend upon the number of cats!

Darwin showed, by most interesting experiments with pigeons, that the various breeds come from the wild rock-pigeon; that dogs are descended, probably, from the wolf; that different varieties can be produced and perpetuated under changing conditions of life; that species are only well marked and permanent varieties. He showed how organs can be changed by use or disuse; such as, the erect ears of wild animals become drooping under domestication; or moles have only rudimentary eyes, covered with skin or fur, because not needed for sight.

In the "Origin of Species," the theory of evolution received proof which was so nearly incontrovertible that the subject was brought prominently before the world as never before. Mr. Alfred Russell Wallace, an able scientist, came to the same conclusion as Darwin in regard to the power of "Natural Selection," and published, at the same time as the "Origin," an essay "On the Tendency of Varieties to depart indefinitely from, the Original Type."

At once Darwin was attacked from every quarter. Probably not since Galileo showed that the earth moves round the sun has a man been so censured and persecuted for his opinions as was Darwin. He was declared atheistic, unsettling the Christian belief, and opposed to the teachings of the Bible. Professor Asa Gray of Cambridge, Mass., a devoted Christian and able scientist, defended and explained Darwin's views, now published in "Darwiniana," claiming that the doctrine of evolution is in no wise opposed to the power and goodness of the

Almighty, and quotes Charles Kingsley's words: "We know of old that God was so wise that he could make all things; but behold, he is so much wiser than even that, that he can make all things make themselves." Kingsley wrote Darwin: "I have gradually learnt to see that it is just as noble a conception of Deity to believe that he created primal forms capable of self-development into all forms needful *pro tempore* and *pro loco*, as to believe that he required a fresh act of intervention to supply the *lacunas* which he himself had made. I question whether the former be not the loftier thought." Gray believed that "to do any work by an instrument must require, and therefore presuppose, the exertion rather of more than of less power than to do it directly." Darwin said, "There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms, most beautiful and most wonderful, have been and are being evolved." Darwin always felt grateful to Asa Gray for his defence. He wrote him: "I declare that you know my book as well as I do myself; and bring to the question new lines of illustration and argument, in a manner which excites my astonishment and almost my envy!...I said, in a former letter, that you were a lawyer, but I made a gross mistake; I am sure that you are a poet. No, I will tell you what you

are, a hybrid, a complex cross of lawyer, poet, naturalist, and theologian!"

Darwin wisely made no reply to his critics. He said, years later: "My views have often been grossly misrepresented, bitterly opposed and ridiculed, but this has been generally done, as I believe, in good faith. On the whole, I do not doubt that my works have been over and over again greatly overpraised. I rejoice that I have avoided controversies, and this I owe to Lyell, who, many years ago, in reference to my geological works, strongly advised me never to get entangled in a controversy, as it rarely did any good, and caused a miserable loss of time and temper.

"Whenever I have found out that I have blundered, or that my work has been imperfect, and when I have been contemptuously criticised, and even when I have been overpraised, so that I have felt mortified, it has been my greatest comfort to say hundreds of times to myself, 'that I have worked as hard and as well as I could, and no man can do more than this.' "

The "Origin" has been translated into French, German, Italian, Dutch, Russian, Swedish, and many other languages. Huxley says of it, "Even a cursory glance at the history of the biological sciences during the last quarter of a century is sufficient to justify the assertion that the most potent instrument for the extension of the realm of natural knowledge which has come into men's hands

since the publication of Newton's 'Principia' is Darwin's 'Origin of Species.' "

The year after the "Origin" was published, Darwin began arranging his notes for his two large volumes, "Variation of Animals and Plants under Domestication," which, however, were not published till 1868. On these two books he spent over four years. They are a wonderful collection of facts, gathered from books and from his own marvelous experiments and observations, confirming and illustrating the law of "Natural Selection" given in the "Origin."

Darwin had already received the Copley medal of the Royal Society, the greatest honor a scientific man can receive in England, and the Prussian Order "Pour le Mérite," founded by Frederick II. The order consists of thirty German members and a few distinguished foreigners. In 1862 the "Fertilization of Orchids" was published, which required ten months of labor. In this work Darwin took the utmost delight. He wrote to a friend who had sent him some of these flowers: "It is impossible to thank you enough. I was almost mad at the wealth of Orchids....I never was more interested in any subject in my life than in this of Orchids." The peculiarities of the flowers therein described, as Darwin says, "transcend in an incomparable manner the contrivances and adaptations which the most fertile imagination of man could invent."

In the "Origin" he describes an orchid which "has part of its labellum or lower lip hollowed out into a great bucket, into which drops of almost pure water continually fall from two secreting horns which stand above it; and when the bucket is half full the water overflows by a spout on one side. The basal part of the labellum stands over the bucket, and is itself hollowed out into a sort of chamber with two lateral entrances; within this chamber there are curious fleshy ridges. The most ingenious man, if he had not witnessed what takes place, could never have imagined what purpose all these parts serve. But Dr. Crüger saw crowds of large humble-bees visiting the gigantic flowers of this orchid, not in order to suck nectar, but to gnaw off the ridges within the chamber above the bucket; in doing this they frequently pushed each other into the bucket, and, their wings being thus wetted, they could not fly away, but were compelled to crawl out through the passage formed by the spout or overflow....The passage is narrow, and is roofed over by the column, so that a bee, in forcing its way out, first rubs its back against the viscid stigma and then against the viscid glands of the pollen-masses. The pollen-masses are thus glued to the back of the bee which first happens to crawl out through the passage of a lately expanded flower, and are thus carried away....

"When the bee, thus provided, flies to another flower, or to the same flower a second time, and is pushed by its comrades into the bucket and then crawls out by the

passage, the pollen-mass necessarily comes first into contact with the viscid stigma, and adheres to it, and the flower is fertilized. Now at last we see the full use of every part of the flower; of the water-secreting horns, of the bucket half full of water, which prevents the bees from flying away, and forces them to crawl out through the spout, and rub against the properly placed viscid pollen-masses and the viscid stigma."

Darwin said: "The Botanists praise my Orchid-book to the skies....There is a superb, but, I fear, exaggerated, review in the 'London Review.' But I have not been a fool, as I thought I was, to publish; for Asa Gray, about the most competent judge in the world, thinks almost as highly of the book as does the 'London Review.' "

Darwin wrote several other books on plants. "The Movements and Habits of Climbing Plants" was published in 1875; "Insectivorous Plants," in 1875; "Effects of Cross and Self-Fertilization," in 1876; "The different Forms of Flowers on Plants of the Same Species," in 1877; "The Power of Movement in Plants," in 1880.

When writing his "Different Forms of Flowers," he said, "I am all on fire at the work; "and of "Insectivorous Plants," "I have been working like a madman at Drosera. Here is a fact for you which is certain as you stand where you are, though you won't believe it, that a bit of hair, 1/78,000 of *one* grain in weight, placed on gland, will

cause one of the gland-bearing hairs of Drosera to curve inwards, and will alter the condition of the contents of every cell in the foot-stalk of the gland."

But he was growing tired with his constant and multifarious labors. He wrote to Hooker: "You ask about my book, and all that I can say is that I am ready to commit suicide; I thought it was decently written, but find so much wants rewriting that it will not be ready to go to printers for two months, and will then make a confoundedly big book. Murray will say that it is no use publishing in the middle of summer, so I do not know what will be the upshot; but I begin to think that every one who publishes a book is a fool."

In 1871 the "Descent of Man" was published. He worked on this book three years, and he wrote to his friend, Sir J. D. Hooker, that it had "half killed" him. For the first edition Darwin received over seven thousand dollars. It had an immense circulation in England and America, and created a furor in Germany.

Darwin believed "that man is descended from a hairy quadruped, furnished with a tail and pointed ears, probably arboreal in its habits, and an inhabitant of the Old World. This creature, if its whole structure had been examined by a naturalist, would have been classed among the quadrumana, as surely as would the common and still more ancient progenitor of the Old and New World monkeys.

"The quadrumana and all the higher mammals are probably derived from an ancient marsupial animal, and this, through a long line of diversified forms, either from some reptile-like or some amphibian-like creature, and this again from some fishlike animal. In the dim obscurity of the past, we can see that the early progenitor of all the vertebrata must have been an aquatic animal, provided with branchiæ, with the two sexes united in the same individual, and with the most important organs of the body (such as the brain and heart) imperfectly developed. This animal seems to have been more like the larvæ of our existing marine Ascidians than any known form."

Most naturalists believe, with Darwin, that man has developed from some lower form, but many urge that at some stage of development he received the gift of speech, and mental and moral powers, from an omnipotent Creator.

Darwin received much abuse and much ridicule for his views. Mr. James D. Hague tells in "Harper's Magazine" of a visit paid to the great scientist, when a picture in the "Hornet" was shown; the body of a gorilla, with the head of Darwin. The latter laughed and said, "The head is cleverly done, but the gorilla is bad; too much chest; it couldn't be like that."

The "Descent of Man" shows the widest research, and is a storehouse of most interesting facts. "Sexual Selection" shows some of the most remarkable provisions

of nature, and is as interesting as any novel. This book, like the "Origin," has been translated into various languages.

In 1872 "The Expression of the Emotions in Man and Animals" was published. Over five thousand copies were sold on the day of publication. It was begun at the birth of his first child, thirty-three years before. He says, "I at once commenced to make notes on the first dawn of the various expressions which he exhibited, for I felt convinced, even at this early period, that the most complex and fine shades of expression must all have had a gradual and natural origin." He wrote to a college friend regarding this baby: "He is so charming that I cannot pretend to any modesty. I defy anybody to flatter us on our baby, for I defy any one to say anything in its praise of which we are not fully conscious....I had not the smallest conception there was so much in a five-month baby. You will perceive by this that I have a fine degree of paternal fervor."

In 1881, "The Formation of Vegetable Mould, through the Action of Worms, with Observations on their Habits," was published. "Fragments of burnt marl, cinders, etc., which had been thickly strewed over the surface of several meadows were found, after a few years, lying at a depth of some inches beneath the turf, but still forming a layer." Ascertaining that this was the work of worms, Darwin made a study of their structure, habits, and work, in his garden, his fields, and in pots of earth kept in his study. The intelligence of worms, the construction of their burrows, and the amount of labor they can perform,

are described in a most entertaining manner. Over fifty thousand worms are found in a single acre of land, or about three hundred and fifty-six pounds. "In many parts of England a weight of more than ten tons of dry earth annually passes through their bodies, and is brought to the surface, on each acre of land....Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. They periodically expose the mould to the air, and sift it so that no stones larger than the particles which they can swallow are left in it. They mingle the whole intimately together, like a gardener who prepares fine soil for his choicest plants....The plough is one of the most ancient and most valuable of man's inventions; but long before he existed the land was in fact regularly ploughed, and still continues to be thus ploughed, by earthworms. It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly organized creatures."

In three years eighty-five hundred copies of the "Earthworms" were sold.

Mr. Darwin was now seventy-two years old. Already many honors had come to him, after the severe and bitter censure. In 1877, he received the degree of LL.D. from Cambridge University. In 1878, he was elected a corresponding member of the French Institute, and of the Berlin Academy of Sciences. In 1879, he received the Baly Medal of the Royal College of Physicians. In 1879, from

the Royal Academy of Turin, the *Bressa* Prize of twelve thousand francs. He valued highly two photographic albums sent from Germany and Holland; one containing the pictures of one hundred and fifty-four noted scientific men; the other, of two hundred and seventeen lovers of natural science in the Netherlands. He wrote in thanks: "I am well aware that my books could never have been written, and would not have made any impression on the public mind, had not an immense amount of material been collected by a long series of admirable observers; and it is to them that honor is chiefly due. I suppose that every worker at science occasionally feels depressed, and doubts whether what he has published has been worth the labor which it has cost him, but for the few remaining years of my life, whenever I want cheering, I will look at the portraits of my distinguished co-workers in the field of science, and remember their generous sympathy."

He was made a member of more than seventy of the learned societies of the world; in America, Austria, India, Belgium, Denmark, France, Germany, Holland, Italy, Portugal, Russia, Spain, Sweden, Switzerland, and elsewhere.

Darwin's work was now almost over. His dear friend Lyell had gone before him, of whom he said, "I never forget that almost everything which I have done in science I owe to the study of his great works." His brother Erasmus, to whom he was tenderly attached, died in 1881. In the spring of 1882 he was unable to work continuously

as usual, and suffered from pain about the heart. On the night of April 18, he had a severe attack and fainted. When he was restored to consciousness, he said, "I am not the least afraid to die." He died the next day, April 19.

Darwin died as he had lived, with a heart overflowing with sympathy and tenderness. He said, "I feel no remorse from having committed any great sin, but have often and often regretted that I have not done more direct good to my fellow-creatures."

In his home life he was singularly blest. His son says, "No one except my mother knows the full amount of suffering he endured, or the full amount of his wonderful patience. For all the latter years of his life she never left him for a night; and her days were so planned that all his resting hours might be shared with her. She shielded him from every avoidable annoyance, and omitted nothing that might save him trouble, or prevent him becoming overtired, or that might alleviate the many discomforts of his ill-health. I hesitate to speak thus freely of a thing so sacred as the life-long devotion which prompted all this constant and tender care. But it is... a principal feature of his life that for nearly forty years he never knew one day of the health of ordinary men, and that thus his life was one long struggle against the weariness and strain of sickness." And yet he accomplished all his wonderful work!

"In his relationship towards my mother, his tender and sympathetic nature was shown in its most beautiful aspect.

In her presence he found his happiness, and through her his life—which might have been overshadowed by gloom—became one of content and quiet gladness."

He was the idol of his children, who used "to bribe him with sixpence to come and play in working hours." "We all knew the sacredness of working time," says Mr. Darwin's daughter, "but that any one should resist sixpence seemed an impossibility....Another mark of his unbounded patience was the way in which we were suffered to make raids into the study when we had an absolute need of sticking-plaster, string, pins, scissors, stamps, foot-rule, or hammer. These and other such necessaries were always to be found in the study, and it was the only place where this was a certainty. We used to feel it wrong to go in during work-time; still, when the necessity was great we did so. I remember his patient look when he said once, 'Don't you think you could not come in again; I have been interrupted very often?'...He cared for all our pursuits and interests, and lived our lives with us in a way that very few fathers do."

His son says: "The way he brought us up is shown by a little story about my brother Leonard, which my father was fond of telling. He came into the drawing-room, and found Leonard dancing about on the sofa, which was forbidden, for the sake of the springs, and said, 'Oh, Lenny, Lenny, that's against all rules!' and received for answer, 'Then, I think you'd better go out of the room.' I do not believe he ever spoke an angry word to any of his

children in his life; but I am certain that it never entered our heads to disobey him....How often, when a man, I have wished, when my father was behind my chair, that he would pass his hand over my hair, as he used to do when I was a boy. He allowed his grown-up children to laugh with and at him, and was, generally speaking, on terms of perfect equality with us."

He was very fond of flowers, and also of dogs. When he had been absent from home, on his return his white fox-terrier, Polly, "would get wild with excitement, panting, squeaking, rushing round the room, and jumping on and off the chairs; and he used to stoop down, pressing her face to his, letting her lick him, and speaking to her with a peculiarly tender, caressing voice."

He was very tender-hearted. A friend who often visited at Down told me that Mrs. Darwin one day urged her husband to punish the little dog for some wrong-doing. He took the animal tenderly in his arms and carried her out-of-doors, patting her gently on the head. "Why, Charles," remonstrated the wife, "she did not feel it." He replied, "I could do no more."

"The remembrance of screams or other sounds heard in Brazil," says Francis Darwin, "when he was powerless to interfere with what he believed to be the torture of a slave, haunted him for years, especially at night. In smaller matters, when he could interfere, he did so vigorously. He returned one day from his walk pale and faint from having

seen a horse ill-used, and from the agitation of violently remonstrating with the man. On another occasion he saw a horse-breaker teaching his son to ride. The little boy was frightened, and the man was rough. My father stopped, and, jumping out of the carriage, reproved the man in no measured terms....

"A visitor, driving from Orpington to Down, told the man to go faster. 'Why,' said the driver, 'if I had whipped the horse *this* much driving Mr. Darwin, he would have got out of the carriage and abused me well.' "

His manner was bright and animated, and his face glowed in conversation. He enjoyed fun, had a merry, ringing laugh, and a happy way of turning things. He said once, "Gray (Asa Gray of Harvard College) often takes me to task for making hasty generalizations; but the last time he was here talking that way, I said to him, 'Now, Gray, I have one more generalization to make, which is not hasty; and that is, the Americans are the most delightful people I know.' "

"He was particularly charming when 'chaffing' any one," says his son, "and in high spirits over it. His manner at such times was light-hearted and boyish, and his refinement of nature came out most strongly. So, when he was talking to a lady who pleased and amused him, the combination of raillery and deference in his manner was delightful to see. When my father had several guests, he

managed them well, getting a talk with each, or bringing two or three together round his chair....

"My father much enjoyed wandering slowly in the garden with my mother or some of his children, or making one of a party sitting out on a bench on the lawn; he generally sat, however, on the grass, and I remember him often lying under one of the big lime-trees, with his head on the green mound at its foot."

He had great perseverance in his work, and used often to say, "It's dogged as does it;" and "Saving the minutes is the way to get work done." It was his habit to rise early in the morning, and after breakfast work from eight to half-past nine, and then read his letters. At ten or half-past, he went back to his work till twelve. After exercise in the "Sandwalk," a narrow strip of land, one and a half acres in extent, with a gravel walk round it, planted with a variety of trees, in which he watched the birds and squirrels, he lunched and read his newspaper. After this he wrote letters, and about three o'clock rested for a time on the sofa, some of his family reading to him, often a novel,—the work of Walter Scott, George Eliot, Miss Austen, or others. At four he walked again, worked from half-past four till half-past five, dined, and usually spent his evenings, after a game of backgammon with his wife, or hearing her play on the piano, in reading scientific books. Conversation in the evening usually spoiled his rest for the night, but he could do a great amount of work if he kept to his regular routine. In each book, as he read it, he marked

passages bearing on his work. In reading a book or pamphlet, he made pencil lines at the side of the page, often adding short remarks, and at the end made a list of the pages marked.

Darwin said of himself: "At no time am I a quick thinker or writer; whatever I have done in science has solely been by long pondering, patience, and industry....I think that I am superior to the common run of men in noticing things which easily escape attention, and in observing them carefully. My industry has been nearly as great as it could have been in the observation and collection of facts. What is far more important, my love of natural science has been steady and ardent.

"This pure love has, however, been much aided by the ambition to be esteemed by my fellow-naturalists. From my early youth I have had the strongest desire to understand or explain whatever I observed; that is, to group all facts under some general laws.... My habits are methodical, and this has been of not a little use for my particular line of work. Lastly, I have had ample leisure from not having to earn my own bread. Even ill-health, though it has annihilated several years of my life, has saved me from the distractions of society and amusement."

Mr. Darwin was never egotistical, or elated by his great success. He always felt and spoke modestly of his work. In the village people of Down he took a cordial interest, helping to found a Friendly Club, which he served as

treasurer for thirty years. He also acted for some years as a county magistrate. The Vicar of Down, Rev. J. Brodie Innes, and Mr. Darwin were firm friends for thirty years, yet, says Darwin, "we never thoroughly agreed on any subject but once, and then we stared hard at each other, and thought one of us must be very ill."

In the hall of the great Natural History Museum in London, a statue of Darwin was placed June 9, 1885, with appropriate addresses.

Darwin's life is a most interesting study. That a boy who seemed in youth to have no special fondness for books, but an especial delight in collecting beetles; who appeared unfitted either for medicine or the church, should come to such a renowned manhood, is remarkable. His perseverance, his industry, his thought, his gentleness, his sunny nature in the midst of suffering, are delightful to contemplate. His books will be an enduring monument. He combined a great intellect and a great heart, which makes the most attractive nature, in either man or woman.

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 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.

Louis Pasteur—A Great Life-Saver

1822-1895

"Gentlemen, I propose a toast—To the peaceful strife of science."

Louis Pasteur.

"Mad dog! Mad dog!" That cry in any country, in any street, is terrifying even today; but how much worse was the cry "Mad wolf!" seventy years ago through the nestling towns of the Jura Mountains! To anxious fathers and mothers looking into the faces of their little children, it brought agonizing pictures: the wildest of creatures abroad in the hills, with glittering eyes and foaming mouth, tearing on and on, and about to descend on their village and their little ones playing in the sun. Very gravely Monsieur and Madame Pasteur cautioned small Louis and his two sisters to stay in the tannery-yard close to the house. With big eyes full of reflected fear, the children listened and promised to obey. Their training in truth made them keep the promise. The fears were not groundless. Instead of the poor old wolf wearing himself out in the forest on trees and roots, he did come flying through the village; eight people in the neighborhood were bitten; and, for a long time, every one in the country round was in terror of that mad wolf.

Louis Pasteur had been a Christmas present to his father and mother and four-year-old sister, for he was born in 1822, only two days after Christmas, in the village of Dole. I suppose no other present was half so welcome.

Though his parents had little to give him but their love, the child soon found his own playthings. We can imagine him cramming frail blue-bells into his grimy little hands for his mother and finding a world of delight in the bits of bark lying round the tannery-yard. Before long he began to feel proud of the good leather which his father made, and we can imagine him standing silently by while the ox or goat skins were unloaded from big carts, or the oak-bark was being ground for tanning. With a child's wonder he must have followed the long process from the scraping off of the hairy coats through the many soakings in the big pits, till, drained, dried, and oiled, there was a fine load of leather for the shoemaker. All this takes work and patience. It is sometimes a whole year before an ox-skin is ready to be made into a boot. In following this process, Louis's mind grew used to watching and waiting. The lessons of the tannery yard were the beginnings of his training in science. They taught him to look for developments.

Besides this, he had regular lessons in the little school near-by. Not till he went to boarding-school, however, do we follow his education with any vivid interest.

There was storm in the sky and gloom in his heart the day he left home for the big city school. Under the flood of rain, the horses pawed restlessly. They found it cold standing still so long while bags and trunks were hoisted to the top of the coach and while Louis and his friend, Jules Vercel, said a hundred good-byes to the same dear people. They were still shouting "Au revoir!" and waving hands buoyantly from under the tarpaulin, as the heavy wheels splashed away down the road. Buoyant they seemed, but their hearts were already swelling with homesickness. Through the mist, they said a silent farewell to the gray tower of Arbois Church. Then the hills dipped down and carried them rattling onward, bound for Paris.

But this homesickness was only a taste of the homesickness to come. Jules did not suffer as much as the younger boy, who, poor fellow, though he was fifteen, lay awake night after night in the far-away city saying to himself: " 'How endless unto watchful anguish night doth seem.' "

The green trees of the tannery were far dearer to him than the glitter of Paris. We can well imagine that as the clocks chimed the hours he wondered if they were all asleep at home and if they dreamed that he was sleeping too. I suppose the moon and stars told him that they were shining down on *them.*

"If I could only get a whiff of the tannery-yard," he confided to Jules, "I feel I should be cured."

At last the head-master, Monsieur Barbet, after trying everything else, wrote a few plain facts to Louis' father.

And so, one November day, Louis Pasteur was sent for. "They are waiting for you," said a messenger, pointing to a little café on the corner. The much-puzzled boy went over to the café. There at the table, with his head in his hands, sat some one dearly familiar—his father.

"I have come to fetch you." There was no rebuke in the tanner's simple greeting. The love-longing had overwhelmed the knowledge-longing in his son's heart that—was all. The father needed no explanations.

Nevertheless, Louis' knowledge-longing was very strong, and he had no idea of giving up study. At Besancon, forty kilometers (less than twenty-five miles), from Arbois, was a college where there was plenty to learn and where he could be prepared for the "École Normale" (normal school). Several times a year his father would go to Besancon to sell his leather. That the father would combine with this business a visit to his son, Louis knew well.

At school, the boy was so careful that people thought him slow. He slighted nothing. Absolute sureness, alone, could satisfy him. "Dear sisters," he would write home, "work hard, love each other. When one is accustomed to work, it is impossible to do without it; besides, everything

in this world depends on that." In one of his letters he spoke of studying mathematics till he got a "pretty bad headache." "But those headaches never last long," he quickly added, not willing to worry any one.

At nineteen he reentered the Barbet boarding-school in Paris. No longer a homesick boy, he had grown tall and self-reliant, and he soon proved himself so capable that he was asked to help with the teaching. By this means, his schooling cost him only one-third of the usual price. Outside of study or teaching hours, he and his great friend, Chappuis, had some good times. But Louis was always in danger of overworking. "You know how we worry about your health; you do work so immoderately," wrote his anxious father. "Are you not injuring your eyesight by so much night work?" Then that troubled father would appeal to Chappuis as a kind of caretaker: "Do tell Louis not to work so much; it is not good to strain one's brain," adding with affection: "Remain two good friends."

Miss Ida Tarbell gives a picture of Chappuis sitting beside him in the laboratory stubbornly determined to get him into the open air "until Pasteur, conquered, jerked off his apron, saying half angrily, half gratefully: 'Well, let us go for a walk.' "

In the Jura home, parents and sisters waited eagerly for Louis' thick letters, all packed with lovingness and the details of his happy work. The hopes of the whole family were centered in the boy at school. We can picture them

gathering round to read his letters aloud, and then each one taking the dear sheets to re-read, alone, to understand them better. How worried they were during one long time of waiting: "Eighteen days! Louis has never kept us waiting so long! Can he be ill?"

"Don't overwork," was the father's anxious warning; "so many noble youths have sacrificed their health to the love of science—Think what a worry it is to me that I cannot be with you to look after you." Again, he wrote, after thanking Louis for his Christmas presents: "For my part, I should prefer a thousand times that this money should still be in your purse, and thence to a good restaurant, spent in some good meals that you might have enjoyed with your friends. There are not many parents, my dearest boy, who have to write such things to their son."

And now the young man, whose father had taught him his alphabet, took a turn at teaching his father and his sister, Josephine. They established a private correspondence school—that little family. "The father would often sit up late at night over rules of grammar and problems in mathematics preparing answers to send to his boy in Paris." Among other helpful things, Louis suggested a cheaper and quicker method of tanning skins; but the father did not adopt it. It was, as yet, unproved; the leather might not be so good or last so long, he argued; because he had always dealt honestly, the shoemakers trusted his goods. He would rather keep their trust than

get rich. It is not hard to trace the strict honesty of Louis Pasteur, in all his scientific searchings, straight back to his tanner father.

Among the young people of to-day it is the fashion to laugh at the fellow who studies hard. "Resistance to knowledge," as Professor Phelps puts it, is a fad. "Grind" is a term of contempt. The average boy quails before it. But the fellow who delights in study never grinds. A few, like Pasteur, have a real hunger for discovery. Pasteur carried that hunger with him when he entered the École Normale. Here, to save time, his chemistry class did not experiment to get phosphorus; they were merely told how to get it; and many were satisfied to go no further. Pasteur, however, worked it out for himself: he bought bones, burnt them to ashes, and then "treated the ashes with sulphuric acid." We can imagine with what pride he wrote the label on his little bottle of home-made phosphorus. "This was his first scientific joy."

By a love for work that was almost a passion, Pasteur, so often called in the scorn of jealous rivals a "mere chemist", went on and on, from questioning lifeless, soulless crystals to waging war for man. His was a long line of interests, and they seem scattered and unrelated. That is because, whenever he found a need, he tried to meet that need with help. Crystals, acids, the ferments of milk and alcohol, the best way to preserve wine and beer, the diseases of silk-worms, hens, goats, pigs, and sheep,—cholera, fevers, and hydrophobia. All these seized his

eager attention. Scientific zeal, patriotism, and love for service goaded him on to further discoveries. He will be lastingly remembered as the Conqueror of Disease.

The tanner's son, in the hidden village of Arbois—the boy who had been called "slow," who had left the Paris school because he was homesick, and had entered the École Normale a little old for his class,—through working and waiting had grown very great, great enough to be known by the common people. The vine-dressers, who tended their grapes on the sunny hills of France, they knew his name. Because Pasteur had found a way to keep vines healthy, they could sell their grape juice, and bring home the shining coins to buy blue ribbons for Annette and stout shoes for Pierre. Pasteur had kept their hearts glad and their homes comfortable, and had saved one of the great industries of France.

By and by the shepherds, the goatherds, and the swineherds, even the poultry-men, heard his name. "Perhaps," one would say, "he would know what has got into our sheep." Twenty had died out of a hundred, beginning to droop only a few hours beforehand.

"It may be Pasteur could cure my hens," a second would suggest, as he leaned over the poor staggering creatures that seemed to have fallen asleep while they were trying to walk.

How much the tanner's son could do who had begun life by "curing" leather! France was his own land, and the

French his own people. In the sight of his eager patriotism, service done for the French was like service done for a big family. We hope that sometimes in the midst of his intensely practical discoveries he rejoiced that hundreds were happier because he had lived and because he had taught them how to get the best results from honest labor.

Of his many works there will be space, in this short sketch, to emphasize only two: his conquest of the silkworm disease, by which he saved one of the great industries of France; and his conquest of hydrophobia, by which he saved human life.

Pasteur had never seen a silk-worm when, urged by the French government, he attacked the epidemic that had raged among the silk-worms for fifteen years. But the boy, Pasteur, had known how much depended on the making of leather and it was easy for the man, Pasteur, as he journeyed into southern France, to see that the hopes of hundreds of families depended on successful silk-worm culture. What other use had those groves of mulberry-trees? With no silk to spin what would become of the mill-workers? Strange as it may sound, Pasteur was in a land where worms seemed more important than people. Three-year-old children understood that, whatever else happened, the fires that warmed the worms must not go out; and, since the worms are the *dainty* members of the family, everything that touched them must be perfectly clean. Silk-worms will not stay on dirty mulberry leaves. Pasteur, beginning with the tiny eggs, or "seeds" as they

are called, used this sure method of protection: The moth, which dies anyway soon after her eggs are laid, was "crushed in a mortar and mixed with a little water; the mixture was examined with the microscope,—and, if a germ of the disease was found, the eggs, between 300 and 700 from each moth, were immediately destroyed with everything belonging to them." It was the old, old law of the survival of the fittest.

Only the eggs from healthy moths are used for hatching, for, as some one has said, "from healthy moths healthy eggs were sure to spring, from healthy eggs, healthy worms; from healthy worms, fine cocoons," and of course from the best cocoons the best silk. Eggs are said to be "Pasteurized" when they are the eggs of a perfectly healthy moth. The word "Pasteurize" has worked into our dictionaries from Pasteur's great name and by it is meant that anything,—milk, for instance, is pure, free from living germs, health-giving. It is something for a man's name to stand in the dictionary, to the end of time, for *health*.

In Pasteur's five years' work to save the silk-worms, he had the satisfaction of seeing disease conquered. He wanted no higher pay. Creeping from millions of "seeds" came millions of worms, so tiny that at first the mulberry-leaf food had to be shredded. Soon, however, they were feeding away with a whispering noise, as if they were starved. Before long, from a moving mass of life, the separate worms showed themselves—great, grayish, velvety things as big as your little finger, fatter and fatter

every day, and ravenously hungry. By and by they tried to stand on their tails in the feeding racks, and reared and stretched their necks as if asking to climb. Then it was time for little Gustave to bring bundles of brier brush—the silk-worms' ladders. And, at last, clinging to tiny branches, there

"set to work millions of spinning worms
That in their green shops weave the smooth-haired silk."

The "reels" spun by one worm are anywhere from a thousand feet to more than two miles long. In the light of Pasteur's cure, it is no wonder that, after years of failure, the silk-worm husking was a jubilee. The cocoons, "heaped in round flat baskets, ready for market, were glorified, seemingly, into heaps of golden and silvern eggs by the afternoon sun." It was a time for feasting on delicious "home-made cheese, homegrown almonds and olives, and good home-made bread." We can easily imagine that during the laughter-filled feast, Marie dreamed of a fine new jacket and Babbette of a knot of bright ribbon, a lace fichu, and a bouquet of artificial flowers.

As for Pasteur, the restorer of all these smiles, it was enough to have brought such joy to unnumbered homes. To him, home had always been sacred. Some one once said: "If you want a definition of happiness, visit the Huxley family." The same thing might have been said of the Pasteurs. Louis had known nothing but love in his

father's low-roofed tannery; and he knew nothing but love in the other home which he and his wife had begun, in May 1849. Sorrows came. They came thick and fast. Three dear little girls were taken away from them, but the father and mother were strong in their belief that all would be again united. The deeper the happiness the deeper the loss, and the deeper the loss the deeper the need of faith in another life. Pasteur was one of the great scientists who kept his solid old-fashioned religion, and his comforting belief in immortality.

And, though he lost three children, a son and a daughter were left. Years later, after the son had entered the army, one bitter January day father, mother, and daughter set out to find him. In the dreadful reports of a hard fight, no news had come of their boy. Cruel suspense was almost as hard as certain sorrow. The same Jules Vercel who long ago had started with Louis Pasteur for boarding-school—Jules Vercel, now a man of fifty—was there to say good-bye to his old friend. He stood faithfully by as Pasteur helped his wife and daughter into a broken-down carriage—the only one left in the village and set forth into the storm. Snow whirled through the air thick with flakes. It drifted the roads with great, white piles. For four days they journeyed, stopping wherever they could for the nights. Part of the way lay through a deep pine-forest, perfectly silent except when heavy masses of snow fell from the spreading boughs. By the time they reached

Pontarlier, where they hoped to find their boy, the poor old carriage barely held together.

Madame Pasteur, with her face worn by cold, weariness, and fear, asked the first soldier she met for news of her son.

"All I can tell you,"—try as the soldier did, the words fell with harsh hopelessness,—"is that out of 1200 men in his batallion, only 300 are left."

But Madame Pasteur did not give up. While she was questioning another soldier, a third stepped up and said,

"Sergeant Pasteur? Yes, he is alive; I slept by him last night at Chaffois. He has remained behind; he is ill. You might meet him on the road towards Chaffois."

Chaffois? They had come right through it without knowing! It lay freezing miles behind them on the snow-banked road. But they could face again the stinging storm if their son was at the journey's end and in need. Barely had they started back when a cart labored by and from that cart some one muffled to the eyes peered into their carriages. And to that some one,—to the fellow who felt a life-time away from home—was it a miracle, or only a fevered-hope,—a beautiful delirious dream,—that his own people had come to him in the storm! Too full of feeling to speak, the little family "embraced without a word." On that bitter January day they were suddenly filled with wonderful warmth. Monsieur Pasteur took his sick son to Geneva to recover. And, no doubt, as he shared

his boy's joyful surprise, he remembered how long ago, another son had been surprised by another father: he was once more a homesick boy, entering, in wonder, a corner café, staring, in half-hope at a familiar head, and rejoicing in the welcome words, "I have come to fetch you." His father had taught him fatherliness and he knew how to bestow it on his worn out soldier boy.

Meanwhile he fathered many, not his own. Returned to his work of healing, as he entered the Zoological garden of the Institute, the children would run to him, throw their arms around him, and bless him with their perfect trust. And somehow the silver coins slipped very naturally out of his pockets into theirs.

"Pasteur is a man who would find advantage from living in a glass house," said Mr. G. M. Crawford. It is beautiful to have such a thing true. And if Pasteur had been in a glass house, through its transparent walls we might have seen that he not only tucked shining presents into the children's pockets but patted their heads, clasped their hands, and kissed their tear-stained faces, though the tears were never there for long.

"My child, it is all over!" he would exclaim soothingly,—"Mon enfant! Mon enfant!" It was hard for him to see even slight suffering, particularly in animals or children, he who had never had the "courage to kill a bird in hunting."

As his step was heard in the hospital, a halting step because he had had a paralytic stroke, the heads on the pillows turned toward him and the faces lighted with smiles of gratitude. It was worth the long hours spent in searching, the slow tests, the patient waiting; it was worth more than medals or degrees, this great love of thankful hearts. Pasteur had plenty of honors; but he counted them as words and ribbons. He was too great to think himself great. The world was the world, full of struggle and need and woe, and the most he could do in his full life was still very little.

Like Agassiz, he had a passion for scientific study and a great gift for teaching. His pupils came away filled with his love of truth; his unwillingness to state a fact unless proved and proved again. His teaching seemed like inspiration, and utterly tireless. It had been so patiently planned beforehand that all the patient preparation was concealed. It was like poured sunlight. Nevertheless, he would never rob a student of the joy of discovery. As a lad, it had meant much to him to make his own phosphorus. "Where will you find a young man," he would ask, "whose curiosity and interest will not immediately be awakened when you put into his hands a potato, when from that potato he may produce sugar, from that sugar he may produce alcohol, from that alcohol ether, and vinegar? Where is he who will not be happy to tell his family in the evening that he has just been working out an electric telegraph? Such studies are seldom, if ever, forgotten." At

the root of all his teaching lay the principle of *usefulness*. It was repeated and repeated again to hundreds. "One man's life is useless if it is not useful to others." As he grew older and realized too fully that the years would not grant him time to solve all his problems, he looked to his pupils to carry on his work. In praise of their faithful persistence he would say: "I pointed the way; but I had only conceived hopes and you bring in solid realities." He craved honors for them far more than for himself. But to his list of saved lives we must add part of the credit of the lives saved by the pupils he had trained.

One of the greatest glories of a sincere teacher is the thought that there may have gone forth from his work or his personality numberless hidden influences. His influence is cumulative and eternal, whether good or bad. If his aims have been good, his influence has been good. And much that he can never have the comfort of knowing may be hidden, but living in other minds and hearts. This thought comforted Pasteur: "Our only consolation, as we feel our own strength failing us, is the consciousness that we may help those who come after us to do more and to do better than ourselves, fixing their eyes as they can on the great horizons of which we only had a glimpse." This idea he hugged for his own encouragement when, like Agassiz, he thought, "Oh, if I only had time!" In his "passion for work" and his faithfulness to teaching, he was very much like Agassiz; in his heroic struggle, under the warning hand of paralysis, he was more like Scott.

To all teachers who have known how it feels to be fretted by teasing little details, his willingness to attend to little details stands as a strengthening example. It is an example to *anyone* who is nettled by the smallness of life's concerns—the gnats that swarm around our busy heads. Pasteur was not too great to look after the "catering; to ascertain what weight of meat per pupil is given at the École Polytechnique; to order the courtyard strewn with sand; the dining-room door to be repaired; and to look after the ventilation of the class-rooms." He was great enough to forget his greatness if little things needed his attention.

Let us see him, at last, however, not as a teacher but as a healer. To cure hydrophobia, before he could experiment on man, he had to experiment on animals. Let those who condemn it ask and answer the question: Is it better that a guinea-pig should suffer a little or that my only child should die? Pasteur never experimented without using chloroform, and, tender-hearted man that he was, he took the greatest care to save any animal from unnecessary suffering. Never had he shot an animal of any kind for sport. But when human life was at stake "Vivisection was a dreadful necessity." Even when he had multiplied his experiments, he said, half-fearfully: "I think my hand will tremble when I go on to mankind."

In Pasteur's life, the years 1885 and 1886 were marked by wonderful strides toward the conquest of hydrophobia. The terrible memory of the mad wolf of his childhood had

never worn away. It came back to him in manhood with fresh horror when, one July morning, an Alsatian mother, poorly dressed and leading a nine-year-old boy by the hand, entered his laboratory. Little Joseph Meister could hardly walk, and his small hands were fearfully bitten. In a voice full of restrained suffering and with beseeching eyes Frau Meister begged Pasteur to save her child. "He was so small!" she sobbed. "When the dog flew at him, he knew no more than to stand still and cover his face with his hands. A man, passing, beat off the beast with an iron bar. But there was my Joseph!—Oh, the dreadful blood!"

"I am no doctor," answered the scientist humbly. "I am only trying to discover cures; but I shall do my best for little Joseph." As he spoke, he gently laid his hand on the child's fair head.

When Joseph found that the treatment was no more than a pin prick, his dreary blue eyes began to shine again; he no longer dreaded the master's touch. Out in the sunny garden, among the rabbits, chickens, and guinea-pigs, he was very happy, and he generally slept more peacefully than the scientist, who tossed back and forth in the fear that the child would die.

But little Meister got well. And, furthermore, in his long stay at the laboratory he grew to be such a friend of "Dear Monsieur Pasteur" that he would run in from the garden, climb into his lap, and beg, with all kinds of childish pleadings, that some specially playful guinea-pig

or pink-nosed rabbit might not be used for experiment. And little Meister had his way, like many other children who loved Pasteur as a father.

One beautiful day in the next October, six little shepherd-boys had led their flocks to a green meadow glistening in the sunlight of the Jura Mountains. Here the juicy grass drew its richness from underground streams, and here the boys found flowery places to stretch out under the blue sky-roof and talk together in their soft French voices. From time to time they would move on to keep near their straying sheep, while bees hummed their way into the flowers' hearts and turned the bright cups upside down with the weight of their velvet bodies. The children's shepherd life was full of restful friendliness. Suddenly one of the boys, pointing to the road, shouted *"Chien enragé! Chien enragé!"* (Mad dog! Mad dog!) Fear raised his voice to a shriek. As the children scrambled to their feet, they saw a great creature turn, and tear towards them. Though they ran as fast as soft ground, wooden shoes, and fright would let them, that was not very fast. The dog came panting on. Then the oldest, a fourteen-year-old boy named Jupille, turned, to save the rest, and faced their maddened enemy, alone. With glazed eyes, and slimy turned-back lips, the dog was close upon him. Leaping into the air, he caught the boy's left hand between his gleaming teeth. Jupille's mountain-training came in play. The hills had taught him strength and swiftness. In his brave tussle, he managed to throw the dog to the

ground, kneel on his back, and with his right hand force the jaws apart to set his left hand free. Of course his right hand was terribly bitten too; but, at last, he got a grip on the animal's neck, and, calling to his little brother to bring him the whip, dropped in the fight, he fastened the dog's jaws tight with the lash. Then he worked with his wooden sabot till the heaving creature was so nearly dead that he could drag him to the brook and end his life.

White-faced, round-eyed, and trembling, the little huddle of shepherd boys drooped back to the village, all of them sure that Jupille would die, and all but Jupille feeling like murderers. (His life was the price of theirs.) But the Mayor, who had heard of Pasteur, sent the great scientist swift word.

Poor Pasteur! As yet his experimenting was too new; he was not ready to risk men. Little Joseph Meister, whom he had saved, had reached him only two days and a half after the attack. Jupille's wounds would be six days old. However, Jupille would have almost no pain (only a pin-prick a day), and it might mean life. The boy was sent for; and, not only, by patient watching, was he saved, but, through the recommendation of the fatherly Pasteur, received a prize for bravery.

Some of the great scientist's experiments were not successful. He had had a chance to treat Meister and Jupille within a week of the day they were bitten. Long postponed treatment was not so sure.

The next November, Louise Pelletier, a little girl of ten, was brought to him over a month after the mad dog's attack! Pasteur did all he could; but it was useless.

"I did so wish I could have saved your little one!" he said to the father and mother. Then, as he shut the door on their sorrow, the great man, himself, burst into tears. He had not explained his bitter disappointment in failure, or his own affection for Louise, nor had he told them that their little girl was just the age of Jeanne,—the first child given him and the first child taken away.

Although Pasteur had this sad failure, before long his fame was world-wide. By means of a public subscription, started by the *New York Herald*, four little Americans—children of poor laborers, were sent across the ocean to the wonderful healer. The mother of the youngest went with them. When her little boy, who was only five, felt the simple needle-prick, he asked, wonderingly, "Is this all we have come such a long journey for?" When, healthy and smiling, the four children came back to America, in answer to hundreds of questions about the "great man" they had no wonderful story. The treatment had been so easy!

But Pasteur had a story. On March 1, 1885, his doubts smothered by success, he could tell France that out of three hundred and fifty patients, only one had died—Louise Pelletier. The victory was wonderful, even taking into consideration that some of the dogs, reported as mad, may not have been so, and that some of the people, who

were *not* treated by him, died, not of hydrophobia, but of fear. There were men in his time who tried to lessen his glory by these two arguments; but there were others who, during his lifetime and since then, have called him, for the lives he saved, the "Greatest Man of the Nineteenth Century." Napoleon, with all his military genius, was not so great, because his business was to destroy life; Pasteur's was to save it. A certain map of the world is dotted all over with Pasteur Institutes for the cure of hydrophobia. And there is at least one man who would call the Nineteenth Century "The Age of Pasteur."

A few days after that great report of only one case lost in three hundred and fifty, the healer's own faith was again shaken. Nineteen Russians, who had been bitten by a mad wolf, arrived in Paris. Some of them were so mangled that they had to be carried at once to the hospital. Others walked bravely along, their dark eyes gleaming—half afraid, half hopeful—under their big fur caps. They knew but one French word—*Pasteur*. As Livingstone first spoke to the Africans with eyes and heart, so Pasteur spoke to these Russians. The word Pity was written all over his face. "I'll do my best to save you, my poor fellows," was his unspoken speech.

Yet there were, as always, ready doubters who, when three of the Russians died, began to attack Pasteur's whole method, apparently forgetting that it had taken a long time for the Russians to reach him, that they were terribly

bitten, and that a mad wolf's bite is much worse than a mad dog's.

If ever any one was stimulated by obstacles it was Pasteur; but he removed obstacles for others. He made all healing free. No one was ever turned away. French, Belgians, Spanish, Portuguese, Russians, they came to him in daily crowds. Some came, as people will, just out of curiosity—just to see Pasteur—the stout little man with the short beard and black velvet smoking-cap and the great name. He was always hard at work. Till within a few months of the very end, his energy went hand in hand with self-forgetfulness. Break-downs threatened him constantly; but the *saving of life*—left sometimes to the power of man—was too close to the *giving of life*—in the power of God—for him to let one great chance slip. Even at the last, he kept his youthful *enthusiasm*,—that pet word of his, meaning "an inward God." There are few things more divine than lives devoted to the hopes of others, whether they waver over sick worms, or sick sheep, or whether they hang on the life of a little child.

Vallery-Radot, in his beautiful story of Pasteur, gives a peaceful picture of the life-saver's last days. Though he could hardly walk or speak, his eyes were still bright, and, as he sat out of doors, "his grand-children around him suggested young rose-trees climbing around the trunk of a dying oak." On September 28, 1895, he gave up his long battle. There was a great national funeral: a military band, "infantry, marines, cavalry, artillery, and municipal

guards,...red-robed Judges and members of University faculties in orange, red, and crimson robes." It was all more showy than the tanner's son would have asked. His simple grave-stone better commemorates his simple start in life. Though his name will always mean intense energetic action, that plain stone speaks of well-earned rest:

"ICI REPOSE PASTEUR"

John Muir-A Pilgrim from Scotland
1838-1914

On the distant coast of Scotland lies the little town of Dunbar, from whose hilltops the children can look out over the wild waters of the North Sea and watch the ships sailing past on many a dangerous voyage. Close by is the old castle-fortress, around which many a battle has been fought. In this little town so rich in history, a young couple, Daniel Muir and his sweet wife Anne, set up house-keeping about eighty years ago, and on the twenty-first day of April, 1838, a baby was born to them, to whom they gave the good old Bible name of John.

As his parents looked at the helpless child, they little dreamed of the long journey he was to make from this quiet home, and of the fame he would win by means of his active mind and his love of all beautiful things.

John's father was a stern man who believed strongly that to spare the rod was to spoil the child. John's mother, on the other hand, had a most tender heart, and many a time she helped John and his brothers escape the whippings they often deserved.

The simplest food was served in the home. On the broad shelf of the dresser stood a row of wooden dishes shaped like tiny tubs. In these "luggies", as the Scotch people call them, John's mother served the breakfast of oatmeal porridge to her children, sometimes adding a

little milk or treacle to each portion. During the meal there was no lively talk of work or play. That would have been wicked, so the father thought, for before each meal began he asked a long Scotch blessing; and while eating, he told his children, their thoughts should be of God and of his kindness in giving them food.

When noon came, a hungry group gathered once more about the table. Again there was the long blessing, after which came dishes of vegetable broth, a little meat, and all the barley-meal scone the children could eat.

In the late afternoon there was another meal, when each child had half a slice of white bread without butter; plain as it was, it was looked upon as a delicacy. There was also barley scone and a cup of "content." This drink, with such a delightful name, was simply warm water to which a little milk and sugar had been added.

In the evening, when work and study were over for the day, a fourth meal was served, consisting of a boiled potato with more barley scone. After this the father took down his Bible, and his wife and the children gathered around him silently, while he read and prayed before sending the little folks to bed.

Not far away from the Muir home lived Grandfather Gilrye, and little John used often to visit the old man and tell him of his childish adventures. Grandfather Gilrye taught John his letters, pointing them out on the signs

over the shops on the other side of the street, when the boy could have been scarcely three years old.

Before John was five, there came a great day in his life—he went to school! Clean and sweet from a sound scrubbing, he stood before his mother while she hung a green bag around his neck. In this bag was his first reader, which was soon to be followed by a second and a third containing stories that seemed so real to John he delighted in reading them over and over again.

Before his school days began, the little three-year-old boy had an adventure which he never forgot. He had gone for a long walk with his grandfather, and after a while the two sat down to rest on a haystack in a big field. Suddenly John jumped up.

"Listen," he said. The boy's quick ear had caught a sharp, thin cry from deep down in the hay.

"It is only the wind," his grandfather answered. But John was not satisfied and began to dig down into the stack. There, at last, he found a family of field mice, a mother and her young, and the sight filled the boy with wonder and delight. In after years, when he traveled in the wildest places on the earth and came upon strange and dangerous animals, he was never more excited than on that day when he discovered a field mouse nursing her young.

John learned songs in school that made him think of the birds which came flying about his home. When the

spring opened, the children sang of the swallows returning from their winter haunts in distant lands. As they repeated the words,

"Welcome, welcome, little stranger,
Welcome from a foreign shore,"

they swung their bodies backward and forward in time with the music.

Then there was the cuckoo song about the wonderful bird that repeated his name so musically. Even the whale, the great beast of the sea, was remembered in the school songs. Sometimes, when John and his mates were playing on the hilltop behind the school, the little boy would look out over the great sea and think of the wonderful creatures beneath those waters.

The coast near by was a dangerous one, and when storms raged high, ships were sometimes wrecked on the rocks below. Then John and his playmates, watching eagerly, hurried to the shore to gather what spoils they might from the stranded ships. In his spare hours John carved toy ships and fitted them out, each with its proper rigging. Then, in the pond near his home, he would sail his boats and send them out on races with those of his boy friends. Even in the schoolroom he drew pictures of all kinds of sailing craft in his books.

John's father, a pious man, believed that no study could be as important as that of the Bible. Consequently, besides school lessons brought home to learn in the

evening, the Muir children were obliged to memorize hymns and chapters in the Bible. At home, as well as at school, the memory was encouraged in a most unpleasant way, for a word or line forgotten was followed immediately by a thrashing. John wrote afterwards that he was driven against his books as soldiers are driven against the enemy. "Up and at 'em" was the command he had to keep constantly in mind.

After all, there was some pleasure in Bible study, for the stern father really wished to be just. Thus, when John had learned to recite "Rock of Ages" without a mistake, he was rewarded by the gift of a penny!

John soon showed that he had an unusual memory. He mastered the New Testament so thoroughly that he could recite it, without help, from beginning to end. He learned some of the books of the Old Testament as well.

Though the school hours were long and there were many home duties, John managed to have a good deal of sport. The most loved playground was Dunbar Castle. There the little Scotch boy and his mates fought over again the battles of long ago. They climbed high among the dangerous peaks around; they had running and wrestling matches; they carried on mock battles, vying with each other in bravery as they remembered the heroes, Bruce and Wallace.

"When I grow up to be a man, I will be a soldier," thought John, and thus in rough games such as wrestling,

prisoners' base, hare and hounds, he strove to show no fear, nor to let a single line in his face indicate the pain that followed the falls or the blows. The whippings he received at home, as well, must be followed by no outcry, a thing which would be a sign of weakness not befitting a future soldier. John Muir was born of the fighting blood of old Scotland, so it is not strange that warfare was his favorite game.

Many a time there were fights in earnest among the boys of Dunbar. Only a coward, they believed, would not accept a challenge. Consequently, there were often black eyes which the parents and teachers accounted for in only one way,—there had been a fight. So, when John appeared at home or at school with a sadly discolored face, he knew that a sound thrashing was sure to follow.

"It is not fair," he would think. "If my father and teacher have the right to thrash me, surely I have the right to thrash my mates." But the older folks could not see the matter in that light; they had forbidden fighting, and disobedience should be punished.

John was a daring little fellow. Again and again he climbed up among steep crags overhanging the sea, in places where wiser folks would not have trusted themselves. In his own home also he faced dangers of which his parents never even dreamed.

This is how it happened. In the northland where John lived, the sun sets so late in the summer time that the light

lasted long after the children were sent to bed. John's next younger brother David slept with him. "Gude nicht," their loving mother would say, after tucking the boys into the old-fashioned bed. "Be quiet and go to sleep like gude bairns," she would add as she left them.

But there was no thought of sleep for those busy brains yet awhile. "Let's do scorchers," perhaps John would whisper, when the last creak of his mother's footsteps had died away; and David instantly showed himself ready for any deeds of daring, or "scorchers", that his older brother might suggest. First of all, there was the "ghost room" next door, into which only a brave boy would think of venturing.

But what was this "ghost room"? Strange as it may seem, many of the boys and girls of Scotland believe in ghosts and witches, the very mention of which brings fear and trembling to the little folks. A foolish servant girl told John that a ghost dwelt in the room next to his, and at night this ghost was quite likely to appear to any person who was brave enough to enter his abode. The girl's story stirred the boy to show his bravery, and he would dare David to take turns with him in making a rush into the "ghost room."

Such a "scorcher" as this Mrs. Muir would have laughed at. But not the scrambles the boys made in their nightgowns out of their dormer window to the high-pitched roof of their house.

In the winter, darkness set in very early. After John and David went to bed, they pretended to take imaginary voyages to far distant countries. Stowing themselves away under the bedclothes, they would pretend to visit places of which they had read in their geography lessons.

The boys traveled among the mountains and valleys of America, already a wonderful land in their imaginings; they saw India with her stores of jewels and rich perfumes; they journeyed to distant lands of ice and snow, and lingered among men and women speaking unknown tongues. Then, suddenly, sleep would overtake them while still far from home, and when their mother came for a parting look at her "dear bairns" before seeking her own pillow, she would find only mounds in the bedclothes beneath which the little travelers lay hidden.

John studied hard and delighted to be a leader in his class. When he was little more than seven years old he entered the grammar school, where lessons at once became very hard. When school ended in the late afternoon the little boy was by no means free. With a strap full of books off he ran to spend the evening, generally at Grandfather Gilrye's, getting his lessons for the next day.

Besides the great amount of work required at school, there were still daily Bible lessons at home. A certain number of verses must be learned perfectly, and thrashings were ready to follow the smallest failure. Did

the little boy lose his spirit under so much discipline? By no means.

Like oases in the desert, free Saturday afternoons and the yearly vacation made delightful breaks in the hard school work. Again and again Mr. Muir would forbid his sons to leave their own yard where he felt sure they would learn no evil.

Ah! but beyond those walls were rocky cliffs, and beaches to which the tide was ever bringing fresh treasures from the sea. Best of all, there were green fields in whose trees birds built their nests. Neither John nor his brothers could resist the thought of the discoveries to be made, even though heavy thrashings were sure to follow. Egg hunting gave great delight to these little savages. One thing, however, always held them silent and wondering.

This was the beautiful song of the skylark. For whole hours John would stand listening and watching as a skylark rose suddenly from its nest in the grass near by. Soaring straight and high overhead, the tiny songster would come to a stop far above the earth, to fill the air with his sweet and wondrous song. Then upward still farther he would fly, till he was quite lost to sight. Again the beautiful song would come floating down, and the little boy would still stand watching, listening, for what was yet to follow,—the sudden downward flight of the bird to the ground below where his mate, sitting on her nest, was waiting for him.

Besides the birds, there were bees to follow, and the opening flowers of spring to search for; there were races in the bright clear air and sunshine; there were scrambles on the forbidden cliffs. Who could be coward enough to let thrashings stand in the way of pleasures such as these?

In one of the school readers were stories which excited John greatly. One of these stories described the wonders to be found in the American forests. It told of the sugar maple with its stores of sweet sap; a person only had to tap this tree in the springtime, when lo! out flowed a liquid sugar with a taste so delicious it could hardly be described. To live in the neighborhood of such trees, and to obtain for one's self a store of "sweets", must make any boy happy, John thought.

Besides the strange things of the earth in far-away America, the book told of wonderful flying creatures. For instance, there was the passenger pigeon that traveled as fast as thirty miles in a single hour, and could find its way home even if carried a thousand miles away. These graceful birds, moreover, according to the book, flew over the American continent in flocks so large that the sky was darkened as they moved along. There were millions of them in a single flock.

Soon after reading these stories, the little boy heard the grown-ups talking of a great discovery which had been made in America,—that of gold. Abundance of sugar and

abundance of gold! What more could any one wish? Surely the children of America were blessed.

One evening John and his brother David were studying, as usual, over at Grandfather Gilrye's. Into the room came Mr. Muir with news that almost took the boys' breath away, so great and wonderful it was.

"Bairns," he told them, "you needna learn your lessons the nicht, for we're gan to America the morn!"

You can scarcely imagine John's feelings. Picture after picture came rushing into his mind,—golden treasure, maple-sugar, flocks of passenger pigeons, and fruits and flowers different from any which he had ever seen. What a glorious world it was! And how fortunate was he, John Muir, to be able to go out into it.

After his father had left the house, the boys noticed that their grandfather did not seem to feel as joyful as themselves. Alas! he was getting old and was to be left lonely and sad. When they promised to send him a box of tree-sugar packed in gold from the new home across the ocean, he said sadly: "Ah, poor laddies, poor laddies, you'll find something else over the seas forbye gold and sugar, birds' nests and freedom. You'll find plenty of hard, hard work."

Before the boys left him for the night, he gave each one a piece of gold to keep in remembrance of him. Then away ran John down the street, shouting to his playmates, "I'm gan to America the morn."

The next morning John and David started on their travels with their father and sister Sarah. The dear mother, three other sisters, and their younger brother were to be left behind until a home should be made for them in the western wilderness of the United States. It was hard to part from the loved ones, yet the joyful thought of America soon chased the pain away.

First there was a short journey to Glasgow; then followed a long voyage of more than six weeks on an old-fashioned sailing vessel. Every moment of the voyage was filled with happiness for the two boys. There was plenty to do and see. Sometimes they worked with the sailors who liked the daring little Scotchmen. They showed the boys how they managed the ship in fair weather and in foul, and taught them the names of the various ropes and sails.

John and David also learned the songs that the sailors sang on calm evenings. There were games which the boys played with other small passengers, chasing each other in glee over the deck of the old vessel. Most exciting of all were the storms, when the ship rocked so wildly that nearly all the passengers lay ill in their berths. At such times John's heart beat fast with delight. He enjoyed the rushing of the wind, the dark clouds sweeping past, the waves chasing each other and sometimes sweeping over the deck of the vessel. Well did the boy afterwards remember the day when the longed-for shores of America appeared in sight; soon the vessel drew up to a big pier,

and eleven-year-old John stepped for the first time on American soil.

His father had at first intended to go to the woods of Canada, but his fellow passengers told him he would find no better place to settle than in the fertile fields of Wisconsin. So, loading the tools and furniture which he had brought from Scotland on a train bound for the west, he and the three children started on their way towards the wilderness.

When the car ride came to an end, there were still one hundred miles to be traveled in a heavy wagon over rough roads. Even then the end had not been reached, for Mr. Muir did not know exactly where to settle. Leaving the children in the town of Kingston, he went out to find a good piece of land which no one else had taken up. He soon returned with the joyful news that he had found a place on the shore of a beautiful lake.

The nearest neighbors were very kind to the newcomers. With their help a small log hut was quickly built on a sunny spot above the lake, and John's sister Sarah set up housekeeping for her father and brothers.

For a few days the boys had spare time in which to wander about the country around their new home. Each hour brought fresh discoveries. For instance, there were many kinds of birds which the children had never seen before, one of these being the beautiful blue jay. The very day of his arrival John discovered its nest filled with green

eggs close to the hut, but the parent birds were so frightened at the nearness of two noisy boys that they lost no time in secretly emptying the nest. How did they manage to carry away the eggs? This was the first question in regard to any creatures of wonderful America that John asked himself. And in the long and busy years afterwards spent with Mother Nature, he was never able to get an answer. Then there were the woodpeckers which bored wonderfully round holes in the trees. How could they succeed so well with no other tools than their own sharp beaks? There were whippoorwills with their sad evening cry, nighthawks, and the brave little kingbirds, and many other flying creatures.

The birds were not the only things that interested John. There were the changing cloud banks of the sky, the frogs in the lily-bordered lake, the flowers, many of them new to the eyes of the Scotch lad; best of all, perhaps, were the thunderstorms, when black cloud-mountains stretched themselves across the sky, and lightnings chased each other in long shafts of dazzling brightness.

At these times John had no thought of fear. Filled with wonder, he would stand silent, looking up at the scene overhead and listening to the mighty crashes of thunder which shook the earth beneath him. During those first weeks in the wilderness, the boy was studying hard in Nature's school. These were "love lessons" as he called them afterwards.

Besides the wild creatures of the fields and forests, John had much to interest him in his own yard and home. There were the patient oxen his father had bought for plowing; there was a mother hog with her family of funny, squealing babies. There was also a lively puppy, and a cat with her kittens for whom she went hunting and brought home many a feast of birds and squirrels. There was a pony on which the boys took turns in learning to ride. Then too there were sociable little field mice which scampered about the children's feet as they knelt with their father at evening prayers.

Work soon began in earnest. A house was built, into which the family moved in the autumn when John's mother arrived with the other children. Trees were cut down and brush burned away. Plowing and planting had to be done, cattle and hogs fed, corn shucked, hay cut, and wood sawed for fuel. John, being the oldest boy, had the care of the work-horses. He became very fond of them, and when one was stolen by an Indian he grieved as though he had lost his dearest friend. The Indian was afterwards caught, however, and the horse brought back to the farm. Then great was the joy at Fountain Lake, for such the new home had been named, as this particular horse, Nob, was very intelligent.

When John was only twelve, he had to do a big share of the plowing, though his head scarcely reached above the handles of the machine; he split rails for fences, he planted and gathered crops, he threshed grain, and he

guided the mower. In summer the little fellow had to get up at four o'clock in the morning, and it was often nine o'clock at night before he could tumble into bed, so tired that he hardly knew how to get there.

Mr. Muir was, as we know, a stern man who believed that tenderness would spoil his children. And so, when John had the mumps during a busy season, he was kept at his work though his throat was so swollen he could take no food except milk, and he became so weak that he sometimes fell in the harvest field. At another time he was seized with pneumonia, and was so ill that he simply could not stand. For weeks he lay between life and death.

The summer season, which should have been happy and care-free, was the busiest of all. Now was the time to gather the harvests of wheat, and to hoe the corn. The scythes must be kept sharp, the cattle and horses fed, water brought from the spring to the house, and wood chopped for the fires. Seventeen hours of hard work, one after another! And then, when the head was dizzy and the back and feet aching, the boy must try to hold his mind steady during the family prayers which ended the day.

The winter brought its own work. The cattle must now be carefully fed and housed, for the cold was often severe. This was the season for cutting down trees, making new fences, and mending old ones. Corn must be shucked and the farm tools repaired.

But even now there were pleasures. One of John's greatest delights was to watch the snowstorms. He quickly discovered that the snow here came down differently from that in Scotland. There, great feathery masses fell upon one's face and clothes, while on the Wisconsin farm the flakes were separate, like crystal daisies. "God's darlings" the boy might have called them, as he afterwards spoke of the shining rock crystals which he discovered in the western mountains.

The evening sky also had great charms for the lad. The stars were brighter than those of the homeland. Sometimes there appeared in the sky the "Merry Dancers", as John had learned to call the aurora. The children at Fountain Lake enjoyed watching the trembling light as it spread over the heavens, or shot in long streams from out of the north.

But the springtime! This was the season of the year John loved most. The work was lightest now, and there was more time to enjoy the wonders of the world around. Millions of passenger pigeons came flying from the south, followed by immense flocks of geese and ducks. First of all the newcomers were the bluebirds. Then came the robin, so ready to make friends, and the gentle brown thrush, with its sweet song of evening.

While John was getting acquainted with these and other birds, he was also making many discoveries. He watched the budding of the different trees and learned

their names; he searched for the opening flowers; he listened to the humming of numberless insects.

A great treat was in store for the Scotch lad during the first days of summer. Then his keen eyes discovered wild strawberries hidden among the meadow grasses and in the bits of open woodland where the sunlight could make its way. Whenever the Muir children had a few spare moments, they would scamper down to the pastures in search of the tempting fruit.

Strawberries were soon followed by dewberries, huckleberries, and cranberries, which John's mother used in making wondrous pies such as had never been tasted in the home across the ocean. Then came the time when stores of nuts were gathered. Doubtless no tree seemed so precious then as the hickory. It gave large supplies of nuts; and also, if deep cuts were made through the bark, syrup as sweet and delicious as sugar would work its way to the surface. John loved this hickory syrup.

There were few holidays at Fountain Lake. On Sunday, of course, only the most necessary work was done, but there was church to attend, and Sunday school for which lessons must be carefully prepared. Only a small part of the day was left in which John and his brothers and sisters could do as they pleased.

There were two days, however, on which the Muir children were free from morning till night. Many were the discussions held by John and his brothers as to the way in

which these should be spent. Should they visit young friends on near-by farms? Should they spend the precious hours reading favorite books? Should they work on machines which John's busy mind had invented? These were some of the questions which the boys asked each other, though they generally ended by spending the holiday on a high rocky hill which they called the Observatory.

During those first years in Wisconsin, John Muir often did what in after years he thought was wrong,—he went hunting. In this cruel sport he acted, as he afterwards called himself, like a little savage. Around the borders of Fountain Lake were the nests of numberless muskrats, gentle little creatures as wise as beavers. And yet, when John went to the lake, he often set traps for these muskrats. In the fields near the house he hunted the busy little badgers which had burrowed their homes in the earth. He killed many a rabbit as it scampered through the woods.

None of the wild animals John discovered were more interesting than the flying squirrel. Then there was its cousin the chipmunk, whose bright eyes often discovered ripened fruit and nuts before the children of Fountain Lake had a chance to pick them.

During the winter season, when snow covered the ground, John watched for the tracks of deer. Indians were often seen following the shy creatures in hot pursuit. Woe

to the poor deer then, for the red men seemed untiring. Mile after mile they would skim along on their snowshoes till at last their prey was worn out. Then whiz flew the arrows, and the victims lay dead before the hunters.

"My sons, you should learn to swim," Mr. Muir said one day. He had little time to teach the boys, so he advised them to watch the frogs.

"See how smoothly they kick themselves along and dive and come up again," he said. "When you want to dive," he added, "keep your arms by your side or over your head, and just kick, and when you want to come up, let your legs drag and paddle with your hands."

John and his brothers were glad enough to receive their father's command and accordingly went down to the lake as often as possible to take lessons from their frog teachers. They were soon able to dive, as well as swim around the edge of the lake where the water was shallow. Then came the Fourth of July. A boy visitor arrived to spend the holiday and it was decided to spend the happy hours at the lake.

Later on in the day, John thought, "This is a good time to try swimming in deep water," and he struck out from the shore towards the boat in which his visitor sat with back towards him, fishing. He reached the boat safely and raised his arm to take hold of the stern, but he did not lift it high enough. And now he felt the force of the upward stroke, forcing him downward. Confused with sudden

fear, he sank to the bottom of the lake. He rose once more, but was too much frightened to call for help, and sank again to the bottom.

Again he rose and sank, till his lungs almost filled with water, and he would soon have drowned had it not been for his strong will. "How foolish I have been," he thought, "not to remember that I know how to swim under water." Accordingly, without trying to raise his head to the surface, he kicked himself along till he reached a more shallow place. He was now able, to get his mouth above the surface and to cry, "I canna get out."

The boat came quickly to his rescue, and he was soon ashore, safe and unharmed but much ashamed of himself for giving way to fear. That night, when he thought of what had happened, he decided to punish himself for behaving, as he thought, in an unmanly way. He crept down to the lake in the darkness, got into the boat, rowed far out into deep water, and took off his clothes. Then, taking a long breath, he dove from the stern; down he went for thirty or forty feet.

Not a fear had he this time, however, as he paddled to the surface. Not yet satisfied, he swam round and round the boat, and then, getting in, made ready for a second dive. Over and over again he dove and swam, each time saying to himself, "Take that."

Eight years were spent at Fountain Lake. At the end of that time, the land had been cleared and shut in by fences,

and a good house and large barns had been built. It seemed at last as though John might be able to have life a little easier. But no! His father now decided to buy a stretch of wild land a few miles away and start a farm there.

John's heart must have sunk at the thought of what this meant,—the old story of land-clearing and stump-digging and house-building to be repeated. And as he, the oldest son, had borne the brunt of the work before, he must expect to bear it again. In fact, he had already taxed his strength so much that he had not grown as he should, and for this reason he had won the nickname of "Runt of the family."

The new home was called Hickory Hill because of the many hickory trees around it. It was beautifully situated, but Mr. Muir found one great difficulty in getting settled: there was neither spring nor stream at hand to supply the family with water. Only one thing could be done, and that was to dig a well near the house. After the work was begun, it was found that below the first ten feet the shaft must be sunk through solid rock. Mr. Muir tried to blast the rock, but did not succeed.

"John," said he, "you will have to do the work with a chisel."

The task that lay before the young man was a great one. Nevertheless he did not dare to refuse, and for many months he dug patiently away through the long hours of each day. Soon after sunrise he was lowered into the dark

narrow well, and there he stayed and chipped away the rock bit by bit till night fell, except for the noon hour when he was drawn up for dinner and a few whiffs of fresh air.

One morning he came close to death. He had been lowered into the well, now nearly eighty feet deep, but was suddenly overcome by deadly gas so that he could not move. His father, not hearing any noise below, was frightened. He shouted to his son to get into the bucket and to hold on. This roused John enough to make him struggle against the choke-damp. He managed to crawl into the bucket and was hoisted up, nearly dead.

Even after this narrow escape, John kept on with the dangerous work until the bed of rock was pierced and fresh water gushed up. There was plenty of work still before him, but at least he was no longer shut out from the fresh air and light.

John Muir loved books. There were few save the Bible in that far western home, but the young man saved the pennies he earned by doing extra jobs, and with these he bought the works of some of the great poets. Shakespeare and Milton gave him the most delight. When he was reading these books he forgot homely farm duties, for he lived in a new and beautiful world. Years afterwards he spoke of the joy that only good books can bring.

Fond as the young man was of reading, there was little time for it because the father's rule was that after the day's work was ended and the family prayers had been said,

every one in the household must go to bed. On winter nights, however, John, who was eager to have every possible moment with his loved books, would loiter in the kitchen after the others had gone to their rest.

"If I can only gain five precious minutes before father discovers the light!" he would say to himself. And when, two or three times, he managed to be undisturbed for ten whole minutes, he thought himself a most fortunate youth.

Mr. Muir became vexed at the idea of having to order his son to bed so often, and once, when John happened to be reading a religious book, he called out: "Go to bed. You must go when the rest do and without my having to tell you." As he finished speaking, he probably thought that as John was reading a religious book, he had been a little too stern, so he added: "If you must read, get up in the morning and do it. You may get up as early then as you will."

How happy John was now! He knew well that as a true Scotchman, his father would dislike very much to break his word. But could he wake any earlier than usual without being called, he wondered. That night he went to sleep with one thought in his mind, *early*. And when he waked in the cold winter darkness and looked at the clock, he could have shouted with joy when he found that it was only one o'clock. Five long hours were before him to do with as he wished.

Should he read? Unfortunately, it was too cold to sit still unless he made a fire, and his father would object to that. "Aha," he said to himself, "I will work on one of my inventions." Accordingly, he went down into the cellar where he kept his tools and started work on a sawmill that should set itself. He had already made a barometer, and a clock whose hand would rise and set with the sun throughout the year. But time for such work had always been scanty. Now, however, he felt suddenly and gloriously rich. Why, there would be many other mornings like this one if he could only succeed in waking up! His wish was granted, and during the rest of the winter he did not fail to rise at one o'clock to enjoy the precious hours before dawn.

In the course of the winter he made a big clock which he fastened on an outside wall of the house. The figures on the face were so large that people working in the fields some distance away could tell the time easily. He also made a self-setting sawmill, and a large thermometer out of a piece of worn-out wash-board.

The thermometer was so sensitive that it was affected by the approach of people when five feet away. "A wonderful invention!" declared one of the neighbors, and Mr. Muir agreed with him. By this time, the other boys had grown up and left the farm to start life for themselves, but John was a home lover, and he still remained with the old folks.

He was dreaming dreams for his future, however. So was his mother who wished he might become a minister, and his sisters who thought he might become a famous inventor. John himself thought, "I would like best to be a physician." He knew it would require a good deal of money for the education needed to be a physician, so he planned to go to some factory or machine shop. He might make enough money there to support himself while he was studying.

Mr. Muir had never encouraged John to think he had a bright mind, so the young man had little faith in himself, though the neighbors were sure that he was a genius. One day he happened to speak to one of these friends of his wish to get work in a machine shop. The man gave him good advice.

"Take some of your inventions to the State Fair," he told him. "As soon as people see them, you may be sure of getting into any shop in the country, for they are out and out original."

Soon afterwards John told his father that he was about to venture out into the world.

"If I should be in need of money," he asked, "will you send me a little?"

"No," replied his father. "Depend entirely on yourself."

It was of no use to say more. The young man, however, had the sovereign which his grandfather had given him

when he left Scotland. He also had ten dollars which he had earned by raising wheat on what his father had considered a useless piece of ground. With this small sum of money and a queer-looking bundle containing two clocks and the odd thermometer he had invented, he started out on his journey.

A ride of nine miles brought him to the village where he was to take the train. There he stayed overnight at an inn. His queer bundle of inventions excited the wonder of the landlord and the other villagers.

The next morning he stood on the platform at the railroad station, waiting for the train to arrive. He had not been near a railroad since his arrival in Wisconsin. "Wonderful!" he thought, as the train thundered along the track and came to a standstill before him. The conductor was instantly interested in John and his inventions, and through his kindness the young man was allowed to ride in the engine and watch the workings of the machinery.

The moments of that strange and glorious ride flew by quickly, and John soon found himself at Madison where the State Fair was being held. When he reached the gate, the keeper, who had already caught sight of the clocks and thermometer, cried:

"Oh! you don't need a ticket. Come right in."

He was now directed to the Hall of Fine Arts, but when he arrived at the grand-looking building he became frightened.

"Exhibit the simple wooden things I have made, here?" he asked himself. "It canna be."

But when he opened his bundle and showed his inventions to the gentleman in charge, his heart was quickly made light again.

"Why, they are wonderfully beautiful and novel," he was told. They will probably be more interesting than anything else at the Fair."

The gentleman's words came true. Nothing else in the exhibit attracted so much attention. Articles were written about them in the Madison papers, and these were copied by other papers in the East. Standing in the crowd of sightseers at the Fair, the young inventor could not help hearing many words of praise, but he took care not to read the articles written about him in the papers. He was afraid that the praise given him there would make him proud.

At the close of the Fair he received a diploma, as well as a prize of about ten dollars in money. He could hardly believe in this sudden good fortune.

During the Fair, young Muir met a man who had invented an ice-boat.

"Come with me," he said to John. "I will give you work in my machine shop at Prairie du Chien." This seemed, at first, a good offer, but after young Muir had worked for the man a short time, he found he was gaining little knowledge. He left the machine shop and did odd jobs for

his board, having time enough besides to study drawing, geometry, and physics.

He was not making much headway towards the education of which he dreamed,—a training at the State University. Therefore, after a few months, he went back to Madison where he earned a little money by making and selling bedsteads that could be set by machinery so as to force the sleepers on to their feet in the morning. During this time also he earned his board by doing odd jobs. But he kept wondering how he could win entrance into the beautiful university with its lawns and lakes and its body of happy students. The question was answered one day by a student there.

"It is easy enough to get an education at the university," the student told him. "Little money is needed except for your board, and if you live on bread and milk, you can get enough food for a week for one dollar."

The way was clear. Young Muir felt sure he could earn enough money to support himself while he was going on with his studies, and was soon numbered among the students at the university. Four wonderful years went by. Spare hours were spent in teaching school, and during the long summer vacations there was always work to be had in the harvest fields.

John Muir did not work for a diploma because, if he followed the regular course, he could not spend as much time on the studies for which his mind was best fitted.

Even now he still worked on new inventions. One of these was a desk on which his books would arrange themselves in the proper position for him to study. Another was a bed that would not only set him on his feet at the hour for rising, but would light a lamp on dark winter mornings.

During his college life, the young man found himself loving nature more and more deeply. He often wandered off into the country to study the rocks and trees and flowers. When the university life came to an end, and the last good-by was said, John Muir's eyes were wet with tears and his heart ached at the parting. Yet there was a great pleasure before him: he had managed to save a little money, and with this to buy needed food, he started on a tramp around the Great Lakes.

When his money was spent, the young man was obliged to seek work on a farm. After a short time he left the farm to make rakes and brooms in a mill, where he invented a machine by which the tools could be made much more quickly than before. Next, he went to a carriage factory, where he met with an accident that made him blind in one eye for several weeks.

This accident filled young Muir with sadness. He had to stay in a dark room and was unable to read. Worse than this was the thought that he might never again be able to enjoy the treasures of fields and woods. The idea was a fearful one. If only sight should be restored!

"In that case," thought the sufferer, "I will devote myself to a study of the wonders God has given us."

At last there came a happy day when he was free to go out into the sunlight; and now, with a gay heart, the young pilgrim began a long tramp southward. He had no luggage except a bundle which he carried on his back.

In this bundle was a change of clothes, a plant press, a Bible, the poems of Robert Burns, and Milton's *Paradise Lost*. On walked the traveler till he reached Florida. During the whole journey, the young man generally slept on the ground and always ate the simplest food.

After enjoying the beauty of Florida for a while, young Muir sailed to Cuba. Here he was seized with a fever which had doubtless been brought on by sleeping in damp woods. He saw that he must seek a drier climate; but where should he go? He thought of the far western country of the United States and decided that he would explore its mountains and valleys.

In the year 1868 John Muir arrived in San Francisco, but he had little interest in cities for they are made by men. He was anxious to get out into "God's country" as soon as possible.

Soon after he stepped foot on the shore of California he asked a man whom he met in the street, "What is the nearest way out of town?"

"Where do you want to go?" said the stranger.

"To any place that is wild," replied Mr. Muir.

The man must have been astonished at the answer. Nevertheless, he gave the needed directions. He said: "You had better go down to Oakland Ferry. From there you can travel eastward toward our mountains." The pilgrim accordingly made his way to Oakland Ferry, and after crossing over, he and another young man with whom he had got acquainted started on a delightful journey towards the lofty Sierra Mountains.

At last they reached a steep, rugged canon whose lofty sides shut them in from the rest of the world. Trails which had been blazed along the way were now covered with snow. If the travelers should lose themselves here in this wild and dangerous country, they might easily starve; or if an accident should overtake them, there would be no one near to give help. But they were too happy to think of fear.

After several exciting adventures, the glorious Yosemite was reached. The clear air was strength-giving; the birds sang songs of welcome; flowers nodded their dainty heads; graceful hares and antelopes darted here and there among the trees. John Muir's heart leaped for joy.

"The rest of my life shall not be spent on my own inventions," he said to himself. "It shall be given to a study of the inventions of God."

This nature lover had little money however, and though he could live on fifty cents a week, even that small

sum must be earned in some way. So it came about that when he went to the Yosemite the next summer, he helped a shepherd tend his flocks in the mountains. After that, having noticed that many trees in the wilderness were felled by the storms, he built a sawmill on one of the slopes and set it to work. While the mill was cutting up the big logs the young man could sketch the country round about him, stopping only when it was necessary to feed the mill.

When it was good weather he slept on a bed of fir boughs, with the clear sky and its millions of lights overhead. But when storms raged he needed shelter, not only for himself but for his books and papers, and the rare specimens he collected in the wilderness around him.

For this reason he built a hut on a jutting crag high over the water wheel of his sawmill. In this little den he kept the cones and rare plants which he gathered, the sketches he made, and the notes he wrote about his discoveries. Neither men nor animals were likely to trouble him here, because the only way to reach the hut was by climbing a long, narrow ladder.

When John Muir afterwards became famous, Emerson, Roosevelt, and other great men visited him in his wild home. Year after year this great lover of God's free blessings spent nearly all of his time in the Yosemite, making interesting discoveries; he studied the wonderful trees of California, the strange plants, and the rocks which had been worn away in past ages. He learned much about

the creatures of the mountains and forests, from the big, clumsy bear to the grasshopper jumping with glee in the sunlight. It grieved this nature lover to hurt anything alive. He once said, "There is one thing that I hate with a perfect hatred,—cruelty for anything or anybody."

During Mr. Muir's life in the Yosemite he went from time to time down to the "bread line," as he called the nearest town. He had two reasons for going there. First, he must buy food; though if he had chosen, he could have satisfied his hunger by catching fish in the streams or hunting game in the forests. But he felt so tender towards all living creatures that he could not even consider such things.

In the second place, he wished to receive letters from his friends. Though he was never lonely in the wilderness, he loved these dear friends. He once said: "When I was in college I nearly starved; I lived on fifty cents a week, and used to count the crackers and jealously watch the candles, but I didn't mind after I got in here,—no bell that rang meant *me,* I was free to go and come, and here were things that were bread and meat to me,—things to fatten my soul, and all as free as the air. Ah! but I've had a blessed time in here. But I did wish the ravens would come and feed me so that I could keep at my studies."

In this wild life Mr. Muir had many exciting adventures. With no one near to bring help in case of accident, he climbed up the sides of dangerous cliffs and

made his way over snow and ice; he braved hurricanes,—yes, and even an earthquake.

When he left his Wisconsin home, you will remember that he had a ride in an engine, which was most exciting to the country lad. But what would that be beside a ride on an avalanche? This was what really happened once to Mr. Muir in the Yosemite. There had been a big storm, and the mountain slopes were covered with a heavy garment of newly fallen snow.

"The country round about must be a glorious sight from the mountain summits above," thought Mr. Muir. So he decided to climb up the side of a near-by canyon, over three thousand feet high, and with the snow loosely as well as deeply packed.

"A tramp of three or four hours will surely bring me to the top of the ridge," decided the traveler, and he boldly started out. He soon discovered he had guessed wrongly. At nearly every step he sank to his waist. Sometimes a plunge would leave only his head above the surface. Still he kept on.

"I can at least reach the summit in time to see the sunset," thought the brave man after many hours of plodding. "The beautiful light shining on the snow-covered peaks and valleys will repay me for my struggle."

His wish was not gratified, however, but in its stead he had a delightful and unexpected surprise. Suddenly all beneath him gave way. He had barely time to realize what

had happened,—he had started an avalanche. Instantly he flung himself on his back and spread out his arms to keep himself from sinking. Then, with a mighty rush, he felt himself being tossed about on the back of the snow monster as it swept down, down, down, to the valley below.

At the end of a minute the strange and wonderful ride was over, and Mr. Muir found himself lying unharmed on the top of an immense mass of snow. The traveler afterwards said of it, "Elijah's flight in a chariot of fire could hardly have been more exciting."

Sometime afterwards, Mr. Muir had another exciting experience in the Yosemite. One morning, at about half-past one o'clock, he was suddenly awakened. The moon was shining brightly. There was no sound except a soft rumbling underground and the rustling of branches on the trees about the little cabin. Mr. Muir knew at once what was the matter.

He sprang to his feet and rushed out of the hut, crying, "A noble earthquake! a noble earthquake!" Was he not fearful for one little moment, you wonder—alone in that great wilderness? No! His one idea was that nature was about to teach him a new and wonderful lesson. And then, with the earth shaking beneath his feet, the air was filled with a mighty roar, as an immense cliff a half-mile away was torn asunder.

Down into the valley below it crashed, a mass of thousands of small bowlders. As it traveled, it seemed a rainbow of glowing fire. The man who watched it tried afterwards to describe the wonderful sound that filled his ears. He said that if all the thunder of all the streams he had ever heard were condensed into one roar, it would not equal this rock-roar. The shocks had not entirely stopped when the listener hurried up the valley and climbed upon the fallen bowlders.

They had not yet settled into their new places, and were still grating against each other as though scolding at having been disturbed in their cliff home. The air was still filled with the dust of falling earth. Through it, however, the explorer could see not far away the beautiful Yosemite Fall shining in the moonlight; it had been unharmed by the earthquake.

Mr. Muir had hastened to this place of danger because he wished to settle what he had asked himself long ago how had bowlders lying at the foot of other cliffs found their way there? He could now answer: They had fallen during earthquake storms such as he had just been watching.

Mr. Muir made another great discovery in the Yosemite. This was that the gorges and canyons had been made by the work of mighty glaciers. Many ages must have passed since the great ice-rivers had done their work; but there was no doubt that they had once worn their way

through this part of the country, grinding against the rocks and slowly but surely wearing deep canons between lofty cliffs.

As years went by, Mr. Muir left his home among the Sierras to make journeys to other parts of the world. He went to Alaska, where he discovered the Muir Glacier. He traveled to Norway and Switzerland to study the work of glaciers there; he made a visit to South America; he joined an expedition to the far north, in search of the lost ship *Jeannette.*

During this voyage he sailed along the shores of Behring Sea, going as far as Siberia. His chief interest there was to study the work of glaciers. In the midst of many wonderful scenes, however, he never lost his love for the beautiful Yosemite Valley and was glad to return there.

When Mr. Muir first went to California, there were great stretches of land in the western country where there were no white settlers. But as time passed by, more and more people moved out into the wilderness. Then the question arose as to whether they should be allowed to buy any of the still unsettled lands which they might choose.

John Muir became much troubled over the matter. "It would be sad, indeed," he thought, "if this beautiful country with its falls and streams and flower-bedecked valleys should be cut up into house lots. No! The United States should always have breathing spaces for her people

where they can wander as freely as the wild creatures of the forest, and feast their eyes on the beauties God has given so abundantly."

Many people did not agree with Mr. Muir. Land stood in their eyes for money only, and they thought it would be a loss to this country to reserve thousands of acres for the pleasure of visitors. The devoted nature lover wrote and talked much on this subject for ten long years. At last the government followed his advice, and in 1890 a national reserve was made about the Yosemite. This came about largely through the persevering work of John Muir.

In 1879 this great naturalist married a Polish lady, Miss Louise Strentzel. Mr. Muir spent much of the time for the next few years with his wife in a lovely valley of central California. The house in which they lived was large and comfortable. They had a vineyard and many fruit trees. Two little daughters were born there.

Mr. Muir was very happy in this home; he enjoyed the company of his wife and children; in his cheerful study he wrote books and articles for magazines, and he edited a newspaper. Yet there was for him but one *home*, and that was the one Dame Nature had given him years ago among his loved mountains.

He often returned to the Yosemite during the rest of his life, for his greatest delight was in the world as God gave it to men. Happy and contented, studying nature

without worry or hurry, Mr. Muir lived on to the good old age of seventy-five.

One December day in the year 1914, the busy man's work was finished. He had lived a beautiful life and had been a very happy man. But what did he do for America? He has helped us to know God better through His wonderful works. He has noted many things in the lives of plants and animals hitherto unknown by men. He has written accounts of his discoveries, which have added to the knowledge and pleasure of wise, as well as ignorant, people. He has taught us to look more tenderly upon all things and creatures in the world. Perhaps his most valuable work was the gaining of a great national park which should be free to the poorest citizen of this United States.

Before John Muir's busy life ended, several American colleges honored him with degrees; he was made a member of noted clubs and scientific societies; wise men of different countries sought to know him, and great men were proud to call him friend. And when he died, he left the people of this country deeply grateful for the advantages and new knowledge which had come to them through the life of John Muir, the "Philosopher of the Yosemite."

Luther Burbank

1849-1926

A few years ago every one who went to California tried to see Luther Burbank, for the newspapers and magazines were filled with stories of the wonderful things he was doing. Plenty of men make houses, automobiles, ships to go on the water, and ships that sail through the air, clothing, and toys, but this man makes new fruits and flowers. It is not an easy thing to do, and Mr. Burbank has found that he needs all his strength and time for his work. So now, at his small farm at Santa Rosa and at his big farm at Sebastopol, strangers find a sign like this:

ALL VISITORS ARE LIMITED
TO FIVE MINUTES EACH UNLESS
BY SPECIAL APPOINTMENT

And during the six busiest months of the year, from April to October, other signs tell that it will cost ten dollars to stay one hour. These signs are not put up because Mr. Burbank is cross or rude, but because these strange new plants have to be watched as carefully as tiny babies. He can't leave them for visitors.

Luther Burbank was born in Lancaster, Massachusetts. When he was a baby in his cradle, his mother and sisters found that nothing made him dimple and crow with delight like a flower. They noticed, too, that

he never crushed a flower, and once, when a petal fell off a flower he was holding, he tried for hours with his tiny fingers to put it back in place. And when he was big enough to run about the house and yard, instead of carrying a toy or a dog or cat in his arms, he was usually hugging a potted plant of some kind, for as people saw his great love for such things, they were on the lookout for cunning plants for the dear little Burbank boy.

One day Luther was trudging across the yard, clasping a small lobster-cactus in an earthen pot, when he stumbled and fell, breaking the pot and plant. He cried for days over the accident.

At school, Luther was a delight to his teachers. There were few black marks against his name. He liked all his lessons, but the books that told him about birds, trees, and flowers pleased him most.

When Luther was old enough to go to Leicester Academy, he had for his dearest chum a boy cousin who knew Agassiz, and who through him became interested in science. This boy wanted to study about rocks and caves, rivers and fish, while Luther watched the birds that perched on the rocks and the trees that grew near the rivers. But the two spent many weeks tramping over the country together.

Luther worked several summers in a factory near his home. He was quick to understand machinery and invented a machine that saved the manager of the factory

a great deal of money, for it would do the work of six men. Luther's family and friends were sure he would be an inventor. But he himself wanted to raise flowers.

Luther saved a little money and started a vegetable garden. He tried experiments with the potato plants until he raised an entirely different kind than had ever grown before. Of course this made him want to experiment with other plants, and he stayed in the hot sun so much looking after them that he had a bad sunstroke. This led to his going to a climate where he might live outdoors during more months of the year, and where he would not be apt to have such attacks.

When Luther reached California, he had only a few dollars, rather poor health, and was among strangers. He tried to get work on farms or orchards, because he wanted to experiment with vines and vegetables. But if he got work, it was usually for only a few days at a time. Finally he was obliged to work on a chicken ranch, where the only place for him to sleep was in one of the chicken coops. The pay was small, and he did not have as much or as good food as some pet dogs get. But all the time he was saying to himself: "If I can have patience, I shall yet get a farm of my own."

By and by he was hired to look after a small nursery (this is what a big plantation of trees is called). He would have been perfectly happy there if sleeping in a damp room had not given him a fever. He was poor, sick, and

almost alone, but not quite, for a very poor woman, who had only the milk of one cow to sell, found him one day lying on a bed of straw, and ever after that insisted on his drinking a pint of her milk each day. He declared that this milk saved his life.

For some years Luther took one odd job after another until he saved enough to buy a small piece of ground. Then he was soon raising plants and making new varieties. He read and studied and tried experiments. Sometimes he failed, and even when he succeeded there was a good deal of fun made of him. Some people thought Luther Burbank was crazy. It seemed such an odd thing for a man to think of doing—making a fruit or a flower that had not been heard of or dreamed of before! But he did not pay any heed to all this sneering. He worked harder than ever. And before long, the first new plants were in great demand, so that by selling them he got money to buy more land. Today some of the largest orchards in California are growing from one of Luther Burbank's experiments. And our country is millions of dollars richer from his new kinds of plums, potatoes, and prunes.

Mr. Burbank bought acres of land, hired armies of workmen, denied himself pleasures and visitors, and did not mind how tired he was, so long as old plants were being made better, or new plants were being created. Pretty soon letters began to come from Russia, France, Japan, England, South America, and Africa, asking for

some Burbank plants and some Burbank advice as to their care.

Mr. Burbank has made more new forms of plant life than any other man. He has worked on two thousand, five hundred species of plants. Besides making flowers more beautiful and of sweeter fragrance, he has done wonders with the cactus plants that grow on prairies. Once all these plants were covered with thorns and prickles, so that the cattle who bit into them rushed away with bleeding mouths, feeling much the same as we should if we put our teeth into a stalk of celery and bit on to fish-hooks and needles. Well, Mr. Burbank has changed all that. The fruit of some of his cactus plants is almost as sweet as oranges; the thorns are all gone so that the stalks are fine food for cattle; some of the leaves make good pickles or greens; and the small plants are used for hedges. So the plants that were in old times a pest and nuisance are to-day, thanks to Mr. Burbank, a comfort to the world.

Luther Burbank is a handsome, courteous gentleman, fond of fun, of young people and children, but you can see how busy he has been in the odd science of making new plants and trees, and as he has plans for a great many more, you will also understand why he really has to have those signs put up around his farm at Santa Rosa.