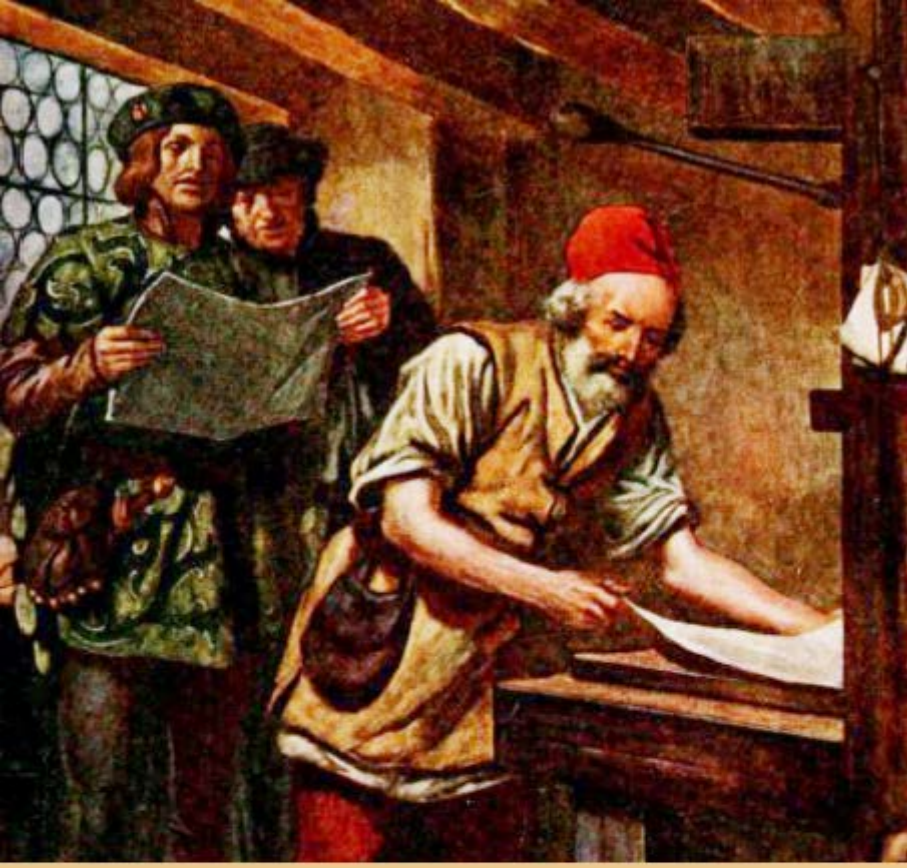


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Stories of Great Inventors

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Table of Contents

Conquests of Invention 1

Early Inventors 5

Laurence Coster, The Discoverer of Type-Printing ... 17

John Gutenberg, The Inventor of the Printing-Press . 24

John Gutenberg and the Invention of Printing 31

The Romance of Pottery—Enameling Earthenware Invented by Palissy 51

Extraordinary Career of Böttgher, the Inventor of Hard Porcelain..... 61

James Watt, the Inventor of the Steam Engine 70

Eli Whitney, The Inventor of the Cotton Gin 77

Samuel F. B. Morse The Inventor of the Telegraph 130

A Knight-Errant of Invention, Charles Goodyear .. 192

The Conquest of the Reaper, Cyrus Hall Mccormick 211

The Inventor of the Sewing Machine, Elias Howe . 226

The Inventor of the Air-Brake, George Westinghouse 241

The Story of the Telephone, Alexander Graham Bell 253

The Franklin of Our Times, Thomas Alva Edison . 267

Machines for the Millions, Henry Ford 293

The Conquest of the Air: Samuel Pierpont Langley, Wilbur Wright, and Orville Wright 306

Wireless, Guglielmo Marconi 322

Conquests of Invention

The story of the development of civilization is one with the story of man's conquests through invention. It is only in the power of mind that man is first among the creatures of earth. Puny in strength compared with the beasts of the jungle, he has reinforced his arm with weapons sharper than the tiger's tooth and surer than the lion's spring. His sight is weak compared with that of the hawk or the eagle, but he has made for himself magic glasses to bring the stars near and to reveal the marvels of the world invisible to the naked eye. Less fleet of foot than the dog or the deer, he has harnessed steam and electricity to carry him over land and sea and to send his thought and spoken word across the world with the speed of lightning.

Everywhere he has conquered through mind,—through applying reason and ingenuity to the problems that nature presents. The world challenged his powers at every turn, and as he met the challenge fairly and squarely, he rose step by step in the scale of existence, winning through struggle a fuller and freer life.

First, living by hunting and fishing, he was the prey of famine when game was scarce or when rival tribes

invaded his hunting-grounds. This hard life of uncertainty and warfare was greatly improved when the hunter learned to tame animals and to live by the milk, the meat, the wool, and the skins, of his flocks and herds. The change brought about by the domestication of sheep and cattle marks a distinct advance in civilization. It was not, however, until with agriculture a supply of food was assured which made a wandering life in search of fresh fields unnecessary, that permanent homes were built, and a new step in civilization reached. With this new stage came the desire for beautiful possessions, and the handicrafts were developed. Men became masters of the arts of weaving, of painting, and of wood-carving, and in working out their fancies in leather and in metals.

Then, as cities grew, the demand for quicker and cheaper ways of making things led to improvement after improvement in labor-saving tools and devices, until finally a new age—the age of machinery—had dawned when "iron men" did in a moment the tasks that had formerly required weary days. The scythe yielded place to the harvester that cut, bound and threshed the grain. As the sharpened stick of the first farmer had been succeeded by the steel plow, so this in turn gave way to the steam plow and the tractor which made possible the cultivation of thousands of

acres with less expenditure of man-power than had been required by a hundred acres under more primitive methods. The spinning-wheel and hand-loom were replaced by cotton and woolen mills; the hand-made garments fashioned by the mother of the family were replaced by machine-made clothes from great factories. Cities were lighted by gas and electricity. Rapid transportation could now bring the fruits of the tropics to those who "never felt the blazing sun that brought them forth"; and all peoples into closer relation one with another. The paper that we read at our breakfast-table gives us news of all the world.

These are some of the conquests of invention. But let us remember that conquests do not always lead to a golden age of prosperity and peace. Let us not dream that the greatness of our country can be measured by the size of our cities or the power of our big machines. Unless these things help to make people better and happier, unless they give fuller life and liberty, they have not really added to our civilization. For the chief wealth of a nation is to be found in the content of its people; and civilization depends upon the understanding, the industry, and the generous spirit with which all work together shoulder to shoulder.

Let us not put our faith in the bigness of our machines but in the strength and courage of the men who labor.

And, since "men are square," our faith will not be in vain if they are given an equal chance and a square deal. The triumphs of invention and the increase of wealth will then mean not new difficulties and dangers but a true conquest.

Early Inventors

An imposing ceremony took place not long ago in the ancient historic city of Syracuse, in the Island of Sicily. A tardy statue was raised by the Syracusans to their most famous man, who has been two thousand years in his grave.

The statue looks out upon the purple waters of the beautiful bay, which, nearly two centuries before Christ, witnessed some of those signal triumphs of science, which have rendered the name of Archimedes forever illustrious.

In the authentic history of invention, indeed, the name of Archimedes stands earliest and first. No doubt there were many inventors, and great inventors, before his time; but Archimedes is the first known inventor whose astonishing labors have come down to us in clear and trustworthy narrative. He is, therefore, entitled to be called the patriarch of science.

And the more we learn of this wonderful Syracusan, the more we marvel at the ingenuity of his genius, and the creative power of his intellect. He is declared to have been equally skilled in all the sciences; in astronomy and geometry, in hydrostatics,

dynamics, and optics. He was the parent of the art of civil engineering. He was the author of a great number of precious inventions. He established the modern system of measuring curved surfaces and solids.

He was the first to prove the important fact "that a body plunged into a fluid loses as much of its weight as is equal to the weight of an equal volume of the fluid." The way in which he discovered this principle is curious and interesting.

His cousin, Hiero, King of Syracuse, wishing to make an offering to the gods of a golden crown, ordered a certain goldsmith to make one for him. It was soon found, however, that the goldsmith had dishonestly made part of the crown of silver. Hiero called upon Archimedes to find out how much silver had been inserted in the crown.

The philosopher was perplexed; but one day, while taking a brimming bath, Archimedes observed that the quantity of water which overflowed was just equal to the bulk of his own body. Leaping out of the bath, he ran homeward, exultantly crying: "Eureka! I have found it!"

He now made two masses, one of gold and one of silver. Filling a vessel brim full of water, he alternately inserted in it the gold and the silver mass. He thus

found the measures of water which answered to a certain quantity of each of the two metals; thereby proved the comparative weight of gold and of silver; and was able to show just how much of the baser metal had been inserted in the golden crown.

The whole life of Archimedes was romantic. His scientific triumphs were striking and brilliant, and the influence of his absorbing labors was marked and enduring upon the progress of the human race. His most noted achievement, perhaps, was the part he took in defending his native Syracuse from the assault of the Romans under Marcellus.

The city was sore besieged by the Roman galleys. It seemed as if nothing could avert its doom.

"The vigorous attempts made by Marcellus to carry Syracuse by storm," says Livy, the Roman historian, "had certainly sooner succeeded but for the interposition of one man, Archimedes; famous for his skill in astronomy, but still more so for his surprising invention of warlike machines. By these, in an instant, he destroyed what had cost his enemy vast labor to construct. Against the Roman vessels, which came up close to the city, he contrived a kind of crow or crane, projected above the battlements, with an iron grapple attached to a strong chain. This was let down on the

prow of a ship, and, by means of the weight of a heavy counterpoise of lead, it raised up the prow, and set the vessel upright on her end."

Another story, the truth of which was long doubted by philosophers, but the probability of which has been shown by the later discoveries of science, is, that Archimedes set the Roman ships on fire by means of mirrors. When the ships were within bow-shot of the shore, Archimedes placed some hexagonal and smaller mirrors, each at a proper distance, opposite the sun, and moved them by means of hinges and metal plates. Directed upon the ships, these were set on fire, and were burned as if by the operation of magic.

The possibility of this remarkable feat of science has since been many times shown. It is asserted that in the sixth century a famous man of science, Proclus, set fire to the Thracian fleet in the harbor of Constantinople, by means of mirrors made of brass. In the last century, the great French naturalist, Buffon, repeated with success the exploit attributed to Archimedes at Syracuse. Buffon, with his apparatus of mirrors, set fire to planks at a distance of two hundred feet, and melted metals and minerals at a distance of forty feet.

In our own day, the problem how to use the heat of the sun by mechanical agency is one of the most absorbing objects of the search of natural philosophers. One of these has recently been bold enough to assert that on any space in the United States, twenty by thirty miles square, enough of the heat of the sun is wasted to drive all the steam engines in the world.

In spite of the well-nigh superhuman efforts of Archimedes in behalf of the proud and lovely city of his birth, it was at length carried by surprise by the Roman legions. As the exultant victors swarmed through the streets, they found Archimedes quietly seated in the public square.

His head was bent, and he was deeply studying a series of geometrical figures, which he had just traced in the sand. He did not seem to be conscious that the city had been captured, or that the Romans had invaded its streets. A Roman soldier, not knowing who he was, ran up to the absorbed philosopher with a drawn sword. Archimedes perceived his murderous intent.

"Hold your hand a little," said he quietly, glancing at the figures in the sand; "only spare my life until I have solved this problem."

But the petition fell on heedless ears; and this greatest man of his age perished by the hand of the rude barbarian. Archimedes was buried with imposing funeral pomp.

Upon his tombstone, in accordance with his own desire, was engraved a cylinder bearing a sphere; a device which represented his discovery of the proportion between a cylinder and a sphere of the same diameter.

But in the hurly-burly of the time he was soon, and for long, forgotten. A hundred and fifty years later, Cicero, wandering in Syracuse, found the tombstone, neglected, lost sight of, and overgrown with weeds and thistles.

And now, at last, in the nineteenth century, Syracuse has remembered her illustrious ancient citizen, and has fittingly reared a *statue* to his memory.

In his great lecture on "The Lost Arts," Wendell Phillips described many inventions the knowledge of which had become extinct, though the products of those lost inventions still survive. He told of others which, having become extinct, had been again revived in later ages.

The re-discovery of ancient and once lost arts, indeed, is a striking phase of the history of mediæval

and modern invention. Many of the most signal scientific triumphs of later times were known at periods concerning which only dim traditions remain.

Some of the uses of steam were known to the ancients, who employed it to grind drugs, to turn spits, and to amuse and to terrify the common people. It is stated by antiquaries that the Romans knew the art of printing; but opposed the practice of it, because it deprived the scribes of their avocation. Certain it is that the Romans made imprints upon their pottery by means of stereotypes.

Printing was known to the Chinese in remote antiquity; and lithography had been a familiar German art three centuries before its re-discovery less than a hundred years ago. The Romans quite understood the properties of gunpowder; but rather played and trifled with it, as they did with steam, than put it to any useful service. As they made steam a bugbear, so they used gunpowder mainly for fireworks.

It is certain that Colt's revolver is only a re-discovery of an ancient weapon; for in the Arsenal of Venice you may see not only revolvers, but rifled muskets and breech-loading cannon, which were made and used in the fifteenth century.

Locomotion by steam was attempted by Blasco da Garay, in the harbor of Barcelona, two centuries and a half before Robert Fulton guided the famous "Clermont" up the Hudson. Dr. Darwin predicted the locomotive and the steamboat, a quarter of a century before Fulton's memorable trip, in the oft-quoted lines,—

"Soon shall thy arm, unconquered steam! afar Drag the slow barge, and drive the rapid car!" When the tunnel was built beneath the Thames, it was believed to be indeed a new thing under the sun; a marvel of modern engineering skill. But it was afterwards found that tunnels had been laid beneath the waters of the Euphrates at ancient Babylon. The Romans built excellent macadamized roads. The idea of the Congreve rocket was borrowed by its re-inventor from the ingenious arsenals of Hindostan. The Chinese, ages ago, lit their houses with coal-gas.

If there is any modern discovery to which we should be most strongly tempted to attribute absolute originality, it would be that of the anæsthetic properties and uses of ether. But in the works of Albertus Magnus, who lived in the thirteenth century,—in the midst of the hurly-burly of the Crusades,—you will find a good practical recipe for preparing ether as an anæsthetic. The same principle,

indeed, was known to many ancient peoples. In the far East, nepenthe and mandragora were used to deaden pain. To a similar purpose the Chinese put mayo, and the Egyptians their soothing and seductive hasheesh.

It was supposed that glass was a discovery of mediæval times, until specimens of it were found in the more elegant of the lava-buried villas of Pompeii.

We must abandon, too, the proud and cherished belief that the electric telegraph was the original device of an illustrious American of the nineteenth century. "The invention of the telegraph," says a recent English scientific writer, "was clearly indicated by Schwenter in 1636. He then pointed out how two persons could communicate with each other by means of the magnetic needle." A century later, in 1746, Le Mounier exhibited a series of experiments in the Royal Gardens at Paris, showing how electricity could be transmitted through iron wire nine hundred fathoms in length.

But a real electric telegraph was actually set to work, in 1774, by Le Sage of Geneva. His instrument comprised twenty-four metallic wires, separated and enclosed in a nonconducting substance. Each wire ended in a stalk, mounted with a little ball of elderwood, suspended by a silk thread. A slight stream

of electricity was sent through the wire; the elder ball at the other end was repelled; and this repulsion indicated a letter of the alphabet.

A device very much like that of Le Sage was invented a few years later by Lomond of Paris.

The discovery that the sun can paint pictures on a plate prepared with certain chemicals, can by no means be justly claimed by Monsieur Daguerre, although he gave his name to the daguerreotype. To the renowned artist who, four centuries ago, decorated the walls of the stately Refectory at Milan with his splendid picture of "The Last Supper," who contended with Michael Angelo for the artistic sceptre of Florence, and who was not only a painter and sculptor of the highest genius, but was also a noted chemist, a successful engineer, a melodious poet, a graceful musician, and an ardent astronomer; to Leonardo da Vinci the world perhaps owes the great idea of photography, which has given so much aid to science, and so much pleasure, instruction, and delight to all mankind.

Six hundred years ago, old Friar Bacon taught his countrymen that many of the wonders which, in their ignorance, they attributed to sorcery, to the machinations of the Evil One, to the weird agency of

ghosts and witches, were really works of nature, or of skilful human art.

It is almost startling, indeed, to see how this learned and far-seeing English monk, of an almost barbaric period, imagined and clearly foreshadowed some of the greatest inventions of modern times. "Instruments may be made," he says, "by which the largest ships, with only one man guiding them, will be carried with greater swiftness than if they were full of sailors. Chariots may be built that will move with incredible rapidity, without the help of animals. Instruments of flying may be formed, in which a man, sitting at his ease, may beat the air with his artificial wings, after the manner of birds. A small instrument may be made to raise and depress the greatest weights. An instrument may be devised by which a man may draw a thousand men to him by force, and against their will. Machines can be constructed which will enable men to walk at the bottom of seas or rivers without danger."

So it was that this bright morning star, rising in the dim dawn of modern science, shot its penetrating ray far athwart the shadows of the future; and discerned, almost clearly, locomotion by steam, the perfection of the principle of the lever, the sounding of the

mysterious ocean depths by the diving-bell, and the successful navigation of the air.

Laurence Coster, The Discoverer of Type-Printing

In Holland there is a very ancient town called Haarlem. It is a drowsy, humdrum old place, with quaint houses of many gables, and irregular grass-grown streets, and long reaches of straight, stagnant canals. Some of the streets are so narrow that you can shake hands with a passer-by on the opposite sidewalk, and in some places the upper stories project so far over the lower ones that two people in opposite houses can easily converse with each other.

On one of these streets stands a house which seems even older than most of its neighbors. It looks as if it were toppling over, and might fall down over the rough sidewalk any windy day. Its windows are full of tiny, dust-covered panes, and its single upper story so projects as to form a shelter and shade over the doorway. This old house is pointed out to strangers who go to Haarlem to see the curiosities of the venerable town as one of especial interest. It is said to be at least six or seven centuries old. But the reason why it is especially worth seeing is that once upon a time, long, long ago, there dwelt in it a man of whom the sedate people of Haarlem are still very proud. His

name was Laurence Coster. He was the warden of a little church which stood not far from his modest dwelling, and passed his time between his not very heavy duties at the church and in the midst of his family at home.

Among other tastes, Laurence Coster was very fond of reading. He lived, indeed, five hundred years ago; and at that period, it need not be said, there were no printed books such as we have now. The only books which then existed were those written on parchment and vellum, and this was done mainly by the monks in their quiet monasteries. It followed that these written books were very rare and expensive. They were not to be found in the homes of the people. Even a great and rich lord could only afford to have a very few of them. They were as much of a luxury in a rich household as a picture by a famous artist is now.

Of course, as books were so scarce and expensive, very few of the common people ever learned how to read. But Laurence Coster was an exception to this rule. He had always been a great student, fond of learning, and preferring solitude to the society of those around him. In the little church of which he was warden there were a few of the monks' manuscript volumes; and these, we may well believe. Coster had

read over and over until he must have well-nigh known them by heart.

Thus Coster lived on to middle age, and then to old age, in a quiet, humdrum, studious existence. He now found his little home peopled with quite a family. His son had married, and lived with him in the old house, and three or four rosy grandchildren delighted Coster's declining years. To give pleasure to these grandchildren, and to teach them what he himself knew, became the joy of his old age.

Old Coster was very fond of strolling by himself in the outskirts of the quiet town. Sometimes, attired in his short seedy cloak, and a hat which was shaped like a sugar-loaf, and had a broad flapping brim, he would saunter along the banks of the slow little river Spaaren, which wound beyond the town. But his favorite haunt was a dense grove which stood a mile or two beyond the limits of Haarlem, and which was little resorted to by any one except himself.

This grove had for many a year been a retreat to which Coster had loved to resort. When he had been a young man, full of sentiment and romantic notions, he had gone out to it to dream of the fair maid of his love. Even now, in old age, he could find on one of the trees the letters which formed the initials of her name,

which he had once fondly carved there when in a sentimental mood.

In a different way this habit of carving letters in the bark of the trees still seemed to delight him. When of a languid summer afternoon he stretched himself out on the short soft moss beneath a beech-tree, he would almost unconsciously tear off some of the bark and begin to fashion letters from it with his knife. One day it occurred to him not only to carve the letters, but to cut them out, put them in his pocket, and carry them home. He thought that it would be the easiest possible way to teach his little grandchildren their alphabet, and so in time enable them to read, if he showed them the letters in the form of playthings.

After a while this became a regular custom with him. He was delighted to see that the letters of bark greatly amused the children, and that they very soon learned to tell one from another. Then the old man became more careful and more skilful in carving the letters. He tried to fashion them as nicely and distinctly as possible, and spent more hours than ever in the grove, absorbed in this pleasant occupation, which was destined to make him famous.

One afternoon Coster had been more than usually successful in cutting the letters out of the bark. His old

eyes twinkled to see how neatly he had made them. He happened to have an old piece of parchment with him, and with this he carefully wrapped up the letters and carried them home in his pocket.

The grandchildren, as usual, were watching eagerly for their dearly loved old grandsire, and as he approached, ran out to meet him and lead him by both hands into the house. They clapped their hands with glee when he took the piece of parchment from his pocket, and, unfolding it, showed them a number of prettier letters than they had ever seen before. They at once took the letters, and vied with each other in pronouncing them, while the old man playfully corrected their mistakes. Meanwhile the old scrap of parchment had been thrown carelessly aside. But it happened that one of the little boys, tired for the moment of playing with the letters, picked up the parchment and unfolded it. Then he cried out in wonder, "Look, grandfather! see what the letters have done!"

Coster took the parchment from the boy to see what he meant. His eyes dilated as he gazed upon the parchment. There, upon its surface, the letters had left a clear imprint. To be sure, the imprint represented the letters reversed, but nevertheless they were there, printed upon the parchment. It soon appeared that

when Coster had carved the letters the bark had been moist with the sap of the tree, and the sap had performed the service of ink.

Old Coster, though a man in a humble sphere of life, was very far from being a dull one. His thoughtful, studious life enabled him to perceive that this printing of the bark letters on the parchment was really a great discovery. What if, by thus having a series of letters, and impressing them again and again upon parchment, books might be multiplied and made cheap for all the world!

Laurence Coster now had a new occupation in life, which absorbed all his hours and labors. By a mere accident, as it seemed, he had discovered the mighty art of *printing with types*. He went to the grove and cut more letters; and then, using ink, pressed them upon a piece of parchment. He reversed the letters, and now they appeared properly placed upon the page. Then he formed words, and printed them also in the same way. He next cut the letters, no longer from the fragile bark, but from the solid wood. He managed to invent a thicker, glutinous ink, which would not blur the page when impressed on the parchment. Then he cut his letters out of lead, and finally out of pewter.

When his ignorant and superstitious neighbors heard what he was doing, some of them declared that he was a madman, while others darkly hinted that he was a sorcerer. After a while they annoyed him so much that he was forced to shut himself up and conceal his work from them; and so he went on, month after month, striving to bring about the realization of the great art of printing, which he perceived to be possible.

One day, while old Coster was thus busily at work, a sturdy German youth, with a knapsack slung across his back, trudged into Haarlem. By some chance this youth happened to hear how the churchwarden was at work upon a wild scheme to print books instead of writing them. With beating heart the young man repaired to Coster's house, and made all haste to knock at the churchwarden's humble door. Who this youth was, and what came of his visit to old Coster, will be told in the next chapter.

John Gutenberg, The Inventor of the Printing-Press

The sturdy young German who, with knapsack on back and staff in hand, knocked at old Laurence Coster's door, was no ordinary youth. Although scarcely more than twenty, he had already seen a great deal of life, and even some of its rougher aspects.

John Gutenberg belonged to a family of high degree, and had been reared in such luxury as could be enjoyed in the rude mediæval time; but he did not allow luxurious living to make him indolent or unambitious. He was an ardent student, and had received the best training which the learned monks could give him. Often, when a boy, he was found poring over the manuscripts which he found in the monasteries where he was educated. He was also very religious in thought and act. Many a time he would earnestly exclaim, what a pity it was that the Bible was a closed book to the masses of the people; that, as it was written by hand on parchment, it could only be possessed either by the churches and monasteries or by very rich people.

Gutenberg's home was at Strasburg, on the banks of the Rhine. He had often dreamed of foreign

countries, and imagined what they and their peoples were like; so one day, being strong of limb and active in exercise, he resolved to pack up his knapsack, attire himself in walking costume, and take a long pedestrian tour. It was while on this jaunt that, by a chance for which all later generations have had reason to be thankful, he heard of old Coster and his discovery, and hastened to present himself at the humble churchwarden's door.

You can imagine the eagerness with which Coster led his young guest in, and how delighted he was to show him just how the printing of his letters worked. While with his rude leaden types the old man pressed letter after letter on the parchment, Gutenberg stood by, rapt in attention. Already he imagined that he saw dimly to what great uses this discovery might be put.

"And see here!" exclaimed Coster, holding up some pages of parchment awkwardly sewed together, "*here is my first book in print.*"

It was a Latin grammar. Old Coster had slowly printed it, letter by letter, and right proud was he of this first triumph of his patient labor.

"But we can do better than this," said Gutenberg. "Your printing is even slower than the writing of the

monks. From this day forth I will work upon this problem, and not rest till I have solved it."

Warmly grasping Coster's hand, and thanking him for showing him his discovery, Gutenberg resumed his knapsack, and trudged out of Haarlem. He had no longer any thought of continuing his tramp into new scenes. His fondness for seeing strange lands had for the while deserted him. His only thought was to get back as soon as possible to Strasburg, where he lived, and to set to work upon the task he had now set to himself.

Gutenberg lived in an age of dense superstition and ignorance. Everything that was new and unfamiliar seemed to the ignorant people of that time to be the work of sorcery; and any one who dared to do things which appeared marvellous in their eyes, was persecuted and pursued as if he dealt in evil magic. No one knew this better than the young Strasburg scholar.

So, on his arrival at Strasburg, he gave out that he was at work making jewelry. Meanwhile he locked himself up in his room, and, scarcely taking time to eat or sleep, devoted himself to the problem how to make Coster's discovery useful to the world. But he found that he was watched and interrupted, and that his

hiding himself so constantly in his room gave rise to dark suspicions among his neighbors. So he repaired to an old ruined monastery, only one or two rooms of which were habitable, and which stood a few miles from the town. Here he thought he could work in peace, for the monastery ruin was in a lonely, deserted place.

Hidden in an obscure corner of this old monastery of St. Arbogaste was a little cell. This cell Gutenberg secured by a great oaken door with heavy bolts, and here he hid the tools and materials needed for his work. At the same time he fitted up a half-ruined room in a more open part of the monastery as a jewelry shop. He engaged two young men to help him polish precious stones and to repair trinkets. In this way he hoped to be able to work at his types in the hidden cell without discovery.

He now set to work, at such times as he could escape into his little cell, in dead earnest. It was not long before he had carved out of some bits of wood with his knife a number of separate types. The happy idea struck him to string these on a piece of wire in the form of words, and at last of sentences. Then, finding that wood was not hard enough, he carved some types, with more difficulty, in lead.

Having made types which satisfied him, Gutenberg used his knowledge of chemistry to make an ink which would leave a distinct imprint, and he soon succeeded in producing such an ink. As he continued to work, the great idea that was absorbing him grew more and more clear. He had his types and his ink, so he made a brush and a roller to put the ink on the types. He had now got as far as printing a whole word or sentence on a piece of parchment; and by changing the movable types about, could form at will new words and sentences.

His next task was to construct "chases," so that the types could be held together, and would print in pages. And at last the idea of a *printing-press* was made a reality.

When Gutenberg had completed and gazed with delight on the first printing-press which had ever been constructed, the main difficulties of his task were over. With his types set in their chases, his different colored inks at his elbow, his rollers at hand to apply the ink, and his press ready to press the types down upon the blank pages, he stood ready to complete the first book printed with movable type.

But poor Gutenberg was not destined to derive much happiness from the results of his labors and the

splendid invention he had made. He worked so hard that the few hours of the night which he took for sleep were disturbed by uneasy dreams. Sometimes he thought that angelic voices warned him not to go on with his printing, for that it would bring untold miseries upon the human race. Then he would rise in the morning, unrefreshed by his slumbers and terrified by the vision, and, seizing a mallet, would be on the point of smashing his printing-press all to pieces. But sometimes other spirits would appear to him in dreams, and urge him to go on with his good work, saying that it would be an immense blessing and benefit to all the world in all future ages. This would inspire him with new energy, and he would toil the next day with a light heart.

But after the printing-press had been made, and he had really begun to print books, his assistants in the jewelry shop betrayed him. They told the magistrates of Strasburg about his long absences and mysterious movements. Their story soon spread through the town, and roused the anger and hatred of the writers of manuscript books, who feared lest printing should ruin their occupation.

Gutenberg's enemies soon compelled him to fly from Strasburg. He was stripped of all he had in the world, and even his life was threatened. So he went

back to Mayence, his birthplace, and there resumed his printing. He took a rich jeweller, Fust, into partnership. But he was not allowed to work long in peace. Fust turned against him, and he was soon forced to leave Mayence as he had left Strasburg.

He was now wretchedly poor, and for a while roamed aimlessly from place to place. But at last he found a home in Nassau, the ruler of which offered him his protection. In that quiet town, Gutenberg set up his press again, and printed many books, and spent the remainder of his days, it is pleasant to say, in rest, comfort and content, although he never got rich from his invention. He died in the year 1468, at the ripe age of sixty-nine; and many years after the statue of him, which may be seen standing in Mayence, was erected in his honor by the descendants of those who had driven him forth, a beggar, from his native city.

John Gutenberg and the Invention of Printing

When Christopher Columbus was a boy, there were few books. Those he might have read were of two kinds, manuscript books and block books. Manuscript books were copies of the Bible, or of books of the Greeks and Romans, written out by hand.

Persons called copyists made a business of drawing or writing manuscript books. Most of the copyists were monks, who lived in monasteries, where often there was a room set apart for their work, called the writing room. Copying was slow work. To copy a book like the Bible took all of a year, and when this was done well it took two or three years.

Manuscript books were written on parchment or vellum. Parchment is made from the skin of sheep and goats; vellum from the skin of very young lambs and kids. The hair is cut from the skin. The skin is put in a mixture of water and lime, and kept there until the fat is removed. It is then taken out, and stretched and rubbed with pumice stone and lime, until thin and smooth.

The parchment and vellum sheets used in the manuscript books were, as a rule, ten inches wide and fifteen inches long. Broad margins were left on all sides. The first letter of the word beginning the first paragraph on a new page was omitted, as was here and there an important word.

When the copyist had finished his work, the separate sheets were turned over to the illuminator or illustrator. The illustrator filled in the margins with a border of flowers or of foliage, interwoven with birds, animals, angels, or saints. The borders were drawn in blue, green, purple, brown, silver, or gold. The important words omitted were written in color, while elaborate initial letters were painted in at the proper places. These decorations gave to the best manuscript books an elegance and beauty beyond anything to be seen in books at the present time.

The illumination or decoration completed, the separate sheets were passed to the book-binder. Books of large size were bound in boards which were sometimes two inches thick. If the binding was not to be ornamented, the board backs were covered with pigskin. If it was to be ornamented, the covering liked best was calf or goatskin. Upon the ornamentation of the bindings of the best books, there worked gilders, jewelers, engravers, and painters. Some of the most

famous books were covered with enameled brass, others with ivory, and still others with gold and silver studded with precious stones.

Because of the work put upon them, manuscript books were sold at a high price, and only the rich could afford to buy them. A Bible, only fairly well written and bound, cost from a hundred and fifty to two hundred dollars. At that time the wages of a laborer were fifteen cents a day, the price of a sheep twenty-five cents, of a cow two dollars, and of a horse five dollars.

Block books, on the other hand, were mostly plain, and made up of a few pictures or of illustrations, interspersed with printed explanations or religious precepts. The *Evangelists*, the first of the block books, had, for example, thirty pages. Fifteen of these were printing, while the other fifteen were full-page pictures. The *Bible of the Poor*, the most famous of the block books, consisted of forty pictures. These were seven and a half inches wide, and ten inches long.

The block books were so named, because they were printed from carved or engraved wooden blocks. In making a block book, a piece of oak, ash, cherry, or apple wood was cut two inches thick, and the width and length of the desired page. One side of the block,

or the face, was smoothed and polished. On this was placed a drawing of the picture, and of the writing to be printed. The surrounding parts of the block were then cut away, so as to leave the picture and the letters of the writing raised, or in relief, making a sort of stamp. This carving required much skill, and the engraving of a single book consumed weeks and even months.

The engraving completed, the rest was easy. The carved block was covered with a coat of thin ink. A sheet of parchment or paper was placed upon it and pressed gently with the flat back of the inking brush. This transferred an impression of the carved picture and writing to the parchment or paper. The different printed sheets were then bound together.

Any number of books could be printed from the same set of blocks; for this reason block books were cheap. The *ABC's* and the *Lord's Prayer* cost two cents, the *Catechism* twenty cents, *Donatus or Boys' Latin Grammar* twelve and a half cents, and the *Bible of the Poor* two dollars. But only small books could be multiplied in this way, for the carving of the blocks was slow work. To prepare the blocks to print the Bible would take at least thirty years, which of course was never done.

Birthplace and Parents of John Gutenburg

John Gutenberg changed all this. He did it by inventing the art of printing from movable type.

Gutenberg was born about the year 1400, at Mainz, a German city on the Rhine, near Frankfort. His parents were of noble blood, and people of means, who took a prominent part in the affairs of the city. Nothing is known of Gutenberg's boyhood days, other than that they were passed amid scenes of strife between the common people and the nobility.

Learning Two Trades

When John Gutenberg was a boy, it was thought beneath the dignity of one of noble birth to do any ordinary labor, or to learn a trade. Despite this belief, he learned not one, but two trades. He learned the art of cutting and polishing precious stones, and of mirror making.

It is not an easy task to-day to learn a trade. It was even more difficult when John Gutenberg was a boy. The trades at that time were in the hands of guilds, or, as we would say, trade-unions. Of those in a trade, only the master workmen were allowed to teach it. The number of boys a master workman might take to teach was limited. The boy while learning the trade,

which took from five to seven years, received no wages. Instead, he often had to pay a considerable sum for his instruction.

A boy on undertaking to learn a trade became an apprentice. As an apprentice, he ran errands, brought tools and materials, took care of the shop, and assisted in other ways. After two years or more, he rose to be a journeyman and served a second two years. In this period, he learned how to handle and to use tools, and how to do simple kinds of work. In the last two or three years of his service, the journeyman conquered the more difficult parts of the trade. As a kind of final examination he made what was called a masterpiece. This was examined by a committee of master workmen. If they were satisfied, with his workmanship, he was admitted to the guild at a great banquet held at his expense, and given the right to set up in business for himself.

A long time to learn a trade? Yes. But John Gutenberg learned two, and at thirty-five was well established at Strassburg with a good paying business. He was also sought out by young men wishing to become cutters of precious stones or makers of mirrors, and was paid for teaching them these arts.

Printing from Movable Type

The idea came to Gutenberg, that all words, all writings, all languages are expressed in a small number of different letters. Our language has, for example, only twenty-six letters. With a large number of letters properly set together, a whole page of text could be printed at once. By resetting the different letters, and by repeating the process of printing, large books could be swiftly multiplied. This idea took possession of him, and after 1436, to the neglect of everything else, he gave his time, his energy, and his fortune to working out the process.

The Discovery of Type Metal

Should you go into a newspaper office and see a printing press print, cut, paste, fold, and deliver in sixty minutes forty-eight thousand newspapers of sixteen pages each, it would be natural to think that the most important part of printing is the press. The most important part, in printing, however, is the type, or the little movable metal letters. For this reason, the key to inventing printing lay in finding the right kind of metal, and in finding an easy way of making type.

Knowing that block books were printed from carved blocks, Gutenberg first tried to make type from

wood. It would seem easy to do this. Yet it proved difficult to carve a good letter upon the end of a small wooden stick. It proved equally hard to cut the sticks of such width that there would be equal spaces between the letters. Even when Gutenberg succeeded in doing this, for he was an expert carver, the ink so softened the wooden type, that after a few impressions the printed letters became blurred. As the printed letters must be clear and distinct, Gutenberg was forced, much against his will, to give up trying to make movable type from wood.

It now occurred to him that lead would serve. From his work in making mirrors he knew how easy it was to mold it. With a simple mold he cast a number of small lead sticks of uniform width and height, and then with no great difficulty he carved a letter on the end of each stick. He seemed to be on the direct road to success, but when he came to print from lead type, he found that it took more pressure than with wooden blocks, and when the pressure was sufficient to transfer the impression to the paper, the lead letters were flattened out.

Since lead was too soft, Gutenberg thought that iron might do. It proved difficult to mold small iron sticks. The iron stuck to the mold, and the sides of the little sticks were so rough that they would not fit

closely together. Expert as Gutenberg was, it was slow work to cut the letters. Worse yet, when the letters were cut, so much pressure had to be used in printing, that the hard iron type cut into the paper.

These attempts at making type from wood, lead, and iron took weeks and months. Thus a great deal of time and labor seemed lost. Yet this was not all true; for Gutenberg learned from these trials that a metal would have to be found, out of which to make type that could be easily cast. He learned that this metal would have to be harder than lead, but softer than iron. He also learned from trying to cut metal letters, that a mold would have to be invented in which the type could be cast.

As lead could be easily molded, and was at that time one of the cheapest metals, Gutenberg set about finding a metal to mix with lead, to give it the needed hardness and toughness. Many are the mixtures he must have tried. On one day, this and that combination of lead and copper was tested. On another, lead and brass were combined, now in this and now in that way; and so on, week after week, month after month. Some of the combinations were fairly good, but Gutenberg was never satisfied with half success. He worked on and on, until he hit upon combining five parts of lead, four parts of antimony,

and one part of tin. The lead supplied the bulk of the type, the antimony the hardness, and the tin the needed toughness. This mixture of metals proved satisfactory. Strange as it may seem, it is about the one used to-day. No better combination of metal for type has ever been found. It is known as type metal, and is only one of the great discoveries of Gutenberg.

Inventing the Type Mold

While Gutenberg was trying to find a metal suitable for type, he was at the same time working upon a mold. Unless an easy way of casting metal type could be found, printing from movable letters could never be made a success.

To understand what he really invented, let us see what tools are now used in making type. The most important of these tools are the punch or master type, the matrix or mold for the face of the letter, and the mold in which the body of the type is cast.

The punch is made by taking a bar of steel about six inches long, and of the width of a printed letter, and three or four times its thickness. Upon one end of this bar is drawn, say, an *H*. The surrounding parts of steel are then cut away until the letter stands out in

bold relief. Each separate letter, both small and capital, requires 1 separate punch.

The matrix, or mold for the face of the letter, is made by taking a bar of copper half an inch thick, and about twice the width and four times the length of a printed letter. A punch is driven into this with a sharp blow. The result is the sunken imprint in the copper of the letter on the punch. This sunken letter becomes a mold for the face of the letter.

The mold consists of two halves. When these halves are put together, their inner sides face each other and form an opening. On the lower side of the mold, and just under the opening, is a place for fastening the matrix. On the upper side, the opening is left open for the inflow of the molten type metal. A dozen or more molds are needed for each set of type.

It was easy enough for Gutenberg to make a mold with which he could cast metal sticks of the same thickness. The difficult problem was to make one which would cast metal sticks of different widths, and at the same time form a letter on the end. He tried many ways of doing this. Months passed before the idea of a separate mold for the face of the letter occurred to him. Matrices were then made of lead, of iron, and of brass. In some, the impress of the letter

was cast; in others it was cut or engraved. But no sooner was one made, than it was put aside. Still other months went by before he thought of the punch. Molds for the body of the type were made first in one way, then in another. Some were of iron, others of lead, and still others of copper, but not one would do. How many years he toiled, in hope and in despair, no one knows. We only know that by trying again and again, and never giving up, he learned that the mold should be of two like, adjustable parts and that the punch should be of steel, and the matrix of copper.

Thus by patient toil, Gutenberg invented the tools needed in casting type. With them he could easily cast two or three thousand letters a day. So well did he do his work, that more than four hundred years have made little changes in these tools, or in the metal from which they are made. Although type-casting machines are now employed, which cast a hundred type a minute, the punch, the matrix, and the mold invented by Gutenberg are in all important points like those in use at the present time.

Inventing the Printing Press

No press was needed in making either manuscript or block books. But when Gutenberg came to print

from metal type, he discovered that considerable pressure was required to transfer the likeness of the letters to the parchment or paper. That this pressure might be quickly given and be uniform over the face of all the type, it became necessary to invent a press.

Gutenberg modeled his printing press after the wine press then in use. It had two upright posts of great strength. These were placed four feet apart, fastened at the bottom to a solid wooden base, and joined together at the top by a heavy crossbeam. The middle of this crossbeam held an iron screw worked by a lever. On the lower end of the screw hung a heavy block of wood called the plate, the under side of which was flat and smooth. By turning the screw, the plate could be forced up or down. Between the two upright posts, and upon the base of the press, stood a strong, four-legged stool, which served to support a heavy wooden platform, four feet wide and six feet long. Upon this was laid the form, or the wooden frame in which the type was locked. Crude as this printing press was, it served Gutenberg well, and presses like it were the only kind used for more than a hundred and fifty years.

The only ink at the time was the writing fluid of the copyists. Gutenberg found that when this was employed in printing, instead of forming a thin black

coat over the type, it collected in drops and blotted the paper. Another kind of ink had to be made, if printing from metal type was to be a success. The Italian painters had lately invented a new paint composed of lampblack and linseed oil. It was probably from them that Gutenberg got a suggestion which turned him in the right direction. At any rate, he hit upon mixing lampblack and boiled linseed oil, and this mixture proved satisfactory. Printer's ink is still made in the same way.

Trouble at Strassburg

Gutenberg seemed to be standing upon the threshold of success, but events intervened to rob him of his reward. For a number of years he had worked night and day, upon different parts of his invention. Into it went, little by little, all the money he had saved, and all he had inherited. To be able to support himself and to continue his work he took three men into partnership. These men paid him a considerable sum of money for their part, and were to share in the profits of the enterprise. As was then the custom, they were sworn to secrecy. Their plan was to complete the invention and print a small religious book. Though Gutenberg and his partners worked steadily for two

years, the invention was not complete before the Christmas of 1439.

The cost of the enterprise, the faith of these men, and the will with which they worked are shown in a talk between Andrew Dritzehen, one of the partners, and a Frau von Zabern:

"But will you not stop work, so that you can get some sleep?"

"It is necessary that I first finish this work."

"But what a great sum of money you are spending. That has, at least, cost you ten guilders."

"You are a goose; you think this cost but ten guilders. Look here! If you had the money which this has cost, over and above three hundred guilders, you would have enough for all your life; this has cost me at least five hundred guilders. It is but a trifle to what I shall have to spend. It is for this that I have mortgaged my goods and my inheritance."

"But if this does not succeed, what will you do then?"

"It is not possible that we can fail. Before another year is over, we shall have recovered our capital and shall be prosperous."

Dritzehen died a few days later. His death left Gutenberg in a bad plight. The two remaining partners became discouraged and were ready to give up. Frau von Zabern told of her conversation with Dritzehen, and the circumstances of his death caused other people to talk. Gutenberg grew fearful that others would learn of the new art. He sent to Dritzehen's home, and warned the people there to let no one see the press. The molds and type he melted. George, the brother of Andrew, now demanded that he be let into the secret, or that the money Andrew had spent on the enterprise be paid back. Gutenberg refused to tell him of the nature of the undertaking, and claimed that instead of being in debt to Andrew, Dritzehen died in debt to him. The dispute was taken to court, where, after a year of delay, it was settled in favor of Gutenberg.

During the trial, witnesses spoke of the "secret work" Gutenberg was carrying on; they spoke of the "beautiful things," of the "costly things" he was making. No one knew just what he was doing. There was a lot of mystery about the whole enterprise. People began to say: "He doesn't want anyone to know." "He is not willing anyone should see." "Something is wrong." "He is practicing the Black Art."

So great was the prejudice against him, and he was now so poor, that it was impossible for him to go on. He went back to polishing precious stones and making mirrors.

Gutenberg was not long content, however, to work at his trade only. After a year or two, he began to think again of his invention, and to spend his evenings upon punches, matrices, and molds. He finally decided to return to Mainz, and set up a printing press.

Printing the First Bible

For four or five years after returning to Mainz, he did what we should call job printing. His success was so marked that a rich money lender became interested. Their plan was to print the complete Bible. It was to be printed in Latin, and was to look in every way like the best of the manuscript books.

The pages were printed in two columns of forty-two lines each. These columns, with the space between of five eighths of an inch, made a page eleven and a half inches long and seven and three fourths inches wide. Great spaces were left for initial letters, and a wide margin was allowed for a border. It often happened that the space for the initial letter and for

the border was not filled in. Yet some of the early printed books rival in beauty of decoration the most famous manuscript books.

The entire Bible, when printed in this way, covered twelve hundred and eighty-two pages, and was bound in two large volumes. It is known as Gutenberg's first Bible, and was the first great work to come from the printing press. An undecorated copy on paper could be had then for four dollars. A decorated copy on vellum was lately sold in London for seventeen thousand dollars.

Cheated by Fust

When Gutenberg entered upon the bold plan of printing the entire Bible, he thought he could have it ready for sale within three years. Plan and toil as he might, three years passed, four years went by, and it was late in the fifth, or towards the end of 1455, before the printed pages were ready to be bound. Yet at last, after five years of disappointment, hard work, and trials, the task was done, and the printed Bible was ready for sale.

But Fust, the money lender, did not go into partnership with Gutenberg to help him perfect a great invention, and to aid him in printing the greatest

of all books. He thought that he saw in the new art a means of making money. He had invested a large sum in the enterprise. After five years, not one cent of this had been returned, nor had he received one penny of profit. This was too much for the money-greedy Fust. With the Bible printed and ready for sale, he saw his opportunity. He would seize the molds, the type, the presses, and all the printed Bibles. In this way he could get back all, and even more than he had invested. To do this, he brought suit in the court for the return of all the money he had spent on the undertaking. An unjust judge decided in his favor. As Gutenberg had no way of paying such a large sum, Fust seized everything, and turned Gutenberg out.

Gutenberg was not, however, to be neglected in his old age. As a reward for his services to the church and to the world, the Archbishop of Mainz made him, in 1465, a gentleman at court, and gave him a pension for life. The pension supplied him with a home, with food, and also with clothing, for the quaint document reads: "We will clothe him every year, always like our noblemen, and give him our court dress."

Gutenberg was not to enjoy his leisure or the honors of a nobleman long. In February, 1468, he became sick and died. He was laid to rest at Mainz.

Honor Paid Gutenberg

Though he died loaded down with debts, and with but few friends by his side, great honors were to come to him as the inventor of the greatest of the modem arts. On one of the first tablets erected to his memory is this inscription: "To John Gutenberg, of Mainz, who, first of all, invented molding letters in brass, and by this art has deserved honor from the whole world." Monuments honoring him are now to be found in many places. His greatest monument will survive them all. It is the printed book.

The Romance of Pottery—Enameling Earthenware Invented by Palissy.

But greater than the achievements of merchants, princes, warriors and even statesmen, are those of the great thinkers whose "thoughts do shake mankind"; of the great physicians who devote their lifetime to the cure of disease and the alleviation of suffering; of the great discoverers who call new worlds into activity and life; of the great inventors who, in the teeth of discouragements innumerable, and difficulties apparently insurmountable, have succeeded in wresting from nature some of her most precious secrets, and conferred untold benefits on mankind. Among the last class must ever be remembered with honor the names of Bernard Palissy and John Böttgher, a brief account of whose singularly interesting and romantic lives I now propose to give.

Bernard Palissy was born in the south of France in 1510. His parents were too poor to give him any school education. "I had no other books," said he afterwards, "than heaven and earth, which are open to all." He learnt, however, the art of glass-painting, to which he added that of drawing, and afterwards, reading and writing. When eighteen years old, the

glass trade becoming decayed, Palissy left his father's house with his wallet on his back, and went out into the world to seek his fortune. For ten years he traveled over Europe, until he married, which put an end to his wanderings; and he settled down to practice glass-painting and land-measuring in the small town of Saintes. Three children were born to him; and not only his responsibilities, but his expenses increased, while, do what he could, his earnings remained too small for his needs. It was therefore necessary for him to bestir himself.

Though only a glass-painter, he had an artistic soul, and the sight of an elegant cup of Italian manufacture directed his mind to the art of the enameling of earthenware. The sight of this cup disturbed his whole existence; and from that moment the determination to discover the enamel with which it was glazed possessed him like a passion. Had he been a single man he might have traveled into Italy in search of the secret; but he was bound to his wife and children, and could not leave them; so he remained by their side, groping in the dark, in the hope of finding out the process of making an enameling earthenware. At first, he was utterly ignorant of pottery. He could merely guess the materials of which the enamel was composed, and he proceeded to try all manner of

experiments to ascertain what these really were. He pounded all the substances which he thought likely to produce it. Then he bought common earthen pots, broke them into pieces, and spreading his compounds over them, subjected them to the heat of a furnace which he erected for the purpose of baking them. His experiments failed; and the results were broken pots and a waste of fuel, drugs, time and labor, not to speak of the opposition of his wife and friends who began to think him mad.

For many successive months and years Palissy pursued his experiments. The first furnace having proved a failure, he proceeded to erect another, out of doors. There he burnt more wood, spoiled more drugs and pots, lost more time, until poverty stared him and his family in the face. In the intervals of his experiments, he occasionally worked at his former callings—painting on glass, drawing portraits, and measuring land; but his earnings from these sources were very small. At length, because of the heavy cost of fuel, he was no longer able to carry on his experiments in his own furnace, but he bought more potsherds, broke them up as before into three or four hundred pieces, and, covering them with chemicals, carried them to a tile-work a league and a half from Saintes, there to be baked in an ordinary furnace.

After the operation he went to see the pieces taken out; and, to his dismay, the whole of the experiments were failures. But, though disappointed, he was not yet defeated; for he determined on the very spot to "begin afresh."

His business as a land-measurer called him away for a brief season from the pursuit of his experiments; but he signalized his return by breaking three dozen new earthen pots, the pieces of which he covered with different materials which he had compounded, and then took them to a neighboring glass-furnace to be baked. The results gave him a glimmer of hope. The greater heat of the glass-furnace had melted some of the compounds; but though Palissy searched diligently for the white enamel he could find none. For two more years he went on experimenting without any satisfactory result, until the proceeds of his land-surveying having become nearly spent, he was again reduced to poverty. But he was resolved to make one last great effort, and began by breaking more pots than ever. Over three hundred pieces of pottery covered with his compounds were sent to the glass-furnace, and thither he himself went to watch the results of the breaking. Four hours passed, during which he watched, and then the furnace opened. The material on one only of the three hundred pieces of

potsherd had melted, and it was taken out to cool. As it hardened, it grew white—white and polished. The piece of potsherd was covered with white enamel, described by Palissy as "singularly beautiful." He ran home with it to his wife, feeling himself, as he expressed it, quite a new creature. But the prize was not yet won—far from it.

To complete the invention he built a glass-furnace near his dwelling, carrying the bricks from the brick-yard upon his back. He was brick-layer, laborer, and all. From seven to eight more months passed. At last the furnace was built and ready for use. Palissy had, in the meantime, fashioned a number of vessels of clay in readiness for the laying on of the enamel. After being subjected to a preliminary process of baking, they were covered with the enamel compound, and again placed in the furnace for the grand crucial experiment. Although his means were nearly exhausted, Palissy had been for some time accumulating a great store of fuel for the final effort, and he thought it was enough. At last the fire was lit, and the operation proceeded. All day he sat by the furnace, feeding it with fuel. He sat there watching and feeding all through the long night. But the enamel did not melt. The sun rose upon his labors. His wife brought him a portion of the scanty morning meal—for he would not stir from the

furnace, into which he continued from time to time to heave more fuel. The second day passed, and still the enamel did not melt. The sun set, and another night passed. The pale, haggard, unshorn, baffled yet not beaten Palissy sat by his furnace, eagerly looking for the melting of the enamel. A third day and night passed—a fourth, a fifth, and even a sixth—yes, for six long days and nights did the unconquerable Palissy watch and toil, fighting against hope; and still the enamel would not melt.

It then occurred to him that there might be some defect in the materials for the enamel—perhaps something wanting in the flux; so he set to work to pound and compound fresh materials for a new experiment. Thus two or three more weeks passed. But how to buy more pots? His money was now all spent; but he could borrow. His character was still good, and a friend lent him enough to enable him to buy more fuel and more pots. These he covered with the new compound, placed in the furnace, and the fire was again lit. It was the last and most satisfactory experiment of the whole. The fire blazed up; the heat became intense; but still the enamel did not melt. The fuel began to run short! How to keep up the fire? There were the garden palings: these would burn. So these were pulled up and cast into the furnace. They

were burnt in vain! The enamel had not yet melted. Ten minutes more heat might do it. Fuel must be had at whatever cost. There remained the household furniture and shelving. A crashing noise was heard in the house; and amidst the screams of his wife and children, who now really thought Palissy's reason was giving way, the tables were seized, broken up and heaved into the furnace. The enamel had not melted yet! There remained the shelving. Another noise of the wrenching of timber was heard within the house, and the shelves were torn down and hurled after the furniture into the fire. Wife and children then rushed from the house, and went frantically through the town, calling out that poor Palissy had gone mad and was breaking up his very furniture for firewood!

For an entire month his clothes had not been off his back, and he was utterly worn out. He was, besides, in debt, and seemed on the verge of ruin. But he had at length mastered the secret; for the last great burst of heat had melted the enamel. The common, brown household jars, when taken out of the furnace after it had become cool, were found covered with a white glaze! For this, he could endure reproach, contumely, and scorn, and wait patiently for the opportunity of putting his discovery into practice as better days came round. His next move was to hire a potter to make

some earthen vessels after the designs which he furnished; while he himself proceeded to model some medallions in clay for the purpose of enameling them. But how to maintain himself and family until the wares were made and ready for sale? Fortunately there remained one man in Saintes who still believed in him—an innkeeper, who agreed to feed and lodge him for six months, while he went on with his manufacture. As for the working potter whom he had hired, Palissy soon found that he could not pay him the stipulated wages. Having already stripped his dwelling, he could but strip himself, and he accordingly parted with some of his clothes to the potter, in part payment of the wages which he owed him.

Palissy then erected an improved furnace, but he was so unfortunate as to build part of the inside with flints. When it was heated these flints cracked and burst, and the spiculæ were scattered over the pieces of pottery, sticking to them. Though the enamel came out right, the work was irretrievably spoilt, and thus six months' more labor was lost. Persons were found willing to buy the articles at a low price, notwithstanding the injury they had sustained; but Palissy, inspired by the spirit of a true artist, would not sell them, considering that to have done so would be

to "decry and abase his honor," and so he broke in pieces the entire batch. At this stage of his affairs, he became melancholy and almost hopeless, and seems to have all but broken down. He wandered gloomily about the fields near Saintes, his clothes hanging in tatters, and himself worn to a skeleton. In a curious passage in his writings he describes how the calves of his legs had disappeared, and were no longer able even with the aid of garters to hold up his stockings, which fell about his heels when he walked. The family continued to reproach him for his recklessness, and his neighbors cried shame upon him for his obstinate folly. So he returned for a time to his former calling; and after about a year's diligent labor, during which he earned bread for his household and somewhat recovered his character among his neighbors, he again resumed his darling enterprise. But though he had already searched about ten years for the enamel, it cost him about eight more years of experimental plodding before he perfected his invention. He gradually learnt dexterity and certainty of result by experience, gathering practical knowledge out of many failures.

At last, after about sixteen years' labor, Palissy took heart and called himself potter. These sixteen years had been his term of apprenticeship to the art, during

which he had wholly to teach himself, beginning at the very beginning. He was now able to sell his wares and maintain his family in comfort. But he never rested satisfied with what he had accomplished. He proceeded from one step of improvement to another, always aiming at the greatest perfection possible. He studied natural objects for patterns, and with such success that the great French naturalist, Buffon, spoke of him as "so great a naturalist as nature only can produce." His ornamental pieces are now regarded as rare gems in cabinets of virtuosi, and sell at almost fabulous prices; a small dish twelve inches in diameter having been sold some years ago for eight hundred and ten dollars. The ornaments on them are for the most part accurate models from life, of wild animals, lizards, and plants, found in the fields about Saintes, and tastefully combined as ornaments into the texture of a plate or vase. When Palissy had reached the height of his art he styled himself, "Ouvrier de Terre et Inventeur des Rustics Figulines."

Extraordinary Career of Böttgher, the Inventor of Hard Porcelain.

Whom, boys, do you admire the more—Vanderbilt or Palissy? the one striving for mere personal aggrandizement; the other toiling and suffering for the general good of humanity. One hundred years hence who will remember that such men as Gould and Vanderbilt and Russell Sage ever existed, while the name of Palissy will last as long as the fine art which he created? And so with the illustrious John Frederick Böttgher, the inventor of hard porcelain, whose life presents a remarkable contrast to that of Palissy, though it also contains many points of romantic interest. Böttgher was born at Schleiz, in the Voightland, in 1682, and at twelve years of age was placed apprentice with an apothecary at Berlin. He seems to have been early fascinated by chemistry, and occupied much of his leisure in making experiments. These, for the most part, tended in one direction—the art of converting common metals into gold. At the end of several years, Böttgher pretended to have discovered the universal solvent of the alchemists, and professed that he had made gold by its means. The news spread abroad that the apothecary's apprentice had discovered the grand secret, and

crowds collected about the shop to get a sight of the wonderful young "gold-cook." The King himself expressed a wish to see and converse with him, and when Frederick I. was presented with a piece of gold alleged to have been converted from copper, he was so dazzled with the prospect of securing an infinite quantity of it, that he determined to secure Böttgher and employ him to make gold for him within the strong fortress of Spandan. But the young apothecary fled across the frontier into Saxony. A reward of a thousand thalers was offered for Böttgher's apprehension, but in vain. He arrived at Wittenberg, and appealed for protection to the Elector of Saxony, Frederick Augustus I. (King of Poland), surnamed "The Strong." Frederick being himself very much in want of money at the time, was naturally overjoyed at the prospect of obtaining gold in any quantity by the aid of the young alchemist. Böttgher was accordingly conveyed in secret to Dresden, accompanied by a royal escort. The Elector, however, must needs leave him there for a time, having to depart forthwith to Poland. But, impatient for gold, he wrote Böttgher from Warsaw, urging him to communicate the secret, so that he himself might practice the art of transmutation. The young "gold-cook," thus pressed, forwarded to Frederick a small vial containing "a

reddish fluid," which, it was asserted, changed all metals, when in a molten state, into gold. This important vial was taken in charge by the Prince Fürst von Fürstenburg, who, accompanied by a regiment of guards, hurried with it to Warsaw. Arrived there, it was determined to make immediate trial of the process. The king and the prince locked themselves up together in a secret chamber of the palace, girt themselves about with leather aprons, and, like true "gold-cooks," set to work melting copper in a crucible, applying to it afterwards the red fluid of Böttgher. But the result was unsatisfactory; for notwithstanding all that they could do, the copper obstinately remained copper. On referring to the alchemist's instructions, however, the king found that, to succeed with the process, it was necessary that the fluid should be used "in great purity of heart;" and as his majesty was conscious of having spent the evening in very bad company, he attributed the failure of the experiment to that cause. A second trial was followed by no better results, and then the king became furious; for he had confessed and received absolution before beginning the experiment.

Frederick Augustus now resolved on forcing Böttgher to disclose the golden secret, as the only means of relief from his urgent pecuniary difficulties.

The alchemist, hearing of the royal intention, again determined to fly. He succeeded in escaping his guard, and after three days' travel, arrived at Eus, in Austria, where he thought himself safe. The agents of the Elector were, however, at his heels. They had tracked him to the "Golden Stag," which they surrounded, and seizing him in his bed, notwithstanding his resistance and appeals to the Austrian authorities for help, they carried him by force to Dresden. From this place he was shortly after transferred to the strong fortress of Köningstein. It was communicated to him that the royal exchequer was completely empty, and that ten regiments of Poles were waiting for his gold. The king himself visited him, and told him in a severe tone that if he did not at once proceed to make gold, he would be hung.

Years passed, and still Böttgher made no gold; but he was not hanged. It was reserved for him to make a far more important discovery than the conversion of copper into gold, namely, the conversion of clay into porcelain. Some rare specimens of this ware had been brought from China by the Portuguese, which were sold for more than their weight in gold. Böttgher was first induced to turn his attention to the subject by Walter von Tschirnhaus, a maker of optical instruments, also an alchemist. Tschirnhaus was a

man of education and distinction, and was held in high esteem by Prince Fürstenburg, as well as by the Elector. He very sensibly said to Böttgher, still in fear of the gallows, "If you can't make gold, try and do something else; make porcelain." The alchemist acted on the hint, and began his experiments, working night and day. He prosecuted his investigations for a long time with great assiduity, but without success. At length some red clay, brought to him for the purpose of making his crucibles, set him on the right track. He found that this clay, when submitted to a high temperature, became vitrified and retained its shape; and that its texture resembled that of porcelain, excepting its color and opacity. He had, in fact, accidentally discovered red porcelain, and he proceeded to manufacture and sell it as porcelain. Böttgher was, however, well aware that the white color was an essential property of true porcelain; and he therefore prosecuted his experiments in the hope of discovering the secret. Several years thus passed, but without success, until accident again stood his friend, and helped him to a knowledge of the art of making white porcelain. One day, in the year 1707, he found his perruque unusually heavy, and asked of his valet the reason. The answer was, that it was owing to the powder with which the wig was dressed, which

consisted of a kind of earth then much used for hair powder. Böttgher's quick imagination immediately seized upon the idea. This white earthy powder might possibly be the very earth of which he was in search; at all events, the opportunity must not be let slip of ascertaining what it really was. He was rewarded for his painstaking care and watchfulness; for he found, on experiment, that the principal ingredient of the hair-powder consisted of *kaolin*, the want of which had so long formed an insuperable difficulty in the way of his inquiries.

The discovery, in Böttgher's intelligent hands, led to great results, and proved of far greater importance than the discovery of the philosopher's stone would have been. In October, 1707, he presented his first piece of porcelain to the Elector, who was greatly pleased with it; and it was resolved that Böttgher should be furnished with the means for perfecting his invention. Having obtained a skilled workman from Delft, he began to *turn* porcelain with great success. He now entirely abandoned alchemy for pottery, and inscribed over his door a distich, which, translated, reads thus:

"Almighty God, the great Creator,
Has changed a gold-maker to a potter."

Böttgher's further experiments with his new furnaces proving very successful, and the porcelain which he manufactured being found to fetch large prices, it was next determined to establish a royal manufactory of porcelain. The manufacture of delf ware was known to have greatly enriched Holland. Why should not the manufacture of porcelain equally enrich the Elector? Accordingly, a decree went forth, dated the twenty-third of January, 1710, for the establishment of "a large manufactory of porcelain" at the Albrechtsburg in Meissen. In this decree, which was translated into Latin, French, and Dutch, and distributed by the ambassadors of the Elector at all the European courts, Frederick Augustus set forth, that to promote the welfare of Saxony, which had suffered much through the Swedish invasion, he had "directed his attention to the subterranean treasures" of the country, and, having employed some able persons in the investigation, they had succeeded in manufacturing "a sort of red vessel far superior to the Indian Terra Sigillata"; as also "colored ware and plates, which may be cut, ground and polished, and are quite equal to Indian vessels," and finally that "specimens of white porcelain" had already been obtained, and it was hoped that this quality, too, would soon be manufactured in large quantities. The royal decree

concluded by inviting "foreign artists and handicraftsmen" to come to Saxony and engage as assistants in the new factory, at high wages, and under patronage of the king.

For all his great services Böttgher was wretchedly rewarded. Two royal officials were put over his head as directors of the factory, while he himself held the position of foreman of potters only, and at the same time was detained the King's prisoner. During the erection of the factory at Meissen, while his assistance was still indispensable, he was conducted by soldiers to and from Dresden; and even after the works were finished he was locked up nightly in his room. All this preyed upon his mind, and in repeated letters to the King he sought to obtain mitigation of his fate. Some of these letters are very touching. "I will devote my whole soul to the art of making porcelain," he writes on one occasion; "I will do more than any inventor ever did before; only give me liberty, liberty!"

To these appeals the King turned a deaf ear. He was ready to spend money and grant favors; but liberty he would not give. He regarded Böttgher as his slave. In this position the persecuted man kept on working for some time, till, at the end of a year or two, he grew negligent. Disgusted with the world and with himself, he took to drinking. Such is the force of

example that it no sooner became known that Böttgher had betaken himself to this vice than the greater number of the workmen at the Meissen factory became drunkards too. Quarrels and fightings without end were the consequence, and ultimately the whole of them, more than three hundred, were shut up in the Albrechtsburg and treated as prisoners of state.

Böttgher at last fell seriously ill, and in May, 1713, his dissolution was hourly expected. The King, alarmed at losing so valuable a slave, now gave him permission to take carriage exercise under a guard; and having somewhat recovered, he was allowed occasionally to go to Dresden. In a letter written by the King in April, 1714, Böttgher was promised his full liberty; but the offer came too late.

Broken in body and mind, alternately working and drinking, though with occasional gleams of nobler intention, and suffering from constant ill-health, the result of his enforced confinement, Böttgher lingered on for a few years more, until death relieved him from his sufferings on the thirteenth of March, 1719, in the thirty-fifth year of his age. He was buried *at night*—as if he had been a dog—in the Johannis Cemetery at Meissen; and such was the treatment, such the unhappy end, of one of Saxony's greatest benefactors!

James Watt, the Inventor of the Steam Engine

In a small cottage at Greenock, near Glasgow, in Scotland, there was living, about a century and a half ago, a very bright but delicate boy. In many ways he was quite unlike other boys of his age. He was very fond of books, yet he disliked going to school so much that, being feeble in health, his parents kept him at home. He was a very truthful boy. When any dispute took place between him and his playmates, his father would always say, "Let us hear what James says about it. From him I always get the truth."

When this boy was seven or eight years old a neighbor said to his father, "Why don't you send this lad to school? He is wasting his time doing nothing here at home."

"See what he is doing," was the father's reply, "before you say he is wasting his time."

The neighbor looked down at James, who was seated on the hearth. He was not amusing himself with playthings, but was very busy drawing triangles and curves and other mathematical lines. "You must pardon my hasty words," said the neighbor; "his

education has not been neglected; he is, indeed, no common child."

Not far away from his own home lived an aunt of James, with whom he often stayed. One day, the aunt found him in the kitchen, studying her tea-kettle. He was bent over it, and was closely watching the steam which puffed from its spout. Then he would take off the lid, hold a cup over the steam, and carefully count the drops of water into which it was condensed. The aunt roundly scolded him for what she thought his trifling. She little dreamed that the boy was taking his first lesson in a science, by the pursuit of which he was destined to change the whole character of the industries of the world, and win for himself an immortal fame.

James Watt's pastimes and tastes, indeed, from earliest boyhood were very different from those of other lads. His father kept a store for the sale of articles used by ships, and it was a favorite recreation of James to spend his time there among the ropes, sails, and tackle, finding out how they were made, and to what uses they were devoted. He was often found in the evening, too, sprawled at full length on the sward of the hill near Greenock, gazing for hours together at the stars. Already an ambition to learn the great secrets of astronomy had arisen in his mind.

When he was fifteen years old, young Watt was known in his neighborhood as a prodigy of learning for his age. He had now been to school for a year or two, and had ardently studied mathematics and natural philosophy. At the same time he had learned a great deal about mineralogy, chemistry, botany, and physiology. Not only had he derived much knowledge from books, but he understood how to apply this knowledge in many ways. He had become a good carpenter; he knew how to work in metals; and he took great delight in making chemical experiments in a little laboratory which he had fitted up at home. But perhaps the most wonderful thing that he did was to construct a small electrical machine, which astonished every one who saw it.

There was a queer old man in Glasgow, which was not very far from Greenock, who kept a small dingy shop, where he mended spectacles, fishing-tackle, and fiddles. In this shop young Watt worked for a while as an apprentice. But he was now eighteen years old, and quite a man in his thoughts and aims. He longed to make his way in the great world; above all, he desired to see London, and learn what could only be acquired in that great city. So one day, supplied with a small bundle of clothes, and accompanied by his friend, John Marr, he set out for London on horseback. It

took the travellers ten days to make their journey, and as Watt had never before been far away from his native place he saw many sights on the way which interested and delighted him.

His father was poor, and Watt carried but a small sum of money with him. So when he at last reached London he looked up some very humble lodgings in an obscure part of the city. He ate only enough to keep body and soul together, and after spending a few days in viewing the wonders of the vast, crowded capital, he set to work on his studies with all his might. He took service with an instrument-maker, and soon became very skilful in making quadrants, compasses, and other instruments.

But so delicate in health was he that he soon broke down with hard work and meagre fare, and was obliged to go back home again. His native air restored his strength, and he resumed work with redoubled zeal. At the age of twenty-one Watt opened a shop of his own in Glasgow, and put out his sign as a mathematical-instrument maker. But he did many other things besides making instruments. He constructed organs, fiddles, guitars, and flutes. At the same time he pursued other studies with the greatest ardor, and soon knew a great deal about engineering, natural history, languages, and literature. He became

well known to the professors and students of Glasgow University, in the shade of which his little shop stood, and his amiable disposition and ripe knowledge made him a great favorite with them, and secured him many warm and valuable friends.

It was while Watt was engaged in these many busy and useful occupations that an incident occurred which changed the whole course of his life, and which in time led to fame and fortune. One day an old steam-engine, made by a man named Newcomen, was brought to him to repair. This engine was the best that had ever been invented; but it was a clumsy affair at best, and could not do better or quicker work than horses. As soon as Watt's keen eye examined it, he saw that the Newcomen engine was not good for much. Yet it showed him that an engine might be made which, with the use of steam, would perform wonders.

From that time he gave himself up to an absorbing study as to how to make a really useful and powerful steam-engine. There was something wanting—what was it? This was the question which perplexed him for days and weeks, and even years: how to keep the cylinder of the engine always as hot as the steam which entered it, and yet to have the cylinder get cold enough to condense the steam when the piston descended. Many a time Watt was on the point of

giving up the problem in despair; but his resolute will kept him at work, and impelled him to persevere bravely.

One day, as with knitted brow he was sauntering across the Glasgow common, all of a sudden an idea struck him which solved the difficulty which had so long worried him. It occurred to him that, since steam was elastic, it would rush into any space or vessel the air in which had been exhausted. He hurried home in a fever of impatience. He constructed a vessel separate from the cylinder, and made a connection between them, and the vessel being exhausted of air, he found that the steam rushed into it.

This was the most important of all Watt's discoveries. He worked away on his engine now with redoubled zeal; but years were to pass before his great object was fully achieved. It was ten years after his walk on Glasgow common before his idea had taken shape in an actual working steam-engine. His health more than once failed him, and on one occasion, so discouraged had he become, he bitterly exclaimed, "Of all things in the world, there is nothing so foolish as inventing!"

But the triumph of his life, bringing with it world-wide renown and ample wealth, came at last. About a

hundred years ago Watt set up his first complete steam-engine in London. It saved labor, and in many industries at once took the place of man and horse power. All the world saw after a while what a wonderful machine it was; but no one then could have foretold to what vast uses the idea of Watt's engine was to be put. We, who live in the days of steamships, railways, great mills, elevators, and a thousand other results of Watt's invention, can more clearly see of what enormous benefit it has been to mankind.

James Watt lived to a happy and prosperous old age, crowned with honors and revered by all his countrymen. He pursued his labors and researches to the end, and many were the ingenious devices which he invented. A fine statue of him stands in the Museum at Glasgow, near which the little model of his steam-engine, made by himself, was long kept for every one to see. The visitor to Westminster Abbey may observe among the memorials of poets, statesmen, and the most famous of Britain's sons, a statue of Watt, in a sitting posture, with an eloquent inscription by Lord Brougham.

Eli Whitney
The Inventor of the Cotton Gin

Childhood

If a teacher should ask her pupils to guess where Eli Whitney, the inventor of the cotton gin, was born, the bright-eyed girl who always has her hand up first, would probably answer, "In the South where cotton grows." And the other pupils would think she must be right.

But strange as it may seem there were very few cotton fields in the South when Eli Whitney was born. And his childhood home was far away from them on a New England farm, near the inland village of Westboro, Massachusetts.

There cold weather came early in the fall and lingered until late in the spring. The snow-covered hills and meadows were the only "cotton fields" that little Eli knew anything about.

He was born on a bleak December day in 1765, more than ten years before the signing of the Declaration of Independence.

The Whitney home was one of those plain New England farmhouses that are still common in that part of the country. This two-storied frame dwelling was

built near the road. A little "stoop" about five feet long and three feet wide served for a front porch.

But if the porch was small, the chimney was large, and the fireplaces were broad and deep. The narrow mantels above were so high that there was no danger of the children's breaking the plates and candlesticks that ornamented them.

The ceilings were low. The rooms were lighted by wide old-fashioned windows with twelve small panes of glass in each sash. The window-sills were so far from the floor that Eli and his sister had to stand on chairs when they wanted to scratch pictures in the frost which, in winter, often covered, the panes in spite of the fires in the big fireplaces.

In the best room there was fine furniture, which had been bought at the shops. But the other rooms were furnished chiefly with homemade tables and chairs. These were neat and strong, and the rooms were comfortable and homelike.

Mrs. Whitney was an invalid, and died while Eli was still a child. The father was a stern, business-like man, who believed that children should be seen and not heard. Eli's brothers were older than he, and therefore his sister, who was nearest his age, was his favorite playmate.

The children had few playthings, but Eli was seldom at a loss for amusement. Although he asked a great many questions, he always asked them for information, and not simply because he wished to say something.

Almost every farmer had some sort of a shop where, in bad weather, he tinkered away at various things and mended whatever was out of order. Mr. Whitney's shop was well fitted with tools, and when not busy on the farm he worked there, making chairs for the house, wheels for his wagons, and many other useful articles.

Eli was very fond of watching his father and older brothers while they were at work, and he soon learned to do many little things himself. As he grew older he liked to work in the shop better than on the farm. He examined all the machinery in the place until he understood it. He wanted to know how it was made, and was not content till he found out.

His father's big silver watch was to him an object of wonder. How could it keep up its steady "tick, tick"? What made the hands move, one so slowly, the other more rapidly?

One Sunday, Mr. Whitney went to church and left his watch at home. Eli stole to his room and pried

open the back of the watch to see the wheels. That was very interesting for awhile, but the works were partly hidden. One wheel was over another. A little metal plate covered something which he wanted to see.

The curious boy was not long in finding the tiny screws that held all in place. He soon had them out, and took the works apart.

So deeply interested was he that had his father come home then, Eli would not have heard his step, and the stern man might have walked right into the room before the mischief maker discovered his presence.

But fortunately for the lad, church lasted a long time in those days, and he had plenty of time to satisfy his curiosity before the odors from the kitchen warned him that it would soon be dinner time, and his father would be at home.

Then he felt somewhat worried, but he had noticed so closely the relation of each of the members to the others that he was able to put the delicate works together correctly. It was with a deep breath of relief that he heard the familiar tick, and he trembled whenever he saw his father look at the watch that day. But it was uninjured, and not until years later when Eli

told him did Mr. Whitney know that it had been meddled with.

Once after an absence of several days Mr. Whitney, on coming home, asked the housekeeper how each of the boys had spent his time while he was away. He learned that one had weeded the onions, and another had mended the stone wall between two fields.

"But what has Eli been doing?" asked the father, noticing that no account was given of him.

"Oh, he has been making a fiddle," she answered.

"Ah," said Mr. Whitney, with a sigh, "I fear Eli will have to take his portion in fiddles. "

The fiddle proved to be a very fine piece of work for a twelve-year-old boy. It was made like any other violin and gave fairly good music. Every one that saw it was astonished; and after that all the musicians in the neighborhood brought Eli their violins to mend when they were out of order. He was usually successful in discovering and correcting any faults in their mechanism.

His father, however, looked upon this work as foolishness. He would have been much better pleased to see Eli do a good day's work on the farm.

Youth

The New England farmers were a very intelligent class of people and understood the value of education. Every settlement had its little school.

Eli Whitney went to the Westboro school, where he studied spelling and learned to read and write. When he began to study arithmetic he made rapid advancement and soon stood at the head of his class. But his pleasantest and most profitable hours were spent in his father's workshop. Every day he grew more fond of working there.

When Eli was thirteen years old his father married a second time. Eli's step-mother took to her new home many choice possessions that she had collected since her girlhood. She liked to look at her treasures and show them to others.

One afternoon she was showing them to Eli and his sister. Among the parcels was a fine set of dinner knives. When she unwrapped them Eli eagerly took one and examined it with a beaming face.

Mrs. Whitney was pleased to see that the boy was interested. "These are very fine knives," she said. "They were made in England. Nothing like them could be made in this country."

At this Eli looked up quickly and said: "I could make them myself if I had the tools; and I could make the tools if I had some common tools to work with."

Mrs. Whitney was displeased and reproved him. She did not think for a moment that this little boy could do such work, or that he even meant what he said. He seemed to her to be bragging and trying to make fun of her for treasuring those knives.

However, in a few weeks Eli had an opportunity to prove the truth of what he had said. By accident one of the precious knives was broken. He took the pieces to the shop for a model, and with his clumsy tools made a knife so like the broken one that Mrs. Whitney could tell it from the others only by the absence of the stamp of the manufacturer on the blade.

It is needless to say that she now regretted her hasty words. From that time she had much greater confidence in the boy's ability to do what he undertook.

Two years later Eli began to use his skill to make money for his father. His occupation was nail-making.

As the Revolutionary War was then in progress, all trade between England and America had stopped. There were then few manufactories of any kind on

this side of the Atlantic. The colonies depended upon the mother country even for such little things as nails.

Nails were made by hand and were much more expensive than they are now. Eli Whitney had often made small quantities of nails for family use, and he had done it very quickly and well. Now that they were so scarce it seemed to him that there would be profit in making them to sell. He spoke to his father about it, saying that he felt sure he could make the work pay if he had certain tools.

The idea pleased his father and he bought the necessary outfit at once. From that time till the close of the war the young mechanic spent all the time he could spare from farm labor in making nails. It proved such a profitable employment that he enlarged his shop and took an assistant.

After the war was over, nails were again shipped to this country and sold for less than young Whitney could afford to make them. He saw that it was useless to try to work against the great nail makers of England.

But he would not think of letting his shop lie idle. He turned it into a factory for the making of walking sticks and hat pins. He was as successful in manufacturing these little articles as he had been in making nails. He was careless in nothing, and often

said, "Whatever is worth doing at all, is worth doing well."

Mr. Whitney had long ceased to regret Eli's fondness for tinkering about the shop. He now expected him to settle down and become a contented, self-supporting mechanic.

But Eli was not satisfied to do this. As he grew older he took more interest in books. In one way or another he had picked up a great deal of general information, and had acquired a surprising amount of useful knowledge. He saw that those who succeeded in life were educated men; and he was ambitious to be more than a common day laborer.

Accordingly, when he was nineteen years old he decided to go to Yale College and get a thorough education.

His father was surprised and somewhat pleased at the idea of having one of his sons go to college. But when the good man spoke to his wife about it she firmly opposed the project. She said that Eli had neither the money nor the knowledge to go to college, and advised him not to think of it, as it would only make him discontented and restless. She told him that since he was already making a good living he ought to be satisfied.

The neighbors agreed with her, and said it would be too bad to spoil such a good mechanic by sending him to college.

The young man now understood that he would get no help from his family. What his stepmother had said was only too true: he had neither the knowledge required to enter Yale College, nor the money that would be required to support him while studying there. But he was not easily discouraged. When he made up his mind to do anything he usually accomplished it.

He said no more about the matter but worked early and late to secure the two things needful. To prepare himself for the entrance examinations he took his books to the shop and studied while his fingers did the work for which they had been trained. He made friends with educated people wherever he could, and got all the hints and helps possible.

Nor was he less zealous to get money. Farm work, shop work, and school teaching occupied his time. He welcomed any task whereby he could earn something to add to the little store he was saving for his education.

Although he was so industrious he was twenty-three years old before he was ready to start to college.

For four years the plucky fellow had made a brave struggle against many difficulties, with no encouragement except from his faithful sister.

And now that he was ready and could say proudly, "Next May I shall enter Yale College," an unexpected misfortune threatened to disappoint his hopes.

He was taken ill and suffered for weeks from a severe fever. For a time his life was in danger. But, the fever having finally been broken, he slowly gained strength and in May he was able to go to college as he had hoped.

At Yale

Every fall hundreds of boys who have just finished high school go from all parts of the country to New Haven, to enter Yale College.

Some arrive on the big steamboats. Others come in on the great railroads over which well-filled trains fly back and forth, to and from Boston and New York.

These students find New Haven a large city. Many noisy factories are there. The broad avenues are bordered by beautiful homes, large business blocks, and other fine buildings. Noble elms grow along the streets. Electric cars, and wagons, and carriages of all kinds rumble over the pavements.

In the heart of this busy city is a great square called the Green, where three historic churches stand.

Just beyond the Green rises a row of fine buildings of brick and stone. These are some of the university buildings. They are so stately that they make the stores near by look small and common.

Passing through a broad arch or gateway, the student finds himself within the Yale yard, or campus. It is a large pleasant quadrangle where elms wave overhead, while their lacy shadows dance on the sunny grass. Boys and young men hurry up and down the long walks with armloads of books.

This quadrangle is shut in by four rows of lofty college buildings. A line of plain, old-fashioned brick halls extends across it. These buildings are so poor and old that they look out of place beside the handsome new ones around them.

When Eli Whitney looked out of the windows of the stage coach that took him to New Haven he saw only a straggling village. At that time only about four thousand people lived in New Haven. But it seemed a large town to the young man from Westboro. He had never dreamed of such elegant structures as Osborn and Vanderbilt Halls; and the plain brick buildings, which look to us poor and common, were so much

better than the neighboring shops that they appeared grand and stately.

When young Whitney went up to take his examinations, he looked with almost a feeling of reverence at the Old Chapel, the Old South, and the Old South Middle, as the buildings are called.

He passed his examinations and entered the first or freshman class.

There are now almost as many teachers at Yale as there were students then. At that time the president and two or three assistants gave all of the instruction. The president had charge of the advanced classes. The lower classes were taught by young tutors.

President Stiles was a very scholarly man. The students were expected to treat him with the highest respect, and they really stood in great awe of him. When he entered the chapel all rose and remained standing while he walked down the aisle bowing with gracious dignity to the right and to the left.

If a boy went to the president's house to see him on some school business, no matter how cold it was, he took his hat off at the gate and kept it off until he left the yard again.

Though the tutors were young men who had not been out of school very long themselves, they were treated with almost as high regard as the president.

The seniors had great power over the lower classes. Shortly after school opened each year there was a meeting of the freshman and senior classes. The freshmen formed a line along one side of the long hall and the seniors lined up along the opposite side. Then the gravest and most dignified member of the senior class stepped forward and gave the freshmen a lecture on college rules and manners.

The younger students were expected to obey all the orders of the seniors, and were punished severely by them for disrespectful behavior.

It would have been very hard for Mr. Whitney, who was then twenty-three years old, to submit to the tyranny of the youths of the upper classes. But he had very little to do with them. He found that he could get board in a private family for much less than it would cost him to live at the college halls, and he took advantage of that chance to save his money.

During the first year he studied Latin, the Greek Testament, and arithmetic. He had the power to put his whole mind on one subject and keep it there as

long as he wanted to, and therefore it did not take him long to get his lessons.

He found that he would have some extra time for work. A carpenter was working at the house where he boarded. Mr. Whitney asked if he might use his tools. The man was afraid the college student would injure them, and refused to let him take them. The owner of the house heard the conversation. He had formed so high an opinion of his boarder that he asked the man to lend him his tools, saying that he would pay for whatever was broken.

The carpenter gave his consent, but watched critically while the college man began to work. He was so astonished when he saw how adroitly he handled every tool, that he exclaimed, "There was one good mechanic spoiled when you went to college." After that Mr. Whitney was permitted to use the tools whenever he liked.

Thus by doing occasional odd jobs, and by working during vacations, he was able to continue at college for the entire course.

As he went into higher classes, he had to spend more time in study. In the second year he took geography, grammar, rhetoric, algebra, geometry, and the catechism, in addition to Greek and Latin. The

teachers were very exacting, and required the pupils to learn their lessons word for word. Some of the text books were dry and uninteresting.

In the third or junior year young Whitney commenced the study of trigonometry and philosophy. He liked both of those subjects very much.

It was with keen pleasure that he went to his recitations in natural philosophy. They were held on the second floor of the Old College, in a corner room where the shutters were usually mysteriously closed. There all of the delicate instruments belonging to the college were kept. A telescope, an air-pump, a magic lantern, and an electrical machine were among its treasures.

One day the teacher of this class said that he was unable to make a certain experiment because his instrument was broken. He added that it would be necessary to send it to Europe to have it put in order, as there were no mechanics in this country skillful enough to mend it.

Eli Whitney looked at it for a moment, and then said, "I see just what is the matter, and I think there is no reason why I cannot mend it."

Although the teacher had great confidence in his student, he was surprised at this offer and scarcely willing to trust such a valuable instrument to him. However, when Mr. Whitney explained to him what would have to be done, and assured him that he could do it, he consented to let him try. The clever workman put it in perfect order, to the surprise and delight of both teacher and classmates.

By that time he had begun to take a more active part in college life. He was known and liked by the students of all classes, and was a prominent member of one of the literary societies.

He made life-long friendships at college with men who were to be the social and political leaders of their time. And he graduated with credit in the spring of 1792.

In Georgia

Having finished college, Mr. Whitney wished to study law and become a lawyer. He had spent all his own money and had even borrowed some from his father to finish his course at Yale. It would therefore be necessary for him to earn more before he could go on with his study.

While he was looking about for something to do, he was offered a position as teacher in a small private school in Georgia. He had had some experience in teaching. Then, too, it would be very pleasant and instructive to spend a winter in the South. So he accepted the position.

It was a hard journey over land from New Haven to Georgia; for in those days there were no railroads, and only very poor wagon roads. For this reason the young traveler embarked on one of the slow boats and went by sea.

He was not alone on his voyage. At New York he met Mrs. Greene and her children who were on their way to their beautiful southern home at Mulberry Grove, a few miles from Savannah. Mrs. Greene was the widow of the great General Nathanael Greene whose victories in the South are remembered by every schoolboy that has read the history of the Revolution.

Mrs. Greene was a brilliant little woman. She was admired and loved by George and Martha Washington, and accustomed to the gayest and most elegant society in the land. Perhaps it was because her famous husband had been so deeply interested in young men who had gone through college and were trying to make something of their lives, that she took

such an interest in the young New England school teacher and mechanic.

She was very kind to Mr. Whitney and made him feel quite at home in her party. It pleased her to see her boys and girls fond of him. They had not been together many days before she had made up her mind that Eli Whitney was no ordinary young man.

When he reached Savannah Mr. Whitney found that the position he had come to fill was not as had been represented to him. The salary was only half as large as he had expected. This was a great disappointment.

On hearing of his trouble, Mrs. Greene said, "Do not think of taking the position. Come to my home and wait till a better opportunity offers. In the meantime you can study law. You will be very welcome. It will be a great pleasure to us to have you with us for a few weeks."

Her children, who were delighted at the idea of having their new friend at their home, added their affectionate entreaties to their mother's invitation. So he was persuaded to visit Mulberry Grove, although he hesitated to refuse the school, and still thought of taking it if he could get nothing better.

He found Mulberry Grove to be a beautiful estate situated on the Savannah River, about fourteen miles from the city of Savannah.

The house was large and magnificent, and furnished with all possible luxury and elegance; for it had been the home of the Tory governor of Georgia in the days before the Revolution. To Mr. Whitney, one of the most attractive features of the house, was the large, well-stocked library.

Around the house was a beautiful garden where all sorts of flowers and fruits grew in abundance. Peaches, apricots, figs, oranges, and plums were in various stages of perfection. The whistle of the mocking bird in the magnolia trees trilled through the warm air.

In the rear of the mansion was the large kitchen, in a separate building. Beyond that were the smokehouse, the coach house, the stables, and the poultry pens fitted for the accommodation of thousands of fowls.

In the distance extended vast corn and rice fields, where the negroes in gay garments were at work planting, cultivating, or harvesting.

Mr. Whitney was much interested in the great plantation. Such luxury was surprising to one brought

up as he had been. Even at that time there was a strong spirit against slavery in some parts of New England. The visitor at Mulberry Grove shared that feeling, and observed the plantation slaves with great interest and sympathy. He learned that they were much afraid of the smallpox, and shortly after his arrival he vaccinated all of them.

Mr. Whitney tried in every way possible to show his appreciation of the kindness of his hostess. If anything was out of order in the house or on the plantation he seemed to know exactly what was needed to make it right.

One day he heard Mrs. Greene complain that her embroidery frame tore the threads of the delicate cloth she was embroidering. He looked at it and pronounced it a clumsy contrivance. He left the room, and soon came back with a very different frame exactly suited to the purpose.

"Where did you get it?" asked Mrs. Greene.

"I made it," he replied, helping her to adjust the work on the new frame.

"But it is such a fine idea," she went on enthusiastically. "Where did you get the idea?"

"Oh, I made that too," he answered, laughing.

The Opportunity

Mrs. Greene was a woman of much importance and had great social influence. She was acquainted with the most prominent families in the country, and was very popular. In the dark days of the war, her husband said that whenever the news reached camp that she was coming to make him a visit, the whole camp was glad. While enjoying one of those happy visits the great soldier wrote to a friend: "Her cheerful countenance and ready tongue quite triumph over my grave face."

Now that the bright little northern lady had come to make her home in the South, old army officers and neighboring planters frequently stopped, on their way to and from Savannah, to have a visit at Mulberry Grove.

One afternoon, when a large party of officers and plantation owners from the neighborhood of Augusta were at the plantation, the conversation was about the discouraging state of affairs in the South, the heavy debt, and the number of people that were going west. One said, "If we could only find a way to separate rapidly the short-staple cotton from the seed it would bring new life to the South." The others agreed that this was so.

"Now," thought Mrs. Greene, "is the time to interest these influential men in my poor young friend, Mr. Whitney." Then she said, "Gentlemen, I have a friend who has just come from the North, a graduate of Yale College. He is a perfect genius at contriving machinery. Indeed, it seems to me he can make anything. Explain to him what is wanted, and I am sure he can help you."

Then she showed them her embroidery frame, and explained its good points, while a servant went to call the young man.

Mr. Whitney was in his room studying hard in a great law book, not thinking of the beautiful country around him, or of its products, when the polite servant summoned him to go below to meet some gentlemen.

"Perhaps they are lawyers. This may be an opportunity," he thought to himself as he hurried down stairs.

He listened eagerly to what the gentlemen said, and learned a great deal about cotton. He became much interested in the subject, and promised to see what he could do.

In those days tobacco and indigo were the chief products of the inland plantations. Large quantities of rice and some cotton were raised near the coast.

There are two kinds of cotton that may be compared just as we compare two varieties of peaches. You know that, while all peaches are very much alike, there are two kinds, the freestone peach from which the stone is easily removed, and the clingstone peach whose stone and pulp adhere so closely that it is almost impossible to separate them. It is so with cotton. There is one black-seed, long-staple variety, that is called sea-island cotton, since it grows well only near salt water. The seeds of this cotton are removed with little difficulty. Then there is the green-seed, short-staple cotton which can be raised on inland plantations. The fiber and seeds cling to each other so closely that it is hard work to get them apart.

For years the planters along the coast had raised enough of the first kind for family use. A rude machine, called a roller gin, was used for separating this cotton wool from the seeds. It consisted of two wooden rollers which turned towards each other and acted on the same principle as the common clothes-wringer. The staple passed between these rollers, and the seeds were either squeezed back or crushed in passing through, just as you have seen buttons treated by a wringer.

Recently large crops of short-staple, green-seed cotton had been raised successfully on the high land.

The climate and soil of the upper country, where rice could not be cultivated, were well suited to the growth of this cotton.

Improvements in the method of spinning and weaving had made a great demand for cotton, and the planters of the upper country wished to turn their tobacco fields into cotton fields. But after the cotton was raised there was no machine to separate the seeds from the fiber. The roller gin could not be used with this kind of cotton, and the separating had to be done by hand.

It was a day's work for a woman to pick the seeds from a pound of cotton, and the women servants were needed for other work.

It was customary on the plantations where cotton was raised to require the slaves to spend their evenings cleaning it. Men, women, and children sat in circles working by the light of tallow candles. Sometimes they sat quiet and sullen at their work. Sometimes they sang plantation songs, or told stories, or made rude jokes and laughed heartily, showing gleaming rows of white teeth. But, whatever expression the dark faces, bent over the snowy cotton, wore, the fingers worked busily, for there was an

overseer close at hand to see that there was no idleness.

Every family of slaves was expected to separate about four and a half pounds in a week in addition to doing the field work. The slaves did not like it, and their masters were little better satisfied. At best, it was slow work, and the planters were anxious to find an improved method for removing the seeds.

Not many days passed before some of Mrs. Greene's friends came back to see what progress the Northerner had made in solving the problem. Eli Whitney had not been idle.

He had never seen cotton in the seed, and as there was none to be had at Mulberry Grove, he had gone to Savannah to get some.

He had experimented a little with it, and had formed a rough plan for a machine. He said that he had thought the matter over carefully and did not doubt that he could make a machine to do the work. But it would be an expensive undertaking, and would so interrupt his law studies that he could not afford to go into it.

His hearers assured him that in case he succeeded he was sure to make a fortune. But he still shook his head. Success was doubtful, he said, even if he made a

good model. Others would use his invention before he could get money to make his machines and put them on the market.

They reminded him of the patent laws designed to protect inventors and prevent others from using their ideas without permission. He still hesitated, saying that it would be hard to enforce those laws.

The truth was, he had no money to spend in making the experiment. Gradually the disappointed planters stopped urging and went away. Mr. Miller, the man who had charge of Mrs. Greene's estate, staid. He had talked much with Mr. Whitney and had heard him explain his plan.

When all the others had gone, he said, "Mr. Whitney I believe you can do this, and if you will undertake it I will become your partner. I will furnish all the money necessary until you get the patent, on condition that I receive half the profits when we begin work."

Mr. Whitney gladly accepted this generous offer.

Making the Cotton Gin

The important question of "Who will pay for the venture?" having been settled, Mr. Whitney devoted his attention to the still greater one, "How may cotton be separated from the seed?"

He had formed a rough plan for a machine which he thought would answer the question satisfactorily. The next thing in order was to test his plan by making the machine and trying it.

Mrs. Greene and Mr. Miller had high hopes of his success and were almost as anxious as he to see a cotton gin actually made and at work. Mrs. Greene had a shop fitted up in the basement, where the inventor worked behind locked doors.

Her children were surprised to find themselves refused admission by their accommodating friend. They became very curious to know what was going on in the mysterious room. But the inventor met all their questions and jests with easy good nature, and let no one but his hostess and Mr. Miller into the secret.

He worked under great disadvantages, for he lacked many necessary materials which were not to be bought even at Savannah. And it required almost as much ingenuity to carry out his plan as it had taken to make it.

His idea was to mount a cylinder on a strong frame, so that it could be turned by hand, or by horse or water power. The cylinder was to be provided with rows of teeth, which passed through narrow openings in a curved plate or grating of metal. The rows of teeth, or circular saws, were to be about three fourths of an inch apart. The cotton was to be put into a box, or hopper, so that it rested against the grating through which the saw teeth protruded. When the cylinder was turned, its sharp teeth would catch the cotton and drag it through the grating, tearing it from the seeds and dropping it on the other side, soft and clean. The seeds, which had been left behind, would fall to the bottom of the hopper and pass out through an opening just large enough to let them pass. They would be uninjured by the process, and ready to be planted for another cotton crop.

Mr. Whitney worked rapidly in spite of many inconveniences. But when all was done except the cylinder, progress stopped for a time. His idea had been to make circular saws and mount them one after the other on the cylinder. To make them, he must have tin or steel plates. As he could not buy or make such plates, he was obliged to contrive some other way of making the teeth on the cylinder.

One day as he was sitting in the quiet parlor, trying to think of something to use in place of the saws, one of Mrs. Greene's daughters came in with a coil of strong wire in her hand.

"I have caught you at last! Won't you help me make a birdcage?" she coaxed, holding out the wire with a bright smile.

Mr. Whitney was always glad to use his quick wits and nimble fingers to please his little friends. But never had he performed a task more cheerfully than this; for the little maid had brought him a suggestion with her request.

With a light heart he returned to his shop and was soon busy cutting pieces of wire into required lengths. Soon the clever workman had a wooden cylinder, armed with rings of wire teeth, mounted and ready for use.

What an exciting moment it was when he put the cotton into the hopper and his hand on the crank! How much the result meant to the man! With glowing cheeks and bated breath, he watched the cylinder turn and the wire teeth carry through the openings of the plate a burden of snowy cotton free from seeds.

That was a moment of victory. Past years of toil and patient striving were forgotten. Visions of

comfort, luxury, and honor, thoughts of his father's and friends' surprise and pleasure, filled his mind for a moment.

Then he dismissed those dreams and studied the working of the machine more closely. He saw that the cotton lint clogged the teeth of the cylinder. There were many little improvements that must be made before the gin was perfect. But the main object was accomplished. He had made a machine that would separate cotton from the seed.

In high spirits he called his friends to share his triumph. Both were delighted. "I knew you could do it," said Mrs. Greene, with tears of pleasure in her eyes.

Mr. Miller was no less enthusiastic. "Our fortune is made, man! You've invented a gold mine!" he exclaimed, bending over to examine the wonderful gin.

The inventor tried to check their ardor by saying that the work was by no means finished. "We must find a way to get the cotton off the teeth," he said, turning the crank slowly and plucking at the stubborn lint.

"That is only a trifle," answered Mrs. Greene gayly. Then she picked up the hearth brush and asked with a light laugh, "Why don't you use that?"

"Thank you, I will," he said, taking the offered brush and trying it. "And now I must get to work again."

Again the doors were locked, and when the confidants were next admitted, they saw a second cylinder that turned towards the first one. It had rows of little brushes which met the wire teeth and swept the cotton off of them as the two cylinders revolved.

Mrs. Greene wanted to celebrate her friend's success. She invited leading men from all parts of the state to come to Mulberry Grove to see the gin in operation.

A booth was built in the garden and decorated with flowers and foliage. There the gin was exhibited. The planters stood around it and watched with wonder and admiration, while it did in a few minutes as much as had hitherto been called a day's work.

That was a great day, and Eli Whitney was the hero of it. Every one praised and congratulated him. They called him the benefactor of the South. He was in high spirits and answered without reserve the many questions asked by the planters. He talked of the difficulties he had had to overcome in making the model. Among other things, he told how he had first

thought of using metal sheets instead of wire to make the teeth of the cylinder.

A new future seemed in store for the South. In fancy the planters saw endless cotton fields sweeping over hill and plain. All decided to plant their rich acres in cotton the next season.

Their astonishment and satisfaction were so great that they could not restrain their feelings. They talked about the wonderful invention everywhere. As the news spread, crowds of curious people visited Mulberry Grove to see the inventor and his marvelous machine.

But Mr. Whitney had not yet obtained a patent on his machine. That is, he had not gotten from the government the right to control the manufacture and use, or sale, of the cotton gin. It was therefore thought best not to show it to many, lest some one should steal the idea and get a patent before Mr. Whitney did. Hence many visitors went away disappointed.

The excitement about it was so great that the gin was not safe. It was kept constantly under lock and key. One night, in spite of that care, some men broke into the shed where the precious machine was kept and took it away.

With all haste possible, Mr. Whitney made another model and sent it to the patent office at Philadelphia, which was then the seat of the national government.

Great Expectations

Papers were made out, formally organizing the firm of Miller & Whitney. At first the two men thought that they would manufacture cotton gins and sell them to planters, or sell the right to manufacture to those who wanted to make gins.

But they decided that it would be more profitable to do the ginning themselves and take their pay in cotton. The planters were willing to give them, in payment for their work, one out of every three pounds of cotton they ginned.

To handle the entire cotton crop of the South would be an enormous undertaking. But these two ambitious young men had not the slightest doubt of their ability to do it successfully. They would need a large number of gins, for cotton was being planted in all parts of the South, and the crop promised to be a heavy one.

It was agreed that Mr. Miller should make the terms and the contracts with the planters and look

after the company's interests in the South, while Mr. Whitney started a factory and got the gins ready for fall work.

The latter had found by experience that there were no advantages in the South for manufacturing. It would be necessary to make the machines in the North and ship them to Georgia. He felt more at home in his college town, New Haven, than in any other northern city. He knew the shipping advantages there; he knew where he could get supplies; he even knew good workmen whom he could employ. Besides, it was the place he preferred for his future home.

In the spring of 1793 he started north. He went first to the capital to take the proper steps to secure his patent. Thomas Jefferson was then Secretary of State. He was interested in the invention, and said he should like to have one for his own use.

Mr. Whitney staid at Philadelphia no longer than was necessary and then hastened to New Haven. He had many friends there who were glad to see him back; but he was too busy to find much enjoyment in their company. He did not even take time to visit his father's home at Westboro as he had hoped to do.

Every letter he received from his partner urged him to push the work, and warned him that there would be a great demand for cotton gins.

Mr. Whitney worked early and late, getting his shop ready, training his workmen, and providing proper tools.

As soon as the first machine was completed he went south with it, to see it set up and put in operation. The progress of the enterprise depended largely on the satisfaction given by the first gin; for on its success depended his ability to borrow money to pay for making others.

The result was all that could be desired. Everything promised the most glowing success. The only difficulty would be to make gins fast enough.

To enlarge the factory and push the work the company needed a little more money than they had. Many were ready to lend to such a promising firm as Miller & Whitney, and a loan of two thousand dollars was secured without difficulty.

Mr. Whitney went back to New Haven where he managed the building of an addition to his shop, and employed a large force of workmen.

His intention was to go to England just as soon as he got his affairs in working order. It was important

that he should go there without delay, to get a patent in that country. But he was true to his old motto, "Whatever is worth doing at all is worth doing well," and slighted nothing in his hurry.

He took the greatest pains to plan every detail of the factory, so that the work could be most quickly and economically done.

His work was delayed by his own illness and that of his workmen. But in spite of such hindrances he had his shop in the best of order when, at the close of the winter of 1795, he went to New York to attend to a few business affairs before leaving for England.

He had been for two years a very busy, hard-working man, but a very hopeful one. All was going well, and the future was bright with promise.

Misfortunes

After a short stay in New York Mr. Whitney returned to New Haven. It was a chill March day when he stepped off the boat at the New Haven dock. One of his friends came out of the crowd to greet him.

"You have hard luck, Mr. Whitney," said the man, taking his hand.

"Why, what's the matter?" asked Mr. Whitney, startled by the grave face of his friend.

"You have been burned out," answered the other.

With a look almost of despair the unfortunate man cried, "Is everything gone?" and seeing the other nod his head sadly, he added, "This is indeed a misfortune," and strode off with such long steps that his friend could scarcely keep pace with him.

Arriving at the scene of the fire he found, in place of his well-ordered shop, a desolate ruin. Valuable papers, twenty finished gins, machinery, and shop were all gone. The results of two years of untiring work lay in ashes.

In every letter, Mr. Miller wrote, "We must have a hundred gins by fall." Those words came to Mr. Whitney at this moment, and he felt helpless and crushed.

But he soon regained his self-control and inquired how the fire had started. He could find out nothing satisfactory about its cause.

Everything had been done in the usual neat and orderly fashion. The night before, the shop had been swept "as clean as a dwelling house." There was not a "hat crown of fire in both chimneys, and not a pailful of chips or shavings in the entire building." The men

left the building to go to breakfast. They had been gone not more than ten or fifteen minutes before the whole building was in flames. When the alarm was given, every workman hurried back, pail in hand, to put out the fire. But they saved only the adjoining building and that with the greatest effort.

As the hearths had just been swept, it was Mr. Whitney's opinion that the fire must have started from one of the brooms used for that purpose. But no one ever knew certainly the cause of the fire.

To repair the loss it was necessary for the firm of Miller & Whitney, to borrow more money. It was not so easy that time, and they had to pay a very high rate of interest for it.

Mr. Whitney received word that two other gins, made after the same plan as his own, but changed slightly, were being used in Georgia. The planters would have gins. They were willing to use Miller & Whitney's; but if they could not have them, they would have others.

The trip to England had to be given up. Mr. Whitney used every effort to get the works started again and make up for lost time.

While he was working with might and main to repair the losses he had suffered, another misfortune

befell him which was perhaps the heaviest blow of all. It was hard to be hurried and to have more gins needed than he could supply. But there was something even harder than that possible. That was to have planters cease to want the gins.

It never occurred to Mr. Whitney that this was possible, yet it was exactly what happened. It came about in this way: A large quantity of poor cotton was ginned in one of the Whitney gins. It was full of knots. The merchants to whom it was sold returned it. Then some ignorant or wicked person said the fault was due to the Whitney gin.

Thus the report that the famous Whitney gin injured cotton and made it knotty was started. It was generally believed, and spread even to London, so that buyers refused to take cotton that had been ginned by the Whitney machine. And those gins which were already set up in the South stood idle.

At first Mr. Whitney could scarcely take the matter seriously. He could not believe that intelligent men would be influenced by a charge so groundless and unreasonable. Some of the cotton that had been returned was sent to him. He examined it and said: "Nature and not our gin put those knots in the cotton. They would have been in it had it been ginned by

hand. As for the gin, it is impossible for it to make such knots in good cotton, as any one may see by trying it."

He soon found that, however unreasonable the report was, it had so influenced the merchants, manufacturers, and planters that they would have nothing to do with the Whitney gin.

The company had had thirty gins at work in Georgia. Some were worked by horses or oxen, and some by water power. One after another they stopped work. Ten thousand dollars had been invested in land to be used for ginning. That was idle and unused.

Mr. Whitney now thought that if he could go to England he might do much to overcome the prejudice against his gin among those who bought and sold cotton. For he knew that if these people could be persuaded to have faith in the gin, the planters would be willing to use it. The trip would cost him one thousand dollars. Neither he nor his partner could furnish so much money, and he was obliged to stay at home and trust to time to cure men of their false notion.

He did what he could at home to show the world that the charge against his gin was unjust. He had seed cotton sent to New Haven where he ginned it to the satisfaction of everyone. Samples were widely

distributed. An agent was sent out through the Carolinas, and even across the mountains to Tennessee, to investigate the cotton industry and introduce the Whitney gin.

The prejudice against the gin gradually died out. But in the meantime a patent had been granted to a Georgia man on what he called an "improved gin." While Whitney's gin had been lying idle his had been gaining in popularity.

The new gin was a saw gin. It was like the Whitney gin, but instead of making the teeth for the cylinder of wire, the "improver" had used sheets of metal, as Mr. Whitney had first thought of doing. The machine was Whitney's and the so-called improvement was his idea.

In the Courts

Mr. Whitney had always, even in childhood, a keen sense of justice. He was not the man to stand back and quietly allow another to take what rightfully belonged to him.

He saw that if steps were not taken at once against this man, innumerable modifications of the Whitney gin would spring up and take the place of the original one.

If he had been an uneducated man he would not have known what to do, and this would probably have been the end of his name in connection with the cotton gin. But both he and his partner were men of intelligence. He knew something of law, and he understood mechanics so thoroughly that he was not to be deceived by apparent resemblances or differences in other machines.

In order to encourage ingenious men to give their time and attention to improving machinery and inventing useful articles, the government issues patent rights to inventors who apply for them.

In Whitney's time a patent gave an inventor the exclusive right to make and use or sell his own invention for a term of fourteen years. It was his property, and he might sell or grant to others all or a portion of that right. But for any one to make and use or sell his machine without having received the right to do so from the inventor, was a legal offense. He who did it was said to *infringe* on the rights of the inventor, and was liable to be fined or otherwise punished.

Mr. Whitney had decided to make and use his own gins, and he was determined to punish all who infringed upon his right.

His first suit was brought against Holmes, the man who had made the saw teeth of metal plate instead of wire. Though it was proved that the idea was Whitney's there was a defect in the patent law that made it impossible for Miller & Whitney to win the case.

The law said that the accused had to be guilty of *making, devising, and using, or selling*. The company could only prove that this man had used, not that he had made the gin.

This decision against Whitney encouraged other infringments on his patent. Men with gins which they claimed as their own inventions appeared in all parts of Georgia offering to gin cotton much below the prices asked by Miller & Whitney.

The planters of Georgia were therefore glad to see the true inventor of the cotton gin defeated. There grew up a bitter feeling against him, and it seemed impossible for him to find justice in the courts of Georgia.

He wrote to a friend, "If taking my life would have done away with my claim, I should have had a rifle ball through me long before this time."

Even those who sympathized with him scarcely dared to go into court and tell the truth.

Once, when his attorneys were trying to prove that the cotton gin had been used in Georgia, they had hard work to find any one who would say so, though at the time there were three gins at work so near that the noise of their wheels could be heard from the courthouse steps.

One suit after another was decided against the inventor. Most men would have given up in despair, but Mr. Whitney had a will like iron. He believed two things: that his invention was a good one, and that truth would win in the end.

And at last, after more than sixty trials, which cost him almost as much as he made out of the cotton gin, he came out victorious and proved the claims of his enemies to be false.

The difference in the cylinder teeth had been one of the chief points of dispute. A man claimed to have invented a different gin because he used saws instead of wire teeth. Mr. Whitney was able to show with the help of trustworthy witnesses that the idea of making the teeth in that manner started with him. He further showed that the principle of the gin was the same whether the teeth were made of wire or on steel plates. To make this point so clear that the most ignorant man on the jury would be convinced, he prepared two

cylinders, one with saw teeth and the other with wire teeth. In one he buried the saws in the cylinder so that only the long, sharp teeth could be seen. In the other he attached the wire teeth to steel plates. When the witnesses came up to swear which one was the invention of Whitney and which the invention of Holmes, they pointed out the wrong one in each case.

At the end of the long struggle all just men were satisfied that Eli Whitney was the first and only inventor of the cotton gin.

The question was not settled, however, until a year before the close of the fourteen years covered by the patent. So, as far as money was concerned, it was of small benefit to him. Some years before, the company had sold to the states of North Carolina, South Carolina, and Tennessee the right of manufacture within state limits. From these sales Mr. Whitney and his partner received enough to pay for the lawsuits in Georgia, and had a few thousand dollars left.

Towards the close of the struggle Mr. Whitney had realized that he could not depend on lawyers, friends, or assistants of any kind for success. He saw that whatever was gained must be gained through his own efforts. As his business was extended over a wide territory, he had to do a great deal of traveling. In

going from New Haven to Savannah he often rode overland in a little two-wheeled cart. The roads were very poor. There were few stopping-places, and those journeys required great exertion and exposure.

He wrote to a friend about these frequent trips saying, "I am perpetually on the wing and, wild-goose-like, spend my summers in the North, and at the approach of winter, shape my course for the regions of the South. But I am an unfortunate goose. Instead of winging through the airy heights with a select company of faithful companions, I must slowly wade through mud and dirt, a solitary traveler."

The cotton gin cost its inventor thirteen of the best years of his life. He gave to it his splendid business ability and his rare genius. In return he received a little more than enough to pay his debts, fame on two continents, and the knowledge that he had multiplied the riches of southern planters, and that he deserved the gratitude of every man, woman and child, who sleeps snugly under a soft cotton-filled comfort on a winter night, or who wears a cool cotton garment on a summer day.

An effort was made to lengthen the term of the patent. But men, to whom Mr. Whitney's invention had brought in six months more than he had gained

from it in fourteen years, said that if that was done Mr. Whitney would become too rich. And the attempt failed.

Making Arms

Several years before the term of Mr. Whitney's patent was ended he had come to the conclusion that he would never obtain a fortune from his cotton gin. He therefore made up his mind to go into another business.

His patent affairs had taken him often to the national capital. He was well acquainted there. The president and many of the leading statesmen were his friends. They looked upon him as a man who united remarkable originality of thought with unusual aptitude for work.

When he said that the United States ought to manufacture its own firearms, and that he was thinking of starting a factory for that purpose, he met with encouragement from these men. He was promised orders, and money was advanced by the government to help him establish his factory.

He chose the location of his armory with good judgment. About two miles from New Haven is a rugged mountain, called East Rock. At its foot flows a

clear stream whose course is broken by a fall. In this picturesque valley Mr. Whitney built his armory and planned to build a mansion. The spot was as convenient as it was beautiful. The waterfall furnished power to run the machinery, and the mountain furnished stone for the walls of the buildings.

The armory was one of the largest manufacturing establishments in the country. All strangers who visited New Haven went to Whitneyville to see it. An observant visitor might read in every detail of the institution, down to the very door fastenings, the boyhood motto of its founder, "Whatever is worth doing at all is worth doing well."

The artistically grouped stone buildings with their arches and gables, the great iron millwheels, the stream walled with stone, and the pretty bridge attracted even the careless visitors.

As the manufacture of arms on a large scale was new work in the United States, Mr. Whitney had to make much of his own machinery and train his workmen. It required skilled artisans to make arms as well as they were made in England, but Mr. Whitney adopted a new plan. Instead of having one man make all the barrels, another all the locks, and so on, he had all the barrels made at one time, all the locks made at

another time, and so on. Every man had some one simple thing to do by hand or by machine on each part. This made it very easy for men to learn the trade.

The machinery for the work was so exact that there was no trouble about the parts of the muskets fitting as some had said there would be. Each lock would exactly fit any one of a thousand guns. At first the makers of arms in other countries laughed and said that such a method could never succeed. But they soon stopped laughing, and before long adopted the Whitney method themselves. It is the method used to-day, not only in making arms but in manufacturing almost all complicated articles.

Mr. Whitney's inventions for making arms are said to have shown as much mechanical genius as the cotton gin. But he had had enough to do with patents, and so he got none of those machines patented.

He was kept busy with large orders from the national and state governments. He found that making instruments of war was much more profitable than his contribution to the arts of peace had been.

The future began to look brighter. The settlement of the cotton-gin struggle relieved him of a great care and much anxiety. The success of his large armory promised independence and comfort for the future.

Last Years

This great inventor, who knew so much about the strong and useful, cared for the gentle and beautiful as well. He had not worked so many years merely that he might be rich in gold and bonds.

He liked beautiful things; he loved refined and educated people; he longed for a happy home. It was to enjoy these blessings that he wished to succeed in business.

He was faithful and tender-hearted. Family and kindred were always dear to him. His sister had been his comrade and confidant. He associated his brother with him in business. Even where he felt no special affection he was always courteous. In his long letters to his father be never forgot to send his best regards to his stepmother.

During the busiest periods of his life he found time to win new friends and enjoy old ones. Men whom he met in business were sure to invite him to their homes, and the ladies he met there always asked him to come again.

He was a tall fine-looking man. The most noticeable features of his strong, kind face were the keen but pleasant eyes and the firm chin. His hair curled slightly over a high forehead.

Though usually dignified and somewhat stately, he could unbend and enjoy a merry frolic with the little folks of his acquaintance, with whom he was a great favorite.

His voice was full and deep, and his conversation was entertaining as well as instructive. Moments snatched from business and spent in pleasant talk were very precious to him.

It is not surprising, then, that as business cares became fewer, he spent much of his time in the society of friends. His carriage was seen frequently in front of Judge Edward's door, and in January, 1817, the distinguished Mr. Whitney's marriage with the judge's youngest daughter was celebrated.

The years that followed were full of happiness. Mr. Whitney was not so wealthy as he deserved to be, but he could completely forget past disappointments and wrongs in the pleasures which he derived from his home and friends.

He enjoyed inventing little things for the house. Once he made Mrs. Whitney a fine bureau. It was fitted with many drawers that were all locked by locking the top one. It was easy to keep mischievous children and prying servants out of that bureau. Mrs. Whitney thought it a wonder and her husband the

cleverest man in the world. And the inventor thought his wife's pleased surprise and her bright smiles the best reward in the world.

Surely no other children ever had so many ingenious toys as Mr. Whitney contrived for his happy little ones, and I am sure he got as much pleasure out of them as they did.

We are glad to know that the closing years of his life were happy and peaceful.

He died in 1825, and was buried in the New Haven cemetery. A costly monument marks his grave. A beautiful street in New Haven bears his name. But his invention of the cotton gin is his greatest monument.

Samuel F. B. Morse
The Inventor of the Telegraph

The Parsonage

Long ago in the days when George Washington was president of the United States, a comfortable dwelling stood at the foot of Breed's Hill on the main street of Charlestown, Massachusetts. There was a big knocker on the front door of this house. That was not strange, for many front doors in Charlestown had large brass knockers, and this was no larger and no handsomer than others. But probably no other knocker in the quiet little village was used so often in the course of a day as this particular one.

Men in broadcloth and men in homespun used that knocker. Liveried coachmen with powdered wigs gave dignified raps therewith, to announce the arrival of dainty ladies clad in rustling silks. Women in tidy calico gowns tapped gentle, neighborly taps with it. Important-looking men, on horseback, muffled in long black traveling cloaks, sometimes hammered away with respectful moderation. Poor people with sad faces and shabby garments came too, with modest, timid taps.

The door opened wide to all. Some staid within only a few moments; many made longer visits. But nearly all left looking well pleased with the world. For this was the home of Mr. and Mrs. Morse, and no one could look cross or unhappy after a visit with them.

Mr. Morse was a Congregational clergyman. He was a good preacher, and often his sermons were printed. He once sent to George Washington, with whom he was acquainted, a sermon on the duties of citizens of the United States, and the president wrote him a pleasant letter, to thank him for it.

The First Congregational Church was filled every Sunday with men and women who were eager to hear what Mr. Morse had to say on religious matters. The church members were fond of their able preacher, and when he got married they showed their affections by the presents they gave to help furnish his house. He sent a list of these gifts to his father and here it is: "An iron bakepan and teakettle; a japanned box for sugar; three iron pots, two iron skillets, a spider, loaf of sugar, mahogany tea table, five handsome glass decanters, twelve wine-glasses, two pint-tumblers, a soup-tureen, an elegant tea set of china, two coffee pots, four bowls, a beautiful lantern, a japanned waiter." Some of these seem to us rather odd wedding presents, but Mr. Morse was well pleased with all of

them. The simple, inexpensive articles prove that the poor as well as the rich wished to show their good will to their preacher.

Mr. Morse's influence extended beyond his church. He was widely known and respected. He was a graduate of Yale College; and had read and studied more than most men of his time. Distinguished foreigners traveling in America often brought letters of introduction to Mr. Morse and were entertained at his home.

Because he was a wide-awake man, interested in all questions of public importance, his own countrymen and fellow townsmen liked to discuss questions of the day with him. Business men were glad to talk over their affairs with a man who had such sound judgment and gave such sensible advice.

But not all of the guests at the parsonage came to see the tall, dignified young preacher who looked so grave and stern and talked so pleasantly. Mrs. Morse had many friends of her own. She belonged to a distinguished family. Her father was a judge and her grandfather had been president of Princeton College. She was well educated and very clever. Besides, she was gracious and kind-hearted, and knew how to make everyone feel at ease.

At first, the Charlestown ladies were afraid the young wife from New York would be a little stiff and formal. They were delighted to find her simple and friendly instead. She quite won the hearts of the plainer women by remarking that she liked Charlestown because the ladies were so informal and went calling in calico dresses. This remark was repeated on all sides, and the ladies soon felt free to "drop in" for neighborly visits. Sometimes she spent the afternoon reading to her friends from her favorite books. At other times she sewed, while she chatted with genuine interest about bed quilts, preserves, and other household matters; for she was a fine housekeeper.

When Mr. Morse had distinguished guests Mrs. Morse always helped him entertain them. The "elegant tea set of china" was then brought into use, and the guests were served by their hostess with fragrant tea and golden sponge cake of her own making. All were delighted by her ready wit and lively conversation. Colonel Baldwin, who came often to talk with Mr. Morse about a great canal which was being built under his directions, said afterwards: "Madam's conversation and cup of tea removed mountains in the way of making the canal. " Most people found the parsonage an attractive place to

spend an evening and soon became deeply attached to Mr. and Mrs. Morse. As time passed they gained a wide circle of friends.

On the twenty-seventh of April, 1791, their first son, the hero of our story, was born, and everyone had high hopes for the child of two such worthy parents. Dr. Witherspoon, the great scholar who had followed Mrs. Morse's grandfather as president of Princeton College, took the little one in his arms and bending his white head over the child, blessed him and prayed that he would live to be as good and great a man as his great-grandfather.

Others were as much interested but not so serious. Dr. Belknap of Boston wrote to Postmaster-General Hazard, in New York: "Congratulate the Monmouth Judge [that was the baby's grandfather] on the birth of a grandson. Next Sunday he is to be loaded with names, not quite so many as the Spanish ambassador who signed the treaty of peace of 1783, but only four! As to the child, I saw him asleep, so can say nothing of his eye, or his genius peeping through it. He may have the sagacity of a Jewish rabbi, or the profundity of a Calvin, or the sublimity of a Homer, for aught I know. But time will bring forth all things."

The four names that the wee, little baby was to be loaded with, were the names of his father, his grandfather, and his great-grandfather—Samuel Finley Breese Morse. They were well known and honored names when they were given to the baby; but they are better known to-day and more highly honored because he bore them.

Early Influences

The baby was christened Samuel Finley Breese Morse; and that name was written in the family Bible. But it was too long for every-day use and the child was called simply "Finley" by his parents and playmates.

Little Finley spent the first seven years of his happy childhood in the pleasant parsonage in Charlestown. He was trustful, and quick to make friends, and grew up to be a gentle, affectionate boy, obedient to his parents, kind to his little brothers, and polite to strangers. But he was by no means perfect, and his love of fun sometimes got him into trouble.

His education was begun very early. He was not sent to kindergarten, for there was no kindergarten then. But when he was four years old his father put him in charge of a poor old lady who kept a little primary school. This school was so near the

parsonage that Mrs. Morse could stand at the front gate and watch the little fellow until he was safe inside the schoolhouse door. The teacher was known among the village people as "Old Ma'am Rand." That title does not sound very dignified, but the people who used it meant no disrespect to the aged lady. She, poor woman, was so lame that she could not leave her chair.

Now Dame Rand always remembered that the children were sent to her to learn to say their a, b, c's, to count, to spell, to read, and to write. The wee tots did not always remember this, but sometimes seemed to think they were sent to school to whisper and play. At such times the teacher found that she could bring her wayward pupils to order most quickly by using a long rattan rod that reached clear across the room.

One day Finley Morse was so quiet that she forgot he was in the room until she heard the boy who sat next to him laugh. Then she saw that Finley was drawing something on an old chest of drawers which stood at the back of the room. She reached out her long rattan and touched his shoulder. "What are you doing, Finley Morse?" she demanded, so sharply that Finley jumped and looked frightened.

"Just making a picture," he said, hanging his head while his comrade giggled.

"What are you making it with?" she asked.

"This pin," he answered, holding up a strong brass pin.

Then the teacher noticed that the other boy was looking at the drawing as if it were interesting, and she inquired grimly, "What is the picture?"

"A picture of a lady," replied the small culprit, looking exceedingly uncomfortable.

That was enough; the old lady knew quite well whose picture these little artists liked to draw, and she was not at all flattered by their choice. "Bring the pin to me," she commanded sternly.

The youngster, all unconscious of what was in store for him meekly obeyed. When he came within reach of the schoolmistress she grasped him firmly and taking the pin, pinned him to her own dress. She looked so severe that Finley was frightened. He screamed and struggled until he tore the teacher's dress and got away.

When Finley Morse was seven years old he had learned all that was taught at Dame Rand's school. His father wished him to have a good education. As there were no good public schools, Mr. Morse decided to send Finley to Andover, first to a grammar school, and

then to Phillips Academy, where he should stay until he knew enough to enter Yale College.

Accordingly, as soon as Finley had finished the primary school his little trunk was neatly packed with new clothes, and the seven-year-old boy said good-by to his parents and younger brothers and the dear old home, and went off to live among strangers. He was a manly little fellow and had been brought up to look forward with pleasure to the time when he should be old enough to go away to school. He studied hard and was happy enough at school, but you may be sure he counted the days as vacation approached when he was to go home for a visit.

He was required to write often to his father to give an account of his life at school. His father was such a busy man that the great Daniel Webster said of him, he was "always thinking, always writing, always talking, always acting." Yet he found time to write to his son long letters full of good advice. Finley read these letters over and over again and then put them carefully away. He saved some of them to the end of his life. Here is part of a letter which Mr. Morse wrote to his nine-year-old son:

Charlestown, February, 21, 1801.

"My dear Son: You do not write to me as often as you ought. In your next, you must assign some reason for this neglect. Possibly I have not received all of your letters. Nothing will improve you so much in epistolary writing as practice. Take great pains with your letters. Avoid vulgar phrases. Study to have your ideas pertinent and correct, and clothe them in easy and grammatical dress. Pay attention to your spelling, pointing, the use of capitals, to your handwriting. After a little practice these things will become natural, and you will thus acquire a habit of writing correctly and well. General Washington was a remarkable instance of what I have now recommended to you. His letters are a perfect model for epistolary writers. They are written with great uniformity in respect to the handwriting and disposition of the several parts of the letter. I will show you some of his letters when I have the pleasure of seeing you next vacation, and when I shall expect to find you much improved.

Your natural disposition, my dear son, renders it proper for me earnestly to recommend to you to attend to one thing at a time; it is impossible that you can do two things well at the same time, and I would therefore never have you attempt it. This steady and undissipated attention to one object is a sure mark of

a superior genius; as hurry, bustle, and agitation, are the never-failing symptoms of a weak and frivolous mind. I expect you will read this letter over several times, that you may retain its contents in your memory. Give me your opinion on the advice I have given you. If you improve this well, I shall be encouraged to give you more, as you may need it."

This letter shows us how much the father expected of his son and how anxious he was to have him improve in every way.

Finley did his best to fulfill his father's hopes. He read and wrote more than most of his classmates. He was especially fond of reading the lives of great men. When he was thirteen years old he wrote an essay on Demosthenes, which was so good that a copy of it was sent to his father who kept it as long as he lived.

When Finley Morse was fourteen years old he finished the course at the academy and was admitted to the freshman class at Yale college. Dr. Morse thought it wise, however, not to send him to college until he was a year older, and so the boy studied at home until the year 1807.

College Life

Dr. Timothy Dwight, the president of Yale College, and Dr. Morse were close friends. When Finley entered college his father wrote to President Dwight asking him to give some attention to the youth, who in spite of his long limbs seemed still a little boy to the affectionate father.

Yale was not so large then as it is now, and the president had an opportunity to get acquainted with many of the students. He took particular pains to be kind to his friend's son. But there never was a boy who stood less in need of a letter of recommendation.

Finley Morse was a fine looking lad, with his father's dignity and his mother's graciousness. Strangers were pretty sure to notice and like him. His teachers were fond of him because he was courteous and studious. He was very popular also with his classmates and took an active part in college life.

The long letters which he sent home regularly were full of news and enthusiasm. Whenever he learned anything that seemed new or wonderful to him, when he got acquainted with an interesting stranger, when he had taken part in any college affair, he thought his father and mother would like to hear about it.

In one letter which is still preserved he told about a meteoric stone which had fallen in Connecticut, not far from New Haven. In another, he told about the trials of the cooks who prepared the food at the college-boys' dining hall:

"We had a new affair here a few days ago. The college cooks were arraigned before the tribunal of the students, consisting of a committee of four from each class in college; I was chosen as one of the committee from the sophomore class. We sent for two of the worst cooks and were all Saturday afternoon in trying them; found them guilty of several charges, such as being insolent to the students, not exerting themselves to cook clean for us, in concealing pies which belonged to the students, having suppers at midnight, and inviting all their neighbors and friends to sup with them at the expense of the students, and this not once in a while, but almost every night....I know not how this affair will end, but I expect in the expulsion of some, if not all, of the cooks."

Although Finley Morse was a leader in students' enterprises he never neglected his work. He did well in all classes, but he was especially interested and successful in chemistry and natural philosophy which were taught by Professor Silliman and Professor Day. It was in Professor Day's natural philosophy class that

Finley Morse first became acquainted with the properties of electricity.

One day after a lecture on the mysteries of electricity Professor Day announced that he would try a few simple experiments. He told all the members of the class to join hands; then one student touched the pole of an electric battery and at the same instant every boy in the line felt a slight shock, which young Morse described as like a slight blow across the shoulders. This experiment was made to give the students some little notion of the marvelous speed with which electricity travels. Next the old laboratory was darkened and a current of electricity was passed through a chain and through a row of metal blocks placed at short distances from one another. The wondering boys saw the flash of white light between the links of the chain and between the blocks.

These simple experiments impressed at least one member of the class so deeply that he never forgot them. Finley Morse said to himself, "Here is a force which travels any distance almost instantaneously, and its presence may be shown at any point in its course by a break in the circuit. This could surely be put to some use in this great world." He wrote to his father giving him an account of the experiments; and, as he could not afford to go home the following

vacation, he spent a large part of it making experiments in the laboratory. He had an inquiring mind, and liked to put in practice the theories which he learned in the class room.

During Finley's senior year his two brothers were also at college. One was in the first year, the other in the second. The three young men had great times together. One day they attracted a crowd by sending up a big balloon from the college campus. This balloon was eighteen feet long. The boys had made it themselves by pasting together sheets of letter paper.

Finley was skillful with his fingers and spent much of his time drawing faces and heads. The walls of his room were covered with crude portraits of his friends.

As years went by he enjoyed this pastime more and more, and though he had had no instruction in drawing and painting, he gradually gained through practice the power of making almost lifelike resemblances.

The first group that he painted is poorly drawn but it is interesting because of the subject. It represents what was probably a typical scene in the Morse household on vacation evenings when the boys were at home. Dr. Morse is standing back of a table with a globe before him. He is evidently explaining

something to the members of his family who are grouped around the table in attitudes of close attention. The mother, who sits at one end of the table, has stopped sewing. The largest boy, who must be the young artist himself, has one hand on her chair, and is leaning eagerly forward. The two younger boys, Richard and Sidney, stand at their father's left. The boys look very quaint and grown-up in their cutaway coats and high stocks. Dr. Morse was the author of a school geography which many of our grandfathers and grandmothers used in their schooldays, and he took pains to interest and instruct his boys about far away countries and peoples. This picture was considered by the family a very fine piece of work.

Most of Finley Morse's early attempts at painting were limited to single portraits. As there were no photographers in those days and people liked to have their own and their friends' pictures taken, just as well as we do now, there was a great demand for small portraits or miniatures. Young Morse became so skillful in this work that in his senior year he was able to pay part of his college expenses with the money he earned by painting miniatures. He charged only five dollars for painting a miniature on ivory, and his friends kept him busy with orders.

In 1810, when nineteen years of age, Finley Morse completed his college course, and the grave question of what he should choose for his life work had to be settled.

Life in London

Finley Morse wished to be an artist. He spent the first year after finishing college at his father's home in Charlestown, studying and painting. Dr. Morse was disappointed over his son's decision, but, when he found how determined the young man was to be a painter he did all he could to encourage and help him. He wished him to have every opportunity to make a success of the art he loved. He, therefore, agreed to furnish the money needed for three years of study in London, since there were no good art schools in America.

One of the most eminent American painters, Mr. Washington Allston, was then spending a year in Boston. Finley Morse made his acquaintance and arranged to go to London with him the next year, as his student. Accordingly, on the thirteenth of July, 1811, they set sail from New York harbor for England.

It was more than a month after his departure from America before young Mr. Morse sat down in his

lodgings in London to write the news of his safe arrival to his father and mother. In this letter he said:

"I only wish you had this letter now to relieve your minds from anxiety, for while I am writing I can imagine mother wishing that she could hear of my arrival and thinking of thousands of accidents which may have befallen me. I wish that in an instant I could communicate the information; but three thousand miles are not passed over in an instant, and we must wait four long weeks before we can hear from each other."

He little thought then that the time was coming when news could be flashed across the ocean in a few seconds by means of his own invention.

Although so far from home Mr. Morse was very happy in London. He was so glad to be where he could learn to paint that he cared for little else. He breakfasted every morning at seven, and began drawing at half-past seven. He kept at his work from half-past seven in the morning until five in the afternoon. Then he dressed for dinner; and after dinner he took a little walk or went to visit Mr. and Mrs. Allston who lived near by and were always glad to see him. He was so fearful of wasting a minute that he did not even go around to see the famous sights of

the great city. His father had given him some letters of introduction to his English friends. These men would have done what they could to make Dr. Morse's son have a pleasant time while in London if they had known he was there, but the young artist felt that he had no leisure for society, and did not deliver the letters.

There was, however, one man in London whom he was impatient to meet, and a few days after their arrival Mr. Allston took him to visit that man. This person was no other than Benjamin West, the great American artist who had been most highly honored in England. The king himself praised his pictures and had his portrait painted by him. West was president of the Royal Academy. Although he had lived many years abroad he loved his native country and was always kind to American artists.

When Mr. Allston introduced Finley Morse to him he received him kindly for the sake of his country and for the sake of Mr. Allston. But when the old artist who had listened to the praise of kings and princes saw this twenty-year-old American youth stand before his great pictures with his sensitive face aglow with appreciation and admiration, he said to himself, "The boy loves it." And from that moment he felt an affection for Mr. Morse for his own sake. He showed

him his pictures and invited him to come to him at any time for help.

Mr. Morse wished to be admitted to the Royal Academy. But before this was possible he must prove himself qualified by making a fine drawing. The first weeks of his stay in London were devoted to that drawing. When it was finished he felt quite proud of it and showed it to Mr. West. The great master was highly pleased.

"It is a remarkable production, and you undoubtedly have talent, sir," he said. "It will do you credit when it is finished."

"Finished," echoed Morse in dismay. "It is finished."

"By no means. See this, and this, and this," said the older man pointing quickly here and there to imperfections which Mr. Morse recognized as soon as his attention was called to them.

He took the drawing home, and as he examined it with more critical eyes, discovered many places which needed touching up. After another week's work he again visited the artist. "I have finished it," he announced triumphantly.

"Not quite, my friend. Look at this muscle and these finger joints,"

The crestfallen artist went to work once more. When he next took it to Mr. West he was greeted with the monotonous, "Very good—go finish it." His patience was exhausted and he said in discouragement, "I have done my best, I can do no more."

"Very well," said Mr. West. "That is all I want. It is a splendid drawing. I might have accepted it as you presented it at first, but that was not your best work. You have learned more by finishing this one picture than you would have learned by drawing a dozen incomplete ones. Success lies not in the number of drawings but in the character of one. Finish one picture, and you are a painter."

This lesson made Finley Morse think of the advice his father had given him when he was a little schoolboy.

After Mr. Morse had got well started in his work he gave a little more attention to the life around him. His father, finding that Finley would not hunt up his friends, wrote to them himself giving them his son's address. They sought him out, and thus the young man met many influential people whose friendship he prized through life. He visited the picture galleries, attended the theater occasionally, and went about the

city a good deal. He became acquainted with Charles Leslie, a young American, who, like him, had come to London to learn to paint. These two young men formed a strong friendship.

Mr. Allston and Mr. West thought better and better of the young man the more they saw of him. But they did not neglect to do their duty as his teachers and tell him when he made mistakes. This was difficult for Mr. Allston, as he had a gentle, affectionate disposition, and it hurt him to see his young friend unhappy or disappointed. But he was too true an artist to tolerate poor work.

One afternoon he entered Morse's studio just as the latter was finishing what he believed to be a good day's work. The student looked up from his work with a bright face. He expected to see a look of approval on his teacher's face and to hear an enthusiastic "Excellent." Instead, Mr. Allston stood looking at the picture for some minutes in silence. Then he shook his head and said, "Very bad, sir, very bad." Mr. Morse turned red with mortification. He felt vexed with his friend, but controlled his temper and said nothing. The other went on, pointing to the figure on the canvas, "That is not flesh; it is mud, sir; it is painted with brick dust and clay." As Morse stood off and looked at the work he felt the truth of this criticism so

bitterly that he was ready to dash his palette-knife through the canvas. But Mr. Allston quietly took his palette, helped himself to some fresh colors, and with a few touches, gave warmth and brilliancy to the painted flesh. He then stood by and gave directions while the young man tried his hand at it. When he went away, Finley Morse felt the deepest gratitude towards the friend who had made him realize how poor his work was, and had shown him that it was possible for him to improve it.

While in London Mr. Morse did two pieces of work which were so excellent that they astonished many of the older artists. One was a great painting of the dying Hercules. This picture was admitted to the exhibition of the Royal Academy at Somerset House. The critics spoke highly of it, and it was named among the twelve best pictures in an exhibition of two thousand. The other piece of work that attracted the attention of lovers of art was a cast of Hercules, which took the gold medal at the Adelphi Society of Arts.

During the last year of his stay abroad Mr. Morse tried to make a little money with his brush, but he could not sell any pictures. Frames, canvas, and colors were expensive, and the money his father had given him was nearly spent. He wrote home:

"I am obliged to screw and pinch myself in a thousand things in which I used to indulge myself at home. I am treated with no dainties, no fruit, no nice dinners (except once in an age, when invited to a party at an American table), no fine tea-parties, as at home. All is changed; I breakfast on simple bread-and-butter and two cups of coffee; I dine on either beef, mutton, or pork, baked with potatoes, warm perhaps twice a week, all the rest of the week cold. My drink is water, porter being too expensive. At tea, bread-and-butter with two cups of tea. This is my daily round. I have had no new clothes for nearly a year; my best are threadbare, and my shoes are out at the toes; my stockings all want to see my mother, and my hat is growing hoary with age. This is my picture in London. Do you think you would know it?"

In August, 1815, Finley Morse started for America. He was rich in knowledge, and experience, and friends, but he was poor in purse.

Painting

Samuel F. B. Morse, as he now signed his name, opened a studio in Boston. There he found many to praise his pictures but none to buy them.

For a while he spent his idle hours inventing a powerful pump. But he was impatient to begin painting, and as no work came to him, he determined to go in search of some.

He knew that in the small villages an artist with a good reputation might succeed in getting some orders for portraits if he were willing to accept very low pay for his services. His father was well known throughout New England as a preacher and writer, and with the help of his friends the artist easily found employment for his pencil among the country people.

He painted portraits in one town until he had no more orders, then he went on to another. He asked only ten or fifteen dollars apiece for his portraits. But living was cheap, and he worked so rapidly that he was able to save money, notwithstanding these low rates. He had supposed that this would be very distasteful work. But he took great satisfaction in earning his own money, and had many pleasant experiences. Indeed, it was on one of these portrait-painting tours that Mr. Morse met the beautiful Lucretia Walker, whom he afterwards married.

Some rich southern friends urged Mr. Morse to try his fortunes in Charleston, South Carolina.

His uncle, Dr. Finley, who lived there, invited him to stay at his home. His first experience there was as discouraging as his winter in Boston had been. People were kind and friendly. They admired his pictures, but no one ordered any. He felt humiliated and made up his mind to go north again. Before going, he asked his uncle to let him paint his portrait as a return for all his kindness. This portrait was such a splendid likeness that nearly every one who saw it thought he would like to have Mr. Morse paint his picture also. Before long he had a list of one hundred and fifty people who had ordered portraits at sixty dollars apiece.

Mr. Morse's reputation as a portrait, painter was soon made in Charleston. The citizens honored him with a commission to paint a portrait of President Monroe. Mr. Morse had a pleasant stay in Washington and painted a strong portrait. The president and his family liked it so much that they requested Mr. Morse to make a copy of it for them.

By dint of hard work Samuel F. B. Morse had succeeded as a portrait painter, but he was not content to spend his life painting portraits. He wished to stop painting merely for money. He was ambitious to paint beautiful landscapes and great historic pictures. But there was no opportunity to do such work in Charleston, and so he resolved to return to the North.

Before leaving the South, Mr. Morse, with the help of some of the leading men of Charleston, established an Academy of Fine Arts.

In 1820, Dr. Morse gave up his church in Charlestown, Massachusetts, and moved to New Haven. His son visited him there, and renewed his acquaintance with some of the college professors. Professor Silliman lived near to Dr. Morse, and Mr. S. F. B. Morse became deeply interested in the professor's electrical experiments.

In the fall he left his wife at his father's home and went to Washington to paint one of the great pictures he had planned. The subject of this picture was the House of Representatives. He worked on it fourteen hours a day and had high hopes for it. But although it was considered a splendid picture, he did not make any money from it. He was therefore obliged to resort to portrait painting again.

He tried at Albany, the capital of New York, but got no orders there. Then he determined to seek his fortune in the great, rich city of New York. He knew he would have a hard struggle; but it proved even harder than he had expected. He had no money; he could get no work; his rent and board had to be paid.

The only thing to do was to fall back once more on the portrait-painting tours.

After a profitable trip through several New England states, and a pleasant visit with his family, he went back to New York with new courage. This time he succeeded better. He had a few pupils and sold some pictures. In the middle of the year; an unlooked-for piece of prosperity befell him. General Lafayette was visiting America. New York city wanted a life-sized portrait of the hero. Mr. Morse was chosen to paint it.

Mr. Morse wrote to his wife at once to tell her about his good fortune. He said: "The terms are not definitely settled. I shall have at least seven hundred dollars, probably one thousand." This seemed quite a fortune to the poor artist. He regretted that instead of going to New Haven for a visit with his wife, he would be obliged by his work to go to Washington. But he wrote home cheerfully: "Recollect the old lady's saying, often quoted by mother, 'There is never a convenience but there ain't one'... I look forward to the spring of the year with delightful prospects of seeing my dear family permanently settled with me in our own hired house in New York."

A month later, on the eighth of February, he wrote Mrs. Morse a glowing account of his arrival at Washington and his meeting with General Lafayette. On that same day his father wrote to him from New Haven a letter full of sorrow telling him that, after a slight illness of two or three days, his fair young wife had died suddenly of heart trouble, and he would never see his beloved Lucretia again.

News traveled slowly by stage coach in those days, and this letter did not reach Mr. Morse until after his wife's funeral. He was almost crushed with grief. His return to New Haven could do no good; but he could not paint, and he wished to be among those who had known and loved his wife. He arranged to meet General Lafayette later in New York, and started immediately for New Haven. After a sorrowful visit there he returned to New York where he finished the portrait of Lafayette, which he afterwards described as follows: "It is a full-length, standing figure, the size of life. He is represented as standing at the top of a flight of steps, which he has just ascended upon a terrace, the figure coming against a glowing sunset sky, indicative of the glory of his own evening of life. Upon his right, if I remember, are three pedestals, one of which is vacant, as if waiting for his bust, while the two others are surmounted by the busts of Washington

and Franklin—the two associated eminent historical characters of his own time. In a vase on the other side, is a flower—the *heliotrope*—with its face toward the sun, in allusion to the characteristic, stern, uncompromising consistency of Lafayette—a trait of character which I then considered and still consider the great prominent trait of that distinguished man."

The artist's struggle seemed over. Now that he cared less to succeed he received more orders than he could fill. Mr. Morse took an active part in the art life of New York. He organized the National Academy of the Arts of Design, and was made its president.

Abroad Again

When Dr. Morse died in 1826 he had the satisfaction of knowing that the son, for whom he had made many sacrifices, was regarded as one of the leading artists of America.

Mr. Morse had done much to arouse an interest in painting in America. He had lectured and written on the subject; he had organized the Academy of Fine Arts in South Carolina, and the National Academy in New York; and above all he had used his brush constantly.

He stood at the head of his profession in New York. Rich men who had picture galleries began to think that their collections were incomplete unless they included one or two of S. F. B. Morse's paintings.

The artist realized that his countrymen had the greatest confidence in his knowledge and ability. He wished to deserve their good opinion and thought that it was his duty to go to Italy, the land of artists, to learn what he could from the pictures of the old masters.

When it was known that Mr. Morse was going to Italy to study and paint, his friends and admirers came to him asking him to paint something for them while he was away. One wanted him to copy some heads from Titian for not more than one hundred dollars; another was willing to give five hundred dollars for a little copy of "Miracolo del Servo;" others gave him money, leaving him free to paint what he chose for them. When he was ready to sail he had almost three thousand dollars' worth of orders.

Mr. Morse staid abroad three years. These were years full of pleasant experiences and successful work. He revisited London and saw his old friend, Leslie, now an eminent artist. Together they talked about

their days of study under Allston and West, and laughed over their early struggles and ambitions.

Leslie introduced his American friend to the most prominent English artists. They were all very cordial to the distinguished representative of American artists.

While in Paris Mr. Morse ventured to call on General Lafayette. The general remembered instantly the man who had painted his portrait, and made him most welcome. "I saw in the American papers that you had sailed for Europe, and I expected you to make me a visit," he said. Although then an old man he had not lost his interest in America and was glad to talk about our country's present, past, and future with one of her most patriotic citizens. The two men became good friends. They walked and rode together often, and General Lafayette invited Mr. Morse to visit him at his country home.

Mr. Morse came to know other distinguished men during his stay in Europe. He and the Danish sculptor, Thorwaldsen, became such good friends that he asked Thorwaldsen to sit for his portrait. He sent this portrait to one of the men who had given him one hundred dollars for painting any picture he might think suitable. This same picture was afterward sold

for four hundred dollars. The buyer, hearing that Mr. Morse had expressed a wish to have this portrait that he might present it to the King of Denmark, generously returned it to him.

The American novelist, Cooper, and the American sculptor, Greenough, became friends and associates of Mr. Morse during his travels on the continent.

Mr. Morse spent a large part of his time in art galleries, studying the pictures of the great artists who had lived before him. Sometimes he brought his easel and canvas to the gallery and copied their work as closely as he could. In this way he learned a great deal.

He loved to be in the Louvre, the great art gallery of Paris. He wished every American artist might visit it. Then the idea of painting a picture of it occurred to him. It was a great undertaking and he did not wish to stay away from his own country much longer. But he was so eager to paint this picture that he worked on it from morning till night. A great plague, the cholera, broke out in Paris in the spring of 1832. Hundreds died daily, and almost everyone who could get away fled from the city in terror. Morse, however, staid quietly there, painting every day as usual, and when the date for his return to America came he had his

picture so nearly finished that he could complete it in New York.

An Important Voyage

When Mr. Morse started for America on the first of October, 1832, he said to himself: "Few American artists have had such splendid opportunities as I have. I must go home and give my countrymen the benefit of what I have learned. I am forty-one years old now. About half of my life, twenty years, I have devoted to art. I have painted many good pictures and gained the respect of artists in my own country and in Europe. I am able to make a comfortable living for my children with my brush. But that is not enough. I must do some grand work that will be remembered when I am dead—something which will show older countries that though America is young she is a great country and can produce great men."

The good ship, which was bearing him nearer and nearer to that country which he loved even better than fair Italy, was called the "Sully." There was a pleasant company of passengers on board. When they met at the dinner table, hungry from the keen sea air, there were lively talks on all sorts of subjects. Mr. Morse often took part in these conversations.

One day some one told about some experiments with electricity which he had read of. Every one was interested. One man remarked, "I have heard it stated that a current of electricity will pass along a very long wire almost instantaneously."

"That is true," said Dr. Jackson of Boston. "It passes over the longest wires that are used in experiments in less than a second of time. Dr. Franklin used wires several miles long and he could detect no difference in time between the touch at one end of the wire and the resulting spark at the other."

"If that is true and the power can be used in any part of an electric circuit," Mr. Morse suggested; "I should think we might send news instantaneously, by electricity."

"It has already been used for giving signals, I believe," one of the company remarked.

"But I mean more than that," explained Mr. Morse; "why could we not write instantaneous letters from New York to Charleston with it?"

All laughed at this odd idea. The ladies joined in the conversation and said that Mr. Morse should let them know when his magic letter-writing machine was ready for use. The Southern people began to complain of the inconvenience of corresponding with

friends in the North. Letters from the South were a month reaching New York by coach, so that one's dearest friend might die and be buried before one knew anything about it.

Mr. Morse knew the truth of this too well. He stopped talking with the others, and after dinner went to a lonely part of the deck where he sat quite still, with his notebook in hand, all the afternoon. Other passengers smiled and said, "Do not disturb the artist. He is trying to decide just what shades he can mix together to get the peculiar blue of the sea for some painting."

But he was not thinking of the color of the sea. His mind was busy with the idea that had flashed into it at the dinner table. He remembered the old experiments in the laboratory at Yale; he remembered the conversations he had had with Professor Day and Professor Silliman in later years; he recalled the lectures on electricity which he had heard Professor Dana give at Columbia College. All that he had ever seen, or heard, or thought about electricity came into his mind and made him think that his notion of writing letters at a distance by means of electricity was no wild dream, but a sensible idea. "It only needs the right man to carry it out. Perhaps I am that man," he told himself. He could not sleep that night, his head

was so full of his new idea. He rose early in the morning and was again busy with his notebook and pencil. It was not long before he took some of his fellow passengers into his confidence and told them his plan.

"First," he began "it has been proved that electricity travels with almost incalculable speed—with the speed of lightning, in short. We can have as much electricity as we desire with the help of a good battery; and the direction in which it goes can be controlled by us. We can send it where we wish by providing a copper wire to conduct it. Second, electricity has great force."

"I don't doubt that," interposed one of the listeners. "I saw lightning strike a tree once. But how are you going to control that force and make it do what you wish it to?"

"There is a very simple and well-known way of getting a powerful up-and-down motion by means of electricity," Mr. Morse answered. "Bend a bar of soft iron into the shape of a horseshoe and wind a coil of wire around it. When that wire is charged with electricity the iron becomes magnetic. Magnets strong enough to lift great blocks of iron are made in this way. As soon as the electrical current is broken the

horseshoe loses its power and the block of iron falls. By simply supplying and breaking the current repeatedly with the help of such a magnet an up-and-down motion can be obtained."

"I have heard all about the horseshoe electromagnet," interrupted one man impatiently. "But I should think it would make a rather clumsy pen. How are you going to use your force to write?"

"I have thought it all out and made drawings of it," replied Mr. Morse. "At one end of the wire will be the battery and the man who sends the message. At the other end will be the pencil for him to write with and the paper for him to write upon. A long ribbon of paper will be attached to two cylinders turned regularly towards each other by clock work, so that the paper will be wound off of one cylinder upon the other. Above this strip of paper will be a bar swinging freely on a central pivot like a balance. This bar will be made to go up or down like a teeter-board, at the will of the man sending the message. There will be a sharp pencil under the end of the bar over the paper. When that end of the bar goes down and right up again the pencil will leave a dot on the paper. If it stays down while the turning cylinders carry the paper along under it, it will make a line. If it stays up while the paper is turned under it, a space will be left. By

combining these dots, dashes, and spaces in various ways a telegraphic alphabet can be made."

"Can you show me how the 'teeter-board' could be made to go up and down?" inquired the man who had asked the first question.

"Why yes. There we shall use the magnet," said the inventor. "There will be a small iron plate at each end of the bar. Over the end which carries the pencil there will be a weak permanent magnet, strong enough to draw up that end of the bar when there is nothing pulling against it. At the other end there will be a strong electro-magnet. When the man writing the letter wishes to make a dot he will send a spark of electricity over the wire and it will magnetize the iron so that the power of the weak permanent magnet will be overcome and the end of the bar under the electro-magnet will go up, forcing the pencil end of the bar down upon the paper. If he wishes to make a dash he can keep on the current and the pencil will stay down on the moving paper, but the moment he breaks the current, up the pencil end will go towards the weak permanent magnet and leave a vacant space on the paper."

All agreed that this was a very fine theory, but they thought it could never be put into practice.

Before the ship entered New York harbor Mr. Morse had filled his notebook with drawings of apparatus for the telegraph. He had also made an alphabet. He had great faith in his plan. One day he said to the captain of the vessel, "Well, Captain, should you hear of the telegraph, one of these days, as the wonder of the world, remember the discovery was made on board the good ship *Sully*." The captain was amused. He regarded the whole matter as merely a visionary dream which even Mr. Morse would soon forget.

Years of Struggle

When Mr. Morse landed at New York, his two brothers, Richard and Sidney, were at the wharf to meet him. On the way to Richard's house, Mr. Morse told his brothers about his great idea. They were surprised. His last letter had been full of his wishes to paint a great picture. Now he was thinking more about his invention than about pictures. They agreed that it would be a wonderful discovery; and listened to his plan with keen interest. His brother Richard invited him to live at his new home, saying a room had been built and furnished especially for him.

During his first days in New York the artist had many visitors. Friends wished to hear about his trip and to see his pictures. It would have been natural under the circumstances for him to cease thinking about electricity and devote his time to his profession. He was out of money, and many people were ready to buy pictures if he would only paint them. Years of ease, enjoyment, and success lay before him if he chose to give his life to art. Privations, hardships, doubt, must be his portion if he undertook to work out his great invention.

Yet he could not dismiss the telegraph from his mind. The more he thought of it the more firmly he believed that God had made electricity for man's use. And he thought he could do no work in the world, more valuable than to make this marvelous force serve man in the telegraph.

He wished to set up the machinery necessary to test his theory. The proper apparatus could not be bought. He had no money to employ craftsmen to make it for him. He therefore undertook to make it himself.

His first workshop was his brother's parlor where he tried to make an instrument for opening and closing the electric current to regulate the dots,

dashes, and spaces. Frequent small accidents and the many interruptions which occurred there, made the inventor think it would be wise to move elsewhere. His brothers, who owned and edited a paper, were putting up a business building down town. When this was done Samuel F. B. Morse took a room in the top story of it. There he lived and worked. There his cot-bed stood. There his neglected easel, and paints, and canvas, and models were stored. There his workbench and lathe occupied the place of honor by the window.

He did not go to see his friends. Few of them felt free to seek him out in his attic chamber. His children were with distant relatives. He lived alone. In the evening when it was so dark that he could not be seen he left his room and went to some grocery, where he bought bread, potatoes, eggs, and such food as he could cook for himself. His clothing was poor and shabby. Could he have gone to work at once with his experiments it would not have been so trying. But he had to spend days and weeks and months contriving tools and implements.

When the committee appointed to choose artists to paint the pictures for the rotunda of the capitol at Washington overlooked Morse and assigned the work to foreign artists, the New York artists were indignant that their leader should be so slighted. They

remembered how ready he was to use his influence for their advancement, and how free to share his knowledge with those who needed instruction.

They wished to show their appreciation of all that he had done. They went to work quietly and secured subscriptions to the amount of three thousand dollars from artists and from others interested in art. This they sent to Mr. Morse with the request that he should paint a great historical picture. They said that when it was finished he might do with it as he pleased. Their only wish was to make it worth while for him to paint such a picture, which they were sure would do credit to America and to all American artists.

When Mr. Morse learned what his fellow artists had done he was deeply moved by their kindness. He exclaimed, "I have never heard or read or known of such an act of professional generosity." He resolved to paint a picture that would prove to them that their confidence in him was not misplaced. But he found that he could not put his heart into the work. He was worried about his invention. It seemed much more important than painting pictures. He finally returned the money with the request that his friends would free him from the engagement.

In 1835 Mr. Morse was made Professor of the Literature of the Arts of Design in the New York City University. He moved from his attic quarters to his rooms in the new university. There he fitted up a very rude electric telegraph. It was made in such a rough fashion that he was almost ashamed to show it to his friends. But, in spite of its crudeness, it actually worked. In that room at the university he sent the first telegraphic messages ever carried by electricity.

Every day he had to leave his absorbing experiments to spend hours teaching young art students to paint. He was glad to have this means of supporting himself, but it interfered greatly with his work.

Encouragement

In 1837 Mr. Morse asked some friends to come into his room to look at his telegraph and see it at work. One of his guests was a student, Mr. Alfred Vail. This young man was deeply impressed with what he saw. He soon afterwards called on Mr. Morse alone to ask some questions.

"Your wire here is not long. What reason have you to believe that your telegraph will act successfully at great distances?" he inquired.

"If I can succeed in working a magnet ten miles away, I can go round the globe," answered the confident inventor. "I have contrived a way of renewing the current with a relay. It would not be worth while to have these relays closer than ten miles from each other. But if I can get a force strong enough to lift a hair at a distance of ten miles I can send a current around the earth. Experiments have been made with wires several miles long, and I have faith that the current can be sent ten miles or further without a relay."

Mr. Vail then asked Mr. Morse why he did not push his experiment more rapidly, and when he learned that the delay was caused by lack of money, he offered to supply the funds needed if Mr. Morse would take him into partnership. Mr. Morse was willing to do so; and the terms of the partnership were soon agreed upon. Mr. Vail's father and brother owned large iron and brass works at Speedwell, New Jersey. His knowledge of iron and brass work was of great service to Mr. Morse in perfecting the mechanical part of his invention.

The partnership was formed in September, 1837. Later in the month Mr. Morse applied to the United States government for a patent on *The American Electro-Magnetic Telegraph*.

Mr. Vail promptly furnished the length of wire needed to make the experiments on the result of which depended the success of the invention. With the help of Professor Gale, of the university, Mr. Morse made those experiments and found that he could manage the magnet through more than twenty miles of wire without a relay.

This was as far as he could hope to carry his investigation without help from the government. To construct and operate a telegraph line on a large scale would be too costly a venture for an individual.

Just at this time the government was making inquiries concerning the various telegraphs which were being invented. Mr. Morse sent the United States Treasurer an account of his recording telegraph and was asked to exhibit his instrument at Washington.

Before taking his telegraph to Washington, Professor Morse invited his New York friends to see his invention in operation. Among his guests on this occasion were many who had regretted that New York's greatest artist had "lost his head over a wild scheme." They were amazed to see the results of what they had considered his "wasted years."

The guests whispered messages to him. The instrument went "click! click!" and dots and dashes began to appear on the strip of paper at the other end of the wire. Then some man who understood the telegraph alphabet read the messages to their surprised senders. The New York newspapers gave full accounts of the affair, and people began to think that after all there might be something in the telegraph.

The most distinguished body of scientific men in America, known as the "Franklin Institute," invited Mr. Morse to visit Philadelphia and exhibit his telegraph before the Committee of Science and Arts. They were so favorably impressed with the invention that they recommended that the government give the inventor means to test it on an extensive scale.

Mr. Morse then went to Washington, where the president, the cabinet officers, and many prominent men saw the telegraph at work, and were filled with astonishment and satisfaction.

Mr. F. O. J. Smith, an influential man, desired to have a share in the invention. Mr. Morse thought favorably of his proposal. A company of four partners was formed. In this company Mr. Morse had nine shares; Mr. Smith, four; Mr. Vail, two; Professor Gale,

one. Affairs looked encouraging; it seemed probable that Congress would make an appropriation of thirty thousand dollars to give the telegraph a test on a large scale.

Mr. Morse and Mr. Smith went abroad to see about getting patents in foreign countries. In England the attorney general refused to consider Mr. Morse's application for a patent, because a description of his telegraph had already been published and that, he said, rendered the idea public property.

In France, Mr. Morse was shown the greatest kindness. Such eminent scientists as M. Arago and Baron Humboldt were eager to know the American inventor and to see his telegraph.

The fact that space had been so conquered by man that, with a little machinery, messages might be sent to all parts of the world in an instant, seemed too wonderful to be believed. But although everybody wondered and admired, France was the only European country to grant the inventor a patent.

Waiting at Last Rewarded

In the year 1840 the United States government issued to Mr. Morse the patent which he had applied for in 1837, before going to Europe. Mr. Morse

returned to America full of enthusiasm. Success seemed close at hand. He found, however, that Congress was interested in other matters.

The general opinion seemed to be that it would be extravagant to put so much money into an experiment whose outcome was exceedingly doubtful. Soon, even Mr. Morse's partners lost heart and gave their attention to affairs which would bring them some immediate return.

Poverty made it impossible for the inventor to push the project further without help. He was so poor that he sometimes had to go hungry. He took up his work at the university once more and taught young men to paint.

There was another way in which he was able to earn a little money. While in France he had met Monsieur Daguerre, who had discovered a way to "paint with sunbeams," or take pictures, which were called in his honor daguerreotypes. Morse learned his methods and was the first to introduce the new art of picture making into America. He gave instruction to many young men who wanted to learn Daguerre's process so that they might go around the country making daguerreotypes.

While obliged to spend some time on tasks by which he could earn a living, Professor Morse never ceased to hope and to work in the interest of the telegraph. He employed an agent at Washington, but finding that he accomplished nothing, determined to go there himself and make one more effort to secure the aid of Congress. His partner, Mr. Vail, who had always been so hopeful and ready to help, now said that he could do nothing more, and Mr. Morse was left to do what he could alone.

At length a bill recommending the appropriation of thirty thousand dollars for testing the Morse telegraph was brought before the House of Representatives. Mr. Morse was very much afraid the bill would not pass the House. He sat in the gallery while it was being discussed. Some of the members ridiculed the bill and made jokes about the telegraph. But when the votes were counted there was a majority of six in favor of the appropriation.

After passing the House of Representatives the bill had to go to the Senate. Mr. Morse knew that many of the senators were in favor of his telegraph and he felt confident of victory there. But as the days went by a new doubt troubled him. It was almost time for the Senate to close, and there was so much business to be considered that there was little prospect of his bill

being acted upon. The last day came. There were one hundred and forty bills to be disposed of. All day Mr. Morse sat anxiously in the gallery. His friends warned him to give up hope. Late at night he went to his hotel with a sad heart.

He had given ten years of his life to perfect the most wonderful invention of the age. He had succeeded, but his work had been treated with indifference. He felt almost hopeless. But he was too great a man to yield wholly to disappointment. He made all preparations to leave Washington early the next day. Then he went to bed and slept soundly.

The next morning Mr. Morse was a little late for breakfast. As he entered the dining room a servant told him that a young lady was waiting in the parlor to see him.

He was surprised to find that his morning visitor was Miss Annie G. Ellsworth, the daughter of his particular friend, H. L. Ellsworth, Commissioner of Patents.

Going forward to take the young lady's outstretched hand, he exclaimed, "What brings you to see me so early in the day, my young friend?"

"I have come to congratulate you," she answered, her face bright with smiles.

"Indeed! For what?" he asked perplexed.

"On the passage of your bill."

"No, you are mistaken. The bill was not passed. I was in the senate chamber till after the lamps were lighted and my friends assured me there was no chance for me," he returned, shaking his head soberly.

"No, no!" she insisted earnestly. "It is you who are mistaken. Father was there at the adjournment at midnight and even saw the president sign his name to your bill. This morning he told me I might come to congratulate you."

At first Mr. Morse was so surprised and overcome by this piece of good news that he could scarcely believe it. When he realized that it was true, he said: "You were the first to bring me this welcome news, Annie, and I promise you that you shall send the first message over my telegraph when it is done."

"I shall hold you to your promise," the young girl answered happily.

Disappointment was turned to joy. He hastened to write the good news to his partners and friends. He wished that his telegraph was ready for use so that he might instantly scatter the glad tidings to the world. He did not leave Washington that day.

The Telegraph

The appropriation made by Congress was large enough to build a telegraph line forty miles long. It was decided that the first line should extend from Baltimore to Washington. The work was begun without delay. Mr. Morse took charge of it himself.

At first the wires were put in tubes and buried in the ground. But that did not work well. Mr. Morse then tried putting them on poles in the open air. This proved a much cheaper, quicker, and more satisfactory method.

On the first of May the National Whig Convention was held in Baltimore, to nominate candidates for the presidency and the vice-presidency. Twenty-two miles of wire were up. Mr. Morse thought it would be interesting to announce convention news in Washington by means of telegraph.

There was a railroad between Baltimore and Washington which ran near the telegraph line. Mr. Morse accordingly arranged to have Mr. Vail get the latest news from the train and telegraph it to him in Washington. This was done and the passengers on the first train to Washington after the nomination of

Henry Clay found that the news had reached the capital long before them.

On the twenty-fourth of May, 1844, the telegraph line was finished. Mr. Morse was at Washington; Mr. Vail, at Baltimore. Everything was in good working order. It was announced that the first message was to be sent. Crowds gathered around the office.

Mr. Morse remembered his promise to Miss Ellsworth. He sent to ask her what the first message should be. She wrote the noble line from the Bible, "What hath God wrought!" Mr. Morse was greatly pleased with the selection. He said afterward, "It baptised the American telegraph with the name of its Author." And all agreed that the work seemed greater than man's work.

Mr. Morse sent the message to Mr. Vail. It looked like this:

.— — …. .— — ….— — …. — — .. —..
(w) (h) (a) (t) (h) (a) (t) (h) (g) (o) (d)
.— — … .. ..— — — …. —
(w) (r) (o) (u) (g) (h) (t)

When Mr. Vail received the message he sent it back to Mr. Morse to let him know that it had reached him all right. It had flown from Washington to Baltimore and back, eighty miles, in a moment.

After the first message, Mr. Morse and Mr. Vail carried on a lively conversation for the entertainment of those looking on: "Stop a few minutes," said Mr. Morse. "Yes," Mr. Vail answered. "Have you any news?" "No." "Mr. Seaton's respects to you." "My respects to him." "What is your time?" "Nine o'clock, twenty-eight minutes." "What weather have you?" "Cloudy." "Separate your words more." "Oil your clockwork." "Buchanan stock said to be rising." "I have a great crowd at my window." "Van Buren cannon in front, with a fox-tail on it."

A few days later the Democratic National Convention was held in Baltimore. As soon as the candidates were nominated the announcement was sent to Washington by wire. The man named for the vice-presidency was at Washington and received immediate notice of his nomination. He replied by telegraph that he declined. When his message was read in the convention a few minutes after the nomination was made, it caused a sensation. To some this rapid communication seemed almost like witchcraft. Many refused to believe that the message really came from the nominee. A committee was sent to Washington to see about it. Of course the committee found that the telegraph had told the truth.

During the first year the telegraph was put in the hands of the post office department of the government. A tax of one cent was charged for every four characters. The income at the Washington office for the first nine days was as follows: during the first four days only one cent; on the fifth day, twelve and a half cents; the sixth day was Sunday and the office was closed; on the seventh day, sixty cents; on the eighth day, one dollar and thirty-two cents; on the ninth day, one dollar and four cents.

Mr. Morse was amused to see the astonishment his telegraph aroused. His own faith in its success had been so strong that he was surprised to find that others had doubted. The newspapers were full of praises for the inventor and his invention; the mail brought him letters of congratulation from all over the world; he was invited to dine with the highest officers of his own country and with ambassadors from foreign lands.

Mr. Morse offered to sell his telegraph to the government for one hundred thousand dollars. The government declined his offer. The reason given was that the expense of operating it would be greater than the revenue that could be derived from it.

A private company was formed and other telegraph lines were soon built. In 1846 the line between New York and Washington was finished and "the Hudson and Potomac were connected by links of lightning."

Mr. Morse went to Europe again in 1845 in the hope of securing patents. He was received everywhere with honor, but he failed in the purpose of his voyage.

In 1846 Mr. Morse's patent was reissued in the United States. He was troubled, however, as most inventors are, by men who claimed his idea as their own, and pretended to be the original inventors of the telegraph. He was compelled to protect his rights repeatedly by going to court. The question was finally carried before the Supreme Court of the United States. After a thorough investigation the judges all agreed that Mr. Morse was the original and only inventor of the Electro-Magnetic Recording Telegraph.

For some time short telegraph lines were built and operated by separate companies. In 1851 the Western Union Telegraph Company was formed to build a line from Buffalo to St. Louis. This company gradually bought and built other lines until it controlled all the

important telegraph lines from the Atlantic to the Pacific and from Canada to the Gulf of Mexico.

The Cable

Mr. Morse was often heard to say, "If I can make the telegraph work ten miles, I can make it go around the globe." He had shown that it could be made to work across continents. But there was some question as to whether it could be made to cross seas.

In 1842, on one moonlight night in October, Mr. Morse made an attempt in a small way to prove that it could be done. As water is a good conductor of electricity it could conduct the electricity away from the wire. The wire, therefore, had to be carefully covered so that the water could not reach it. Mr. Morse insulated the wire for his first experiment by wrapping it in hempen strands which were afterwards covered with pitch, tar, and rubber. This cable, two miles in length, was wound on a reel and placed in a rowboat. When night had fallen and all was quiet in New York harbor, a small boat put out from the shore. There were two men in the boat. One rowed while the other sat in the stern and unwound yard after yard of the slender cable. The man at the stern was Mr. Morse. At dawn the next day he was up, trying to send

messages over the first submarine telegraph in the world. To his surprise, after transmitting a few words the wire ceased to do its work, and no wonder! a ship in the harbor, had caught the cable with her anchor, the sailors had dragged it on deck, and not knowing what it was, cut out a piece of it and sailed away.

Ten years later when an attempt was being made to establish electrical communication between the island of Newfoundland and the American continent, the idea of laying a cable across the Atlantic occurred to Mr. Cyrus W. Field. He consulted Mr. Morse, who encouraged him to undertake the work. Soundings had proved that there was in the ocean bed an almost level plateau between Newfoundland and Ireland. This would form a safe bed for the cable to rest on. A company was formed to construct a trans-Atlantic cable. Mr. Morse was made the electrician of the company.

The first difficulty lay in finding a perfectly waterproof cover for the wire, which would help to form a light and flexible but strong cable. Then came the question of laying the cable without breaking it.

The first attempt was made in 1857. The cable then used was twenty-five hundred miles long. The wire was insulated by gutta percha, and that was

protected by a twisted wire rope. "The flexibility of this cable was so great that it could be made as manageable as a small rope, and was capable of being tied round the arm without injury. Its weight was but one thousand and eight hundred pounds to the mile, and its strength such that it would bear in water over six miles of its own length if suspended vertically."

The greatest care was observed in running the cable off of the reel to see that there should be no strain upon it. But, in spite of the strength of the cable and the care and skill of those who laid it, the slender rope snapped and the cable so carefully made lay useless, at the bottom of the sea.

Another company was organized, another cable was made, another expedition was fitted out. Another strand snapped, and another valuable cable was lost.

The third attempt was partly successful. The cable was laid and for a few days gave good service. Then for some unaccountable reason it failed to work. The fourth attempt was a failure, but the fifth, made in 1866, proved, to the satisfaction of all, that Samuel F. B. Morse did not exaggerate when he said it was possible to send an electrical current round the globe.

The Inventor At Home

Mr. Morse was an artist and loved beauty. Through most of his life he had been obliged to deny himself beautiful things. He was a quiet, home-loving man. He had been so poor that he had not even a cottage home of his own.

The first money he made from his telegraph was given to charity. As his fortune increased he decided to satisfy his desire for a beautiful home. He selected a picturesque grove on the Hudson River where he built a fine house which looked like an Italian villa. Because of the great locust trees growing there, he named his home Locust Grove.

At this home Mr. Morse assembled the children (now grown up) from whom he had been so long separated; thither he brought his second wife; there he entertained the friends who had been faithful in the old, toilsome days; there he received distinguished visitors from many lands.

The inventor lived quietly and happily at Locust Grove. Sometimes, when he was an old man with snowy beard, he might be seen enjoying the summer air under his fragrant trees while his grandchildren played about him in the grass. But he liked best the

great library where he had collected the books, the pictures, the statues which he had wanted so long.

The latter part of his life was not, however, spent in seclusion. As his fortune grew, his social and business obligations increased. In the winter time he left Locust Grove and lived in a stately mansion in New York City. He was a man of importance and influence, well known throughout America and Europe.

He died in 1872.

A Knight-Errant of Invention
Charles Goodyear (1800-1860)

Charles Goodyear had finished his arithmetic while the others of his class were still, with knit brows or screwed-up faces, wrestling with the problems of the day. He was idly playing with a problem of his own making,—a problem bound up in a small lump of India rubber.

"It's strange stuff, when you stop to think about it," he said to himself. "How can it be so tough and so stretchy at the same time?" Then he began to finger a thin scale of the same puzzling substance that had been peeled from a bottle. "I think it might make first-rate aprons and other useful things if one could roll it out in the right way and keep it somehow from melting and sticking together," he hazarded.

When the boy's class was called, he rose promptly to his task; but the idea that the bit of rubber had brought remained with him after the affairs of school and sums were forgotten.

He was a quick, studious lad, this Charles Goodyear. It seemed as if the mysteries of books had no terrors for him. Printed pages that looked strange and forbidding to many others talked quite simply to

Charles. "He should be a minister," the neighbors agreed.

For a while the boy accepted it as settled that he should one day wear the black suit and the serious look of a devoted pastor, like the leader of their church at Naugatuck. To this little village, eighteen miles from New Haven, Mr. Goodyear had removed when Charles was a very young lad, to make use, in his business, of the water-power of the swift river.

An American manufacturer in the early days of the nineteenth century was a real pioneer. Amasa Goodyear made buttons—the first pearl ones in America—and during the War of 1812 supplied the Government with metal buttons. He also made clocks, spoons, and farming-tools.

"An incident of my boyhood which made a deep impression on my mind," said Charles Goodyear, "was my father's experience with hay-forks. He succeeded in making a light, springy implement of steel, a great improvement on the heavy iron articles then in use. But it was soon apparent that the very excellence of these forks caused them to be looked on with suspicion by the people who were to profit by them. They were so different; they could not be practical and durable, it was objected. We had to give

some of our product to neighboring farmers and beg them to grant us a trial in order to get a single one of our articles in use. I saw then that in business a man needed the resolution of the pioneer backed by the determination to do good to people in spite of themselves."

When Charles was a lad of fifteen he gave up the idea of being a minister. He saw that his father was not able to send him to college, indeed, that he could ill spare his help in his business. "Besides, it may be that the hardware trade needs men who want to make the world better even more than churches do," he thought. Perhaps something of the pioneer spirit of the boy's ancestor, Stephen Goodyear (who was, after Governor Eaton, the chosen leader of the first settlers of New Haven) made him long to blaze a new trail.

"I think that my place is in the world of business after all," he said when people asked why he had given up the idea of college. "I like to work with hands and head together."

At seventeen he went to Philadelphia, where he served for four years as apprentice to a hardware merchant, endeavoring to master every phase of the trade. Then he returned to his father's shop. He soon showed a wonderful skill in the use of tools and a

cleverness in contriving ways of improving the various implements turned out by the Goodyear manufactory.

"His gift was in the way of mechanics, after all," people said.

But Charles knew better. "I have no natural knack that way," he explained to one of his friends. "In fact, I even hate the whirr and whirl of machinery. But I long to make poor, clumsy things better. They seem to cry out to be improved. I should want to do it even if I did not have to earn a living. It should be possible for a business man to show that he cares for something more than the money that comes in and to live according to a better maxim than that which says: 'Things should be made so that they will not last too long.' "

When Goodyear was twenty-four years old he married and two years later set up in Philadelphia a hardware store stocked with goods from his father's workshop. After he had succeeded, despite the general prejudice against American-made articles, in building up a trade that reached to many sections of the country, his business failed because his kindly, trusting nature led him into giving credit wherever it was asked. Money was slow in coming in and some

dealers who had taken his goods and his credit never met their bills. There came dark days when Goodyear, who assumed full responsibility for his firm, was put in prison for debt. Never for a moment losing heart, however, he had his bench brought to the jail and worked there to complete inventions that he was sure would be the means of repaying all his creditors as well as meeting the needs of his family.

"It must have been a bitter experience to go under through no fault of yours," Goodyear's friends said, "and to see others who had more capital to weather the days of bad debts reap a harvest out of the business you had built up and the goods of your own making."

"Well," Goodyear replied, with his slow, thoughtful smile, "I don't think you can prove the worth of a man—or of his career—in dollars and cents. I am not disposed to grieve because others have gathered the fruits of my planting. Man has real cause for regret when he sows and no one reaps."

For ten years Charles Goodyear was constantly besieged by the demands of those who held claims against his business, and through the harsh laws of the time he was again and again imprisoned, since he refused to declare himself bankrupt. This would have meant freedom from all claims, but at the cost of

turning over all that remained of his business, including his unfinished inventions.

"And I did not want to be released from anything; I only asked the chance to pay to the last penny," Goodyear mourned. "But it is certain that if one's conscience is clear and his purpose true he can find that even an experience such as mine is not without its silver lining. For I know that it is possible to find happiness everywhere, even within prison walls."

Later, Goodyear must have more fully appreciated that the trouble which made him yield first and last all the rewards of his agricultural inventions to others was a blessing in disguise, since because of it he turned his efforts into an entirely new channel where lay his real lifework.

One day while looking about a New York wareroom containing rubber goods, he chanced to observe that the life-preservers were defective, and, returning a few days later, he offered the merchant an improved tube for inflating them.

"You are a clever inventor," declared the gratified merchant. "Now, if you could only manage to hit on some way to prevent rubber from spoiling in hot weather you might make a fortune for yourself and at the same time save our factories from failure. We have

risked all our capital in this business and unless help comes we must go to the wall."

Charles Goodyear looked at the man in amazement. It seemed impossible that they should have gone so far without first having overcome that difficulty. In a flash he remembered how as a boy at school he had marveled over the wonderful properties of rubber. Now he said to himself, "Perhaps it remains for me to make this discovery that will bring to the world a new gift. It is true that I am ignorant of science, but new truth is often hidden from the learned and made known as if by accident to the one who perseveres and who observes everything related to the object of his search."

Soon Goodyear was so intent upon the quest that he could think of nothing but rubber. It was as if upon learning the secret of tanning or curing this substance so that it might be unchanged by changes of heat and cold depended not only his fortune but life itself.

He knew that Americans began to import gum elastic from Brazil in 1820, when he was learning the hardware business in Philadelphia. Crudely formed shoes, also brought from South America, sold for a good price because of their waterproof character. It seemed natural to believe that clever Yankees might

succeed at this craft better than the dusky natives of the land of rubber trees and reap a goodly harvest. Much capital was put into the business. Beautifully fashioned shoes, coats, and other articles were made of the unmanufactured gum which, having been brought as ballast in ships from Brazil, was obtained at a small cost. A ready market was found for these attractive products and more capital was invested.

But alas, the cold clutch of winter put the American-made rubber garments to an unforeseen test. In a speech which Daniel Webster made some years later, defending Goodyear's title to the invention which made rubber serviceable to man, he said: "I well remember that I had some experience in this matter myself. A friend in New York sent me a very fine cloak of India-rubber, and a hat of the same material. I did not succeed very well with them. I took the cloak one day and set it out in the cold. It stood very well by itself. I surmounted it with the hat, and many persons passing by supposed they saw standing by the porch the Farmer of Marshfield."

With warm weather there came an even more crushing blow to the dealers in the new rubber goods. Their interesting articles began to melt away, and with them the capital and the credit of the Roxbury Rubber Company.

Goodyear's sympathy and zeal were both enlisted in the cause. He knew the wrongs and the bitterness of business failure where the fortunes of the innocent and helpless are often wrecked through the fault or the misfortune of others. Besides, it seemed to him clear that human beings stood in need of just what this puzzling new substance could supply. Therefore it remained for some one to remove the difficulties that stood in the way of its use. And he was persuaded that Charles Goodyear was the man chosen for this task. Here was his opportunity and his real mission. As a knight of old he accepted the challenge of fate and set forth to win rubber for the use of man. With the determination and the ardor of a crusader he set about his life-work.

He began without equipment, mixing some of the gum elastic by hand and pressing it out in thin sheets with his wife's rolling-pin on a backing of flannel. Of this rubber-covered goods he made shoes, and set them in a row to wait for a change of season.

"My work always proceeded slowly because perforce I must often wait months for the frosts of winter and then for the heat of summer to put its worth to the trial," Goodyear explained. "I had indeed to 'learn to labor—and to wait'!"

It occurred to Goodyear that the stickiness of the rubber might be due to the turpentine with which it had been mixed; and, learning that there were on the market some casks of rubber sap diluted with alcohol, he resolved to put the matter to the test. Perhaps of this he could make the rubber that should answer his purpose.

Jerry, the lively Irishman who was at this time Mr. Goodyear's helper, knew of the inventor's hope. " 'T would be fun to give him a surprise like, and bring a smile to his countenance!" said Jerry to himself. So the night the new rubber arrived he spread the liquid gum over his work-trousers as he had seen Mr. Goodyear cover his pieces of cambric and flannel. The result seemed highly satisfactory.

"That's the thrick!" said Jerry, gleefully. "I'll show that an Irishman can beat a Yankee at the inventing."

All went well. The rubber gave a fine glazed surface to the overalls, and Jerry sat down complacently in front of the fire to go on with his appointed task of mixing the gum; but when he attempted to rise he found it was impossible even to move. The legs of his trousers were stuck firmly together, and Jerry himself was fastened down to his work-bench. The inventor

did indeed smile when he came to the rescue and cut his helper free of the rubber trap.

"Well, Jerry, you've proved beyond doubt that we can't blame our troubles on the turpentine," he said. "The rubber's the real rogue, and I'll not rest till I bring it to terms."

But this dramatic display of the stickiness of rubber completely discouraged Goodyear's friends. They refused to help or encourage him further with his experiments. "Any sane man should see now that it's no use," they said.

But Goodyear found a little home for his family in a neighboring village and the means of paying its rent from the sale of his furniture. To further the work his wife even sold the precious linen that she had spun by hand in her girlhood days.

"If only, like the girl in the fairy tale, I could learn the trick of spinning gold!" she said, smiling bravely.

"Fate will spin a golden thread for many perhaps, because of what we are willing to do—and to do without, for a while now," replied Goodyear.

But many trials and much discouragement had to be met and mastered before the golden fortune came.

A series of tests were made with various chemicals. One day Goodyear's hopes were raised by the

discovery that when the gum elastic and magnesia were boiled in lime-water the stickiness disappeared. But alas, he saw that a dash of acid quickly ate away the lime coating, revealing the same melting rubber beneath, and he knew that the remedy was still to be sought. Then the day came when he noticed that where a little nitric acid had come in contact with his rubber the stickiness was gone. "Perhaps this is my chance,—my door of opportunity if I can learn to fit the key," he said. Eagerly he followed up the hint with experiments, and developed the *acid-gas* process of treating rubber, from which he now made tablecovers, aprons, and similar articles.

These were satisfactory in every way, and it seemed that success was at last his. A manufacturer agreed to take him into partnership and begin making the rubber articles on a large scale. But then—once more Fortune turned her wheel and Goodyear was again down and without the means to provide food for his family. For a great panic came; many banks closed their doors and many businesses were wrecked. Among those who failed was the manufacturer who had undertaken to turn out the rubber articles by the acid-gas process.

Afterward Goodyear said: "It was in the end easy to understand. I was not to be allowed to pause in my

labors until I had arrived at the goal and learned the secret of vulcanization. Under the spur of necessity I kept on until a new gift was won."

It was indeed a sharp goad, the necessity that urged Goodyear to even greater effort. One day he was forced to pawn his umbrella to the ferryman in order to pay his fare across the river to New York. "I'm used to facing what comes in the way of weather," he remarked cheerily. He even smiled when he took his most precious keepsakes to the pawnshop.

"I never doubted," he once said, "that I was the one chosen to do a needed work, and I could not turn back. So how could I doubt that I must one day reach the goal?"

The days were not long enough for his work; he carried on his experiments far into the night. Never was there a man more single-minded in his devotion to a cause. In order to test the qualities of his products he even went about dressed in rubber.

People called him a crank. "If you meet a man who has on an India-rubber cap, stock, coat, vest, and shoes, with an India rubber money purse *without a cent of money in it,* it is he," a man once said when he was asked to point out Mr. Goodyear.

In those days, when anybody wanted to say that an investment was worthless, he didn't say, "It's a wildcat scheme," or "Something will soon prick that bubble"; he said "It's an India-rubber venture!" And if you could have seen the deserted rubber factories bearing dismal witness to wrecked fortunes you might have understood.

To the abandoned plant of the Eagle Rubber Company, Goodyear went. Perhaps he might persuade some one to set the wheels moving again when he brought the result of his experiments to the business. But no one could be induced "to send any more good money after bad." The pilgrimage was not, however, fruitless; for he found there a Nathaniel Hayward, at one time foreman of the works, who was making a few rubber articles for sale in a small way. Goodyear was at once interested in the process of "curing" the rubber that Hayward employed. He mixed the gum elastic with sulphur and then gave it a sun-bath with good result.

"I was told in a dream that sun and sulphur would do the work," he declared. "The plan works and I've taken out a patent."

"If I could patent a few of my dreams, I should not be afraid of want," said Goodyear smiling, "but I will

agree to pay you for yours when I put on sale some goods made in the sun and sulphur way."

This was the first step toward vulcanization. The process worked well for goods that had only a thin surface to be treated; but, as Goodyear learned to his sorrow, the dream patent didn't go deep enough. Once more he went ahead confidently to meet success. Once more Fortune turned her wheel, and he found himself again in the depths of want,—but not of despair. There was one more vital lesson to be learned and necessity pitilessly urged him on.

He took a contract from the Government to supply mail-bags of the new material. They were beautifully formed and colored cleverly to imitate leather. What a good advertisement they would prove! Surely his fortune and that of the despised rubber goods would now be established on a firm foundation! The bags were put on exhibition and much admired. But alas! they could not hold their own against the heat of summer. Goodyear saw that the battle was not yet won.

"How can you still keep on with that forlorn hope?" people asked. "It is madness to persist further in the face of the needs of your family. Go back to the

hardware business and the work of making a decent living."

"I have more than hope," replied Goodyear. "I have *faith* that my work is not in vain. The long road must have an ending; and rest and reward belongs to the one who presses on to the end. It is clear that the world needs rubber; my work must meet that need."

The story of the hardships Goodyear endured is one of the saddest that can be imagined, and yet this knight-errant of invention was not sad, because he never doubted that good would result, and for its sake he was willing to meet whatever came. It was as if he said to good fortune and to ill, "There is something in the spirit of man that your favors cannot bribe or your frowns betray!"

Then one evening, when he was sitting with his family in the kitchen, trying the effect of heat on the rubber which he had mixed with sulphur, he threw out his hand to add emphasis to a remark and suddenly brought his specimen in contact with the red-hot stove. And something amazing happened! In a moment he had forgotten what he was saying, forgotten where he was and those about him. It was as if he were alone in the world with that little piece of rubber, which instead of melting had strangely

hardened. The stickiness was quite gone. How utterly astounding, when the one sure thing had seemed to be that a high temperature would melt rubber! Was it possible that this was true only up to a certain degree, and that an intense heat would cure the trouble that less heat caused?

His daughter in describing this great moment said, "As I was passing in and out of the room, I casually observed the little piece of gum which he was holding near the fire, and I noticed that he was unusually animated by some discovery which he had made. He nailed the piece of gum outside the kitchen door in the intense cold. In the morning he brought it in, holding it up exultingly. He had found it perfectly flexible, as it was when he put it out. This was proof enough of the value of his discovery."

The discovery came early in the year 1839. Patiently the inventor set to work with new tests to try the effect of acids as well as of varying degrees of heat and cold on his new substance. The exact temperature which gave the best result must also be carefully determined. He worked on in the face of the blank indifference and unbelief of all about him, who could not conceive of any good coming from this rubber that had wrecked a good man's life and addled his brains. "But as for me," said Goodyear, "I felt myself

amply repaid for the past, and quite indifferent as to the trials of the future."

For he knew that at last success had crowned his efforts and that through his labors a new gift had been won for mankind,—the fifth necessity of life, it is sometimes called to-day. The new process was called *vulcanization*, for it seemed that the spirit of Vulcan's forge was indeed at work in the magic change.

The greater part of the money which his patent brought him was used in making experiments.

"Why bother to test novelties when there are things tried and proved that yield profits?" he was asked.

"If I had been working first and last for profits, I should never have made my discovery," said Goodyear. "Money is indispensable for the perfecting of improvements, but it is trial and necessity that bring hidden things to light. As I pushed on through the days of want to my invention, so I shall continue through the days of plenty to put it to the test in different ways."

Mr. Parton in his sketch of the inventor says: His friends smiled at his zeal or reproached him for it.

It has only been since the mighty growth of the business that they have acknowledged that he was right,

and that they were wrong. They remember him, sick and wasted, now coming to them with a walking-stick of India rubber, exulting in the new application of his material, and predicting its general use, while they objected that it had cost him fifty dollars; now shutting himself up for months trying to make a sail of rubber fabric, impervious to water, that should never freeze, and to which no sleet or ice should ever cling. There is nothing in the history of invention more remarkable than the devotion of this man to his object.

So to the last through the week-day of a life of struggle, Charles Goodyear devoted himself to his cause. On Sunday morning, July 1, 1860, when the bells were ringing for church, this loyal soldier and servant laid aside his armor and entered upon the reward of his labors.

"His greatest glory," said his son, William H. Goodyear, Curator of Fine Arts at the Brooklyn Museum, "is not that he discovered vulcanization, but that, having discovered it, he scorned the wealth which the discovery created, except in so far as it helped him in the nobler task of continuing to create new industries."

The Conquest of the Reaper
Cyrus Hall Mccormick (1809-1884)

"It is strange that after all the years that have passed over the world since men began to plant wheat they still gather in the harvests slowly and painfully by hand,—much as they did in Bible times," said a hard-working Virginia farmer one day. He was speaking aloud a thought that had come to him more than once, and for Robert McCormick to think meant to act. He could think even when he was swinging a heavy cradle under a July sun, when most harvesters were conscious of nothing but aching backs and addled brains. And, in a log workshop that stood next the farmhouse, he worked away on every rainy day as industriously as ever he made hay when the sun shone. Here there was a forge, an anvil, and a carpenter's bench, and here he put together much of the furniture that made the home comfortable, as well as tools and machines for making the farm work easier.

"It will perhaps be a farmer who invents some better way of getting in the wheat than by sickle or cradle," he said to himself over and over. "And what if it should happen that Robert McCormick is that

farmer!" So he set himself to the task of making something to lighten the labor of the next harvest time.

"What is that funny thing for!" asked his little son Cyrus, who stood in the door of the workshop one day looking with wide eyes at the queer big machine his father was making. "What are you putting all those sickles on sticks for?"

"It's to cut wheat, my boy," said the father, "if I can only make it work. When our horses pull it along it should cut as much grain as several men without getting a crick in its back, or having to stop to mop its brow and drink cider."

The boy liked to see the lively twinkle that came in his father's eyes when he was happy over an idea. It must indeed be jolly to know how to make what you wanted, and nothing could be better fun than to discover new ways of doing things. He, too, would learn the cunning of tools. So, on the days when his father worked over his reaper, Cyrus stayed near by, watching and keeping up a rap-a-tap of his own with hammer and nails.

There were, it seemed, many difficulties in the way of getting a machine-reaper to do its work as it should. The whirling rods whose task it was to whip the wheat

up against the line of waiting sickles found the wiry, bending grain unexpectedly obstinate. It got so twisted and tangled and bunched that the machine was choked and the sickles helpless. If only the wheat could be depended on to grow straight and even till the great moment of the harvest! If it were never wet or bent to earth by storms! If the ground itself were free from unpleasant bumps and hollows!

"You'll find that there is nothing yet to take the place of honest toil, Friend McCormick," said the neighboring farmers, winking at each other slyly with a solemn relish.

"I don't look to see the day when work will be out of date," replied Robert McCormick, quietly. "But I do hope that the day is not far off when we shall be able to do more things,—to get more that is worth while by the sweat of the brow!" He did not give up trying to make a machine that would reap his grain, but he worked and experimented within his workshop where no one but those of his own family knew of his attempts and his failures.

Of all the children, the boy Cyrus watched with particular sympathy and interest. He knew that his father was a wise man. Even the clever lawyers and the most learned minister of that part of Virginia came a

long way to talk with him and ask his advice. Besides he understood all the marvels of tools, and could fashion things deftly with his hands as well as picture them with words.

That farm between the Blue Ridge and the Alleghanies was at once a home and an independent community. The wool of their own sheep was spun into yarn and woven into cloth for their winter clothes and blankets. Shoes were cobbled there, too, and stockings, caps and mufflers were knitted in odd moments. There were days when soap was boiled, candles molded, meat cured, and the various kindly fruits of the earth dried and preserved. To have been a child in that home was in itself a practical education. Cyrus's mother may never have heard that the ideal training for a child is that where head, heart, and hand have chance for free and natural exercise, but she acted as if she had.

Mrs. McCormick believed in hard work, but she was never too busy with her own affairs to do a good turn for a friend. Happening along one day when some neighbors were rushing about trying to save some hay from a storm, she tied up her horse, seized a rake, and fell upon the task with all her might. "If we don't make haste the rain will beat us," she said.

Though a woman who was always ready to turn her hand to the work of the moment, she knew, too, how to enjoy life. She loved to walk among her flowers, to see her pet peacocks strut about the lawn, and to ride behind a pair of spirited horses. There were no dull days to one of her ambition and power of enjoyment; each hour was full of rich possibilities.

Not Robert McCormick, but Cyrus, the son of this wise, progressive father and energetic, ambitious mother, was destined to give the world the first successful harvesting machine.

"How the past lives in each one of us in all that we do!" said Cyrus McCormick thoughtfully, years after his reaper had brought wealth to his family and prosperity to many. "As I owed to my father my turn for inventing, so I owed to my mother the ambition and determination to turn my work to good account by making my invention a business success." There was, too, something of the stanch, never-say-die courage of his long line of Scotch-Irish forefathers in the strength of purpose with which he forged ahead despite all difficulties.

But if we must look to his past to explain the power of a man, we must find in his present the circumstances that make his opportunity. The

thousands of hardy pioneers who had marched westward taking up the limitless, fertile lands that the Louisiana purchase brought to the newly formed nation, found their farming with wooden plows, sickles, and scythes a life-destroying round of drudgery for a bare subsistence. Is it any wonder that many of them dropped sowing and harvesting to push still farther westward for adventure and for gold? Is it any wonder that the hard struggle for a poor living in a rich, unworked country sharpened the wits of the workers and led them to seek out ways of saving labor? The industrial revolution to win freedom from the tyranny of toil followed the political revolution. Machines for spinning and weaving came into being. The steel plow took the place of the hoe, the cradle succeeded the sickle, and still the fields of grain cried out for a new way of gathering in the harvest.

Robert McCormick was not the first farmer to rebel against the hot toil of the swinging scythe or cradle. Many had tried to devise ways of making some sort of reaper. Cyrus McCormick, who made the machine that stood the test and won success, was the forty-seventh inventor of a harvester.

"I began to work on my reaper when I was a boy sitting on a slab bench in the 'Old Field School,' looking at the daylight through the window that was

just a gap where an upper log had been cut away," he said. "I had borne the heat and burden of the long summer days in the wheat fields and I knew what work meant. As I sat in my father's workshop watching him struggle with his reaper I whittled a smaller cradle that would not be so back-breaking to swing as the one that had fallen to my lot, and my thoughts flew faster than the flying chips. The reaper *must* win out."

The "Old Field School" got its name because it was built on one of those stretches of land, starved and overworked by the wasteful farming of single crops that took all and gave nothing to the soil. The very spot where he was sent to peg away at spelling and arithmetic was an object-lesson. Farmers certainly went about things in stupid ways or there wouldn't be old fields. Nature didn't work after that fashion. How the old earth renewed her strength year after year!

Cyrus McCormick decided to study surveying, showing his inventive turn here by cleverly fashioning the quadrant that he was to use. "I shall be ready to mark out the new fields that your reaper will conquer one of these days," he said to his father.

But after fifteen years of effort Robert McCormick gave up the struggle. The reaper promised well, and it

did cut the grain,—but only to toss it about in a tangled mass.

"Not much gained after all the planning and contriving!" said the father ruefully.

"It is good, and I shall make it my business to prove it," vowed Cyrus.

He believed in the reaper as he believed in his father and for the sake of both he mightily resolved to carry on the work to the day of success. So he began where his father left off. The reaper must be something more than a powerful mowing-machine. It must meet the practical problem of dealing with the grain as it stood in the field, divide it systematically for the cutting and handle it properly when cut.

Look now at the model of the first machine that harvested real wheat in a real field. Remember that forty-six other inventors had struggled without success for the same end. All of them had failed to deliver the grain in a way to make their inventions a practical saving of time and labor. Cyrus McCormick's reaper had at the end of its knife a curved arm or divider to separate the grain about to be cut from the rest. There was also a row of fingers at the edge of the blade to hold it firmly in the position to be cut. Then that same knife had not only the

forward push as the horses drew the machine over the field, but it also gave a side sweep so that none of the grain could escape as it fell on a platform from which it was raked by a man who followed the harvest.

The practical economy of this practical farmer's reaper was shown first in the way the shafts were placed on the off-side so that it could be pulled, not pushed, the horses walking over the stubble while the cutter ran its broad swath through the bordering grain; and second, in the way the big driving wheel that turned the reaping-blade also carried the weight of the machine. Compared with the complete harvesters that we know to-day, this was indeed an uncouth, clattering, loose-jointed contrivance,—but it worked. Drawn by two horses, it cut six acres of oats in one afternoon, the work of six laborers with scythes. It was as if Hercules had appeared to add to his great labors a still greater work.

Nowhere was help needed as it was in the harvest fields, for grain must be cut when it is ripe. All that cannot be reaped in a few days is spoiled. A farmer might plant his wheat, the fields might laugh with the golden plenty, but if there were not laborers enough at the right moment there could be no bread.

The short reaping-season also made a special difficulty for the inventor. So short a time there was for putting his machine to the test,—so long a time to wait before fresh fields of waving grain made another trial possible!

There were, as we have seen, difficulties enough in the way of making a machine to cut grain; but there was a harder task than that of cutting wet wheat in a bumpy, hillocky field. There was the obstinate prejudice of ignorant men who feared anything that spelled change.

Look at Cyrus McCormick when he brought his machine for a public exhibition near Lexington, in 1832. There were as many as a hundred interested or curious spectators,—lawyers and politicians eager to see a new thing, farmers with excited, doubting faces, and sullen laborers who feared that this monster might steal their daily bread.

Young McCormick's strong, serious face was pale but determined. He did not wince even when his reaper side-stepped at a particularly ugly hump in the hilly field.

"Here, here, young man!" cried the owner of the field. "That's enough now! Stop your horses! Can't you see that you are ruining my wheat!"

The red-faced farm-hands were no longer tongue-tied. "Any one might know it was all humbug!" rumbled one.

"We'll keep to the good old cradle yet,—eh, boys?" jeered another. A group of piccaninnies, teeth agleam with mirth, chuckled and turned handsprings of delight.

Cyrus McCormick looked about at men and boys, calloused and bent by toil that yielded them less than a nickel an hour through long days of twelve and fourteen hours. "We are all slaves to the things we know and are used to," he said to himself. "I shall have to go slow, but I'll be sure." Farmers and laborers, no more than the jovial negro boys, dreamed that the thing they feared and ridiculed would prove the great bread-giver that was destined to set them all free.

At just the moment, however, when Cyrus McCormick was resigning himself to defeat a champion rode to the rescue.

"You shall have the chance you are after," said a man who had been watching McCormick and his machine narrowly. "Just pull down that fence over there and see what you can do in *my* field."

Here was new hope and fairly level ground. The inventor drove gratefully to the test and laid low six

acres of wheat before sundown. He had made good. The conquering reaper was driven in triumph into Lexington, where it was put on exhibition in front of the court-house. "That machine is worth a hundred thousand dollars!" declared a learned professor of a finishing school for young ladies with solemn emphasis. But young McCormick knew it would prove nothing more than a fortnight's wonder unless he could first make machines and then make farmers buy them. The inventor would have to turn manufacturer and promoter. And if Cyrus McCormick had not been an inspired man of business as well as an inventor the reaper would probably have been as the forty-six other attempts at harvesting-machines.

For several years he worked away,—farming to earn his bread and the chance to go on studying the way his reaper behaved under all conditions. A happy day came when a new sort of cutting-edge handled wet grain almost as well as the dry. The future looked really bright when, in 1842, after ten years of toil without encouragement and without capital in his father's little log workshop, he succeeded in selling reapers to seven farmers who were interested to the extent of one hundred dollars each.

The great day of the reaper really dawned, however, when it first saw the prairies. Here on the vast fertile plains of the Middle West the harvest so far outstripped the power of the harvesters that the cattle were allowed to feed in the wheat-fields that the farmers were unable to cut. When Cyrus McCormick saw the Illinois prairies at harvest time,—saw men, women and little children toiling frantically to save as much of the wheat as possible during the short time of crop-gathering before the heads of grain were broken down and spoiled,—he knew that the time had come for him to leave his log workshop.

"I must make my reapers, myself, to be sure that they are made right," he said, "and I must pick out the right place for getting material and shipping the machines through the West."

There were anxious hours spent in studying the map for the most favorable spot on the waterway of the Great Lakes. The hour of the inventor's destiny had indeed struck when he selected Chicago as the site of his future factory. It certainly took faith and imagination to see in the rude little collection of unpainted cabins huddled together on a dismal swampy tract without sewers, paved streets, or railroads the place of opportunity for a big business. But as Cyrus McCormick had seen in vision his

machine triumphantly gathering up for the use of man harvests that would vanquish the fear of famine, and give daily bread to hungry thousands that should people the vast lands of the untouched West, he now saw a great city rise in the place of this dreary, struggling little frontier settlement.

The story of the success of McCormick through the building up of his business was now one with the story of the prosperity of the prairie states and the growth of Chicago as a leading railway and shipping-center, and mistress of the wheat markets of the world. Year by year as the country grew and the task of reaping harvests for ever-increasing hordes of hungry peoples from many lands who came seeking bread in the generous new states, the power of the reaper grew. Other inventors added to its strength. It was a proud day when the self-raking, self-binding machine passed over the great wheat-fields, one driver on the high seat triumphantly replacing a score of sweating farm-hands that the old method of farming had employed.

To-day every child who has been to the country thinks the brisk self-binders and the great community threshing-machines as natural a part of the farm world as the sheep and the cows. He sees a huge tractor fed by oil or gasolene pull plows, harrows, harvesters, and

threshers; or sometimes a dauntless little Ford gaily leading now one and now another sort of planting or cultivating machine along the furrows. None of these things seems strange or particularly remarkable. To him the miracle will be seen in that first rude reaper put together by Cyrus McCormick in the little log workshop among the Virginia hills.

The Inventor of the Sewing Machine Elias Howe (1819-1867)

A small boy of six years was busy stitching wire teeth into the heavy "cards" that were to be used in straightening out the cotton fiber in the mills of New England. His father was a hard-working farmer, but he could not coax from his stony fields crops large enough to feed eight hungry children, so he had to turn his hand to other tasks such as grinding meal for the farmers of the neighborhood, sawing and planing boards and splitting shingles. The boys and girls of the family early learned how to help out in various tasks, for one pair of hands could not do everything.

"Maybe some day I'll make a mill to stitch these old cotton cards," boasted the little boy, whose fingers soon tired.

Elias Howe was never tired, however, watching his father's mills at work, and it was a proud day when he could help with the grinding and the sawing. He was a lively lad and full of fun; and he managed to make merry while he worked about the busy machines or took his part in the farm tasks. The ways of machinery were his chief delight.

"The boy takes after his uncles; they were never happy unless they were working with tools and contriving new ways of doing things," said his father.

The two brothers of the older Elias Howe had more than an ordinary inventive turn. One of them, William Howe, invented a truss or supporting frame that is still in use for roofs and bridges.

Little Elias Howe was constantly getting valuable ideas from what went on about him, and his ready skill with tools was won through doing the everyday tasks of home and farm that fell to his lot. Those were times when one did not at once go to a store to buy what was needed in the way of household utensils and farm equipment. People first studied how to make or mend what was at hand. Elias became an adept in the art of piecing together and making over things. As he learned by doing his wits became as nimble as his fingers, and his cheerfulness over a task made him a general favorite.

"No one like Elias for grit and gumption," people said. "He is a hard-working lad, but easy company. And a boy who sticks to things the way he does has something in him that deserves to succeed."

Elias Howe went to school in his native village—Spencer, Massachusetts, about twenty miles from

Worcester—during the winter months; and in the spring of his twelfth year he began to work for his "keep" on a neighboring farm.

"There'll be one boy less to feed at home," he said. "And I'll learn the A-B-C's of farming."

But the boy, though wiry and willing, had never been strong, and, moreover, a troublesome lameness made him unfitted for heavy farm work. So he went back to work in his father's mills until he was sixteen, when he started as apprentice in a machine-shop at Lowell. When, two years later, a panic led to the closing of all the mills in that town, Howe went to Boston, where he found a place in the shop of Ari Davis, a manufacturer and repairer of surveying-instruments and timepieces.

"Davis was an odd duck—you wouldn't think to look at his queer head that it held so many ideas," Howe said years later. "But instrument-makers and inventors of different machines knew where to go for help and suggestions, as bees know where to find honey. Nothing could have been better for me than the experience I got in Davis's shop. It was there that my idea of the sewing-machine was born. A man who was trying to invent a knitting-machine dropped in

one day. 'Why bother about that thing?' said Davis. 'Why don't you make a sewing-machine?' "

Young Howe listened carelessly. He did not dream that the turning-point in his life had been reached. His attention was caught by the boastful emphasis with which he heard Davis declare, "A sewing-machine would be no great wonder! I could make one, myself!" Then the idea flashed into the mind of the apprentice, who since he was a tiny boy, had longed to make machines, that he might be the fortunate inventor.

"Many people try things; few have the perseverance to carry their attempts on to success," he said to himself. "I shall win by sticking to this idea till something comes of it. There should be fame and fortune in it, for it will save hands much weary work. It will mean a new life to women who, like my mother, have a family of children to keep in clothes."

So he set to work with a will. As a starting-point, Howe knew machinery as an Indian knew woodcraft. He could hardly remember the time when he had not understood the ways of wheels, ratchets, and springs. At Lowell he had had practical experience with spinning-machines and power-looms. He was, moreover, used as we have seen, to exercising

ingenuity in making things. So it was not quite a leap in the dark when he said, "I will make a sewing-machine; I will not turn my face from the task till I have won success."

Perhaps if he could have seen the dark way ahead his heart might have faltered. Would the bright fortune that beckoned at the end of the long road have been able to lure him on despite all the trials and hardships that were to test his soul before he was to see any result of his work?

As Howe watched his wife sewing he tried to imagine a machine that would be able to go through the same motions. This led him off on a false trail. There were many attempts and many failures before the idea suddenly flashed through his brain that his machine was not obliged to move as the hand did. Why should his mighty stitcher that was to do the work of many hands not move in a manner of its own?

"A mere trifle—like a chance thought—often seems to be the thing that changes a whole life story," said Howe. "But perhaps there is no such thing as chance. It may be what we call little things are those that really count for most."

At any rate, the idea of a machine working out a new stitch was the turning-point in the story of his

invention. Machines that made a chain-stitch were in existence; he had probably seen or heard of one of these. He dreamed, however, of making something that would work in a new and better way. It is small wonder that he imagined a shuttle as playing a part in his machine, for all his life he had seen shuttles flying to and fro in looms.

"Why not make a sort of loom stitch where one thread is woven in and out with another?" he said to himself. There were more trials and failures, but he realized exultingly that he was on the right track. At last he hit upon his lock-stitch, where his needle plying ever up and down in the same spot threw, when under the cloth, a loop which was interwoven with the thread from a shuttle that clicked back and forth at regular intervals.

Elias Howe was now sure that he had a good thing, but he knew that there were many points in which his machine needed improvement. He must have time to experiment and to make a perfect model. What was he to do! He had to earn the living of his family; and with all his skill and hard work he often received only nine dollars a week. That gave him no chance to save or to work on his invention.

"At that time I was frequently so tired when I came in from my day's work," said Howe, "that I could do nothing but go to bed, longing for a rest without a to-morrow calling me out to the same grind. I made up my mind that the only chance of bettering myself and my family lay in the direction of my invention, so I went to live at my father's house. He had faith in my venture, and for a while under his roof I gave all my time to the sewing-machine."

"Young Elias Howe is a clever workman," said the neighbors, shaking their heads. "It is a pity that he spends his time on queer inventions when he ought to be getting steady employment."

This chapter in Howe's life came to a sudden close. A fire destroyed his father's shop and for a time left the older man without means to help his son. But if trouble seemed ever to be dogging the footsteps of young Howe, Hope stood at the turn of the road to give him courage. He found a friend in need, a friend who had just come into a tidy legacy and who dreamed of a lucky stroke that would suddenly turn it into a real fortune.

"Come and live with me," said George Fisher. "Your family will have a comfortable home while you spend all your time on the sewing-machine. We will

form a partnership and when success comes we will share the profits."

"But I must work and save long enough to get money for necessary tools and materials for my model," protested Howe.

"Turn to your partner!" said Fisher. "Here is five hundred dollars which I will risk in the cause."

After months of work, when each of the partners was wearing a suit of clothes stitched on the completed model, it seemed as if success must be at hand. But, behold, an unforeseen difficulty! Here was the wonderful invention ready and waiting for a world that did not seem to know or care that it stood in need of just what the Howe sewing-machine could supply.

Clothing manufacturers shook their heads, "It will cost us a great deal of money to make a new start with your machines," they said. "Why should we do that and perhaps bring down on us riots from people thrown out of work, when we are doing very well just as we are?"

But Howe refused to take this rebuff seriously. "It may take a little time," he said, "but in the end people can't help seeing that what saves labor lengthens life. That is only common sense."

The next step was to take out a patent.

"That means a journey to the Patent Office," said Howe. "But where am I to get the money for the fare to Washington! I cannot look to Fisher for another loan; he will rue the day he ever heard of me and my sewing-machine."

"Will you man an engine for a while!" he was asked. "Another locomotive engineer is badly needed just now."

"I'm your man," replied the inventor, pluckily. But more than grit and gumption are needed to run a train. Howe's frail body, worn by toil and hardships, could not stand the strain of the heavy work and the exposure to sudden changes of heat and cold. Just in the nick of time Fisher came to the rescue.

"Are you mad!" he cried. "Why, man, you are killing yourself! There are a few dollars more where the others came from to take us together to Washington. I find you need watching."

When at the capital, Howe seized the opportunity of exhibiting his rapid stitcher at a fair, where it drew wondering crowds who one and all admired but turned away without even considering the possibility of buying such a machine. Fisher's faith in the venture was all at once dashed to the ground.

"If I could only see a chance of getting back the two thousand dollars that I have put into your machine, I should not ask for a share in a fortune," he said gloomily. Then, looking at the worn face of his friend, he added generously, "You have risked more than I have."

Elias Howe refused to lose heart, however. "The place really to get a start is England," he said. "Surely the large garment factories there will open their doors to us."

The journey to England was taken with high hopes that made the hard conditions of steerage travel seem as nothing. And, sure enough, a London manufacturer, William Thomas, who saw at a glance the value of the machine in his business, bought one for $1,217 on condition that he might patent the invention in England.

"You can do nothing yourself on this side of the water," he said. "It is enough for you to manage your ventures in America. I will agree to pay you three pounds for every machine that I sell."

This seemed a fair offer and Howe was indeed helpless. Pressing debts must be paid without delay. He took Thomas's promise in good faith, and at the same time agreed to work for three pounds a week at

the task of making a machine especially fitted for the heavy stitching required in some branches of the manufacture.

When this new stitcher was completed Thomas made no attempt to conceal his readiness to part company with his inventor-workman. And Howe never received a penny for the machines sold in England on which Thomas was realizing a royalty of ten pounds each.

It is said that the darkest hour is just before the dawn. The lowest ebb of Howe's fortunes had now been reached. Perhaps he was saved from despair by the faith that a new day was about to break.

Pawning his precious first machine and his American patent, and pulling his forlorn baggage on a hand-cart to the wharf, he took passage in the steerage to return to New York and the daily grind of a machine workman. He had scarcely landed when news reached him that his wife was dying.

"What good of success now when the one who has shared all my hardships cannot have a part in better days, even if I win?" thought the unhappy inventor.

Now it seemed as if he must give up the struggle. His friends scarcely recognized the heartbroken, hopeless man. "He has grown old in a single day!"

they said. "What a pity, when good nature and cheer were always his way no matter what trouble came. And there isn't a better mechanic in America, if he could be persuaded to give up his crazy inventions."

But just at this time news came that the sewing-machine was becoming famous, and that those who had taken advantage of his absence in London to steal his invention were about to make the fortune for which he had labored in vain. This wrong roused something of the old spirit in Elias Howe. Even such an able opponent as Isaac Morton Singer, whose name has become a household word with the sewing-machines he manufactured and sold, found that he had more to reckon with than at first appeared. Howe defended his case ably in court after court and the justice of his claims were always fully and freely recognized. From the forlornest poverty, with his models and patents pawned in a foreign land, he at last rose above every obstacle and won success.

The way in which this victory was made possible by his father—who from first to last had faith in him and came to the rescue when all else failed, even mortgaging his farm to provide the money for pushing the claims of his patents—is a beautiful and inspiring story. The success of the sewing-machine owed much to the business ability and shrewd

advertising of Singer, who had been an actor and theatrical manager and knew how to employ to the utmost the devices of lime-light and bill-board in his big venture. "For success you need not only a live idea but an alert promoter," he said. "The people will not go after a new thing; it must go after them." He organized the business on sound and permanent lines, and he was quick to see and apply new inventions that would add to the effectiveness of the machine. The treadle, in place of a wheel turned by hand, and a needle moving up and down instead of sideways were improvements made by Singer.

Howe was during his last years a rich man, and happy in seeing his wealth a source of happiness and comfort not only to his family and friends but to many others. The thought of the lightened toil in households everywhere, due to his labors, always made his eyes kindle and a glow transfigure the worn lines of his face. "It would have been worth all the years of struggle even if I had not lived to taste success," he said.

One of his chief rewards was the thought of his machines working without rest day and night on the uniforms, shoes, tents, knapsacks and cartridge-boxes for the Union soldiers during the Civil War. Many car-loads of sandbags for their defense were also rushed to

the front with a despatch that, but for Howe's invention, would have been unthinkable.

"You have served your country more than you could have done if you had been a regiment in the field!" protested a friend when Howe talked of enlisting.

This seemed to put a new idea into the inventor's mind. Through his energy and influence he mustered the Seventeenth Regiment of Connecticut Volunteers and he provided all the officers with horses.

"You must go as our colonel," the men voted.

"I am grateful for the honor and for your confidence," Howe replied, "but I should not be worthy of either if I did not know my limitations well enough to decline. I shall, however, go with you in the ranks."

Despite lameness and failing health, Private Howe served some weeks as regimental postmaster, riding from the camp near Baltimore back and forth to the city every day with mailbags which seemed doubly his charge because they had been stitched on one of his own machines.

But the inventor's health did not permit him to see active service for long. He lived, indeed, only a few

years to enjoy the fruits of his hard-won success. He died in 1867, at the early age of forty-eight, leaving to others the opportunity and the credit of carrying to completion the improvements on his machine which he had dreamed of making.

"I used to see him often going about the house with a shuttle in his hand," said his daughter. "He never gave up trying to turn his ideas to good account."

For Elias knew that true success lies not in the reward at the end of the journey but in the spirit that, having traveled hopefully, looks ever on to some new goal of effort. And if one could have put into words the message of his last days, I think it would have been this:

"I have worked much; I have won much. Now I am content to leave the struggle and the reward to those who will go on with my work. For no one lives or dies to himself, and even when we realize it least, we are all workers and sharers together."

The Inventor of the Air-Brake
George Westinghouse (1846-1914)

The boy George Westinghouse seemed to give small promise of the man. He was a laggard in school and a laggard in the sports that are the delight of most boys. He had a curious love of lingering aimlessly about his father's shop; and sometimes he seemed able to amuse himself unaccountably by playing with a few bits of wood for hours at a time.

His mother gave him the name of his father, saying hopefully that perhaps he would prove a real junior in native power and gifts. George Westinghouse senior was a man of weight in the community, the country of fertile farms and wide-awake farmers in Schoharie County, New York. Combining mechanical ability with shrewd business sense, he made various improvements on threshing-machines and other agricultural implements and manufactured them in his own shops.

Young George Westinghouse seemed entirely without his father's practical sense. Never was there a colt who objected more to bit and bridle.

"My first vivid recollection is of the way I hated all restraint," said Westinghouse once, smiling with

reminiscent relish. "I had a fixed notion that what I wanted I must have. Somehow, that idea has not entirely deserted me throughout my life. I have always known what I wanted and how to get it. As a child, I got it by tantrums; in mature years, by hard work."

"Unless you can learn to run in harness you will never amount to anything, my son," his father would say. "Now if you want to be of use in the shop, watch the men who know the ways of tools."

But George soon tired of the humdrum story of saw and plane. At his own bench his appointed tasks were left unfinished while he tried to construct a little engine of his own contriving, or perhaps a water-wheel that should engage the hurrying stream in a fashion he happened to fancy at the moment.

"Trumpery—trumpery and nonsense!" said Mr. Westinghouse one day, and seizing George's latest pet invention he threw it on the scrap-heap. The boy's eyes blazed and he set his teeth hard to keep back the angry words.

"Never mind, lad," said the foreman, sympathetically, after Mr. Westinghouse had passed beyond hearing. "There's a bit of a room up in the loft where the boss never goes. There you can have your things and play with them as you like, with no one to

mind or meddle." So George had his den where he went to work out his inventions. The time came when he designed and made the complete model of a rotary engine in this secret nook among the rafters.

The way of the inventor is hard, even when he happens to be born the son of an inventor. For to be original means to be different and in that difference lies the possibility of much doubt and misunderstanding. George Westinghouse was "different" in that he seemed to take small interest in the proper concerns of his father's shops. A new threshing-machine had no power to kindle his enthusiasm. He also was a difficult pupil in school. It baffled his instructors to understand why a youth who was so ready in mathematics and so keen in reasoning along certain lines should be so heavy and inexpressive when it came to most of the lore of books.

One teacher alone realized that there was real power in the tongue-tied lad. "He is the kind whose thought must take shape in action, not in words," she said, with rare understanding.

"We all owe more to certain of our teachers than we know," Mr. Westinghouse once said. "I am glad that I realized at the time how much a certain capable

schoolmarm who was also a lovely and lovable woman meant in my life at a time when I needed the right sort of encouragement."

Young Westinghouse was indeed the sort whose thought took shape in work, not in words. There we have the keynote to his character and his success; and his thought was of the kind that rebelled against fixed grooves, that thirsted to go along paths of its own finding. His early faults that made his staid father shake his head were the sort that showed power of an uncommon sort.

It was necessary, however, for him to know discipline,—to tame his spirit by learning what ends were worth while and to go after them by work, not by "tantrums." His first real lessons were those he worked out alone in his loft workshop when he found that a fellow never got anywhere with his best notions unless he stuck to one thing until he conquered its difficulties and brought it to some conclusion. So he grew out of the fitful, impractical experimenter who made many more or less aimless beginnings, into the resolute workman and inventor who could hang on to a problem with a grip that never relaxed until he arrived at a satisfactory solution.

More valuable lessons in self-mastery were learned through his experience in the Civil War, first as scout in a cavalry regiment, later as acting third assistant engineer in the navy, a position which he earned by his excellent military record and his mechanical skill. While on board the *Stars and Stripes* he put in his odd hours at a lathe, turning out by its means a model of a sawbuck engine. For change of circumstances could not change his native bent. His interest in making machines was a part of himself and not to be left behind with his familiar tools in his den at home.

Later, when the war was over, and George, obedient to his father's wishes, entered the scientific department of Union College, it was seen that the pressure of prescribed studies could not stamp out his original work. Even during the hours when he was supposed to be devoting himself to the irregularities of French verbs and German idioms he was making sketches on his cuffs of locomotives or engines of one sort or another. The president of his college undertook to bring this unsatisfactory student into line.

"How do you like college, Westinghouse!" he began, with tactful cheerfulness.

"I dare say I should like it very well," replied George frankly, after a moment's hesitation, "if I had time to give my mind to my studies."

And then the astonished Dr. Hickok learned that here was not a case of an idle student, heedlessly wasting the golden opportunities of youth. "He has a mind of his own and the mind to use it," he advised George's father. "It will be useless to try to keep him in college at work in which he has no heart."

So George was allowed a bench in his father's shop and he soon proved that he had learned to run in harness now, during working hours at least. Even the stern and exacting father admitted that he was a competent workman, who could turn out a neat job at the point needed. But still the real interest of the days was found in the "den," where some ideas that had come to him during his experience in the navy were at this time taking shape in the rotary engine already referred to.

It was always a mechanical problem, a practical need, that engaged the attention of this young man whose thought "took shape in work." Once when watching a wrecking-crew work painfully to get some derailed cars back on the track, the idea came to him

for a car-replacer which he reduced to definite form in a drawing before he went to sleep that night.

George Westinghouse now had an opportunity to demonstrate his business ability, the power to size up a situation and "go after" an object until it is attained. With little encouragement from his father, he succeeded in getting a small amount of capital together from several investors in the city, formed a company, and set about interviewing various railroad men in order to introduce his car-replacer. Coming now in direct contact with railroad problems, he found himself one day face to face with another idea. He saw that of all parts of a track the frogs had to be most frequently replaced. This meant continual tearing up and patching that caused not only expense but delay to traffic. Westinghouse, then, made a cast-steel reversible frog that was twenty times more durable than the cast-iron parts in use up to that time. But of course one couldn't build up a fortune on frogs whose virtue was their long life. When once roads were equipped, a new supply was not needed for a long time. It was well, therefore, that young Westinghouse did not rest his hopes here but was already seeking new worlds to conquer.

Once more a need was presented dramatically through a railroad accident. One day, as

Westinghouse stepped from his train to see why it had come to a sudden stop with no station in sight, he saw the ground strewn with broken cars and their hapless cargo.

"Must have been gross carelessness,—a collision on a straight, smooth stretch of road like this," he remarked.

"No," he was told, "the engineers saw each other and both tried to stop but couldn't."

"Why not? Brakes out of order?"

"No, but all the brakes and brakemen in the world can't bring a train to a standstill all at once. It takes time to signal to the brakemen and time again for them to clamp on the brakes. This swift iron age of ours must pay toll for its speed."

This was the kind of challenge that fired George Westinghouse. A need without a remedy! Impossible! It was clear that the brakes which moved with such slowness on a fast train needed reforming. Could they not all move together by means of a chain that extended the length of the train? Might not some power, controlled by the engineer, pull the chain at need and clamp the brakes on all the wheels by one action?

What power could handle and control the mighty chain that should run the length of a train of many cars? Steam? Could steam from the engine pass to the cylinders on the different cars that should take care of the slack of chain made by the operation of the brakes? Even in summer the steam would be condensed long before it reached the last cars; in cold weather the condensed steam would freeze.

Then it happened that the man and the idea of the hour were brought together as if by chance. George Westinghouse picked up a stray copy of a new magazine, which opened to an article that caught his attention, about a remarkable engineering feat,—the digging of the Mont Cenis tunnel eight miles through the Alps from France to Italy by means of rock drills operated by compressed air. George Westinghouse gave an exclamation of delight. He had found the key to his door of opportunity. Compressed air should be the power to work at the bidding of the engineer in setting the brakes. If the power of air could be sent through pipes thousands of feet to dig a passage for man through the heart of a mountain range, it could pass unchanged from engine to caboose along any train of cars. Then the man whose thoughts took shape in action began at once to turn his idea into reality. The very day that he read about the tunneling

of the Alps by means of compressed air he made the first drawings of his famous air-brake.

A new idea must meet the right sort of man if it is to gain a foothold in the world. The man who works for the things of which people have never even dreamed must have the stern staying qualities of the pioneer. Even after Westinghouse had translated his idea into complete working drawings and models of the mechanism planned, it was long before he could make the railroad men entertain the notion up to the point of making an actual demonstration possible. The heads of one leading railway system after another turned a deaf ear to all pleadings for a practical test. And when at last a trial was granted and won, when Westinghouse was able to wire home the news of the dramatic trial trip which proved beyond question the value of the invention, his own father had so little faith in its practical success that he declined to invest any money in the venture.

Fate, however, was more kindly. The time had come for the air-brake and a very pretty drama was staged by fortune for the man of the hour. There was the train equipped for the trial trip with officials of the Panhandle Railroad and a few invited guests from other companies in the rear car. There was Westinghouse, tense but confident, looking over the

apparatus in the cab. He looked over the engineer, too, and saw a clear-eyed, capable young man. "Well," he said, by way of parting caution, "all I ask is that you give this a fair show. Good luck to you!" This with a firm, heartening hand-shake that left in the engineer's grasp, together with the will to do his utmost for this new brake entrusted to him, the surprising bonus of a fifty-dollar note. And his smile of reassurance to the astonished master of the engine gave no suspicion of the truth that the inventor had given his last dollar.

With the stage all set for the great act, fortune now pulled the strings. A deaf drayman, despite all warnings, started to drive his wagon over the track, when his frightened horse made the matter more desperate for the frenzied driver by throwing him across the rails in front of the rapidly approaching locomotive. The engineer saw the danger ahead. Now for the new brake. A powerful twist at the valve, and the compressed air rushed through the pipes to the cylinders under the cars, and the brakes were clapped to their wheels with a mighty jerk. The train came to a dead stop just four feet short of the helpless drayman. A life was saved and the new air-brake was the hero of the day.

Given the practical ability and character which Westinghouse brought to his task, the triumph of his

invention was now assured. When it had to hold its place against competitors he was able to meet varying conditions triumphantly. His quick-acting air-brake proved its worth on long freight-trains as well as on passenger-cars against all electrically operated devices.

But this success was to Westinghouse but the means of going on to further achievement. He turned his attention to a block system of safety signals where the warning is automatically flashed by electricity while compressed air does the heavy work of signaling. Then the matter of various electric projects for lighting, for street railways, for harnessing the inexhaustible energy of Niagara as a source of electric power for millions of people, engaged his attention. Westinghouse was a name to conjure with in the industrial world.

Always thinking in acts, and, when the door closed on one achievement, looking to the future with the cry, "Now for the next job!" George Westinghouse went on from one success to another. Practical American that he was, in his years of triumphant service for man in our Age of Steel, making its speed safe and its ways sure, he recalls to our thought the old saying: "Words are the daughters of earth; Deeds are the sons of heaven."

The Story of the Telephone
Alexander Graham Bell (1847)

The story of Alexander Graham Bell's early life is a wonderful tale of scientific adventure.

His father and his grandfather before him had been specialists in elocution and the laws of speech. They had written important texts on the subject, and one in particular, "Visible Speech," reduced the mechanics of word-formation to a science that had practical application in the teaching of foreign languages and the correction of speech defects.

"As I look back and see the points in my early life that led to my work on the telephone," said Dr. Bell, "I see that one important element was my love of music. I could play the piano by ear before I could read or write. I knew, too, all sorts of musical instruments in a sort of way. I knew how they were made and the way in which sounds were produced.

"A second element of even greater importance was that I came of a family that had made a study of oral speech for two generations before me. People who lisped or stammered came to my father to be taught how to place the vocal organs in forming sounds."

Then Dr. Bell went on to relate how his father encouraged his boys to make a hobby of voice work.

"You are fond of making things," he said one day. "Do you think you could make a speaking-machine!"

It was a fascinating idea. Graham undertook to model the mouth from a skull, making the tongue and soft parts of the throat of rubber stuffed with raw cotton; while his brother Melville worked upon the lungs and vocal cords. When they got their creature into shape, however, they were too much excited to complete the bellows that was to do duty as lungs. As one boy blew through a tube and the other moved the lips of the machine out came a "sound like a Punch and Judy show" crying "Mama" quite distinctly.

Of course the boy who knew music and so much of human speech longed to know more about the marvels of sound. When sixteen years old he started out with enthusiasm to teach elocution and to make further experiments with the laws of acoustics. One day, when he believed he had arrived at some important discoveries, he went to consult Alexander Ellis, a leading scientist who was translating into English the "Sensations of Sound," by Helmholtz. "Very interesting tests," remarked Ellis sympathetically, "but the German master of physics

has already given these facts to the world—and more completely." Then he invited Bell to his house and showed him how Helmholtz had set tuning-forks vibrating by means of electromagnets, and had succeeded in imitating the quality of the human voice by blending the tones of a number of tuning-forks.

Now the young man who had succeeded in making a talking-machine leaped in fancy to something that had no place in Helmholtz's experiments.

"Why not make a musical telegraph?" he hazarded, "a telegraph with a number of keys like a piano, capable of sending a like number of different tones at one time over a single wire." He recalled that when he sang a tone close to the piano strings, the string tuned to that pitch would vibrate in answer. He jumped to the conclusion that tones could actually be carried over wires and reproduced by means of the electromagnet. He had the thrill of a Columbus coming in sight of land. How was he to know that scores of other inventors had caught a glimpse of the same magic shore and had sailed all round it, but that it had melted before them like a mirage! This idea was to Bell, however, a kindly will-o'-the-wisp that led on to the search for the telephone.

The young man pushed forward his study as if he were determined to follow the advice to "learn everything about something and something about everything" in a day—or, rather, overnight. For his days were spent in teaching, and hours which should have been given to sleep were seized for research. The day of reckoning came, when a serious breakdown seemed certain. His father was thoroughly alarmed, and with reason, for two of his sons had been carried off suddenly by the dread White Plague.

"Another climate and life in the open," said the doctor, and the father insisted on his son giving up his cherished projects to seek health on a farm in Canada. But while planting crops and garnering renewed vigor the young inventor of twenty-six found time to work out with the Mohawk Indians some of his father's theories of speech.

Then word came of the chance to introduce this system of lip-reading at the school for the deaf in Boston; and young Bell, with health fully restored now, entered upon the work with all the zest in the world. So great was his success that he was called to a professorship in Boston University, where he gave instruction in his method of language-teaching for the deaf.

It seemed as if fair fortune were trying to lure the gifted young teacher away from his interest in inventions. He opened a School of Vocal Physiology which met with instant success. His work was filling a great need. Almost he was persuaded that here lay his true lifework.

Then it was that by a little deaf child he was led back into the paths, of experiment. Five-year-old Georgie Sanders lived in Salem, and there the teacher was persuaded to make his home for a time with his pupil. Association with the Sanders family revived Bell's passion for science, and their cellar was turned over to him for a laboratory.

That cellar workshop was for three years a place big with effort and promise. There coils of wire, magnets, and tuning-forks lay about in a strange medley, that gave, however, the first hint of the day when speech was to be carried across continents by means of the electric current. Bell worked feverishly and furtively while the world slept. That time was his own and safe from interruption; for now that he felt himself on the threshold of success he was jealously fearful lest some one would steal his great idea and push ahead through the open door.

"Often in the middle of the night," said Thomas Sanders, the father of the little deaf pupil, "Bell would wake me up, his black eyes blazing and his crisp, curly hair fairly bristling with excitement. Sending me to the cellar, he would plunge out to the barn and begin to signal along his experimental wires. If I noticed any improvement he would execute a war-dance of delight and go happily to bed. If things proved disappointing, however, he would settle down doggedly at his work-bench for a further tryout."

Another pupil of Bell's took his hand and gently helped him along the road of accomplishment—and beyond to the Inn of Content. Fifteen-year-old Mabel Hubbard, with her appealing ways and understanding smile, completely won the heart of the young professor who taught her to speak; and in a few years they were married. Her father, Gardiner G. Hubbard, became a stanch ally of Bell and later of the telephone.

"Do you know," said Bell to Hubbard one day, his dark eyes glowing and his voice vibrating with mysterious emphasis, "do you know that if I sing the note G close to the strings of this piano that the G-string will answer me?"

"Well, what of that?" asked Hubbard, wondering not so much at the words as at the dramatic emphasis.

"It is a fact of tremendous importance," replied Bell. "It means that we may some day have a musical telegraph, which will send as many messages at one and the same moment over one wire as there are notes on that piano."

Hubbard took to the idea with ready sympathy and support; but when the day came that Bell confided his dream of sending speech over wires, the man of affairs was alarmed. He felt that the promising inventor was in danger of turning visionary.

"Stick to a practical possibility; don't go chasing after a will-o'-the-wisp that can never in any event be more than a scientific curiosity," he warned. "Go on with the musical telegraph which may really make your fortune."

"If I can make a deaf-mute talk I can make iron talk," responded Bell.

Now he began to take up a new and a gruesome kind of experiment with the human ear itself. Taking the complete organs of hearing from a dead man's head, he arranged the sections of the skull so that a straw which rested against the ear-drum at one end touched a piece of moving smoked glass at the other. A new sort of "visible speech" resulted, for when he spoke with loud distinctness into the ear, the

vibrations of the drum appeared in tiny, waving lines upon the glass.

"If a little membrane like the ear-drum can vibrate a bone," said Bell, "then an iron disk may be made to vibrate an iron rod,—or, at least an iron wire." In that moment the idea of the telephone flashed in vision before the imagination of the inventor. He distinctly saw two iron disks (like ear-drums), miles apart, but brought into contact by means of an electric wire which could catch the vibrations of sound from the disk at one end and instantaneously reproduce them at the other.

There remained now the task of turning his idea into practical reality,—a task made doubly difficult because the friends who were giving him financial aid still insisted on his devoting himself to the musical-telegraph idea. Encouragement came, however, when a visit to his patent lawyer at Washington gave an opportunity to consult the eminent scientist Joseph Henry, who, it will be remembered, had given Morse valuable assistance with his telegraph. It seemed as if the wisdom of the past were meeting the daring enterprise of a new age when America's Prophet of Science—seventy-eight years old now—sat shoulder to shoulder with the young inventor of twenty-eight, as he examined and tested his apparatus.

At length the verdict came. "You are in possession of the germ of a great invention," said Henry, "and I would advise you to work at it until you have made it complete."

"But," interposed Bell, despairingly, "I have not the necessary experience with electricity."

"Get it," was the reply that seemed to infuse courage and determination into the inventor as by an electric current.

For three months Bell pressed on with his tests, until one day his assistant heard distinctly the twang of a watch-spring over the wire. That sound was to Bell as the blare of a victorious trumpet. Now he succeeded in convincing Sanders and Hubbard. As for the assistant, Watson, he had in him already a devoted ally.

"If Morse, who was a painter, could muster enough knowledge of electricity at the age of forty to carry forward his idea of the telegraph, our case is by no means hopeless," Bell said to Watson.

Many months passed with trial after trial, during which the infant machine refused to do little more than make distressing indistinct noises. Then one great day—it was March 10, 1876,—the assistant heard quite clearly over the wire the words, "Mr.

Watson, come here, I want you." Never was summons responded to with more headlong speed as Watson rushed from the room with the news of victory. "I can hear you!" he shouted at the door. "I can hear the words!"

The days that followed were passed in coaxing the infant wonder to speak with greater distinctness. "During the summer of 1876," said Watson, "the telephone was talking so well that one didn't have to ask the other man to say it over again more than three or four times before one could understand quite well, if the sentences were simple."

This was the year of the Centennial Exposition in Philadelphia, and Gardiner Hubbard, who was one of the commissioners in charge of the exhibits, arranged a place for the telephone in a corner of the Department of Education; and obtained a promise from the judges to visit the obscure niche between wall and stairway where it was set up.

The fateful Sunday afternoon came when the great men in their rounds passed before the little table where Bell waited, tense and eager. All were weary and indifferent, for the hour was late and the day very warm. Here was an odd, homespun sort of contrivance. One of the men took up a receiver idly

and laid it down without even putting it to his ear. Yawning, they agreed that their hotels promised more interest than new wonders.

It proved, however, that Fortune was just pausing long enough to get the stage properly set for Bell's great triumph. At that moment of seeming defeat in walked Dom Pedro, Emperor of Brazil, accompanied by the Empress Theresa and their suite.

"Professor Bell, I am delighted to see you again!" said the emperor, who was greatly interested in work for the deaf, and had once visited Bell's class in "Visible Speech" at Boston University.

Everybody was wide awake now, as Dom Pedro put the receiver to his ear, while Bell went to the transmitter at the end of the room. Then the royal visitor lifted his head and looked about him dramatically. "My God!—it talks!" he cried in amazement.

Now Joseph Henry took the receiver. "I shall never forget," said one of those present, "the look of awe that passed over that grand old man's face as he heard the iron disk speak with the accents of the human voice."

Next came Sir William Thomson, later known as Lord Kelvin, the great electrical scientist and engineer

of the first Atlantic cable. "It does speak," he said. "It is the most wonderful thing I have seen in America." And that was the verdict of the judges,—that of all the gifts to the Nation on the one-hundredth anniversary of the ringing of the Liberty Bell the telephone was the first in importance.

Notwithstanding its brilliant introduction to America, the baby wonder shared the fate of other great inventions and had to fight hard for a foothold in the business world. But the men in control had the vision and the courage of pioneers, reinforced by sound organizing ability; and so in spite of the indifference and ridicule of the ignorant, and the bitter enmity of the powerful telegraph interests, who looked upon it as a trespasser upon Western Union territory, the telephone won its way.

Did the great scientists who gathered about Bell at the Centennial and marveled that the electric waves could be made to carry and reproduce faithfully the complex sound-waves of the human voice, dream of how the telephone might one day figure in the affairs of men? Perhaps that is to ask the question, "Is the oak-tree more marvelous than the acorn from which it sprang?"

Let us think for a moment of some of the marvels that hide behind the word "telephone" in the world to-day. Think of a great switchboard with its maze of wires that are woven in and out, in and out, to the tune of the flashing light-signals, connecting any number of a vast city system with any other in a moment. Think of the underground lead-encased cables that pass under the streets of our cities,—great ropes of massed wires over which hundreds of messages pass magically side by side, and in and out, as the strands ravel off at their various destinations. Now there are underground cables connecting Washington, New York, and Boston. That came about in a dramatic fashion. The storm that swept over the country at the time of the inauguration of President Taft carried down so many wires that communication between Washington and the rest of the country was cut off for several days.

"That must never happen again," said the Bell engineers. "We must see to it that our capital is never out of touch with the rest of the country."

Picture the wires of our country,—the nerves of the Nation. The big underground cables are like the spinal cord from which intelligence goes out in all directions to every body cell. So the wires go over rivers, mountains, and deserts, and under the sea. At

points where wires stop the messages can leap through the air from shore to island shore, or to ships at sea, by wireless.

Is there in all the realm of Wonder-Lore a more marvelous story than that of the telephone?

The Franklin of Our Times
Thomas Alva Edison (1847)

A man who could see through the outer shell of things and read something of their meaning has called Edison "The Franklin of the Nineteenth Century." But the crowd made a marvel of his inventions as if he had the magician's wand or secret spell and insisted on calling him the "Wizard of Menlo Park" even after his plant had been transferred to West Orange. The Wizard is, however, glad that he has two deaf ears to turn to praise of this sort.

"There are many gains that more than balance my loss of hearing," he says whimsically. "I can go about New York, for instance, seeing what I like and hearing little of the rush and roar. And I am not troubled by this foolish talk about my wizard tricks. I have always been ready to put things to the test and to learn from what happens. That and the will to work while others sleep are the only spells I know."

The really great men are always very simple. There is a homespun directness about those who care for the gold of achievement rather than the tinsel of appearance. And there is indeed a striking parallel between Franklin, who with kite and key coaxed

lightning from the clouds, and Edison, who has summoned that mighty power to do the bidding of man in many ways.

The keynote of Franklin's character was thrift,—real thrift that means wise use of one's gifts and opportunities. We see this not only in the sayings of Poor Richard but also in the way he followed his own teaching throughout his most amazing career. For the man who began as printer and became scientist, inventor, and statesman, was first and last the most useful citizen of his day.

So with the Franklin of our own time. While we marvel at the range of his powers and the number of his accomplishments we find the explanation the same,—not magic but thrift.

As a boy he was called queer and stupid. Surely no child with all his wits would think that he could sit on goose-eggs as successfully as the mother goose and actually try it out. Other children often asked silly questions, but they didn't *act the goose* as he did!

There never was such a boy for asking why. And if you couldn't meet his every why, then why not? The school in the little town of Port Huron, Ohio, where he sat at the foot of his class for three months didn't know what to make of a boy who couldn't learn out of

books as the others did, but was always asking something that wasn't in the lesson at all.

His mother, however, knew that he wasn't stupid. She had once been a teacher, one of the wise sort who know life, as well as books. "Wouldn't you rather have a child who really thinks than one who says things parrot fashion every time you call his name?" she asked the boy's teacher, indignantly. She would teach her boy at home. He should not go to a school that called a boy a dunce and did everything to make him one by clipping the wings of his thought and imagination whenever he tried to use them.

So "Al" Edison was taught by his mother, and before he was twelve they had read several wise books together,—books that answered questions and gave one much to think about, such as Sear's "History of the World," and the Dictionary of Science. And the things young Al Edison learned seemed like windows opening out on new things to wonder about.

He spent his pocket-money at the drug store, not for candy, but for chemicals to try some of the experiments he had read about. Soon there were in the cellar of the Edison house some two hundred bottles labeled "poison" to scare away the curious.

Batteries and test-tubes and chemicals cost more than a small boy can command, even when, as was the case with Al Edison, he worked on a ten-acre truck farm and sold his peas, lettuce, and tomatoes, from door to door through the town. Besides, hoeing corn in July was hot work, especially when one longed to be down in the cellar with his precious bottles.

"Why not let me sell papers on the train to Detroit?" asked the enterprising lad one day. "I see my way to do quite a business and I could spend some hours every day at the public library."

Of course that appealed to his mother. He carried his point and did indeed build up a flourishing business. While selling newspapers, magazines, and candy on the train, he won permission from the conductor to use an empty compartment of the mail-car to carry baskets of vegetables and fruit back to Port Huron where he opened a little store with one of his boy friends as clerk.

Nor did he have to be parted from his laboratory while on the road. The baggage-car would hold more than his stock of newspapers and a fresh supply of produce for his store. Soon he transferred to it his stock of jars and bottles which had increased greatly

because he was now prosperous enough to buy many new and fascinating articles.

But, alas! the course of young ambition does not always run smooth, even on an express-train where one has been allowed to have everything his own way for a time. There came one day a sudden jolt that threw a stick of phosphorus out of its place to the floor of the car laboratory, where it burst into flame and set the car on fire.

The conductor rushed water to the scene and put out the fire, but his wrath still blazed, and as the train came to a stop for a station he flung the unlucky experimenter from his traveling workshop with all his precious possessions in a sorry heap, giving the culprit at the same time such a sounding cuff over the ears that they never recovered from the shock. The inventor's deafness dates from that day.

"Spilt milk doesn't interest me," said Edison years afterward. "I have spilt lots of it and while I have always felt it for a few days, it is quickly forgotten and I look ahead to the future."

The next day the boy, with his father's permission, set up his workshop in a spare room of the Port Huron home, and he passed through the cars of the train to Detroit with his pile of newspapers and candies as if

nothing had happened. It was not in him to harbor a grudge against the conductor, whose first duty was to guard the lives and property in his care. Nor did he cry out against his own hard luck, even though not only his chemical outfit but also his cherished printing-apparatus had been sadly wrecked. For, besides experimenting with gases and batteries, the young "candy-butcher" had actually set up a practical printing-office in the mail-car compartment that he had come to look upon as his own. There he had printed the "Weekly Herald," of which he was reporter, editor, business manager, type-setter, and all the rest; and, taking advantage of the eager demand for news during the feverish years of the Civil War, he had sold as many copies of his enterprising sheet as he could turn out.

Now in his home workshop he set up another newspaper—"Paul Pry," he called it—that was to satisfy the demand for items of local interest. These publishing-ventures showed young Edison's native shrewdness and gave scope for his initiative and imagination during the months when he was eagerly devouring the contents of the Detroit Public Library, shelf by shelf. But perhaps the greatest good for the future that came out of this chapter of his boyhood

was the interest he developed in the telegraph and through it in electricity.

He had learned the advantage of sending news by wire when getting items for his paper. He had also had the enterprise to send ahead to way-stations bulletins of important war news, in order to create a demand for his sheets when the train arrived.

"My chum and I used to hang around telegraph offices," said Edison, and we rigged up a line between our homes of stovepipe wire with bottles as insulators, set on nails driven into trees and short poles."

Fate, having prepared the young actor for the next act of his life drama, set the stage for a "popular hero" scene. The train-boy was waiting at a station while freight-cars were being shifted about, when he saw that the small son of the station agent was in the middle of a track on which a train was rapidly approaching. Down went papers and packages as the lad flung himself at the child and swept him out of the path of the locomotive with not an instant to spare.

"Good boy, brave boy!" repeated the tearful father as he wrung the hero's hand, cut and scratched as it was by the stones on which he had fallen by the track. "What can I do for you? I know," he said, in a burst of inspiration, "you would like, maybe, to learn to be a

train operator. Well, I'll teach you all I know of the business."

It is easy enough to find time for what one really wants to do, even in the crowded life of such a man of business as young Edison. A boy was found to fill in on the train for part of the run, reserving for Al the section of the route between his home and the station where his grateful telegrapher worked. He had already mastered the Morse alphabet; what he had chiefly to learn was the abbreviated code employed in railway work to save time. Some of the figures used in this way have become generally known, such as *23*, which stood for accident or death and was regarded as a bad sign; and *73*, which stood for congratulations and good wishes.

Then after several months of study and practice Edison fell heir to the position of telegraph operator at Port Huron. He was at this time sixteen years old and as busy asking questions—chiefly now of the scientific books and the opportunities for experiment that came his way—as he had been as a child when his insistent *why* and *again why* to all about him used to wear out the patience of every one except his mother.

He tried to get the men who worked with electricity to explain something of its *what* and *why*.

"The telegraph men couldn't explain how it worked," he said afterward, "I remember the best explanation I got was from an old Scotch line repairer who said that if you had a dog like a dachshund long enough to reach from Edinburgh to London, and if you pulled his tail in Edinburgh he would bark in London. I understood that, but I couldn't grasp what went through the dog or over the wire."

And to-day Edison says he is no nearer the answer to the question of what this electricity is with which he works than he was at that time.

The next years of Edison's life as a telegraph operator gave him a varied experience in many places and led him to confine his study and experiments to electrical problems. The possibilities of electricity became the concern of his working-hours. "Chemical experiments which had been my first love took on the nature of holiday excursions," he has said.

At this time he developed an instantaneous vote-recording machine designed to save Congress the time of roll-calls. It was an entire success; its only fault was that it was too perfect for imperfect human beings. The chairman of the congressional committee to whom Edison exhibited his model said solemnly: "Young man, if there is any invention on earth that we

don't want at the Capitol, it is this. One of the greatest weapons in the bands of a minority to prevent bad legislation and gain time for further consideration is the roll-call."

Edison at once saw the truth of this and instead of blaming fate for having led him off on a false trail he said: "That first invention taught me a valuable lesson, for I determined from then on to canvass the need or the demand before setting out to produce a supply of something which might not be able to secure a foothold in the world."

The next years of many inventions, including important devices in the perfecting of the telephone and the making of the first talking-machine, gave Edison when he was still a young man of thirty a world-wide fame. Then he put aside his fascinating experiments with the phonograph to take up the problem of lighting.

The brilliant arc-light was in general use in lighthouses and along important thoroughfares in England and America. This light not only was too powerful and too costly, but it also required too much attention for ordinary purposes. Everybody said, however, that it was the only practical electric light. In 1879 Professor Tyndall, the leading British scientist,

declared, "Though we have possessed the electric light for seventy years, it has been too costly to come into general use."

This was a problem after Edison's own heart. "Just wait a while," he said, "and we will make electric light so cheap that only the wealthy can afford to burn candles."

He realized that the lighting of houses, stores, and other interiors was the need of the hour. So he devoted all his thought to the task of developing a light of the size, cost, and convenience of the ordinary gas-jet.

Experiments had been made with incandescent lights, for when it was discovered that the electric current heated the wire through which it passed, many electricians dreamed of finding a substance that could be raised to the point of incandescence or white heat without being consumed. In 1845 a young American inventor, J. W. Starr, patented in England a lamp with a strip of carbon in the middle of a vacuum tube. He made for exhibition in America a splendid cluster of twenty-six of these lamps, one for every State in the Union at that time. He was confident that he had the light of the future. But, alas! on the voyage to America the brilliant promise of the young

inventor's life was extinguished. He died, at the age of twenty-five, and the practical development of his idea died with him.

It was thought, however, that Starr had satisfactorily demonstrated that carbon was the most favorable material for the incandescent conductor because it did not readily unite with oxygen (i.e., it could stand a high temperature for an appreciable time without being consumed) and also offered great resistance to the passage of the electric current, which meant that it might quickly be brought to the light-giving stage. But carbon, even in the best vacuum that could be devised, was burned out too soon to make the lamp a commercial success. A mechanism was arranged to supply new carbon sticks as fast as those in use were exhausted, but this made necessary globes that could be easily opened; and the lamps had also to be provided with a stop-cock arrangement for connection with air-pumps to restore the vacuum after each opening. Hence the incandescent lamps before Edison's time were great clumsy affairs and furnished light, without refilling, for only a few hours.

"It can't be done," said the leading scientists in America and England, when it was understood that Edison was determined to produce a practical electric light for houses.

"I am free to admit," said Professor Tyndall, "Edison has the power to grasp general facts and principles and then to work out from them some new practical combination before undreamed of. But as I know something of the difficulty of the electric-light problem, I should prefer seeing it in his hands to having it in mine."

The undaunted Franklin-like temper of mind that would never allow a practical problem to remain unchallenged and unsolved was at work. The child who had flung a repeated "why?" or "how?" or "how do you know!" at each easy-going answer that unthinking people gave to his questions was the father of the experimenter who was now working night and day to find the ideal substance for an incandescent lamp.

Would platinum perhaps meet the need? Many tests were made before he was satisfied that the answer to the riddle was not tangled in the coil of a web-like thread of this grayish wire. And now carbon. If a delicate enough filament could be produced, might it not be enclosed in an air-tight tube and so be given life for a longer time than people had dreamed possible? After many attempts, each leading to a failure which whetted his appetite for new experiments, he discovered that a delicate, hairlike

thread of carbon seized and held the bright light of the electric current in a way that might well be called "white magic." He had succeeded in sealing in a glass globe from which the air was exhausted a loop of carbonized cotton thread which glowed with a wonderful soft radiance. Upon this tiny thread hung the key to the problem of the world's light. That thread, like the one which Ariadne gave to her hero in the myth of the Slaying of the Minotaur, led Edison through a new labyrinth of endeavor. He was sure that there must be some substance even better than the cotton thread. That would do for a beginning, as a clue, but it pointed on to something that would give even more remarkable results. He tried carbonized paper, cardboard, tissue-paper wrought into fairy-like filaments. Then various kinds of fibers from every imaginable substance,—flax, cocoanut hair, celluloid, and all sorts of wood, stems of plants and grasses. It was as if he were calling up for question all the growing things of earth. Nothing that came to hand was safe from experiment.

One day he picked up a palm-leaf fan and tore off a strip from its bamboo edge. This was tried as hundreds of other things had been tried. A slender bamboo thread was carbonized and enclosed in a

globe, and at last here was the better thing which he had sought.

No sooner was Edison convinced that there was something about bamboo which seemed to make it the destined light-giver, than he determined to scour the lands that produced this wood to obtain the best varieties for his purpose. A messenger was despatched to China and Japan to collect as many specimens of bamboo as were to be found there. Hampers of samples were shipped to Edison's laboratory in New Jersey, where fibers from each were tested. In this game of survival of the fittest a certain Japanese variety won, and arrangements were made with an enterprising farmer of Nippon to ship a steady supply of the selected kind.

But even now Edison was not satisfied. "How do I know but that there is still in some spot of earth an even better substance," he thought. And he went on with his search through other lands and the far islands of the sea. A hardy adventurer with the perseverance of the true scientist, Mr. Frank McGowan, wandered through the vast jungles of the Amazon in the cause. Then to Montevideo, up the River de la Plata, through Argentine, Paraguay, and southern Brazil he went, fighting wild animals and Indians, encountering poisonous insects, reptiles, fever, hunger, and thirst.

No hero of myth or legend in search of the Golden Fleece or the Enchanted Apples of the Hesperides, endured more than did the searcher for the wood fiber that should serve as the slave of the Edison lamp.

And still the inventor went on with the quest! One day Mr. James R. Ricalton, principal of a school in Maplewood, New Jersey, who had considerable reputation as a naturalist and traveler, was asked by Edison if he were willing to carry on the search in the Orient.

"Are you in the mood for a vacation?" asked Mr. Edison, looking quizzically at the schoolmaster. "I want a man to ransack all the tropical jungles of the East, to find a better fiber for my lamp. I expect it to be found in the palm or bamboo family. How would you like the job?"

"It suits me," was the prompt reply.

"Can you go to-morrow?"

"Well, there are the little details of getting a leave of absence from my board of education and finding a substitute to take my place," said Mr. Ricalton. "How long shall I plan to be away?"

"How can I tell?" demanded Edison; "perhaps six months; perhaps six years. No matter how long it takes, find the right thing."

The schoolmaster made his plans and then took a lesson from the Wizard in methods of trying out the specimens of bamboo which he should find. Let us quote from Mr. Ricalton's own account of his journey:

It so happened that the day I set out fell on Washington's birthday, and I suggested to my boys and girls at school that they make a line across the station platform near the school at Maplewood, and from this line I would start eastward around the world, and if good fortune should bring me back I would meet them from the westward at the same line. As I had often made them toe the scratch, for once they were only too well pleased to have me toe the line for them.

This was done, and I sailed via England and the Suez Canal to Ceylon, that fair isle to which Sinbad the Sailor made his sixth voyage, picturesquely referred to in history as the brightest gem in the British Colonial Crown. I knew Ceylon to be eminently tropical; I knew it to be rich in many varieties of the bamboo family, which has been called the King of the Grasses; and in this family I had most hope of finding the desired fiber. Weeks were spent in this paradisaical isle. Every part was visited. Native wood craftsmen were offered a premium on every new species brought in, and in this way nearly a hundred species were tested, a greater number than was found in

any other country. One of the best specimens tested in the entire trip around the world was found first in Ceylon although later in Burmah...

From Ceylon I proceeded to India, then to Burmah, where the Giant Bamboo already mentioned is found also; but beside it no superior varieties were found. After completing the tour of the Malay Peninsula I had planned to visit Java and Borneo; but having found in the Malay Peninsula and in Ceylon a bamboo fiber which averaged a test from one to two hundred per cent better than that in use at the lamp factory, I decided it was unnecessary to visit these countries or New Guinea, as my "Eureka" had already been established, and that I would therefore set forth over the return to the western hemisphere, searching China and Japan on the way. The rivers in southern China brought down to Canton bamboos of many species, where this wondrously utilitarian reed enters very largely into the industrial life of the people, and not merely into the industrial life but even into the culinary arts, for bamboo sprouts are a universal vegetable in China; but among all the bamboos of China I found none of super-excellence in carbonizing qualities. Japan came next in the succession of countries to be explored, but there the work was much simplified, from the fact that the Tokio Museum contains a complete

classified collection of all the different species in the Empire, and there samples could be obtained and tested.

*Now the last of the important bamboo-producing countries in the globe circuit had been done and the home lap was in order; the broad Pacific was spanned in fourteen days; my natal continent in six; and on the 22nd of February, on the same day, at the same hour, at the same minute, one year to a second, "Little Maud," a sweet maid of the school, led me across the line which completed the circuit of the globe, and where I was greeted with the cheers of my boys and girls. I at once reported to Mr. Edison, whose manner of greeting my return was as characteristic of the man as his summary and matter-of-fact manner of my dispatch. His little catechism of curious inquiry was embraced in four small words—with his usual pleasant smile he extended his hand and said: "Did you get it?" This was surely a summing up of a year's exploration not less laconic than Cœsar's review of his Gallic campaign. When I replied that I had, but that he must be the final judge of what I had found, he said that during my absence he had succeeded in making an artificial carbon which was meeting the requirements satisfactorily; so well, indeed, that I believe no practical use was ever made of the bamboo fibers thereafter.**

**From Dyer and Martin's Life of Edison, New York: Harper & Brothers.*

It might be asked, Did Edison regret the nine years of experimentation and the hundred thousand dollars which his use of bamboo filaments had cost him when he discovered a way of producing artificial carbon much better than that furnished by any plant fiber? Never for a moment does he count that time lost which has been given to putting each factor of his problems to the test.

For many years the carbon light seemed to answer all purposes. Then metals were again tried. To-day the best lights are made from tantalun and tungsten.

The story of the carbon light is given here because it shows in a dramatic way the character and methods of work of the great inventor. He is always asking questions and where most people accept as final the opinions or statements of others, he never regards a point settled or takes a thing for granted until he has made a practical test. And in his tests he leaves no stone unturned, no corner of possibility unexplored.

After Edison had made painstakingly nine thousand experiments on his storage battery, and was still seeking the right factors for success, one of his

assistants remarked sympathetically, as he looked at the pile of note-books containing the story of the fruitless quest up to that point, "Isn't it a shame all this work and no results?"

"Results!" exclaimed Edison, "Why, man, I have gotten a lot of results! I know several thousand things that won't work."

Trials, then, never meant discouragement but the clearing of the way for the next thing in order. "The only way to keep ahead of the procession is to experiment," he says. "Stop experimenting and you go backward. If anything goes wrong, experiment until you get to the very bottom of the trouble."

After some ten thousand experiments with the storage battery the happy combination sought seemed won at last. The manufacture of batteries was going forward merrily. Then one day the order came from the master to scrap the lot and stop the work until certain further improvements had been made.

"Then," said one of his laboratory helpers, "came another series of experiments that lasted over five years. But secrets have to be long-winded and roost high if they want to get away when the 'Old Man' goes hunting for them. He doesn't get mad when he misses

them, but just keeps on smiling and firing and usually brings them into camp.

"That's what he did with the battery, adding improvements here and there until now we have a finer battery than we ever expected."

No expense is spared that may mean success to an experiment and so progress in the pursuit of knowledge. The thrift of the master is never a hoarding of resources but conservation and use to the best advantage. "Millions for progress but not one cent for stupid waste," is the slogan of this Franklin of our day. He uses in his laboratory still some strips of platinum that he rescued when a lad in his teens from some batteries abandoned as junk in a freight-yard in Canada. He has, however, embarked all of his capital in more than one venture, as when he spent over a million dollars in the attempt to extract ores from powdered rock by magnets. When experiments finally convinced him that the time was not ripe to make his plan a commercial success, he came up with the smiling challenge to fate, "Well, now for the next thing. It's all for some good. Keeps me from getting a big head. We learned a great deal and it will be of benefit some day perhaps."

The bulldog grip with which Edison seizes and holds a problem which he attacks is shown in the following incident. One of his engineers, whom he had set to work on a certain problem, reported shortly with three drawings which Edison examined and set aside as useless.

"Well, then," said the engineer, "that's too bad because there's nothing else to do."

"Do you mean," said Edison, wheeling quickly and looking the man full in the face, "that these drawings represent the only way to do this work?"

"I certainly do," replied the engineer unflinchingly. That was on Saturday. When the "Old Man" appeared at his works on Monday morning he placed on the engineer's desk sketches showing forty-eight possible ways of meeting the situation, one of which was singled out, slightly modified and put into successful practice.

Edison's faithfulness to an idea is shown in the way he developed his phonograph, which was put aside for ten years while he worked out the problem of lighting. Then, as he developed the making of moving pictures, he dreamed of combining the film and the phonograph in a way to make the screen people talk. Great difficulties were encountered: As—to mention

but one—light and sound travel at different rates and one cannot "register" joy or sorrow for the camera at the same moment that a record is being made of the spoken words. That is, however, one of the interesting problems that Mr. Edison keeps with him,—a possible triumph for some to-morrow that will crown with success the experiments of many hopeful and busy yesterdays.

In the same way he has worked to make really worth-while moving pictures that will teach while they amuse. To do this he has gone outside of studios and laboratories and studied children. Gathering up a group of small boys, for instance, he looks at a "feature" with them, trying to see it through their eyes and get in this way the point of view, let us say, of the ten-year-old world.

As the matter of lighting the homes of people forced the inventor to put on the shelf for a while his fascinating talking-machine, so the great war forced him to lay aside many interesting schemes to take up the life-and-death matters of national defense. As Chairman of the Naval Consulting Board he "did his bit," developing ways of meeting the submarine peril. An apparatus was developed that could detect the sound of a torpedo at a distance of four hundred yards, which together with a device for the quick

change of the course of ships, gave practical protection to cargo-carrying vessels. A search-light powerful enough to go through water and still do its proper work was called into being and also a device to help the lookout men detect the periscope at a distance by shutting out the cruel glare of the sun on the water and at the same time making the sight more sensitive.

Edison, the chemist, so long kept in the background by the demands of his electrical experiments, also had his "innings" during the war. Some important substances used largely in the manufacture of drugs and dyes had been imported from Germany. Could America learn to make its own? Here was a practical need to be met; and the boy who had once found in the possibilities of chemicals the most fascinating kind of play now turned that interest to good account. After eighteen days he had found the secret of making phenol or carbolic acid and at the end of the month his works were tuned up to turning out a ton of this chemical in a day.

So it is that Edison has worked through a long life. When asked what his secret of achievement is, he always says, "Hard work, based on hard thinking." Each day dawns with fascinating possibilities, for "the world is so full of a number of things!" As we have

seen, he goes at his hard work with all the spirit that a boy puts into a great game, and each day is a new world. "Edison has the happy faculty," to quote his biographers, "of beginning the day as open-minded as a child—yesterday's disappointments and failures discarded and discounted by the alluring possibilities of to-morrow."*

*Dyer and Martin: Life of Edison.

Machines for the Millions
Henry Ford (1863)

Round as a biscuit,
Busy as a bee,
The prettiest little thing,
You ever did see!

How many children have said in their happy singsong this riddle-rhyme of the watch,—the thing that is to them the chief pocket-wonder of their world. All grown-ups know the power of the "tick-tick" to amuse and as a most particular favor sometimes open up the magic case to let a small friend "see the wheels go round." To all children the sight of the tiny wheels is a wonderful thing; to some children it is school and holiday rolled into one,—the beginning of their real interest in life and their life-work.

Such a boy was Eli Whitney, who on one thrilling day when his father was at church dared to take that gentleman's precious watch to pieces. He had at stolen moments studied the little wheels and dreamed about the way they fitted together and worked. Now he longed above everything else to take them apart, touch them one by one, and learn the trick of each which was the secret of the marvelous teamwork that

ticked off seconds and hours. That watch was Eli Whitney's first real school. He learned as he struggled with its wheels the first principles of machinery, and the longing to know more. That is the story of the cotton-gin.

It will be remembered that George Stephenson also learned from clocks and watches many things which he later put to use in the making of locomotives. This is the story of another boy whose first school was a watch. From it he learned to love the ways of machines. It may be said that the idea of the Ford motor-car and the factory where everything goes "like clockwork" came from a watch.

Little Henry Ford was looking with delight at the real watch which a boy friend was exhibiting proudly. Both boys forgot that it was Sunday and that their mothers expected them to follow along properly into church.

"Oh, ho!" said Henry, "your watch isn't going. Let me see if I can't set it off." Here was the chance he had longed for as far back as he could remember,—to see the inside of a watch. Fearful but fascinated, Will Bennett handed over his treasure and, forgetting church and possible punishment in store at home, they went together to the shop of the Bennett farm.

There Henry made a small screw-driver by filing a shingle nail and set off on the big adventure. Church was over, dinner time came and went, the long spring afternoon was drawing toward evening, and still Henry was working with the tiny cogs and springs. The anxious owner of the watch, torn between despair and hope, was held in leash by Henry's enthusiasm.

"You *said* you'd put it together again all right!" he was saying for the hundredth time when their anxious parents descended upon them.

"An' so I would if folks'd only let me be till I could finish!" Henry declared hotly. He had, indeed, fitted most of the parts together and he passionately longed to prove, by setting them going, that they were in working order.

"I suppose," Henry Ford said years afterward in recalling that great day, "that we came in for all the punishment that was thought right and proper. But I have forgotten about that. What I do remember is the way I began to experiment with all the clocks and watches within reach. Only my father's watch was sacred. Every clock in the house shuddered when it saw me coming."

The ordinary run of the farm tasks had little charm for Henry. They were always the same tiresome round with nothing new to work out. In the farm shop, however, he found something more to his taste. Here were tools like so many hands trained to special work, needing only the mind to direct their effort.

Tool-power was a wonderful thing. He set himself to the task of learning to use it. It was a great day when he turned out a device for opening and closing gates. Every time his father was saved from jumping off the wagon to swing back a gate he should realize that something worth while came of "fussing about in the shop."

When Henry was fourteen his world was suddenly changed by the death of his mother. In that busy home, where the daily round had always gone with the happy regularity of clockwork, the mainspring was broken. Now the farm duties were empty of all interest and the hours that the boy could spend in the shop seemed the only real part of his days. From scraps of old plows, harrows, and wagon tires, he made a small steam-engine that really went. He had a moment of rare triumph when he charged down that pasture lot at ten miles an hour, tooting an ear-splitting whistle, but no one seemed particularly impressed except the frightened cows.

The mechanical journals which he devoured as other boys do tales of adventure pointed the way to big opportunities in the iron-works at Detroit. He dreamed of going there to seek his fortune with the things he loved, great engines that did the tasks of giants. Then there came a day in his sixteenth year, when spring was in the air, that he suddenly decided to take matters in his own hands and make his dreams come true. His seat at school was empty that day.

The train that drew into Detroit gave a long whistle of triumph as if to proclaim that the great adventure of living was fairly begun for one boy at least. It did not take him long to make his way to the factory where steam-engines were made.

"I'm looking for a job," he said to the big, red-shirted foreman.

Something in the determined voice made itself felt over the roar of the machinery and the hurry and confusion of the works. The foreman stopped long enough to look the boy over and to recall that an extra helper or two would come in handy just then. "Come to work tomorrow. I'll see what you can do," he said. "Pay two and one half a week."

For a number of weeks Henry worked in the machine-shop from seven till six, sometimes at the

forges, sometimes making castings or assembling the parts of the engine. In the evening he worked for two hours at a jeweler's, mending clocks and watches. For of course it was impossible, even in those good old days of cheap living, to find a clean, wholesome place to eat and sleep for two and a half dollars a week. As it was, the boy must often have missed the abundance of the farm kitchen as he did the fresh country air and the home faces, but his work had always for him the zest of adventure, because there was always some fresh problem to be solved.

His father, who had followed him to Detroit and talked with him earnestly, said: "If this is the school of your choice, stick to it as long as you want. You know where your home is; it'll be there when you find yourself wanting something besides engines."

As the days went by an idea came again and again to the young machinist, who had never known what it was to work like a machine. Always on the alert to discover how to do something in a better way, he saw that there was waste of time and effort at many points in the great factory.

"See here," he said one day to the man next him; "nothing's ever made twice alike. We waste a lot of time and material assembling these engines. That

piston-rod will have to be made over; it won't fit the cylinder."

"Oh, well," was the easy-going reply, "it won't take long to fit it. We do as well as we can."

But Henry had in his mind a factory where there would be no waste of man-power or of tool-power; where each worker would be so perfectly fitted to his job that there were no false motions. One day when he had in his hand a new watch for which he had paid three dollars, he had a vision,—a vision of a plant where everything went like clockwork, "a gigantic machine taking in bars of steel at one end and turning out completed watches at the other."

"There would be a fortune in it," he exulted, "and for the millions watches like this in my hand for fifty cents!"

It is possible that people might to-day be using Ford watches at home instead of riding about in Ford cars if circumstances had not called the dreamer back to the home acres at this time. His father was ill and there was need of his hand at the helm. Then when there was no longer the same need, he still stayed, for there was a country girl who made home ways seem better than anything else, even better than the ways of smooth-running machines.

But in a home of his own on a thriving farm, he sat by the lamp in the evenings reading the magazines that told about the world of factories and machine ideas. He had seen something about a Frenchman who had invented a horseless carriage, run by an engine. The idea fascinated him.

Not long afterward, on a visit to Detroit, he saw a steam-driven fire-engine go puffing down the street. He stared at it as if he had never seen anything of the sort before. "Such waste," he muttered to himself. "More than half the power used in carrying that huge boiler of water about!" He couldn't forget that steam-engine. It had to be heavy because one couldn't have driving-steam without boiling water. How, then, was one to get away from the weight and the waste of power? Could the engine be run in some other way? What of these gas-engines that were being tried in some places? Could a simple, practical engine be run by gasoline?

This idea filled his days now. While he worked in the fields he was dreaming of gas-engines put to work for people in a way to help most.

"I'm going to leave farming and go back to the city, where I can have a chance to make my engine," he announced one day to his wife.

Of course it seemed a wild thing to do. But as it was plain that he would think of nothing else, one had to make the best of it. After all, he would soon find out if there were anything in his scheme, and either finish it or throw it on the scrap-heap. So his wife set herself cheerfully to the task of moving to the big city.

Several years passed,—years full of hard work, first as engine-doctor and then as one of the subordinate managers in the Edison electric-lighting plant of Detroit. But they were years of hopeful adventure, because the engine idea was taking shape in iron and steel. Many times Henry Ford's enthusiasm kept him in the work-shed at the rear of his house all night.

"How could you stand that sort of thing when you had to be at work next morning?" Ford was asked.

"I was never sick," he replied. "It isn't overworking that breaks men down, if they have heart in their work. Overplaying and overeating make most of the trouble."

It was a queer-looking thing to have taken so many months of planning and contriving, that first engine. A piece of pipe salvaged from the scrap-heap at the Edison plant made its one cylinder. Four antiquated bicycle wheels fitted with extra heavy rims and pneumatic tires were mounted on a light buggy frame

made, like all the rest, from odds and ends of material. But it went!

It was three o'clock on a dark winter morning when that first Ford car chugged out of its shed on its first journey into the world. The ground was covered with slush and the rain came down in torrents, but the moment was one of triumph. The engine worked! Each throb and jerk was a promise of success, but also a call to further effort. There was a long road ahead.

"I knew my real work with the car was just begun," he explained afterward. "I had to get capital somehow, start a factory, get people interested,—everything. Besides, I saw a chance for a lot of improvements in that car."

As we have seen, Henry Ford was not the inventor of the gas-engine. He had read in his machinist's journal of the work of Lenoir in France, Otto in Germany, and others. The Frenchman Lebon, in 1804, proposed firing compressed gas and air by an electric spark. In America, Charles E. Duryea (a bicycle worker like the Wright brothers) made in Springfield, Massachusetts, the first American automobile. A man named Haynes—of Kokomo, Indiana—was a close second. The honor of the invention of the gas-engine which has made possible

both the automobile and the aeroplane belongs to no one man.

Ford was one of a number of men who were struggling to make practical gasolene motors. He differed from the others, however, in that his goal was a cheap car for the many, not another luxurious carriage for the few. "I thought the more people who had a good thing the better. My car was going to be cheap, so the man that needed it most could afford to buy it," he said. "Then I saw it put to work on the farm, saving many from the grinding toil I knew at first-hand." He succeeded, as all the world knows, in making his car and in building up the largest automobile business in America. What was the secret of his success?

"Ford is a genius," declared Edison; "there is no other way of explaining him. I put to him a problem of the laboratory, and while men with the technical training of experts calculate and differ. Ford goes through the thicket of non-essentials, straight to the point, as if by instinct. So it is with the organization of his business: his genius for human engineering was shown in the work with and for his workers."

Some might see the reason for Henry Ford's success in his single-mindedness. As the making of his

engine had been the mainspring of his existence for ten years, so the ideal of a business with everything as perfectly adjusted as clockwork grew and developed. The principle of standardization which he had once thought of applying to the making of cheap watches was now applied to turning out motorcars and tractors for the millions. There was to be no room for waste. Every part was to be machined to exact size, so that no fitting afterward in the assembling-room should be required. When the machine "found itself," it would be seen that all parts fitted together to the fraction of an inch. As the Ford engine worked, so also did the standardization idea.

So, too, was Ford's intelligent generalship in the management of his army of workers a factor in his success.

"Does it pay," says Henry Ford, "to give the workers a chance for a contented life? What makes better workers must make better work and better business. The whole world is like a machine, every part as important as every other part. We should all work together, not against each other. Anything that is good for all the parts of the machine is good for each one of them."

What is the "conquest" of the cheap motorcar? Ask the man in the street who uses it in his business and who tours in it during his holiday hours. Making a life is as important clearly as making a living, and the automobile helps with both by bringing the country close to the city,—making it possible for the dwellers in streets to taste the joys in the open, and for farmers to cover in an hour the journey to town and city that formerly took half a day.

The railroad broke down the barriers that separated city from city and town from town. The motor-car has carried further this work of destroying distance and adding to life by the saving of time and toil.

The Conquest of the Air
Samuel Pierpont Langley (1834-1906), Wilbur Wright (1867-1912), and Orville Wright (1871)

A small boy was lying on a hilltop watching the flight of a sea-gull.

"How does he do it?" he wondered aloud. "How is it that he can float about like that without any effort? It is only when he begins to mount into the air that he flaps his wings; now he is hardly moving them at all. He is held up by the air just as a kite is."

This was not the first time that young Samuel Langley had watched the sea-gull's flight. In fancy he, too, was soaring, held up magically by a wonderful understanding of the power of the air.

"There must be something about the air that makes it easy," he pondered. "The birds have the secret, but I can't even guess it!"

That night at dinner he surprised the family by saying suddenly: "Birds swim in the air as fish swim in the water. We have learned the secret of letting water hold us up; why can't we do the same with the ocean of the air?"

"What of good old Gravity, my son?" teased his father. "That law is still alive and active, is it not?"

"But," persisted the boy, "the hawks and the gulls are heavier than the air. There is nothing of the balloon sort about them."

"But they have wings, my boy, and they know how to fly," returned Mr. Langley, looking at the boy's puckered brow with amusement.

"Well, why should it be such a joke,—the idea of a person learning to fly!" returned Samuel. "Why shouldn't people make a sort of airship with wings and sail through the air?"

Many boys besides young Langley had dreamed of winning wings. Indeed, in all ages of the world people have longed to slip the moorings that tie them to earth and float "over the hills and far away" with the freedom of flight.

Samuel Langley went beyond wishing and longing. He studied the flight of hawks and gulls carefully and noted that their wings were motionless except when they turned them at a different angle to meet a new current of wind. "I began then," he said, "dimly to suspect that the invisible ocean of the air was an unknown realm of marvelous possibilities."

Years after, Professor Langley, the world-famous scientist and head of the Smithsonian Institute, came back to this problem that had fascinated him as a boy. "Nature has solved the puzzle of flight; why not man?" he said. He began to study the mathematics of flying and became convinced that the formulas given in the books concerning the increase of power with increase of velocity were all wrong. "At that rate a swallow would have to have the strength of a man!" he exclaimed. He devised a sort of whirling table with surfaces like wings to test with exactness just how much horse-power was required to hold up a surface of a certain weight while it was moving rapidly through the air, and by this means discovered and demonstrated the fundamental law of flight, known as Langley's Law, which tells us that the faster a body travels through the air the less is the energy required to keep it afloat.

After proving that birds are held up like kites by pressure of the air against the under surface of their wings, he made experiments to show that their soaring flight is aided by "the internal work of the wind;" that is, by shifts in the currents of air, particularly by rising trends, which the winged creatures utilize by instinct. Watch a hawk as it circles through the air, dipping its wings now at this angle,

now at that, and you will realize that the wind is his true and tried ally. He trusts himself to the sweep and swirl of the air, just as a swimmer relies on the buoyancy of the water.

Having demonstrated so much through experiments with his whirling table. Dr. Langley determined to construct a real flying-machine, with wide-spreading planes to sustain it in the air while it was driven along by a steam-engine which furnished power to the propellers. This machine, which he called an "aërodrome" (air run), was put to the test on May 6th, 1896. Dr. Alexander Graham Bell, who was present at the trial and who took pictures of the machine in mid-air, declared, "No one who witnessed the extraordinary spectacle of a steam-engine flying with wings in the air, like a great soaring bird, could doubt for one moment the practicability of mechanical flight."

Though his effort to carry his experiments to the point of commercial success ended in disappointment, Langley never lost faith in the future of his airship.

"I have done the best I could with a difficult task," he said, shortly before his death in 1906, "with results which, it may be hoped, will be useful to others. The

world *must* realize that a new possibility has come to it, and that the great universal highway overhead is soon to be opened."

While the crowd was still laughing at the absurdity of a learned man's attempting to fly, there were eager young men seriously at work on the problem. "We had been interested in flight since our toy-making days," said Wilbur Wright, "but it was the knowledge that the head of the most prominent scientific institution in America believed in the possibility of human flight which led us to enter heart and soul upon the quest. He recommended to us moreover, the books which enabled us to form sane ideas at the outset. It was a helping hand at a critical time, and we shall always be grateful."

So it is that the work of one man is passed along as a torch to those who carry on after him.

Why did Wilbur and Orville Wright, the inventors of the first successful heavier-than-air flying-machine, take up the problem of flight? Get a lively child in the habit of thinking, then give him a live subject to think about, and something is bound to come of it.

There was a simple house in Dayton, Ohio, not very different from its neighbors; but it was a real home with windows that opened out on the world of

ideas. Books were the familiar friends of the children who lived there and they learned to use their eyes and to think about what they saw.

One day their father came in looking mysterious. There was something partly hidden in his hand. What could it be? Before they could get more than the most tantalizing glimpse he tossed it suddenly into the air. Then, instead of falling to the floor as the boys expected, it flew across the room until it struck the ceiling. It fluttered about there a few moments, to the delight and wonder of Wilbur and Orville, who cried, "It's a bat!" Then it fell to the floor. Picking it up and examining it eagerly, the boys saw a "light frame of cork and bamboo covered with paper, which formed two screws, driven in opposite directions by rubber bands under torsion."

"It's a helicopter," said their father. Bishop Milton Wright was a teacher and an editor who was known to the people of the community as a man of wide knowledge. He had been, too, a great traveler, and had brought back to that home in Dayton ideas from many parts of the world. He explained how the new toy rose in the air by means of its spinning, screw-like propellers. But helicopter (which their father said meant "screw-wing") did not mean as much to them as their own name did, so the boys continued to call it

a bat, and, since it was a frail toy with a short life, they tried their hand at making other "bats."

What was to hinder their making really sizeable ones? Alas! it turned out that the larger the bat the less at home it was in the air. They turned then to kites as the really reliable flyers. Their kites were the talk of the town boys until they decided that they were too old to be seen flying kites.

But all the time their kites had been tugging at the strings they held, the puzzle of flight had been tugging at their fancy. They tried to understand something of the behavior of their toys as the wind tossed them about. Then as they grew older they turned to books, to learn what other people had found out about flying. When they read in the summer of 1896 that Otto Lilienthal, in the effort to balance himself in his "gliding machine," had fallen to his death, they began to study the question seriously.

That matter of balancing was the great difficulty. Lilienthal, who had given much thought to the mechanics of birds' flight, had made himself wings like those of a soaring hawk or buzzard and, throwing himself from the summit of a hill, had tested his theories as he glided through the air of the valley. He thought he could keep his balance by shifting his

weight as the wind shifted, but alas! he had not won the "wings of the wind." So down he came to earth, one more pitiful Icarus.

"It is clearly not possible for a bird-man to keep up with the wind flaws by shifting his weight," the Wrights agreed.

These aspiring scientists who now set to work to solve the problem of flight were partners in a bicycle shop of Dayton. "Clever chaps and good business men," the neighbors said. "They might have gone to college like their two older brothers and sister, but they decided to hold things together at home for their father, who travels about a great deal." Their mother was a college woman and a capable all-round home-maker. She died about the time these younger Wrights were through high school. "They won't lose out, however, in the long run, by looking out for their father as well as for themselves."

That bicycle shop in Dayton soon began to see strange sights. As they pictured the practical problems of "gliders" the brothers made models and tried out experiments. Lilienthal failed because his weight and the distance he might move could not be changed to meet the disturbing force of changing air currents, which steadily increase with size of wings and rate of

wind, they decided. Some plan might, they thought, be devised for big machines to allow the flyer to shift the slant of different parts of the wings and thus make the wind a "friendly enemy" by compelling it actively to restore the balance it had threatened.

"This shifting of the wing surfaces must be an automatic winning of equilibrium through reflex action as in the riding of a bicycle," they next decided.

A gliding-machine of light spruce and steel wire and cloth pinions was built, with a rudder in front to guide and to counterbalance shifts in the center of air-pressure. There were two planes, curved to imitate a bird's wings, moved by cords controlled by the reflex action of the bird-man's body as he lay stretched flat across the middle of the under wing.

"We will keep to gliders," the Wrights vowed. "It's foolish to trust delicate and costly machinery to wings that we have not learned to use. Besides it would certainly be well to discover what the wind can do in keeping us up before we call in another power."

Days were spent in studying the mechanism of birds' flight, for, following the experiments of Langley, they became convinced that soaring birds were nature's aeroplanes with the power of balancing themselves and rising or falling on currents of air.

Now for a chance to put to the test of actual practice their theory of automatic balance!

Lilienthal's method of coasting down hill on the air seemed a poor makeshift. Perhaps at Kitty Hawk, North Carolina, on the stretch of sand-dunes between Albemarle Sound and the Atlantic, they might find winds of the right strength to provide a real trial. The Weather Bureau assured them that the winds there were the steadiest and strongest of any that blew. Their machine might be launched like a kite with men to hold ropes fastened to the end of each wing. There would be time to try out the principles of equilibrium before the bird drifted down at last upon the dunes.

But no kindly wind blew at Kitty Hawk in the autumn of 1900 powerfully enough to carry the glider up as planned. They flew it then as a kite without a pilot on board. "All we gained by the test was an increased longing for further experiment," they said afterward. "So far the results might be called encouraging, but we got, of course, no opportunity for practice in balancing. Far from learning to fly, we had not even tried our wings."

The brothers, who had taken up flying as a sport, found their high adventure was leading them far into the most fascinating of science's unexplored fields.

The air-pressure on surfaces of a variety of shapes was measured and tested at different angles, and the results carefully tabulated and compared. This meant the making of many difficult experiments under the most baffling conditions. There seemed little enough in the way of achievement to show for months of exacting work, yet they knew that they were proceeding in the only sure and sane way.

In like manner the experiments of 1901 and 1902, with larger machines to which vertical tails were added to assist in balancing seemed to give small return for great effort. The experimenters summed up the results in these words:

In September and October, 1902, nearly one thousand gliding flights were made, several of which covered distances of over six hundred feet. Some, made against a wind of thirty-six miles an hour, gave proof of the effectiveness of the devices for control. With this machine in the autumn of 1903 we made a number of flights in which we remained in the air for over a minute often soaring for a considerable time in one spot without any descent at all. Little wonder that our unscientific assistant should think the only thing needed to keep it indefinitely in the air would be a coat of feathers to make it light!

At last the moment seemed to have come when they might permit themselves to try power-flight. They had worked out in actual practice a system of balance for calms and for winds. A twelve-horsepower gas-engine, weighing 240 pounds, was placed on an aeroplane which with the pilot weighed about 745 pounds. Then, on December 17, 1903, four flights were made at Kitty Hawk against a wind blowing twenty miles an hour.

They knew now that the problem of equilibrium was solved. Where earlier aviators like Lilienthal had tried to hold their own in the air by shifting the position of the body, the Wrights had worked out a scientific method of balancing by warping the wings of their machine. If a sudden change in their position or in the direction of an air current hit their plane, a lever caused the ends of the planes toward the earth to warp down and the opposite wing ends to warp up. This meant, as they had repeatedly demonstrated, a definite gain in buoyancy for the lower wings and a corresponding loss in lifting-power for the upper ones. Then, as the machine righted itself, the lever was moved in time to prevent it canting to the other side. This method of control through the warping of the ends of flexible planes was the Wrights' great discovery.

They were reaping the reward now of their patient study and experimentation and found that it was possible to be on the "sure ground" of dependable laws and established facts while high in the clouds. At last it was possible for man to fling himself confidently in the ocean of the air relying upon the lifting-power of arched wings driven at a great speed by a light high-power engine. Thus it is the velocity of the aeroplane that keeps it up. Some one has said that flight in the heavier-than-air machines is like skating rapidly on very thin ice. The air doesn't have time to get away from underneath. "If we go fast enough, the wind does not trouble us," said the French aviator Védrines. "We trouble the wind. We outride the fiercest of storms."

The first Wright machine had five hundred square feet of wings and a speed of forty miles an hour. At the rate of eighty miles an hour only one hundred and twenty-five square feet of sail surface would be needed. But if an aviator should try to drop speed to the point of ten miles an hour he would need eight thousand square feet of wing spread to keep him in the air. This makes it plain why the aeroplane cannot go slowly.

The Wrights were going ahead quietly with experiments in circular flying over a field near Dayton when the world found them out. Now amid the shouts

and plaudits of the crowd, the inventors who had given men wings kept their heads and their mental balance as steadily as they had maintained equilibrium in flight. "When all the world would have made them strut their hour as popular heroes," one writer observed, "the Wrights refused and kept a serene and even course. For instance, all official Washington used to go out to watch Orville Wright's flights at Fort Myer, and the newspaper men became exasperated because he would not take advantage of so favorable an opportunity to do something dramatic."

While in Europe they were everywhere applauded and feted. Kings and popular heroes vied with one another in doing them honor. But everywhere people were amazed that they never yielded to the temptation to do something spectacular,—to cut a dash while the nations stood at attention.

"Will you not try for the prize offered the first aviator to cross the English Channel?" Wilbur Wright was asked.

"No," he replied; "it would be risky to no purpose. It would not prove anything more than a journey overland."

While the Wrights went on making experiments in their aircraft and giving lessons in flight other birdmen rose to fame. In France, particularly, Louis Bleriot and the Séguins led the advance in aeroplane-construction. The French developed the monoplane type of flying-machine and also devised the undercarriage of wheels which made ascent possible from the ground instead of from a specially prepared track.

In the Great War the aeroplanes played a leading part. They were "the eyes of the army," doing scout duty and directing the range of batteries. At sea they did the most effective patrol and convoy work. No ship was ever attacked by U-boats while under the escort of aeroplanes. Special planes were developed with machine-guns capable of firing through the propeller without harming it to bring down enemy air-craft. Many machines were equipped with automatic cameras for map-making and with radio apparatus and special devices for sighting and bomb-dropping. The air service, then, plays a most important part in the defense of our country.

In May, 1918, an air line between Washington and New York was instituted for the carrying of mail, about two hours and a half being allowed for the trip. In crossing mountains and deserts and in maintaining

communication with remote corners of the country as when men are on scout duty over our timber lands to detect and report forest fires, the aeroplane is proving indispensable.

Surely, the greatest and the most dramatic victory for mankind in the early years of the twentieth century was the conquest of the air.

Wireless
Guglielmo Marconi (1874)

Each of us in the world to-day is indeed the heir of all the ages, but few know how to use to advantage the marvelous inheritance from the past. To each the days of opportunity come—

And marching single in an endless file,
Bring diadems and fagots in their hands;
To each they offer gifts after his will,
Bread, kingdoms, stars, and sky that
holds them all.

But like careless children, intent on the toys of the moment, we give small heed to the real gifts of the hours.

This is, however, the story of a boy who was alive to the meaning of his heritage. Guglielmo Marconi was born in 1874 in Villa Griffone near Bologna, Italy. From his Irish mother and Italian father he inherited, it seemed, the strength of two lands and two races. His blue eyes looked out seriously on his world of wealth and the privileges of noble birth. Power meant to him opportunity to do something that would really count in the world.

He went to school a while in Bologna, for another while in that fair city of art and poetry, Florence. But it was not the pictures nor the stories of the past that charmed the fancy of this Italian boy. The wonder-story of the real things everywhere about him—the story without beginning or end—had opened his eyes and set him thinking.

He was such a quiet, shy lad that his people thought a taste of the life of the English schools might call him out of himself. So for a time he went to Bedford and later he had some experience of what it means to be a Rugby boy. But neither cricket nor football could lure him away from the play of wonder in science. His holidays were always spent in trying out, through experiments of his own, the fascinating problems of physics. Electricity had been his particular hobby from the time he was eleven or twelve years old.

It was when he was a student at the University of Bologna that he came face to face with his problem, and knew that he would never give up until he had found a solution. His work under Professor Righi gave him the key to his door of opportunity; for Professor Righi was an enthusiastic disciple of the great German scientists Helmholtz and Hertz and knew all about the

outposts of discovery that their achievements had won.

"It was while Professor Hertz was demonstrating with a Leyden jar and two flat coils of wire at the Technical High School in Carlsruhe, just as I am working before you now," impressively declared Righi, one day, "that he came upon his great idea. He noticed that the discharge of electricity from the jar (a very small one, you will note) through one of the coils would induce a current in the other coil *if there was a gap in the inducing coil.* For the spark caused when the current jumped the gap set up electrical vibrations that gave rise to powerful currents in the neighboring wire. He soon determined that these currents were noticeable, even though the coils were separated by a considerable distance. It was clear to him then that one might send out electrical waves through space without wires."

Young Marconi listened breathlessly. From the time he was sixteen he had been fascinated by the thought that it might be possible to send wireless signals. He had read everything he could find relating to the matter. He knew Morse had proved, in 1842, that the electric current could be sent through water without wires, and that others had proved the possibility of using the earth as a conductor. Joseph

Henry had clearly demonstrated that the electricity sent out from a Leyden jar is wave-like, moving through the earth or water as ripples spread out over a pond following the fall of a pebble. Marconi knew, too, that people working with a telephone receiver near a telegraph wire had distinctly heard music from a neighboring wire that was being used to test Edison's musical telephone. The sounds had leaped in some way across the air gap to the telephone on the other line. And he knew that Edison, in 1885, had made use of these induced currents to signal to a moving train from a wire near the railway.

What, now, was it that Hertz had found? Eagerly Marconi hung on the words of his professor, who seemed to be speaking to him alone.

"So it was," Righi went on, "that Hertz made almost by accident the great discovery that the vibrations or waves of light and of electro-magnetism are alike in that they go with the same speed through the all-pervading ether; their difference lies in the wave-length. These electric waves (now properly called Hertzian waves) are reflected from conducting surfaces as light is from polished surfaces. Pray note," Professor Righi added, "that I say Hertz came to his discovery *almost* by accident; for the chance could only have come to one who had eyes to see and

understanding to grasp the meaning of what he saw. In short, Hertz is the most able experimenter in physics that the world knows. In eighteen-eighty-six he followed his first achievement by one even more remarkable. Across a gap in a coil of wire (having no electric contact with a battery) he made tiny sparks leap out at the moment of the appearance on another coil with a longer gap of the spark made by the electrical discharge from a Leyden jar."

"Now," thought young Marconi, "it must be plain to everybody that a power has been found that will send messages through space with the speed of light. Perhaps one of the great men like Hertz will to-morrow come forward with a way to telegraph without wires, but in the meantime I'll see what I can work out." So he set up poles at different points on his father's estate to hold sending- and receiving-instruments. By means of a Morse telegraph-key in circuit with a spark-gap he flashed dots and dashes (short or long sparks) by varying the length of the strokes. He knew, however, that he had but made a beginning with these short-distance messages. Others had accomplished as much. Would he be able to go beyond scientific experiment and follow up discovery with a practical invention?

When Marconi was twenty-one he had succeeded in sending signals over a distance of a mile. Noticing one day that an instrument on the opposite side of a hill was affected, he knew that the waves had penetrated the solid rock. "Surely, then," he said to himself, "there is no limit to the distance over which wireless messages may be sent. But in order to make the waves work over greater distances I must have a more sensitive receiver." Many painstaking experiments followed to produce the best *coherer* or instrument for detecting the faintest electrical currents. Then at last a satisfactory receiver was made with a sensitive *coherer* to catch the electric waves, and a *decoherer* to produce the sounds corresponding to dots and dashes with the making and breaking of the current. The receiver had, moreover, to be so tuned or harmonized with the sending-instrument as to register the electric waves from that particular transmitter.

In 1896 Marconi decided that the time had come to make his invention known to the world. He applied for a patent in England, at the same time submitting his plans to the postal-telegraph authorities. From the London post-office he signaled to a station on the roof a hundred yards away. The next year he set up a mast a hundred and twenty feet high on the Isle of Wight

from which he sent experimental signals to a steamer with a sixty-foot mast for the receiving-instrument. He had discovered that the height of stations increased their range. It occurred to him that greater height might be secured through the use of kites or balloons, but he soon decided that these would not prove practicable under all conditions and in all weathers.

"As the length of a receiving-pole is limited," he then said, "I must increase the range by increasing the electrical power at the sending-station."

Now we hear at long-distance stations a crack as of thunder when the electric current bridges the spark-gap of the transmitter and the flame that accompanies the crack is as large as a man's wrist.

On November 25, 1901, Marconi left England for Newfoundland. To the questions of reporters who clamored for a marvel that would be good for a column at least, he said he hoped to show that the time had come when one might send signals to boats three hundred miles away. He felt sure, however, that he had everything in readiness for sending the wonder-waves across the ocean from England to America. But he was determined to wait for the

accomplished fact to announce itself without heralding.

At Poldhu, on the coast of Cornwall, England, a station was established with a group of twenty tall poles strung with wires from pole to pole. Huge power-driven dynamos furnished the electric current and converters replaced the induction-coils of the early experiments. At Cape Cod, Massachusetts, another station with powerful machinery for generating electricity had also been built. Storms had done great damage to the masts at both points; but Marconi, unwilling to wait for them to be fully restored, determined on a trial from Signal Hill near St. Johns, Newfoundland, which was some six hundred miles nearer Poldhu than the Cape Cod station.

Thursday, December 12, 1901, was the great day when the first wireless message crossed the ocean. "At three o'clock in the afternoon, on December ninth, begin sending me a simple signal. Let it be the three dots of the S. Keep sending it at intervals until six o'clock," had been the directions given to the home station.

Between those hours (11:30 a.m. to 2:30 p.m. by Newfoundland time) Marconi was at his post on

Signal Hill, waiting. The wire, carried aloft by a great kite (for the building of a special aerial for the test was of course too costly) passed through the window of one of the government buildings, to where Marconi sat with a telephone receiver held to his ear. At last (it was a half-hour after noon on December 12th, that being four o'clock in England) he heard very faintly three short ticks. Listening breathlessly until there came again the three magic strokes, he called to his assistant to learn if his ears, too, could catch the sound brought by the ether waves, two thousand miles across the Atlantic. Again and again now came the three clicks—faint still, but fraught with wonderful promise. Man had learned to use the wings of light and lightning, spanning time and space with his thought.

Of course there was no powerful sending-apparatus in Newfoundland to flash back to Cornwall the news of the great victory. That had to be sent by cable.

Each conquest of invention is a triumphal arch through which man looks to an untraveled world of new achievement. So when Marconi saw his signaling without wires filling a great need in the sending of messages from ship to ship or ship to shore, across oceans and through the uncharted sea of the sky, he

turned his thought to the problem of the wireless telephone. But here America took up the work, and while Marconi and other great scientists were struggling with the tremendous difficulties of the task, the group of telephone scientists known as the Bell Engineers, under the leadership of John J. Carty, working with all the advantages of perfect team-work of trained hands and brains, reinforced by ideal equipment, together won the goal. On September 29, 1915, the voice of a man speaking into his desk telephone in New York was taken up by the sending apparatus of the navy wireless station at Arlington, Virginia, and flashed on the wings of the ether waves through space. Some of these waves were caught at the station of Mare Island, California, and by means of the *amplifier* which is to the wireless telephone what the coherer is to Marconi's apparatus, the words were made distinctly audible to Mr. Carty, who sat with the telephone receiver at his ear, listening to his friend in New York.

"It is not, however," explained Mr. Carty, in an address before the Franklin Institute of Philadelphia, in May, 1916, "the function of the wireless telephone to do away with the use of wires, but rather to be employed in situations where wires are not available, as between ship and ship and across large bodies of

water. The ether is a universal conductor for wireless telephone and telegraph impulses and must be used in common by all who wish to employ those agencies of communication. In the case of the wireless telegraph the number of messages which may be sent simultaneously is much restricted. In the case of the wireless telephone, owing to the thousands of separate wave-lengths required for the transmission of speech, the number of telephone conversations which may be carried on at the same time is still further restricted, and is so small that all who can employ wires will find it necessary to do so, leaving the ether available for those who have no other means of communication. This quality of the ether which thus restricts its use is really a characteristic of the greatest value to mankind, for it forms a universal party line, so to speak, connecting together all creation, so that anybody, anywhere, who connects with it in the proper manner, may be heard by every one else so connected. Thus, a sinking ship or a human being anywhere can send forth a cry for help which may be heard and answered."