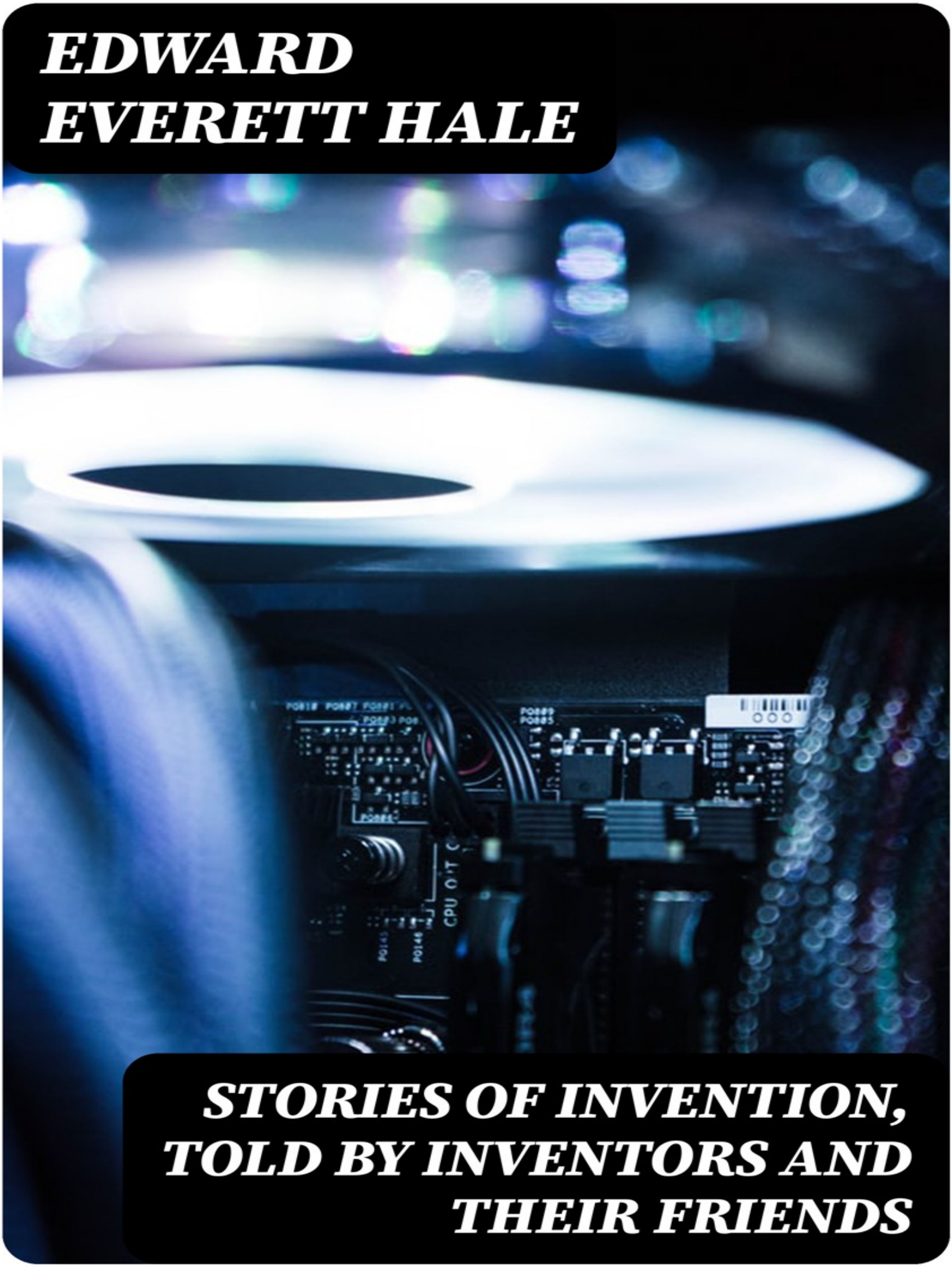
EDWARD EVERETT HALE



STORIES OF INVENTION, TOLD BY INVENTORS AND THEIR FRIENDS

Edward Everett Hale

Stories of Invention, Told by Inventors and their Friends

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PREFACE.

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This little book closes a series of five volumes which I undertook some years since, in the wish to teach boys and girls how to use for themselves the treasures which they have close at hand in the Public Libraries now so generally opened in the Northern States of America. The librarians of these institutions are, without an exception, so far as I know, eager to introduce to the young the books at their

command. From these gentlemen and ladies I have received many suggestions as the series went forward, and I could name many of them who could have edited or prepared such a series far more completely than I have done. But it is not fair to expect them, in the rush of daily duty, to stop and tell boys or girls what will be "nice books" for them to read. If they issue frequent bulletins of information in this direction, as is done so admirably by the librarians at Providence and at Hartford, they do more than any one has a right to ask them for. Such bulletins must be confined principally to helping young people read about the current events of the day. In that case it will only be indirectly that they send the young readers back into older literature, and make them acquainted with the best work of earlier times.

I remember well a legend of the old Public Library at Dorchester, which describes the messages sent to the hard-pressed librarian from the outlying parts of the town on the afternoon of Saturday, which was the only time when the Library was open.

"Mother wants a sermon book and another book." This was the call almost regularly made by the messengers.

I think that many of the most accomplished librarians of to-day have demands not very dissimilar, and that they will be glad of any assistance that will give to either mother or messenger any hint as to what this "other book" shall be.

It is indeed, of course, almost the first thing to be asked that boys and girls shall learn to find out for themselves what they want, and to rummage in catalogues, indexes, and encyclopædias for the books which will best answer their necessities. Mr. Emerson's rule is, "Read in the line of

your genius." And the young man or maiden who can find out, in early life, what the line of his or her genius is, has every reason to be grateful to the teacher, or the event, or the book that has discovered it. I have certainly hoped, in reading and writing for this series, that there might be others of my young friends as sensible and as bright as Fergus and Fanchon, who will be found to work out their own salvation in these matters, and order their own books without troubling too much that nice Miss Panizzi or that omniscient Mrs. Bodley who manages the Library so well, and knows so well what every one in the town has read, and what he has not read.

I had at first proposed to publish with each book a little bibliography on the subjects referred to, telling particularly where were the available editions and the prices at which they could be bought by young collectors. But a little experiment showed that no such supplement could be made, which should be of real use for most readers for whom these books are made. The same list might be too full for those who have only small libraries at command, and too brief for those who are fortunate enough to use large ones. Indeed, I should like to say to such young readers of mine as have the pluck and the sense to read a preface, that the sooner they find out how to use the received guides in such matters,—the very indexes and bibliographies which I should use in making such a list for them,—why, the better will it be for them.

Such books as Poole's Index, Watt's and Brunet's Bibliographies, and the New American Indexes, prepared with such care by the Librarians' Association, are at hand in

almost all the Public Libraries; and the librarians will always be glad to encourage intelligent readers in the use of them.

I should be sorry, in closing the series, not to bear my testimony to the value of the Public Library system, still so new to us, in raising the standard of thought and education. For thirty years I have had more or less to do with classes of intelligent young people who have met for study. I can say, therefore, that the habit of thought and the habit of work of such young people now is different from what it was thirty years ago. Of course it ought to be. You can say to a young learner now, "This book says thus and so, but you must learn for yourself whether this author is prejudiced or ill-informed, or not."

You can send him to the proper authorities. On almost any detail in general history, if he live near one of the metropolitan libraries, you can say to him, "If you choose to study a fortnight on this thing, you will very likely know more about it than does any person in the world." It is encouraging to young people to know that they can thus take literature and history at first hand. It pleases them to know that "the book" is not absolute. With such resources that has resulted which such far-seeing men as Edward Everett and George Ticknor and Charles Coffin Jewett hoped for,—the growth, namely, of a race of students who do not take anything on trust. As Professor Agassiz was forever driving up his pupils to habits of original observation in natural history, the Public Library provokes and allures young students to like courage in original research in matters of history and literature.

EDWARD E. HALE.

ROXBURY, April 1, 1885.

STORIES OF INVENTION

TOLD BY INVENTORS.

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I.

INTRODUCTION.

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There is, or is supposed to be, somewhere in Norfolk County in Massachusetts, in the neighborhood of the city of Boston, a rambling old house which in its day belonged to the Oliver family. I am afraid they were most of them sad Tories in their time; and I am not sure but these very windows could tell the story of one or another brick-bat thrown through them, as one or another committee of the people requested one or another Oliver, of the old times, to resign one or another royal commission. But a very peaceful Rowland has taken the place of those rebellious old Olivers.

This comfortable old house is now known to many young people as the home of a somewhat garrulous old gentleman whom they call Uncle Fritz. His real name is Frederick Ingham. He has had a checkered life, but it has evidently been a happy one. Once he was in the regular United States Navy. For a long time he was a preacher in the Sandemanian

connection, where they have no ordained ministers. In Garibaldi's time he was a colonel in the patriot service in Italy. In our civil war he held a command in the national volunteer navy; and his scientific skill and passion for adventure called him at one time across "the Great American Desert," and at another time across Siberia, in the business of constructing telegraphs. In point of fact, he is not the relation of any one of the five-and-twenty young people who call him Uncle Fritz. But he pets them, and they pet him. They like to make him a regular visit once a week, as the winter goes by. And the habit has grown up, of their reading with him, quite regularly, on some subject selected at their first meeting after they return from the country. Either at Lady Oliver's house, as his winter home is called, or at Little Crastis, where he spends his summers, those selections for reading have been made, which have been published in a form similar to that of the book which the reader holds in his hand.

The reader may or may not have seen these books,—so much the worse for him if he have not,—but that omission of his may be easily repaired. There are four of them: Stories of War told by Soldiers; Stories of the Sea told by Sailors; Stories of Adventure told by Adventurers; Stories of Discovery told by Discoverers.

Since the regular meetings began, of which these books are the history, the circle of visitors has changed more or less, as most circles will, in five years. Some of those who met are now in another world. Some of the boys have grown to be so much like men, that they are "subduing the world," as Uncle Fritz would say, in their several places, and that

they write home, from other latitudes and longitudes, of the Discoveries and Adventures in which they have themselves been leaders. But younger sisters and brothers take the places of older brothers and sisters. The club—for it really is one—is popular, Lady Oliver's house is large, and Uncle Fritz is hospitable. He says himself that there is always room for more; and Ellen Flaherty, or whoever else is the reigning queen in the kitchen, never complains that the demand is too great for her "waffles."

Last fall, when the young people made their first appearance, the week before Thanksgiving day, after the new-comers had been presented to Uncle Fritz, and a chair or two had been brought in from the dining-room to make provision for the extra number of guests, it proved that, on the way out, John Coram, who is Tom Coram's nephew, had been talking with Helen, who is one of the old Boston Champernoons, about the change of Boston since his uncle's early days.

"I told her," said he to Uncle Fritz, "that Mr. Allerton was called 'the last of the merchants,' and he is dead now."

"That was a pet phrase of his," said Uncle Fritz. "He meant that his house, with its immense resources, simply bought and sold. He was away for many years once. When he returned, he found that the chief of his affairs had made an investment, from motives of public spirit, in a Western railroad. 'I thought we were merchants,' said the fine old man, disapproving. As he turned over page after page of the account, he found at last that the whole investment had been lost. 'I am glad of that,' said he; 'you will remember now that we are merchants.'"

"But surely my father is a merchant," said Julius. "He calls himself a merchant, he is put down as a merchant in the Directory, and he buys and sells, if that makes a man a merchant."

"All that is true," said Uncle Fritz. "But your father also invests money in railroads; so far he is engaged in transportation. He is a stockholder and a director in the Hecla Woollen Mills at Bromwich; so far he is a manufacturer. He told me, the other day, that he had been encouraging my little friend Griffiths, who is experimenting in the conservation of electric power; so far he is an inventor, or a patron of inventions.

"In substance, what Mr. Allerton meant when he said 'I thought we were merchants,' was this: he meant that that firm simply bought from people who wished to sell, and sold to people who wished to buy.

"The fact, that almost every man of enterprise in Massachusetts is now to a certain extent a manufacturer, shows that a great change has come over people here since the beginning of this century."

"Those were the days of Mr. Cleveland's adventures, and Mr. Forbes's," said Hugh.

He alluded to the trade in the Pacific, in which these gentlemen shared, as may be read in Stories of Adventure.

Uncle Fritz said, "Yes." He said that the patient love of Great Britain for her colonies forbade us here from making so much as a hat or a hob-nail while we were colonies, as it would gladly do again now. He said that the New Englanders had a great deal of adventurous old Norse blood in their veins, that they had plenty of ship-timber and tar. If they

could not make hob-nails they could make ships; and they made very good ships before they had been in New England ten years.

Luckily for us, soon after the country became a country, near a hundred years ago, the quarrels of Europe were such, that if an English ship carried produce of the West Indies or China to Europe, France seized, if she could, ship and cargo; if a French ship carried them, English cruisers seized ship and cargo, if they could. So it happened that the American ships and the American sailors, who were not at war with England and were not at war with France, were able to carry the stores which were wanted by all the world. The wars of Napoleon were thus a steady bounty for the benefit of the commerce of America. When they were well over, we had become so well trained to commerce here, that we could build the best ships in the world; and we thought we had the best seamen in the world,—certainly there were no better. Under such a stimulus, and what followed it, our commerce, as measured by the tonnage of our ships, was as large as that of any nation, and, if measured by the miles sailed, was probably larger.

All this prosperity to merchants was broken up by the War of 1812, between the United States and Great Britain. For two years and a half, then, our intercourse with Europe was almost cut off; for the English cruisers now captured our vessels whenever they could find them. At last we had to make our own hob-nails, our guns, our cannon, our cotton cloth, and our woollen cloth, if we meant to have any at all. The farmers' wives and daughters had always had the traditions of spinning and weaving.

When Colonel Ingham said this, Blanche nodded to Mary and Mary to Blanche.

"That means," said the Colonel, "that you have brought dear old mother Tucker's spinning-wheel downstairs, and have it in the corner behind your piano, does it not?"

Blanche laughed, and said that was just what she meant.

"It does very well in 'Martha,'" said the Colonel. "And can you spin, Blanche?"

Blanche rather surprised him by saying that she could, and the Colonel went on with his lecture. Fergus, who is very proud of Blanche, slipped out of the room, but was back after a minute, and no one missed him.

Here in Massachusetts some of the most skilful merchants—Appletons, Perkinses, and Lawrences—joined hand with brave inventors like Slater and Treadwell, and sent out to England for skilful manufacturers like Crompton and Boott; thus there sprung up the gigantic system of manufacture, which seems to you children a thing of course. Oddly enough, the Southern States, which had always hated New England and New England commerce, and had done their best to destroy it when they had a chance, were very eager to secure a home-market for Southern cotton; and thus, for many years after the war, they kept up such high protective duties that foreign goods were very dear in America, and the New England manufacturers had all the better prices.

While Uncle Fritz was saying this in substance, Ransom, the old servant, appeared with a spinning-wheel from Colonel Ingham's music-room. The children had had it for some charades. Kate Fogarty, the seamstress of the

Colonel's household, followed, laughing, with a great hank of flax; and when the Colonel stopped at the interruption, Fergus said,—

"I thought, Uncle Fritz, they would all like to see how well Blanche spins; so I asked Ransom to bring in the wheel."

And Blanche sat down without any coaxing, and made her wheel fly very prettily, and spun her linen thread as well as her great-grandmamma would have done. Colonel Ingham was delighted; and so were all the children, half of whom had never seen any hand-spinning before. All of them had seen cotton and wool spun in factories; in fact, half of them had eaten their daily bread that day, from the profit of the factories that for ten hours of every day do such spinning.

"Now, you see," said the well-pleased Colonel, "Blanche spins that flax exactly as her grandmother nine generations back spun it. She spins it exactly as Mrs. Dudley spun it in the old house where Dr. Paterson's church stands. It is strange enough, but for one hundred and fifty years there seems to have been no passion for invention among the New Englanders. Now they are called a most *inventive* people, and that bad word has been coined for them and such as they.

"But all this is of the last century. It was as soon as they were thrown on their own resources that they began to invent. Eli Whitney, a Worcester County boy, graduated at Yale College in 1791. He went to Georgia at once, to be a tutor in a planter's family; but before he arrived, the planter had another tutor. This was a fortunate chance for the world; for poor Whitney, disappointed, went to spend the

winter at the house of Mrs. General Greene. One day, at dinner, some guests of hers said that cotton could never be exported with profit unless a machine could be made to separate the seeds from the 'wool.' 'If you want anything invented,' said Mrs. Greene, 'ask my young friend Mr. Whitney; he will invent anything for you.' Whitney had then never seen cotton unmanufactured. But he went to work; and before he was one year out of college, he had invented the cotton-gin, which created an enormous product of cotton, and, in fact, changed the direction of the commerce of the world.

"Well, you know about other inventions. Robert Fulton, who built the first effective steamboat, was born in Pennsylvania the same year Whitney was born in Massachusetts.

"Hector, you are fond of imaginary conversations: write one in which Whitney and Fulton meet, when each is twenty-one; let Daniel Boone look in on them, and prophesy to them the future of the country, and how much it is to owe to them and to theirs."

"I think Blanche had better write it—in a ballad," said Hector, laughing. "It shall be an old crone spinning; and as she turns her wheel she shall describe the Ætna Factory at Watertown."

"There shall be a *refrain*," said Wallace,—

"'Turn my wheel gayly;
Spin, flax, spin.'"

"No," said Hatty; "the refrain shall be

'Four per cent in six months,
Eight per cent in twelve.'

We are to go to Europe if the Vesuvius Mills pay a dividend. But if they *pass*, I believe I am to scrub floors in my vacation."

"Very well," said Uncle Fritz, recalling them to the subject they had started on. "All this is enough to show you how it is that you, who are all New Englanders, are no longer seafaring boys or girls, exclusively or even principally. Your great-grandmother, Alice, saved the lives of all the crew of a Bristol trader, by going out in her father's boat and taking her through the crooked passage between the Brewsters. You would be glad to do it, but I am afraid you cannot."

"I should rather encourage those who go to do it," said Alice, demurely, repeating one of their familiar jokes.

"And your great-grandfather, Seth, is the Hunt who discovered Hunt's Reef in the Philippines. I am afraid you cannot place it on the map."

"I know I cannot," said Seth, bravely.

"No," said the old gentleman. "But all the same the reef is there. I came to an anchor in the 'Calypso,' waiting for a southwest wind, in sight of the breakers over it. And I wish we had the pineapples the black people sold us there.

"All the same the New Englanders are good for something. Ten years hence, you boys will be doing what your fathers are doing,—subduing the world, and making it to be more what God wants it to be. And you will not work at arms' length, as they did, nor with your own muscles."

"We have Aladdin's lamp," said Mary, laughing.

"And his ring," said Susie. "I always liked the ring one better than the lamp one, though he was not so strong."

"He is prettier in the pictures," said George.

"Yes," said the Colonel; "we have stronger Genii than Aladdin had, and better machinery than Prince Camaralzaman."

"I heard some one say that Mr. Corliss had added twenty-seven per cent to the working power of the world by his *cut-off*," said Fergus.

The Colonel said he believed that was true. And this was a good illustration of what one persevering and intelligent man can do in bringing in the larger life and nobler purpose of the Kingdom of Heaven. Such a man makes men cease from *labor*, which is always irksome, and *work* with God. This is always ennobling.

"I am ashamed to say that I do not know what a *cut-off* is," said Alice, who, like Seth, had been trained to "confess ignorance."

"I was going to say so," said John Rodman.

"And I,—and I,—and I," said quite a little chorus.

"We must make up a party, the first pleasant day, and go and see the stationary engine which pumps this water for us." So the Colonel met their confessions.

"But does not all this indicate that we might spend a few days in looking up inventions?"

"I think we ought to," said Hatty. "Certainly we ought, if the Vesuvius pays. Imagine me at Manchester. Imagine John Bright taking me through his own mill, and saying to me, 'This is the rover we like best, on the whole. Do you use this in America?' Imagine me forced to reply that I do not know a

rover when I see one, and could not tell a 'slubber' from a 'picker.'"

The others laughed, and confessed equal ignorance. "Only, John Bright has no mills in Manchester, Hatty."

"Well, they are somewhere; and I must not eat the bread of the Vesuvius slubbers, and not know something of the way in which slubbers came to be."

"Very well," said Uncle Fritz, as usual recalling the conversation to sanity. "Whom shall we read about first?"

"Tubal Cain first," said Fergus. "He seems to have been the first of the crew."

"It was not he who found out witty inventions," said Fanchon, in a mock *aside*.

"I should begin with Archimedes," said Uncle Fritz.

"Excellent!" said Fergus; "and then may we not burn up old Fogarty's barn with burning-glasses?"

The children dislike Fogarty, and his barn is an eyesore to them. It stands just beyond the hedge of the Lady Oliver garden.

"I thank Archimedes every time I take a warm bath. Did he not invent hot baths?"

"What nonsense! He was killed by Caligula in one."

"You shall not talk such stuff.—Uncle Fritz, what books shall I bring you?"

It would seem as if, perhaps, Uncle Fritz had led the conversation in the direction it had taken. At least it proved that, all together on the rolling book-rack which Mr. Perkins gave him, were the account of Archimedes in the Cyclopædia Britannica, the account in the French Universal Biography, the life in La Rousse's Cyclopædia, Plutarch's

Lives, and a volume of Livy in the Latin. From these together, Uncle Fritz, and the boys and girls whom he selected, made out this little history of Archimedes.

II.

ARCHIMEDES.

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Archimedes was born in Syracuse in the year 287 B. C., and was killed there in the year 212 B. C. He is said to have been a relation of Hiero, King of Syracuse; but he seems to have held no formal office known to the politicians. Like many other such men, however, from his time down to Ericsson, he came to the front when he was needed, and served Syracuse better than her speech-makers. While he was yet a young man, he went to Alexandria to study; and he was there the pupil of Euclid, the same Euclid whose Geometry is the basis of all the geometry of to-day.

While Archimedes is distinctly called, on very high authority, "the first mathematician of antiquity," and while we have nine books which are attributed to him, we do not have—and this is a great misfortune—any ancient biography of him. He lived seventy-five years, for most of that time probably in Syracuse itself; and it would be hard to say how much Syracuse owed to his science. At the end of his life he saved Syracuse from the Romans for three years, during a siege in which, by his ingenuity, he kept back Marcellus and his army. At the end of this siege he was killed by a Roman soldier when the Romans entered the city.

The books of his which we have are on the "Sphere and Cylinder," "The Measure of the Circle," "Conoids and Spheroids," "On Spirals," "Equiponderants and Centres of Gravity," "The Quadrature of the Parabola," "On Bodies floating in Liquids," "The Psammites," and "A Collection of Lemmas." The books which are lost are "On the Crown of Hiero;" "Cochleon, or Water-Screw;" "Helicon, or Endless Screw;" "Trispaston, or Combination of Wheels and Axles;" "Machines employed at the Siege of Syracuse;" "Burning Mirror;" "Machines moved by Air and Water;" and "Material Sphere."

As to the story of the bath-tub, Uncle Fritz gave to Hector to read the account as abridged in the "Cyclopædia Britannica."

"Hiero had set him to discover whether or not the gold which he had given to an artist to work into a crown for him had been mixed with a baser metal. Archimedes was puzzled by the problem, till one day, as he was stepping into a bath, and observed the water running over, it occurred to him that the excess of bulk occasioned by the introduction of alloy could be measured by putting the crown and an equal weight of gold separately into a vessel filled with water, and observing the difference of overflow. He was so overjoyed when this happy thought struck him that he ran home without his clothes, shouting, 'I have found it, I have found it,'—Εὕρηκα, Εὕρηκα.

"This word has been chosen by the State of California for its motto."

To make the story out, it must be supposed that the crown was irregular in shape, and that the precise object

was to find how much metal, in measurement, was used in its manufacture. Suppose three cubic inches of gold were used, Archimedes knew how much this would cost. But if three cubic inches of alloy were used, the king had been cheated. What the overflow of the water taught was the precise cubic size of the various ornaments of the crown. A silver crown or a lead crown would displace as much water as a gold crown of the same shape and ornament. But neither silver nor lead would weigh so much as if pure gold were used, and at that time pure gold was by far the heaviest metal known.

Fergus, who is perhaps our best mathematician, pricked up his ears when he heard there was a treatise on the relation of the Circle to the Square. Like most of the intelligent boys who will read this book, Fergus had tried his hand on the fascinating problem which deals with that proportion. Younger readers will remember that it is treated in "Swiss Family." Jack—or is it perhaps Ernest?—remembers there, that for the ribbon which was to go round a hat the hat-maker allowed three times the diameter of the hat, and a little more. This "little more" is the delicate fraction over which Archimedes studied; and Fergus, after him. Fergus knew the proportion as far as thirty-three figures in decimals. These are 3.141,592,653,589,793,238,462,643,383,279,502. When Uncle Fritz asked Fergus to repeat these, the boy did it promptly, somewhat to the astonishment of the others. He had committed it to memory by one of Mr. Gouraud's "analogies," which are always convenient for persons who have mathematical formulas to remember.

When those of the young people who were interested in mathematics looked at Archimedes's solution of the problem, they found it was the same as that they had themselves tried at school. But he carried it so far as to inscribe a circle between two polygons, each of ninety-six sides; and his calculation is based on the relation between the two.

Taking the "Swiss Family Robinson" statement again, Archimedes shows that the circumference of a circle exceeds three times its diameter by a small fraction, which is less than 10/70 and greater than 10/71 and that a circle is to its circumscribing square nearly as 11 to 14. Those who wish to carry his calculations farther may be pleased to know that he found the figures 7 to 22 expressed the relation more correctly than 1 to 3 does. Metius, another ancient mathematician, used the proportion 113 to 355. If you reduce that to decimals, you will find it correct to the sixth decimal. Remember that Archimedes and Metius had not the convenience of the Arabic or decimal notation. Imagine yourselves doing Metius's sum in division when you have to divide CCCLV by CXIII. Archimedes, in fact, used the Greek notation,—which was a little better than the Roman, but had none of the facility of ours. For every *ten*, from 20 to 90, they had a separate character, and for every *hundred*, and for every *thousand*. The *thousands* were the units with a mark underneath. Thus α meant 1, and α̱ meant 1,000. To express 113, Archimedes would have written ριγ. To express 355, he would have written τνε; and the place which these signs had in the order would not have affected their value, as they do with us.

We cannot tell how the greater part of Archimedes's life was spent. But whether he were nominally in public office or not, it is clear enough that he must have given great help to Syracuse and her rulers, as an engineer, long before the war in which the Romans captured that great city. At that time Syracuse was, according to Cicero, "the largest and noblest of the Greek cities." It was in Sicily; but, having been built by colonists from Greece, who still spoke the Greek language, Cicero speaks of it among Greek cities, as he would have spoken of Thurii, or Sybaris, or the cities of "Magna Græcia,"—"great Greece," as they called the Greek settlements in southern Italy. In the Second Punic War Syracuse took sides against Rome with the Carthaginians, though her old king, Hiero, had been a firm ally of the Romans. The most interesting accounts that we have of Archimedes are in Livy's account of this war, and in Plutarch's Life of Marcellus, who carried it on on the Roman side. Livy says of Archimedes that he was—

"A man of unrivalled skill in observing the heavens and the stars, but more deserving of admiration as the inventor and constructor of warlike engines and works, by means of which, with a very slight effort, he turned to ridicule what the enemy effected with great difficulty.

"The wall, which ran along unequal eminences, most of which were high and difficult of access, some low and open to approach along level vales, was furnished by him with every kind of warlike engine, as seemed suitable to each particular place. Marcellus attacked from the quinqueremes [his large ships] the wall of the Achradina, which was washed by the sea. From the other ships the archers and

slingers and light infantry, whose weapon is difficult to be thrown back by the unskilful, allowed scarce any person to remain upon the wall unwounded. These soldiers, as they required some range in aiming their missiles upward, kept their ships at a distance from the wall. Eight more quinqueremes joined together in pairs, the oars on their inner sides being removed, so that side might be placed to side, and which thus formed ships [of double width], and were worked by the outer oars, carried turrets built up in stories, and other battering-engines.

"Against this naval armament Archimedes placed, on different parts of the walls, engines of various dimensions. Against the ships which were at a distance he discharged stones of immense weight; those which were nearer he assailed with lighter and more numerous missiles. Lastly, in order that his own men might heap their weapons upon the enemy without receiving any wounds themselves, he perforated the wall from the top to the bottom with a great number of loop-holes, about a cubit in diameter, through which some with arrows, others with scorpions of moderate size, assailed the enemies without being seen. He threw upon their sterns some of the ships which came nearer to the walls, in order to get inside the range of the engines, raising up their prows by means of an iron grapple attached to a strong chain, by means of a *tolleno* [or derrick], which projected from the wall and overhung them, having a heavy counterpoise of lead which forced the line to the ground. Then, the grapple being suddenly disengaged, the ship, falling from the wall, was by these means, to the utter consternation of the seamen, so dashed against the water

that even if it came back to its true position it took in a great quantity of water."

"Fancy," cried Bedford, "one of their double quinqueremes, when she had run bravely in under the shelter of the wall. Just as the men think they can begin to work, up goes the prow, and they all are tumbled down into the steerage. Up she goes, and fifty rowers are on each other in a pile; when the old pile-driver claw lets go again, and down she comes, splash into the sea. And then Archimedes pokes his head out through one of the holes, and says in Greek, 'How do you like that, my friends?' I do not wonder they were discouraged."

The bold cliff of the water front of Syracuse gave Archimedes a particular advantage for defensive operations of this sort. They are described in more detail in Plutarch's Life of Marcellus, who was the Roman general employed against Syracuse, and who was held at bay by Archimedes for three years.

Here is Plutarch's account:—

Marcellus, with sixty galleys, each with five rows of oars, furnished with all sorts of arms and missiles, and a huge bridge of planks laid upon eight ships chained together,[1] upon which was carried the engine to cast stones and darts, assaulted the walls. He relied on the abundance and magnificence of his preparations, and on his own previous glory; all which, however, were, it would seem, but trifles for Archimedes and his machines.

These machines he had designed and contrived, not as matters of any importance, but as mere amusements in geometry,—in compliance with King Hiero's desire and

request, some little time before, that he should reduce to practice some part of his admirable speculations in science, and by accommodating the theoretic truth to sensation and ordinary use, bring it more within the appreciation of people in general. Eudoxus and Archytas had been the first originators of this far-famed and highly prized art of mechanics, which they employed as an elegant illustration of geometrical truths, and as a means of sustaining experimentally, to the satisfaction of the senses, conclusions too intricate for proof by words and diagrams. As, for example, to solve the problem so often required in constructing geometrical figures, "Given the two extremes to find the two mean lines of a proportion," both these mathematicians had recourse to the aid of instruments, adapting to their purpose certain curves and sections of lines. But what with Plato's indignation at it, and his invectives against it as the mere corruption and annihilation of the one good of geometry, which was thus shamefully turning its back upon the unembodied objects of pure intelligence, to recur to sensation, and to ask help (not to be obtained without base subservience and depravation) from matter; so it was that mechanics came to be separated from geometry, and when repudiated and neglected by philosophers, took its place as a military art.

Archimedes, however, in writing to King Hiero, whose friend and near relative he was, had stated that, given the force, any given weight might be moved; and even boasted, we are told, relying on the strength of demonstration, that if there were another earth, by going into it he could move this.

Hiero being struck with amazement at this, and entreating him to make good this assertion by actual experiment, and show some great weight moved by a small engine, he fixed upon a ship of burden out of the king's arsenal, which could not be drawn out of the dock without great labor by many men. Loading her with many passengers and a full freight, sitting himself the while far off, with no great endeavor, but only holding the head of the pulley in his hand and drawing the cord by degrees, he drew the ship in a straight line, as smoothly and evenly as if she had been in the sea.

The king, astonished at this, and convinced of the power of the art, prevailed upon Archimedes to make him engines accommodated to all the purposes, offensive and defensive, of a siege. These the king himself never made use of, because he spent almost all his life in a profound quiet and the highest affluence. But the apparatus was, in a most opportune time, ready at hand for the Syracusans, and with it also the engineer himself.

When, therefore, the Romans assaulted the walls in two places at once, fear and consternation stupefied the Syracusans, believing that nothing was able to resist that violence and those forces. But when Archimedes began to ply his engines, he at once shot against the land forces all sorts of missile weapons, with immense masses of stone that came down with incredible noise and violence, against which no man could stand; for they knocked down those upon whom they fell in heaps, breaking all their ranks and files. In the mean time huge poles thrust out from the walls over the ships [these were the derricks, or *tollenos*, of Livy]

sunk some by the great weights which they let down from on high upon them; others they lifted up into the air by an iron hand or beak like a crane's beak, and when they had drawn them up by the prow, and set them on end upon the poop, they plunged them to the bottom of the sea. Or else the ships, drawn by engines within, and whirled about, were dashed against the steep rocks that stood jutting out under the walls, with great destruction of the soldiers that were aboard them. A ship was frequently lifted up to a great height in the air (a dreadful thing to behold), and was rolled to and fro and kept swinging, until the mariners were all thrown out, when at length it was dashed against the rocks, or let fall.

At the engine that Marcellus brought upon the bridge of ships,—which was called *Sambuca* from some resemblance it had to an instrument of music of that name,—while it was as yet approaching the wall, there was discharged a piece of a rock of ten talents' weight,[2] then a second and a third, which, striking upon it with immense force and with a noise like thunder, broke all its foundation to pieces, shook out all its fastenings, and completely dislodged it from the bridge. So Marcellus, doubtful what counsel to pursue, drew off his ships to a safer distance, and sounded a retreat to his forces on land. They then took a resolution of coming up under the walls, if it were possible, in the night; thinking that as Archimedes used ropes stretched at length in playing his engines, the soldiers would now be under the shot, and the darts would, for want of sufficient distance to throw them, fly over their heads without effect. But he, it appeared, had long before framed for such occasion engines