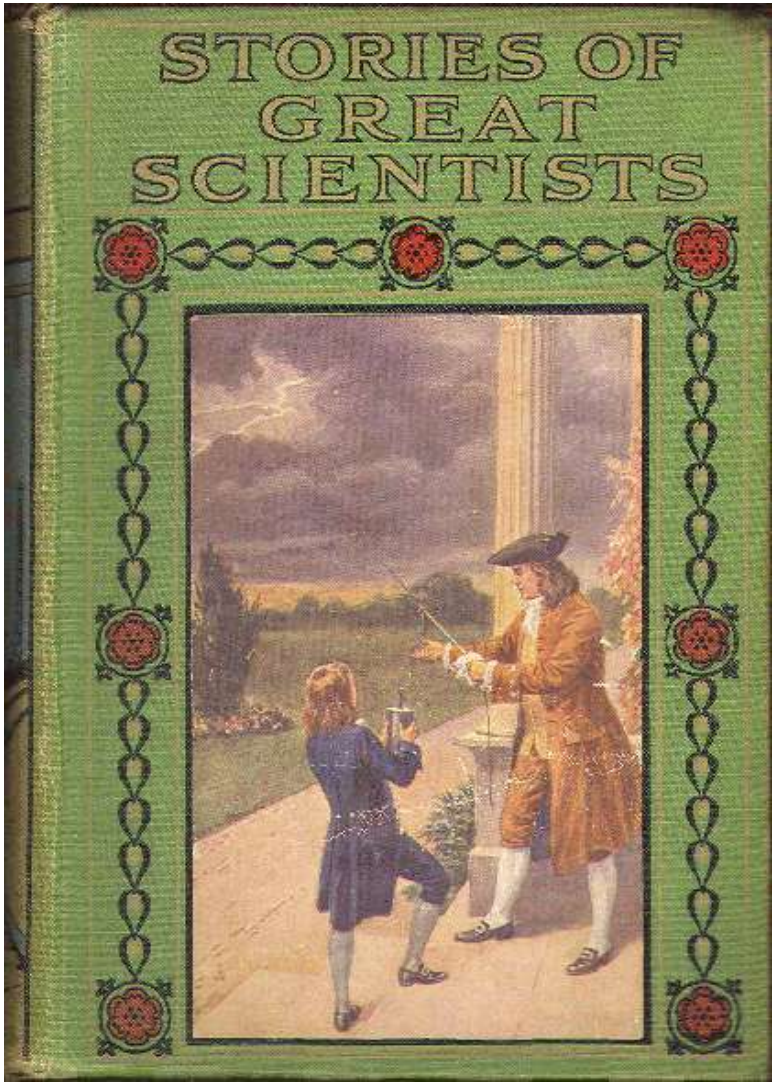

STORIES
OF
GREAT SCIENTISTS

AN INTERESTING ACCOUNT OF THE LIVES,
ENDEAVOURS, FAILURES, AND SUCCESSES
OF THE WORLD'S GREAT SCIENTISTS

BY

CHARLES R. GIBSON, F.R.S.E.

AUTHOR OF "THE ROMANCE OF MODERN ELECTRICITY," "SCIENTIFIC IDEAS OF TO-DAY,"
"WHAT IS ELECTRICITY?" "OUR GOOD SLAVE ELECTRICITY," &c. &c. &c.

WITH MANY ILLUSTRATIONS

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BENJAMIN FRANKLIN AND HIS SON EXPERIMENTING WITH LIGHTNING.

PREFACE

The biographies of great Scientists are of necessity filled with a multitude of detail, much of which is of little or no interest to the general reader; hence the author of the present volume has endeavoured to give a description of the lives of some of the most outstanding men of Science in an easy and readable form. It is not claimed that this is the first work of such a character, but, so far as the author knows, it is the first to deal with the subject in a comprehensive manner, linking the Ancient to the Modern. In order to make the story as readable as possible, it has been deemed better to avoid a constant reference to the dates at which the different events have occurred in the men's lives, and to state rather the ages of the men at such times. The date of birth and death of each Hero is, however, mentioned in the text, and also beneath the respective chapter headings.

The author fully realises the serious disadvantage in acquiring incorrect information, especially in one's youth, so he has taken all possible care to state only facts that are reliable, and, whenever possible, to dispel popular errors that have arisen. It has not been considered sufficient merely to retell a tale in popular language, but it has been a matter of conscience to authenticate all the information so far as that is possible. This necessarily has entailed research work, which might seem to some writers unnecessary labour for a popular volume such as the present one, but in the past the author has felt amply rewarded by his works of a similar nature being recognised as conscientious productions. There have been criticisms such as "It is easy to see that the author has not taken for granted accounts, usually abounding in errors, which less conscientious writers have given." In the present volume there has been no sacrifice of accuracy for the sake of sensation or effect.

The author is once more indebted to his friends Professor James Muir, D.SC., M.A., Royal Technical College, Glasgow, and H. Stanley Allen, M.A., D.SC.,King's College, London, for very kindly reading through the whole of the proof-sheets; also to Professor Sampson, Astronomer Royal for Scotland, for reading the chapters relating to William and Caroline Herschel; and to Emeritus Professor John G. McKendrick for his kindly interest in the proof-sheets.

The author is indebted also to the following friends for assistance with the illustrations: Professor James Muir, Glasgow; the Wolf Safety Lamp Co., Ltd., Leeds; the Electric Co., Ltd., London; the Westinghouse Co., Ltd.; Siemens Bros., Ltd.; the Poulsen Co., Ltd.

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CHAPTER I

WHO ARE THE HEROES OF SCIENCE?

If we agree with the poet Milton that "Peace hath her victories, no less renown'd than War," we shall have no difficulty in appreciating the statement that there are *Heroes of Science*. It goes without saying that the word *Heroes* does not signify *Martyrs;* fortunately, there have been very few martyrs of Science. Men need not sacrifice their lives because of their scientific beliefs. Wherever Men of Science have been imprisoned, and in a few isolated cases put to death, we shall find that it has been owing to their conflict with the religious beliefs of the people.

There have been martyrs of Science in other respects. Within recent years several X-ray operators, intent on healing disease in others, have been attacked by invisible radiations which have brought about a slow and lingering death. Then there have been cases of men willing that some dangerous experiment should be performed upon them, in the hope that others might benefit by the experience thus gained.

However, the *Heroes* whose lives we are about to consider are men who have been in the forefront of the advancement of knowledge. It is true that some of these have had to sacrifice much; to undergo great hardships and yet fight on. Some have had to suffer the ridicule of the wise men of their time, and the hatred of those who should have been their friends. But the word *Heroes* is used here in no such restricted sense, although it is certain that every Hero of Science must have made some sacrifice in his daily life. We may count all who have made a great advance in Science to be true Heroes. Of course, it is impossible to consider the lives of all such men.

Unfortunately, there are many of the Heroes of Antiquity whose biographies are almost entire blanks, while among the more modern Men of Science there are many who have done much useful work, but in whose lives there have been no outstanding features which would interest the general reader. For these reasons the Heroes selected for our present purpose are those in whose lives we find most of general interest; they are all prominent Men of Science.

Many of us, when children, received instruction in Biblical History, being told the story of some incident in the life of Joseph at one time, the story of Jacob at another, and the story of Moses at another time. Each story was of interest to us, but the interest was increased greatly when we found how all these individual stories were linked together. How old Jacob sent his sons to Egypt to buy corn; their meeting with Joseph; his settling his father Jacob, or Israel, in Egypt; the increasing descendants of Israel causing a later Pharaoh to fear for his kingdom; their consequent bondage; and the ultimate release of these children of Israel by Moses. For the same reason I have endeavoured to link up, so far as it is possible, the stories of the different Heroes of Science. I have gone back to the beginning of Science, some two thousand and five hundred years ago, and I have called a halt at the other end, only omitting the Scientists living at the present time.

This arrangement will help to emphasize the very long break in the advance of Science, which lasted throughout the Middle Ages. Indeed, we shall have to jump from the beginning of the Christian era right on to the time of Queen Elizabeth, with only two prominent stepping-stones between.

> "Up rose the hero,—on his piercing eye
> Sat observation; on each glance of thought
> Decision follow'd, as the thunderbolt
> Pursues the flash."
>
> JOHN HOME

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CHAPTER II

BEFORE THE TIME OF CHRIST

The first man to adopt the title of *Philosopher* was an illustrious Greek named Pythagoras, who lived about six hundred years before Christ. The title of Philosopher, which means "Lover of Wisdom," seems more modest than the earlier title of "wise men" which had been adopted by the sages.

We may look upon Pythagoras as the first man to consider things in a really scientific spirit. Of course, there were the "seven wise men" who lived before Pythagoras, but we know very little about them. The one whose name is best known is Thales, but he left no writings. All we know of him is through quotations of his sayings made by later Greek writers; but what concerns us at present is that we know absolutely nothing of his life.

We know many interesting facts about Pythagoras, but as neither he nor his disciples have left any record concerning their own lives, we have to depend upon the writings of others who lived many centuries later. I mention this fact because we know how stories are apt to grow if they are handed on from one to another without being definitely recorded. It may be unconsciously that the imagination adds little details, or that some one makes a suggestion which is later on accepted as an actual fact. Then some of the biographers of Pythagoras have been very careless. I was amused to find one biographer, who wrote in 1707 a most interesting account of the work of Pythagoras, stating that this illustrious philosopher met no less a personage than Moses when in Egypt. The mistake is very apparent, as Moses lived one thousand years before Pythagoras. The contemporaries of Pythagoras would be Daniel and Ezekiel, but there is no record of his having met these prophets.

Although there are very many stories concerning Pythagoras that we are bound to treat as mere fables, the main facts concerning his life are doubtless known. But why should we, in these modern times, be interested in this Greek Philosopher who lived about two thousand five hundred years ago? It is surely of general interest that this far-distant sage declared that this Earth was not the centre of the universe, around which all the other heavenly bodies danced attendance, but that our world is travelling round and round the Sun.

Even now it is difficult to realise that we are on the surface of a great planet flying through space with a speed a thousand times greater than that of an express train. It is not quite so difficult to realise the daily turning round of the Earth, although when we watch the Sun rise in the East, mount the sky, and set in the West, we feel that we cannot blame the Ancients for believing that the Sun was travelling around the Earth.

Of the men who set the Earth in motion, there is no doubt that the name of Galileo stands out most prominently. We shall see in a later chapter the very important part which he played, but here we have a man living two thousand years before Galileo, and teaching the same great truth, There seems little doubt that this theory of Pythagoras was accepted not only by his immediate disciples, but by the great line of astronomers who followed in several succeeding centuries.

One of the pupils of Pythagoras taught that the Earth was spinning round upon her own axis, making one revolution each day. It does seem strange that for century after century men should abandon these ideas, and that the revival of these old theories a few centuries ago should have caused such an uproar as we shall see later. But our present interest lies in the life of this early Greek Philosopher.

Pythagoras was a native of the little island of Samos in the Aegean Sea (now the Archipelago). This island was a place of considerable importance in the time of Pythagoras. When a youth of about eighteen years of age, Pythagoras left his island

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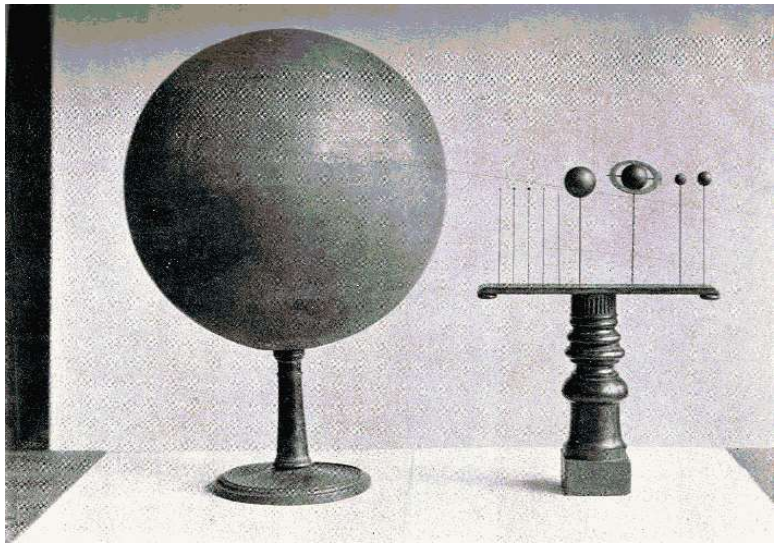
home to go in search of further knowledge. His travels took him to Egypt, where he settled for many years. There seems to be little doubt that Pythagoras remained there about twenty-five years, and during that time he acquired a great deal of knowledge.



MODELS OF THE SUN AND PLANETS
THESE MODELS SHOW THE COMPARATIVE SIZES OF THE SUN AND PLANETS. READING FROM LEFT TO RIGHT WE SEE THE SUN, MERCURY, VENUS, MARS, THE EARTH, THE ASTEROIDS, (MINOR PLANETS), JUPITER, SATURN, URANUS AND NEPTUNE.

Some historians tell us that Pythagoras believed in the transmigration of souls; that he believed he himself had distinct recollections of having existed previously in other forms. There is a story told of how on one occasion when he saw a dog beaten, and hearing him howl, he bade the striker desist, saying, "It is the soul of a friend of mine, whom I recognise by his voice."

Racier, writing more than two hundred years ago, refers to a number of passages in the works of Pythagoras which seem to discredit his supposed belief in the transmigration of souls, and Dacier suggests that it was some of the later Pythagoreans who adopted this creed in order to assist them in their reformation of the people. However, one need not be very much surprised if Pythagoras himself did hold such views in those far-off pre-Christian days. Do we not see ideas equally ridiculous being supported by intelligent people to-day, and after all these ages of enlightenment?

We do not know what creed Pythagoras taught, for the religious part of his teaching was not made public, but it is evident that the teaching was of high moral tone, and there are many references which show that his disciples were devoted to their master and to one another. I give one story, just as it was translated by Dacier in his old book:—

"A Pythagorean went from home on a long journey, and falling sick in an Inn, spent all that he had. His Disease growing more stubborn and dangerous, his Landlord, who by good luck was charitably inclined, continued to take the same Care of him as when his money lasted, and furnished all the Expellee out of his own pocket. The sick Man grew worse and worse, and being very sorry not to have wherewith to satisfy his Benefactor, he asked him Pen, Ink and Paper, writes his Story in a few Words, puts at the bottom of it a Symbol of Pythagoras, to show he was a Pythagorean, and recommends to his Host to post up that Paper in some public Place as soon as he had buried him. He dies the next day, and when he was laid in the ground, the Landlord, who expected no great matters from the bill, posted it up nevertheless at the Gate of a Temple. Some Months passed away, and nothing came of it. At length a Disciple of Pythagoras passing that way, read the Paper, sees by the Symbol 'twas written by one of the Fraternity, goes immediately to the Landlord, reimburses him all his expences, and gives him a reward besides for his civility."

These Symbols of Pythagoras were sentences which meant more than appeared on the surface. One might describe them as disguised proverbs. Here are a few examples, with their hidden meanings:—

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(1) "Eat not fish whose tails are black." *(Frequent not the company of infamous men, who have had their reputations blackened by ill actions.)*

(2) "Stir not up the Fire with a Sword." *(We ought not to inflame persons who are already at odds.)*

(3) "Go not in the Public Way." *(We ought not to follow the opinions of the people, but the counsels of the wise.)*

(4) "Sow Mallows, but never eat them." *(Pardon all things in others, but nothing in yourself.)*

In these days, when the question of Women Suffrage is in evidence, it is interesting to note that Pythagoras was the first of the sages to emphasise the importance of women, and to admit them to his public lectures. Several women became philosophers in the time of Pythagoras. Among these was his own wife, and possibly her influence may have assisted the novel movement. So we see that the modern problem of "Women's Rights" was existent two thousand five hundred years ago.

Pythagoras must have been a very strong disciplinarian. It is stated that his pupils had to serve an apprenticeship of five years' silence, during which time they were "only to hear, without daring to start the least question, or propose the least doubt." I quote these instructions because some writers seem to suppose that the five years were solitary confinement. This mistaken idea may have arisen through a wrong translation. But it is quite evident that during this period of silence the pupils received constant instruction, for even when the period was reduced in some cases to two years, the pupils were said to be "initiated in the Sciences."

The feeling of brotherhood among this sect was emphasised by their having one common purse. No matter how large a fortune any member might have, it had to be thrown in along with the others. This common treasury was looked after by a number of chosen men called "Economists." Their business capacity must have been good, for if any member desired to retire he received more than his original contribution. If a member retired through lack of interest, a tombstone was erected to his memory, for he was counted as good as dead, having lost a desire for wisdom.

The daily life of the students began with music in the morning. Pythagoras was a great believer in the good influence of music. Then Pythagoras led them abroad to walk a while in some delightful places. After that they spent a quiet time in the Temple. When they came from the Temple "they used a little Exercise for the sake of their Health, and then din'd on a little Bread and Honey, without Wine; when Dinner was over they minded the Publick." Later they attended Lectures, then more plain food, and so on.

One of the earlier biographers states that Pythagoras believed "the Air was full of the Spirits he called Demons and Heroes, whom he regarded as the Ministers of the Supreme God; it was these Spirits or Genii that sent to Men, nay even to Animals, their Dreams, their Diseases,.and their Health." We can hardly suggest that this was a prophecy of the modern discovery of Microbes, although these much-maligned members of society were existent, of course, in those far-off days.

There is no very clear record of the fate of Pythagoras, but there is no doubt that all the Pythagorean schools were willfully destroyed by fire, and that many of his followers perished in the flames. Some say that Pythagoras himself was burned to death in this way, but this seems to be mere conjecture. Most historians believe these acts to have been brought about by the Pythagoreans meddling in political affairs; but Dacier (1707) makes no mention of political trouble. He tells of a young man, Cylon, who belonged to a rich and proud family, having applied to Pythagoras to be received as a disciple, and being refused, the young man determined on revenge. He spread such evil reports that there was a general rising against the Pythagoreans throughout the country, the movement ending in the burning of the schools by the mob. Dacier states also that

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Pythagoras was starved to death at the age of between eighty and ninety.

The Pythagorean schools did not disappear with their master. Some of these schools of learning were in existence at the time of Alexander the Great, nearly three centuries after the time of Pythagoras.

There was another Greek philosopher who lived shortly after Pythagoras, and whose name—Anaxagoras—is not well known, but who ought to be of interest to us. This early Scientist declared that all matter existed originally in the condition of atoms, and that order was produced out of this chaos of minute atoms by the influence and operation of an Eternal Intelligence. Remember that this Philosopher lived before the time of Christ!

It is of interest, also, in these days of modern Science to find that Anaxagoras declared that all known substances were simply aggregations of these atoms, and, moreover, that every substance was composed of inconceivably minute particles of the same material. This statement is of special interest because it is so similar to our latest discovery of electrons, or inconceivably minute particles of negative electricity, which constitute the atoms when grouped together in miniature solar systems, all the variety of atoms being merely different aggregations of identical electrons, with an equivalent of positive electricity.

Anaxagoras belonged to a very wealthy family, but he did not trouble about the fortune which could have been his; he preferred seeking knowledge. When he was still a young man he went to Athens, and became a great teacher. It is interesting to know that the great Socrates was one of his pupils in Athens, although the name of Socrates will not be included in our list of Heroes, for he did not believe in Science.

Anaxagoras was imprisoned for stating that the, Sun was a large ball of fire, and that it might be perhaps as big as Greece. But it is clear that Anaxagoras did not think of a ball of incandescent gas as we do now. He pictured the heavens as a solid vault, while the stars were composed of burning stones thrown up by the Earth. It was when those stones reached the upper regions of the heavens that they were made to burn by their contact with the surrounding ether.

It was because the beliefs of Anaxagoras clashed with the religious ideas of his time that he was imprisoned. He "contravened the dogmas of religion," for Apollo, the favourite god, was connected with the Sun. However, it is evident that Anaxagoras was held in high esteem. On his deathbed he was asked by the Magistrates of the town what funeral honours he desired. The old man's reply was, "Give the boys a holiday," and for several centuries this annual holiday was held in the schools.

The next great name that interests us is that of Aristotle, whose influence we shall find extending through the twenty centuries separating him from Galileo. Aristotle was the founder of most of the Sciences. But what do we know about the man himself? We are fortunate in having a better biography than in the case of Pythagoras, whose case, again, is even better than that of most Greek philosophers; indeed, in many cases their biographies are entire blanks.

Aristotle was born, in the year 384 B.C., in a Greek colony on the frontier of Macedonia, where his ancestors had lived for many generations. His father was physician to Amyntas II, King of Macedonia, and the boy Aristotle became intimate with the King's son Philip. But Aristotle's father died when our hero was seventeen years of age. To most young men of that age there would be danger in inheriting a large fortune. It is quite evident that Aristotle was not ruined by his wealth, although some critics of modern times have tried to add scandal to his great name.

Aristotle, the wealthy youth, went to Athens, the brain and heart of Greece, his chief object being to enter the school of Plato, who was by far the most famous figure of that day. It seems strange to us, who can consult daily papers as to the movements of great personages, to find that Aristotle, on arriving at Athens, discovered that Plato was absent. Aristotle

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had to wait three years for Plato's return. Many young men would have found this a grand excuse for passing the time in amusement. But Aristotle spent his time in hunting for useful books and making an earnest study of them. The obtaining of books in those days was something very different from our experience. Aristotle had to pay as much as seven hundred pounds for the works of one author.

There was one curious figure in Athens in the time of Aristotle, and it may be of interest to remark upon this eccentric character in passing. He was Diogenes the Cynic, who dressed himself in the coarsest wear, lived in the plainest fashion, and ultimately took up his residence in a tub. He was the son of a banker who was convicted of debasing coin. Diogenes was supposed to be implicated in the fraud, and he fled to Athens. Reduced from affluence to poverty, he said that "the magnificence of poverty attracted him." He told the people that wealth prompted him to vice, and that poverty would aid him to virtue. Of course, he was poor by necessity, but being poor he made himself ostentatiously poor.

The position which Diogenes held may be realised in the following incident. While on a visit to Greece Alexander the Great was evidently curious to see this eccentric character. The King accosted Diogenes in his tub. "I am Alexander," said the King. "I am Di genes," said the Cynic. "Can I do anything to serve you?" said the King. "Yes! Stand out from between me and the Sun," said the Cynic; upon which the King turned away, saying, "If I were not Alexander I would be Diogenes."

It will be understood that these few remarks about Diogenes do not claim for him the title of a hero of Science; he is merely of interest to us here because of his living in Athens at the same time as Aristotle. Another noted figure in Athens at that time would be the great orator Demosthenes, who, it will be remembered, overcame a bad stammer in his speech by practising with pebbles in his mouth. There were many Philosophers in Athens in Aristotle's time, but their names are not so familiar to the general reader.

For seventeen years Aristotle remained with Plato, and during that time the pupil became master in many branches of knowledge. Aristotle's independence of mind led him into a different system from that of Plato, so that at Plato's death he was not chosen as his successor. Having been twenty years in Athens, Aristotle left when Plato died, and took up his abode in Asia Minor with Hermias, an enlightened prince. This man's life had been somewhat romantic. He had begun life as a slave, then, rising to be vizier, he ultimately became ruler himself. He, too, had been a pupil of Plato at Athens. Aristotle married a niece of Hermias. This prince, not long afterwards, met a cruel death at the hands of a Greek officer, who was in the service of the Persians. Aristotle and his young wife went to Mytilene, then the cradle of literature. But his wife died while there.

Aristotle's old playmate Philip had now become King of Macedonia, and having a son Alexander, then about fourteen years of age, he asked Aristotle to become tutor to the boy. And so we find Aristotle acting as private tutor to Alexander the Great. Aristotle remained in this post until the assassination of his friend the King brought Alexander to the throne.

Aristotle then returned to Athens. He is said to have received from Alexander the Great as much as two hundred thousand pounds to spend in his researches, but no doubt the sum stated is an exaggeration. Aristotle opened a school, which became a rival of that of his old master Plato. The disciples of Aristotle became known as "Peripatetic Philosophers." It is very often stated that this title peripatetic was derived from the fact that Aristotle walked to and fro while lecturing. But this was by no means an uncommon custom, as the schools were held out of doors in shady groves. The garden or "gymnasium" in which Aristotle taught was named "Peripatos," signifying covered walks, and there is not the least doubt that it was this name of the school which gave to his disciples the title of peripatetic. In similar fashion we find that Plato lectured in a grove, belonging to one Academies, and therefore named Academia, from which we have our name Academy.

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For thirteen years Aristotle lectured in his school, and it was probably during this time that he did most of his writing, having the assistance of his pupils. His stay in Athens was brought to an abrupt end through the unexpected death of Alexander the Great at the early age of thirty-two. The feeling in Athens was against Macedonia, and as Aristotle was a well-known friend of the King of Macedonia, his position was a difficult one. He was accused of blasphemy, evidently on the ridiculous complaint that he had raised statues to the memory of his friend Hermias and to his young wife. Aristotle very wisely got out of Athens before the crowd passed sentence of death upon him, but he did not live long in his retirement, passing away at the age of sixty-two.

The great German Philosopher Hegel has said of Aristotle: "He penetrated the whole universe of things and to him the greater number of the philosophical sciences owe their origin."

CHAPTER III

UNIVERSITY PROFESSORS OF TWO THOUSAND YEARS AGO

In the preceding chapter we have seen how Alexander the Great was tutored by the Greek Philosopher Aristotle. Although Alexander did not become a Scientist, we have his name connected indirectly with the great University of these Ancient days. This was the Alexandrian Museum and Library, or what we should now describe as a University. Alexander's connection is that he founded the city of Alexandria, which city soon took the place of Athens as the seat of learning.

The great University was founded by Ptolemy I, King of Egypt, and no expense was spared in the equipment of this great school. Its library is said to have contained seven hundred thousand books, the literature of Rome, Greece, India, and Egypt. This gigantic library was practically destroyed during the siege of Alexandria by Julius Caesar.

Our present interest lies in the lives of the professors and distinguished scholars. Some readers may be surprised to learn that there were as many as fourteen thousand students in this Ancient University.

Unfortunately, we know very little of the lives of these Ancient professors, but the first professor of Mathematics is of special interest to us. This was none other than; Euclid, whose *Elements of Geometry* was written two thousand years ago. But his is one of the biographies, which is an entire blank.

Among the other professors of this far-off time was Aristarchus, who with the aid of Geometry attempted to calculate the distance of the Sun and Moon from the Earth. His results were far from the truth; his geometry was right, but his

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error lay in the measurement of the angle, and that was due to the very imperfect instruments he possessed.

Another succeeding professor, named Eratosthenes, attempted to measure the Earth, and he came remarkably near the truth. His calculation gave the circumference as thirty thousand miles, whereas we know now that it is about twenty-five thousand miles. We have much more accurate means of measuring angles, but it was Eratosthenes who showed us how to measure this great globe upon which we reside, and of which we can only see a very small part at one time. This old Greek Philosopher, at the age of eighty years became blind, and was so wearied of life that he voluntarily starved himself to death.

Another person living about this time, whose name is quite familiar to the general reader, was the great Greek, Mathematician Archimedes. Although Archimedes lived at Syracuse, Sicily, where he was born in 287 B.C., he went as a student to this great University of Alexandria. By that time Euclid had passed away, but other eminent men filled the important posts of professors.

Archimedes was the devoted friend of Hiero, the King of Syracuse; indeed, Archimedes seems to have been a relative of the King, on whose behalf he invented many terrifying engines of war.

To the general reader Archimedes is best known in connection with his detection of the fraud of the jeweller who made King Hiero's crown. It will be remembered that the King had given a certain quantity of pure gold to an artificer to make into a crown, and when the crown was made, the King for some reason or other suspected that he had been cheated. He had suspicions that the jeweller had kept some of the pure gold and used silver to make up the shortage. But the King could not think of any means by which such a fraud might be detected; the crown had the appearance of pure gold and its weight corresponded with the amount of gold supplied by him. In his difficulty he very naturally, consulted his scientific friend Archimedes. The problem puzzled the great mathematician. So much so that his mind became absorbed by it, and on going to the Baths one day he was doubtless trying to seek some solution of the difficulty. His attention was attracted by water overflowing from his bath as he stepped into it. This very simple occurrence suggested a plan by which he might solve the King's difficulty, and jumping out of the bath, and without stopping to dress, he rushed along the streets, shouting in his excitement "Eureka! Eureka!" (I have found it! I have found it!).

Galileo believed that Archimedes had discovered a much more exact method of testing this matter than is given in the story handed down by the Greeks. Galileo's explanation is that Archimedes used a long beam as a. balance, a piece of gold being placed at one end, and weights added to the other end until an exact balance was obtained. Having done this in the ordinary fashion, he allowed the gold to dip into a vessel of water, so that the gold was entirely immersed. Now he found that the gold appeared to weigh less, for it was supported in some measure by the water. Archimedes noted the exact difference in weight. He then repeated the experiment with a piece of silver, noting carefully the exact difference in weights. And again with the crown, which was supported by the water in a manner indicating that its density was intermediate between that of gold and silver. The fraud was apparent. And so Archimedes was the first to discover the laws of hydrostatics.

Archimedes' end was very sudden. His friend King Hiero had died a few years previously at the age of ninety-two. When the Romans took Syracuse in 212 B.C., old Archimedes, then seventy-five years of age, was absorbed in his mathematics. He was busy drawing geometrical figures on the sand, when a Roman soldier rushed upon him. And although Archimedes shouted to him not to spoil his circles, the soldier cut him down. The soldier who thus ended the life of the greatest mathematician of Antiquity must be held responsible for so cruel a deed. For the Roman general Marcellus, who was besieging Syracuse, had given specific instructions that Archimedes and

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his house were to be spared. It is to the credit of Marcellus that he desired this, for he was aware that the two years' struggle in overcoming Syracuse had been so long only because of the ingenuity of Archimedes. And that the Roman general was sincere in his instructions is evident, for the joy of his triumph over the city was marred when he learnt of the death of Archimedes. Marcellus directed an honourable funeral, and he befriended the relatives of the great mathematician.

By the expressed desire of Archimedes, the figure of a cylinder encircling a sphere was put upon his tombstone, to commemorate his discovery of the relation between the volume of a cylinder and sphere. When the great Roman orator Cicero visited Syracuse one hundred and forty years later, he found the tombstone of Archimedes overgrown with thorns and briars, and he blamed the people of Syracuse for neglecting the memory of their most ingenious citizen.

Returning to our consideration of the great University at Alexandria, of which Archimedes was at one time a student, we come to the name of Hipparchus. We should like very much to study the life of Hipparchus, the real founder of Astronomy, but unfortunately we know nothing whatever of his life. We do not even know whether he acted as a professor in the University, or whether he was merely a student there, but we have a record of his astronomical achievements. As these, however, tell us nothing of the hero himself we must pass them over, except to remark that Hipparchus practically founded that system known later as the *Ptolemaic system*, which sought to account for the motion of the planets with the Earth as the central body.

This brings us to the name of Ptolemy, another great astronomer at Alexandria, but we should remember that Hipparchus and Ptolemy were separated by three centuries, the former having lived about 160 B.C., and the latter about A.D. 140. Again we find another blank as far as the biography of this great man is concerned. One sometimes finds this great astronomer being confounded with Ptolemy, King of Egypt, who founded the great University of Alexandria, and who was succeeded by a very long line of Ptolemies. Of course, there is no connection between him and the famous astronomer who followed some centuries later.

Ptolemy was also a great geographer, but it is in connection with his planetary system that his name is best known. As already stated, it was the older idea of Hipparchus that Ptolemy extended and perfected. This so-called Ptolemaic system seemed to account so well for the motions of the planets that it held sway for the next fifteen hundred years. We shall see later what trouble Copernicus and Galileo experienced in displacing the Ptolemaic system.

Of course, we shall remember that while Ptolemy's system was counted right for so many centuries, he regarded the Earth as a stationary body in the centre, whereas the real explanation of the Sun being the central body had been taught more than seven hundred years previously.

Ptolemy is the last outstanding figure of this great University of two thousand years ago, and we have seen that our old school friend Euclid was its first professor of mathematics.

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CHAPTER IV

ROGER BACON
1214-1294

AN ENGLISH MONK OF THE THIRTEENTH CENTURY

To any one who has taken no interest in the history of Science, it may seem strange to leap from the beginning of the Christian era—or the two thousand years ago of the preceding chapter—right into the thirteenth century. But for any connecting link between these two far-distant periods, we have to go to the Arabs.

We have seen that the great Astronomer Ptolemy brings us well into the second century A.D., and although the Alexandrian University flourished till the seventh century, we have no record of any outstanding men of Science during these centuries. It may have been that people thought Science to have been completed by the Ancients. Occasionally one finds people of to-day suggesting that we have discovered all of importance that there is to discover. In any case we have this long delay in any further advance.

With the downfall of Rome in the fifth century we are not surprised to find a complete halt in their Science, but we may be surprised to find that it was the Arabians who took up the subject in the eighth century A.D. Indeed, this must seem strange to those whose ideas of these people are taken from the modern Arab, who is generally very unlearned, if not ignorant.

I remember, when I was a boy, being interested in watching a number of Arab boys who were present in some considerable force at the Paris Exhibition of 1889. It was amusing to see them racing upon their diminutive steeds in the very long, narrow stables; it seemed most foolhardy. It was remarkable how they vied with one another in a most reckless manner, but always remaining good-natured about it. The action of those brown-complexioned youths corresponded exactly with Carlyle's description of the Arabs: "Something most agile, active, yet most meditative, enthusiastic in their character, a people of wild, strong feelings and iron restraint."

But in the eighth century the Arabs became a most important people. Although their huge peninsula bulks very large on an atlas, it was not Arabia that was the true home of Science. The Arabian Empire had extended far and wide. Not content with capturing such towns as Jerusalem and Damascus, they founded the great city of Bagdad, in Asiatic Turkey, a name familiar to the young folk of modern times through the story of Aladdin and his lamp as told in *The Arabian Nights' Entertainments.*

They also founded Cairo, in Egypt, and the town of Cordova, in Spain, and in all their great cities they set up schools of learning which soon became famous. Many people, from all civilised lands, flocked to Cordova for instruction in Literature and Science. In this way the Arabs kept the Sciences alive for many centuries.

It is interesting to note that in their early days of Science, the Arabian Monarch offered the Emperor of Greece five tons of gold and a perpetual treaty of peace if he would allow a certain learned philosopher to give scientific instruction in Arabia.

During the Middle Ages the most popular books were those that came from the Arabians, and probably among the most thrilling books of our own childhood we should still reckon *The Arabian Nights' Entertainments,* which, although coming to us through the French, was of Arabian origin.

The Arabs were great admirers of Aristotle, and it was they who made the writings of the ancient Greek philosopher known in Europe. We may find the names of many Arabian philosophers in our encyclopaedias, but of their lives we know

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practically nothing, and even their names would not be recognised by the majority of modern Scientists. Most of the Arabian philosophers practised as physicians, being experts in the properties of medicinal herbs. They were the founders of chemical pharmacy, so that when a modern physician writes out a prescription he is following the lead of these Arabs of long ago.

There is one Arabian philosopher, Alhazan, about whom we have a few particulars. He was a native of Mesopotamia and lived shortly before our own country was taken by William the Conqueror, which is not so very far short of one thousand years ago, or midway between the present and the time of Christ. This ingenious man, Alhazan, came to Egypt and offered the Kalif a great scheme in connection with the overflowing of the River Nile. His scheme was not practicable, and the Kalif was so annoyed that it is probable he would have put Alhazan to death had the Philosopher not pretended to be mad. He succeeded in keeping out of the way until the Kalif's death, whereupon he reappeared and proved himself to be a great Scientist.

Alhazan was very much interested in Optics; he demonstrated the phenomenon that light always travels in straight lines, although that fact was made known by Ptolemy many centuries earlier. Alhazan was a born experimenter. He darkened a room and then admitted a beam of light through a slit in the shutter. If the atmosphere of the room were clear of all dust, he should have seen only a patch of light upon the floor or wall, according to the position of the slit in the shutter. But if there are dust particles floating about in the air, these serve to reflect some of this light as it passes through the invisible air. Alhazan was aware of this fact, for he says "the light is made clearly visible in the air mixed with dust."

I may remark in passing, that in order to obtain the photograph facing this page, it was necessary to shake a chalky duster in the air. This photograph serves to illustrate another important experiment which was made by Alhazan. It was known to Ptolemy, and was referred to in his early book on Optics. In demonstrating it Alhazan took a glass vessel filled with water, and not being able to have dust floating throughout the water, he added a little milk, which served the same purpose in the water as the dust particles did in the air. In the modern form of the experiment it is usual to replace the milk by a little red ink or other fluorescent substance, and to use a powerful lantern to produce the beam of light. Of course, the object of the demonstration is to show how the beam of light is bent, upon passing from one medium to another.

But why bring these facts about the Arabs into a chapter entitled "Roger Bacon"? Because there seems to me to be a clear connection; Roger Bacon was a keen student of the scientific writings of the Arabs, and in particular the works of Alhazan. In this way our hero links together the Ancient and the Modern Sciences, for although Bacon had no immediate followers, we may consider him as the founder of Modern Science.

The position of Science as Bacon found it was most unsatisfactory. He tells us that he found only one teacher who really understood Aristotle, and this one teacher was modest, passing unnoticed, while the others, with a great show of learning, became famous. This so aroused the indignation of Bacon that he wrote a scathing criticism of the teachers, pointing out that they were totally ignorant of the true foundation and method of Science. It goes without saying that this did not add to our hero's popularity. However, after having spent sixteen years in Paris, the seat of learning, and having gained the degree of Doctor of Theology, he returned to Oxford.

Roger Bacon, who was then about thirty-six years of age, became a Franciscan monk. The fame of his learning spread in Oxford, but as he made a practical study of Chemistry and Physics, he was supposed to be aided in his experiments by infernal spirits, and there was a feeling of suspicion concerning him.

To realise what the world thought of this Scientist one has only to peruse an old book which was translated into English

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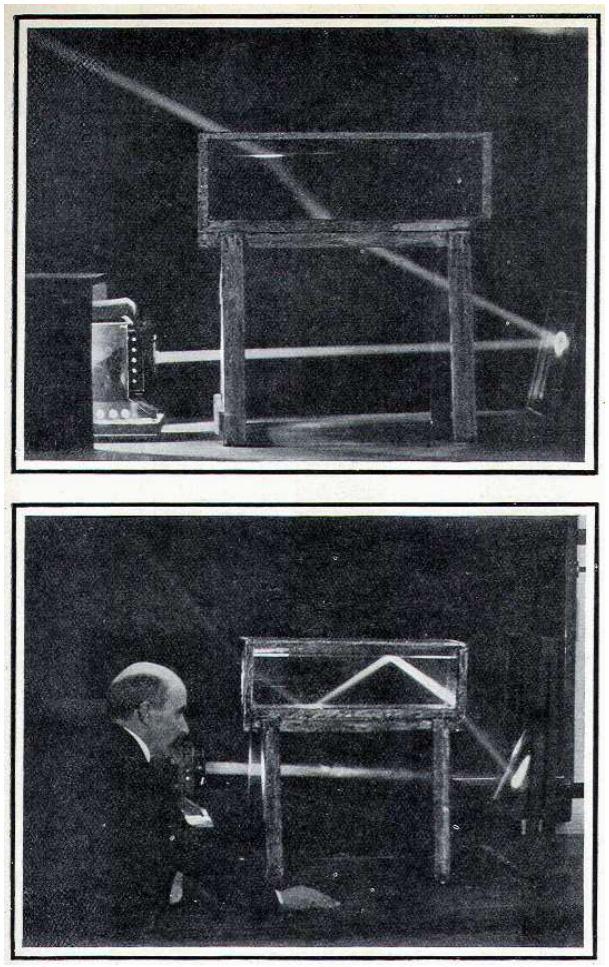
three centuries ago under the title *The Famous Historie of Fryer Bacon*. Here we find the sort of magic with which the people credited this English monk. We are told that he was summoned before the King and Queen to show his magic powers to them.



REPEATING AN ARABIAN EXPERIMENT OF ONE THOUSAND YEARS AGO
THE UPPER PHOTOGRAPH SHOWS A BEAM OF LIGHT BEING BENT WHEN PASSING FROM AIR TO WATER AND BACK TO AIR. THIS IS A REPETITION OF ALHAZAN'S EXPERIMENT (PAGE 42). THE APPARATUS SHOWN IS SUCH AS IS USED TO-DAY. IN THE LOWER PHOTOGRAPH THE BEAM OF LIGHT IS BEING REFLECTED BY THE SURFACES OF THE WATER.

This *Famous Historie* relates how, by the waving of his wand, he summoned excellent music, such as had never; been heard before; then there came forth, from nowhere, people who danced and then vanished away as they had come. By another wave of the magic wand there appeared tables covered with the richest fruits, and so on, and so on. It is even related in this *Historie* that the King and Queen did eat some of the rich fruits which had, been conjured up from nothingness.

This supposed history of Roger Bacon ends with a description of his death in a cell, in which he had locked himself, after making a bonfire of all his writings, the very last episode being "his grave he digged with his owne nayles, and was laid there when he dyed."

It does seem strange that people should believe such utter nonsense, and yet for centuries Roger Bacon was considered to be some sort of wizard. Even in the beginning of the eighteenth century Bacon was looked upon as nothing more than an ingenious Alchemist, so that it is only in comparatively recent times that a true history of Roger Bacon has been made out, chiefly from a study of his own works.

We need not be surprised to find that Bacon sought for the Philosopher's Stone, and that he believed also in Astrology. We shall find many great minds still believing in these "Sciences" several centuries after his time. But Bacon's studies were all serious; he did not practise Alchemy or Astrology for any personal gain. His advance in knowledge is most remarkable if we consider his surroundings. The mass of the people were quite unlearned. If a man could write, or even if he could read, that was proof that he was one of the clergy.

Even most of the monks in Bacon's time were ignorant of Mathematics. He tells us most of those who applied themselves to Mathematics in those days stopped at the fifth proposition in Euclid, and it is interesting to note that the title by which we knew this proposition in our schooldays—"Pons Asinorum" (The Asses' Bridge)—was given to it in Bacon's time. It is clear

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that Bacon must have given a great impetus to Mathematics, for we find an old monkish historian writing of one of the Franciscan monks: "Friar Bungay was profoundly versed in Mathematics; which was either the work of Satan or of Roger Bacon."

Bacon had not been back in Oxford for many years when the Head of his Holy Order interdicted his lectures at the University, and he was sent back to Paris to be placed in confinement under the Head of the Franciscan Order there. No doubt the reasons advanced would be that Bacon was not orthodox, and that he employed magic in his experiments, but from what happened later one may suppose the real cause to be his open criticism of the ignorance and vice of the clergy.

For ten years Bacon was confined in Paris, prohibited from publishing any writings, and kept under constant supervision. We have no details of his solitary confinement there, but it is said that he suffered great privations, being denied even sufficient food. It is difficult for us to realise what this imprisonment must have meant to a man of such great genius, who saw so much farther ahead than any of his captors. He had given up all hope of ever communicating any further knowledge to the world, when a request from Pope Clement IV reached him, desiring to see his scientific writings. The Pope had been Papal Legate in England while Bacon was at. Oxford, and he had heard of Bacon's fame; indeed, this high dignitary had desired to see Bacon's writings at that time, but the interdict prevented his wish being gratified. Now that he was Pope he could set aside the orders of the Parisian dignitaries.

That Bacon was immensely pleased to receive this request during his imprisonment is evident from a personal description of his circumstances and feelings at that time, of which he tells us in the opening chapter of one of his great works. But he had no writings to send; he had been forbidden to publish anything, and he no doubt believed that anything he might write would be destroyed. However, he had plenty of scientific knowledge in his head, and he lost no time in putting his ideas down in writing. It is remarkable that in less than two years he had completed three large treatises. These he wrote, of course, in Latin, which was the written language of the educated at that time. He dispatched his writings to the Pope by the hand of one of his students who is known to us as "John of London." It was unfortunate that just about the time the manuscripts reached Rome the Pope was taken seriously ill and did not recover, so we have no record of what Clement IV thought of the works. It is significant, however, that Bacon was released from his confinement and permitted to return to Oxford.

Once more a free man, Bacon devoted all his time to scientific study, and more particularly to experimental Physics.

But Bacon could not refrain from urging the necessity of more efficient study on the part of the monks, and in his writings he denounced their ignorance and vices. The result of these noble outbursts was that, after three years' freedom, he found himself thrown into prison, and all his books condemned. For about fourteen years he remained a prisoner, and entering at the age of sixty-four he would be an old man of seventy-eight years before he was once more set at liberty. This last liberty was granted at the request of several influential English noblemen. Even at this advanced age Bacon wrote a Compendium of Theology. He passed away about the age of fourscore years.

It is well to note that Roger Bacon was not the inventor of gunpowder, nor of the telescope, although his name was associated with these inventions for a long time. Gunpowder, while referred to by Bacon in his writings, was known for several centuries before his time. The telescope was not invented for centuries after Bacon, as we shall see when we come to consider the life of Galileo. Bacon knew the use of optical lenses, and he invented the magnifying-glass, which, however, is not the same as a telescope.

The first title which I had noted for the present chapter was "The Two Bacons," but I feared that many readers might object to the inclusion of Francis Bacon as a Scientist, and I

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doubt if he fulfils the definitions with which I set out in the first chapter. He did not add any thing of importance to our knowledge of Science, but it is debatable how far modern Science has been influenced by the writings of Bacon.

While Francis Bacon was a great man of letters, a famous lawyer, and so on, that does not bring him within the scope of the present subject, but I do think there is a real connecting-link in this way. Francis Bacon, who lived about three hundred and fifty years after Roger Bacon, was a prominent figure in the Court of Queen Elizabeth, and Dr. William Gilbert, who did much for Science, was one of Queen Elizabeth's physicians at that time, so I think it is reasonable to suppose that Gilbert would be influenced by Francis Bacon, who declared so very vehemently that Science was altogether on the wrong track. He declared that the true philosopher should not be a mere disputant, but an experimentalist, and it is well known that Gilbert was a great experimentalist. We should remember that at this time public thought was divided into two classes. Science was thought to be impossible, or it was considered to be complete already. Francis Bacon has some claim of mention in the present subject because of his attempted reformation of Science, but he himself made no scientific discoveries. Under these circumstances, I have thought it sufficient to give only a very general outline of this great man.

Francis Bacon was born in the Strand, London, in the year 1561, and after being taught at home he went to Cambridge, and later to Paris. Francis was the youngest son of a large family, and his father, Sir Nicholas Bacon, was arranging to purchase an estate for Francis, but before this had been arranged the old gentleman died suddenly. Although all the other sons were well provided for by the father, they only let Francis get his share of the residue of the estate. In this way he was left tolerably poor, considering his father had been so wealthy. Francis made this poor beginning much worse by borrowing money, with the result that he was always in debt.

Although a Member of Parliament, he received no remunerative post from Queen Elizabeth, but in the reign of King James he became Attorney-General and Lord Chancellor. His actions when holding these high posts brought about his imprisonment in the Tower of London at the age of sixty years, but his sentence was remitted. It is very doubtful if Bacon was guilty of any real bribery, but he confesses to receiving money in the form of gratuities when cases had been tried and the verdicts made known. Before this time he had been raised to the peerage.

After the release from his short imprisonment, Bacon devoted himself to his scientific writings, but his famous *Advancement of Learning* was written at a much earlier date and during one of the vacations of Parliament.

We have noted that Francis Bacon was not an experimental Scientist himself, although he was a very strong supporter of the experimental method. But I think sometimes that Bacon might have become a great experimenter had his time not been so very fully taken up with Parliamentary and State duties, for at the age of sixty-five we find him making an experiment, which unfortunately was indirectly the cause of his death.

Driving in his carriage one winter day through the Highgate district of London he wondered if snow would act as a preservative of animal flesh. He stopped his carriage at a cottage, where he purchased a fowl, which, when killed, he asked to be stuffed with snow. He himself assisted in the operation, and during the experiment he contracted a sudden chill, and became so seriously ill that he had to be taken to the neighbouring house of the Earl of Arundel, where he died after a few days' illness, being then only in his sixty-sixth year.

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CHAPTER V

COPERNICUS AND HIS FAMOUS THEORY 1473-1543

NICOLAS COPERNIK—BETTER KNOWN TO US AS COPERNICUS

We have seen that Pythagoras taught that the Earth is not the centre of the Universe, but that it is flying through space in a ceaseless journey around the Sun; and Pythagoras lived before the time of Christ. But this theory had practically ceased to exist throughout the Middle Ages, till it was revived by Copernicus in the fifteenth century. For that reason it is known to us as the Copernican System.

Copernicus lived about one hundred years before Galileo, whose name is so prominent in connection with the fixing of this theory in the mind of man. This was the time when the great Christopher Columbus lived.

Nicolas Copernik was the name of our hero, but he is best known under the Latin form of his name—Copernicus. He was born in Polish Prussia in 1473, and although his birthplace, Thorn, was then in Poland, it is now in Prussia. We know practically nothing of his parents except that his father was a merchant.

When we learn that Copernicus was taught Latin and Greek at home, we might suppose that his father must have been an accomplished scholar, but as his father died when Copernicus was only ten years of age it is probable that these languages were acquired after his father's death. This is very probable, for the boy was then taken care of by his uncle, who was a Bishop. At the age of seventeen Copernicus went to the University of Cracow, which town was the old capital of Poland.

His uncle, the Bishop, desired that Copernicus should enter into Holy Orders, but he proved an unsuccessful candidate for a Canonry, and was sent to Rome to study. There he became very friendly with an illustrious astronomer, who obtained for him the professorship of Mathematics in Rome.

Copernicus made great progress in the study of Astronomy. He soon rivalled his distinguished friend and master. After several years of successful teaching of Mathematics in Rome, Copernicus returned to his native land and settled down in the position of Canon of one of the principal churches in Poland. Here he passed a quiet life, devoting one part of each day to the duties of his holy office, another part to giving free medical advice, and the remainder of his working day to study. At this time he would be about thirty-five years of age. He had no desire to make a great reputation for himself, nor did he care to enter into controversy, and so he worked away on his own account, trying to establish the theory that the Sun, and not the Earth, was the central body. He kept his manuscript to himself, revising and re-revising it year after year. It is quite possible that Copernicus knew that the Church would not favour his theory, and so his best plan was to prepare his book upon the subject. This book, *De Revolutionibus Orbium*, was his life-work, and was not completed until he was fifty-seven years of age. But even then he did not seek to publish it. The MS. lay dormant until a few years before his death, and only owing to the pressure of his friends did he agree to publish it. That would be about twelve years later. In the meantime the idea had been severely criticised by many of those who heard of the work. The great German Reformer Martin Luther, who was then living, thought Copernicus a fool to hold such opinions. He was even ridiculed on the stage at a public performance.

While Copernicus was a scholarly student, and devoted great care to plotting out the motions of the planets, and to the Mathematics of Astronomy, we must remember that Science had been dead for many centuries and was only beginning to be revived. Hence many of the arguments used by Copernicus,

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although they passed for logic in these days, would seem quite ridiculous nowadays. For instance, Copernicus adopted the same "argument" as Aristotle did, that the planets must move in regular circles because the circle was the most perfect and only natural form. For the same reason the Earth was spherical. Then his idea of the motion of the planets was similar to the ancient conception of the heavenly bodies being fixed in gigantic crystal spheres which, in his theory, circled around the Sun. However, he was the first to prove that the Earth is really a planet flying through space just as Jupiter, Saturn, and the other planets are. Pythagoras had suggested this, but he had offered no proof of his theory.

It is difficult for us to realise what a complete revolution of man's ideas this theory required. Indeed, man's position had been very much like that of the little child to whom everything seems centered around itself. Everything that takes place in the Baby's world has special reference to the Baby. Man had imagined for ages that he was on a firmly fixed Earth, around which all the heavenly bodies danced attendance. Now he was asked to believe that this great big world of his was in reality a mere speck in the Universe; that he was on the surface of a comparatively small planet continually flying through space.

This great awakening did not come really during the lifetime of Copernicus. Indeed, he never saw his great book published. The first copy is said to have been placed in his hand when he was on his death-bed, but it is very doubtful if he could realise what it was. Then we must remember that a book which was practically a technical treatise, written in Latin, was not read by the general public. A hundred years later Galileo wrote upon the same subject in the vulgar tongue (Italian) instead of in Latin. The reason which Galileo gave was that, although people might have "a decent set of brains, yet not being able to understand things written in gibberish, take it into their heads that in these crabbed folios there must be some grand hocus pocus of logic and philosophy much too high up for them to think of jumping at. I want them to know, that as Nature has given eyes to them just as well as to philosophers for the purpose of seeing her works, she has also given them brains for examining and understanding them." But that was a century later than Copernicus. It took the Church a long time to realise that this theory was the beginning of a great revolution of thought.

Immediately preceding Galileo there came one Tycho Brahé, who did not adopt the theory of Copernicus, but whose great astronomical observations, as we shall see in the succeeding chapter, led on to the establishment of the Copernican System by Galileo.

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CHAPTER VI

TYCHO BRACHE
1546–1601

ASTROLOGER, ALCHEMIST, AND MEDICAL QUACK, BUT A MOST DISTINGUISHED ASTRONOMER

The name of Tycho Brahe, though foreign to us, would not seem strange to his fellow-countrymen in Denmark. Indeed, the name Tycho is still used among the Danes.

In the ordinary course of events Tycho would have become a soldier. He was born at a time (1546) when learning was left very much to the monks. He came of a noble family who lived on the estate of their ancestors, but the present owners were not wealthy. It was usual that the sons of gentlemen should devote their lives to the protection of their country, or spend their time in hunting. For such avocation it was considered that no book-learning was necessary, and had the intentions of Tycho's father been fulfilled it is probable that we should never have heard his name. But it so happened that an uncle, who had no family, desired to adopt one of his nephews. The uncle and aunt were desirous of having the entire upbringing of the boy, but so long as Tycho was the only son, his parents could not part with him. However, there seems to have been a definite understanding that ultimately the boy would go to the uncle, for we find Tycho getting special instruction in reading and writing, and later on in Latin and Literature. All this was in opposition to his father's ideas, but the uncle, on the other hand, was a well-educated man.

After the death of Tycho's father, who left five sons and five daughters, the uncle sent Tycho to the University of Copenhagen. The boy was then only thirteen years of age, so he must have been a very apt pupil, though it is interesting to note that our own Lord Kelvin entered Glasgow University at an earlier age even than this. Tycho's uncle's ambition seems to have been to give his nephew a good education in philosophy and law, so that he might be able to fill some of the great political offices.

While Tycho was a law student at Copenhagen there was a great deal of talk about an eclipse of the Sun which had been prophesied to occur on a certain, day. The interest of the people was not a scientific one; Science was a thing of the past so far as these people were concerned. But, according to their notions, this eclipse of the Sun might carry with it the destiny of a whole nation, and no doubt the Astrologers would have been busy in framing predictions.

Of course, all this about Astrology seems strange to us, but if we picture a people totally devoid of all knowledge of Astronomy, we can understand that when they found that Astrologers were able to predict definite happenings in the heavens, it seemed natural that they should be able to predict also what should happen on this Earth.

When the twenty-first day of August, 1560, dawned, there would be considerable excitement, for that was the very day upon which the Astrologers had said the Sun would be darkened. Tycho, now a boy of fourteen years, was one of the anxious watchers, and when things happened in the heavens just as they had been predicted, he was carried away with enthusiasm. He, too, would learn to predict not only what should take place in the heavens, but among the nations also. In other words, Tycho decided there and then that he would become an Astrologer; a profession far removed from that of an Astronomer. He purchased books dealing with the planetary motions, which books would, of course, state that the Earth was the centre of the Universe.

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We may presume that Tycho's uncle was not party to this idea of the youth becoming an Astrologer, for we find Tycho, at the age of sixteen years, being sent with a tutor to Leipzig to extend his knowledge of law. But his hobby had a far greater fascination for him than the study of law. All his spare time was devoted to a study of the heavens, and all his spare pocket money went to the purchase of books on Astronomy. Tycho would sit up at night, presumably without his tutor's knowledge, and study the stars. He could soon distinguish the different planets and trace their apparent motions. With the aid of a pair of rude compasses and a celestial globe no larger than an orange, this youthful astronomer found that some of the accepts calculations of the planetary motions did not agree with his own calculations, and so Tycho resolved to devote his life to obtaining accurate information concerning the motions of the heavenly bodies.

To the average youth such a task would have seemed impossible, for the whole of Tycho's training had been in philosophy and law; he had never studied Mathematics. But he had reached that stage at which he could learn on his own account, and so, without the aid of any master, he gained the necessary knowledge of arithmetic and geometry. Tycho found some of the predicted motions of the planets so very far out, in some cases a whole month, that he determined to make more accurate instruments for observing. Telescopes were not invented until the succeeding generation.

Tycho had practically completed his study of law, when news came that his uncle had died, leaving his fortune to Tycho.

Now he was free to settle in Denmark to pursue his astronomical studies with freedom. But we are told that his relatives and friends were not pleased that he should have abandoned law for what seemed to them a ridiculous and useless occupation; that, indeed, they made things so uncomfortable for Tycho that he left Denmark and settled in Germany.

We must remember that Tycho's study of Astronomy was closely connected with Astrology; the great plague which devastated Europe later was believed by him to be due to the conjunction of two of the planets having taken place in a certain part of the heavens which had a special connection with pestilence.

While pursuing his astronomical observations in Germany Tycho attended a wedding feast. He may have attended many more, but we know of this one because while at this feast he had a quarrel with a fellow-countryman. The occasion of the dispute had reference to their mathematical acquirements. Matters were evidently smoothed over for the time, but about a fortnight later Tycho and this quarrelsome guest happened to meet again, at some festive games. Instead of letting bygones be bygones they revived the fdrmer quarrel. So serious did the matter appear to them that they decided to fight a duel with swords, but how this should decide which was the better mathematician is difficult to see. However, the fight did not take place in the heat of the moment, but two days later. It was a dark December evening, and one biographer states that they fought in total darkness. But surely there must have been sufficient light to enable the combatants to see the position of each other, or the seconds might have fared badly. However, the result was that Tycho had his nose cut off by his opponent. To lose one's nose would not improve one's personal appearance. And if we try to picture Tycho as described by some of his biographers, we can well imagine that the loss of his nose would not add to his good looks. He was of middle size, and had "reddish yellow hair" and a ruddy complexion.

Tycho did the best he could under the circumstances. He had an imitation nose made. This artificial nose has been described by some as a nose of gold and silver; by others it is spoken of as a construction of putty and brass. His nose would be a decided novelty in these days, and would be of general interest. He seems to have had some difficulty in getting the nose to remain in its proper place, for he is said to have carried

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with him a box of cement with which he could replace the nose when it fell off.

While Tycho was still a young man of twenty-two years, he had a very large quadrant instrument made by which he could make more perfect observations. The best workmen were employed for a month making this huge instrument, which required twenty men to carry it to its place of fixture.

At the age of twenty-five Tycho had become famous as an Astronomer, and when he returned to Denmark he was received as a great man. The King invited him to Court, an uncle provided him with an observatory and a laboratory, and for a time Tycho became a very keen alchemist. There have been many honest alchemists who earnestly sought to produce gold from silver, and to discover not only a panacea for all ills, but a tonic which should prolong life indefinitely.

Tycho worked hard in his laboratory; he was an enthusiast in everything he took up of his own accord. Upon leaving his laboratory one night, the sky happened to be very clear, and Tycho observed overhead a bright star which he had never seen before. Of course, Tycho was so familiar with the heavens by this time that he would very quickly spot a stranger. But this seemed so impossible a thing that he called his servants out to assure him that the star was really there. He hurried off to his observatory and noted down the exact position of this new star, so that he might find out if it moved or if it were a fixed star. Tycho's friends joked him about this new star, but he was able to point it out to them, for it was bright as Venus at her best. Strange to say, the new star began to diminish; it remained visible for a little more than a year, then faded out altogether. Tycho was able to say definitely that this temporary star was very far distant, away among the fixed stars. Other temporary stars have appeared and disappeared in similar fashion, and we believe these to be great masses of incandescent gas produced by some collision or disruption far off in space. Tycho, who was now twenty-seven years of age, fell in love with a peasant girl. He shocked the dignity of his friends by marrying this girl who had been brought up in so humble a position. Some two years later Tycho decided to remove from Denmark, so he set off by himself on a tour of inspection on the Continent, ultimately fixing upon Basle as a permanent residence "not only from its centrical position, but from the salubrity of the air, and the cheapness of living."

Tycho returned home and made all preparations for the departure of himself and family to Basle. Just then a messenger arrived with a letter from the King of Denmark asking Tycho to meet him at Copenhagen. To Tycho's great surprise the King entreated him to remain in Denmark. He offered Tycho a certain island where he could have peace to make celestial observations. His Majesty presented Tycho with the sum of twenty thousand pounds wherewith to build a large observatory on the island. He also made over to him an estate in Norway, which would yield him an income, and in addition to all this he undertook to give him a pension for life of four hundred pads a year. Needless to say, Tycho gladly accepted this very handsome offer, and he expressed the hope that by such means he might make discoveries that would be a credit to his native land.

Tycho's observatory was a veritable castle, but it was no plaything; Tycho put in twenty years' earnest work, and work that counted much for future generations of men. He did the first really accurate work in Astronomy, and all without the aid of any telescope, the discovery of which we shall consider when we inquire into the life of Galileo, who was born in Italy when Tycho was a lad of eighteen. These two great men never met. A mutual friend recommended Tycho to write to Galileo. This he did, but the acquaintance went no further.

We must not picture Tycho as a recluse away in his island home. He had always a number of students resident at the observatory, and he had constant visitors from many different countries. Among the royal visitors we find James I of England, who spent eight days at Tycho's observatory. Of course, it was King James's marriage with Anne of Denmark that took him to these quarters.

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The description of Tycho's house in the observatory reminds one of the country mansion of the great French conjurer, Robert Houdin. Tycho had invisible bells which communicated with every part of his establishment, and with the gentlest touch he could summon any of his pupils before him. When some stranger was present Tycho would mutter in a mysterious manner, "Come hither, Peter!" whereupon one of his pupils would suddenly appear before them. In this and similar ways Tycho would mystify his visitors. Then he had a great collection of automatic devices of his own invention, which interested all visitors.

But there was one of Tycho's "curiosities" which must have been very unpleasant to his guests. He kept an idiot boy named Lep, who lay at Tycho's feet during meals, and whom he fed with his own hand. Tycho imagined this idiot to be something wonderful, and no matter what guests were present, every one had to keep quiet when this boy spoke, so that Tycho might note down what the boy said. Tycho believed that the boy's mind could foretell the future. Such scenes must have been most distressing.

Tycho was so superstitious that if, on leaving his house, he happened to meet an old woman or a hare, he would not proceed farther, but returned immediately to his home.

In the subtitle to this chapter I have described Tycho as a Medical Quack. This is quite justified, for although Tycho was not a trained physician, he doctored many invalids who flocked to his island. One must suppose that his cures were, like those of present-day quacks, performed on persons who were hypochondriacal, or highly imaginative and nervous persons. However, he had invented what we should call nowadays a patent medicine, which was in great demand and is said to have been on sale in every apothecary's shop in Germany.

Such things aroused the jealousy of the medical profession, and when Tycho's great benefactor, the King, died, leaving his young son to fill the throne, the physicians helped to stir up a feeling against Tycho. So many adverse things were said about Tycho and his work that a committee, what we should call now a Royal Commission, was appointed to inquire into the value of Tycho's work, for he was still drawing his income from the State. This committee had the audacity to report that Tycho's work was absolutely worthless and that it would be ridiculous to allow him to draw any income from the Treasury.

Deprived of his estate in Norway, and of his pension, Tycho was compelled to give up his great observatory, in which he had worked and lived for twenty years. It will be remembered that Tycho had been left his uncle's fortune, amounting to about twenty thousand pounds, and he had doubtless accumulated money from his famous medicine. But all his fortune had been spent upon his great observatory, which in all must have cost not less than forty thousand pounds. We can understand what a heartbreak it must have been for Tycho to be forced to abandon all this. He had to retire to a house in Copenhagen, to which he carried all his smaller instruments.

Not long after this Tycho determined to leave Denmark altogether. He returned to his island and collected all the other instruments that were movable, along with his books and crucibles. He hired a ship and set sail, accompanied by his wife, his family of nine, many pupils and assistants, and a number of servants. The plague, which was then spreading in Europe, prevented Tycho taking up a permanent residence.

He was introduced to the Emperor of Bohemia, who was "addicted to alchemy and astrology." The Emperor gave Tycho the choice of several castles for an observatory. In addition to this he settled a very substantial annual pension upon him. And so Tycho established a school at Prague, where he employed many good calculators as assistants. Among these assistants was Johann Kepler, whose life we shall consider in the succeeding chapter.

Tycho's health gave way, and he lived only four years after leaving his happy island home in Denmark. His life of

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fifty-five years was a crowded one. He was a devout man, a great student of the Holy Scriptures, and there is no doubt that it was on religious grounds that he did not accept the theory of Copernicus that the Earth was not the centre of the Universe.

One is pleased to know that Tycho's widow and family were not left in want, for the Emperor purchased Tycho's instruments for a very large sum of money.

The great value of Tycho's work was his making Astronomy and accurate Science, and something more than a mere aid to Astrology. Considering the instruments with which he had towork, Tycho's observations are a marvel of accuracy; he never made one careless mistake. Tycho Braché laid the foundation upon which modern Astronomy has been builded.

CHAPTER VII

JOHANN KEPLER
1571-1630

FROM POT-BOY IN A TAVERN TO IMPERIAL MATHEMATICIAN AND ASTRONOMER

Although Johann Kepler was a pot-boy in a tavern, his parents were both of noble families.

But Johann got a very bad start in life. His parents had degraded themselves; they had come down in the world. The last straw seems to have been that Johann's father had become security for a friend, and this friend had absconded, leaving Johann's father to pay the piper. It was then that he sold off all of value that he possessed and became a tavern-keeper, and it was in this tavern the son worked for several years.

There was no happy home life for the boy. His mother was a woman with a terrible temper, so much so that her husband was glad to go abroad as a soldier. Just when Johann should have been sent to school he became a victim to smallpox. On his recovery he went to school, but after two years of irregular attendance he was withdrawn so that he might act as pot-boy in his father's tavern. He seems to have been kept at this menial work for five years, by which time he would be fourteen years of age. He then returned to school, but only for a very short time, as he developed a severe illness, while his parents, at the same time, were both suffering from smallpox.

We see that Kepler had passed the ordinary school age without any proper schooling. How different from Tycho Brahé who had entered the University at thirteen years of age. But at the age of fifteen years Kepler was admitted to a monastery which prepared students for the University at Tubingen.

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We have been picturing this unfortunate boy without placing him in any particular part of the world, except for the preceding paragraph. The name Johann will probably have placed him in his native land of Germany. It is usual to speak of Kepler as John Kepler, but this has always seemed to me unfortunate; indeed, I have found some young friends thinking of Kepler as an Englishman. Probably this error has arisen through these young people only hearing of Kepler in connection with Sir Isaac Newton's work. However, the birthplace of Johann Kepler was a small town about ten miles from Stuttgart, and he was born prematurely a few days before the Christmas of 1571. He remained delicate throughout life.

His time at the University was interrupted not only by repeated illnesses, but by family troubles. It was at this time that the mother's violent temper drove the father to a foreign land, where he died. It is reported that the mother quarrelled with every one of her relations. It is to Johann Kepler's credit that, despite all these troubles, he succeeded in gaining his degree of Bachelor, coming out second in the examination.

It is interesting to note that when Kepler was about twenty years of age he became a convert to the Copernican theory, which brought the Sun to a standstill and set the Earth in motion. His conversion was due to a lecture on the subject delivered in the University. Galileo's conversion to this theory is supposed to have taken place about this time also, but we must remember that the surroundings of the two men were very different. Kepler was allowed perfect freedom of thought in Germany, whereas Galileo had no such liberty in Italy. It is interesting to note that when Galileo first heard of the Copernican theory, he thought it was "a piece of solemn folly." However, we shall hear more of him in the succeeding chapters.

At the age of twenty-three years Kepler became Professor of Astronomy at Gratz, but this Science was not accounted of much importance in these days, except so far as it was of value to Astrology. Kepler was not physically fit to become an Astronomer such as old Tycho was in Denmark at that time. Kepler suffered from weak eyes, and his delicate constitution prohibited him exposing himself to the night air. Neither was it as a Mathematician that Kepler excelled, but he had a wonderfully vivid imagination, and so his strength lay in devising theories concerning the motions of the heavenly bodies. Some people think that theories are mere guesses at the truth, but unless a "guess" or hypothesis can be supported by established facts it is not allowed to remain. Kepler made many very wild guesses, he has left us a record of some of these, but he did not stop there. He put all his theories to the test. Sometimes he thought he had established them, but when he found out some error later, he never failed to make it known, and to demolish his own theory.

But when considering the theories of others Kepler sometimes became very sarcastic. For instance, when a new or temporary star appeared, similar to that seen by Tycho Brahé some thirty years previously, those philosophers who were known as Epicureans put forward a theory that the new star was due to a fortuitous concourse of atoms. Kepler wrote a good deal of sarcastic nonsense about this, finishing up in the following fashion: "I will tell those disputants, not my own opinion, but my wife's. Yesterday, when weary with writing, and my mind quite dusty with considering these atoms, I was called to supper, and a salad I had asked for was set before me. 'It seems then,' said I, aloud, 'that if pewter dishes, leaves of lettuce, grains of salt, drops of water, vinegar, and oil, and slices of egg had been flying about in the air from all eternity, it might at last happen by chance that there would come a salad.' 'Yes,' says my wife, 'but not so nice and well dressed as this of mine.'"

As Kepler was not capable of being an active observer of the heavens, it was necessary that he should rely upon the observations of others in constructing his theories. For this reason Kepler paid a visit to Tycho Brahé at Prague, to which I referred in the preceding chapter. At that time Tycho would be about fifty-four years of age, while Kepler would be twenty-nine. After returning home from that visit, Kepler received a

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pressing invitation from Tycho to become his assistant, and so Kepler and his wife set out for Prague. Again misfortune overtook our hero. He fell ill on the journey and was delayed for seven months. During that time all his savings disappeared, and he had to ask Tycho for financial assistance.

Tycho and Kepler became the best of friends. They undertook to compute a new set of Astronomical Tables, which would entail an enormous amount of labour, but Tycho died in that same year. Kepler was appointed to Tycho's post of Imperial Mathematician, and he was promised a liberal salary by the Emperor, but unfortunately the Treasury was already overtaxed by heavy war expenses, and Kepler's salary was always in arrears. Indeed, Kepler did not receive enough to keep him and his family, and he had to set up as an Astrologer, while he continued his real astronomical work in earnest. He was not in earnest about Astrology; we saw that Tycho Brahé was a real Astrologer, believing in his own predictions. Kepler was only an Astrologer in the same sense as we have fortune-tellers at country fairs to-day; merely as a means of livelihood. There was this difference, that the modern Astrologer often knows nothing of Astronomy.

Kepler did not like to resort to this means of making money. A few years later, when he had to raise funds in a similar manner, he wrote: "I have been obliged to compose a vile prophesying Almanac, which is scarcely more respectable than begging." Kepler was scarcely ever free from money difficulties, and it is all the more creditable to him that he did such excellent work.

The most outstanding of Kepler's discoveries are those truths known to the student as *Kepler's Laws*. The first of these laws states that the planets move in ellipses, with the Sun in one focus. This was a truly great discovery. The famous philosopher Aristotle had said that the heavenly bodies moved in circles, and we have seen that there was no doubt in Aristotle's mind, for the circle was the only perfect and natural motion. And because Aristotle had declared this long ago, generation after generation accepted the statement as an established fact. Astronomers could not get the motions of the planets to agree with a simple circular motion. They made an elaborate system of one circle carrying another circle. Then, believing the earth to be the centre around which the planets moved, they placed the Earth at some distance from the true centre in order to try and account for the different positions of the planets at different times. All this arrangement developed by Ptolemy, and known as the Ptolemaic System, was very much complicated.

How, then, did Kepler discover that the path of a planet is of an oval or elliptic form? Simply by guessing one thing, and when he found that would not do, guessing another possible solution. But it required a strong mind to break away from the universally accepted doctrine of Aristotle.

As we are considering only the life of Kepler, we need not detail the other two laws which he discovered. We are more concerned about the welfare of our hero, whose scientific ardour could not be extinguished by all the worries of this life. About this time his wife became very seriously ill, and before she had recovered, their three children were attacked by smallpox, which caused the death of his favourite son.

There seemed little use in Kepler remaining at Prague, as mere promises of payment of salary would not meet his household bills. And so he set out for Austria, where he believed he might obtain a Chair of Mathematics. On his return home he found his wife in a very despondent condition, and not long afterwards she was attacked by an infectious fever which proved fatal.

Kepler felt that his son and daughter required the care of a mother, so he decided to marry again. He asked his friends to select a suitable wife for him. Why he adopted this plan is not quite clear. To suppose that it was because he was too engrossed with his studies to trouble about the details of such an affair does not explain matters, for he had to consider no less than eleven different candidates.

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The first candidate was a widow, who had been a family friend, but when Kepler, who had not seen the lady for some years, heard that she had decided in the end not to accept his offer, his description of her was that "there is no single pleasing part about her." This lady had two marriageable daughters, and later on these young ladies were added to Kepler's list. His reason for refusing one of the other candidates was that she had learned nothing but showy accomplishments. Another was too old, while another was "too proud of her birth and quarterings." In one case the courtship lasted several months, but in the end the lady jilted him.

Kepler's description of another selected candidate makes amusing reading: "She has, undoubtedly, a good fortune, is of good family, and of economical habits; but her physiognomy is most horribly ugly; she would be stared at in the streets, not to mention the striking disproportion of our figures. I am lank, lean, and spare; she is short and thick: in a family notorious for fullness, she is superfluously fat."

Kepler was at this time a little over forty years of age, but he refused the eleventh selection of his friends because of her excessive youth. The final result was that he went back to number five on his list, and declared that she was the one he had really been in love with all the time. Kepler says of her: "Her person and manners are suitable to mine, no pride, no extravagance. She can bear to work; she has a tolerable knowledge how to manage a family; middle-aged, and of a disposition and capability to acquire what she still wants."

Kepler had settled down with his new wife, when he received the offer of a professorship in Italy. This offer was respectfully declined; his reason was that he would not have the freedom of speech to which he was accustomed. The wisdom of this decision will become apparent when we consider the life of Galileo in the succeeding chapter.

Kepler's financial troubles were not at an end yet, the Government were always far in arrears with his salary.

It is interesting to note that he dedicated one of his books to King James I of England. But why he did so is not quite clear. Possibly because King James had shown interest in the work of Tycho Brahé. Of this book Kepler wrote: "The die is cast; the book is written, to be read either now or by posterity, I care not which. It may well wait a century for a reader, as God has waited six thousand years for an observer." However, not long after the publication of his *Harmonies of the World* Kepler received a visit from the English Ambassador at Vienna, and we may presume that this visit was owing to the dedication of the book to King James. The Ambassador urged Kepler to take up his residence in England, but Kepler declined this invitation. To those of us living in these Islands it is amusing to read that one of Kepler's reasons was that he "dreaded the confinement of an island." One wonders if Kepler's geography were at fault.

Kepler received a very handsome offer from the Duke of Friedland, one of the most distinguished men of that day, to take up his residence in Silesia. At last Kepler's misfortunes seemed to be at an end. The Duke treated him liberally. He provided him with an assistant for his calculations, and he presented him with a printing press. He also obtained for Kepler a professorship.

Later we find Kepler making one more attempt to get his arrears of pension paid by the Imperial Assembly. Probably Kepler thought to provide for his wife and family; he was now fifty-eight years of age. However, his mission was useless, and this seems to have worried him. His health, never good, was weakened by over-study, and he died at the close of his fifty-ninth year, leaving his wife and seven children. They were left very poorly off, but they would have been comparatively rich had the long arrears of their father's pension been paid.

Kepler led a very busy life. He published no less than thirty-three separate works, and left twenty-two volumes of manuscript. In addition to his astronomical work, he was a pioneer in the region of Optics. He was a devout Christian, and a serious student of the Holy Scriptures.

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CHAPTER VIII

GALILEO GALILEI
1564-1642

THE MAN WHO MADE US BELIEVE THAT THE EARTH GOES ROUND THE SUN

Probably every one has some childhood recollections of the story of Galileo. But, if we have made no study of his life, we may have retained exaggerated impressions of the tortures and imprisonments to which he was subjected for the sake of the truths which he proclaimed. It will be of interest to consider some of the real facts that are known about this true hero of Science.

Galileo's father was not wealthy although he came of a very old and noble family, many members of which had held high positions in the Republic of Florence during the two preceding centuries. The family name was Galilei, so that our hero's full name was Galileo Galilei. The Christian and the surname are so very much alike that they remind one of first lessons in Latin Grammar—Mensa, Mensce. It is of interest to inquire how this strange similarity of names came about. The family name of the Galileis' ancestors was Bonajuti. But in the fourteenth century one of the family, whose name was Galileo Bonajuti, became a famous statesman, and in order to perpetuate his Christian name, his descendants agreed to alter their family name from Bonajuti to Galilei.

Our hero is known by his Christian name Galileo, but the similarity of the Christian and surnames is not the reason for this. We should think it strange if we heard the great Gladstone spoken of merely as William, or the famous Disraeli always referred to as Benjamin. But the Italians very often preferred to call their great men by their Christian names, by the places of their birth, or even by nicknames. We speak of Michelangelo, the great painter, but how many people know that his surname was Buonarroti? Indeed, the name Michelangelo Buonarroti looks quite strange. We speak quite freely of the great Dante, but the majority of people would require more than three guesses to hit upon his family name. His name was Dante Alighieri. Then Raphael Sanzio is better known to us by his Christian name. Of course, there are other great Italians who are known by their surnames.

Galileo's father was a learned man. He was a distinguished writer, but his literary work must have been a hobby, for he was a wool merchant, and required to earn his daily bread. The native place of the family was Florence, but Galileo's father was resident in Pisa on account of business, and so it happened that our hero was born in that town, which is famous for its great leaning tower, a photograph of which is shown here.

Galileo was born in the year 1564, so we may picture Galileo as a schoolboy in Italy while Queen Elizabeth and Mary Queen of Scots were reigning in England and Scotland.

So soon as Galileo had completed his elementary education, he was sent to a monastery to receive a thorough literary education at the hands of the monks. He came very near accepting holy orders himself, but his father had other plans for him. His first intention had been to apprentice Galileo to the wool-merchant business, so that he might be of financial assistance to the family. But as Galileo showed exceptional talents, his father decided that the youth should go to the University and study Medicine.

It is in his student days that we see the first signs of Galileo's independence of thought. He had the audacity to question some of the time-honoured doctrines of the ancient philosopher Aristotle. It is difficult for us to realise fully the courage that was required to take such an unusual step. To do so

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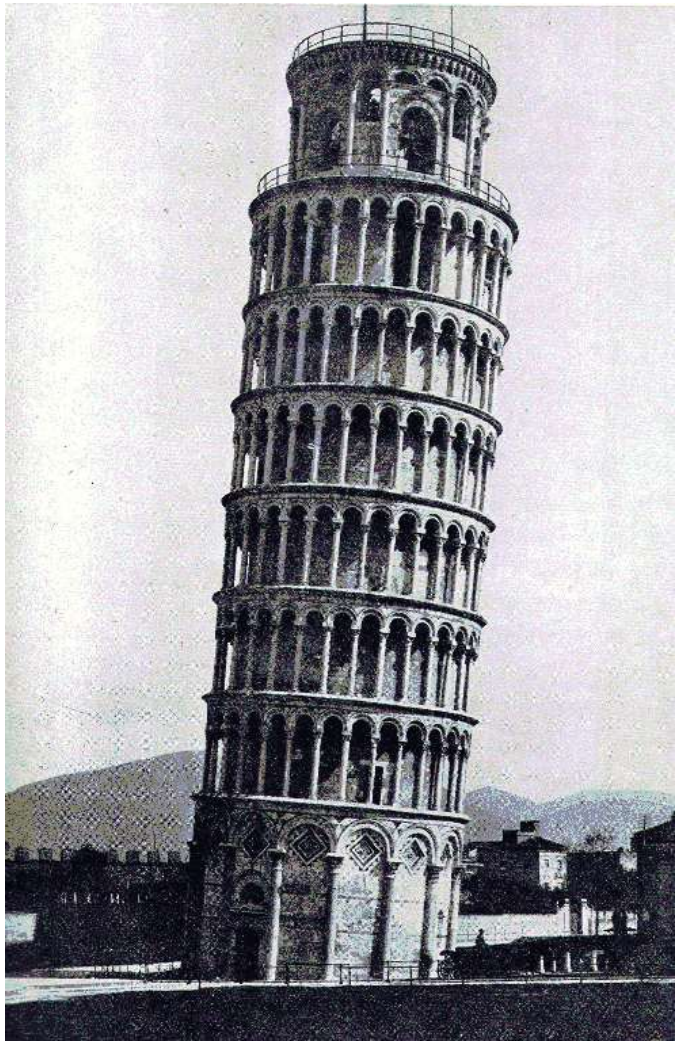
we must keep in mind that in these days a man did not attempt to prove any theory by argument or experiment; it was deemed sufficient if he could give chapter and verse in Aristotle. Galileo's questioning spirit earned for him the title of "The Wrangler," and it goes without saying that this title carried with it no such honour as it did until recently in one of the great English Universities. It is interesting to note that the modern title has been derived from the fact that in the early days of these examinations for mathematical degrees there was a public disputation to test the powers of the candidate, and the successful student was named "The Wrangler."

By the time Galileo had reached the age of twenty years he was an excellent Latin and Greek scholar, and an accomplished artist and musician; still, with all these accomplishments he was very unpopular because of his questioning spirit. There is no doubt that the lad acquired this spirit of independent thought from his father. There occurs this passage in one of his father's books: "It appears to me that they who in proof of any assertion rely simply on the weight of authority, without adducing any argument in support of it, act very absurdly."

One of the most interesting incidents in Galileo's student days was the far-reaching discovery which he made while sitting in the Cathedral at Pisa. It came about in a very simple way. His attention happened to be attracted by the swinging motion of a large hanging lamp, which the verger had set in motion in the act of lighting it. The lamp had probably been pulled to one side and then let go, for it continued to swing to and fro for quite a long time. Of course, its to-and-fro travel would become shorter and shorter until finally it would come to rest. It was a very common, everyday occurrence to which most people would pay no attention. But this young student noticed that the lamp seemed to take just as long to make one of its shorter swings as it had done to make a longer swing. Indeed, he had been impressed, from his first notice of it, with the apparent rhythmic regularity of the motion. There were, of course, no watches in these days, but the medical student, by feeling the regular beat of his own pulse, was able to determine that his surmise was correct.



THE LEANING TOWER OF PISA
FROM THE TOP OF THIS FAMOUS TOWER, GALILEO MADE HIS EXPERIMENT OF LETTING TWO UNEQUAL WEIGHTS RACE TOGETHER TO THE GROUND. THE RESULT OF HIS EXPERIMENT UPSET IDEAS THAT HAD EXISTED FOR CENTURIES, EVER SINCE THE DAYS OF ARISTOTLE.

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Galileo saw that the pendulum provided a regular measure of time. In his day there were some very rough and ready timekeepers, but it does not seem to have occurred to him that his pendulum would be of any service in that direction, although he did make the supgestion half a century later. What appealed to him was the usefulness of such a good timekeeper in enabling a physician to check the pulses of his patients. And so Galileo invented what he called a "pulsilogia." It was simply a length of cord with a weight, so arranged that he could alter the length of the cord conveniently.

The physician could adjust the length of cord so that the pendulum would count out the normal rate of a man's pulse, say about seventy beats per minute. Then it was an easy matter to alter the length of the cord to bring the pendulum into time with the patient's pulse, and it would be apparent whether it was too rapid or too slow. Any irregularity in the beat could be detected also. The axle, which wound up or unwound the cord, carried an indicator which pointed to figures marked on a dial, and in this way the physician could see at a glance the rate of the patient's heart-beats. The physicians were delighted with this invention of the medical student and the pulsilogia soon came into general use.

While Galileo was studying medicine he became interested in Mathematics. His father was well versed in this subject, but at that time the Science was looked down upon by the Italians as a thing of very little value, and Galileo's father purposely kept the subject away from his son, as it did not seem to be a necessary subject for his profession.

There is an interesting story told of how Galileo was attracted at first to Mathematics. A friend of his father was tutor to the pages of the Grand Duke's Court, and while the Court of Tuscany was stationed at Pisa, Galileo went to see this friend of the family. It is said that on one occasion, as Galileo reached the half-opened door of the room in which this great mathematician taught, he overheard some problem of Euclid being explained. Galileo listened to the exposition of this subject, which, although it was "as old as the hills," was entirely new to him. It is said that he not only remained in hiding during this lecture, but that he returned each day to hear more of this fascinating subject. Whether this tradition is well founded on fact or not, it is true that Galileo became so fascinated with Mathematics that he neglected his medical studies, and applied to Ricci, this friend of his father, for more instruction. The great mathematician was delighted with the boy's aptitude for the subject, but when Galileo's father found that the medical studies were being neglected, he asked his friend Ricci to discontinue the lessons. But Galileo was quite able to continue the study on his own account. Indeed, he made such rapid progress that his father could not do otherwise than acknowledge that the youth was a born mathematician. And so it was agreed that his medical studies could be abandoned.

I think this concession says a good deal for the father's unselfishness. He had hoped that as a physician Galileo would be of financial assistance to the family. On the other hand, mathematicians were so poorly paid that the professor in Pisa University earned less in a day than any ordinary tradesman of to-day earns in a single hour. Indeed, the salary of the Professor of Mathematics was almost the same as any office boy gets in his first year of business.

With all his great intellect, which had been made evident already by the production of many brilliant essays, Galileo had a very hard fight to gain the vacant Chair of Mathematics in Pisa, with its lordly salary of thirteen pounds per annum. The disregard in which Mathematics was held in Italy is emphasised when we compare this salary with that obtained by professors of other subjects in the same University; these were counted in hundreds of pounds.

But how would Galileo be received at the University, where he had been nicknamed "The Wrangler"? The professors were all hostile to him, with the exception of the professor of physiology, who had been appointed since Galileo's student days.

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We know that as a student Galileo had been bold enough to argue against some of the theories of the great Aristotle. Now as a professor he was still bolder, offering to disprove one of Aristotle's "truths" by actual experiment. The great Philosopher had said that the time taken by an object to fall was dependent upon the weight of the object. A ten-pound weight would fall in one-tenth the time of a one-pound weight. Galileo had argued the matter and had come to a different conclusion. If two single pound weights each travel at the same rate and fall side by side, will they travel twice as fast if they are merely tied together? His argument was longer than this simple statement, but it was on lines such as these.

So sure was Galileo of his many arguments that he invited the professors and students to accompany him to the great leaning tower, from the top of which he could conveniently let two different weights try an honest race. Galileo mounted the great tower with his weights, which some writers state to have been a one-hundred-pound shot and a one-pound shot, but Galileo was no Samson to carry a hundredweight up to the top of an eight-story building. It is more probable that some of the older writers, who mention a ten-pound and a one-pound shot, are correct. If one weight should travel even in one-tenth of the time of the other, the difference in their times of reaching the ground from such a height would be quite apparent.

I wonder how these assembled Aristotelians felt as Galileo climbed the tower to perform this experimental test. Probably every one of them was prepared to have a good laugh at the expense of the youthful professor who had so far forgotten himself as to dare to question the truths of the greatest of all philosophers; an authority of nearly two thousand years' standing. Possibly some of the older men would be feeling glad to have an opportunity of putting an end to what they considered to be very near to blasphemy.

Picture this crowd of learned professors and students, all positive what would happen. The heavy weight would come flying down, leaving the smaller weight to follow at a respectful and ever-increasing distance. That was bound to happen because the great Aristotle had declared it to be so, long, long ago. But the thoughts passing through the mind of Galileo would be different. He knew what would happen because his reason told him. No doubt there would be a referee at the top of the tower to see a fair start made. The race began and the suspense was broken by the simultaneous thud of the two weights upon the ground. It is difficult to realise what must have been the feelings of the assembled crowd. Some writers say,."Yet the Aristotelians, who with their own eyes saw the unequal weights strike the ground at the same instant, ascribed the effect to some unknown cause, and preferred the decision of their master to that of Nature herself." I doubt if they all did really disbelieve their own eyes. Secretly they must have felt that their master's logic had received a shock. Doubtless they would try all they could to invent reasons why in this particular case the two weights did happen to fall together. Had they honestly disbelieved their own eyes, they would surely have set about making other experiments to support their views. But it is very difficult to give up ideas that have persisted for centuries. Besides, if they should acknowledge frankly even to themselves that Galileo was right, how many more of Aristotle's great doctrines might be false also? Their best plan seemed to be to try and silence this upstart. And so poor Galileo was hissed at his public lectures. The people would feel that they could take this step with safety, for it was well known that Galileo had got into the Grand Duke's bad books.

The Grand Duke had asked Galileo to tell him what he thought of an invention which one of His Royal Highness's sons had made. The Prince had made a model of a large hydraulic machine with which he declared he could dredge the harbour of Leghorn. Galileo reported that the invention was useless, and this decision was proved to be correct when an actual machine was tried. But the Prince was very angry with Galileo, and every one seemed so much against him that the young professor felt compelled to resign his Chair.

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Through the good influence of a friend he obtained the Chair of Mathematics at Padua University, at a salary of thirty-two pounds, or two and a half times as much as he had at Pisa. But Galileo needed all this and more, for by this time his father had died, and the responsibilities of the family rested upon him as the eldest son. He did not improve matters by promising dowries—which were the necessary accompaniments of marriage in those days—for his two sisters.

It is unnecessary to go into all the detail of Galileo's financial troubles. It is of more interest to find that he augmented his small salary by giving private lessons, keeping student boarders, and by becoming what we should now describe as a consulting engineer. Then he opened a workshop in his house for the manufacture of his mathematical instruments. He employed a workman, who came to reside in his house, bringing with him his wife and child. Galileo had to maintain them and pay a small salary over and above.

Our chief thoughts of Galileo centre round the very prominent support he gave to the theory of Copernicus that the Earth goes round the Sun. Italy still held to the theory of Ptolemy in which the Earth was the immovable centre of the Universe. In his lectures Galileo still taught this older theory, but in a letter to Kepler he writes: "Many years ago I became a convert to the opinions of Copernicus." Then he goes on to explain that he prefers to keep silent on the subject, "so great is the number of fools."

Galileo's fame as a mathematician had spread, and many foreign princes and other students came to Padua to be present at his lectures. Among these was an English student, Harvey, who afterwards became famous on account of his discovery of the circulation of the blood.

But if Galileo was so prudent as to refrain from teaching the Copernican theory, how did he ever get into trouble with the Church of Rome? The first step that took him towards a public announcement was his invention of the telescope, and that in turn came about in the following fashion.

An apprentice to a Dutch spectacle-maker had fitted up a curious toy in this optician's shop. The toy consisted of two spectacle lenses so arranged that the weather-cock on a distant church could be seen much nearer and upside down. News of this scientific toy reached Galileo, who seems to have perceived at once that such an arrangement might be of use in spying out the distant heavenly bodies. Although Galileo did not foresee the tremendous advance which this invention would bring about, he is said to have sat up all night thinking out the matter and constructing the first real telescope. But it is the inventor more than the invention that interests us at present.

Galileo tells us that when he showed his invention in Venice, even old men climbed the highest church towers to see ships through his spy-glass. These ships seen approaching the harbour could not be seen with the unaided vision for two hours later.

When Galileo took the instrument to Padua University, he found the Senate so interested in it that he presented the telescope to them. They appreciated this gift so much that they not only raised Galileo's salary to two hundred and twenty pounds, but appointed him professor for the whole of his lifetime. Perhaps it should be remarked that Galileo's salary was not sprung from thirty-two pounds to two hundred and twenty; it had been increased several times, and at the time of his presentation of the telescope it had reached one hundred and fifteen pounds.

In the following chapter we shall see how Galileo's telescope set him on that stormy road which led him to the Inquisition.

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CHAPTER IX

GALILEO BEFORE THE DREADED INQUISITION

In the preceding chapter we have seen how Galileo came to invent the telescope, and now we wish to see how it was that his telescope set him on the road which led ultimately to the Holy Inquisition.

The greatest of Galileo's telescopic discoveries was his detection of four small planets circling around that gigantic planet which we call Jupiter. Imagine the feelings of Galileo! No man had ever beheld such a scene before; he was "infinitely amazed thereat." But Galileo was humbled; he gave thanks to God, who had been pleased to make him the first observer of marvellous things, unrevealed to bygone ages.

The Grand Duke of Tuscany became so interested in the discovery of Jupiter's satellites that Galileo determined to call them by the Grand Duke's family name—Medici—and so these planets were christened the Medicean Stars. Not long after this Galileo was invited to become Mathematician and Philosopher to the Court of Tuscany at Florence. This was a post that he had desired, because it would give him time to make further investigations.

The interest in Galileo's new stars was not merely local. The Court of France was quite excited about the matter. The French Queen was one of the Medici family; she had married King Henry IV of France. We are told that when a telescope from Galileo arrived at the Palace, the Queen was so eager to see the moon's appearance through the telescope that she did not wait for the instrument to be placed in position, "but went down upon her knees before the window, thereby greatly astonishing the Italian gentlemen who had brought the telescope into the Royal presence."

We learn from a letter of Galileo's to the private secretary of the Duke of Tuscany, that the French Court had been very anxious that Galileo should name some heavenly body after their King. Galileo did not make this fact known until after the assassination of Henry IV, and his reason for quoting from the letter was to show what an honour was supposed to be connected with his discovery.

The part of the letter from the French Court which refers to this royal request reads thus: "The second request, and the most pressing I can make you is, that when you discover some other beautiful star, you would call it by the name of the great Star of France, by far the brightest in all the earth; and rather by the name of Henry than by the appellation of Bourbon, if it so please you. By so doing, you will do a very just, right, and proper thing; you will gain renown, and likewise lasting riches for yourself and your family. Of this I can assure you on my honour. Therefore, pray discover as soon as possible some heavenly body to which his Majesty's name may be fitly attached."

But what had the professors and students of the old Aristotelian school to say to this new discovery of their despised philosopher? They tried to prove in their own fashion that the new planets did not exist. Here is one of their arguments, set forth by a great astronomer of Florence. There were only seven apertures in the head—two eyes, two ears, two nostrils, and one mouth; and again, there were only seven metals, and only seven days in the week, therefore there could be only seven planets. Another argument was that as the supposed planets were invisible to the naked eye, they could exercise no influence on the earth; and being useless, they therefore did not exist.

Others argued that the new planets could not exist because Aristotle had made no mention of them. One great mathematician declared that before the new planets could be

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seen they must first be put inside the telescope. Professors refused to be convinced, declining to look through a telescope. When Galileo was told of the death of one of these obstinate professors, he said, "He did not choose to see my celestial trifles while he was on earth; perhaps he will now he has gone to heaven." One should admire Galileo for granting such a violent opponent so good a resting-place.

Galileo was very sarcastic in his reply to the many arguments offered against the existence of the new planets. He said the arguments were so weighty, that had he heard of them earlier he would have been bound to acknowledge that only seven planets could exist, but now that he had actually seen the four new planets he did not consider the arguments sufficiently strong to destroy the heavenly bodies. Even some of those Aristotelians who did look through the telescope at Jupiter's satellites declared that the whole affair was a huge deception; while the telescope was good enough for examining terrestrial objects, it was altogether false and deceptive when applied to the heavens. Galileo made several important astronomical discoveries, and these were spoken of as Galileo's "celestial novelties." Other astronomers who had obtained telescopes laid claim to having discovered some of these things before Galileo, but there is no doubt that Galileo was first in each case.

He determined to go to Rome and show his new discoveries. He was received as a great man. A commission of four scientific members of the Roman College reported that they were convinced of the truth of Galileo's discoveries. The Pope, Paul V, assured Galileo of his good-will, and before Galileo left for home he had a large number of admirers in Rome. However, when he published a book on *Floating Bodies* he had all the Aristotelians up in arms against him. But how did Galileo get into serious trouble with the Church of Rome?

Galileo's old pupil Castelli was now Professor of Mathematics in the University of Pisa, Galileo's first post. Castelli was forbidden to teach that the Earth went round the Sun. Nevertheless, he was a faithful disciple of Galileo; indeed, it was his very faithfulness that brought trouble upon his master. Castelli was at a dinner-party at the table of the Grand Duke of Tuscany, and among the guests was a brother professor who was an out-and-out Aristotelian. This man tried to poison the mind of the Dowager Duchess. He said that although Galileo's discoveries about the heavenly bodies were true, yet he was wrong entirely in supposing that these proved that the Earth went round the Sun. He declared that to say so was in direct opposition to the Holy Scriptures, and that therefore the Church was in danger. The Dowager Duchess asked Castelli what he had to say in the matter. This faithful follower of Galileo did his best to keep the Bible out of the discussion, but this was impossible, as the question to be answered was whether or no the new doctrine about the Earth's motion was compatible with the Holy Scriptures. Castelli succeeded so well in defending Galileo's doctrine that all the guests agreed with him, only the Dowager Duchess opposed him, while the Aristotelian professor who had raised the question took no part in the argument.

Castelli wrote a long letter to his master Galileo, telling him what had occurred at the dinner-party. A complete copy of this letter is given in an Appendix at page 333. It was in answer to this letter that Galileo penned the letter which ultimately got him entangled with the Holy Office. As this letter is of special interest also, a copy of it is given in the Appendix, immediately following Castelli's letter. The idea of the letter is fairly well summed up in a sentence which Galileo used on another occasion: that the Bible was intended to teach us not how the heavens go, but how to go to heaven.

There is no doubt that Galileo intended his letter for his friends' private satisfaction only. But it seems doubtful if Castelli recognised it as such; indeed, some historians say that he had many copies made so that they might be circulated widely, his object being to convince others of the great truths. On the other hand, Galileo seems to have believed that a copy of the letter was obtained by treachery and handed to certain monks.

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A Jesuit, preaching at one of the cathedrals in Florence, attracted the attention of the people by taking as his text what was intended as a pun on the name of Galileo Galilei, the astronomer, and a thrust at his followers and their telescopes: "Ye men of Galilee, why stand ye gazing up into heaven?" The first head of his sermon was that mathematics was a diabolical art, and the second was that as mathematicians were the authors of every heresy, they ought to be exiled from all Christian States. Galileo wrote about this to one of the high dignitaries of the Church, with whom he was very friendly, and this holy father replied that he was greatly mortified that a Dominican should have committed such a piece of foolery, and that he would endeavour to get the preacher to retract what he had said from the pulpit.

The matter did not end in so simple a manner. For this preacher, Father Caccini, was called to Rome to be questioned by the Holy Office. Needless to say, this enemy of Galileo did all in his power to blacken our hero's character. The Holy Office listened to what was in reality mere hearsay among the monks. So-and-so had once told him that another person had said this and that. This so-called evidence, along with a copy of the ill-fated private letter from Galileo to Castelli, were the beginning of Galileo's trouble with the Holy Office.

Galileo went to Rome thinking he could set matters right. The authorities appeared to be quite friendly to him, but Galileo could see that all was not right. However, he was not prepared for what was to come. The official experts of the Inquisition were asked to report upon Galileo's doctrines. They declared that his statement that the Earth moved round the Sun was "false and absurd philosophically, and formally heretical, inasmuch as it expressly contradicted the doctrine of the Holy Scriptures."

The Inquisition instructed Cardinal Bellarmine "to summon before him the said Galileo and admonish him to abandon the said opinion"—that the Earth moved round the Sun. Galileo promised to obey. There the matter seemed to end, and soon afterwards Galileo returned to Florence.

A few years later Cardinal Barberini, a personal friend of Galileo, was elected to the papal throne. He took the title of Pope Urban VIII. An influential friend urged Galileo to travel to Rome in order to congratulate the Pope in person. Although Galileo was not at all strong he made this journey, and was amply repaid by the very cordial reception he got. When Galileo left Rome, the Pope wrote a most generously worded letter regarding him to his patron the Grand Duke of Tuscany. With reference to the Copernican theory that the Earth moves round the Sun, the Pope said "the Church had not condemned this system; and that it should not be condemned as heretical, but only as rash."

About a dozen years later (1630) Galileo completed his great work, which is known as the *Dialogue on the Two Principal Systems of the World*. The two systems were the *Ptolemaic System*, at the centre of which was the Earth, and the *Copernican System*, at the centre of which was the Sun. Galileo once more journeyed to Rome in order to get permission to publish this book. The manuscript was carefully read by the officers of the Church, and their permission was given to print the book, provided a suitable preface and conclusion were inserted. The purpose of these seems to have been that it should be made clear to the reader that the idea of the Earth going round the Sun was purely hypothetical.

Galileo left Rome, promising to make these stipulated additions.

A serious outbreak of plague prevented Galileo sending back the amended manuscript to the printers at Rome. He asked permission to have it printed in Florence, and this was granted provided that Galileo sent the preface and conclusion to Rome to pass the Censor. This high official seems to have detained the manuscript of these beyond all reasonable time. But at last the great book was published (1632) and Galileo sent copies of it to his followers throughout Italy. Those for Rome were delayed on account of the plague. But not long after the arrival of the book in Rome a communication was sent to the Inquisition by a Jesuit.

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The result of this was that Galileo's publisher was ordered to suspend the publication and to send to Rome all copies which he had in his possession. But by that time there was not a single copy left.

Poor Galileo! He had obtained full permission of the Church to publish his great work, and now these same authorities withdraw the book. But why should Galileo's personal friend Pope Urban VIII turn against him? Some of the earlier historians have blamed Galileo for wantonly defying and insulting the Church in his dialogues, but not only did he refrain from any such imprudence, he inserted many reservations simply to please the Censor.

The idea of writing in dialogues was very old and not uncommon.

Galileo had three speakers in his book. One of these he called *Salviati*, after an old personal friend long deceased. This speaker advocated the Copernican theory, while another of the speakers, who was a half-convert, and who had many objections to raise, was named *Sagredo*, after another personal friend who had died some time previously. The third spokesman was named *Simplicio*, after one of Aristotle's contemporaries and supporters. He raises all the Aristotelian difficulties in accepting the Copernican System. This man shows up very poorly as compared with the two others, and, indeed, he appears a simpleton.

Galileo's enemies, the Aristotelians, led the Pope to believe that Galileo had willfully put this Simplicio into the dialogues to represent the Pope. These enemies were able to point to some arguments used by Simplicio which were those suggested by Pope Urban himself. Galileo brought up every argument he could think of against the Copernican theory, but needless to say, he was not so ungrateful as to willfully insult the Pope. But the Pope believed the evil suggestion, and he was furious. He was easily persuaded to take action against the book.

The Duke of Tuscany thought there must be some misunderstanding, as Galileo had obtained full permission to publish the book. The Duke ordered his Ambassador at Rome to call upon the Pope and explain matters, but he had a bad reception, and at this interview the Pope spoke of Galileo as "he who did not fear to make game of me." Some writers have not been willing to accept this version of what took place, saying that all along the Pope had the best of feelings towards Galileo; that it was merely the doctrine, and not the man, that concerned him. However, it is difficult to accept this suggested interpretation.

Galileo was then accused of deliberately transgressing the command laid upon him sixteen years previously: to abandon the idea that the Earth goes round the Sun, We must remember, however, that in the interim the Holy Office had given Galileo permission to publish the very book over which all this trouble was now being made. The Pope himself was aware of the command to abandon the theory; indeed, he was one of the Cardinals who had had to investigate the matter, and, moreover, he was an unwilling party to the command.

Galileo's case was handed over to the Inquisition, and he was ordered to appear at Rome within the next month. But our hero was in very indifferent health, and now well advanced in years. Besides these disadvantages, there was a great risk of plague, which had broken out again, so that travelling was dangerous. We can sympathise with the old man trying to put off the evil day. He offered to submit himself to the Archbishop, who was the Inquisitor in Florence. But the Pope insisted on Galileo going to Rome to appear in person before the Inquisition there. There was further delay on account of illness, but ultimately Galileo set out in a litter, or bed-chair, provided by the Grand Duke.

Three weeks later Galileo arrived in Rome, not to be cast into prison, but to remain in comfort at the Embassy, the only condition laid upon him being that he stayed indoors. There was a long delay of about two months before the old man was

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brought before the dreaded Inquisition. It is to the Pope's credit that even during the trial he did not allow Galileo to be treated as an ordinary prisoner; he was never placed in a prison cell, much less a dungeon. And we should remember that it was the custom to put princes, prelates, and noblemen in the dungeons while the trial lasted. While Galileo could not be allowed to return to the Embassy each evening, he was housed comfortably in the building of the Holy Office; his doors were not even required to be locked.

Galileo's friend the Ambassador urged him not to attempt to defend himself, and so our hero recognised that discretion was the better part of valour. Some writers have deplored Galileo's lack of courage. They have drawn comparisons between him and the Christian martyrs. But surely the cases are in no way similar; there was no question of conscience. Had Galileo elected to be burned at the stake, his cause would not have been helped forward one bit. His cause was not one that called for any such sacrifice. Whether a man believes that the Earth goes round the Sun, or the Sun round the Earth, will not affect his spiritual welfare.

At Galileo's first appearance before the Inquisition he defended himself in so far that he declared he did not consider that he was disobeying his previous admonition by writing the book which had brought him there. The Inquisition insisted that the admonition said "not to teach in any way whatever, verbally or in writing." Galileo was surprised at this reading of the admonition of sixteen years ago, but anxious to end matters as soon as possible, he replied, "It may be so, but I do not remember it." But unfortunately the poor old man did not content himself with that. He proceeded to try and convince his judges that his book argued as much in favour of one system as the other; indeed, that its arguments favoured the old idea. Of course, we know that the intention of the book was to defend the Copernican theory, and that fact must have been quite apparent to the Inquisition. This put Galileo in a bad position; it made the duties of the Inquisition more difficult. There is not the least doubt that the Inquisition desired to make the trial as easy as possible for the aged philosopher.

The Commissary-General, who was one of the judges, proposed privately to the others that he should be allowed to point out to Galileo that he was hurting his own case in denying the real purpose of the book. This was agreed to, and after some kindly argument the good-hearted judge persuaded Galileo to confess his error. Hence at the next trial we find Galileo making a humiliating confession.

At a further trial Galileo was commanded to deny the doctrine that the Earth is not the centre of the Universe, and that it moves. His reply was: "I do not hold, and have not held, this opinion of Copernicus since the command was given that I must abandon it. For the rest I am here in your hands; do with me as you please." No doubt we have a feeling of disappointment, but we must remember that this abjuration was arrived at by fear of actual torture being resorted to should he refuse to recant. The popular story that as Galileo rose from his knees he muttered, "But nevertheless it moves," is acknowledged now to be quite absurd. No doubt many of us thought it quite ridiculous even in our schooldays.

The Inquisition felt that it was necessary to pronounce sentence of perpetual imprisonment. Galileo had gone contrary to the teachings of Holy Scripture, at least so they thought or pretended to think. However, his imprisonment was of a very lenient order. He was allowed to reside in that villa in the garden of which he had years before shown his "celestial novelties" the Cardinals and others. Of course, the whole affair must have been a very great punishment to the aged philosopher, but we have a very different picture from that of actual torture and imprisonment in secret dungeons.

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CHAPTER X

A GLIMPSE OF GALILEO'S PRIVATE LIFE

In tracing the story of Galileo, in the two preceding chapters, I have avoided purposely much that is of interest in his private life, in order to make the different steps towards the Inquisition quite clear. There are some points of interest, however, which throw further light upon the character of our hero.

Some readers may have wondered how Galileo got along, while Professor of Mathematics at Pisa, on the small salary which he received. He tells us that he gave public lectures on his own account; he gave private tuition, and he kept as many as twenty students as boarders, looking after the housekeeping himself. It is interesting to note that the late Lord Kelvin's father, Professor Thomson, had to resort to public lectures on his own account when he became Professor of Mathematics in Glasgow University. The reason for the small salary in this case was that the retired professor had the first claim on the salary, and there was not much left for the new professor. But we shall hear something of Professor Thomson when we come to consider the life of his distinguished son, Lord Kelvin.

In Galileo we find the same ingenious mechanical ability as in Lord Kelvin; both employed workmen to manufacture and sell instruments which they had invented.

We have remarked already that part of Galileo's financial difficulties was due to the payment of dowries promised to his two sisters' husbands. His brother was also a burden upon him; not only did he fail to pay his share of the dowries, but he required assistance for himself and his family. Then Galileo had to provide money to place his two daughters in a convent. One of these girls, whose religious name was Sister Maria Celeste, was a great favourite with the father. That the father and daughter were very much devoted to one another is abundantly clear from the correspondence preserved by Galileo.

THE HOME OF GALILEO GALILEI.
GALILEO IS ONE OF THE MOST INTERESTING HEROES OF SCIENCE. THE STORY OF HIS LIFE IS TOLD IN CHAPTERS VIII, IX, AND X.

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Maria Celeste was always wondering in what way she might be of any assistance to her "very illustrious and most beloved lord and father," as she so often styled him. We hear very little of the other sister, who seems to have been wanting in the devotion of Maria Celeste, who was a great comfort to her father. Galileo preserved all her letters, and although his letters to her were probably destroyed at the convent upon her death there, we can see from Maria Celeste's replies that her father's letters were very much prized by her. On one occasion she writes, "I put by carefully the letters you write me daily, and when not engaged with my duties I read them over and over again. This is the greatest pleasure I have."

Sister Maria Celeste was so very grateful to her father for every attention paid to her that one is inclined to think she had in mind the fact that she had no legal claim upon her father. Her mother had lived with Galileo without any marriage ties, and when she married another, evidently with Galileo's good-will, she left the two daughters and the one son with the father. But Maria Celeste was a very real daughter to her father; her distress at his misfortunes is most pathetic. When news came that Galileo was free to leave Rome Maria Celeste wrote: "I wish I could describe the rejoicing of the Mother and Sisters. On hearing the news Mother Abbess and many of the nuns ran to me, embracing me and weeping for joy and tenderness."

Galileo was known personally to those in the convent through his visits to his daughter. They even asked him on one occasion to mend their convent clock (a primitive timekeeper) and to help them in other ways.

Galileo's son Vincenzio was often a great worry, as well as a cause of considerable expense. The selfishness of the son is in sorry contrast to the daughter's devotion. But one is pleased to find that Vincenzio was attentive to his father in his old age. It was Vincenzio who drew the flan of a pendulum clock according to his aged father's dictation. But before the idea could be carried out Galileo died, and strange to say, the son did not make any use of the idea till seven years later. Unfortunately, while he was engaged in this first attempt to construct a pendulum clock he, too, fell ill and died. It was some five or six years later that the distinguished Dutch scientist Huygens constructed the first clock controlled by the regular to-and-fro swing of a pendulum.

These few incidents give us a glimpse of Galileo's private life. We cannot wonder that at times he became despondent under the treatment he received at the hands of the Inquisition. While he was not subjected to physical torture, we find him suffering under the great restraint put upon him. On one occasion we find him cursing the time he has devoted to these labours, and regretting having given so much of his results to the world. "I feel even the desire to destroy for ever, to commit to the flames, what remains in my hands. Thus I should satisfy the burning hate of my enemies. These thoughts aggravate my numerous physical sufferings, and cause me persistent insomnia."

It is of interest to note what great personages were living in our own country while Galileo was playing his important part in Italy. We saw in the preceding chapter that while Galileo was a schoolboy in Italy, Queen Elizabeth and Mary Queen of Scots were reigning here. But they had both passed away before Galileo's troubles began, for at the time he invented the telescope James VI of Scotland had become James I of England. Even he had died before Galileo was in serious trouble with the Inquisition, so that Charles I was King of England at the time of Galileo's death.

Among the great personages who lived here during Galileo's lifetime were Shakespeare, and, of course, Lord Francis Bacon. Also the famous Dr. William Gilbert, who was the first to make a serious study of those phenomena which are classified under the title of Electricity and Magnetism. It is interesting to find that Galileo, in his dialogues, gives great praise to Gilbert, for we know that Bacon, on the other hand, sought to belittle Gilbert's great work.

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Our world-famous poet John Milton visited Galileo in his captivity in Italy. This was long before Milton became blind; he was then a young man of twenty-nine years. Galileo by that time was totally blind, and had reached more than the allotted span, being about seventy-five years of age. When Milton addressed the Lords and Commons against the proposed licensing of printed books, he made mention of his visit to Galileo in his captivity.

It is interesting to note that in the year in which Galileo died the great English scientist Sir Isaac Newton was born.

Galileo's great mind was active to the very last, despite his constant sufferings. Some of his enemies sought to prevent Galileo's friends burying the philosopher's body in consecrated ground, but this permission was granted, on the understanding that the great public funeral, which had been arranged, should be abandoned. The Pope requested also that the proposed public monument should be cancelled. But modern Italy has done much to amend matters. In 1841 an exquisite temple of Galileo was opened; the cost of this monument is said to have been forty thousand pounds. Since then the Scientific World has done public homage to his name on three occasions. First on the three-hundredth anniversary of his birth, then on the three-hundredth anniversary of his first lecture in Padua, and more recently on the tercentenary of the invention of his telescope. All these great international commemorations should help us to realise how very much we owe to this great Hero of Science.

CHAPTER XI

THE GREAT SIR ISAAC NEWTON
1642-1727

We have seen that as Galileo was called off this world's stage, Sir Isaac Newton was ushered on, the death of the former occurring in the same year as the birth of the latter, which was in 1642.

Judging by appearances the infant Newton seemed to have but a poor chance in this world; he was so very small and so delicate. Indeed, he had such a slender hold on life that two women, who were sent to a neighbouring house for some medicine for the infant, did not expect to find him alive on their return. Newton used to tell how he had often heard his mother say that when he was born he was so small that they might have put him into a quart mug. His father had died a few months after marriage, at the age of thirty-six, so that our hero was born an orphan. The widowed mother named the infant Isaac after his deceased father.

The manor-house of Woolsthorpe (Lincolnshire), in which Newton was born, had been in the possession of the family more than a hundred years. It produced only a small income, about thirty pounds per annum, leaving out of account what could be made by working the farm.

When Isaac was still a child his mother was married to the Rev. Barnabas Smith, rector of a neighbouring parish. Isaac was left under the care of his maternal grandmother, who saw that he got as good an education as could be got in the neighbouring villages. At the age of twelve he was sent a little farther afield, to Grantham. Although this town was only half a dozen miles distant, it was necessary for the boy to board in the

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town, so that he might attend the Grammar School. He boarded with an apothecary named Mr. Clark.

Isaac had not distinguished himself at school, unless by being very often in the lowest place in his class, but from what follows we shall see that he cannot have been taking any very serious interest in his lessons; probably his mind was engrossed in other thoughts. But one day, as he was on his road to school, a schoolmate gave him a very nasty kick in the stomach, whereupon Newton challenged the boy to fight. The duel came off in the churchyard, and Newton proved the victor, but not content with this physical victory, he determined to get above this boy in his class. By applying his mind to his lessons, Isaac not only surpassed his antagonist, but soon found himself at the top of the school.

Had Newton lived at the present time he would, I fear, have been unpopular, for he did not join much in his schoolfellows' games, although he found plenty of time to construct models of machines and other contrivances. He made an excellent working model of a large windmill that was being erected in the neighbourhood of his school. Among the other things that he made there was a water-clock. The idea was, of course, a very old one; he allowed water to drop at a regular rate, and as the level of the water in the cistern fell, a wooden float operated the hand of the clock. Rough and ready as all such "clepsydras" were so far as keeping good time, the inmates of the apothecary's house often peeped into Isaac's bedroom to see what time it was. Hour-glasses, or as they are more descriptively named sand-glasses, were the most common time-keepers in those days.

As Newton had a definite hobby he would never find time to hang upon his hands. He was keen in everything at which he worked, being described as "a sober, silent, and thinking lad." It is refreshing to see a glimpse of innocent mischief in this seriously-minded boy. He had shown his playfellows how to construct paper kites, and in what manner they would fly best. He had also constructed paper lanterns to hold candles and light the boys to school on dark winter mornings. This led to the one little piece of mischief recorded of his boyhood. Knowing that the country folk were very suspicious about comets, Newton tied one, of his lanterns to the tail of a kite, and put this up in the air on a dark winter night; he succeeded in terrifying the villagers.

One occasionally sees, in the windows of bird-fanciers, small mouse-mills in which a live mouse gives motion by running in a sort of treadmill. It is interesting to note that this was invented by Isaac Newton in his boyhood. According to one learned French writer, Newton called his mouse the Miller, "because it directed the mill, and ate up the flour as a real Miller might do."

When Newton was fourteen years of age his step-father died, and his mother returned to the manor-house. As Isaac had now reached the age at which most boys were ready for work, his mother thought it was time he should begin his apprenticeship to farming, and so he returned home from Grantham.

Although Isaac's twice-widowed mother was now Mrs. Smith, I shall continue to speak of her as Mrs. Newton. She had the small income derived from Woolsthorpe, and a larger income (about eighty pounds per annum) from a neighbouring estate which she possessed, but it was necessary to increase the annual income by farming the land around the manor-house. At the same time, we must remember that money went much farther in those days.

As Isaac would be the proprietor of Woolsthorpe it was natural to take for granted that he was to be a farmer. With this object in view he was sent to Grantham on each market day, under the care of an old and trusted man-servant. But Isaac made a shockingly bad apprentice. As soon as they reached Grantham, and had put up their horses at the Saracen's Head Inn, Isaac left the old servant to look after the marketing, while he himself went off to his old lodging in the Apothecary's house, to spend his time among the chemist's stock of books, and remaining

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there until called for on the return journey. The young master's conduct must have been very disappointing to the old servant. It would be hopeless to teach him anything about marketing; indeed, sometimes the old man did not succeed in getting his pupil to reach Grantham. On these occasions the would-be instructor had to be content to leave the boy under a hedge by the roadside with some book of study, and on the return from the Grantham market he would find Isaac still buried in his book.

I have no doubt that this trusted old servant would feel compelled to inform Mrs. Newton that Isaac would never make a farmer. Indeed, she must have foreseen this herself, for when she sent Isaac to the fields to watch the sheep or cattle, he would perch himself under a tree, intent on some book, or keenly interested in making some model, quite oblivious of the fact that his charges were wandering among the corn. Some parents would have taken the books out of the boy's reach, and insisted that he must attend to his duties, but Mrs. Newton acted more wisely; the boy was not reading for amusement, he was thirsting for knowledge. We may presume that she consulted her brother who was rector of a neighbouring parish, for it seems to have been the boy's uncle who suggested that the idea of farming should be abandoned, and that Isaac should return to Grantham to be prepared for college.

Isaac still found time for working with his hands. Having made close observations of the shadows produced by the Sun on the front of the apothecary's house, he set about constructing a sundial. It was quite an ordinary thing for the country people to consult "Isaac's dial "when they wished to know the time. Of course, sundials are of very ancient origin, but dials had to be made to suit the place and situation. Isaac had no knowledge of how to adjust these to the latitude of a place, and so he depended entirely upon his own observation. He erected two similar dials on the manor-house at Woolsthorpe, and one of the stones of the wall upon which the dial was carved is now preserved in London by the Royal Society, not because of any scientific novelty, but because of its sentimental value.

Newton used to tell, in later life, how he remembered the great storm that occurred on the day on which Oliver Cromwell died? The force of the wind was very great, and Newton had attempted to measure it in a rather ingenious manner. First he jumped with the wind, marking off the longest distance he could cover. Then he jumped against the wind, making a similar measurement, and afterwards comparing the difference between these longest jumps. When his companions were surprised at his saying that any particular wind was a foot stronger than any wind he had measured before, he would take them to see the marks of his jumps. Of course, there was a very large personal equation entering into any such measurement.

At the age of eighteen years Isaac was sent to Trinity College, Cambridge, at which college his uncle had been a student. It may be noted in passing that Cambridge had not been long inclined to Mathematics; it was only in the beginning of the seventeenth century that the University authorities showed themselves specially interested in Mathematics.

Newton did not take any distinguished place in his college classes. His schooling had been inferior to that of the majority of his fellow-students. But Newton had made a name for himself in the small world which he had left at Grantham. We are told that on the day on which Newton left the public school, in order to go to Cambridge, the old schoolmaster, with the pride of a father, placed his favourite pupil in the most conspicuous place in the school, and, with tears in his eyes, having made a speech in praise of Newton's character and talents, held him up to the school as a proper object of their love and imitation.

We know practically nothing of Newton's first few years at Cambridge, but two recorded facts show how very easily he mastered a new subject. His clergyman uncle had given him a book on Logic while he was at home, and so thoroughly had Newton mastered this subject that when he attended the lectures on Logic at college, his teacher was surprised to find the lad was further advanced than he himself was. This teacher invited

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Newton to attend a series of lectures he proposed giving to some Gentlemen Commoners. And in order that the youth might be able to follow the lectures his teacher advised him to read Kepler's Optics. Here we have a very direct link with our hero of Chapter VII, who had died only twelve years before Newton's birth. Newton mastered Kepler's book so thoroughly that when the lecture time came his teacher found the student was conversant already with all that he could tell him.

About three years after Newton's arrival at Cambridge, he happened to be at a fair which was held on the outskirts of the town. There he bought a book on Astrology, in which he came upon a geometric figure which he could not understand. In order to find out the meaning of this figure he bought a book of Euclid, and after glancing through it until he found what he required, he cast it aside, surprised that any one should trouble to demonstrate so many truths that were so self-evident. Some readers may be a little surprised at Newton's verdict, for in our schooldays a number of the problems did not seem to us so very Q.E.D., which symbols, although signifying *quod erat demonstrandum*, we pretended to read "quite easily done." Indeed, we sometimes used this translation in a rather sarcastic sense. But Newton himself found out later that the problems were not all so very self-evident as to require no explanation, for when he was examined for a scholarship, the Professor of Mathematics (Dr. Barrow) formed a very poor opinion of Newton's knowledge of Euclid. And at a later period in life Newton writes: "I regretted having applied myself to the works of Descartes (Geometry), and other algebraic writers, before I had considered the 'Elements of Euclid' with that attention which so excellent a writer deserved."

When twenty-two years of age Newton took his B.A. degree, but evidently without taking any prominent place in the examination list. In this same year (1665) the college was dismissed because of the Great Plague, which in the autumn cut off sixty thousand people in London alone. It was during this vacation at his own home that Newton saw the historic apple fall from the tree.

I remember, when I was a boy, listening to a lecture on Newton. The lecturer was an amateur, and he sent us away with the idea that it was Newton who discovered gravitation or, in other words, that it was he who first suggested that apples fell down because the Earth attracted them and all other bodies to it. I wonder how the other members of the audience felt when they found later that gravitation was well known long before Newton's time, and that his discovery was of far greater interest because he extended the idea of gravitation far beyond the compass of this Earth. He suggested that it was the same attractive force which bound the Moon to the Earth, and the Earth and the other planets to the Sun.

The story of the falling apple has been disbelieved by some writers, because Newton did not mention it to the scientists to whom he stated his first ideas of Gravitation. Newton himself did not record the story, but that is not very convincing evidence, for he might not consider such an apparently trivial affair to be of general interest. But the story was confirmed by Newton's niece, who lived in his household for the last twenty years of his life. She told Voltaire that the story was true, so that our only questioning of this evidence could be whether the niece ever got the story confirmed by her uncle, or whether she herself believed the story because she had probably heard it so often. Sir David Brewster saw the apple tree in 1814, and took away part of its roots, but in 1820 the tree was so decayed that it was cut down, the wood being carefully preserved thereafter.

The truth seems to be that Newton, then about twenty-three years of age, was sitting under the apple tree, thinking about the forces of Nature. He was well acquainted with Descartes' ideas of the planets being carried round in whirlpools of a space-pervading fluid, each having its own eddy by which it was impelled and kept in position. Probably this theory, though long upheld, would appear too fanciful to Newton, because he had calculated by means of Kepler's Laws (mentioned in Chapter

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VII) that a central force at the Sun would account for the motion of the planets at their respective distances. The falling apple would suggest to him the idea that the common force of gravitation might extend beyond this Earth, and so he sought to apply its laws to the whole Universe. But when he calculated what the pull of Gravity would be at the distance of the Moon, he did not get his figures to agree with observed facts regarding the velocity of the Moon, and so the great philosopher laid the matter aside. Indeed, he seems to have been quite satisfied that his idea was a mistaken one, for he, tells us later that he gave no further thought to the matter, nor did he even mention his idea to any one.

After Newton had remained at his country home for about two years, the Plague had so far abated that he returned to Cambridge. He would have little time for any original research work till he passed his final examination for his MA. degree. In this examination he came out twenty-third on the list. It is difficult for us to realize that such a great genius as Newton should not have been an easy first in all examinations. Indeed, one is inclined to surmise that the great thinker did not give his undivided attention to the subjects for the examinations; he would be more concerned in acquiring knowledge that might be more useful to him, than what was of temporary interest to enable him to pass an examination. It is evident that for some years his studies covered a very wide field.

Dr. Barrow, the Professor of Mathematics, was so impressed with Newton's mathematical powers, that he decided to secure Newton's election to the Chair, while he himself resigned and devoted his energies to the study of Theology. Newton, in this way, became professor at, the age of twenty-six.

The name of Newton is very prominent in connection with the subject of Light, and it is evident that he had mastered a great deal of that subject before he became Professor of Mathematics. For while Dr. Barrow still occupied that important Chair, he had written a book on Optics, and he had asked Newton to read the manuscript for him. Young Newton had been able to make some important suggestions, but some parts of the subject were still primitive. A single quotation from Dr. Barrow's book will show the ideas of colour which he and Newton entertained at that time. "The blue colour of the sea arises from the whiteness of the salt which it contains, mixed with the blackness of the pure water in which the salt is dissolved."

It was the duty of the Professor of Mathematics in these days to lecture once a week on such subjects as Astronomy, Geography, or Optics, and Newton took Optics as the subject of his early lectures. These lectures contained a great deal of original research, but he did not publish them until after his election to the Royal Society of London, which was a few years later.

There is preserved an interesting letter written by Newton about this time, and as it throws some light upon his character, a few quotations will be of interest. A young gentleman, who was going abroad to see the world, had written to Newton asking advice. A few of the general rules laid down in Newton's reply are these: ". . . It is the designe of travellers to learne, not to teach. . . . If you bee affronted, it is better in a forraine country, to pass it by in silence, and with a jest. . . . Your credit's ne'er the worse when you return into England, or come into other company that have not heard of the quarrell. But, in the second case, you may beare the marks of the quarrell while you live, if you outlive it at all. . . . Such excuses as these—'He provok't mee so much I could not forbear'—may pass among friends, yet amongst strangers they are insignificant, and only argue a traveller's weaknesse."

Then in a long list of things to be observed by the traveller, we notice that Newton had some belief in Alchemy, for one instruction to the young man is: "I you meet with any transmutations out of their own species into another, as out of iron into copper, out of any metall into quicksilver, . . . those, above all, will be worth noting, being the most luciferous." And again he says: "There is in Holland one—Borry, who some years

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since was imprisoned by the Pope, to have extorted from him secrets (as I am told) of great worth, both as to medicine and profit, but he escaped into Holland where they granted him a guard. I think he usually goes clothed in green. Pray enquire what you can of him, and whether his ingenuity be any profit to the Dutch. You may enquire if the Dutch have any tricks to keep their ships from being all worm-eaten in their voyages to the Indies."

In laying down the general rules in this letter Newton remarks that his friend will no doubt have considered many of these already—"but if any of them be new to you, they may excuse the rest; if none at all, yet is my punishment more in writing than yours in reading."

The foregoing letter is sometimes referred to as having been written by Newton to "a young friend." It is true that the friend was young, but Newton was one year younger. I remark upon this because, if one reads this celebrated letter by itself, one is apt to picture Newton as a man of advanced years, whereas he was only twenty-six years of age at the time he wrote this letter.

We have some interesting information concerning Newton's life at college, written in the year in which Newton died. It was written in a letter by the son of John Wickens; the father had been Newton's chamber-fellow at college for about twenty years. The following extracts from this letter will be of interest: "My father's intimacy with him came by mere accident. My father's first chamber-fellow being very disagreeable to him, he retired one day into the walks, where he found Mr. Newton solitary and dejected. Upon entering into discourse, they found their cause of retirement the same, and thereupon decided to shake off their present disorderly companions and chum together, which they did as soon as conveniently they could, and so continued as long as my father stayed at College.

"I have heard my father often say that he has been a witness of what the world has so often heard of Sir Isaac's forgetfulness of food when intent upon his studies; and of his rising in a pleasant manner with the satisfaction of haling found out some proposition without any concern for a seeming want of his night's sleep, which he was sensible he had lost thereby.

"He was turning grey, I think at thirty, and when my father observed that to him as the effect of his deep attention of mind, he would jest with the experiments he made so often with quicksilver, as if from thence he took so soon that colour.

"We have been the dispensers of many dozens of Bibles sent by him for poor people, and I have now many by me sent from him for the same purpose, which as it shows the great regard he had for religion, I cannot but desire that by you it may be made public to the world."

Then we have some interesting records also written at the time of Newton's death by one of his assistants. This writer, Dr. Humphry Newton, evidently not a relative, was with Sir Isaac during the time he wrote his world-famous *Principia*, at which time Newton was about forty-five years of age. The following are a few extracts from this letter. "His carriage was very meek, sedate, and humble, never seemingly angry, his countenance mild, pleasant, and comely. I cannot say I ever saw him laugh but once, which was at that passage which Dr. Stukeley mentioned in his letter to your honour, which put me in mind of the Ephesian philosopher, who laughed only once in his lifetime, to see an ass eating thistles when plenty of grass was by." The occasion to which the writer refers was when Sir Isaac asked a friend, to whom he had lent Euclid, what progress he had made in that author, and how he liked him. He answered by desiring to know what use and benefit in life that study would be to him. Upon which Sir Isaac was merry.

The writer of the letter goes on to relate how Newton kept so very close to his studies that he took no exercise, thinking all hours lost if not spent in study. He had few visitors, but he took delight in their company when they spent an evening with him. "When invited to a treat, which was very seldom, he used to return it very handsomely, and with much satisfaction to

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himself." He was so very intent upon his studies that "oftimes he has forgot to eat at all, which when I have reminded him he would reply 'Have I?' and then making to the table, would eat a bit or two standing, for I cannot say I ever saw him sit at table by himself.

"He very rarely went to dine in the hall, except on some public days, and then if he has not been minded, would go very carelessly, with shoes down at heels, stockings untied, surplice on, and his head scarcely combed."

One is not surprised to learn that Newton was often very absent-minded; he was so absorbed in study. His assistant says: "At some seldom times when he designed to dine in the hall, he would turn to the left hand and go out into the street, then making a stop when he found he had made a mistake, would hastily turn back, and then sometimes instead of going to the hall, he would return to his chamber again. In his chamber he walked so very much that you might have thought him to be educated at Athens among the Aristotelian sect. . . . I believe he grudged the short time he spent in eating and sleeping. . . . He was very charitable, few went empty-handed from him."

Dr. Stukeley, who was a personal friend of Newton, although forty-five years younger than our hero, has left us many anecdotes concerning Newton. From one jotting in the doctor's diary it is evident that Sir Isaac could not have been a musical enthusiast. The doctor happened to remark that he had just been to an opera, whereupon Newton said that he had never been at more than one; "the first act he heard with pleasure, the second stretch'd his patience, at the third he ran away."

Then the learned doctor gives us some illustrations of Newton's absent-mindedness. When he had friends to entertain, if he went into his study to fetch a bottle of wine, there was danger of him setting to work and forgetting all about the waiting friends.

On one occasion when he was riding home he led his horse up a hill, and when he desired to remount, he found that his horse had slipped the bridle and gone away without his perceiving it, and he held only the bridle in his hand all the while.

We have seen from the letter of Sir Isaac's assistant that the Philosopher was very careless about his dress and personal appearance. It was quite natural that a man whose mind was so absorbed in study, and who even grudged time spent in eating, should find little time to get his hair cut regularly, or to spend time in looking after his clothing; there was no affectation in Newton. Dr. Stukeley confirms Newton's carelessness of dress: "He would go out, and would have walked the length of a street before he noticed he was not dressed, and therefore had to hasten back to his home quite ashamed."

On one occasion Dr. Stukeley called to see Newton, who happened to be, as usual, absorbed in some problem in his study. The visitor waited, possibly thinking that Sir Isaac would not be long, as his dinner was already served on the table. After waiting a very long time the learned doctor, becoming both impatient and hungry, sat down at, the table and ate the chicken prepared for Sir Isaac. After a further spell of waiting the great Philosopher put in an appearance, and having greeted his friend he sat down at the dinner-table. On finding nothing but bones he merely remarked that he had quite forgotten that he had already dined. It was too bad of the younger man playing this trick upon Sir Isaac; no doubt he quieted his conscience by the knowledge that his old friend was very guilty of neglecting his food.

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CHAPTER XII

MORE ABOUT SIR ISAAC NEWTON

In most writings dealing with the life of Sir Isaac Newton the greater part of the space is occupied with his works. It is true indeed that "We live in deeds, not years; in thoughts, not breaths; in feelings, not in figures on a dial" (Bailey); but it is a little disappointing to find so little about the man himself.

In the opening chapter, and elsewhere, it was made clear that our present interest lies in the lives of these heroes, but it will be necessary to touch upon two very prominent parts of Newton's work, so that we may form a clear conception of his greatness.

His extension of the laws of Gravity to the whole wide Universe is the most prominent of all his works, but his researches in the subject of *Light* are of immense importance to Science. To the general reader the most noteworthy discovery which Newton made in Optics, and which is understandable without any scientific training, is the composition of Light. It was he who advanced the theory that Light is a combination of different rays producing different colour sensations, and that white light is a mixture of all these.

It is true that Newton's idea that Light was a projection of infinitesimally small corpuscles had to be abandoned long afterwards, but I believe his contemporaries were more responsible for the existence of this theory than Newton was. He did not wish to make any "guess" as to the physical nature of Light. This is made quite clear in his *Hypothesis* which he communicated to the Royal Society. He explains that the reason why he has advanced this theory is because he has observed "the heads of some great virtuosos to run much upon hypothesis," and because some people seemed incapable of understanding his theory of Light when put in an abstract form, whereas they readily understood it when he used this hypothesis , he therefore made use of it. Then he adds: ". . . I shall not assume this or any other hypothesis, not thinking it necessary, . . . yet while I am describing this, *to avoid circumlocution and to represent it more conveniently*, I shall speak of it as if I assumed it and proposed it to be believed." He further states that he is not willing to answer objections against this idea.

The italics in the foregoing quotations are mine; I am desirous of emphasising the ideas with which Newton set out, for we shall see in a later chapter how the Scientists of a later century cried out when Thomas Young dared to declare Light itself to be merely waves in the ether of space. Young's undulatory theory was accepted later, but at that time a scathing criticism was poured upon him, because he said these flying corpuscles did not exist. I think it is not generally understood that Newton laid no stress upon these corpuscles; their invention was merely to please the "virtuosos" who insisted upon something graphic.

In urging this defence of Newton, I do not suggest that Newton ever thought for a moment that Light itself consisted of ether waves. I am not overlooking the fact that he would have a very real difficulty in accepting such a suggestion, for the waves which he pictured were longitudinal like those of Sound, whereas Light consists of transverse waves, such as those on the surface of water. What I maintain is that Newton personally did not care for the corpuscular idea. Speaking of it in another place, he says, "To avoid dispute, let every man here take his fancy."

It should be noted in passing, that Newton invented a reflecting telescope, a class of instrument which will be referred to later in connection with Herschel.

Early in the preceding chapter we saw that Newton had tried, but had failed, to prove his idea that it was Gravity which held the heavenly bodies in their fixed orbits. He had calculated the effect of Gravity at the distance of the Moon, and he found that the resulting figures did not agree with observed facts, so he

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laid the matter aside without even mentioning it to any one.. This was when he was about twenty-three years of age. When he was forty years of age he heard of a new measurement of the Earth, which would materially affect his former calculation. The result of his new calculation was that he had very evident proof that it was our old friend Gravity that was the pulling force in the whole wide Universe. It is difficult to realise that Newton should put the papers away in his desk and tell no one of his great discovery, and yet that is just what did happen. It may be that he wished to avoid any controversy, and either publish the papers later or even to leave them to be published after he had gone; but these are merely guesses at his reasons. The way in which his discovery became known is of interest.

About two years after Newton's solution of the problem, it so happened that Sir Christopher Wren, well known to us as the architect of St. Paul's Cathedral, in London, was discussing with two friends the possibility of the motion of the planets being due to a force obeying the inverse square law. The idea had occurred to these men quite independently; they knew nothing of the papers lying in Newton's desk, or of his early idea in the garden at his home. Sir Christopher's two friends are of interest to us. One was the astronomer Edmund Halley, whose name is familiar to us in connection with "Halley's Cornet," which he had discovered shortly before the time of this meeting with which we are dealing. The visit of this comet to the neighbourhood of our planet so recently as 1911 attracted a good deal of attention. The other friend was Robert Hooke, a very learned man, who anticipated Newton in some points.

What interests us at present is that Sir Christopher Wren and Halley both acknowledged they could not find any way of proving the idea of Universal Gravitation, but Hooke said that he had done so. Halley tells us that Sir Christopher thereupon said that he would give them two months to show him a proof, "and besides the honour, he of us that did it should have from him the present of a book of forty shillings." As nothing came of this challenge, Halley went to Cambridge to consult his friend Newton upon the subject. Without telling of the discussion in London, Halley merely asked what would be the curve described by the planets on the supposition that they were controlled by a force obeying the inverse square law. When Newton replied off-hand that it would be an Ellipse, Halley was greatly surprised, and asked him how he knew it, whereupon Newton told for the first time that he had worked the matter out, and that he had proved also beyond a doubt that it was Gravity that linked the Solar System together. Newton looked for the papers which he had placed in his desk two years earlier, but he could not find them. However, he promised to send them to Halley, and he did so.

During this visit of Halley to Cambridge, Newton had shown him the manuscript of a tract which he had entitled *De Motu*, and which dealt with the subject of celestial motion. Halley asked that this might be sent to him also, so that he might have it recorded in the *Transactions of the Royal Society*. It is interesting to note that the secretary who acknowledges the receipt of this was the young man (Aston) to whom Newton had written the letter of advice on travelling some fifteen years earlier; which letter is referred to at page 117. This tract *De Motu* was the forerunner of the truly great book which Newton wrote later, and which is known throughout the scientific world as Newton's *Principia*.

Newton sat in the House of Commons for one year, during the reign of William and Mary. He was Member for Cambridge University, and he conscientiously looked after the interests of that great seat of learning with which his life is so intimately connected. He would be about forty years of age at that time.

Two years later he became very seriously ill, which is not surprising considering the vast amount of brain-work he did, without taking a proper amount of sleep or food. When thinking of his constant toil, one is apt to forget how very delicate he was in infancy. It is remarkable that his health held out so long, but John Wickens, his chamber-fellow for twenty years, tells us that

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Newton sometimes suspected himself "to be inclining to a consumption," and that he mixed for himself certain medicines at such times.

It is generally believed that Newton's mind became deranged at this time, and while no one could be greatly surprised if his brain did suffer from the severe strain put upon it, there seems good reason to doubt that there was ever more than a nervous breakdown.

The cause of the malady was generally ascribed to the loss of valuable manuscripts in the fire which occurred in his laboratory. This well-known story runs thus: "Newton had a favourite little dog called Diamond. One winter's morning, while attending early service, he inadvertently left his dog shut up in his room; on returning from chapel, he found that the animal, by upsetting a taper on his desk, had set fire to the papers on which he had written down his experiments; and thus he saw before him the labour of so many years reduced to ashes. It is said that on first perceiving this great loss, he contented himself by exclaiming, 'Oh, Diamond! Diamond! thou little knowest the mischief thou hast done.' But the grief caused by this circumstance injured his health and, if we may venture to say so, for some time impaired his understanding." In another version of the same story, instead of quietly rebuking the poor dumb animal, we are told that his excitement was so great that every one thought he would have run mad when he saw what had happened, But there seems to be very substantial evidence to lay on the other side.

In a letter written by Newton's assistant, to whom I have referred already, he gives us the following information, which is direct evidence and not mere hearsay. "He kept neither dog nor cat in his chamber, which made well for the old woman his bed-maker, she faring much the better for it, for in a morning she has sometimes found both dinner and supper scarcely tasted of, which the old woman has very pleasantly and mumpingly gone away with."

The foregoing statement seems to me to take the whole value of the previous evidence away. Even although the story of the accident contains the name of the dog, and the words of Newton's rebuke, it must go in the face of this first-hand evidence. And if we have to discard such an apparently exact story, why not the inexact statement of the mental malady? There are some letters of Newton which are supposed to be proof that his mind was affected at this period. I have read them very carefully, and I am quite convinced that many a person, suffering merely from a nervous breakdown, has written much stranger letters. Newton's own statement, written at that time to a friend, is another piece of evidence in support of the theory of a nervous breakdowns. He wrote. "I am extremely troubled. . . . I have neither ate nor slept well this twelvemonth." No mention of sudden grief at the loss of papers.

To this day students at Cambridge are told how there were two holes cut in the door of Newton's chamber: one hole, much larger than the other, for the use of his cat, the smaller one for the convenience of the kitten. The joke is, of course, that the kitten required a smaller hole to pass through the door than did its mother. But I fear this amusing story must go also in the face of the direct evidence quoted. Indeed, it would be difficult to realise Newton taking care of a dog or a cat, he was so unmindful of himself. What he required was some one to take care of him. We have good reason to believe that the reason why Newton never married was a financial one. When he was an inmate of the apothecary's house at Grantham, there were several girls residing in the household, and the boy Isaac was very good in amusing them and in making playthings for them. One of these girls remained a friend of Newton throughout life, and at the age of eighty years she admitted to another friend of Newton that the great Philosopher would have married her but for his small income and the smallness of her portion. This lady, whose maiden name was Storey, was twice married, but Newton, as we have seen, remained a bachelor to the end.

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Newton was in his eighty-fifth year at the time of his death, which occurred on the 20th of March, 1727. He presided at a meeting of the Royal Society in London on the second day of March, but was taken ill the following day, so that his last illness was of less than three weeks' duration. He suffered great pain, which he bore without a murmur. He was buried in Westminster Abbey, where one can see the monument erected in his memory. During his last illness some friends were testifying to the great esteem in which he was held in the world, but Newton replied: "I know not what I may appear to the world; but to myself I seem to have been only like a boy playing on the seashore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me."

The eminent poet Pope, who was about forty years of age at the time of Newton's death, wrote the following epitaph, which was placed on an iron tablet put upon the wall of the room in which Newton was born.

"Nature and nature's laws lay hid in night,
God said 'Let Newton be' and all was light."

There has been so very much of interest in Newton's life, directly bearing upon Science, that I have not touched upon the time when he became Master of the Mint, at the age of fifty-five, which was after the serious illness to which special reference has been made already. It is of importance to note that, contrary to statements made upon the Continent, Newton's mental powers remained unimpaired to the end. At the age of seventy-five he was returning one evening from the Mint, when he received a copy of a mathematical problem sent to this country by Leibnitz "for the purpose of feeling the pulse of English Analysts." It was 5 p.m. when Newton received this problem, which was presumably a very severe test to the most expert mathematicians, but the aged Philosopher, after a busy day in making arrangements concerning the coinage of the country, was able to solve this problem set by the famous German mathematician.

In closing it may be of interest to note that Newton lived in no less than six reigns. He was born a few years before Charles I was beheaded; he lived through the inglorious reign of Charles II, and the intervening Commonwealth of Oliver Cromwell; also the reign of William and Mary, at whose coronation he was present: the twelve years of Queen Anne, at whose hands he received his knighthood, upon the occasion of her visit to Cambridge; and the slightly longer reign of George I, at whose Court Newton was a well-known figure; but George II had only entered upon the first year of his prosperous reign in the year of Newton's death.

Queen Caroline, wife of George II, seems to have been of a scientific turn of mind. While she was Princess of Wales she used to propose such difficulties to Newton "as none but himself could answer to her satisfaction"; and she was often heard to declare in public, that she thought herself happy in living at the same time and conversing with so great a man.

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CHAPTER XIII

BENJAMIN FRANKLIN
1706-1790

"HE SNATCHED THE LIGHTING FROM THE SKIES AND THE SCEPTRE FROM TYRANTS"

We have first-hand information concerning the life of Benjamin Franklin, for although he did not publish an autobiography, he wrote down the story of his life in the form of a very long letter to his son.

While it is true that Franklin rose "from printer's boy to first Ambassador of the American Republic," I think that statement by itself is apt to give an impression of even a humbler origin than was the case. His father was well-to-do, and came of a family of some account. Benjamin tells us concerning his ancestors that "they lived in the same village, Ecton, in Northamptonshire, on a freehold of about thirty acres, for at least three hundred years, and how much longer could not be ascertained."

Franklin leaves us an interesting word-picture of his great-grandfather, which shows that his ancestors were made of proper stuff. This great-grandfather lived during the reign of Queen Mary, at a time when there were persecutions perpetrated by Popery. The old gentleman kept his Bible in a safe hiding-place and yet in a position very convenient for reference. He turned a footstool upside down and then tied the open Bible within the bottom of the stool, so that the book was hidden entirely when the stool stood upon its legs. While reading to his family, with the upturned stool on his knees, one of the children would keep watch lest an officer of the Spiritual Court should come along, and on any alarm being given, the stool was immediately placed upon its feet again.

Benjamin's father, who had been a wool-dyer in this country, emigrated, about the year 1682, to that part of America then known as New England, but Benjamin, who was the fifteenth in a family of seventeen, was not born till twenty-five years later. Although he was born in Boston in 1706, he was a British subject, the Americans being then but colonists of Great Britain. New England was still young, the father of Benjamin's mother having been one of the first settlers in that part.

In the New World Benjamin's father commenced business as a candle and soap-manufacturer, on a small scale.

Although Benjamin had only two years' schooling, which was between the age of eight and ten years, he must have received good tuition from his father, for he was able to read before he went to school. He tells us that his father always made it a point that the table-talk was of interest and instruction to the children. There was never any discussion of their food; that was strictly prohibited. Even if the food was not to their minds, or was extra pleasing, or was not well cooked, no remark whatever was to be made. Benjamin tells us that with this good training he found in later life that he was quite indifferent to what kind of food was set before him. He found this a great convenience in travelling; he did not envy those whose delicate tastes were often bringing them into conflict with the innkeepers. This avoidance of thinking about the food became such a habit with Franklin that he says, "Indeed, I am so unobservant of it, that to this day I can scarce tell a few hours after dinner of what dishes it consisted."

Another habit formed by Benjamin was to waste no time. No doubt he was taught this by his father, for he showed signs of this habit at a very early age, as we may gather from the following incident. When a child he felt that the very long graces which his father said before and after meals occupied a good deal of time. One day, while the little fellow was watching the

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winter's meat being salted and stored away in casks, he asked his father if it would not do to say grace over the whole lot once for all as it would save a lot of time.

His father had desired at first that his youngest son, Benjamin, should be a clergyman, but with the expenses of bringing up a family of seventeen he did not care to go to the further expense of a college training. At ten years of age Benjamin was put into his father's business, but the cutting of wicks and the pouring of molten wax into candle-moulds did not interest the boy. After two years of such work he told his father that he disliked the business, whereupon his father very wisely offered to find him some business which should be more congenial. But it is often no light task to determine for what business a boy is best suited, and so his father took Benjamin' on his walks with him, to let the boy see different tradesmen at work, and that he himself might observe the boy's inclinations. There was some thought of apprenticing him to a cutler, but the fees demanded seemed to the father unreasonable. He had observed that all Benjamin's pocket-money was spent on books, and that the boy had a decided bookish inclination, and so it occurred to him that the printing trade would be a congenial one to Benjamin. An older brother had been set up in business as a printer, and so it was arranged that Benjamin should become an apprentice to him. The apprenticeship was to be a very long one, for Benjamin, who was then twelve years of age, was not to be free till he came of age.

Benjamin found the work very congenial, especially as he could borrow copies of the books from other apprentices. Sometimes he was required to return these books by the morning, but on such occasions he would sit up the greater part of the night till he finished the book. Later on a merchant who frequented the printing-office offered Benjamin the use of his large library.

During his early apprenticeship Benjamin became a vegetarian; the idea was suggested by some book he had read, but the real advantage that Benjamin saw in this diet was that the meals were more easily eaten, leaving more time for reading, and the cost of the food was less, so that he had more pocket-money for buying books. When his purse was not long enough to meet his demand for books, he would sell those he had read and buy the new ones.

While Benjamin was thoroughly interested in the printing business, he was not very happy in it, for his brother was often unkind to him. Benjamin was only a stepbrother to his master, their father having been married twice, but one can only surmise from what follows that Benjamin's stepbrother was jealous of the boy's quickness in learning.

After Benjamin had served a few years of his apprenticeship, it so happened that his stepbrother began to publish a newspaper, the second in New England. People had tried to dissuade the brother, as they considered one newspaper quite sufficient for New England. Those who wrote the news for this paper were in the habit of meeting at the printing office to discuss matters. The youthful Benjamin, then only fifteen years of age, thought he would like to try his hand at writing articles. He knew very well that his brother would not allow him, and so he wrote in a disguised hand and pushed the anonymous manuscript beneath the door of the printing office after closing hour. He heard the journalists discuss his production next day, and the verdict was very encouraging; indeed, it was the general opinion that the article had been written by some well-known man of learning. This and other similar articles were published, and at last Benjamin informed his stepbrother and the journalists that he had been the anonymous author. The journalists were genuinely interested in him, but the stepbrother was exceedingly displeased, and thought the boy was far too vain.

Benjamin's position in the printing office was by no means improved by the foregoing incident, but it so happened that his brother got himself into trouble with the authorities for publishing some political offence, for which he was sent to prison for one month, and he was deposed from the editorship of the newspaper. Benjamin took charge of the business in the

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absence of his brother, and on his return it was arranged that Benjamin should edit the paper, but he and his brother could not work peaceably together. Benjamin had already served five years of the long apprenticeship into which his father had led him. There were another four years still to serve, although Benjamin was already an expert printer, and so the lad determined to cut short the continual unpleasantness. His only hope was to take French leave, and so he embarked upon a ship sailing for New York, meantime selling his books in order to pay his passage and give him a little cash in hand.

The New York printer to whom he applied for work told him that he had no work, but that his son in Philadelphia might require assistance. Benjamin went off to Philadelphia by ship, and after a stormy voyage arrived at the printing office, to find that the printer's father whom he had seen in New York had travelled on horse-back and had arrived in Philadelphia before him. The son had no work to offer him either, but the father took Benjamin over to the opposing firm, where he found employment.

Not long after Benjamin had got to work in Philadelphia, the husband of one of his sisters spoke to the Governor of the province concerning the lad. The Governor, on hearing of Benjamin's abilities, suggested that he should set up in business on his own account as he would soon outstrip the other printers, whose work was very inferior. Benjamin made a voyage home to ask his father for the necessary capital. While on this visit home Benjamin related his adventures to an old chum, Collins, who thereupon determined to go also to Philadelphia. It was agreed that Collins should go by land to New York, and await Benjamin there, who would follow by ship as soon as his father had come to a decision. But his father considered Benjamin was too young to be in business for himself. However, he promised that if the lad had saved some money by the time he was twenty years of age, he would help him out with the rest of the capital. While at home Benjamin visited the printing office of his stepbrother, who disliked him the more because he had been successful.

Benjamin set out once more by ship for New York, but this time with the good wishes of his parents and friends. When he reached New York he found his friend Collins awaiting him. During all the years that Franklin had known Collins he had been a thoughtful and studious lad, especially expert in mathematics. But now he found that Collins had taken to brandy-drinking, and Franklin was horrified to hear that Collins had not been sober a single day since his arrival in New York. To make matters even worse, Collins had been gambling, all his money was gone, and he was in debt for his lodgings. Poor Franklin, who saved every penny he could towards buying new books, had to pay up Collins's debts and his passage from New York to Philadelphia.

In Philadelphia Franklin found that Collins was a burden on his hands. The lad, although provided with excellent recommendations, could not get work as a clerk. Franklin says, "Whether they discovered his dram-drinking by his breath or by his behaviour, he met with no success in any application, and continued lodging and boarding at the same house with me, and at my expense." Frequent quarrels arose, as Collins would not mend his ways, and their friendship ended in the following manner. When out on the river one day with some other young fellows, Collins refused to row when it was his turn to do so. Franklin insisted that Collins should do his share of the work, although the others were willing to let him off. Collins then ordered Franklin to row in his place or he would throw him overboard. Franklin still insisted that Collins must row, whereupon Collins went forward and struck at Franklin, who described his own actions in the following words: "When he came up and struck at me, I clapt my head under his thighs, and rising, pitched him head foremost into the river. I knew he was a good swimmer and so was under little concern about him." Franklin kept the boat out of Collins's reach until he saw that the swimmer was thoroughly tired, when he took him into the boat, but all pretence at friendship disappeared after that. A little later Collins left for the West Indies.

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We have noted that Franklin had become a vegetarian, and it is rather amusing to learn how he returned to an ordinary diet. He tells us that during one of the voyages between Boston and Philadelphia, the crew caught some excellent cod-fish, which when fried smelt most appetising. His vegetarian principles determined that he should eat nothing that had been alive, the idea being that it was not right to massacre the fish, which had done no injury to deserve death. But when Franklin saw some of the fish being opened, and he espied a quantity of small fish in the stomachs of the cods, he argued that if the fish ate one another he had a perfect right to eat them, and so ended Franklin's vegetarianism.

While Franklin was employed by the printer at Philadelphia, the Governor of the province offered to set him up in business for himself. The Governor told Franklin that he would give him letters of credit whereby he could purchase a printing press in England, and at the same time gain some useful experience in a London printing office. Franklin got ready to sail for England: a very great undertaking in these days when the voyagers were dependent upon the wind to carry them to their destinations.

Franklin could not understand why the Governor made so many excuses for delay in giving him the necessary letters of credit. In the end he was told that if he went on board the ship, which was about to sail, the Governor would send the letters down to the ship in the mail-bag and the captain would hand them to him on the voyage. The lad believed this promise, but before he reached England he found that he had been most cruelly deceived; there was not a single letter of any kind for him. And so the youth was stranded in London, to make the best he could of it for himself. Some readers may wonder what object the Governor could have in behaving in such a manner to young Franklin. But have we not seen people act very similarly in these more modern days, with the sole object of making themselves agreeable and important by their proposed assistance?

However, Franklin soon got employment in a large printing office in the City. He lodged in the street still called Little Britain, and next to his lodgings was a second-hand bookshop, whose owner was good enough to let Franklin have the use of many books. Later on he found employment in a still larger printing office, where he was not content to do just as much work as the other employees.

His fellow-workers, of whom there were about fifty, had formed the habit of drinking ale at their work; indeed, an alehouse boy was in attendance at the printing office to receive the men's orders. As Franklin did not follow their custom they nicknamed him the "Water-American." But it occurred to some of them later that this Water-American could do more work than they could, despite their six pints of ale drunk during working hours. They remarked also that for three half-pence he got "a large porringer of hot water-gruel, sprinkled with pepper, crumbled with bread, and a bit of butter in it." This seemed a much better bargain than did a pint of beer, and many of the printers followed Franklin's example.

One day when on the Thames with a boating party Franklin swam from Chelsea to Blackfriars, performing many feats of activity, both upon and under the water. Owing to this event he received an invitation from the Chancellor of the Exchequer to teach his sons to swim, and this request was accompanied by an offer to set Franklin up as a swimming master in , but the kind offer did not tempt the young printer.

During the eighteen months spent in the London printing shops, Franklin had remained on intimate terms with a merchant who had been a fellow-passenger on the long voyage from America. Franklin speaks very highly of this gentleman. He tells us that the merchant had formerly been in business in London, but things had not gone well with him and he had been forced to ask his creditors to accept part payment of their accounts as a settlement of his indebtedness. After this he had emigrated to America, where he had been very successful, and he was in London at this time to purchase a large consignment of goods for

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his store. On his return to London he had invited all his old creditors to dine with him. They were very pleased to accept the invitation, as they owed him no grudge; and when they expected nothing but the evening's entertainment they were greatly surprised to find, when the plates of the first course were removed, under each man's plate a bank order not only for the remainder of the old debt, but with interest added to date.

This very honest merchant offered to take Franklin back to Philadelphia and to give him good employment in his store there. Franklin, who would be about twenty years of age at that time, accepted the kind offer, and they set sail together. This was in the month of July, and the voyage across the Atlantic, which takes us about one week, took them nearly three months, as they did not land in America till the month of October. While Franklin was employed in the store, his master was taken seriously ill and died, whereupon the youth returned to his printing business. Franklin himself had a very serious illness about this time, so serious that he did not expect to recover, and even wrote out his own epitaph, which was as follows

THE BODY OF BENJAMIN FRANKLIN
(LIKE THE COVER OF AN OLD BOOK, ITS CONTENTS TORN
OUT AND STRIPPED OF ITS LETTERING AND BINDING)
LIES HERE, FOOD FOR WORMS
YET THE WORK ITSELF SHALL NOT BE LOST
FOR IT WILL, AS HE BELIEVED, APPEAR ONCE MORE
IN A NEW AND MORE BEAUTIFUL EDITION
CORRECTED AND AMENDEDBY THE AUTHOR

Fortunately there was no occasion for the use of the epitaph. Franklin became manager of the printing office in which he had worked before leaving for London. He improved the business immensely, teaching every printer the best way of doing his work. He showed his master also how he could mould new type for himself and thus save much time and delay in getting it from England. So soon as the master thought that he had learned all he could from Franklin, he told the young man that as his wages were too high he could go. One of the apprentices in the printing office followed Franklin and suggested that they might set up in business together. As this lad's father was willing to buy a printing-press and type for them, the matter was easily settled.

While waiting for the press and type to come from London, Franklin got a pressing invitation to return to the printing office to assist with an important and difficult order for paper-money. Franklin made the first copper-plates ever made in America for the printing of the paper-money, and these were a great success. When, at last, the printing-press arrived from across the seas, the two young men set up in business. They soon had plenty of work, requiring to work both late and early in order to keep up with the demand. They started a newspaper which also proved a success. But unfortunately Franklin's partner did not act wisely. He was scarcely ever sober, and he made a very poor printer. Not long after their beginning business this lad left Philadelphia to go to farming, where he might be out of the way of temptation. The printing business flourished exceedingly, and in the midst of a very active life Franklin found time to take a leading part in a Debating Club and in the formation of a Library, which was the first lending library in America.

About this time he married a Miss Read, in whose father's house he had lodged in his early days in Philadelphia, in which town he still was. Miss Read's first impression of the boy Benjamin Franklin was rather amusing. She happened to be standing at her father's door on that morning when Franklin first set foot in Philadelphia. Being practically a runaway; he had no travelling-box, and as he passed Miss Read his pockets were bulging out to an enormous extent, being filled with such articles as shirts and stockings. What added to the ridiculous picture was the fact that he had just purchased some bread, and getting much more than he had expected, he was busy eating one very large roll, while he had another one tucked under each arm. Love does not seem to have been at first sight, but before Franklin left for London they were lovers. However, during Franklin's absence the girl married a young man, who did not turn out a success. He

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deserted the young wife, and died somewhere abroad. Franklin had kept up a friendly correspondence with the Read family, and now that he was established in business he married the young widow.

When Franklin was twenty-six years of age he published his famous Almanack, which he continued to publish for a quarter of a century. This annual publication was known throughout the civilised world as "Poor Richard's Almanack." It received this title because Franklin wrote a preface to it each year, signing it "Richard Saunders." The early prefaces were written in a very pathetic tone, as though Richard were adopting this form of livelihood as a last resort. This publication contained so much good sense and so much interesting general information, which was not easily obtained in those days, that it soon became very famous and was translated into several foreign languages.

These old Almanacks make interesting reading, the style of some parts reminds one of the ancient symbols of Pythagoras, to which I referred in Chapter II. For instance, here is one of Poor Richard's sayings: "It is hard for an empty sack to stand upright." (It is difficult for a man in want to act always honestly.)

After ten years' absence from Boston, Franklin paid a visit to his home, where he received a very warm welcome. It is interesting to learn that on this visit he and the stepbrother, under whom he had learned printing, became perfectly friendly. This brother had fallen into ill-health and could not hope to live long. Benjamin offered to look after the brother's son and to train him for business. On Benjamin's return to Philadelphia he prospered so well in business that he was able to devote a good deal of time to public affairs. He became Clerk to the Assembly of his Province (Pennsylvania), and also filled the position of Deputy Postmaster-General. By the time he had reached forty-two years of age, he was able to leave his printing business in the hands of his partner, and to devote himself to public affairs and to philosophical studies.

CHAPTER XIV

FRANKLIN AS A SCIENTIST

By the time Benjamin Franklin had reached middle age he had become the best-known and most important man in America; but what interests us at present is his connection with the scientific world.

We have to pass over the greater part of his later life, which was devoted to serving his country as American Minister in London, and later at the Court of France. We must also pass over the important part he played in the transition of America from being a British colony to a self-governing country—the United States of America.

Franklin had been such a constant reader from childhood that he must have come to know something of Science as then understood, but his first serious study of a scientific subject seems to have been on the occasion of a visit paid to Boston by Dr. Spence, of Scotland. That was in the year 1746, at which time Franklin would be about forty years of age. Dr. Spence showed Franklin some of his electrical experiments, and it is supposed that Franklin bought the apparatus from the lecturer at the close of his visit.

Not long afterwards Franklin wrote a paper on "The Sameness of Lightning with Electricity," and this was communicated to the Royal Society of London by one of its members. It is generally stated that the learned members laughed at the idea. But this cannot be quite correct, for the idea of lightning being a huge electric spark was by no means new; it had been suggested a generation earlier, and the sameness had been remarked upon by great men, such as Sir Isaac Newton. Franklin's paper does not set forth the idea as new, but he was the first to propose a method of proving the idea. It was he who suggested means of tapping the supposed electricity of storm-

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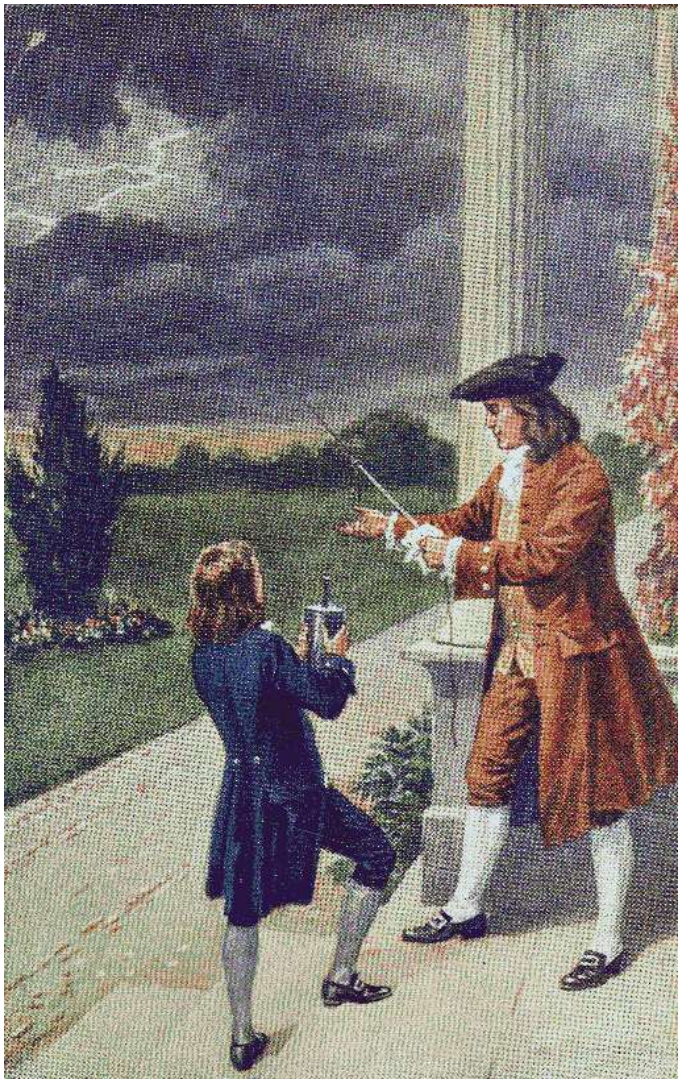
clouds, and bringing it quietly to earth. There is no doubt that it was the boldness of this idea which amused the learned members of the Royal Society, and we can sympathise with them; it would appear to be quite ridiculous.



BENJAMIN FRANKLIN AND HIS SON EXPERIMENTING WITH LIGHTNING.

The gentleman who had communicated Franklin's bold suggestion to the Royal Society had faith in the American statesman's ideas, and he took steps to have it published. It appeared in *The Gentleman's Magazine*, and also in pamphlet form. A copy of the pamphlet was received by some French Scientists, who followed out the idea on the lines suggested by Franklin. By means of an iron rod placed at a considerable height, they succeeded in drawing electricity from storm-clouds. Before news of this successful experiment had time to reach Franklin, he had become impatient waiting for the completion of a high spire from which he intended making his experiment. In the meantime it occurred to him that a kite might serve to carry up the conductor even to a greater height.

When Franklin and his son went out to try this experiment they must have felt the importance of the trial; it would either confirm or contradict a world-famous suggestion. There were thunder-clouds about, but they passed without giving any sign of electricity at the metal key attached to the end of the string tethering the kite. Franklin held this himself by means of a silk handkerchief which was to act as a non-conductor. He tells us that he had almost despaired of success, when suddenly he observed the loose fibre of the string to move towards an erect position. He then presented his knuckle to the key, and received a strong shock accompanied by a bright spark. His bold idea was proved to be possible. He repeated the experiment, charging a Leyden jar, and making other well-known electrical experiments.

Other experimenters made similar experiments with kites, and with iron rods placed high in the air. No one intended bringing a lightning discharge down the kite string, but it is apparent that they were running some risk. One experimenter, who used a metal wire in place of the wetted kite string, found that with this better conductor he got results which alarmed him; an enormous flash occurred, accompanied with a deafening report, and producing a hole in the ground. The iron rod set up

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by a Russian professor was struck by lightning, and he being near the free end of it at the moment received a fatal shock.

Franklin suggested the idea of placing pointed conductors on high buildings, leading a wire direct to earth, in order to protect the building against lightning. People were very slow to adopt this novel suggestion, although many of them were very anxious to protect their houses against lightning, some superstitious folk going the length of placing an innocent leek upon the roof as a protection. One of the early lightning conductors had to be removed because the peasants in the neighbourhood insisted that its presence had brought about such a dry summer that their crops had been wasted.

Many years later a Londoner tried to detract from Franklin's lightning conductors by declaring that conductors placed low down were far more effective than if placed high in the air, and further that round knobs were far superior to sharp points. The man who advanced this theory gave a demonstration of some experiments with round knobs at the Pantheon in London. Many people supposed these experiments to support the man's declaration, but some Fellows of the Royal Society came along and showed the matter to be absurd. Had the experimenter been sincere we could owe him no grudge for putting another theory in opposition to Franklin's suggestion, but it is quite evident that he was not honest in the matter, for when three scientists made experiments in the Pantheon to decide the matter, this man, although present, refused to look at them or to attempt any reply.

When word was sent to Franklin concerning this would-be detractor, along with the information that at this man's request the King had got the pointed conductors taken down from his palace and round knobs put up instead, Franklin replied in a very characteristic letter, from which the following is a quotation: "I have never entered into any controversy in defence of my philosophical opinions; I leave them to take their chance in the world. If they are right, truth and experience will support them; if wrong, they ought to be refuted and rejected. Disputes are apt to sour one's temper, and disturb one's quiet. I have no private interest in the reception of my inventions by the world, having never made, nor proposed to make, the least profit by them. The King's changing his pointed conductors for blunt ones is therefore a matter of small importance to me."

We saw in a preceding chapter how Sir Isaac Newton was worried by spending so much time in supporting his philosophical opinions; he would certainly have had more peace of mind had he acted in the same way as Benjamin Franklin, but such an attitude is very difficult to maintain, and Newton felt it a duty to support his theories.

Franklin's great feat in "snatching the lightning from the skies" is the one thing which stands out most prominently in his scientific career, but he did much valuable work to advance the then youthful science of Electricity. He set forth improved theories of electricity; he dispensed with the idea of two separate fluids and devised the single-fluid theory. It was he who applied the terms positive and negative to electrical theory, and he made important discoveries in connection with the Leyden jar. A generation ago we departed from the idea of a subtle fluid, and came to think of electricity as a mere condition of things, but now we are quite convinced that the early idea was correct; indeed, we have proved beyond doubt that electricity is a real, existing thing.

At present we are interested in the man more than in his science; it is sufficient for our purpose to know that he was a hero of Science. Witness the testimony of the illustrious Dr. Joseph Priestley, whose life we shall consider in the succeeding chapter. In his *History of Electricity*, Priestley wrote of Franklin's work: "Nothing was written upon the subject of Electricity which was more generally read and admired in all parts of Europe."

When Franklin was resident in England as American Minister, he made an extensive tour on the Continent, where he was warmly welcomed by all the men of science. In France he

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was introduced to Louis XV, and was elected a member of the famous Academy of Science. Previous to this he had been elected an honorary Fellow of the Royal Society of London, and had received honorary degrees from several Universities in Great Britain, as well as in America. In London he was made welcome in the houses of all the great people. He had among his acquaintances such men as Adam Smith, the famous political economist, David Hume, the great historian, and Dr. Joseph Priestley, already mentioned. Franklin was an interested spectator at the Coronation of George III.

The later years of Franklin's life were spent in Paris as an American Minister to the Court of France. It is difficult to realise how a man of his age could get through the work which he did. One extract from his diary will give us some idea of the busy life he led outside of his political duties. At the date of this entry our hero was over seventy-two years of age. "December 13th, 1778. Paris. A man came to tell me he had invented a machine, which would go by itself, without the help of a spring, weight, air, water, or any of the elements, or the labour of man or beast, and with force to work four machines for cutting tobacco; that he had experienced it; would show it me if I would come to his house, and would sell the secret of it for two hundred louis. I doubted it, but I promised to go to him in order to see it.

"A Mons. Coder came with a proposition in writing, to levy six hundred men, to be employed in landing on the coast of England or Scotland to burn and ransom towns and villages, in order to put a stop to the English proceedings in that way in America. I thanked him, and told him I could not approve it, nor had I any money at command for such purposes; moreover, that it would not be permitted by the Government here.

"A man came with a request that I would patronise and recommend to Government an invention he had, whereby a hussar might so conceal his arms and habiliments, with provision for twenty-four hours, as to appear a common traveller; by which means a considerable body might be admitted into a town, one at a time, unsuspected, and afterwards assembling, surprise it. I told him I was not a military man, of course no judge of such matters, and advised him to apply to the Bureau de la Guerre. He said he had no friends, and so could procure no attention. The number of wild schemes proposed to me is so great, and they have hitherto taken so much of my time, that I begin to reject all, though possibly some of them may be worth notice."

Franklin says in another place: "It is amazing the number of legislators that kindly bring me new plans for governing the United States."

"Received a parcel from an unknown philosopher, who submits to my consideration a memoir on the subject of elementary fire, containing experiments in a dark chamber. It seems to be well written, and is in English, with a little tincture of French idiom. I wish to see the experiments, without which I cannot well judge of it."

These were the interruptions in a single forenoon. In reading these extracts from Franklin's journal one wishes he had told us what he found out about the wonderful machine mentioned in the first paragraph. It certainly reads like a fraud. It is interesting to note in connection with the paragraph last quoted, that the unknown philosopher turned out to be no less a personage than the wicked Marat, one of the most infamous characters of the French Revolution, and who was in a great measure responsible for the cruelties and massacres which took place some fourteen years later than the date of Franklin's correspondence with him.

No matter how much one believes in every person having a distinct hobby, one would be willing to allow that such a crowded life as that of Franklin left no room for a hobby. And yet we find that he amused himself sometimes in composing light essays, and printing them himself by means of a small set of types and a press which he kept in his house.

Sometimes Franklin wrote very amusing articles, such as the following, which was addressed to "The Authors of the

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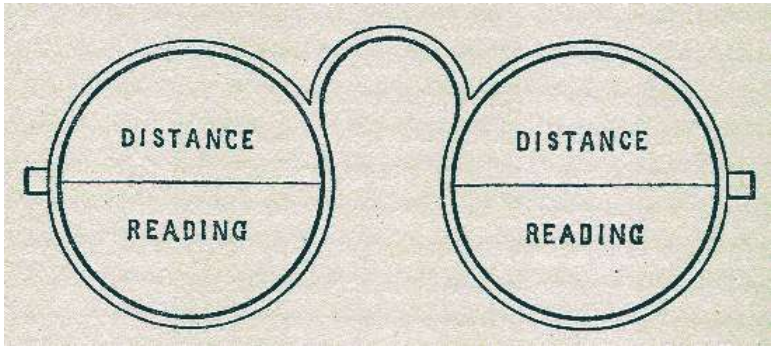
Journal of Paris," and was signed "A Subscriber." The title of this article, which is given in full in his Memoirs, is "An Economical Project for Diminishing the Cost of Light." In this racy article he explains that he had recently seen a new lamp about which there had been some stir. He says that he suspected that the cost of oil in the new lamp was still proportional to the amount of light given. But he had gone to bed puzzled over the new lamp as he fell asleep. He was wakened by an accidental noise at six o'clock in the morning, and he was surprised to find a flood of bright light in his room. At first he thought that it must be due to some of those new lamps about which he had been puzzling, but on getting up to seek the origin of the light he found that one of his domestics had omitted to close the shutters on his windows and that the light came from the rising sun. He goes on to pretend that he has made a great discovery, and that one scientist stoutly denies the possibility of the light being due to the Sun at so early an hour, which was presumably spring or summer time. This imaginary scientist declares that as there could be no light from the Sun and therefore no light that could enter the room from without, it is evident that the open shutters had merely allowed the darkness to escape. Franklin continues in apparently sincere fashion to dilate upon his great discovery, the conclusion of which is that instead of burning tons of candles at a late hour at night, a much cheaper light was to be got from the early morning sun; just the idea of the recent Daylight Saving Bill. Franklin works out the annual saving per annum that would be possible by such means in Paris. He says that if people find any difficulty in rising at so early an hour, the church bells could all be tolled, and if any people should prove obstinate "let cannon be fired in every street to wake the sluggards effectually." Once more he proclaims his original discovery. "Possibly some may say the Ancients knew that the sun rose at certain hours; I do not dispute it, but it does not follow they knew he gave light as soon as he rose. This is what I claim as my discovery."

In looking over Franklin's correspondence I was surprised to come across the following diagram, showing a pair of spectacles arranged for long distance and for reading. In his letter, Franklin explains that he had found two different pairs of spectacles to be very inconvenient, so he had taken them to an optician and got the lenses cut in two and fitted into one frame as shown above. "By this means I wear my spectacles constantly, I have only to move my eyes up or down." We are all familiar with a recent adaptation of the same idea, but it is of interest to find that the idea originated with Benjamin Franklin about one hundred and fifty years ago.



Many eminent scientists were living at the same time as Benjamin Franklin, whose long life closed only ten years before the dawn of the nineteenth century. At Sir Isaac Newton's death Franklin was twenty-one years of age, he was still a young man when our next three heroes (Priestley, Cavendish, and Herschel) were born, and he lived for some time after the births of the three heroes who succeed these in the following pages (Dalton, Young, and Humphry Davy).

While Franklin was in Paris he was one of the scientists appointed by the King of France to investigate the claims of Mesmer, the founder of Mesmerism, then known as Animal Magnetism. Mesmer was a German physician, who claimed to work wonderful cures by means of his newly discovered animal magnetism, a power which he professed to transmit to his patients. Mesmer had met with great applause and profit in

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Germany, and was beginning to succeed equally well in France when the King caused this scientific inquiry to be made.

The report drawn up by Franklin and the other members of this Commission was not to the liking of Mesmer. It was his custom to use apparatus by which he professed to produce the animal magnetism. One method was to place the patient beneath a mesmeric tree, whereupon he fell into the trance. The report of the investigators stated that it seemed probably that about one person in every ten could be mesmerised, but that the outward magnetism did not exist; it was entirely a case of working upon the imagination of the patient.

Franklin's committee took some of the patients, and after blindfolding them pretended to place them under the mesmeric tree, whereupon they fell into the mesmeric state although the tree was not near them. Then they placed these blindfolded patients directly beneath the tree, but led them to believe that they were not near the tree, and the result was that the tree had no effect. The conclusion of the report was that Mesmer's cures were a fraud except in special cases where imagination was of assistance, and that his declaration of having discovered animal magnetism was a complete fraud; it was simply a reflex action of the mental upon the physical.

Mesmer ultimately fell into disrepute and was forced to retire, but he has had many imitators. The subject reappeared at a later date in its proper form under the title of "Hypnotism."

In dealing with the later part of Franklin's life, chiefly from the Science side, we are apt to overlook how extremely active he was up to the last. He was consulted on every political question which was of importance to America. Science was therefore a hobby with him. Until middle age he was a very active business man, a master-printer, and during the long remainder of his life he was a very busy politician. But Science was more than an ordinary hobby with him; he was a born philosopher, and he has made a lasting name for himself in the Science of Electricity. We have seen how the old gentleman amused himself composing and printing breezy essays, and in addition to this he was a keen chess-player. He tells us that one evening in France he sat at chess from 6 p.m. till sunrise.

When Franklin was eighty years of age he retired from his duties at the Court of France and returned to his native land. He had proposed doing this some years earlier, but those in authority urged him to remain. He has left us an interesting diary of his journey and voyage. He set out from Paris in a litter suspended between two mules with the muleteer riding another. Some days he was on the road so early as 5 a.m., and yet he speaks of the journey as a comfortable one. It was a sort of triumphal march, for he was met at different points by the nobility, military officers, and representatives of learned societies.

On arriving at Havre, after a six days' journey, he had ten days to wait before his ship was ready to sail across the English Channel. After reaching Southampton he had another delay, but we must not think of him as an impatient old man, for he tells us: "I went at noon to bathe in Martin's salt-water hot bath, and floating on my back, fell asleep, and slept near an hour by my watch, without sinking or turning, a thing I never did before, and should hardly have thought possible. Water is the easiest bed that can be made."

At last he set sail for America during the end of July, to land on the other side of the Atlantic in the middle of September, a very slow voyage as things go nowadays, but a whole month shorter than one of his earlier crossings. During that earlier voyage he wrote in his diary: "For a week past we have fed ourselves with the hopes that the change of the moon (which was yesterday) would bring us a fair wind." Imagine being becalmed on the Atlantic for a whole fortnight! We may realise what sort of passenger ships were in use in Franklin's day by an incident which he relates. On one occasion the captain of the ship had been boasting, before leaving port, that his vessel could beat all comers. But after putting out to sea his ship was overtaken by another vessel of similar size. The captain of Franklin's ship,

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suspecting that the cargo had been placed too far forward, ordered the whole passengers and crew, about forty persons in all, to stand down in the stern of the ship, whereupon she, very quickly overtook her competitor.

Franklin was very silent about his religion, although we have glimpses of his ideas at times, such as in a letter relating to the death of a friend: "Existing here is scarce to be called life; it is rather an embryo state, a preparative to living; a man is not completely born till he is dead."

In a letter to a friend who wrote to Franklin inquiring about his creed, he replied: "It is the first time I have been questioned upon it. I do not take it amiss. Here is my creed. I believe in one God, the Creator of the Universe. That He governs it by His Providence. That He ought to be worshipped. That the most acceptable service we render to Him is doing good to His other children. That the soul of man is immortal, and will be treated with justice in another life respecting its conduct in this."

Franklin lived for some years after his return to America, and passed away at the age of eighty-four. The very great respect in which he was held is attested by the fact that Congress ordered one month's general mourning throughout the United States, while France proclaimed three days' special mourning. Needless to say the epitaph which the youth Benjamin Franklin had written sixty years earlier (see page 145) was not used upon his tombstone, but the words quoted beneath the title of the preceding chapter are to be found upon the statue erected in his memory in Philadelphia:

"He snatched the lightning from the skies and the sceptre from tyrants."

CHAPTER XV

THE REVEREND DR. JOSEPH PRIESTLEY 1733—1804

THE CLERGYMAN-PHILOSOPHER

Those of us who made a hobby of Chemistry in our boyhood will associate the name of Priestley with the discovery of Oxygen. One of the early experiments of the amateur chemist is to heat some potassium chlorate and manganese dioxide in a glass flask and draw off a plentiful supply of oxygen gas. If the young chemist is a thoughtful lad, and is not content merely to watch all sorts of things burning in oxygen with an intense brightness, he will soon become impressed with the tremendous importance of oxygen in Nature; it is the most abundant of all the elements. I remember being very much interested to learn that it was a clergyman who discovered oxygen, and the name of the Rev. Dr. Joseph Priestley was permanently fixed in my mind. But this discovery is by no means the only claim which Priestley has for a place among the Heroes of Science.

In the preceding chapter we found that because Benjamin Franklin was a very active politician, it was necessary for our present purpose to pass over a very large part of his life. We have to deal with Priestley in the same fashion, as he was a very active clergyman, and his voluminous works on Theology do not come within our present interest.

We are fortunate in having something akin to an autobiography left by Priestley, just as we had of Franklin. The opening sentence of Priestley's Memoirs is of interest: "Having thought it right to leave behind me some account of my friends and benefactors, it is in a manner necessary that I also give some account of myself; and as the like has been done by many

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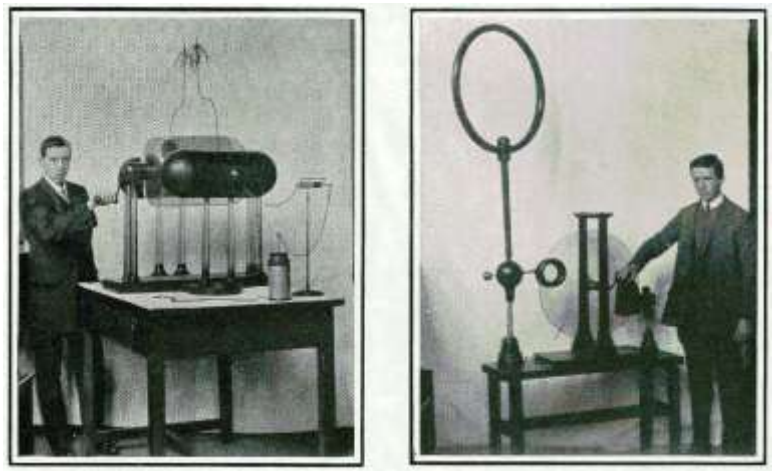
persons, and for reasons which posterity has approved, I make no further apology for following their example." So said the Rev. Dr. Joseph Priestley, and how very different is his attitude from that of a French Scientist who published a book under the title *Lives of Distinguished Scientific Men*, and whose first chapter is "The History of my Youth."

Priestley's father was a maker and dresser of woollen cloth, and his mother was the daughter of a farmer. His parents were well-to-do, but not wealthy. Joseph was only six years of age when his mother died, but he could remember the very strict manner in which she trained him. On one occasion she happened to find him playing with a pin, and on learning that he had brought the pin from his uncle's house, she sent him back with it, not because of the value of the pin, although they were all hand-made in those days, but, as Priestley remarks, in order to impress upon his mind "a clear idea of the distinction of property."

Joseph Priestley was born near Leeds in 1733, six years after the death of Sir Isaac Newton. As we shall find Priestley meeting Benjamin Franklin later, it is of interest to note that when Priestley was born, Franklin would be about twenty-seven years of age.

At the death of Mrs. Priestley her husband was left with the care of six little ones, so he allowed an aunt who had no family of her own to adopt Joseph, he being then six years of age. Our hero speaks very highly of this aunt, who sent him to the best local schools, where he mastered Latin and Greek very quickly. By the time he had reached his sixteenth year he was an excellent classical scholar, and during the holidays he learnt Hebrew. Priestley did not merely master classics in the sense in which we learn these languages at school or college; he was able to correspond in Latin, and he was so far advanced with his self-taught Hebrew that he was able to act as teacher of it to a clergyman, who in return taught Priestley Chaldee, Syriac, and Arabic. But at the age of sixteen his health became unsatisfactory and he had to abandon his academic career.

It was thought that a business life would be best for his health, so he set himself to learn modern languages that would be useful for such a purpose. Without any assistance he acquired a thorough knowledge of French, Italian, and Dutch. Very soon he was able to write and translate business letters in these languages for his uncle. This must have been very pleasing to the uncle, but his aunt had set her heart upon Joseph being a clergyman. By the time he was twenty years of age his health had improved so much that his aunt sent him to an academy, where he could continue his former studies with a view to becoming a clergyman.



PIONEER ELECTRICAL MACHINES
IT WAS BY MEANS OF MACHINES SUCH AS THESE THAT ELECTRICITY WAS OBTAINED IN THE DAYS OF BENJAMIN FRANKLIN AND THE REV. DR. JOSEPH PRIESTLY.

Priestley tells us that as a boy he was of a very serious turn of mind. Of course, his aunt was very strict about all religious matters, and in common with the people of that time she kept the Sabbath very strictly. Priestley tells us "no victuals were dressed on that day in any family, no member of it was permitted to walk out for recreation, but the whole of the day was spent at the public meeting, or at home in reading,

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meditating or prayer." But his aunt, who was a Nonconformist, was not narrow-minded; Priestley tells us "her house was the resort of all the Dissenting ministers in the neighbourhood without distinction," and that even those who were most obnoxious to the people because of their heresy were made welcome so long as the worthy lady believed them to be honest and good men. Priestley was allowed to hear the conversation of these visitors, and possibly it was this freedom of thought which made him question religious ideas on his own account.

Priestley was soon equipped for the duties of a clergyman, but he could not conform his opinions to all the ideas then accepted by the Church, and so, when he got a call to a small country church, he did not become popular. Another drawback to popularity was an impediment in his speech, which hindered him greatly as a preacher. The young clergyman was greatly distressed by this physical defect, and he did all in his power to overcome it; indeed, he persuaded his aunt to spend twenty guineas in sending him to London to be cured by a quack who advertised certain cure, but unfortunately, when he returned, he found that his speaking was worse than ever.

In this small country charge he had a nominal salary of forty pounds, which in point of fact never exceeded thirty pounds, and on occasions fell far short of that. For a time he was dependent upon charitably disposed friends sending him an occasional five-pound note to help him out. Priestley's aunt knew of the smallness of clergymen's salaries, and she had promised that if Joseph would become a minister she would leave him quite independent of his salary. But it came about that a niece who was deformed required the money, and Priestley was quite agreeable that the promise should be cancelled, and the money given to this girl who could not be expected to make her own way in the world. He says that his aunt had given him a good education, which was even more valuable than giving him an estate.

After three years in his first charge the Rev. Joseph Priestley, then twenty-five years of age, received a call to another country district. This removal meant a journey from Suffolk to Cheshire, and travelling in those days was quite an undertaking. A man going from London to Manchester might take so long as a fortnight, for there was no stage-coach, and the traveller had to depend upon some travelling merchant who transacted business in the different villages as he went along. Even at the time when Priestley's Memoirs were published, after his death, it took the stage-coach a day and a hall to go over the wretched roads from London to Manchester; a journey we can make nowadays in less than four hours.

When Priestley was settled down in his second charge he augmented his salary by teaching. He had a school of thirty boys and half a dozen girls. He was busy teaching from 7 a.m. to 4 p.m., with only one hour for dinner, and at 4 p.m. he went straight from school to private tutoring, from which he was not free till 7 p.m. In addition to these twelve hours of activity, he studied, and even began his literary work. Of course, he would have the sermons which he preached in his previous charge, but it should be noted that through all his busy life he never neglected his duties as a clergyman; he tells us that he always counted these duties his greatest honour.

But what set this clergyman on the track of Science? Of course, one might say of Joseph Priestley, as of Benjamin Franklin, that he was a born philosopher, but up till the time of Priestley's second charge he does not seem to have paid any particular attention to Science. In order to add to the popularity of his school he bought some scientific apparatus, by means of which he taught his pupils something of natural philosophy. He tells us that he taught the scholars in the senior class to take charge of the apparatus, and he allowed them to entertain their parents and friends with experiments. In this way he considerably extended the reputation of his school.

After three years in his second charge, Priestley was appointed classical teacher in the Nonconformist Academy at Warrington. Here he passed six of his happiest years, having more leisure to give to his literary work. At the age of thirty he

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married the daughter of an ironmaster, and his married life was a very happy one, as is witnessed by one of his sons, who edited his Memoirs.

While at Warrington Priestley visited London, where he met the famous Benjamin Franklin, with whom he became very intimate. Franklin encouraged Priestley to write *The History of Electricity*, which in one's bookshelves to-day looks exactly like an old family Bible. I remember, on going through a lot of old books in a library many years ago, being very much surprised to find this *History and Present State of Electricity, with Original Experiments*. It was the date, 1767, that surprised me, for it meant that this big, bulky book had been written a generation before the discovery of the electric current, when man knew only of electrified bodies. This great book was written in less than one year, during which time Priestley had to lecture on classics for five hours each day. While writing it he kept sending on the manuscript to his friend Benjamin Franklin to read. About this time Priestley received the honorary degree of LL.D. from Edinburgh University, and a little later he was elected a Fellow of the Royal Society of London, because of his researches in Electricity.

After six years' residence in Warrington Priestley accepted a call to Leeds, where he devoted much time to theological writings, and in addition to overtaking all his ministerial duties, he was able to devote some time to chemical researches. I was about to say—to a study of Chemistry—but this Science scarcely existed at that time. One is apt to forget how recent is the Science of Chemistry. A few years ago a very learned Chemist remarked to me that many years ago, when he was a young man, he could boast that he knew the whole of Chemistry. Now the Science has advanced so far that, with all his great increase of knowledge, he could by no means repeat the same boast to-day.

Priestley's name is very definitely associated with the subject of "different kinds of air," which was the way in which the different gases were described in his day. It is interesting to note how this subject, which helped to make him famous, was first brought before his notice. He tells us that it happened through his living in a house next a brewery, and that he began by amusing himself with experiments on the "fixed air" produced in the brewery. This "fixed air" is no other than our well-known carbonic acid gas, which serves many useful purposes, although it will not support life or combustion. Priestley received a gold medal from the Royal Society for his research work on gases.

While acting as clergyman at Leeds, it was proposed that Priestley should accompany the famous Captain Cook on his second voyage to the South Seas, but objections were raised because some of Priestley's religious ideas were considered to be unorthodox. How this should be a disqualification for such a scientific post it is difficult to imagine.

Remembering what an important part the Grand Dukes of Tuscany played in the life of Galileo Galilei, it is of interest to note that Joseph Priestley, living one hundred years after Galileo, received a request from the then Duke of Tuscany to have made for him in England a very large electrical machine.

We may be surprised to find our scientific clergyman leaving his college lectureship to go into the household of the Earl of Shelburne, afterwards Lord Lansdowne, who was a Cabinet Minister in the reign of King George III. Priestley tells us that he was nominally Librarian to Lord Shelburne, but that in point of fact he was merely a companionable friend. Needless to say that Priestley had no desire for a life of ease or luxury. What concerned him was that he could get on with his important theological works, which he could not otherwise write, nor publish at his own expense. This must have been a considerable sacrifice to Priestley, for it meant separation from his family during the whole of the winter months.

After having been with Lord Shelburne for six years, Priestley accepted a call to a Dissenting church in Birmingham. He was at this time about forty-seven years of age. It seemed as

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though all would go well in the new circumstances. He had many friends, and he became a very active member of a small Scientific Society named *The Lunar Society*. This Society was kept very select, there never having been more than eight or ten members at any one time. They met at each other's houses for dinner once every month. The day of the meeting was the Monday nearest the full moon, and Priestley gives as the reason for this, "in order to have the benefit of its light in returning home." It was this arrangement that gave the name to the Society, and not any idea of making a special study of lunar matters. Of course, the moonlight was of considerable importance to pedestrians in those days, for William Murdoch, the manager of James Watt's engine works, and a member of this Society, had not invented the use of coal gas as an illuminant at that time.

These dinner-parties were begun at two o'clock in the afternoon, and the meetings did not break up till eight in the evening. There was nothing of a religious or political connection; the subjects of discussion were confined to Literature, Science, and Art. Priestley says the members were "united by a common love of Science, which we thought sufficient to bring together persons of all distinctions, Christians, Jews, Mahomedans, and Heathen, Monarchists and Republicans." In the list of members we find the names of James Watt, his partner, Matthew Boulton, and, as already stated, their works manager, William Murdoch. Another member was Dr. Erasmus Darwin, grandfather of the famous Charles Darwin, whose life we shall consider later. Other members whose names are familiar to us were William Herschel, the Astronomer; Josiah Wedgwood, the Potter; and Thomas Day, a wealthy and eccentric philanthropist, best known to us as the author of *Sandford and Merton*. This gentleman was killed in 1789 by being thrown from his horse while riding.

In connection with this Lunar Society there is an interesting letter from James Watt to Charles Darwin's grandfather:

"I beg that you would impress upon your memory the idea that you promised to dine with sundry men of learning at my house on Monday next, and that you will realise the idea. For your encouragement there is a new book to cut up, and it is to be determined whether or not heat is a compound of Phlogiston and empyreal air, and whether a mirror can reflect the heat of the fire. I give you a friendly warning that you may be found wanting whichever opinion you adopt in the latter question; therefore be cautious. If you are meek and humble, perhaps, you may be told what light is made of, and also how to make it."

It is particularly interesting to note the primitive ideas held by our great-grandfathers concerning the nature of Heat and Light. We shall see later how Humphry Davy, when a lad, demonstrated that Heat was not a material thing.

Priestley's remark, already quoted, that the Society was open to Monarchists and Republicans has special significance. These were the days of the French Revolution, and Priestley was, of course, on the side of the Revolutionists. It so happened that some of those of similar sympathies in Birmingham held a dinner on the anniversary of the taking of the Bastille, but Priestley tells us that he had nothing whatever to do with this celebration. Nevertheless, an unreasoning mob attacked his chapel and his house. They had no respect for the reverend gentleman's valuable manuscripts. These they tore to pieces, and arranged to make a bonfire of them and the house. Some of the crowd made a vain attempt to light the mass with sparks from one of Priestley's large electrical machines. Fortunately, before the house was attacked its occupants were at a safe distance, but it must have been a shock to Priestley to see his house, his papers, and his apparatus utterly destroyed by fire.

Priestley gives us an interesting account in his Memoirs of those times. His friends advised him to fly to France for protection, but the most he would permit was the taking of a place for him in the London coach in another name. However, the friend who had the courage to receive him in London had thought it necessary to provide a dress that should disguise him,

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and also a method of escape should the house be attacked, and for some time he would not permit him to go out of doors.

When Priestley decided to settle in London, he found it almost impossible to get a house, which in the end had to be taken in the name of a friend. The landlord declared that he was running a great risk, for not only did he believe that this house would be destroyed, if it became known that Priestley was there, but in addition he thought the crowd would proceed to the landlord's own residence, although it was twenty miles out of London.

For three years Priestley acted as clergyman in a small chapel at Hackney. Of course, he had a perfectly clear conscience, and it is doubtful if ever he would have left London on his own account, but he found that his sons were being persecuted also, merely because they were his sons. Chiefly for that reason he determined to emigrate to America.

The strong feeling against Priestley was not all contained within the unreasoning mob at Birmingham. He tells us that at a dinner of all the Prebendaries of a cathedral-church the conversation happened to turn on the riots in Birmingham, and that a clergyman stated that if Priestley were mounted on a pile of his own publications, he (the clergyman) would willingly set fire to them and burn the author with them, whereupon all the party present declared that they would be willing to do likewise. By this time Priestley was shunned by the Royal Society, but entirely on account of his religious beliefs.

Even more important than Priestley's chemical researches was the tremendous impetus which he gave to the Science of Chemistry, which was then only in its infancy. We should remember that Priestley had to invent his own chemical apparatus.

In 1794, at the age of sixty, the Rev. Dr. Joseph Priestley sailed for New York, the voyage taking about two months, which seems to have been a good average passage in those days. His reception in the young States was very cordial. He received addresses from the Scientific Societies. He was offered the post of Professor of Chemistry in the University of Pennsylvania, and, although he declined it, he was offered the Principalship at a later date, which he felt he must decline also. He settled down in Philadelphia, the home of Benjamin Franklin, who had died a few years earlier.

As evidence of the great intimacy which had existed between Franklin and Priestley, it may be mentioned that the day before Benjamin Franklin left Great Britain for the last time he spent with Priestley alone.

There is one statement in Priestley's Memoirs regarding Franklin which I can never understand. It reads: "It is much to be lamented that a man of Franklin's general good character, and great influence, should have been an unbeliever in Christianity, and also have done so much as he did to make others unbelievers." This statement is surprising, and seems to be contradicted entirely by Franklin's own statement (see page 162); indeed, it seems to me that what one might pick out as being unorthodox in Franklin's religion is to be found also in that of Priestley's. There has surely been some misunderstanding!

Priestley was a very active man up to the last days of his life, although he was practically an invalid for the last two years. His mind, however, remained perfectly clear, and in this connection it is surprising to find that in his prime he had been subject to very strange lapses of memory. He would write upon a subject, and then find later that he had already published the very same ideas, and had performed experiments which he was now giving as new. He tells us that on one occasion he had written and published an article in pamphlet form, and was almost terror-stricken to come across the manuscript of an identical article in his desk, as to the writing of which he had not the faintest recollection. Even on referring to his own published writings he sometimes came across passages which seemed to be entirely new to him.

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All through life Priestley took entire charge of his own laboratory, not even allowing a maid to kindle his fire. The old gentleman usually had this done before the other members of the household were astir, and throughout life his most serious work was always done in the mornings.

He lived to see Volta's discovery of the electric current, and in his closing years he made experiments with Volta's Pile, the original of all electric batteries. He was busy writing on theological subjects up to the very end of his life.

The description of Priestley's last days, as given in the Memoirs by his son, makes interesting reading. The old gentleman was perfectly aware that he was dying, and he very quietly tried to arrange his unfinished work to make its completion as easy as possible. He stopped the printing of a second volume that the third might be commenced, as otherwise he would not see that it was started on the lines that he wished. He called his grandchildren to his bedside before they went off to bed, and he told them that he, too, was going to have a sleep, a very long sleep, but that he would meet them again in another world. He made all arrangements, just as though he were merely going off on a long journey, and so he slept away at the age of seventy years, in the presence of his son and his son's wife, his own wife having predeceased him about ten years earlier.

CHAPTER XVI

THE HON. HENRY CAVENDISH 1731-4810

THE ECCENTRIC MILLIONAIRE CHEMIST

The majority of the heroes whose lives we have considered have been men who required to earn their daily bread. Our present hero, Henry Cavendish, was the eldest son of a peer, the grandson of two Dukes, and the nephew of the third. Duke of Devonshire. The family of Cavendish can be traced back about one thousand years, being descended from a Norman family already famous in the days of William the Conqueror.

Henry Cavendish happened to be born in Italy, at Nice, which has belonged to France since 1860. His mother was delicate and had gone to Nice on account of her health. She died about two years after Henry was born, but he had a younger brother, Frederick. Henry was born in the year 1731.

We know practically nothing of the boyhood of Henry Cavendish, but we know that he went to Cambridge when he was eighteen years of age, and that he matriculated in the first rank. It was said that his father, Lord Charles Cavendish, was very much annoyed that his son would not prepare himself for a political career, and that he accordingly cut down his son's allowance to five hundred pounds a year, a very small sum for his position. But one cannot imagine that this was really the case, for Henry was so painfully shy and eccentric that it must have been most apparent to his father that a public life would never do for his son; it is more probable that the father could not well afford to give him more.

The life of Cavendish was that of a recluse, and although he was left a large fortune by a relative during his father's

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lifetime, he never came out of his shell, except to attend scientific meetings of the Royal Society, or to be present at their club-dinners and their social meetings at the house of the President, Sir Joseph Banks. All his excursions into society were in pursuit of knowledge.

Cavendish had two houses; one near the British Museum, and the other, "a country residence," at Clapham Common. He was so eccentric that his neighbours believed him to be out of his mind, but he surprised them on one occasion with his quick action and courage by saving a lady from a mad cow.

He seemed utterly indifferent to any social life. Some have supposed that he was a woman-hater, but this also might be explained by his ridiculous shyness. His maid-servants were ordered to keep out of his sight on pain of instant dismissal. Happening one day to meet a house-maid on the stair with a broom in her hand, he immediately ordered a back stair to be built to the house. If he wished to give any instructions about his dinner, he would leave a note on the hall table. I doubt if the inmates of the house would know anything of his life except that on coming in from a meeting he would glide quickly into the study and shut himself in there alone. It was a rare thing for him to have any company.

In Cavendish's house at Clapham the large drawing-room was converted into a laboratory, and even the lawn was spoilt by a huge wooden erection. From this he had access to the top of a large tree, from which he made scientific observations. He kept his library in a separate mansion, because he did not wish to meet those who were at liberty to use his books for scientific research.

One Fellow of the Royal Society tells us that if Cavendish did happen to ask any one to dine with him at his house, he invariably gave them a leg of mutton, and nothing else. On one record occasion four scientific men were to meet at his house for dinner, and Cavendish had put a note on the hall table ordering a leg of mutton. The idea was evidently too much for the housekeeper, and it is stated that she had the audacity to approach her master upon the subject; but probably she may have sent one of the men-servants with her message. In any case, it was suggested to the scientist that a leg of mutton was not enough on this occasion when four guests were coming, the idea being that a more elaborate menu should be arranged, but when Cavendish was informed that the housekeeper did not consider a leg of mutton sufficient for the occasion, he simply said: "Well then, get two."

One of the few journeys that Cavendish made was to visit James Watt at Birmingham, and it is interesting to know of this visit which was made after the great controversy raised by their friends as to which of these two great men had first discovered the composition of water. James Watt was only a few years younger than Cavendish, whereas the hero dealt with in the succeeding chapter, Humphry Davy, and who was also known to Cavendish, was nearly fifty years his junior.

Lord Brougham, although much younger than Cavendish, used to meet him at the Royal Society and at the scientific gatherings at the house of the President, Sir Joseph Banks. Lord Brougham says: "I recollect the shrill cry Cavendish uttered as he shuffled quickly from room to room, seeming to be annoyed if looked at, but sometimes approaching to hear what was passing among others. His dress was of the oldest fashion, a greyish green coat, a small cocked hat, and his hair dressed like a wig (which possibly it was) with a thick clubbed tail. He never appeared in London unless lying back in his carriage. He probably uttered fewer words than any other man (not at all excepting the monks of La Trappe)."

We have many recorded instances of Cavendish's extreme shyness and eccentricity. One scientist who used to meet him at these scientific gatherings tells us that the first time he saw Cavendish was at Sir Joseph Banks's house in Soho Square. The narrator of this incident was telling Sir Joseph of some experiments which he had made with the recently invented voltaic battery, when he observed an old gentleman in a faded

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suit of clothes, very attentive to what he was describing. "When I caught his eye he retired in great haste, but I soon found he was again listening near me. Upon inquiry I heard that it was Mr. Cavendish, but at the same time was cautioned by Sir Joseph to avoid speaking to him, as he would be offended."

Another scientist states that he adopted a plan suggested by Dr. Wollaston, which was never to attempt directly to draw Cavendish into conversation, but to talk as it were into vacancy, never looking at him, and then it was not unlikely that he might join in the conversation.

Cavendish had reached middle age before he published an account of any of his discoveries, but he soon became famous, both in Great Britain and on the Continent. One evening, at Sir Joseph Banks's house, an Austrian gentleman was introduced to Cavendish, as he had come to this country with the special object of meeting the great scientist. But the foreigner must have been very disappointed, for while he made some most complimentary remarks to Cavendish, that gentleman seemed to be keeping an eye on the crowd of people in the drawing-room, and seeing an opening in the crowd he suddenly "darted through it with all the speed of which he was the master, nor did he stop till he reached his carriage, which drove him directly home."

It is of interest to note that this eccentric genius, living a hundred and fifty years ago, was in a position to have invented a taxi-meter for cabs. He made a wooden instrument, called a way-wiser, which he attached to the wheels of his carriage, and thereby measured the number of miles he travelled.

Needless to say, Henry Cavendish never sat to have his portrait painted, and he was dead before the days of photography. But an artist did make a picture of him. He did this during a dinner-party connected with the Royal Society, and, of course, without the knowledge of Cavendish.

This eccentric genius seems to have had no regard for his property. We are told that on one occasion his bankers, finding an enormous sum of money accumulating in Cavendish's current account, thought it only right to draw the attention of Cavendish to this fact, so that he might arrange for the investment of the money. But his reply was that if they found the balance an inconvenience he could remove it elsewhere. There seems little doubt that it was this utter disregard for his own property that made him thoughtless about others, and for this reason I think any statement as to his lack of charity is unjust.

On one occasion it was suggested to Cavendish that his library would be better for a rearrangement, and that a certain old gentleman, well versed in literary matters, would gladly undertake this. The arrangement was that the old gentleman should live in the house, but his friends hoped that the wealthy Cavendish would make some money payment also, as the old gentleman had not much of this world's goods. However, when the arrangement of the library had been completed, the old gentleman left without any mention of such payment. Some time later the name of this old gentleman happened to be mentioned in Cavendish's hearing; possibly the subject was brought forward on purpose. Cavendish asked how the poor fellow was, and when informed that he was getting along with difficulty, Cavendish remarked that he was sorry for him, whereupon some one said, "We had hoped that you would have done something for him, sir!" "Me, me, me, what could I do?" Then it seemed to dawn on him suddenly, and he asked if a cheque for ten thousand pounds would be of any service, and it goes without saying that the friends of the old gentleman would assure the eccentric millionaire that the sum mentioned would be more than sufficient to meet the necessities of the case.

Cavendish asked his heir, Lord George Cavendish, to meet him once a year, and then only for half an hour. His brother Frederick scarcely ever saw him, although they were said to be attached to one another. But one cannot imagine affection to be one of the characteristics of so eccentric a hermit as Henry Cavendish. His brother was said to have been of a very cheerful disposition, and very generous, though somewhat eccentric also.

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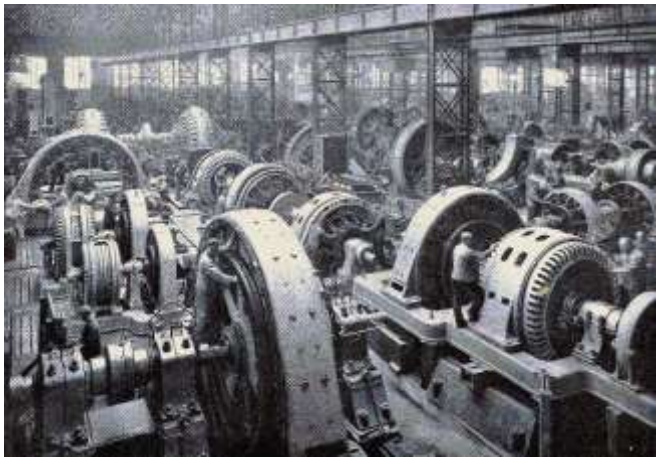
The Hon. Henry Cavendish was a philosopher of the highest rank. Cavendish did not confine his studies to Chemistry; he did valuable work in connection with Electricity. Some of the work of Cavendish was unknown till the middle of the nineteenth century, when Lord Kelvin suggested that all the unpublished papers of Cavendish should be examined. This was done by Clerk Maxwell, whose life we shall consider in a succeeding chapter. Many very valuable scientific notes were found; some of these were on the backs of letters or envelopes. It was found that Cavendish had—unknown to any one—forestalled Michael Faraday and other scientists in their original discoveries in Electricity.



SOME MODERN GENERATORS OF ELECTRICITY
THE ABOVE ILLUSTRATION SHOWS A GROUP OF DYNAMOS BEING TESTED AT THE WORKS OF THE ELECTRICAL COMPANY, LTD.

He seemed to have no interests whatever apart from scientific pursuits. He was most accurate in his work, though he gave no attention whatever to the appearance of his apparatus. On one occasion a lady of rank (said to have been the Duchess of Gordon) was permitted to visit his laboratory, and when she came to a long row of utensils never intended to meet the eye, she was hurried past without any explanation of the processes of crystallisation for which this eccentric millionaire had used them. It may be said of Cavendish that he weighed this globe upon which we live, that he analysed the air we breathe, that he discovered the composition of the water which we drink, and that he led the way into entirely new fields of knowledge.

There is something very pathetic about the few facts we know concerning his end. He had reached his eightieth year, and so far as we know he had never been ill, but he took his first and only illness in a very philosophic manner. It is said by some that Cavendish made observations up to the very end as to the progress of disease in his own body, and the gradual extinction of his vital powers, but this is not evident from any personal statements made at the time of his death. One is not surprised to learn that even at the approach of death this lonely man desired still to be alone. His man-servant had been told not to come into the room until a certain hour, Cavendish having probably calculated that his life would have ebbed away by that time. But the servant was doubtless anxious about his dying master, and ventured to return earlier than the appointed hour, whereupon the old gentleman was not pleased. He asked the servant to repeat a message which he had given him to deliver to his heir so soon as the servant was satisfied that his master was dead. Being pleased with the repetition of the message, the old gentleman asked for the lavender water, and told the servant to leave him till the hour named. Returning in half an hour the servant found that his master had expired.

Because we have no evidence of Cavendish's religious beliefs it would be wrong to suppose, as some have done, that he was perfectly indifferent to religion. From what we have seen of his ridiculously shy and retiring nature it will be very evident that Cavendish was not the sort of man to talk about his religion. Although it has been stated that he never attended any place of worship, it would be unreasonable to infer that he did not worship his Creator. I for one could not imagine Cavendish sitting through a church service with the probability of being stared at by those around him.

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CHAPTER XVII

WILLIAM AND CAROLINE HERSCHEL 1738–1822 AND 1750–1848

A DEVOTED BROTHER AND SISTER WHO MADE ENORMOUS ADVANCES IN ASTRONOMY

There are several cases of eminent scientists having been assisted in their scientific work by their wives, but I cannot recall any case, other than that of the Herschels, in which the co-workers were brother and sister. If we picture our Heroes of Science as fighting against Ignorance by leading the way into new Knowledge, then we see William Herschel striking out in an entirely new direction and opening up a new world of thought. Indeed, as we proceed with a study of his life, we shall see that the words of the old Scotch divine, already quoted in the opening chapter of this volume, were very true of Herschel:

> "Up rose the hero,—on his piercing eye
> Sat observation; on each glance of thought
> Decision follow'd, as the thunderbolt
> Pursues the flash."

The Herschels, as their family name suggests, came from Germany, and their coming is of interest. When William was seventeen years of age he entered the army, becoming a member of the band of the Hanoverian Guards; at this time his sister Caroline was about five years of age. Their father was a musician in this band, a profession which did not provide a very large income for a large family of growing boys and girls. But the father found time for healthy mental recreation in such subjects as Astronomy; he was a cultivated man and thoroughly interested in the education of his family.

The Herschels' mother would not have been persuaded by the modern suffragettes to join their ranks. She believed a woman's place was in the home, but so extreme was she in this that she prevented her daughter Caroline obtaining a reasonable education, such as her father would have liked her to receive. She might have lessons in all that pertained to cooking, sewing, and household duties, but all else seemed to the mother not only unnecessary, but harmful. Even allowing for the fact that she lived nearly two hundred years ago, one cannot help feeling that the mother was very old-fashioned in her ideas; she thought that her husband and her sons would have been better without so much education, and that she would have had them more at home if they had fewer interests.

Whatever may have been wanting in the ordinary schooling of William Herschel was amply remedied by the personal education he received from his father. This fact is very evident from the Recollections of Caroline, in which, when referring to her brothers playing solos in the orchestra of the Court, she says: "I remember that I was frequently prevented going to sleep by the lively criticism on music on coming from a concert, or conversations on philosophical subjects which lasted frequently till morning, in which my father was a lively partaker. Often I would keep myself awake that I might listen to their animating remarks, for it made me so happy to see them so happy. But generally their conversation would branch out on philosophical subjects, when my brother William and my father often argued with such warmth, that my mother's interference became necessary, when the names Leibnitz, Newton, and Euler sounded rather too loud for the repose of her little ones, who ought to be in school by seven in the morning. But it seems that on my brothers retiring to their room, where they shared the same bed, my brother William had still a great deal to say; and frequently it happened that when he stopped for an assent or reply, he found his hearer was gone to sleep, and I suppose it was not till then that he bethought himself to do the same."

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In her childhood Caroline became devoted to her big brother William, and some of her early recollections of him are most touching. It was a terrible grief to her, when she was a little girl, to see her father, with her brothers Jacob and William, leave along with their regiment for England. King George III, who was also Elector of Hanover, had become uneasy about the rumours of the French preparing to storm Great Britain, and so he sent for the Hanoverian Guards to come to England and assist in case of any such untoward event as was rumoured. But as nothing so dreadful came to pass, and as the French invaded Hanover, about a year later, the Hanoverian Guards were then ordered back to Hanover, and so we find the Herschels once more in their native land. Jacob had brought with him some fine English clothes and other luxuries, but William's only extravagance had been a copy of Locke's *Essay on Human Understanding*.

When nineteen years of age William returned to England alone. It is generally stated that he deserted the army, and that he received a formal pardon for this offence from George III, on the occasion of his first audience in 1782. It is very pleasing to learn that this legend is a mistaken one entirely, and that William received an official discharge when his father applied for it on his son's behalf in 1762. A complete copy of the original discharge paper (German) is given in Dr. Dreyer's interesting biographical sketch in "The Scientific Papers of Sir Wm. Herschel," which have been collected by a joint committee of the Royal Society and the Royal Astronomical Society.

We know little of the first few years during which William lived in England, but he had a hard struggle as a professional musician. By the time he had reached twenty-six years of age, he had been appointed teacher of the band in an English militia regiment, and shortly after that he became the organist in a chapel at Halifax.

Some years later we find him in a more lucrative position as organist in Bath, which was then the most fashionable resort in England. Previous to this appointment Herschel had paid a hurried visit to his parents. His departure was once more a terrible ordeal for his sister Caroline, then fourteen years of age.

After William had resided for a few years in Bath, it so happened that the Musical Director of Public Concerts brought his youthful daughter on to the concert stage. She seems to have charmed the fashionable world not only by her voice, but by her personality. Before she was seventeen she became engaged to a wealthy suitor, one of her many admirers, whereupon she retired from the concert platform. It was this that suggested to William Herschel, the professional musician, that his sister Caroline, then about twenty-one years of age, might make a success as a concert singer in England. I should like to emphasise this point, as it is often stated that Herschel brought his sister over to help him in his astronomical work.

Before this time their father had died, at the comparatively early age of sixty-one. Caroline had then started to learn millinery and dressmaking, so that she might be able to support herself. She was busy with such matters when a letter came from William, proposing that his sister should be allowed to come to England as a singer. Her brother Jacob, who was by no means a favourite of hers, ridiculed the idea, as Caroline had learnt nothing of singing. Despite all discouragement she began when alone to try to imitate the solo parts of concertos," Shakes and all," such as she heard them playing on the violin. That this Cinderella of the home did not then neglect her household duties is evident, for she set about knitting as many stockings as would last the family for two years.

At last William arrived to conduct his sister to England, she having obtained her mother's consent. They had to travel to the coast in an open post-waggon, the journey taking six days, and then several additional days at sea. Caroline's experience on arriving in England was rather dreadful. One incident she relates in the following words: "We mounted some sort of cart to bring us to the next place where diligences going to London would pass. But we had hardly gone a quarter of an English mile when the horse, which was not used to go in what they called the

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shafts, ran away with us, overturning the cart with trunks and passengers. My brother, another person, and myself, all throwing themselves out, I flying into a dry ditch."

Then Caroline records her first impression of London: "In the evening when the shops were lighted up, we went to see all that was to be seen in that part of London, of which I only remember the optician's shops, for I do not think we stopped at any others."

William had made already a name for himself as a musician in Bath, not only as a teacher, but as a composer of anthems, chants, and catches. A considerable portion of his musical compositions still exist in manuscript, although a great deal was lost, a locked box containing it having been stolen from the chapel at Bath. We do not hear Herschel's compositions played nowadays, but this does not necessarily mean that they are not good enough. They were appreciated by Herschel's audiences. There is the possibility that little of his music was ever published. It is stated in Caroline's Recollections that, on William's hurried visit home not long before her father's death, the orchestra were invited to a concert at which her brother William's compositions were performed, to the great delight of his father, "who hoped and expected that they would be turned to some profit by publishing them, but there was no printer who bid high enough." There was one catch, *The Echo*, which Caroline tells us was published, but with the exception of it, she says, none of them ever appeared in print.

When Caroline came to Bath, she must have been impressed with the very earnest life her brother William was living. Every moment was of value, for by this time he was keenly interested in Astronomy, and his musical profession was merely his means of livelihood. He was giving lessons on Astronomy to some of his pupils, and he was both reading and thinking very hard. He had previously prepared himself for this by a serious study of mathematics.

In the *European Magazine* of 1785 there are some particulars concerning Herschel's life about this time. We are told that many times after a fatiguing day of from fourteen to sixteen hours spent in his musical work, he would retire at night with the greatest avidity "to unbend the mind" with a few propositions in Maclaurin's *Fluxions*, or other books of that sort. Of course, he could not have done this unless he had been an enthusiast.

When I have heard it argued that we should not ask our young people, who work for nine or ten hours, to attend an evening school, I have quoted such cases as Herschel's. If a young person is in earnest, it will do him or her no harm whatever to attend a continuation class; it will be a mental recreation.

Here was William Herschel keen to be at Astronomy, but he did not neglect his ordinary duties. He had brought his sister over from Germany with the idea of making her a professional singer, and so he gave her two or three singing lessons every day. He gave her also lessons in English and Arithmetic, but these seem to have been entirely during meals, with discourses on Astronomy by way of relaxation. These talks upon Astronomy had been begun in the six days' travel in the open post-waggon, on their way to the German coast.

But William was so busy that, apart from her singing lessons, it was only at meal-times that Caroline saw him, and even then it was necessary to use the time for English lessons. The natural result was that poor Caroline felt very home-sick. Her brother Alexander was also an inmate of the house, but he too was busy.

Caroline had looked forward to seeing more of her brother William during the Easter holidays, but by that time he was so fatigued that "he retired to bed with a bason of milk or a glass of water, and Smith's *Harmonies and Optics*, or Ferguson's *Astronomy*, and so went to sleep under his favourite authors."

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It was most natural that Herschel should wish to see the heavenly bodies about which he had read and thought so much. Telescopes, although invented nearly two centuries earlier, were still luxuries. But there happened to be a two-and-a-half-foot telescope for hire in Bath, and Herschel took advantage of this. He seems to have determined at once to make a larger one for himself. As it was a reflecting telescope which he proposed to make, he thought he might be able to purchase a mirror for it in London. Word came from the opticians in London that no mirror had been made so large as was asked for, but that one could be made at a certain price. Herschel thought the price unreasonable, and so he determined to make his own mirror.

When the summer holidays came round, Herschel began his work in real earnest. Poor Caroline saw almost every room in the house turned into a workshop. A cabinet-maker was hard at work, making a tube and stands of all descriptions, in a handsomely furnished drawing-room. Her brother Alexander was busy with a large turning-machine in a bedroom, and so on. Such arrangements must have been rather alarming to the housekeeper, but all would seem quite reasonable to the enthusiastic Astronomer. I know personally of an enthusiastic Zoologist abroad going the length of putting a pair of young giraffes into a handsomely furnished bedroom, because they had contracted cold on their journey to him. His wife was from home, but I doubt if even household arguments would have damped his enthusiasm.

Even when Herschel had turned his house into a workshop, he was not free of musical duties. He had to leave his hobby to attend rehearsals, and to compose glees and catches for the next winter's concerts. He would return from a concert and set to work without taking time to change his dress, so that many a lace ruffle was torn or bespattered with molten pitch. He could not work fast enough, and several times he had reminders of the old proverb, which says, "the more hurry the less speed." On one of these occasions he lost a finger-nail and was found in a fainting condition.

No matter how desperate William was to hurry on the completion of his telescope, he did not neglect family duties. Just as he was trying to snatch every spare moment to get to his workshop, news arrived from Hanover that his youngest brother, Dietrich, had run away from home, with the avowed intention of going to India with a young idler not older than himself. Immediately upon receipt of this news William laid down his tools and set out for Hanover. During his absence it was discovered that the lad was laid up in an inn at Wapping (England), so Alexander went off and brought him to Bath. But it took William several weeks to make his double journey.

On his return from Hanover he set to work on his telescope in real earnest, not even taking his meals in peace. Although not so bad as Sir Isaac Newton, who never took time to sit down to meals if alone, Caroline tells us that her brother was never unemployed at meals, while both tea and supper had to be served to him in his workshop to save any interruption.

While William was engaged in the tedious work of grinding and polishing mirrors, his sister would sit in the workshop and read to him such books as *Arabian Nights* or *Don Quixote*, and sometimes she would lend a hand in the work.

Caroline proved a success as a singer, and became the principal artiste at the next winter's concerts, but by this time William was so keen about Astronomy that he would gladly have been quite free of music. The writer in the *European Magazine* of 1785, to which I have already referred, tells us that Herschel would leave the orchestra in the theatre during the interval between the acts to run home and look for a moment at some heavenly body.

One night Herschel was busy studying the Moon, and as it was in the front of his house he had to take his telescope out on to the road. He tells us in his Journal: "Whilst I was looking into the telescope, a gentleman coming by the place, where I was stationed, stopped to look at the instrument. When I took my eye off the telescope, he very politely asked if he might be permitted

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to look in, and this being immediately conceded, he expressed great satisfaction at the view. Next morning the gentleman, Dr. Watson, junr. (now Sir William), called at my house to thank me for my civility in showing him the Moon, and told me that there was a Literary Society then forming at Bath, and invited me to become a member of it, to which I readily consented."

It is remarkable how few people ever trouble to have a look through a telescope at our faithful satellite, or any of the great planets, which like ourselves are travelling through space in a constant journey around the Sun. I know of one very fine Observatory, which was built "to interest the rising generation of the town and neighbourhood in the study of Astronomy," and to my knowledge there are comparatively very few of the residents who ever take advantage of it.

This chance meeting with Sir William Watson did not mean a passing acquaintance. Sir William became a constant visitor at Herschel's workshop, often lending a hand himself. From this time forward Herschel became known as an amateur astronomer.

Caroline tells us of what might have proved a very serious accident in her brother's workshop. When melting the metal in a furnace, preparatory to casting a large reflecting mirror, the furnace began to leak, "and both my brothers and the caster and his men were obliged to run out at opposite doors, for the stone flooring flew about in all directions, as high as the ceiling. My poor brother fell, exhausted with heat and exertion, on a heap of brickbats."

With one great bound William Herschel leaped into fame. The cause of this was, of course, his discovery of a new planet. Astronomers had been viewing the heavens through telescopes for nearly two hundred years, and they had no thought of there being any other great planets in our solar system than those which had been known from antiquity; these being in the order of their distance from the sun—Mercury, Venus, the Earth, Mars, Jupiter, and Saturn. I have included the Earth, although the ancients did not reckon it as a planet.

Naturally there was considerable excitement among Astronomers, and a great deal of general interest among the public, when it was announced that this musician at Bath had seen another great planet away in space, a fellow-traveller around the Sun.

This great discovery was made, not by chance, but by a persistent and systematic searching of the heavens. One who visited Herschel some years later tells us that the astronomer made each star pass through the field of the telescope at least three times, so that he might make no error. The planet was discovered a few days before Caroline's thirty-first birthday, when Herschel himself was forty-three years of age, and still an amateur Astronomer. But his discovery brought him honours from practically every scientific society in the world. He was elected a Fellow of the Royal Society of London, and received the honorary degree of D.C.L. from Oxford University. There is evidence that up till this time his name was unknown, except locally, for in the accounts of his discovery his name is spelt in no less than half a dozen different ways, one being as far out as Mersthel.

It will be understood that Herschel made his great discovery before he had been introduced to King George III. I think it is not generally noticed that more than a year elapsed between the discovery and Herschel's introduction to the King, although the Herschels had been informed by friends from time to time that it was expected that William would be commanded to appear before His Majesty.

Herschel's letters from London to his sister, whom he always addresses as "Dear Lina," make very interesting reading. These tell of his different visits to the King, and it is evident how pleased he was to have his work recognised, both by the King and by the Astronomers: "You see, Lina, I tell you all these things. You know vanity is not my foible, therefore I need not

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fear your censure." And in another letter: "Among Opticians and Astronomers nothing now is talked of but what they call my great discoveries. Alas! this shows how far they are behind, when such trifles as I have seen and done are called great. Let me but get at it again!"

Not only was the King himself interested, but so were all the members of the Royal Family. One evening, when the King and Queen were gone to Kew, the Princesses were desirous of seeing the new telescope, but wanted to know if it were possible to see without going out on the grass, which probably was wet. Herschel arranged to have the instrument taken into the Queen's apartments. Unfortunately the sky was completely clouded, and after showing the young ladies the speculum mirror and the movements of the telescope, Herschel gave up all hope of the sky clearing.

It has been stated, and by authors for whom I have the greatest respect, that Herschel showed a good deal of worldly wisdom in having prepared an artificial Saturn of pasteboard, which he affixed to the garden wall, and that with the aid of lamps he showed this to the Princesses as though it were the real planet, and that they went away much pleased.

Of course, with a Herschel-reflecting telescope one does not look directly towards the object, but towards the mirror in the telescope. But Herschel did not cheat the Princesses. In a letter to Caroline, telling her of this incident, he writes: "When the evening appeared to be totally unpromising, I proposed an artificial Saturn as an object, since we could not have the real one. I had beforehand prepared this little piece, as I guessed by the appearance of the weather in the afternoon we should have no stars to look at. This being accepted with great pleasure, I had the lamps lighted up which illuminated the picture of a Saturn (cut out in pasteboard) at the bottom of the garden wall."

It is quite evident from Herschel's letter that there was no attempt to cheat the Princesses. He proposed to them the artificial Saturn, and they accepted the proposal with pleasure. I remark particularly upon this point, for I remember hearing the other version of the story, given in a lecture by a very able man, when I was a boy, and finding confirmation of the story by more than one good author, I did not doubt it. I felt it was rather mean of Herschel to deceive the Princesses. I can remember being quite relieved, some years later, when I read Herschel's letter to his sister, from which I have quoted.

CHAPTER XVIII

HERSCHEL BECOMES A PROFESSIONAL ASTRONOMER

The title of this chapter is proposed to emphasise the fact that, although William Herschel discovered the new planet while he was a professional musician, it is quite erroneous to think of all his great work as being that of an amateur Astronomer.

Herschel left Bath to see King George III, with every intention of returning to his musical profession, but Alexander and Caroline were placed in a very awkward position, for the pupils and others became very impatient at their teacher's long absence from home. When William did come home, it was to pack up his belongings and transfer the household to the outskirts of Windsor, where the King desired Herschel to live in future.

The King gave Herschel a salary of two hundred pounds, which must seem to us as very inadequate, but Herschel was only too pleased to be free of his musical profession that he might devote all his time and energy to Astronomy. His enthusiasm is apparent when we learn the kind of residence with which he was pleased: "stables where mirrors could be ground, a roomy laundry, which was to serve as a library," and so on. And when Caroline was appalled with the prices of everything from coal to butcher-meat, her brother assured her that they could live

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on eggs and bacon, which would cost "next to nothing now that they were really in the country."

So far we have seen Caroline as the household drudge in her home at Hanover, then as housekeeper to her brother and at the same time a professional singer, only aiding her brother in his astronomical work indirectly. Now, after ten years' residence in England, she became a real assistant-astronomer, her brother giving her a telescope with which she was to "sweep for comets," and to write down all remarkable appearances which she saw in her "sweeps."

Caroline began her astronomical work in the garden, when her brother was from home, and at first she did not like being out there on cold winter nights "without a human being near enough to be within call." We may anticipate somewhat by noting that Caroline became the discoverer of no less than eight comets. But greater than all this was her absolute self-denial in so very faithfully assisting her brother William.

We have an interesting description written by one who visited the brother and sister at their observatory near Windsor. The large telescope was in the garden, and was moved by an assistant who stood below it. In the room near it sat Herschel's sister, who had Flamsteed's Atlas open before her. As Herschel gives the word to his sister, she writes down the circumstances of the observation. In this way he examines the whole sky without omitting the least part, and he hopes to make a complete survey in four or five years. At that time he had found about nine hundred double stars and almost as many nebulae. The visitor then states that he himself went off to bed when at 1 p.m. the thermometer showed nineteen degrees of frost, but that Herschel observed all night, only stopping for a few moments every three or four hours. His sister would probably insist upon him taking a cup of coffee during these short breaks in his work.

On some occasions Herschel found his shoes frozen to the ground, when he had looked long at a star. Caroline remembered seeing the thermometer at one and a half degrees below zero, on the Fahrenheit scale, for several nights in the same year. Imagine working in thirty-three and a half degrees of frost! The ink in the room was sometimes frozen, and even that was sheltered compared to Herschel who stood out in the open air all the time.

As Herschel worked all night, one would not be surprised if the daytime had been occupied with sleep and rest, with some time given to writing out the results of his observations; but that would not be a true picture. In the daytime he was a telescope-maker, and here is a record of some of the telescopes which he made:—

200 seven-foot telescopes at 200 guineas each

150 ten-foot telescopes at 600 guineas each

80 twenty-foot telescopes at 3000 guineas each

making a total value of over £370,000. The prices quoted were the values in 1785.

It became a fashionable craze to have one of Herschel's telescopes, but although our hero was a prosperous telescope-maker, his real interests were in observing and studying the heavens.

The devotion of his sister Caroline can scarcely be better illustrated than by the following extract from her Diary; she is referring to the huge forty-foot telescope which her brother had erected in his garden by this time: "The evening had been cloudy, but about ten o'clock a few stars became visible, and in the greatest hurry all was got ready for observing. My brother, at the front of the telescope, directed me to make some alteration in the lateral motion which was done by machinery . . . . At each end of the machine was an iron hook, such as butchers use for hanging their joints upon, and having to run in the dark on ground covered a foot deep with melting snow, I fell on one of these hooks, which entered my right leg above the knee. My brother's call, 'Make haste!' I could only answer by a pitiful cry,

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'I am hooked!' He and the workman were instantly with me, but they could not lift me without leaving nearly two ounces of my flesh behind. The workman's wife was called, but was afraid to do anything, and I was obliged to be my own surgeon." Later the doctor said that had a soldier met with such an accident he would have been entitled to six weeks' nursing in a hospital. The one consolation to Caroline was that the weather for a few nights was dull, so that her brother was not the loser through her accident, and it so happened that for about a fortnight "there was no necessity for my exposing myself for a whole night to the severity of the season." Here was Caroline back at her trying work, when even a soldier would have been another month in hospital.

The fear of accidents did not intimidate these enthusiastic Astronomers. Caroline says: "I could give a pretty long list of accidents which were near proving fatal to my brother as well as myself. To make observations with such large machinery, where all around is darkness, is not unattended with danger, especially when personal safety is the last thing with which the mind is occupied." Surely this brother and sister were true heroes, beyond the definition laid down in Chapter I?

It will be observed that Caroline's descriptive writing does not betray any lack of early education, but it is said that her spelling was very deficient; this, of course, does not appear in her published Recollections. Her brother William gave her constant lessons in English, whenever she settled here. Even the constant association with her brother and his friends would be helpful to her speaking and writing. Indeed, I do not think that it is generally realised that even had Caroline learnt no grammar, she might yet have acquired a beautiful style of speaking and writing, for these are in reality imitative arts.

Occasionally work was so pressing in the day-time that Caroline says: "If it had not been sometimes for the intervention of a cloudy or moonlight night, I know not when my brother (or I either) should have got any sleep." And referring to one occasion when William had to go to Germany to present a telescope from King George III to the University of Gottingen, Caroline relates how she kept herself "from suffering by too much sadness" by what she calls "bustling work."

Although there is no intention of including an account of the scientific work of Herschel, it is of interest to note that the name he gave to his new planet was *Georgium Sidus*, as a compliment to George III. We remember how eager Henry IV of France had been to have a heavenly body named after him. But Herschel's proposal met with severe criticism and opposition. I find this matter referred to in the *Edinburgh Review* of April, 1809, In reviewing a work on Astronomy by the then Professor of Astronomy at Cambridge, the critic takes the author severely to task for referring to this planet as the *Georgian Planet*, "in compliance with a fashion peculiar to the English."

The title of "Uranus" had been generally accepted by this date, and the name was an appropriate one; Uranus being in Greek mythology the father of Saturn, whereas the newly discovered planet was farther out in the solar system than Saturn, which till then had been believed to be on the outskirt of our system. But Caroline writes of the moons of Uranus as the "Georgian Satellites" even twenty years after this date.

One French Astronomer suggested that the planet should be called "Herschel" after its discoverer, but this was not accepted for the same reason as the King's name, it being considered improper that the name of any man should be attached to a great heavenly body.

I remember getting into conversation with a "Professor of Astrology" at a country fair many years ago. I was surprised to find on the printed papers which he filled up for his patrons, that one of the planets under which his patrons might be born was named "Herschel," but I found that the man had no idea to what planet this referred; he believed that among his big stock of planets there was one named Herschel.

Caroline became a professional Astronomer, being appointed by the King as assistant-astronomer at a salary of fifty

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pounds per annum. This salary, though seeming ridiculously small to us, was very welcome to Caroline, who was then about thirty-seven years of age. She had always had entire charge of her brother's purse, and his instructions to her had been to use whatever she desired for her own personal use, and merely state in the account-book "For Car." opposite any sums thus expended. But Caroline had never let these exceed eight pounds in any one year.

Before Caroline was forty years of age she was released from housekeeping duties, as her brother William married the widow of a wealthy London merchant. But Caroline's separation from her brother's home life must have been a great trial to her; she very wisely refrains from including that period in her Recollections.

Herschel was not a youthful bridegroom, having reached the age of fifty before he married. His wife was a Glasgow lady, being the daughter of Dr. Wilson, the eminent Professor of Astronomy at the University of Glasgow. When Herschel visited Glasgow, a few years after his marriage, he received the Freedom of the City.

We have an interesting description of William Herschel, written about this time, in the *Diary and Letters of Madame D'Arblay*, whose maiden name was Fanny Burney, and who was a distinguished novelist at that time. The following is an extract: "In the evening Mr. Herschel came to tea. I had once seen that very extraordinary man at Mrs. De Luc's, but was happy to see him again. He is perfectly unassuming, yet openly happy, and happy in the success of those studies which would render a mind less excellently formed presumptuous and arrogant.

"The King has not a happier subject than this man. Mr. Locke himself would be quite charmed with him.

"He seems a man without a wish that has its object in the terrestrial globe. At night Mr. Herschel, by the King's command, came to exhibit to His Majesty and the Royal Family the new comet lately discovered by his sister; and while I was playing at piequet, the Princess Augusta came into the room and asked me to accompany her." Then referring to what she saw as being nothing grand nor striking, she remarks: "There is no possibility of admiring his genius more than his gentleness." Then she adds: "His wife seems good-natured; she was rich, too! and astronomers are as able as other men to discern that gold can glitter as well as stars."

We set out with our hero as Mr. William Herschel, then we saw that he had received the honorary degree of D.C.L. of Oxford, from which time he was known as Dr. Herschel, and ultimately we find him being knighted, so that he was then known as Sir William Herschel.

In the Memoir and Correspondence of Caroline Herschel the publishers have inserted a picture of Sir William, beneath which I notice they say "Sir William Herschel, Bart.," but he was not a baronet. Had Sir William been a baronet, his son, his only child, who became a great Astronomer, need not have been knighted by William IV and created a baronet by Queen Victoria upon the occasion of her coronation; both of these acts would have been unnecessary had Sir William been more than a knight. I mention this particularly because a learned friend assured me on one occasion that Sir William was a baronet. As a matter of fact, although he is spoken of most often as Sir William Herschel, he was knighted only a few years before his death. The only notice of this honour in Caroline's Diary is: "April 5th [1816]. My brother, received the Royal Hanoverian Guelphic Order."

From the date of the foregoing it will be observed that Herschel's knighthood was given by the Prince of Wales (afterwards George IV) while acting as Regent, during the final and permanent insanity of George III. Herschel was then not far from his eightieth year.

The poet Thomas Campbell visited Herschel in his old age, and there is preserved a letter giving the poet's impression. He was impressed with the great simplicity, kindness, and

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unassuming manner of Herschel. And when the old Astronomer said, "I have looked farther into space than ever human being did before me. I have observed stars of which the light, it can be proved, must take two million years to reach the earth," Campbell, who was then thirty-five years of age, was quite overcome by the modesty of manner with which Herschel made this statement.

In the preceding chapter on Priestley we saw that Herschel was a member of the Lunar Society at Birmingham, although he must have been more of an honorary member or simply a guest. We saw that James Watt was also a member of that very select Society, and it is interesting to know that Herschel and Watt were very friendly; the great Astronomer on one occasion appeared as a witness on behalf of Watt in a law case.

Although Benjamin Franklin was only about thirty years Herschel's senior, yet by the time Herschel sprang into fame, Franklin was already an old man of seventy-five, and was then residing in France. But the old American Statesman and Philosopher was, with the rest of the world, interested in Herschel's discoveries, of which he said: "I hardly know which to admire most; the wonderful discoveries made by Herschel, or the indefatigable ingenuity by which he has been enabled to make them."

Amongst the multitude of visitors at Herschel's observatory at Slough was the Prince of Orange, and Caroline remarks that the Prince's questions were sometimes of a remarkable kind. Finding neither of the Herschels at the observatory on one occasion when he happened to call, the Prince left the following note: "The Prince of Orange has been at Slough to call at Mr. Herschel's and to ask him, or if he was not at home, to ask Miss Herschel, if it is true that Mr. Herschel has discovered a new star, whose light was not as that of the common stars, but with swallow tails, as stars in embroidery. He has seen this reported in the newspapers, and wishes to know if there is any foundation to that report."

For more than the last twenty years of his life William Herschel had only indifferent health, which necessitated frequent absences from home. During these periods his faithful sister took his place at the observatory, working extremely long hours, and going with only one or two hours' sleep on many occasions. Had Caroline happened to die young, there is little doubt that her early death would have been put down to her leading such a strenuous life, but fortunately she did not die young; had she lived two years longer she would have reached one hundred years.

Her brother William had died in 1822, so that Caroline lived for a quarter of a century after the death of "the dearest and best of brothers." She removed to Hanover, where she spent the remaining years, but keeping up her interest in Science to the end. During her lifetime no less than four sovereigns had reigned over Great Britain, but her brother lived only in the reign of George III and the first two years of his son George IV, although he was still alive when Queen Victoria was born.

If we say, speaking figuratively, that Copernicus and Galileo set the Earth in motion through space, we may say in the same sense that Herschel set the solar system moving through space; that it was he who discovered that the so-called fixed stars were in motion, and indeed that he was the founder of Stellar Astronomy.

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CHAPTER XIX

JOHN DALTON
1766-1844

THE COLOUR-BLIND CHEMIST WHO GAVE US OUR CHEMICAL ATOMS

John Dalton was born in a little village near Cockermouth, in Cumberland, the date of his birth being 1766, or approximately one hundred and fifty years ago, and in the reign of George III. Our hero was born in a thatched cottage in which his father earned a living as a handloom weaver. Both his parents came of families belonging to the Society of Friends, and their boy naturally became a Quaker also.

As a schoolboy John was not brilliant, but he was persistently persevering. This trait of his character became very noticeable when a rich Quaker friend undertook to give Dalton, and a young man twice his age, special lessons in arithmetic. When a difficult problem was set for these two young friends, the older one was very willing, after a first vain attempt at its solution, to ask for an explanation, whereas John Dalton pleaded for more time, determined to master it for himself. Sometimes he would even ask if he might keep the problem over-night, so that he might try and work it out in the morning, which he often succeeded in doing.

When Dalton was twelve years of age he nailed up a large sheet of paper, on the front of his father's cottage, announcing that John Dalton had opened a school for both sexes on reasonable terms, and that paper, pens, and ink could be bought within. This boy-schoolmaster had a number of pupils ranging from infants to boys and girls of seventeen. With the bigger boys he must have been at a decided disadvantage when there was any occasion for punishment. This original style of school was carried on for two years, but as it became apparent that John would never make a fortune out of his reasonable terms, it was decided that he should turn farmer. This may have been suggested by the fact that John had an uncle who was a farmer and who had no sons to follow him in possession of the farm. John was set to learn ploughing on a patch of land which his father, the weaver, farmed on his own account.

In the evenings, so soon as outdoor work was over, John sat down to study, and to some purpose, for by the time he was fifteen he was appointed an assistant in a Quaker school at Kendal, in which his older brother was already a teacher. The distance from Dalton's home to this town amidst the English Lakes was forty miles, but there was no regular conveyance, so the lad of fifteen set out to cover the distance on foot, carrying his belongings in a cloth bundle, and armed with a large umbrella, which he thought would be fitting to his new post.

After a few years the proprietor of the school retired, and the two Daltons carried it on with some success on their own account. The financial success was not great; the total income for any one year did not exceed one hundred pounds. The terms that the former proprietor had charged for scholars boarding in the school were ten shillings and sixpence per quarter, and when the Daltons announced an increase of the charge to fifteen shillings they stated that they hoped the terms would not be thought unreasonable, as there had been an increase in the cost of food materials.

John still gave all his spare time to study, and he seems to have been taken up with mathematics, for one of the pupils, in describing the school, has stated that the boys preferred John as their teacher, not only because he was less rough, but because his mind was so taken up with mathematical problems that the boys' mistakes would pass unnoticed. This is so like many schoolboys of to-day, quite pleased to get through with their lessons anyhow, with no real concern as to the acquisition of knowledge, or the training of their minds.

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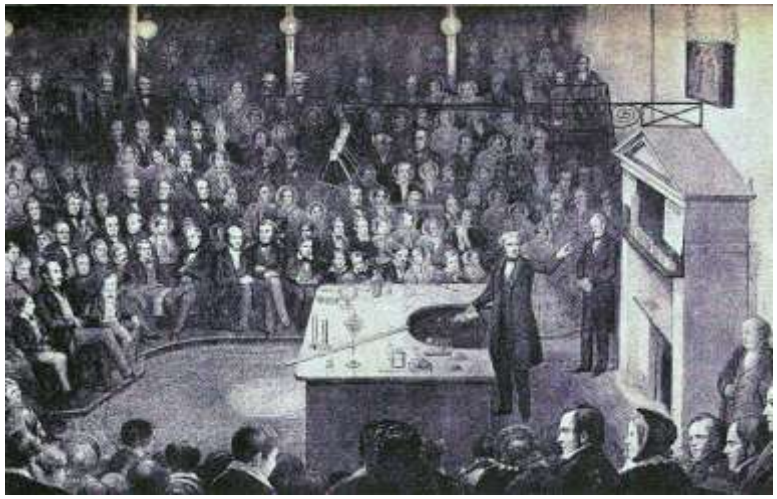
After twelve years' residence in Kendal, John Dalton, then twenty-seven years of age, received the appointment of tutor of Mathematics and Natural Philosophy in the New College, Manchester. This college was practically a continuation of the Warrington Academy in which one of our heroes, the Rev. Dr. Joseph Priestley, had been a lecturer (page 169). The college was a practical protest against the large Universities excluding Unitarians and Quakers, which even Oxford and Cambridge did in these days.

Dalton seems to have been about thirty years of age before he took any definite interest in chemistry; indeed, it is a wonder that he found time even then, as his tutorial duties employed him during most of the day and evening. He retired from the college after six years, so that he might devote more time to chemistry. He opened a small laboratory in the neighbourhood of his lodgings, but he had to make his living as a private tutor.

Dalton soon made a name for himself as a chemist, and when he announced his theory of chemical atoms he became famous at home and abroad. Long afterwards a learned French chemist came over from Paris in order that he might see the great English chemist. He thought all he would have to do would be to come to Manchester, and there find Dalton in some great College or University, but instead of that he had to search for his lodgings in a clergyman's humble home in a back street. Dalton was then sixty years of age, and when the French savant was ushered into the room, he found the old gentleman peering over a boy's shoulder at some figures on a slate. The distinguished Frenchman thought there was some misunderstanding, but when he asked if he had the honour of addressing Monsieur Dalton, that worthy gentleman replied, "Yes! Wilt thou sit down whilst I put this lad right about his arithmetic?" Right throughout life Dalton had to support himself by teaching, until he was sixty-seven years of age, when the Government granted him a pension in token of his great work. It was a pity that this great man had to spend so much valuable time in ordinary school-teaching.

After Dalton had become famous he was invited to lecture in the Royal Institution in London. This was when Humphry Davy was a young assistant in the institution, he being a dozen years younger than Dalton. In a letter from John Dalton to his brother he tells that Humphry Davy has rooms next to his in the Institution, and his description of Davy is: "He is a very agreeable and intelligent young man, and we have interesting conversations in an evening. The principal failing in his character is that he does not smoke." Then Dalton proceeds to tell how Davy took him into the Lecture Theatre and made him go through his first lecture. Davy first of all acted as audience, and then he made Dalton the audience while he read the lecture, and together they criticised it.



A FAMOUS LECTURE THEATRE
THIS PICTURE SHOWS THE LECTURE THEATRE OF THE ROYAL INSTITUTION (LONDON). MANY OF OUR HEROES OF SCIENCE LECTURED HERE, INCLUDING DAVY, DALTON, FARADAY, TYNDALL AND HUXLEY. IN THE PICTURE FARADAY IS SEEN DELIVERING A LECTURE BEFORE A DISTINGUISHED AUDIENCE.

Dalton's impression of London is given in another letter, and he was of much the same opinion as the young curate in *The Private Secretary*, who kept saying, "I don't like London."

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Dalton says: "London is a most surprising place, worth one's while to see once; but the most disagreeable place on earth for one of a contemplative turn to reside in constantly." His words remind one of the Japanese proverb: "He who has never climbed Fujiamha is a fool; but he who has climbed it more than once is a greater fool."

Dalton's impression of Edinburgh is very different: "It is worth while coming an hundred miles merely to see Edinburgh. It is the most romantic place and situation I ever saw; the houses touch the clouds. In this place they do not build houses side by side as with you; they build them one upon another. My own lodgings are up four flights of stairs from the front street, and five from the back. I have just one hundred steps to descend before I reach the real earth. To look down from my windows into the street at first made me shudder, but I am now got so familiar with the view that I can throw up the window and rest on the wall, taking care to keep one foot as far back in the room as I can to guard the centre of gravity."

Dalton never married. He lived for thirty years in the humble home of his friend, the Rev. William Johns, of Manchester. It is interesting to note how a chance observation led to so long a residence and lifelong friendship. The facts have been related by the clergyman's daughter: "As my mother was standing at her parlour window, one evening towards dusk, she saw Dr. Dalton passing on the other side of the street, and, on her opening the window, he crossed over and greeted her. 'Mr. Dalton,' said she, 'how is it that you so seldom come to see us?' 'Why, I don't know,' said he, 'but I have a mind to come and live with you.' My mother thought at first that he was in jest; but finding that he really meant what he said, she asked him to call again the next day, after she should have consulted my father. Accordingly he came and took possession of the only bedroom at liberty, which he continued to occupy for nearly thirty years. And here I may mention, to the honour of both, that throughout that long connection he and my father never on one occasion exchanged one angry word, and never ceased to feel for each other those sentiments of friendly interest which, on the decline into years of both, ripened into still warmer feelings of respect and affection."

Miss Johns gives also a description of Dalton's daily life. He spent practically the whole day in his laboratory, coming over for dinner, but always when it was nearly finished, which practice was doubtless to save spending too much time at meals. He would go over to his laboratory before breakfast and light the fire, and but for his meals he remained in the laboratory till nine o'clock in the evening. After supper they would all sit round the fire for a little while the clergyman and the chemist smoked their long pipes, but after that Dalton would study till midnight.

Although Dalton never married, he was by no means a woman-hater. In a letter to Mrs. Johns, writing from London, he says that he might have described the fashionable dresses of the ladies, but that he was too much taken up admiring their pretty faces. And in a letter to his brother, written on another occasion altogether, he acknowledges having fallen in love with a widow, upon whom he had called in connection with her son's studies at the Manchester College: "During my captivity, which lasted about a week, I lost my appetite, and had other symptoms of bondage about me, as incoherent discourse, etc., but have now happily regained my freedom."

In another confidential letter to his brother he goes into raptures over the charms of another young lady. Dalton used to say that he had had no time to marry, but there seems little doubt that it was because he could not well afford to set up house.

The name of our hero is prominent in connection with the subject of colour-blindness, which defect was known at one time as Daltonism. There is a story told of Dalton, while schoolmaster at Kendal, making the purchase of a pair of stockings as a present for his mother. Seeing the stockings in a shop-window labelled "Silk and Newest Fashion," he went in and bought a pair, thinking they would be something out of the ordinary for his mother, who, would doubtless wear home-knit

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hose of a heavier kind. The presentation pair of stockings proved to be more uncommon than John had anticipated. When his mother opened the parcel she said: "Thou hast bought me a pair of fine hose, John, but what made thee fancy such a bright colour? Why, I can never show myself at meeting in them." John thought there was something wrong with his mother's eyesight, as the stockings appeared to him to be of a dark bluish drab colour. When he expressed his surprise to his mother she exclaimed: "Why, they're as red as a cherry, John." But John called his brother Jonathan to decide the disputed point, and the latter agreed with his brother that their mother's vision was seriously at fault. She, not being satisfied with this double judgment, took the stockings to her neighbours, and came back with the general verdict, "Varra fine stuff, but uncommon scarlety."

The foregoing story is interesting, and I have no doubt is substantially correct, but it is stated as "the first event which opened John Dalton's eyes to the fact that his and his brother's vision was not as other men's." But this is evidently not so, for I find that in a paper which Dalton read to the Philosophical Society of Manchester, in 1794, he says: "I was never convinced of a peculiarity in my vision till I accidentally observed the colour of the flower Geranium zonate by candlelight in the autumn of 1792." From the date of this discovery we find that he was still at Kendal, which he left during the following year, so that the incident of the stockings was evidently prior to the discovery by candlelight. Contrary to the generally accepted idea, I can quite understand that the stocking incident did not convince Dalton that there was any peculiarity in his vision, he would think that it was merely the description of the colour that was at fault. Perhaps my point will be made clear by the following incident.

On one occasion when I was reading a paper relating to colour-blindness to a learned Society, an eminent Professor of Medicine asked me if I could explain a case which had come under his notice, in which he found a very intelligent gentleman of seventy years of age who had come through life quite ignorant of the fact that he was colour-blind. In reply I quoted a passage from Dalton's original paper, which I think makes the matter quite clear: "I was always of opinion, though I might not often mention it, that several colours were injudiciously named." And again: "When I used to call pink sky-blue and incur the ridicule of others, I used to join in the laugh myself, and then nobody thought I was in earnest; nor did I think at that time that there was such a great difference in the appearance of colour to me and others as there now seems there is. I thought we differed chiefly in words, and not ideas."

In one of Dalton's letters he tells how he had been at the house of a friend who was a dyer, when, besides his friend and himself, there were present the dyer's wife, a physician, and a young lady friend. The question of colour-vision was evidently raised, for the dyer's wife; brought in a piece of cloth to see how Dalton would describe it. He said that the last time he called upon them he was wearing a suit just of that colour, and that he should describe it as a reddish snuff-colour. This was quite a good joke to the rest of the party, as the cloth was of a grass-green colour, and certainly not the sort of colour that Quaker Dalton would wear. They told him he would not be allowed into the Meeting-house in such a green coat.

When Dalton was preparing to visit the French savants in Paris, he visited his tailor in Manchester, and ordered a suit of clothes to be made for the occasion. He took a look round among the pieces of different cloths and settled his choice upon one which he considered appropriate. Had his tailor fulfilled the order, the devout Quaker would have appeared among the learned men of France dressed in a complete suit of bright scarlet. However, the tailor, who was evidently aware of Dalton's so-called "Daltonism," pointed out to his client that this particular material was used only for making hunting coats. Dalton was so frank about his defective colour-vision that he must have received much good-humoured chaff on the subject. For instance, in reply to a letter written by Dalton, in which he

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had made inquiries concerning the colour-vision of a family, the following remark is made concerning our hero: "I find by your accounts you must have very imperfect ideas of the charms which in a great measure constitute beauty in the female sex: I mean that rosy blush of the cheeks which you so much admire for being light blue, I think a complexion nearly as exceptional in the fair sex as the sunburnt Moor's or the sable Ethiopian's, consequently (if real) a fitter object for a show than for a wife."

Dalton read more than one hundred scientific papers to the Literary and Philosophical Society of Manchester, of which he was President for many years. He used to make quaint remarks from the President's chair, being very fond of a sly joke. For instance, on one occasion when some one was reading a paper which was stupid and meaningless and was quite apparently a waste of the Society's time, Dalton remarked in a very audible whisper to the Secretaries who sat near him, "Well, this is a very interesting paper for those that take any interest in it."

Dalton was a great walker, proof of which we had in his forty-mile walk from his home to Kendal, a journey which he repeated often, preferring to walk at least a good bit of the way. While in Manchester he was still fond of country walks. The only other recreation he had was a game of bowls with some friends every Thursday afternoon at the "Dog and Partridge," some three miles distant from the centre of Manchester. But despite all his incessant toil and hurrying of meals, Dalton kept good health, until he had a slight paralytic stroke at the age of seventy-one. However, he recovered very quickly, and although he had a second slight stroke the following year, he lived on and was able to go about for another seven years. Indeed, he was going about as usual up to the very last, but on coming in one evening his servant noticed that his hand trembled, more than he had ever seen it before, when making an entry in his meteorological book. He passed away the following morning, "imperceptibly as an infant sinking into sleep."

And so the old Quaker of seventy-eight years was laid to rest. The people of Manchester asked that the funeral might be a public one, and we have evidence of the high esteem in which Dalton was held in the fact that no less than forty thousand people visited the darkened Town Hall where his remains were placed prior to the funeral. His life-long friend, Miss Johns, said, "His reverence for the great Author of all things was deep and sincere, as also for the Scriptures."

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CHAPTER XX

SIR HUMPHRY DAVY
1778–1829

A GREAT CHEMIST, AND THE INVENTOR OF THE MINER'S SAFETY LAMP

It is always of special interest to hear of a boy of humble origin and destitute condition rising to be a great man. This was my first impression of Sir Humphry Davy, and it must have been shared by many boys who read a very interesting book relating to great men; a copy of this book I possessed when a boy of nine years of age. It pictured Mrs. Davy and her family left "in very distressed circumstances," and being taken care of by a charitably disposed gentleman. Such an impression is not easily removed, and I notice that even the spelling of the word Humphry having been given throughout the story as Humphrey has made it difficult for me to use the correct spelling in later life.

It is true that the origin of Humphry Davy was comparatively humble, in so far that his parents were not wealthy, but he came of a long-established family. His father, although described as a wood-carver, had taken up this profession from the artistic side, and when he came into possession of a small estate, which had belonged to his family for at least two hundred years, he continued to pursue the art of wood-carving as a hobby.

On the family tombstones their ancestors could be traced back to 1588, and it is clear that they were of the middle class, as the descriptions affixed to the names of the deceased were given generally as that of "yeoman," and occasionally "gentleman."

Humphry Davy's grandmother was a member of one of the oldest families in Cornwall. Her dowry was fifteen hundred pounds, which was quite a handsome fortune in those days. It is said that the Davys could trace their ancestry back to a noble family who came over with William the Conqueror.

Humphry's mother was left a widow at the age of thirty-four, our hero being then sixteen years of age. Mrs. Davy was left with an income of one hundred and fifty pounds a year, but with a debt of thirteen hundred pounds, due to some unfortunate mining investments made by her husband. Not only did Mrs. Davy succeed in giving her family a good education, but she determined to pay off the debt which her husband had left. To this end she went into partnership with a French lady who, with her sister, had fled to England from France because of the French Revolution. These ladies established a millinery business, in which Mrs. Davy remained a partner for some years, until she came into possession of a family estate which brought her an income of three hundred pounds per annum, whereupon she retired from business. But what is of special interest is that she succeeded in paying off the whole of her husband's debt.

Humphry Davy was born in 1778, away down in that most southerly point of our Island, Penzance, in which town his paternal ancestors had been settled for a very long time. When his father and family removed to the estate already mentioned, Humphry, who was then nine years of age, remained in Penzance for the sake of his schooling. The estate, however, was only a few miles out of the town, so that Humphry could pay his parents a visit, riding there on his pony "Derby."

He was a clever boy, but not a prodigy. Before he could read he gave evidence of a remarkably retentive memory by reciting a great part of that big volume *The Pilgrim's Progress*. Other favourite books of his childhood were . *Aesop's Fables* and the *Arabian Nights*. When scarcely five years old he made rhymes, and recited them at Christmas parties, attired in some fanciful dress. We know, on the authority of his brother, that Humphry's disposition as a child was remarkably sweet and

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affectionate. We may be sure he was a favourite with his schoolmates, for they used to gather around him and listen to him relating wonderful stories. And besides this he was in great demand for writing valentines and love-letters for other boys.

When a child the great Sir Humphry Davy was content to fish with a bent pin and with a bit of bread as bait, a method of angling not yet extinct among little folk. In later years our hero became a keen fisherman.

In a letter written when he was twenty-four years of age, Humphry happened to ask his mother how his younger brother was getting along at school, and he added, "I recollect I was rejoiced when I first went to Truro School, but I was much more rejoiced when I left it for ever."

One is not surprised to learn that young Humphry preferred the society of persons older than himself; he would find most boys of his own age disinclined to talk about such advanced subjects as those in which he began to take an interest. On one occasion when he was discussing some question with a Quaker, who was much older than himself, the Quaker said, "I tell thee what, Humphry, thou art the most quibbly hand at a dispute I ever met with in my life."

Living in a district in which there were copper and tin mines, the boy Humphry became interested in Geology, and would be seen going about with one pocket filled with specimens of rocks, while the other was filled with fishing tackle.

During the time he was residing in Penzance with a family friend—a physician—Davy was in the habit of disappearing to the garret, where he carried out a variety of chemical experiments. Occasional explosions alarmed the household, but although the worthy doctor declared that they would all be blown up into the air some day, that the boy was incorrigible, and was an idle dog, yet the ending of his scoldings usually took the form of some quiet chaff, calling the boy "the philosopher," and playfully nicknaming him "Sir Humphry."

Knowing the boy Humphry's studious disposition, we are apt to picture him as of a soft nature; indeed, the early impression I formed of him was that he was effeminate. I have no doubt that this impression was due to a picture of him in the boy's book to which I have referred already, which picture gave him a decidedly girlish look. But young Davy was something very different; not only in appearance, but in character. His courage was unmistakable; on one occasion he was bitten by a dog that was believed to be rabid, whereupon this thoughtful youth whipped out his pocket-knife and cut out the part which was bitten, and then hastened off to the surgery, where he was at that time an apprentice, and cauterised the wound himself.

Davy had every intention of becoming a doctor, but because he was seen so much at the mines, and among the rocks with a hammer, one looker-on said that "he thought more of the bowels of the earth than of the stomachs of his patients; and that when he should have been bleeding the sick, he was opening veins in the granite. That instead of preparing medicines in the surgery, he was experimenting in the garret." But I do not think that this can possibly be a true picture of young Davy. It should be classed as circumstantial evidence; it was the impression received by one who happened to see Davy only at his play. Although we have no details, it has been stated of Davy that he was most attentive to his patients, and more especially to the poorer ones.

Davy had an impediment in his speech, and although it was nothing so serious as that which worried Joseph Priestley, Davy tried to overcome it by following the example of Demosthenes, in so far that he would go down to the shore and practise speaking aloud. He did overcome the defect to a considerable degree, but the result was apparent in after-years, when he formed a habit of speaking in public with a peculiar intonation which seemed strange to his audiences, and which, unfortunately, was very often mistaken for affectation.

Humphry had no ear for music, and in later life it was a source of amusement to those with whom he worked to hear him

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trying to hum a tune while absorbed in some experiments. When a lad, his friends had tried to teach him the air of "God save the King," but they gave him up as hopeless. I met with a similar case in my school-days, the boy being quite unable even to distinguish between the air of the National Anthem and any other popular tune. Indeed, I offered him a prize on one occasion if he could name two out of six well-known airs when whistled to him, but he failed to guess even one, and as boys we had no very extensive programme of music.

By the time Humphry Davy was seventeen years of age he had begun to criticise the standard books on Chemistry, and more especially the accepted theory of heat, which was that heat was a material thing. At this time Davy's apparatus consisted chiefly of wine-glasses, tea-cups, tobacco pipes, and earthen crucibles, while his chemicals were those in common use in medicine. Like many another boy interested in Chemistry, Davy made his early experiments in his bedroom, and sometimes in the garret.

By this time Davy was a really enthusiastic chemist, so that he could not help talking of it to any one from whom he might gain information. It so happened that Gregory Watt, a son of the famous James Watt, had gone to Penzance on account of his health, and it chanced to be at the Davys' house that he boarded. This gentleman had come straight from Glasgow University, where he had been studying Science, and we may be sure that he would find an eager questioner in the lad Humphry Davy. Another such friendship which Humphry formed when he was a youth was with Josiah Wedgwood, the famous potter, who had resided also in Penzance for the benefit of his health.

It will be of interest to note Davy's early experiment in connection with the nature of Heat, which was supposed at that time to be a material thing. He caused two blocks of ice to be rubbed together by a clockwork mechanism, all of which he placed under the receiver of an air-pump, and withdrew the surrounding air so that no heat could reach the apparatus or the ice, the whole arrangement resting on a block of ice. He showed that heat was actually produced merely by the friction between the rubbing surfaces of the ice-blocks, and that therefore heat could not be a material thing. Count Rumford, of whom we shall hear later, did original work in this direction. It soon became clear that the temperature of a body is due to the vibratory motion of its particles.

In the earliest form of the experiment referred to Davy had no air-pump, nor had he ever seen such a thing, but he converted a medical syringe into an air-pump. This syringe had been given to him in a case of surgical instruments by the surgeon of a French vessel which was wrecked off Penzance. Davy had been glad to get this case of instruments, not that they would be of use to him in his medical apprenticeship, but because he could turn many of them to use in his chemical experiments.

After four years' apprenticeship to the surgeon-apothecary at Penzance, Davy was offered a post at Bristol, where a Pneumatic Institute had been built. Davy accepted the post of superintendent of this Institute, which was a hospital for the purpose of applying different gases to the patients as cures for diseases. As the work would be largely experimental, Davy would have plenty of opportunities for original work.

On Davy's journey to Bristol he met the mail-coach from London, covered with laurels and ribbons, bringing news of Nelson's stupendous victory over the French fleet in the Battle of the Nile.

Dr. Beddoes, who was one of the principals of the Pneumatic Institute, was very impulsive in his methods, often jumping to a conclusion without giving the problem proper consideration. On one occasion his friend Mr. T—called to consult him upon the case of his wife, and the doctor prescribed a new remedy, but in the course of the day he sent word in haste to say that before Mrs. T—took the medicine, its effect might be tried upon a dog. We are left in the dark as to the fate of Mrs. T—or the dog.

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Davy wrote to his mother about this time: "We are going on gloriously, our patients are getting better; and to be a little conceited, I am making discoveries every day."

Dr. Beddoes found Davy a capital worker, and no sooner had the young chemist discovered the properties of nitrous oxide gas, than the doctor immediately jumped to the conclusion that it was a cure for paralysis. Young Davy was to take charge of the experiments upon the patients, of whom, by the way, there were sometimes as many as eighty.

A paralysed man was selected for this new treatment, and it is very evident that the patient had no idea of the kind of treatment he was to undergo, for when Davy placed a pocket thermometer beneath the man's tongue in order to take his temperature, the man mistook this for the treatment, and declared that it gave him a feeling throughout his whole body. Davy pretended to take the matter quite seriously, and after removing the thermometer, he asked the patient to call the following day for a repetition of the treatment. For two weeks this patient called each day and had the thermometer placed beneath his tongue, and at the end of that time he left the Institute a cured man.

Davy had not told Dr. Beddoes what kind of "treatment" he had really given the man, but as the worthy doctor was going to rush off and publish the remarkable proof of the action of nitrous oxide, Davy had to let him into the secret.

This is the gas commonly used by dentists as an anaesthetic. On one occasion while Davy was experimenting with this gas upon himself he was nearly killed, and he resolved never to attempt so rash an experiment again.

Davy was so keen in his work and in his study of Chemistry, that he rose two hours before breakfast in order to get time for writing. But he did not cut himself off from the world; he was a keen angler, and he kept a dog and gun for his shooting expeditions.

One of his friends has left us a description of Davy's fishing clothes. He had a suit made of bright green cloth, and having bought a hat, in a raw state from the manufacturer, he dyed it green with some pigments of his own composition. The idea of this green clothing was to elude the observation of the fish, by appearing as much as possible as part and parcel with the bank of the river. When shooting he put on a bright scarlet cap, but that was to protect himself against any other sportsman mistaking him for prey, or failing to observe his presence.

While at Bristol Davy got an offer to act as Assistant Lecturer at the Royal Institution, London, which had been founded a short time previously. The purpose of this Institution, which, of course, still flourishes, was to diffuse a knowledge of Science and of its applications to the common purposes of life, and to excite a taste for Science amongst people of high rank. Davy accepted this post, and in the succeeding chapter we shall see how he made the Royal Institution famous.

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CHAPTER XXI

HUMPHRY DAVY GOES TO LONDON

The first impression that Humphry Davy made on his arrival at the Royal Institution was not favourable. The chief promoter, Count Rumford, was so disappointed with the ungainly appearance and peculiar manner of Davy that he feared to let the young man deliver a lecture. However, no sooner had the young Chemist begun his lectures than he became exceedingly popular. He could explain things in a way that his audience understood. His lecture-room became "crowded with men of first rank and talent, blue-stockings, and women of fashion, the old and the young, all crowded eagerly into the lecture-room." Sometimes his audience would number one thousand, and very soon young Davy became "the lion of Society."

Without going into any detail of Davy's work, we may note one outstanding line of research. The elements Potassium and Sodium had existed only in the form of compounds. Humphry Davy discovered a means of extracting the metals Potassium and Sodium from their compounds, by a process in which the large electric battery of the Institution played an important part. This was in the year 1807, not many years after Volta's discovery of the electric current and his invention of the electric battery.

We are told by the assistant of Davy, that when the great Chemist saw the minute globules of Potassium burst through the crust of potash, he could not contain his joy, and actually bounded about the laboratory in ecstatic delight. It was a great discovery; no man had ever seen the metal Potassium before.

About this time Davy contracted a severe fever, which he believed to be typhus fever. He thought that he had become infected on a visit to Newgate Prison, where he had been asked to make investigations regarding a suitable disinfectant for this dread disease, which was very prevalent in the prison at that time. Davy was distressed in case he should die before he had an opportunity of publishing the results of his experiments. During his two months' illness there were so many anxious inquiries that a daily bulletin was issued by the doctors.

On his recovery he received a great welcome by the scientific world, and before he was thirty-two years of age he held first rank among Chemists. That Davy had a good deal of common sense is evident from many of the jottings in his notebook, one of which reads: "A man should be proud of honours, but not vain of them."

Davy's pioneer experimenting was not without considerable risk to himself. On one occasion an explosion of the chemicals with which he was working nearly cost him his eyesight. Writing to inform his brother of the accident, he said:

> "My sight, I am informed, will not be injured. It is very weak. I cannot see to say more than that I am,
>
> "Yours very affectionately,
>
> H. DAVY

Humphry Davy had not been long at the Royal Institution before he was elected Professor of Chemistry. During part of the time he occupied this Chair he had Michael Faraday as his chief assistant. The way in which Faraday was first introduced to Davy is of interest, and will be dealt with in the succeeding chapter on Michael Faraday.

When Davy made his famous experiments in separating the elements Potassium and Sodium from the compounds in which they had been so securely locked, he used a large battery of six hundred cells. Later he had an immense battery of two thousand cells. Of course, such large batteries have become unnecessary since the invention of the dynamo. But it was with this huge battery that Davy discovered what he called the

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electric arch, and what we now call the electric arc. Davy found that the battery current passing between two charcoal points produced an intensely bright source of light. As he held the carbons in a horizontal position, the heated air in rising caused the flame of light to curve or arch upwards. And although there is no arching between the vertical carbons in a modern electric lamp, we still describe it as an arc lamp to distinguish it from the incandescent glow lamp.

It is interesting to learn that two of our preceding heroes, the eccentric Cavendish, and the Astronomer, William Herschel, were present when Davy performed some of his experiments in private.

When Davy was thirty-four years of age he married the widow of a wealthy London merchant, just as Herschel had done. In a letter to his brother announcing his engagement Davy wrote: "Mrs. Appreece has consented to marry me; and when the event takes place I shall not envy Kings, Princes, or Potentates."

I find the following announcement of the marriage in the *Gentleman's Magazine* of April, 1812:

"Sir Humphry Davy to Mrs. Appreece. The ceremony was performed at her mother's house in Portland Place, by the Lord Bishop of Carlisle."

The bride was not only a woman of considerable fortune, she must have been very accomplished, for it was said of her that she had learned everything, and had been everywhere. Two of the most interesting letters written by Sir Walter Scott were addressed to this lady, who became Lady Davy upon her second marriage, her husband having been knighted two days before their wedding. Humphry Davy's knighthood was conferred by the Prince Regent, who afterwards became George IV.

Some time later we find Sir Humphry and Lady Davy setting out for a trip on the Continent. Our hero took Michael Faraday with him to act as secretary, and Lady Davy had one of her maids with her. But when the party were landed from their sailing boat on the French coast, they were all arrested, France being in a state of war. It took a week for information to come from Paris granting the illustrious chemist and his party a safe journey, which had been guaranteed to them before they set out for France.

Among the French scientists to welcome Sir Humphry Davy was Professor Ampere, whose name we honour by using it to denote one of the units of electrical measurement; we speak of a current of so many " amperes."

During this same trip, when Davy reached Italy, he met the discoverer of the electric current, Professor Volta, whose name we have embodied in the unit of electric pressure; we describe a current as being of so many "volts" pressure. We are told that Professor Volta waited in full dress to receive Sir Humphry Davy, and that the French scientist was greatly taken aback at the carelessness of Davy's dress; a dress of which an English artisan would be ashamed.

During his stay in Paris Davy was conducted over the great Louvre, but the famous pictures did not excite his wonder. He hurried through the galleries, merely remarking to his guide on the extremely good collection of fine frames.

Remembering Davy's indifference to Music, and now this indifference to Art, one might be tempted to think that the great philosopher was devoid of all sentiment; but, far from it, he was himself a poet. One contemporary, who was well able to judge, said that if Davy had not become the first chemist of his time, he would have become a great poet. There is quite a collection of his poems given in his Memoirs; here are a few lines of one which was composed by Davy when he was a lad of seventeen:

"THE SONS OF GENIUS"

After some verses descriptive of Genius, Davy proceeds:

"Inspired by her, the sons of genius rise
Above all earthly thoughts, all vulgar care;

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Wealth, power, and grandeur, they alike despise,
Enraptured by the good, the great, the fair.

"A thousand varying joys to them belong,
The charms of Nature and her changeful scenes;
Theirs is the music of the vernal song,
And theirs the colours of the vernal plains."

Further on in the same poem, referring to "the Sons of Nature," Davy says:

"When the red lightnings through the ether fly,
And the white-foaming billows lash the shores;
When to the rattling thunders of the sky
The angry demon of the waters roar;

"And when, untouch'd by Nature's living fires,
No native rapture fills the drowsy soul;
Then former ages, with their tuneful lyres,
Can bid the fury of the passions fall.

"Like the tumultuous billows of the sea
Succeed the generations of mankind;
Some in oblivious silence pass away,
And leave no vestige of their lives behind.

"Others, like those proud waves which beat the shore,
A loud and momentary murmur raise;
But soon their transient glories are no more,
No future ages echo with their praise.

"Like yon proud rock, amidst the sea of time,
Superior, scorning all the billows' rage,
The living sons of genius stand sublime,
The immortal children of another age."

On Davy's return to this country he was asked to try and discover some means of preventing explosions of fire-damp in coal-mines. During his absence there had been a very serious colliery disaster due to fire-damp having become ignited by the miners' naked lights, and these explosions had become so common that the miner's occupation was a most dangerous one.

First of all Davy succeeded in making a lamp which was perfectly safe, but which, unfortunately, would not keep alight when fire-damp was present, so that the miner would be left in the dark, and might find it impossible to get out of some of the burrowings which constitute a coal-mine. But Davy did not rest content; he continued to think and experiment till he had invented a lamp which was absolutely safe and would continue to burn with safety in the presence of fire-damp, and enable the men to see their way out of the mine.

Sir Humphry Davy went down into the most fiery mines with his lamp, to show his entire confidence in its safety. The coal-owners invited Sir Humphry to a dinner, at which they made him a present of very valuable plate, as a token of gratitude for this humane invention. It is to Davy's credit that he refused to listen to his friends' requests that hg would take out a patent for the invention; he preferred to make it a present to his fellow-men, and we benefit from it to this day. It is almost inconceivable that some explosions in our own time have been traced to miners being so absolutely selfish as to have false keys made to enable them to open their safety lamps and light their pipes. Of course, we see some miners with naked lights on their caps, but these men are working in mines that are quite free from fire-damp.

When one friend of Sir Humphry Davy urged him to protect his invention by a patent, and secure a fortune thereby, the reply was: "It might undoubtedly enable me to put four horses to my carriage; but what would it avail me to have it said that Sir Humphry drives his carriage and four?"

Not only in our own country, but on the Continent also, was Sir Humphry Davy honoured because of this great invention: it showed to the world the practical value of Science.

On the death of Sir Joseph Banks, the President of the Royal Society, Sir Humphry Davy, although only forty-two

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years of age, was elected to that post, which is the highest honour that can be given to an English scientist. The traditions of this chair, which Sir Isaac Newton had occupied so long, were upheld ably by Sir Humphry Davy for seven years. Failing health forced him to resign, and to seek recovery abroad.

The nature of Davy's illness was a paralytic stroke, which occurred while he was out shooting over a peer's estate. His mind was in no way affected, and it was believed that a trip on the Continent might restore his health, he being still a few years short of fifty.

Sir Humphry set off with his brother, who has left us a descriptive account of their journey in these pre-railway days. When they landed on the French coast they bought a post-chaise, in which they drove across the Continent, in journeys of about forty miles per day; less than we can now cover in one hour. The carriage wheels sometimes stuck fast in the bad roads, and on occasions their coachman would prefer to drive them across ploughed fields. The thermometer inside the carriage stood below freezing-point, and some leeches, carried in the carriage pocket, were frozen during the whole journey.

Sir Humphry recovered so far that his brother was able to leave, but the letters which the great chemist wrote home are rather pathetic: "It suits me better to wile away my days in this solitary state of existence, in the contemplation of Nature, than to attempt to enter into London Society, where recollections call up the idea of what I was, and the want of bodily power teaches me what a shadow I am." But we must not picture Davy as being a helpless invalid, for in a letter to his brother, in which he expresses the desire that his brother might visit him, he says: "I would then show you my kind little nurse, to whom I owe most of the little happiness I have enjoyed since my illness. I shoot here a little, mount my ponies, and employ myself a good deal in literary pursuits." Nor must we picture Davy as an old man; he was only fifty years of age.

I remember when I came across the letter, from which the preceding extract is taken, I wondered at Lady Davy not taking the place of "the kind little nurse," but from another part of the biography I think it is apparent that the "little nurse " was the son of an old friend. Here is the passage to which I refer: "Sir Humphry Davy, during the latter days of his life, was cheered by the society and affectionate attentions of his godson, the son of his old friend Mr. James Tobin. He had been the companion of his travels, and he was the solace of his declining hours." Of course, travelling in wintertime was a very different thing in those days from anything we have experienced, but so soon as Lady Davy received word, some time later, that her husband had been taken seriously ill at Rome, she left England at once and hastened to his side.

The second paralytic stroke came about in a very simple way. Sir Humphry was sitting, after breakfast, dictating an addition to one of his books, when upon attempting to rise, he was alarmed to find that he had lost the power of his limbs, although there was no pain or loss of intellect. Medical assistance was called in immediately, and the usual application of leeches was tried. In a letter dictated to his brother he says: "I am dying from a severe attack of palsy, which has seized the whole body, with the exception of the intellectual organ. I am under the usual severe discipline of bleeding and blistering; but the weakness increases, and a few hours or days will finish my mortal existence. I shall leave my bones in the Eternal City."

Immediately upon receipt of this letter his brother, who was acting as physician to the Forces in Malta, set out for Rome. He had some little difficulty in finding Sir Humphry, as the only address he had was Rome. Their meeting was very touching; the invalid believed he had only a few hours to live, and he desired to take full advantage of such precious time. He welcomed his brother with a smile, and, in a most cheerful voice, told him to take the event as a philosopher. Sir Humphry proceeded to explain some experiments in which he had been engaged, with

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the object of discovering the electric power of the torpedo fish, and he desired his brother to follow up the subject.

Sir Humphry sent his brother to the market-place to buy a torpedo fish so that he might explain the matter to him more easily. Contrary to expectations, the invalid lived throughout the night, and writing several days later, his brother says: "He considered this the exact and appropriate time for his death. The following morning when I went to him and drew back his curtains, he expressed great astonishment that he was alive. He said that he had gone through the whole process of dying, and that when he awoke he had difficulty in convincing himself that he was in his earthly existence, and that he was under the necessity of making certain experiments to satisfy his mind that he was still in the body."

After this Sir Humphry accepted his brother as his physician, and they both gained new hope. The invalid spent quiet days, having such books as *The Arabian Nights* read to him, and after the arrival of Lady Davy he was able to go out each day in their carriage. He expressed a desire to leave Rome, and Lady Davy preceded them each day from place to place in order to make suitable arrangements for the arrival of her invalid husband, but only a small part of the day was taken up with travelling, as the day's journey seldom exceeded five miles.

At Geneva, Sir Humphry was grieved to learn of the death of his old friend Dr. Thomas Young, a fellow-professor in the Royal Institution. Sir Humphry dined at the table that evening, but went off to bed about 9 p.m. His great life ebbed out that night. His body was buried at Geneva, for he had expressed the desire that it should be buried wherever he died. There was a public funeral, at which there were many English friends. The professors and the students of the University of Geneva were present. The students had expressed a desire to carry the body to the grave, but the authorities did not see their way to grant this unusual request. And so, at the comparatively early age of fifty-one years, this Hero of Science passed from the world's stage in the year 1829.

CHAPTER XXII

MICHAEL FARADAY
1791–1867

PRINCE OF EXPERIMENTERS; ASSISTANT TO SIR HUMPHRY DAVY

No one can take an interest in the history of Electricity without being impressed with the great importance of Faraday's discoveries, but one may know his work without knowing the man. I was impressed with this many years ago, when the late John Tatlock, of Glasgow, who at one time was one of Lord Kelvin's assistants, told me the following incident concerning Faraday.

When a young man, Tatlock was passing the old Andersonian College, the forerunner of the colossal Royal Technical College, in Glasgow, when the janitor called to him and asked if he would care to hear Michael Faraday preach on the following day—Sunday. Tatlock thought at first that the janitor was jesting, but when given a note of the time of place and meeting he very naturally decided to be one of the audience. On Sunday he made his way to the address given, where in a back court he found a very small hall, in front of which stood Faraday in conversation with two old gentlemen. At the appointed hour the meeting was begun, with only a dozen or two of an audience in the small hall. There stood Faraday, at a time when the world was ringing with his praise, giving a simple discourse on "Brotherly Love." My old friend told me that the one thing at which he marvelled most was the exceptional knowledge of the Bible, which was apparent by the ease with which Faraday turned from one quotation to another, and his whole address was practically a stringing together of passages of Scripture. The smallness of the meeting-place is accounted for

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by the fact that Michael Faraday belonged to that small religious sect known as *Sandemanians* or *Glassites*. Their religious creed is practically the same as other Protestant bodies, but they do not believe in having professional clergymen, and they have some customs special to their own church.

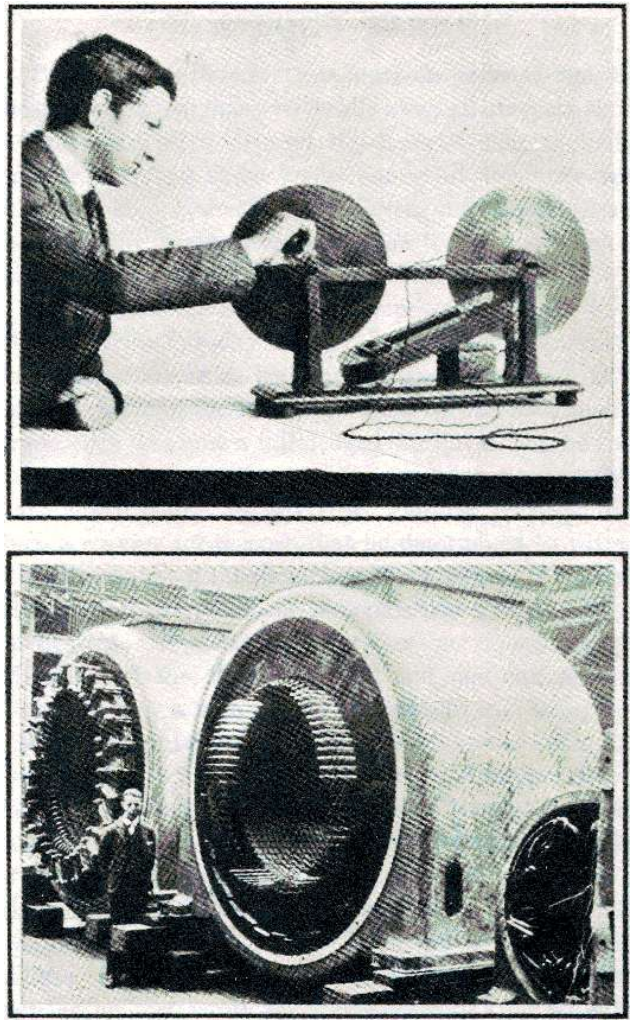
Faraday, in common with most of us, followed the religion of his parents, but because he belonged to a deeply religious sect we are not to picture him flaunting his religion before the world, as some small sects are liable to do. One of his friends has said: "Never once during an intimacy of fifteen years did he mention religion to me, save when I drew him on to the subject."

His father was employed as a blacksmith in London, and lived in a very humble position. The blacksmith's wife was "particularly neat and nice in her household arrangements," but there was nothing outstanding about Faraday's parents.

He was born in London in 1791, and although we are looking back from the twentieth to the eighteenth century, the cry is not a very far one. It is one hundred and twenty years since Faraday was born, but it is not forty-five years since he died, so that there are many people still living who can remember him.

Our hero very nearly lost his life when a boy. He tells how he was playing about in a loft above the smithy in which his father worked, and stepping backwards he fell through an open space in the floor. The opening happened to be right above his father's anvil, and fortunately for him and for the world, his father was bending over his work at the moment when the boy Michael came down. Had he not fallen right on to his father's back, he would doubtless have been killed upon the anvil.

As a schoolboy Faraday attracted no special attention, but he tells us himself, "I was a very highly imaginative person, and I could believe in the *Arabian Nights* as easily as in the *Encyclopaedia;* but facts were important to me and saved me. I could trust a fact, and always cross-examine an assertion."



THE BIRTH OF THE DYNAMO
THE UPPER ILLUSTRATION SHOWS THE SIMPLE KIND OF MACHINE BY WHICH FARADAY SUCCEEDED IN OBTAINING AN ELECTRIC CURRENT. THE BOY IS TURNING A WOODEN WHEEL WHICH DRIVES A COPPER DISC. WHEN THIS METAL DISC IS REVOLVED BETWEEN THE POLES OF A MAGNET A CURRENT OF ELECTRICITY FLOWS FROM THE CENTRE TO THE EDGE OF THE DISC, AND THE CURRENT MAY BE CONDUCTED AWAY BY A WIRE CIRCUIT. THE LOWER ILLUSTRATION SHOWS PART OF A MODERN MACHINE FOR GENERATING ELECTRIC CURRENTS.

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Like many boys leaving school, he seemed to have no particular bent, and so he became errand-boy to a book-seller, whose shop was in the neighbourhood of the Faradays' humble residence. But Michael Faraday was one of those sensible boys who mean to take life in earnest, and who would put his heart into whatever work he was set to do. Some of his duties were very humble, such as delivering newspapers at the customers' houses, but Faraday carried out his simple duties to such good purpose, that at the end of one year the bookseller offered to take him as an apprentice to learn bookbinding, without asking the premium which was usual for such a training. This must have been appreciated by Michael's father, who could not well afford to pay a premium, Michael being only one of a large family.

By this time Faraday was fourteen years of age, but he did not, like so many boys, idle away all his spare time; he got permission to read the books belonging to his master. Among these books one great favourite with him was Mrs. Marcet's Conversations on Chemistry, and he said long years afterwards that it was this book in particular which had led him into Science.

By the time his seven years' apprenticeship was up in the bookshop Faraday had become very much interested in Science, but as he had had no special training, there seemed nothing for it but to stick to the bookbinding trade. He was now a full-fledged workman, and he took a situation with another employer, who was evidently a hard taskmaster. In any case, Faraday had acquired such a craving for Science that he determined to write a letter to the great Sir Humphry Davy, asking if he could give him any employment in connection with the Royal Institution. Faraday had written previously to the President of the Royal Society, and one can scarcely blame so busy a man for not replying to this letter sent without any introduction. But Faraday was keen, and he doubtless felt as though he knew Sir Humphry Davy, for he had attended some of his public lectures, and had taken voluminous notes, to which he had added drawings of the apparatus used in the experiments. As proof of his interest in Science, Faraday sent to the great Chemist this notebook, which is now preserved in the museum at the Royal Institution. Davy, great and busy man as he was, wrote the following very kind letter to Faraday:

December 24, 1812

"Sir,

I am far from displeased with the proof you have given me of your confidence, and which displays great zeal, power of memory, and attention. I am obliged to go out of town till the end of January; I will then see you at any time you wish. It would gratify me to be of any service to you; I wish it may be in my power.

"I am, sir, your obedient humble servant,

H. DAVY

How Faraday must have treasured that letter from one who was famous throughout the world!

The great Chemist was as good as his word; he made an appointment for Faraday to meet him at the Royal Institution. He received the youth very kindly, but pointed out to him that Science was not a money-making business, whereas he might do very well in the book-binding business. Davy was evidently impressed with the lad's capabilities, for he promised him the book-binding of the Institution and his own private work also. This was very kind, but Michael Faraday was eager to become a scientist, and no doubt Davy saw that the lad would not be satisfied with a business life.

Not very long after this Faraday was going off to bed in his humble home, after a hard day's work, when the household was disturbed by a loud knock at the door. A footman had alighted from a grand carriage and had left a note for Michael Faraday. This was a request from Sir Humphry Davy that he should call upon him the next morning. I wonder if Faraday slept

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much that night! Nothing would prevent him keeping this appointment.

Sir Humphry, finding the young man was still as eager as ever to get into scientific employment, gave him the place of assistant in the laboratory of the Royal Institution, from which he had been forced to dismiss the former occupant on the previous day.

This was not long before Davy's continental tour, and by that time he was so impressed by Faraday's general interest that he took him with him on his travels, to act as secretary and as assistant, for even then Davy carried a miniature chemical laboratory about with him. On their return about a year and a half later, Faraday was reappointed assistant in the Royal Institution.

When he was thirty years of age he was still assistant, but then to Davy's successor, and his salary was only one hundred pounds, with residence in the Institution. At this age Faraday married the daughter of a silver-smith, following the custom of the Sandemanians at that time by marrying one of their own sect. In his love-making and throughout his wedded life he was most chivalrous. When his successor, Professor Tyndall, was going over Faraday's book of Diplomas and Honours, he came across the following entry in Faraday's own handwriting: "Amongst these records and events, I here insert the date of one which, as a source of honour and happiness, far exceeds all the rest. We were married on June 12, 1821."

Faraday had no children of his own, but he was so fond of children that he adopted a little niece, and when his day's work was over he would go up to his rooms and play with this little one at bagatelle or charades, or he would read to her. When other children came to visit them, he would play hide-and-seek with them in the large Lecture Theatre, and then take them up to see his tuning-forks or resounding glasses. He would often take his little niece to the Zoological Gardens, and he would join in her merriment, sometimes laughing at the monkeys' tricks till the tears rolled down his cheeks. His love for children was so great that when he went out to a dinner-party he must see the little ones, who were sometimes brought down in their nightgowns to him. It was his great love of children that suggested to him the public lectures for boys and girls home from school for the Christmas holidays, which custom is carried on, by men of science, to this day at the Royal Institution each Christmas. Faraday himself conducted these lectures for nineteen years. He entered into the spirit of the thing so well that it is said one would have thought that he had never seen the experiments before, and that he was about to clap his hands with boyish glee at the unexpected results.

Faraday was a hard worker, and found it necessary to refuse almost all invitations to dinner-parties and other social gatherings, but he did not cut himself off from the world. He used to take open-air exercise on his velocipede, and he would entertain his friends with his flute.

He was always gentle and a true gentleman, and although he was truly sympathetic he was by no means what is termed "soft." On one occasion, when a young man, he was hurrying along Holborn Pavement on a Sabbath morning to attend the Sandemanian meeting, when some small missile struck his hat. He would have thought it accidental, had it not been quickly repeated, whereupon, glancing upwards, he saw a head hastily withdrawn from an open window in the upper storey of a closed linen-draper's shop. Roused by the affront, he marched up to the door and knocked. The servant opening it said that there was no one at home, but Faraday declared he knew better, and pushed his way upstairs. There he found a number of draper's assistants, who professed to know nothing of the matter, but Faraday taxed them very severely for their annoyance of wayfarers on a Sabbath morning, and before he left they apologised for their behaviour.

Another occasion when Faraday showed a little temper was when he and another scientist had gone down a Durham coal-mine to make inquiry on behalf of the Government into the

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cause of a serious explosion, which had taken place in this mine shortly before that time. While sitting in the mine questioning some of the men Faraday asked where they kept their gunpowder, and when they coolly told him that he was sitting on a bag of it, he very naturally "gave them a piece of his mind" upon their carelessness.

On another occasion Faraday wrote a scathing letter in connection with two Italian philosophers who had tried to do his work an injustice. But these were exceptions to the rule, and only serve to show us how very well Faraday had himself in control.

Here is an incident which will serve to show how remarkably kind and thoughtful he was. One of his pupils had been appointed Director of the Chemical Department of the War Establishment at Woolwich, through the influence of Faraday. This pupil tells us that on the occasion of his first lecture he was feeling very nervous. To his dismay, when he went into the Lecture Hall there was his professor, who happened to be in Woolwich on that day. But Faraday put him at his ease at once. Coming forward and shaking hands warmly with the young lecturer, Faraday said that he had looked in to see if he could be of any assistance to him, and this Prince of Experimenters set about acting assistant to his former pupil.

It may seem strange that Faraday himself never lectured till he was thirty-two years of age, and then only because the professor was absent. He did not become a regular lecturer until he was thirty-six years of age. But we must remember that he did not enter the Royal Institution till he was twenty-two years of age, and he had had no university or college education. Up to that time he was entirely an amateur scientist, but his letters to his young Quaker friend Benjamin Abbott make interesting reading. They are included in Faraday's correspondence collected by Dr. Bence Jones, the then secretary of the Royal Institution.

While Faraday's lectures were a great success, it was as an experimenter, and more especially as a discoverer, that he became famous. It was he who discovered the principle which made the modern dynamo possible, and brought about all the practical applications of electricity on a large scale. Had Faraday been a practical inventor such as Lord Kelvin was, we should probably have had the dynamo a generation earlier, but Faraday confined himself to the Science side entirely. The only point of actual contact I can think of between Faraday's personal work and the practical applications of Science was his appointment as Adviser to Trinity House in connection with Lighthouses, and in this capacity he did much useful work. For a few years Faraday did come into indirect touch with the business world in doing some work as an analytical chemist, but we shall consider this later.

Another fundamental principle laid down by Faraday was what electricians call "self-induction," and this was of great value in connection with the early cables across the Atlantic. Then came Faraday's experimental proof of the intimate connection between light, electricity, and magnetism. These few remarks will be sufficient to convince the general reader that Michael Faraday has a just claim for being called a Hero of Science. It was a great work of Faraday's, the breaking down of the barriers which used to separate one department of Science from another.

Strange to say, this Prince of Experimenters, this great discoverer, was not a mathematician. A continental Scientist has said: "It has been stated on good authority that Faraday boasted on a certain occasion of having only once in the course of his life performed a mathematical calculation: that once was when he turned the handle of Babbage's calculating machine." If Faraday did say this, it must, of course, have been in jest. We find him assisting his niece with her lessons, and making her problems in arithmetic easy and interesting by his lucid explanations. Faraday was doubtless an expert arithmetician, but he had no training in higher mathematics. He certainly had a mathematical

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mind. The great mathematician Clerk Maxwell, of whom we shall read in a later chapter, when referring to some of Faraday's work, said: "It shows him to have been a mathematician of high order, and one from whom the mathematicians of the future may derive valuable and fertile methods." Of course, Maxwell does not mean that Faraday used higher mathematics in the ordinary sense.

Amongst the letters received by Faraday were two from the great Napoleon, while he was Prince Louis Napoleon. These were personal letters asking his scientific advice on particular points. The first letter was written when the Prince was imprisoned in the fortress of Ham, and in this letter he tells Faraday that his writings have brightened the hours of confinement.

Then there is a letter to Faraday written by King Edward VII, when he was Prince of Wales, and about fifteen years of age:

Windsor Castle, *January* 16, 1856.

"DEAR SIR,

I am anxious to thank you for the advantage I have derived from attending your most interesting lectures. Their subject, I know very well, is of great importance, and I hope to follow the advice you gave us of pursuing it beyond the lecture-room; and I can assure you that I shall always cherish with great pleasure the recollection of having been assisted in my early studies in chemistry by so distinguished a man.

"Believe me, dear sir,

"Yours truly, Albert Edward

Faraday's sympathetic nature was evident not only in words, but in deeds. One of his biographers, Dr. Gladstone, wrote: "When I had my wife and my only son taken away, and I myself lay ill of the same fatal disease, he [Faraday] called at my house, and in spite of remonstrances found his way into the infected chamber. He would have taken me by the hand, if I had allowed him; and then he sat awhile by my bedside, consoling me with sympathy and cheering me with the Christian hope."

Faraday had always a very pleasant way of doing things. For instance, he was asked on one occasion by the managers of the Royal Institution to make some intimations before proceeding with his public lecture. One intimation referred to some one who was in the habit of keeping his hat on in the Institution. Faraday said: "The second case I take to be a hypothetical one, namely that of a gentleman wearing his hat in the drawing-room."

He was always very thoughtful for his audience. When he was well up in years he found, before one of his lectures, that his throat was not only troubling him to inconvenience, but that it was painful to exert his speech. However, his lecture had been advertised and there was a large audience gathered in the Lecture Theatre. When he rose to deliver his lecture he apologised to the audience for his voice. He said that he would like to keep his appointment with them if they would excuse his imperfect utterance. Some one then suggested that the lecture might be postponed, one medical man even saying that it would be very hurtful to Faraday to proceed, but the lecturer said that it would be most inconvenient to many, to ladies who had sent their carriages away, and to gentlemen who had possibly put off other engagements. "On this the whole audience rose as of a single impulse, and a number of persons surrounded Faraday, who now yielded to the general desire to spare him the pain and inconvenience of lecturing."

An interesting anecdote related in connection with Faraday refers to one of his handy men in the Royal Institution. He had taken into his employment an old soldier, Anderson, one who would do just exactly as he was told. On one occasion Faraday was busy making some optical glass, and he told Anderson to stoke the furnaces steadily, and keep the temperature as constant as possible, for the production of the

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glass was a tedious one. When at last Faraday had succeeded in his experiment, and was no doubt busy thinking of other schemes, he went off to his rooms, forgetting to tell the old soldier that he had finished. In the early morning he was horrified to find the faithful old servant still stoking away at the furnace, which he had kept up to its full heat all through the night.

There is one anecdote concerning Faraday that I think does not appear in any of his biographies. It was told me by an old gentleman who, during Faraday's lifetime, took a great interest in the philosopher's work. Faraday was asked by the inventor of "a very powerful electromotor" to give his opinion of it. Very probably the request came from friends who had been asked to put money into the venture. In any case, Faraday paid a visit with some friends to see the exhibition machine. The source of power was an electric battery, the energy of which was easily estimated by Faraday, and although the fly-wheel of the motor looked large and heavy, he knew very well that there was little power in it. Looking round he saw a broomstick standing in the room, and picking this up he applied it as a gentle brake upon the fly-wheel, bringing it almost to a standstill, then replacing the broomstick where he got it, he left the room without making any remark.

In the illustration facing page 250 we see a simple form of apparatus devised by Faraday for the production of an electric current by revolving a conductor between the poles of a magnet.

When Faraday was nearly seventy years of age, he saw a dynamo producing an electric current, by means of a coil of wire rapidly revolved between the poles of very large permanent magnets, just as we have on a small scale in those magneto-electric machines with which some young people like to deal out electric shocks to their friends. But Faraday did not live to see the great electrical industries established.

There is one incident which I should have liked to pass over, because it reflects upon the disposition of Sir Humphry Davy, and yet I feel it necessary to mention it in order to make the picture of these two great men as complete as possible. The most I could conscientiously do was to omit it from the chapters dealing with Davy, and let it come in here after we have formed a clear impression of that great philosopher. It is unfortunate that the great Sir Humphry Davy's friendship with Faraday was marred. I should like to have been able to bring forward some reasonable excuse on behalf of Davy, such as failing health or some misunderstanding, but there are no extenuating circumstances. Davy, as President of the Royal Society, tried to prevent Faraday's election as a Fellow of that learned Society, he even ordered Faraday to withdraw his name. Davy seems to have been carried away with his own exalted position, and to have thought—very wrongly—that Faraday's humble origin should debar him from the Royal Society. The whole affair must have been distressing to Faraday, and it detracted from the popularity of Davy. But Michael Faraday bore him no ill-will in after years, and we should hasten to remember how Sir Humphry befriended the bookbinder who desired an entrance into scientific work.

Faraday preferred to remain plain Michael Faraday all his days, although he was offered a knighthood. He even declined the Presidentship of the Royal Society and other honours. He preferred to remain a poor man, because to have become rich would have required the time he devoted to pure Science. In his younger days he had done some analytical work for business firms and the Government, and had made an income of one thousand pounds a year. One of his contemporaries assures us that Faraday could very easily have increased this to five thousand pounds a year. But unselfish Faraday wilfully dropped all such means of becoming rich, not because he could not have enjoyed life with plenty of money to spend, but because he believed he could be of more service in Science. It was a noble spirit, and we are indebted to him to-day.

Here is an extract from a letter written by Faraday to the Deputy Master of the Trinity House, when making arrangements in connection with his accepting the post of scientific adviser:

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"In consequence of the good-will and confidence of all around me, I can at any moment convert my time into money, but I do not require more of the latter than is sufficient for necessary purposes."

Faraday always looked back with pleasure upon his early home; he was proud of his humble parents. When in the days of his fame Faraday was sitting to enable a great sculptor to make a bust of him, some of the sculptor's chisels accidentally fell and made a jingling noise. The sculptor apologised, fearing that the disturbance might annoy the aged philosopher, but Faraday assured him that the noise had only brought to his mind many happy recollections of the blacksmith's shop in which his father had worked.

When Faraday's memory and health began to fail, the Prince Consort suggested to Queen Victoria that she might give Faraday the use of a comfortable house on the green near Hampton Court. This the Queen did, first having the house thoroughly repaired so that it would be no expense to Faraday, and there he spent his remaining days, still having the use of his rooms in the Royal Institution whenever he cared to go there. The Queen and the Prince Consort had been present at some of Faraday's public lectures, and the Prince much esteemed and valued Faraday's genius, and we have already seen the pleasure that the young Prince of Wales had derived.

By Faraday's own request, his funeral was of the simplest character, the burial being carried out in perfect silence, as was the custom of his church. Just as the coffin was being lowered into the grave, a few scientific friends came out from the shrubbery and respectfully joined the family group.

CHAPTER XXIII

CHARLES DARWIN
1809–1882

THE SCIENTIST WHO WAS BOLD ENOUGH TO DECLARE THAT MAN HAS BEEN EVOLVED FROM LOWER FORMS OF LIFE

When considering the life of the Rev. Dr. Joseph Priestley we made the acquaintance of Dr. Erasmus Darwin at the Lunar Society meetings. Another member of this select and interesting scientific Society was Josiah Wedgwood, the famous potter. These two men were great friends, and it so happened that a son of Erasmus Darwin married a daughter of Josiah Wedgwood, and these were the parents of our present hero, Charles Robert Darwin.

Charles Darwin is the first of our list of heroes who was born in the nineteenth century, although Eccentric Cavendish, Parson Priestley, Astronomer Herschel, Colour-blind Dalton, Chemist Davy, and Experimental Faraday all overlapped the eighteenth and the nineteenth centuries, just as most of us have lived in the nineteenth and the twentieth centuries. Charles Darwin was born at Shrewsbury (England) in the year 1809, and consequently during the reign of King George III.

We are fortunate in having an autobiography of Charles Darwin, which he wrote for his wife and children, but parts of which have been quoted by his son—Francis Darwin. In the opening sentences of Charles Darwin's autobiography he says: "I have attempted to write the following account of myself, as if I were a dead man in another world looking back at my own life. Nor have I found this difficult, for life is nearly over with me. I have taken no pains about my style of writing."

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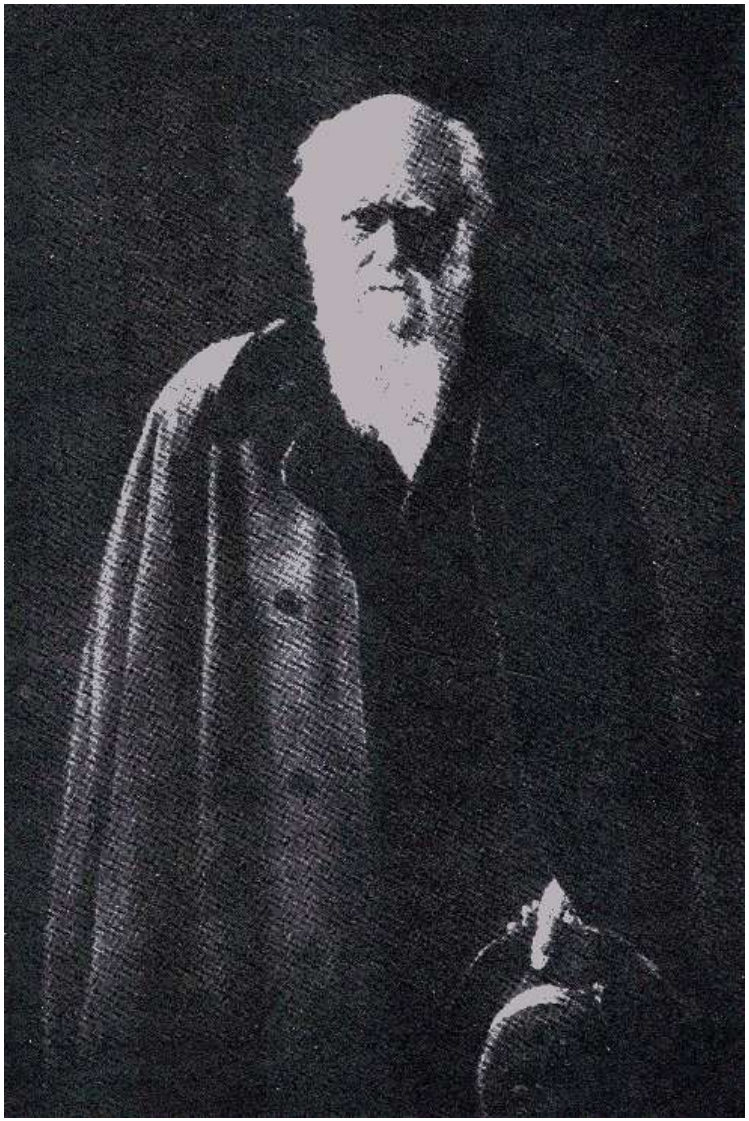

A TRUE HERO OF SCIENCE
THE NAME OF CHARLES DARWIN IS KNOWN THROUGHOUT THE CIVILISED WORLD. HIS THEORY, OF HOW MAN WAS CREATED BY A GRADUAL EVOLUTION FROM SIMPLER FORMS OF LIFE, HAS REVOLUTIONISED OUR IDEAS.

Like some others of those great men whose lives we have considered in the preceding chapters, Darwin was not a brilliant schoolboy. "I have been told that I was much slower in learning than my younger sister Catherine, and I believe that I was in many ways a naughty boy." However, at eight years of age he was trying to make out the names of all the plants he saw, and he was busy collecting all sorts of things, such as shells, birds' eggs, insects, and minerals. He had an exceptional imagination, which, of course, is a very useful possession for a scientist, but sometimes apt to get a boy into trouble if he lets it take control of his words. Darwin tells us of several occasions when he allowed his boyish imagination to carry him beyond the bounds of truth in his desire to cause sensation among his playmates. For instance, when quite a little fellow, he told another small boy that he could produce coloured primroses by watering them with certain coloured fluids—"which was, of course, a monstrous fable, and had never been tried by me."

As a little fellow Darwin was what schoolboys describe as "easily taken in." He tells us how a boy of the name of Garnett took him into a cake shop one day and bought some cakes, for which he was not asked to pay, as he had an account there. But Darwin could not understand how his young friend got the things without payment, and he asked an explanation. His young friend was evidently gifted with a very lively imagination also, for he said: "Why, do you not know that my uncle left a great sum of money to the town on condition that every tradesman should give whatever was wanted without payment to any one who wore his old hat and moved it in a particular manner?" He then showed Darwin the secret of moving the hat, and offered to give him another practical proof of these facts. They went into another shop, where the boy or his people had an account kept, and he asked for some small article, moving his hat in the proper manner, and, of course, obtained his purchase without payment. Garnett then offered to lend Darwin the hat so that he might go into the cake shop and make a purchase without payment. "I gladly accepted the generous offer, and went in and asked for some cakes, moved the old hat and

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was walking out of the shop, when the shopman made a rush at me, so I dropped the cakes and ran for dear life, and was astonished by being greeted with shouts of laughter by my false friend Garnett."

By the time Darwin had finished school he says he was considered by all his masters and by his father as a very ordinary boy, rather below the common standard of intellect. When quite a little chap he read *Wonders of the World*, and to this book he attributed his desire to travel in remote countries.

Darwin and an older brother used to make chemical experiments in a tool-house in the garden, and when it became known in school that Darwin could make oxygen, hydrogen, and other gases, he received the nickname "Gas."

This amateur chemistry was a great pleasure to Darwin. It is remarkable how keen boys get on chemistry if they are set off on lines which they can understand. On one occasion I sent some chemicals, apparatus, and notes of experiments to some little friends in a boarding-school. I was surprised to receive by post a few days later a packet containing two cases of shaving soap., purchased out of the boy's tuck money. When I was out at the school some time later I said to one of the young friends that I hoped they were not merely amusing themselves with the apparatus, but were taking an interest in the explanations accompanying the experiments, whereupon the youngster assured me that they were so keen about the whole subject, that he thought sometimes they were " just like men after drink." This is only one of many personal incidents showing how keen the average boy is in pursuing chemistry if it is made easily intelligible.

To return to our subject, we find that as Darwin was doing no good at school his father wisely took him away at a rather earlier age than usual and sent him to Edinburgh University. The intention was that he should study Medicine, but Darwin tells us that from various small circumstances he became convinced that his father would leave him property enough to subsist on with some comfort, though he did not imagine that he should be so rich as he became, and this knowledge did not give him any impulse to strenuous effort to learn Medicine. Darwin's father was a doctor, but that he was a man of wealth is evident, for we find him on one occasion lending a manufacturer ten thousand pounds without security to help him over some difficulty.

It is very pleasing to see Darwin's great admiration for his father. In the autobiography there are many repetitions of such remarks as these: "My father, who was by far the best judge of character whom I ever knew," declared—so and so. . . . "My father, who was the kindest man I ever knew." . . . "My father, who was the most acute observer I ever knew." And again, "My father, who was the wisest man I ever knew." These were not the expressions of a boy's limited knowledge, but the mature opinions of a man with a great brain.

Young Darwin never got over the "creepy" feeling in the practical work in his medical career. He tells us that he attended two very bad operations in the Edinburgh Hospital. One of these was on a child, but he rushed out before it was completed, and never again could he be induced to be present at another operation. Of course, an operation in these pre-chloroform days must have been very different from what it would be to-day. Quite recently a famous surgeon, on coming out from performing an operation on a lady to whom no anesthetic could be given, remarked to my brother, that if surgery had to be without chloroform, he for one could not do it, and it was quite apparent that the ordeal had been most trying even to this man of great nerve.

Darwin began to take an active interest in Science while resident in Edinburgh, and he tells us of one occasion when he was taken to a meeting of the Royal Society of Edinburgh, where he saw Sir Walter Scott in the chair as President. "I looked at him and the whole scene with some awe and reverence." The one subject which became of absorbing interest to Darwin was Natural History. He paid a negro to teach him

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how to stuff birds; he went out with the Newhaven fishermen to trawl for oysters, so that he might examine them; and he became acquainted with the curator of the museum.

In the summer vacations Darwin became a keen sportsman. On one occasion, when staying with his uncle, Darwin rose before daybreak, slipped into his shooting boots, which he always kept ready by his bedside, so as not to lose a moment in putting them on in the morning, reached a distant part of the estate before it was light enough to shoot, and toiled with the game-keeper the whole day through thick heath and Scotch firs.

Although young Darwin was to be an independent gentleman, his father wished him to be of some definite service in life, and not to become an idle sporting man. When his father heard that his son disliked the idea of becoming a physician, he proposed that he should become a clergyman. The young man felt rather attracted towards the life of a country clergyman, but he asked time to consider the subject, as he doubted if he could subscribe to all the dogmas of the Church of England, although he "did not in the least doubt the strict and literal truth of every word in the Bible." In recording these facts Darwin says, "Considering how fiercely I have been attacked by the orthodox, it seems ludicrous that I once intended to be a clergyman."

As Darwin was to be a clergyman he was sent to Cambridge University at the age of nineteen years, but he did not prove a success in Classics nor in Mathematics, and he got on very slowly.

Darwin, like Sir Humphry Davy, could not perceive a discord in music, nor could he hum any tune correctly. Just as with Davy, even to distinguish "God save the King " was a complete puzzle yet, strange to say, Darwin was fond of music and would hire the chorister boys to sing in his rooms.

One is surprised to learn that although Darwin was a great collector of beetles at this time, he merely collected them and made no scientific study of them whatever. His keenness as a collector, however, is well illustrated by the following remark in his autobiography: "One day on tearing off some old bark, I saw two rare beetles, and seized one in each hand; then I saw a third and new kind, which I could not bear to lose, so that I popped the one that I held in my right hand into my mouth. Alas! it ejected some intensely acrid fluid, which burnt my tongue, so that I was forced to spit the beetle out, which was lost, as was the third one." Speaking of these days of beetle-catching, Darwin has said: "No poet ever felt more delighted at seeing his first poem published than I did at seeing, in Stephen's *Illustrations of British Insects*, the magic words 'captured by C. Darwin, Esq.'"

Darwin tells us that the one thing which influenced his career more than anything else was the friendship of Professor Henslow, at Cambridge. This professor, who had a great knowledge of Natural History, kept open house for the students once every week, and young Darwin became so great a favourite that he was known among the dons as "the man who walks with Henslow." One of the books which had a great influence upon Darwin's mind was the *Introduction to the Study of Natural Philosophy*, written by Sir John Herschel, son of our old friend Sir William Herschel (Chapter XVII).

After having been three years at Cambridge, Darwin went on a short geological tour during the summer vacation. On returning home he found a letter from his friend Professor Henslow telling him that Captain FitzRoy of the British Navy, who was going on a voyage to explore the Southern Seas on behalf of the Government, was willing to give up part of his own cabin to any young man who would volunteer to go with him without pay as Naturalist on board H.M.S. *Beagle*. Darwin was instantly eager to accept the offer, but his father did not think it would be wise, and so the young enthusiast wrote that evening declining the offer. Next morning he went out shooting on his uncle's estate, when his uncle sent for him, offering to drive home with him and talk the matter over with his father, as the uncle thought it would be a wise occupation. Darwin's father

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frankly accepted the advice of his brother-in-law, and by way of consolation, young Darwin, who, strange to say, had been rather extravagant at Cambridge, said, "I should be deuced clever to spend more than my allowance whilst on board the *Beagle,"* whereupon the father answered with a smile, "But they tell me you are very clever."

Darwin had an interview with Captain FitzRoy and all was arranged, but later on he learnt that he had run a risk of being rejected on account of his nose. The Captain believed himself to be an able judge of character by the outline of a man's features; and he doubted if any one with a nose like Darwin's could possess sufficient energy and determination for the long voyage. It is interesting to note in this connection that the old-world philosopher Pythagoras, whose life we have considered in Chapter II, had the same belief in a man's character being in accordance with his features. Dacier, writing three hundred years ago, says of Pythagoras: "First he considered their physiognomy, and from thence drew the general trend of their inclinations."

Darwin's enthusiasm in setting out on this voyage was so great that although he secretly believed that he had heart disease, he would not consult a doctor lest he should order him to stay at home; he was determined to go at all costs. The heart trouble fortunately turned out to be a simple case of palpitation.

Darwin was on board H.M.S. *Beagle* for five years, and during this long voyage he collected an enormous number of facts in Natural Science. He shot specimens of all the different kinds of birds, he examined all the marine specimens he could find, he made a geological survey of each country they visited, and collected a large number of tell-tale fossils.

Darwin was twenty-seven years of age when he returned home. He was kept busy writing for two years, preparing his Journal and other books. During the greater part of this time he was resident in London. After this he married, and a few years later he bought an estate in Kent, and retired there, not to rest, but to work earnestly during the remainder of his life. Unfortunately, his health became a trouble to him, so that he had to give up dinner-parties and other social gatherings, nor could he and his wife entertain their friends for the same reason.

Darwin counted his *Origin of Species* the chief work of his life, and we know what a tremendous influence it has had upon modern science. The book had an enormous sale, and was translated into almost every European language. It was no rash publication; it was twenty years in the mind of Darwin before it was published. When he set out on his voyage of exploration he was a firm believer in the general idea that the Creator had made each separate species of animal once for all. This idea had been questioned by several great minds half a century before Darwin's time, and our old friend Dr. Erasmus Darwin, the grandfather of our present hero, was the first to state a definite theory of the law of descent. Charles Darwin had read his grandfather's books, but the proofs were so slender that he was not impressed with the theory. Unfortunately, the followers of these early evolutionists had not been content to deal only with what few facts were known, but had allowed their imaginations to run away with their judgment, so that the theory of evolution had lost all credence. Not many years before Darwin's famous voyage two learned scientists had debated the question of evolution before the Paris Academy, and the one who upheld evolution was defeated so completely that the question was supposed to be settled for all time.

During the voyage of the *Beagle* Darwin became impressed with certain facts which seemed to him difficult to reconcile with the idea that God had created each species separately. As the voyage proceeded and facts accumulated Darwin was convinced that the old dogma could not be upheld. He saw quite clearly that all living things had been evolved through long ages from simpler forms of life.

There can be very few thoughtful people who doubt the general principles of evolution to-day. It is surely quite needless to remark that although man's body has been evolved in a gradual way, Man is quite distinct from other creatures; the

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Creator "breathed into his nostrils the breath of life; and man became a living soul."

One cannot but admire the quiet way in which Darwin brought forward his definite theory of evolution; there was no attempt whatever at sensationalism. Indeed, in the Introduction to his later book, *The Descent of Man*, he says, "It seemed to me sufficient to indicate, in the first edition of my *Origin of Species*, that by this work light would be thrown on the origin of man." His only reference to man occurs in this one short sentence on the last page but one of this great book; when referring to future researches he says, "Much light will be thrown on the origin of man and his history."

Although there was no attempt at sensationalism in Darwin's book, it could not be expected that people would calmly throw over the long-embedded ideas of special creation without grave consideration. Strange as it may seem, there are intelligent men to-day who still picture the world as having been created in seven days of twenty-four hours each. I know a few such men, but they have never studied the question, and in each case I believe it is religious scruples that prevent them going into the matter for themselves. Some people, I trust very few, imagine that Darwin was an atheist, and that the theory of evolution is opposed to any proper religious beliefs. Are we to imagine that the Creator will be displeased if we study His works and discover His plans? If so, we have no right to all practical applications of scientific discovery; the steam-engine, the dynamo, the motor, all are the outcome of our discovery of the forces which the Creator has placed in the world. The more we study His works, the more reverence do we acquire.

The Church did believe at first that the new doctrine of evolution was dangerous to religion, but Darwin was content to wait; he knew that in the end the truth must prevail. Our hero did not strive to become famous; his desire was to advance man's knowledge; he was, indeed, a true Hero of Science.

Charles Darwin had a lofty, noble spirit; he was truly unselfish; he was modest, simple, and sincere, a great lover of truth and fair play. Like a wise father, he made companions of his children. "He allowed his grown-up children to laugh with and at him, and was, generally speaking, on terms of perfect equality with us." So wrote one of his sons, four of whom occupy high places in the scientific world, and are honoured and respected by their fellow-men.

I do not think it necessary to touch upon the religion of Charles Darwin, except to remark that, despite all his frank statements of doubt, he appears to me a good Christian, for he acted honestly and uprightly according to his serious beliefs.

Darwin had never enjoyed very robust health, and in later years had suffered much. After a short but painful illness he passed away at the age of seventy-three. So retired was the family life in Kent that the news of the great scientist's death was not known in London till two days after he had breathed his last. It was the desire of the family to have the burial a local and private one, but the nation showed the very high regard in which they held this great Biologist, and all classes of men were anxious that the funeral should be national, and that the burial should be among Great Britain's illustrious dead in Westminster Abbey. The sympathy of the public was so great that the family felt bound to accept this tribute to his memory.

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CHAPTER XXIV

LORD KELVIN AND HIS BROTHER JAMES KELVIN
1824—1907

When Sir William Thomson was raised to the peerage, it seemed at first a pity that his name, which had become so very well known in connection with his inventions and discoveries, should disappear, but the world adapted itself very quickly to the new title. It is now Lord Kelvin who invented this, or discovered that, although almost all these things were done while he was either plain Mr., Dr., or Sir William Thomson.

The selection of Lord Kelvin's title was a very happy one, for the River Kelvin circles round the base of the hill upon which the University of Glasgow is built, and his whole life is very closely knit with the University. Then again, his mother had lived in Kelvin Grove, which stood on the banks of the Kelvin, long before the University was taken out west to that neighbourhood. The author has very vivid recollections of the old mansion-house, which when he was a boy had been turned into a museum, the estate having become a public park. This Kelvin Grove or West End Park has been the site of Glasgow's great International Exhibitions, and the mansion-house has been taken down in recent years.

Our hero's father was born in Ireland, but his ancestors originally were Scotch; a good many generations of them, however, had been born and bred in the Emerald Isle. Kelvin's great-great-great-grandfather left Scotland for Ireland and settled down as a farmer, the same farm continuing in the family for about two hundred years. Kelvin's father was born on this farm. When the father was at school he made such headway that he very quickly rose to the position of assistant teacher.

Lord Kelvin used to tell how his father came over to study at Glasgow University before the days of steam-boats or railways. He had to take passage by any kind of sailing boat he found available. On one occasion the voyage took four days, the little vessel having been becalmed and carried three times round the small island of Ailsa Craig by flow and ebb of the tide. Our hero used to tell how on one of these trips his father and some fellow-students landed at Greenock and set off to walk the twenty miles to Glasgow. When on their way to Glasgow they saw across the fields a tall black funnel moving steadily along. On making their way towards this curiosity, they found Henry Bell's first steamboat, the Comet, making her way down the River Clyde.

Lord Kelvin's father proved himself such a capable mathematician that, as soon as his University training was over, he was appointed Professor of Mathematics in the Royal Academical Institution in Belfast. It was while James Thomson held this professorship that his sons James and William (Lord Kelvin) were born, James in 1822, and William in 1824.

While the title of this chapter is "Lord Kelvin and his brother James," it is natural that the story should centre round William, who, although two years younger, was first in fame.

Their mother died when William was only six years of age, and two years later the family left Ireland, their father having been appointed Professor of Mathematics in Glasgow University. In these days the College was situated in what is now the centre of the city.

It has been stated that James and William Thomson never attended any school, but received the whole of their education from their father until they entered the University. This statement has been contradicted by some writers, but two members of the family have assured me that Lord Kelvin and his brother (their father) both told them that neither of them ever attended any school, and except for some lessons in writing, neither of them had any teaching but from their father until they

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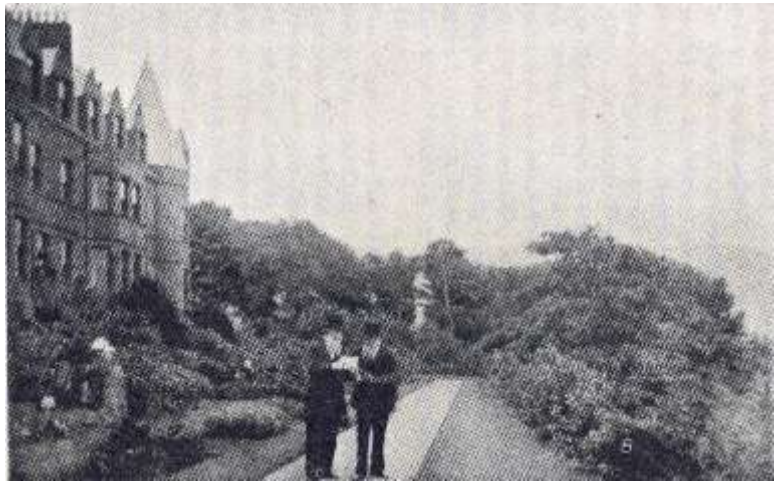
entered the University. Like Darwin's father, the Thomsons' father made companions of his family. He was an exceptionally busy man. He would rise at four o'clock in the morning to work at his books, for he wrote many books on mathematics, but he always had time to give to his children. They eagerly watched for his return home, and what a warm welcome he always got! He would tell them stories till dinner-time, and after dinner the globes were placed on the table and the children all gathered round to hear something about this great round ball on which we live. Little Willie was perched up on the table beside the globes, and sometimes his brother James would get up beside him. Before William was four years of age he was taking an intelligent part in each day's lesson.

A few years later, when they had become motherless, their father was both father and mother to them. He would read to them before they went off to bed; sometimes it would be stories from *The Arabian Nights*. He would lie on the sofa as he read, with his little ones clustered around him, little Willie usually in his arms. Our hero was a great pet with his father, but his sister, the late Mrs. King, says, "I do not remember that any of us were ever in the slightest degree jealous of William on account of our father's making him a little more a pet than the rest of us. We were proud of him, and indeed we thought the child petted the father even more than the father petted the child, but we saw plainly that the fondling of the little son pleased him. Willie always slept in a small bed in our father's room—that is, after his nursery days—because he had for some years a tendency to sleep-walking, which for a time caused some anxiety."

His sister tells us that one of her earliest recollections was of an artist coming to ask permission to paint a picture of William—"the most beautiful baby"—as an angel. On the way to the studio old Nurse Sally proudly bought little blue shoes and white silk socks to set off her little one, and she was sorely disappointed when she found that the artist did not consider these necessary embellishments to an angel. People must have remarked upon the beautiful baby, for the first recorded speech of our hero is when, at the age of two years, he was found sitting before a looking-glass, "Pitty b'ue eyes Willie Thomson got!" Fortunately, William Thomson did not grow up filled with conceit, as so many people prophesy of children if any complimentary remark is made in their hearing.

When Lord Kelvin's father came to Glasgow, his emoluments from the University were really "less than nothing," for by an agreement the Professor, who had retired, received a certain sum which turned out to be greater than the whole income derived from the Chair. Professor Thomson, however, gave afternoon lectures for ladies, the subjects being Geography and Astronomy, an entirely new departure, but one which turned out very popular. Fashionable ladies crowded to these lectures, which were continued for several years, till the pressure of other engagements compelled him to give them up.



LORD KELVIN AND HIS BROTHER JAMES
THIS PHOTOGRAPH, WHICH WAS TAKEN BY MISS MARY HANDCOCK THOMSON, SHOWS HER UNCLE, LORD KELVIN, AND HER FATHER, PROFESSOR JAMES THOMSON, AT LORD KELVIN'S COUNTRY RESIDENCE IN SCOTLAND.

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When William was eight years of age, his father allowed him and his brother James to attend his mathematical class as listeners. On one occasion a question was asked to which no student in the large class could give an answer, whereupon William, eight years of age, called out, "Do, papa, let me answer it." On another occasion a difficult problem had been given out to the students, and William, though not yet a student, tried to work it out at home. He had not succeeded before going to bed. Later in the evening, when he was supposed to be sound asleep, his voice was heard through the house shouting "Eureka! Eureka!" His father, going up to see what it was about, found the little barefooted figure standing in his nightgown on the landing, excited and triumphant. The solution had flashed on the child's mind in bed, and was already, by the help of the stair gas, scribbled on a slate he had placed at his bedside.

The old treat of being read to was kept up by the father. Mrs. King writes: "Whilst our father read, Anna and 1 sewed—not fancy work, but flannel petticoats and the like; and our brothers lay on their backs on the floor with their arms extended, to give them a rest and help them to grow up straight."

The two brothers matriculated as students of the University at the same time, William being only ten years of age and his brother James twelve. The two brothers were greatly attached to each other all through life. Many of us have recollections of seeing them together, just as they are seen in the accompanying photographs (pages 282 and 300). For these photographs the author is indebted to his friend Miss Mary Hancock Thomson, daughter of Professor James, Lord Kelvin's brother.

When William habitually took the first place and James the second, although he was older, there never was the faintest taint of boasting on the one side, or jealousy on the other.

When James was only fourteen years of age, and travelling down the Clyde by steamer to their summer quarters, he observed the great loss of force caused by the manner in which the steamer's paddles struck the water and rose, carrying an immense weight of water with them. The ingenious boy set about making a model of a wheel, with paddles so adjusted to dip perpendicularly into the water, strike directly backwards, and rise with out encumbrance. His father took the model to Glasgow and consulted some practical men, when he found that something to serve the same purpose had been invented and patented only a few weeks previously.

When boys, William and James made a hobby of Electricity. They made electrical machines without any assistance, and they worked very happily together, both keen upon their hobby.

Mrs. King gives us an interesting picture of home life, when she and her sister taught the boys to dance quadrilles and lanoers, "a branch of education in which they were very deficient." William professed utter scorn for dancing and had indignantly refused lessons from a master; James had refused them too, though with less show of indignation; but neither of them objected to learn from their sisters, and the lessons ended with merry gallops up and down the long drawing-room. In spite of all his scorn, William enjoyed dancing parties very much; James, who was never so physically strong, did not bother about these parties.

When their father found it necessary to take a younger brother, Robert, to London to have a surgical operation performed, he took the whole family with him. Mrs. King, who was then about twenty-one years of age, writes: "I saw the poor little boy stretched, all bound, on the table before the operation began, and stood or the mat outside the door while it was going on, listening to his moans—it seemed a long time—and I was the first admitted when it was over. There was no chloroform in those days to drown pain. But he was very brave and patient." The little fellow recovered well, and his father took the others to see the sights of London.

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When in London William and his sister used to rise very early and take a walk while the others were still in bed. They generally went to St. James's Park, carrying some bread with them to feed the water-fowl, and a few apples with which to refresh themselves while they sat on one of the seats chatting. Then, when the little brother had quite recovered, they set off for a trip on the Continent.

After spending a fortnight in Paris the father took the two girls a trip through Switzerland, leaving the boys in Paris to learn the language. A journey through Switzerland was very different then from now; they had to hire a travelling carriage by the month. Mrs. King's description of their journey is graphic: "Early on a magnificent July morning we rattled out of Paris, with two postilions cracking their whips madly, and urging the four horses to dash along at top of their speed. This was to make a sensation in the street; for when we got fairly beyond the city our pace was regulated with more moderation. But all through our travels, when approaching or leaving a town or post-house, the same lively demonstration was repeated. Even when simply passing through a little village we drove furiously, at the risk of running over the poor little children who rushed out to see the sport."

During the next two winters James took the degrees of B.A. and M.A., but William took no degrees, although he passed the necessary examinations. The reason was that it was thought better he should go to Cambridge without having graduated in another University. In writing to his brother at this time he styled himself "B.A.T.A.I.A.P.," signifying "B.A. to all intents and purposes."

It is of interest to note that the great African explorer and missionary Dr. Livingstone was one of the Thomsons' fellow-students.

The father took them all to Germany the following summer. He intended the boys to make a thorough holiday of the tour, so he insisted that all work should be left behind. But just two days before leaving home William had got Kelland's book on *The Theory of Heat*, and was shocked to be told in it that the great French mathematician Fourier was mostly wrong. William put Fourier's book into his box, so that he might look into the matter under dispute. When the family were settled down in Frankfort for two months' holiday, William used to slip quietly down to the cellar every day to read a bit of Fourier, but when his father discovered what he was doing, he was not very hard on the boy. One day, when William was sitting studying the book, he suddenly sprang up and excitedly exclaimed, "Papa! Fourier is right, and Kelland is wrong!" His father was very doubtful, but he found that the boy was quite right. William, then sixteen years of age, wrote a paper on the subject to the *Cambridge Mathematical Journa*l. The great English mathematician Professor Kelland, who was thus taken to task by the young student, felt a little hurt at first, but ultimately he became very friendly with young Thomson, and so long as he lived the friendship continued.

While in Germany Professor Thomson allowed William and James to go off on a walking tour through the Black Forest. James had reason to regret this expedition, for something in his shoe hurt one of his feet and caused him to put undue stress on the other leg, but he trudged on, not wishing to give in. Some weeks later it was found that the joint of his knee had been seriously injured. This undermined his strength and left him even less robust than he had been. This was very unfortunate, as arrangements had been made for him to serve an apprenticeship to engineering in Dublin. He essayed to do so but had to return home in a short time.

In the following autumn William entered Cambridge. He was just seventeen years of age, but was well prepared to enter the great University. It is amusing to read some of the inquiries of the great philosopher in his first letter to his sister after settling down in his rooms at Cambridge. He asks if, when making coffee, he should put the coffee in before or after the water is boiling, and also whether he should keep it boiling after

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the water is put in. "In your first letter inform me of the necessary particulars." He happened to use the word "gyp" in this letter, and in reply to his sister's inquiry as to the meaning of the word he writes that it is a noun substantive and is the name given to a college servant, the word being derived from a Greek word meaning a vulture, from their ravenous disposition.

Thomson did not cut himself off from the world in order to become a student. He very wisely took a real interest in outdoor sports. He became an expert oars man, and when he won the silver sculls he said it was better than winning an examination. He was keen in everything he took up. Sometimes when rowing in a race he would so exert himself that, when he passed the winning post in front of every one, he was in an almost fainting condition. He dieted himself for racing, and he was so enthusiastic that it was said he would have run to the top of a steeple and called "Bo!" if he could have been assured that such a proceeding would be of use. His life formed a great contrast to that of his brother James, who was an invalid at home. It is evident that William's health was robust, for he continued bathing in the river before breakfast, right on to the frosty weather of November. In addition to his outdoor recreations he became a musician, and was the means of forming a musical society among the students, choosing the French horn as his own instrument in the orchestra.

Young Thomson proved himself a remarkably good mathematician. His friends felt sure that he would be Senior Wrangler, but he came out second in this examination. He was in reality second to none. The first man had practised for six months the art of writing out textbook work at a prodigious speed, and quantity counted for much. Doubtless the first man was a very excellent mathematician, but not equal to Thomson. This was soon evident, for in the examination for the Smith Prize Thomson had an easy win, and in this examination there is room for some originality and not merely textbook work. The Senior Wranglership has been abolished in recent years.

Young Thomson's place as a mathematician at this early age is well illustrated by the following remark made by one of the Cambridge Examiners to another: "You and I are just about fit to mend Thomson's pens." Before he left Cambridge he had won a Fellowship of St. Peter's College, which brought in an income of two hundred pounds per annum.

For some years the aged Professor of Natural Philosophy in Glasgow University had become so infirm that he could not continue his classes. Temporary assistance had been obtained so that the old gentleman could still retain his professorship. Young Thomson's father, Professor James Thomson, was very anxious that, when the Chair should become vacant, his son should be able to fill it. His correspondence shows how he had fixed his heart upon this object, and William, too, was anxious to do all in his power to equip himself for such an honour.

When the time did arrive, and young Thomson was duly elected to the Chair of Natural Philosophy, it was a very great pleasure to his father. There was an entire absence of conceit in the young Professor's character, and this was an additional charm. He was only twenty-two years of age. He was very disappointed with his introductory lecture, but the only real fault was that he read it far too fast, and finished long before the appointed hour. By the end of the first session he could not feel disheartened. A letter from his sister to her husband describes his first prize-giving: "The prizes were distributed to-day, and William showed to great advantage. He was received with deafening cheers, beyond anything I ever witnessed on the noisy first of May. The young Professor was cheered and cheered again, and the students seemed never to tire of shouting 'Three cheers more for the young Professor!' And, best of all, the grave old professors on the bench forgot their dignity, and joined in the applause with hands and feet.

"William himself looked so young and so modest that it was really quite touching to see him. He spoke with great self-possession and distinctness . . . when he sat down the applause

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was renewed till one might have feared that the hall would have been endangered."

In later life it was very pleasant to hear Lord Kelvin refer to "my brother James"; sometimes "my brother James, who invented the word poundal." (This is one of the units of force.) His lordship often acknowledged having learnt from James, while James had unbounded pride in William. A stranger seeing the two old gentlemen talking eagerly together might have thought that they were quarrelling. There is a sentence in a letter from the great German physicist Helmholtz, written from Glasgow to his wife, which describes the point very well: "It is really comic to see how the two brothers talk at each other, and neither listens, and each holds forth about quite different matters."

James was first appointed Professor of Engineering in Belfast, and later at Glasgow University, where he occupied the Chair for sixteen years, when he retired owing to failing eyesight.

When the author was a boy, Professor James Thomson showed him how to make an electric battery. First there was the purchase of eight cheap glass tumblers, then some odd pieces of zinc and copper sheet from the plumber, and these, with some bits of wire, a little saw-dust, and some bluestone, made two excellent batteries of four cells each, sufficient to work two telegraph models. The idea of the learned Professor was excellent, for the method of producing an electric current from materials in everyday use prevented any feeling of mystery so far as the apparatus was concerned; all electric apparatus, no matter how intricate, appeared henceforth in its true light, composed of pieces of ordinary glass, wood, and metal, arranged to produce certain results.

Dr. James Thomson could enter into a boy's fun. On one occasion, when a young friend was collecting beetles, he was asked by Dr. Thomson to go to his house and see a large specimen which he had secured for him. There, under an upturned glass and partly hidden in green leaves, was an immense beetle, whose family was to be determined; but alas! the Professor was playing a trick on his young friend—the wonderful insect so cleverly disguised was made of chocolate.

Professor James Thomson made some valuable discoveries, but we are not concerned with his work; a collection of his scientific papers is at present in the press.

There was one very dark week for the Thomsons in 1892. During an epidemic of influenza Professor James, Mrs. Thomson, and their younger daughter all died within a few days of each other.

It has been quaintly said that William would not have been William without James, and that James would not have been James without William.

Referring to the illustration at page 111, Miss Mary Hancock Thomson informs me that the two brothers are discussing a paper which her father was writing for the British Association. They used to walk up and down that long walk in front of the house (Netherhall, Largs) discussing scientific problems. Miss Thomson says: "The garden scene is the most characteristic one of the kind I ever managed to take, though I made many attempts. Always if they knew I was photographing them they stood straight up like two soldiers, and looked quite uninteresting and not the least bit characteristic This was a snapshot when they thought I was only arranging my camera."

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CHAPTER XXV

KELVIN AND THE ATLANTIC CABLES

In the preceding chapter we have seen Professor William Thomson (Lord Kelvin) installed in the Chair of Natural Philosophy in the University of Glasgow. In preparation for his candidature for the Chair he had gone to Paris, at the suggestion of his father, and studied in the laboratory of the noted French scientist Regnault. But in Glasgow there was no experimental laboratory. What apparatus there was in the University was merely for lecture demonstration. Some of this apparatus was a hundred years old, while little of it was less than fifty years old.

Thomson appealed to the University authorities for funds to equip an experimental laboratory, but the only room he could get for the purpose was a disused cellar. The late Professor Ayrton, who was one of Thomson's students in the 'sixties, says, "Thomson's students experimented in his one room and the adjoining coal-cellar, in spite of the atmosphere of coal-dust, which settled on everything, produced by a boy coming periodically to shovel up coal for fires. . . . But oh! the delight of those days! Would we have exchanged them, had the choice been given us, for days passed in the most perfectly designed laboratory of the twentieth century without him? No! for the inspiration of our lives would have been wanting."

This unpretentious undertaking of young Thomson's was the first physical laboratory to be put at the disposal of students in any University.

Throughout the home letters of Thomson up to this point, one cannot help noticing how often the name of his cousin Margaret Crum of Thornliebank is introduced. She was really only a half-cousin, the full cousinship being between the respective parents. The boy-and-girl friendship culminated in a betrothal, and the young couple were married a few months later. Their wedded life was a very happy one, but unfortunately, Mrs. Thomson's health gave rise to anxiety, and for many years she was an invalid. The summer vacation spent abroad failed to establish her strength. She lived through the stirring times of the first attempts to lay the Atlantic cables, and she saw her husband become famous, she herself becoming Lady Thomson when her husband was knighted by Queen Victoria in 1866.

A few years later Lady Thomson became so much worse that she could not go abroad, but she was able to be taken to the coast. For her sake Sir William decided to spend the winter at the coast, and he was willing to resign his Professorship of the Chair to which he was greatly attached, but fortunately, the University authorities granted him a long leave of absence. He was untiring in his constant attention to his invalid wife. But she passed away at the age of forty, after eighteen years of wedded life. She was a most accomplished woman and loved by all who knew her.

In the letters of the late Dr. John Brown, author of *Rab and His Friends*, Lady Thomson is referred to in words of the very highest praise. In another of Dr. Brown's letters there is an interesting reference to William Thomson, while he was a young professor in the old college. The great English novelist Thackeray, when in Glasgow with Dr. Brown, had dined twice with the Thomsons, and writing to one of the Crums, Dr. Brown said, "I knew Thackeray would go to your heart. . . . He was delighted with your William Thomson; he said he was an angel and better, and must have wings under his flannel waistcoat. I said he had, for I had seen them."

It was during Mrs. Thomson's lifetime that William met with a very serious accident when curling on the ice at Largs. He fell and broke his leg, and the accident turned out very serious, as the hip-joint was injured. After many months of brave suffering he was left lame for life, and always walked thereafter with a decided halt. This accident befell him when he was thirty-six years of age, which was a few years after his first voyage in connection with the laying of the pioneer Atlantic cable.

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Professor Silvanus P. Thomson remarks in his *Life of Lord Kelvin*, that "often as the story of the Atlantic cable has been told, the precise part which Thomson played in the enterprise has never been fully stated. The work which he undertook for it was enormous; the sacrifices he made for it were great. The pecuniary reward was ridiculously small. The actual position which he held was relatively subordinate, and must have been at times galling. Yet he bore himself throughout with the most unswerving courtesy and delicacy of feeling."

Our present interest does not lie in the story of the Atlantic cable; we can only take a glimpse at young Thomson in his pioneer work. It will be understood that he was not the official Electrician; that gentleman did not accompany the expedition, although urged to do so. In this way Thomson did not have the instruments he would have liked, but he had permission to use his own galvanometer, which was very much more sensitive than the clumsier apparatus of the official Electrician.

At the close of the first voyage a very interesting letter appeared in the newspapers, written by one of the staff accompanying Thomson. Referring to Thomson's marine galvanometer, this writer says: "It is closed up in a plain deal box, which is placed on a frame, equally primitive, attached to springs. Yet this little 'Jack-in-the-Box,' as we often call it, does the work of every instrument on the table in its own peculiar way, and a deal more accurately. . . . It is rather an exciting occupation to watch the tell-tale signals as we pay out. Few but the sailors ever sleep soundly. Professor Thomson frequently does not put off his clothes at night.

"To-night we had an alarming crisis. We had signalled the *Niagara* 'Forty miles submerged,' and she was just beginning her acknowledgment, when suddenly, at 10 p.m., communication ceased. According to orders those on duty sent at once for Dr. Thomson. He came in a fearful state of excitement. The very thought of disaster seemed to overpower him. His hand shook so much that he could scarcely adjust his eyeglass. His face was deadly pale. After consulting his marine galvanometer, he said the conducting wire was broken but still insulated from the water. . . . The scene in and about the electrical room was such as I shall never forget. The two clerks on duty watching, with the common anxiety depicted on their faces, for a propitious signal; Dr. Thomson in a perfect fever of nervous excitement, shaking like an aspen leaf, yet in mind clear and collected, testing and waiting, with half-despairing look for result; Mr. Bright (the brilliant young Engineer-in-Chief) standing like a boy caught in a fault, his lips and cheek smeared with tar, looking to the Professor for advice; . . . the Captain viewing with anxious look the bad symptoms of the testing as pointed out by Dr. Thomson. Behind, in the darker part of the room, stood various officers of the ship. Round the door crowded the sailors of the watch, peering over each other's shoulders at the mysteries, and shouting 'Gangway!' when any one of importance wished to enter. The eyes of all were directed to the instruments, watching for the slightest quiver indicative of life. Such a scene was never witnessed save by the bedside of the dying. Dr. Thomson and the others left the room convinced they were once more doomed to disappointment. The clerks continued sending regular currents. . . . Suddenly one sang out, 'Halloa! the spot has gone up forty degrees.' The clerk at the ordinary instrument bolted right out of the room, scarcely knowing where he went for joy; ran to the poop and cried out, 'Mr. Thomson! the cable's all right; we got a signal from the *Niagara*.' In less than no time he was down, tested, found the old dismal result, and left immediately. He had not disappeared in the crowd when a signal came which undoubtedly originated in the *Niagara*. Our joy was so deep and earnest that it did not suffer us to speak for some seconds. But when the first stun and pleasure passed, each one began trying to express his feelings in some way more or less energetic. Dr. Thomson laughed right loud and heartily. Never was more anxiety compressed in such a space."

Charles Tilston Bright, who was Engineer-in-Chief, and was only twenty-six years of age at that time, has said of

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Professor Thomson: "He was a thorough good comrade, good all round, and would have taken his turn at the wheel of the paying-out brake if others had broken down. He was also a good partner at whist when work was not on; though sometimes, when momentarily immersed in cogibundity of cogitation, by scientific abstraction, he would look up from his cards and ask, 'Who played what?'"

Thomson has said of Bright: "The first Atlantic cable has given me the happiness and privilege of working with the late Sir Charles Tilston Bright. . . . To his vigour, earnestness, and enthusiasm was due the successful laying of the cable. We must always feel deeply indebted to our late colleague as the pioneer in that great work, when other engineers would not look at it, and thought it absolutely impracticable."

The official Electrician, who did not accompany the expedition, proved a poor servant to the Company. Thomson's treatment of him was almost more than human. Some of the friends of this official even tried to depreciate Thomson's work by writing to the *Press* that his inventions were "regarded by all practical telegraphers as perfectly childish."

The ultimate grand success of ocean telegraphy is apparent in our everyday life, and no one who reads the complete story of the various pioneer enterprises can fail to be impressed with the fact that success was due to the ingenuity of Lord Kelvin, who made it possible to see and to record the delicate signals transmitted two thousand miles beneath the ocean.

CHAPTER XXVI

KELVIN AND HIS STUDENTS

The following anecdotes have all been authenticated by old assistants or students of Lord Kelvin's, and are not included in the story merely for amusement, but to demonstrate different characteristics of our great nineteenth-century hero. Many of these anecdotes have not been published previously.

Kelvin's brain worked so quickly that it made him impatient; things could not move quickly enough for him, and one pictures him as though he were always hurrying to catch a train. On one occasion his assistant could not get him away to keep an appointment at which they were both due. A cab had been in waiting for some time, and at last the assistant got the learned Professor safely into the cab. But he was still thinking of other things, and was quite absorbed till the jog-trot motion of the easy-going horse suddenly brought him back to material things, and reminded him that they were in a hurry. Pulling down the carriage window he shouted to the coachman, "Drive quicker, I say! Drive quicker!" He then let his mind soar once more into mathematical or scientific heights, but was recalled almost immediately by the energetic manner in which the coachman was urging on the cab-horse. Down went the window again: "Don't whip that horse, I say! Don't whip that horse!

Kelvin was a great lover of animals, as the following story related by his sister, Mrs. King, will show. She tells how once when he was visiting them in Berkshire he expressed a wish to see the fine antlered deer in a neighbouring park, and they went out in search of the animals. It was evening, and the deer had settled for the night among the bracken. Some of the party were going to give a shout to rouse the deer, that they might show themselves to advantage as they bounded away; but he pleaded with his friends not to do so, "because they had just

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warmed the place where they were lying, and it would be a shame to disturb them." So the animals were left in peace, and the party wended their way home again.

It has been said repeatedly that Kelvin was no teacher. Some past students have said that they learnt nothing from his lectures, but on the other hand there are those who have declared that these lectures were excellent, most lucid, and most inspiring. Speaking figuratively, one might say that a great deal of the ground upon which Kelvin had to sow was not sufficiently prepared to receive the seed. With all due deference to those who gained little or nothing from his lectures, it is clear that the real students who worked at their textbooks and did not expect all the necessary knowledge to be put into their heads during the lectures received great inspiration from Lord Kelvin's teaching.

LORD KELVIN IN PRIVATE LIFE
LORD KELVIN'S NAME IS WELL KNOWN IN CONNECTION WITH THE MEANS FOR TAKING DEEP-SEA SOUDINGS. IN THE ABOVE PHOTOGRAPH, TAKEN BY HIS NIECE, MISS MARY HANCOCK THOMSON, LORD KELVIN IS SEEN READING A SOUNDING TAKEN FROM HIS YACHT. HIS BROTHER JAMES IS LOOKING ON.

Another point worth illustrating is the fact that Kelvin really believed the average man knew far more than he did. On one occasion he called up a raw student and put a question to him, and although it was quite apparent to the class that the student knew no more of the subject than the desk in front of him, nothing would have persuaded the learned Professor of this obvious fact. Putting the question in one form after another, it resolved itself in the end to a simple "Yes!" or "No!" and when the student answered correctly in the affirmative, Kelvin quite lost his temper with him, and thumping the lecture-table he exclaimed, "Man, I knew you knew it! Why do you make me drag it out of you bit by bit?" Of course, such scenes were greatly appreciated by the other students, who could not see their fellow-student in the same charitable light as did their good-hearted Professor.

Kelvin's lectures were filled with such matter as Sir J. J. Thomson has recently described as "purple patches." He would digress from the subject with which he set out, and give a great deal of valuable information, but in some cases it would be difficult to see what really led him on to these side issues. For instance, the lecture notebook of one of his real students shows that, in a lecture on Dynamics, the Professor set out with some remarks upon Force, but very soon went off into the field of Optics, and only near the very close of the lecture got back on to the original subject, but all the time he was giving most valuable information; there was no waste of time. That he did not keep by any stereotyped plan is evident from the following incident related by one of the assistants. Suddenly entering the lecture-room on the last stroke of the bell, the Professor shouted to his assistant, "What have we to-day? What have we to-day?" And when his assistant replied that it was Optics, the Professor, evidently influenced by some thoughts that had occurred to him, probably on his way to the lecture-room, shouted, "Take it away, I say! Take it away! I'll take Dynamics!" And so the assistant had to make haste to undo all the careful work expended in fitting up the apparatus for that day's lecture, and, amidst the good-natured banter of the students, arrange the apparatus suitable for the new subject.

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It was always a field-day when the ballistic-pendulum was brought out, and the assistant had an old Jacob rifle loaded and in readiness for the Professor. There was great excitement and mock alarm when Sir William took the rifle, and placing it in the grooved rests so arranged as to ensure a bull's-eye, fired at the large bob of the pendulum. The smoke had not cleared away before the Professor was at the blackboard calculating the velocity of the bullet, the assistant having shouted out the amount of displacement of the weighted pendulum.

Thomson was very original in his lecture experiments, making use of such common articles as eggs, jellies, cobbler's-wax, and all kinds of odd stuff to illustrate his remarks. In one lecture on spinning bodies he showed the difference in behaviour between a raw and a boiled egg. This was one of his well-known experiments, and on one occasion a student thought to create some confusion by substituting two eggs which he himself had brought with him in place of the two eggs prepared for the experiment and already on the lecture-table. The students waited to see the huge joke, but the learned Professor set the two eggs spinning, shouting, "Both boiled, gentlemen!" and passed on.

Another lecture appreciated by the students was one on Sound, in which Kelvin gave some demonstrations on the French horn, of which he was a master. But on the closing day of the session his lecture was more than ordinary. When the students entered they found the lecture-table covered with apparatus. The lecture began at nine in the morning, and at ten o'clock Kelvin would announce that any students requiring to attend other classes might go, but that he would continue the lecture for those who cared to wait. At eleven o'clock a similar announcement was made, and again at twelve o'clock. Messengers from his house had to return with the information that he was still lecturing. The small band who remained till one o'clock would then part after singing "Auld Lang Syne."

One peculiarity in Kelvin, and it is strange to understand, was that he did not seem to notice when a man was under the influence of intoxicants. It is well known locally that one of his assistants had a weakness in taking more refreshment than was wise. Kelvin would come into the laboratory sometimes and give this man instructions when it would have been quite apparent to any one else that the man was not capable of taking in the meaning of the instructions. The students knew this faithful old assistant's weakness, so that they thoroughly enjoyed the Professor's innocent remarks on the following occasion He was about to discourse on the diffusion of liquids, in which alcohol was one of the substances. Turning to some mixtures which had been prepared, he remarked that his assistant had made numerous experiments in the mixing of water and alcohol. Needless to say that there was a roar of laughter from the students, but the Professor thought he must have made some mistake, and when he explained that what he had meant to say was that his assistant had mixed large quantities of alcohol and water, he, of course, only added to the merriment.

There are many true anecdotes which illustrate the same point as the preceding one, and it is worth while recording one other. On this occasion the Professor had been shouting for this same assistant without any response, and when he quietly appeared in the doorway behind the lecture-table he was greeted by a voice from one of the back benches, "A gill of your best, and be quick!" but what the Professor understood of this is not stated.

On one occasion Kelvin quieted a disturbance in his class by shouting, "Gentlemen! are you schoolboys or are you philosophers?"

From the fact that Lord Kelvin sometimes did not see what the students were laughing at, one is not to suppose that he had no sense of humour. Far from it; he would sometimes make sly jokes. For instance, when the great English physicist Joule, who was one of Kelvin's staunch friends, was visiting his lordship's workshop, he came across a large coil of piano wire, and asked for what this was to be used. When Kelvin replied that it was for sounding, Joule asked: "What note?" "The deep C," said Kelvin slyly, as it was for taking soundings in the ocean.

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Kelvin's name is closely linked to the subject of deep-sea sounding, and in the photograph facing page 300 we see him and his brother James reading a sounding that has just been taken from Kelvin's yacht. His name is also connected very intimately with the modern forms of the mariner's compass.

Another incident which shows Kelvin's humour occurred when he was about seventy-six years of age. His secretary handed him a pen to sign a document; Kelvin was a poor writer at the best, but on this occasion he evidently made a worse scrawl than usual. Throwing the pen aside, he held the signed document from him, saying, "Look at that, it's like the writing of a man twice my age." The signature of a man one hundred and fifty-two years of age was not a bad joke.

The following little incident will serve to show two great men at play. Long before the days of cinematographs, Kelvin and Clerk Maxwell, whose life we shall consider in the following chapter, were amusing themselves with a zoetrope, or wheel-of-life, while cruising on board a yacht. Clerk Maxwell had drawn the picture of a small bridge which fell to pieces as one watched it in the instrument. He was a clever draughtsman and had ornamented the bridge with small rosettes which revolved when the zoetrope was set in motion. Kelvin noticed this and asked what made them revolve, whereupon Maxwell said he was surprised that one who was a Wrangler and a Smith's prizeman could not see that. "But what does make them revolve?" All the answer he got was, "I made them revolve for fun."

It is often stated that Kelvin made mistakes in simple multiplication upon the blackboard, much to the amusement of his students, but this statement is not quite correct. There is no doubt that he was more at home in the differential calculus than in the multiplication table, the knowledge of the latter being of a very mechanical nature; but he did not put mistakes upon the blackboard. He would turn to one of his assistants and say, "Seven times eight?" and woe to the assistant if he made a slip. Kelvin knew at once when the right answer was given. On one occasion an assistant heard him say, "Eight times nine?—A hundred and what?—No! it can't be a hundred, for ten to the power of two's a hundred."

It is difficult to realise how rapidly a mind such as that of Lord Kelvin worked. On one occasion when the author was sitting immediately behind Lord Kelvin at a special lecture, given in his own room, by Sir Oliver Lodge, we had a demonstration of lightning calculation. Lodge had remarked that the rate of electric oscillation in a particular case would be enormous, and was about to pass on, when Kelvin stated the figures, which were unthinkable. Lodge thanked the great mathematician, remarking slyly that he had no doubt the figures were correct, but he doubted if any one else could corroborate them.

As one might expect, Kelvin and his brother James had excellent memories. A good illustration of James's memory was shown only about a year before his death. The occasion was a dinner-party, and although it was previous to the days of suffragettes, the conversation turned upon the subject of a franchise for women. James referred to some ancient Greek writer's opinion of women, and Kelvin challenged his brother to quote, whereupon James recited the ode in Greek, and then translated for the benefit of the unlearned.

It is well known that Kelvin was a devout religious thinker, and never wavered from his simple statement that "all living things depend on one everlasting Creator and Ruler." Kelvin was a regular and sincere worshipper in the church of which he was a member.

Four years after the death of Margaret Crum he married Frances Anne, daughter of Charles R. Blandy, of Madeira. There were no children of either marriage. One cannot imagine a more devoted wife than Lady Kelvin, nor could her husband have exceeded his devotion to her. After Lord Kelvin's retirement they resided on their estate at Largs, on the west coast of

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Scotland, and it was there that his lordship died at the age of eighty-three, after three weeks' illness, which began with a chill.

By general consent the burial was in Westminster Abbey, and the funeral was attended by a multitude of scientists, not only of his fellow-countrymen, but from every continental country. His name will go down to our children's children along with that of Galileo and Newton.

CHAPTER XXVII

JAMES CLERK MAXWELL
1831—1879

A GREAT LEADER IN MODERN SCIENCE; "A MOST PERFECT EXAMPLE OF A CHRISTIAN GENTLEMAN"

Two scientific friends, Professors of Natural Philosophy, each remarked to me that he supposed I should be including Clerk Maxwell in the Heroes of Science. His was the first name that each of these learned friends mentioned. There is a great natural charm about this Prince of Philosophers, although the general reader might fail to grasp the immensely great value of his scientific work, it being confined to mathematical and theoretical science, at no point directly touching the practical applications of Science.

James Clerk Maxwell was born in that year (1831) in which Michael Faraday discovered the electro-magnetic principles which have led to the great practical applications of electricity. At the time of Clerk Maxwell's birth Professor Faraday would be about forty years of age.

Clerk Maxwell was of gentle birth, his father being a Scottish laird, although a younger son. For centuries the family had been associated with all that was most distinguished in Scotland. John Clerk Maxwell was intensely interested in his son James, whose life we are about to consider.

James was an only child, excepting a sister who died in infancy. We have an interesting picture in a family letter of this only son at the age of three years. Even at this early age he must have been a great inquirer, for in this letter it is said, "the words

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'Show me how it does' were never out of his mouth. He also investigated the hidden course of streams and bell-wires. . . . As to the bells, they will not rust; he stands sentry in the kitchen, and Mag runs through the house ringing them all by turns, or he rings, and sending Bessy to see and shout to let him know, and he drags papa all over to show him the holes where the wires go through."

The boy James was not without mischief, for on one occasion when he heard a servant-maid bringing the tea-tray along a passage, he blew out the light and lay across the doorway, with what result we are left to imagine. At ten years of age we see him riding his favourite pony behind his father's carriage. He was genuinely interested in all outdoor games, but the report given to his father by the tutor concerning his lessons was hat the boy was very slow at learning. The real fact was that the tutor was very inefficient at teaching, and took an entirely wrong way with the child. To strike a pupil with a ruler and pull his ears till they bled was not the way to instil knowledge into the mind of a spirited boy.

When James was sent to reside with an aunt in Edinburgh, so that he might attend the Edinburgh Academy, he was no ordinary boy. His little eccentricities earned for him the nickname "Dafty," which, like many another boy's nickname, was very wide of the mark. However, on one occasion he turned upon those who were tormenting him, and to such good purpose that they left him in peace for the future.

Clerk Maxwell, like many others who became great men, did not take the first place in school, but at fourteen years of age he gained the gold medal for Mathematics. Before he was fifteen years of age he wrote an original mathematical paper, which proved of such value that it was communicated by Professor Forbes to the Royal Society of Edinburgh, of which his father was a Fellow. The paper of this schoolboy met with great approbation among the men of science.

His father sought to encourage him in Science, taking him to some of the meetings of the Royal Society, and also buying him magnets and chemicals. But the state of the boy's health became an anxiety to his parents. He was often absent from school, and his father could not take him to any scientific meetings. But we must not picture Clerk Maxwell as a delicate boy. One of his playmates describes how James used, when bathing, "to take a running header from the bank, turning a complete somersault before touching the water." At other times he would dive from a height, first with his face to the water, and the next time backwards, saying that to do so was good for the circulation.

At sixteen years of age he went to Edinburgh University, where he was recognised as a genius, and was allowed the free use of the scientific apparatus for making original experiments. Maxwell was by no means a recluse; he was keen to get out to the games, but was willing to sacrifice his play if he could help some fellow-student. For instance, one student had hurt his eyes in making experiments on light, and he was ordered to stop reading, although he had been keen to prepare for his examination. Clerk Maxwell found him sitting in his room with closed eyes, and rather depressed about his enforced idleness, whereupon our hero offered to be eyes to the blind; and very often he would give up an hour of recreation to enable this student to prepare for his examination.

Mr. John Clerk Maxwell had thought of preparing his son for the Scottish Bar, but it was suggested that he should rather send him up to Cambridge. Perhaps the thought of parting with his son weighed with the father, for while James had been resident in Edinburgh his father was a constant visitor at the aunt's house. There was a perfect affection and confidence between father and son. But the father wished to do whatever would be best for his son, and so he consulted those who could help him to come to a decision. It is interesting to note that one of those whom the father consulted was Professor William Thomson, afterwards Lord Kelvin. Thomson was then a youthful

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professor in Glasgow University; he would be only seven years older than Clerk Maxwell.

Ultimately it was decided that our hero should go to Cambridge. On going there he took with him his scraps of gelatine, gutta-percha, and unannealed glass, bits of magnetised steel and such-like. His fellow-students recognised him as a very uncommon person, and every one was attracted by his gentlemanly ways, and by his conversation. One of his student friends has said: "No one could converse with him for five minutes without having some perfectly new ideas set before him; sometimes so startling as to utterly confound the listener, but always such as to well repay a thoughtful examination." But this deep thinker, engaged even then in original research work, was known among his friends as the most genial and amusing of companions.

I remember hearing, from what source I cannot recollect, an amusing story of Clerk Maxwell, which I have not seen in print. One night he had been entertaining some fellow-students with a large gyroscope, and they were all surprised at the length of time it continued to spin; indeed, it was still spinning when they separated to go off to their several rooms. In the morning Clerk Maxwell heard some of his friends coming up the stairs to his room, before he was out of bed, and remembering their surprise at the spinning gyroscope, he sprang out of bed, set the top spinning, and was back in bed, apparently sound asleep when the students entered. How long they were in solving the mystery I cannot say. It must have seemed to them at first as though Maxwell had solved the problem of perpetual motion.

Clerk Maxwell tried some experiments with his hours of work and sleep. One of his fellow-students has related how Maxwell would come out of his room at two o'clock in the morning, and take exercise "by running along the corridor, down the stairs, along the lower corridor, then up the stairs, and so on, until the inhabitants of the rooms along his track got up and lay *perdus* behind their sporting-doors to have shots at him with boots, hair-brushes, etc., as he passed." He was still keen on bathing and boating. On one occasion he was upset out of his "funny" trying to take off his jersey after he had shipped his oars, but to such an expert swimmer it was in no way alarming. We find his father referring to the incident in a letter: "Were you carrying your watch when you were upset in your funny? and if so, how did it agree with the douking?"

When at home on his father's estate near Dumfries, Clerk Maxwell did not shoot, and when a friend informed him that the neighbours thought it a pity that he was "so little suited for a country life" he thought it a huge joke. The truth was that he had such a love for animals that he would not shoot them. He never denounced vivisection, thinking that it might serve a useful purpose, but he said that he could never do it.

Here is a description of the appearance of our hero: "A slight contraction of the chest; a stature which, although above the average, was not tall enough to carry off the weight of his brow, made him less handsome standing than sitting. His hair and incipient beard were raven-black."

On one occasion at Cambridge the mathematical lecturer was working out a difficult problem on the blackboard. He had filled the board three times over with figures, and had not yet reached the end of the calculation, when Clerk Maxwell asked if it would do to solve the problem by means of a geometric figure, and he showed that with a single figure and a few lines the solution of the problem could be obtained. But with all his great mathematical skill and exceptional genius, when he himself became a lecturer at Cambridge, he had great difficulty in imparting his knowledge to others. And later, when he became Professor of Natural Philosophy at Aberdeen, the same difficulty was apparent. One of his friends has stated that, "either from shyness or momentary excitement, or the despair of making himself understood, would land him in chaotic statements, breaking off with some quirk or ironical humour." But the Professor was a good friend to his students, as the following incident will show. At the Marischall College, Aberdeen, the professors were allowed an unlimited number of books from the

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Library, and could even borrow a book for a friend, whereas no student was allowed more than two volumes at a time. Maxwell would take out books and lend them to his students, and when his colleagues thought it necessary to complain of this irregularity, Maxwell explained that the students were his friends.

His father died about the time Clerk Maxwell was appointed to the Professorship in Aberdeen, and needless to say, this sad event was a great trial to the devoted son. When twenty-seven years of age he married a daughter of the Principal of the Marischall College, and his married life was one of great happiness. One cannot imagine any man more devoted to his wife, and we shall see some proof later of his devotion.

The whole of the correspondence of Clerk Maxwell is of great interest, but much of it deals with scientific subjects beyond the layman's knowledge. Here, however, is an example of something in lighter vein, such as was continually coming up in his letters. It is an extract from a letter written to a friend who in after-life became one of Maxwell's biographers. An additional interest attaches to this letter as it refers to Lord Kelvin while still a young man, then Professor William Thomson. Maxwell writes:

"I was writing great screeds of letters to Professor Thomson about those Rings (Saturn), and lo! he was a-laying of the telegraph which was to go to America, and bringing his obtrusive science to bear upon the engineers, so that they broke the cable with not following (it appears) his advice. However, I know nothing. List to the new words to a common song, which I conceived on the railway to Glasgow. As I have only a bizzing, loose, interruption-to-talking-&-deathblow-to-general-conversation memory of the orthodox version, I don't know if the metre is correct; but it is some such rambling metre anyhow, and contains some insignificant though apparently treasonable remarks in a perfect thicket of vain repetitions. To avoid these let—

(U) = 'Under the sea,' so that 2(U), by parity of reasoning, represents two repetitions of that sentiment. This being granted, we shall have as follows:

"THE SONG OF THE ATLANTIC TELEGRAPH COMPANY

"2(U)
Mark how the telegraph motions to me,
2(U)
Signals are coming along,
With a wag, wag, wag;
The telegraph needle is vibrating free,
And every vibration is telling to me
How they drag, drag, drag,
The telegraph cable along.

"2(U)
No little signals are coming to me,
2(U)
Something has surely gone wrong,
And it's broke, broke, broke;
What is the cause of it does not transpire,
But something has broken the telegraph wire
With a stroke, stroke, stroke,
Or else they've been pulling too strong.

"2(U)
Fishes are whispering. What can it be,
2(U)
So many hundred miles long?
For it's strange, strange, strange,
How they could spin out such durable stuff,
Lying all wiry, elastic, and tough,
Without change, change, change,
In the salt water so strong.

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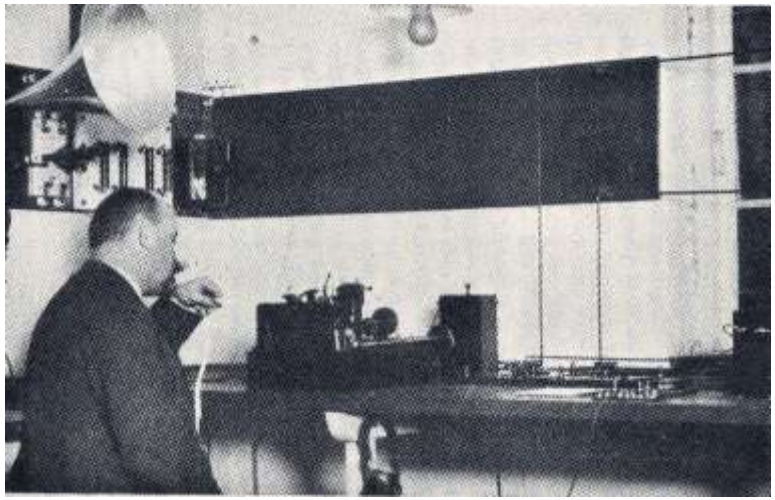
"2(U)
There let us leave it for fishes to see;
2(U)
They'll see lots of cables ere long,
For we'll twine, twine, twine,
And spin a new cable, and try it again,
And settle our bargains of cotton and grain,
With a line, line, line
A line that will never go wrong."

Little did Clerk Maxwell think that his own scientific work was one day to lead men on to the invention of wireless telegraphy. It was Clerk Maxwell who first predicted the existence of electro-magnetic waves, such as we use to carry our wireless messages through space. We may say that he discovered these waves by his mathematics, but a quarter of a century passed before the young German, Professor Hertz, discovered a means of demonstrating the presence of these waves by actual experiment.

On leaving Aberdeen, owing to his college being fused with others, Maxwell was urged to become a candidate for the vacant professorship in Edinburgh University. The preference was given, however, to his friend, Professor Tait, and it goes without saying that this made no difference whatever in the friendship of these two great men. Shortly after this Maxwell was appointed to the Chair of Natural Philosophy in King's College, London, where he carried out many important investigations. He performed many of his experiments at his home in Kensington. Sometimes he had occasion to work with his colour-box close up to the window, and as it was a large black box, measuring about eight feet in length, the neighbours thought he was mad to spend so many hours staring into what they believed to be a coffin.

During his stay in London, Maxwell used to meet Michael Faraday, who was then about seventy years of age. One evening Clerk Maxwell, then about thirty years of age, was making his way from the Lecture Theatre of the Royal Institution, when Faraday observed him entangled in the crowd. Remembering the young Professor's work on the movements of particles of matter, Faraday shouted to him, "Oh, Maxwell, cannot you get out? If any man can find his way through a crowd it should be you."



RECEIVING A WIRELESS MESSAGE
THE MODERN MARVEL, "WIRELESS TELEGRAPHY," IS THE OUTCOME OF THE PIONEER WORK OF JAMES CLERK MAXWELL AND PROFESSOR HERTZ.

During the time they were resident in London he and Mrs. Maxwell took regular exercise on horseback. Maxwell bought a beautiful pony for his wife; it was a high-bred, spirited animal, with arched neck and flowing tail. Maxwell himself bought the pony at a fair, and he broke it in, riding side-saddle, with a piece of carpet to take the place of a habit. Shortly after this Maxwell was laid low with a severe attack of smallpox, it being supposed that he had become infected at the fair at which he bought this pony. During this trying illness his wife was quite alone with him, the servants only coming to the door of the sickroom. Maxwell used to say that his wife's careful nursing on this occasion saved his life.

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A few years later, when Maxwell was riding a strange horse, he struck his head on the bough of a tree, and received a scratch which was followed by erysipelas. This proved to be a very serious affair, but his devoted wife once more nursed him back to health and strength.

When thirty-five years of age Maxwell resigned at King's College, and retired to his estate near Dumfries, in Scotland. He was never absent much from home, but was busily employed writing his great treatises on Heat and on Electricity and Magnetism. His longest absence from home each year was when he went as Examiner to Cambridge. On these occasions, despite the pressure of examination papers, he wrote to his wife every day, and sometimes twice a day, telling her everything that would interest her, even the dress of lady friends.

When his wife was seriously ill he himself assisted in nursing her, and his concern for her is well illustrated by the following incident. When watching by her bedside one evening a terrier snapped at him and bit him in the face. The dog held on to Maxwell's nose, but rather than disturb his wife, he quietly lifted the dog and carried it from the room, still holding on to his nose.

This busy scientist took an interest in everything in which Mrs. Maxwell was interested. On one occasion he found that she was distressed with a sense of failure in her first attempts at cottage-visiting, so he read to her Milton's sonnet on his blindness, the last few lines of which read:

". . . thousands at his bidding speed,
And post o'er land and ocean without rest,
They also serve who only stand and wait."

Maxwell himself would visit any sick person in the village, and would read and pray with them in cases where such ministrations were welcomed. He and Mrs. Maxwell would always go to London in spring, and so, with busy days, the years of retirement passed quickly.

About this time (1870) the Chancellor of the University at Cambridge, the Duke of Devonshire, desired to build a Physical Laboratory in connection with the University. The Duke was a great-nephew of our eccentric friend the Hon. Henry Cavendish, and the laboratory, when completed, was named, and is still called, the Cavendish Laboratory. In recent years it has been the scene of Sir J. J. Thomson's remarkable scientific work.

Clerk Maxwell was urged to become the first professor in charge of the Cavendish Laboratory, and he accepted the post only because Professor William Thomson could not be persuaded to leave Glasgow, and because Maxwell's friends urged that it was therefore his duty to fill the Chair himself. He planned the new laboratory most carefully, and to-day Science reaps much benefit from his labours.

During these years at Cambridge he kept up his interest in his Scottish home. At Easter-time he made it a point always to leave Cambridge in time to officiate at the communion in the little Scottish kirk where he was an elder.

Unfortunately, a serious malady began to undermine his strength. Before the close of the session (1877) he complained of a choking feeling after meals, but it was about two years later before he mentioned the matter to his doctor, and only then in an incidental way when writing about Mrs. Maxwell. All at Cambridge noticed a change; there was a want of the old vivacity. A rest at his Scottish home did not seem to do much good, and when specialists were consulted they told him quite frankly that he had only about another month to live. His only concern was the happiness of his wife.

As they were at some distance from a doctor it was thought better to remove either to Edinburgh or Cambridge, and Maxwell selected the latter, where he might still do some work. He suffered much, but seldom mentioned it. His mind and memory remained perfectly clear up to the very end. Every one marvelled at his fortitude in suffering. About an hour before his death he was able to whisper some instructions to the doctor, but these did not concern himself; they were requests on behalf of

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his devoted wife. "He breathed deeply and slowly, and, with a long look at his wife, passed away."

At his death James Clerk Maxwell was only forty-eight years of age. The doctor who was with him at the end said that no man ever met death more consciously or more calmly. Another doctor, who knew him well, wrote the words which are used in the subtitle to this chapter, "A most perfect example of a Christian gentleman," and with this verdict the nurses and all who knew him heartily agreed.

CHAPTER XXVIII

A GRAND MARCH PAST

A REVIEW OF THE HEROES DESCRIBED IN THE FOREGOING PAGES, WITH CONTEMPORARY MEN OF SCIENCE ADDED TO THE PICTURE

In these days of Cinematograph Theatres or Picture Houses it is possible to see the life history of a growing plant depicted before one in a few minutes. A flowering plant which took several weeks to bud and blossom is seen to do so on the lantern screen within the space of a few minutes. In taking such a cinematograph film, one photograph has been taken at the outset, and the next one several hours, or it may be many hours, later, and so on during the space of several weeks. Then, when the photographs are made to follow one another very rapidly upon the lantern screen, we see in a few minutes what actually took place during a period several thousand times longer.

Suppose for a moment, and it will want a good deal of imagination, that it had been possible to arrange all the Heroes of Science in one long regiment, commencing thousands of years ago, and that we had taken pictures of them at stated intervals long distant from one another. If we could then pass these imaginary pictures rapidly before us, we should have something like the following.

Away in the dim distance, and almost entirely out of focus, we see the seven wise men of Greece, and then in much sharper focus we see old Pythagoras surrounded by a band of faithful students; a picture of brotherly love. Some little space after Pythagoras comes Anaxagoras, wealthy and beneficent, but a prisoner for his scientific ideas concerning the heavenly bodies.

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The next outstanding figure that attracts attention is the great Aristotle, whose learning is respected, not only by those around him, but by a long string of following generations. Among the crowd immediately around Aristotle we can pick out the curious figure of Diogenes the Cynic with his simple cloak, but haughty manner. And in this picture we see also young Alexander the Great, to whom Aristotle had been tutor, and there is Plato, not pleased altogether with the teaching of his former pupil Aristotle. The great Socrates is merely passing through this picture taking no heed of anything connected with Science.

The next group, following fairly close to the preceding one because of the rapidity of the imaginary cinematograph, shows old Professor Euclid with his geometrical figures; and in the same picture we see other professors of the same Alexandrian school, and the large crowd of thousands of students cannot but attract attention. Among the professors we see Aristarchus, wondering how with Euclid's figures he could estimate the distance between the Earth and the Sun, and there is Eratosthenes, trying to think out a plan by which he can measure the Earth.

While the two preceding Alexandrian figures seem to us almost as strangers, we feel as though we knew the next outstanding figure—the ancient mathematician Archimedes of Syracuse. We see him accompanied by his lifelong friend King Hiero, with his crown which became famous. In a succeeding picture we see the great Roman orator Cicero visiting the tomb of Archimedes, and bewailing the fact that this most ingenious man was slain by a Roman soldier. Between the two preceding pictures there passed the rather dimly lighted figure of Hipparchus, interesting because he was the real founder of Astronomy.

By this time we have reached the short period during which Christ lived upon this Earth. Our next picture is of the great astronomer Ptolemy declaring that he believes the Earth to be the central body around which the Sun and other heavenly bodies move, and he succeeds in a manner to account for all the different motions, but it is doubtful if many of his audience can follow him.

At this point one might almost think that something had gone wrong with our imaginary cinematograph, for there is a long spell of very indistinct pictures in which we see that almost all the figures are Arabs. We can make out little but that they are a most intelligent-looking people, and that some of them are busy translating the old works of Aristotle, while others are weaving wonderful tales for the young people of succeeding centuries. One figure—that of Alhazan—stands out clearly because he is making definite experiments with beams of light. It is evident also that among this crowd of Arabians there are many physicians, most of whom are busy writing out prescriptions.

There is another apparent break in the continuity of our imaginary cinematograph film, and then we suddenly see a studious monk, whom we recognise as Roger Bacon. He is busy reading some of the writings of the ancient Arabians, who have passed out of sight some time before. We see that Bacon is looked at askance, as though he were a wizard, and the last glimpse we have of him is as an old man being released from prison.

Another blank in our picture, when suddenly we see old Copernicus quietly writing out his proofs that the Sun, and not the Earth, is the central body around which all the planets circle, but he is on his death-bed before his book reaches the world.

Then another blank in our run of pictures, and curiously enough among the next figures that appear there is another Bacon—Francis Bacon—but while he points out the necessity of advance in Science, he is too busy with political and literary pursuits to give a helping hand himself. But in the same picture we see one of Queen Elizabeth's physicians, Dr. William Gilbert, busy rubbing sticks of glass and other substances, declaring that these will become electrified in the same way as amber. As we look at this man writing his great book De Magnete we are reminded of the words of the great English poet Dryden, who

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followed close after him: "Gilbert shall live till loadstones cease to draw."

There seems to be a much steadier light producing our pictures now. We see distinctly the Danish astronomer Tycho Brahe with his curious imitation nose, and in the same picture is the great Galileo, with one of the telescopes he has made. Beside Tycho we see Johann Kepler, with a wondering look in his eyes, for he is always puzzling about the why and wherefore of the movements of the heavenly bodies. We see the English poet, John Milton, paying a visit to the aged Galileo. In this picture it is old Galileo who is blind, while the poet still has his eye-sight. The English physician Harvey, who discovered that our blood continually circles through our bodies, is seen also on a visit to Italy in the time of Galileo.

The picture immediately following and overlapping that of Galileo in point of time shows the famous French philosopher Rene Descartes explaining the necessity of a mysterious medium or ether throughout all space. In the same picture but not together we see the greatest of English philosophers, Sir Isaac Newton. Although he never met Descartes, he studied that philosopher's work on Geometry. In this picture we see also the German scientist, Otto von Guericke, with his newly invented air-pump, and in still another part of the picture is the Dutch philosopher Christian Huygens. Nearer in point of place to Newton, we see the Honourable Robert Boyle, son of the Earl of Cork. He shows no sign of affectation, and is a true scientist.

Immediately around Newton are his friends, Sir Christopher Wren, with his plans for St. Paul's Cathedral in London; Edmund Halley, who discovered the comet in which we are interested on each occasion it pays a visit to the neighbourhood of our planet; Robert Hooke, who in some points anticipated Newton; David Gregory, who was one of the first to teach the doctrines of his friend Newton. Gregory's uncle, also a professor, was struck blind at the age of thirty-six, while showing the satellites of Jupiter to his students. The Gregory family are always of interest, because no less than sixteen members of the family have held British professorships, three brothers at the same time occupying the Chairs of Mathematics in three Universities.

AN AMUSING CARTOON
WHEN FARADAY WAS SAILING DOWN THE THAMES HE WAS SO IMPRESSED WITH THE POLLUTION OF THE RIVER THAT HE WROTE A LETTER TO *THE TIMES* DEPLORING THE CONDITION OF THINGS. *PUNCH* FOLLOWED WITH THE CARTOON SHOWN ABOVE.

Overlapping the previous picture in point of time, we see the great American statesman and philosopher, Benjamin Franklin, with the kite by means of which he robbed the

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lightnings of much of their terror. Beside him is his friend the Rev. Dr. Joseph Priestley, who gave a great impetus to the study of Chemistry. And in this same picture, though not connected with Franklin, we see James Watt, Dr. Erasmus Darwin, Josiah Wedgwood the potter, Sir William and Caroline Herschel with their enormous telescope. In this picture there is the figure of a Roman Catholic priest, Spallanzani, a distinguished scientist in Italy in his own time, though not well known in our day. He should be of particular interest to us, as he was one of the very first to recognise the existence of Bacteria.

Along with James Watt we see Dr. Joseph Black, the discoverer of what we describe as latent heat, and in another part of the picture we see the eccentric Hon. Henry Cavendish trying to avoid every one around him. In still another part of the picture we see Edward Jenner, the English physician who introduced vaccination for smallpox.

Then, switching our cinematograph on to the Continent, we see at the same time, in Italy, Professor Galvani making electrical experiments upon the legs of a dead frog, and disputing with Professor Volta as to the cause of these phenomena. And in a simple experiment by Volta we witness the birth of electric batteries and the discovery of the electric current. In France we see the Astronomers Lalande, Lagrange (grandson of Descartes), and Laplace, and the Chemist Lavoisier, one of the founders of modern Chemistry. This poor fellow was executed by the busy guillotine in the Reign of Terror.

Coming back to Great Britain we find Count Rumford, an American, who set out in life as plain Benjamin Thompson, and who fought on the side of the British in the American War. This scientist, by the way, married the widow of Lavoisier, but they did not live happily together. His name is connected with the science of Heat, and with the founding of the Royal Institution in London. We see him engaging young Humphry Davy as an assistant for this great Institution, and we see Davy in turn befriending the enthusiastic Michael Faraday. Faraday is followed by Tyndall and by Huxley, who championed Science against the orthodoxy of the Church.

Contemporary with Sir Humphry Davy we see his fellow-professor Dr. Thomas Young withstanding the scathing criticisms poured out upon his definite views of the wave theory of light, which are now accepted by all. In the same picture we see some continental friends, Professor Ampere of France, whose name we have memorialised in one of our electrical units; Arago, the French physicist and astronomer; and shortly before Sir Humphry Davy passes out of the picture we see the Danish philosopher, Hans Christian Oersted, discovering that an electric current passing through a wire will attract a neighbouring magnet.

Among the many scientists in this part of the picture we find Sir Charles Wheatstone with the stereoscope of his own invention, and with the pioneer needle telegraph instrument which he and Cooke invented.

In the same nineteenth-century picture we see Pasteur, the French Chemist, whose work on Hydrophobia laid the foundations of our knowledge of Bacteria. In another part of the picture we see Sir James Young Simpson, who introduced the use of Chloroform as an anaesthetic. There is also Lord Lister, the eminent surgeon, and one of the world's greatest benefactors, through his introduction of the antiseptic treatment in Surgery.

Nearing the end of our imaginary cinematograph film, we see Charles Darwin very quietly launching his definite theory of Evolution, which was to work a revolution in man's ideas.

By far the most prominent figure in the last part of the film is that of Lord Kelvin; with him we see his devoted brother James; his lifelong friend Joule, who discovered the mechanical value of heat; his staunch friends, the German physicist Helmholtz, the English mathematician sir George Stokes, and his earlier friend Professor Kelland, whose criticism of the French mathematician Fourier was called in question by Kelvin

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when a boy; and the last very prominent figure in this group is James Clerk Maxwell.

Contemporary with the foregoing group we see the young German professor Heinrich Hertz, who demonstrated the existence of Clerk Maxwell's electro-magnetic waves and thus laid the foundations of wireless telegraphy. Following him we see Professor Curie, the discoverer of Radium, and towards the end of the imaginary film we see Sir William Huggins, who has done so much valuable work with the spectroscope in reading the Chemistry of the stars. His devoted wife, who has so ably assisted him, is not included in the picture which includes only those Heroes who have passed away.

CHAPTER XXIX

CONCLUSION

When viewing the Grand March Past in the preceding chapter, we paid attention to the order in which the different Heroes of Science crossed the stage of life; we did not consider the length of time each actor remained upon the stage.

It may be a surprise to some readers to learn that a string of seven individual actors links up the time of Copernicus with the present day. Copernicus had just quitted the stage when Tycho Brahe stepped on, and in the case of Tycho and the other five men forming this chain, one had not disappeared until the succeeding actor was already on the stage; this will be seen from a glance at the following note:—

COPERNICUS passed away only three years before the birth of

TYCHO BRAHE. At the time of Tycho's death

GALILEO was nearly forty years of age.

SIR ISAAC NEWTON was born in the year in which Galileo died.

BENJAMIN FRANKLIN was twenty years of age when Newton died.

SIR HUMPHRY DAVY was a schoolboy of twelve at Franklin's death.

LORD KELVIN was a bright boy of five years when Davy passed away.

Thus by seven steps we get back to the close of the Middle Ages. We know that during the Middle Ages Science made practically no progress, and that the fault lay in the people believing that they must first of all find the causes before they could understand the effects. They would have considered that they were degrading their pure philosophy if they had condescended to study mere phenomena.

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Going back through the Middle Ages we pass Roger Bacon, and before him the Arabian Scientists, and finally we reach the point of real progress, before the time of Christ, with which we set out. To some people any date B.C. seems to be approaching infinity, or at least to be a good way towards the beginning of things, whereas the time of William the Conqueror takes us nearly half-way back to the time of Christ. Indeed, the beginning of the Christian era is very, very recent compared to the advent of man upon this planet.

It is natural that the lives of Galileo, Newton, and Kelvin stand out more prominently than the others in this account of the Heroes of Science. These three great men lived seventy-eight, eighty-five, and eighty-three years respectively, and in the majority of cases the lives of all our heroes were well above the average life of men. Out of the list of fifty-three men given in the Appendix (page 339), no less than thirty-five passed the allotted span of threescore years and ten.

When we think of the amount of work done by these men, surely we must be convinced that hard work—apart from worry—will never kill a man, and that if we wish to have a long and happy life, the best we can do is to work hard and keep one's mind alive to all the interests of mankind. Of course, this will not guarantee long life, for there are many outside causes with which we have to contend. On the other hand, a life of indolence or mere pleasing of oneself cannot be a really happy one, though it may drag out beyond the allotted span. One of the great poets of the eighteenth century (Cowper) has said:

> "An idler is a watch that wants both hands,
> As useless if it goes as if it stands."

When we consider the enormous advance which has been made in scientific knowledge, and when we think of the wide field still to be explored, surely we shall not grudge any grants that the State may give towards Scientific Investigation. It is a matter of national importance to us. We wish to be in the forefront, not only in the number of Dreadnoughts we possess.

CHAPTER XXX

THE LETTER WHICH GOT GALILEO INTO TROUBLE

It may be of interest to some readers to see the full text of the letters referred to in Chapter IX. The first of these is a letter sent to Galileo by his old pupil, then Professor Castelli of Pisa. The occasion referred to was a dinner-party at the palace of the Grand Duke of Tuscany:

"On Thursday I dined at their Highnesses' table. The Grand Duke asked me how my lectures were attended. I entered into various minute particulars, with which he appeared much pleased. He asked whether I had a telescope. I answered that I had; and with this I gave an account of my observation of the Medicean planets the preceding night, and Madama Serenissima (the Dowager Duchess) inquired their position. And hereupon some began to say that indeed these must be realities, and not deceptions of the instrument; and their Highnesses began to question Dr. Boscaglia, the professor of physics, who answered that the existence of these planets could not be denied. I took occasion to add what I knew of your wonderful invention, and of your having fixed the periods of the revolution of the said planets. Don Antonio was at table, who showed by his countenance how much pleased he felt with what I said. At length, after many solemn ceremonies, dinner came to an end, and I took leave; but scarcely had I quitted the Palace when Madama Serenissima's porter came after me, and called me back. But before I narrate what followed, I ought to tell you that during dinner Boscaglia was talking privately to Madama for a while; and he said that, if it were conceded that the celestial novelties discovered by you were realities, then only the motion of the earth was incredible, and could not be, for the reason that Holy Scripture was manifestly contrary to it.

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"To return: I entered her Highness's apartment, where were the Grand Duke, Madama the Archduchess (wife of the Grand Duke), Don Antonio, Don Paulo Giordano, and Dr. Boscaglia. Here Madama, after a few inquiries as to my condition in life, began to argue against me with the help of the Holy Scriptures; and I, after making a proper protest, began a theological exposition in such a masterly manner that you would have been delighted to hear me. Don Antonio helped me, and so encouraged me that, though the majesty of their Highnesses was enough to appal me, I behaved like a paladin. The Grand Duke and the Archduchess were on my side, and Don Paulo Giordano brought forward a passage of Scripture very opportunely in my defence. So at length Madama Serenissima was the only one who contradicted me, but it was in such a manner that I judged she only did it to draw me out. Signor Boscaglia said nothing either the one way or the other.

"All the particulars of this audience, which lasted two hours, shall be told your lordship by Signor Nicolo Arrighetti. But I ought to tell you that, as I was praising you, Don Antonio joined in, in what way you may imagine; and when I had taken leave, he offered me his services in the most princely manner, and desired me to give you an account of what had taken place, and what he had said; and said in these very words: 'Write thou to Signor Galileo that I have made thy acquaintance, and tell him what I said in her Highness's chamber.'"

Here we have a copy of Galileo's reply to his enthusiastic disciple:

"It seems to me that it was well said by Madama Serenissima, and insisted on by your reverence, that the Holy Scripture cannot err, and that the decrees therein contained are absolutely true and inviolable. But I should have in your place added that, though Scripture cannot err, its expounders and interpreters are liable to err in many ways; and one error in particular would be most grave and most frequent, if we always stopped short at the literal signification of the words. For in this wise not only many contradictions would be apparent, but grave heresies and blasphemies. For then it would be necessary to give God hands and feet and ears, and human and bodily emotions; such as anger, repentance, hatred, and sometimes forgetfulness of things past, and ignorance of the future. And in Scripture there are found many propositions, which, taking the bare sense of the words, appear contrary to the truth, but they are placed there in such wise in order to accommodate themselves to the capacity of the vulgar; so that for those few who merit to be separated from the plebeian crowd, it is necessary for wise expositors to produce the true meaning, and to explain the particular reasons for which they have been thus worded. It being laid down, therefore, that Scripture is not only capable of divers interpretations, but that in many places it requires an interpretation differing from the apparent meaning of the words, it seems to me that in mathematical disputes it must be interpretated according to the latter mode. Holy Scripture and Nature are both emanations from the Divine Word: the former dictated by the Holy Spirit; the latter, the executrix of God's commands. Holy Scripture has to be accommodated to the common understanding in many things which differ in reality from the terms used in speaking of them. But Nature, being on the contrary inexorable and immutable, and caring not one jot whether her secret reasons and modes of operation be above or below the capacity of men's understanding: it appears that, as she never transgresses her own laws, those natural effects which the experience of our senses places before our eyes, or which we infer from adequate demonstration, are in no wise to be revoked because of certain passages of Scripture, which may be turned and twisted into a thousand different meanings. For Scripture is not bound to such severe laws as those by which Nature is ruled. For this reason alone, that is, to accommodate itself to the capacities of rustic and undisciplined men, Scripture has not abstained from veiling in shadow its principal dogmas, attributing to God himself conditions differing from, and contrary to, the Divine essence. And who can assert or sustain that, in speaking incidentally of the Sun, or of the Earth, or of other created bodies, Scripture should have elected to restrain

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itself rigourously to the strict signification of the words used? May it not be, that, had the truth been represented to us bare and naked, its intention would have been annulled, from the vulgar being thereby rendered more contumacious and difficult of persuasion in the articles concerning their salvation? This, then, being conceded, and it being manifest that two truths cannot be contrary to each other, it becomes the office of wise expounders to labour till they find how to make these passages of Holy Word concordant with those conclusions, of which either necessary demonstration or the evidence of our senses have made us sure and certain. . . . As we cannot be certain that all the interpreters are divinely inspired, I think it would be prudent if men were forbidden to employ passages of Scripture for the purpose of sustaining what our senses or demonstrated proof may manifest to the contrary. Who can set bounds to the mind of man? Who dares assert that he already knows all that in this Universe is knowable? And on this account, beyond the articles concerning salvation and the stability of the faith, against the unchangeableness of which there is no danger of any valid and efficacious innovation being introduced, it would perhaps be best to counsel that none should be added unnecessarily; and if it be so, how much greater the disorder to add to these articles at the demand of persons who, though they may be divinely inspired, yet we see clearly that they are destitute of the intelligence necessary, not merely to disprove, but to understand, those demonstrations by which scientific conclusions are confirmed.

"I believe that the intention of Holy Writ was to persuade men of the truths necessary to salvation; such as neither Science nor other means could render credible, but only the voice of the Holy Spirit. But I do not think it necessary to believe that the same God who gave us our senses, our speech, our intellect, would have us put aside the use of these, to teach us instead such things as with their help we could find out for ourselves, particularly in the case of these sciences, of which there is not the smallest mention in the Scriptures; and, above all, in Astronomy, of which so little notice is taken that the names of all the planets are not mentioned. Surely if the intention of the Sacred writers had been to teach the people astronomy, they would not have passed the subject over so completely."

The foregoing letter is surely remarkable; it was written three hundred years ago.

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CHAPTER XXXI

APPENDIX II

The following list of men mentioned in the text may be of interest. They are placed in chronological order, with the dates of birth and death in front of each name:

1214–1294.	Roger Bacon.	1738–1822.	Sir Wm. Herschel.
1473–1543.	Copernicus.	1742–1794.	Antoine Lavoisier.
1540–1603.	William Gilbert.	1745–1827.	Alessandrino Volta.
1546–1601.	Tycho Bridle.	1749–1823.	Edward Jenner.
1561–1626.	Sir Francis Bacon.	1749–1827.	Marquis de Laplace.
1564–1642.	Galileo.	1753–1814.	Count Rumford.
1571–1630.	Johann Kepler.	1766–1844.	John Dalton.
1578–1657.	William Harvey.	1773–1829.	Thomas Young.
1596–1650.	Rene Descartes.	1775–1836.	Andre Ampere.
1602–1686.	Otto von Guericke.	1777–1851.	Hans Christian Oersted
1626–1691.	Hon. Robert Boyle.	1778–1829.	Sir Humphry Davy.
1629–1695.	Christian Huygens.	1791–1867.	Michael Faraday.
1632–1723.	Sir Christopher Wren	1802–1875.	Sir Charles Wheatstone
1635–1702.	Robert Hooke.	1809–1882.	Charles Darwin.
1642–1727.	Sir Isaac Newton.	1811–1870.	Thomas Young Simpson
1646–1716.	Gottfried Leibnitz.	1818–1889.	J. P. Joule.
1656–1742.	Edmund Halley.	1819–1903.	Sir George Stokes.
1661–1708.	David Gregory.	1820–1893.	John Tyndall.
1706–1790.	Benjamin Franklin.	1821–1894.	Hermann von Helmholtz.
1728–1799.	Joseph Black.	1822–1895.	Louis Pasteur.
1729–1799.	Lazaro Spallanzani.	1824–1910.	Sir William Huggins.
1731–1810.	Hon. Henry Cavendish	1824–1907.	Lord Kelvin.
1732–1807.	Joseph de Lalande.	1825–1895.	Thomas Huxley.
1733–1804.	Rev. Joseph Priestley	1827–1912.	Lord Lister.
1736–1813.	Comte Lagrange.		

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