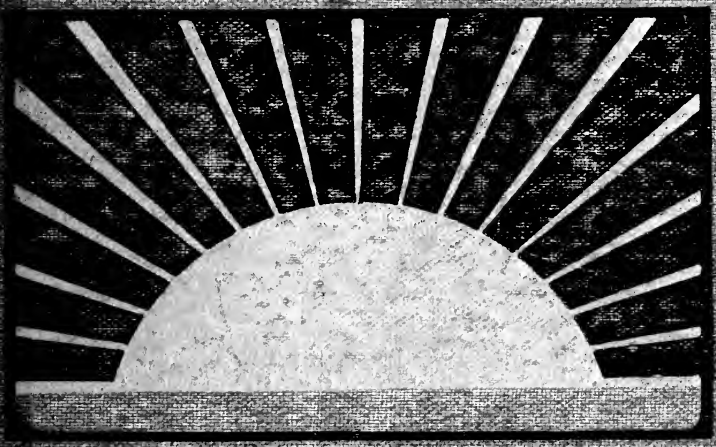
PIONEERS OF PROGRESS



MEN OF SCIENCE

GALILEO

W. W. BRYANT

GALILEO GALILEI

PIONEERS OF PROGRESS

MEN OF SCIENCE

EDITED BY S. CHAPMAN, M.A., D.Sc.

GALILEO

BY

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GALILEO.

CHAPTER I.—BIRTH AND EDUCATION.

In the year 1343 one Tommaso Bonajuti, being elected to the Council of Twelve in Florence, changed his family name to Galilei. His grandson, Galileo Galilei, a century later, was a celebrated physician, professor of medicine at the University of Florence, and became chief magistrate of the Republic. This Galileo's brother had a great-grandson Vincenzio, the father of the great Galileo, whose life forms the subject of this volume. We shall consistently drop the surname in our references to him, following a custom of the Italians in speaking of their great men; such as Dante, Raphael, and Michelangelo.

Vincenzio Galilei was a skilful and accomplished musician, with a good knowledge of classics and mathematics, but want of means and the expense of a growing family had sent him into commercial life, and induced him to choose for his eldest son's future career the business of a cloth-dealer, as something of fairly good standing and also lucrative.

This son Galileo was born in Pisa on February 15, 1564, the year that saw the birth of Shakespeare, and his education began in a day-school there with some assistance from his father at times when business did not take him away from Pisa. Vincenzio's help with lessons seems to have been confined to Greek and Latin to the

exclusion of mathematics. It may sound odd to modern ears, but there is no doubt of the fact that in those days the objection to the study of mathematics was that it did not pay, as we shall be reminded later on.

At thirteen Galileo was sent to the monastery of Vallombrosa, near Florence, for the conventional classical education, but he only stayed about two years, and was then hurriedly removed by his father, who found him in danger of yielding to the attractions of monastic life, and thus abandoning the career projected for him. The boy showed no special aptitude for business, but had a natural leaning towards mechanics, and like Newton at a later date, made toy machines at an early age. He had inherited a full share of his father's musical ability, and besides theoretical knowledge he learnt to play on various instruments, even surpassing his father's skilful performance on the lute. He showed, moreover, considerable facility in other arts, poetry, and especially drawing and painting, and though his inability to choose an artistic career restricted him almost entirely to criticism, his opinion was greatly valued by several painters of repute. Vincenzio could not be blind to the unsuitability of commercial pursuits for a youth of such accomplishments, and may have regretted what had seemed the necessity in his own case. He therefore abandoned the idea of the cloth trade, and cast about for a paying profession. His own experience taught him that neither mathematics nor music could be regarded as satisfactory from this point of view, and besides, Galileo had so far learnt nothing of mathematics. The choice, possibly influenced by the career of the boy's distinguished namesake, fell on the medical profession, and in his eighteenth year Galileo was sent to the University of Pisa to study under the celebrated physician Andrea Cesalpini, in addition to the usual course in philosophy.

Now Vincenzio himself, as shown in his writings on musical theory, had a rooted objection to taking things on trust, so it is not surprising that Galileo found himself continually at issue with his teachers in philosophy, and thus early struck the keynote of his stormy career. What passed for philosophy in those days had degenerated almost entirely into blind repetition of the statements and doctrines of ancient philosophers, and particularly of Aristotle. But Aristotle and the Greek philosophers generally were not accustomed to put their highly speculative theories to the test of actual experiment, however easy and obvious such experiment might be. They contented themselves with discussions as to what ought to happen according to their preconceived notions of physical laws, rarely attempting to see what does actually happen. Galileo's mind worked in a very different way, and refused to bind or blind itself in such a manner, so he promptly questioned what appeared to be doubtful statements and did not hesitate to contradict if he felt he had a clear case against them. He soon gained such notoriety in this way that he was nicknamed the Wrangler by his fellow-students, and heartily disliked by the professors, who were not only sticklers for tradition, but probably found it less troublesome to rely on memory than on intelligence.

In what we should call his Freshman's term Galileo made his first notable discovery. In the Cathedral of Pisa he noticed a lamp swinging suspended from the roof, and remarked that as the swings died away they did not seem to get slower or quicker. He tested this by counting his pulse-beats, having no other means at hand for measuring time, and found the time of swing to be practically constant. He at once saw that the rule would work both ways, and that a swinging weight would provide a check on the regularity of the pulse, a matter of

some importance to the medical profession. Instruments of various patterns which he constructed for this purpose were welcomed with delight by leading doctors, and used under the name of Pulsilogia. All the patterns were founded on the original idea of a pendulum bob, swinging, as is now well known, more quickly as the supporting string was shortened, by drawing it through a hole or winding it round a wheel; so that the length of the string gave a measure of the rapidity of the pulse-beats when the swings were made to coincide with one or more beats. The use of the pendulum for regulating clocks was still in the far future, and it is doubtful whether Galileo ever really made this application, though before his death he seems to have had it in mind.

He was now nearly nineteen, and had still been kept away from mathematics. Some months before his entry into the University his family had returned from Pisa to Florence, and among their friends in that city was a capable mathematician named Ricci, attached to the Tuscan Court as tutor to the grand ducal pages. During Galileo's second year at the University the Court was in residence at Pisa, and Galileo naturally renewed his acquaintance with Ricci. Going to call on him one day he happened to find him lecturing on Euclid to his pupils, and stayed outside an open door to listen without announcing his presence. He was so fascinated by the new ideas, for which his brain must have been pining unawares, that he began to make a practice of secretly listening to Ricci until he plucked up courage to speak to him openly on the subject. After this it was plain enough sailing for a time, for Ricci gladly afforded all assistance in his power. But the inevitable neglect of medical studies, as well as the failure of every application for a free scholarship, convinced Galileo's father that he was not likely to get an adequate return for the crippling

expense of his son's university career, which he decided to curtail; so that Galileo gave up any idea of the medical profession and left Pisa without completing his full course.

We thus find Galileo back in Florence at the age of twenty-one, determined to devote himself entirely to mathematics and physics, with the aid of Ricci whenever the Court was in residence at Florence. Meeting with the works of Archimedes he conceived a profound admiration for that philosopher, and was dissatisfied with the vague accounts generally given of the solution of the celebrated problem always associated with the word "Eureka". This, it will be remembered, consisted in the detection of the presence of inferior metal in the Crown of Hiero, tyrant of Syracuse, without any injury to the crown, the weight of the crown being equal to that of the gold provided by Hiero. Archimedes found that the crown displaced more water than an equal weight of pure gold did, and calculated the extent of the goldsmith's fraud. Galileo set himself to consider how this calculation must have been performed, and constructed his Hydrostatic Balance for this purpose. This instrument, called "la Bilancetta," had some resemblance to a steelyard. Galileo also devoted himself to the determination of the centre of gravity in solids of different forms, and this work with the pulsilogia and bilancetta attracted the attention of the Marquis del Monte, who, being himself a competent mathematician, formed a just estimate of the young man's capabilities, and strongly recommended him to the Grand Duke of Tuscany, but without any immediate success.

The necessity of an income of some kind in default of medical fees, compelled Galileo to obtain pupils in mathematics and mechanics, and naturally he applied for every vacant mathematical professorship to be found.

After failing to secure such an appointment at Bologna (1587), Padua (1588), Pisa (1588), and Florence (1588) —though the Pisa appointment was in the gift of the Grand Duke—he was on the point of going to the East in 1589 to "seek his fortune" in the company of a friend, when the Pisa professorship again fell vacant, and he secured the post with a salary of about five shillings a week. We cannot wonder at Vincenzio's poor opinion of mathematics as a means of livelihood, especially as the professor of medicine received more than thirty times as much. The position, however, was worth much more than its meagre official salary, as it naturally brought Galileo more pupils and probably raised his fees.

CHAPTER II.—UNIVERSITY PROFESSORSHIPS.

GALILEO, having thus acquired some economic security, threw himself with increased ardour into the investigations that he loved, and set to work systematically to test by experiment everything in Aristotle's mechanics. The stirring in men's minds which produced the Reformation had already caused a few isolated attempts to replace dogma by proof, but no one previously had made such determined assaults on the "peripatetic" stronghold. No sooner did Galileo find any rebutting experiment than he promptly pilloried the discredited dogma, exposing it in his lectures. Once more, therefore, he drew upon himself the enmity of those professors who had objected to his sceptical attitude as a student. The best-known instance of the success of his campaign is that associated with the celebrated Leaning Tower of Pisa. According to Aristotle the velocity of falling bodies is proportional to their weight, so that a weight of a hundred pounds would fall a hundred times as fast as a weight of one pound. Galileo asserted that but for the resistance of the air, which varies with the size and shape of the body, both would fall at the same rate. The parapet of the Leaning Tower offered a very convenient opportunity of testing the point. The experiment was tried by Galileo, and in the event the heavy weight beat the light weight by about two inches. Curiously enough, many of his opponents claimed the victory for Aristotle, as the heavy weight fell more quickly than the light one, and Galileo caustically

pointed out that they were trying to make his two inches cover up Aristotle's ninety-nine yards, the amount by which the heavy weight should have won the race to the ground on Aristotle's hypothesis.

It was at this period that Galileo produced one of his literary efforts in the form of a burlesque, "In Abuse of Gowns," ridiculing the University ordinance which compelled professors to wear their gowns on all outdoor occasions as well as when lecturing. Various sonnets and other effusions would also appear to have been written during his first professorship.

A combination of circumstances arose to cut short even the three years for which Galileo had received his appointment. The feeling of nearly all his colleagues was against him ; he was mulcted of part of his miserable stipend for any accidental failure to lecture ; moreover, he had undertaken to help in the support of his brother and sisters, the eldest of whom, Virginia, was married in 1591, Galileo pledging himself to provide her dowry. Perhaps most important of all was the animosity of Giovanni dei Medici, the Grand Duke's natural son, an engineer and architect who designed a big dredging machine to clear Leghorn harbour. Galileo reported to the Grand Duke, after examining the model at his request, that it was useless, as indeed proved to be the case. These causes combined proved sufficient to induce Galileo to resign his post and return to Florence, where he found himself, his father having died soon after Virginia's marriage, almost entirely responsible for the daily wants of his mother and the two younger sisters ; his brother Michelangelo had been trained as a musician but did not yet contribute anything to the family exchequer. A more lucrative post was imperatively required, and the Padua professorship being still vacant, as it had been when Galileo applied for it in 1588, four years before, he

obtained the support of his friend the Marquis del Monte, and through his aid and that of his friends succeeded in securing the post against the rivalry of the man who had defeated him for the Bologna professorship. He was appointed for four years certain at a salary three times as great as he had received at Pisa, roughly £40 a year. Besides this increase, the greater number of students at Padua meant a much larger income from pupils. For their benefit he wrote a great number of treatises (some of which have been lost, as they were for a long time only in manuscript), treating of such diverse subjects as fortifications, the geometry of the sphere, and mechanics, that is to say, the lever, the pulley, and the screw, including that of Archimedes for raising water. In this was the first development of the principle that what is gained in power is lost in speed, the foundation of equilibrium conditions. In his first summer at Padua Galileo and two friends went to sleep in a cool or perhaps poisonous draught from a cavern, with fatal effects soon afterwards, except in Galileo's case, though his previously strong constitution did not save him from acute chronic disorder.

Some three years later he invented the geometrical and military compass, known to us as the sector, for mechanically solving a great many problems, and this with other similar inventions met with such practical success that he started a workshop in his house and employed a staff of mechanics to make them under his personal supervision. Some of the ideas were plagiarised by Simon Mayer (or Marius) under cover of another man's name, but Galileo had no difficulty in proving priority.

The four years of the appointment had stretched to six years, as was contemplated by the conditions, and Galileo carried on for a seventh year without raising any

question. His friends then pestered the Doge on his behalf for an increase of salary, pointing out that his Bologna rival was now receiving more than Galileo, and succeeded in having the appointment secured for a second six year period with a salary of £70, approximately. He now had a wide European reputation as a teacher, and among those who came to Padua for his lectures were the Archduke Ferdinand, afterwards Emperor of Germany, and several other princes. Harvey, the discoverer of the circulation of the blood, probably attended a course of Galileo's lectures. The next step was a move into a large house for the accommodation of resident pupils. Galileo looked after the catering himself and made practically no profit on the housekeeping. There was a large garden to which he added extra ground with vines, and in the cultivation of which he took a considerable share.

Apparently Galileo marked the occasion of his increase of salary by setting up an establishment for a Venetian lady by whom he had three children within the next few years, but at the same time he had to bear the increasing burden of the maintenance of the other members of his family, of which he had now for some years been the head. His brother was continually sponging on him, and even when Galileo succeeded in getting him established in good positions as Court Musician, first in Poland and afterwards in Bavaria, it was Galileo who had to advance the money for an expensive outfit, hardly any of which did Michelangelo ever repay. Virginia's husband caused fresh trouble by threatening to bring an action against Galileo for the unpaid balance of his wife's dowry, and another sister Livia was married in 1601, her brothers guaranteeing her dowry, which meant that the whole responsibility for this also fell upon Galileo. It may be urged in palliation of the irregular nature of Galileo's private household that no wife would have

allowed so much to be spent in such ways, but that he felt bound to take his father's place, whatever the cost. It was in 1601 that he began to earn additional fees by undertaking the tuition during the holidays, which he usually spent at Florence, of the Grand Duke's son, Cosmo, both of whose parents held Galileo in high esteem, the Grand Duke regarding him as the greatest mathematician in Christendom, while the Grand Duchess Cristina believed him the greatest of astrologers. In spite of the vogue of this pseudo-science, it is difficult to suppose that Galileo had any real faith in astrology, though he did not refuse to cast horoscopes, just as he lectured on Ptolemy's system after he became a convinced Copernican.

In 1602 Galileo invented his air-thermometer which was not perfected until some years after his death. Two years later the sudden appearance of a bright new star in Ophiuchus provided him with a new interest, and he lectured on it in the great hall of the University. The ordinary lecture rooms were frequently unable to hold the large numbers of students who flocked to hear the new ideas propounded by Galileo, and it is said that sometimes even the great hall was insufficient, so that he had to lecture in the open air. Galileo's conclusions about the new star, though not now acceptable, included at any rate the fact that it was as distant as other stars and not an atmospheric phenomenon. The suggestion that it belonged to the region regarded by the Aristotelians as perfect and unchangeable led to direct conflict, and Galileo openly argued in favour of the theory of Copernicus against that of Ptolemy, who had followed Aristotle. His third term of six years began in 1604, but there was as before delay on the part of the Venetian Council. Once more, in spite of the objections urged by some, among which his irregular household was not forgotten,

a fresh increase of salary was voted, partly on the very ground of his increasing family. On the whole he was very well treated by the republic, his salary, which now amounted to about £115, being higher than that of any previous mathematical professor, and his new doctrines being permitted without any protest from the Council.

The next new subject attacked was magnetism. Galileo admired the work of Gilbert of Colchester, the famous author of "De Magnete," whose habit of mind was very similar to that of Galileo in its reliance upon experiment and its bold speculations. Galileo invented an armature for increasing the lifting power of a "load-stone," finding that small magnets were more efficient than large ones, and that when shaped specially they could be made to support a mass of iron weighing some forty times their own weight.

CHAPTER III.—GALILEO'S TELESCOPE.

WE now come to the most important epoch in Galileo's career. In 1609, being at Venice, he heard for the first time of the invention of a telescope the previous year in Flanders, and at once determined to think the matter out to see whether he could find the principle of construction. He soon succeeded in fitting two lenses in a tube, so that objects viewed through it were magnified, and his second attempt was still more satisfactory. His success was speedily reported to the Venetian Council, who summoned him to exhibit his spy-glass, which was already much more efficient than the Flanders one, besides which it showed objects upright whereas the first telescopes inverted them. The Doge wished to possess one, and Galileo promptly offered to present the one with which the Council had been so pleased, and when he had taken it to the palace he was complimented on the efficient manner in which he had served the State for seventeen years, and informed that instead of waiting until his third term of office had expired, the Council had determined to raise his salary at once to nearly double what it had been at the last augmentation, and to confirm the appointment for life at the new salary of 1000 florins, or about £220.

It is considered by some that Galileo's discovery is greatly discounted by the previous success in Holland, but as the latter was due to a pure accident, while Galileo's was by design, others will be inclined to give

him the greater credit, reserving an even higher meed of praise for one who deliberately invents a contrivance of great importance without any previous hint as to its possibility. The aperture of the Doge's telescope was about $1\frac{3}{4}$ inches. It was the second instrument of its kind, but has been lost. Its magnifying power was 3 diameters, and it showed objects 22 miles distant on the earth. On his return to Padua he made a third telescope with a power of 8 diameters, soon followed by a fourth with a power of 20 diameters. This instrument he turned towards the sky, observing the moon and Jupiter, and soon found opportunity on a visit to Florence to show it to his old pupil Cosmo, now Grand Duke, since the death of Ferdinand early in the year. It is interesting to note that three weeks before Ferdinand's death Galileo had cast his horoscope at the request of the Grand Duchess, and promised many more years of life.

Early in 1610 came the fifth telescope, magnifying more than 30 diameters. With this Galileo began his series of astronomical discoveries, except that of the appearance of the moon, begun with the fourth telescope, and shown by its means to the young Grand Duke the previous year. In his tract, the "Sidereus Nuncius" (or Sidereal Messenger), printed at Venice in the same year, he announced the first fruits of his search with the new instrument; first the diversified surface of the moon, with many markings not visible to the naked eye; mountains four or five miles high, and the "earthshine," which he attributed to its true cause; next, the great number of stars revealed by the telescope in clusters, including the true structure of the Milky Way. The planets, moreover, which in his fourth telescope were seen to differ from stars, in showing discs instead of points of light, yielded fresh surprises to the fifth telescope. It was on January 7, 1610, that with this instrument directed towards Jupiter

Galileo first saw three bright objects close to the planet. Repeated observation proved that these, with a fourth, which must have been on the first night hidden by the planet, were moons revolving round Jupiter. This conclusion was reached in a very few weeks, and Galileo gave the newly discovered bodies the name of "Medicean stars" in compliment to the Grand Duke and his three brothers.

Meanwhile Galileo had fitted up a workshop for the manufacture of telescopes, finding, however, that only about one in ten of his object glasses was good enough to show the "Medicean stars". The demand for the new instrument was great, as Galileo's telescopes were much more efficient than any to be procured elsewhere, so that his workmen, who made also hundreds of his other instruments, geometrical compasses, hydrostatic balances, air thermometers, magnets, and so on, were kept busy, though Galileo ground all his lenses himself until his sight failed. It was some time before the superiority of other forms of telescope for very high magnifying power was realised. Galileo's principle still survives in field glasses, where the power is not high and when the inverting effect of the astronomical telescope is inconvenient, especially as the erecting eyepiece involves loss of light. The Grand Duke Cosmo II. asked for the telescope with which these discoveries were made, but Galileo, though he at once consented, nevertheless kept it for his own use, ostensibly only on loan. Its focal length was $5\frac{1}{2}$ feet and aperture $2\frac{1}{4}$ inches.

During the earlier part of 1610 more than a hundred telescopes, accompanied by copies of the "Sidereus Nuncius," were sent to princes and learned men of Italy, France, Flanders, and Germany, and the French Court in particular, where Marie dei Medici was queen, desired to bespeak for the King, Henry of Bourbon, the privilege of

giving his name to the next striking discovery in the heavens. Many savants, however, refused to accept Galileo's discoveries, some even declining to look through a telescope, rather than risk seeing something in whose existence they would not believe. Galileo did not at this time state openly in the "Sidereus Nuncius" the conclusion to which his discoveries had driven him, namely, that the earth moves round the sun, and not the sun round the earth. He spoke of it and lectured about it, not realising how he would be affected by the furious outcry against it. Kepler, the greatest astronomer of the time, accepted everything in full confidence, though the mystic numbers in which he delighted were liable to be upset by such new discoveries. Simon Marius (Mayer) claimed priority in the discovery of Jupiter's moons, as he had previously claimed it in the case of the proportional compass, but there is no doubt that both claims were fraudulent. In the endeavour to increase his list of discoveries and comply with the earnest wish of the Italian Queen of France, Galileo next turned his attention to Saturn. He found no satellite, but under the imperfect definition of his telescope he noted that the planet appeared triple, the appearance being caused, as was discovered later, by the ring projecting on both sides of the ball. To avoid the chance of being again accused of adopting other people's discoveries, he published this one in the form of a jumble of letters, which when sorted out, would spell the words:—

"Altissimum Planetam Tergeminum Observavi,"

meaning, "I have found the furthermost planet (Saturn at that time, as Uranus and Neptune were not yet discovered) to be triple," the fact of the matter being that the imperfect definition of his telescope caused the ring of Saturn, which was then open as viewed from the earth, to resemble companion stars, one each side of the central

ball. These attendant objects gradually diminished in apparent size, and after two years disappeared altogether, the ring being then edgeways as seen from the earth. This occurs every fourteen years, though naturally the fact was quite unknown to Galileo, and he was very much taken aback at the vanishing of the new objects, which suggested to him a reference to the Greek myth of Saturn swallowing his children. He predicted their reappearance and observed them again as the ring widened out. Later he realised the dark space on each side of the ball between it and the ring, but, as he gave no indication of having grasped the significance of this appearance, it is probable that he did not really understand it. The true explanation was discovered some years after his death, by Huygens, with a telescope of magnifying power of 100 diameters. It is needless to emphasise the additional annoyance caused to the Aristotelians by this new evidence of change in the "immutable" heavens.

To Galileo himself the successive discoveries and the controversies they aroused brought a large increase of students and pupils from all directions, and his teaching work grew to such an extent that he could find very little time for original research. He felt that after twenty years he had had enough of this labour and was desirous of finding more leisure. He had gratefully accepted the life-appointment at Padua, but was only too ready to relinquish it when an opportunity of escape was offered. His great European reputation made it seem desirable to the Tuscan Court to attach him permanently to the Grand Ducal service, and negotiations were opened between Galileo and the Duke's Secretary of State. Galileo stated plainly how irksome he found the necessity of spending so much time on pupils on account of his family expenses, and even the amount of lecturing required,

though this was not very great. He also said how many inventions he had in mind, many of them only of use to princes making war; he enumerated books in contemplation, some of them already in hand, on the structure of the universe, on local motion, on mechanics, on sound and speech, on light and colours, on the tides and other subjects, besides works on military science, manœuvres, fortification, etc. In addition to these and other proposed reprints and publications, he pointed out how much time he wanted for observation of the Medicean stars in order to construct tables of their motion, and for other astronomical pursuits. The result of the negotiations was his nomination by Cosmo II. as First Mathematician of the University of Pisa, and also Philosopher and Mathematician to the Grand Duke, but with no obligation to lecture nor to live at Pisa.

CHAPTER IV.—DISCOVERY OF SUN-SPOTS.

IT now appeared that Galileo had everything in his favour, a good permanent salary and abundant leisure for his favourite pursuits, with the support of a powerful prince. But the event proved that this was a very bad exchange for the Padua post, and it was not very long before the philosopher must have begun to regret leaving the one government in Italy where he would have been perfectly safe. Before Galileo entered its service, the Venetian republic, finding that the Jesuits were scheming to obtain control of education, starting with a school of their own, had decreed that no Jesuit should be allowed to teach in its territory. On the intervention of the Pope, who supported the Jesuit cause by laying Venice under an interdict, the senate retorted by expelling the Jesuits altogether. In no other part of Italy was absolute freedom of thought possible.

At first, however, all was plain sailing; the very first month of Galileo's return to Florence was marked by another important discovery. Once more he hid it in an anagram while repeating his observations to ensure himself against mistakes:—

"Haec immatura a me iam frustra leguntur o.y."

The intention of this device, which was frequently employed, was to secure priority and prevent plagiarism. Many of Galileo's previous discoveries had been claimed by others. When he was quite sure he was right he sent the solution,

"Cynthiæ figuras aemulatur mater amorum,"
i.e. Venus imitates the phases of the moon. It had been regarded as an objection to the theory of Copernicus that Venus and Mercury ought to show phases but did not, and also that Venus ought to appear much larger when nearest the earth. Galileo's new discovery disposed of these objections, making it clear that Venus did show phases and that it did appear much larger when nearer the earth, but that as it was then nearly "new" most of its disc was not illuminated, so that it did not look so bright and consequently not so large to the naked eye.

Galileo found little trustworthy evidence of phases of Mars or Mercury, as the former does not reach crescent shape, and the latter is always close to the sun, but at any rate he found no reason to doubt that both these planets shared the motion of revolution round the sun. There seems to have been a suspicion in his mind that his credit might be assailed at Rome by the many enemies whom he had made, not only by his opposition to the Aristotelian tradition, but by his great skill in argument, his pungent satire, and his capacity for turning the opposition into ridicule after adducing ingenious points in its favour. It was not altogether unlike the case of Socrates, whose system of debate must have been excessively annoying to anyone who dared seriously to maintain any proposition against him. Be that as it may, Galileo now considered it expedient to go to Rome to make his discoveries known at first hand to the leaders of the Church and forestall any possible accusation. The Grand Duke not only granted him leave of absence but provided for his journey and arranged for him to lodge at the Tuscan Embassy in Rome. Under such auspices and armed with many letters of introduction, including one to Cardinal Barberini (afterwards Pope Urban VIII.), he had no difficulty in obtaining a hearing

and opportunity of demonstrating his discoveries, or "celestial novelties". Cardinal Bellarmine arranged for the appointment of four commissioners to examine and report. The commissioners, chosen for their scientific attainments from among the members of the Roman College, although previously prejudiced against the new discoveries, were constrained to admit the reality of the observations, and to this extent the Church's sanction was secured. The Pope, Paul V., received Galileo favourably and other high dignitaries followed his example, while the Academy "dei Lincei" (of the lynx-eyed ones), precursor of the present Italian scientific society of the same name, elected him a member. His friends were well satisfied with the result of his visit to Rome.

It was during this visit that Galileo announced another new discovery, which entailed to all appearances more important consequences than any that had gone before. In April, 1611, he declared the existence of spots on the sun, and showed them to several leading people. At first inclined to regard them as small planets revolving round the sun, he soon found that this would not explain the appearance, and in the following year he announced positively that they were actually on the sun's surface, and rotated with the sun in rather less than a lunar month, their shape being irregular and occasionally variable. Possibly a delay of a year in the making of this discovery might have changed the course of his subsequent career, for it so happened that during 1611 a Jesuit father, Christopher Scheiner, Professsor of Mathematics at Ingolstadt, also discovered sun-spots, or claimed to have done so. The weight of evidence is unmistakably in favour of Galileo, but the question of priority is really of very small consequence if different people make absolutely independent discoveries. It is surprising at the present time to note the careful computation of differ-

ence of longitude to settle rival claims to the discovery of a new comet which has been picked up on the same night by different comet seekers. The discovery of Neptune more than seventy years ago is a classical instance of the amount of attention this priority question continues to excite. We need not, therefore, wonder that three centuries ago this discovery of sun-spots caused acute controversy, especially as Scheiner's explanation of the phenomenon was that already discarded by Galileo, namely, that the spots were really small planets revolving close to the sun. Other observers about the same time made the same discovery, and one of them, Fabricius, is generally accepted as the first to publish his observations, so that in modern times he is usually credited with priority. The idea of change or imperfection in the sun was exceedingly repugnant to accepted tradition. Scheiner was only permitted to publish his discovery anonymously, but nevertheless he was supported against Galileo by the Jesuits as a body, and we may regard this as the actual beginning of Galileo's serious troubles.

About the same time Galileo had been drawing his own conclusions from observations of the moon. Having determined that the moon always turned the same face towards the earth, as easily proved by the configuration of its surface, he saw at once that the lunar day must be of the same length as the lunar month, and became convinced that no plants or animals could exist under such conditions.

A controversy on a totally different subject was the cause of the publication of Galileo's discourse on Floating Bodies in 1612. Aristotle had stated that the chief cause of a body floating was its shape, so that ice floated not because it was lighter than water, but because it was flat. Presumably neither Aristotle nor any of his followers had ever tried whether a ball of ice would sink. The

subject came up for discussion at one of the Grand Duke's scientific parties, and Galileo took up the cudgels against the opinion of Aristotle. The company was divided, and among those who supported Galileo's side was Cardinal Barberini, who afterwards became Pope Urban VIII. The chief point alleged by the Aristotelian side was that a thin slab of ebony will float while a ball of ebony sinks at once. Galileo pointed out that the thin slab would also sink if it was wetted all over, and that similarly a flat piece of lighter wood would not remain at the bottom but would rise in spite of its shape. He performed many ingenious experiments with bodies compounded of wax and lead so as to be nearly of the same specific gravity as water, but apparently failed to point out that the floating of heavy bodies involves not only the hydrostatic pressure but also capillary action which is a distinct phenomenon. His treatise contained many experiments and clever arguments but met with violent opposition. Galileo himself always seems to have arrived very quickly at his conclusions, but the great difficulty of convincing others led him to multiply his experiments far beyond what he considered necessary in his own case; and this naturally strengthened his convictions. In this way he justified the aphorism that Ignorance had been his best teacher.

Many attacks on his principles of hydrostatics as set forth in the "Discourse on Floating Bodies" were published, and produced scathing replies either from Galileo himself or from his loyal pupil Castelli. The most elaborate attacks, by Colombe and Grazia, called forth the most detailed refutation, an essay printed at Florence in 1615, ostensibly by Castelli but really written by Galileo himself. It is not to his credit that in this essay, after completely crushing the arguments of Colombe and Grazia, he suggests that as he is only the pupil, they would

have been much more severely pulverised if Galileo had thought it worth while to tackle them himself. It is fairly certain that this rather cheap sneer would have been seized upon by his enemies as a special grievance if the true authorship had been discovered before his death. At the same time the plan of complete or partial anonymity has frequently found favour, especially in controversial questions.

CHAPTER V.—GROWTH OF OPPOSITION.

GALILEO had now an influential following, many of his pupils being themselves professors by this time and aiding in the spread of his ideas. But on the other side were very many more enemies, not only the professors who pinned their faith to Aristotle, but also the Jesuits who had supported Scheiner's claims, certain Churchmen who feared the progress of free thought, and many other people who objected to anything of the nature of an innovation. These now about the year 1612 seem to have decided to join forces and choose a new line of attack, being unable to disprove Galileo's facts and arguments by meeting him on his own ground. They raised the popular cry that the Church was in danger, and that Galileo's astronomical views were contrary to Scripture. The leading authorities at Rome did not initiate this. Several of them in fact, including the before-mentioned Cardinal Barberini, openly expressed their admiration of Galileo's work. But an Aristotelian professor suggested to the Grand Duke's mother, on a certain occasion when Galileo's pupil Castelli had been extolling his master's astronomical discoveries, that these discoveries were doubtless genuine, but that Galileo's inference that the earth rotated on its axis and revolved about the sun could not be true, as it was contrary to Scripture, which plainly states that God "made the round world so fast that it cannot be moved". Castelli objected to bringing the Bible into the question, but being challenged, he took up

the position that the new views were not contrary to Scripture, winning over some of those present to his side, though the Dowager Duchess Cristina appeared unconvinced. It was in consequence of this that Galileo wrote his famous letter to Castelli, taking the stand that the language of the Scriptures is such as is suited to the intelligence of those for whom they were written, and that the interpretation must necessarily be revised in the light of new facts. He also maintained that the Copernican system raised no more difficulty than the Ptolemaic, when it was pinned down to verbal explanation of literal statements in the Bible. In short his view was that the Bible was intended to teach men morals, and not science, and that it could not be regarded as a court of appeal in scientific matters, many of its expressions being vague, and others misunderstood by commentators. He concluded with a discussion of Joshua's miracle, laying stress upon the fact that the important point was the prolongation of the hours of daylight, and that literal acceptance of the account in the Bible in its primitive language would involve absurdities in relation to the "primum mobile," which, according to the Aristotelian philosophers, carried the sun with it.

Castelli was delighted with the argument in the letter and circulated copies of it. But it provided just the handle that Galileo's enemies were seeking, in order to embroil him with the ecclesiastical authorities. Sermons were preached on both sides, the Copernican view being supported publicly by a Jesuit preacher in the Cathedral, for it must be understood that by no means all of the Jesuits were united against Galileo. A copy of the letter to Castelli was sent to the Inquisition with an unsigned denunciation of those who held the doctrine that the earth moves and not the heavens. This was of course aimed at Galileo though it did not mention his name,

presumably because he was known to have influential friends at the Vatican. The Inquisition tried to obtain the original letter but failed to do so, and the copy was submitted to expert opinion, which pronounced that on the whole the document could not be said to belie Catholic doctrine. Accordingly fresh evidence against Galileo was sought, and it was alleged that his religious opinions were suspect, because he was in correspondence with Germans and others, possibly heretics, and was a member of the Academy "dei Lincei". Galileo heard that his letter to Castelli was being used to secure a condemnation of the Copernican doctrine, so he sent a copy to Rome to be submitted to Cardinal Bellarmine and other prominent men, promising to follow it with a fuller treatise, since the first letter was only written on the spur of the moment. His friends, including Prince Cesi, founder of the Academy "dei Lincei," recommended him to avoid theology altogether in his argument about mathematical and physical matters, but the advice was already too late. The promised fuller treatise, the letter to the Grand Duchess Cristina, would not affect the position, as the Inquisition was already preparing its attack in secret, based on the evidence already received. Galileo, not knowing how far things had gone, thought his best plan would be a personal visit to Rome, remembering how well he had been received on his first journey thither. He went accordingly in December, 1615, but, though cordially received to all appearance, he soon found the task of defence a bigger one than he had expected, as he himself as well as the doctrines was being attacked. It might have been well for him to confine himself to the personal attacks as he might have succeeded in disposing of them. But he felt bound to persevere with his efforts on behalf of the Copernican theory, after obtaining apparently satisfactory assurance

in regard to his own orthodoxy. His feeling of security did not last long, for in February, 1616, the Qualifiers of the Holy Office reported on two statements from Galileo's work on sun-spots. These embodied the Copernican doctrine that the sun is the fixed centre of the world; which they declared to be false and absurd philosophically, and formally heretical, the companion doctrine that the earth rotates and also revolves round the sun meeting with practically the same condemnation. Cardinal Bellarmine sent for Galileo in accordance with these findings and warned him of the error of these opinions. Galileo probably regarded the whole matter as a mere formality as far as he was concerned. At the same time the book of Copernicus himself and another setting forth the same theory were suspended "until correction," while a third work in which a Carmelite, Foscarini, argued that these doctrines were not contrary to the Bible, was prohibited altogether. It appears clear that Galileo was not asked to recant his opinions, and he actually obtained a certificate from Cardinal Bellarmine to this effect three months later, but something which happened at the citation in February had very far-reaching results. The plausible explanation is that the admonition of the Cardinal was noted in writing by a secretary, but that the Commissary of the Inquisition, who was present in virtue of his office, took upon himself to "dot the i's and cross the t's" by amplifying the Cardinal's admonition, and telling Galileo that he must not hold, teach, or defend the opinions in question; this officious comment was also entered in the minute, though Galileo, who was only concerned with the Cardinal's pronouncement, took no notice of it, and perhaps did not even hear it. His bow of acknowledgment to the Cardinal's statement seems to have been interpreted by the secretary as indicating acquiescence in the other

matter also, Galileo's consent being noted accordingly in the minute. The probability of this view, which is practically that of Professor Favaro, the most diligent student of Galileo at the present day, is much increased by the fact that the minute was not signed. In the event, as we shall see, this weakness of evidence was ignored.

Galileo was assured by the Pope himself that his fears of continual persecution were groundless, but the Tuscan ambassador felt that Galileo was doing himself no good by staying on at Rome and arguing with people, so he gave a hint to his master, and Cosmo recalled Galileo to Florence.

While at Rome Galileo had found time to write to Cardinal Orsini a treatise on the tides, afterwards amplified in his great work on the two systems of the world, to which we shall refer later. He also made definite proposals to the Court of Spain upon a new method of determining longitude, which would be of great importance to a seafaring nation. Ever since his discovery of Jupiter's moons, with their frequent eclipses, he had kept in view the possibility of accurately predicting these phenomena, and had observed for six years with a view to perfecting his tables of their movements. His idea was that local time being determined by observing the sun at noon, the further observation of the time of one of these eclipses in Jupiter's system, compared with that given in the tables, would give the difference of longitude between the observer and the place for which the tables were computed. The negotiations with the Spanish Court led to nothing, owing partly to the difficulty of obtaining the observations on a moving ship, and to the absence of reliable chronometers to carry on the local time from noon till dark. The Grand Duke tried the method in the Tuscan Navy, but it was practically a failure.

CHAPTER VI.—CAUSES OF THE OPPOSITION.

IT will be well to pause for a while to consider why the system of Copernicus should now have met with such an increase of opposition, after having been more or less tolerated or ignored for nearly eighty years, during which its most bitter opponents had been not the Roman Church nor the Jesuits, but Luther and other Reformers. It was Luther in particular who insisted on the most literal interpretation of Scripture, and he had certainly not received a liberal education, so that his attitude is quite intelligible, Copernicus being, moreover, a dignitary of the Church to which Luther was opposed.

The tendency of the Reformation, however, was to encourage men to think for themselves, and not to accept blindly the guidance of priests, even in theological matters, and this tendency was bound sooner or later to produce a reaction. It may be that Galileo's ideas, had he lived fifty years earlier, might have received general acceptance before the uneasiness due to the Reformation had created an atmosphere favourable to official Church interference. It is also quite likely that had Galileo been content to adopt Tycho Brahé's system as a working hypothesis, he might have avoided the main difficulty, since the only difference was that involving the earth's revolution round the sun, instead of the sun's round the earth. As a working formula Tycho's system is practically in use now, except that the circular motion, to which Galileo still clung even after Kepler had discovered that the

orbits are all elliptical, has been discarded. Copernicus had required a great deal of faith to support his system in the face of enormous practical difficulties. Galileo's telescope had disposed of some of these difficulties, by showing that the stars are much farther off than the planets and the sun, and that certainly some of the planets do revolve about the sun; Jupiter's moons also showed the possibility that the earth might not be the centre of the system, although it clearly has a moon revolving round it.

But what was really required was a proof rather than a plausible hypothesis, and this Galileo considered that he had found in his tidal theory. He had an incomplete grasp of the idea of relative motion, and he thought that as the earth is rotating and revolving round the sun the actual velocity of a point on the surface would be greater when it was turned away from the sun and less when turned towards the sun. Then assuming that the oceans behaved like water carried in a vessel, he said the water will pile up in the direction of rotation on the earth's surface, where it is moving more slowly, and will also pile up in the opposite direction, where it is moving more quickly, so that there will be high water twice a day, as is actually the case. Many other learned men, with much greater knowledge than was possible in Galileo's day, have completely failed to solve the problem of the tides, so that Galileo's want of success is quite easy to understand. It is not so clear that his opponents understood where his failure lay, but the failure is undeniable, and it seems perfectly clear that if he had produced a real proof of the earth's rotation, the "official" opposition would have been withdrawn. Even Cardinal Bellarmine himself plainly stated that if such proof were forthcoming, it would be necessary to revise the interpretation of some parts of Scripture. Clearly, then, it

would have been politic of Galileo to have waited for more convincing proofs before allowing any question of "theology" to be raised. It is easy to say that he did not raise these questions himself, and only responded to challenges, but if his temperament had been less argumentative he could have avoided the plain issue. He considered himself a faithful son of the Church, which required unquestioning obedience; and yet, when his position was pronounced untenable on theological grounds, he was not sufficiently humble to retire gracefully, but maintained his argument and endeavoured to prove that it was not irreconcilable with Scripture. Such an attitude in a layman was bound to raise fierce opposition, apart from the prejudice of certain of the Jesuits. The net result was that the doctrines themselves suffered for the time from his enthusiastic advocacy, and, as we have seen, some works, which might otherwise have been ignored, were placed under the ban of the Inquisition. He himself retired to Florence with an uneasy feeling that he must be more circumspect in dealing with the Copernican system, but hardly aware that anything definitely forbidding it had been said to him.

CHAPTER VII.—PUBLICATION OF "IL SAGGIATORE".

GALILEO'S health was bad for some time after his return to Florence, and though he wrote and circulated long private letters he was unable to do much in the way of observation even of the bright comet of 1618. He must have made some observations, however, for he came to the conclusion that comets were atmospheric phenomena, but his views, published ostensibly by one of his pupils, gave offence to the Jesuit College at Rome, and called forth from Father Grassi, whose opinions were attacked in the pamphlet, a violent reply full of abuse of Galileo. He was urged to take up the cudgels himself, but waited for three years partly on account of ill-health, and partly from caution. The Papal *Imprimatur* was granted in 1623 after various impolitic passages had been altered by members of the Academy, to whom it was first submitted, and the essay published under the title of "Il Saggiatore" (Assayer). Pope Paul V. had died shortly before this, and his successor Gregory XV. died while the work was being printed, so that a new Pope was at the Vatican when the book appeared, and this new Pope, Urban VIII., was none other than Cardinal M. Barberini, who had frequently shown sympathy with Galileo. To him the "Saggiatore" was consequently dedicated, and Galileo must have hoped confidently to meet with less opposition in the future. The success of the book was immediate and well justified the delay in publication, but it gave great offence to the Jesuits, whose champion found his arguments turned into ridicule with great dialectic skill

and in the choicest Italian. The Pope was much pleased and had the book read aloud at table, while the general of the Jesuits forbade its mere mention among members of the order.

We may note that Cardinal Bellarmine, who had taken a prominent part in the opposition to Copernican views, had died about the same time as Pope Paul V., so that for this reason also Galileo thought that another visit to Rome would now be expedient. Ill-health and other matters, however, delayed the project, about which Galileo's elder daughter was most enthusiastic. Both daughters were by this time nuns, having taken the veil under the names of Maria Celeste and Arcangela. Galileo had broken up his establishments on leaving Padua, and brought the girls to Florence, the boy Vincenzio, then only four years old, remaining for two years longer with his mother, who, soon after he was removed from her care, married in her own station of life, with Galileo's approval and financial assistance. The convent appeared to be the only resource for the daughters, as their father's means were not enough to make them independent, and the stigma of their birth was a bar to them in other directions, besides furnishing a frequent cause of complaint to Galileo's mother. In course of time Vincenzio was legitimised by the Grand Duke, but it was Maria Celeste who proved of the greatest comfort to her father, Vincenzio being idle, selfish, and extravagant, not unlike his uncle Michelangelo, while Arcangela was frequently ailing and discontented. Many of Maria Celeste's letters are extant and show her constant solicitude for her father, and her anxiety to help him in every possible way, writing out letters for him, mending or laundering his linen, making little delicacies to tempt his appetite, and so on, as she found occasion.

In 1624 Galileo went to Rome once more and had several audiences with the new Pope, who received him in a most friendly manner, but absolutely refused to remove the embargo from Copernican doctrines. We may conclude from the evidence of the sympathy he displayed that this was a matter more of policy than conviction. Ecclesiastical authority was being assailed in many directions, and it was felt that its strongest bulwark must be the Bible. To admit the possibility of error in the Bible itself was unthinkable, and as to the translation and interpretation of it, any suggestion of even uncertainty would appear to weaken the authority of the Church dignitaries who took the responsibility for the accepted language and interpretation. The Pope's argument, as given to Galileo, was that if anything stated in Scripture appeared to present insuperable difficulty, it must not be called impossible, or else there would be an implicit limitation of Omnipotence. The acceptance of this argument would at once demolish all Galileo's plausible hypotheses, and he returned to Florence disappointed of his main object, though bearing many evidences of the Pope's personal favour, in the form of valuable gifts, and the promise of a pension for his son. This pension was subsequently transferred to Galileo himself, as Vincenzio refused to undertake the religious exercises which were a condition of acceptance. Moreover, Galileo's friend and patron Cosmo dei Medici having died in 1624, the Pope warmly commended Galileo to the new Grand Duke Ferdinand, now a boy of thirteen, eulogising not only the philosopher's services to science but also his religious sentiments.

It was during this visit to Rome that Galileo was shown a microscope. He speedily grasped the principle and proceeded to make better ones, with image not inverted, just as he had in the case of the telescope without

seeing the early inverting pattern. His microscopes were soon as much in demand as his telescopes, as they were much more powerful and gave better definition than those previously made.

There is no doubt that he was all the time pining for a favourable opportunity of openly defending the Copernican system. An attack made on it by Ingoli in 1616, addressed to Galileo, had remained unanswered at the time, owing to the hostile attitude of the Inquisition. Kepler answered it in 1618 in his "Epitome of the Copernican Astronomy," but Galileo felt that he might now venture to reply more fully, taking special precautions to emphasise the point that he was merely treating the system as a working hypothesis. He professed to have two objects in view, one personal, to clear himself from the suspicion of having propounded an absurd and irreligious theory, by showing that he had supported it before it was under theological ban, and that from every other point of view it was quite reasonable and probable; the other, from a sense of loyalty to Church and country, to give the Protestant Copernicans of Germany the true explanation of the apparent rejection of their system in Italy. On the advice of friends he only circulated his reply in manuscript, and was told that the Pope approved of it after hearing passages read, saying that the Church had not condemned the Copernican doctrine as heretical, but as rash.

It is not at all surprising that this and other similar encouraging reports should have convinced Galileo that the time was getting ripe for the complete victory of the new system, provided that it advanced cautiously at first. So for the next four years, 1626 to 1629, he did little else, in the intervals between frequent attacks of illness and domestic troubles, but concentrate his energies on the production of his most imposing astronomical work,

the "Dialogues on the Two Principal Systems of the World". The domestic troubles included not only illness of his daughters and annoyance at unsatisfactory reports of his son, but also difficulties in connection with his selfish brother, who, having now a family of seven, came to the conclusion that it would be an excellent thing for him to send them to Florence to live on Galileo. The latter, on the question being raised, offered temporary quarters until his brother should obtain work in Florence. The whole family except the eldest daughter took advantage of the offer. Galileo sent the eldest boy Vincenzio to Rome to study music in charge of his friend Castelli, and there, but for his bad conduct, he would have had the pension refused by his cousin, which in consequence, as we have seen, was transferred to Galileo. The nephew soon had to leave Rome, and before the end of the year (1628) Michelangelo had them all back again at Munich, though Galileo was willing to keep them. During the same year the other Vincenzio, Galileo's son, completed his Law course at the University of Pisa and took his Doctor's degree. He was nevertheless disinclined to seek a post in the Civil Service, for which he was now qualified, but preferred to idle away his time at home.

About this time an unsuccessful attempt was made to deprive Galileo of his practical sinecure at Pisa, some of his enemies questioning the power of the Grand Duke to assign a university salary to a man who neither lectured nor lived at Pisa; but it was decided that Ferdinand had power to do this, and to avoid the possibility of the question being raised again, the young Grand Duke appointed Galileo to a permanent post of equal value in the magistracy of the University, so that his income and leisure were if possible more secure than before.

CHAPTER VIII.—THE "DIALOGUES ON THE TWO SYSTEMS OF THE WORLD".

AT the end of the four years, the dialogues being now completed except for introduction and index and a final revision, Galileo determined to go once more to Rome to arrange for the printing. Castelli, now the Pope's mathematician, highly approved this decision, as also did Riccardi, the chief censor, and others, who retailed remarks made by the Pope, disclaiming any responsibility for the action taken in 1616 against the Copernican doctrines. But when it came to the point the Pope insisted that the title originally chosen, "Dialogues on the Flux and Reflux of the Tides," did not indicate the real purpose of the work, which was a discussion of the relative merits of the systems of Copernicus and Ptolemy. Besides requiring that this be made more clear, and that the subject be treated as merely a hypothesis, Urban laid it down that his own favourite argument, which has already been mentioned, must be inserted at the end. Galileo accepted the conditions, and the manuscript was passed by Riccardi as censor after a few alterations had been made by his assistant.

Thus in the summer of 1630 we find Galileo back in Florence with the coveted *Imprimatur* granted on the understanding that a preface and conclusion as demanded by the Pope should be added. The plague was then raging in Florence, and it spread to the suburb of Bellosguardo where Galileo lived. One of his employees, a glass-blower, was attacked by it and died, and Vincenzio

fled with his wife, a sister of one of Maria Celeste's intimates at the convent, leaving his infant baby out at nurse and his invalid father almost alone. Vincenzio, however, was too idle to stay away long from his father's house when the panic was over, and the next year we find him back again helping to choose a villa nearer the convent. Such a one was found at Arcetri, and is still known as Villa Galileo, and contains a room arranged as a Galileo museum.

The plague was not the only cause of delay. Prince Cesi, of the Academy, to whom Galileo intended entrusting the work for superintendence during the printing, died a few weeks after Galileo's return from Rome, and Galileo, being unable on account of the plague to send the MS. away, determined to have it printed at Florence instead of Rome. On hearing this the censor Riccardi desired to look at the book again, but it seemed risky to send the whole work while communications were still interrupted on account of the plague, and Galileo therefore suggested a compromise, under which he was to send to Rome only the additions, the preface and conclusion, not before seen at Rome, while the body of the work should be submitted to a deputy censor at Florence appointed for the purpose. The one chosen, Stefani, Counsellor of the Inquisition in Florence, was so pleased with the work and the tone of humility in which it was written that he not only made none but the slightest verbal alterations, but declared that so far from putting obstacles in the way they ought to have urged Galileo to publish it. But it was otherwise in regard to the preface, which was kept at Rome an unconscionable time and only returned in July, 1631, after the Tuscan Ambassador Niccolini had made formal protest. Stefani was ordered to revise the whole work once more, and then the licence was at length granted for printing the book in Florence.

The plan of the work, as indicated by the word dialogue, is that of an argument between supporters of the two systems. There are, however, three interlocutors instead of two, as it seemed expedient to provide a third party to weigh the merits of the controversy provided by the two champions, and to represent what is now commonly called "The man in the street". Galileo gave the name of Simplicio, a noted commentator on Aristotle, to the personage who has to produce all the arguments against the new system, however foolish they may be. To the other characters he gave the names of two former friends of his own, Salviati of Florence, who speaks really for Galileo himself, and Sagredo of Venice, who is responsible for common-sense objections, and for the introduction of a lighter vein from time to time, but who, as is only natural, is very ready to be convinced by Salviati's arguments. The exigencies of the censorship prevented any of the most powerful arguments being pushed right home, as it was necessary at every critical point to emphasise the formality that the Copernican system was not to be regarded as true but only as a not impossible hypothesis. Some such display might be made by a skilled fencer against a hopelessly inferior opponent, who wears, however, a coat of adamant guaranteed to shatter the blade that touches it, so that no victory is to be allowed, every stroke being obliged to recoil.

Of the four days over which the dialogue is spread, the first combats the Aristotelian doctrine of perfect and unchangeable heavens by means of the evidence of new stars and sun-spots, and emphasises the similarity between the earth, moon, and planets, pointing to Jupiter with his attendant moons as a model of the solar system with its attendant planets. The chief point on the second day is the principle of the difference between common and relative motion. The objection to the earth's rotation,

that if true a stone dropped from a tower would not fall at its foot, is met by the fact that in a moving vessel a stone dropped from the top of a mast does fall at its foot, although the Aristotelians, not having tried the experiment, maintained that it would fall towards the stern. On the score of simplicity, therefore, a daily rotation of the earth, once admitted as possible, is obviously far more probable than a daily rotation of the whole universe about the earth. The precession of the equinoxes is brought in finally to show how much more complicated and improbable are the motions necessary to reconcile the facts with the Ptolemaic theory. On the third day the revolution of the earth about the sun is considered, of course as a mere hypothesis. The great difficulty contemplated by Copernicus was that, if the earth really went round the sun, in an orbit nearly two hundred million miles in diameter, the stars ought to show a displacement corresponding to the great change in view-point through the year. The modern reply is that they do, but this could not be proved until nearly two centuries later, though Galileo, speaking as Salviati, grasped the position very clearly. He pointed out that on the one hand the stars must be so far off that the relative displacement of nearer ones is too small to be detected by his instruments, while on the other hand their apparent size, which would on the hypothesis of enormous distance lead to inconceivable dimensions, is an optical illusion; this is shown by their remaining as points when viewed through a telescope, unlike the comparatively near planets which show discs under sufficient magnifying power. Reference to Gilbert's work on the magnet indicates that Galileo had some inkling of the idea that crystallised later in Newton's theory of universal gravitation. The fourth day elaborates Galileo's erroneous theory of the tides, to which previous reference has been made.

If we wish to form a clear idea of Galileo's services to science, we must not only take account of his great inventions and discoveries, but also of his elegant style, his comprehensive sagacity and fertility of argument, whether on behalf of truth or in the exposure of error. This was insisted upon in the Supplement to the 7th Edition of the "Encyclopædia Britannica" by Professor Playfair, who wrote: "The 'Dialogues on the Two Systems' are written with such singular felicity that one reads them at the present day, when the truths contained in them are known and admitted, with all the delight of novelty, and feels one's self carried back to the period when the telescope was first directed to the heavens, and when the earth's motion with its train of consequences was proved for the first time. Of all the writers who have lived in an age which was only emerging from ignorance and barbarism, Galileo has most entirely the tone of true philosophy, and is most free from the contamination of the time in taste, sentiment, and opinion."

CHAPTER IX.—TROUBLES ENSUING ON PUBLICATION OF THE "DIALOGUES".

THE great work appeared in February, 1632, and specially bound copies were prepared for sending to Rome, but owing to the plague these were delayed, none being seen even by Castelli until May. By the summer several copies reached Rome, among the first possessors being the two Cardinals Barberini (the Pope's brother and nephew), the Tuscan Ambassador Niccolini, and the Censor Riccardi. The book circulated in all parts of Italy and was eagerly read and applauded among men of independent mind. From Venice, however, to which a manuscript copy had been sent, came a note of warning in March, too late to stop publication, recommending that for safety's sake it would be better not to print the book, but to distribute MS. copies to public libraries in the great towns of Europe, with permission for further copies to be made by those who desired them. In this way all who were unprejudiced would be able to obtain the work, while those who sought a weapon against Galileo would be deprived of that afforded by publication and dissemination among the ignorant.

But the success of the book on the one side was only a measure of the intensity of the opposition on the other, and Riccardi soon realised this, and remarked a few weeks after receiving the book, "The Jesuits will now persecute Galileo with the utmost bitterness". He had already heard that objection had been taken to the title

page, but was relieved to find that what had been taken for a skit on the Papal arms was only the printer's device, appearing on all books issued by his firm.

Scheiner, who had in 1630 published a fierce attack on Galileo in his "Rosa Ursina," found his arguments roughly handled in the new work, and took a leading part in the agitation against its author. It was next objected that the preface was in different type, though this was naturally due to the long delay in returning it from Rome; so that the printer had begun on the work itself without waiting for the preface. It was also alleged that the Pope's mighty arguments against Copernicus, which Galileo had undertaken to insert, had been omitted. This was not even true, for the Pope's argument about Omnipotence was duly inserted at the end of the book, and being professedly directed against Copernicus was put into the mouth of Simplicio as a matter of course. It was then admitted that this was the case, but the suggestion was made that Galileo had deliberately insulted the Pope by putting his argument in the mouth of Simplicio, and that Galileo wished to imply that the Pope was a "simpleton". Although Simplicio distinctly states that he had the argument from a "very eminent and learned personage," and although the name of Simplicio was chosen for quite other reasons than that suggested, this ingenious innuendo succeeded to all appearance. Unlikely as it may sound, the Pope was so enraged that he lent a ready ear to further insinuations that the dogmas of the Catholic Faith were in danger from the Copernican doctrines, and that Galileo had obtained the *Imprimatur* by false pretences. It is certain that Galileo himself attributed his subsequent troubles to the idea thus cunningly suggested that he had been making game of the Pope. It is also clear that something must have

supervened to alter the Pope's known previous sympathetic attitude towards Copernicanism.

Galileo meanwhile, though prepared to meet the usual "scientific" opposition, felt sure that he had safeguarded himself from any accusations made on behalf of the Church. He was therefore astounded when in August, 1632, his publisher received an order from the Inquisition forbidding the sale of the book until further notice. A few days later came the news of the appointment of a special Commission at Rome by order of the Pope to examine the book and report. The Commission was under the presidency of the Pope's nephew, Cardinal F. Barberini, and included nobody with any pretensions to scientific knowledge, such as Castelli, to whom the Pope expressly objected.

Failing to obtain any friendly representation on the Commission, Galileo appealed to the Grand Duke, who demanded on his behalf the right to defend himself against his accusers, expressing his surprise that a book which had been submitted to the censorship and revised in accordance with its directions, and had then received the Papal *Imprimatur*, should two years afterwards be prohibited as suspicious; he desired therefore that copies of the accusations should be forwarded to Florence. The Grand Duke's instructions were sent to his ambassador Niccolini, but he encountered great opposition when he attempted to carry them out. The Pope, evidently much irritated against Galileo, exclaimed that both he and Riccardi had been deceived, and cajoled into granting the licence for the book and for its printing at Florence, and that by appointing a special Commission instead of sending the book straight to the Inquisition he was far more generous to Galileo than the latter deserved, since he "did not fear to make game of me". He added that there was no question of "defence," as the rule was for the

Holy Office to pronounce judgment and then summon the offender to recant.

Those well qualified to form an opinion on the proceedings of the Commission came to the conclusion that the Copernican doctrines would not be condemned "Ex Cathedrâ," but probably "corrected" in order to maintain the decree of 1616. After a month's sittings the Commission reported that Galileo had, in spite of all warnings, treated the earth's motion as a fact and not merely an hypothesis, that he had attributed the tides to this untrue assumption as to the earth's motion round the sun, and lastly, that he had deceived the authorities by suppressing all mention of the command laid upon him in 1616. This third point is evidently the only one on which verbal corrections would be of no avail, and we now see the deadly effect of the unsigned minute of the earlier proceedings, of which a fuller account has already been given (in Chapter V.). It is evident that on this charge the whole strength of the case against Galileo depended. It does not seem to have occurred to anybody to doubt the validity of the written evidence of the minute, which clearly does not represent the sense of the proceedings to which it refers, as we have pointed out in dealing with Cardinal Bellarmine's admonition. The clique which was working against Galileo must have rejoiced when this unexpected weapon appeared; and Cardinal Bellarmine himself, who, as we have seen, though opposed to the new doctrines was not so strongly prejudiced as to have his sense of justice obscured, could no longer rise to explain the true state of affairs at the time of the minute of 1616. There was no question raised as to the want of a signature authenticating the minute, because, there being no legal trial, no legal points such as this could be brought up.

On the findings of the Commission the Pope sent word

to Niccolini that Galileo's affairs would be handed over to the Inquisition, and Galileo himself was cited to appear before the Commissary-General at Rome in October. Galileo was in very poor health, and had been suffering from severe ophthalmia, and moreover, the plague was raging again, so being now of an advanced age he appealed to Cardinal F. Barberini, the Pope's nephew, to try and avoid the necessity of going to Rome, suggesting that the Inquisition should appoint delegates in Florence to investigate his case. Niccolini did his utmost to obtain this concession, but the Pope insisted that Galileo must come to Rome himself, in a litter, and as slowly as might be necessary for his health. The journey was postponed on account of a fresh attack of illness, and time dragged on till the end of December. The Pope then announced that no further evasion could be tolerated, and that Galileo must be brought in irons if necessary, unless he was declared unfit to travel, a commissioner with a physician being sent to report on this point.

The Grand Duke, helpless to protect Galileo against the Inquisition, arranged for him to be transported in Grand Ducal litters to the Tuscan Embassy at Rome. As we have remarked before, Venice was the only state in Italy that would have dared to defy the Inquisition, and Galileo was now reaping the bitter fruits of his leaving Padua. Even so late as the beginning of these proceedings he had received the offer of reinstatement at Padua on his own terms, his Dialogues to be printed in Venice. Apparently the offer came too late, or Galileo underestimated the danger he was in, or else felt too strongly bound to the service of the Grand Duke.

After a miserable journey at the most inclement time of the year, and a twenty-day quarantine at the frontier, Galileo reached the Tuscan Embassy at Rome, and by special favour was allowed to remain there in seclusion,

seeing nobody without express permission. It was now known that the whole proceedings hinged on the question of the injunction of 1616, which Galileo maintained that he had obeyed in the sense in which he had understood it. In the course of the weeks that dragged on while the preliminaries of the case were in progress, Niccolini succeeded in dissuading Galileo from his expressed intention of defending himself to the last, counselling complete submission as the quickest and safest course.

CHAPTER X.—GALILEO BEFORE THE INQUISITION.

AT last, on April 12, 1633, Galileo appeared before the Commissary-General and the Procurator-Fiscal of the Inquisition. In answer to questions he said he supposed he was summoned on account of the book, which he admitted was written by him. When asked about the injunction laid on him in 1616, he clearly showed that he was only aware of Cardinal Bellarmine's admonition, which he claimed to have obeyed. On the further question of the strict command detailed in the minute on which, as we have seen, the case against him principally rested, he reiterated that if such a command had been issued he had forgotten it. He did not deny it, as he had promised complete submission, but he still maintained that he had not even acted contrary to the command "not to hold or defend" the opinions in question, but had actually shown that the arguments of Copernicus were weak and inconclusive.

He was detained in comfortable quarters belonging to the Procurator-Fiscal, and allowed to take exercise in the corridors, to have his meals sent in by Niccolini, and to have free correspondence with him. It is noteworthy, and does not agree with the ordinary ideas about Galileo's treatment by the Inquisition, that all previous prisoners since its foundation more than four centuries before had been straightway confined in the secret dungeons, from the beginning of their trial.

Three days later three counsellors of the Holy Office

pronounced that Galileo had disobeyed the order of 1616, and did really hold and defend the obnoxious doctrines, but it was the practice to omit no means of obtaining full admission from the prisoner himself. To ensure this, prior to his next appearance before the tribunal, the Commissary-General had a private interview with Galileo, and persuaded him to promise full confession, so that it should be possible for the Court, without weakening its reputation, to deal leniently with him. Accordingly, on April 30, Galileo appeared before the Court a second time, and made a statement that he had examined his book again carefully to see whether he had put the Copernican case too strongly, and found that in some of the arguments he had been carried away by pride in his own subtlety of reasoning in a false cause, and had put the false case too strongly, so that, contrary to his intention, it appeared to be true. He was then allowed to withdraw, but as he saw that the Court was not satisfied he returned and offered to add one or two more days to the Dialogues and to confute the doctrines to the best of his ability. He was then allowed to return to the Tuscan Embassy, to the delight of the Ambassador Niccolini.

On May 10 Galileo was summoned a third time, and produced a written confession of the truth of the minute of 1616, adding an appeal for clemency on the ground of his age and infirmity. He had evidently been persuaded once more, and perjured himself still further for the sake of peace. He thought that now the worst was over, though Niccolini was less sanguine.

On June 16 the Pope presided at a private meeting of the Congregation, and it was decided that Galileo should be tried, under threat of torture, as to his real convictions, should be made to recant before a plenary assembly of the Inquisition, and condemned to imprisonment at their pleasure: also that he should be forbidden to discuss the

motion of the earth and the sun at all under pain of punishment as a relapsed heretic, and that his book should be prohibited. The decree was not at once made public, so that Niccolini put in a further plea for a speedy end to the trial, and was informed by the Pope that it was already ended, that Galileo would soon be sentenced, and that afterwards he would consult with Niccolini in order to minimise the distress Galileo would suffer. By way of letting him down gently, Niccolini only told Galileo that the trial would soon end, and that his book would be prohibited. This course was suggested by the Pope, who said things might possibly take a better turn.

On June 21 Galileo appeared before the judges once more. He stated in reply to questions that since he had been ordered to abandon them, he had not held the opinions of Copernicus as to the motion of the earth, and this he repeated when threatened with torture if he did not speak the truth. He signed his depositions and was detained somewhere in the Inquisition buildings till June 24. On June 22 he was summoned to receive sentence. The names of ten Cardinal Inquisitors were prefixed to the document read to Galileo, in which was recounted the whole gist of the proceedings of 1616, with its findings, including the famous minute, and an account of the admissions, forced and otherwise, made by the accused in the course of the further proceedings in the matter of the Dialogues. The successive steps were detailed showing how Galileo had first denied the accusations and defended himself, and then withdrawn his arguments and admitted his guilt, ultimately answering, under rigorous examination, "like a good Catholic". Then followed the actual sentence: Galileo being "vehemently suspected of heresy" for holding the doctrine of the motion of the earth, decreed contrary to Holy Scripture, has incurred grievous pains and penalties, but will be absolved if he will "ab-

jure, curse, and detest the said errors and heresies, and every other error and heresy" in a prescribed form. But as a warning to himself and others, the book is to be prohibited by public edict, Galileo is to be formally imprisoned in the Inquisition at the judge's pleasure, and is to recite once a week for three years, by way of penance, the seven penitential psalms, the judges reserving the right to mitigate the penalties. Only seven of the ten Cardinal Inquisitors signed the decree, so that it does not seem to have been unanimous.

Galileo then knelt before the Inquisition, read aloud the prescribed form of abjuration, and signed it. This must have been the climax of the moral torture of the last ten months. We may acquit the Inquisition of having inflicted physical torture, and Galileo's actual imprisonment could only have been for the three days, June 21 to 24, and was probably not even in a dungeon. It seems as if a very little harshness of this kind at the beginning of the trial would have been enough to kill the old man, who was already ill, but he would then have escaped practically all the punishment intended. The moral bullying to which he was subjected is very like the physical twisting of a boy's arm, until he admits that his tormentor is a "perfect gentleman," or some such obvious falsehood. So generally has the abjuration been regarded as compulsory perjury on the part of Galileo, that more than a century after his death a story was invented that immediately after his public denial of the earth's motion he muttered "Eppur si muove," but though doubtless he thought something of the kind, it is absolutely certain that the story is false.

True to his promise to Niccolini, the Pope substituted banishment to one of the Grand Duke's villas near Rome, for imprisonment in the Inquisition buildings, but we cannot acquit him of personal responsibility for much, if

not all, of Galileo's previous suffering, responsibility not as Pope, for no "Ex Cathedrâ" pronouncement was made, and the doctrines were not condemned by the Church, but as a man who listened too readily to insinuations touching his dignity, and used his official position to avenge a fancied slight, not perceiving that it was not Galileo but his enemies that were really "scoring off him".

Galileo naturally was much depressed, not at the prohibition of his book, but at the personal proceedings which had impelled him to do such violence to his conscience. The sentence and abjuration were published as widely as possible, especially in Padua and Florence, and all the Papal officials who had favoured Galileo during the course of the proceedings were punished, including Castelli, Riccardi, and the Florentine Censor.

Galileo petitioned the Pope to allow him to return to Florence or its neighbourhood, and though this was not immediately granted, he was permitted to retire to Siena on June 30, and after further pressure exerted in his favour, to his villa at Arcetri on December 9, after an absence of nearly a year.

CHAPTER XI.—LAST DAYS OF GALILEO.

GALILEO had now regained his home but not his freedom, special permission being required before he could go into Florence. He was suffering from several ailments and wished to live within easy reach of his physician. For this purpose he petitioned early in 1634 for leave to move into Florence. The reply was a mandate from the Inquisition forbidding him to ask again, under pain of being at once removed to Rome and actually confined in the prison of the Holy Office. Soon after this his beloved daughter, Sister Maria Celeste, who had almost despaired of seeing him again, owing to serious illness during his long absence, sank under her sufferings and died in April. Galileo was so ill that he expected soon to follow her.

Shortly afterwards he heard definitely, what he might have suspected before, that it was only the fact of his being out of favour with the Jesuits that had brought him into such trouble at Rome. Otherwise he could have held and taught any doctrine he pleased. Perhaps this galvanised him into fresh energy, for he soon set to work again on his projected new "Dialogues on two new sciences". These were Cohesion and Resistance to Fracture, and Uniform, Accelerated, and Projectile Motion, embodying the foundations of Dynamics. The books are full of interesting experiments. The form is similar to that of his forbidden work, the same interlocutors being introduced, and we find them discussing falling bodies, the motion of a pendulum, lines of quickest descent, the para-

bolic motion of projectiles, and other themes connected with dynamics, the strength of beams, the possible finite velocity of light, the harmonic vibrations of strings, the explanation of concords and discords, and similar subjects, some of them only occurring as digressions.

The MS. was completed in 1636, but the Inquisition had forbidden any of Galileo's work to be published, even reprints of his previous books, to which no exception had been taken. He tried to find a publisher outside Italy, but the presence of Scheiner in Germany and the fear of opposition from him and the Jesuits caused one project after another to be abandoned, until finally Elzevir produced the work at Amsterdam in 1638. Galileo pretended that this was pirated from a MS. copy, in order to observe the letter of the embargo laid on him by the Inquisition.

As soon as the MS. had been completed he projected a fresh series of problems, including the subject of Percussion, and also resumed his plan of determining longitude at sea by observation of Jupiter's satellites. The negotiation with Spain had dragged to an end in 1632, but in 1636, hearing that a prize of 30,000 scudi was offered by Dutch merchants for a sure method, Galileo offered his plan through his friend Diodati at Paris, using this means in order to keep the officials of the Inquisition in ignorance of what he was doing. His sight was failing, and when the Dutch Government sent him a gold chain as a sort of retaining fee, he was found in bed totally blind. He refused to keep the chain, fearing that he would be unable to complete his calculations. As a matter of fact his "Ephemerides" were afterwards completed, but owing to a series of accidents they were not published for two centuries.

His last astronomical discovery before his sight failed altogether was the explanation of what is called the

moon's libration, by which we see rather more than half the surface of the moon, as it shows a little more to the north, south, east, or west. He became totally blind in December, 1637, and at length the entreaties of his friends for more liberty began to have greater effect. He had very occasionally been allowed to pay short visits, with precautions as to travelling at night so as not to be seen, but early in 1638 the Pope gave Castelli to understand that a proper petition might now receive consideration. This was sent, but the Pope also required a report from the local Inquisitor as to the reality of the infirmities, and even when Galileo was allowed, upon this report being favourable, to move to Florence, his son was set to watch over his movements and to see that his visitors did not stay long, while he himself had to get special permission from Rome even to go to church at Easter.

A few months later Castelli was allowed to come to Florence and visit Galileo, partly in connection with the "Ephemerides" of the Medicean stars, which the Tuscan Lord High Admiral wished to take to Spain. Galileo returned to Arcetri in January, 1639, probably being ordered to do so, as his health had slightly improved. Being now close upon seventy-five years of age and very infirm, it appeared unnecessary to insist upon such close restrictions, and visitors were permitted more freely, including foreigners of distinction, some of whom visited Italy principally with the object of paying their respects to Galileo. It was in that year that the visit took place to which Milton referred when he wrote, "I found and visited the famous Galileo, grown old, a prisoner to the Inquisition for thinking in Astronomy otherwise than the Franciscan and Dominican licensers thought". A few months later the poet returned to Florence after paying a round of visits to other places and wintering in Rome.

In 1639 Viviani, "the last disciple of Galileo," came to live with him at the age of eighteen, and remained on the most intimate terms with him for the rest of the philosopher's life. In 1640 the old man was challenged by one of the Grand Duke's brothers to respond to an argument that the faint light on the "dark" part of the new moon, which Galileo had attributed to earth-shine, was in reality phosphorescence. This Galileo did very effectively with all his old dialectic skill.

Even later he was urged to reply to another argument against the Copernican system, but he had taken to heart the oft-repeated warnings he had received on the subject, and though readily demolishing the point raised against the system, he declared that no good Catholic could doubt the insufficiency of the Copernican doctrine in face of the unanswerable argument of the Divine Omnipotence, but as all the other systems were demonstrably false, it would be necessary to wait for a new one of which both science and theology can approve. It is quite clear that this is only a sarcastic evasion and cannot be understood to mean that he had really changed his mind.

His very last mechanical suggestion was the application of a pendulum to regulate a clock. His son Vincenzio made a drawing of the design from Galileo's dictation, but the plan was interrupted by his mortal illness, and Vincenzio himself also died before completing the clock.

Castelli tried to be with his old master to the end, but had to return to Rome towards the close of 1641. Torricelli, known to fame as the inventor of the barometer, shared with Viviani and Galileo's son the duties of amanuensis, but the sands were now rapidly running out, and the end came on January 8, 1642, when Galileo died after receiving the Pope's blessing.

His enemies were still unappeased, and though they

failed in their endeavours to dispute his right to make a will, and to be buried in consecrated ground, they were able to do something, for the Pope, hearing that a public funeral and a marble monument were in contemplation, prevailed by threats upon the Grand Duke Ferdinand to cancel the arrangements.

Nearly a century later the monument in the Church of Santa Croce at Florence was erected by means of funds left for the purpose by Viviani, whose remains as well as Galileo's were removed thither.

CHAPTER XII.—CONCLUSION.

VIVIANI was Galileo's first biographer, but as he only knew him for the last few months of his life, many of his statements, being derived from hearsay, are not trustworthy. He gives a description of his appearance as he knew him, a square, well-knit figure rather above medium height, and a cheerful and pleasant face with plenty of hair and beard which had been of a reddish colour. His temper was short, but he was ailing for nearly fifty years, and much is forgiven in such a case, even without the provocation he was continually encountering for a longer period still. He was fond of congenial society, but rarely discussed mathematical or mechanical subjects with strangers. He was also fond of gardening, and country life generally. He was rather particular about wine, of which perhaps his liking was too great, considering the infirmities of body and of temper from which he suffered. He had a remarkable memory for classics and poetry, old songs and stories. He was a magnificent teacher, being able to grasp the difficulties of less rapid thinkers in a way not always found among professors.

When we come to consider his claims to fame, it is necessary to pay due regard to a sense of proportion. It is a commonplace to observe that his astronomical discoveries were bound to be made as a direct consequence of the invention of the telescope, so that, though he is popularly known almost entirely by them, they cannot be rated very highly in comparison with his achieve-

ments in other directions. The science of dynamics may be said to have been started by him, and he came very near to more than one great discovery for which later scientists have earned undying glory. In his meditations on Gilbert's treatise on the magnet, for instance, the theory of gravitation does not seem far away. There is no doubt that in statics, dynamics, and hydrostatics, his work was of much more value to succeeding generations than the astronomy that brought him into such trouble.

As regards the great controversy about the Copernican system, several suggestions have been made which we find a difficulty in accepting. It has been argued that Galileo's violent support of his case, like that of a "flat-earth" enthusiast, was due to the insecurity of his convictions, the inference being that he was not satisfied himself. But surely reformers are bound to make far more noise in proportion to their numbers than those who are contented with things as they are. On the other hand, it has been argued that, being absolutely sure he was right, he ought therefore to have defied the Inquisition, daring them to punish him. Would anybody, one may be permitted to inquire, really be prepared to go to the stake in defence of the "dogma" that twice two are four? Such martyrdoms have nearly always been associated with religious persecution, and not with any scientific controversy, however acrimonious: and the ostensible ground of Galileo's trial was theological, as otherwise it would have been difficult, if not impossible, for his enemies to attack him with such disastrous effect. In just the same way had his dialectic forerunner Socrates been condemned ostensibly for "impiety," and paid the penalty with his life.

The path of one born before his time is indeed liable to be a thorny one, but those who follow reap the benefit,

finding many of the thorns trampled away by the pioneer, and the road made plain, though often difficult to follow or to widen. To that extent Galilèo's sufferings must have hastened the triumph of Copernicanism. This triumph was inevitable in any case, just as practically all the things for which the Chartists rose in riot, have since been peacefully enacted.

The enduring fame of Galileo, who now ranks among the greatest of Italians and of philosophers, is emphasised not only by monuments and inscriptions but by a national edition of his works in twenty volumes, and by the celebration of such epochs as the tercentenary of his birth, held at Pisa in 1864, and that of his inaugural lecture at Padua, which representative scientists of the world attended at Padua in 1892.

We will conclude with an extract from Professor Grant's appreciation of Galileo's services to the science of motion. He says: "The sagacity and skill which Galileo displays in resolving the phenomena of motion into their constituent elements, and hence deriving the original principles involved in them, will ever assure to him a distinguished place among those who have extended the domains of science. It is perhaps impossible, in the present advanced state of mechanical philosophy, to form a just estimate of the difficulties which then interposed towards a precise and luminous view of the fundamental principles of motion. It is universally admitted that those phenomena which come under the daily observation of mankind, and which on that account do not possess any salient features on which the imagination can repose, are generally those which are most liable to elude the inquiries of ordinary minds. The principles which Galileo established by his sagacious researches had the effect of elevating mechanical science to the dignity of one of the most important subjects which can concern

the attention of mankind. They were essential elements in the train of investigation which conducted Newton to the sublime discovery of universal gravitation; and in fact they constitute the basis upon which the vast superstructure of the physico-mathematical sciences has been reared."

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