
The Musician's Son

The detached belfry of Pisa Cathedral leant dangerously southwards. It looked peculiar, but the phenomenon attracted no attention outside the city itself. Tuscans were used to ostentatious towers on both private and public buildings, and it was accepted that, from time to time, one or other of them might come crashing to the ground.

This zealous tower building encapsulated two of the traits characteristic of the Tuscan: firstly, his intense need to draw attention to himself, quite literally to raise himself above others. Secondly, his almost miraculous combination of craftsmanship, technical expertise and artistic talent which had made Tuscany, and particularly its capital Florence, into the Western World's undisputed centre for architecture, sculpture and painting during an age that an admiring future was to christen the Renaissance.

This golden age was definitely on the wane by the year 1564.

Cosimo I de' Medici was Duke of Tuscany. The Medicis had originally been physicians, but had later turned to banking and business. For more than a century the family had dominated Florence with its power and wealth. But new times had arrived in Europe, an age of absolute monarchy, and power had to be legitimised by reference to a ruler's noble lineage and divine right. Cosimo had acquired a ducal title and established himself as absolute ruler. He had moved from the Palazzo Vecchio in the city's ancient, pulsating centre, across the river Arno to the huge and enclosed Palazzo Pitti. There, at a regal distance from the humdrum life of the city, the Duke and his court lived with a pomp that would have been the envy of many a European king.

The musician, Vincenzo Galilei, was the same age as Cosimo de' Medici. He too came from an old Florentine family with a medical ancestor. There,

any similarity with the Medicis abruptly ceased. Wealth and power had notably eluded the Galilei family.

The Duke's court was a place of work for Vincenzio, an arena in which he could play the lute and viola da gamba. But he could not get enough commissions there or in Florence as a whole. Things got even more difficult when he married Giulia, a woman twenty years his junior. Her family came from Pisa, and Vincenzio felt forced to move there. This was no easy decision for a patriotic Florentine. But the cost of living was lower in Pisa, a musician had less competition there and, above all, his wife had family in the city, practical, hard-working folk in the woollen trade who could offer a poor relation a little work now and again.

The bond between Florence and Pisa had never been very cordial. In his *Divine Comedy*, Florence's greatest son, Dante Alighieri, depicts Pisa as the cradle of treachery, and places some very eminent Pisans in the deepest depths of Hell. But the two cities were no longer rivals of equal rank. From its position as one of Europe's richest and most powerful city states, Pisa had degenerated into a sleepy Tuscan provincial town, firmly ruled from Florence.

Vincenzio had married to keep the Galilei family going: his Giulia was pregnant. On 15 February 1564 the couple's eldest son was born in a rented house near the church of Sant' Andrea, half way between the university and the Medicis' local palace. Following a relatively common Tuscan tradition, the boy was given the singular form of the family name as a Christian name: Galileo. He was called after the original 15th century founder of the line, the doctor now buried in no less a place than the church of Santa Croce.

Vincenzio Galilei was not only a skilled musician and noted composer. He was a learned man. What interested him most was the theory of music. He had studied with well known humanists in Venice and Rome, and was engaged in writing a great thesis in which he was ambitiously attempting to revive contemporary music by returning to the principles of antiquity.

Young Galileo was not an only child. His mother Giulia gave birth to six more children in rapid succession, but only one brother and two sisters lived to adulthood. Vincenzio soon realised that his eldest son was uncommonly gifted and lavished special attention on him. He taught Galileo to play the lute, and the boy soon became a skilful player.

He also learnt two other things from his father's toil with his thesis. The first was that one should never be content with accepted wisdom, even if it came from the most authoritative sources, but combine theoretical deliberations with practical experiments and arrive at one's own conclusions.

The second was that such pioneering work was often, quite literally, undervalued. Vincenzo constantly struggled to provide for himself and his family. In 1572 he moved back to Florence alone. Cosimo had just been elevated to *Grand Duke*, and the celebrations offered an opportunity for a good musician to shine at court. But Giulia and the children had to remain with her family in Pisa, and it is tempting to imagine young Galileo overhearing his mother's relatives making remarks about who had to support him and his brother and sisters.

In 1574 Grand Duke Cosimo died. He was a temperamental tyrant who once killed a servant on the spot because he had told Cosimo's son that his father was considering re-marrying; but he was also a generous patron and enterprising ruler who had brought material prosperity to his central Italian Grand Duchy. The majority of Tuscans harboured no high expectations of his son, Francesco. Their worst fears were realised. Francesco's spouse died under mysterious circumstances, after which he held an extravagant wedding ceremony with his infamous lover, Bianca. Even worse was the fact that the new Grand Duke protected his younger brother Pietro, who had strangled his wife in a fit of jealousy.

It was at this court that Vincenzo was to earn most of his living. The change of grand dukes did not alarm him, for he brought Giulia and his children to live with him in Florence. The family settled close to one of the bridges over the Arno, Ponte delle Grazie. It was a practical place to live. The Grand Duke's Palazzo Pitti lay close by.

Ten-year old Galileo had come home. His family belonged in Florence. Ever after he considered himself to be a Florentine. But his father was not satisfied with the education the boy could receive in the city of his ancestors. The following year he sent Galileo to the remote monastery at Vallombrosa – the “shady valley” – north of Regello in Valdarno, some twenty miles south-east of Florence.

The contrast with a city like Florence could hardly have been greater. The monastery was beautifully situated, but was completely isolated and at an elevation of over 3,000 feet, surrounded by a forest of broad-leaved trees as well as heavy, dark spruces with ivy-clad trunks.

Vincenzo knew what he was doing. The monks of this monastery belonged to the intellectual Florentine tradition. It was an inspiring environment, far beyond the standard of monasteries generally. Here, the gifted young boy could learn Greek, Latin and logic.

Galileo was an assiduous student who thoroughly enjoyed life in these isolated, spartan surroundings. But the boy liked it even better than his

father had hoped. After a couple of years he wanted to join the order, and offered himself as a novice.

Perhaps it was youthful religious passion that lay behind this decision, but Galileo also perceived that the strict life of a monk would provide him with opportunities for work and study, free from the material cares that the life of a citizen brought with it. Vincenzo, however, had no sympathy with his eldest son's decision. In 1579, he took the winding mountain road up to the monastery and brought the fifteen-year-old back home to Florence.

His father's motives may have been to prevent Galileo becoming stuck in a location and environment which, in the long run, would never be able to provide him with sufficient challenges. But it is more likely that cold financial calculations lay behind this "rescue expedition". Vincenzo would have to make contributions to the running costs of the monastery if his son were to become a monk. *Daughters* might feasibly be candidates for monastic life. They had to be subsidised as well, of course, but if they married instead, their father had to find a dowry, so daughters were costly in any event. But a son like Galileo ought to find himself paid work, so that he could help out with the family's expenses.

But what career was his son to choose?

A Gifted Young Tuscan

Galileo Galilei was an impoverished young man with big ambitions and many talents. He was to prove a brilliant writer. He was musical like his father. He could draw and paint, and he seriously considered making his livelihood in art – a career that traditionally was very prestigious in Florence, where training opportunities were second to none.

Galileo well knew what an artist's life was like. It was at about this time that he struck up a close friendship with Lodovico Cardi, known by the name Cigoli, who was barely five years his senior. At an early age this gifted painter was commissioned by the Medici family and was rated as the finest among his contemporaries in Florence.

His father's work and his own environment inclined Galileo more towards art than to science. But in the wake of the Renaissance, the line between these two areas was not very clearly defined. Vincenzo's musical theory made use of mathematics and physics – indeed, music as a taught subject was reckoned as one of the quadrivium subjects, together with arithmetic, geometry and astronomy. (The linguistic disciplines – trivium – were grammar, rhetoric

and logic.) Painting was seen as closely related to geometry, principally because of the theory of perspective. It was taken as read that painters had to study anatomy. The young Cigoli was so keen on dissection that he contracted a serious and long-lasting illness through over-exposure to cadavers!

Vincenzo, however, was not enthusiastic about his son's artistic pretensions. He knew only too well what kind of existence such a life had to offer. And painting was at least as insecure as music. His father had a better idea. Galileo was to study medicine and become a prosperous doctor, like their ancestor. Good son that he was, Galileo laid his painting ambitions aside and obeyed his father's wishes.

Medicine was far from being a poor career choice for a young man with ambitions. The discipline was particularly prestigious in Italy, whereas in most other European countries theology still dominated the universities. It was a comprehensive education. In those days subject boundaries were not clear cut – it is questionable if “disciplines” in the modern sense existed at all. Natural philosophy, logic and mathematics were “medical subjects”, as well as the very recently developed anatomy, with its spectacular dissections. Mathematics and astronomy were important for doctors principally because they had to be able to cast accurate horoscopes for their patients. They had little more in their armoury with which to fight serious disease.

Galileo returned to his native city, Pisa, in 1581 as a 17-year old student. He had come to the provinces. The city's hub, Piazza dei Cavalieri, could not compare either in size or liveliness with the Piazza Signoria in Florence, even though its beautiful palace boasted fine external frescos by Cosimo's court painter, Vasari. Similarly, the intellectual life of the University of Pisa was nothing like that of centres like Bologna or Padua. It was an educational establishment without international cachet, where the average professor was as interested in his social status as in academic achievement.

Galileo began to attend the lectures that were relevant to medicine, and it was not long before it became apparent that he was no ordinary student. He was not content to repeat his teachers' dogmatic interpretation of accepted truths.

It is said that Galileo's first scientific discovery was made in Pisa Cathedral during Mass. From his pew in the church he noticed a chandelier that was swinging to and fro, and he noted that the time these small oscillations took was constant and unrelated to how far the lamp swung.

This observation would, many years later, lead to the construction of the pendulum clock and a hitherto unknown accuracy in the measurement of

time. But in the first instance the young medical student and some friends made a simpler contrivance, a so-called *pulsilogium*. The measurement of pulse was an important diagnostic tool for the doctors of that period. Galileo constructed a pendulum, the length of which could be adjusted so that it swung in time with the patient's pulse. Now the doctor could read a diagnosis directly from the length of the pendulum!

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In 1583 Grand Duke Francesco came to Pisa as usual, where his court spent their time between Christmas and Easter. The Medici family had owned a palace there for many years, and Francesco began the building of a newer and larger one, in the best district, down by the Arno. In this way he could add lustre to the city and remind the Pisans of who held power in Tuscany.

Grand Duke Francesco's retinue contained a mathematician and military engineer by the name of Ostilio Ricci. He came into contact with Galileo and discovered that the young student was interested in mathematics.

The teaching of mathematics at the university was extremely poor. The subject had a low status compared to general natural philosophy. Ricci opened a new world to the young student, the world of algebra and geometry. He made Galileo acquainted with the works of a Venetian named Niccolò Tartaglia, who had probably been Ricci's own teacher, and who was regarded as the greatest Italian mathematician of the 16th century.

Tartaglia left his mark on the history of mathematics. He was the first to find a general method of solving cubic equations. Galileo, however, skimmed rather quickly through this new arithmetic, even though it clearly had practical applications. He did precisely as his father had done in the musical sphere, he turned to the inheritance from antiquity. As far as mathematics was concerned this meant the rediscovery of Euclid and Archimedes. It was this traditional, classical mathematics with its strong emphasis on geometry, that fascinated him. And it was Ricci who opened his eyes to this aspect of Tartaglia's work as well: Tartaglia had in fact translated, annotated and published Euclid and Archimedes in new editions and had thus made them accessible.

Galileo was a impecunious student, who sorely needed a lucrative profession. But the revelation that mathematics had opened up to him was more important than either his father's exhortations, or a possible future as a physician. It may also have helped that Ricci indicated a possible career path that would satisfy even the most ambitious: with the right contacts and

the necessary skill one might end up as mathematician to a grand duke – a position that provided social rank and means beyond anything a doctor, or for that matter a professor, could aspire to.

Such an association with a court did of course also mean that any fall from grace would be a long one.

Vincenzio probably understood his son. He was working hard on his musical theory, and had finally completed his great thesis in dialogue form (*Dialogue on Ancient and Modern Music*). He argued polemically with his professional adversaries, while at the same time developing his theory in new directions with the aid of pure acoustic experiments.

But musical theory brought no money in. Vincenzio was simply unable to support his wife, three children and a student. In 1585 he had to ask Galileo to interrupt his studies at Pisa and return home to the Ponte delle Grazie, without a degree.

To Rome and the Jesuits

Galileo hurled himself into mathematics with an energy that showed he had finally found a calling, a direction to his life. Even without a degree he was undoubtedly one of the most knowledgeable men in Italy regarding mathematics. But this was of little use unless his talents were recognised. At home in Florence there was no mathematical set. He did a bit of private tutoring and spent one winter in Siena. In order to get on he had to make contacts.

With this in mind, Galileo set out on his first journey to Rome.

The Rome to which the young Florentine mathematician came in the autumn of 1587 was completely different to the Renaissance city where Rafael and Michelangelo had been great heroes earlier in the century. A lot had happened in the intervening period, the essence of which can be summed up in two words: Reformation and Counter-Reformation.

The papacy had strengthened its grip on the Church. Luther's Reformation in northern Europe was a seismic shockwave that demanded a new direction. The Council of Trent (1545–1563) spelt out the basic tenets of the Catholic faith, and at least got rid of some of the blemishes that Luther had pointed to. It was the start of a fight to win back its lost standing – the Counter-Reformation.

The Council of Trent accentuated the splits within Europe by defining the Catholic Church's ideological foundation: absolute monopoly on Christian

teaching and interpretation. Every bit as important as the ideology was the inception of two executive organs to carry out the Counter-Reformation: the Jesuit Order (1540) and the reorganised ecclesiastical surveillance apparatus in the area of faith, the Roman Inquisition (1542). At the same time the popes began to view themselves more and more as absolute rulers; not merely as spiritual leaders, but also as princes of the Papal States, just like other sovereigns in autocratic Europe.

When Galileo arrived in Rome, he found himself in the midst of energetic upheaval in the city on various levels. Pope Sixtus V Peretti unrelentingly tore down cramped, old blocks of houses and constructed wide, straight thoroughfares between the main churches. The streets echoed to the constant noise of cobbles being pounded into place – more than a hundred streets were permanently surfaced in a five-year period.

And so Galileo could travel dry-shod over the cobblestones to the powerful, learned and influential organisation he had decided to contact – the Jesuits.

The young Jesuit Order had been founded in Paris by the Spanish nobleman, Ignatius Loyola. With a background in the army and higher education, Loyola built up within a few years an effective, elitist organisation that greatly emphasised teaching and scholarship, and which became the pope's strongest weapon against Luther's doctrines. Not least, the Jesuits achieved startling results in their missionary work, both in Asia and South America.

The two chief seats of the organisation's operations were in Rome and they had just been completed: the *Il Gesù* Church and the large, fortress-like centre of learning, *Collegio Romano*, which occupied an entire block in the middle of Rome between the Pantheon and the main street, Via del Corso.

In only a few years the Collegio Romano had become a very important institution and was considered to be one of the foremost universities of its age. When Galileo arrived there, 2,100 young men had either taken their degrees, or were still studying for them. There were also large Jesuit colleges in many other places including Köln, Trier and Munich.

Northern Europe was an important area of operations for the Jesuits, and there they undoubtedly helped to stem the tide of Lutheranism and Calvinism. The Jesuits literally conquered higher education. A key college was situated in Leuven (Louvain) in what is now Belgium, on the border between Catholic and Calvinist Europe. One of the Jesuit's keenest intellects, Robert Bellarmine, was at work there, but he would soon be returning to Rome to take up positions of even greater importance.

The Jesuits were famed for their somewhat unorthodox working methods, in which infiltration and undercover work was not unknown. One of Bellarmine's students at Leuven, a Norwegian called Laurits Nilsson from Tønsberg, was sent to Protestant Stockholm, where – in the guise of a Protestant priest! – he built up an influential school and swayed King Johan III, who had married a Catholic, to such an extent that the King wanted to reintroduce Catholicism into the country, a notion that the clergy and his brothers soon put a stop to.

Galileo had not come to Rome and the college for religious reasons. The Jesuits had realised that if they wanted to wield influence, their scholastic calibre had to be of the very best, and the Collegio Romano could congratulate itself on possessing the greatest contemporary mathematician anywhere in Italy, Father Clavius.

Christopher Clavius was around fifty years of age. Originally German, he had been admitted to the Jesuit order at the age of seventeen and had spent most of his life in Italy. He wrote a number of textbooks on various mathematical and astronomical subjects, books that Galileo knew from his studies. He played a key part in the committee set up by Pope Gregory XIII which, just a few years before in 1582, had instigated a great reform. The result was the Gregorian Calendar, which is the foundation of our computation of time to this day. In brief, Father Clavius was a pivotal man to know for anyone wishing to make a career in mathematics on the mainland of Italy.

Totally unknown and unqualified, the 23-year old Tuscan was not overawed by the impressiveness of the Collegio Romano. He immediately sought out Father Clavius. Galileo explained his theories for calculating the centre of gravity of various objects, an area of study the Jesuit mathematicians were already interested in.

Clavius was impressed. He praised the practical work Galileo had done, and discussed the fundamental problems that arose as soon as mathematical models were transferred to the real, physical world: and indeed, whether this was even possible. The ideal, geometrical sphere touches a geometrical plane at just one point. But as soon as one uses a *real* sphere on a *real* plane, there is a contact *surface* of greater or lesser extent, between the two. As a result there were those who maintained that mathematics was, in a manner of speaking, self-absorbed; that it might indeed deliver incontrovertible proof, but only when dealing with abstracted mathematical subjects. Father Clavius, on the other hand, argued that mathematics was a necessary bridge between the abstract (“metaphysical”) world and the one that actually existed.

Vincenzio Galilei's work on the relationship between string lengths and the perception of pitch reflected a practical attitude to mathematics as a working tool. Galileo's approach was the same, he showed this even as he watched his pendulum in Pisa Cathedral. This basic philosophy, that technical models could be used to reveal definite knowledge of the outside world, was strengthened by the ideas from the Collegio Romano. Presumably he was given lecture notes to take away with him and study at home in Florence.

His visit to Rome was proof of just how high Galileo was aiming. Working as a private tutor in his native city was to waste his time and talents. Nevertheless, Jesuit goodwill was not enough to secure him a permanent position. A professorship was vacant in Bologna, but it went to Giovanni Magini who was nine years older and had good connections with Duke Gonzaga in Mantua.

Galileo had to be content to travel back to Florence, to his family and his private lessons. But there were things happening in his native city: two sudden deaths. They set in motion a train of events that eventually would secure Galileo his first chair in mathematics.

A Surveyor of Inferno

It was rare for the citizens of Florence to see anything of their lord, Grand Duke Francesco de' Medici. He spent most of his time isolated in his villa in Pratolino with his extremely unpopular former mistress, now the Grand Duchess Bianca. Rumours in the city had it that they experimented with poisons which Bianca was to use in her murderous projects. The worst suspicions seemed to have been borne out when both of them died suddenly, on the same day in October 1587.

In fact, it was malaria that had killed them. At all events, that was the story of his brother and successor, and since Ferdinando was of a different stamp to Francesco, he was believed. Ferdinando de' Medici had been made a cardinal at the age of fifteen and had then spent many years in Rome, where he proved himself to be a womaniser of a somewhat unseemly sort for a churchman, but also a brilliant administrator and an avid collector of antique statues. He bought a large house on the slopes of Monte Pincio in order to have somewhere to store his collection. It was called the Villa Medici. But now he had to return home to Florence and his grand ducal title.

On the whole Ferdinando was a good ruler. He left the Church and married a distant relative. She was Christina of Lorraine, the granddaughter

of King Henri II, a woman who was to be of great significance to Galileo. But more important for the mathematician's immediate future was Ferdinando's choice of his successor as cardinal.

It was generally accepted that a powerful family like the Medicis had to maintain their representation within the College of Cardinals. But now there was no suitable family member available. Instead, Grand Duke Ferdinando sought the election of a man he trusted – Francesco Maria del Monte.

The new Cardinal was not notably interested in questions of theology. Del Monte was a well educated aesthete, a man with a taste for the good life, but also seriously interested in poetry, art, music and science. He was well versed in Vincenzo Galilei's musical theory. Cardinal del Monte was not opulently rich, but lived very comfortably in the Palazzo Madama near the Piazza Navona. He liked latching on to promising young men and helping them – he was the first to discover Caravaggio's unruly artistic genius.

The Cardinal had a brother. His name was Guidobaldo and he was a mathematician.

During his visit to Rome, Galileo had become acquainted with Guidobaldo del Monte, although it did not help him very much in his quest for a position. Now, suddenly, the situation had drastically altered: Guidobaldo's brother was not only a cardinal, but was the Grand Duke's trusted man in Rome.

Galileo spoke to Guidobaldo, Guidobaldo to the Cardinal, the Cardinal to Grand Duke Ferdinando. The result was that in the autumn of 1589, Galileo could again return to his birthplace, Pisa, now as the 25-year old professor of mathematics.

But before leaving Florence, he gave a lecture in the city's prestigious Academy, founded to promote Tuscan as the foundation for the common Italian written language. He had been set the task of describing the location and dimensions of Dante's Hell. Florence was not a city to take its famous authors lightly. A well-known dramatist had once been exiled because he had announced that the sainted Catherine of Siena was a better writer than Florence's own Boccaccio!

The young freelance mathematician took his listeners by storm.

He was intimately versed in *The Divine Comedy* and the universe that was depicted there. Galileo explained the precise construction Dante had calculated for his Hell. It was shaped like a broad funnel, with its opening up on the surface of the earth. In each of its descending *circles* ever worse punishments were meted out to ever worse sinners, and using his skill in geometry, Galileo worked out the diameter of the various diabolical departments, in which various devils tortured the unhappy sinners for all

eternity. The circles got narrower and narrower until they ended up at the centre of the Earth, where Lucifer himself reigned and everything was everlasting frost and ice – as far away from Heaven, light and warmth as it was possible to get.

Lucifer was at the centre of a sphere. Galileo did not need to produce arguments for this. His educated audience knew only too well that the earth was round. Every scholar had known that since antiquity. Eratosthenes of Alexandria had with fair accuracy calculated the circumference of the Earth 200 years before Christ – admittedly with a bit of luck in his assumptions. Thus Galileo had a starting point for estimating the relative dimensions.

In the matter of the *relationship* between the Earth and the rest of the universe, Dante, and all other learned men, held to a model that had been perfected by Ptolemy, another Greek from Alexandria, in the second century AD. Very briefly it can be described as follows: the Earth is the fixed and stable centre of the universe. Around it revolve the heavenly bodies at various distances, attached to invisible spherical shells – spheres – which propel them in circular orbits.

This *Ptolemaic* model seemed hardly more than plain and self-evident common sense – after all, that was how one experienced the Sun, Moon and stars. But Dante's universe was also a marvellous, ingenious alloy of cosmology and theology. Throughout the Middle Ages Ptolemy's thoughts had combined with theological ideas to form a mighty construction, in which God and his angels inhabited the different spheres – or heavens. The interplay between theology and astronomy was extremely intricate. For example, the tilt of the Earth's axis was explained by the Fall: as we know, this ended the state of paradise and brought transition and death into the world. God introduced the seasons and thus "the passage of time" by the simple expedient of tipping the Earth slightly out of its formerly "perfect" position.

But Galileo's subject was Hell. According to Dante, these funnel-shaped circles were created when Lucifer was thrown out of the upper reaches of Heaven, hit the Earth with great force – quite literally as a fallen angel – and then bored into the soil right to the centre of the sphere.

However, the young mathematician who had so impressed his fellow citizens with his understanding of Hell's dimensions, knew something that very few of his listeners had appreciated. An obscure canon by the name of Copernicus from the faraway Baltic coast, had developed a new theory. This theory was slowly permeating educated European circles. It was recklessly daring and could demolish the entire ingenious Ptolemaic edifice.

Galileo did not utter one word about this to the Academy in Florence, because something else was quite clear to him: such a huge cosmological and theological structure would never fall without resistance.

The Spheres from the Tower

The University of Pisa was situated close to the river Arno. The Medicis had built a fine rectangular building around an internal courtyard with a covered arcade, beneath which lecturers and students could stroll and argue in a dignified manner. The main subject for discussion, at least in the subjects concerned with natural philosophy, was Aristotle. His disciples had been called Peripatetics – those who walk about – because it was claimed that the master had taught in this way.

Aristotle's thoughts about the natural world had congealed into an unsailable system of instruction. In principle, his physics built on observation and the logical deductions arising from it. But the observations could be random and certainly were not systematised by means of controlled experiments. Emphasis was placed on the logical and philosophical conclusions – to such an extent that all the *practical* knowledge that had gradually accumulated, linked to technical advances in architecture and shipbuilding or the construction of clocks and the manufacture of spectacle lenses (to mention but a few), had barely impinged on university teaching of the fundamental physical questions concerning the natural world.

Many professors found greater academic prestige in interpreting an obscure passage of Aristotle than in observing for themselves. And academic discussion must adhere rigidly to the Master's pattern. It was still possible to hear, as a capping argument: *Iipse dixit!* – “He said so himself!” There were many, of course, who realised that not *every* answer to natural mysteries could be found in 1900-year old treatises, but nevertheless the Aristotelian framework of understanding limited their imagination and thought processes.

The very young Professor Galilei in occupying his chair at Pisa was not at all disconcerted that he had no degree himself. Thirty years later he was to write, comparing “good philosophers” to bad ones:

“I believe (...) that they fly, and that they fly alone like eagles, and not like starlings [storni]. It is true that because eagles are scarce they are a little seen and less heard, whereas birds that fly in flocks fill the sky with shrieks and cries wherever they settle, and befoul the earth beneath them.”¹

No one should doubt that Galileo considered himself to be one of the eagles. While his older, Aristotelian colleagues flocked round their Master's books, the 25-year old sought new paths.

But he, too, found inspiration in a Greek thinker. Galileo's declared model was Archimedes. In addition, he was virtually an Italian, as he had lived and worked in Syracuse, a Greek colony in Sicily. Archimedes combined observation with rigorous deduction and achieved practical results from this. The famous law that bears his name was the result of a knotty problem he was set by the despotic ruler of Syracuse: to calculate the ratio of gold to silver in the king's crown.

By contrast with the logical and speculative Aristotle, Archimedes began harnessing the powerful tool of *mathematics* to calculate and describe physical processes. Galileo was professor of mathematics. He clearly saw that a fundamental uprating of the subject would give qualitatively better natural science.

The establishment at Pisa was interested in the principles of movement, that branch of physics which would later be called *kinematics*. One of his elder colleagues had written a huge work, *On Motion (De motu)* which was circulating in manuscript form. The author was quite clear that Aristotle's doctrine of motion was wanting in certain respects, but even so he could not manage to free himself from tradition.

The young, newly appointed Galileo was not especially impressed with *On Motion*. But instead of going on the offensive against this entire massive bastion of physical theory, he decided to aim at a single, but very moot point, one where observations could easily be made: he would describe a "heavy body" in "natural motion" – what we today would call "free fall".

Aristotle made two fundamental errors in his description of falling objects. Firstly, he maintained that any falling object would achieve a certain fixed speed, and secondly, that such speed was proportional to the weight of the object. Or, to put it another way: every falling object falls with a definite, "in-built" speed, the heavier the object the higher the speed.

Galileo demonstrated the absurdity of this last contention with a simple mental experiment. One takes two stones of similar weight and ties them together – now, all at once, they will fall twice as fast as they would separately! It is also flies in the face of all experience that a sphere weighing one kilo falls one metre in the same time it takes a ten kilo sphere to fall ten metres.

Galileo decide to investigate the matter from basic principles. Presumably he used – as his first biographer states – the obvious place for experiments

in free fall: the famous detached, leaning belfry near the city's cathedral. In contrast to nearly everywhere else in Italy, the cathedral environs were not the city's main meeting place, but lay in peaceful seclusion by the north walls, so the chances of hitting passing townsfolk with falling iron balls was minimal.

He dropped wooden and iron balls, but the results of the experiments were far from conclusive. He could easily see that the balls fell at roughly the same speed, but that the iron ball hit the ground a little before the wooden one. He had no way of making precise observations, no clocks then were accurate enough to measure the fall times.

His observations were good enough to show that Aristotle's theories did not hold water, and Galileo tentatively launched his own. He concluded initially – and wrongly – that a body's falling speed is proportional to its mass density ("specific gravity"), a concept he had studied thoroughly in his work on Archimedes. He also realised that its speed was closely related to the medium it was falling through: an iron ball and a wooden ball might fall at roughly the same speed through air, but in water they behaved quite differently! Archimedes had taught him the concept of buoyancy, and this led him to reject yet another erroneous Aristotelian assumption: that bodies have an in-built "lightness" that operates in opposition to their "weight". The fact that wood floats in water is not due to its "lightness" lifting it up – it is simply that the material has a lower specific gravity than water.

However, for the time being he was saddled with the misconception that a falling body reaches a certain, stable speed of its own accord. It was then totally impossible, with the tools at his disposal, to measure the speed – far less the acceleration – of a sphere dropped from a tower.

Galileo did not only take Archimedes' point of view and argue for practical experiments to rebut Aristotle and inflexible academic thought, he also made sure he provoked his colleagues at Pisa on a more personal level.

Professorship brought with it the duty of donning a certain loose fitting official garb, based on the Roman toga. The young professor of mathematics had little time for the assumed and, to his mind, superficial dignity that this garment bestowed on its wearer. He penned a three-hundred-line lampoon² on the toga in all its essence. Not only could one trip up on such a garment, but as he pointed out, it also swathes the body in an impractical way. All clothing ought to be designed so that men and women could readily obtain an idea of each other's physical attributes, indeed: "it would be best to go about naked"! But worse still was the way the toga's dignity prevented the professors from visiting the brothel. That forced them, quite literally, to take

the matter into their own hands – a pastime that was every bit as sinful as visiting a bordello, but considerably less satisfying.

And so Galileo made his mark as an oppositional paradoxer. It was impossible for him, as yet, to give written vent to this same colourful lack of respect in his own subject. Galileo actually wrote his own version of *On Motion*, but he did not try to get it printed. His free fall experiments were spectacular, but deficient, and it is probably a myth that the other professors and students gathered admiringly at the foot of the tower. There was still too much he did not understand.

From Pisa to Padua

Musician, composer and theoretician, Vincenzo Galilei, had married when he was more than forty years old. In 1591, that family-proud Florentine died at home in Florence. He had a permanent place in musical history, as well as a wife and four children, all of whom except Galileo and his sister Virginia, had no means of support.

The death meant that the young professor took over the responsibility for the entire family – a mother who was sometimes difficult and who was to live for another thirty years, a brother who was a minor and two sisters. His sister Virginia may have just got married, but a most important part of the marriage settlement had not been concluded: Vincenzo had not had the means to pay more than a fraction of the agreed dowry. The balance fell to Galileo – in regular instalments.

His younger sister, Livia, was just thirteen and was sent to a convent for the time being, but the convent cost money too. And his sixteen-year-old brother Michelangelo had, naturally, to continue the musical education he had begun.

As a newly appointed professor of mathematics Galileo earned 60 scudi per annum. It was almost a starvation wage. His colleagues in more prestigious fields were considerably better paid; professors of philosophy might earn up to 300–400 scudi. A really well-known painter could get 50 scudi for a single picture, or even 75 or one hundred in really favourable circumstances. A good doctor also brought in his 300 per annum.

These new responsibilities meant that he had to earn more money. The prospects for an imminent salary increase at Pisa were slender. Nor was the intellectual climate of his toga-clad colleagues especially inspiring with their stagnant Aristotelian dogmatics. Consequently, Galileo was most interested

when a position at the University of Padua became vacant in the autumn of 1592.

Padua is not far inland from Venice, on the Po plain. The university was one of the oldest and most renowned in Italy, and was known as “Il Bo” – “The Bull”, probably after an inn that reputedly stood close by. It was housed in an old palace and its banqueting hall was the scene of disputations and academic ceremonial. And, like Pisa, it had an internal quadrangle, which was surrounded by two storeys of colonnades above which the proud tower of the palace reared over staff and students alike.

From a scientific perspective the fact that Padua possessed Europe’s oldest botanical gardens was of greater importance. Botany (like zoology) was a “progressive” science. The contact with America was a factor that contributed to the undermining of traditional natural history – it proved that there were many animal and plant species which neither Aristotle nor the other ancient authorities had known anything about. When Galileo arrived in the city, the botanical gardens at Padua had just taken delivery of an entirely new American species, which was being grown and observed with great interest. This was *soleanum tuberosum*, as it would later be called – also known as the potato.

The University of Padua was an intellectual powerhouse. This was partly because, as a seat of learning it had not been established by papal or imperial privilege, like most others. It had grown up out of the civic culture of the city and had what can only be called a “liberal profile”. In 1564, Pope Pius IV had decreed that everyone who gained a degree from an Italian university, had to swear an oath of allegiance to Catholic doctrine. However, at Padua the university authorities managed to create loopholes in the provision that enabled northern European – Protestant – students to continue applying for places there.

It was at Padua that Vesalius had laid the foundations of modern anatomy with his controversial dissections, half a century before Galileo came to the city. During Galileo’s time *The Bull* got its famous “anatomical theatre”, complete with tribunes where students and other interested spectators could follow the dissections in detail. No less impressive is the fact that as early as 1678 Padua gave a degree to the world’s first female university undergraduate, the philosopher Elena Lucrezia Cornaro.

Mathematics were another strong point. There was a number of applicants for the chair in mathematics, including the same Magini who a few years earlier had wrested Bologna from Galileo. Once again, Galileo had to count on his Roman contacts, the del Monte brothers. They originally

came from Venice, and had influential friends both there and in Padua. In a concerted effort they managed to secure the post for Galileo – with a salary of 180 scudi, three times the rate at Pisa.

Padua belonged to the Venetian Republic. For centuries that powerful canal city had been laying claim to large areas of the hinterland. Galileo had to move away from his homeland in Tuscany, and as a servant of the state he required the permission of Grand Duke Ferdinando. This was graciously forthcoming.

In one sense Venice was quite similar to Florence: there, too, the golden age of architecture and art was drawing to a close. The city's greatest painter of all, Titian, was dead, after a career that spanned most of the 16th century. But Venice was still a republic, and its style was considerably more sober and civic than the Grand Duke's court. The authorities did not spend money on the ostentatious celebrations that Ferdinando in Florence had gradually become addicted to – preferably with a stage full of “volcanoes” and fire-spitting dragons. The Venetian Senate was more interested in sensible, public projects: the Rialto Bridge – as beautiful as it was practical – across the Canal Grande had just been completed in 1592.

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