radiation are familiar to workers in the terrestrial laboratory. Synchrotron radiation is an example; the bremsstrahlung of electrons, the production of neutral pions in *p-p* collisions, and the annihilation of electron and nucleon pairs are others. Some proposed mechanisms are, and perhaps always will be, purely speculative in the sense that they are not directly observable in the laboratory. The inverse Compton effect, possibly one of the sources of a metagalactic sky glow of hard photons, is in this class. There is little chance that spontaneous creation of matter, even if it occurs in nature, can be observed on a terrestrial scale. And the extreme physical conditions proposed for neutron stars are beyond our ability to reproduce. Only through interpretation of astronomical data can we test the validity of these ideas. The many pictures of the universe given by the vast electromagnetic spectrum are essential to the synthesis of our concepts.

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Our Heritage from Galileo Galilei

Galileo's refusal to rely on authority for scientific truth is a principle we may be in danger of forgetting.

R. E. Gibson

This year we celebrate the 400th anniversary of the birth of two men: William Shakespeare, playwright, of London, and Galileo Galilei, gentleman, of Florence. Both of these men were discerning students of human experience, masters of expression who wove the material they gathered into artistic forms that captivated the interest and excited the admiration of their fellows. Both enjoyed a full measure of recognition and acclaim from their contemporaries.

However, it is hard to find further resemblances between these two men or between the legacies they left the world. Shakespeare stands in history as the supreme product of an age; the fruits of his genius represent the pinnacle of an art—the art of portraying human nature at its noblest and at its weakest through the vehicle of the English language on the dramatic stage. His works are read by every schoolboy today and loved by all devotees of the drama and students of human nature.

Galileo, on the other hand, was a pioneer who blazed the trail to a new age, whose thought, action, and writing laid the foundations for a revolutionary approach to an understanding of nature, and, later, of man. So well were these foundations laid that succeeding generations have built upon them the elegant and viable structure called modern science. Galileo's books are not widely read today; his immortality resides in the growth of our understanding of the world around us.

There is another important point of difference. We know little about the inner life of William Shakespeare; little of the man himself shines through his writings. In contrast, Galileo's writings reveal his mind and soul, his vanity and his wisdom, his humor and his petulance, the ideas and ideals that guided his thought and conduct.

We have, therefore, the opportunity to examine the ideas and principles of one who had to fight to overthrow an outworn academic establishment and to demonstrate to the intellectual world the power of methods we now take for granted. We can compare his principles and practices with our own to see whether modern science is surviving the effects of power and prestige any better than did the system it replaced.

Galileo was born at the right time and in the right environment. This statement may strike many as strange in view of the hidebound outlook of the Italian schoolmen and the attitude of the church. Yet it is hard to find another environment anywhere at that time in which universities such as Padua existed and where wealth was allied with taste and appreciation of genius of all kinds. It was an arena in which Galileo's gifts for the dramatic could find full scope.

Galileo also inherited natural gifts which, appropriately cultivated, endowed him with great intellectual capacity, mechanical ingenuity, artistic taste and skill (he excelled in music and in painting), outstanding powers of expression and, I believe, a sense of humor. He was a man who could have won recognition and fame in almost any walk of life, but who was irresistably drawn to the study of mathe-

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matics and to the observation of nature to provide material for this form of artistic expression. He was, moreover, a man of indomitable will and courage, an adventurer in an age that loved adventure.

Galileo was born in 1564, the year in which Michelangelo died. He came of a noble Florentine house which had once (1300–1450) been rich and powerful but had become so impoverished that Galileo's father, Vincenzio Galilei, a mathematician and musician of some ability, had difficulty in supporting his family of seven. Galileo was educated in the monastery of Vallombrosa, near Florence, where he received a firsthand acquaintance with the best Latin authors and gained considerable proficiency in Greek and logic. His early education laid the foundation for the brilliant style and elegance of his later writings. It is also reputed to have attracted him very strongly towards a religious life—he even joined the novitiate. Both of these results of his early education have significance for an understanding of his subsequent career.

At the age of 17 he entered the University of Pisa as a student of medicine, a career urged upon him by his father. It says much for Vincenzio Galilei that he willingly made great sacrifices to set his brilliant son on the road to a lucrative profession. However, the father's plans for his son were undone when Galileo heard by chance a lecture on geometry by Ricci, a mathematician attached to the Tuscan court and, ironically enough, a friend of Vincenzio's. From then on he made mathematics his chief study. It was just before the Ricci lecture that Galileo had made his famous observation of the swinging of the great hanging lamp in the cathedral at Pisa.

Exhaustion of the family exchequer made it necessary for Galileo to leave Pisa in 1585 at the age of 21 without a degree and to return to Florence to live with his family. He used his time to good account, for in 1588 he came back to Pisa as lecturer in mathematics, already famous for three papers he had written—one on a hydrostatic balance he had invented, one on the properties of the cycloid, and one on the center of gravity of solids. Even at this age his capacity as a thinker was paralleled by his ingenuity as a doer, and both were outstanding. At Pisa, where his salary was approximately $75 per annum, he started his work in dynamics. His popularity with the students, his biting sarcasm, his polished rhetoric, and his experimental attack on their bankrupt Aristotelianism earned him the intense hatred of the local scholars, and he found it advisable to leave Pisa.

Returning for a while to Florence, he continued his studies there until 1592, when, through the influence of his patron Guido Ubaldi, the Marquese del Monte, he was appointed to the chair of mathematics at Padua. Relieved of financial worries, he now had the opportunity to carry on his work in the atmosphere of a first-class university. In the 18 years he spent at Padua he laid the groundwork for his mathematical theories of motion, carried out his experiments in mechanics, gained European fame as a lecturer in a variety of subjects, both theoretical and practical, drew the important distinction between temperature and heat, invented a rudimentary thermometer (thermoscope), and finally brought about that crucial event in the history of science—the improvement of the telescope and its use in exploring the heavens.

Galileo's Telescope

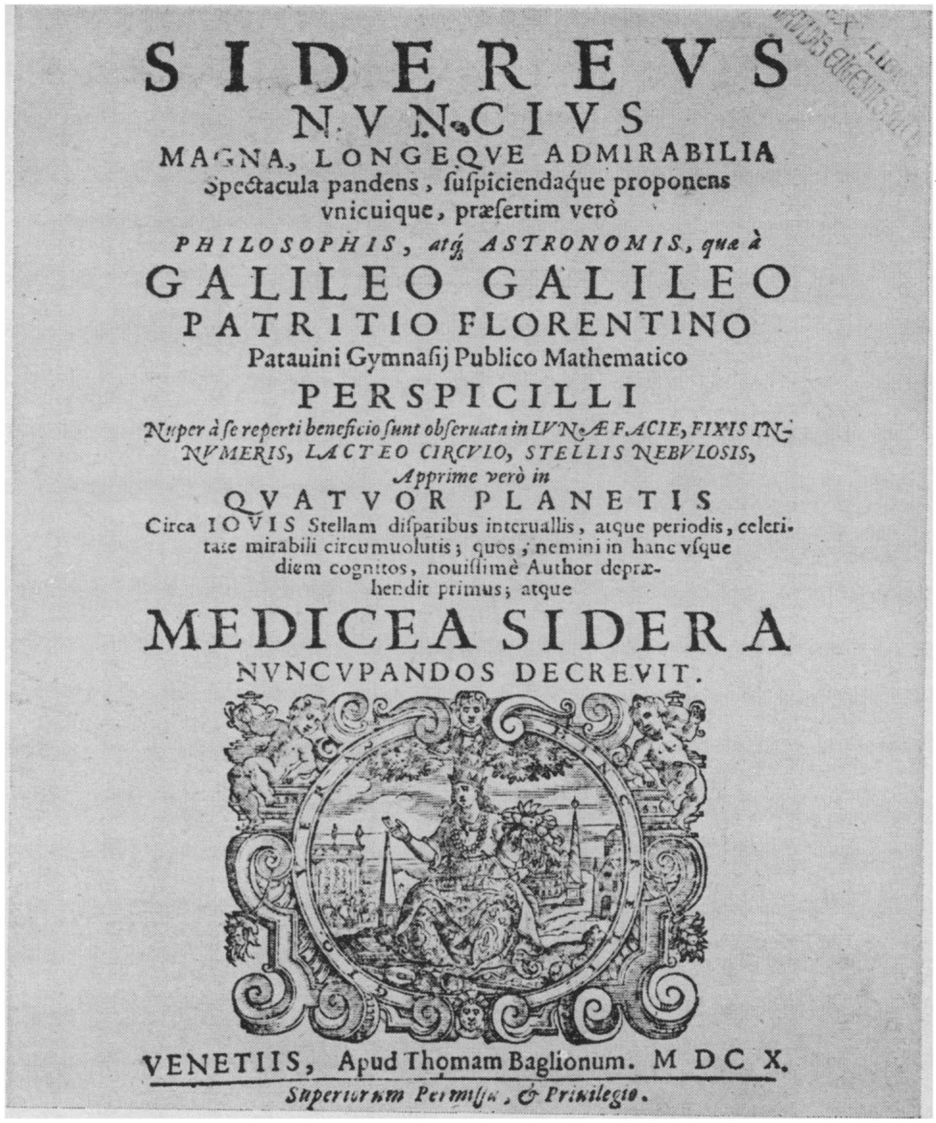
The speed with which Galileo constructed his telescope was astounding. Rumors of Lippershey's invention of a spyglass reached Venice in June of 1609. Galileo at once saw its significance, and after a night's reflection on the principles of refraction, he applied his mechanical ingenuity to make a 3-power magnification telescope. This he improved to give a 32-power magnification, and with the new aid to his senses he immediately started his survey of the heavens. Early in 1610 he published in Venice his *Sidereus Nuncius*, a small work containing a rich harvest of revolutionary astronomical information. It contained enough experimental information to blow sky-high the conventional astronomy of his time. The fact that somewhat less than a year elapsed between Galileo's first hearing of the possibility of a new instrument for observation and the publication of such startling results suggests that he may have been waiting expectantly for this augmentation of his abilities to explore the heavens. Figure 1 is a reproduction of the title page of *Sidereus Nuncius*. It shows concisely the contents of the book and also indicates that false modesty was certainly not one of its author's failings.

At the end of 1610, Galileo left Padua for a professorship at the University of Florence, which offered him lifetime tenure. Within a year he left Florence for a prolonged visit to Rome, where his telescope and his discourses brought him fame, adulation, and the esteem of the pope and princes of church and state. He returned to Florence confident of friendship in high places and obviously pleased by it. He had been appointed by the Grand Duke of Florence to membership in the Academy with a handsome salary. He now felt he could take a firm stand against the Aristotelians who refused to believe the theories of *Sidereus Nuncius* and their implications. He published six letters on solar spots in which he rebutted his detractors and took a firm stand on behalf of the Copernican system. In his lectures to princes and scholars at the Academy, he emphasized the Copernican theory and at the same time sought to bridge the gap between the new concepts and the current interpretation of the Scriptures. In 1615, through his friend Cardinal Robert Bellarmin, Galileo received an unofficial warning to confine his lectures to physics and to avoid theology, since his excursions into the latter subject were giving offense in influential ecclesiastical circles. He did not take the warning too seriously and went to Rome, where he thought he might convince the church authorities by the weight of his arguments and the power of his rhetoric. Disappointment was in store for him. On 24 February 1616, the consulting theologians of the Holy Office declared that the proposition that the sun is immovable in the center of the universe was absurd philosophically and formally heretical. Furthermore, they found the proposition of the diurnal motion of the earth to be "open to the same censure in philosophy and equally erroneous as to faith." Shortly thereafter, Galileo was officially forbidden to "hold, teach or defend" the condemned doctrine. He promised to obey. A month later the Congregation of the Index reiterated the censure of the theologians of Copernicus's great book *On the Revolution of Heavenly Bodies*. It was not, however, declared heretical. It was also understood that the new theory of the solar system could be held as an hypothesis by scholars.

Galileo returned to Florence not ill pleased and, indeed, buoyed up by friendly conversations with notables of the church. However, he spent the next seven years in studious retirement near Florence. At the end of this time (1623) he published *Il Saggiatore*, one of the most brilliant polemical works ever written. It was received with acclaim by ecclesiastical and scientific authorities alike. It seemed that his troubles were over. When he visited Rome the next year he received many tangible and intangible evidences of the pope's esteem. However, he was unsuccessful in having the decree of 1616 revoked.

Trial and Recantation

There now follows the last phase of Galileo's career, a phase with which everyone is familiar. In 1630 he finished writing his great work, *A Dialogue on the Two World Systems*, which, when published in 1632, attracted international attention. It gave, among other things, strong experimental evidence of the truth of the Copernican theory and did more than anything else had to assure the acceptance of this theory. In his foreword, Galileo indicated that he thought the hypothesis of Copernicus was still unproved and took some pains to disguise his real beliefs, but he did not fool the Inquisition. It summoned him to trial and, after threats, secured from him a recantation. It is of interest to note that an important question at issue was the diurnal motion of the earth. Galileo had never been able to produce real solid experimental evidence in support of this view. J. Rose, however, points out (*1*, p. 657) that in his observations of the chandelier in the cathedral at Pisa, he had before his eyes the proof he needed. But it was not until nearly 200 years later that Foucault set up his famous pendulum in the Pantheon in Paris.



SIDEREVS
NVNCIVS
MAGNA, LONGEQVE ADMIRABILIA
Spectacula pandens, ſuſpiciendaque proponens
vnicuique, præſertim verò
PHILOSOPHIS, atq; ASTRONOMIS, quæ à
GALILEO GALILEO
PATRITIO FLORENTINO
Patauini Gymnaſij Publico Mathematico
PERSPICILLI
Nuper à ſe reperti beneficio ſunt obſeruata in LVNÆ FACIE, FIXIS INNVMERIS, LACTEO CIRCVLO, STELLIS NEBVLOSIS,
Apprime verò in
QVATVOR PLANETIS
Circa IOVIS Stellam diſparibus interuallis, atque periodis, celeritate mirabili circumuolutis; quos, nemini in hanc vſque diem cognitos, nouiſſimè Author depræhendit primus; atque
MEDICEA SIDERA
NVNCVPANDOS DECREVIT.
VENETIIS, Apud Thomam Baglionum. M DC X.
Superiorum Permiſſu, & Priuilegio.

Fig. 1. Title page of the first edition of *Sidereus Nuncius*. Translation: "The Starry Messenger. Revealing great, unusual, and remarkable spectacles, opening these to the consideration of every man, and especially of philosophers and astronomers; as observed by Galileo Galilei, Gentleman of Florence, Professor of Mathematics in the University of Padua, with the Aid of a Spyglass lately invented by him, In the surface of the Moon, in innumerable Fixed Stars, in Nebulae, and above all in Four Planets swiftly revolving about Jupiter at differing distances and periods, and known to no one before the author recently perceived them and decided that they should be named The Medicean stars." [F. Hoyle, *Astronomy*, Doubleday, New York, 1962]

The recantation by Galileo has always been a source of concern and dismay to his admirers. However, by the time of the trial, the *Dialogue on the Two World Systems* had spread widely throughout the civilized world and carried his message to thousands. In view of his belief that the truth of nature does not depend on human authority, Galileo may have wondered whether a spectacular martyrdom on his part would have added anything to human knowledge. His contribution had already been made, and nothing could stop it. Furthermore, he still had something else to do—he had to collect into one work his discourses on mechanics and physics in general. His *Dialogue Concerning Two New Sciences* was finished in 1636 and published in Leyden 2 years later. Its impact and influence have been tremendous.

Shortly after his discovery of the diurnal and monthly librations of the moon, an event which is of some interest in connection with modern work on gravity gradient stabilization of earth satellites, Galileo became blind. For five years he continued to work with undiminished powers of mind, dictating correspondence and new ideas to his pupils, Viviani and Torricelli. During this time he received visits from Milton and Descartes, although he was still formally a prisoner of the Inquisition. He died in 1642.

The Christmas after Galileo died, Isaac Newton was born. Thirty-eight years later the Royal Society of London was founded. About this time, the star of science set in Italy, not to rise again until centuries later.

Results of Galileo's Work

In the course of his long and active life Galileo made a large number of practical contributions to the useful arts: the pendulum clock, the telescope, the hydrostatic balance, and the thermometer, as well as instruments for use in civilian and military engineering were the outcome of his perceptive and imaginative mind. He received letters patent from the Doge of Venice granting him a monopoly on the proceeds from some of his inventions. However, it is on his ideas that we wish to dwell, and I cannot do better than quote from E. A. Burtt (*2*, p. 95) in order to summarize his contributions and place them in perspective:

> It is difficult indeed to leave Galileo without pausing a moment to reflect on the simply stupendous achievements of the man. The space at our disposal forbids such supererogatory disquisitions, but just consider that the history of thought must turn to this single individual as the one who, by experimental disproof, overthrew a hoary science, who confirmed by sensible facts a new theory of the universe that hitherto had rested on *a priori* grounds alone, who laid the foundations of the most stupendous intellectual conquest of modern times, the mathematical science of physical nature; and then, as if these accomplishments were not enough, we must turn to him likewise as the philosopher who sufficiently perceived the larger implications of his postulates and methods to present in outline a new metaphysic—a mathematical interpretation of the universe—to furnish the final justification for the onward march of mechanical knowledge. Teleology as an ultimate principle of explanation he set aside, depriving of their foundation those convictions about man's determinative relation to nature which rested upon it. The natural world was portrayed as a vast, self-contained, mathematical machine, consisting of motions of matter in space and time, and man with his purposes, feelings, and secondary qualities was shoved apart as an unimportant spectator and semi-real effect of the great mathematical drama outside. In view of these manifold and radical performances Galileo must be regarded as one of the massive intellects of all time. In every single respect of importance, he broke the ground or otherwise prepared the way for the only two minds in this advancing current of thought comparable to his own—Descartes and Sir Isaac Newton.

Events in the Life of Galileo Galilei

1564	Born 15 Feb. Shakespeare born, Michelangelo died.
1581	Entered University of Pisa.
1585	Left Pisa without degree.
1586	Hydrostatic balance.
1588	Lecturer at Pisa—Parabolic Trajectories.
1592	Padua; experiments in mechanics.
1609	Constructed improved telescope—3×, then 32×.
1610	*Sidereus Nuncius*: moon surface, structure of Milky Way, moons of Jupiter, phases of Venus.
	Left Padua for Florence.
1611	Visit to Rome; exhibited telescope.
1613	Letters on solar spots; attacked doctrine of Aristotle.
1615	Second visit to Rome; warning by Holy Office.
1616	Copernican theory declared unsound; Galileo returned to Florence.
1616–23	Studious retirement near Florence.
1623	*Il Saggiatore*: sun spots and comets.
1630	*Dialogo dei due Massimi Sistemi del Mondo* (published in 1632).
1633	April—trial.
1636	*Dialoghi delle Nuove Scienze* (published in 1638 in Leyden).
1637	Discovery of diurnal and monthly librations of the moon. Became blind.
1642	Died 8 Jan., was buried in Santa Croce; Newton born Christmas Day.
1660	Royal Society of London founded.
1667	Accademia del Cimento ceased.

[*Sources*: J. Rose (*1*); E. A. Burtt (*2*); J. Seeger, *Physics* **5**, fasc. 1, (1963); C. Singer, *A Short History of Scientific Ideas* (Oxford Univ. Press, New York, 1959)]

Methods, Motivation, and Philosophy

If we look into the methods used by Galileo we find that they are the ones used consciously or unconsciously by every sincere practitioner of scientific research from his day to this. Underlying all his thought was the assumption that nature is a simple, orderly system whose every proceeding is thoroughly regular and inexorably necessary. "Nature doth not that by many which may be done by few." Furthermore, his thinking was dominated by the conviction that to understand the pattern of nature we must express observations of it in quantitative terms—nature is the domain of mathematics: "Philosophy is written in that great book which ever lies before our eyes—I mean the Universe—but we cannot understand it if we do not first learn the language and grasp the symbols in which it is written. This book is written in mathematical language." These two assumptions underlie all scientific thought of today, even though we now attack problems in fields where even Galileo feared to tread and use mathematics of which he never dreamed.

His methods depended essentially on a systematic combination of powerful and exact thought and ingenious experiment. Burtt (*2*) analyzes Galileo's methods into three steps, *intuition* or *resolution*, *demonstration*, and *experiment*, using Galileo's own terms. Knowledge of natural phenomena enters our consciousness through our senses, which may be fortified by instruments. By examining this knowledge critically and ensuring that our observations are reproducible by others, we obtain a series of valid experiences. The problem now is to arrange these experiences in a consistent, satisfying pattern which we hope reflects faithfully the pattern of nature.

Galileo's first step of intuition or resolution was to examine the sensory experience of phenomena to isolate the elements in terms of which the phenomena could most easily and completely be translated into mathematical form. This involved the formulation of simple quantitative concepts that could be used in mathematical expressions. These concepts Galileo derived by abstraction from nature itself rather than by application of anthropomorphic intuition. Thus corpuscles (atoms), motions, accelerations, geometric configurations, and masses, became the elements from which his models were made. The second step (demonstration) was to apply mathematical reasoning to combine these elements into patterns that reproduced already familiar phenomena and to extend the reasoning to demonstrate new or more general propositions. As a check on this process, and particularly to convince skeptics, he found it well to devise, where possible, demonstrations whose conclusions could be developed by new experiments. With concepts, principles, and truths so established, he could proceed to more complex related phenomena and then extend his concepts and mathematical laws to explain the evidence of his senses. Galileo followed these three steps, perhaps not realizing that he had set in motion a system full of positive feedbacks in consequence of which the output of the intellectual machine was to increase exponentially for centuries.

The power of Galileo's intellect is nowhere more evident than in his examination of the elementary concepts of qualities of matter and space that formed his basis for comprehensive patterns of understanding. He distinguished between primary qualities of matter and secondary qualities—the former inherent in matter itself, the latter the product of an interaction of the body possessing certain primary qualities with the sense organs of a human or animal observer. Following a close line of reasoning based on these concepts he arrived at the kinetic theory of heat.

I quote his own words as he wrote about the subject in *Il Saggiatore* (*2*, pp. 75–78).

> But first I want to propose some examination of that which we call *heat*, whose generally accepted notion comes very far from the truth if my serious doubts be correct, inasmuch as it is supposed to be a true accident, affection, and quality really residing in the thing which we perceive to be heated. Nevertheless I say, that indeed I feel myself impelled by the necessity, as soon as I conceive a piece of matter or corporeal substance, of conceiving that in its own nature it is bounded and figured in such and such a figure, that in relation to others it is large or small, that it is in this or that place, in this or that time, that it is in motion or remains at rest, that it touches or does not touch another body, that it is single, few, or many; in short by no imagination can a body be separated from such conditions: but that it must be white or red, bitter or sweet, sounding or mute, of a pleasant or unpleasant odour, I do not perceive my mind forced to acknowledge it necessarily accompanied by such conditions; so if the senses were not the escorts, perhaps the reason or the imagination by itself would never have arrived at them. Hence I think that these tastes, odours, colours, etc., on the side of the object in which they seem to exist, are nothing else than mere names, but hold their residence solely in the sensitive body; so that if the animal were removed, every such quality would be abolished and annihilated. . . .
>
> I say that I am inclined sufficiently to believe that heat is of this kind, and that the thing that produces heat in us and makes us perceive it, which we call by the general name fire, is a multitude of minute corpuscles thus and thus figured, moved with such and such a velocity; . . . But that besides their figure, number, motion, penetration, and touch, there is in fire another quality, that is heat—that I do not believe otherwise than I have indicated, and I judge that it is so much due to us that, if the animate and sensitive body were removed, heat would remain nothing more than a simple word.

This was written before the rise and fall of the phlogiston theory and nearly two centuries before Rumford observed the heat generated during the boring of cannon.

Galileo's Legacy

By the example of his life and work Galileo bequeathed to posterity three more intellectual ideals. These are (i) his recognition of the dynamic nature of science; (ii) his faith in the unity of all creation, which led him to look for consistency in all valid knowledge or human experience; and (iii) his passionate antagonism to any kind of dogma based on human authority. I have saved a discussion of these qualities in Galileo for the end because I fear that it is in these areas that we are not paying sufficient attention to preserving the heritage he left the world.

Realizing how much there was to learn and how little he knew, Galileo suggested that it was better sometimes for people "to pronounce that wise, ingenious and modest sentence, 'I know it not' rather than to suffer to escape from their lips and pens all manner of extravagancies." In this he resembled Faraday in "suspending judgement" until systematic knowledge had progressed to a point where it was able to supply a valid and consistent basis for informed judgment. In these days scientists as well as their colleagues in other professions are prone to issue opinions when facts require the phrase "I know it not" to avoid confusion.

The authorities of the church interposed no objection to the Copernican theory of the universe being held as an hypothesis, an intellectual toy to be played with in ivory towers, but they sternly forbade its being taught widely or its implications on religious dogmas being explored. Galileo could not really accept this dichotomy. It seems that he had to develop, at least for himself, a consistent pattern of creation that took into account all knowledge. In particular, he felt compelled to reconcile honestly the intellectual inventory he had acquired through his classical and religious studies with that he had acquired by observation of and reflection on the physical universe. This innate intellectual integrity was, it seems to me, responsible for the trouble he got into with the Inquisition. The attitude of the church, particularly the educated authorities, was friendly to him; his own attitude to the church was that of a faithful son, but a son who had to believe in the essential unity of God and his creation.

This ideal shines through the career of the first great modern scientist. But it is not fashionable now; the present tendency is for the scientific community, now grown powerful, to behave much as the church did in Galileo's time—that is, it permits religious beliefs and the findings of scholarship to be treated as hypotheses but does not attempt to assimilate them with its own theories. And theologians and scholars regard science in the same way.

Criteria of Truth

In his foreword to the *Dialogue concerning the two Chief World Systems*, Einstein (*3*) wrote,

> "The *leitmotif* which I recognize in Galileo's work is the passionate fight against any kind of dogma based on authority. Only experience and careful reflection are accepted by him as criteria of truth."

The insistence on this principle characterized many who preceded and followed Galileo, such as Paracelsus, Agricola, Bruno, Bacon, Newton, Boyle, Hooke, Descartes; indeed, without it the progress of scientific research would have been delayed for centuries. A fruitful scientific investigation almost always starts with a conflict between preconceived notions and a new experience. However, the circumstances under which Galileo lived and worked, his inexorable analysis and ability to devise crucial experiments, coupled with outstanding polemical eloquence, dramatized the casting away of the shackles of human authority as a necessary step toward the discovery of truth.

What has become of this ideal whose pricelessness Galileo appreciated so well? It has been and still is widely accepted in theory, but as Einstein remarks, "We are by no means so far removed from . . . [the] situation [prevailing in Galileo's time] even today as many of us would like to flatter ourselves." Human authority still dominates a large part of our intellectual life.

There are two parts to Einstein's statement, that Galileo waged a war against all kinds of dogma based on human authority, and that he accepted experience and careful reflection as the only criteria of truth. It is to the latter part that we must direct our attention. If we do so the former follows immediately, but "experience and careful reflection" require work—hard unspectacular work. Lazy people prefer to avoid this; they prefer to buy their mental inventory second hand. There is always a strong tendency for humanity at large to invite dogmas based on authority as the easy way of life, and there are always plenty of dogmatists who seek and enjoy the *cathedra* from which their words are accepted without question.

Let me pose a few questions whose answers may indicate where we stand today in the light of Galileo's thinking.

(i) Do we, in our schools and colleges, foster the spirit of inquiry, of skepticism, of adventurous thinking, of acquiring experience and reflecting on it? Or do we place a premium on docility, giving major recognition to the ability of the student to return verbatim in examinations that which he has been fed? Do we watch games or play them?

(ii) Do we regard with satisfaction the increasing deference being paid to scientific "authorities" in matters extending over the whole range of society's activities? Do we take satisfaction in the growing hierarchy of scientists and in the credence given to the opinions of committees of "top-flight" scientists and engineers?

(iii) Are we really disturbed by the increasing concentration of authority over scientific and technical matters in higher levels of national government?

(iv) Are we content with the economic and social theories we have inherited? Are we attempting to synthesize our knowledge of science and technology into a consistent pattern with our use of their products in promoting the welfare of humanity? Are we dominated by dogma based on human authority in these areas?

(v) We place too much emphasis on science in our education; we must return to teaching the humanities. But do we really reflect on what this means? Are we merely attempting to escape the rigorous discipline required by the approach to truth through experience and reflection and to substitute the approach through the doctrines of schoolmen?

(vi) Do we really believe that science is the synthesis of human experience, gathered by all sincere individuals who practice Galileo's methods, or do we look on it as a compromise of human opinions based on the dialectic skill or social and political status of those who hold the opinions?

Galileo's concepts of nature, the universe, and the position of man in the universe strongly influenced the thought of Isaac Newton, giving him a foundation on which to build the master structure. The philosopher John Locke, a friend of Newton's, saw the philosophical implications of the New Science and expressed them clearly. Among the students of Locke's writings was Thomas Jefferson, and the Lockean philosophy is strongly reflected in the Declaration of Independence, the charter of a new social order far removed from Florence and Padua. On the occasion of the 400th anniversary of his birth, we who enjoy this new society have, therefore, special reason to cherish the memory of the gentleman of Florence.

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Savants, Sandwiches, and Space Suits

Universities engaged in research and development must find ways to protect their intellectual "property."

Joe H. Munster, Jr., and Justin C. Smith

A year ago a senior medical researcher stated that when he left his present post all he expected to leave behind was his reprints. That was a year ago. Today the law might take a less charitable view of his right to do so. Sponsors of supported research, both public and private, are taking an increasingly keen interest in what they are receiving in return for their support. They are seriously concerned with the protection of what they regard as their "property." That property, as recent cases indicate, is not the same thing as the end product. It is the researcher's knowledge. This is not necessarily arcane scientific knowledge—it may be knowledge about something as plebeian and commonplace as the method of operating a hamburger stand. The individual possessing the knowledge may not even be a researcher, as the term is generally used.

Time marches on. The image of the researcher, and particularly that of the academic researcher, has changed. There was a time when the idea of the research scholar implied white hair, absent-mindedness, mussed and mismatched clothes, and an interest in nothing but the ivory-towered solitude of serene contemplation, with no intrusions from such places as the business world. Now the research scholar is a smartly dressed individual working in a stainless steel laboratory and usually not only well acquainted with what is going on in trade but also keenly interested in current developments in the business community.

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