

LEONARDO DA VINCI: UNIVERSAL MAN OF THE RENAISSANCE

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| 1452 | Born |
| 1472 | Admitted to Florentine painters' guild |
| 1482–1499 | In service of Ludovico Sforza of Milan |
| 1516 | Entered service of Francis I of France |
| 1519 | Died |

More than any other figure, Leonardo da Vinci is commonly regarded as the exemplar of that uniquely Renaissance ideal *uomo universale*, the universal man.

Leonardo, the spoiled, loved, and pampered illegitimate son of a well-to-do Florentine notary, was born in 1452 at the very midpoint of Florence's magnificent Renaissance century, the Quattrocento. The boy grew up at his father's country home in the village of Vinci. His precocious genius and his talent for drawing led his father to apprentice Leonardo to the artist Verrocchio in Florence. While Verrocchio is best remembered as a sculptor, it should be noted that he was, like most Florentine artists of his time, a versatile master of other artistic crafts, and that his *bottega*—like Ghiberti's earlier or Michelangelo's later—was not only a lively school of craftsmanship and technique but a place where people gathered to gossip and talk over a wide range of subjects. Here the young Leonardo's multiple talents bloomed.

At the age of twenty, Leonardo was admitted to the painters' guild and soon after set up his own shop and household. He was well enough received, and commissions came his way. But, for reasons that are not entirely clear, he seems not to have been marked for the lavish patronage of the Medici family—as were so many of his fellow artists—or of any other great Florentine houses. The fashion of the moment preferred those artists like Alberti and Botticelli who mingled learned humanism with their art and could converse in Latin with the humanists, poets, and philosophers who dominated the intel-

lectual scene in Florence. But Leonardo knew no Latin. His education consisted only of apprenticeship training and beyond that a hodgepodge of self-instruction directed to his own wide-ranging interests, in some areas profound and original, in others hopelessly limited and naive. It is also possible that Leonardo may simply have set himself apart from the circle of his fellow artists and their patrons. There are hints of alienation and jealousy and even a vaguely worded reference to a homosexual charge against him that was brought before a magistrate and then dropped. But it is most likely that Leonardo's own restless curiosity was already carrying him beyond the practice of his art.

In 1482 Leonardo left Florence for Milan and the court of its lord, Ludovico Sforza, one of the most powerful princes of Italy. In the letter Leonardo wrote commending himself to Ludovico, which has been preserved, he described himself as a military architect, siege and hydraulic engineer, ordnance and demolition expert, architect, sculptor, and painter; he ended the letter, "And if any one of the above-named things seems to anyone to be impossible or not feasible, I am most ready to make the experiment in your park, or in whatever place may please your Excellency, to whom I commend myself with the utmost humility."¹ Humility indeed! The universal man had declared himself.

Leonardo spent the next seventeen years—the most vigorous and productive of his life—at the court of Milan. He painted *The Last Supper* (1495–1497) for the Dominican Convent of Santa Maria delle Grazie. He conceived and created the model for what might well have been the world's greatest equestrian statue; but the statue, memorializing Ludovico Sforza's father, the old soldier-duke Francesco, was never cast, and the model was destroyed. In addition, Leonardo created gimcrackery for court balls and fêtes—costumes, jewelry, scenery, engines, floats, spectacles. But increasingly he was occupied with studies of a bewildering variety of subjects. The notebooks he kept reveal drawings and notes on the flight of birds and the possibility of human flight; military engineering, tanks, submarines, exploding shells, rapid-firing artillery pieces, and fortifications; bold schemes for city planning and hydraulic engineering; plans for machinery of every sort, pulleys, gears, self-propelled vehicles, a mechanical clock, and a file cutter; detailed studies of plant, animal, and human anatomy that go well beyond the needs of an artist; a complete treatise on painting and another on the comparison of the arts. Despite the fact that much of this body of work—including a treatise on perspective that was reputed to be far in advance of other such works—was scat-

¹Quoted in E. G. Holt (ed.), *A Documentary History of Art* (New York: Doubleday, 1957), vol. I, pp. 273–75.

tered and lost, some seven thousand pages have survived, all written in a code-like, left-handed mirror script.

Leonardo's handwriting is of particular interest, for it is indicative of a special side of his nature—almost obsessively secretive, aloof, touchy, and suspicious of others. These qualities are part of the traditional image of Leonardo that has been passed down to us, beginning with his earliest biography, by his younger contemporary Vasari.

In Praise of Leonardo

GIORGIO VASARI

*Giorgio Vasari (1511–1574) was himself something of a universal man. He was an artist of more than middling ability who worked all over Italy. He was also a respected functionary, the familiar of popes, princes, and dignitaries, as well as artists and scholars. But his most important achievement was his book *Lives of the Most Eminent Painters, Sculptors and Architects from Cimabue until Our Own Time*, the first edition published in Florence in 1550. Wallace K. Ferguson has called it “a masterpiece of art history.”² In fact, the book is more than a masterpiece of art history, for it virtually created the concept of art history itself.*

Vasari introduces “our present age” with his treatment of Leonardo. But this biography, despite its extravagant praise of Leonardo’s genius, is seriously limited. Vasari had access to many of Leonardo’s notes, even some that we no longer have, but he was more familiar with the art and artists of Tuscany. It is clear that he had not actually seen several of Leonardo’s most important works, in Milan and elsewhere. And much of the information he provided on Leonardo’s life was nothing more than current rumor or gossip about him. Vasari, furthermore, was himself a pupil and lifelong admirer of Leonardo’s great contemporary Michelangelo (1475–1564), and it was Vasari’s thesis that the whole tradition of Italian art reached its fulfillment in Michelangelo. It might be recalled also that Michelangelo despised Leonardo; they had at least one nasty quarrel. And Michelangelo was fond of saying that Leonardo was a technically incompetent craftsman who could not complete the projects he began. Whether by design or not, this charge became the main line of criticism in Vasari’s biography of Leonardo, and it has persisted alongside Leonardo’s reputation as an enigmatic genius.

*We look now at Vasari’s account from *Lives of the Most Eminent Painters, Sculptors and Architects*.*

The greatest gifts are often seen, in the course of nature, rained by celestial influences on human creatures; and sometimes, in supernatural fashion, beauty, grace, and talent are united beyond measure in one single person, in a manner that to whatever such an one turns his attention, his every action is so divine, that, surpassing all other men, it makes itself clearly known as a thing bestowed by God (as it is), and not acquired by human art. This was seen by all mankind in Leonardo da Vinci, in whom, besides a beauty of body never sufficiently extolled, there was an infinite grace in all his actions; and so great was his genius, and such its growth, that to whatever difficulties he turned

²In *The Renaissance in Historical Thought: Five Centuries of Interpretation* (Boston: Houghton Mifflin, 1948), p. 60.

his mind, he solved them with ease. In him was great bodily strength, joined to dexterity, with a spirit and courage ever royal and magnanimous; and the fame of his name so increased, that not only in his lifetime was he held in esteem, but his reputation became even greater among posterity after his death.

Truly marvellous and celestial was Leonardo, the son of Ser Piero da Vinci; and in learning and in the rudiments of letters he would have made great proficience, if he had not been so variable and unstable, for he set himself to learn many things, and then, after having begun them, abandoned them. Thus, in arithmetic, during the few months that he studied it, he made so much progress, that, by continually suggesting doubts and difficulties to the master who was teaching him, he would very often bewilder him. He gave some little attention to music, and quickly resolved to learn to play the lyre, as one who had by nature a spirit most lofty and full of refinement; wherefore he sang divinely to that instrument, improvising upon it. Nevertheless, although he occupied himself with such a variety of things, he never ceased drawing and working in relief, pursuits which suited his fancy more than any other. Ser Piero, having observed this, and having considered the loftiness of his intellect, one day took some of his drawings and carried them to Andrea del Verrocchio, who was much his friend, and besought him straitly to tell him whether Leonardo, by devoting himself to drawing, would make any proficience. Andrea was astonished to see the extraordinary beginnings of Leonardo, and urged Ser Piero that he should make him study it; wherefore he arranged with Leonardo that he should enter the workshop of Andrea, which Leonardo did with the greatest willingness in the world. And he practised not one branch of art only, but all those in which drawing played a part; and having an intellect so divine and marvellous that he was also an excellent geometrician, he not only worked in sculpture, making in his youth, in clay, some heads of women that are smiling, of which plaster casts are still taken, and likewise some heads of boys which appeared to have issued from the hand of a master; but in architecture, also, he made many drawings both of ground-plans and of other designs of buildings; and he was the first, although but a youth, who suggested the plan of reducing the river Arno to a navigable canal from Pisa to Florence. He made designs of flour-mills, fulling-mills, and engines, which might be driven by the force of water: and since he wished that his profession should be painting, he studied much in drawing after nature. . . . He was continually making models and designs to show men how to remove mountains with ease, and how to bore them in order to pass from one level to another; and by means of levers, windlasses, and screws, he showed the way to raise and draw great weights, together with methods for emptying harbours, and pumps for removing water from low places, things which his brain never ceased from devising;

and of these ideas and labours many drawings may be seen, scattered abroad among our craftsmen; and I myself have seen not a few. . . .

He was so pleasing in conversation, that he attracted to himself the hearts of men. And although he possessed, one might say, nothing, and worked little, he always kept servants and horses, in which latter he took much delight, and particularly in all other animals, which he managed with the greatest love and patience; and this he showed when often passing by the places where birds were sold, for, taking them with his own hand out of their cages, and having paid to those who sold them the price that was asked, he let them fly away into the air, restoring to them their lost liberty. For which reason nature was pleased so to favour him, that, wherever he turned his thought, brain, and mind, he displayed such divine power in his works, that, in giving them their perfection, no one was ever his peer in readiness, vivacity, excellence, beauty, and grace.

It is clear that Leonardo, through his comprehension of art, began many things and never finished one of them, since it seemed to him that the hand was not able to attain to the perfection of art in carrying out the things which he imagined; for the reason that he conceived in idea difficulties so subtle and so marvellous, that they could never be expressed by the hands, be they ever so excellent. And so many were his caprices, that, philosophizing of natural things, he set himself to seek out the properties of herbs, going on even to observe the motions of the heavens, the path of the moon, and the courses of the sun. . . .

He began a panel-picture of the Adoration of the Magi, containing many beautiful things, particularly the heads, which was in the house of Amerigo Benci, opposite the Loggia de' Peruzzi; and this, also, remained unfinished, like his other works.

It came to pass that Giovan Galeazzo, Duke of Milan, being dead, and Lodovico Sforza raised to the same rank, in the year 1494,³ Leonardo was summoned to Milan in great repute to the Duke, who took much delight in the sound of the lyre, to the end that he might play it: and Leonardo took with him that instrument which he had made with his own hands, in great part of silver, in the form of a horse's skull—a thing bizarre and new—in order that the harmony might be of greater volume and more sonorous in tone; with which he surpassed all the musicians who had come together there to play. Besides this, he was the best improviser in verse of his day. The Duke, hearing the marvellous discourse of Leonardo, became so enamoured of his genius, that it was something incredible: and he prevailed upon him by entreaties to paint an altar-panel containing a Nativity, which was sent by the Duke to the Emperor.

³The date was actually 1482.

He also painted in Milan, for the Friars of S. Dominic, at S. Maria delle Grazie, a Last Supper, a most beautiful and marvellous thing; and to the heads of the Apostles he gave such majesty and beauty, that he left the head of Christ unfinished, not believing that he was able to give it that divine air which is essential to the image of Christ.⁴ This work, remaining thus all but finished, has ever been held by the Milanese in the greatest veneration, and also by strangers as well; for Leonardo imagined and succeeded in expressing that anxiety which had seized the Apostles in wishing to know who should betray their Master. . . .

While he was engaged on this work, he proposed to the Duke to make a horse in bronze, of a marvellous greatness, in order to place upon it, as a memorial, the image of the Duke.⁵ And on so vast a scale did he begin it and continue it, that it could never be completed. And there are those who have been of the opinion (so various and so often malign out of envy are the judgments of men) that he began it with no intention of finishing it, because, being of so great a size, an incredible difficulty was encountered in seeking to cast it in one piece; and it might also be believed that, from the result, many may have formed such a judgment, since many of his works have remained unfinished. But, in truth, one can believe that his vast and most excellent mind was hampered through being too full of desire, and that his wish ever to seek out excellence upon excellence, and perfection upon perfection, was the reason of it. "Tal che l'opera fosse ritardata dal desio,"⁶ as our Petrarca has said. And, indeed, those who saw the great model that Leonardo made in clay vow that they have never seen a more beautiful thing, or a more superb; and it was preserved until the French came to Milan with King Louis of France, and broke it all to pieces.⁷ Lost, also, is a little model of it in wax, which was held to be perfect, together with a book on the anatomy of the horse made by him by way of study.

He then applied himself, but with greater care, to the anatomy of man, assisted by and in turn assisting, in this research, Messer Marc' Antonio della Torre, an excellent philosopher, who was then lecturing at Pavia, and who wrote of this matter; and he was one of the first (as I have heard tell) that began to illustrate the problems of medicine with the doctrine of Galen, and to throw true light on anatomy, which up to that time had been wrapped in the thick and gross darkness of ignorance. And in this he found marvellous aid in the brain, work, and hand of Leonardo, who made a book drawn in red chalk, and

⁴The head of Christ was finished, along with the rest of the painting. Vasari was repeating gossip and had not seen the work.

⁵Rather of the Duke's father, Francesco, the founder of the Sforza dynasty.

⁶"So that the work was hindered by the very desire of it."

⁷Louis XII of France. The incident of the model's destruction took place during the French occupation of Milan in 1499.

annotated with the pen, of the bodies that he dissected with his own hand, and drew with the greatest diligence; wherein he showed all the frame of the bones; and then added to them, in order, all the nerves, and covered them with muscles; the first attached to the bone, the second that hold the body firm, and the third that move it; and beside them, part by part, he wrote in letters of an ill-shaped character, which he made with the left hand, backwards; and whoever is not practised in reading them cannot understand them, since they are not to be read save with a mirror. . . .

With the fall of Ludovico Sforza and the French occupation of Milan in 1499, the artist returned to Florence.

Leonardo undertook to execute, for Francesco del Giocondo, the portrait of Mona Lisa, his wife; and after toiling over it for four years, he left it unfinished; and the work is now in the collection of King Francis of France, at Fontainebleau. In this head, whoever wished to see how closely art could imitate nature, was able to comprehend it with ease; for in it were counterfeited all the minutenesses that with subtlety are able to be painted. . . .

By reason, then, of the excellence of the works of this divine craftsman, his fame had so increased that all persons who took delight in art—nay, the whole city of Florence—desired that he should leave them some memorial, and it was being proposed everywhere that he should be commissioned to execute some great and notable work, whereby the commonwealth might be honoured and adorned by the great genius, grace, and judgment that were seen in the works of Leonardo. And it was decided between the Gonfalonier⁸ and the chief citizens, the Great Council Chamber having been newly built . . . and having been finished in great haste, it was ordained by public decree that Leonardo should be given some beautiful work to paint; and so the said hall was allotted to him by Piero Soderini, then Gonfalonier of Justice. Whereupon Leonardo, determining to execute this work, began a cartoon in the Sala del Papa, an apartment in S. Maria Novella, representing the story of Niccolò Piccinino,⁹ Captain of Duke Filippo of Milan; wherein he designed a group of horsemen who were fighting for a standard, a work that was held to be very excellent and of great mastery, by reason of the marvellous ideas that he had in composing that battle. . . . It is said that, in order to draw that cartoon, he made a most ingenious stage, which was raised by contracting it and lowered

⁸The title of the chief magistrate of Florence.

⁹A mercenary commander who had worked for Florence.

by expanding. And conceiving the wish to colour on the wall in oils, he made a composition of so gross an admixture, to act as a binder on the wall, that, going on to paint in the said hall, it began to peel off in such a manner that in a short time he abandoned it, seeing it spoiling.¹⁰ . . .

He went to Rome with Duke Giuliano de' Medici, at the election of Pope Leo,¹¹ who spent much of his time on philosophical studies, and particularly on alchemy; where, forming a paste of a certain kind of wax, as he walked he shaped animals very thin and full of wind, and, by blowing into them, made them fly through the air, but when the wind ceased they fell to the ground. . . .

He made an infinite number of such follies, and gave his attention to mirrors; and he tried the strangest methods in seeking out oils for painting, and varnish for preserving works when painted. . . . It is related that, a work having been allotted to him by the Pope, he straightway began to distil oils and herbs, in order to make the varnish; at which Pope Leo said: "Alas! this man will never do anything, for he begins by thinking of the end of the work, before the beginning."

There was very great disdain between Michelagnolo Buonarroti and him, on account of which Michelagnolo departed from Florence, with the excuse of Duke Giuliano, having been summoned by the Pope to the competition for the façade of S. Lorenzo. Leonardo, understanding this, departed and went into France, where the King, having had works by his hand, bore him great affection; and he desired that he should colour the cartoon of S. Anne, but Leonardo, according to his custom, put him off for a long time with words.

Finally, having grown old, he remained ill many months, and, feeling himself near to death, asked to have himself diligently informed of the teaching of the Catholic faith. . . . [He] expired in the arms of the King, in the seventy-fifth year of his age.¹²

Leonardo the Scientist

JOHN HERMAN RANDALL JR.

From Vasari's time to the present, there has clung to the image of Leonardo da Vinci a kind of Faustian quality, linking him to the origins of modern science. Throughout his life, and increasingly from middle age on, Leonardo was preoccu-

¹⁰Michelangelo was assigned a companion panel and also abandoned his work on it before it was completed.

¹¹Pope Leo X, the former Giovanni Cardinal de' Medici.

¹²Vasari is inaccurate. In the year Leonardo died, 1519, he actually was sixty-seven.

pieced with technical studies and scientific experiments, often to the detriment of his art. But the judgments of modern scholars on "Leonardo the scientist" are much more varied and more circumspect than those upon "Leonardo the artist."

We turn first to the views of a distinguished philosopher and historian of science, especially medieval and Renaissance science, the longtime Columbia University professor of philosophy John Herman Randall Jr. This selection is from his article "The Place of Leonardo da Vinci in the Emergence of Modern Science."

Leonardo was not himself a scientist. "Science" is not the hundred-odd aphorisms or "pensieri" that have been pulled out of his Codici and collected, by Richter, Solmi, and others. "Science" is not oracular utterances, however well phrased; it is not bright ideas jotted down in a notebook. "Science" is systematic and methodical thought. . . .

"Science" is not just the appeal to experience, though it involves such an appeal, as Leonardo stated in answering those critics who had censured him as a mere empiric: "If I could not indeed like them cite authors and books, it is a much greater and worthier thing to profess to cite experience, the mistress of their masters." "Science" is not the mere rejection of authority, the case for which is well put by Leonardo: "He who argues by citing an authority is not employing intelligence but rather memory." . . .

It is true that during Leonardo's youth—the second half of the Quattrocento—the intellectual influence of the non-scientific humanists had been making for a kind of St. Martin's summer of the "authority" of the ancients, and that his life coincides with this rebirth of an authoritarian attitude toward the past. Leonardo's protests were magnificent, and doubtless pertinent. But they are not enough to constitute "science." "Science" is not merely fresh, first-hand observation, however detailed and accurate.

Above all, "science" is not the intuitions of a single genius, solitary and alone, however suggestive. It is cooperative inquiry, such as had prevailed in the Italian schools from the time of Pietro d'Abano (d.1315; his *Conciliator* appeared earlier)—and such as was to continue till the time of Galileo—the cumulative cooperative inquiry which actually played so large a part in the emergence of modern science. . . .

In practice, Leonardo always becomes fascinated by some particular problem—he has no interest in working out any systematic body of knowledge. His artist's interest in the particular and the concrete, which inspires his careful, precise and accurate observation, is carried further by his inordinate curiosity into a detailed analytic study of the factors involved. His thought seems always to be moving from the particularity of the painter's experience to the universality of intellect and science, without ever quite getting there. . . .

No evidence has ever been offered that anybody in the sixteenth century capable of appreciating scientific ideas ever saw the Codici of Leonardo. . . . But since the scientific ideas expressed therein were all well-known in the universities of Leonardo's day, and were accessible in much more elaborated form in the books the scientists were reading, there seems to be no "problem" of tracing any presumed "influence" of Leonardo on the development of sixteenth-century scientific thought in Italy.

The *Trattato de la Pittura, or Paragone*, was not printed until 1651, but its existence in manuscript form suggests that it had been read much earlier by the Urbino circle. It was put together from various manuscripts of Leonardo by an editor whose identity is not known, but who seems to have been responsible for its systematic organization—an organization which later editors have uniformly tried to improve upon.

With Leonardo's anatomical studies, the story is somewhat different. There is no evidence that Vesalius¹³ ever actually saw his drawings; but in view of the marked similarities between them and his own much more systematically planned and organized series of drawings, it is difficult to think that he did not. . . .

Turning now from the things that Leonardo, despite all the adulations of his genius, was clearly not, let us try to state what seems to have been his real genius in scientific matters. During the Renaissance, as a result of the surprising dissolution of the rigid boundaries which had previously kept different intellectual traditions, as it were, in watertight compartments, the many different currents of thought which had long been preparing and strengthening themselves during the Middle Ages managed to come together, and to strike fire. The explanation of this phenomenon can ultimately be only sociological—the breaking down of the fairly rigid boundaries that had hitherto shut off one discipline and one intellectual tradition from another. Whatever its cause, the confluence of many different intellectual traditions in the fertile, all-too-fertile mind of Leonardo renders his views an unusually happy illustration of the way in which very diverse intellectual traditions managed during the Renaissance to unite together to create what we now call "modern science."

There is first the "scientific tradition," the careful, intelligent, cooperative and cumulative criticism of Aristotelian physics, which began with William of Ockham.¹⁴ . . . In his reading Leonardo was in touch with this scientific tradition, as Duhem¹⁵ has shown.

There is secondly Leonardo's enthusiasm for mathematics, which

¹³The Flemish anatomist at the University of Padua who in 1543 published the first modern, scientific descriptive treatise on human anatomy.

¹⁴The important nominalist philosopher of the early fourteenth century.

¹⁵The nineteenth-century French physicist and philosopher.

goes far beyond its obvious instrumental use. It is very hard to assay the precise sense in which Leonardo thought of mathematics as the alphabet of nature: in this area much work remains to be done. There seems to be in Leonardo no trace of the popular contemporary Pythagoreanism or Platonism. If we examine Leonardo's conception of mathematics as depicted in his drawings, not as inadequately stated in his prose, we find that it differs markedly from the static and very geometrical notion of Dürer.¹⁶ It is movement, not geometrical relations, that Leonardo is trying to capture. There is much in his drawings that suggests a world envisaged in terms of the calculus—like the world of Leibniz¹⁷—rather than in terms of the purely geometrical vision of the Greek tradition. In his mathematical vision of the world, Leonardo seems to belong to the realm of “dynamic” and “Faustian” attitudes, rather than to the static geometrical perfection of Greek thought.

There is thirdly the tradition of what Edgar Zilsel has called the “superior craftsman”—the man who is not afraid to take an idea and try it out, to experiment with it. . . . As a pupil of Verrocchio [Leonardo] had no fastidious objections to sully his hands with “experiment.” This habit of Leonardo's of descending from the academic cathedra and actually trying out the ideas of which he read had broad repercussions: it is one of the activities of Leonardo that seems to have become generally known, and to have awakened emulation. The consequences of Leonardo's willingness to experiment are to be found in the “practical geometry” of Tartaglia, the greatest of the sixteenth-century Italian mathematicians. Galileo, of course, was in this tradition of the “practical geometers”; he too was an indefatigable inventor. Indeed, Leonardo can fairly claim to belong not to the line of scientists but to the noble tradition of the inventors. . . .

Many of Leonardo's aphorisms treat the matter of the proper intellectual method. He has much to say on the relation between “reason” and “experience,” and what he says used to lead commentators to impute to him the anticipation of Francis Bacon's “inductive method”—God save the mark, as though that had anything to do with the method employed by the pioneering scientists of the seventeenth century!

Neither experience alone nor reason alone will suffice. “Those who are enamored of practice without science are like the pilot who boards his ship without helm or compass, and who is never certain where he is going.” On the other hand, pure reasoning is without avail: “Should you say that the sciences which begin and end in the mind have achieved truth, that I will not concede, but rather deny for many

¹⁶The great German artist, a contemporary of Leonardo.

¹⁷The great German philosopher and mathematician of the seventeenth century who shares with Newton the discovery of the calculus.

reasons; and first, because in such mental discourse there occurs no experience, without which there is no certainty to be found."

But Leonardo does not bother to give any precise definition of what he means by his key terms, "experience," "reason," "certainty," or "truth." Certainty depends on "experience," but "there is no certainty where one of the mathematical sciences cannot apply, or where the subject is not united with mathematics." And—maxim for all inventors!—"Mechanics is the paradise of the mathematical sciences, because in it they come to bear their mathematical fruits." . . .

These aphorisms as to the relation between reason and experience are no doubt rhetorically effective. But we have only to compare such vague utterances with the very detailed analyses of precisely the same methodological relation which were being carried out at this very time in the Aristotelian schools of the Italian universities to realize the difference between an artist's insights and the scientist's analysis.

Leonardo was above all else the anatomist of nature. He could see, and with his draughtsmanship depict clearly, the bony skeleton of the world—the geological strata and their indicated past. He could also see everywhere nature's simple machines in operation—in man and in the non-human world alike. . . .

As a genuine contributor, then, to the descriptive sciences, Leonardo reported with his pencil fundamental aspects of nature the great machine—in anatomy, geology, and hydrostatics. As a writer rather than as a graphic reporter, Leonardo shows himself an extremely intelligent reader. But he was clearly never so much the scientist as when he had his pencil in hand, and was penetrating to the mechanical structure of what he was observing.

Leonardo the Technologist

LADISLAO RETI

A substantial group of modern scholars agrees with Randall. Some, however, do not. In the following selection, we will sample the views of one of them, Ladislao Reti, a historian of science and medicine and an authority on Leonardo's scientific and technical manuscripts. Reti not only attaches more importance to Leonardo's scientific work than does Randall; he vigorously denies Randall's charges that Leonardo failed to exhibit a sustained, systematic body of scientific thought; that he stood alone outside the tradition of science; that he failed to develop a methodological terminology; and that he failed to influence the evolution of science beyond his own time. But most of all, Reti disputes Randall's view that science is abstract conception. Rather, he takes the position that science must be the accumulation of

particular observations and applications. Reti views "Leonardo the scientist" as "Leonardo the technologist," and he insists that a technologist of such brilliance and inventiveness as Leonardo cannot be so readily dismissed. "The greatest engineer of all times" surely deserves a place in the history of science.

Varied as Leonardo's interests were, statistical analysis of his writings points to technology as the main subject. As was acutely pointed out by Bertrand Gille in a recent book, judging by the surviving original documents, Leonardo's *métier* was rather an engineer's than an artist's.

However we may feel about this opinion, it is disturbing to take an inventory of Leonardo's paintings, of which no more than half a dozen are unanimously authenticated by the world's leading experts.

Contrast this evident disinclination to paint with the incredible toil and patience Leonardo lavished on scientific and technical studies, particularly in the fields of geometry, mechanics, and engineering. Here his very indulgence elicited curious reactions from his contemporaries and in the minds of his late biographers. They regretted that a man endowed with such divine artistic genius should waste the precious hours of his life in such vain pursuits. And, of course, as the well-known episodes of his artistic career testify, this exposed him not only to criticism but also to serious inconveniences.

But were Leonardo's nonartistic activities truly marginal?

Documentary evidence proves that every official appointment refers to him not only as an artist but as an engineer as well.

At the court of Ludovico il Moro he was *Ingeniarius et pinctor*.¹⁸ Cesare Borgia called him his most beloved *Architecto et Engengnero Generale*.¹⁹ When he returned to Florence he was immediately consulted as military engineer. . . . Louis XII called him *nostre chier et bien amé Léonard da Vincy, nostre peintre et ingénieur ordinaire*.²⁰ Even in Rome, despite the pope's famous remark on hearing of Leonardo's experiments with varnishes preparatory to beginning an artistic commission, Leonardo's duties clearly included technical work, as is documented by three rough copies of a letter to his patron Giuliano de' Medici. Nor was his position different when he went to France at the invitation of Francis I. The official burial document calls him *Lionard de Vincy, noble millanois, premier peintre et ingénieur et architecte du Roy, mescanichien d'Etat, et anchien directeur du peinture du Duc de Milan*.²¹

We can thus see that Leonardo had a lively interest in the me-

¹⁸Engineer and painter.

¹⁹Architect and Engineer-General.

²⁰Our dear and well-loved Leonardo da Vinci, our painter and engineer ordinary.

²¹Leonardo da Vinci, Milanese nobleman, first painter and engineer and architect of the King, state technician, and former director of painting of the Duke of Milan.

chanical arts and engineering from his earliest youth, as evidenced by the oldest drawing in the Codex Atlanticus, to the end of his industrious life. Thousands of his drawings witness to it, from fleeting sketches (though always executed with the most uncanny bravura) to presentation projects finished in chiaroscuro wash. Often these sketches and drawings are accompanied by a descriptive text, comments, and discussion.

The drawings and writings of Leonardo on technical matters, though scattered throughout the notebooks and especially in the Codex Atlanticus (a true order probably never existed nor did the author attempt to make one), represent an important and unique source for the history of technology. . . .

It is far from my intention and beyond my possibilities to discuss Leonardo's technology as a whole on this occasion. Enough is said when we remember that there is hardly a field of applied mechanics where Leonardo's searching mind has left no trace in the pages of his notebooks. To illustrate Leonardo's methods I shall limit myself to discussing some little-known aspects of how he dealt with the main problem of technology, the harnessing of energy to perform useful work.

At the time of Leonardo the waterwheel had been improved and in some favored places wind was used to grind corn or pump water. But the main burden of human industry still rested on the muscle power of man or animal. Little thought was given to how this should be used. Animals were attached to carts or traction devices; fortunately collar harness was already in use, multiplying by five the pulling strength of the horse. Men worked tools by hand, turned cranks, or operated treadmills. Of course, power could be gained, sacrificing time, with the help of levers, screws, gears, and pulleys. Little attention was given to the problems of friction, strength of materials, and to the rational development of power transmission. At least this is the picture suggested by studying the few manuscripts that precede Leonardo, devoted to technological matters.

Leonardo's approach was fundamentally different. He firmly believed that technological problems must be dealt with not by blindly following traditional solutions but according to scientific rules deduced from observation and experiment.

When Leonardo searched for the most efficient ways of using the human motor, the force of every limb, of every muscle, was analyzed and measured. Leonardo was the first engineer who tried to find a quantitative equivalent for the forms of energy available.

In MS H (written c. 1494) on folios 43 v and 44 r (Figs. 1 and 2) there are two beautiful sketches showing the estimation of human muscular effort with the help of a dynamometer. The force is measured in pounds which represent the lifting capacity of the group of muscles under scrutiny. In figure 1 no less than six different cases covering the whole body are examined, while in figure 2 Leonardo



Figure 1
MS H, fol. 43v.

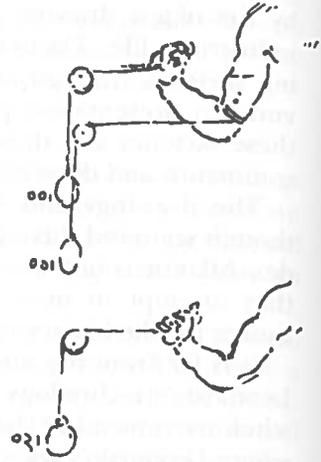


Figure 2
MS H, fol. 44r.

tries to compare the force of the arm in different positions and points of attachment. Between the last two drawings a diagram shows the arm as a compound lever. In many other instances Leonardo compares the human body with a mechanical system, anticipating Borelli. We shall see one of them on folio 164r, *a* of the Codex Atlanticus. . . .

The interest of Leonardo in the maximum efficiency of muscle power is understandable. It was the only motor he could have used in a flying machine; a project that aroused his ambition as early as the year 1488 and in which he remained interested till the end of his life.

The efficiency of the human motor depends not only on its intrinsic strength but also on the ways the force is applied. Indeed, what is the greatest strength a man can generate, without the help of mechanical devices like levers, gears, or pulleys? In a very interesting passage of MS A, folio 30v (Fig. 3), Leonardo answers the question:

A man pulling a weight balanced against himself (as in lifting a weight with the help of a single block) cannot pull more than his own weight. And if he has to raise it, he will raise as much more than his weight, as his strength may be more than that of another man. The greatest force a man can apply, with equal velocity and impetus, will be when he sets his feet on one end of the balance and then leans his shoulders against some stable support. This will raise, at the other end of the balance, a weight equal to his own, and added to that, as much weight as he can carry on his shoulders.

Masterly executed marginal sketches illustrate the three different cases. The problem has been already touched on folio 90v of MS B,

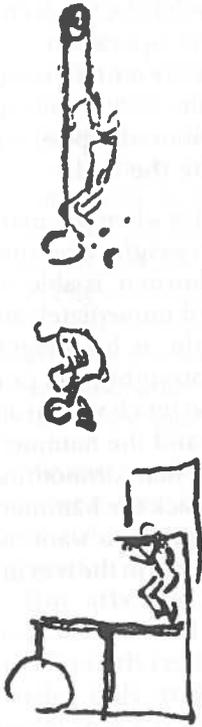


Figure 3

MS A, fol. 30v.

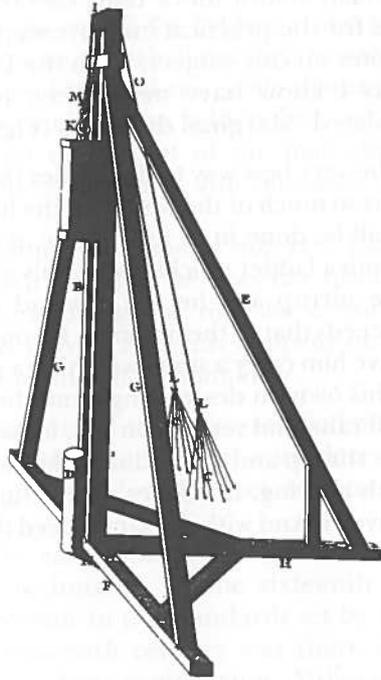


Figure 4

Belidor, *Architecture Hydraulique*, pt. 2,
p. 128, pl. 8.

where the following suggestion is made beside a similar sketch: "See at the mill how much is your weight, stepping on the balance and pressing with your shoulders against something."

But Leonardo was always anxious to integrate theory with application. His own advice was: "When you put together the science of the motions of water, remember to include under each proposition its application and use, in order that this science may not be useless" (MS F, fol. 2v).

I should like to select, among many, a few cases in which Leonardo demonstrates the usefulness of his rules. One of them is pile driving for foundation work or the regulation of river banks. The simplest pile-driving machine consists of a movable frame, provided with a drop hammer raised by men pulling at a rope provided with hand lines. After being raised, the hammer is released by a trigger. The operation is repeated until the pile has been sunk to the necessary depth. In Belidor's classic treatise we may see the figure of this age-old device (Fig. 4).

Leonardo, often engaged in architectural and hydraulic projects, obviously had a more than theoretical interest in the operation. . . .

As for the practical improvements, I should like to present a group of notes on this subject, from the Leicester Codex, folio 28v, which so far as I know have never been reproduced, commented upon, or translated. Marginal drawings (Figs. 5 and 6) illustrate the text.

The very best way to drive piles (*ficcare i pali a castello*) is when the man lifts so much of the weight of the hammer as is his own weight. And this shall be done in as much time as the man, without burden, is able to climb a ladder quickly. Now, this man shall put his foot immediately in the stirrup and he will descend with so much weight as his weight exceeds that of the hammer. If you want to check it thoroughly, you can have him carry a stone weighing a pound. He will lift so much weight as is his own on descending from the top of the ladder and the hammer will raise and remain on top, locked by itself, until the man dismounts the stirrup and again climbs the ladder. When you unlock the hammer with a string, it will descend furiously on top of the pile you want to drive in. And with the same speed the stirrup will rise again to the feet of

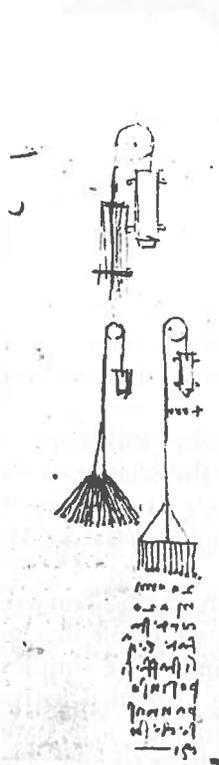


Figure 5
MS Leicester, fol. 28v.

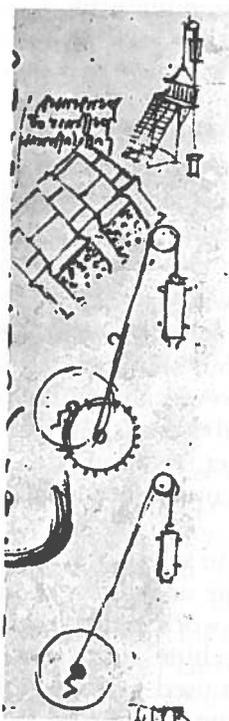


Figure 6
MS Leicester, fol. 28v.

the man. And this shall be done again and again. And if you want to have more men, take several ropes that end in one rope and several ladders to allow the men to reach the top of the ladders at the same time. Now, at a signal from the foreman, they shall put their feet in the stirrups and climb the ladder again. They will rest while descending and there is not much fatigue in climbing the ladders because it is done with feet and hands, and all the weight of the man that is charged on the hands will not burden the feet. But one man shall always give the signal.

Pile driving by raising the hammer by hand is not very useful, because a man cannot raise his own weight if he does not sustain it with his arms. This cannot be done unless the rope he is using is perpendicular to the center of his gravity. And this happens only to one of the men in a crowd who is pulling on the hammer.

We can further observe in the sketches of the Leicester Codex that Belidor's first two improvements had already been considered by Leonardo: the substitution of a large wheel for the block and use of a capstan or a winch. . . .

But arts and techniques can be easily lost when genius is not understood and assimilated. The technology of the sixteenth and seventeenth centuries was much inferior to the standards set by Leonardo; only at the end of the seventeenth century was there a renewal that led to the beginning of modern engineering. A thorough study of Leonardo's technical activities and ideas, even if presented in the disorderly state of the mutilated and plundered heritage, points to him, as Feldhaus has correctly remarked, as the greatest engineer of all times.

Questions for Review and Study

1. How does Vasari both praise and criticize Leonardo in his biographical sketch?
2. How do you imagine Leonardo saw himself, as an artist or as a scientist? Explain.
3. Why do you think Leonardo left so many of his projects uncompleted?
4. To what extent can Leonardo be regarded as a scientist? Comment.
5. Can Leonardo really be considered "the greatest engineer of all times"? Give your reasons.

Questions for Comparison

1. Compare Cortés (see p. 225) and Da Vinci as expressions of the Renaissance spirit. How far removed were these men from the medieval

concern for a unified Christian order? In what ways did each man still belong to the Middle Ages? To what degree did Christianity inspire their work? How did each display a "Faustian" exertion of the human will? What explicit or implied notions of progress are evident in their respective projects? Whose feats shed a more favorable light on Western culture?

Suggestions for Further Reading

The two standard editions of Leonardo's notebooks are *Notebooks*, translated and edited by Edward McCurdy, and *The Notebooks of Leonardo da Vinci*, edited by Jean Paul Richter, as well as a small collection of excerpts, titled *Philosophical Diary*, translated and edited by Wade Baskin. There is also the recent *Leonardo on Painting*, edited by Martin Kemp. Of the many collections of his artistic works, one of the best is *Leonardo da Vinci*, the catalogue of the comprehensive Milan Leonardo Exposition of 1938. Another, relevant to the emphasis of this chapter, is *Leonardo da Vinci: Engineer and Architect*, the catalogue of a major exhibit in 1987. A. E. Popham's *The Drawings of Leonardo da Vinci* is the most complete collection of the drawings, with a comprehensive introduction. Several general works on Leonardo can be recommended: *Leonardo da Vinci*, edited by Morris Philipson, a well-selected set of articles and special studies, and *Leonardo*, by Cecil H. M. Gould. Both these books recognize the two aspects of Leonardo's life and work that are generally dealt with, the scientific and the artistic. Of the works on Leonardo the artist, the best is Kenneth M. Clark's *Leonardo da Vinci*; it may well be the best work on him of any sort. See also *The Artist and the Man*, by Serge Bramly, and *Leonardo da Vinci*, edited by E. H. Gombrich, a collection of essays on Leonardo and a partial catalogue of paintings and drawings. For Leonardo's mechanical engineering interests, the pioneer studies are by Ivor B. Hart, *The Mechanical Investigations of Leonardo da Vinci*, and a later work by Hart updating the research, *The World of Leonardo*. In this regard, see also Giancarlo Maiorino's *Leonardo da Vinci*. For Leonardo's anatomical studies, see Elmer Belt, *Leonardo the Anatomist*; Kenneth D. Keele, *Leonardo da Vinci's "Elements of the Science of Man"*; and Martin Clayton, *Leonardo da Vinci*.

A special interest in Leonardo was stirred by two works of Sigmund Freud, *Leonardo da Vinci: A Study in Psychosexuality* and *Leonardo da Vinci and a Memory of His Childhood*, in which Freud treated Leonardo as the subject of his most extensive attempt at psychohistory. The works are full of errors and not solidly based on research, but they thrust into the forefront of controversy about Leonardo the questions of his homosexuality and the paralyzing duality of his interests in science and art. Two later books in this controversy are *Leonardo da Vinci*, by Kurt R. Sissler,

and *The Sublimation of Leonardo da Vinci*, by Raymond S. Stites, the latter a large, detailed, and difficult book but an important revisionist study of Freud's tentative conclusions.

Although its assertions and research are now dated, students may still enjoy a famous historical novel by Dmitrii Merezhkovskii, *The Romance of Leonardo da Vinci*.

For the background to Leonardo's biography and the Renaissance, see Wallace K. Ferguson's *Europe in Transition, 1300–1520*, and Ernst Breisach's *Renaissance Europe, 1300–1517*. And for an attractive and readable book on the Italy that formed Leonardo, see *Power and Imagination*, by Lauro Martines. (Titles with an asterisk are out of print.)

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