Leonardo da Vinci and The Scientific Revolution of Renaissance Visual Arts

by Nora Hamerman

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FIGURE 1(b). *Jacopo de' Barbari, "Portrait of Luca Pacioli," c. 1498.*

FIGURE 1(a). *"The Creator as Architect of the Universe," Toldeo Cathedral Treasury, Toldeo, Spain.*

Wim Swaan

A revolutionary change was effected in the visual arts by the Golden Renaissance, reflected in the mid-fifteenth century shift in the curve of potential population density, which coincided with the Council of Florence and with Nicolaus of Cusa's treatment of the paradox of circular quadrature. Subsequently, Leonardo da Vinci carried out a second revolution in art, based on a deeper understanding of Cusanus' ideas.

A comparison of three representations of a figure drawing with a compass, provides a sharp image of the progress in the visual arts during the Renaissance. In Figure 1(a), we see the Creator imagined in human form as Architect of the Universe, impose order with the compasses of the master mason. This is a detail of the title page of Genesis from the Bible given by St. Louis of France to his cousin St. Ferdinand of Spain in the middle of the thirteenth century. Despite the beautiful notion of God

Photo Vatican Museums

FIGURE 1(c). *Raphael, Archimedes detail from "The School of Athens," 1509-11, Stanza della Segnatura, Vatican Palace, Vatican City.*

creating by means of circular action, the picture is completely flat, suggesting that the geometric knowledge of God cannot be made intelligible to human beings, just as the mathematical knowledge of the master masons who built the Gothic cathedrals was passed secretively through the families and the guilds.

Jacopo de' Barbari's portrait of Luca Pacioli giving a geometry lecture, shown in Figure 1(b), dates from around 1490. On the slate Pacioli demonstrates the construction of a pentagon from the equilateral triangle. On the right is a wooden model of a dodecahedron. Above hangs a crystal model of a 26-sided semi-regular solid. The painting is constructed according to the principles of artificial perspective, the conquest by which painting was uplifted from a mechanical art to the level of science in the fifteenth century. Unlike the Gothic example, the picture is composed in such a way as to express the achievements its celebrates. A three-dimensional space is convincingly rendered on a two-dimensional surface through the application of projective geometry.

Pacioli, the student of a great Renaissance painter, Piero della Francesca, was not an artist. He was the professional mathematician who collaborated with Leonardo da Vinci on the book, *The Divine Proportion,* in the 1490's. This portrait immortalizes Pacioli's accomplishment in identifying the ratio he called the Divine Proportion, known today less precisely as the Golden Section, as a unique expression of self-similar spiral action in the universe, characteristic of living things. Yet this concept is not adequately conveyed by the painting, which places a nearly motionless aggregate of particulars within a fixed space. For example, the student or assistant to Pacioli takes no real part in the limited action.

The third example, Figure 1(c) [SEE also, inside back cover] is from 1510, only a few years later. It is Raphael Sanzio's portrayal of the Greek mathematical physicist Archimedes giving a geometry demonstration.[1] Although it stands on its own, this picture is actually a detail of "The School of Athens" fresco in the Vatican, which was a Christian view of the contributions of pagan Classical Greek science. An imaginary, inverted cone superimposed on the episode, with its vertex at the point where Archimedes' compass rests on the slate, allows us to trace a spiral which would connect the faces and hands of the youths who participate in the class. They are not passive recipients of fixed information, but each individual absorbs and transmit the lesson to others who are in the process of arriving.

This illustrates the third, and highest level of spatial construction in painting, based directly on the discoveries of Leonardo da Vinci.

The *Divine Comedy* Of Dante Alighieri

The most efficient reference point for this progress in the science of painting is the method popularized in the *Divine Comedy* by Dante Alighieri, who is depicted in Figure 2 illuminating the City of Florence with his poem, which was written in the first two decades of the fourteenth century. On the left, center, and in the sky behind him are portrayed the three canticles of the *Divine*

FIGURE 2. *Domenico di Michelino, "Dante Alighieri Reading His Poem," 1465, Cathedral of Florence, Florence, Italy.*

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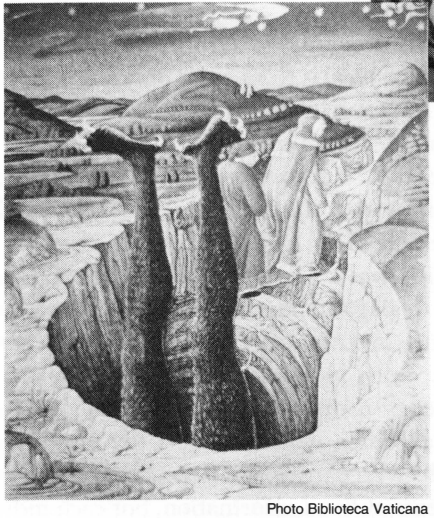
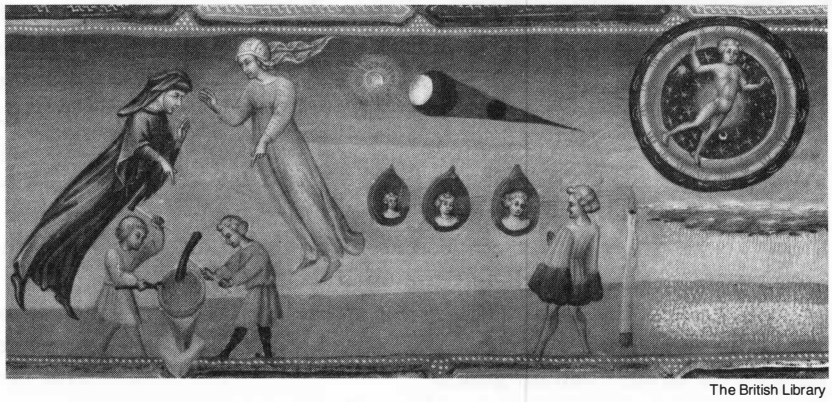


FIGURE 3. *Gerolamo Guglielmi, "Urbino Codex of the Divine Comedy," c.1480, illustration to Canto 34 of Inferno.*

Photo Biblioteca Vaticana

FIGURE 4. *"Yates-Thompson Codex of the Divine Comedy," c.1440, illustration to Canto 2 of Paradiso.*



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Comedy, a vernacular Italian epic of a journey of a living man, Dante himself, through the world of the afterlife, where divine justice is accorded to each individual's soul.

The lowest domain in this world, Inferno, is the domain of the greedy infantile ego. Selfish, sensually based love, as expressed by the Greek word *eros,* is the dominant emotion. Geometrically speaking, this is the domain of a fixed geometry based on algebra. Philosophically, it is the domain of Aristotle.

The highest domain, in the third Canticle of the *Comedy,* is Paradise. Filled with polyphonic music, it corresponds psychologically to the mature human being, in whom reason and feeling are harmonized by creativity in the image and likeness of God. The dominant emotion is *agapē,* the Greek word used in the New Testament for the universal love characteristic of the Creator. This corresponds to the level o f the transfinite.

Dante connects these two realms by an intermediate domain, Purgatory. This is the emotional level of the growing adolescent, who accepts the validity of external laws and the order of society, but whose emotions are still tied to the earthly paradise of selfish desires. At its best, the kind of love exemplified by the good citizens of Purgatory is conveyed by the Greek word *philia,* or brotherly

love.

Dante and his guide, the Latin poet Virgil, take a spiral journey down the internal (negatively curved) surface of an inverted, irregular cone. The spiral combines rectilinear motion with circular action, and accomplishes work. The souls in Hell are condemned to their fixed circles. Dante and Virgil accomplish work by coming to understand the geometry of evil as they descend through Inferno, from lust, irrational anger, and greed; to violence; to fraud; and finally to treason.

Consider how Dante communicates the non-linear shift between each of the three domains, with its different particular laws. In the pit of the ninth and final circle, or station, of Inferno, Virgil carries Dante, clinging to his neck, as they climb down the giant pelt of the hideous Lucifer, who is encased in solid ice. Then Virgil makes a 180-degree turn. This is a *phase-change,* comparable to the qualitative shift which occurs when ice turns to water at zero degrees centigrade.

Dante's terror at this turns to hope when he and Virgil emerge out the other side of the earth, where they glimpse Mount Purgatory and see the stars (SEE Figure 3).

Purgatory is the domain of shadow and time, where the selfish impulses of Hell are negated, and the infernal noise of disorderly sensuality is replaced by unison singing of hymns. The journey upward on the outside, positively curved surface involves physical effort, in contrast to the all too easy descent into Hell. While seemingly mathematically similar to the spiral journey to the apex of Inferno, it is physically going in the opposite direction, negating the negation of evil.

Passing through the gateway of Purgatory, Dante is required to deny the evidence of sense certainty. The angel instructs him that he may not turn around to verify with his eyes the noise of the gate shutting behind him, which he hears with his ears. The paradox is then heightened by art. For in a divinely created series of relief sculptures which is shown to him, Dante contemplates an art so powerfully realistic that a small war breaks out between his senses. Ultimately, Dante is made to confront the full horror of the deadliest of the seven deadly sins—pride, the irrational obsession with one's fixed knowledge.

Having completed the seven cornices of Purgatory, where the sins of pride, envy, rage, laziness, greed, gluttony, and lust have been purged, Dante must find the courage to walk through a wall of fire. This is a *phase-change* again, reminiscent of the qualitative shift in form from liquid to vapor, which then tends to rise. To do this he must draw upon a higher love—*agapē*—by thinking of the image of a beloved woman who has died, Beatrice. The best of the Platonic legacy of antiquity, embodied by his guide the poet Virgil, is not adequate to carry him further on his journey. For this the *imago Dei* bestowed by Christian faith is required.

Dante tries to follow the example of Beatrice by gazing into the sun, the glory of God, but his mortal eyes are too weak to stand the intense light. So, he rises to Paradise by gazing into the reflected light in her eyes, a metaphor for Platonic dialogue. Now, the positive energizing force of divine love has replaced the relatively entropic "negation of the negation," as the motor of his continued journey.

Paradise is the domain of true scientific inquiry. especially concerning the science of optics. Dante and Beatrice discuss the origin of the spots on the Moon, the first level of his journey through the physical universe as it was understood by the astronomy of the time. Dante offers a hypothesis based on purely quantitative considerations, which Beatrice refutes by proposing two experiments, and then offers a higher hypothesis of her own (SEE Figure 4). This is the first instance where a scientific experiment and the process of hypothesis formation is introduced into a poem.

In the final canto of the Paradise, Dante grapples with making the Trinity intelligible, by offering a series of metaphors of the paradox of the One and the Many. One of these evokes the optical phenomenon by which a single

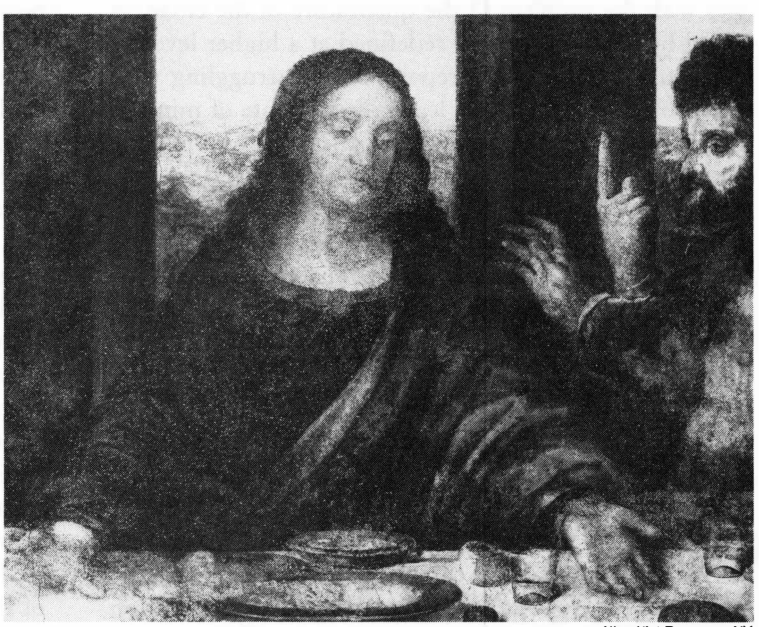

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FIGURE 5. *Leonardo da Vinci, detail of Christ, "The Last Supper," 1495-98, S. Maria delle Grazie, Milan, Italy.*

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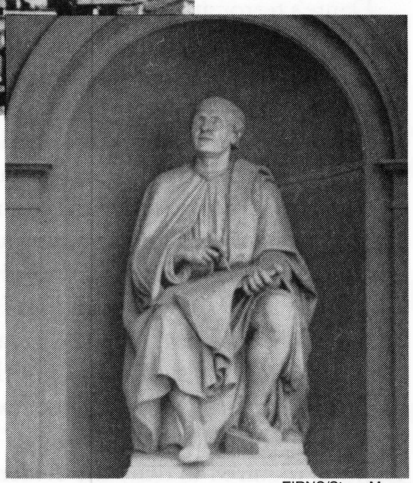

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FIGURE 6. *(a) Above: Cathedral of Florence, dome designed and constructed by Filippo Brunelleschi. (b) Bottom right: Statue of Filippo Brunelleschi, Florence, Italy. (c) Top right: Leon Battista Alberti, "Self-Portrait," bronze medal, c. 1435.*

light—the one, which is white—is split by a prism into the three primary colors, red, yellow, and blue.

Dante's final image is that of the geometer who struggles with the problem of the quadrature of the circle, as posed by Archimedes and redefined at a higher level by Nicolaus of Cusa. Dante reports that in struggling with this problem, he suddenly leaped to the state of mind in which his intellect and his will were moved on the same path by which Love—*agapē*—moves the sun and the other stars.

And as Dante looks directly into the dazzling pure light of God, at the center of the Empyrean, he sees "our own effigy." This is Christ, the man-God, and no depiction comes closer than Leonardo da Vinci's Christ of the "Last Supper" (SEE Figure 5).

Leonardo and The Science of Perspective

When Dante wrote the *Divine Comedy* just after A.D. 1300, the growth surge of European population density from the highpoint of the Gothic cathedral-building era had drastically stagnated, thanks to the triumph of usury. Then cataclysm struck. In 1342 the most powerful banks of Europe, the Florentine Bardi, Peruzzi, and Accaiuoli, collapsed after the King of England defaulted on his debts. In 1348, the Black Death swept through Europe from Asia, brought by slave ships from the Black Sea, as the catastrophe of the Mongol invasions in China spread to the West, carrying off as much as fifty percent of the population of major urban centers, especially in Italy and southern France. From the family, to the Church, to the Holy Roman Empire, every institution crumbled in the face of this twofold crisis. By 1400, the population had collapsed to the levels of two centuries earlier. Yet by the middle of the fifteenth century, starting around the time of the Council of Florence of 1439, the growth curve had resumed its vertical climb.

The Renaissance was shaped in Florence on the basis of the cultural optimism of Dante, St. Augustine, and Plato. Filippo Brunelleschi, the first modern architect, swept aside the secretive power of the medieval masons,

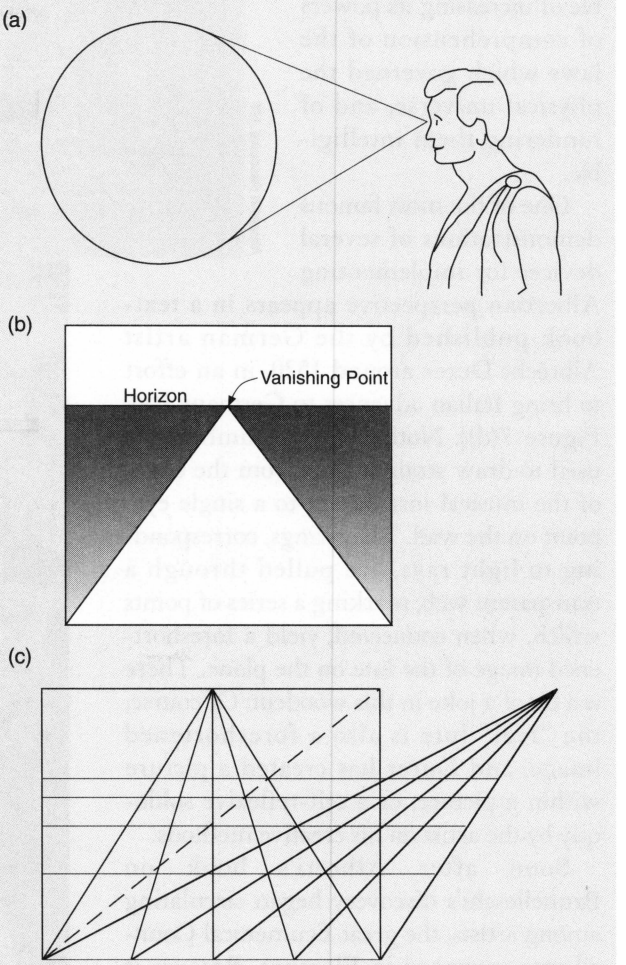
and established the principle of intervention into history by an individual of genius. His dome for Florence cathedral, shown in Figure 6(a) was the technological, artistic, and economic marvel which heralded a new golden age. Brunelleschi, portrayed in Figure 6(b) drawing with a compass and looking up at his dome, also rediscovered painter's perspective, applying the laws of projective geometry to the problem of representing three-dimensional reality on a two-dimensional surface.

Leon Battista Alberti [SEE Figure 6(c)], another Florentine genius, adapted and wrote down Brunelleschi's discovery in a book in Italian published in 1436, as the dome was being completed and just before the convening of the great Ecumenical Council in Florence in 1439, where the Eastern and Western Christian churches were reunified around higher principles which subsumed differences between particular cultures and rituals. Brunelleschi's discovery thus became known as Albertian perspective. This kind of construction can easily be taught to young children, and should again become a standard part of the school curriculum.

Brunelleschi and Alberti simplified vision to a single eye and imagined that rays of light enter the eye, which is a passive recipient, in a cone or pyramid [SEE Figure 7(a)]. Each line intersects the plane of the picture, which is interposed between the three-dimensional object of sight and the eye, in one and only one point, thus permitting a lawfully ordered mapping process. Figure 7(b) shows the single vanishing point, corresponding to the eye, which is placed on the horizon of the picture. All the orthogonals from the scene or object being represented, are mapped to converge on this point. And in Figure 7(c), we see how a series of lines are mapped onto the plane from the three-dimensional original in Albertian perspective. Note that the topological features are maintained, such as the number of corners, but the shape becomes distorted according to the distance and angle of vision of the interposed plane. Such distortions are called "foreshortening."

Brunelleschi set up a famous experiment to convince others of his discovery. He painted the Baptistery, a famous local building, from the door of the nearby cathedral. He drilled a small conical hole in the painting at the vanishing point. When a person stood in the cathedral door and looked through the hole in the back of the painting, holding a mirror in the other hand, he could verify that the painted image corresponded exactly to the real

FIGURE. 7. *Development of Albertian perspective.*



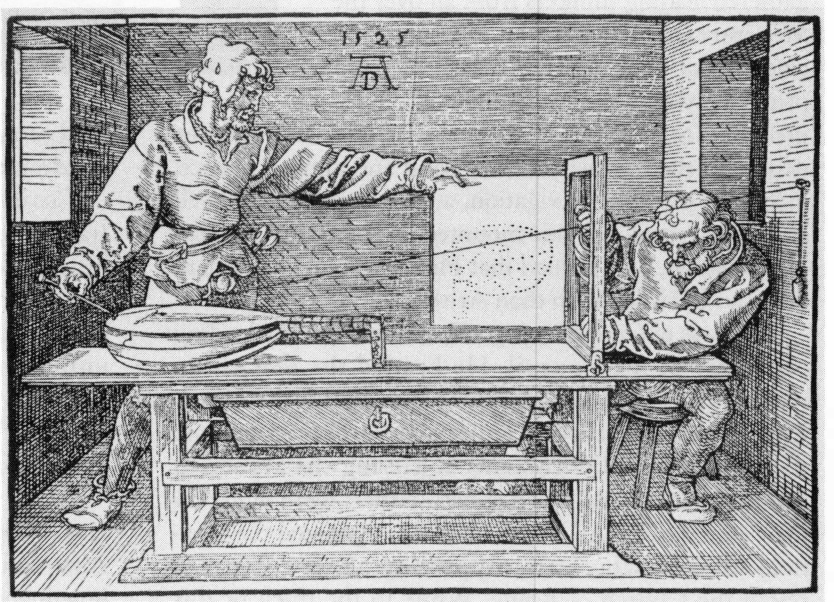


FIGURE 7(d). *Albrecht Dürer, "A Man Drawing A Lute," 1525.*

building. This showed that the human mind was capable of increasing its powers of comprehension of the laws which governed the physical universe, and of rendering them intelligible.

One of the most famous demonstrations of several devices for implementing Albertian perspective appears in a textbook published by the German artist Albrecht Durer around 1520, in an effort to bring Italian advances to Germany [SEE Figure 7(d)]. Notice how a plumb line is used to draw straight lines from the edges of the musical instrument to a single eyepoint on the wall. The strings, corresponding to light rays, are pulled through a transparent web, marking a series of points which, when connected, yield a foreshortened image of the lute on the plane. There is a bit of a joke in this woodcut: Of course, the "real" lute is also a foreshortened image, and Durer has created a picture within a picture, or a self-reflexive soliloquy by the artist on his creative methods.

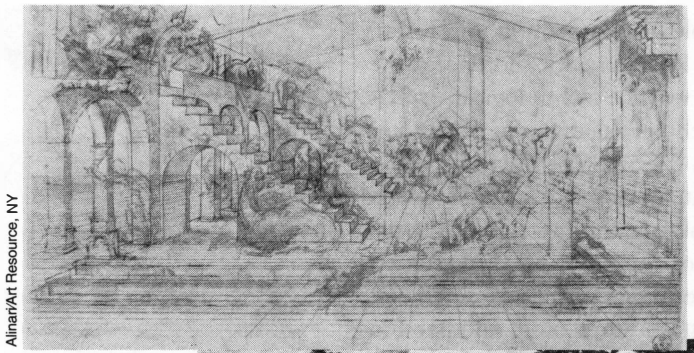


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FIGURE 8. *(a) Below: Leonardo da Vinci, "Adoration of the Magi," 1498. (b) Left: Architctural study for "Adoration of the Magi.*

Soon after Alberti's book on Brunelleschi's discovery began circulating among artists, the great Ecumenical Council was convened in Florence. Because it gathered leading thinkers from all over the Mediterranean world and Africa, the council not only debated the theological principles which unify all Christians, but it provided the forum, outside the official sessions, for debate on the frontiers of theoretical and applied science, including printing, navigation, and mapmaking, as well as for the crucial polemic mounted by the Greek philosopher Plethon, who argued that Plato was more consonant with the Christian faith than Aristotle.

Nicolaus of Cusa [SEE page 43, this issue] was a leading organizer of the Council. He headed the delegation which traveled to Constantinople to invite the Greek Emperor and Orthodox church hierarchy, and while there he gathered documents bolstering the argument that early Greek and Latin church fathers were united in their concept of the Trinity. He then organized the German princes, who were supporting an anti-Pope, to rejoin the Church of Rome. While in the thick of this ecclesiastical and political battle, in 1440, Cusa published *On Learned Ignorance,* tackling afresh the problem of the quadrature of the circle posed by Archimedes.

Cusanus' work circulated among leading Platonists in Italy, where from 1458 to 1464 he spent the last years of his life as the highest official under Pope Pius II. This work formed a major inspiration for the ideas of Leonardo da Vinci, born near Florence in 1452. Leonardo's unfinished "Adoration of the Magi" [SEE Figure 8(a)], begun in 1480, demonstrated the transformation from the hypothesis of linear perspective to the higher hypothesis which we will term "spherical perspective."

In the preparatory study shown in Figure 8(b) [SEE also, back cover], Leonardo showed his mastery of the Albertian scheme by mapping one of the most intricate imaginable networks of orthogonals converging on a single vanishing point. But the problem of this perspective

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FIGURE 9.
Sandro Botticelli, "Adoration of the Magi," 1476.

construction by itself, is that it cannot account for what is most important: the *phase-change* from a lower to a higher geometry. The limitation is inadvertently expressed by a theoretical treatise on painter's perspective written in the middle of the fifteenth century in Italy. The author, Piero della Francesca, asserted that painting consists of three elements: color, outline, and the diminution of forms in space, yet only the third can be treated scientifically. He poured scorn on any artist who does not master and indeed, advance, the science of perspective. However, as Leonardo later realized, perspective is really the science of vision, and therefore it must encompass all aspects of the visual universe. In his treatise on painting, Leonardo theorized fully three kinds of perspective—perspective of color, of forms, and of diminution. We do not live in an airless Euclidean space in which a single eye receives straight lines which are neither bent nor refracted.

Moreover, of course, human and animal figures do not stand like geometrical cylinders and spheres in this crystalline space, but they move. Sandro Botticelli, an older artist of Leonardo's generation, had grappled with this problem. In his "Adoration of the Magi" (SEE Figure 9), Botticelli showed a parade of figures dominated by the members of the Medici family who unofficially ruled Florence, converging on the Holy Family, which is seated under the shelter of a manger perfectly constructed according to the Albertian rules. Yet despite the colorful costumes and animated postures of individuals, the picture remains static. Indeed, by comparison to Leonardo's nearly contemporary "Adoration," the key figure, the Christ Child bestowing a blessing on the oldest of the Magi, is so small he can hardly be distinguished.

Examine Leonardo's version. Here, he uses the light itself to organize the picture in a higher geometry than that dictated by the Euclidean spatial fiction which Albertian perspective accepts implicitly. Thus, Leonardo's Christ Child, who leans energetically away from his mother's protective lap, initiates a spiral motion which acts to transform the entire surrounding area. The Magi were, after all, astrologers—Zoroastrians who practiced an evil cult of magic in which the forces of dark and light were considered in eternal battle for the universe—and Leonardo shows these figures as it were at the very moment of their transformation. At the left and right, an old and a young philosopher flank the painting as if to announce its deeper meaning to the viewer. They are, unlike the figures who occupy a similar position in Botticelli's picture, outside the contemporary political elite of Florence, and appeal to a more universal notion of the concrete individual.

The new perspective system based on light and shadow is fully exemplified by Leonardo da Vinci's "Virgin of the Rocks," a completed altarpiece (SEE Figure 10). A very old Oriental tradition had it that Christ was born in a grotto, but this is the first painting to create an ambiguity as to whether we are inside the cave looking out, or outside the cave looking in. Leonardo has perched us on the boundary between positive and negative curvature. The subject is a common Florentine one, that of the infant St. John the Baptist visiting the Virgin and Child and an attendant angel.

The painting has two distinct sources of light. One is

the natural light source which illuminates the sky in the background. The other is a supernatural light which picks out the hands and faces of the four figures.

Each person is distinguished by a different quality of gesture. The human precursor of Christ, John the Baptist, kneels and joins his hands in prayer, a gesture of bondage. The Virgin Mary, the first convert to Christianity, with her acceptance of the mission given to her by the angel in the annunciation, urges John forward with her right hand while covering the child with a protective gesture with her left. The Christ Child below lifts his right hand in a gesture of blessing. The octave interval between the Virgin and Child is punctuated by the pointing hand of the angel, which divides the interval at the distance of a musical fifth. Leonardo, himself an accomplished musician, was highly conscious of the beauty of proportions embodied in such intervals.

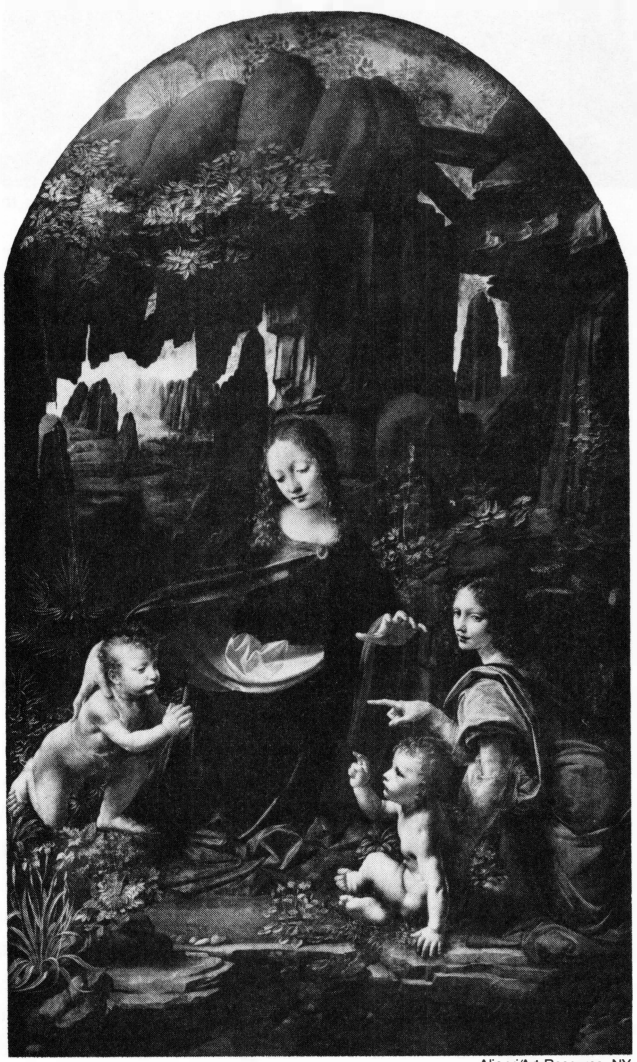

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FIGURE 10. *Leonardo da Vinci, "The Virgin of the Rocks," 1483-86, Louvre, Paris, France.*

The angel, a purely spiritual being, alone looks out and connects the viewer to the painting. The head is turned in three-quarter view, maximizing the effect of implicit motion. Leonardo creates a beautiful geometric shape in the outline of the head, but without drawing a hard line. The "line" is the optical result of the meeting between areas of light and dark, which he often blurred in the final phases of painting by smearing it with his finger.

No doubt Leonardo also meant to allude to Plato's parable of the cave in the *Republic,* one of the first Platonic dialogues to have been translated in fifteenth century Florence. Plato imagined the human race to be like a group of persons chained inside a cave, whose only notion of reality were the shadows which project on the wall of the cave from a fire outside. When one prisoner escapes and returns to report that their prisoner perceptions are being created by manipulators outside, his fellow slaves try to kill him. Plato told this parable to illustrate the falsity of sense-perception as the basis of knowledge.

Leonardo demonstrated that Albertian perspective was inadequate to portray reality because everything depended on a single centric ray. Painters had long realized that there were serious limitations to Albertian single-point perspective. In an instance such as that of a row of columns illustrated here in Figure 11(a), artificial perspective would cause the outer columns to appear much wider than the middle one, even though they were all the same size. However, Leonardo rejected any notion of a return to the simple empirical methods of the pre-Alberti generation. In one passage of his notebooks he warns: "Perspective comes in where judgment fails as to the distance of objects which diminish. The eye can never be a true judge for determining with exactitude how near one object is to another which is equal to it,"[2] and he proceeds to offer a mathematical construction for making this determination.

In a drawing from the early 1490's [SEE Figure 11(b)], Leonardo showed sketches of an Albertian construction of a long room, and an unfolding double-helix which suggests both his observations of the self-organizing patterns in water flows, and the self-development of living forms. Elsewhere he wrote, concerning perspective: "Just as a stone flung into the water becomes the center and cause of many circles, and as sound diffuses itself in circles in the air: so any object, placed in the luminous atmosphere, diffuses itself in circles, and fills the surrounding air with infinite images of itself. And is repeated, the whole everywhere, and the whole in every smallest part."[3]

Leonardo did not abandon single-point perspective, but he transformed it by studying the areas of ambiguity which are formed by caustics, as seen in Figure 11(c),

which are formed by intersecting families of curves. This takes us to the domain Leibniz later called transcendentals. Instead of only focusing on the centric ray, he devoted attention to the phenomena which occur on the peripheries of vision, especially as these are affected by atmosphere.

Leonardo was the first hydraulic engineer in history to study the effects of changing velocities on water flows, which he illustrated in many drawings [SEE Figure 11(d)]. He stated that his concern was to discover how to measure the flow of water, which involved using discontinuous quantities, or units of measurement, to divide the continuous, hydrodynamic flow.

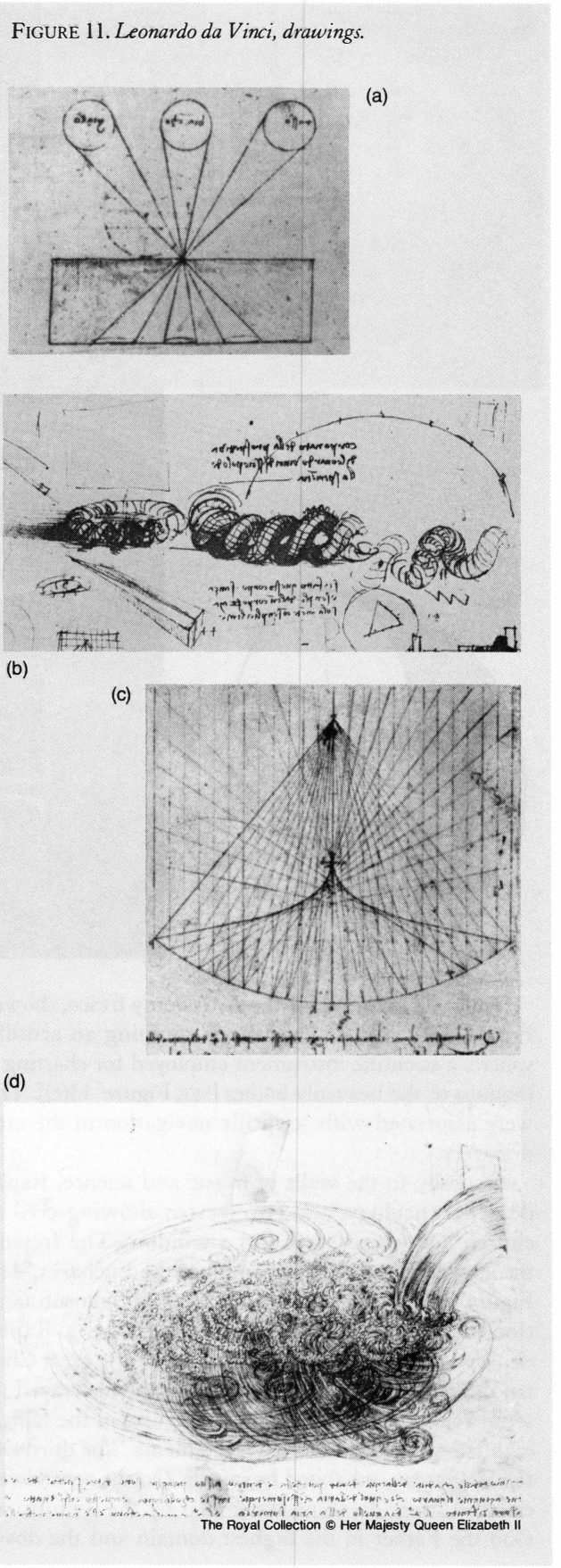
Raphael Elaborates Leonardo's Discoveries

Only twelve authentic paintings by Leonardo da Vinci have come down to us, and many of those are not completed. It was largely left to an artist of the next generation, Raphael Sanzio, born in 1483, to apply Leonardo's discoveries. Raphael's Archimedes, shown in Figure 1(c), is not merely a figure in the "School of Athens"; he is actually acting to create the painting in which he appears, for by correcting for foreshortening, we can overlay the design on Archimedes' slate to the orthogonals of the architecture behind the figures representing physical sciences in the "School of Athens" fresco [SEE Figure 12(a)].

Thus Raphael poetically created the context in which Plato intervenes into the Vatican against the influence of Aristotle, who flanks him under the arch in the center background of the full "School of Athens." This fresco is part of a squarish room in the papal apartments called the *Stanza della Segnatura* [SEE Figure 12(b)]. Raphael's murals on the four walls and ceiling represented the totality of human knowledge from the standpoint of Christian Platonism, which was at its apogee in 1510 in the Church, when Raphael painted these frescos. He imagined the room as if the different gatherings of great thinkers were projected onto the negatively curved inside of a sphere. Figure 12(c) shows a spherical quadrant in which a figure stands at the center of a sphere; this matches the perspective of the *Staza della Signatura.* In the vault, the concepts connecting these fields of human knowledge are depicted.

For example, between the "School of Athens," representing physical science, and the adjoining wall of "Parnassus" representing poetry and music, Raphael shows Astronomy [SEE Figure 13(a)]. Thus, the Platonic concept of the Harmony of the Spheres lies at the boundary between the domains of music and physical science.

FIGURE 11. *Leonardo da Vinci, drawings.*



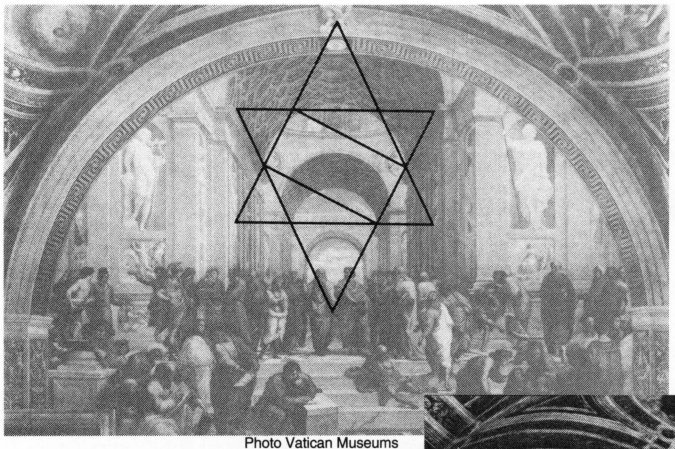


Photo Vatican Museums

FIGURE 12. *(a) Left: Raphael's "School of Athens" with overlay of Archimedes' slate diagram. (b) Below: View of the Stanza della Segnatura, showing Raphael's "School of Athens" and "Parnassus" frescoes, Vatican Palace. (c) Bottom Left: Diagram of perspective in the Stanza della Segnatura.*

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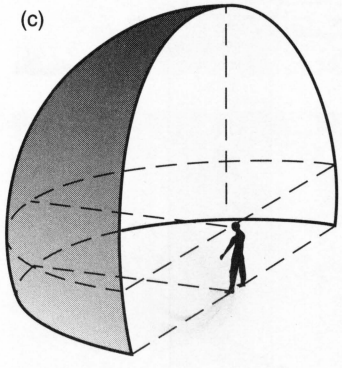


Raphael's drawing for the Astronomy fresco, shown in Figure 13(b), shows that she is spinning an armillary sphere, a scientific instrument employed for charting the motions of the heavenly bodies [SEE Figure 13(c)]. These were associated with scientific navigation in the era of discovery.

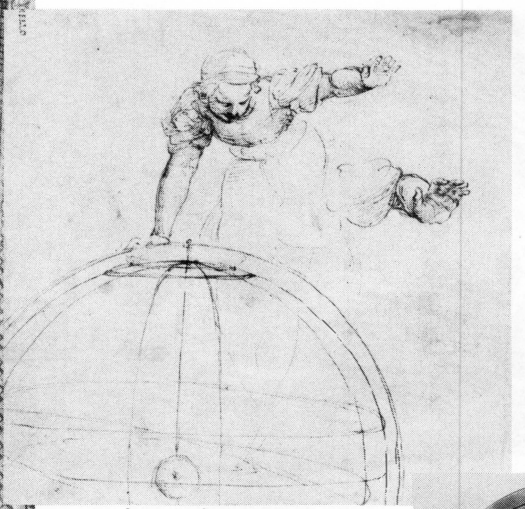
Opposite to the walls of music and science, Raphael depicted theology, and two frescos showing civil and church law which surround a window. The fresco on theology, entitled "The Triumph of the Eucharist,"[4] [SEE Figure 14(a)] celebrates the doctrine of Transubstantiation of the host as the true body of Christ. Raphael depicted three levels. On the ground are the great Christian theologians of 1,500 years. Above them, arrayed on a semicircular cloud are twelve key figures of the faith, six each from the Old and New Testaments. The third tier is the Empyrean, inhabited by angels. On the central vertical axis, these domains are joined by the Trinity, with God the Father in the highest domain and the dove of the Holy Spirit below shown in the midst of the twelve Old and New Testament saints. Between these two levels is the third member of the Trinity, Christ flanked by Mary and John the Baptist. Below on the altar, Raphael depicted the earthly presence of the Trinity in the Eucharist, which is the subject of debate and adoration among the gathered theologians.

In Figure 14(b) we have drawn lines to illustrate how the great circles of an armillary sphere correspond to the composition of Raphael's "Triumph of the Eucharist"; hence, theology is shown to be in harmony with the cosmology of the universe, as it was understood to be in Raphael's day. And in Figure 14(c), at the upper right corner in this detail, we see how Raphael depicted the angels in the Empyrean as if projected on the inner surface of a sphere and seen from the sphere's center.

Raphael's last masterpiece, where he most profoundly applied Leonardo's revolution in perspective, is the "Transfiguration," a large altarpiece painted in oils just

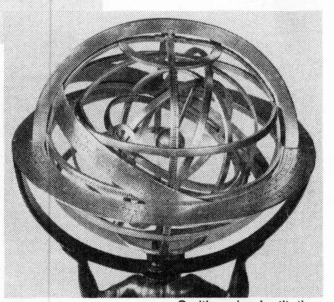
Photo Vatican Museums

FIGURE 13. *(a) Left: Raphael, "Astronomy," detail of ceiling vault, Stanza della Segnatura. (b) Below: Raphael sketch for "Astronomy."*



Graphische Sammlung Albertina, Vienna

FIGURE 13(c). *Armillary sphere, Italian, sixteenth century.*



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before his death in 1520 (SEE front cover, this issue). It was painted in competition with a similar-sized altarpiece by Sebastiano del Piombo, a Venetian follower of Michelangelo. Raphael was regarded by these rivals as the artistic heir to Leonardo, who had left Rome for France where he died in 1519.

The altarpiece depicts the episode in the Gospel where Christ, transfigured with the two prophets Moses and Elijah at either side, appeared to his three closest disciples, Peter, James, and John. For the first time in history, Raphael combined this subject with the episode which follows it in the Bible. While Christ was transfigured on Mount Tabor, in Jerusalem the remaining disciples were confronted by a woman with a possessed son and asked to cast out the devil; they were helpless.

Raphael organized his picture into three domains:

- The earthly one is dominated by darkness. Here we see the bewildered apostles, unable to act in concert, and the mother of the possessed boy. However, at the same time we see a divine light which points to the later cure of the child after Christ's transfiguration
- An intermediate level is represented by the three disciples on Mount Tabor, who recoil from Christ's splendor.
- At the highest level Christ rises in an explosion of radiance, surrounded by clouds from which the voice of God the Father emanates, proclaiming that Jesus is his son.

Following the example of Leonardo, Raphael has used the differing qualities of light to unify the painting, which allows him to avoid being locked into a single perspective system which could never show the progression through these qualitatively different fields. From the standpoint of Albertian perspective the lower domain has one vanishing point, but the top of the mountain has been tilted to reveal the three startled disciples. In the sky we look upward toward the figure of Christ.

In the background at the right, dawn is breaking, and the natural light of day provides a reference against which the other light sources may be compared. Exactly as in Dante's *Divine Comedy,* which progressed from the darkness of Inferno, to the shades of Purgatory, to the pure light of Paradise, Raphael distinguishes the three levels of the drama by different kinds of light whose pro-

FIGURE 14(a). *Raphael, "The Triumph of the Eucharist," Stanza della Segnatura, Vatican Palace.*

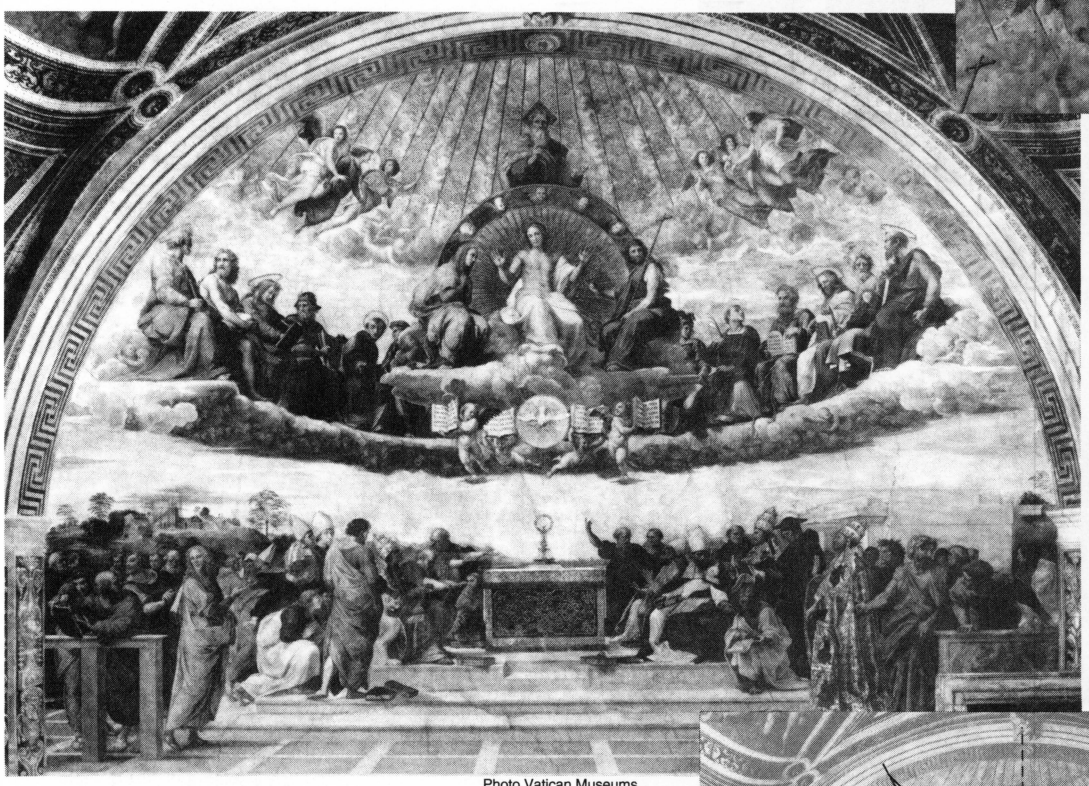

Photo Vatican Museums

FIGURE 14(c). *Detail, "The Triumph of the Eucharist."*

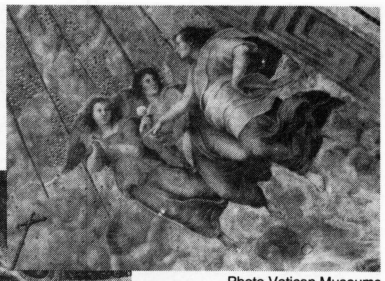

Photo Vatican Museums

FIGURE 14(b). *Diagram, "The Triumph of the Eucharist."*

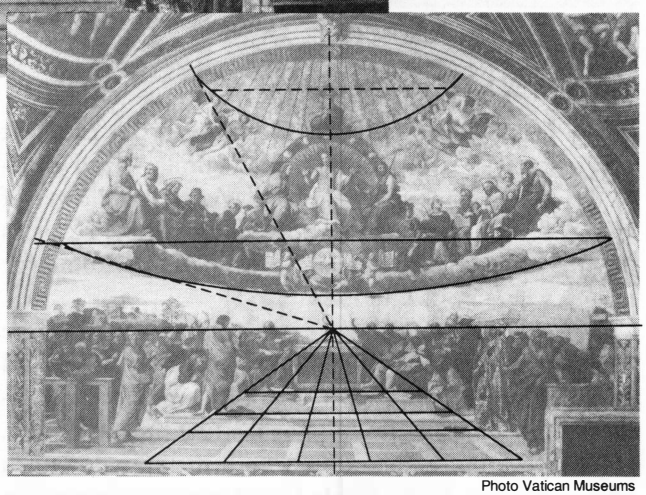

Photo Vatican Museums

gression is used to unify the composition.

In conclusion, we can bring this back to the point stressed by Lyndon LaRouche in his "History as Science" essay: the crucial role contributed by individual ideas and by individual personalities in the shaping of history. Leonardo and Raphael were two such individuals. While they were living, they were able to guide their followers, and even such hostile rivals as Michelangelo, to a quality of work they were unable to match once these masters were gone. Even when, a century later, in Spain and Holland, the great painters Rembrandt and Velasquez were able to honorably take up where Leonardo and Raphael had left off, they did it without attempting to advance Leonardo's efforts to define the scientific practice of painting in written theoretical form. That task remains to the next generation, when the brutality of the twentieth century has been put behind us, and mankind can once more embrace Leonardo's and Raphael's ideas of beauty and perfection in art.

NOTES

1. Konrad Oberhuber, in *Raffaello: Il Cartone della Scuola di Atene* (Milan: Silvana, 1972), Fontes Ambrosianae No. 47, definitively proved that this figure is not Euclid, as traditionally believed, but Archimedes.
2. Manuscript fragment Institut de France C, 27b (1490-91), cited in J.P. Richter, *The Notebooks of Leonardo da Vinci* (New York: Dover, 1970).
3. Manuscript fragment Institut de France A, 9b (1492), cited in J.P. Richter, *ibid.*
4. This fresco has been traditionally misnamed the "Disputation on the Sacrament."