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RENAISSANCE SYMMETRY BAROQUE SYMMETRY AND THE SCIENCES

Renaissance and Baroque, two terms unknown in the ages they describe, are now an integral part of the general public's cultural vocabulary. The first encompasses European civilization from the mid-fifteenth century to around 1550, and the second refers to developments in the seventeenth century, with the intervening fifty years forming a period of transition termed Mannerism. Beginning with the appearance of Heinrich Wölfflin's *Kunstgeschichtliche Grundbegriffe* in 1915,[1] these two great epochs of intellectual development have been described quite successfully by juxtaposing the one with the other. Wölfflin, for example, saw five great categories of discrimination between the two, namely Linear and Painterly, Plane and Recession, Closed and Open Form (Tectonic and A-tectonic Form), Multiplicity and Unity (Multiple Unity and Unified Unity), and

[1] *Principles of Art History: The Problem of the Development of Style in Later Art*, trans. M. D. Hottinger, Dover Publications, 1950.

[2] Garden City: Doubleday, 1955.

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Clearness and Unclearness (Absolute and Relative Clearness). More recently, Wylie Sypher in *Four Stages of Renaissance Style*[2] has extended the list with the polar characteristics of Cyclic-Broken (Cyclothym-Schizothym), Exact-Abstract (Representational-Nonrepresentational), Visual-Haptic, Nearseeing-Farseeing, Dark-Light, Horizontal/Vertical-Oblique/Spiraling, and Points/Lines-Planes/Volumes.

While it is true that the Baroque was more a reaction against the immediately preceding Mannerist period than against the Renaissance style, to which it in many ways returned, as John Ruppert Martin has indicated in his excellent study *Baroque*,[3] dichotomous categories like those of Wölfflin and Sypher are in general valid and facilitate enormously the appreciation of the cultural endeavors of both periods. If Wölfflin's and Sypher's systems show flaws, it is only because their terms are necessarily restrictive, being limited as they are to the visual arts and literature, respectively. More general statements about the two periods can be made and other areas of intellectual enterprise, as will be shown here by reference to the sciences, can be incorporated into the systems utilized so successfully by art historians. One finds the most salient intellectual divergence in the different concepts of symmetry postulated by thinkers in the two periods, plus in the equally important but oft-neglected scientific ideas of space, time, and mass. An examination of these areas will hopefully clarify the fundamental differences between the Renaissance and the Baroque.

Symmetry

The most casual observer of a Renaissance painting, sculpture, or building by a Piero della Francesca, a Pollaiuolo, or a Brunelleschi sees immediately that the creator of the object conceived of symmetry as balanced, harmonic, and geometric. The artist's inspiration came from the newly discovered and more accurately interpreted Greek and Roman documents of the Platonic school, which were widely diffused in all areas of intellectual endeavor, creating artistic predispositions

[3] New York: Harper & Row, 1977.

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much like Freud's ideas at the turn of this century appeared simultaneously in artistic works. From the Neoplatonists came the idea that symmetry depends on *the relation of the parts to the whole*. This means that the outer structure—whether the picture frame, the dimensions of an edifice, the verse form, the literary genre, the musical parts, the bodily proportions—is the primary agent of cohesion, to which the various parts then relate. The structure is therefore a closed system, as opposed to the open framework of Medieval thought. Likewise, the intent of the structure is to *control* the event described or depicted, in contrast to the Medieval method of merely incorporating it into the corpus of already understood lore by rationalizing it.

The most obvious result of the new mentality is the revived use of Euclidean geometry in architecture, city planning, astronomical systems, mathematics, and the scientific one-point perspective so dominant in the Renaissance. In the Baroque period, by contrast, the concept of symmetry is totally different. The observer of a painting by Rubens or a sculpture by Bernini sees a totally different kind of symmetry, one that depends on *the relation of the parts to each other*. Here the outer structure is discounted as a principle of cohesion in favor of an internal network of relationships. Baroque design is therefore typically unsystematic and unbound, for the symmetry depends on the dynamic interplay of the events or parts or personages to each other within a quite arbitrary frame. It also means that any "system" that tries to impose a structure on phenomena is going to be discredited. Francis Bacon, in fact, did precisely this in his *New Organon*, delineating the four Idols that impede proper knowledge of nature. In Aphorism 44 he stated:

> Lastly, there are idols which have immigrated into men's minds from the various dogmas of philosophies, and also from wrong laws of demonstration. These I call Idols of the Theater, because in my judgment all the received systems are but so many stage plays, representing worlds of their own creation after an unreal and scenic fashion. Nor is it only of the systems now in vogue, nor only of the Ancient sects and philosophies, that I speak; for many more plays of the same kind may yet be composed and in like artificial manner set forth; seeing that errors the most widely different have nevertheless causes for

> the most part alike. Neither again do I mean this only of entire systems, but also of many principles and axioms in science, which by tradition, credulity, and negligence have come to be received.[4]

Numerous corollaries can be derived from this basic difference in Renaissance and Baroque symmetries. First, to understand a product of the Renaissance one must think of the structure as being made of basic building blocks; in other words, any system can legitimately be broken into simpler constituents, each of which is a part of the whole, yet still a fragment of it. Scientific one-point perspective thus utilizes a grid framework of rectilinear horizontal and vertical lines to organize a picture's visual information, and only then does it derive diagonals from them to create the illusion of deep space. The Renaissance anatomist Andreas Vesalius is concerned with the "fabric" of the human body, as the title of *De Fabrica Corporis Humani* (1543) indicates, rather than with how the human system operates. Brunelleschi's Pazzi Chapel (1432) also breaks the structure into equal symmetrical parts held together by a pre-established geometrical design. Form, in other words, invariably precedes content.

In the realm of science, Nicholas Copernicus is a prime example of the irrepressible desire for structural order and harmony. In the famous preface to his *De Revolutionibus Orbium Coelestium* (1543), Copernicus attempted to explain how and why he came to postulate for Earth the three simultaneous, uniform, circular motions of diurnal axial rotation, annual orbital motion, and annual conical motion of the axis. It turns out that his reasons were literary and aesthetic rather than mathematical and scientific, for he was more interested in finding a coherent *structure* than a mathematically valid solution to the heavens' movements; and the major impetus to his search for a better system was the disagreement among the authorities concerning the old one:

> I was induced to think of a method of computing the motions of the spheres by nothing else than the knowledge that the Mathematicians are inconsistent in these investigations. ... Nor

[4] *The New Organon*, ed. Fulton H. Anderson, Library of Liberal Arts, 1960, p. 49.

> have they been able thereby to discern or deduce the principal thing—namely the shape of the Universe and the unchangeable symmetry of its parts. With them it is as though an artist were to gather the hands, feet, head and other members for his images from diverse models, each part excellently drawn, but not related to the single body; and since they in no way match each other, the result would be monster rather than man.[5]

Chafed by the confusion and irregularities imposed on what should be an orderly universe created by a rational god, Copernicus turned, not to the heavens in true empirical fashion, but to the newly popularized Classical texts:

> I therefore took pains to read again the works of all the philosophers on whom I could lay hand to seek out whether any of them had ever supposed that the motions of the spheres were other than those demanded by the mathematical schools. I found first in Cicero that Hicetas had realized that the Earth moved. Afterwards I found in Plutarch that certain others had held the like opinion. (*De Revolutionibus*, p. 55)

Buoyed by the authority from ancient literature, Copernicus then approached the heavens to prove with observations what he aesthetically believed to be true. He found there the overall symmetrical design he desired the universe to exhibit:

> Thus assuming motions, which in my work I ascribe to the Earth, by long and frequent observations I have at last discovered that, if the motions of the rest of the planets be brought into relation with the circulation of the Earth and be reckoned in proportion to the circles of each planet, not only do their phenomena presently ensue, but the orders and magnitudes of all stars and spheres, nay the heavens themselves, become so bound together that nothing in any part thereof could be moved from its place without producing confusion of all the other parts and of the Universe as a whole. (*De Revolutionibus*, pp. 55-56)

Copernicus' notion of the universal fabric is thus precisely the same as the Renaissance artist Leonbattista Alberti's famous

[5] Nicholas Copernicus, "Dedication of the *Revolutions of the Heavenly Bodies*," in *Prefaces and Prologues to Famous Books*, New York, Collier, 1938, p. 55.

definition of Beauty: "A harmony of all the parts, in whatsoever subject it appears, fitted together with such proportion and connection, that nothing could be added, diminished or altered, but for the worse."[6]

In the Baroque era this building-block mentality of symmetrical parts forming a harmonious whole is no longer viable. The Baroque mind sees each component of a system as being consistent extrinsically with all the others and intrinsically with itself. The parts are therefore not fragments of the whole, nor subservient to the structure, nor really related to the outer framework. In a Baroque painting, such as Rubens' *The Garden of Love* (1630) or Rembrandt's *The Night Watch* (1642), the internal design is interwoven in such a way that no one component can be separated out of the reticulum of visual display. Heinrich Wölfflin sensed this disparity between the two styles and described it thusly:

> In the sixteenth century the picture elements group themselves round a central axis or, if this does not exist, so as to produce a perfect balance of the two halves of a picture which, though not easily definable, makes itself clearly felt when contrasted with the freer order of the seventeenth century. It is a contrast such as is defined in mechanics by stable and unstable equilibrium. But the representative art of the baroque has the most decided aversion to stabilisation about a middle axis. Pure symmetries disappear, or are made inapparent by all kinds of disturbances of balance. (*Principles of Art History*, p. 125)

A further consequence of these symmetries is the sense of *energy* a work of each period possesses. In the Renaissance a work of art is generally confrontational and static. Ample space is provided for the subject matter depicted or described, and the event usually begins within the framework and recedes directly inwards to the central point of interest. The energy implied in the work is therefore created not by physical action but by the tension among the parts in their relation to the structure. A Renaissance work can thus be described as a

[6] Cited in *A Documentary History of Art*, ed. Elizabeth G. Holt, Garden City, Doubleday, 1957, I, 230.

static system of objects held together by numerous springs of equal tension, each pulling on the others, and all held stationary by the container. This is not the case in the Baroque, where the energy is physically unbounded and non-directed. In a painting like Rembrandt's *The Night Watch* the action is involuted upon itself in such a way that a virtual sphere of animation is created, as if the two-dimensional square frame somehow contained a round mass of energy. This illusion creates the immediate effect of advancing motion for the spectator, what John Ruppert Martin calls "the integration of real and fictive space" (*Baroque*, p. 157). The effect in terms of energy is that a Baroque work appears to have more energy than its structure can contain. Each constituent thereby exhibits much more impact, more dynamism and presence within the work, than a mere fragment of a whole would normally have. If the Renaissance concept of energy is a set of springs, then the Baroque concept of energy is an expanding component within too small a container. This is what gives Baroque works their sense of proximate explosiveness: the sum of the energies in the constituents is far greater than the container of the constituents —whether a picture frame, a literary genre or mode, a poetic verse form, a sculptural or architectural surface—can legitimately hold. A Baroque object thus makes valid the mathematical formula $(A)+(B)+(C)>(A+B+C)$.

In summary, the Renaissance sees the world as an assemblage of entities that make up a coherent whole. These entities, moreover, are particles of matter in the sense that they have a certain unity within themselves, although not a truly independent existence, since they are parts that aggregate into a whole. The Baroque, on the other hand, views the world as a dynamic web of interrelated events. None of the properties of the reticulum is fundamental to the outer structure, yet each is indeed fundamental to the matrix framework of the reticulum itself, for it is the overall consistency of their mutual interrelationships that determines the structure of the entire dynamic web. Such a difference between the two epochs explains the quite artificial construction of Renaissance systems and the very natural construction of Baroque ones. There are no straight lines in nature; rectilinearism exists only in the mind of man, for it is a metaphysical property that requires mathematical calculation and manual construction. But nature does contain spider's webs. This is why it is legitimate to use the term "organic" for Baroque works, as so many thinkers from Alfred North Whitehead to the present have done. As Arnold Hauser described it, when discussing the concept of infinity in Baroque art: "The work of art in its totality becomes the symbol of the universe as a uniform organism alive in all its parts. Each of these parts points, like the heavenly bodies, to an infinite, unbroken continuity; each part contains the law governing the whole; in each the same power, the same spirit, is at work."[7]

The scientific advances that took place in each epoch show the same development as that observed in the arts. The Ptolemaic theory of the universe, based on a system of concentric solid spheres enclosing the Earth, Moon, Mercury, Venus, Sun, Mars, Jupiter, Saturn, the fixed stars, and the crystalline sphere, all held in place by a *primum mobile*, served the Medieval world well to explain the logical correctness of God's hierarchical creation. Copernicus dumps this system, however, in favor of one where the Sun takes the central position. As explained earlier, he does this because such a cosmology gives a greater geometric harmony to the universe; in other words, the planets in his system move in circular uniform motion more regularly than they did in the Ptolemaic system. He retains the idea of solid spheres for each planetary orbit, as well as the important concept of an outer shell that mantles and gives movement to all the inner objects. His universe is thus first and foremost static, for uniform circular motion is really not "motion" at all, since it is always and everywhere precisely the same. His universe is also totally separate parts that make up a complete whole. The spheres remain self-contained, one against the other, each with its own constant amount of energy and each harmonically proportional to the others.

The Baroque concept of the universe emerges in Johann Kepler's three laws of planetary motion: the planets move in *elliptical* paths with the Sun occupying one of the two foci of

[7] *The Social History of Art*, trans. Stanley Godman, New York, Vantage, n.d., p. 182.

each orbit, the orbital speed of a planet is such that it sweeps through equal areas of the ellipse in equal intervals of time, and the ratio of the squares of the planets' orbital periods is proportional to the ratio of the cubes of their average distance from the Sun. It is first and foremost a dynamic system, where the planets revolve in non-Euclidean ellipses around the Sun with distance and time interlocked in a mutual dependence. Moreover, the planets pull and push each other in such a way that the dynamic energy of each affects the motion of the rest. If Copernicus' universe was described arithmetically in terms of harmonic proportions—equal parts that make up a whole—the Baroque universe must therefore be described as a calculus of unequal instants along unequal curves. Furthermore, the outer framework is discarded simply because it is no longer needed, for the planets now hold themselves together in an internal reticulum of interactions. To summarize, while a Renaissance work expresses a minimal amount of binding energy among the parts but a strong outer binding force between the parts and the frame, the Baroque expresses a strong binding energy among the parts and a minimal amount of binding force between them and the containing structure.

There is an important lesson to learn from these two variant conceptions of symmetry. It means that when one examines Renaissance art he should expect to find symmetrical and harmonic structures that bind the parts to the whole. Renaissance works can therefore legitimately be described arithmetically and geometrically. If one looks for a concomitant structure in Baroque art, however, he will not find it; for the patterns and relationships are not there but rather in the interplay of parts with each other and with themselves. This likewise implies that in a Baroque work more than in a Renaissance one the events and objects are going to be so organically interconnected that in order to explain one of them the investigator would need to understand all the others, which is pretty much of an impossibility. The thinkers of the Baroque age knew this, and it is why they looked differently at the universe about them. A valid general statement about the Renaissance mind is that it generally asks *what* the structure of an object or a system is. Copernicus' major desire was to formulate a clear and logical framework for the heavens, a *what* that would explain the phenomena, whether such a system would "save the appearances" or not. He therefore did not begin by calculating different modes of cycles or motions or distances, but by rearranging the independent fragments of the whole structure. First take the parts and put them in different arrangements with each other, he said, then see what the visual phenomena of each planet's motion in relation to the others reveals about its cycles and distances. Copernicus thus worked from the outside in, and not *vice versa.* Brunelleschi's Pazzi Chapel (1432), constructed one hundred years earlier than Copernicus' hypotheses, although within the same mental framework, shows a similar pattern of thought. The outer great circle within the great square must be constructed before the inner analogous circles within the squares of the walls, floor, and roof can be associated with it.

In the later Baroque era, Galileo and Kepler ask *how* events transpire, and their answers differ radically from the *why* and *what* of their predecessors. Furthermore, a *how* question has the innate advantage of being limitable to one piece of a whole set of phenomena, thus skirting the unsolvable problem of a macroscopic description. Kepler was able to determine the elliptical orbits of the planets because he was concerned solely with *how* the planets moved. The questions of what they were, or why they moved, or even the overall structure of the universal system were left to one side. Galileo could describe the problem of how objects fall because his mentality allowed him to isolate that phenomenon from those of weight, physical characteristics, and size. One sees the same isolation of an event in the paintings of Caravaggio, Velasquez, Rubens, and the other Baroque artists. They describe a single instant in a single action rather than a whole event in all its timeless completeness. It is the fundamental difference between a painting like Velasquez's *The Maids of Honor* or Caravaggio's *The Conversion of St. Paul* and Botticelli's *Primavera* or Masaccio's *The Tribute Money.*

Anatomy shows the same evolution. Vesalius was interested in determining *what* the human body contained; and he described its contents in precise, logical order from the inside out, which was a rather illogical way, although an aesthetically pleasing one. William Harvey, on the other hand, could ask fifty years later *how* the human body operates. In a supremely Baroque manner, he conceived of the circulatory function of the blood where the heart was a self-perpetuating machine moving the blood through the body. He was likewise unconcerned with the *why* or *what* of blood, attending solely to *how* it moved through the body, for he had the innate sense to isolate the problem of the blood stream from the system in which it appeared, disregarding what blood was supposed to be. His book *De Motu Cordis et Sanguinis* broke with the traditional view of the body as a "fabric" by taking a dynamic approach to the human system rather than a static one, and by seeing the heart as a mechanical instrument and not as a pressure cooker providing heat. By asking how the heart operated as opposed to what it was, he could conclude that it was "a piece of machinery in which though one wheel gives motion to the other, yet all the wheels seem to move simultaneously."[8]

Another typical case is the evolution of inertial physics. The Medieval mind, concerned with understanding the *why* of phenomena, accepted Aristotle's suggestion that bodies fall to their "natural" place in the universe if unmolested by violent motion. Thus earthy objects fell to earth, watery objects fell to water, airy objects rose to air, and fiery objects rose to fire. Movement as such was not involved in the problem, since all objects ascend or descend in a line directly towards the center of their natural destination. Aristotelian physics also deduced that the free fall of an object depended on its weight, so that if an object was twice as heavy as another it would fall with twice as much velocity, given the same medium. Thus if V is velocity, R the medium, and H heaviness, VxH/R and $Tx1/H$.[9] The direction of fall is of course vertical toward the center of the earth, regardless of relative motions. So a stone dropped from the top of the mast of a moving ship necessarily falls behind the mast, since the ship will have moved from under the vertically falling stone.

[8] From Herbert Butterfield, *The Origins of Modern Science*, New York, Free Press, 1955, Chapter 3.

[9] See Dudley Shapere, *Galileo: A Philosophical Study*, Chicago, University of Chicago Press, 1974, pp. 36-43.

The attraction of objects by the earth was thus explained by the Aristotelians in such a way that the answer to *why* they fell was resolved. *What* fell was quite simply weight. However, when Copernicus put the sun in the center of the universe and gave the earth itself multiple motions, those who accepted his theory could no longer abide by Aristotle's explanation. Galileo Galilei was the first person to truly resolve this paradox, and he did it by simply ignoring the why or what of the matter and addressing himself to the question of *how* objects fall to the earth. By confronting the dilemma in this way, he could thus discount the problem of causes and concentrate solely on events. He determined—as did Kepler about the heavens—that the fall of an object has nothing to do with its weight or size or physical properties but solely with the amount of time in which it covers a certain distance: $D = \frac{1}{2}AT^2$. This is quite simply the way things fall, and it is always true.

The consequences of these diverse symmetrical patterns for art and science appear clearly in the distinct view each age had of three concepts long held fundamental to scientific development, yet somewhat neglected by investigators of other areas of the Renaissance and Baroque: space, time, and mass.

Space

The Platonically inspired rage for a symmetrical pattern characterizes the Renaissance use of space in every intellectual endeavor. In painting it takes the form of scientific one-point perspective; in cosmology it is exhibited in the insistence on uniformly moving concentric spheres; in drama it is the three unities of time, place, and action; in anatomy it is the concept of independent overlapping parts of bones, internal organs, muscles, skin; in poetry it is the shell of the poetic mode; in music it is the four-part motet and Pythagorean octave; in architecture it is the geometric proportion of the classical orders; in sculpture it is the Platonic inner form that Michelangelo carves the dross matter away from. In every case a structure holds space in a finite amount, and the objects, events, or words held within the space form a coherent and symmetrical pattern in their relation to the container.

The painters' use of scientific one-point perspective is the best-known example of this tendency. All objects in a Renaissance painting are part of a space directed towards one point, ideally at the middle of the container and at the eye-level of the viewer. There is also a sense of distance in that the illusion is created that objects smaller or farther up or overlapped in the picture frame are farther away; but it is never infinite distance, because the eye is always led to some concrete thing or point that stops it. It is contained, bounded, limited space.

This was a revolutionary step away from the concept of space in the Middle Ages, when the painter was solely interested in the psychological relationship that objects held to each other and unconcerned with the physical distances of entities from each other. Thus the most important figure would be in the middle of the picture and larger than anyone else, regardless of the spatial relationships.

The contrast between the Medieval and Renaissance concept of space is most readily seen in the development of map-making. In the late Middle Ages mariners used what are today called portolans. These maps show a strip of coastline and give the names of all the towns and landmarks a mariner will encounter. They also have a crude rose compass and radiating lines to show the direction the mariner must follow from one point to another. The portolans do not give the *distance*, but only the *direction*. Medieval painting does the same thing; one can tell who is in front or behind or beside, but not how far things are from each other, nor how deep the space is, for it is the directional relationships that matter and not the distances.

In 1400 Ptolemy's *Geographica* reached Florence, brought by the Greek teacher Manuel Chrysoloras; and by 1410 it had been translated into Latin. The book showed in detail how to project a spherical object onto a flat surface by using a square grid of longitudes and latitudes, compensating for the distortion. The early Renaissance mentality was evidently ready for this technique, for it appeared almost immediately in maps and painting, blocking out space and thus making distance an integral part of the visual field. Masaccio's use of a grid for his fresco, *The Holy Trinity*, in Santa Maria Novella, Florence, is well known. Space was now divided geometrically into equal parts and so could be measured as never before, and the painters

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strove to imitate it to such an extent that Leonbattista Alberti could define painting in its terms: "Painting, then, is nothing other than a cross-section of a visual pyramid upon a certain surface, artificially represented with lines and colors at a given distance, with a central stance established and lights arranged" (*Documentary History of Art*, I, 209).

The concept of space as a straightline measurable distance between two points held for over a century. It was simple, concrete, and direct; it gave new life to algebra and, more specifically, geometry, of which it was an integral part. In fact, its chief weakness—that it only served for straightline distances—did not appear to disturb anyone until the middle of the sixteenth century, when those anti-Classical experimenters now called Mannerists began to work with non-Euclidean curves. El Greco's mystical conception of space was a major breakthrough, as were the variants to one-point perspective by Brueghel in the North. Tycho Brahe, the idiosyncratic astronomer who is a paradigm of the Mannerist mentality, made some extraordinarily important decisions about the heavens that just as extraordinarily were reflected analogically in contemporary painting. In 1572, when a new star appeared in Cassiopeia, Brahe decided it was in the heavenly sphere and not in the sublunar one, thus denying the incorruptibility and perpetuity of the heavens. With the great comet of 1577, he again broke with traditional thought and declared that planets do not move in solid spheres but in orbits, thus eliminating the venerated structural frame for heavenly bodies and paving the way for the consideration of spatial infinity. Later, he correctly observed that the center of motion of comets is the sun and even considered non-circular orbits for them, a detail not overlooked by Johann Kepler twenty years later. In an analogical way, the Venetian Mannerist Tintoretto is disrupting the classical concepts of space when in *The Last Supper* (1592-94) in San Giorgio Maggiore he has the lines that lead the spectator's eye to the vanishing point disappear into a dark corner of the painting, a literal black hole of infinite nothingness. Brahe's weird concept of the planetary systems eerily exhibits the same off-centeredness as one of Tintoretto's or El Greco's paintings.

It is during this same time (1569) that Gerardus Mercator vastly improved on the Ptolemaic conformal map by using straight lines as loxodromes, or rhumb lines, rather than circles around a central point. Mercator did this by increasing the spacing of the parallels by specified amounts from the equator to the poles, i.e., by increasing apparent distance between the latitudes. This clearly breaks with the Renaissance artistic tradition to imitate the appearance of objects in nature, as well as the earlier scientific efforts to "save the appearances" of the celestial motions, because it intentionally *distorts* the shape of the countries in high latitudes, causing them to appear larger than they are. For Mercator, then, the principal interest was the correct calculations of distance and direction rather than correct appearances of objects, which is a conceptual mentality that draws him squarely into the forthcoming Baroque era.

The Mannerist experimentations with rectilinearism gave way in the Baroque to the complete dissolution of straight lines. Caravaggio, Velasquez, Rembrandt and Rubens all turn to a non-linear format where scientific one-point perspective is rejected in favor of the concept of organic unity. Furthermore, when geometric structures are used to organize space they are no longer Euclidean, but spirals, ellipses, cubes, rhomboids, and parabolas. Examples abound in the paintings of Rubens, such as the swirl of movement in *The Garden of Love*, the true spiral in *The Battle of the Amazons*, where the movement of space begins with the largest figures at the bottom of the painting and spirals into the upper center, and *The Peasants' Dance,* which is a composition based on the cube. Velazquez takes equal liberties with the use of space, extending it to include the spectator in *The Maids of Honor*, breaking it into planes of residence in *The Spinners*, and even curving it into a concave lens in *The Water Carrier of Seville* so that the spectator sees the objects at the top of the picture (the bottom of the old man's face) from a lower angle and the objects at the bottom of the picture (the water jar) from a higher angle. The same technique is used also in his *The Old Cook*.

Gianlorenzo Bernini takes radical liberties with space in altar pieces like the *Saint Teresa in Ecstasy,* where he includes spectators on each side of the viewer. For the martyrdom and ascension of Saint Andrew in Sant'Andrea al Quirinale, Rome, Bernini orchestrates a whole series of events for the viewer. As one stands before the presbytery, he sees 1) a reliquary on the altar holding earthly remains of the saint, 2) a large painting of the saint's crucifixion, which is flanked by two pointing angels, 3) a magnificent plaster composition above the painting with a cascade of golden *putti*. Sun rays, and an adult angel holding a garland to crown the saint (the angel is juxtaposed with another with a clarion over the entrance of the little church), 4) another statue of the saint placed between the arc of the presbytery and the dome in which Andrew is resting on a cloud that bears him to heaven, 5) a ceiling design of Saint Andrew in glory, and 6) heaven itself in the central dome directly overhead, represented by the dove of the Holy Spirit. The viewer thus participates actively in the martyrdom and apotheosis of the saint as if it were happening physically before his eyes in a series of ascending events. El Greco had created a similar simultaneity of action in *The Burial of Count Orgaz* (1586), itself a step away from the foreshortening of space in the High Renaissance; but El Greco's space in this painting remains rectilinear, proceeding directly upward from the world of the flesh to the world of the spirit, whereas Bernini's space begins horizontally and soars upward in a parabolic curve with ever-increasing velocity to a vertical position.

In religious settings, the eye is led through this mixture of real and implied space to the ultimate point of existence, which is the godhead. A sense of infinity is thus avoided in works like Pozzo's ceiling painting *Saint Ignatius in Glory* (Sant'Ignazio, Rome) because the eye stops at God. In secular paintings, however, especially in the later landscapes of Rubens (after 1630) and in those of the Dutch masters, there is nothing to stop the eye from moving away into an illusionistic infinity, which of course it does. Such a conception of space is only logical in an age where Giordano Bruno is burned at the stake for refusing to renounce belief in an infinity of worlds; where Galileo has proved that $D = \frac{1}{2}AT^2$ anywhere and everywhere in the universe; and where Isaac Newton is formulating laws for color, motion, gravity, and force that are likewise universally true. In the words of John Ruppert Martin, who has also perceived this relationship between the infinite space of the artist and that of the scientists:

> It is not too much to say that the sense of the infinite pervaded the entire Baroque age and coloured all its products. The awareness of the physical unity of the universe is reflected in the new attitudes adopted by many Baroque artists towards the problem of space. Their *aim*, as one might put it, is to break down the barrier between the work of art and the real world; their *method* is to conceive of the subject represented as existing in a space coextensive with that of the observer. Implicit in this unification of space, in which everything forms part of the continuous and unbroken totality, is a concept of infinity analogous to that framed by some of the greatest thinkers of the period. (*Baroque*, p. 155)

Time

As long as space was conceived as uniform and either rectilinear or circular, as it was in the Renaissance, it could be measured arithmetically and geometrically solely in terms of distance. It was static and sequential. But when space became extended and dynamic, as it was in the Baroque, the factor of time entered the picture; and it is time that becomes the new obsession of the Baroque. Galileo Galilei is clearly the major figure in the new advances. Before, him, people had asked questions in which time was a function of distance; if a stone falls X feet in one second, how long will it take to fall 100 feet? Clearly, since they thought the individual weight, the size, and the physical composition of the object all had a bearing on velocity, it was the only way they could generalize a formula. Galileo revolutionized science by making time an independent function, calculable by itself and inexorable. It is now distance that depends on time, and all secondary qualities are irrelevant to the problem. If an object falls for 10 seconds, how far will it fall? The answer is: *since* the object falls at a rate of 32 feet per second per second, *therefore* in 10 seconds it will fall 1600 feet. Time thus does not flow 1, 2, 3, 4, ... *n*, but continually increases and decreases in relation to distance, depending on the circumstances, in precisely calculable quantities. Kepler understood this, and therefore could correctly describe the movements of the planets as ones that covered equal areas in equal times, regardless of the distance covered by the planet in its orbit (which at the time Kepler did not know to be an ellipse). Rubens understood it, and in paintings like *The Battle of the Amazons* and *The Fall of the Damned* created illusions that make the viewer's eye pattern increase in velocity as it follows the spiral of activity into the painting. Brueghel had intuited it when he did *The Parable of the Blind* and conceived of his falling figures as a simultaneous event; and Rubens created the same effect in *The Peasants' Dance*, where the dancers are caught in a cube of movement that is a coherent motion in time. The culmination of this development is the invention of calculus by Newton in England and Leibniz on the continent. What could be a better finale for the Baroque world than a system to calculate non-uniform motion on the one hand and non-Euclidean curves on the other?

Time thus becomes a vital factor in the conception of motion —now a dynamic velocity—over a distance. One no longer looks at a painting or a statue, but now literally spends time with it, following events expressed in non-uniform motion over curved distance. There is in effect no other way to experience Baroque works like Bernini's altar in Sant'Andrea al Quirinale or Borromini's facade for San Carlo alle Quattro Fontane or Narciso Tome's *El transparente* in the ambulatory of the Toledo cathedral. By the same account, now that time is an independent, measurable factor, it can be "caught" in one instant of action, an unrepeatable moment in time in which often the painter presents his subject as being caught off guard, as if the sitter had just discovered the painter was there. Bernini's sculptures, in Rome's Borghese Gallery, of Apollo and Daphne, the young David, and Pluto and Persepone also catch one instant of an action.

The evolution of the clock shows similar stages in regard to time. The first real advance in clockwork was the invention of the escapement mechanism in the last quarter of the thirteenth century. Called by D.S.L. Cardwell "perhaps the greatest single human invention since the appearance of the wheel,"[10] the escapement permitted the first true regularly interrupted motion. Its main drawback was that it lacked isochronism: the heavier the weight, the more rapid the swing of the arm. The second advance in clockwork was the introduction of the fusee around 1500. Credited to Leonardo da Vinci, the fusee has two drums, one with a spring and the other with a variable radius, coupled by a cord or chain so that as the spring unwinds the gear ratio progressively changes, giving thereby a constant pressure to thus move the timepiece isochronically. Both the escapement and the fusee are instruments that attempt mechanically to create isochronal intervals which can then be applied to the notion of time.

But what is time? Is it a measuring instrument invented by man to gauge events? Is it necessarily dependent on weight? Galileo Galilei approached the problem after an alleged chance observation of the swinging church lamp in Pisa's Duomo and discovered the properties of the pendulum, in particular that—as with gravity—time has nothing to do with weight but only with distance. He found that a pendulum is *naturally* isochronal, for it makes every swing in the same time, independent of weight or the size of the arc, yet dependent on the length of the pendulum. As Christiaan Huygens formulated it years later, $T = 2\pi\sqrt{L/G}$. In regard to both gravity and the pendulum, then, time for Galileo and his successors became a measurable entity rather than a measuring device; it was real, a valid part of nature as much as a tree or a planet or mass were. This indeed was a tremendous advance from the Renaissance notions of the physical world.

Mass

With the concept of mass one reaches the culmination of the direction that Baroque thought took during the seventeenth century, for it brings time and space back into relation with the object's physical properties of volume and density. Isaac Newton mathematized it in his second law, which states

[10] *Technology, Science and Culture*, London, Heinemann, 1972, p. 14.

that the mass of a body is directly proportional to the force acting on it and inversely proportional to the acceleration: $M = F/A$. We now describe this relationship by saying that bodies have equal masses if, under similar circumstances, they suffer equal changes of motion in a given time. Newton also equated mass with inertia, thus explaining the absence of weight as a factor in Galileo's famous formula for free-falling bodies ($D = \frac{1}{2}AT^2$), for heavier objects will have to overcome more inertia and will need more force to accelerate than lighter objects.

Galileo had not fully grasped the true relationships between weight, mass and inertia, mainly because he held weight to be a secondary quality, as opposed to the primary qualities of position, motion, magnitude, etc. Despite his reasons for doing it, the important fact is that Galileo and his contemporaries eliminated weight from the field of kinematics, correctly claiming that it had nothing to do with motion and extension, which are the primary properties of the physical universe. As Descartes once said: "Give me extension and motion, and I will construct the universe."[11]

Galileo also defined inertia as the property of a material object to maintain its state of motion. He proved it by dropping balls down an inclined plane and showing that, ideally, the balls will always travel up another inclined plane to the same height from which they were dropped, regardless of the distance travelled. Therefore, if the plane levels off, the ball will theoretically travel forever on the horizontal plane at the speed it reaches at the bottom of the incline. No Aristotelian could have accepted this law of inertia. For them, the property of weight, which Galileo discounted entirely and Newton converted into mass, was *the* essential factor in movement: the greater the weight the greater the velocity, all other things being equal. Furthermore, since objects with weight were "earth" objects, they had to necessarily fall vertically to the earth, and any other direction or movement would be a violent motion caused by some ouside force. Horizontal motion as such did not even exist

[11] Quoted by John Herman Randall, Jr., *The Making of the Modern Mind*, Boston, Houghton Mifflin, 1926, pp. 241-42.

in the Aristotelian lexicon, much less infinite, perpetual, horizontal motion.

The Renaissance, despite the numerous advances it made in other areas, was incapable of breaking away from this Aristotelian concept of weight. Even Galileo continued to believe that motion would be circular if all other factors were eliminated. The reflection of these ideas in the other areas of intellectual endeavor is subtle, but it is there. The clearest example of the shift from weight, as the attraction of a body by the earth, to mass, as volume multiplied by density, is with falling objects in painting and sculpture. In the Renaissance, one rarely finds a true falling body. People are painted as standing firmly on the ground, with their weight balanced on both feet. If objects leave the ground they are invariably sustained in some way, as in Pollaiuolo's *Hercules Strangling Antaeus* (c. 1475), which is a brilliant interplay of two equal weights, or in Vincenzo de' Rossi's satyrical and totally Manneristic depiction of the same event in the Palazzo Vecchio, Florence, where Antaeus is inverted over Hercules. Objects literally "in the air" are hard to find in the Renaissance. In Masaccio's *The Holy Trinity*, for example, considered by most scholars to be the first truly Renaissance painting, Christ and the cross are being held by God the Father, who is not floating in the eternal *aevum* but is standing firmly on a platform behind the cross. The soaring angels of Medieval ideal space have also come to earth in the Renaissance, and are depicted as standing or kneeling around the religious figures they adore. In architecture one also finds this solid relation to the earth, where objects are held in place by the symmetry of their weights.

As in other areas, the Mannerist period of the second half of the sixteenth century represents the breaking up of the traditional ideas of weight. Brueghel's *Landscape with the Fall of Icarus* is a typical example of how the artists begin to experiment with falling objects. Architectural anomalies also appear, as the Palazzo del Te by Giulio Romano, where the keystones are placed in such a way that it appears they will fall at any moment. But it is in the Baroque period that the concept of weight is discounted from material bodies and is replaced by volume times density. Figures in the Baroque literally soar in every direction. Fat *putti* proliferate in Rubens' works. Bernini's altar pieces ascend into the space above them; Baroque building facades grow upward in defiance of all logical ideas of weight, and their embellishments hang into empty space, as does the giant medallion on the upper story of San Carlo alle Quattro Fontane. The most obvious advance is in ceiling painting, initiated in the Baroque by Guercino and Pietro da Cortona and perfected by Pozzo and his contemporaries. There, figures appear to physically float in space, oblivious to the pull of gravity, yet retaining a most earthy volume and density. Weight as such has no meaning for these artists, as it had none for Galileo. Objects in the artistic world as in the scientific world literally continue in their state of motion unless acted on by an outside force, for they are held in space by an equivalence of mass and inertia. There is no valid explanation other than this one for the rejection of weight as a requisite for realism by Baroque artists. As in science, weight was quite simply no longer a factor for realism, being replaced by volume and density in terms of motion and distance.

The Baroque artists were not necessarily reading Galileo's and Descartes' works, much less those of Isaac Newton, whose *Principia Mathematica* did not appear until 1687; but they all had the same mental set. In other words, their efforts proceeded in an analogical manner; for they worked in different media, but their minds were functioning in the same way. Thus Baroque scientists had as much in common with Baroque artists as Renaissance scientists did with Renaissance artists; and *vice versa*, Baroque scientists were as different from Renaissance scientists as Baroque artists were from Renaissance artists. The symmetry formulated by the one is the same symmetry depicted by the other, and the nomenclature of one can be transferred successfully to the area of the other. Motion, space, time, mass; all are terms that describe every area of endeavor in a respective period equally well.

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