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Words and Numbers

Word and number are on shaky terms. Something wants them apart, as if the few tattered bits of ancient academic garb still strung between the humanities and the sciences only thinly veil some ultimate incompatibility; as if all that old stuff about a quest for the unity of knowledge could no longer really be taken seriously; as if deep down most of us believe, at least for practical purposes, that word and number are the fundamental particles in discrete hemispheres of cerebral life, each self-sufficient in its own jurisdiction. Maybe that's why we feel uneasy when quality and quantity get mixed—when, for example, someone sees symbolic meaning in a number (i.e., treats it like a word) or when, conversely, someone tries to reduce qualities to statistics. Nobody wants to be just another number (or for that matter, consistent that we are, to be lodged in room 13, if indeed a hotel exists with a thirteenth room or floor). Yet most of us choose sides and pledge allegiance somehow. Students, for example, commonly view themselves as either word people or number people, self-images that maintain their grip long after the initial shock of those unbalanced college-board scores has been forgotten. Many consequently lock themselves into half a curriculum when choosing skills courses and electives, seldom sensing how profound an influence the word/number dichotomy is exerting on their studies, their hobbies, their careers.

The split is taken for granted to such an extent today that it is difficult, if not impossible, for most of us to imagine things any other way. The symposium on culture, held here in 1979 and celebrated anew in earlier issues of this journal, may be cited as a convenient illustration of this split. One implicit agenda (although, particularly for Hugh Kenner and Huston Smith, often explicit) proved to be *cultures* rather than *culture,* expecially the continuing debate about what C.P. Snow termed the "two cultures." But the concern about the dichotomy itself, what

Huston Smith labeled the "slash" between the humanities and the sciences, betrays an awareness of, even a nostalgia for, a former unity now lost. We sense that the relationship between word and number, as one feature of the paradigm, was not always so shaky. On the contrary, many of those whose writing and thought have survived from the early periods of Western culture appear to have moved back and forth between word and number easily and naturally, and some of the most cherished achievements of our heritage have been valued in intervening times as marvels of science and art alike. We look back on this with vague disquiet. Something in us resists the notion that Euclid's *Elements of Geometry* is also a work of verbal art and Dante's *Divine Comedy* also a work of science. And we are amazed to learn that Chaucer was eulogized by his contemporaries as scientist no less than as poet (or for that matter that Hugh Kenner, a literary critic, recently published a technical manual entitled *Geodesic Math and How to Use It*).

Recently an even more dramatic cause for surprise has emerged: the discovery that major medieval poets like Dante and Chaucer utilized number as an integral and necessary part of their craft; that they devoted thoroughgoing attention to the numerical features of their texts at all stages of composition; that they even appropriated the mathematical knowledge of their age in ingenious and often quite technical ways; that for them number was an essential and, it seems, totally natural component of *literary* art.

The present essay is concerned with this discovery and some of its implications for the study of Western culture. My purpose in the first regard is not to demonstrate the case in the usual sense of this term but rather to summarize and briefly exemplify findings which I have begun to report in detail for more specialized readerships elsewhere.[1] My present concern with the implications, on the other hand, grows out of a familiar idiosyncracy of specialized studies—the limited scope they typically allow for exploring larger issues like implications for the discipline as a whole or for other disciplines. Ideally one benefit of research in the humanities, beyond rediscovering intellectual and cultural achievements of the past, lies in promoting fuller appreciation of the stances from which *we* now view those achievements. There is, after all, a certain hermeneutic reciprocity between *what* is known and *when* it is known. As Goethe expressed it: "Nicht alles ist zu allen Zeiten möglich" ("Not everything is possible at all times"). And there is a sense in which achievements of the past hold up a mirror to the present. The emergence of number-based designs where we have least expected them is a rather dramatic case in point. It challenges us to reassess the assumptions on which our expectations were based by examining neglected points of contact between mathematics and poetry, both in Western esthetics and in the traditional liberal arts curriculum. Accordingly, I attempt in this essay to introduce representative findings about number-based design techniques in literature as part of a larger inquiry into some of the reasons, past and present, why these findings now come as such a surprise—and why they should not.

It is instructive to begin with two specific examples of medieval thinking that few modern readers would find self-explanatory. The

1. See for *Beowulf: Essays in the Numerical Criticism of Medieval Literature*, ed. Caroline D. Eckhardt (Lewisburg, Pa.: Bucknell University Press, 1980), pp. 185–210; and *Studia Neophilologica* 53 (1981): 1–33. For Chrestien's *Erec: Mediaeval Studies* 43 (1981): 250–296; and *Symposium* 35 (1981): 57–86. For Hartman's *Iwein: Colloquia Germanica* 10 (1976): 97–120; and *Res Publica Litterarum* 2 (1979): 81–107. For Chaucer's *Troilus: Chaucer Review* 16 (1982); a book on the subject is in preparation.

first is an excerpt from the definition of the discipline of geometry given by one of the more influential later medieval textbooks, the *Didascalicon* by Hugh of St. Victor (twelfth century). It begins unexceptionably enough:

> *Geometry is the discipline treating immobile magnitude, and it is the contemplative delineation of forms, by which the limits of every object are shown.*[2]

But then it proceeds:

> *Putting it differently, geometry is a "fount of perceptions and a source of utterances" (fons sensuum et origo dictionum).*

One modern student of Hugh's text sought to explain this startling derivation of *verbal* elements ("utterances") from geometry as follows:

> *Application of this phrase to geometry may be related to the view of mathematics, geometry in particular, as concerned with visible form, and to the view that form, in turn, is the source of a thing's species or genus and name.*[3]

The second example of medieval thinking is from the one-hundredth and final canto of the *Divine Comedy* (ca. 1300). At the ecstatic climax of Dante's visionary journey through the spiritual cosmos of hell, purgatory, and heaven, the poet portrays himself entering into the Divine Presence and gazing rapt upon the eternal light. He relies on the following remarkable simile to express the inexpressible:

Qual è 'l geomètra che tutto s'affige
per misurar lo cerchio, e non ritrova,
pensando, quel principio ond' elli indige,
tal era io a quella vista nova:
veder voleva come si convenne
l'imago al cerchio e come vi s'indova.

As is the geometer who wholly applies himself
to measuring the circle, and finds not,
in pondering, the principle of which he is in need,
such was I at that new sight.
I wished to see how the image conformed
to the circle and how it has its place therein.[4]

At first encounter with the *Divine Comedy* the modern reader is impressed and puzzled alike, not only by this particular passage, but also by the frequency and intensity with which Dante draws on the mathematical disciplines for his imagery throughout the poem. Dante specialists too have been puzzled. The standard commentary by the dean of American Dante scholars, Charles S. Singleton, gives the following gloss for this passage:

> *No poet was ever more daring in his final simile, in so long a poem, daring to bring into this very end the notion and image ("cold," as in geometry or mathematics!) of the geometer who studies the circle in the vain attempt to square it. . . . The amazement of the modern reader must arise from the abstractness, the geometrical nature, of the vision of God that terminates so long a journey.*[5]

In fact, beyond expressions of wonderment, commentators have had little to say on Dante's mathematics—a curious circumstance, considering that more is thought to have been written about the *Divine Comedy*

2. Jerome Taylor, trans., *The Didascalicon of Hugh of St. Victor: A Medieval Guide to the Arts* (New York: Columbia University Press, 1961), p. 71.

3. Ibid., p. 203.

4. *Paradiso* 33. 133–138. Text and translations here and below are from *The Divine Comedy*, ed. and trans. Charles S. Singleton, 6 vols. (Princeton: Princeton University Press, 1970–75).

5. Singleton, *Divine Comedy*, 6:584.

over the centuries than about any other book besides the Bible.

The puzzlement of lay reader and specialist concerning both these medieval texts raises intriguing questions about how modern literary sensibilities have changed and how the liberal arts tradition has evolved since Hugh of St. Victor and Dante wrote; questions, that is, about the history of literary history, about the development of Western esthetics, and about the role of the mathematical disciplines in that development. These are, of course, encyclopedic topics. But since they have rarely been considered as a group, even a brief look at their points of contact yields fresh perspectives on each.

The Liberal Arts Tradition and the Two Cultures

Profound changes in cultural attitudes are often hard to detect, let alone track, while they are taking place. Only in hindsight can cultural historians reliably plot the points before and after the change and graph the intervening trajectory with any confidence. Among the more trustworthy clues to historical change are culturally laden words and their gradual shift in meaning over time. Since the language in which a society articulates itself offers the richest record of that society's conceptual life—an inventory of its collective consciousness, as it were—certain words stand out in texts of the past like artifacts in a time capsule, waiting to tell a later age a story they could not wholly reveal in their own. The examples need not be ancient or profound. Take the word *arts* in the once-familiar name College of the Liberal Arts. Just over a decade ago, on December 4, 1970, the Board of Trustees of Syracuse University formally approved a change in the name the college had been known by for nearly a century. What had been Liberal Arts (since 1872) became Arts and Sciences.[6] The longstanding use of the word *arts* to identify the traditional disciplines of the humanities and natural sciences was no longer felt to be adequate. Doubtless fine arts, and apparently also literature and philosophy, could still qualify as arts. But biology? Chemistry? Geology? Physics? Mathematics? In a news release issued December 9, 1970, John J. Prucha, formerly chairman of the geology department and then in his second year as dean of the college, was quoted as having given the following explanation for the change in name:

> *People often do not realize that the college includes and places strong emphasis on the sciences. . . . People in the University and elsewhere expressed surprise at my appointment as dean because I was a scientist. How can you leave science, they asked. . . . We want to suggest that the college embraces the sciences as well as the humanities.*

Whatever concerns of policy and politics may have entered in, the renaming of the college attests to a change in the popular understanding of the term *arts*. Whatever they are—and the use of the word to characterize the humanities is also not without its confusions—the arts are somehow not sciences (and vice versa), and the umbrella term *liberal arts* was no longer felt to be suitable for a curriculum including, say, both natural sciences and languages. Of course this shift in the meaning of *arts* is symptomatic of a more profound change in the way the traditional disciplines themselves are perceived, both on the

6. Archival documentation was kindly supplied by Amy Doherty, archivist, Syracuse University, George Arents Research Library.

campus and beyond. Whatever unity may have obtained at some earlier time—and there is, in the academic community at least, lingering recollection of some past unity—the sciences and the humanities seem today so different in goals, methods, and uses in society that any ancient kinship now appears hardly very relevant, and even difficult to imagine as ever having been legitimate.

The split goes deeper than the formula arts/sciences might at first suggest—beyond mere methodological differences—to a fundamental mutual incomprehension of what colleagues are doing across the quad. Part of the problem is of course linguistic. As specialization produces highly technical vocabularies, specialists in different parts of the world can communicate with one another, while those in different fields on the same campus cannot. Perhaps until the time of Goethe and Humboldt—George Steiner's cutoff point—it was possible for a man of exceptional ability to feel at home in both the humanistic and the mathematical cultures; Leibniz, in fact, had still been able to make notable contributions to both.[7] But this is no longer a real possibility. The calendar of the sciences is obviously not open to renegotiation.

7. George Steiner, *Language and Silence* (New York: Atheneum Publishers, 1967), pp. 16–17.

The ancient wholeness symbolized in the word *university* and embodied originally in the once-traditional liberal arts curriculum can be overstated, the sense of loss overdramatized; indeed, the old unity had its incipient fissures as far back as we can trace. But the loss is real nonetheless, and its consequences for the study of Western culture are not fully appreciated among humanists. And here the two-cultures debate offers a lesson widely overlooked: Any cultural change marked by so important a loss creates barriers to understanding between our age and former ages, because it multiplies opportunities for silent assumptions to interfere, unobserved, with the historian's work.

As one consequence, the factors that broke Western consciousness into separate orders of word and number have already had a profound—if little noticed—impact on the study of early Western culture. The point is readily illustrated. The literary scholar specializing in medieval languages and literatures, but trained within the thought compartments of the modern fragmentation, will tend to think that poetry is poetry; science, science. He will not naturally look for connections. He will of course have learned that the basic curriculum of medieval schools (initially in monasteries, later at major cathedrals) consisted of the seven so-called *artes liberales* ("free, or liberal, arts"): three verbal disciplines called the *trivium* (grammar, logic, rhetoric) and four mathematical disciplines known as the *quadrivium* (arithmetic, geometry, music, astronomy). The scholar will be aware too that the Latin word *artes* had a considerably broader meaning than *arts* today; it meant something like "skills schooled in theoretical fundamentals." It was therefore akin to *scientia* ("knowledge"), in which sense the word is still found in this university's logo: *Suos cultores scientia coronat* ("Knowledge crowns those who cultivate it").

The literary scholar will probably also have been taught that artists, in this broader sense, were those who studied and applied theoretical principles to their arts. Therefore the true musician for medieval curricular authorities like Augustine (fourth century) and Boethius (fifth century) was the person who understood the numerical principles

of harmony (the subject of the third of the four mathematical disciplines) rather than the person who merely sang or played a musical instrument, however accomplished. That same scholar may even have read representative texts used to teach the verbal disciplines in medieval schools, particularly grammar and rhetoric. But his training probably did not include so much as an introduction to the mathematical disciplines, even music; and like his teachers he may never have felt compelled to read a medieval schoolbook on arithmetic or geometry, let alone to consider the possible relevance of *ars arithmetica* and *ars geometrica* to *ars poetica.*

A modern literary scholar so trained will, understandably, be amazed by Hugh of St. Victor's definition of geometry and by Dante's fondness for mathematical similes. But there are other factors in his puzzlement. The modern scholar's discipline of literary history has its own history, with a tradition of thought patterns that lead deeper into the world of words and farther away from the world of numbers. He will not automatically recognize, let alone appreciate, conjunctions of word and number in early Western thought.

Literary History

The yearning to recover origins—"roots" in the parlance now popular—has an archetypal currency. But sometimes it asserts itself with special claims. If it seizes an individual, the product may be a genealogical tree, perhaps a new ethnic awareness, even an *Aeneid.* If it seizes an age, the result may be a renascence or, with luck, a Renaissance. When it intensified in the emerging nation-states of late eighteenth- and early nineteenth-century Europe, it led to an intellectual movement now commonly labeled romanticism—one characterized by, among other things, a quest for the soul of one's "folk," one's language, one's culture. The most visible achievement of this intellectual movement was a congeries of academic disciplines devoted to rediscovering cultural roots. Indeed it is ultimately to this intellectual movement that we owe our modern sense of history. Because much that is recoverable in any culture is bound with its language(s), interest turned dramatically to earlier stages of the European vernaculars; to the new "linguistic archaeology" made possible by the discovery of systematic laws of change governing the Indo-European language family; to the editing of long-neglected manuscripts; to the establishment of critical principles and methodologies for dealing with texts from earlier eras; in short, to the development of the modern philologies.

More than a century and a half later, these and related historical disciplines have now reached an age when it is possible to examine *their* history. The explosive growth of knowledge about our past that research in these disciplines has produced has also brought with it various crises of methodology and goals in this century and, in the past few decades most noticeably, increasing self-reflection. It has now become characteristic of the modern philologies, as in most historical disciplines, to reflect on their own past and what that past implies about the validity and scope of all that has been achieved. One lesson learned is that the English, Germanic, and Romance philologies, for all their accomplishments in making the writings of the past accessible to the present, need very much to be aware of their roots, particularly of the

lingering claims of romanticism on the more interpretive aspects of their work. For just as any quest for lost origins can lead the seeker to find what he hopes to find (and miss what he is not looking to see), so too the early philological study of the European vernacular cultures was shaped, even scripted, by the context of romanticism from which it emerged. This genetic predisposition, so to speak, reached far beyond simply allowing parochial motivations for the quest to taint and filter the findings. It preset fundamental paradigms of thought before much of the evidence could be taken in hand.[8]

One of these paradigms was an assumed opposition between cultural products felt to have derived primarily from the native Teutonic culture of the north and those more directly indebted to the literate Judeo-Greco-Roman civilization that spread across the Alps from the Mediterranean. With this paradigm came numerous corollary oppositions like primitive/refined, mythical/rational, pagan/Christian, oral/literary. As individual works of literature were judged against such paradigms—largely unconsciously and partly in tacit competition with the "classics" studied by the established Greek and Latin philologies—certain "romantic" notions about early European poetry arose. Notable among these was the conception that this poetry was essentially bardic rather than "literary," created more by the collective *Geist* of the folk than by the individuals who committed the words to parchment; that is, not so much a product of consciously sophisticated art as the naive expression of man's unspoiled nature in a less cultured, purer state.

Although the more simplistic versions of such notions are widely discredited today, and although a century and a half of philological scholarship has vastly increased our understanding of many aspects of our medieval heritage in particular, early romantic assumptions have had a residual impact on the popular image of the Middle Ages as dark, primitive, even barbaric. They still present troublesome obstacles to clear-headed assessment of some medieval poetry. Cultural clichés, like ethnic prejudices, die hard, even for scholars. Bibliographies of the last three decades, for example, record several reincarnations of the nineteenth-century view that medieval poetry—indeed all literature before Gutenberg—was fundamentally oral in conception. In fact, early proponents of one hypothesis, known widely as the *oral-formulaic theory,* drew such uncompromising distinctions between the compositional techniques of "literature" and "oral poetry" that their particular paradigm would reduce even so sophisticated a poem as the Old English epic *Beowulf* (ca. 700) to the transcription of an improvised mead-hall performance by an unlettered though gifted singer.

Although few strict adherents of this view remain today, the theory would tend to direct the attention of our hypothetical scholar, as it has many others, away from more explicitly literary issues toward research on preliterary origins, presumed methods of oral composition, and suspected influences from folklore, fairy tale, and myth. Swayed by the paradigmatic contrast between oral and literary now pandemic in the professional literature, he would not merely be puzzled by the discovery of mathematical techniques of structure in *Beowulf;* he would flee such a proposition in no less horror than if Grendel himself came to visit at his carrel.

8. The concept *paradigm* is adapted here in the broader of the two senses Thomas S. Kuhn made vivid for the historiography of science—the sense he later characterized as "disciplinary matrix." See his *Structure of Scientific Revolutions,* 2d ed. (Chicago: University of Chicago Press, 1970), especially pages 174–210; and the reflections by Michael Polanyi in *Scientific Change,* ed. A.C. Crombie (New York: Basic Books, 1963), pp. 375–380. The subsequent controversy has to do more with the claimed consequences than with the existence of paradigmatic thinking. See Thomas Kuhn's "Reflections on My Critics," in *Criticism and the Growth of Knowledge,* ed. I. Lakatos and A. Musgrave (Cambridge: Cambridge University Press, 1970), pp. 231–278. For a survey of the controversy and its context, see Frederick Suppe, "Afterword—1977," in *The Structure of Scientific Theories,* ed. Frederick Suppe, 2d ed. (Urbana: University of Illinois Press, 1977), pp. 617–730, especially pages 643–648.

At first, anyway. But some more recent tendencies in scholarship could well prevail on our hypothetical scholar to reconsider his initial reaction. It is becoming increasingly evident tht medieval poets were typically preoccupied with form, with conferring shape, with reordering materials inherited from diverse sources into new, sometimes profound, sometimes curious, but almost always ambitious combinations. Medieval architecture offers a convenient and illuminating analogue: The impressive stone structures that have survived from the Middle Ages throughout northern Europe attest eloquently to an explosion of artistic energy during the period—energy that measured itself, in this instance, against the most intractable and permanent material then available and found its appropriate expression in ambitious designs combining gargoyles and geometry, carefully structured symbolism, and awesome engineering. This analogue needs no translation. The recent work of our scholar's colleagues in art history further illustrate to what extent medieval architecture and medieval poetry, for all their differences, sprang from a common esthetic and embody similar strivings.

The literary scholar would also find recent research in the history of Western philosophy pointing him back repeatedly, and more insistently of late, to the seminal sources of medieval esthetics: the ancient Judaic and Greek accounts of the creation of the universe. These myths not only determined the essential character of subsequent Western cosmology (some see in the image of man and world they project the ultimate source of Western technology as well) but also provided a model for artistic creation that was at once inspiring and compelling. The basic texts were of course the Old Testament, notably Genesis, and Plato's *Timaeus;* the accounts both give are so similar and so compatible that they were thought throughout the Middle Ages to have shared in a common revelation. In both texts the Creator (or Demiurge) appears as a supreme architect who constructs the universe in an orderly progression from general to specific according to a rational design governed by rigorously logical principles. Because this Divine Architect is not capricious, because his universe embodies faithfully the model in his mind, because man's mind is fashioned in the divine image, the rationale of the cosmos is presumed from the start to be eminently knowable: Its principles can be studied, its beauties emulated. And in both the biblical and Timaean accounts the divine model for creation is defined as fundamentally mathematical. For example, in a passage quoted ubiquitously in the Middle Ages—and considered by some to be "the keyword of the medieval world view"[9]—the Creator is praised for having "disposed all things according to measure and number and weight" (Wisd. of Sol. 11:21).[10] Similarly, the book of Proverbs depicts the Creator preparing the heavens and surveying the depths "with a certain law and compass" (Prov. 8:27–28) —an image popular in medieval iconography and still found fully developed as late as the seventeenth century in Milton's *Paradise Lost.*[11]

Given the imagery of the Creator as geometer, circumscribing his handiwork with cosmic compass, impressing the eternal laws of geometry (literally "earth measure") onto all matter, it would not surprise our scholar to learn that this model had a profound influence on medieval literary theory. Writing at the end of the twelfth century, in

9. Otto von Simson, *The Gothic Cathedral* (1956; reprint ed., New York: Harper & Row, Torchbooks, 1964), p. 25.

10. Biblical quotations are taken from the Douay Version.

11. *Paradise Lost* 7. 224–31, ed. Merritt Y. Hughes (New York: Odyssey Press, 1962): "And in his hand / He took the golden Compasses, prepar'd / In God's Eternal store, to circumscribe / This Universe, and all created things: / One foot he centred, and the other turn'd / Round through the vast profundity obscure, / And said, Thus far extend, thus far thy bounds, / This be thy just circumference, O World. / Thus God the Heav'n created, thus the Earth." More than three centuries earlier Dante had recorded the same remarkable model similarly: "Then it began: 'He that turned His compass / round the limit of the world, and within it / marked out so much both hidden and revealed . . .'" (*Paradiso* 18. 40–42). For the earlier iconography, cf. von Simson, *Gothic Cathedral,* p. 35n and plate 6a. The imagery Plato used in the *Timaeus,* the dialogue most influential in the Middle Ages, is strikingly similar; see especially 33B–34A.

what was to become the most widely circulated medieval treatise on literary theory, the *Poetria nova* ("New Poetics"), Geoffrey of Vinsauf applied the analogy of architectural design to poetry as follows:

> *If anyone is to lay the foundation of a house, his impetuous hand does not leap into action: the inner design of the heart* measures out *the work beforehand, the inner man determines the stages ahead of time in a certain order; and the hand of the heart, rather than the bodily hand,* forms the whole in advance, *so that the work exists first as a mental model rather than as a tangible thing. In this mirror let poetry itself see* what law must be given to poets. . . . Let the inner compass of the mind lay out the entire range of the material. Let a certain order determine *from what point the pen should start on its course, and where the outermost limits shall be fixed. . . . When, in the recesses of the mind,* order has arranged the matter, *let the art of poetry come to clothe the matter with words.*[12]

12. Geoffrey of Vinsauf, *Poetria nova,* lines 43–49, 54–58, 60–61, cited from the translation by Ernest Gallo, *The Poetria Nova and Its Sources in Early Rhetorical Doctrine* (The Hague: Mouton, 1971), p. 17 (emphasis added).

And upon reading so explicitly architectural, even geometric, a model for poetic composition ("compass of the mind," etc.), our scholar would perhaps recall with new understanding the familiar definitions of beauty by the standard medieval authorities like Augustine and Aquinas. (Augustine: Beauty derives from four principles—number, form, unity, order; that which pleases in beauty is shape; in shape, proportion; and in proportion, number. Aquinas (13th century): Beauty requires three things—integrity, due proportion, and clarity.) And our scholar might sense that many medieval poets—faced with such esthetic imperatives as Augustine's *numerus* ("number") and Aquinas's *debita proportio* ("due proportion") and inspired by the ancient biblical and Platonic models of a *deus architectus* or *deus geometres*—would quite naturally seek ways to inform their creations with the pleasing proportions of nature.

As a linguist the scholar may now also take fresh note of certain commonplace etymologies that had once struck him as a peculiar but whose relevance to the history of literature and literary esthetics—let alone to the history of Western education—had not registered before. He will remember that technical terms of poetry theory like *rhyme* and *meter* have twins in the world of mathematics; that the word *rhyme,* for example, developed from the Old English *rīm,* which meant *number.* His etymological dictionaries will recall for him further that Old English *rīm* was itself derived, first by borrowing, then by gradual metamorphosis in sound and meaning over the centuries, from the Latin word *rhythmus* ("rhythm") and that the *rhythm* of poetry and the *-rithm-* in *arithmetic* share a common conceptual heritage. And then perhaps the many other number/word pairs in modern European languages would rise to consciousness: telling time and telling tales, toll/tell, count/recount (a story), *conter/raconter, zählen/erzählen,* and so forth.

Impressed now by so many signs pointing to an earlier unity of word and number in Western consciousness, notably in the period of the literature he loves, our scholar begins to find some old enigmas of his discipline realigning themselves in new patterns of relevance. He recalls, for instance, that a major crux of editorial scholarship has been the curious presence of explicitly numbered divisions in the manuscript

texts of many medieval literary works (*incipit liber tertius,* "Here beginneth Book Three"; *explicit liber quintus,* "Here endeth Book Five"). And he begins to suspect that in these long enigmatic features of textual transmission—features, incidentally, which modern editors frequently ignore, finding no obvious literary purpose in them—lie the keys to "architectural" design techniques like those described by Geoffrey of Vinsauf. In such features are (1) designs for the *physical* disposition of textual parts, such as number of sections in the work and number of lines in the sections (since most medieval poetry is in verse form, lines of verse are countable units, by their formal organization and presentation on the manuscript page); and (2) designs for the ordering of word and theme (persons, events, times, places, etc.). These are indeed in the spirit of the Gothic cathedrals and of Dante's metaphorical vision.

The Mathematical Arts and Medieval Poetry

Our hypothetical scholar is, of course, not so hypothetical. He could be any one of the many European and American medievalists who, in the last thirty years, have begun to study the influences of the four mathematical *artes* on medieval poetry. At the start he would have found himself in a vast uncharted landscape where just about everything remained to be learned, or relearned. The tasks would be complicated by the usual uncertainties of reconstructing, by inductive means alone, suspected designs from artifacts; and further complicated by the accumulated consequences of both the romantic origins of the scholar's discipline and the two-cultures syndrome. For until only quite recently, very few scholars were equipped with both the philological and mathematical training needed to study medieval sources in the history of mathematics and science. As a result, only a few items among the considerable holdings of mathematical manuscripts in European and American libraries had received scholarly attention; even fewer still had been competently edited. The history of mathematics in the Middle Ages was—and for most medievalists still is—a dark chapter. Small wonder, then, that the first researchers in the field approached the poetry with a new form of the old romantic notions about the "dark ages": Medieval poets, they assumed, could probably add and subtract well enough. But could they multiply and divide large numbers like those involved in the line totals of long poems; extract roots to determine proportions based, say, on the Phythagorean theorem, and such? And how would they compute at all with those awkward Roman numerals?

Only in the last few years has the emerging evidence begun to indicate that the designs some major medieval poets worked out for their long poems are in fact no less ambitious in the numerical dimension than in the verbal. Indeed, all spheres of traditional Western number lore have now been found represented in these designs: musical proportions (octave, fifth, major third, etc.), astronomical computations used in reckoning Easter dates and other matters of chronology, practical geometry, number symbolism, astrology, and, most of all, proportionality based on the constant proportions of basic geometric figures.

Certain numerical characteristics are shared by five major medieval literary works long valued for their other virtues: (1) the Old English *Beowulf* (ca. 700); (2) the Old French courtly epic of *Erec,* by Chrestien de Troyes (ca. 1170); (3) the Middle High German courtly epic of *Iwein,* by Hartman von Ouwe (ca. 1200); (4) Dante's *Divine Comedy* (ca. 1300); and (5) Chaucer's *Troilus* (ca. 1382).

In all five, the physical dimensions of the text (e.g., line totals and section totals) are shaped by formal divisions marked off by numerals, rubrics, or punctuation (or some combination of these) in the manuscripts. In all five, these formal divisions conform to sophisticated and rigorously precise number-based designs. The elaborateness of the designs indicates that the authors worked out the numerical dimensions in detail prior to (or in the embryonic stages of) composition and that the texts were then literally *composed into* these designs, utilizing the various symmetries, stress points, junctures, and other lines of relation created by the *numerical* properties of the abstract schemata. The basic structural principle governing these particular designs is proportionality of the general type *A* is to *B* as *C* is to *D.* In part, the proportionality was derived from the constant properties of simple geometric figures like the square, the circle, the equilateral triangle, and the regular pentagon, as well as various permutations involving these constants.[13] In addition to whatever inherent esthetic appeal these designs may have had, they placed a quite powerful structural tool in the poet's hands: By locating thematic correspondences at *positionally* corresponding points within the text's dimensions, he was able to relate certain text passages to each other without explicitly stating the nature of the connection. This was a kind of structural syntax. The accumulating evidence on at least those five poems mentioned is that their authors exploited the compositional power of their designs with meticulous attention to detail and in highly creative ways.

13. Examples of constant properties for simple geometric figures: *Square:* side is to diagonal as 1 is to $\sqrt{2}$. *Circle:* circumference is to diameter as, roughly, 22 is to 7, i.e., π. *Equilateral triangle:* radius of circumcircle is to side as 1 is to $\sqrt{3}$. *Regular pentagon:* apothem is to altitude as 1 is to $\sqrt{5}$.

It is difficult to give truly representational examples of the techniques involved without drawing in technical details about manuscripts, textual dimensions, language, and narrative that are beyond the present scope. But one pattern in Dante's *Paradiso* may serve to illustate the *type* of pattern most prevalently found in all five works. Twice in the *Paradiso* (and in fact only these two times in the *Comedy's* entire 14,233-line text) the word *triangol* ("triangle") appears:

O se del mezzo cerchio far si puote
triangol sì ch'un retto non avesse.

Nor if in a semicircle a triangle can be so
constructed that it shall have no right angle.[14]

Non capere in triangol due ottusi.

Two obtuse angles cannot be contained in a triangle.[15]

Both instances allude to important theorems in Euclid's *Elements.*[16] The two theorems are conceptually and procedurally interrelated and have historically been considered together. In Dante's text, however, the two allusions are separated by almost 500 lines of verse.

14. *Paradiso* 13. 101–102.

15. *Paradiso* 17. 15.

16. Bk. 3, prop. 31: "In a circle the angle in the semicircle is right." Bk. 1, prop. 32: "In any triangle the three interior angles of the triangle are equal to two right angles." Cited here from Thomas L. Heath, ed., *The Thirteen Books of Euclid's Elements,* 2d ed., 3 vols. (1925; reprint ed., New York: Dover, 1956).

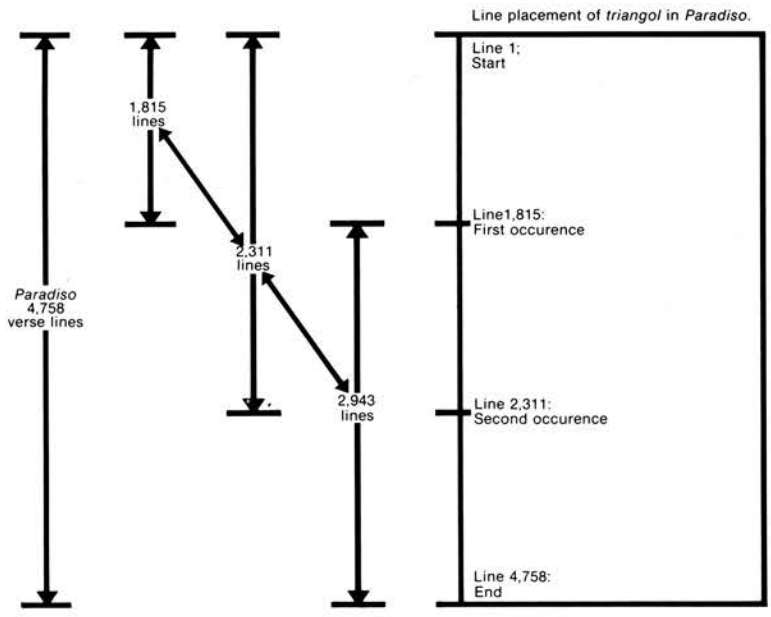

Figure 1. Proportional placement of the two occurrences of the word *triangol* in Dante's *Paradiso* 13. 102 and 17. 15). Diagonal arrows emphasize proportional logic of the pattern. Proportionality is 2,943 / 2,311 = 2,311 / 1,815 (approximate) and is an allusion to Euclidean theorems (*Elements* 3. 31 and 6. 13).

We find that within the 4,758 verse lines of the *Paradiso,* the first occurrence of the word *triangol* is in line 1,815, which is 2,943 lines from the end. The second occurrence is in line 2,311 (see Fig. 1). Manipulating these numbers, we discover that 2,311 is the mean proportional between 2,943 and 1,815; that is, 2,943 is to 2,311 as 2,311 is to 1,815 (calculations here and below to the nearest integer). Dante's placement in text exhibits considerable precision; if the *triangol* in line 2,311 came even one line earlier, the proportion would not hold.

Figure 1 gives a possible conceptualization of the text as a kind of physical artifact, a finite set of verse lines viewed as a continuum of countable units. The figure also illustrates how poets like Dante may have imagined the placement of words within such a continuum; that is, as textual loci separated from one another and from the beginning and end of text by specified intervals. Note that in Figure 1 the various intervals are indicated vertically. The figure may be seen as a kind of window in which the text scrolls up and down like a column of verse lines, each line written horizontally, one on top of the other as on a scroll or page.

This evidence gives good reason to conclude that these particular values were chosen to embody the proportionality of the "obvious" case to which Euclid's proposition 3.31 applies—the isosceles right triangle (half square) in a semicircle. As shown in Figure 2, if diameter *AC* of semicircle *ABC* (which is also the hypotenuse of inscribed isosceles triangle *ABC*) is 2,943, (quadrant) arcs *AB* and *BC* are each 2,311 (2,943 x $\pi/4$). Similarly, if diameter *DF* (hypotenuse) is 2,311, arcs *DE* and *EF* are each 1,815.

We see here, then, three typical features of this highly deliberate means of textual patterning: use of precisely calculated proportionality as a shaping and unifying technique; derivation of the proportionality from simple geometric constructions; and direct relevance of the numerical properties of the pattern to what the text says. There are

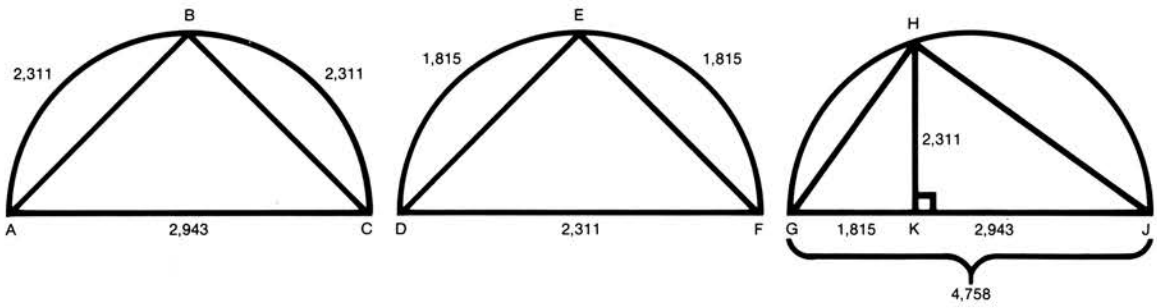

Figure 2. Geometrical constructions alluded to in *Paradiso* 13. 102. *Semicircle ABC:* If diameter *AC* equals 2,943, then quadrant arcs *AB* and *BC* each equal 2,311. *Semicircle DEF:* If diameter *DF* equals 2,311, then quadrant arcs *DE* and *EF* each equal 1,815. *Semicircle GHJ:* If diameter *GJ* equals 4,758 (verse total of *Paradiso*), and *JK* equals 2,943, and *GK* equals 1,815, then *HK* equals 2,311. Thus 2,311 (more precisely 2311.2) is the proportional mean between 1,815 and 2,943. (See n. 16; Fig. 1; and Euclid, *Elements* 3. 31 and 6. 13.).

numerous patterns of this general type in each of the five works, all equally precise and some rather more complex, although allusion to a specific geometric derivation is rarely so explicit as it is here.

The obvious question that such intricate patterning brings to mind is, Why? Why would these noted poets go to such lengths to give shape to their creations, even to the point of devising mathematical patterns for the recurrence of individual words? It seems to fly in the face of common sense (i.e., modern presuppositions about what poetry is—and isn't). Among the intellectual rewards that make this field of research so stimulating are the wide range of answers that this question inspires (about both medieval and modern conceptions of literary art) and the new paths of inquiry it is charting across old disciplinary lines. Some answers have already been suggested above: the Divine Architect as model author writing the book of nature, the cosmological tradition, emphasis on the kinship of word and number in medieval education, the general preoccupation with formal subtlety in medieval art. Other answers to this question of *why* could be added, ranging from private motivations, like the ambition to overcome self-imposed formal constraints (the sonnet is a medieval invention), to the more public inducements supplied by a literary tradition, especially the models set by other poets—and even the expectations imposed by them. The appearance of comparable techniques of such intricacy in the five important works mentioned above—texts written in different languages in four different centuries spanning almost 700 years—strongly suggests that use of these techniques was conventional. There is already evidence of direct influences: A thirteenth-century German writer named Stricker, for example, incorporated into one of his Arthurian romances patterns of proportionality that presuppose direct knowledge of mathematically equivalent patterns in Hartman's *Iwein*—patterns using both the same ratios and the same words. Similarly, Chaucer is now known to have studied and emulated specific patterns in Dante's *Comedy* when he composed the *Troilus*.

Whatever the particular impetus for each individual design, their similarities suggest that the underlying aesthetic motivation was more or less constant in all five instances. Whether or not any single statement of aesthetic theory influenced all five authors, there is one text whose influence was pervasive enough throughout the Middle Ages to

affect all five, at least indirectly: the creation account in Plato's *Timaeus.* Its theory of proportionally ordered beauty invites comparison. (The major part of the *Timaeus* was available to the Latin West in a fourth-century translation, with commentary, by Chalcidius.) Representative highlights illustrate immediately the degree to which the poets' design techniques coincide with the tenor of the Timaean esthetic. The Creator, or Demiurge, says Plato,

> *brought order out of disorder, considering that this was in every way better than the other. . . . Nothing can be beautiful that is like any imperfect thing. . . . Two things cannot be rightly put together without a third; there must be some bond of union between them. And the fairest bond is that which makes the most complete fusion of itself and the things which it combines; and proportion is best adapted to effect such a union. . . . And for these reasons . . . the body of the world was created, and it was harmonised by proportion.*[17]

It other words, the beauty of creation is founded on order, order on unity, and the unity of diverse things on proportionality.

17. Plato *Timaeus* 30A–32C. See Benjamin Jowett, trans., *Great Books of the Western World,* vol. 7 (Chicago: Encyclopaedia Britannica, 1952).

The value judgments presupposed in this aesthetic—order is to be preferred to disorder, unity to disunity, and so forth—remain fully intelligible, though not fully transferable, to modern tastes. Less immediately understandable today is the application of this line of thinking to the specific case of verbal art; for the reasons examined above, we no longer share the medieval assumption of natural, even self-evident, kinship between word and number. It is true, of course, that affinities between poetry and mathematics have not gone totally unnoticed in our own time; significant essays on the subject include Scott Buchanan's *Poetry and Mathematics* (1929; reprint ed., 1975), David Eugene Smith's *The Poetry of Mathematics* (1934), and certain of George Birkhoff's *Collected Mathematical Papers* (1950), as well as individual contributions to *Mathematik und Dichtung* (1965) edited by Helmut Kreuzer. But these essays tend to treat such affinities as something newly discovered, something requiring scholarly demonstration—something, that is, decidedly not self-evident. For example, in the concluding chapter of one of the outstanding books of modern literary scholarship, the *Anatomy of Criticism,* Northrop Frye called attention to what he termed "the curious similarity in form . . . between the units of literature and of mathematics, the metaphor and the equation."[18] This is indeed a striking similarity at a most fundamental level, the level of basic units of intellection. To the modern mind it seems, as Frye labeled it, "curious."

18. Northrup Frye, *Anatomy of Criticism* (Princeton: Princeton University Press, 1957), p. 352.

It was not at all curious to the Greeks, who used the same word, *αναλογία (analogia),* for both verbal analogy and numerical proportion, just as they used the one term *λόγος (logos)* for both *word* and *number.* In his extensive treatment of the underlying proportional nature of metaphor in the *Poetics,* for example, Aristotle described metaphor by analogy as a comparison not between two things but between two comparable relationships between pairs of things—in other words, an equality of ratios. He illustrated the point by analyzing the structure of the metaphor *evening of life:* As old age *(D)* is to life *(C),* so is evening *(B)* to day *(A).* for Aristotle the underlying form of such metaphors was arithmetic proportion. As he put it: Metaphor "from

analogy is possible when there are four terms so related that the second *(B)* is to the first *(A)*, as the fourth *(D)* is to the third *(C)*."[19] Conceptually, then, the use of arithmetic proportions by medieval poets is closely connected with the structure of metaphor—whether or not these poets were attracted to proportional designs for this reason. The metaphor in the climatic Dantean passage cited near the start of this essay illustrates Aristotle's point eloquently: As the geometer *(A)* is to the principle of the circle *(B)*, so was the poet *(C)* to the divine vision *(D)*; algebraically: $A/B = C/D$.

19. Aristotle, *Poetics* 21. 1457b. See Ingram Bywater, trans., *Great Books of the Western World*, vol. 9 (Chicago: Encylcopaedia Britannica, 1952).

The echo that comes back to us from our question *why* is thus more than just *why not?* The designs created by these medieval poets with word *and* number open up large new areas for enjoyment as well as study, and challenge modern readers to respond to both, much the way the intricacies of music like Bach's can be enjoyed and studied by the mind as well as the ear. Will modern readers respond? Certainly the availability of calculators and computers makes both responses easier today. But perhaps not easy enough. Moreover, there has been enough of value in these poems for generations of readers without conscious attention to the architecture within; the discovery of the designs now will not alter that fact, at least for most. Stated differently, the new dimension of art in these poems should not be overemphasized merely because it has so long been out of view. But it should also not be ignored. The fact that these design techniques were so fundamental to the compositional process in these works and apparently so pervasive during earlier periods of our culture (there is some evidence of comparable practices both before and after the Middle Ages) will likely have significant implications both for the history of mathematical learning in the West and for literary scholarship. For example, the findings provide concrete insight into the mathematical interests and sophistication of those who authored the designs—insights that are available, as far as we know, from no other surviving source and that open a chapter of the history of science once thought irrevocably closed. Similarly, the designs have a truly unique practical value for interpretation of the poetry. This is because the uses the poets made of their designs, both in choosing and arranging verbal and thematic parallels, result in a kind of authorial commentary on the organization of the narrative material. That is, because the internal logic of the designs can largely be verified, they are much like a map or blueprint that enables us to retrace, in ways not otherwise possible, lines of thought and emphasis that had *demonstrable* validity for the poets themselves.

Whatever the scholarly boons, however, the designs' main claim on our attention is the natural one they presumably had for the writers who devised them: They are marvelous creations for conscious delight. But there is also for us a secondary joy born of awe at the sheer achievement of the thing, as at the engineering, still only faintly understood, that made the great stone edifices of the same age last into ours—without the aid of calculators and computers. Which brings to mind a homely modern analogue with some convenient symbolism: The final version of this essay was "written" on a console—the same one that also supplies numerical data for recovering the designs. The proportionality seems about right, even on the surface: This particular console even has two keyboards, one a separate

calculatorlike pad for numbers only, the other with a more or less standard typewriter format—letters *and* digits, *alphanumerics* in the jargon. But it's on the inside that the simile holds best: Whether the writer is telling or counting, the microprocessor goes about its invisible business in its own silent language, Englishing the result instantly with integrated codes ($A = 65, B = 66 \ldots Z = 90; a = 97, b = 98 \ldots z = 122$, etc.), thus—almost condescendingly, one sometimes feels—permitting the author to distinguish whatever numbers and words with whatever separate keys and codes he might wish. No doubt the machine's word-processing wizardry would have amazed a Dante or a Chaucer no less than it does their modern readers. But in one regard, we may speculate, Dante and Chaucer would have had it easier than the Connecticut Yankee: For them there would be no divided culture, no cleft consciousness, to distract or subtract from the beauty of it all.

Illustration by John Bonner.