Łukasiewicz' exegesis of Aristotle's syllogistic is disputed in Arthur N. Prior, "Łukasiewicz's Symbolic Logic," in *Australasian Journal of Philosophy*, **30** (1952), 33–46, and is discussed in Gunther Patzig, *Die Aristotelische Syllogistik: Logisch-philologische Untersuchungen über das Buch A der "Ersten Analytiken"* (Göttingen, 1959); English trans. by J. Barnes, *Aristotle's Theory of the Syllogism: A Logico-philological Study of Book A of the Prior Analytics* (Dordrecht, 1968), *passim*, esp. 196–202.

For a general evaluation of Łukasiewicz' philosophical and logical ideas, see Henryk Skolimowsky, *Polish Analytical Philosophy: A Survey and a Comparison with British Analytical Philosophy* (New York, 1967), 56–72.

GEORGE GOE

LULL, RAMON (*b.* Ciutat de Mallorques [now Palma de Mallorca], *ca.* 1232; *d.* Ciutat de Mallorques [?], January/March [?] 1316), *polymathy*.

A Catalan encyclopedist, Lull invented an "art of finding truth" which inspired Leibniz's dream of a universal algebra four centuries later. His contributions to science are understandable only when examined in their historical and theological context. The son of a Catalan nobleman of the same name who participated in the reconquest of Mallorca from the Moors, Lull was brought up with James the Conqueror's younger son (later crowned James II of Mallorca), whose seneschal he became. About six years after his marriage to Blanca Picany (1257) he was converted from a courtly to a religious way of life, following a series of visions of Christ crucified. He never took holy orders (although he may have become a Franciscan tertiary in 1295), but his subsequent career was dominated by three religious resolutions: to become a missionary and attain martyrdom, to establish colleges where missionaries would study oriental languages, and to provide them with "the best book[s] in the world against the errors of the infidel."[1]

Lull's preparations lasted a decade; his remaining forty years (from 1275, when he was summoned by Prince James to Montpellier, where he lectured on the early versions of his Art) were spent in writing, preaching, lecturing, and traveling (including missionary journeys to Tunis in 1292; Bougie, Algeria, in 1307; and Tunis late in 1315), and in attempts to secure support from numerous kings and four successive popes for his proposed colleges. During Lull's lifetime only James II of Mallorca established such a foundation (1276, the year of his accession); when he lost Mallorca to his elder brother, Peter III of Aragon, the college at Miramar apparently was abandoned (*ca.* 1292). In Lull's old age his proposals were finally approved by the Council of Vienne (1311–1312); and colleges for the study of Arabic, Hebrew, and Chaldean were founded in Rome, Bologna, Paris, Salamanca, and Oxford after Lull's death. Pious tradition has it that he died after being stoned by Muslims in Bougie (January 1316[?]), although his actual death is variously said to have occurred in Bougie, at sea, or in Mallorca; modern scholars doubt the historicity of his martyrdom. As for his third resolution, it led to the various versions of Lull's Art—and all his scientific contributions were by-products of this enterprise.

James the Conqueror's chief adviser, the Dominican Saint Ramon de Penyafort, dissuaded Lull from studying in Paris, where his age and lack of Latin would have told against him; he therefore studied informally in Mallorca (1265[?]–1273[?]). His thought was thus not structured at the formative stage by the Scholastic training which molded most other late medieval Christian thinkers; this fostered the development of his highly idiosyncratic system by leaving his mind open to numerous non-Scholastic sources. These included cabalism (then flourishing in learned Jewish circles in both Catalonia and Italy), earlier Christian writers discarded by Scholasticism (for instance, John Scotus Eriugena, whose ninth-century *De divisione naturae* influenced Lullian cosmological works, notably the *Liber chaos*, either directly or indirectly—and hence also his Art), and probably also Arabic humoral medicine and astrology. The Augustinian Neoplatonism of the Victorines also proved important, partly because of its continuing prominence but mainly because its marked coincidences with both Islamic and cabalistic Neoplatonism favored the creation of a syncretistic system which was firmly grounded in doctrines equally acceptable to Christians, Jews, and Muslims.

This fusion occurred after the eight years Lull spent in Mallorca studying Latin, learning Arabic from a slave, reading all texts available to him in either tongue, and writing copiously. One of his earliest works was a compendium of the logic of al-Ghazālī in Arabic (1270[?]); it has since been lost, although two later compendia with similar titles survive—one in Latin, the other in Catalan mnemonic verse. In all, Lull wrote at least 292 works in Catalan, Arabic, or Latin over a period of forty-five years (1270–1315); most of them have been preserved, although no Arabic manuscripts have yet been traced and many Catalan and Latin works remain unpublished. His initial awkwardness in Latin, coupled with his desire that knowledge be made available to non-Latin-speaking sectors of society, made Lull the first person to mold Catalan into a literary medium. He used it not only in important mystical works, poetry, and allegorical novels (none of which concerns us here) but also to deal with every learned subject which engaged his attention: theology and philosophy; arithmetic, geometry, and astronomy (often mainly astrology), which, together with music, formed the quadrivium (the higher division of the seven liberal arts); grammar, rhetoric, and logic (the trivium); law; and medicine. Thus, Lull created a fully developed learned vocabulary in Catalan almost a century before any other Romance vernacular became a viable scholarly medium. Almost all Lull's works in such nonliterary fields were connected in some way with his Art, because the "art of finding truth" which he developed to convert "the infidel" proved applicable to every branch of knowledge. Lull himself pioneered its application to all subjects studied in medieval universities—except for music—and also constructed one of the last great medieval encyclopedias, the *Arbor scientiae* (1295–1296), in accordance with its basic principles.

Yet the Art can be understood correctly only when viewed in the light of Lull's primary aim: to place Christian apologetics on a rational basis for use in disputations with Muslims, for whom arguments *de auctoritate* grounded on the Old Testament—widely used by Dominicans in disputations with the Jews—carried no weight. The same purpose lay behind the *Summa contra gentiles* of Aquinas, written at the request of his fellow Dominican Penyafort, whose concern for the conversion of all non-Christians (but particularly those in James the Conqueror's dominions) thus inspired the two chief thirteenth-century attempts in this direction; the *Summa contra gentiles* was finished during the interval between Lull's discovery of his own calling and his interview with Penyafort. But whereas Aquinas distinguished categorically between what reason could prove and that which, while not contrary to reason, needed faith in revelation, Lull advanced what he called necessary reasons for accepting dogmas like the Trinity and the Incarnation. This gave his Art a rationalistic air that led to much subsequent criticism. Lull himself described his Art as lying between faith and logic, and his "necessary reasons" were not so much logical proofs as reasons of greater or lesser congruence which could not be denied without rejecting generally accepted principles. In this respect they were not appreciably more "rationalistic" than Aquinas's "proofs" that the truths of faith were not incompatible with reason. But the differences between the two apologetic systems are far more striking than their resemblances.

Lull regarded his Art as divinely inspired and hence infallible (although open to improvement in successive versions). Its first form, the *Ars compendiosa inveniendi veritatem* or *Ars maior*[2] (1273–1274[?]), was composed after a mystical "illumination" on Mount Randa, Mallorca, in which Lull saw that everything could be systematically related back to God by examining how Creation was structured by the active manifestation of the divine attributes—which he called Dignities and used as the absolute principles of his Art. Examining their manifestations involved using a set of relative principles; and both sets could be visualized in combinatory diagrams, known as Figures *A* and *T*. The original Figure *A* had sixteen Dignities, lettered *BCDEFGHIKLMNOPQR*; the original Figure *T* had five triads, only three of which (*EFG* + *HIK* + *LMN*) were strictly principles of relation, the others being sets of subjects (God + Creature + Operation, *BCD*) and possible judgments (Affirmation + Doubt + Negation, *OPQ*). All early versions had a proliferation of supplementary visual aids, which always included diagrams showing the four elements, and—with the obvious exception of Figure *T*—most features of the system were grouped into sets of sixteen items, lettered like the Dignities.

This quaternary base seems to provide the key to the origins of the Art's combinatory aspect, apparently modeled on the methods used to calculate combinations of the sixteen elemental "grades" (four each for fire, air, water, and earth) in both astrology and humoral medicine. A major simplification in the *Ars inventiva* (*ca.* 1289) eliminated the elemental features, reduced the diagrams to four (unchanged thereafter), reduced Figure *T* to the nine actual relative prin-

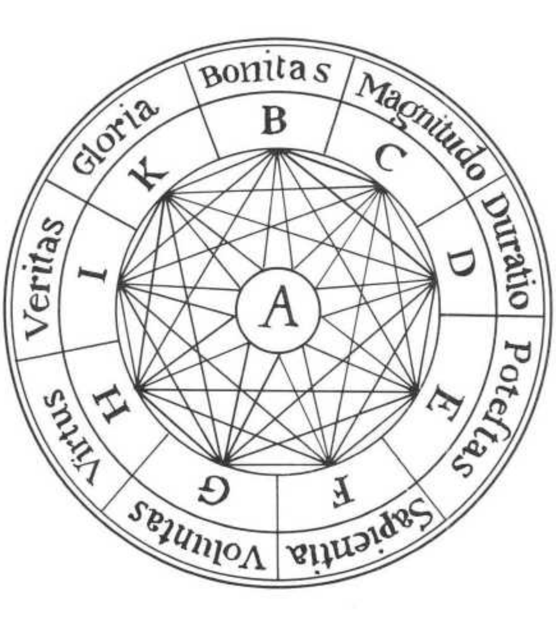

FIGURE 1. The Lullian "Dignities."

Alphabetum seu principia huius artis sunt aut		A (1. Essentia, 2. Unitas, 3. Perfectio)	B	C	D	E	F	G	H	I	K
Praedicata	Absoluta		Bonitas	Magnitudo	Æternitas seu Duratio	Potestas	Sapientia	Voluntas	Virtus	Veritas	Gloria
	T. Relata seu respectus		Differentia	Concordantia	Contrarietas	Principium	Medium	Finis	Maioritas	Æqualitas	Minoritas
Q. Quaestiones			Vtrum?	Quid?	De quo?	Quare?	Quantum?	Quale?	Quando?	Vbi?	Quomodo? Cum quo?
S. Subiecta			Deus	Angelus	Coelum	Homo	Imaginatio	Sensitiua	Vegetatiua	Elementatiua	Instrumentatiua
V. Virtutes			Iustitia	Prudentia	Fortitudo	Temperantia	Fides	Spes	Charitas	Patientia	Pietas
V. Vitia			Auaritia	Gula	Luxuria	Superbia	Acidia	Inuidia	Ira	Mendacium	Inconstantia

FIGURE 2. The "alphabet" of Lull's *Ars brevis* (1303).

ciples (Difference + Concordance + Contradiction, Beginning + Middle + End, and Majority + Equality + Minority) and the sixteen original Dignities to the nine shown in Figure 1. In still later versions the symbolic letters *BCDEFGHIK* acquired up to six meanings that were ultimately set out in the gridlike "alphabet" of the *Ars generalis ultima* and its abridgment, the *Ars brevis* (both 1308), from which Figure 2 is reproduced. The traditional seven virtues and seven vices have been extended to sets of nine, to meet the requirements of the ternary system; the last two of ten *quaestiones* (a series connected with the ten Aristotelian categories) had to share the same compartment, since the set of fundamental questions could not be shortened and still be exhaustive.

The most distinctive characteristic of Lull's Art is clearly its combinatory nature, which led to both the use of complex semimechanical techniques that sometimes required figures with separately revolving concentric wheels—"volvelles," in bibliographical parlance (see Figure 3)—and to the symbolic notation of its alphabet. These features justify its classification among the forerunners of both modern symbolic logic and computer science, with its systematically exhaustive consideration of all possible combinations of the material under examination, reduced to a symbolic coding. Yet these techniques taken over from nontheological sources, however striking, remain ancillary, and should not obscure the theocentric basis of the Art. It relates everything to the exemplification of God's Dignities, thus starting out from both the monotheism common to Judaism, Christianity, and Islam and their common acceptance of a Neoplatonic exemplarist world picture, to argue its way up and down the traditional ladder of being on the basis of the analogies between its rungs—as becomes very obvious in Lull's *De ascensu et descensu intellectus* (1305). The lowest rung was that of the elements, and Lull probably thought that the "model" provided by the physical doctrines of his time constituted a valid "scientific" basis for arguments projected to higher levels. Since this physical basis would be accepted in the scientific field by savants of all three "revealed religions," he doubtless also hoped that the specifically

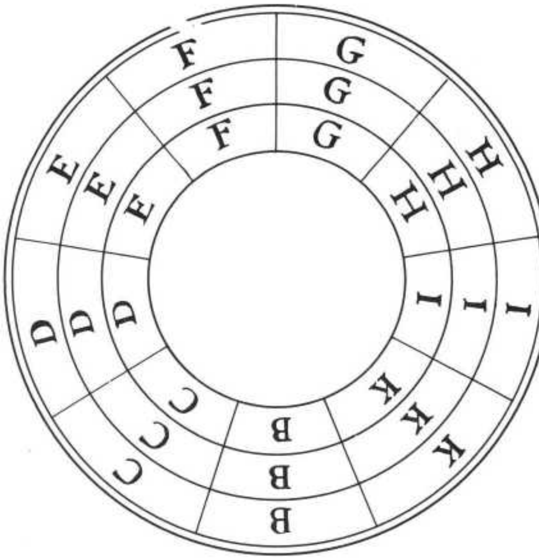

FIGURE 3. The fourth figure of the later Art: the inner wheels rotate independently, allowing all possible ternary combinations of the letters *BCDEFGHIK* to be read off.

Christian conclusions which he drew in the apologetic field would be equally acceptable. It even seems likely that what hit him with the force of a divine "illumination" on Mount Randa was his sudden recognition of such a possibility.

There is no evidence that Lull's Art ever converted anybody, but his application of the combinatory method to other disciplines (begun in the four *Libri principiorum*, *ca.* 1274–1275) was followed by numerous later Lullists; the Art's function as a means of unifying all knowledge into a single system remained viable throughout the Renaissance and well into the seventeenth century. As a system of logical inquiry (see Lull's *Logica nova* [1303] for the strictly logical implications, disentangled from other aspects), its method of proceeding from basic sets of preestablished concepts by the systematic exploration of their combinations—in connection with any question on any conceivable subject—can be succinctly stated in terms taken from the *Dissertatio de arte combinatoria* (1666) of Leibniz, which was inspired by the Lullian Art: "A proposition is made up of subject and predicate; hence all propositions are combinations. Hence the logic of inventing [discovering] propositions involves solving this problem: 1. given a subject, [finding] the predicates; 2. given a predicate, finding the subjects [to which it may] apply, whether by way of affirmation or negation."[3]

Recent research has concentrated on the clarification of Lull's ideas, the identification of their sources, and the nature of their influence on later thinkers—especially Nicholas of Cusa and Giordano Bruno. Major advances in all these fields have taken place since the 1950's, but much more research is still required. The specific origins of Lull's doctrines regarding the elements, whose importance has been fully recognized only since 1954 (see Yates), are particularly significant. A proper exploration of the antecedents of his *Opera medica* is a prerequisite for establishing Lull's final place in the history of Western science. In this connection it must be mentioned that although Lull himself was opposed to alchemy (but not to astrology, a "science" he sought to improve in the *Tractatus novus de astronomia* [1297]), his methods had obvious applications in the alchemical field—and they were so applied in a host of pseudo-Lullian alchemical works, most of them composed more than fifty years after his death. These works explain the traditional (but false) "scientific" view which made him "Lull the Alchemist."

NOTES

1. *Vida coëtanea*. The Latin (dictated by Lull [?], probably 1311) says "book," which doubtlessly agreed with Lull's original resolve; the plural, in the fourteenth-century Catalan text (modernized in *Obres essencials*, see I, 36), would better fit the series of "improved" versions of the Art itself, which first took shape almost ten years after Lull's conversion.
2. References to an *Ars magna* in later centuries are usually either to the definitive *Ars magna generalis ultima* (1308) or to Lull's system in general. The alternative title of the first version recalls Roger Bacon's *Opus maius* (1267); the connections between Lull and Bacon have yet to be investigated, but many resemblances may well be due to common Arabic sources.
3. "Propositio componitur ex subiecto et praedicato, omnes igitur propositiones sunt combinationes. Logicae igitur inventivae propositionum est hoc problema solvere: 1. Dato subiecto praedicata. 2. Dato praedicato subiecta invenire, utraque cum affirmative, tum negative" (G. W. Leibniz, *op. cit.* [in text], no. 55, in *Sämtliche Schriften und Briefen*, 2nd ser., I [Darmstadt, 1926], 192).

BIBLIOGRAPHY

I. ORIGINAL WORKS. The larger of the standard eds. in Catalan is *Obres de Ramon Lull*, 21 vols., with 9 more planned (Palma de Mallorca, 1901–), cited below as *ORL*. *Obres essencials*, 2 vols. (Barcelona, 1957–1960), cited below as *Ob es*, contains the chief literary works; the modernized text has many errata, but there are excellent general introductions and a select bibliography.

Collections in Latin are Beati Raymundi Lulli, *Opera omnia*, I. Salzinger, ed., vols. I-VI, IX (VII and VIII unpublished) (Mainz, 1721–1742), contains 48 works, repr. Minerva GMBH, cited below as *MOG;* reprint of *Quattuor libri principiorum* from *MOG* I (Paris–The Hague, 1969), cited below as *QLP; Opera parva*, 3 vols. (Palma, 1744–1746), 15 works, 12 of which are not in *MOG;* and *Opera medica* (Palma, 1742)—it and *Opera parva* are to be issued in Gerstenberg Reprints. A modern critical ed. is *Raymundi Lulli Opera latina*, 5 vols., of 30 planned (Palma, 1961–), thus far previously unpublished works, cited below as *ORL*.

Major scientific works and versions of the Art are *Ars compendiosa inveniendi veritatem/Ars maior* (1273–1274[?]), *MOG* I; *Ars Universalis* (1274–1275[?]), *MOG* I; *Liber principiorum theologiae*, *Liber principiorum philosophiae*, *Liber principiorum juris*, *Liber principiorum medicinae* (1274–1275[?]), *MOG* I, *QLP; Liber chaos* (1275–1276[?]), *MOG III*; *Ars compendiosa medicinae* (1275–1276[?]), *Opera medica; Logica Algazalis* (*ca.* 1281), which is related to the Catalan verse *Logica del Gatzel* (after 1282[?]), *ORL* XIX; *Ars inventiva [veritatis]* (1289[?]), *MOG* V; *De levitate et ponderositate elementorum* (1293), *Opera medica; Arbor scientiae* (29 Sept. 1295–1 Apr. 1296), in various rare eds., in Catalan as *Arbre de ciencia* (simultaneous[?]), *ORL* XI–XIII, *Ob es* I; *Tractatus novus de astronomia* (1297; unpublished), Latin text discussed in Yates (1954; see below), Catalan MS is British Museum, Add. 16434, to appear in *ORL;* and *Liber de geometria [nova et compendiosa]* (1299), ed. by J. M. Millás-Vallicrosa (Barcelona, 1953), considered unreliable—see R. D. F. Pring-Mill, "La geometría luliana," in *Estudios Lulianos*, **2** (1958), 341–342.

Other works by Lull are *Liber de natura* (1301) (Palma, 1744); *Logica nova* (Palma, 1744); *Liber de regionibus sanitatis et infirmitatis* (1303), *Opera medica; De ascensu et descensu intellectus* (1305) (Palma, 1744); *Ars brevis* (1308), *Opera parva* I; *Ars generalis ultima/Ars magna [generalis ultima]* (1305–1308), in L. Zetzner, *Raymundi Lulli opera ea quae ad . . . artem . . . pertinent* (Strasbourg, 1598, 1609, 1617, 1651); and *Vita coëtanea* (dictated [?] 1311), B. de Gaiffier, ed., in *Analecta Bollandiana*, **48** (1930), 130–178, in Catalan as *Vida coëtania, Ob es.*

II. SECONDARY LITERATURE. See E. Colomer, S.J., *Nikolaus von Kues und Raimund Lull* (Berlin, 1961); C. E. Dufourcq, *L'Espagne catalane et le Maghreb aux XIII^e et XIV^e siècles* (Paris, 1966); J. N. Hillgarth, *Ramon Lull and Lullism in Fourteenth-Century France* (Oxford, 1971); Erhard-Wolfram Platzeck, O.F.M., *Raimund Lull, sein Leben, seine Werke, die Grundlagen seines Denkens*, 2 vols. (Düsseldorf, 1961–1964), vol. II contains the fullest bibliography of Lull's writings and Lullian studies; and Frances A. Yates, "The Art of Ramon Lull: An Approach to It Through Lull's Theory of the Elements," in *Journal of the Warburg and Courtauld Institutes*, **17** (1954), 115–173; and "Ramon Lull and John Scotus Erigena," *ibid.*, **23** (1960), 1–44; but see R. D. F. Pring-Mill, in *Estudios Lulianos*, **7** (1963), 167–180.

See also *Estudios Lulianos*, which began publication in 1957, and E. W. Platzeck's comprehensive survey of research from 1955 to 1969 in *Antonianum*, **45** (1970), 213–272.

R. D. F. PRING-MILL

LUMMER, OTTO RICHARD (*b.* Gera, Germany, 17 July 1860; *d.* Breslau, Germany [now Wrocław, Poland], 5 July 1925), *optics.*

After completing his dissertation in 1884, Lummer became an assistant to Helmholtz; and in 1887 he followed the latter to the newly founded Physikalisch-Technische Reichsanstalt (PTR) in Berlin. Helmholtz, his revered teacher and his constant model, was for Lummer, as Gehrcke recalled, the "absolute standard as a research worker and as a man." In 1889 Lummer became a member of the PTR, and in 1894 he was given the title of professor. Lummer did not qualify for lecturing until 1901, at the University of Berlin.

As early as 1849 Haidinger had announced the existence of interference fringes that occur on mica plates and that, unlike Newton's rings, "do not move when the plates producing them are displaced." These fringes of equal inclination, caused by interference between rays emerging after multiple internal reflections from a parallel-sided plate, were rediscovered (for the third time, after Haidinger and Mascart) by Lummer in 1884 in Helmholtz' laboratory at the University of Berlin; they became known as Lummer fringes. Helmholtz, who had not perceived the phenomenon because of his nearsightedness, was not willing to accept the existence of the interference effects. He was soon convinced, however, and called Lummer's dissertation "an unusually good work."

Since Lummer fringes are the result of differences in path length of many wavelengths, Lummer arrived at the idea, in 1901, of developing the plane parallel plates into a spectroscope of the highest resolution. This device had the advantage of possessing greater resolving power than the interferometer produced in 1897 by Fabry and Perot. The considerable drawback of low luminous intensity, caused by the glancing incidence of the light, was eliminated in 1902 by Gehrcke, who cemented a prism to the plate with Canada balsam. The new apparatus, for which Lummer proposed the name Lummer–Gehrcke interference spectroscope, proved to be an excellent tool for spectroscopy and superior to the simple line grating.

At the PTR, Lummer had the task of working out the bases for a suitable international primary standard of luminosity. In 1889 he constructed, with Brodhun, an exact photometer, the Lummer-Brodhun cube. The new instrument fulfilled "through optical arrangements all the conditions of an ideal grease spot," something that the previously employed real grease-spot photometer could not do. In photometry it became necessary to hold constant the light sources that were being compared. The existing bolometer was not exact enough for Lummer's needs. In 1892, with F. Kurlbaum, he constructed a surface bolometer, which superseded all the previous types. Lummer thus gradually approached the field in which he was to have his greatest successes: thermal radiation.

In 1898, after preliminary work concerning, among other things, the production of the blackbody, Lummer tackled the problem of determining the Kirchhoff function depending only on wavelength and temperature—that is, he was seeking the emissive power of the blackbody. With Pringsheim he confirmed Wien's displacement law and also, with greater precision, Wien's radiation law, which Wien had stated in 1896 and Paschen had experimentally ascertained. In 1900, however, Lummer and Pringsheim discovered the "nonvalidity" of this law, which they called the Wien-Planck spectral equation: It "is thereby demonstrated that the Wien-Planck spectral equation does not yield the blackbody radiation that we measured in the region of 12μ to 18μ."

The competing team of Rubens and Kurlbaum verified this important result and derived from their measurements a conclusion that went even further: