then investigated how the characteristic quantities of general bundles change with refraction, thus obtaining what he called the system laws of optical systems. But Gullstrand did not restrict himself solely to the consideration of spherical surfaces; one of his longest papers deals with the construction and tracing through of aspheric surfaces.

Unacquainted with the work of H. R. Hamilton, he solved difficult mathematical problems simply by developing the necessary quantities in a series around the coordinates of the principal ray. He considered mathematical methods, such as the calculus of variation and vector methods, to be false ornaments. This prejudice makes his papers long and clumsy, but they contain a number of valuable and little-known results. H. Boegehold, C. W. Oseen, and the writer have endeavored to give simpler derivations of his beautiful results. However, there are limitations to his method. In the case of a branch point, for example, the series development does not work.

Gullstrand was a fighter, discovering several inaccuracies in the normal treatment of optical problems; he spent much of his time studying these inaccuracies, which were mostly a result of approximate pictures being applied to describe finite realities. For instance, the Sturm conoid described an astigmatic bundle as a bundle of rays going through two straight lines perpendicular to each other and to the principal ray. Gullstrand showed that such a manifold bundle of rays is not a normal system, that is, it cannot originate from an object point. Another fallacy was that the collinear image formation, which is the coordination of lines in object and image space such that the rays from any object point unite in a fixed image point, could not have been taken as an approximation to the real image formation, because the former cannot be obtained by optical means (with the trivial exception of the plane mirror). Unfortunately, books are still published disregarding these simple truths.

Gullstrand represents a scientist of very rigorous standards, and as such, he was highly respected by his peers for his intelligence and integrity. His advice was widely sought, even outside his special sphere of interest; among other honors, he was a member and later president of the Nobel Prize committee.

BIBLIOGRAPHY

I. Original Works. Gullstrand's works include "Objektive Differential-Diagnostik und photographische Abbildung von Augenmuskellahmungen," in *Kungliga Svenska vetenskapsakademiens handlingar,* **18** (1892); "Allgemeine Theorie der monochromatischen Aberrationen und ihre nächsten Ergebnisse für die Ophthalmologie," in *Nova acta Regiae Societatis scientiarum upsaliensis* (1900); "Die Farbe der Macula centralis retinae," in *Archiv für Ophthalmologie,* **62** (1905), 1-72, 378; "Die reelle optische Abbildung," in *Kungliga Svenska vetenskapsakademiens handlingar,* **41** (1906), 1-119; "Tatsachen und Fiktionen in der Lehre von der optischen Abbildung," in *Archiv für Optik* (1907), 1-41, 81-97; and "Die optische Abbildung in heterogenen Medien und die Dioptrik der Kristallinse des Menschen," in *Kungliga Svenska vetenskapsakademiens handlingar,* **43** (1908), 1-58.

See also *Einführung in die Methoden der Dioptrik des Auges des Menschen* (Leipzig, 1911); "Die reflexlose Ophthalmoskopie," in *Archiv für Augenheilkunde,* **68** (1911), 101-144; "Das allgemeine optische Abbildungssystem," in *Kungliga Svenska vetenskapsakademiens handlingar,* **55** (1915), 1-139; "Ueber aspharische Flächen in optischen Instrumenten," *ibid.,* **60** (1919), 1-155; "Optische Systemsgesetze zweiter und dritter Ordnung," *ibid.,* **63** (1924), 1-175; and "Einiges über optische Bilder," in *Naturwissenschaften,* **14** (1926), 653-664.

II. Secondary Literature. For information about Gullstrand and his work see H. Boegehold, "Ueber die Entwicklung der Theorie der optischen Instrumente seit Abbe," in *Ergebnisse der exakten Naturwissenschaften,* **8** (1929), 1-146; M. Herzberger, "Allvar Gullstrand," in *Optica acta,* **3** (1960), 237-241; J. W. Nordenson, "Allvar Gullstrand," in *Klinische Monatsblatter für Augenheilkunde,* pp. 560-566; C. W. Oseen, "Allvar Gullstrand," in *Kungliga Svenska vetenskapsakademiens årsbok,* (1937); "Une méthode nouvelle de l'optique géometrique," in *Kungliga Svenska vetenskapsakademiens handlingar,* **3** (1936), 1-41; and M. von Rohr, "Allvar Gullstrand," in *Zeitschrift für ophthalmologische Optik,* **18** (1930), 129-134.

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GUNDISSALINUS, DOMINICUS, also known as **Domingo Gundisalvo** or **Gonsález** (*fl.* Toledo, Spain, second half of the twelfth century), *science translation, philosophy of science.*

Gundissalinus' date of birth is unknown, although conjecture has offered 1110; there is some evidence that he was still alive in 1190. He was archdeacon of Segovia, but his intellectual activity was centered at Toledo, where a flourishing school of translators, under the patronage of such archbishops as Raymond of Toledo, introduced a considerable amount of Arabic and Judaic materials to the Latin West during the twelfth century.

Many of the translations were done with the collaboration of two scholars, one knowledgeable in Arabic, the other in Latin, with a vernacular serving as common ground. The translations attributed to Gundissalinus were probably done in this fashion, although only in the manuscripts of the translation of the *De anima* of Ibn Sīnā (Avicenna) is Gundissalinus' name specifically linked with that of a cotranslator, Abraham ibn Daūd (Avendauth). In addition to the *De anima,* Gundissalinus' name has been connected with translations of Ibn Sīnā's *Sufficientia* and *Metaphysics,* as well as a portion of his *Posterior Analytics,* together with the *Logic* and *Metaphysics* of al-Ghazzālī; the *Fons vitae* of Ibn Gabirol; the *De intellectu,* the *Fontes questionum,* the *De scientiis,* the *Liber excitativus ad viam felicitatis,* and the *De ortu scientiarum* of al-Fārābī; the *De intellectu* of al-Kindī; and the *Liber de definitionibus* of Isaac Israeli.

Gundissalinus was the author of five philosophical works which drew heavily on the Arabic-Judaic materials of his translations as well as on Latin sources. He was the first to provide the Latin West with an introduction to Arabic-Judaic Neoplatonism and the first to blend this tradition with the Latin Christian Neoplatonism of Boethius and Augustine. His *De unitate* is such a syncretic work. It is rich in aphorisms which were quoted frequently during the Middle Ages, for example, "Quidquid est ideo est quia unum est." Gundissalinus' *De anima,* likewise a compilation from his translations, is essentially a presentation of Avicennian psychology and ideas from Ibn Gabirol, although it utilizes material from other sources, such as Augustine and the treatise *On the Difference Between Soul and Spirit* of Qusṭā ibn Lūqā.

Gundissalinus' *De processione mundi* is taken from numerous sources: Ibn Sīnā, Ibn Gabirol, al-Ghazzālī, al-Fārābī, Boethius, Porphyry, the *Epistola de anima* of Isaac de Stella, possibly the *De deo Socratis* of Apuleius, and his own *De unitate.* Its editor, Georg Bülow, considers it a late work. The *De processione* was used in the thirteenth century by both William of Auvergne (William of Paris) and Thomas Aquinas. Gundissalinus' *De immortalitate animae,* again dependent on Arabic materials, is a well-written treatise proving the indestructibility of the soul, using arguments based on the soul's own nature which were to become standard in the Middle Ages. The *De immortalitate* was reworked in the thirteenth century by William of Auvergne.

The *De divisione philosophiae* is a classification of the sciences which served as a source for later classification schemes. It incorporates al-Fārābī's work on the classification of the sciences (the *De ortu scientiarum*) and utilizes a wide variety of other sources: classical Latin, Arabic, and Aristotelian. Since it draws on Gerard of Cremona's translation of the Arabic mathematician al-Nayrīzī, the *De divisione* was likely written after 1140, since Gerard's translating activity probably did not begin before that year. The *De divisione* begins with a prologue followed by a section containing six definitions of philosophy taken from various sources.

The sciences are classified into three major groups: propaedeutic sciences, including grammar, poetics, and rhetoric; logic; and philosophical sciences. The latter are further divided into theoretical and practical sciences. The theoretical sciences are subdivided in turn into physics, mathematics, and theology. Physics contains eight subjects, and mathematics has seven. Following this discussion, Gundissalinus inserts a section from Ibn Sīnā's *Posterior Analytics.* Treatment of the practical sciences, which include politics, economics, and ethics, concludes the treatise.

Gundissalinus' classification transcends the conventional subject matter of the *trivium* and the *quadrivium.* He includes a section on medicine as a branch of physics, and the seven subjects subsumed under mathematics include discussions of *scientiae de aspectibus, de ponderibus,* and *de ingeniis,* in addition to the four subjects of the *quadrivium.* The *De divisione* was directly used by Robert Kilwardby in his own treatise on classification, and its influence is further revealed in the works of Michael Scot, Vincent of Beauvais, and Thierry of Chartres.

BIBLIOGRAPHY

I. Original Works. Editions of Gundissalinus' writings include M. Menéndez y Pelayo, *Historia de los heterodoxos españoles,* I (Madrid, 1880), 691–711, text of *De processione mundi;* Paul Correns, "Die dem Boethius fälschlich zugeschrieben Abhandlung des Dominicus Gundisalvi *De unitate,*" in *Beiträge zur Geschichte der Philosophie des Mittelalters,* **1,** no. 1 (1891), 1–11; Georg Bülow, "Des Dominicus Gundissalinus Schrift von der Unsterblichkeit der Seele," *ibid.,* **2,** no. 3 (1897), 1–38; Ludwig Baur, "Dominicus Gundissalinus *De divisione philosophiae,*" *ibid.,* **4,** nos. 2–3 (1903), 1–142; Georg Bülow, "Des Dominicus Gundissalinus Schrift von dem Hervorgange der Welt (*De processione mundi,*" *ibid.,* **24,** no. 3 (1925), 1–54; and J. T. Muckle, "The Treatise *De anima* of Dominicus Gundissalinus," in *Mediaeval Studies,* **2** (1940), 23–103.

II. Secondary Literature. On Gundissalinus or his work, see M. T. D'Alverny, "Avendauth?" in *Homenaje a Millás-Vallicrosa,* I (Barcelona, 1954), 19–43, esp. the arts. by P. Alonso listed in ftn. 14, pp. 24–25, including "Las fuentes literarias de Domingo Gundisalvo," in *Al-Andalus,* **11** (1947), 209–211; C. Bäumker, "Les écrits philosophiques de Dominicus Gundissalinus," in *Revue thomiste,* **5** (1897), 723–745; and "Dominicus Gundissalinus als philosophischer Schriftsteller," in *Beiträge zur Geschichte der Philosophie des Mittelalters,* **25,** nos. 1–2 (1927), 255–275; D. A. Callus, "Gundissalinus' *De anima* and the Problem of Substantial Form," in *New Scholasticism,* **13** (1939), 338–355; A. H. Chroust, "The Definition of Philosophy in the *De divisione philosophiae* of Dominicus Gundissalinus," *ibid.,* **25** (1951), 253–281; P. Duhem, *Le système du monde,* III (Paris, 1958), 177–181; E. Gilson, *History of Christian Philosophy in the Middle Ages* (New York, 1955), pp. 235–239, 652–653; Nicholas M. Haring, "Thierry of Chartres and Dominicus Gundissalinus," in *Mediaeval Studies*, **26** (1964), 271–286; R. W. Hunt, "The Introductions to the *Artes* in the Twelfth Century," in *Studia Mediaevalia in Honor of R. J. Martin* (Bruges, 1948), pp. 85–112; L. Löwenthal, *Pseudo-Aristoteles über die Seele. Eine psychologische Schrift des 11. Jahrhunderts und ihre Beziehung zu Salomo ibn Gabirol* (*Avicebron*) (Berlin, 1891), pp. 77–113; J. Teicher, "Gundissalino e l'Agostonismo avicennizante," in *Rivista di filosofia neoscholastica* (May 1934), pp. 252–258; and L. Thorndike, *A History of Magic and Experimental Science*, II (New York, 1923), 78–82.

More general works are A. Jourdain, *Recherches critiques sur l'âge et l'origine des traductions d'Aristote* (Paris, 1819), pp. 107–119; Artur Schneider, "Die abenländische Spekulation des zwölften Jahrhunderts in ihrem Verhältnis zur aristotelischen und jüdisch-arabischen Philosophie," in *Beiträge zur Geschichte der Philosophie des Mittelalters*, **17**, pt. 4 (1915), 39–72; M. Steinschneider, *Die europäischen Übersetzungen aus dem arabischen bis Mitte des 17. Jahrhunderts* (Graz, 1956), pp. 40–50, 260–261; and R. de Vaux, *Notes et textes sur l'avicennisme latin aux confins des xii^e et xiii^e siècles* (Paris, 1934), pp. 141–142.

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GUNTER, EDMUND (*b.* Hertfordshire, England, 1581; *d.* London, England, 10 December 1626), *navigation, mathematics.*

Little is known of Gunter's origins or the details of his life. Of Welsh descent, he was educated at Westminster School and Christ Church, Oxford, graduating B.A. in 1603 and M.A. in 1605. He subsequently entered holy orders, became rector of St. George's, Southwark, in 1615, and received the B.D. degree later that year. In March 1619 he became professor of astronomy at Gresham College, London, retaining this post and his rectorship until his sudden death at the age of forty-five.

Gunter's contributions to science were essentially of a practical nature. A competent but unoriginal mathematician, he had a gift for devising instruments which simplified calculations in astronomy, navigation, and surveying; and he played an important part in the English tradition—begun in 1561 by Richard Eden's translation of Martín Cortes' *Arte de navegar* and furthered by William Borough, John Dee, Thomas Harriot, Thomas Hood, Robert Hues, Robert Norman, Edward Wright, and others—which put the theory of navigation into a form suitable for easy use at sea. Gunter's works, written in English, reflected the practical nature of his teaching and linked the more scholarly work of his time with everyday needs; the tools he provided were of immense value long afterward.

Gunter's first published mathematical work was the *Canon triangulorum* of 1620, a short table, the first of its kind, of common logarithms of sines and tangents. His account of his sector, in the *De sectore et radio* of 1623, had circulated in manuscript for sixteen years before its publication. The sector, a development from Hood's, included sine, tangent, logarithm, and meridional part scales; its uses included the solution of plane, spherical, and nautical triangles (the last formed from rhumb, meridian, and latitude lines). With improvements, the British navy used it for two centuries, and it was also a precursor of the slide rule. Gunter solved such problems as finding the sun's amplitude from its declination and the latitude of the observer by adding similar scales to the seaman's cross-staff. Comparison of the amplitude with the sun's direction, measured by a magnetic compass, was known to give the compass variation; but although Gunter's own observations in 1622 at Limehouse were about five degrees less than Borough's 1580 results there, a statement of the secular change of variation awaited the further decrease observed by Gunter's Gresham successor, Henry Gellibrand.

Gunter's other inventions may have included the so-called Dutchman's log for measuring a ship's way. Henry Briggs acknowledged his suggested use of arithmetical complements in logarithmic work and the terms cosine, contangent, and such are probably Gunter's own; his use of the decimal point and his decimal notation for degrees are to be noted. Gunter's chain, used in surveying, is sixty-six feet long and divided into 100 equal links, thus allowing decimal measurement of acreage. Largely following Willebrord Snell, Gunter took a degree of the meridian to be 352,000 feet; this decision gave English seamen a much improved result.

BIBLIOGRAPHY

I. ORIGINAL WORKS. Gunter's chief works went through six eds. by 1680 and were successively augmented by their editors. They are *Canon triangulorum, sive tabulae sinuum et tangentium artificialium ad radium 10000.0000. & ad scrupula prima quadrantis* (London, 1620)—the British Museum copy (C.54.e.10) is bound with Henry Briggs's rare *Logarithmorum chilias prima* (London, n.d. [probably 1617]) and contains copious MS additions; *De sectore et radio. The Description and Use of the Sector in Three Bookes. The Description and Use of the Crosse-Staffe in Other Three Bookes. . . .* (London, 1623), a work of great practical importance; and *The Description and Use of His Majesties Dials in White-Hall Garden* (London, 1624)—the British Museum copy (C.60.f.7) gives evidence of Gunter's friendship with Ben Jonson—describes the large complex of dials, which stood until about 1697. A copy of the enl. 2nd