ALBERTUS MAGNUS, SAINT, also known as **Albert the Great** and **Universal Doctor** (*b.* Lauingen, Bavaria, *ca.* 1200; *d.* Cologne, Prussia, 15 November 1280). *Proficient in all branches of science, he was one of the most famous precursors of modern science in the High Middle Ages.*

Albert was born in the family castle and probably spent his childhood at the family manor in nearby Bollstädt—whence he is variously referred to as Albert of Lauingen and Albert of Bollstädt. His birth date could have been as early as 1193 or as late as 1206 or 1207. His family was wealthy and powerful, of the military nobility, and he received a good education.

He studied liberal arts at Padua, where, over strong opposition from his family, he was recruited into the Dominican Order by its master general, Jordan of Saxony—identified by some (but probably falsely) as Jordanus de Nemore, the mechanician. He likely studied theology and was ordained a priest in Germany, where he also taught in various priories before being sent to the University of Paris *ca.* 1241. In Paris he was the first German Dominican to become a master of theology and to lecture in the chair "for foreigners" (1245–1248). In the summer of 1248 he went to Cologne to establish a *studium generale*: among his students were Thomas Aquinas, Ulrich of Strassburg, and Giles (Aegidius) of Lessines.

He began the administrative phase of his career as provincial of the German Dominicans (1253–1256). Subsequently he became bishop of Regensburg (1260), a post he resigned in 1262. The latter part of his life was spent in preaching and teaching, mainly at Cologne. He took part in the Council of Lyons (1274) and journeyed to Paris in an unsuccessful attempt to block the famous condemnation of 1277, where some of Aquinas' teachings were called into question. His health was good and he had great powers of physical endurance, even to old age, although his eyesight failed during the last decade of his life. Albert was canonized by Pope Pius XI on 16 December 1931 and was declared the patron of all who cultivate the natural sciences by Pope Pius XII on 16 December 1941.

Albert's principal importance for the history of modern science derives from the role he played in rediscovering Aristotle and introducing Greek and Arab science into the universities of the Middle Ages. Before his time, what was to become the subject matter of modern science was usually treated in encyclopedias, which assembled a curious mélange of fact and fable about nature, or in theological treatises, which described the cosmos in terms of the six days of creation, as recounted in Genesis and variously analyzed by the church fathers. Aristotle, of course, had already made his entry into the Latin West through the translations of Gerard of Cremona and James of Venice, among others; but Christendom was generally hostile to the teachings of this pagan philosopher, particularly as contained in his *libri naturales* ("books on natural science"). In 1210, the ecclesiastical authorities at Paris had condemned Aristotle's works on natural philosophy and had prohibited their being taught publicly or privately under pain of excommunication. Although this condemnation was revoked by 1234, it had a general inhibiting effect on the diffusion of Greek science in the schools of the Middle Ages.

Albert seems to have become acquainted with the Aristotelian corpus while at the Paris priory of St. Jacques in the 1240's. Here too he probably began his monumental paraphrase of all the known works of Aristotle and Pseudo-Aristotle, to which are allotted seventeen of the forty volumes in the Cologne critical edition of Albert's works (see Bibliography). The project was undertaken by Albert, then studying and teaching theology, at the insistence of his Dominican brethren, who wished him to explain, in Latin, the principal physical doctrines of the Stagirite so that they could read his works intelligently. Albert went far beyond their demands, explaining not only the natural sciences but also logic, mathematics, ethics, politics, and metaphysics, and adding to Aristotle's exposition the discoveries of the Arabs and of whole sciences that were not available to him. The gigantic literary production that this entailed was recognized as one of the marvels of his age and contributed in no small measure to Albert's outstanding reputation. Roger Bacon, a contemporary who was not particularly enamored of the German Dominican, complained of Master Albert's being accepted as an authority in the schools on an equal footing with Aristotle, Avicenna, and Averroës—an honor, he protested, "never accorded to any man in his own lifetime."

Like all medieval Aristotelians, Albert incorporated considerable Platonic thought into his synthesis, and even commented on a number of Neoplatonic treatises. In several places he represents himself as merely reporting the teachings of the Peripatetics and not as proposing anything new; some historians charge him, on this basis, with being a compiler who was not too judicious in his selection of source materials. Those who have studied his works, however, detect there a consistent fidelity to Aristotle's basic theses, a clear indication of his own views when he thought Aristotle in error, a repudiation of erroneous interpretations of Aristotle's teaching, and an explicit rejection of Platonic and Pythagorean physical doctrines—all of which would seem to confirm his Aristotelianism. J. A. Weisheipl, in particular, has stressed the differences

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between thirteenth-century Oxford masters such as Robert Grosseteste, Robert Kilwardby, and Roger Bacon (all of whom were more pronouncedly Platonist in their scientific views) and Paris masters such as Albert and Aquinas (who were more purely Aristotelian). Whereas the former held that there is a successive subalternation between physics, mathematics, and metaphysics (so that the principles of natural science are essentially mathematical, and the principle of mathematics is the unity that is identical with Being), the latter held for the autonomy of these sciences, maintaining that each has its own proper principles, underived from any other discipline.

Albert's early identification as a precursor of modern science undoubtedly stemmed from his empiricist methodology, which he learned from Aristotle but which he practiced with a skill unsurpassed by any other Schoolman. From boyhood he was an assiduous observer of nature, and his works abound in descriptions of the phenomena he noted, usually in great detail. Considering that his observations were made without instruments, they were remarkably accurate. Some of the "facts" he reported were obviously based on hearsay evidence, although he was usually at pains to distinguish what he had himself seen from what he had read or been told by others. *Fui et vidi experiri* ("I was there and saw it happen") was his frequent certification for observations. Sometimes, as Lynn Thorndike has well illustrated in his *A History of Magic and Experimental Science,* even these certifications test the reader's credulity; what is significant in them, however, is Albert's commitment to an empiricist program. He stated that evidence based on sense perception is the most secure and is superior to reasoning without experimentation. Similarly, he noted that a conclusion that is inconsistent with the evidence cannot be believed and that a principle that does not agree with sense experience is really no principle at all. He was aware, however, that the observation of nature could be difficult: much time, he remarked, is required to conduct an experiment that will yield foolproof results, and he suggested that it be repeated under a variety of circumstances so as to assure its general validity.

On the subject of authority, he pointed out that science consists not in simply believing what one is told but in inquiring into the causes of natural things. He had great respect for Aristotle, but disagreed with the Averroists of his day on the Stagirite's infallibility. "Whoever believes that Aristotle was a god, must also believe that he never erred. But if one believes that he was a man, then doubtless he was liable to error just as we are." His *Summa theologica,* for example, contains a section listing the errors of Aristotle, and in his *Meteorology* he observes that "Aristotle must have spoken from the opinions of his predecessors and not from the truth of demonstration or experiment."

Albert recognized the importance of mathematics for the physical sciences and composed treatises (unfortunately lost) on its pure and applied branches. Yet he would not insist that the book of nature is written in the language of mathematics, as Galileo was later to do, and as Roger Bacon intimated in his own lifetime. Rather, for Albert, mathematics had only a subsidiary role to play in scientific activity, insofar as it assisted in the discovery of physical causes. Mathematics is itself an abstract science, prescinding from motion and sensible matter, and thus its applications must be evaluated by the science that studies nature as it really exists, *in motu et inabstracta* ("in motion and in concrete detail").

The mechanics of Albert was basically that of Aristotle, with little innovation in either its kinematical or its dynamical aspects. One part of Albert's teaching on motion, however, did assume prominence in the late medieval period and influenced the emerging new science of mechanics. This was his use of the expressions *fluxus formae* and *forma fluens* to characterize the scholastic dispute over the entitative status of local motion. Arab thinkers such as Avicenna and Averroës had pursued the question whether this motion, or any other, could be located in the Aristotelian categories; the question quickly led to an argument whether motion is something really distinct from the terminus it attains. Local motion, in this perspective, could be seen in one of two ways: either it was a *fluxus formae* (the "flowing" of successive forms, or locations) or a *forma fluens* (a form, or absolute entity, that is itself a process). Although Albert made no clear dichotomy between these two views and allowed that each described a different aspect of motion, later writers came to be sharply divided over them. Nominalists, such as William of Ockham, defended the first view: this equivalently denied the reality of local motion, equating it simply with the distance traversed and rejecting any special causality in its production or continuance—a view that stimulated purely kinematical analyses of motion. Realists, such as Walter Burley and Paul of Venice, on the other hand, defended the second view: for them, local motion was an entity really distinct from the object moved and from its position, and thus had its own proper causes and effects—a view that stimulated studies of its more dynamical aspects.

Albert mentioned the term *impetus* when discussing projectile motion, but spoke of it as being in the medium rather than in the projectile, thus defending the original Aristotelian teaching; certainly he had no treatment of the concept to match that found in the work of fourteenth-century thinkers. His analysis of gravitational motion was also Aristotelian: he regarded the basic mover as the generator of the heavy object, giving it not only its substantial form but also its gravity and the motion consequent on this. He knew that bodies accelerate as they fall, and attributed this to their increasing propinquity to their natural place.

The cause of sound, for Albert, is the impact of two hard bodies, and the resulting vibration is propagated in the form of a sphere whose center is the point of percussion. He speculated also on the cause of heat, studying in detail how light from the sun produces thermal effects; here his use of simple experiments revealed a knowledge of the method of agreement and difference later to be formulated by J. S. Mill. He knew of the refraction of solar rays and also of the laws of refraction of light, although he employed the term *reflexio* for both refraction and reflection, as, for example, when discussing the burning lens and the burning mirror. His analysis of the rainbow was diffuse in its historical introduction, but it made an advance over the theory of Robert Grosseteste in assigning individual raindrops a role in the bow's formation, and undoubtedly prepared for the first correct theory of the rainbow proposed by another German Dominican, Dietrich von Freiberg, who was possibly Albert's student. In passing, he corrected Aristotle's assertion that the lunar rainbow occurs only twice in fifty years: "I myself have observed two in a single year."

Although he had no telescope, he speculated that the Milky Way is composed of stars and attributed the dark spots on the moon to configurations on its surface, not to the earth's shadow. His treatise on comets is notable for its use of simple observation to verify or falsify theories that had been proposed to explain them. He followed Grosseteste in correlating the occurrence of tides with the motion of the moon around its deferent. He favored the mathematical aspects of the Ptolemaic theory of the structure of the solar system, contrasting it with that of al-Biṭrūjī, although he acknowledged the superiority of the latter's theory in its physical aspects. Albert accepted the order of the celestial spheres commonly taught by Arabian astronomers; he knew of the precession of the equinoxes, attributing knowledge of this (falsely) to Aristotle also. Like most medieval thinkers, Albert held that heavenly bodies are moved by separated substances, but he denied that such substances are to be identified with the angels of Christian revelation, disagreeing on this point with his celebrated disciple Thomas Aquinas.

On the structure of matter, when discussing the presence of elements in compounds, Albert attempted to steer a middle course between the opposed positions of Avicenna and Averroës, thereby preparing for Aquinas' more acceptable theory of "virtual" presence. In a similar vein, he benignly viewed Democritus' atoms as equivalent to the *minima naturalia* of the Aristotelians. He seems to have experimented with alchemy and is said to have been the first to isolate the element arsenic. He compiled a list of some hundred minerals, giving the properties of each. During his many travels, he made frequent sidetrips to mines and excavations in search of specimens. He was acquainted with fossils, and made accurate observations of "animal impressions" and improved on Avicenna's account of their formation. Albert suggested the possibility of the transmutation of metals, but he did not feel that alchemists had yet found the method to bring this about.

Extensive as was Albert's work in the physical sciences, it did not compare with his contributions to the biological sciences, where his powers of observation and his skill at classification earned for him an unparalleled reputation. Some aspects of his work have been singled out by A. C. Crombie as "unsurpassed from Aristotle and Theophrastus to Cesalpino and Jung." His *De vegetabilibus et plantis,* in particular, is a masterpiece for its independence of treatment, its accuracy and range of detailed description, its freedom from myth, and its innovation in systematic classification. His comparative study of plants extended to all their parts, and his digressions show a remarkable sense of morphology and ecology. He drew a distinction between thorns and prickles on the basis of their formation and structure, classified flowers into the celebrated three types (bird-form, bell-form, and star-form), and made an extensive comparative study of fruits. His general classification of the vegetable kingdom followed that proposed by Theophrastus: he ranged plants on a scale reaching from the fungi to the flowering types, although, among the latter, he did not explicitly distinguish the monocotyledons from the dicotyledons. He seems to have been the first to mention spinach in Western literature, the first to note the influence of light and heat on the growth of trees, and the first to establish that sap (which he knew was carried in veins—like blood vessels, he said, but without a pulse) is tasteless in the root and becomes flavored as it ascends.

On plant evolution, Albert proposed that existing types were sometimes mutable and described five ways of transforming one plant into another; he believed, for example, that new species could be produced by grafting. Here he registered an advance over most medieval thinkers, who accounted for the succession

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of new species not by modification but by generation from a common source such as earth.

Albert's *De animalibus* includes descriptions of some fabulous creatures, but it also rejects many popular medieval myths (e.g., the pelican opening its breast to feed its young) and is especially noteworthy for its sections on reproduction and embryology. Following Aristotle, Albert distinguished four types of reproduction; in sexual reproduction among the higher animals he taught that the material produced by the female was like a seed (a *humor seminalis*), differentiating it from the catamenia (*menstruum*) in mammals and the yolk of the egg in birds, but incorrectly identifying it with the white of the egg. The cause of the differentiation of the sexes, in his view, was that the male "vital heat" could "concoct" semen out of surplus blood, whereas the female was too cold to effect the change.

He studied embryology by such simple methods as opening eggs at various intervals of time and tracing the development of the embryo from the appearance of the pulsating red speck of the heart to hatching. He was acquainted, too, with the development of fish and mammals, and understood some aspects of fetal nutrition. His studies on insects were especially good for their descriptions of insect mating, and he correctly identified the insect egg. He showed that ants lose their sense of direction when their antennae are removed, but concluded (wrongly) that the antennae carry eyes.

Among the larger animals, he described many northern types unknown to Aristotle, noting changes of coloration in the colder climates, and speculating that if any animals inhabited the poles they would have thick skins and be of a white color. His knowledge of internal anatomy was meager, but he did dissect crickets and observed the ovarian follicles and tracheae. His system of classification for the animal kingdom was basically Aristotelian; occasionally he repeated or aggravated the Stagirite's mistakes, but usually he modified and advanced Aristotle's taxonomy, as in his treatment of the ten genera of water animals. His anthropology was more philosophical than empirical in intent, but some have detected in it the adumbration of methods used in experimental psychology.

Apart from these more speculative concerns, Albert made significant contributions also to veterinary and medical science, dentistry included. In anatomy, for example, he took the vertebral column as the basis for structure, whereas in his day and for long afterward most anatomists began with the skull. He was reported to have cures for all manner of disease, and despite his own repudiation of magic and astrology came to be regarded as something of a magician. Many spurious works, some utterly fantastic, were attributed to him or published under his name to assure a wide diffusion—among these are to be included the very popular *De secretis mulierum* ("On the Secrets of Women") and other occult treatises.

Albert's productivity in science was matched by a similar output in philosophy and theology. In these areas his teachings have been overshadowed by those of his most illustrious disciple, Thomas Aquinas. The latter's debt to Albert is, of course, considerable, for Aquinas could well attribute the extent of his own vision to the fact that he stood on the shoulders of a giant.

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WILLIAM A. WALLACE, O. P.

ALBRECHT, CARL THEODOR (*b.* Dresden, Germany, 30 August 1843; *d.* Potsdam, Germany, 31 August 1915), *surveying, astronomy.*

Albrecht's father, Friedrich Wilhelm Albrecht, and both grandfathers were soap boilers. Indeed, his maternal grandfather, Christian Friedrich Pohle, was a senior official of the soap boilers' guild of Dresden. Carl, however, did not continue the family tradition. His parents recognized the boy's intelligence, and set him on quite another path in that era when technology and the exact sciences flowered. As a student his major fields were mathematics and the natural sciences, but he occupied himself independently with astronomy and meteorology. About 1865, after passing his examinations at the Polytechnicum in Dresden, which at that time was an engineering school, Albrecht studied astronomy at the University of Leipzig in order to follow his special inclinations and to enlarge his theoretical knowledge.

From 1866 on, Albrecht was an assistant in the central European degree measurement project while continuing his studies. In 1869 he graduated from Leipzig and was immediately accepted at the newly founded Geodetic Institute in Potsdam, an indication that he already had a good scientific reputation. In 1873 he was appointed director of the astronomy department of the Geodetic Institute, a post he held until his death. In 1875 he became professor; in the same year he married Marie Stiemer.

The Geodetic Institute quickly became one of the leading research institutes in astronomy and geodesy. From 1895 on, Albrecht also directed the International Latitude Service, a cooperative group of various research institutes in many countries that sought the precise determination of the geographic degree of latitude.

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HANS BAUMGÄRTEL

ALBUMASAR. See **Abū Maʿshar.**

ALCABITIUS. See **al-Qabīṣī.**

ALCMAEON OF CROTONA (*b.* Crotona, Magna Graecia, *ca.* 535 B.C.), *medicine, natural philosophy.*

Alcmaeon, the son of Peirithoos and a pupil of Pythagoras, is often reported to have been a physician. There is no support for this in ancient sources, however, although Diogenes Laertius stated that Alcmaeon "wrote mostly about medical affairs." As far as we can judge, he also wrote about meteorological and astrological problems and about such philosophical questions as the immortality of the soul. It may therefore be best to call him a natural philosopher, deeply versed in medicine, who was in close contact with both the Pythagoreans and the physicians in Crotona (in this connection we may also think of his contemporary, the physician Democedes of Crotona). One must also keep in mind that at that time the "physiological" side of medicine was treated predominantly by philosophers, Hippocrates being the first to "separate medicine from philosophy," as Celsus states in the preface to *De re medicina.* Aris-