THE ARABICS AND SCIENCE

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Through his study of the history of science, George Sarton acquired a great respect for the Arabian period. While working on his "Introduction to the History of Science" he felt hampered by his lack of knowledge of Arabic. He therefore spent the academic year 1931-1932 in the Near-East to study classic as well modern Arabic. Sarton possessed the talent of languages : he spoke fluently Dutch, French, English, German, Italian, Swedish, Danish, Turkish and Spanish, was very knowledgeable in Latin and Greek and had fair notions of Hebrew, Chinese and Portuguese (1).

Nevertheless, he felt it a must to study Arabic, which on its own proves how important Arabs have been in the development of sciences. Sarton agreed with Kremer and Urdang (2) that "The light of science in the Middle Ages burned only gloomily, and it was oxygen of Arabian origin which made it bright again".

By Arabian period we mean the period from the 7th to the 12th century. Before this period, the Arabs were a nomadic people of the Arabic peninsula about whom little is known as a consequence of their lifestyle. Their way of life apparently did not prevent them from being happy, and ancient writers, such as Dioscorides, had the name of Arabia always preceded by the epithet 'happy", Arabia Felix, which is still the case in the 16th century when Dodonaeus wrote : "These varieties of cane can be found in India and in Happy Arabia".

In the early 7th century, the prophet Mohammed (570-632) appeared on the scene. Up to then the Arabs had not played an appreciable role in the history of the world. At that time, however, they founded a strong theocratic state and were to determine world destiny for three centuries. The "holy war", declared by the Prophet,

made them stop their internal disputes and massacres and occupy, in less than a century, Syria, Asia Minor, a large part of Central Asia and the North-African coast. In the early 8th century they conquered Spain and Southern Europe. The northbound expansion was halted in 732 by the victory of Charles Martel on Adoer al Rahman. In the East, Byzantium prevented the advance of Islam, which made it possible for Charlemagne to found the Carolingean Empire, bringing later to an end the scientific monopoly of the Arabs.

The Prophet had promised that all who died with the sword in their hand would have their soul brought straight to Allah. The Arabs who, as all nomads, had a bad record, saw here the chance to secure eternal life and thus the disciples of the Prophet established in a short time a vast empire, stretching from Spain to the Indus. Although the Empire would become devided in various caliphates and included various races, they kept their unity by their religion, Islam, and by their written language, Arabic.

In the process of the founding of the Islamic Empire, which included victory over civilized nations, a rather unique fact in the history of mankind occurred : the conquerors did not destroy — as happens usually : Vae Victis ! — the conquered and their culture. The inhabilitants of the desert were staggered by the beauty they contemplated in Egypt, Greece, Italy and elsewhere. Instead of burning all they found, these simple people wanted to take part in the culture they happened to be confronted with for the first time. With their open mind, their clean and sound reasoning, their mathematical approach, these natural men tried to assimilate the spirit of the conquered civilized nations.

They soon started to translate and to order the many works they had laid their hands on. The essence of the whole Arabic resides in the fact that "they translated and ordered". These translations made Arabic the language of scholarship of that time. When the Arabic Empire faded away, everything will again be translated, from Arabic to Latin, the new language of scholars. Thus the West inherited from Hellas and Rome as well as from the Indian and Persian cultures by way of the Arabs.

The second merit of the Arabs resides in the fact that, using their mathematical approach, they ordered the widely scattered scientific works. They assimilated the existing sciences and gave them a clearer profile. They were not innovators buth conservators who, according to L. Elaut "constructed the showcase of the thinking of Antiquity in an Oriental magnificence' (3). They melted all existing knowledge in a stately clock with a beautiful sound.

To systematize Arabic sciences is very difficult since the representatives of some sciences are also found in others. Thus Avicenna, the coryphe of Arabic science, was as much physician as philosopher, astronomer, meteorologist, mathematician, lawyer, geologist, physicist as a poet and diplomat. Al-Kindi (ca 800-873), the oldest known Arabic philosopher, was also mathematician, physician, astrologist, and musician at the court of caliphe Al-Mamoen. According to the Fihrist al oeloēm (Index of Sciences), written by Mohammed Al-Nadim, a bibliographic work reporting the Muslim civilization up to 987 (4), he wrote 25 opera philosophica (inclusing works on Aristotle and Porphyrius), 11 treaties on mathematics, 8 on the sphere, 8 on musicial theory, 24 on astronomy, 27 on geometry, 21 on the orbit of heavenly bodies, 24 on medicine, among which his famous Aqrabadhin or Book on Composite Drugs, in which, by the ethymology of plant names in various languages, he proved to be an outstanding linguist, 9 works on astrology, 14 on the atmosphere and metereology, 10 on the calculation of distances, 5 on preconception and finally 36 on technology and chemistry.

Most Arabic scholars were encyclopedists *avant la lettre*, universal minds who sometimes wrote on the most various subjects. Their main concern was not to search for the new but to understand the old, to compare what was already found and to order and comment on the various theses.

From the 6th century BC a great explosion of the human mind occurred. The Greek natural philosophers built systems which were to become the basis of all sciences. Thus Thales of Milete claimed that water was the main principle, the archē, from with the whole world took its origin. Anaximenes of Milete thaught this to be air, whereas Herakleitos of Ephese favored the idea that it was fire.

Empedokles and Leukippos proposed as a compromise that there were 4 principles or elements : fire, air, water and earth. Demokritos, a pupil of Leukippos, specified that each element was made up of atoms and that these atoms (*a-tomos*), which cannot be split further) were typical for each of the 4 elements. Each of the 4 atoms possessed its own shape, size and weight, the fire atom being the smallest and lightest of the four.

When Hippocrates found that the data of the macrocosm were also applicable to the microcosm (man), he developed his theory of the 4 body liquids or humors : blood, slime, yellow bile and the hypothetical black bile, on which Aristotle was to apply later the stoïcheia or basic qualities discerned by our tactile sense : cold, humidity, heat and dryness. Thus originated the familiar correlation between elements, body liquids, temperaments, main organs, seasons, astrology and bloodletting.

The Arabs did not change anything in this natural philosophy of the Greek. Although Islam put its own accent on Mohammedan philosophy, the whole Arabic philosophy was a comment on the philosophy of the Greek. This is no sign of ignorance since later on, when the Arabic works were translated into Latin, the West also did not change anything in the natural philosophy of the Greek and the Arabs. Many centuries later revolutionary men will stand up and blow up all these theories : Paracelsus, Vesalius, Copernicus, Harvey, Galilei, Newton, Van Helmont and many more.

The Arabics brought no reformations. These were to occur in the West many centuries later. This does not mean that the Arabs did not add to the existing sciences. There certainly was an evolution and in each discipline of science Arabs did bring substantial complements, mostly comments, be it that essential reforms did not take place.

It should be emphasized that many scholars were brought under the denominator Arab who in fact were no genuine Arabs. Many Jewish and Christian scholars were active in the Mohammedan world and wrote in Arabic. Avicenna, Rhazes, Haly Abbas were Persians, Serapion, Avenzoar, Averroës and Albeithar were Spaniards. The

cement that held there together was Islam. Their interest in science and their justification to study originated from the Coran. The Prophet had proclaimed : "Do teach science which maintains the feat of the Lord. Who communicates knowledge resembles the man who distributes alms. He who possesses knowledge is a subject of veneration and love. Science protects against error and sin, illuminates the path to heaven, assists through the burdens and joices of life. To our friends it is an ornament, to our enemies a shield. To study is as salvatory as to fast. The teaching of science is as precious as prayer".

The unity of thinking of the Arabs was much favoured by the pilgrimages to Mekka, the religious center of the whole Mohammedan world, where yearly a large diversity of people, ranging from Spain to India, mixed on the accasion of hadj, exchanging goods as well as ideas. The caravan trade in spices and aromates was of the greatest importance for pharmacy and expanded the arsenal of drugs as much as later the discovery of America.

Pharmacy itself is the only discipline which owes everything to the Arabs, its existence to start with. Greeks and Romans had so-called pharmacopoloi and pharmacopolae, respectively, but they were mere physician's servants. The physicians, who were not allowed, on the basis of their status, to perform handwork, usually had two servants at their service : one of them, usually a barber expert in handling the razor, was allowed to incise abscesses, to perform amputations and to cauterize the wound with a glowing iron; the other one collected herbs, pressed them out, cooked them etc... under the supervision and responibility of the physician. Both barbers and pharmacopolae, on the sly, exerted their practices independently. It is well known from the literature that every Roman could obtain a poison, a love or an abortion potion from the pharmacopolae. It were the Arabs who first realized that the simultaneous practices of medicine and pharmacy are incompatible and who decided that pharmacy ought to be practiced by independent and trained responsible persons. They founded schools and opened the first pharmacy in Bagdad in 770. Here also the influence of the Prophet Mohammed was decisive : "O servant of God, use medicines, as the Lord did not allow pain without a remedy against it".

Surgery as well obtained its civil rights from the Arabs. No longer had the barber to perform surgical interventions secretly as treaties were drafted at their intention, aiming at codifying their work. It is fair to mention here Aboel qāsim or Albucasis (936-1013) of Cordoba, the ingenious instrument builder who designed more than 200 instruments, in particular for tooth extractions (5). Aboel qāsim is also of importance in obstetrics. He did not invent the forceps but built a tong-like device to deliver the trapped fetal skull *per vias naturales* (6).

In the field of medicine the Arabs produced many clinicians without essentially modifying the current concepts. No fourth grand-master joined Hippocrates, Galen and Dioscorides. A great obstacle to progress was the fact that dissection was prohibited. On religious grounds the study of cadavers was not allowed and the descriptions by Galen had to suffice. This does not mean that the Arabs did not produce great physicians. A series of names are still respectfully cited, such as Rhazes (ca. 865-923), a great Persian scholar with a large experience acquired during daily contacts with patients in the Great Hospital in Bagdad, who wrote more than 200 treaties, half of them devoded to medical subjects; his main work, dedicated to the Persian Prince Mansoer and later translated as Liber Medicinalis Almansoris, was to become a much used handbook in the West. His second important work, Kitab-alhāwī, known in Europe as Liber continens, is a kind of encyclopedia of Greek medicine, enriched with results drawn from his own experience. He was a great clinician, observing that fever is not a disease but a symptom and describing the differences between smallpox and measles. He is still often cited in relation with ophtalmology.

Avicenna (980-1037), Ibn Sina, was born in Persia from Turkish parents, as shown by anthropologists in 1970 by craniological examination. The same also revealed that he died fairly young and that he had a particularly high I.Q. This is confirmed by his autobiography, which reads "When I was 10 I knew the whole Coran (78.000 words !) by heart, at 18 I was familiar with the entire philosophy, logic, physics, mathematics, geometry, arithmetics, astrology, music, theology, Arabic letters and many more study subjects. Never did I meet somebody who was superior to me in

knowledge". A 30 m high tower, consisting of 12 columns, symbols of the 12 sciences in which Avicenna excelled, was erected on the mausoleum built in 1950 on his tomb in Hamadhan. He certainly was the greatest and most universal mind in the whole Arabic period, acquiring the name of Al-sjaich al-ra'is, i.e. Prince of scholars. His Qanoen fi't tibb, litterally Canon of canons, the rules of medicine, i.e. the principles and laws of medicine, was a standard work in the Arabic world and later in the Latin world, also with regard to its volume (more than a million words). It was to become, in the early phase of the art of printing, next to the Bible the most printed book. It was translated into Latin by Gerard of Cremona. Between 1470 and 1500, 16 prints were edited and again 20 between 1500 and 1660. Up to 1650 it was used as a textbook at the universities of Louvain and Montpellier. Sarton wrote about Avicenna : "His triumph was too complete, it discouraged original investigations and sterilized intellectual life" (7).

Ali Ibn al-Abbas or Haly Abbas (930-994) was court-physician of the Prince and director of the Great Hospital of Bagdad. He wrote a book on theoretical and practical medicine, Liber artis medicinae qui dicitur regalis, which was the first Arabic medical book to be translated into Latin.

Ibn Zuhr, Avenzoar Jr. (1091-1162) was an Arabic-Spanish physician, who discovered the food enema and Acarus scabiei.

Averroës (1126-1198), pupil and friend of Avenzoar, was a physician but is better known as a jurist and philosopher. Dante saw him in hell among the famous pagans : "I saw Averroës, who made the big comment" (IV, 143-144), referring to his comment on Aristotle.

Maimonides (1135-1204), spiritual son of Averroës, philosopher and theologist as well as court-psychician to Sultan Saladin, wrote a brilliant critic of Galen. He is very important in the history of dietetics.

Ibn Abi Oesaibiah (1203-1273) was the principal medical historian. He wrote bio-bibliographies of 400 Greek, Syrian, Persian, Indian

and Arabic physicians. The work is most useful, not only for medecine but also for many other sciences, as many physicians were also mathematicians, astronomers, philosophers, physicists or all of these at the same time.

The most famous ophtalmologists were Rhazes, Aboel Kasim, Avicienna and particularly Ali ben Isa, who wrote a vademecum for the ophtalmic surgeon. He praised the use of both fluid and dry collyria and described 130 eye diseases and 143 medicines.

Arrazi is of importance for veterinary medicine. His book Kitāb almansūrī filbaytara (Veterinary medicine in Almansoer's book) deals with diseases of dogs, hunting panthers and lynxes. It is remarkable that, although Muslims were passionate horse lovers, before the 14th century no scientific or medical treatises on horses were available.

The Arabs also paid full credit to agriculture. "Who plants is giving alms heaven is taking into account" said the Prophet. Ibn Al-Awwan (end of the 12th century) wrote an important work on agriculture, Kitāb al-falāha, which contains much information on agriculture and horticulture, breeding, chicken- and bee-culture. The Arabs also paid attention to the culture of medicinal plants, the properties of which are described in herb tables. Albaitar from Malaga (1197-1248), whose name means "son of the veterinary doctor", was the most important pharmacogne. He was inspector of pharmacies and a very obliging man. His Liber Magnae Collectionis, also named Liber simplicium medicamentorum, gives a description of 145 simplicia of mineral origin, 130 of animal origin and 1800 of vegetable origin and was regarded by Sarton as "the greatest from the time of Dioscorides to the middle of the sixteenth century" (8).

A(l)benguefit (997-1068), one of the most important physicians of his time, born in Spain and living in Toledo, wrote a Herbal Book, based on the works of Dioscorides and Galen but much more surveyable and comprehensible for Western man. It was translated by Gerard of Cremona as Liber de medicamentis simplicibus. The same author also wrote an important book on balneotherapy.

In the field of astronomy the Arabs added little new altough many were interested in this science and were given much support by some caliphes. Thus caliph Al Mamoen, who ruled from 813 to 833, founded the school "House of Wisdom" in Bagdad, a precursor of the universities, including a real observatory. He also built an observatory in the Tadmor valley. The Arabic astronomers studied mainly the Almagest (Syntaxis mathematica) of Ptolomaeus to which they brought minor modifications as the latter was a summary of all the astronomics knowledge and insights of the Babylonians and the Greek. The best known Arabic astronomer is Al-Battānī (858-929), who, besides his contribution to trigonometry, defined a number of astronomic entities with the utmost accuracy. He also replaced the cumbersome Greek cord calculations by the sinus function and completed the introduction of the *umbra extensa* and *umbra versa* functions, corresponding to the present tangens and cotangens. His influence would last until Copernicus. Al-Zarqālī or Arzachel (Cordoba 1029 - Toledo ca. 1100) became famous as designer of the so-called Toledan planet tables, which were translated in the 12th century by Gerard of Cremona and later replaced by the astronomical tables or Tabulae Alphonsinae of the learned king Alphonsus al-Sabio of Castile. Al-Zarqālī is also famous for his astrolabium, the saphae Arzachelis.

Astrologers, sand readers, horoscope casters were present in all sultan courts and left many writings, the scientific character of which is debatable.

In the field of philosophy the Islamic philosophers faced the same problem Christian philosophers would be confronted with: their task was to bring pagan wisdom in agreement with the doctrines of their own faith. They were particularly inspired by aristotelism. Among the many Arabic philosophers two names should be emphasized to full advantage : Avicenna and Averroës (Cordoba 1126-Marrakesj ca. 1198).

Averroës was a fervent disciple and admirer of the doctrine of Aristotle, which he wanted to apply litterally, even if some principles were not in agreement with his own Islamic faith. His influence gave rise, in Paris in the middle of the 13th century to a philosophi-

cal trend, called averroïsm, i.e., aristotelism according to Averroës, the breaking-point of which was obligatory unity of material and form and the unity of intelligence of all men. This would lead, according to church authorities, to pantheïsm and provoked serious quarrels not only in Paris but even more so in Italy and England.

According to Avicenna "logic was a means to make the unknown intelligible by making use of the known. Knowledge which is not evaluated on the scale of logic is debatable and therefore no true knowledge". In his magisterial work Sjifa (Book of the cure of the soul), Avicenna provides the connection with natural sciences, which at the end were considered as part of philosophy, thus transforming Sjifa into an encyclopedia which, apart from the 4 philosophical summae (logic, physics, mathematics and metaphysics) included all exact sciences.

The founder of Islamic philosophy is without any doubt the philosopher and physicist Al-Fârâbî (870-950), who commented on a number of works of Aristotle as well as on the Almagest of Ptolomaeus. In one of his writings he compares the philosophy of Aristotle with that of Plato, paying more attention to agreements than to differences. Al-Fârâbî was also a musician. It is remarkable how philosophers-physicians were also theoreticians in the field of music : Razes, Al-Kindi and Avicenna, who defined music theory as "a mathematical science, where it imports whether the melody is in harmony or dysharmony". Ibn Butlan, a Christian physician who lived in Bagdad in the middle of the 11th century also thaught by making use of synoptic tables. In his book Taquim al-sihha, "The Health Tables" he deals with the properties of diet, sleep, purgatives, copulation, bathing, fumigation as well as music. Sarton wrote in his Introduction to the History of Science : "Music can be transferred by contact more easily than nearly any other activity and practical music is sooner or later followed by theoretical music. Thus it can be said that Mohammedan science permeated into Christianism partly on the wings of music".

Trade becomes an honorable profession, as also the Prophet did business. Trade gives birth to industry, paper and sugar refinery plants being the most important Arabic industries. Applied chemistry

is by definition based on chemistry as a science. Before the Arabic period it is more appropriate to talk of alchemy rather than of chemistry. It has been erroneously claimed that the Arabs invented alchemy (*al-chemy*). According to others, chemistry is derived from the Egyptian word "Kimia", meaning black magic. Homer Dubs, professor of Chinese at Oxford University, suggests that alchemy, as well as elixir, notwithstanding the Arabic prefix al or el, is of Chinese origin.

Arabic alchemy is dominated by Ǵeber (Djâbir) or rather by the large number — nearly 3,000 — of writings attributed to him. According to Sarton "The most famous alchemist of Islam Jabir ibn Haiyan seems to have had a good experimental knowledge of a number of chemical facts; he was also an able theoretician, but it is impossible to appreciate his scientific merit with any finality until a comparative study of all the writings ascribed to him and to Geber has been completed" (9). Geber was probably born in Koefa on the Euphrate and died in 815. It is still unclear, however, what is due to Geber and what should be attributed to the Pseudo-Geber. In the 10th century the most important representative of alchemy is Rhazes, who wrote the Book of Mystery of Mysteries. Avicenna also practiced alchemy although he was doubtful about transmutation, i.e., the transformation of "sick" metal into precious metals. The goals of alchemy were not reached neither before or after the Arabs. In this respect the Arabic period was again a conservative one.

In the field of physics most attention should be given to Al-Haitham, better known as Alhazen or Alhazenus (965-1039) who by his work on optics (Kitâb al-manâzir or Opticae Thesaurus) strongly influenced European physics. He dared to criticize Ptolemaeus and Euclid and to oppose personal experiments against their theories on optics. He was not only a physicist but also an stronomer, mathematician and physician.

As to mathematics, the Arabs were not only the keepers of Greek, Babylonian, Indian and Hebrew mathematical and astronomical knowledge, but also made a contribution of their own to the development of this science. Of great importance were the Stoïcheia (Elements) of geometry and arithmetics of the Alexandrian mathema-

tician Euclid, which form the basis of elementary arithmetics. There were at least three translations of Euclid's Stoïcheia in Arabic and a large number of summaries, among which one by Avicenna, published in his Sjifa on mathematics. Another mathematician, by the name of Alhazenus, commented on the difficulties of Euclid's book and refuted some of his theses such as one stating that all heavenly bodies get light from the sun.

The so-called Arabic ciphers are derived from the Indian decimal position system. Zero is called sifr (=empty) in Arabic, hence cipher, extended to the nine other symbols (10). These ciphers delivered us from the intricate manipulations of Roman ciphers. It should be noted that it would last until the 16th century before this simplification would be adopted in the West. As stressed by Sarton "Mountains and seas and even desert plains are smaller obstacles to the diffusion of ideas than the unreasonable obstinacy of man. The main barriers to overcome are not outside, but inside the brain".

Many names could be cited in relation with mathematics : Al-Kindi, Avicenna, Averroës, Maimonides and the Persians Al-Gazzāli (1050-1111) and Omar Khayyam (died ca. 1123) whose works Sarton regards as "one of the high peaks, perhaps the very highest of medieval mathematics"(12). The time of Omar Khayyam usher in the end of the golden century of Muslim science, the end of Muslim monopoly.

Mathematics is a science which fascinated scholars of all times : Babylonians, Egyptians and Greek. Archimedes, Diophantos, Euclid, Pythagoras and so many more are widely known names. Roman hegemony marked a halt. With the Arabs a resurgence of interest took place. Al-Khwārizmi of Bagdad (9th century) wrote the famous book Hisab al-dzjebr wal moeqābālah (The art of solving equations). Al-dzjebr, hence algebra, an Arabic name, not an Arabic invention.

For the Arabs, geography, geology and cartography were most important, given the vastness of their empire and the compulsory pilgrimages to Mecca over land and sea. Soon the works of Ptolemaeus were to be translated from the Syriac and Hebrew into Arabic. Tables with distances, roads and provinces were a must. The

large world map of the great Moroccan Al-Idrīsī (born in Ceuta in 1099, died 1166), with 2500 names of cities, rivers, mountains and regions, is famous (13). Aboe 'l-Hassan al Masoedi of Bagdad (died in Cairo 957) produced a description of the whole empire in 30 volumes. He was initially very successful but his thesis that an evolution occurred from mineral to plant, from plant to animal, and from animal to man led him into disgrace.

There are also many historical works, such as The Chronicle of Nasrids, kings of Granada, by Ibn Al-Khātib (1313-1374), the last of the great Muslim historians; the World History of Assatibī (15th century), The Book of Pearls, divided according to the classical Arabic scheme : the world since creation untill the birth of the Prophet, the life of the Prophet, and the world history of Islam. Al-Biroeni (973-1050) is undoubtedly the most critical among the historians and is regarded as one of the greatest scholars in Mohammedan civilization history. Sarton praises his critical mind, without equal in the Middle Ages. He claimed that the fact that "Allah is omniscient" does not justify ignorance (14). His masterpiece is Tarkh al-Hind, the History of India : its religion, philosophy, literature, chronology, astronomy, laws and astrology before 1030. He also wrote dissertations on astronomy, arithmetics, cosmography, medicine and physics, being an exponent of the universal Arabic mind.

The Arabic period has been described by some as a scientific clique of scholars and interested caliphes. It should be emphasized, however, that they promoted the diffusion of science, as exemplified by a popular encyclopedic work, dealing with all scientific disciplines, published by the Brothers of Basra or Brothers of purity around 950.

This brings to an end this diagonal survey of the Arabic scientific period in world history. The many names cited are the most prominent ones but there were in fact many more. That so many were cited is felt to be justified by the saying of Sarton "Society can poison Socrates, crucify Jesus or behead Lavoisier, it cannot cause them to be born, it cannot dictate their task"(15).

Arabic culture has been the indispensable link in the development

of human civilization. It took the Arabs two to three centuries to absorb and to put in order the sciences of Antiquity. In later centuries they developed their own research but did not achieve spectacular innovations.

In the writing of history one has been tempted to avoid the Arabic period on the excuse that sources are inaccessible and that one has to be satisfied with the Latin translations which were transmitted to us. Some changes did occur in recent years and Arabic manuscripts are more and more studied, although a large number is still awaiting publication. Here too the harvest is great and the workers few.

For us, Westerners, this period represents the transmission of science. We are seized with alarm when we come to think of a world in which the Arabic period would not have had its place. How much poorer would we, people of the Old World, have been ... We are indebted to the Arabs for not behaving, in times of conquest, like destroying barbarians, for keeping and transmitting the old cultures and, according to Sarton, for the following reason : "If there had been some ferocious eugenists among them, they might have suggested some means of breeding out all the Christians because of their hopeless inferiority"(16).

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