dence among the control population by 6 percent on the basis of the incidences at 88 and 200 μc/kg (*6*). The projected incidences for man based upon cats weighing 2.5 kg and having a life expectancy of 15 years range from 54 to 84 percent (Fig. 5). These incidences divided by the 6 percent established for the mouse give quotients of from 9 to 14.

These extrapolations from mice through dogs and cats suggest that strontium-90 is from 7 to 14 times as toxic in man as in mice. The lowest dose that could be shown to have any effect in the mouse was 8.9 μc/kg, which decreased the time interval to the appearance of reticular tissue tumors. This is equivalent to 1 μc retained per kilogram, or to a body burden of 70 μc per 70-kg man. Dividing this dose by the mouse-to-man factor of from 7 to 14 leads to the estimate that the minimum effective dose in man may be a body burden of from 5 to 10 μc of strontium-90.

Danger from Present Fallout Contamination

Perhaps it is merely coincidence that the 6 to 15 μc estimated for the minimum effective dose in man based on the radium method of extrapolation and the 5 to 10 μc estimated from the mouse, dog, and cat data are so similar. In spite of their very tentative nature, these calculations are presented here to illustrate how experimental animal data may be used. In the next few years there should be additional information on radium toxicity in man, since several hundred persons with a possible radium burden are currently under investigation. Consequently, the level of minimum effect will be known with greater exactness. Also, the dog experiments now in progress in several laboratories should provide information over a range of doses so that extrapolations from mouse through dog to man will be possible at more than one level.

The lowest prediction of a harmful dose to man that can be made from the present data attaches significance to the statistically insignificant differences in average survival time at the lowest doses in the mouse experiment. The line passing through these points intersects the control value at an injected dose of 0.4 μc/kg. This dose is equivalent to a retained dose in mice at 600 days of 0.044 μc/kg, or to a body burden in a 70-kg man of 3.08 μc. If the life-shortening factor in going from mouse to man is as great as the estimated tumor-inducing factor—an unlikely assumption for several reasons—a threshold value for man would lie between 0.22 and 0.44 μc of strontium-90. A more likely value is one that lies between 5 and 15 μc, as discussed above. In any case, the present contamination with strontium-90 from fallout is so very much lower than any of these levels that it is extremely unlikely to induce even one bone tumor or one case of leukemia.

References and Notes

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2. This work was performed under the auspices of the U.S. Atomic Energy Commission. The views expressed are my own and do not necessarily reflect those of the Biological and Medical Research Division of Argonne National Laboratory.
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George Sarton, Historian of Science and New Humanist

"Am flying to-morrow morning to Montreal. Vale *G S*" wrote George Sarton on 21 March 1956. He was scheduled to give a lecture in Montreal on 22 March but became ill on the way to the airport and died that day in his Cambridge, Massachusetts, home. Thus, while he was still active and mentally young, the life on earth of this great historian of science came to an end—a life which had begun 72 years earlier, on 31 August 1884 in Ghent, and which had bridged two continents and more, both physically and spiritually.

Death has not ended Sarton's influence. He had continually emphasized the idea that the history of science is not the sum of the histories of the separate sciences but rather their integration, that it is itself a specialty built on a thorough understanding of the methods of science and of history, and that it requires more than the leisure hours of capable scientists or of scholarly historians. He frequently referred to it as a new discipline, and he established it as such in the United States. It bears his mark. Thanks to his persistent pleas, expressed in letters, talks, and published works, and the interest he stimulated, there are now chairs of the history of science and courses or series of courses in that subject in many of our leading universities. Moreover, scholars the world over consult his numerous publications, of which *Isis* and the *Introduction to the History of Science* are the best known (*1*).

George Sarton's early education was obtained first at the Athénée in Ghent and then at that in Chimay. He attended the University of Ghent in the department of philosophy, studied by himself for a year, and returned to the university to study the natural sciences, chemistry and crystallography, and mathematics, in which he received a doctorate in 1911 (*2*).

In 1908 he wrote a chemical memoir (*3*) which gained for him a gold medal offered by the four Belgian universities and a silver laurel branch from the city of Ghent. In these early years he also wrote romantic books and poems (*4*), an exercise which contributed to the development of his eminently readable prose.

Influenced by the writings of Comte, Tannery, Duhem, Poincaré, and others, while he studied pure science, Sarton grew increasingly more interested in the history and philosophy of science. He came to believe that the basis of all

scientific philosophy was the history of science, and by the close of 1912 had determined to devote his life to establishing it as an independent discipline on the same plane with the other scientific disciplines. On it would be focused the history of mankind, because the only human activities which Sarton considered cumulative and progressive are the scientific ones.

In 1911 he had married an English artist. The young couple bought a home at Wondelgem, near Ghent, and there, in 1912, a daughter was born. Sarton's wife was the ideal helpmate. She quietly bore the brunt of their economic difficulties and never complained. Back of George Sarton's dedication to the history of science was Eleanor Mabel Elwes Sarton's dedication to her husband.

In Wondelgem Sarton accumulated notes on the history of science and launched *Isis,* a journal devoted to that subject. The first issue appeared in March 1913. But World War I destroyed the even tenor of the days. After packing the notes in a small metal trunk and burying them in the garden late at night, the Sarton family fled before war's horrors—across the border into Holland and on to England. In 1915 they came to the United States.

The first years in the New World were hard ones. It would not have been difficult to earn a living as a teacher of mathematics or of science or of French. Yet, although he was continually short of funds, it never occurred to Sarton or to his wife that he should earn money otherwise than by teaching the history of science. It was for that purpose that he had come.

A group of Harvard friends collected a small sum of money which they gave to the university to enable Sarton to spend two years in research and teaching. In addition, he delivered the Lowell lectures in Boston. In August 1918 he became research associate of the Carnegie Institution of Washington and chose to live in Cambridge, Massachusetts, with the great Widener Library for use as though it were his own. His offer to give a course in the history of science at Harvard in exchange for a separate room in the library was accepted in 1920, and in 1940 he was named professor.

Volume 2 of *Isis,* begun in June 1914, was completed in September 1919. A trip to Belgium to make the necessary arrangements with the printers was the occasion for the joyful recovery of his buried notes and of a large portion of his library.

Sarton described *Isis* as one result of a philosophical reaction to the analytical trends of 19th-century science (*5*). From its very inception *Isis* was intended as the organ of the new discipline. Its name was chosen because it evoked "the period of human civilization which is perhaps the most impressive of all,—its beginning" (*6*) and because the title of a review should be as short as possible. It was to be a synthetic, critical, international, and, in a sense, dogmatic review of the sciences from the historical, philosophical point of view, studying their evolution and logical sequence and less concerned with the science of the present than with that of the past (*7*). Beyond this, *Isis* was to have a mission—to underline the lessons of tolerance and wisdom which history presents. It was to denounce the imperialistic tendencies which Sarton found some scholars trying to impress on the science of their country or their race (*8*). It was to be more a philosophical and sociological review than a collection of historical erudition. One or more articles by Sarton in every issue set the tone.

Among the most important features of *Isis* are the "critical bibliographies," of which the last under Sarton's direction appeared in volume 44 (1953). There he wrote, "The seventy-nine bibliographies edited by me contain over 100,000 notes, many of which are short reviews. I must have written an average of seven such notes per day for 15,000 consecutive days almost without respite." A scholar who starts a topic in some aspect of the history of science without consulting the critical bibliographies is treading on thin ice!

On 12 January 1924 the History of Science Society was founded, primarily to guarantee and promote the publication of *Isis.* But Sarton remained the editor and, until 1941, was financially responsible for it. In 1953, I. Bernard Cohen, who had been managing editor for a number of years, became editor, and Sarton at last felt free to devote himself to his planned *A History of Science,* which was to be the reworking of his course lectures. Only the first volume, *Ancient Science in the Golden Age of Greece* (1952), appeared in his lifetime.

In 1936, to relieve *Isis* of the load of longer papers too short to appear separately but deserving publication, another periodical, named *Osiris,* was founded. It was never supported by the History of Science Society, but solely by Sarton.

Sarton had a capacity for friendship and a humility about his own place in the world. Sometimes this humility took on the air of preaching, but if this manner is accepted in the sense in which it was intended, it only enhances Sarton's stature. His attitude of preaching is partly the mark of a teacher but also reflects his deep disturbance over changes occurring in the world. Sometimes he was bitter about the attitudes adopted by people; sometimes he spoke against wealth, stressing its unimportance. In 1938 he wrote, "The German atrocities are terrible; they make me ashamed of being a man!" (*9*). But in 1944 he seemed happy when he wrote "My 60th birthday was admirably celebrated—first with a magnificent Festschrift . . .,—second (even better) with the liberation of my native country and the end of a terrible nightmare" (*10*). On Christmas 1951 he added, "What we need above all is Peace" (*11*).

He had the ability to boil down a statement, to restate material in simpler terms, making a comparison with something familiar to his audience, without ever being too glib or too flippant. His method of drawing analogies is characteristic of his authorship. He had no tolerance for inaccuracies. He was tireless in his own application and expected others to exercise the same patience and critical attitude in their work.

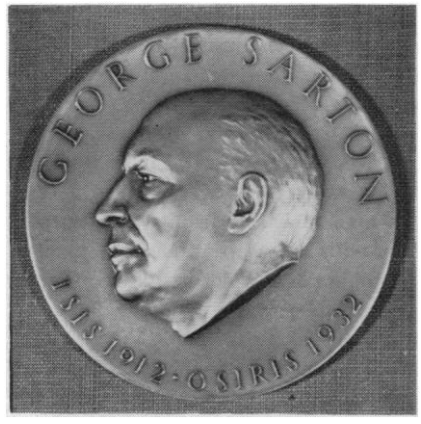
Although Sarton was fully aware that we are living in a changed world, one that has changed more in the 20th century than in all the preceding ages, he had reverence for the old because all that he found best in the world is very old—the things which add meaning to our life, such as charity, the love of truth, religion, art, all the graces of life. He stressed the value of quiet study and meditation, for to be intellectually sound one must leave space in life for these. As a young man he was a frequent concertgoer, and later he accumulated a delightful library of recorded music. All his life he saw beauty about him, and his travels gave him the opportunity to visit the beauty spots of the world and drink them in.

For George Sarton science was "the totality of positive knowledge" (*12,* p. 118). He expressed himself as follows: "*Definition.* Science is systematized positive knowledge, or what has been taken as such at different ages and in different places. *Theorem.* The acquisition and systematization of positive knowledge are the only human activities which are truly cumulative and progressive. *Corollary.* The history of science is the only

history which can illustrate the progress of mankind. In fact, progress has no definite and unquestionable meaning in other fields than the field of science" (*13*). This may not be everyone's definition of science or everyone's view of the history of science, but it was the foundation on which Sarton built. Whereas he considered scientific method the most elaborate discipline of thought ever conceived, he did not consider it all-sufficient. It is inapplicable to art, religion, and morality and may always remain so. Furthermore, he dreaded its possible misapplications.

Sarton's history of science, an all-embracing picture of the impact of scientific progress on mankind and the effect on science of man's environment, was a means, not an end. The end was the philosophy of science. He felt that the history of science should make us less conceited about our share in total human evolution. It, alone, can give us a clear and complete consciousness of the advancements of modern science and will permit us to appreciate its real significance. Since the past interests only because of the future, and acquires all its real significance only in the light of the present (*14*), the historian of science must be alert to the scientific problems of today. As Sarton put it: "The chief requisite for the making of a good chicken pie is chicken; nay, no amount of culinary legerdemain can make up for the lack of chicken. In the same way, the chief requisite for the history of science is intimate scientific knowledge; no amount of philosophic legerdemain can make up for its absence" (*15*).

The history of ancient and medieval science is as useful and necessary as that of modern science, but not all historians of science need study the whole. A study of any special branch gains in technical richness what it loses in regard to the larger subject. Subdivisions lead to a better understanding of periods which require special techniques (*16*). The historian of science must be grounded in historical facts as well as in scientific ones and be familiar with the methods by which these two kinds of facts are obtained and interpreted (*17*). Sarton believed in joining the biographical side of the history of science with the history of ideas (*18*, p. 33). A man must be examined entire. Nor can one stop with the achievements of the outstanding men because the final results in science are independent of their discoverers (*19*, p. 99) and because, in the gradual preparation of any discovery, a number of smaller ones usually figured (*18*, pp. 21–22).



The George Sarton medal. Sarton was the first recipient of the medal. The award was made on 29 December 1955 at a luncheon at the Mayflower Hotel, Washington, D.C., during the annual meetings of the History of Science Society, held in conjunction with the American Historical Association. The medal was made possible by a generous gift from Chas Pfizer and Company, Inc.

After delivering his Lowell lectures, devoted to Leonardo da Vinci, Sarton felt that he must make a thorough survey of the ancient and medieval science leading to Leonardo. It was then that he formally planned his *Introduction* (*20, 21*). Thanks to the recovery of his notes and library, he was able to begin the writing in January 1921. Each chapter contains the summary of a period, followed by a detailed analysis of the work of the individuals in that period, complete with invaluable bibliographical information. The fundamental purpose of the *Introduction* was "to establish the history of science as an independent and organized discipline," to define this study, and to show the importance thereof, not only for the philosophy of science but for any positive philosophy (*22*). It and *Isis* did just that. With the 14th century, five centuries short of his goal and a half-century short of Leonardo, Sarton stopped his *Introduction* in order to devote his remaining years to writing the shorter books which had been slowly maturing in his mind (**21**, vol. 3, p. 5).

The emphasis on the human side of science which is apparent throughout the Sarton writings is the result of a continuous effort to humanize science, to integrate it with the other elements of our culture, to inject into it a little of the historical spirit, of reverence for the past. The Old Humanists were concerned only with the classical arts and letters and their derivatives in Europe and could hardly conceive that scientific efforts had any other value than their enormous utilitarian and financial one. The New Humanism was, so to speak, built around science. The history of science was the bridge between the old humanist and the scientist, and the construction of that bridge was deemed by Sarton to be our main cultural need (*18*, pp. 57–58).

Sarton's humanist had to explore and defend the ideals of Eastern peoples as well as those of the West and to show that the writings of classical antiquity and of the Old Testament are not the only writings deserving consideration; that their tradition would not have survived or would have been delayed without Arabic intervention.

Convinced that Oriental studies were necessary to develop the whole man, to picture the whole civilization, to integrate the past and the present of science with the arts and religions, Sarton spent six months in the East studying Arabic, and countless hours, in the next 20 years, at home perfecting his knowledge of this language and the culture to which it was a gateway. He corresponded in Arabic with numerous Eastern scholars. He was not going off on a tangent. He was digging deep. He aimed to show the immense contribution of Eastern people to our civilization. The history of science begins in the Middle East (*23*). Later, the medieval Arabic-speaking peoples added to the Greek heritage before handing it over to their Latin successors. The creation, or slow incubation, of the experimental spirit, of which we hear so much in the 20th century, was the main and least obvious achievement of the Middle Ages, first primarily due to the Muslims, then to the Christians (*19*, pp. 99–100). From the middle of the 8th to the end of the 11th century, Arabic-speaking peoples, including some Jews and Christians, marched at the head of mankind, and their language became the international language of science.

The study of the history of science presupposes teachers of that discipline and its inclusion in the curriculum. Sarton outlined in detail both general and special courses in the history of science and the qualifications of the teachers. They must have a firsthand knowledge of science. He explained the value of experiments performed in classes. Harvard's natural science courses are now given in a lecture room equipped for showing experiments illustrating the history of science.

Sarton stressed the study of languages. This must begin with a thorough understanding of one's own. It is generally agreed that a practical knowledge of Greek and Latin is prerequisite to the original study of ancient science. He thought it equally true, although less obvious, that some knowledge of Arabic and even of Hebrew is necessary to a complete understanding of medieval science (*24*). He saw no need for the creation of an artificial language or for the adoption of an international one. *Isis* recognized six languages as international: English, French, German, Italian, Latin and Spanish (*25*). Scholars who wish to be read should write in one of these (*26*). Sarton saw no reason for the United States libraries to subscribe to journals written in what he called the "small" languages, but thought one of the libraries should try to collect all the material in a given tongue, another should concentrate on a different one.

Charles Singer calls Sarton "one of the great teachers of our age" (*27*). This is because he was a superb organizer of knowledge and an integrator. In addition he had a powerful personality. Students thronged his lecture classes. But he was not quite so successful with individual graduate students, partly because he was frequently bitter about the state of the world and held the fate of individuals to be of little consequence in terms of the whole of mankind. This seems inevitable for one whose life was so altered by political events. He was impatient to get on with what he considered the more important tasks. I, myself, found him unstinting of his time, his energy, his advice, and his encouragement. In 1929, when I asked to study under him, he wrote, "I am afraid we shall not be able to get around Radcliffe's regulations" (*28*). But he wrote to the secretary of that college, "It is true that no A.M. degree has ever been granted by Radcliffe in that subject [history of science], but I cannot consider that as a preemptory argument. I am sure you will be at one with me in hoping that Radcliffe will do many things in the future that it has never done before" (*29*). His plea was successful.

He never considered courses satisfactory advanced training in the field. Following them "is but a poor method & the sooner you can wean yourself from it, the better for you.—The only way to train yourself as a historian is to carry on historical investigations under expert guidance" (*30*). This expert guidance is what he provided to a fortunate few in his office, with the whole of Widener Library as a laboratory. And there one learned that even working with a gifted teacher is not sufficient; it is the actual doing which matters. Run down every reference, read every footnote, seek the original version, and do it yourself. Check everything, document everything, and provide an index.

A man such as Sarton was bound to ripen with the years. When he changed his opinion he did not hesitate to say so. For example, in the second volume of *A History of Science,* (*31*) he altered the dates he had previously assigned to some men of antiquity and to the Dead Sea scrolls. Years of research changed his estimate of the Renaissance. In 1929 he said, "If one excepts the extraordinary climax which occurred toward the end of that period, in 1543, the Renaissance was less a genuine revival than a halfway rest between two revivals" (*32*). The first of these, beginning in the second half of the 11th century and culminating in the 13th, was stimulated by the introduction of Greco-Arabic knowledge into Western Europe; the second began with the development of the experimental method in the 17th century. The day before his death Sarton wrote, "My statement of 1929 has been somewhat toned down in my Appreciation (Philadelphia 1955) and will be further corrected in Six Wings. . . ." In the former he emphasized what he considered the role of the Renaissance in "the slow metamorphosis of ancient and medieval traditions into modern ones" (*33,* p. 132). He announced his interpretation of the period as both a revival of antiquity and a discovery of something new, and he carefully examined "Renaissance awareness and knowledge of the old scientific classics as revealed by the incunabula and the sixteenth-century books" (*33,* p. 6). He described the work of hundreds of individuals who, between 1450 and 1600, revived the old, or pointed out new directions in science. In *Six Wings: Men of Science in the Renaissance* (*34*), rather than focusing on the retention, reintroduction, or reinterpretation of past science, he emphasized the men of science of the period. In this way he showed Renaissance science as a part of Renaissance life. In his last work (*31*) he made allusion to "Renaissance minds," spoke of a certain book as "a monument of the French language of the Renaissance," and made a distinction between what scholars of the Renaissance could, and what we no longer can, appreciate. In other words, his change of view was incorporated into his general thinking. In the latter part of his life he was not as dogmatic as in his youth, when he had staunchly supported the belief that the history of science was the only proper approach to the past. He came to realize that the history of religions, the history of arts and crafts, the history of laws and institutions is each an avenue of approach (*35*).

By his lectures, books, and articles, as well as through his students and his colleagues throughout the world, George Sarton spread his interpretation of the history of science. The path he pointed out will not soon be forgotten.

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