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(*b*. Baghdad [?], 908; *d*. Baghdad, 946),

mathematics, astronomy. For the original article on Ibrāhīm see *DSB*, vol 7.

Ibrāhīm Ibn Sinān Ibn Thābit Ibn Qurra composed a survey of the whole field of geometrical analysis, contributed an original quadrature of the parabola, and gave the first general treatment of horizontal sundials. He was a member of a family that had produced distinguished scientists since the time of his grandfather, Thābit ibn Qurra, and Muhammad al-Nadim wrote that "During his time no one appeared who was more brilliant than he was" (alNadim 1970, vol. ii, 649). As he made clear in the preface to his work on the parabola, he saw it as his role to preserve and add to his family's reputation, and in this he was eminently successful.

Early Life . As the son of the personal physician to the Caliph al-Muqtadir, Ibrāhīm would have been raised in a well-to-do household and would have had the best education possible. Clearly precocious, he wrote in his autobiography that he began his mathematical researches at the age of fifteen and wrote a number of treatises by the time he was eighteen.

Both Arabic biographical sources and Ibrāhīm's autobiography indicate that at some point his family suffered persecution, probably when Ibrāhīm was in his mid-twenties, at the hand of the Caliph al-Qahir, and were forced to take refuge in Khorasan, a large region, not closely defined, east of Iraq. Ibrāhīm's father, Sinān, converted from the Sabian sect to Islam under pressure from al-Qáhir, although it appears that his children may have remained Sabian. Ibrāhīm married and had a son named Ishaq.

Dials . Ibrāhīm describes in his autobiography, composed sometime between the age of twenty-five and his death at the age of thirty-eight, the works he had written. Those he characterized as astronomical are *On Shadow Instruments*; *On the Motions of the Sun*; and *On Ptolemy's Approximate Methods for the Anomalies of Mars, Saturn, and Jupiter*. In the group he calls mathematical are *On Tangent Circles; On Analysis and Synthesis; Selected Problems*[in Geometry]; *Measurement of the Parabola*; and *Drawing the Three*[Conic] *Sections*.

Of *On Shadow Instruments*, there survive only Book 1 and a fragment of the beginning of Book 2 of his revision of an original that had been written in his teens. (He wrote later that he detested the prolixity of his teenage work.) *Of Shadow Instruments* was the first treatise on a general method for the design of plane sun dials, whatever the orientation of the dial's face. He based it on the idea that a plane dial with arbitrary orientation may be considered a horizontal dial for an appropriate place on the earth's surface.

The surviving fragment from Book 2 deals with the shape of hour lines on sundials, lines described by the tip of the gnomon's shadow at a fixed time of day over the course of a year. Ibrāhīm's grandfather, Thābit, had explicitly stated, but not proved, that some hour lines were not straight. Ibrāhīm proved this, but only part of the proof survives in the existing fragment of Book 2. (Paul Luckey's restoration of the proof implied that Ibrāhīm's proof only worked for certain hour lines, and this has been confirmed by a remark of Ibn al-Haytham in his *Treatise on the Hour Lines*.) Finally, although the surviving sections deal with plane dials, we learn from the autobiography that missing parts of Book 2 as well as the whole of Book 3 dealt with nonplanar dials—concave or convex spherical dials as well as concave conic dials.

In his autobiography, Ibrāhīm stated that after writing about the armillary sphere for his colleagues, he wrote a work on it "in different terms" for a craftsman who was making one for him. This adds further evidence to what is already known from Abū al-Wafā al-Būzjan̄ in his *Geometrical Constructions for Artisans* about communications between mathematicians and craftsmen in medieval Islam.

Geometry . The first three of Ibrāhīm's mathematical works are all variations on a single theme: the geometrical method of analysis and synthesis. His complaint about what he called the "abbreviated" argument of his contemporaries in this regard is well-known, and his autobiography makes it plain that he wrote these three works to provide examples to students of three versions of this ancient method. The student would begin by progressing in stages through the (mostly) easy problems in *On Tangent Circles* (now lost), which contained a careful version of current practice. The student would, next, find in his *On Analysis and Synthesis* a careful discussion of the full method as found in Apollonius's *Cutting Lines in Ratios*. (Here the student would also find a classification of problems according to the number of solutions and the need for further conditions.) Finally, in *Selected Problems* the student would find (mostly analyses only, omitting the syntheses, of) forty-one geometrical problems to illustrate the current abbreviated practice.

In *On Drawing the Three Sections*, Ibrāhīm wrote that there was no instrument by which one could draw the conic sections. Consequently, he said, he wrote this treatise on how to find as many points as one wishes on a given section. (Abū al-Wafā' al-Būzjanī, in his treatment of burning mirrors in his *Geometrical Constructions*, reproduced Ibrāhīm's method for drawing a parabola.) However, Abū Sahl al-Qūhī wrote a late-tenth-century treatise, *On the Complete Compass*, which describes just the kind of instrument that Ibrāhīm said did not exist in his time. Thus, Ibrāhīm's remark provides a fairly narrow window, around the mid-tenth century, for the introduction of the complete compass in medieval Islam.

In the preface to his *Measurement of the Parabola*, Ibrāhīm referred to two earlier versions, both of which were lost. He also called special attention to the fact that he used only three theorems and was able to give a direct proof rather than—as in earlier treatments—a proof by contradiction.

Additionally, Ibrāhīm wrote a commentary on the *Conics* of Apollonius (lost), a *Description of the Notions/Theorems Used in Astronomy and Geometry*, and a "Letter of Ibrāhīm b. Sinān to Abu Yusuf al-Hasan b. Isra il on the Astrolabe." (This last work is, however, disputed.) Finally, he stated in his autobiography that he gathered his miscellaneous papers into a volume of about three hundred pages, of which he had the sole copy.

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J. L. Berggren