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## Later Islamic Science

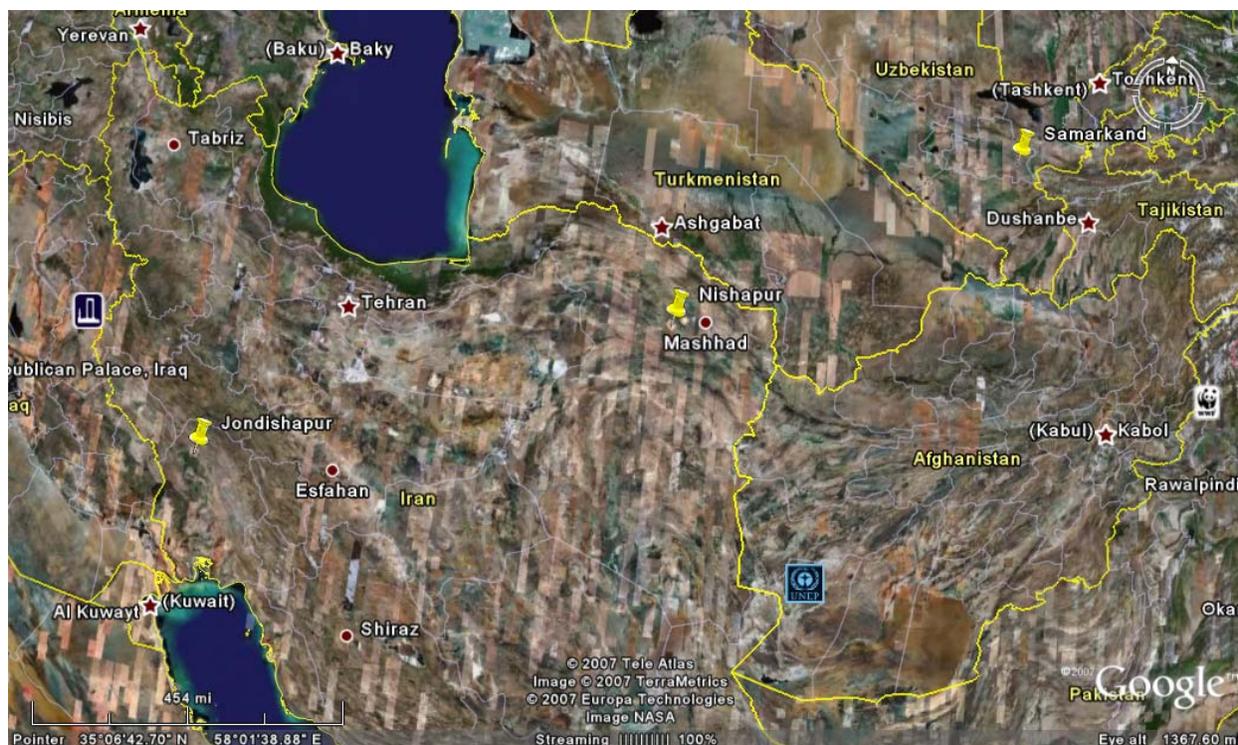
*This is a First Draft ...*

### The Islamic World

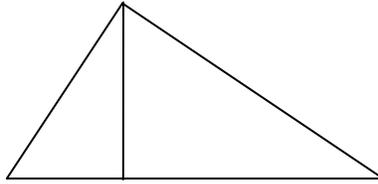
Our interest here is in the scientific developments that took place in the Islamic world. We will look at a few of the most famous of the Islamic scientists, and only mention very briefly the political context in each case: the spread of Islam over much of the known world, and the subsequent political changes, were very complex. For example, after Baghdad, Cordoba in Spain became the preeminent center for science, but Spain was under the Umayyads, not the Abbasid caliph. Furthermore, some of the greatest Islamic scientists were Persian, and political developments there included a Shia revival in the tenth century, the Sunni Abbasids thereby losing their eastern empire, followed by a Turkish (Sunni) takeover—the Turks having been brought in as a palace guard.

### Omar Khayyam

[Omar Khayyam](#) was born in Nishapur, in present-day northeastern Iran (see map) in 1048, a time when most of Persia (Iran) was under (Seljuk) Turkish rule. Initially, he did not find it a good environment for scholarly work, and in 1070 moved to Samarkand (see map). He did manage to write a famous book on Algebra.



His main contribution to that subject is a serious attack on cubic equations, such as finding  $x$  given that  $2x^3 - 2x^2 + 2x - 1 = 0$ . This particular problem has a geometric origin:



Given that for the right-angled triangle shown, the sum of the height and the shortest side is equal to the hypotenuse, find the ratio of the length of the shortest side to that of the other side.

Later Malik Shah, the third Seljuk sultan, and his Persian vizier al-Mulk, invited Khayyam to head up his observatory in Esfahan (his capital city, directly south of Teheran, see map). Khayyam measured the length of the year, getting 365.242198...days. This is correct to within one second: the error is in that last digit only!

Unfortunately for Khayyam, his friend the vizier was murdered by a terrorist group, the Assassins, who specifically targeted important political figures, on the road to Baghdad in 1092, and Malik-Shah died soon after that. His widow discontinued the observatory funding, but later his son Sanjar founded a center in Turkmenistan where Khayyam continued to do mathematics.

Omak Khayyam is also famous for his writings, such as the [Rubaiyat](#). However, these have a distinctly irreligious flavor, and he had to tread carefully to minimize trouble with the Muslim religious authorities.

*Note:* many of the above facts are from the [St Andrew's website](#).

## Al-Tusi

Nasir al-Din al-Tusi was born in Tus, in northwest Iran (near Nishapur) in 1201.



He studies as a child at a mainly Shia religious school in Tus, followed by secondary education in Nishapur. However, around 1220, the Mongols invaded the area, causing much destruction. Al-Tusi found refuge with the Assassins in their mountain fortress at Alamut :



It isn't clear whether or not al-Tusi was actually a prisoner, but it is clear that he did some important scholarly work in this relatively quiet environment, writing on astronomy, mathematics, philosophy and ethics.

Nevertheless, when the Mongols, led by Ghengis Khan's grandson Hulagu (pictured below), took Alamut in 1256, al-Tusi switched sides, and the Mongols appointed him their scientific advisor.



Al-Tusi was with the Mongols when they attacked Baghdad in 1258. Apparently if the Caliph (the last of the Abbasids) had surrendered, little damage would have been done, but instead he refused, told Hulagu that God would avenge, but the Caliph did little to prepare defenses. The Mongols attacked (after a brief siege organized by a Chinese general), wrecking the Grand Library and throwing all the books in the river, burning down mosques and other buildings that were the work of generations, slaughtering the citizenry with abandon, breaking up the canal system that had kept the area fertile, and leaving too few survivors to repair the canals. This was the end of Baghdad as a cultural center for many centuries. The Mongols went on to fight with Egypt, but this time they were turned back in what is now the West Bank by superior Egyptian

cavalry, in 1260: the same year that the Hulagu's brother Kublai Khan became Emperor of China, with his capital at Beijing. The Mongols in the Far East reached their limit when they attempted to invade Japan in the 1270's and 80's: their fleet was destroyed by a massive typhoon, one the Japanese termed *kamikaze*, meaning divine wind.

After Hulagu destroyed Baghdad, he constructed, at al-Tusi's suggestion, a magnificent observatory at Maragheh in northwest Iran (see map above) with al-Tusi in charge. The observatory opened in 1262, and al-Tusi brought together many scholars and scientists. The observatory became, essentially, a university: al-Tusi had several pupils who made important contributions, and in fact his role was central in reviving Islamic science.

[Al-Tusi](#) himself developed plane and spherical trigonometry and wrote the first complete book on the subject. He also made the first really significant advance on Ptolemy's *Almagest*. Although Ptolemy's work described the planetary motions well, it contained some aesthetically unappealing features—it had strayed far from Plato's long ago suggestion that all should be described in terms of combinations of circular motions. In particular, accounting for the lack of coplanarity of planetary orbits required what amounted to an up-and-down linear component in planetary motion. Perhaps al-Tusi's most famous achievement was to demonstrate how such motion could be generated by a combination of two circular motions, see the animation at [Tusi couple!](#)

Here's his original explanation, from a [Vatican exhibit](#):

