On the 'Origins' of Science

The following extracts are taken from the third annual 'British Academy Lecture', delivered by **Professor Sir Geoffrey Lloyd FBA** *on 18 November 1999 at the British Academy. He considers below three case studies taken from the ancient world illustrating the different conditions under which scientific investigations were carried out.*

In 1998 the Academy launched a major new lecture series, the annual keynote British Academy Lecture, to mark the move to Carlton House Terrace. Lectures are intended to address a wider audience than the purely scholarly and to advance public understanding of the subjects the Academy exists to promote.

Babylonian records for the study of the heavens are enormously rich, stretching back to the second millennium BCE. We find many predictions in the early omen texts, taking the form of conditionals: if so and so (the sign), then so and so (the outcome).

But then from some time around the mid-seventh century there was a shift – many of the phenomena that had figured in the protases of the omen texts, the if- clauses, came to be rigorously classified and precisely predictable, that is not just in terms of an ideal pattern but including the deviations from such.

The possibilities of determining, in advance, when a planet would become visible after a period of invisibility, or when an eclipse of the moon or the sun would occur, offered an altogether new scope for prognostication. Admittedly much remained beyond that scope. The scribes squabbled not just about what could be predicted, but about what had in fact been observed. One writes: '[He who] wrote to the king, my lord, "the planet Venus is visible" ... is a vile man, an ignoramus, a cheat! ... Venus is [not] yet visible'. But a clear difference opened up between a style of prediction that focused on the good or bad fortune that would result *if* a celestial phenomenon occurred, on the one hand, and, on the other, one that predicted such celestial phenomena themselves.

The ability to predict phenomena did not mean that they were no longer considered ominous. On the contrary, eclipses, in particular, were still considered inauspicious – not that they were thought to be causes of evil events to come, only signs of them. At the stage when the scribes were able to predict one (or its possibility), they could and did warn the ruler, who set about diverting disaster from himself by the ritual of the substitute king (*namburbû*). Some wretch who was considered dispensable was put on the throne, so that whatever mischance befell would happen to him, not to the real king, who was addressed meanwhile as 'the farmer'.

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The Chinese distinguished between *li fa* and *tian wen*. The first is conventionally translated 'calendar studies', but it included other computational work as well, for example in connection with eclipses. The latter is the study of the 'patterns in the heavens', essentially qualitative in character, but including both cosmography and the interpretations of celestial phenomena thought to be ominous.

These studies were a matter of *state* importance, indeed of personal concern for the emperor. He was considered responsible not just for the welfare of the state, but for preserving harmony between heaven and earth. The so-called 'monthly ordinances', *yueling*, set out precisely what the ruler and the whole court had to do to ensure this harmony, the music to be played, the kind of food to be eaten, down to the colour of the dresses the court ladies should wear. The *yueling* texts end the account of each month with dire warnings as to what will happen – natural disasters and political ones – if the ritual is not followed to the last detail.

The heavens needed to be scrutinised for *any* sign that might be thought to contain a message for the ruler, his ministers, or any aspect of state policy. That involved, potentially, a vast programme that was carried out in an Astronomical Bureau designated for the purpose.

The Bureau lasted for some 2000 years, down to the last imperial dynasty, the Qing. Their more purely astronomical performance was mixed. Among the more notable successes were firstly calendar regulation, and determining more and more accurate lunar and solar eclipse cycles; and secondly, discriminating between what was strictly predictable and what was not. Among the latter, Chinese records of novae, supernovae and sunspots are the most complete we have down to the seventeenth century. If mistakes were made – when an eclipse that had been predicted did not occur, for example – they were sometimes excused by the argument that the special virtue of the emperor had averted the phenomenon. The incorrectness of the prediction was then not chalked up *against* the astronomers, but *for* the emperor.

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Different conditions prevailed in Greece, where students of the heavens did not usually work for kings, and could not count on regular support from state institutions. Although I am not one, usually, to risk generalizations, let me propose the following observations with regard to Greek astronomy in the fourth century BCE. First, reputations depended on impressing not a ruler, but your contemporaries, not just fellow specialists but even the general public. Secondly, teaching was one of the main ways of earning a living, and that is connected, thirdly, with the institution of the public lecture or debate, the main vehicle both for building up a reputation and for attracting the necessary fee-paying pupils (what may be not too anachronistically termed the lecture circuit).

Correspondingly, there was a premium on originality: you were not going to impress a lecture audience very much by telling them what they knew already. One tactic often used to get your own, new, ideas across was the demolition of everyone else's: that favoured the highly critical scrutiny of foundations. For your own part, you had to try to make your own position immune to such criticism: in this context, a rigorous notion of demonstration was developed and used in fourth-century Greek mathematics and related inquiries.

The key fourth-century astronomer was Eudoxus. The main feature that marked his work out from that of, say, the Babylonians was that he attempted geometrical models from which the movements of the planets, sun and moon could be derived and so explained. It is pretty clear that he fell some way short of giving a fully quantitative would-be demonstrative model – that was not to be achieved until Ptolemy in the second century CE – but that was almost certainly his aim.

The contrast with what we know of Babylonian astronomy is a double one. From the seventh century, the Babylonians were in a position to make some impressive predictions of certain planetary phases on the basis of observed periodicities, but they had no interest whatever in geometrical models, setting out the configurations of the planets and showing how their apparent irregularities could be seen as the product of a combination of regular motions. Much later than the Babylonians, in the fourth century, Eudoxus made at least a start at geometrization.

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The three case studies I have sketched out suggest first that science developed very differently in Babylonia, China, and Greece, both in the nature of the investigations undertaken, and in terms of the social and intellectual institutions within which the investigators worked. And in some cases there appear to be connections (between the work and the institutions), not that I am proposing a determinist thesis, that the institutions determined the outcome, as if every individual was similarly affected by them. That clearly would be extravagant.

But then the second point that emerges is the *tension* between different factors that may all be thought to have had some part to play, a tension that serves to underline that there was no one factor that *just* favoured development. The advantages and disadvantages of each system are, in a striking way, the mirror images of one another. On the one hand, state support, the creation of institutions such as the Chinese Astronomical Bureau, carried enormous advantages, offering stable employment for a very considerable staff of specially trained investigators. Yet such institutions could also inhibit innovation – state interests determined the agenda – and they ran the risk of ossification.

On the other hand, without such institutions individuals were far more free to choose their own research programme – and yet have no secure job. The rivalries that went with such insecurity in Greece contributed to the radical scrutiny of assumptions, but just as surely inhibited the formation of a consensus, the sense of the advantage of a joint endeavour of individuals united behind an agreed research programme. For all the impressiveness of Greek intellectual whizzkiddery, for continuity of sustained effort in the observations of the heavens the Chinese won hands down.

Professor Lloyd is jointly organising an international symposium on the nature of Greek and Chinese sciences to be held in July 2000, for which he has received Academy support through the British Conference Grants scheme.