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A transparent revolution

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Why did the great scientific advances that transformed the world between the 13th and 17th centuries all occur in western Europe? Alan Macfarlane believes the answer is crystal clear.

One of the most significant transformations in human history occurred in western Europe between the 13th and 17th centuries. This was the rapid increase in our understanding and representation of nature that we call the Renaissance and the scientific revolution. When we ask why this change occurred in this area rather than in Chinese or Islamic civilisations, we receive no satisfactory answer. Nor do we have any real idea of why the change happened then, or why, against all the odds, it happened at all.

The main difficulty seems to lie in our methodology. We reject teleological explanations, yet if there was no design or end in view, what set of circumstances could have led to such a momentous accident? Furthermore, while we feel dissatisfied when we invoke material causes, particular economic or ecological resources in one part of the world, we are equally dissatisfied with intellectual or cultural causes, a superior rationality or richer culture.

Gerry Martin and I have tried to develop a method that will overcome some of these difficulties and provide new insights into old problems. One part consists of breaking down the distinction between the Renaissance and the scientific revolution, treating both as aspects of one movement towards more reliable knowledge. Another is to link material and intellectualist interpretations by exploring the idea of a triangle or loop that integrates the intellectual, material, economic and cultural dimensions of life.

Very often in history we see an increase in theoretical understanding combined with reliable knowledge of some feature of the natural world, usually based on experimentation. This generation of new knowledge can lead to significant innovations, the embedding of a richer understanding in new or improved physical artefacts. These artefacts - if they are useful, in demand and relatively easy to produce - are often disseminated in huge quantities. These objects then change the conditions of life and may well feed back into the possibilities of further theoretical exploration. They can do this in two ways, by generating the wealth that enables more effort to be applied to the generation of new knowledge, or by providing better tools for improved understanding.

This triangle has occurred in many spheres of life, most notably in agriculture. The loop is enduring when artefacts are widely disseminated, and it can be a cumulative process. The speed of movement round this triangle of knowledge-innovation-quantification and the frequency of its repetition is what we often mean by the development of human civilisations.

Our research focuses on the working-out of one case of this model. It shows how glass beads, counters, toys and jewellery were made almost universally in Eurasia. For this purpose, glass-blowing is not absolutely required, nor does this use have much influence on thought or society, but rather on luxury goods and aesthetics. Basically glass is a substitute for precious stones. Hardly any of the potential of glass as an instrument for gaining knowledge or improving the physical environment is exploited.

Another use is for vessels, vases and other containers. This was largely restricted to the western end of Eurasia. There was very little use of glass for vessels in India, China and Japan. Even in the Islamic territories and Russia, the use of glass declined dramatically from about the 14th century with the Mongol incursions. The great developers were the Italians, first the Romans and later the Venetians. Here there begin to be links between improved glass and new knowledge, for example, the fact that the fine glass needed for the earliest microscopes was made from fragments of Venetian *cristallo* . Likewise, the development of tubes, retorts and measuring flasks was made possible by this western development.

Window glass was to be found only at the western end of Eurasia until recently: China, Japan and India hardly developed this use. Its most dramatic development was even more limited. The great window revolution mainly occurred in Europe north of the Alps. Two of the most important factors behind this were the cold climate and religious architecture, incorporating the Gothic stained-glass window. Glass transformed architecture, social life and thought, but only in depth in northwestern Europe.

Another use comes from the reflective capacity of glass when silvered. The development of glass mirrors covered the whole of western Europe, but largely excluded Islamic civilisation, perhaps for religious reasons. Glass mirrors were also not developed in India, China and Japan. Yet they are a crucial feature in the development of the sciences of optics and the understanding of perspective in art.

A final major use of glass is for lenses and prisms and, in particular, their application to human sight in the form of spectacles. While the concept of the light-bending and magnifying properties of glass was probably known to all Eurasian civilisations, only in western Europe did the practice of making lenses really develop, mainly from the 13th century. This coincides precisely with the medieval growth in optics and mathematics, which fed into all branches of knowledge, including architecture and painting. Only in western Europe after about 1280 did spectacles with lenses begin to develop.

The reasons for the differential development of glass are largely accidental. They have nothing much to do with intention, planning or individual psychology. Yet these accidents then began to move western European societies round the knowledge triangle. Improved glass fed into more accurate knowledge, that knowledge was used to improve glass and so on. One could argue that the great experiments in increasing knowledge from Roger Bacon to Newton, or from Giotto to Rembrandt, can be seen as one set of epiphenomena generated by this loop.

Glass did not force the amazing deepening of knowledge, but rather made it possible by providing new instruments: microscopes, telescopes, barometers, thermometers, vacuum flasks, retorts and many others. At a deeper level, it literally opened people's eyes and minds to new possibilities and turned western civilisation from the aural to the visual mode of interpreting experience. We have examined 20 famous experiments that have changed our world, chosen at random. Fifteen of them could not have been performed without glass. Putting it another way, the collapse of glass manufacture in Islamic civilisations and its decline in India, Japan and China made it impossible for them to have had the type of knowledge revolution that occurred in western Europe.

Sciences such as histology, pathology, protozoology, bacteriology and molecular biology would not exist were it not for glass. Astronomy, the more general biological sciences, physics, mineralogy, engineering, palaeontology, volcanology and geology would have been very different. Without clear glass, there would be no gas laws, no steam engine, no internal combustion engine, no electricity, no camera and no television. Without clear glass, we would not have had the visualisation of bacteria that prompted our growing understanding of infectious diseases. It is at the centre of the medical revolution since Pasteur and Koch.

Without the chemistry that depended on glass instruments, we would have had no understanding of nitrogen and so no artificial nitrogenous fertilisers. Much of the agricultural advance of the 19th century would not have occurred. There would have been no way of demonstrating the structure of the solar system, no measurement of

stellar parallax, no way of substantiating the conjectures of Copernicus and Galileo. This initiated a line of inquiry that, through the application of glass instruments, has revolutionised our understanding of the universe and deep space, altering our whole cosmology. Furthermore, without glass we would have no understanding of cell division (or of cells), no detailed understanding of genetics and certainly no discovery of DNA. Without spectacles, most of the population in the West over the age of 50 would not be able to read this article.

So glass is a giant and an unforeseen accident, and at the same time it follows a predictable pattern of movement round the triangle: deeper reliable knowledge enabling the innovation of artefacts and the quantity production of these new artefacts. This heralded both our modern world and the material basis for the further generation of new reliable knowledge. While the movement around the triangle was confined to one region, it was powerful enough to make the world we live in.

Alan Macfarlane is professor of anthropological science, University of Cambridge. Gerry Martin is a former managing director and co-founder of Eurotherm Ltd. He has long been a historian of glass instruments, particularly microscopes. *The Glass Bathyscaphe* is published by Profile Books in July. Further information: www.alanmacfarlane.com

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