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REFLECTIONS ON 'THE GREAT DIVERGENCE' : RELIABLE KNOWLEDGE OF THE WORLD

Alan Macfarlane, King's College, Cambridge, England CB2 1ST

What is the question?

Anyone who has looked at the long term history of human civilizations over the last fifty thousand years will notice that one of the most significant transformations occurred roughly during the period 1200-1800. This affected the most important and powerful of the human capacities, the sense of sight and the way in which people think. What I am referring to is the rapid increase in the detailed understanding and representation of nature which we label generally the 'Renaissance' and the 'Scientific Revolution'. Anyone who compared the nature of painting in 1200 in Europe with that in 1800, or the amount of chemical, physical and biological knowledge in Europe in 1200 and 1800 would not hesitate to pronounce that a revolution had occurred.

We know that it happened, but after that there is little agreement. Firstly, we do not know when, exactly, it happened. The central events are dated by historians at different points, some stressing each century from the fourteenth to eighteenth. Secondly, we are still uncertain as to why either the Renaissance or Scientific Revolution occurred; all the theories put forward are partially satisfactory, but they do not yet add up to an explanation. Thirdly, we do not understand why it happened where it did, that is to say in western Europe.

This last question is particularly relevant to a Chinese audience. As almost everyone who has thought comparatively knows, if in 1200 one had guessed where a great break-through in precise knowledge of the world might occur, one would definitely not have chosen backward western Europe. The main contenders would have been the Islamic civilizations or, above all, Sung China. This, of course, is famously known as 'the Needham question' after the massive effort by Sir Joseph Needham through his studies of Chinese science and civilization to try to understand why the knowledge revolution did not occur in China, but did in Europe.[1] To which, of course, he had no solution.

Trying to avoid the question.

When faced with an apparently insoluble huge problem, one sensible approach is to pretend that it does not exist, or is unimportant, or that the question has not been properly posed. This is the approach of a number of distinguished comparative thinkers over the last years, who have argued that there really was no substantial difference between knowledge systems in 'the East' and 'the West' before about 1800, or, if they existed, they had little practical importance until after that date. The consequence of this view is that any solution to the divergence between east and west,

[1] The numerous vast volumes in the series 'Science and Civilization in China' edited by Joseph Needham and his collaborators are usefully synthesized in Joseph Needham, *The Shorter Science and Civilization in China*, 4 vols. Abridged by Colin A.Ronan, Cambridge Univ. Press, 1980, 1994,1995.

which can no longer be disguised when they clashed technologically and militarily in the middle of the nineteenth century, must lie in events after about 1800. I shall very briefly allude to perhaps the most interesting example of this approach, the work of Ken Pomeranz in *The Great Divergence* (Princeton Univ. Press, 2000)

In this work he argues that in terms of agriculture, technology and general economic sophistication, China and 'Europe' were more or less level and hardly differentiated until about 1800. After that date, because of two special factors, the use of coal and the access to wealth in the 'ghost acres' (invisible wealth drawn from the Third World), Europe began to become economically and technologically superior. But what of the 'Needham question', the conventional wisdom that Europe by 1800 had undergone a 'knowledge revolution' which had not occurred in Eastern Asia?

Basically, Pomeranz ignores this dimension. He does this by using several strategies. Firstly, he more or less totally ignores the work of Needham and his students – there is only one footnote reference to Needham (in relation to clocks) and only one volume of his multi-volume works is in the bibliography. Secondly, he reduces the whole of the Renaissance and the Scientific Revolution to something which, after Margaret Jacob, he calls a 'scientific culture'. This is basically a minor form of institutional style, 'increased literacy and printing, the spread of scientific societies, relatively accessible public lectures' (p.44). This minor form of activity was localized (almost exclusively English) and late (1600-1750) phenomenon in that one country. Part of it was related to some instruments, 'clocks, watches, telescopes, eyeglasses etc.' (p.67), but these were of little practical importance, except marginally in ocean-going navigation, since 'their principal uses were as amenities for the well to do…' In other words they were toys or luxuries.

As for the question whether this 'scientific culture', already shrunk to a minor blip of short duration in one culture, was at all special to Europe, we have to 'leave open, pending further research, how unique this culture was'.(p43) Possibly 'Europe may have had a significant edge' in this minor form of activity, 'though we need more research to be sure'. (68) So the whole vast revolution which changed the world on its course, from Giotto to Rembrandt, from Roger Bacon to Newton, is turned into a minor English cultural style, which may not really be much different to what happened in China in any case. That is one way to deal with the problem.

The methodological problem.

Of course, anyone who has witnessed the easy arrogance and ignorance of many western thinkers, or who has become aware of the technological and scientific progress of East Asia in the last century, has sympathy with the attack on the older theories of the 'European Miracle'. The problem of even asking the question as to why European knowledge systems were revolutionized between 1200 and 1800 and Chinese and Japanese ones were not, is that it immediately seems to lead one into various unpleasant forms of explanation. It encourages teleological thinking – that the west was somehow going towards some goal, some pre-destined superiority. It encourages semi-racist ideas that somehow people in the west were more inventive, ingenious, intelligent, creative or whatever. And negatively it can lead to the talk of great civilizations like China or Japan being stuck, non-progressive, backward-looking, repressive or whatever. As we learn more about these civilizations, none of

these things seem true. Both China and Japan were diverse, creative and 'progressive' over the centuries. Yet they did not have the knowledge revolution. So how can one devise a theoretical methodology which takes one away from teleology, yet does not leave one in the field of pure chance? Which admits that Leonardo da Vinci, Galileo, Newton, did change the world, but not because they were somehow more gifted than their Chinese or Japanese counterparts?

If we reject teleological explanations, and 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.

A new methodology.

Gerry Martin and I have tried to develop a method which will overcome some of these difficulties and provide new insights into old problems.[2] 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 the material and intellectualist interpretations by exploring the idea of a triangle or loop which integrates the intellectual, material, economic and cultural dimensions of life.

Very often in history we see an increase in theoretical understanding, 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 artifacts. These artifacts, 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 which 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 artifacts 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 civilizations.

The triangle in action: the development of glass.

The working out of one case of this model is described in our book. It shows how glass beads, counters, toys and jewelery were made almost universally in all the civilizations of 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

[2] To be published as Alan Macfarlane and Gerry Martin**, The Glass Bathyscaphe: How Glass Changed the World** (Profile Books) on 17 July 2002 in the U.K. and **as Glass: A World History** (Chicago University Press) in the U.S. two weeks later.

potential of glass as an instrument for gaining knowledge or improving the physical environment is exploited. Such glass objects have been found widely in Japan, China, India and elsewhere from very early on.

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 fourteenth century with the Mongol incursions. There are a number of reasons for this. In China and Japan the common drink was a hot one, tea. This is best served out of pottery or porcelain. Pottery and porcelain of famous beauty became the universal storage medium. Who needs fine glass with Chinese porcelain at hand? And in India and Islamic civilizations, pottery was increasingly used for religious and economic reasons.

The great developers were the Italians, first the Romans, and later the Venetians. This is probably linked to the universal high class drink, wine, but there are other reasons as well which meant that from very early on western Europe took to the use of glass containers in a large way. That they did so begins to create the 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'. The growing use of glass containers and the skill in making them also fed into the development of tubes, retorts and measuring flasks. These were the essential tools for the development of western chemistry and biology. This was made possible by this unique western development.

Window glass was also only to be found at the western end of Eurasia until recently; China, Japan and India hardly developed this use. Again there were a number of reasons for this. In China, for example, it was often too hot to have glass windows. The superb mulberry paper was a far cheaper and more efficient window covering, as it was in Japan where the ubiquitous earth-quakes also made glass a hopeless material for windows. In Islamic civilizations, the heat again precluded the use of large glass windows. The effects of climate, geology and so on can be seen ever within Europe.

The most dramatic development of window glass was even more limited. The great window revolution mainly occurred in Europe north of the Alps. Two of the main 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 north-western Europe.

A further 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 civilization, perhaps for religious reasons. Glass mirrors were also not developed in India, China and Japan. For a number of reasons, including an attitude to the personality and the availability of good bronze mirrors, glass mirrors were absent. Yet they are a crucial feature in the development of the sciences of optics and the understanding of perspective in art. We argue in our book, for example, that it is impossible to imagine that the western Renaissance could have occurred without the glass mirror.

A final major use of glass is for lenses and prisms and in particular their application to human sight in the form of spectacles. The concept of the light-bending and magnifying properties of glass was probably known to all Eurasian civilizations, and was certainly known to the Chinese from the twelfth century at least. Yet only in western Europe did the practice of making lenses really develop, mainly from the thirteenth 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. Their absence in China and Japan, we argue, may have been partly related to a difference in eye problems in the two parts of Eur-Asia. In western Europe, the problem was long-sightedness in old age, so that people could no longer read from their mid-forties. For this glasses made with a convex lens were needed and this was relatively easy to make. In China and Japan in the past, as certainly today, the major problem was short-sightedness, myopia. We argue that this may have been related to the strain put on the eye by reading and learning Chinese characters. For whatever reason, high rates of short-sightedness meant that not only were glasses not absolutely essential (one can always read by bringing the object closer), but the making of concave lens glasses, which myopia requires, is much more difficult. Without spectacles, the microscope and telescope would not have been invented – and the consequences of those two inventions are well known.

Some effects of glass on knowledge.

So the reasons for the differential development of glass are largely accidental. They have nothing much to do with intention, planning or individual psychology. They are not the result of superior intellect or superior resources in the west. Yet these accidents, such as the absence of the superb porcelain of China, 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 in art and science, 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 the 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 civilization from the aural to the visual mode of interpreting experience. In the appendix to the book we examine twenty famous experiments which have changed our world, chosen at random. Fifteen of them could not have been performed without glass tools. Putting it in another way, the collapse of glass manufacture in Islamic civilizations and the fading away in India, Japan and China made it impossible that they could have had the type of knowledge revolution that occurred in western Europe.

The following sciences would not have existed without glass instruments: histology, pathology, protozoology, bacteriology, molecular biology. Astronomy, the more general biological sciences, physics, mineralogy, engineering, paleontology, vulcanology and geology would also have been very different. Without clear glass there would have had no gas laws, no steam engine, no internal combustion engine,

no electricity, no cameras and no television. Without clear glass we would not have had the visualization of bacteria, little understanding of infectious diseases which is at the centre of the medical revolution since Pasteur and Koch.

Without the chemistry which depended crucially on glass instruments we would have had no understanding of nitrogen and so no artificial nitrogenous fertilisers. Much of the agricultural advance of the nineteenth century would not have occurred without glass. 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 enquiry that, through the application of glass instruments, has revolutionized our understanding of the universe and deep space, thus completely 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 a majority of the population in the west over the age of fifty would not be able to read this article.

So glass is both a giant and unforeseen accident and at the same time it follows a predictable pattern of movement round the triangle: deeper reliable knowledge enabling the innovation of artifacts and the quantity production of these new artifacts. 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.

Some effects of glass on society.

Glass is not just a tool to think with, but also a tool to improve comfort and efficiency. The period between the thirteenth and eighteenth centuries in Europe saw many of these potentialities unfold and they are an important part of the story of the intellectual effects. As we have already seen, the intellectual and the material are interlinked. Many of the ways in which glass began to embed increased reliable knowledge in shaping humankind's artefactual world then fed back into increasing the possibilities of further rapid advances in reliable knowledge.

Just as it improved comfort and the length of the working day through windows, glass probably affected health. Glass lets light into interiors and is a hard and cleanable surface. This was one of its attractions to the fastidious Romans in relation to utensils, and likewise for one of the great glass-using and representing civilizations, the Dutch. With their enormous windows, it was in the Netherlands that the use of glass developed most. Transparent glass lets in light so house dirt becomes apparent. The glass itself must be clean to be effective. So glass, both from its nature and the effects it has, is favourable to hygiene. That the two major glass-using civilizations of the seventeenth century, Holland and England, should be widely noted for their cleanliness and their good health seems to be linked. Of course, the Japanese houses achieved even greater cleanliness by other methods and without glass. But in a cold northern climate windows were probably a very important factor.

The new substance did not merely alter the private home, but in due course transformed the growing consumer society. Here the focus shifts northwards to England and a century later. The lead glass sheets produced by using coal were ideal

for a nation of shopkeepers to glaze their shop fronts with and foreigners marveled at the results in the eighteenth century. The change was well captured by a French visitor to England. 'What we do not on the whole have in France,' he notes, 'is glass like this, generally very fine and very clear. The shops are surrounded with it and usually the merchandise is arranged behind it, which keeps the dust off, while still displaying the goods to passers-by, presenting a fine sight in every direction.'

As well as houses and shops, the new application began to transform agriculture and knowledge about plants. The use of glass in horticulture was not an invention of the early modern Europeans. The Romans had used forcing houses and protected their grapes with glass. This Roman idea was revived in the later middle ages, from about the fourteenth century, where glass pavilions for growing flowers and later fruit and vegetables begin to be noticed. As glass became cheaper and particularly flat window glass improved in quality, the development began to exceed the Roman use. The growing of orange trees under glass was noted in 1619 and a heated glass house was built in 1684 in the Apothecaries Garden at Chelsea. As this happened glass cloches and greenhouses improved the cultivation of fruit and vegetables, bringing a healthier diet to the population. Just as the glass window lengthened the working day for the humans, so it did for plants, changing, as it were, the climate and using solar energy to grow nutritious food for humans. A transformation which is now happening as a result of plastic in many cold, dry and windy parts of the world such as northern China, happened in another way much earlier with glass.

Finally we can note a plethora of other useful inventions which altered material life. Among those that have been noted are storm-proof lanterns, enclosed coaches, watch-glasses, lighthouses and street lighting. Thus travel and navigation was improved. Or again there is the effect of glass bottles, which increasingly revolutionized distribution and storage. For example glass bottles created a revolution in drinking habits by allowing wine and beers to be more easily stored and transported. Since both of these drinks with their tannin and hops were medically very important, the effects may again not only have been to encourage manufacture, trade and agriculture, but also to improve the health of people who could more easily avoid drinking polluted water. The ways in which glass altered the flexibility of storage and distribution is a revolution similar to that caused when freezing and canning opened up new possibilities in the second half of the nineteenth century.

Thus, at first through drinking vessels and windows, then through lanterns, lighthouses and greenhouses and later through cameras, television and many other artefacts our modern world built round glass has emerged. Through another chain of events it revolutionized health. Microscopes made the discovery of bacteria possible, the germ theory that emerged led to the conquest of much infectious disease. Glass even affected what humans believed (stained glass) and how they perceived themselves (mirrors). So it entered human civilization at all sorts of angles, but at first only in one part of the world. This did not happen until the later nineteenth century on a large scale in Japan or China. These different aspects were also all interconnected in complex ways. For example windows improved the workshops, spectacles lengthened the working life, stained glass added to the fascination and mystery of light and hence a desire to study optics. It is this rich set of inter-connections of this largely invisible substance which makes it so powerful and fascinating.

Conclusion

The approach we have taken helps us to re-look at large historical questions and also not to feel uncomfortable when doing so. We can admit differences, that the divergence between the two ends of Eur-Asia is much deeper than the two hundred years or so suggested by Pomeranz and others. We can admit that certain systems are technically superior to others, without suggesting racial or other superiority. We can admit the role of accident in history, without making all of history just a matter of chance. We can investigate the realm of ideas and aesthetics without reducing it all to economic or social factors. We can note the long causal chains which lie behind differences, and the way in which many of the most important events in world history were the result of unintended consequences. That the superb pottery and porcelain of China and Japan, combined with the drinking of hot tea, should mean that these East Asian civilizations could not have a Renaissance or Scientific Revolution of the kind that occurred in the west is not at first obvious an obvious thought. But it is a more acceptable explanation than ascribing it to some defect in Chinese ideology, politics or culture. It is a giant accident, but looking back we can seen why, without being in any way inevitable, it did happen.