(fertile2)

(Gerry Martin September 1993)

Thoughts on the absence of industrial capitalism and of science in Tokugawa Japan.

Late Tokugawa Japan had achieved a high level of commercial capitalism, centred on the urban areas but nevertheless spread fairly uniformly across the country - a mode of social and economic organization which seems to have been fairly stable for at least two or three hundred years.

This commercial capitalism did not lead to a high rate of product innovation, nor to anything resembling industrial capitalism, nor to a stable and growing body of science until there was extensive and repeated contact with the western world in the last quarter of the nineteenth century and beyond into the twentieth century when both industrial capitalism and science/technology became deeply established.

Capitalism in Western Europe and N. America has long been associated with the rise of both industrialism, including a considerable amount of product innovation, and with the rise of science and of technology. The almost complete absence of these in Japan, in the face of a strong commercial capitalism required explanation.

The explanatory powers of any model would be strengthened if they were also able to account A) for the rather similar situation in parts of India and some of the Arab and other Middle Eastern countries, which can have long established stable trading systems in which individuals trade for profit but which, like Japan, settle into an equilibrium trap with low technology and no industrialization, and B) for the fairly extensive, but transient and ultimately disappearing science in China and in the Arab countries, and for small scale activity such as the systematic growing of test areas of different seeds for plant selection and improvement and selection in Japan, with thinking and method that loosely parallells 'scientific method' but which never blossoms into a growing body of 'reliable knowledge'.

There is a possibility that an explanatory model which postulates a marked non-linearity in the way in which new knowledge is acquired may be helpful.

We have discussed many times that, in trying to understand social behaviour there are no 'new thoughts' - someone has always been this way before, we are merely re-arranging the scenery. I have no doubt that this model is in this category, and that the several bits of the model have been worked out thoroughly in the literature, but I am not aware of them yet; also, Simon and Steven are far ahead of me in understand how new knowledge is acquired and we should discuss it with them before taking this type of model at all seriously.

By a 'marked non-linearity in the way in which new knowledge is acquired' I mean that there is a level of understanding of the world which is fairly readily acquired by observation and experience, but that to go even a small way beyond this may require an enormous amount of effort, and probably a completely differently structured society.

An example would be the creation of a cutting edge. Palaeolithic man could readily observe that some stones, if broken, yielded a sharp edge which could be used for cutting flesh or wood. He would have to handle with care of he would cut himself, but which would very quickly break down in use and become so blunt as to be worthless. He could learn to deliberately reduce the angle at the edge (secondary working) so that, although not so sharp to start with, he had a tool which lasted much longer. A modern workman will do the same, grinding a chisel to an angle balancing sharpness and strength, and altering the angle according the material he wishes to cut.

To go beyond this knowledge, to understand the general classes of materials from which useful cutting tools can be made and to fashion some of these materials, such as steel, from natural materials requires a higher level of knowledge and experience, and not a little serendipity. Japan and China and many other societies were deeply into this stage, and in the case of Japan very high levels of craft skill were applied to cutting tool fabrication - swords, particularly - that belied the depth of knowledge existing in the society about the materials used.

The next layer of knowledge, which is still far from complete, requires understanding of the characteristics of the atoms of which the material is composed, the way in which these atoms relate to each other, the strength of bonds between different combinations of them, the way they form regular three-dimensional relationships, which we call crystals, the size of the crystals the way that the crystals are modified both in composition and in shape and size by different heating and cooling programmes, the way in which some of the atoms in the materials are arranged within and between the crystal - and all this as an area of knowledge before we start considering the bulk properties of the material and the technology of shaping it to its final form.

This is the type of knowledge that we grace with the umbrella name 'science'. The societies which produce this type of knowledge are complex and sophisticated - I shall make some conjectures about the nature of 'complex and sophisticated' societies later, which may have implications in an explanatory model.

A second example of this higher level of knowledge is the relationship between work and heat, the subject of excellent research by Simon's group. If you rub your hands together hard for a few seconds, then hold them against your cheek, they feel quite warm. If you rub two flat pieces of wood together hard, you get the same effect. You have converted mechanical work into heat. Some societies use the effect, using a dry stick in a groove to produce a flame. The effect is widespread and anyone will observe it in ordinary everyday activities. We can also observe that more work produces more heat. But as soon as we try to quantify the effect, asking how much work produces how much heat we run into deep conceptual and practical problems of quantifying heat, quantifying work, measuring each, designing apparatus to standardize the effect. Otto Sibums papers on Joule detail some of the complexities of trying to answer a seemingly simple question, and if we add to these the complexity of producing reliable and accurate thermometers and balances, we can visualize the great complexity and sophistication needed in a society to tackle this sort of knowledge.

I have said that I think that the acquisition of new knowledge may be very non linear, being fairly easy at the craft knowledge stage and very much harder just beyond that stage, and have some suggestions about the nature of the 'difficult' stage. You will see that these suggestions do not provide anything like a complete solution to the origin of scientific knowledge, but rely heavily on the various cultural conditions being appropriate - that is, they rely on the type of analysis which you are developing.

If we accept Czintmihaly's'?? thesis, as described in 'The Domain of Creativity', creativity can be likened somewhat to biological evolution. The likening is just a metaphor, and as with any metaphor it can be carried too far, but the essence of the thesis, that the creative act parallells the generation of variation, and that from a large body of competing variations those who judge the variations (he calls the judges the 'field') select those which seem best to fit the assessment criteria currently in vogue. This thesis seems compatible with Simon's works on discovery, in which he rejects the notion of discovery being 'heroic', assignable to a single individual at a definable time.

The history of individual cases of 'discovery' that is, the acquisition of new knowledge which appears to the field, to be more reliable than the old knowledge, seems to show that very large amounts of variation are required from which the new knowledge is selected - and the new knowledge immediately is subjected to waves of variation, or creative thoughts, to refine it or to refute it. Frequently, a line of thinking runs into a dead-end, and variation from an entirely different area of activity provides the means of setting it off on a new track. An interesting example of this occurs in the development of the microscope. Our new understanding of genetics springs from the discovery of DNA and the double helix, which in turn rests on the discovery of the chromosome and the processes of cell division. This relied entirely on the steady improvement in the resolving power (the ability to see fine detail) of the light microscope. The microscope had been invented, around 1610, in Holland, but its resolving power had been limited by two types of error, or aberration. One of these, spherical aberration, limited the angle at which light could usefully be collected from the small objects under observation.

The other, chromatic aberration, produces colour fringes around objects. These made it impossible to see very small objects such as the smaller bacterial or chromosomes.

Chromatic aberration was very much reduced in 1757 with creative inputs - variation - over the previous ninety years from Newton, the Dutch scientist Huygens, the Swedish mathematician Klingersterna, the Swiss mathematician and physicist Euler, an English lawyer and amateur optician Chester Moor Hall, the French physical experimenter and lecturer Desagulier, the Italian count Rizzetti and three London opticians, George Barr and George Dolland.

The solution lay in a combination of two lenses, one convex shaped (fig), made from soda (crown) glass and one concave (fig) made from lead (flint) glass. Crown glass was widely produced in most countries of Europe, although the special centre of production was Venice, or rather, the Venetian island of Murano.

Lead/flint glass was a London development, undertaken in the 1670s by George Ravenscroft to provide an English glass to compete with the very considerable imports from Venice, particularly wine glasses.

Achromatic lens combinations were designed and made originally for telescopes and it was not until 1807 that they were adapted for the microscope.

I have written this very brief and vastly incomplete summary of the development of the microscope (as mentioned earlier I am writing a fuller account separately) to illustrate the great amount of variation required to produce advance in just one detail, albeit a crucial detail, in the great network that eventually led to microbiology, antibiotics, DNA, genes...

Even to advance knowledge on this detail, variation came from at least seven European countries, over a period of 250 years. Crucial inputs came from activities that were initially not connected with the microscope at all - competition for imported wine glasses!

The picture emerges of a vast network of activity - some theoretical, some craft, some technological, some commercial, much driven by pure curiosity (there were no commercial applications at all for the microscope, except as an aid to demonstrators, from its initial development around 1610 until about 1850).

Also, the variations are put into the network from a large number of geographic locations. This seems to correspond well with the idea of the 'conceptual space' suggested by Herbert Smith and expanded and explored by Maggie Boden and Dave Perkins. We create new ideas by rearrangement of data within our individual conceptual spaces. We continuously run into dead-ends, in which the data within our conceptual space is inadequate to have significant creative outcome, to produce meaningful variation to throw into the network. Logical thought cannot take us any further - there is not enough data to bite on. Experiment can help, but is necessarily rather tightly focussed - what experimenter, faced with a desire for an achromatic lens system, but with no certainty at all that it would work, could embark on an extremely expensive search for a new type of glass, of whose desired properties he was only dimly aware, to produce an improvement in a product which no manufacture could specialize insufficiently to make a livelihood?

It is on such tenuous threads as this that the discovery of DNA depends. What seems to happen is that new data comes into our conceptual spaces from other minds and other activities operation in quite different cultural environments, so that their conceptual spaces have substantially different sets of data.

The need is for an abundance of intellectual technological and manufacturing activity operating in different centres, with sufficiently strong barriers around them to maintain their own cultural identity, their own special conceptual spaces, but with just enough leakage to provide a trickle of new data to the other conceptual spaces in the network.

Individuals working closely together tend to erode the barriers rather quickly, and common schools of thought develop - conceptual spaces become too similar and new data for creative variation dries up.

If what I have described bears any relationship with reality, it goes some way to providing an explanation for the presence or absence of scientific activity in a society. The problem becomes one of creating a sufficiently large and varied network, intellectual, technological, manufacturing, to sustain itself. Above a certain level of activity, a certain abundance of conceptual spaces, boundaried but leaking, the creation of new 'reliable knowledge' can proceed. Below this level, it will atrophy. You can have spurts of local activity, such as astronomical clocks or magnets in China or seed selection in Japan, and these activities can flourish for a while until the possibilities resident within the conceptual spaces involved are exhausted, and then they will die away.

The conditions required to obtain the size and variability of network needed to be self sustaining are evidently vary rare, and I'm not a sufficiently good medieval historian to have much confidence in my ruminations, so I offer them solely to invite correction.

The mechanism for the creation of a large, diverse network, with leaky barriers between the various networking units may well have been the translation of Arabic and Greek texts into Latin in Europe between 1000 AD and 1200 AD. These made available to scholars from many parts of Europe a great deal of the scientific thinking which had occurred during the previous fifteen hundred years - intellectual and technical activity which seems to have arisen in circumstances rather similar to the Chinese science activities, in which there is a cluster of activity but without a sufficiently developed network to sustain it. Islamic scholars had brought this together (but not including Chinese work) and had translated it into Arabic.

I have made some little diagrams to represent sustainable and unsustainable situations, with a suggestion of how the most notable 'sustained' situation - W. Europe since 1000 AD may have occurred.

Diagramatic representation of knowledge producing activity.

Diagram:

1) Single centre of activity. Soon runs out of new data, activity terminates.

Diagram:

2) Few centres of activity. Ultimately unsustainable, eventually terminates.

Diagram:

3) Many centres of activity. Sustainable, grows to scientific revolution. Problem. How do you start with many centres?

Diagram: Possible solution to problem.

E.L. Jones in 'The European Miracle', provides a very persuasive explanation of the unusual growth of the manufacturing economy in Europe, relating it to the great diversity of smallish societies in contact with each other and interacting in a complex network.

I have suggested a mechanism for the growth of science which equally depends on an abundance of boundaried but leaking groups.

A great difference between England and Japan is that England has been part of this large network, although on its outermost fringes, for two thousand years; Japan for little over a century. In the Achievement Project, specialists in a variety of artifacts - textiles, glass, agricultural products, weaponry, metals - have traced thought the history of their adoption and development in England.

The pattern is remarkably consistent. The artifacts were first imported from the European mainland. A local market developed - often a luxury market, and local manufacture was commenced, frequently with some sort of state assistance win the encouragement of foreign specialist workmen or in the granting of monopolies.

Developments made abroad were imported into this country and incorporated in local manufacture. This seems to have been the picture of English industrialization for over three hundred years, until around 1700 to 1750, the balance started to tip; England an importer of innovation fairly rapidly began to innovate, and soon became a major importer of innovation back into the European network and, by that time, the North American colonies.

The culture and economic circumstance of England (and I think we must include Scotland) have provided extremely fertile ground for a phase of economic growth. Exactly the same pattern is shown in Japan, but, with a more dramatic differential between Japan and the western economies, and with revolutions in transport and communication on a much compressed timescale.

The comparisons you are drawing between Japan and England are, in my opinion, very real and meaningful, but they are comparisons of cultures an economic patterns which provide fertile ground for economic and scientific growth. The seeds planted in this growth come mainly other parts of the network, and in the absence of the network there would not be enough seeds for growth to occur.

I have suggested in these notes some conditions that may be appropriate to the acquisition of knowledge - science - under sustainable or unsustainable circumstances.

It could be useful to consider the implications of this for the growth of industrial capitalism, and the breakthrough from commercial to industrialism.

I take it that the potential for commercial capitalism - the exchange of goods and services, with the expectation of some benefit - profit - by both buyer and seller - is universal, and where it is absent it is because of traditional or legal constraints that inhibit the production of goods or services to exchange, or inhibit the process of exchange, or confiscate the profits of exchange.

Industrial of manufacturing capitalism is much more complex, and it may be useful to try to divide it into its component parts.

We can envisage an industrial capitalism in which the artifacts exchange are of a craft nature, embodying only a very low rate of innovation, and this innovation when it does appear being mainly decorative or, if functional incorporating quite small improvements of knowledge.

A second form of industrial capitalism would have a larger rate of innovation affecting the function of the artifact (it is important to differentiate between functional and decorative innovation), but with the innovation coming from outside the society which is making the artifacts - that is, from the network with which the society is interacting. The implications are clear - no network means re-innovation.

A third form of industrial capitalism would have a large rate of innovation affecting the function of the artifacts but with that innovation being generated largely within the same society.

This third form is the one we associate with Golden Ages, with bursts of economic activity and relative success in comparison with surrounding societies, when a particular society is exporting back to the network more innovation than it is importing.

The third form seems always to develop through the second form, it seems to be always transient, and it seems, in its innovations, to incorporate new knowledge.

If this observation is correct, and if the explanatory model for the acquisition of new knowledge is correct (the need for an abundance of interacting or networking centres, boundaried so that can maintain integrity of their conceptual spaces but leaky so that data can pass to other boundaried conceptual spaces, and a non-lineal, bistable situation related to the number of separate conceptual spaces in the network) then we can see why Japan and other societies with advanced commercial capitalism could not proceed to the second or third forms of capitalism described above, until they become part of an existing knowledge producing network.

All this raises a host of questions. What are the conditions for 'fertile ground' for forms two and three? I suspect that they are largely the forms you describe, plus insertion into a large network.

What are the conditions for the creation of the abundant, boundaried intellectually oriented groups needed to produce the science network?

Why does form three, innovative industrial capitalism revert to predominant commercial capitalism?

How do entrepreneurs emerge in each of these three forms?

How dependent are the networks to the rate of creation of new knowledge and to the rate of interchange of data.