

Science, Technology, Society: Prologue

Arno Bammé

Human interaction with the natural world surrounding us is an anthropological, almost timeless, necessity. What has changed in the course of history is the social form that such interaction takes. Three sociohistorical turning points have shaped our relationship with the environment, primarily by defining the various means through which we approach it. The crucial question in this context is therefore as follows: How do they differ and how are they the same? Ultimately, it is a question of how society construes 'nature' – contemplation versus active intervention – and how it changes itself by doing so. The object of the first turning point was what Niklas Luhmann called the 'society' of society, that of the second, in a nutshell, the 'nature' of society and that of the third the rejection of this dualism leading to the fusion of nature and society. This essay can thus be read as a corrective to all grand sociological theories. Luhmann, for example, knows of no 'nature' of society, since in his view, nature is part of the environment. This, he tells us, is a premodernist way of looking at things, which if it has any validity at all, then only for the age of the Greek Miracle. These days, nature and society have long since fused together to become a single hybrid entity.

There is widespread agreement that (natural) science translated into *technology* provides humans all over the globe with equal scope for socioeconomic production. Tools and craftsmanship have their historical origin in the immediacy of human labour and the human production process. Technology, on the other hand, is different, being a hybrid that combines both craftsmanship and science – which is why it is so difficult to explain the technologically mediated condition we find ourselves in today in the context of co-evolutional interaction between 'society' and 'nature'. The abstract imperatives of (natural) scientific thought underlying the design principles of contemporary technology have their origin not in our concrete dialogue with material nature, which is where they are brought to bear in most instances, but rather in our communication with fellow

humans. The West's purely conceptual striving for knowledge derives its sociohistorical basis not from the unmediated process of labour and production, but from the interactive process of exchange, as manifested in its most abstract form in the circulation of goods, in other words in the market. It was here, and only here – and not in their processing of external nature, for example – that the Ancient Greeks were superior to the Mesopotamians and Ancient Egyptians. The abstract (proto-)scientific mathematics of the Ancient Greeks, for example, evolved far removed from the applied mathematics, arithmetic and geometry of the Babylonians and Egyptians, even if parts of it were influenced by them or developed in polemical opposition to them. Their arithmetic and geometry was an art intended for direct application in practice, which had nothing to do with the abstract conceptualism – generalization according to logical principles – that characterized the mathematics of the Greeks. Doubtless the Mesopotamians and Egyptians would likewise have made the transition to scientific thinking had they been able to explain it solely in terms of their own production practice, in other words by sophisticating their techniques of land cultivation and urban development, in both of which they were for a long time far ahead of the Greeks.

The first turning point, the Greek Miracle, placed the relationship between humans and other humans, i.e. society, on a rational footing. The systematic exchange of goods that spread throughout Ancient Greece between 800 and 200 BCE gave rise to forms of purely abstract thought and it is these that distinguish the course taken by Western culture from that of all other cultures.

Exchange entails abstracting from all the physical properties of the goods that are to change hands. It does not alter the physical makeup of the things themselves. Exchange is an act aimed solely at the transfer of property rights and hence at a change of purely social significance. Yet it is a very real act, and its realization demands cognitive skills and a capacity for abstraction in the highest degree. Equivalent is exchanged for equivalent. Commodities are not by nature comparable, but exchange makes them so. Everything perceived is subjected to quantifying principles. Commodities that differ in terms of quality are exchanged without either diminishing or enhancing the value of the assets held by the persons

engaged in the exchange – which of course is not the case when commodities change hands as a result of looting, robbery or piracy.

The exchange of equivalents is the result of centuries of experience and a long sociohistorical learning process which began in a specific place and at a specific time, namely in the Aegean, where the early Phoenicians and Ancient Greeks, unlike other Mediterranean peoples, engaged in systematic long-distance and overseas trade. Unlike the Greeks, the Phoenicians did not have money and therefore practiced an increasingly routine system of barter, which according to Herodotus took the form of a 'silent exchange of goods'. At each port of call, the Phoenician trader would lay out the commodities that he wished to exchange on the nearest beach and leave them there overnight. Next day, he would find whichever goods were being offered in exchange placed next to his own wares. If the equation seemed acceptable, the trader would simply take the said goods with him. Otherwise, he would leave them there and return next day to find a larger quantity of goods on offer, which he could then either take with him, or again reject by leaving them where they were. This process could drag on for several days and might never be concluded at all, if the parties engaged in it were unable to agree. To make commodities that were essentially different comparable and so be able to calculate his gain, the Phoenician trader had to be able to abstract their value from their actual content or utility. This process of abstraction became all the more essential once the Phoenicians' main rivals in the Mediterranean, namely the Greeks, began circulating coinage as a medium of exchange and before long universalizing it as the standard equivalent of the goods being traded. That moment in history when the systematic exchange of goods became the predominant principle of social synthesis at the same time marked the birth of purely abstract thought – a process which Sohn-Rethel describes as the genesis of cognitive abstraction out of real abstraction. The process was accompanied and expedited not only by the introduction of coinage, but also by the advent of alphabetic script, both of which advances constituted an extraordinary political, moral and intellectual leap forward. *Logos* took the place of *mythos*. All the salient features of what we now call 'science', including the notion of a subject that is identical with the self, the principles of formal logic

and abstract thinking, critique and systematic questioning and all the many rules and mechanisms governing them, abstraction and isolation, deduction and reduction, causality and probability as well as all conceptual forms and methods have their origin in Ancient Greece – and nowhere else.

But the situation was not without contradictions. The economy of the Greek polis remained deeply divided by a gap that it was unable to bridge. Its commodity-based economy was confined to the margins of society. There was no internal market to commodify human labour. Instead there was on the one hand the *chrematistikon*, a money-based economy abstracted from personal relations, and on the other the *oikonomia*, a family-type subsistence economy based on the labour of slaves. Proto-scientific reflection on this situation was the preserve of a tiny minority of *polis* inhabitants who, being exempted from physical labour, were able to devote themselves exclusively to the work of the mind. Since without slave labour they would not have existed at all, there was no need for them to grapple empirically and experimentally with the technical problems arising out of the appropriation of nature. Their primary concern was to find a political solution to the hegemonic problems arising out of the ambivalence between a subsistence and a monetary economy. The long *symposion* of Greek philosophy thus had less to do with the relationship between humans and things than with the relationship between humans and other humans. The concept of ‘proof’, for example, which these days we use as a logical tool in the scientific pursuit of truth, was known to the Greeks who invented it as a purely rhetorical means of persuasion.

The practice of delegating labour to the lower classes and to slaves in particular led to a social cementation of intellectuals that was to endure for more than a thousand years. Because their interpretation of nature – to the extent that it existed at all – was confined to social categories, their thinking remained stuck at the purely conceptual level and lacked all reflective, empirical recourse to ‘the things themselves’. In such a social system, technical progress is either thwarted altogether or at least greatly impeded, and the only obvious way of enhancing society’s productivity is to step up the use of slave labour. After all, there are scarcely any economic incentives to revolutionize the means of production in a production

process which rests on slave labour. The technology employed for everyday production under such circumstances essentially rests on knowledge derived from experience. What it lacks is theory-driven, experimental empiricism, which was not to evolve until after the European Renaissance under Newton. The consequence was stagnation.

The second turning point, the European Miracle, placed the relationship between humans and nature on a rational footing. This was when an economy whose products are first and foremost commodities came into its own. No longer confined to the margins of society, it was now in a position to transform the very core of society, primarily by making human labour a commodity that could be bought and sold like any other. Post-Renaissance European society began commodifying human labour by subsuming it under the accumulation of capital – at first only formally in manufacturing and publishing, for example, but then in real terms in what we now call ‘big’ industry. Money was no longer ploughed back, as it had been in the societies of Ancient Greece, but was instead accumulated so that it could grow. Viewed in terms of social history, the introduction of wage labour was a major, albeit late, developmental feat on the part of post-Renaissance Europeans, the importance of which can scarcely be overestimated. The very idea of wage labour demands two difficult cognitive steps: The first is the perception of human labour as something independent of both the labourer and the end result or product of his or her labour – if you buy an object from an independent craftsman (whether that craftsman is a free man or a slave with *peculium* is immaterial), what you are buying is not labour, but rather an object which the craftsman made at a time and subject to conditions of his own choosing, whereas if you buy ‘labour’, what you are buying is something purely abstract, namely ‘manpower’, which you can then deploy at a time and subject to conditions of your own choosing. Secondly, the system of wage labour requires a means of measuring work so that it can be paid for. This is usually done by introducing a second abstract concept, that of ‘working hours’. The historical barrier that prevented Ancient Greece from evolving into a civil society was overcome in the second miracle, the ‘European Miracle’. Starting in northern Italy followed by England and then the rest of Europe, trading capital became industrial capital.

Whereas the inhabitants of the Greek *polis* used reason to liberate themselves from social torpor, substituting *logos* for *mythos* in both philosophy and in politics, the people of post-Renaissance Europe used their minds to develop economic and technological means of liberating themselves from the fetters of *nature*. Spearheaded by secular merchants, artists-cum-engineers and craftsmen, this development took place independent of the universities, which at that time were still straitjacketed by Scholasticism. The scientific societies and academies that began emerging around this time and in England in particular the informal, invisible ‘colleges’ that were the precursors of the Royal Society all played a crucial role in this development. As a small, but quarrelsome continent with a long coastline, Europe’s part in post-Renaissance world history echoed that played, but never perfected, by small and quarrelsome Greece in the ancient world of the Mediterranean – albeit at a more sophisticated level. And as in Antiquity, there were other influential factors at work here in addition to the geopolitical ones: the introduction of Arabic numerals and above all the number zero, the invention of double-entry bookkeeping and book printing, the transition from geometrical to algebraic problem-solving and infinitesimal calculus as well as the shift from Catholicism to Protestantism in northern Europe. This development can be understood only by analysing the *technical* revolution underlying the change on the one hand, and the *economic* interests that motivated it and drove it forward on the other.

In Renaissance Europe, unlike in Ancient Greece, economic calculation began to hold ever more sway over production in society. The first sustained economic stimulus to the systematic, across-the-board mechanization of production came when the axis of world trade shifted away from the Mediterranean to the Atlantic coast of Europe. One consequence of this was the collapse of the capitalist economy of northern Italy which had been flourishing for more than two hundred years and now sank into a state of permanent crisis. The loss of the world market was compounded by the need to raise wages in order to stanch the haemorrhage of qualified labour. The impending disaster, it seemed, could be averted only by lowering production costs. This was done primarily by replacing expensive humans with cheap natural forces such as water and then

steam. The economy of natural forces, which meant the substitution of natural forces for human labour and inevitably implied a diminishing of the latter, was the central concern of mechanics in the fifteenth, sixteenth and seventeenth centuries, the study of which nevertheless presupposed the mastery of purely theoretical concepts.

A distinction must be drawn between the 'technical revolution', as it is usually described, that found purchase in post-Renaissance Europe and what Karl Marx later called the 'industrial revolution', just as the question as to the origin of the 'European Miracle' must be treated separately from the question 'Why was England first?'. The *industrial revolution* was set in motion by the invention of engines which produced power *themselves*, whether through combustion or through the generation of steam. This opened up such scope for the widespread use of *mechanical drives* that before long a vast range of machine-tools could be deployed to do the work formerly done by a commensurably large host of human labourers. The *technical revolution*, on the other hand, was a necessary precondition for this development, which in a long-drawn-out process laid the groundwork for the industrial revolution by revolutionizing the types of technology used, but without precipitating the mass transfer of human labour from workshop to factory floor. What it revolutionized was first and foremost the means of production – meaning tools, which thereupon became belt-driven *machine-tools* which could be used for an ever wider range of applications. Once that had been accomplished, the remainder of the technical revolution was taken up with increasing the number of machine-tools that could be attached to the drive. The disproportionate increase in mechanical resistance caused by the use of ever more complex and ever more sophisticated transmissions meant that situations in which the limits of practical mechanics became evident were by no means uncommon even before, and certainly during, the period of pre-industrial manufacturing. Yet it was these problems that ushered in the *scientific revolution* inextricably linked to the technical, at whose heart was the mechanics of inertia. Inseparable from its emergence and coming to fruition is the name of one man: Isaac Newton.

The Western understanding of nature which was perfected by Newton and which ultimately manifested itself in a technology capable of trans-

forming nature, has both an abstract, theoretical underpinning with roots that can be traced back to Ancient Greece and a concrete, empirical basis that began to carry weight only in post-Renaissance Europe. Newton's great feat was his integration of mathematical method with the findings of empirical inquiry, which he accomplished by linking the two together in the measuring experiment. What informs his science is not geometry, as was the case with Galileo Galilei, but algebra, and the status he accords mathematics in natural philosophy is not that of nature's underlying principle, as it was for Galilei, but that of an aid to visualization. Newton, unlike Francis Bacon, was systematic in placing empirical inquiry, in other words experimentation, at the service of *a priori* assumptions. In the quantifying study of nature through measuring experiment, theory is used not as a means of explaining known facts; on the contrary, theoretical criteria are applied in order to ascertain what can and cannot be regarded as an empirically known fact in the first place. It was here that Newton broke new ground, which is why his development of the measuring experiment as a qualitatively new method of scientific inquiry is undoubtedly his greatest accomplishment. His concept of scientific knowledge put an end to the dualism of mathematical abstraction versus sensory perception that still informed the works of both Galilei and Bacon. He thus formulated the fundamental criteria of technical-instrumental reason which would later be brought to bear in the technological advances of the late nineteenth century. Nature as we perceive it enters the *experiment* and the *production process* as something fit for purpose and emerges from them as something functional that can be made use of. Nature is functional to the extent that it is repetitive, constant and definable. Thus it provides a basis for both the exact sciences and for industrial methods of production which, having at first been organizationally and institutionally separate, began to fuse together from around 1880 onwards. What we know as 'big industry' grew out of the conglomerate of the rural putting-out system, organized long-distance and overseas trade, traditional crafts and state-owned manufactories.

The answer to the question 'Why was England first?' is to be found in the threefold combination of empirical recourse to nature as manifested in Newton's measuring experiments, in the creation of an internal

market as the principle of social synthesis and in the commodification of human labour. The Greeks did not succeed in linking their purely rhetorical proof with empirical proof and had no notion of systematic, controlled experimentation. This synthesis was not achieved until the late seventeenth century, by which time the socio-economic preconditions had changed beyond recognition.

The third turning point after which society and nature fused together to become a single hybrid whole placed the relationship between humans and this hybrid on a rational footing. It was at this point that Newtonian experimentation as a synthesis of nature and culture left the safe haven of the laboratory and took possession of society in the form of technology implemented in real time and on a scale of 1:1. The dualism of engineering as a form of social practice which shapes the world and science as theoretical reflection on that world was reconciled in the synthesis of technology. Whether it is Thalidomide, DDT, Hiroshima or Struthof, in each case the traditional distinction between the microcosm of the scientific laboratory in which experts experiment with theories and phenomena and the macrocosm of the larger political context in which non-experts bring values, opinions and passions to bear loses much of its validity. Society itself becomes a laboratory and the world an experimental field. The hole in the ozone layer, writes Bruno Latour, is too much of a social phenomenon to be truly natural, just as the strategies of CEOs and heads of state are too dependent on chemical reactions to be reduced to power play and lobbying alone. Nature and society, scientific action and everyday practice are to a large extent reconciled through the medium of technology.

'Big industry' took Newton's systematic linking of the axiomatic with the empirical out of the closed confines of the laboratory and out into the world. But because the principles according to which the world functions are so much more diverse than those that apply in the sterile atmosphere of the laboratory, unplanned and unintended side-effects were not long following. Ulrich Beck coined the term 'risk society' to describe this. DDT, for example, which in the laboratory had seemed such a promising insecticide, turned out to spawn DDT-resistant strains of mosquito when applied in the real world. There are therefore good reasons for proclaiming the end of the *Newtonian Age*, since the experimental set-ups

of the classical, mechanistic sciences cannot possibly do justice to the diversity, complexity and dynamism of social reproduction. Yet there are equally good reasons for proclaiming the culmination of the *Newtonian Age*, to the extent that the whole world has now become an experimental field for us humans. Not surprisingly, the old instruments that were put through their paces in the laboratory are no longer up to the task of solving the problems occasioned by this development. For the world has two salient and ineluctable characteristics which the laboratory does not have: uncertainty and multivalency. To be able to do justice to these, traditional academic science has no choice but to open up to society and to develop new, post-academic approaches in a process which is likely to be fraught with contradictions.

To avoid becoming socially irrelevant and meaningless, science must *first* prove itself to be receptive to external aims and approaches, including aims which have little to do with its own imperatives, by entering social fields of practice. By generating 'socially robust knowledge' it will change the form it has hitherto taken and henceforth have a *direct* impact on society. No longer reducible to its cognitive dimension, it will become an approach to problem-solving that is both cognitive *and* social. This transformational process will be most pronounced in those disciplines which until now have fallen under the heading of technical subjects and the social sciences. Out of these will emerge what in some cases will be completely new 'disciplines': so-called hybrid or secondary sciences. The inscribing of social aims, norms and values into engineering as a result of social practice is a fate shared by both the technical subjects that are steadily gaining in importance and the social sciences, which are likewise becoming weightier. Thanks to this common ground, they are now closer to each other than to the classical natural sciences. *At the same time*, the relationship between science and the public at large is increasingly defined by cognitive structures and processes similar to those which were once typical of the forms of communication used in both the natural sciences and the humanities. To the same extent as everyday social practice is becoming increasingly orientated to the knowledge-acquisition and problem-solving strategies which like all purposeful action fall within the ambit of traditional science, so the epistemic boundaries between scientific

knowledge and everyday knowledge are becoming increasingly blurred. To put it another way, society is liberating itself from the tutelage of academic knowledge not only by transforming (or marginalizing) it, but also by appropriating its own rules in its everyday practice – wherever this makes sense. Society, in other words, is scientizing itself and becoming *reflexive*.

This reciprocal process of interpenetration is interpreted in contemporary discourse on this subject – most of it in the English-speaking world – as the transition from academic (*Mode 1 Knowledge Production*) to post-academic science (*Mode 2 Knowledge Production*). To a certain extent, it could be argued that *Mode 2* constitutes a return to the concrete forms of knowledge anchored in everyday life with which the Mesopotamians and Ancient Egyptians concerned themselves – albeit on a higher socio-historical level. This certainly does not signal the sudden disappearance of those forms of abstract thought which since their emergence in Ancient Greece, and with Newton as intermediary, have continued to shape our understanding of knowledge ever since. But once safely ensconced in the concrete problem-solving strategies of everyday social practice, their old form of institutionalization loses its significance as a place in which universal truths are sought and found. Not even the very specific arithmetical arts of the Babylonians disappeared altogether, despite the Greek Miracle.

The dividing line drawn by the Greeks between society, the *polis*, and nature, was later erased by Newton. The human community, once an enclave in a non-human environment, is now well on its way to becoming a global society encompassing, and even usurping, all life on this planet. The distinction between the artificial and the natural which was so pivotal to the Greeks is diminishing all the time. The natural is being swallowed up by the sphere of the artificial and a new kind of ‘nature’ is emerging: a total artefact which with technology as its medium is at the same time ‘society’. The works of humans which have become the world and which not only affect us but have an effect through us have developed such a powerful dynamism – a dynamism capable of rendering all the old geographical and temporal limits null and void – that actions and decisions on an unprecedented scale are now essential. From Ancient Greece right up to the European Renaissance human knowledge and power were too

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limited for the distant future or the whole earth to be thrown into the causality equation. Instead of wistfully guessing at the possible consequences of their actions in an unknown future, our forebears' chief concern was the moral quality of what they were doing at any given moment, when what counted for most were the rights of their coevals. With technology to mediate between humans and their environment, however, human consciousness now has less to do with the individual than with the whole species. Its unparalleled causal reach stretches far into the future, flanked by a knowledge which, as incomplete as it may be, extends far beyond all that was previously known. And as our actions demonstrate very clearly owing to the sheer scale of their geographical and temporal impact or the irreversibility of their consequences, the thinking that had its roots in the small and manageable world of the Greek *polis* is gone for good. For Aristotle, the human capacity for *theoretical* thought made him superior to nature, even if as a purely contemplative tool, it inevitably remained extraneous to it. The emancipated *practical* intellect generated by post-Newtonian science as heir to the theoretical mindset of the Greeks, on the other hand, confronts nature not just with ideas and concepts, but first and foremost with *actions* which are certainly not extraneous to it. With a reach and depth that now encompass the entire biosphere, it is no longer compatible with the purely contemplative view of things, premised as it was on the unconscious functioning of the whole.

Prof. Arno Bammé

Director of the Institute for Advanced Studies on Science, Technology and Society (IAS-STS)

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