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Putting the "limits of science" into context

The provocative questions raised by Professor Steiner have enabled us, thanks to the Gulbenkian Foundation, to come together and to reflect on the limits of science. The theme of limits is not a new one. At the turn of the 20th century, both in mathematics and in physics, the leaders of the field began to worry that the most important problems might have been solved, implying that nothing more of real scientific significance remained to be done. The prevailing sense was one of having exhausted the known stock of open questions. Perhaps not surprisingly, the feeling of gloom at the prospect of having no exciting challenges left met with a wider cultural trend of exhaustion and of widespread malaise. This is a forceful reminder that science does not proceed in isolation from society. From time to time, fascinating parallels to broader cultural phenomena may appear, matched by developments that occur inside of science. Questions raised on scientific grounds may have a profound resonance in society and may even be influenced by societal trends, as has been argued for physics in the Weimar republic (Foreman, 1971).

Historical hindsight tells us what happened next. The complaints of having reached the limits of science were followed shortly afterwards by some of the most spectacular breakthroughs in physics and mathematics. The scientific answer to the anxiety of exhaustion consisted in a paradigm shift that left no stone of classical physics on the other. It brought about quantum theory, which vastly extended our understanding of the world as well as leading, decades later, to some of the stunning technological

innovations that populate our lives today. History therefore teaches us to be cautious about thinking that the limits of science being near. Often, a new set of questions or novel research technologies suffice to turn the curious scientific mind in a new and productive direction. It should therefore not come as a surprise that the answer given to Professor Steiner's questions during the symposium was a resounding "no". Quite the contrary, instead of seeing limits, we were exposed to exciting new questions that have arisen from recent work, leading to further study of phenomena and their interrelationships to be discovered.

Of course, Professor Steiner's diagnosis of the uninterrupted belief in unending scientific progress and the arguments that in his view seriously undermine this belief went much deeper. They follow the tradition of European cultural critique of science that reached one of its culminating moments in the 30s of the past "short century", as Eric Hobsbawm has called it. I refer here especially to Edmund Husserl's *Crisis of the European Sciences*, published in 1936 at a time when the rise of the dark forces of National Socialism in Germany and other forms of totalitarianism elsewhere could no longer be ignored. For Husserl, the crisis of European science existed in the fact that the rationality embodied in science had nothing with which it could oppose fascism and other forms of brutal repression (Husserl, 1936). It is a cultural critique that has lost none of its pertinence, since it reveals in a shocking way the limits of rational thought in its – supposedly civilizing and humanizing – impact on society.

Rather than follow in this – and it would be impossible anyway to attempt to match Professor Steiner's erudition and eloquence – I want to explore some of the more mundane problems that science faces today: a general public that often appears frustrated and distrustful of science, that "talks back to science" and questions the very benefits that scientists and engineers are convinced they bestow upon society. The broader public clearly does not share the

belief in a more or less unlimited scientific progress, since many of the uncertainties that come with it remain unanswered. I agree with Lewis Wolpert and the title of his book, *The Unnatural Nature of Science*, that the lay public may think there is something "unnatural" in what scientists do, but I also think that the cognitive gap that Wolpert addresses is vastly overestimated. To further "the public understanding of science", as the movement to overcome the cognitive gap is called, has not brought the expected results. Providing more information and imparting more knowledge about science has not resulted in greater acceptance of science. While people do learn and appreciate the science that is of direct concern to them, they fail to show the same enthusiasm in other respects that scientists do. The gap is not so much a cognitive gap, but one of actual human experience confronting the expectations, hopes, and fears raised by science in the making.

To illustrate my point, let us briefly move back to the beginnings of modern science in the 17th century, to the so-called scientific revolution. I say "so-called", because it is widely taken for granted today that a "scientific revolution" occurred that had its heroic figures and institutions like the Royal Society and a handful of others. Yet, historians of science working on this period have started to question whether there ever was such an event as a "scientific revolution" (the term itself dates only from the 1930s) or a single institution that helped to bring it about. Instead, the newly emerging picture is one of a much more varied, geographically dispersed landscape in which various groups of modernizers, institutions, and associations held beliefs and became interested in the pursuit of new ideas and projects, extending unevenly in time and space over large parts of Europe.

The historian of science John Heilbron distinguishes between revolutionary ideas that can occur any time and everywhere, on the one hand, and revolutionary situations, on the other. As in politics, revolutionary situations arise also in science when the legitimacy

of the previously accepted order and ways of "doing things" are questioned and eventually overthrown. This is what happened in the 17th century, when the modernizers started to turn away from Aristotle and other ancient texts. They became interested in Descartes' program of inquiry, following the method he had proposed. Others were attracted by the pragmatist vision of Francis Bacon that science could be used to improve the lives of people or had other ideas how to put an experimentalist approach in the inquiry of "mechanical philosophy" to practical use. The modernizers were dispersed throughout Europe and were to be found in provincial places in Germany, France, Naples, and elsewhere. They included lawyers and doctors and those who were keen to set up their own academies. They formed new alliances. But a revolutionary situation does not amount to an actual revolution. Its making was a much longer and convoluted process. In the later 17th century serious savants began to question the inspired authorship of the bible and made the Old Testament the work of several anonymous hands. The contemplation of the existence of men before Adam caused confrontation everywhere (Heilbron, 2007). Although we regard the outcome of this revolution as glorious, maybe the process is yet unfinished.

United by their enthusiasm for a new program and adopting an empirical approach towards probing reality, they firmly believed that the newly generated knowledge would allow science to deliver on the utopian expectations they held. This shared belief was not yet underpinned by any evidence that science would indeed be able to deliver what we have come to expect from it today. The Lisbon and Barcelona goals of investing 3% of GDP in R&D was light years away and so was the confident assumption we can make today, namely that without investment in fundamental research there will be no further economic growth. What happened in the 17th century with the institutionalization of science went far deeper

than embracing a utilitarian means/end scheme. Free inquiry and uninhibited access to the production of new knowledge, unimpeded by Church, Monarchy, and the State, became a social value in its own right. When we are mired in the controversial discussion of values today, we tend to forget that free scientific inquiry is a basic social value, promulgated by the modernizers of a widespread scientific movement in the 17th century, a value that must keep its firm place among the other values that we try to accommodate today.

The changing image of Nature: Isis unveiled

Today Nature is high on the political agenda, even if it does not come under this name. The discussion of climate change, its causes, and its consequences, is ubiquitous in national and international policy fora. Barely emerging from a string of controversies on genetically modified organisms, the next controversies over the risks associated with nanotechnologies are in the making. Human embryonic stem cell research continues to meet with fierce opposition on religious and political grounds. Decision-makers and citizens alike are thus dealing continuously with certain aspects of how to intervene, manipulate, and change Nature. The image of Nature is thereby also changed. Nature appears in the form of the image of our threatened planet Earth, the famous icon of the photograph taken from outer space. But the image of Nature is also changed by the flood of pictures that invade public space and perception. They allow us to see the inside of our bodies and our cells or to follow the developmental stages of an organism. Nature is no longer only what is “out there”, but we are intervening in and manipulating the Nature inside us – our cells and gene sequences, our immune system and perhaps even our germline – in an unprecedented way. It has become obvious that “to know life, is to remake life”, since, already on the molecular level, no intervention is possible without altering “natural” processes.

Our relation to Nature has always been contradictory. Nature has been perceived as threatening and terrifying as well as sweet and consoling. It was to be conquered and also to be protected from the impact of human conquest. It is perceived as being fragile and therefore increasingly appealing to human stewardship, while inviting ever more clever interventions at the same time. Above all, Nature is no longer regarded as being immutable. It has ceased to be the order that was once seen to be above and beyond the reach of the political and social order, since the laws of Nature were exempt from any attempt to subject it to political will, thus creating the necessary space of autonomy in which scientific creativity could unfold. Even Nature's laws are subject to the laws of evolution, while human intervention operates on evolution on much briefer time scales. What entire civilizations believed for thousands of years, the immutable order of Nature, shaped symbolically by the different religions, has vanished within a few decades.

This provokes resistance and creates a vacuum. There are attempts to re-moralize Nature and to invest it with a moral authority according to which what is "natural" is also considered to be good. We have witnessed the rise and spread of creationism and of intelligent design in the wake of what has been called "the return of religion". This is certainly a much broader phenomenon, but it thrives in the vacuum that has arisen by the disappearance of natural order as a point of reference and orientation for human conduct. Intelligent design can be interpreted as a response to evolution without a telos in the wider context of a changing image of Nature stripped of its moral authority. One of few impressive books in the ongoing debate about science and religion is by Philip Kitcher, a philosopher of science. He takes the arguments of the proponents of I.D. seriously and subjects them to meticulous scrutiny, only to show that they have been extensively debated before in the history of science and subsequently dismissed on the

basis of very strong arguments and empirical evidence. Kitcher's reproach to I.D. is that it deliberately ignores the history of this skeptical questioning and does not accept its outcome (Kitcher 2006).

Another little book probing into our relations with Nature is by Pierre Hadot, a classicist. He writes on a fragment bequeathed to us by Heraclites. The rather obscure sentence is captured in Greek by three words, *phusis kruptesthai philei*, which are usually translated into English as: Nature likes to hide herself' (although Hadot comes up with other fascinating translations). Starting from this fragment, he traces the iconographic representation of Nature from antiquity onwards. Nature is usually depicted as a woman, often a goddess – hence the title the book *Le voile d'Isis* - with Man attempting to unveil her in order to reach behind the veil and to appropriate her secrets. Hadot concludes that in our age this image of Nature has ceased to hold its power over the imagination. Today, only philosophers speak about her secrets any more when pondering the essential questions of humanity (Hadot, 2004). I concur with Hadot.

The attempts by scientists to unveil Nature by ruse rather than force, by setting up clever experiments and employing cunning techniques for her manipulation, is the way science is practiced. We have numerous testimonies from scientists, affirming the joy that results from overcoming Nature's perceived reluctance to yield her secrets. Today, the iconic representation of Nature as a veiled goddess has disappeared, but she also no longer seems to hold any secrets. The reasons lie partly in the ability of science to create an unending stream of new epistemic objects (and we have seen plenty of good examples during this conference). They emerge from scientific practices and the employment of new research techniques and technologies. In the life sciences, for example, new entities are being created with techniques like those allowing us to remove the cell nucleus and fill it with a genome

taken from the same, or even another, species. These new entities, hybrids and chimeras, are epistemic objects that acquire visibility. They become part of the flood of images that the ever more powerful scientific visualization techniques put at our disposal. As images, they circulate freely in the public sphere where they associate equally freely with other images of the private or collective imagination. No one, neither scientists nor even the media whose role is indispensable in the distribution of these images, is in control of the effects they produce. By rendering them visible, the newly created entities are no longer hidden under the veil of Isis. Nature has, so it seems, finally revealed her secrets.

But there is a price to be paid for Nature's new visibility. The scientific objects thus created are taken out of their original context. They are abstracted, isolated, and reconfigured, made mobile in order to enable their insertion into another context. Freed from their original context, they can travel. They can be marked and tagged and stored in bio-banks for future use. In some cases, ownership is established over them in the form of patents and other intellectual property rights. The price to be paid for the new visibility and abstraction from context is that they become detached from human experience. Let us take the example of human-assisted reproduction techniques, by now a widely accepted and routine practice. In every society, people have had knowledge about kinship relations and human reproduction, even if this knowledge was sometimes scientifically wrong. But they lived in a world in which to make a child required more than a mother and father. It was a world in which gods could intervene and virgin births were possible or where the man seen in a woman's dream could become the father of her child.

Compare this to the strict protocol according to which every step of an *in vitro* fertilization has to be meticulously followed and documented. This is done in the name of transparency, another governance principle to render visible what was often hidden

before. It is required to know how many mothers and fathers are involved in the process, their respective rights and obligations need to be specified, and their status and relationship to each other and to the child must be defined. Knowledge that for thousands of years has been embedded in human experience with all its shades of ambiguity and with boundaries blurred between the biological and social is turned into something that is scientifically correct, publicly visible, and tractable at every step. It needs to be regulated in order to become transparent. Or take the example of Ritalin, a drug widely prescribed now in the US against the ill-defined symptoms of ADD, attention deficit disorder. Ritalin acquires its status as the hallmark of parental control over unruly children since its effects on the neural networks of the child can be made visible and hence become evidence for its effectiveness. The visibility of the drug's effects, however, eclipse other effects of parental control that may also impinge or even have more long-term effects on the child: the school that the child is sent to, the peers it associates with, exposure to TV, the influence of siblings, and a host of other factors whose effects on the neuronal network cannot easily be shown and thus are readily dismissed. By having revealed Nature's presumed secrets and rendering them fully visible with the help of powerful visualization techniques, the daily human experience in which previous knowledge was embedded is rendered invisible and becomes irrelevant.

The gap between scientific knowledge and everyday experience, between science rendering publicly visible the processes and procedures through which new epistemic entities are created and abstracted from their original context and the messy, ambiguous social world with which they now intersect is not primarily a cognitive one. The gap that has opened up is between human experience and the always messy accommodation of knowledge and practice therein and the impeccable and unassailable scientific visibility to which Nature's previously held secrets have been

exposed. Visibility has consequences that are both epistemic – the illusion of total control – and societal.

Limits of science or societal constraints of science?

As you may have guessed from my remarks, the only limits to science that I see are those imposed by our biological evolution and the culture into which we are born and in which we live. Historically, the perceived limits to science have often been overcome by shifting towards a different set of questions and by adopting a novel perspective, frequently triggered by new research tools. Instead of limits, I prefer to speak of the various constraints that science faces. They range from the incompleteness of knowledge that we possess today to the uncertainties inherent in any process of research where the outcome remains unpredictable.

Increasingly, however, constrains stem from the – often contradictory – demands and expectations that various social groups and citizens, industry, business, and the state articulate regarding the enormous potential that science and technology offer today. As with any other potential, its eventual realization proceeds through selective elimination of a number of options. This process is a highly contingent one, but the emerging new social forms must prove sufficiently robust in their various scientific, technological, social, cultural and economic dimensions, and mutual interactions. Robustness is one of those design principles that is crucial in the development of an organism as well as in the emergence of a technical and social system. Since it is never possible to realize the potential in its entirety, the elimination of options is a precondition for its realization. Constraints function to shape the new newly emerging assemblies of new ideas and reconfigurations of technical, social, and organizational solutions.

In an act of utter simplification, let me mention just three of the constraints that I regard as important in the process of societal

accommodation and integration of today's potential of science and technology. One of the main driving forces of science is curiosity. It is an emotion, or even a passion, with which all human beings are born, equipping us to explore the world around us. As every parent knows, something happens to this inborn curiosity when children are sent to school, but curiosity nevertheless manages to survive and to thrive in other ways. It has become institutionalized in two areas of social life: in science and in art. Institutionalization means that a space of (relative) autonomy has been granted to a group of practitioners and their institutions. Allowing them to follow where curiosity leads them means they can explore the hitherto unknown realms of knowledge (or ways of knowing, seeing, and doing). They will come up with findings that are unexpected and with discoveries or inventions previously not known. In following its own impulses, curiosity pleads for a kind of immunity from societal control. Curiosity as a passion is amoral – not immoral – because it does not know where it will end up and yet pursues its paths. Therefore, all societies have set up attempts to tame curiosity. They vary enormously, however, in whether they succeed in striking the necessary balance: taming curiosity too much will stifle scientific (or artistic) creativity, while letting it run wild is not acceptable to society (Nowotny, 2008).

One of the strands of societal efforts to tame scientific curiosity is economic, consisting in attempts to channel curiosity into those fields of creative research that promise economic returns. We see a marked tendency of private funding moving into those areas that look economically profitable. Many of these efforts are reflected in a societal discourse that I call the *innovation discourse*. This is not the place to explore it further. Another taming effort arises from the heightened level of democratization that liberal-democratic societies have reached in the past decades. Beginning with the environmental movement, novel demands for a more participative and deliberative democracy were raised and more accountability is being asked from all institutions, including science. One of the

arguments is that not everything that scientists and technologists come up with should be realized. Especially the real or perceived risks associated with new technologies need careful scrutiny, assessment, and management. The public discourse that captures these taming efforts is the *risk discourse.* It acts as a constraint on many technological developments and proposed solutions, challenging the ability of a technology that could shape society. Again, I cannot pursue the theme further.

The third constraint appears in the guise of a public discourse that has led to the establishment of ethical review boards and numerous committees dealing with the moral and ethical issues that creative research bring to the fore. This is the *value discourse*. It is arguably the most recent and perhaps also the most challenging constraint that science faces. Its difficulty is linked to the fact that Nature is no longer seen as a source of moral authority. At the same time, it has become clear that science cannot answer many of the most pertinent questions that have arisen in the context of the latest achievements of the life sciences. Questions like “when does life begin?” or “what is an embryo?” figure prominently in the ethical and moral discourse. They refer to values about which science has nothing to say. Answers can only come from a civil society that has become inherently pluralistic and therefore must seek to find a viable consensus on issues that are likely to divide. Moreover, values are often shaped by culture and historical experience and they are bound to change as society continues to evolve.

Let me conclude by emphasizing that science is well-advised to take these constraints seriously and to engage in an open and honest way in all of the three public discourses in which it features so prominently. Science does not face presumed limits, it faces very real constraints. While limits impede, constraints challenge the creativity and imagination of science and technology to come up with solutions and results that – if appropriated and integrated

into everyday life and experience again – will become a powerful driving force in the ongoing co-evolutionary process with society.

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