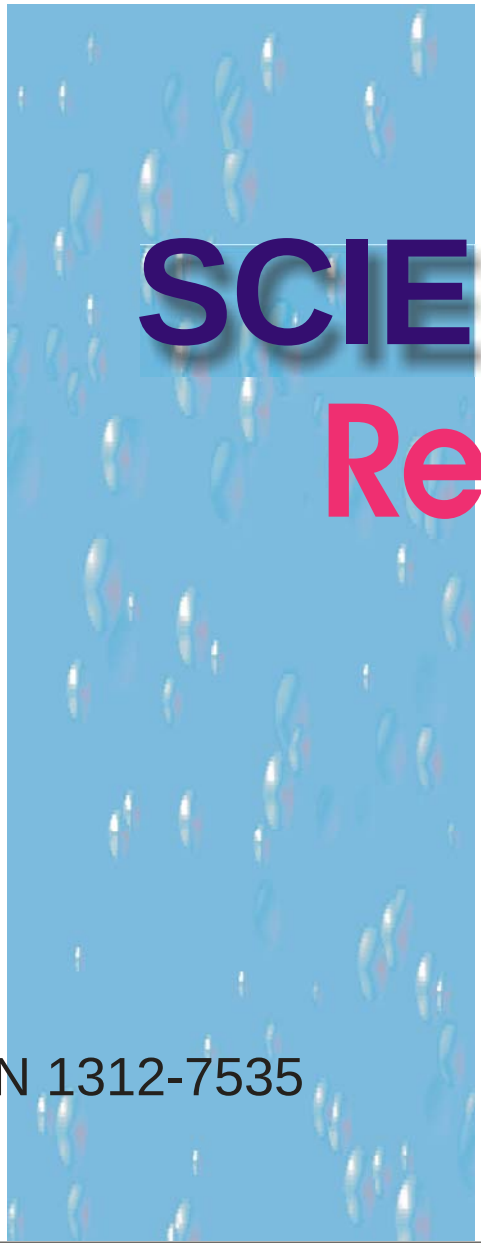
SOUTH-WEST UNIVERSITY
·NEOFIT RILSKY·
BLAGOEVGRAD, BULGARIA

VOLUME 5
2007



SCIENTIFIC Research

ISSN 1312-7535

ELECTRONIC ISSUE

Jürgen Mittelstrass
Center for Philosophy of Science
University of Constance
D-78457 Constance
Germany

The Limits of Science and the Limitations of Knowledge*

All of us have had the sobering experience of (really) knowing only a few things and not knowing a great many. All of us become painfully conscious of our intellectual limits both in private and professional affairs, that is, conscious of what we do not know and probably never will. Brains, it seems, have only a finite capacity to absorb, and life is short and for that reason alone unsuited to dreams of limitless knowledge - even ignoring the fact that one can imagine much more pleasant activities than stuffing oneself anew everyday with knowledge. Although Aristotle once said that all men, by their own nature, strive for knowledge (*Met*. A1.980a21), he certainly did not mean the bookworm and the secluded scholar. Curiosity, which according to Aristotle is the form in which the human striving for knowledge is usually expressed, is more than scientific curiosity; it asserts itself in daily life, in travel, in experiencing the unusual and strange, in confronting closed doors and keyholes.

What is this peculiar feeling of confronting *limits* of knowledge, which unlike political and geographic boundaries are apparently not easy to cross? Is the occasional individual displeasure at knowing too little in the end the expression of a universal human incapacity, namely the incapacity to know everything, that is, to comprehend everything that exists in scientific form or even in non-scientific form?

Thinking this way already makes you half a philosopher. Indeed from the beginning it has been one of the favourite occupations of philosophy not only to ask about the conditions of origin of knowledge (how knowledge arises, what it presupposes) and about the essence of knowledge (what distinguishes knowledge from opinion, for instance), but also about the *limits of knowledge*. Normally this meant limits of knowledge in the sense that the capacity and organisation of the human understanding is simply not sufficient to answer all the questions that can be posed, nor to explore everything that can in any way be thought to be explorable. Human understanding is conceived as something like a lamp (or a search light) - knowledge reaches as far as its beam of light; beyond the reach of the beam lies darkness. Knowledge so to speak limits itself because the understanding is limited in its reach. And where it gropes about without light, it is blind, it fails to grasp its object and must abandon the field to others - mystics, esoterics, dreamers, all of them equipped with supposedly superhuman abilities. These businesses are booming again at the moment. An understanding that confronts its limits longs for the more simple, at least for the intellectual less taxing approaches to limitless knowledge - and the smaller the understanding the greater the longing.

But these are not the limits that I want to talk about, nor do I mean the limits of speculative or speculating knowledge, but rather the limits that really or perhaps only apparently arise for our *scientific* understanding. Indeed, the limits of knowledge are not only a theme for the

everyday understanding or for philosophy but also for science itself, at least - now as reflection on the limits of science - at the point where science begins to become philosophical, that is, to view itself with philosophical eyes. This does not happen often, but it does occasionally happen.

My paper has four parts. First I shall pursue the question whether science is completable; second I shall adduce arguments for its incompletability; thirdly I shall consider factual and ethical limits (the latter using a concrete example); and finally I shall argue for practical but against theoretical limits.

Completed Science?

My introductory remarks may have sounded rather negative or at least regretful, as if we were obliged to submit to the inevitable. As a matter of fact, wherever we speak of the limits of knowledge, we become small as a rule, we experience our own limits, we draw anew the boundaries between the human situation and the divine. In the Middle Ages the limits of knowledge were always boundaries between the knowledge-seeking human and an omniscient God. Where the philosopher stopped, for instance, at the distinction between the natural and the supernatural, there the theologian began, and where he got stuck, for instance, with the promise of beatific vision after death, there frolicked the mystics, magicians, ecstatics and elves. Even Faust, as we know, did not get much farther (and not just because of Gretchen).

Opposed to these notions of the limits of knowledge nourished by negative experiences or too-far-reaching reveries, there is a quite different notion that is even very positive, namely the notion of a *completion* or at least completability of knowledge. Limits of knowledge - that could also mean that knowledge comes to a standstill when *all is known*, when the world has given the human understanding knowledge of all that there is to know, when all corners have been searched, all riddles solved, all problems cracked, all Gordian knots cut and all things that seem impossible are provided with eggs of Columbus. Limits would lose their intimidation or their disappointment; they testify not to the failure of human understanding but rather to its triumph.

As a matter of fact, the history of science is full of expectations, prophecies and assurances in this direction. I want to present a few examples. In 1754 Denis Diderot, a brilliant writer, philosopher and (along with the mathematician d'Alembert) editor of the great French *Encyclopaedia* (published from 1751 to 1780) wrote: I can almost assure you

that in Europe within the next century we shall not count three great mathematicians. This science will stand quite still where it was left by the Bernoullis, Euler, Maupertuis, Clairaut, Fontaine, and d'Alembert. They have erected the Pillars of Hercules. We shall not pass beyond them. Their works will continue through the centuries to come just like the Egyptian pyramids, whose stones, covered with hieroglyphics, invoke in us an awful idea of the power and resources of the men who erected them (Diderot 1875-1877, II, 11).

Mathematics and physics (the names listed stand for both) may come to be completed; science, like the pyramids, would become a grand exhibition piece visited by science tourists without a scientific future of their own.

American physicists in the 1970s expressed similar thoughts to the National Academy of Sciences:

It is possible to think of fundamental physics as eventually becoming complete. There is only one universe to investigate, and physics, unlike mathematics, cannot be indefinitely spun out purely by inventions of the mind. The logical relation of physics to chemistry and the other sciences it underlies is such that physics should be the first chapter to be completed. (...) Some unsolved problems might remain in the domain earlier characterized as organized complexity, but these would become the responsibility of the biophysicist or the astrophysicist. Basic physics would be complete; not only that, it would be manifestly complete, rather like the present state of Euclidean geometry (Bromley *et al*. 1972, 80).

In the same vein, David Lindley in 1994 spoke of the end of physics (Lindley 1993), albeit with reference to the problem of a transformation of physics into a sort of l'art-pour-l'art mathematics. And Steven Weinberg says much the same:

My belief in a final theory rests (...) on the fact that our picture of nature has become ever more simple. (...) Of course, the mathematics has become more complicated, more difficult, more abstract. But the physical principles have become more elegant, more natural, and above all there are fewer of them. (...) And progress in the direction of simplicity must come to an end at some point (Weinberg 1999, 192).

In this opinion, too, it is clear that the end of science is not the expression of incapacity in the sense of limits given to or forced upon human understanding; rather it can also be the expression of the achievement of the human understanding, indeed of its triumph over nature. Such limits of knowledge are filled-out boundaries; beyond these boundaries lies nothing that could be of scientific interest or which could present new tasks for science. America can only be discovered once (even though there might still be others who also consider themselves to be the discoverers), and the same holds, one would think, for nature. Once nature is discovered, once nature's laws are recognised and codified in textbooks, once everything has become simple in Weinberg's sense, there is nothing more to discover, and knowledge comes to a standstill. It can no longer be disappointed and replaced by better knowledge. It is no longer on the agenda of human understanding.

The extent to which such notions have gained currency was made clear by John Horgan, former editor of *Scientific American*, whose book *The End of Science* created a furore (Horgan 1996). According to Horgan, the end of science is near in the sense that its success is its own end. According to him, all great discoveries have been made and all great theories written, all scientific questions answered; what remains is only scientific mopping-up, calculating decimal places, or didactic variations on a theme that can no longer be changed anymore. Science, in other words, is complete, and the human understanding has to look for new tasks and challenges beyond science. A peculiar notion.

The Sphere of Knowledge

To the picture of a completed science, whose boundaries would be the boundaries of an impressive empire, we can oppose a different picture. It is the picture of a science that perhaps does not accord with the fantasies of the philosophers of science, who are infatuated sometimes with the infinite fallibility of science, sometimes with visions of its perfection, but it does accord rather well with the reality of science. This reality, known to every scientist, tells us that for every scientific problem that is solved new problems arise, that for every question answered new questions are posed, that for every insight gained a new ignorance is revealed.

And that this ignorance does not merely refer to further decimal places is a very common experience of daily scientific work. We are dealing with questions like: How does a single cell develop into a complete organism? How did the galaxies arise, how did the whole universe arise? What goes on in black holes? What is (between philosophy and neuroscience) consciousness? One question succeeds the other and all of them are far from answered. We can visualise the problem in a picture that takes up a metaphor already used (in another context) by the philosopher and mathematician Blaise Pascal (Pascal 1963, 525-528)[1], and employed again (in our context) by Herbert Spencer (Spencer 1890, 16f.): Scientific knowledge is a sphere floating in a space of ignorance and growing ever larger. As the sphere grows, its outer surface grows, too, and thus the surface of contact with ignorance grows.

This picture, which sees no limit to knowledge, can be interpreted in two different ways: a pessimistic version and an optimistic version. The *pessimistic* interpretation says (and here a small reminder from mathematics class may be useful but mercifully not absolutely necessary): If it is the *radius* of the sphere that represents knowledge, then, as the sphere increases in size, the area of the surface increases faster than the length of the radius, namely, as the second power. Thus ignorance grows faster than knowledge, or in other words: Scientific research produces a faster growth of ignorance than of knowledge. This is a startling but - at least with regard to the elementary mathematics involved - correct result. In the *optimistic* version it is not the radius of the sphere that represents knowledge but its *volume*. As the sphere grows, its volume grows faster than its surface, namely as the third power of the radius. In this case (scientific) research still produces ever more ignorance, but knowledge is growing faster than ignorance.

Whichever interpretation of this sphere of knowledge one chooses, one thing is clear in this picture, and probably also in the experience of those scientists who do not deal immediately with the grand theories of their disciplines or with the grand design of all knowledge: The growth of knowledge does not make the world of the unknown, of the not-yet-explored any smaller, but rather larger. Research tasks grow with (growing) knowledge; there is no limit to the unknown. Rather it is the proximity, the constant contact to the unknown, sometimes - not only in the minds of philosophically minded scientists - the scent of the unthinkable or unimaginable (or what is taken to be so) that keeps science under its spell, that constitutes its stamina, even where what is already known seeks to present itself as knowledge on the brink of completion, or seems to be unreachable with the available means, or even seems to be inaccessible in principle for epistemological reasons. Here the limits are really dissolved, and (scientific) knowledge presents itself as essentially limitless. Neither are there boundaries with which the scientific understanding collides and gets a bloody nose, nor are there boundaries that form the contours of something completed. Is then the answer to the question, "Are there limits to (scientific) knowledge?" a simple: No?

Limits of Science

Whoever gives a negative answer to the question as to the limits of (scientific) knowledge draws not only the vehement opposition of the proponents of the finitude thesis - the realm of the (scientifically) knowable is finite, therefore knowledge itself is finite -, he also opposes in a certain sense the everyday understanding and the philosophical understanding as well. For the everyday understanding, the existence of limits is something completely normal. Luck has its limits, skill in any area is limited by lack of skill at some point, alongside fulfilled wishes there are also unfulfilled ones. For the philosophical understanding, especially when it

still sees itself as allied with the theological understanding, the existence of limits is something quite plausible and even alluring - where there are no limits, there is no reflection, no deep contemplation of limits; and in such reflection and in such contemplation the philosophical understanding is particularly strong.

Historians of science see this too, in as much as they connect science with scientific progress. In a book on the idea of progress from 1932 we can read:

Science has been advancing without interruption during the last three or four hundred years; every new discovery has led to new problems and new methods of solution, and opened up new fields for exploration. Hitherto men of science have not been compelled to halt," (As you see, women in science had not yet been discovered in the 1930s.) "they have always found means to advance further. But what assurance have we that they will not one day come up against impassable barriers? The experience of four hundred years, in which the surface of nature has been successfully tapped, can hardly be said to warrant conclusions as to the prospect of operations extending over four hundred or four thousand centuries. Take biology or astronomy. How can we be sure that some day progress may not come to a dead pause, not because knowledge is exhausted, but because our resources for investigation are exhausted - because, for instance, scientific instruments have reached the limit of perfection beyond which it is demonstrably impossible to improve them, or because (in the case of astronomy) we come into the presence of forces of which, unlike gravitation, we have no terrestrial experience? (Bury 1960, 3f.).

Here limits in the negative sense appear, limits as unwanted limitations on (scientific) knowledge.

Philosophy of science discusses these questions, mainly in relation to the natural sciences, in the form of two theses (see Rescher 1978, 6ff.): (1) The thesis of the complete or asymptotic exhaustive survey of nature. This accords with the thesis of finitude, if we understand finitude as completion. According to this thesis, the history of scientific discoveries is either absolutely finite or at some point enters into an asymptotic approach to what can be known at all. The place of innovation would be then taken by mere elaboration and further precision. At some point science would have no future any more because, again, everything discoverable would have been discovered and everything would have been explained that was in need of a scientific explanation, and even the mopping-up operation, the calculation of further decimal places, the classification of additional cases that add nothing essentially new would gradually come to a close. (2) The thesis of the complete or asymptotic exhaustion of information capacities. This is the thesis that our historian of science propounded. According to this scenario, scientific information capacities are either absolutely finite or at some point enter into an asymptotic approach to absolute information limits. Here, too, elaboration and further precision would replace innovation. Science would have exhausted its own possibilities for research and articulation and an "information barrier" would arise between science and nature, irrespective of whether investigation of the latter had reached a point of exhaustion. To overcome this barrier we must turn to science fiction - travelling with Star Trek and the space ship Enterprise off into scientific Wonderland.

The question, "Does (scientific) progress still have a future?" is thus only an apparent paradox. The question is, however, in fact unanswerable within the framework of the cited theses. This is evident, even without invoking once again the picture of the sphere of knowledge, from the connection between our research activity and our *goals*. If research is characterised

not only by means of the states of research which have been achieved within individual disciplines (say, with regard to answering scientific questions) but also by means of the (internal and external) purposes associated with it (and this is doubtless the case, as a comparison of Newtonian physics with Aristotelian physics, each of which pursued completely different purposes, makes clear), then the notion of an end to scientific progress would include not only the assertion "We know everything (that we can know)" but also the assertion "We know all the purposes (that we can have)." The number of purposes, however, is unlimited, even if we take into account the limits to a scientific transformation of the world and of humankind. In other words: in order to answer the question, "Does (scientific) progress still have a future?" we would in some way already have to know what we do not know yet - what only progress or its failure to materialise could show us. In this sense then there are no limits to science. This applies also to the question of whether our sphere of knowledge rolls finitely or infinitely onward.

There is one thing that we can nonetheless know: our *resources* are finite. They are long since insufficient to provide science with what it needs in light of its growth and its wealth of ideas. There is also reason to believe that the higher the state of research reached, the more means must be applied to make equivalent advances (Nicholas Rescher [1978, 79-94] calls this Planck's principle of increasing expenditure). At one time a few silver coins were enough to move the world, even the scientific world; today it takes a large percentage of the gross national product of a country. Think of the construction and running of large particle accelerators in physics that devours huge sums in order to isolate one single further building block of the universe or to add further decimal places to measurements that are considered significant or to confirm experimentally some constants of nature. Thus the discovery of the top quark, the last of the quarks according to the standard model of particle physics, demanded the employment of a group of 450 scientists from 35 institutes for about twenty years and devoured thousands of millions of Dollars. The question of marginal utility may be posed in science, too.[2] However, propositions and judgements of this kind depend not unproblematically on a *qualitative* and *quantitative* evaluation of (scientific) innovation. In the last analysis it is not the mass of scientific production which today creates more and more problems in distinguishing between relevant and non-relevant results, but the quality of research that counts, and is the essence of scientific progress. In any case it is true that progress limits itself if its costs grow faster than its results.

There are other limits that can be added, for instance, *ethical* limits. Such limits to scientific progress become evident today especially in the area of reproductive medicine and genetic engineering. The question is whether, driven forward by scientific progress, we are also *allowed* to do everything that we are *able* to do, for instance, intervening in the germ line of humans or cloning humans. Ethical limits to scientific (and technological) progress generally are drawn wherever these, instead of improving the living conditions of humans, turn against us, threatening and deforming us. A threat to or deformation of humans exists wherever humans are seen only as means not as persons, wherever, speaking with the German constitution, the inviolability of the dignity of man is no longer guaranteed. The physicist Max Born, who did foundational work in quantum theory, remembered:

In my youth it was still possible to be a scientist without paying much attention to the practical applications of science in technology. To-day this is no longer possible; for natural science is inextricably entangled with social and political life. (...) Nowadays every scientist is a member of the technical and industrial system in which he lives. Therefore he must also carry part of the responsibility for a rational use of his results (Born 1962, 63).

Albert Einstein was somewhat more sceptical on this score in 1948: "The tragedy of modern man lies in the fact that he has created conditions of existence for himself for which he is unprepared by his phylogenetic development" (Einstein 1975, 494). What he means is that the impulses of the brain stem are stronger than the controls of the cerebrum.

In contrast to the (usually rather philosophical) question of the limits of knowledge, the question of the limits of scientific knowledge in particular cases is concrete, and thus, in the sense of real limits, it is also answerable. In the case of economic limits we are dealing with *factual* limits (there is not enough money); in the case of ethical limits we are dealing with *normative* limits (the obligatory and the permitted limit the possible). The fact that questions of economic and ethical limits are not always easy to answer depends on the fact that, in the case of economic limits, decisions as to priorities have to be made, and, in the case of ethical limits, we encounter a mixture of science and world view. Humans are not perfect beings, neither in regard to epistemology, nor with regard to economics and ethics.

A current example of the question of ethical limits may help to clarify this, namely, the current debate about cloning, in particular about the possible production of human clones (see Mittelstrass 1999). This debate began with such a shock and has been pursued so hectically because the new potential of genetic technology has suddenly made possible something that once seemed to be forever beyond the horizons of human intervention, namely, the fabrication of a human being. It seems that boundaries drawn by nature itself are disappearing.

Producing clones means producing living creatures with the same genetic information, either by exchanging cell nuclei or by dividing embryos at very early stages of development. Cloning thus means that the genotype - that is, the primary hereditary material of two (or more) individuals - is the same - which does not mean that their phenotypes (the aggregate of external traits resulting from the genotype) are identical. Not all traits of an organism are wholly determined by the effects of the genes. The developmental conditions of an organism, including, in the case of humans, social and cultural conditions, also play an important role. In the case of identical (monozygous) twins, this has long been known. This makes it clear, by the way, that the production of clones is a thoroughly natural process; it is a replication mechanism that is quite common in nature, for instance, in bacteria and other microorganisms. What is new is only that this method can now be "artificially" applied to higher vertebrates. And what is of ethical significance is whether this kind of procedure may permissibly be applied to humans.

As a rule, especially in the arguments of theologians and philosophers, cloning humans is taken to be a severe infringement of human dignity, inasmuch as the *natural individuality* of humans is abrogated. On the one hand, an argument may be adduced appealing to the special relation in humans between two things, which in German are distinguished as *Leib* and *Körper*,[3] that is, between the body as experienced phenomenologically and the body as a physical object. On the other hand, claims can be made about the character of humans as *ends in themselves*, who are to be protected from any kind of instrumentalisation - such as the cloning of humans is taken to be. These are strong words that seem to be able to overturn any counterargument.

Nonetheless, it should first of all be recognised that there is an infringement of human dignity neither in the identity of the genomes of two people - identical twins are individual persons and bearers of human dignity - nor in the procedure of cloning itself. In this procedure, no person yet exists whose dignity could be attacked. On the contrary, as was made clear by a

recent intervention, an infringement of human dignity occurs only through "the fact that a human being is produced as a means to an end that is not he himself, and that to this purpose, genetic identity with another human being is imposed on him" (Eser *et al.* 1997, 364-365). This would be the case, for instance, in cloning for the purpose of producing donor organs or tissue - that is, establishing an individual organ bank. But this notion - the clone as a storehouse for spare parts - is absurd, since the clone, just as a natural twin, is of course an individual with all the rights that we associate with individuals. The fact that one (the clone) is just like the other (the cloned) is a circumstance that we have long been accustomed to in identical twins, whereby no one imagines that the one is (only) there for the other. Twins, too, are persons just like non-twins, and thus enjoy all the protections of the laws that enlightened societies afford to individualities.

There are, furthermore, a number of arguments that speak in favour of cloning or the affordance of such reproduction possibilities. What if the cloning procedure is used as a method of treating infertility or is applied to avoid serious hereditary illnesses? Even a widow's wish for a child very much like the one she has just lost (Kitcher 1997, 336) might be a permissible reason for applying the cloning procedure. In such cases, there is an infringement neither of the principle of the inviolability of human dignity nor of the closely connected determination of man as an end in himself, as formulated for instance in Kant's second form of the Categorical Imperative. Remember that even this formulation of ends in themselves is both realistic and humane: "Act so that you use humanity, whether in your own person or in the person of any other, always at the same time as an end, never merely as a means" (Kant 1911, 429). If we use Kant in our arguments we should read Kant closely. He argues here that we must not treat a person *merely* as a means but always *also* as an end. Kant intends no complete exclusion of the means perspective here. Had he said: never under any circumstances as a means, then every instance of human reproduction would be morally reprehensible, because it is always, as is the act that leads to it, not only determined by the person as a purpose. The progenitors of a child think not only of the happiness of the child but also of their own. In another formulation: It would be completely unrealistic to assert that up to now the only thought at the conception of children has been the happiness of the future child, and not for instance the happiness of the parents or compensation for the loss of an earlier child (see Gethmann 4/1998, 2).

Thus it is clear that - whatever apparently powerful arguments have been pulled out of the arsenal of philosophers and theologians (see Birnbacher 1998, 114) - cloning itself is not in any sense "in itself" reprehensible, but only in connection to particular human intentions. However, the question of principle remains. How much technology do we want to place in the stead of traditional modes of behaviour that are considered natural? After all, with the technology of cloning we change not only future generations, but we also change ourselves, at least in our self-understandings. In other words: Wherever boundaries are crossed, which, as in the case of human reproduction, seem to be set by nature, we must analyse very precisely and without recourse to individual intuitions or to ideological prejudices just where such boundaries ought to lie in the future. For man is a being without measure that can only live by means of measures. To find these measures and thus to set the right limits is difficult even when, as in the case of our example, they seem clear to many people, for whatever reasons.[4]

Productive Incompleteness

If the reflections that I have presented here are correct, or expressed somewhat more modestly, if they do not seem implausible, then the question, "Are there limits to knowledge?" formulated here as the question, "Are there limits to science?" can actually be answered, in the ethical and economic sense, with a clear Yes (though in the ethical case this is not always easy), and in the epistemological case with just as clear a No - possibly limited by the consideration that only the progress of science itself or its failure to progress can really show whether the scientific understanding in fact has (internal or external) limits.

Besides, scientific thought is so to speak constantly re-inventing itself, realising itself in its constructions and destroying itself with its constructions. The phoenix is the symbol of science just as the owl is the symbol of philosophy. Science creates itself, just as philosophy considers itself and what it has seen. Science thrives on the mortality of knowledge, philosophy on the immortality (or better limitlessness) of reflection, which therefore constantly encounters itself, while science forgets and discovers. Only the concept of construction holds the two, philosophy and science together. For philosophical reflection, too - so long as it does not just reproduce itself hermeneutically - constructs, devises new worlds, only to fill them again with its age-old experiences.

Those who find these statements too speculative, too philosophical, may prefer the more modest formulation, which is however equivalent in content, that scientific knowledge must as a rule be taken to be imperfect or incomplete and incorrect, though not in the sense of a defect - such a notion would in fact presuppose an attainable perfection or completeness - but in the sense of an openness of scientific knowledge in principle. Furthermore, paradoxically formulated, the boundlessness of science, in the sense of an interminable progress of knowledge, lies precisely in the limited character of knowledge, in its finitude and corrigibility.

Here I would like once more to invoke the sphere of knowledge. It floats in a space of ignorance and grows ever larger, thus increasing its surface of contact with ignorance. Or in another formulation: the limits of science are either *error limits* - the scientific understanding gets stuck in it own insufficiency - or *economic limits* - scientific progress becomes unaffordable - or *moral limits*, which are ever more often given in cases where scientific progress is directed against humankind itself. In any case, any standard or measure of science, also that which sets limits to its progress (in the realm of economics or ethics) is a *practical* one, not a *theoretical* one. Errors turn out to be normal, resources turn out to be finite, (ethical) norms turn out to be compelling, although this is not due to any insurmountable properties of the knowable or of the knowing subject’s understanding. This means that science does indeed have practical limits, but no theoretical limits. And this equates the human and the divine in science.

***** This is a slightly revised version of a paper read at the annual meeting of *Euroscience* in Freiburg in July 2000. In the meantime an expanded German version has been published in Mittelstrass 2002.

1) Pascal refers to the cosmos here as an infinite sphere whose center is everywhere and whose periphery is nowhere. See also Herbert Spencer, who already uses the metaphor in the sense envisioned here (Spencer 1904, 12). On the following, see Mittelstrass 1992, 83-88.

2) On this and the distinction between positive cognitive limits (knowledge is complete) and negative cognitive limits (knowledge encounters insurmountable limits) see Tetens 2000.

3) On the basis for this distinction see Plessner 1970, 11-171. According to Plessner, man *is* his phenomenological body (*Leib*) and *has* it as a physical body (*Körper*); he is a "*Leib im Körper*" as opposed to an animal that is its (physical) body and has it as its phenomenological body (Plessner 1982).

4) Another example could be given by recent stem-cell discussions. Here it is particularly the question of when human life begins which touches ethical problems. In a strict sense, there is no unequivocal biological answer to this question; and because this is so, there is (although not only because this is so) no unequivocal ethical answer either.

References

Birnbacher, D. (1998). Die Fortpflanzung hat ihre Unschuld verloren: Ein Gespräch. *Information Philosophie, 3*, 112-116.

Born, M. (1962), *Physics and Politics*. Edinburgh and London: Oliver & Boyd.

Bromley, A. *et al*. (1972), *Physics in Perspective I*. Washington D.C.: National Academy of Sciences.

Bury, J. (1960), *The Idea of Progress: An Inquiry into Its Origin and Growth*. New York: Dover Publications.

Diderot, D. (1875-1877), *Oeuvres complètes*, vols. I-XX, ed. J. Assèzat and M. Tourneux. Paris: Garnier.

Einstein, A. (1975), *Über den Frieden: Weltordnung oder Weltuntergang?*, ed. O. Nathan and H. Norden. Bern: Lang.

Eser, A. *et al*. (1997), *Klonierung beim Menschen: Biologische Grundlagen und ethisch-rechtliche Bewertung. Jahrbuch für Wissenschaft und Ethik, 2, 357-373.*

Gethmann, C. F. (4/1998). Ethische Argumente gegen das Klonieren von Menschen. *Europäische Akademie zur Erforschung von Folgen wissenschaftlich technischer Entwicklungen Bad Neuenahr-Ahrweiler GmbH: Academy Letter, 9.*

Horgan, J. (1996). *The End of Science: Facing the Limits of Knowledge in the Twilight of the Scientific Age*. Reading Mass.: Addison-Wesley Publications.

Kant, I. (1911), *Grundlegung zur Metaphysik der Sitten* (1785). In: I. Kant, *Gesammelte Schriften*, vol. IV, ed. Königlich-Preussische Akademie der Wissenschaften. Berlin: Georg Reimer.

Kitcher, Ph. (1997), *The Lives to Come: The Genetic Revolution and Human Possibilities*. New York: Simon & Schuster.

Lindley, D. (1993), *The End of Physics: The Myth of a Unified Theory*. New York: BasicBooks.

Mittelstrass, J. (1992). Die Wissenschaften und das Neue. In: J. Mittelstrass, *Leonardo-Welt: Über Wissenschaft, Forschung und Verant*wortung. Frankfurt: Suhrkamp, 74-95.

Mittelstrass, J. (1999). The Impact of the New Biology on Ethics. *European Review: Interdisciplinary Journal of the Academia Europaea*, 7, 277-283.

Mittelstrass, J. (2002). Gibt es Grenzen des Wissens? In: J. Mittelstraß, *Wissen und Grenzen: Philosophische Studien*. Frankfurt: Suhrkamp, 120-137.

Pascal, B. (1963). *Oeuvres complètes*, ed. L. Lafuma. Paris: Éd. du Sevil.

Plessner, H. (1970). Lachen und Weinen: Eine Untersuchung der Grenzen menschlichen Verhaltens (1941, ed. 1961). In: H. Plessner, *Philosophische Anthropologie. Lachen und Weinen. Das Lächeln. Anthropologie der Sinne*, ed. G. Dux. Frankfurt: S. Fischer, 11-171.

Plessner, H. (1982), *Gesammelte Schriften*, vol. VII. Frankfurt: Suhrkamp.

Rescher, N. (1978), *Scientific Progress: A Philosophical Essay on the Economics of Research in Natural Science*. Oxford: Blackwell.

Spencer, H. (1890), *First Principles*. Edinburgh: Williams and Norgate.

Spencer, H. (1904), *The Works*, vol. I. London: Macmillan.

Tetens, H. (2000). Kommt die Grundlagenforschung an ein Ende? Wissenschaftstheoretische Überlegungen zu den Grenzen der Wissenschaft. in: J. Mittelstrass, *Die Zukunft des Wissens (XVIII. Deutscher Kongress für Philosophie. Konstanz, 4.-8. Oktober 1999. Vorträge und Kolloquien*). Berlin: Akademie Verlag, 132-145.

Weinberg, St. (1999), Die Welt ist kalt und unpersönlich. *Der Spiegel*, 30, July 26, 192.