WHAT LIMITS DO TECHNOLOGY AND SCIENCE HAVE?*

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Where is the life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?
T. S. Eliot, Choruses from *The Rock*

0. *Why reflections on such boundaries are topical*

That there must be limits somewhere in a trivial truth. In connection with *technology*, all industrial nations have recently become aware that the process of collectively mastering nature runs up against external limits. The insight that there are limits to growth has become a *commune bonum*. Who would care to deny it? Official Marxism, of course, denounces the thesis as a mere demagogical device. Such a denunciation is declamatory —everybody knows that the resources and reserves of our planet cannot be infinite and that emigration to outer space is but a fantasy—, but it has to be made because according to Marxist creed, the goal of the historical process is the raising of the human species to a unitary subject progressively mastering nature.[1] According to the formula shared by all believers in Marxian "emancipation", the global goals is to extend mastery over nature and to eliminate mastery over people. But this formula is naive since man himself is a part of nature. Moreover mastery over nature implies mastery over people. It all depends on who the subject of the mastery is and to what end it is

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1 Asymptotic growth is but a theoretical alternative —that would not be a very inspiring perspective. The point made here is that Marxism is a form of progressivism, that it conceives of itself as a more efficient executor than capitalism of the Baconian revolution: of the utilitarian conception of science, which is to aim knowledge at power over nature *disregarding the limits*. Cf. (Jonas, 1976), p. 86 and (Radnitzky, 1977), p. 792.

exercised. The Marxist way of thinking on this issue is still permeated with an optimism about technology, with the progressivism characteristic of the time when Marx and Lenin wrote their classics. A backlash to this boundless optimism has now developed —in the West, where such views can be expressed— in the form of pessimism about technology: in reaction to the unavoidable disappointment of the unreasonable (because unfulfillable) demands placed on the technology based on science, critics have overemphasized the negative side effects of our uses of technology. Revisionist Marxism in the West has finally even gone so far as to condemn current technology and science as being intrinsically and irremediably in the service of "bad" (capitalist) forces. Here we see two extreme attitudes towards technology: the belief that eventually technology will solve almost all of our problems on the one hand and a generalized distrust on the other. Obviously all exponential growth hits a ceiling somewhere. The questions to ask are, "What sorts of limits are set to technology? Where are they located? What can technology based on science achieve, and what possible dangers inhere in various of its uses?"

Attitudes towards *science* have followed a parallel pattern. The 19th century exhibited a widespread scientism, the optimistic belief that in the realm of knowledge science would eventually answer all (reasonable) questions (as technology based upon science was supposed to provide solutions to all our practical problems). Scientism is roughly the view that *science has no boundaries*. This is a European phenomenon; the most exaggerated claims for science's capacities were made in France. One of its main critics, F.A.v. Hayek, speaks in his classic study of scientism[2] of "the spirit of l'École Polytechnique". Thus Condorcet expected man to learn all of nature's laws, eventually taming nature and becoming a power equal to nature. This is indeed "one of the grandest expressions of *hubris* in an age not characterized by exces-

[2] Cf. (Hayek, 1952), Part II, esp. pp. 105-116.

sive humility".[3] From France scientism spread like an infectious disease. It is with us today in the form of Marxist scientism, and has also spread to other circles, *inter alia* to all those who want to derive a moral "ought" from a scientific "is".[4]

In certain quarters the awareness of intrinsic limits to our use of technology, an awareness which has largely arisen because negative side effects have made themselves felt, has led to an over-reaction directed against science itself since it is the source of technology. Taking a position against technological progress often expresses a rejection of our technologically based civilization. As such it is either naive romanticism or a dishonest refusal to recognize one's own parasitism, since the drop-out's very existence presupposes the maintenance of the civilization by others. (Moreover, even the staunchest advocate of this style is likely to be grateful for technological progress at least when he sits in the dentist's chair.)

The negative attitude towards science itself ultimately comes to a head in the form of two sceptical doubts. The first is a doubt about whether scientific progress is in general beneficial —knowledge may even seen not only as potentially dangerous but also as something acquired at too high a price. As Robert Musil expressed it in his novel *Man Without Identity: "Man hat Wirklichkeit gewonnen und Traum verloren."* ("One has gained reality and lost the dream.") The second doubt cuts even deeper: it is doubted —although this seems paradoxical— whether sciences has *made* progress. Certain philosophies of science with a large following not only question the historical hypothesis that science has made progress (e.g. Thomas Kuhn's position) but also dispute the claim that a reasonable conception of cognitive progress can be developed —the so-called Incommensurability Thesis—

3 Cf. (Manuel, 1965), p. 97.

4 For a penetrating analysis of origin and character of Marxist scientism, and for devastating critique, cf. (Jaki, 1966), esp. pp. 481-500, cf. also (Radnitzky, 1976a). The political implications of the "Is/Ought"-distinction are dealt with, e.g., in (Radnitzky, 1979a).

and thus ultimately question whether methodology is possible (above all Paul Feyerabend in his two-volume treatise, *Against Method*).[5] In order to disentangle some of the competing claims we need to reflect on limits —this time on the bounds of *science.* It lies in the nature of the issue that such reflections proceed at a high level of generality. Hence what follows is essayistic, and unashamedly so. Before grappling with the main issues, we will have to clarify the key concepts involved —Science and Technology— enough that the reader understands which sense I am here using for these words. In a brief preliminary summary I wish to set out an outline of this conceptual analysis and of the theses which will be defended.

For our purposes, "*scientific research*" will be characterized as an activity in which nothing is allowed to be dogmatized, nothing immunized against criticism, especially against criticism resulting from intersubjective experience. The distinction between science and non-science does not entail any depreciation of non-science, of realms of life other than research. "*Technology*" is explicated as a system of recommendations about the means for achieving certain pregiven goals. These recommendations are based on presumed knowledge about lawful interrelationship. Hence technical recommendations have to be justified with reference both to empirical knowledge and to value premisses, including cost-benefit analyses. This wide sense of technology includes social and medical technologies, etc. The five theses to be defended are: *Limits of science* – Thesis I: The very fact that we distinguish between science and non-science shows that *science has excluding bounds*, that something is in principle outside science. Examples are art, religion and philosophical reflection on existential themes. But science and philosophy are interdependent: there is a co-agency between

[5] For a most recent debate between Paul Feyerabend and the Popperians (John W. N. Watkins, A. E. Musgrave, etc.), cf. (Radnitzsky and Andersson (eds.), 1978), for reflections on the political implications of a sceptical position in philosophy of science cf., e.g., the Postcript of (Radnitzky, 1979c).

the philosophical presuppositions of science and the feedback into philosophical cosmology and anthropology (Max Jammer). The denial of excluding bounds, the restriction of the term "knowledge" to *episteme,* is a sympton of scientism. Deciding whether science has terminating limits —whether there is a final, completed state of science— must rest both on an ideal of science and on a descriptive image of historical science. The "finalization" view, according to which science is a cumulative process, approximating a final, completed state, is popular but false. Thesis II: *Science has no terminating limits.* This is the "Kant-Popper thesis of a problem propagation": science is an unending quest because solved problems give rise to new problems. Cognitive progress consists essentially in progressing from problems to "deeper" problems. *Limits of technology.* Thesis III: Corresponding to the excluding limits of science (when knowledge is taken to be wider than *episteme*) there are in the realm of human action *excluding bounds* of technology: something is in principle outside its scope, e.g. attaining values and deciding about ultimate goals. Here we have the distinction between technological-pragmatic action and moral action, between rationality (Kant's *Klugheit*) and wisdom. Thesis IV: Since science has no *terminating limits,* neither does technology. But there are limits set by logical and empirical impossibility. Assertions about empirical impossibility are always fallible, and predictions as well as technological forecast are risky. "Technical" possibility depends on the state of basic science and also on cost-benefit factors. Thesis V: There are limits to our *use* of technology as *such.* Estimating costs of all sorts requires value judgments, which ultimately fall outside the scope of science. The general guideline here can only be that oldest precept of Greek ethics: "Moderation in all things."

1. *Clarification of key concepts*

1.0. Before we can ponder the question of boundaries, it behooves us to define the key concepts, "science" and "technology". These definitions are stipulative; I certainly do not claim to have identified the essence of science or of technology.

1.1. The problem of explicating the concept of science and distinguishing it from non-science, the so-called *demarcation problem,* has loomed large in recent philosophy of science. The logical empiricists have approached the problem of "empirical significance", of the empirical import of theoretical terms (or the status of "theoretical entities") as a problem of the relationship between two languages, "observation" language and "theoretical" language. The problem has produced a voluminous literature and is still a live issue.[6] Karl Popper regarded the demarcation problem as a fundamental one.[7] He criticized the inductivist-verificationist solutions offered by the Vienna Circle as being in principle inadequate. I think his polemical situation may have been one of the reasons for his evaluation of the problem as fundamental. Another was probably the intellectual and political climate of Vienna in the 1930's, with National-Socialists and Marxists propounding ideological doctrines which they claimed to be "scientifically based" and making their own absurd demarcations such as "German physics" vs. "Jewish physics" or "Marxist science" vs. "bourgeois science". At any rate, his own estimate of the problem's importance seems to have become more ambivalent.[8] Here I will defend the thesis that the demarcation problem is important mainly in the context of political debate, as a problem of *applied* methodology

[6] Cf., e.g. (Radnitzky, 1968/1970), I: pp. 112-145.

[7] Cf. (Popper, 1934), p. 9, in the Engl. transl. (1959), p. 34, where he writes, "Of these two problems (the problem of induction and the problem of demarcation) —the source of nearly all the other problems of the theory of knowledge—, the problem of demarcation is, I think, the more fundamental."

[8] In (Popper, 1972), p. 29, he writes, "Only after the solution of the problem of induction did I regard the problem of demarcation as objectively important, for I had suspected it of giving merely a definition of science. This seemed to me of doubtful significance (owing perhaps to my negative attitude towards definitions), even though I had found it very helpful for clarifying my attitude towards science and pseudoscience."

not of methodology itself (§ 3.1 below). For in methodology, once one has abandoned the verificationist (including the probalist) quest to justify the claim that a theory is true, it can be seen that what matters is not a rule for whether or not to recognize something as a "scientific proposition", but a preference rule. This is of course the Popperian line through and through. Usually it is said that Popper's demarcation criterion hinges upon the falsifiability requirement. However, upon closer reading it can be seen that the core of his distinction is the idea of a criticist policy. This approach makes it possible to combine a through-going fallibilism with a workable conception of cognitive progress: the question, "When is it rational to accept a theory" is replaced by the question, "When it is rational to regard one of two competing theories as superior to the other, and hence to prefer it?" Though knowledge cannot be justified, as foundationalism (*Begründungsphilosophie*) thought and still thinks, it can nevertheless be improved, and sometimes our attempts to improve it succeed. The history of science offers convincing examples of the possibility of the growth of knowledge, of the deepening of knowledge. Growing knowledge, cognitive progress, is possible thanks to the criticistic methods, whose employment, while no guarantee of progress, is still one of the conditions of the possibility of such success. We cannot justify our general theories, but we can improve them, or replace them with better ones, by subjecting them to criticism. The role of experience here is completely different from the one it has in foundationalism up through the logical empiricism, inductivism, and confirmation theories: experience is no longer an establishing arbiter but exclusively a critical one. The criticistic method serves to *distinguish rational from non-rational procedure*: a way of proceeding is rational if and only if it employs the criticistic method. This method is essentially "negatively" hypothetical-deductive. Put in its most general form: when one has succeeded in deducing from a sentence a consequence which seems "unacceptable", then this sentence has to that extent been successfully criticised.

This concept of critique is thus also applicable outside the realm of philosophy of science and empirical research.

Within the rational manners of proceedings we can make a *distinction between science and non-science.* To draw this distinction is a problem of explication: for certain goals —and we shall shortly return to what these are— the intuitive concept of science is to be replaced by a concept of science which is a better instrument for these particular goals. The intuitive idea of science, our explicandum, is partially defined by the goal of the activity, "cognitive progress". Cognitive progress is the goal of empirical enquiry in general; scientific research is that empirical enquiry which can demonstrate at least a minimum amount of method. Since the goal of research is cognitive progress, i.e., improvement, expansion and deepening of our knowledge about empirical reality, within scientific research the criticistic policy must include *empirical* criticism as an essential component.

This has two consequences: 1) The demand that theories must be tested, are to be subjected to empirical criticism, makes sense only if the theories are falsifiable. That falsifiability thus constitutes a component of the explicated concept of science is therefore a corollary of the insight that in empirical research the criticistic policy must essentially contain empirical criticism. 2) Insofar as science is primarily seen as an activity, as research, methods and strategies are more important than theories. Now it is possible to interpret most theories so that under this interpretation they are falsifiable. But a falsifiable theory can always be rescued from a falsification by adding *ad hoc* hypotheses. From this it follows that a general method, *a policy, is scientific* if and only if auxiliary hypotheses are not introduced *ad hoc* or, if such an introduction is expressly declared to be a temporary, purely heuristic device, then the method is scientific if and only if these hypotheses are retained only if they lose their *ad hoc* character. For this reason the question, "When is introducing an auxiliary hypothesis *ad hoc,* and when is it illegitimate to retain an additional hypothesis which was originally introduced *ad hoc* as a temporary heuristic expedient?" is a topical problem for every methodology. Popper's answer can be summarised as follows: (i) Introducing an additional hyphotesis *ad hoc* is illegitimate if this is done to preserve the theory from falsification and if the price to be paid for this is a decrease of the theory's empirical content, i.e., of the information contained in the class of potential falsifiers.[9] For this reason the scientific method dictates that a potential falsifier must be specified in advance: that one must be able to say what kind of experimental result or observation one would recognise as falsifying the theory. The as yet unsolved difficulty consists in defining "*ad hoc*" objectively —to speak of the intention of the researcher would be to lapse back into psychologism. (ii) But the salient point is whether an auxiliary hypothesis which was originally introduced *ad hoc* as a heuristic expedient but without reducing the empirical content of the theory is retained even if there is no reason to assume that it will be testable independently of the theory and will stand up to such a test. The circumstance alone that such an *ad hoc* auxiliary hypothesis is falsifiable is *in*sufficient. And so the core of the *scientific method as critical policy* à la Popper is the *prohibition of immunisation strategies.* The demand for the falsifiability of scientific theories is only a corollary of the requirement of the method of empirical criticism. The criticistic policy is for still another reason more important than falsifiability. A non-falsifiable hyphotesis belongs to the realm of non-science. This assertion is descriptive, not evaluative. But if a hypothesis claims scientificality and is simultaneously immunised against falsification, then it is not only non-science but in addition pseudo-science. This is a negative evaluation, and this version of the solution of the demarcation problem has an important function in *political* debate and critique of ideologies.

This answer of Popperian methodology to the question of

[9] Cf. (Popper, 1934/1957 (Engl. transl.), § 35.

what scientific method is, relieves us of the task of first having to indicate what is to be meant by "science" before being able to reflect on "scientific method". The criticistic *policy* including empirical criticism is the distinguishing feature of science, since it is the core of the "scientific method". The prohibition of immunisation methods plays an important role in research. The demand that theories be falsifiable results as a precondition for the realisability of the method of empirical criticism. In the context of comparing theories, on the other hand, the distinction falsifiable/non falsifiable hardly plays a role, since the researcher seldom, if ever, is faced with the task of choosing one theory from a pair, one of which is unfalsifiable, that is, has no empirical content at all.

It might here be worthwhile to add a warning: the distinction between science and non-science by no means implies that other activities, other realms of life are less valuable. To draw such a conclusion would be a sure sympton of scientism, a most unscientific attitude. Also, within non-science one must separate pseudo-science, i.e. non-science illegitimately claimed to be scientific, from other non-science for which non such claims are made, such as art and religion. Only for pseudo-science does the methodological verdict that a theory is non-scientific carry with it a deprecation. Here methodology unmasks pretences and exposed false credentials.

1.2. Within the realm of purposive-rational action one can distinguish between the realm of thought, which includes commonsense inquiry, scientific research, etc., and the realm of practical action, i.e., action for realising concrete practical goals. By 'practical goals' we mean here goals other than cognitive progres; by 'practical activities', enterprises in which cognitive progress can indeed occur as a means to the end, but does not play the role of the overarching goal of the enterprise. A *technical practice* is a set of concrete, practical courses of action; a *technique* a method or manner of proceedings for realising a particular practical goal —in the typical case a manner of proceeding based on a technology—;

'technology' is used here for a system of hypothetical imperatives and not as knowledge of laws (as some writers prefer, e.g. Mario Bunge and Hans Albert). The spectrum is enormous —including the technique of piano playing, the special techniques of a painter or an artistic school, the relaxation techniques in yoga, as well as the technique of space navigation. In ordinary usage the word "technique" is seen primarily in connection with artefacts, with hardware, but also with manufacturing processes and assorted software.

Of what sort are the *good reasons* which can be advanced for accepting a particular technological recommendation? The reasons fall into two *dimensions*: 1) that the technology is effective —only if the knowledge of laws on which the technology is based enables us to make predictions which stand up to testing can, following the pertinent technological recommendation, help us to realise the desired goal. 2) The overarching goal of the technology must be desired and moreover the costs of all kinds which go along with employing the necessary means must be accepted. *If* both conditions are fulfilled, then we must follow the technological prescription —otherwise we act irrationally. This is the sense in which it is claimed that technological rules have the form of *hypothetical* imperatives. Criticising the assertion that the knowledge on which the technology is based is sufficiently reliable falls in the realm of methodology, of theory-appraisal —a moment which cannot be avoided in any research enterprise.

Evaluating the goals and the costs is an axiological or an ethical problem. Needless to say, it cannot be posed within a technology itself. The philosophical tradition speaks of the pre-eminence of Practical Reason (Primat der praktischen Vernunft).

With the help of the two dimensions mentioned in the good reason for following a technological recommendation, two different typological descriptions can be made of special technologies. First, *types of technologies* can be distinguished *according to the sort of presumed knowledge on which they* *are based.* Here the *spectrum* extends from magic, a technology which is based on myth, i.e. a theory handed down in a dogmatic fashion and not being critically examined (such as a theory about the gods' behaviour towards people) and guides ritual practice (e.g. a ritual rain-dance), across technologies of handicraft, which are based on commonsense knowledge or on observed correlations and guides the practice of a handicraft, and up through scientific technologies, technologies based on knowledge of laws which in turn are explainable by theories. This proposed word usage is not to be taken to imply that the models of explanation mentioned are also adequate, but only that presumed explanations —correct or incorrect— are available and that one appeals to them in employing the technology and in this sense claims "to base the technology on scientific knowledge".

To make clear the distinction between magic on the one hand and handicraft and scientific technology on the other, we can resort to the demarcation criterion introduced earlier. The effectiveness of ritual actions for bringing about rain can be empirically tested, but the mythical theories grounding the asserted connection between ritual and rain are not empirical theories, insofar as the non-occurrence of the predicted event would not lead to rejecting the myth, but rather to protecting the supporting myth from falsification with *ad hoc* additional hypotheses and explanations, in short, to immunisation methods.

The *distinction* between *handicraft technologies* and *technologies based on science* is more difficult to explain. The methods of judging the presumed knowledge, the hypothesised laws on which the technological recommendations are based, are the same in both cases. The craftsman employing the presumed laws in various situations tests them in a way which differs from testing in the context of scientific research only in that the latter proceeds more methodically, more strictly and with greater precision. Sometimes the results of employing technologies can even give occassion for rechecking scientific claims. The concept of science specified by the demarcation criterion introduced above is descriptive. (In accordance with this demarcation criterion, Lysenko's theory, for example, is scientific (since falsifiable) although false. On the other hand a procedure which immunizes it against the demolition of its truth-claims would *eo ipso* be a procedure which has placed itself outside the "game of science".) The distinction between handicraft technology and scientific technology rests solely on whether the knowledge of the laws appealed to can also be *explained*, i.e. could be deduced from a more general hypothesised law or theory (not yet falsified). For only if this is the case can it also be explained with the help of this theory why the hypothesised law does not hold in certain areas of application. For every hypothesised law has a limited realm of validity and of application. The distinction can be summarised with the help of the well-known schema of falsification: a theory T together with auxiliary hypothesis A implies logically that if initial conditions of the sort J are actualised, an event of type P occurs. In a handicraft technology and a technology based on observed correlation, the knowledge consists of the presumed connection "if J then P" but one cannot explain why this is so and thus can also not be certain that a causal law is involved and not a correlation which might be brought about by a a third factor. A prime example of a handicraft technology would be the Bessemer technology of steel production. Bessemer himself indicates that he found the presumed law only by accident; he says "his knowledge consisted only of what an engineer must necessarily observe in the foundry or smith's shop".[10] If one cannot explain the if-then sentence, then one does not know its realm of application either and one can suddenly find oneself in situations where the technology does not function. Thus Bessemer, for example, found that in particular cases his technology of steel production

[10] The effect here was that "an unmelted whell on a pig of iron exposed to the draft showed that air was a powerful decarbonizer". (Anderson, 1975), p. 32, a study which provides a penetrating account of the development of technology.

failed. He said himself that for him this was "as a bolt from the blue". Only when a theory was available with whose help the presumed hypothesised laws on which the Bessemer technology was based could be explained could it also be explained why Bessemer's method did not work for ores containing phosphorus. Only with the Thomas procedure was a technology based on science created: expressed in our schema, now the theory *T* and the auxiliary hypotheses *A* were available from which the hypothesised laws could be derived. Against a widely spread conception it must be maintained that first in the 20th century have there really been technologies based on science. At the turn of the century "empirical engineering" was still of incomparably greater significance in industry than technological innovations based on scientific discoveries. The difference between scientific technologies and handicraft technologies can best be illustrated by considering the "context of *discovery*". In the paradigmatic case of a scientific technology the sequence is as follows: there is a pressing practical problem on hand as well as a relevant scientific theory; there follows a stage of searching for clues and conjectures about how to develop technologies with the help of this theory. The classic example is the development of nuclear technology from atomic theory as soon as it was recognised that this theory had implications for releasing great energy from atoms. In handicraft technology, as we have already seen in the example of Bessemer's technology, from everyday or professional experience one suspects a constant conjunction of two factors and one attempts, as it were by happy chance, to transfer this experience into a technical practice.

To illustrate that the sense of 'technology' introduced here is a *wide* one, *two examples* may be useful. Methodology itself is a "quasi-technology"; it has certain striking similarities with technology in the sense defined above, but there are also differences. Methodology consists essentially of global recommendations (any algorithm being out of the question) about how to act in certain types of research situations in order to improve the chances of achieving the pre-given aim, cognitive progress; and the reason given for following the recommendation is that in doing so you facilitate reaching your goal. But there are also striking differences. While in technology the global aim is pre-given and is to be defined, clarified and specified from outside the technology, it is one of the main tasks of methodology to explicate the aim, the idea of "scientific progress" (and to provide fallible but objective indicators for progress in the sense explicated). Secondly, while a technology is based on presumed knowledge about lawful interrelationships, the attempt to base a methodology upon empirical science (be it history of science or whatever) *in the same way* would involve a vicious circle. For, appraising whether the knowledge to which one appeals as one's basis has sufficient evidential support, or a sufficiently high degree of corroboration, or what have you, is itself the task of methodology, and appraising methodologies cannot be done in the same way as methodologically appraising theories of empirical science. To suppose that it can is an instance of a reductionist fallacy —identifying methodology (something closely akin to technological art) with an empirical science.

According to our definition, making *research policy would qualify as a technological art.* There the global aims are pregiven by governmental or institutional policies (such as, e.g., whether more funds are given to cancer research or to space exploration), while questions such as how to balance allocation appropriately between basic and applied research in the same field (as in our example within cancer research between basic biomedical science and clinical research) are problems of research policy as a technological art. Since the researchers in the field concerned have the best, probably the only, expertise available, and since they may have to rely on *Fingerspitzengefühl,* on a sensitivity based on tacit knowledge, research policy as we know it is to this extent more like a technical art than a technology proper, and it may well remain so.[11] But in some other respects it can base recommendations at least partially on social sciences (sociology of science, organization theory, etc.), together with the history of science (a *Geisteswissenchaft*) and on methodology (a quasi-technology).

Our wide conception of technology of course also includes the so-called social technologies; even democratic voting procedures would qualify as a technology whose aim is to set the framework for certain types of decision-making and goal establishment in groups —only in groups and only within the public-political sphere (cf. § 3.1). This is a technology whose justification appears to be rather special. In spite of all its difficulties (differences in internal preference structures leading to Arrow's paradox, vote-trading leading to variations of the so-called prisoner's dilemma),[12] its attractiveness stems from the fact that the alternatives are dictatorship and coercion (or at best a combination of coercion and democratic method).

2. *Boundaries of science*

2.0. The distinction between science and non-science implies that there is something outside science, for if the distinction were such that the property of "being non-science" were not exemplified in our world, the very distinction would be useless and never would have arisen. The question is where the line is to be drawn. But before attending to that, it is appropriate to ask what *sort* of boundaries may exist. Following Kant[13]

[11] Cf., e.g. (Radnitzky, 1976c), (Radnitzky, 1979b), § 0.1.

[12] A promising strategy for improving the technology of making social choices is found in the work of G. Tullock. For a survey, cf. (Tiedeman and Tullock, 1976).

[13] Cf. (Kant, 1873), § 57, in the edition (Kant, 1911), p. 352. Kant writes, "In mathematics and in natural philosophy (i.e. science), human reason admits of limits ("excluding limits") but not boundaries ("terminating limits"), namely, it admits that something indeed lies without it, at which it can never arrive, but not that it will at any point find completion in its internal progress." ("In der Mathematik und Naturwissenschaft erkennt die menschliche Vernunft zwar Schranken, aber keine Grenzen, d.i. zwar daß etwas außer ihr liege..., aber nicht, daß sie selbst in ihrem inneren Fortgang irgendwo vollendet sein werde. Die Erweiterung... geht ins Unendliche.")

and N. Rescher[14] we propose to make distinction between excluding limits (Kant's *Schranken*), which are the borders between science and non-science, and terminating limits (Kant's *Grenzen*), which are the limtis which would be reached if science were to come to a final state in which all "scientifically askable" or "statable" questions had been answered.

2.1. *Excluding bounds.* That something is outside science is trivially true if only —to reformulate the above remark— because this is an adequacy requirement on any solution to the demarcation problem: A demarcation criterion cannot allow everything to count as science, for then it would be no criterion at all. *Outside science* are all the other realms of life (*Lebensbezüge*), such as art, religion, philosophy and literature. In section 0.1 we emphasize that a demarcation criterion must not be taken as implying any deprecation of those spheres of life, interests and activities lying outside science; indeed, those facets of life are of the highest importance for human existence. If we deny that there can be "knowledge" in these spheres, we are proposing to restrict the word "knowledge" to *episteme*, empirical knowledge, the highest form of which is scientific knowledge. As a merely stipulative definition this would have no theoretical consequences. Yet it is likely that in practice such a definition would function persuasively, i.e. it would carry implicitly the suggestion that only *episteme* is worthy of the honor of being called "knowledge". Perhaps the fundamental experiences and accomplishments of life such as death, birth and love have less character of questions which may be answered than that of perennial themes (this position was taken by the early Wittgenstein and also by Arne Naess), "existential themes" on which people can and do reflect. Whether or not such reflections are questioning, they are obviously in principle outside the realm of science. This part of the excluding bounds is so clearly visible that it cannot fail to be recognized.

[14] Cf. (Rescher, 1979).

Does this bound co-incide with the boundary between *science* and *philosophy*? From the viewpoint of intellectual history it seems appropriate to speak of *feedback* more than of boundaries. Philosophy can be seen as the "mother science" out of which the various scientific disciplines develop in an on-going process, like branches of a tree.[15] These disciplines then in turn give rise to methodological and philosophical problems. From the point of view of a single research enterprise another aspect of the interdependence of science and philosophy comes to light: each research enterprise has its preconceptions and very general presuppositions, some of them "metaphysical" (what Max Jammer has called "philosophical input").[16] This input may be fruitful or may be a hindrance for scientific progress. On the other hand, the results of research (Jammer's philosophical output conclusions"), at least if these results have the magnitude of a "scientific revolution", have repercussions at the level of world-picture hypotheses and of the image of man. This sort of output is important to the extent to which it effects changes, in particular in eliminating assumptions in our world-view which are recognized to have been mistaken. In general, such scientific results are the raw material out of which philosophical cosmology and philosophical anthropology have to construct and continually to remake our image of world and man. The world-picture hypotheses are by definition not part of science itself; but the demarcation criterion functions here not only to cordon off non-science, in this case "metaphysics", from science. It may function also as an admission criterion: certain world-picture hypotheses may become so rich in empirical content that they eventually become empirically criticizable in a more direct way than by the above mentioned "repercussions". In sum, *a clear recognition of the existence of excluding bounds is necessary in order to avoid a totalization which eventually would be self-defeating.*

[15] This can be seen from titles of books such as, *Philosophiae naturalis principia mathematica auctore Isaaco Newtono*, 1687.

[16] Cf. (Jammer, 1979).

2.2. *Terminating limits*

2.20. A position on the question of whether science has terminating limits and, if so, of what sort and where exactly these limits may lie, involves a combination of a general *ideal* of science and a *picture* of actual science. We propose to deal with this issue by briefly contrasting the view that there are, or hopefully will be, terminating limits in that science can reach a final state with the opposed view that science is in principle an unending quest, a self-perpetuating process. Underlying these metascientific views are two rival views of human knowledge: the "inductivist-verificationist/probabilificationist" view and the "conjecturalist" view of human knowledge.

2.21. *The closed, utopian, "finalization" image of science and its corresponding ideal of science.* The logical empiricists have articulated one *ideal* of science, which gives highest priority to the desideratum of certainty. Roughly, a propositions counts as a "scientific" proposition, is admissible to the system of propositions constituting the Ideal Science, if an only if it is true and has been shown to be true. This is the key idea of verificationism, be it the absolute or the probabilistic version. (According to probabilistic verificationism, a proposition is acceptable if and only if it has been probabilified to a "sufficiently high degree on the basis of the available (ideally,, "all" relevant evidence). Here experience plays a positive role (and hence the label "positivism" is not unjustified); experience establishes a proposition's credentials. The ideal projects an ideal final state: when "all" evidence is in, ideally the degree of confirmation of the fundamental propositions of science will have reached certainty, or at least it will asymptotically approach it. In this scheme the concept of "scientific merit" is primarily a qualitative one: the question is one of acceptance or non-acceptance and the concept of progress is to be explicated in terms of the degree to which actual scientific theories approximate to the ideal articulated.[17]

What picture of actual science corresponds to this ideal? If one did not think that the science we know, historically given science, might be expected to come closer and closer to the state this ideal projects as worth striving for, then the ideal would appear utopian and would not be viewed as capable of providing even a regulative idea for science. And conversely, those who feel committed to the ideal will tend to see actual science as something which grows cumulatively, conserving what has been established (one and for all) and adding new items. If science does grow cumulatively, then it is realistic to hope that in the long run our science will reach or approximate the final state envisioned by the ideal. As N. Rescher has pointed out, this way of perceiving science appears to be based on an "analogy with the course of terrestrial exploration after the Middle Ages":[18] a progressive capturing of an essentially finite domain.

This picture of actual science has been very popular, both with philosophers such as Ernst Haeckel as a scientist speculating or C. S. Peirce as a methodologist, with historians of science such as G. Sarton[19] and with famous scientists. One needs only to remember Galileo's famous thesis that we should be able through science to attain a knowledge about reality which in a limited field may be as perfect and absolute as divine knowledge (which is distinguished from ours by being all-encompassing), or Laplace's thesis that scientific progress consists of a gradual approach to the "omniscience" of the Supreme Mind. They, like most scientists, thought that the ideal of science as absolute, i.e. certain and perfect, knowledge was not utopian. Many scientists believe this to this day.[20] Moreover, today certain socioligists of science

[17] The main program of logical empiricism may be seen as the task to articulate, with a maximum of precision and clarity, this ideal of science. This is the main thesis of Part I of (Radnitzky, 1968/1970).

[18] Cf. (Rescher, 1979).

[19] Cf. (Sarton, 1931), esp. pp. 10f. and (Sarton, 1936), p. 5.

[20] N. Rescher in (Rescher, 1978), gives a striking example from (Bromley *et al.*, eds., 1976), p. 26.

propound a theory which conceives the course of science as proceedings through three model phases, a "pre-theoretical" phase, then a "paradigm-guided" phase and eventually a "finalization" phase —hence this theory has been labelled "finalization theory".[21] In the second phase "the field reaches some kind of completion, that is a fundamental theory by which all the problems in the respective area of research are solved 'in principle'".[22] This clearly presupposes that the fundamental problems in a scientific discipline are in principle finite! (Remember Rescher's reference to the analogy with terrestrial exploration after the Middle Ages.) Böhme *et al.*, go on to assert, "Fundamental theories already contain the basic structure of their subject matter".[23] When the happy state has been reached, when "a discipline is in principle completed [*sic. GR*]; in that event further theoretical problems, and thereby, finalizations, will depend on the emergence of practical problems".[24] That means that a point can come when all the fundamental problems of a discipline have been solved, and "Once that point is reached an external goal of research [i.e., a practical, societal problem, *GR*] can become the regulative of where and with what intensity theory will further develop".[25] In this third phase, the "finalization" phase (which apparently every discipline reaches by historical necessity), a strange thing happens: "the development of natural science into a normative science"[26] occurs when "... social norms [are]... incorporated into the concepts of natural sciences".[27] In this ideal, final state —which,

[21] Cf. (Böhme *et al.*, 1976 (1973)).
[22] Cf. (Böhme, 1976), p. 314.
[23] *Loc cit.*, p. 317. Whatever 'contain' may mean in this context, this is clearly certistic foundationalism and the authors explicitly acknowledge that their theory is "contrary to the assumptions of fallibilism (Popper...,)", *loc. cit.*, p. 316.
[24] *Loc. cit.*, p. 319.
[25] *Loc. cit.*, p. 315.
[26] *Loc. cit.*, p. 321.
[27] *Loc. cit.*, p. 324. A phenomenon which, as the authors correctly point out, "is not accessible to the analytic philosophy" —to grasp it one must be in possession of their "dialectical" method and have recognized, as all Marxists do, that "it is precisely the restriveness of bourgeois society which also limits the universality of science", *loc. cit.*, p. 325.

needless to say, can be realized only when bourgeois society has been replaced by a socialist society— i.e., in the Marxist society "Where natural science is normative, the point of reference of scientific generality should be universality in society, not in nature. Thus generality in the form of unlimited reproducibility would yield to the generality of social consensus".[28] The "finalization" theory is so patently false, even absurd, that it would not be worthwhile to criticize it. It does however with its thesis of the "finalized" state of disciplines provide a politically workable legitimation for a certain policy for science, an extremely short-sighted policy. In the name of the "social relevance of science" —a justifiable cause, which these thinkers have totalized— funding for basic research can be drastically curtailed or stopped by politicians in good conscience: one points to the "finalization" theorists who, *le case écheant*, assure politicians and the public that this or that discipline has reached the hoped-for state of being "finalized". This means that now its problems come to it exclusively from outside, are defined by "the people", i.e., by the self-styled emancipators claiming to execute the will of the (not yet fully conscious) masses. In short, theories such as the "finalization" theories must, despite their ridiculousness, be criticized[29] because politicians of leftish leanings may utilize them for their own purposes —as has happened in some cases in West Germany (especially in the state of Hessen) and Austria. Moreover, by attempting to replace the correspondence notion of truth (*Wahrheit im Darstellungssinn*) and the idea of objective (fallible) indicators of truth with a consensus conception of truth, they pave the way for Party dogmatism. That the finalization image of science as a description is historically false is widely recognized, thanks not least to the work of T. S. Kuhn; that the ideal of science underlying it is utopian in the negative sense can best be seen

[28] *Loc. cit.*, p. 325.
[29] Cf. (*Andersson*, 1976), (Radnitzky, 1976c), esp. pp. 398ff, (Radnitzky, 1976a), § 3.1, pp. 28-31, and (Andersson, 1977).

by looking at the criticism of the ideal of certain, finalized scientific knowledge by Popper and his followers.

2.22. *The open-ended image of science and the ideal of science underlying Popperian methodology*. Popperian methodology grew out of the criticism of the methodology of the logical positivism of the Vienna Circle and its underlying ideal of science. The *ideal* of science underlying the Popperian methodology differs drastically from that of logical empiricism. Certainty, the top-priority desideratum in logical empiricism's ideal of science, is rejected as being not only unfulfillable in principle but also counter-productive even as a regulative idea, above all as being an impediment to realizing the reasonable desiderata in our intuitive ideas of science and cognitive progress. Truth and the idea of more or less accurate representation (*mehr oder weniger zutreffende Darstellung*) is retained as a regulative idea and is shown to be perfectly compatible with fallibilism, and thus a *comparative* concept of scientific merit, scientific progress, becomes the center of concern. (Hence methodology is concerned with formulating and giving good reasons for preference rules rather than for acceptance/rejection rules.)

The desiderata of the Popperian ideal of science are roughly the following. First, it is an earmark of progress that a successor hypothesis more correctly represent certain aspects of reality than its predecessor. Roughly this means that the relative size of its truth content (better: corroborated content of empirical information) in comparison with its falsity content (better: discorroborated content) is larger than is the case for the predecessor hypothesis. Experience plays here the negative role of providing criticism of hypotheses, not that of confirming them or establishing their truth (*begründend*) as it does in all forms of verificationism. Since the possible degree of corroboration is a function of the content of empirical information, a second earmark of progress is content-increase: a theory T' is better in this respect than T if T' dominates T in empirical content. Since a large-scale increase in content, particularly an increase in corroborated content (a desideratum applicable to theories *after* empirical testing) can only occur together with an increase in "depth",[30] "depth" of explanations, of theories and above all of problems is another desideratum. The form of the ideal science is throughout deductive, i.e. only non-amplificatory transformations are admitted. The re-transmission of falsity from a falsified conclusion to at least one of the premisses is a valid move, while the re-transmission of truth from confirmed or corroborated conclusions (in general from conclusions assumed to be true) to the premisses is an invalid move. This deductive form (an important desideratum) was lost in probabilistic verificationism; this was the price that had to be paid for the vain quest for certainty. In sum, the core idea of progress is this: "... science should be visualized as progressing from problems to problems —to problems of ever increasing depth".[31]

The picture of actual science that jibes with this ideal is that of an open-ended science. Common to both the ideal and the descriptive picture is the basic thesis, which could be called *"the Kant-Popper thesis of problem propagation"*, that each problem solved generates new problems,[32] that

[30] Cf. (Popper, 1963), p. 202, (Radnitzky, 1977b), § 4.3. Just to hint at what is meant here by "depth", we may use a simple example. The explanation of solar eclipses by means of Kepler's laws of planetary motion is on a certain level of "depth". Newton's explanation of the Keplerian laws (or better, his derivation of improved successor hypotheses to which the Keplerian laws may be seen as an approximation) is on a "deeper" level. Newtonian theory corrects the original law hypotheses in the process of explaining them. This is a sure sign that the new theory is deeper. Newton's deeper explanation is made possible by the introduction of new concepts, causal concepts, which are not contained in Kepler's law hypotheses. Einstein's theory is deeper than Newton's and makes possible a new perspective and an improvement of our world-picture hypotheses about causality, etc. In the transition from Newton to Einstein, "depth" is even more prominent than increase in content, since the general theory of relativity (which contradicts Newtonian theory) has few corroborators over Newton's theory (the precession of the perihelion of Mercury, bending of light, red shift).

[31] Cf. (Popper, 1963), p. 222.

[32] Cf. (Kant, 1783), § 57, in ed. 1911, p. 352. "every answer given on principles of experience begets a fresh question, which likewise requires its answer..." / (Original text: ''... da ..., eine jede nach Erfahrungsgrundsätzen gegebene Antwort immer eine neue Frage gebiert, die ebensowohl beantwortet sein will...''). Cf. also (Popper, 1963), p. 195.

"there can be no explanation which is not in need of a further explanation". A measure of the degree of progress is how much "deeper" the new problems raised are.[33] It seems to us that whether one stresses problems and questions or answers and theories is but a matter of emphasis. The two are interrelated, as H. G. Gadamer's formula "the hermeneutics of the question" suggests. No questions are without presuppositions, which limit the range of askable questions; and the presuppositions are the result of answers to previous questions. When presuppositions change, certain questions become "pointless".[34] For example, a new theory may show some of the questions asked under an older theory not to require an answer since they rested on false presuppositions. This sort of change in presuppositions is bound to occur in connection with major cognitive changes, since the successor theory will contradict its predecessor as, for example, Einstein's contradicts Newton's.[35]

The history of science illustrates all this: the collected results of research constitute a body of knowledge which does not accumulate, but rather grows organically. Some parts are retained (normally in a revised form, such as the abovementioned improved successor hypotheses deduced from a new theory which explain why the old hypotheses accounted for what they did), and some items are new, replacing old components which drop out altogether (and sometimes continue to exist only in history's cabinet of curiosities). This process of growth can also be seen in the sets of questions surrounding the body of theses and conclusions accepted at various points of time. In the process of replacing some components in the body of knowledge by others, the presuppositions of some old problems may be falsified, and hence these problems will drop out while new ones will become statable on the basis of new presuppositions. At any particular time

[33] Cf. (Popper, 1963), p. 222 (Rescher, 1979), § 3.
[34] (Rescher, 1978), § 3.
[35] (Popper, 1972), pp. 16, 205; (Popper, 1975), p. 97; (Radnitzky, 1976b), pp. 533f.

the set of fundamental theses accepted by the scientific community will be finite, as will the set of consequences thus far deduced from them, while the number of deducible consequences is infinite. The set of accepted theses grows organically, is not accumulating but changing. And there are, as Kant emphasized in 1783, no *terminating limits*. *Science is in principle an infinite process without a definite beginning* (since every question has its presuppositions, and every thesis used as presuppositions is itself an answer to a prior question) *and without a definite end* since solved problems always give rise to new ones. Every item in the body of knowledge with empirical content is *fallible in principle*. But there may *nonetheless be progress*, and indeed we have examples of cognitive progress —and these examples are the paradigmatic examples of what we mean by "progress". Perhaps science is the only area of human endeavour in which the existence of progress is beyond any reasonable doubt (*pace* P. Feyerabend and all the "relativists", arguably including T. S. Kuhn).[36] This, as Popper has always emphasized, provides no guarantee of future progress, but still a reasonable hope for it. On the other hand, the hope for a final perfect state is utopian and, if taken seriously, would impede actual future progress since it would introduce a fatal dogmatic spirit into the scientific enterprise.

3. *Boundaries of technology*

3.0. The thesis that there are excluding bounds of science sets the scene for considering excluding bounds of technology. The question of whether technology has terminating limits is, for at least one interpretation of limits, implicitly answered by the thesis that there is no final state of science. But special problems crop up in connection with the issue of the real practicability of certain technologies —and this issue is essential in a consideration of technology—, and these problems lead back to the excluding bounds of technology *per se*.

[36] Cf. (Radnitzky, 1976b), § 1 and (Radnitzky, 1977b), § 6.

3.1. *Excluding bounds of technology.* In the realm of thought, of "knowing" in the wide sense —in the *bios theoreticos*— religion, art and philosophical reflections on existential themes are in principle all outside the scope of science. In the sphere of *action*, the conduct of life, the *vita activa*, there is a clear counterpart to this: attaining values, deciding about ultimate goals, in particular about goals in the existential-personal sphere, the choosing of a way of life when *by our action* we answer the question "How shall I live?" —these issues lie in principle outside the scope of action directable by technologies. Of course, reflecting on and interpreting the situation on the one hand and acting and decision making on the other are bound together in a hermeneutic circle. Interpretation and deliberation must precede reasonable and responsible decision making, while without affective commitments there would be no motive for such reflection and interpretative efforts. In any concrete situation the two facets of life are inseparable. Yet in analysis they must be distinguished in order to see how they are interrelated. The philosophical tradition clearly distinguishes within the realm of action between technical or pragmatic action (Kant's concept of *Klugheit*) and moral or ethical action (treating each individual as an end in himself), between purposive rationality (Max Weber's *zweckrationales Handeln*) and wisdom. The idea of basing the conduct of life on science, the "*wissenschaftliche (exakte) Lebensführung*", is an aspect of scientism, the counterpart in the conduct of life to epistemological scientism. It leads to the "Man without Identity" —the hero and antihero of Robert Musil's novel— to a historical relativism which loses the normative problem altogether and must ultimately leave decisions to impulse, chance and external forces.

The above remarks are aimed at combatting the dogmatic ideologues of the Party or, in the West, the believers in "emancipation", who claim to "know" what human beings should be and what they should become, the phantasmagoria of Marxian *der Neue Mensch*. This utopia has been so cherished that even the intermediate stages on the road to utopia have appeared to be worthwhile goals. Bald assertions and hope are the secularized theologumenon of the Christian expectation of the Second Coming; secularized because Marx transfer the role of God to "society" and attempts to support the whole, both intermediate stages and utopia, on scientific technologies, especially social technologies. Marxism is scientistic both in theory and in practice.[37] Here (as mentioned is § 0) the demarcation criterion becomes indispensible for unmasking false pretenses of "scientificality"; here applied methodology can be of service in the political discussion. Classical Marxism was steeped in scientism,[38] the denial of excluding bounds of science, and this predisposed it towards a "practical" scientism, the idea that with help of science we can get to technologies enabling us eventually to solve all practical problems, i.e. the denial of excluding bounds of technology. Of course in this concept of science in the wide sense of *Wissenschaft*, or *nauka*, the social sciences and history (Geschichtswissenschaft) are the center of interest and they are seen as fundamentally no different from natural sciences.

The "neo-Marxist" or revisionist "*Emanzipatoren*" in the West, e.g. the so-called Critical Theorists of the Frankfurt School, have tried a totally different approach. They distinguish sharply between natural science and the human sciences, assert that the natural sciences are governed only by "technical interest" (Habermas's *technisches Erkenntnisinteresse*), and widen the concept of science (*Wissenschaft*) so that it will include the so-called "*kritisch engagierten Sozialwissenschaften*" —roughly, social sciences and social philosophy committed to an evaluative critique of capitalist society. For instance, in the collection, *The Positivism Dispute in German Sociology*,[39] the concern is not at all positivism, but giving a

[37] Lenin's view (stated in his *What is to be done?*) was, as is well known, that the Party first must educate the proletariat; which is not able by itself to find its way to a *scientifically* based class-consciousness.

[38] Cf., e.g. (Radnitzky, 1976a), § 2.

[39] Cf. (Adorno *et al.*, 1975 (1969).

persuasive definition of 'science' which makes science relevant for *legitimating* total solutions to problems of an entire society (*gesamtgesellschaftliche Problemlösungen*). The tag-word 'positivism' is then used to discredit any methodological critique of their persuasive definition of 'science'. To this end the "*kritisch engagierte Sozialwissenschaften*" (the engaged, critical social sciences) eventually turn into (*sit venia verbo*) the technology for emancipation. And so their critique of scientism capsizes into an absurd concept of science —like the one we have seen in the "finalization theories"— and their critique of technocracy into a totalized concept of technology.

3.2. *Terminating limits of technology*. If science never reaches a final state, then technology based on science will also have no terminating limits in this sense. But mathematics and science predicts certain limitations: it tells us what is impossible. There are different sorts of possibilities/impossibilies. Mathematics (and here investigations of and studies working with formal languages are conceived as parts of mathematics) can prove, for example, that it is logically impossible to construct a Turing machine capable of computing certain functions. From accepted theories of empirical science it follows that certain technical achievements are *empirically impossible*. (E.g. terrestrial speed cannot exceed 16,000 miles per hour, because any object travelling with a higher velocity will escape the earth's gravitational field.) Such predictions are fallible in principle and demand exactly the degree of confidence we place in the theories from which the predictions follow.

What is intriguing is not so much empirical possibility or impossibility as the question of what *within* the realm of the empirically possible (that which is not ruled out by accepted scientific knowledge) may be actually "realizable" or may not be so realizable. A first interpretation of "realizable": it is predicated that the basic scientific theory on which the technology under consideration would have to be based will "become available" within the forseeable future. A necessary condition for this "becoming available" is that it is in principle possible to produce the relevant knowledge. This involves predicting the possible future development of one or more scientific disciplines: walking a tightrope between rational betting and science fiction (which admittedly on a few occassions has been prophetic).[40] The above example of terrestrial speed is trivial because we are so sure of the empirical impossibility, but it is easy to give others which are interesting, such as the question of *cyborg man* technologies.[41] Looking at the problem from the other end, we come to the socalled technological forecasting. Here the spectrum ranges from efforts to think up possible new technological applications of extant theories of basic science, through R&D to fortune telling. Predictions of this sort are of course inherently risky. Extrapolations from existing technology cannot even for a short time span including the results of "technological breakthroughs".[42] Indeed, the impossibility of predicting in any detail at all which parts of today's basic research may

[40] Cf. (Radnitzky, 1976a) pp. 31 f., commenting on a naive law enacted by the Social-democrat government of the State of Hessen in the Federal Republic of Germany to the effect that scientists had to warn the authorities of any research in *basic!* science which might give rise to "dangerous" or "unwanted" technologies. Historical examples for the unforseeability of such possible future technological relevance are also given there.

[41] Medical technology has increased the number of people who reach old age but has not increased our maximum life span. "All men are mortal" (unless taken as a defining characteristic) is taken to be a synthetic but "unfalsifiable" sentence. But this view misinterprets "falsifiability" as definite falsifiability: the hypothesis is highly corroborated and is supported by highly corroborated theories about life above the unicellular level. No extant theories would claim it to be empirically impossible for a human brain to live for an indefinite period of time supported by a prosthetic body, an artificial (and easily replaceable) support system superior to a human body for the brain. Will it become possible to develop the technology required to actualize cyborg man If so, is cyborg man desirable? This leads back to philosophical reflections about death (outside science) and to value judgments about ultimate goals (outside technology). The life span of the species would still be finite, if only because of the finite duration of our solar system.

[42] For example, the transistor could not be "forseen" when no "material science" existed. Hence during the 40's and later it would have been impossible to have predicted the technological revolution in miniaturization. And prophecies in the 50's that automation and cybernetics would create the society of over-abundance proved false.

in the future yield rich dividends in new, unexpected technologies together with the historical frequency of such unforseen benefits constitutes the so-called *overhead argument*, still the most effective argument for justifying the expenditure of public funds on basic research.

In sum the following facets come into play: (i) *Predictions* of what sort of scientific results may be reasonably expected (as in rational betting). In some cases such global predictions may, to a limited extent, be possible; more detailed predictions will be feasible only insofar as the research project in question is one of applied research. (ii) *Predictions* about the possibilities of technological applications of such results. "Technological forecasting" comprises both of these facets, but especially the latter. (iii) *Predictions* about the social consequences that would probably ensue if certain uses were actually made of those technologies. (iv) *Assessment* of anticipated social consequences of such uses from the viewpoint of certain social-political norms ("technology assessment"). Obviously this moral assessment is a totally different task from the scientific task of making predictions.

How important it is to make these distinctions, above all to distinguish between research and the application of technologies based upon the results of that research and to distinguish also between basic and applied science is shown by the current debate about recombinant DNA research. DNA recombination is a recently developed laboratory technique acclaimed as a breakthrough for understanding human genetics. Critics have called for limitation of such research and among the confusions on which their criticism is based is a confounding of the above facets. Let us make a brief inventory of the critics' arguments. (a) They claim that there is a danger of negative side-effects of such research, e.g. in the form of new pathogenes. This argument is met by pointing out that the so-called biological containment is carried out meticulously: one experiments only with organism which cannot survive outside the laboratory (e.g. because they need a certain gas not found in natural environment). Hence this type of argument does not loom large. (b)Critics claim that there are special barriers in this field, i.e. that one must not interfere with biological development. This is either a variant of (a) or else, insofar as it implies that it regards a certain sort of new knowledge as potentially harmful, an expression of modern obscurantism. (c) The critics claims that genetic engineering conjures up visions of a Brave New World. This, the critics' main argument, is clearly directed against the *application* of knowledge and not against knowledge and research as such. Yet the critics request that certain *limitations ought to be placed upon a particular kind of research* and the only reason by which they could support such a request is that the *application* of certain technologies which such research might make possible would lead to undesirable consequences. However, to prevent certain *uses* of knowledge is a political issue, not an issue of research policy making. Only if you confound application and research as well as basic and applied research can this type of argument be used to request a moratorium of e.g., recombinant DNA *research*. Hence the argument can be countered by pointing out that it springs from that particular conceptual confusion and moreover that accepting the argument would not be rational and would be a dangerous policy. For, among other things, it would be inefficient, and so long as such a moratorium is not carried out world-wide and thus cannot effectively be controlled, if a particular country (say the United States) were to refrain from carrying on such research, that country would not longer be informed about what is technologically possible in the field concerned and moreover it could even be blackmailed by small countries. (In the present case it is relevant that such biological research does not need large resources and cannot be uncovered by means of, e.g., satellites.) The argument reflects a basic distrust of all scientific-technological progress. Hence it is worth-while to examine the critics' motivation and strategems. The critics —typically Western "Leftists"— aim to gain power for themselves, i.e., power to steer research. Previously the strategem used was based on

Baconian optimism: "Science hat a great emancipatory potential (*emanzipatorisches Potential*); but it can deploy that potential only if globally planned, viz. by the 'progressive' forces." This was the line from Bukharin to Bernal, etc.[43] After the devasting results of that sort of research policy in the USSR became generally known even in the West, a new strategem had to be found: "Sciences has many hazards; these can be guarded against only if limitations are placed upon research, if science is controlled, i.e., controlled by the self-appointed Leftist 'critical sociologists of science'." Recombinant DNA research offers a good example for bolstering such claims. Both strategems are based upon a refusal to recognize the distinction between basic and applied research. Of course, the research process is basically the same. But the distinction is very clear: a research enterprise belongs to basic research insofar as its problems are selected solely with an eye to cognitive progress. The distinction is not only useful but indispensable for preventing confusion in the discussion of research policy, because the type of argument applicable differs drastically in the two cases: it is easy to justify funding for applied research —if you want the aim (solution if a practical problem) and regard the costs as acceptable, then you are obliged (if you are to behave rationally) to be willing to fund that type of research which is considered a necessary and efficient means of solving the practical problem in question.[44] However, for ideological reasons, practically all Leftists refuse to recognize this distinction, and more often then not even do not make a distinction between application of technologies and research, and thus eventually request that certain limitations be placed not only on the application or possibly the development of certain technologies, but even on research in a certain area. One could label these "*artificially created or ideologically based boundaries of technology and science*".

In the above we have disregarded a further possible argu-

[43] Cf., e.g., (Radnitzky, 1976a) and (Andersson, 1976b).
[44] This is spelled out in, e.g. (Radnitzky, 1976c).

ment that to achieve the practical aims achievable by means of technologies based on, e.g., recombinant DNA research, there are other means which are less costly that there are attractive alternatives. For if the basic knowledge required for a certain technology is considered to be in principle possible to achieve, there still remains the question of whether the required investment in the special basic research, applied research and development is economically feasible. And the question of whether applying the technology under consideration is feasible in the present situation puts the emphasis still more strongly on *cost-benefit*. This is a very compelling limit. Whether a technology is actually realizable is a function not only of the states of the basic science and technological art, but also of the relative costs compared with the costs of other technological modes.[45] In a cost-benefit analysis all sorts of costs must be taken into account, political, social, etc., as well as other non-monetary costs. They all limit the feasibility of technologies. An important sort of cost is that of the side effects (cf. § 0). Here we encounter a definite *limit* to technology, or better, *to our use of technology as such*. The process of collective control of nature reaches external limits, since the side effects of the process cannot indefinitely be compensated for with new and deeper counter-measures. For nature's capacity to neutralize and absorb such side effects is, like nature itself, limited. If the species attempts to turn the relationship of controlled symbiosis into a one-side relationship of reshaping, then the species overextends itself. Such a program is particularly pronounced in Marxism, but not only there.[46] According to Marxist theory, the goal of the historical process is the fusion of all subjectivity, of all personal identity, in a homogenous process of the collective mastery of nature by the non-individuated human as "nature with needs" ("*Bedürfnisnatur*"). The general slogan of

[45] E.g. whether electronic delivery for paper may become a competition with mail or credit-cards etc., this is primarily a question of whether it becomes cost-effective, competitive.

[46] Cf., e.g. (Radnitzky, 1976c), p. 379, (Radnitzky, 1977a) §1.2.

"emancipation" runs: extending mastery over nature, eliminating mastery over people. This is naive, for, first, man is himself a piece of nature, and second, mastery over nature implies mastery over people —the unstructured society is a figment of the imagination of certain ideologues. The all-important questions are instead, "Who is to the subject of this mastery (*Herrschaft*)? And to what end is it exercised?" The thrust of radical emancipation, the idea of a society based on an emancipated "nature with needs" (man as *Bedürfnisnatur*), as it is propounded, e.g. by the New Left or in Germany by the Critical Theorists and affiliated schools, has an immanent tendency towards totalitarianism,[47] as does the idea of "objective" needs over and above biological needs: the elite of the emancipators will be ready to tell the people what their objective needs are and should be.

The above-mentioned attitude of "total reshaping" (*des totalen Machens*), the belief that technology as such has no limits set by nature itself other than those of the empirically possible, is based, as was already mentioned, on the false assumption that nature has an unlimited capacity to neutralize all side effects. But even apart from such empirical considerations, the position cannot be justified in the dimension of goals. For there is no collective goal of humanity, with reference to which *all* other effects could be relegated to the class of "side effects".[48] The ideology of total reshaping, the progressivist stance towards nature which sees nature only as *materia prima* to be molded according to any goals whatever, is then reapplied to human beings themselves, in the belief that "the New Man" could be planned (partly perhaps through genetic manipulation and partly through social engineering). The difficulty is the same: just as there is no collective goal of mastering nature for humanity, some goal which would demote all other effects to the status of costs worth bearing, so also it cannot be said how the New Man

[47] Cf., e.g., (Spaemann, 1977) esp. pp. 187 f.
[48] Cf. (Spaemann, 1977), p. 182.

should be constituted, for in order to answer such a question of values and goals, we would have to know that the function of the human being is.[49] For this reason I would claim that the burden of proof lies with those who advocate such expansionistic manipulations of nature and of human nature. Analogously, the societal optimum, or the maximum and minimum, of any functions, results and circumstances (such as the balance of equalities and inequalities in society) cannot be defined by references to society itself, because a social system is not an end in itself. One the contrary, such problems as ascertaining the optimum for certain functions, etc., would not even arise if there were no social system. What an optimum, etc., is cannot be defined without an element of natural law, i.e., without a conception of the sub-system "man" as something "by nature", so that the goals of human life and the optima, etc., for the social system can be derived from that concept of "human nature".[50] In sum, these particular limits of technology as such can only be recognized in a realm which is itself outside the excluding bounds of science-cum-technology, only in ethics in its wide sense as conduct of life (*Lebensführung*), in a normative "theory" of how to lead one's life. Whether an element of natural law can be acknowledged is similarly a question of philosophical-anthropology or a question to which religions offer answers. Not even the view that each individual should be granted and assured of the greatest possible freedom to decide his own interests can count on universal assent. The apostles of emancipation, for example, would want to force upon individuals also the role of those "to be emancipated" —in the name of

[49] We may know what, e.g., an ox should be like if we bread oxen in order to eat them. But what should the human being be like? Even religious texts do not give us much guidance here. For example, the Christian Bible tells us that man is to be a likeness of his heavenly Father — but this does not help us to formulate the goals of a breeding program (R. Spaemann).

[50] Cf. (Spaemann, 1977), p. 192; (Tonini, 1978), p. 142; "...comment peut-on inscrire dans le devenir de l'humanité une pensée rationnelle et éthique qui puisse guider la conduite humaine, si l'on ne connait l'identité de l'homme et celle de l'humanité dans cette énorme conflagration cosmique au sein de laquelle nous ne sommes rien?"

the utopia, needless to say. There seem to be no guidelines which would seem reasonable to all, except for the one rule most pertinent to the question of technology but not only to it; that oldest rule of Greek ethics which says, "Moderation in all things".

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RESUMEN

El artículo comienza con dos preliminares. Primero se pregunta por qué el análisis de las fronteras en la ciencia y la tecnología es de interés actual. Es indudable la existencia de ciertos límites y una opinión ya generalizada es que la tecnología, el proceso por el cual se intenta dominar la naturaleza, se enfrenta con limitaciones externas. Aquellos que niegan que haya límites al crecimiento lo hacen por razones ideológicas. La pregunta que interesa es: ¿qué tipos de límites existen? El movimiento "anti-ciencia" surge de una desilusión con la ciencia: se esperaba que la ciencia respondería todas nuestras preguntas y resolvería todos nuestros problemas, pero ahora resulta claro que esa idea es errónea y que la ciencia tiene fronteras. Dada esta situación conviene analizar el tipo de fronteras que la ciencia presenta y dónde se localizan. Este análisis es de interés actual ya que hay doctrinas populares acerca de la existencia de ciertos tipos de límites (por ejemplo la teoría de "finalización") y doctrinas acerca de la no-existencia de límites ("cientificismo"). El exponer su falsedad se ayudaría a combatir la contaminación que existe en nuestro medio ambiente intelectual.

En el segundo preliminar se aclaran los conceptos clave de "ciencia" y "tecnología". Las definiciones propuestas no implican ningún esencialismo; funcionan únicamente para asegurar que conocemos vagamente cómo son usados estos términos en el artículo para evitar malentendidos. Con respecto al "problema de demarcación", sostengo que explicar la distinción entre ciencia y no-ciencia es importante en un contexto político, pero en el contexto metodológico el verdadero problema consiste en saber valorar comparativamente los diferentes logros de teorías rivales. Para nuestros propósitos, la "investigación científica" estará caracterizada como una actividad en la que no está permitido dogmatizar nada y nada está inmunizado contra ningún tipo de crítica, especialmente si ésta resulta de una experiencia intersubjetiva. La distinción entre ciencia y no-ciencia no lleva consigo una depreciación de la no-ciencia, de actividades distintas de la investigación. La "tecnología" es explicada como un sistema de recomendaciones acerca de medios para lograr ciertos objetivos preestablecidos. Estas recomendaciones están basadas en un supuesto conocimiento de las interrelaciones permitidas. Por lo tanto las recomendaciones técnicas deben justificarse con referencia tanto al conocimiento empírico como a premisas de valor incluyendo

análisis de costo-beneficio. Este sentido amplio de la tecnología incluye tecnologías sociales, médicas, etcétera.

Después de estos preliminares sigue la parte principal del artículo que consiste en presentar y defender cinco tesis. Límites de la ciencia. Tesis I: el mismo hecho de distinguir entre ciencia y no-ciencia muestra que la ciencia tiene límites excluyentes y que en principio existe algo fuera de la ciencia. Ejemplos de ello son arte, religión y reflexión filosófica sobre temas existenciales. Pero la ciencia y la filosofía son interdependientes. Hay una influencia mutua entre las suposiciones filosóficas de la ciencia y la realimentación en la cosmología filosófica y la antropolgía (Max Jammer). La negación de límites excluyentes, la restricción del término "conocimiento" a "episteme" es un síntoma de cientificismo.

Decidir si la ciencia tiene límites terminales (si existe un estado final completo de la ciencia) debe fundamentarse tanto en un ideal de ciencia como en una imagen descriptiva de ciencia histórica. El punto de vista de "finalización" de acuerdo con el cual la ciencia es un proceso acumulativo que se aproxima a un estado final completo es popular, pero falso. Tesis II: la ciencia no tiene límites terminales: ésta es la tesis del "problema de propagación de Kant-Popper"; la ciencia es una búsqueda sin fin porque la solución de problemas da lugar a nuevos problemas. El progreso cognoscitivo consiste esencialmente en progresar desde problemas "simples" hacia problemas más "hondos". Límites de la tecnología. Tesis III: paralelamente a los límites excluyentes de la ciencia (cuando el conocimiento se toma en un sentido más amplio que el episteme) hay en el ámbito de la acción humana fronteras excluyentes de tecnología: algo está en principio fuera de su alcance, como, por ejemplo, la obtención de valores o las decisiones acerca de fines últimos. Aquí tenemos la distinción entre acción tecnológica pragmática y acción moral, entre racionalidad (el Klugheit kantiano) y sabiduría. Tesis IV: como la ciencia no tiene límites terminales, tampoco la tecnología. Pero hay límites impuestos por imposibilidades lógicas y empíricas. Las afirmaciones sobre imposibilidades empíricas son siempre falibles y tanto las predicciones como las previsiones tecnológicas son arriesgadas. Las posibilidades "técnicas" dependen del estado de la ciencia básica y de factores de costo-beneficio. Tesis V: hay límites de nuestro uso de la tecnología como tal. La estimación de costos de todo tipo requiere de juicios de valor que en última instancia caen fuera del alcance de la ciencia. El criterio general aquí sólo puede ser ese antiguo precepto de la ética griega: "todas las cosas con moderación".

[G. R.]