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THE BOUNDARIES OF SCIENCE AND TECHNOLOGY

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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. 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, almost a triviality. Who would care to deny it? Only official Marxism, which denounces the thesis as a mere demagogical device. Such a denunciation is necessary 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. According to the formula shared by all believers in "emancipation" (Emanzipationsgläubigen), the global goal is to extend mastery over nature, to eliminate mastery over people. But this formula is naive, since man himself is a part of nature and since mastery over nature implies mastery over people. It all depends on who the subject of the mastery is and to what end it is excercised. To combat such pollution of our intellectual environment by official Marxism, aped by the "emancipatory" doctrines popular in the West, we must reflect on the limits of technology. All exponential growth reaches a limit, a ceiling where it levels off. The question to ask is, "In what ways is technology limited? Where are the limits located?"

Awareness of the limits of technology has arisen largely because negative side effects have made themselves felt. In certain quarters this has led to an over-reaction directed against science, as the source of technology, in the form of the so-called anti-science movement, and also to a rejection of our technology--based civilization. This attitude is either naive romanticism or dishonesty refusing to acknowledge its parasitism, since the existence of the drop-out presupposes the maintenance of the civilization by others. The psychological motive behind such an extreme reaction is likely to be a feeling of having been deceived by technology and by the science underlying it. Such disillusionment is an unavoidable consequence of placing unreasonable (because unfulfillable) demands on science and on the technology based on science. These demands are the symptom of the attitude called scientism.

Scientism is roughly the view that science has no boundaries, i.e. that eventually it will answer all questions and provide solutions for all our practical problems. This is a European phenomenon; the most exaggerated claims for science's capacities were made in France. One of its main critics, F.A. Hayek, speaks in his classic study of scientism[1] of "the spirit of l'Ecole 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 excessive humility".[2] From France scientism spread like an infectious disease. It is with us today in the form of Marxist scientism,[3] and has also spread to other circles, *inter alia* to all those who want to derive a moral "ought" from a scientific "is". Once again, the antidote to such pollution of our intellectual environment is reflection on limits -- this time on the boundaries of science. It is in the nature of the issue that such reflection takes place at a high level of generality. Hence what follows is essayistic, unashamedly so -- with due apologies to those present with great expertise in science and in technology.

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; we do not claim to have identified the essence of science or of technology. But to ensure communication it must be made clear how we are using the terms.

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.[4] Karl Popper regarded the demarcation problem as a fundamental one.[5] 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". At any rate, his own estimate of the problem's importance seems to have become more ambivalent.[6] 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 (§3.1 below). For in methodology, once one has abandoned the verificationist (including the probabilist) 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. The assumption here is that methodology should, among other things, assist the researcher. And the researcher is not normally confronted with the task of choosing between one theory with empirical import and another which doesn't contain empirical information. Instead, he has the task of choosing between rival theories, competing explanations, etc. In general, he must appraise the comparative achievement of competing problem solutions. And so what he needs is an explication of the idea that a theory T' is "better" than its rival or predecessor T, i.e. a clarification of what "better" should mean in his context (e.g. more content of empirical information, better evidential support, etc.), and he needs indicators for ascertaining, when confronted with a pair of rival theories, whether one of them actually fulfills these criteria for being "better" than the other. That is to say, he needs indicators in order to decide whether there are good reasons to hypothesize that T' is better than T with respect to some property under consideration, and hence whether it is (*ceteris paribus*) rational to prefer T' to T. These indicators may be fallible, but they must be objective: they must be independent of the situation in which they are being used, of the person using them, etc. Formulating such preference rules and legitimating those proposed, i.e. giving good reasons why following them may facilitate scientific progress, are among the primary tasks of methodology. Although the appraisal concerns all sorts of products of research, hypotheses, explanatory patterns, procedures, criteria, etc., 'theory appraisal' may be used as a *pars pro toto* label.

For the present purpose it is sufficient to remember that the key idea underlying all demarcation criteria is that a theory is *empirical* (its truth is not an issue here – e.g. Lysenko's theory is scientific but false) if and only if it can be criticized through intersubjective experience, i.e. through appeal to an arbiter outside human control, and an empirical theory is scientific if it has in addition a certain degree of systematicity. However, since science is fundamentally research rather than a body of results, it might be more appropriate to focus on procedures and to propose that a procedure should be regarded as *scientific research* if and only if it is empirical in that it subjects hypotheses, theories, etc. to criticism based on evidence, i.e. based on less general hypotheses (describing, e.g., types of observable events) whose correctness has been intersubjectively checked and can be rechecked any time (and hence, although they are fallible in principle like all empirical statements, there appears for the time being no reason to question their correctness), and the procedure is moreover "sufficiently" systematic in that conjectures, once made, are controlled by being scrutinized and empirically tested.

An empirical scientific theory is never shown to be true. This is impossible if only because there are no epistemic ultimates, no secure basis, as the foundationalist philosophers (Begründungsphilosophie) once believed and some still believe. A theory is in principle fallible and revisable. But sometimes we have good reasons for holding that a certain theory has come closer to the truth than its rivals or its predecessors. By this we mean that its ratio of corroborated content (truth content) to discorroborated content (falsity content) is larger than that of its rivals. Fallibilism must not be identified with scepticism. And Popperian fallibilism must not be confused with so-called naive falsificationism. Since for every theory there is at least some "negative evidence" or, if you please, some "discorroborating instances", according to naive falsificationism every theory must simply be regarded as false as soon as such evidence becomes "known". From this viewpoint the development of science appears wholly discontinuous and irrational. However, since fallibilism also regards "data--sentences" ("corroborators", "evidence base" or what have you) as fallible, the truth of the premises of a falsificatory or discorroborating argument can never be conclusively established. Since fallibility is regarded as characteristic of all empirical statements, 'criticizable' in the above definition of 'empirical' means always criticizable, always revisable, never at any moment or phase of research immune to criticism. (Of course, in any argument something has to be presupposed, because we cannot problematize all components of an argument or procedure simultaneously. But none of them is sacrosanct.) This is the core of science as an activity, and, so Popperians would claim, scientific research may serve as the paradigm of rational problem solving in general.

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 symptom 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 no such claims are made, such as art and religion. Only for pseudo-science does the methodological ascertainment that a theory is not scientific carry with it a deprecation. Here methodology unmasks pretences and exposes false credentials.

1.2. "Technology" is sometimes defined as hypothesized laws in the context of application. We propose to conceive of technology as a system of rules, and to call a rule a technological recommendation or prescription if it advises us which means to use to achieve certain pre-given goals. The argumentative pattern is that of the so-called hypothetical imperative: if you wish to realize the aim and regard the proposed means as effective and efficient, and if (of course) you regard the estimated costs (of all sorts) to be acceptable, then you have to use those means; otherwise you would be behaving irrationally. A technique would then be a routinized procedure based on a particular technology. The most general technology would, under this stipulative definition, be praxiology in Kotarbiński's sense: the theory of effective and efficient purposive rational action.

The good reasons for accepting a certain technological recommendation fall into two dimensions. (1) That the technology is effective: Only if the presumed knowledge about the relevant lawful relationships is sound, only if it enables us to make true predictions, will following the technological prescriptions based on it help us to realize the over-all goal. Assessing such knowledge claims, i.e. appraising theories, is a methodological problem. (2) That we accept the goals and costs: Only if we approve of the global goal and consider the costs worth bearing do our factual beliefs obligate us to make use of the proposed means -- if we are not to behave irrationally. The justification of the goal itself as well as the acceptance of the cost, the evaluative problem, lies in a different sphere from that of assessing the factual claims. That the global goal cannot be problematized within the technology itself is contained in the very definition of technology here proposed.

These two dimensions in justifying a technological recommendation suggest two typological descriptions of technologies. (1) Technologies can be typologized according to the status of the presumed knowledge on which they are based. Here the spectrum ranges from magic, based on mythical knowledge (e.g. a rain dance), through handicrafts based on commonsense knowledge or observed factual correlations, to technologies based on science, in which the underlying knowledge contains explanations of the assumed lawful interrelationships, explanations of why, if certain initial conditions are brought about, a certain type of event ensues. A schema of the scientific knowledge base would be: a theory T together with auxiliary theories A logically entails that, if initial conditions I are brought about, then the state of affairs or type of event P (Vorgang) obtains -- $(T \,\&\, A \rightarrow (I \rightarrow P))$. In the case of a handicraft or other technology based merely on correlations, one cannot explain the sequence (if I then P), which means that one does not know what additional factors may be relevant. (For example, when Bessemer found that his steel-producing technology did not work in certain cases, the realization was for him "as a bolt from the blue".[7] Only when a theory was available which could explain why it did not work for ore containing phosphorus did steel production become (with Thomas's procedure) scientifically based (since it now had the T and A of our schema).) Technology based on science is a phenomenon which has arisen only in this century. Even at the end of the 19th century "empirical engineering" loomed larger than technological innovations based on science.

To forestall any possible misunderstanding it may be worthwhile to add the following comments on the distinction between "technologies based on science" and other technologies. The notion of "technology based on →

science" here uses a narrower concept of science than that used in the first section, which was roughly that assertions be empirically criticizable and that theories have a certain degree of systematicity. Science was viewed as "the long arm of commonsense inquiry", a concept which only takes into account what we could call the context of testing and refining. Appraising the presumed knowledge on which the technological prescriptions are based is in principle the same for both crafts and technology based on science. If the craftsman tries out this piece of presumed knowledge in different conditions, he is testing in a way much like testing in standard scientific enterprises (although in the latter case the degree of systematicality strictness and precision are bound to be higher), and even technological results could sometimes be part of the evidence on which such knowledge claims are criticized. (Even the effectiveness of a rain dance may be empirically checked, but the mythical theories behind the claimed relation between the ritual and the incidence of rain will not qualify as empirical theories, since the failure of the technology would not lead to their rejection but to ad hoc explanation and immunizing strategies.) An agricultural technology based on hypothesized laws based on Lysenko's theory will not work, this time because the hypothesized laws and the theory (a scientific theory) on which they are based are both false. The term 'science' cannot be reserved here for true theories, and thus technologies can be based on science and yet be ineffective. As long as the alleged knowledge upon which the technology under consideration is based is empirically criticizable, it may be said to base on science in the sense in which this term is introduced in section 1. But this broad sense is not adequate for the present distinction because according to this wide sense also all handicrafts would qualify as "being scientifically based". The distinction proposed here between a craft and a technology based on science hinges upon whether or not the piece of alleged knowledge on which the technological prescription is based has been explained, derived from a more general law or theory. Only if it can, can one claim (rightly or wrongly) that the relationship is a causal one and only then can one use the theory to explain and to predict apparent expectations. (Of course such predictions will be successful and such explanations good explanations only if the theory is a good one.) For the theory empowers us to claim that the relation is lawlike and not just a correlation which may be due to the presence of a third (still unknown) factor, etc. The prototypical case of a technology based on science can, however, best be illustrated by looking at the context of discovery.[7a] In the paradigmatic case, the sequence runs as follows: there is a general scientific theory already on hand and (usually) certain pressing practical problems, and one casts about in one's mind looking for ways to develop technologies with the help of the theory (or theories). A choice example would be the development of nuclear technology from atomic theory once it was realized that the theory had implications about the release of high energies from atoms. Bessemer's technology of steel production might serve as a prime example of a "craft technology", because he himself says that he hit upon the effect[7b] purely by chance; he says his "knowledge consisted only of what an engineer must necessarily observe in the foundry or smith's shop." In such a "craft technology" one is not in a position to claim any causal relationships to obtain, and is not obligated to be able to explain one's successes. So much on the relationship between technology and science. (2) Alternatively, technologies can be typologized according to the sorts of goals or values appealed to. For instance, in medical technology the overarching values are "values of health" or "values of continued life" (Vitalwerte) -- as distinct from "values of knowledge", hedonistic, ethical, aesthetic, religious, social, economic or what have you, values. The two typologies can yield various cross--typologies.

Methodology itself is a "quasi-technology"; it has certain striking similarities with technology on 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 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 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 pre-given 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 allocations 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. 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 Geisteswissenschaft) and on methodology (a quasi-technology). Our wide conception of technology of course also includes the so-called social technologies; even the study of 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),[7c] 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[8] and N. Rescher[9] 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 limits 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 questionings, 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.

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.[10] 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"[11]). 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.

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.

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 proposition 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.[12]

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":[13] 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[14] 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.[15] Moreover, today certain sociologists of science propound a theory which conceives the course of science as proceeding 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".[16] 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'."[17] 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."[18] 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."[19] 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."[20] 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"[21] occurs when "... social norms [are] ... incorporated into the concepts of natural sciences". [22] In this ideal, final state -- which, 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 general →

ity should be universality in society, not in nature. Thus generality in the form of unlimited reproducibility would yield to the generality of social consensus."[23] 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 êcheant, 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" or 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 ridiculouness, be criticized[24] 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 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 represents 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",[25] "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 the premises 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 premises 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."[26]

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 propogation", that each problem solved generates new problems.[27] A measure of the degree of progress is how much "deeper" the new problems raised are.[28] 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".[29] 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.[30] 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 above-mentioned 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 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, <u>no terminating limits</u>. <u>Science is in principle an infinite process without a definite beginning</u> (since every question has its presuppositions, and every thesis used as a presupposition is itself an answer to a prior question) <u>and without a definite end</u> 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 (<u>pace</u> P. Feyerabend and all the "relativists", arguably including T.S. Kuhn).[31] 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. <u>Boundaries of technology</u>.

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.

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 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 transfers 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.[32] 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,[33] the denial of excluding bounds of science, and this predisposed it towards a "practical" scientism, 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, the concern is not at all positivism, but giving a 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 science predicts certain limitations: it tells us what is impossible. There are different sorts of possibilities. 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 that within the realm of the empirically possible (that not ruled out by accepted scientific knowledge) which is actually "realizable". A first interpretation of "realizable": it is predicted 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).[35] 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.[36] Looking at the problem from the other end, we come to so-called 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 include the results of "technological breakthroughs".[37] Indeed, the impossibility of predicting in any detail at all which parts of today's basic research may in the future yield rich dividends in new, unexpected technologies together with the historical frequency of such unforeseen benefits constitutes the so-called overhead argument, still the most effective argument for justifying the expenditure of public funds on basic research.

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.[38] 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-sided relationship of reshaping, then the species overextends itself. Such a program is particularly pronounced in Marxism, but not only there.[39] 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 "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 be 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,[40] 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". 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 should be constituted, for in order to answer such a question of values and goals, we would have to know what the function of the human being is.[42] 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. On 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".[43] In sum, these particular limits of technology 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 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: that oldest rule of Greek ethics which says, "Moderation in all things."

FOOTNOTES

† I wish to thank Professor Max Jammer and Mr. Michael Warder for having suggested the theme of this lecture.

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

[2] Cf. (Manuel, 1965) p. 97.

[3] For a penetrating analysis of its origin and character, and for devastating critique, cf. (Jaki, 1966), esp. pp. 481-500, Cf. also (Radnitzky, 1976a).

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

[5] 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."

[6] 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."

[7] Cf. (Andersson 1975), p. 32.

[7a] Cf. (Andersson, 1975) pp. 20ff.

[7b] The effect here was that "an unmelted whell on a pig of iron exposed to the draft showed that air was a powerful decarbonizer." (Andersson, 1975) p. 32.

[7c] A promising strategy for improving the technology of making social choices is found in the work of G. Tullock. For a survey, cf. (Tideman and Tullock, 1976).

8 Cf. (Kant, 1783) §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".

9 Cf. (Rescher, 1978).

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

11 Cf. (Jammer, 1977).

12 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).

13 Cf. (Rescher, 1978).

14 Cf. (Sarton, 1931) esp. pp. 10f. and (Sarton, 1936) p. 5.

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

16 Cf. (Böhme *et al*., 1976 (1973)).

17 Cf. (Böhme, 1976) p. 314.

18 *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.

19 *loc. cit.* p. 319.

20 *loc. cit.* p. 315.

21 *loc. cit.* p. 321.

22 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 "dialectial" method and have recognized, as all Marxists do, that "it is precisely the restrictiveness of bourgeois society which also limits the universality of science". loc. cit. p. 325.

23 loc. cit. p. 325.

24 Cf. (Andersson, 1976), (Radnitzky, 1976c) esp. pp. 398 ff, (Radnitzky, 1976a) §3.1 pp. 28-31, and (Andersson, 1977).

25 Cf. (Popper, 1963) p. 202, (Radnitzky, 1978) §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 improved the original law hypotheses in the process of attempting to explain 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).

26 Cf. (Popper, 1963) p. 222.

27 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..."

28 Cf. (Popper, 1963) p. 222, (Rescher, 1978) §3.

[29] (Rescher, 1978) §3.

[30] (Popper, 1972) pp. 16, 205; (Popper, 1975) p. 97; (Radnitzky, 1976b) pp. 533f.

[31] Cf. (Radnitzky, 1976b) §1 and (Radnitzky, 1978) §6.

[32] 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.

[33] Cf., e.g. (Radnitzky, 1976a) §2.

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

[35] Cf. (Radnitzky, 1976a) pp. 31 f., commenting on a naive law enacted by the Socialist 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 unforeseeability of such possible future technological relevance are also given there.

[36] 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.

37 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.

38 E.g. if 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.

39 Cf., e.g. (Radnitzky, 1976c) p. 379, (Radnitzky, 1977) §1.1.

40 Cf., e.g., (Spaemann, 1977) esp. pp. 187 f.

41 Cf., (Spaemann, 1977) p. 182.

42 We may know what, e.g., an ox should be like if we breed 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).

43 Cf. (Spaemann, 1977) p. 192.

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