On the Feasibility of a Cognitive Approach to the Study of Science*

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Zur Möglichkeit eines kognitiven Ansatzes in der Wissenschaftssoziologie*

Inhalt: In diesem Aufsatz werden drei neuere Ansätze in der Wissenschaftssoziologie vorgestellt, die Alternativen zu dem bisher dominanten institutionellen Ansatz darstellen. Obwohl die Ansätze sich in ihren methodologischen und epistemologischen Voraussetzungen, wie auch in ihrer Zielsetzung, voneinander unterscheiden, weisen sie dennoch Gemeinsamkeiten auf, die es erlauben, sie als kognitiven Ansatz auszuweisen. Die Betonung liegt auf kognitiven Prozessen in der Erzeugung und im Wandel wissenschaftlicher Ideen statt auf der Untersuchung institutionalisierten Verhaltens und auf den informationsverarbeitenden Aspekten im Wissenschaftsbetrieb. Die konventionelle Ansicht von einer linearen Entwicklung der Wissenschaft wird abgelehnt. Daraus lassen sich für die Wissenschaftssoziologie eine Reihe von Konsequenzen ableiten, die zur Diskussion gestellt werden.

Abstract: In this paper three new approaches to the study of science are discussed that have emerged only recently and offer alternatives to the hitherto dominating institutional approach in the sociology of science. Although the three alternatives differ in many respects, they share certain features in common which qualifies to subsume them under the heading of a cognitive approach: the emphasis is on cognitive processes in the production and change of scientific ideas rather than on institutionalized behaviour, they disregard the conventional view of linear scientific development and focus on the constructivist information processing aspects in the production of scientific knowledge. The discussion is opened on several consequences of these alternatives.

Introduction

Among the more interesting developments in the sociology of science, a tendency can be noted to move away from a purely 'institutional' or 'behaviouristic' approach. As will be remembered, questions of this approach centered upon the 'social influences that produce conformity to scientific norms and values' and on the 'scientists' commitment to the particular goals of his profession' (KLIMA 1972). They rested on the somewhat arbitrary distinction between 'internal' aspects of science to be found in scientific thought governed by the internal standards of the scientific method, and the 'external' behaviour of scientists, open to social influences that mould it and the norms governing it. This distinction appears no longer as the only valid line of inquiry. *Cognitive processes* like those involved when scientists do science receive increasingly attention and the question of *conceptual change* has re-emerged both in general awareness and in professional writing. Concomitantly the old question of the interplay between social factors at large and form and content of thought is in the process of being assessed anew.

Perhaps even more interesting, preoccupation with cognitive aspects of science has had a liberating effect in the sense that a number of hitherto unquestioned assumptions appear now to be the outcome of either convention or particular ideologies. What has been especially attacked is the conventionally accepted view of *science as the accumulation of a body of knowledge* that has, ever since its breakthrough achieved in the West 200 years ago, grown in linear fashion and will continue to do so. This view has been criticized for having too close intellectual ties with the conception of 'progress without costs' and is seen to be the direct outgrowth of the positivistic tradition of the enlightenment (BÖHME et al. 1972). The history of science has been reconstructed solely in terms of its results and of conditions which led to them, thereby creating a false impression of the inevitability or uniqueness of this development. By questioning this conception, the door has been pushed open and will eventually lead to alternative views of science.

It is with the *search for alternatives to the 'linear growth model'* of science that this paper is mainly concerned with. It is quite likely that present climate of doubt of unlimited growth and progress is a powerful undercurrent for this search. On a more mundane level, it is certainly true that "man has made negative experiences with the way in which

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science has been practiced historically, e.g. environmental problems, militarization of science and anthropofugal tendencies in science" (BÖHME et al. 1972: 314) which might lead to a reassessment of past achievements and a shift in future standards. But before engaging in future predictions the alternative models of scientific growth have first to be presented. Due to different intellectual backgrounds and research traditions, the answers that have emerged as alternative views of science are bound to be expressed in different languages, with different emphasis on conventional or unconventional strategies of thought and presentation and will differ as well in scope and purpose of the analysis. Nevertheless, they share certain features in common, which led me to subsume them under the heading of a '*cognitive approach*': they turn to the cognitive processes involved in the production and change of scientific ideas and as all cognitive processes lend themselves to a great number of variations and transformation, the persistent tendency to make the history (and future) of science look linear and cumulative is easily avoided. The result is not one, but many scientific universes; the rejection of the logician's and philosopher of science' claim that truthfulness or falsity of any theory can be determined with the help of 'inner-scientific', logical criteria alone; the rejection of the view that order is discovered out there, instead of being imposed by the cognitive information-processing system; and the forceful beliefs that facts are created, albeit with unequal significance attached to them, and that scientific thought is but one special case of ordinary thought. As such it is open to all sorts of influences exerted from its socio-economic environment, but the boundaries are yet to be determined.

With these cognitive guidelines in mind, let us turn to different alternatives which, for the sake of convenience of presentation, I have grouped into three sections.

1. The evolutionary alternative; or on the way towards eco-science.

The most traditional of the three alternatives to be presented here, is undoubtedly the one that takes the biological model of evolution as a more or less closely argued analogy for the development of scientific ideas. An evolutionary

trace is already present in KUHN's work (KUHN 1970). KUHN claims that the choice between competing paradigms is not and cannot be determined merely by the evaluative procedures characteristic in normal science, nor that the issue of paradigm choice can be unequivocally settled by logic and experimentation alone. On the criteria governing the process of acceptance of a new paradigm, he remarks: "Verification resembles the process of natural selection; in a specific historical situation under given possibilities, the one most fit for survival is selected" (KUHN 1970: 145ff.).

As was to be expected and has received ample comment, KUHN has been sanctioned and attacked for suggesting that non-scientific, external criteria might decide the outcome of competing paradigms (LAKATOS & MUSGRAVE 1970). The attack has been greatly facilitated by impreciseness, conceptual errors and weak argumentation, most of which KUHN readily admits in the postscript to the second edition of his 'revolutionary' oeuvre. Under the influence of attack and defense, however, certain notions survived and emerged more pointedly than in the original presentation of the first edition. Among them is the notion of paradigm as shared examples which clearly now is the central issue and which is now much closer to basic cognitive processes as they have been investigated in cognitive psychology (e. g. the emphasis on the grouping of stimuli pattern and acquired similarity relations and rules that govern the recognition of similarity, the emphasis on tacit knowledge that can be evoked only through rules etc.). Secondly, KUHN's belief in scientific progress, in later scientific theories being the better scientific theories, has been somewhat shaken under the influence of the cognitive nature of the paradigm. Although a scientific theory is still regarded to be better than its predecessors for being a better instrument for discovering and solving puzzles, or being a better representation of what nature is 'really like', KUHN admits that he can no longer see in the succession of theories a coherent direction of ontological development. On the contrary, he sees for instance EINSTEIN's general theory of relativity to be closer to ARISTOTLE's than either of them to NEWTON's.

That the step from the early KUHN's revolutionary accounts of the development of science to an all embracing *evolutionary* research programme is a

short one, has been demonstrated by STEPHAN TOULMIN (TOULMIN 1972). After rejecting both, the over-systematized, universal claims of formal logic as well as historico-cultural relativism, the stage is set to move from a systematized to a "populational" analysis of concepts and of collective concept use. A theory of conceptual change must be able to explain on what occasion and by what procedures a basic set of collective concepts in science or elsewhere (!) is displaced by another; it must explain why our thinking remains relatively unchanged in some areas over long periods and why others change rapidly and drastically. For this purpose, TOULMIN proposes to turn towards the DARWINian 'populational' theory of variation and selection. DARWIN's 'four basic commonplaces' are restated in terms which TOULMIN holds applicable for conceptual development.

- 1) The concept of species is translated into 'more or less separate and well-defined disciplines', each characterized by its own concepts, methods, aims. Though mutable, each discipline displays recognizable continuity, particularly in the selection factors that govern changes in its content.
- 2) What has to be explained are therefore both continuity and change which involve the dual process of variation (through continuing intellectual innovation) and selection.
- 3) The combined action of this dual process gives rise to conceptual change, which manifests itself, like a new species, only when further conditions are met. To prove their advantages, ideas must meet in a suitable 'forum of competition'.
- 4) Finally, a mechanism of adaptation to the intellectual ecology is assumed which takes the form of an interlocking process of genetic endowment and ecological opportunities. Failing suitable niches, the genetic potential of a given organism population will remain unexploited, while in the absence of a suitable population, the ecological demands of a niche will go unmet. It can thus be said that niches exist partly in virtue of a population and a population exists partly in virtue of a niche. The intellectual counterpart of this 'complex complementary relationship' are to be

seen in problem-situations in the intellectual ecology which creates a certain range of opportunities for intellectual innovations.

TOULMIN is ready to admit that "DARWIN's straightforward populational schema" may not in all cases give a correct answer to the question of change, but he claims that the balance between variation and selection within a population of ideas, is one of the possible processes by which historical entities preserve their identity. Apparently, TOULMIN sees more room for the possible development of ideas than the historical record of its actualized achievements allows one to infer.

Yet the main point of TOULMIN's scientific Neo-Darwinism lies not so much in inducing a sense of awareness – however vague and imprecise – for the interplay between concepts and environment, but is to be found in his rejection of what he calls the over-systematized view of science, which is at the same time, a-temporal, formal and universal. The basic problem for TOULMIN is to account conceptual change while still clinging to the notion of epistemological rationality as defining all scientific pursuits. Rationality is therefore shifted from being a characteristic of a particular system of propositions or concepts, to become a characteristic of the procedure by which one set of ideas is changed into another. Rationality is transmuted from being a sub-species of logicity to become a sub-species of procedure. "In non-intellectual matters . . . we judge the rationality of man's conduct by considering not how he habitually behaves, but rather how far he modifies his behaviour in new and unfamiliar situations, and it is arguable that the rationality of intellectual performances should be judged . . . by considering not the internal consistency of a man's habitual concepts and beliefs, but rather the manner in which he modifies this intellectual position in the face of new and unforeseen experiences" (TOULMIN 1972: 486). – If nature has its 'natural selection' process, science has finally acquired its 'rational adaption' procedures.

Further metaphorical indulgence in DARWINian terminology can be found in an article by G. BÖHME et al. who are engaged in proposing additional criteria with the help of which the

'survival value' of scientific theories might be determined (BÖHME et al. 1972).

The authors suggest that higher survival value can be detected by asking how adequate scientific theories are in granting higher survival value to the scientific community which produced them. Survival values of ideas become defined in terms of survival value of those who hold and propagate them. This can be specified by asking whether a scientific theory is capable of being transmitted, either through the channels of a 'school' or by generating new problems. Secondly, the survival value of a theory will be higher when it confirms to the dominant interests of the larger society and thus meets some needs or requests not further specified by the authors.

Apart from the functionalist flavour of these formulations, they point anew to a search for cognitive mechanisms through which the needs and interests of the society at large are fused and interrelated with the cognitive structure of science itself. This suggestion may not be a radically new one, yet it comes at a time where the analysis of cognitive mechanisms is also pursued in other areas. Interest in cognitive representations as a basis for the investigation of cognitive psychology and artificial intelligence where the question how human beings model their environment has emerged as the central issue¹. The cognitive theory of human information processing maintains that human behaviour – in the widest sense – is guided by internal models or representations of the 'external' world. The term cognition thereby refers to all processes through which sensory input is transformed, reduced, elaborated, stored, recovered and used (NEISSER 1969). These models or representations may be considered as cognitive structures that act as powerful mechanisms through which is determined what is and what is not recognized, which stimuli patterns can be abstracted from the environment,

how they are grouped to form new units and how they will be further processed.

If the 'intellectual ecology', the needs and interests of society are to make any impression at all on scientific theorizing, it is quite likely that this will be achieved not only through the way in which the profession is organized, what means it has at its disposal, its conditions of work and its socialization, but it will be effectuated also through selective cognitive processes which may well operate through mechanisms similar to the ones PIAGET has described for the intellectual development of the child (FLAVELL 1963). As far as the evolutionary model proper is concerned, one is, however, well advised to remain rather sceptical. It is not for the first time in the history of sociological thought, that great confusion might result from an unfortunate tendency to describe phenomena in metaphorical evolutionary terms which do not lend themselves to such a description and which show only a vague resemblance to the phenomenon of biological evolution, namely a non-linear branching out process. Evolution, as biologists have repeatedly pointed out, is a concept which does not apply to individuals, but rather to a whole population. TOULMIN's claim that scientific disciplines constitute 'species of ideas' seems to me rather far-fetched and apart from the perceptual phenomenon of grouping those ideas together which, in our view, share essential similar features, I fail to see the permanent, hereditary features of the species of ideas.

More serious however is the fact that a closer investigation of the proposed analogy between an evolution of ideas and that of biological species reveals that the analogy falls flat on its face, if one takes it for anything more than a loose metaphor. Evolutionary theory has explained evolution in terms of three properties of this process: multiplication, heredity and variation. While it can be said that ideas multiply and variations do occur, the hereditary aspect is sorely neglected (and indeed negligible) in the realm of ideas. Certainly, there is transmission and tradition of ideas, schools may be founded and the young are to be taught. But if heredity of ideas were to be used in a sense approaching the sense it has in biology, it would imply that 'like has to beget like', that ideas, in

1 The literature on cognitive psychology and artificial intelligence is too vast to be enumerated here. A good overview may be gained from the lecture notes of the NUFFIC international summer course 1972, edited by G.J. DALENOORT; a survey article by H. TRANSGAARD; NEISSER's book on cognitive psychology and the journal COGNITIVE PSYCHOLOGY.

order to reproduce themselves would have to reproduce themselves entirely and as exactly as possible. While there must be some continuity of ideas, every scientist would shiver at the idea that the younger generation should come as close as possible to reproducing the ideas held by the older. Nor is it of great help to appeal to the distinction between genotype and phenotype. For a biologist, genotype is that part of an organism which is replicated, while phenotype is a structure or a sequence of structures developing under the instructions of a genotype whose function it is to ensure the reproduction of a genotype. Selection acts on the phenotype, and it is generally admitted that there are many steps between the phenotype and the genotype. Nor is mutation to be equated with 'innovation': mutation in fact lowers fitness, as if this were not so, evolution would proceed without natural selection (WADDINGTON 1969).

Still another serious problem (even for Neo-Darwinism in biology today) is the fact that the theory of evolution *cannot explain the evolution of increasing complexity*. If fitness is seen not only in terms of sheer survival of number, but taken to mean the process of reproduction and the probability of survival in a given environment, it can be interpreted as meaning the adaptively complex (SMITH 1969). Evolutionary theory can predict in the short run that individuals will change in such a way that their fitness in the existing environment will be increased (which also presupposes a theory of this environment which remains to be written). But this increase in fitness may be achieved through both, an increase or a decrease of complexity. There is no lack in biology of numerous examples where adaptation, albeit in an increasingly complex environment, has led in the direction of decreasing complexity of the organism (WADDINGTON 1948). But who wants to propose, when using an evolutionary model to explain the development of scientific ideas, that science also adapts by degenerating? And even if one were to make such a proposition and turn to an investigation of the unsuccessful, degenerate, forgotten ideas, and to assume that the ideas or their creators in some sense 'choose' to let them degenerate, one still would have to explain why. The main issue of biological evolution – how populations deal with unknown futures – may indeed not be too far away from the question how ideas deal

with unknown futures, but it still is an unresolved question. WADDINGTON may have put his finger on the right spot when he describes the amazing work of biological mechanism which can operate so effectively on the basis of inadequate information, and comes to the conclusion: "Life might be defined as the art of getting away with it; and Theoretical Biology as the attempt painstakingly to explicate just how it is done" (WADDINGTON 1969: 122).

Thus we are led to note a lack of fit between the evolutionary model and its application to scientific theories: even if ideas were to lend themselves to be regarded like species, there appears to be a premium attached not to reproduce themselves in exactly the same way, but to beget new offsprings, preferably of higher complexity. The 'ecology of ideas' does not only consist of various conditions that must somehow be interpreted "on the basis of inadequate information", they must be cognitively processed if they are to lead towards the complex interplay between cognitive and social structures which nobody seems to deny.

It therefore appears more fruitful to take a long second look at the cognitive transformation processes that operate between scientific ideas and social structure, than merely to dwell upon tenuous analogies, however simple they may appear. The vast comparative data material which has been compiled on the history of science, both within the European context and outside, especially for China, has hardly been used for anything else so far than to demonstrate the superiority of modern Western science (BEN-DAVID 1971). Yet, one could just as well ask why different conceptions of science have existed in different types of societies and how general ideologies have been linked to the 'cognitive map' of scientists in guiding not only their perception of what constitutes a problem, but also in influencing their processing strategies, their rules of representation, their cognitive style².

Renewed anthropological interest in traditional belief systems and attempts to represent entire

2 It is increasingly recognized by psychologists that such differences exist and ought to be further investigated. See for instance B. LLOYD (1972) and COLE et al. (1971).

cognitive systems have shown, that a high degree of 'rationality' and of order is to be found in most cognitive systems, however primitive their economic development may be³. It also emerged that many traditional cognitive systems are influenced by 'emotional needs', needs for certain kinds of personal relationship which may be linked to the fact that their cognitive systems depend largely on the use of a personal 'idiom'. Although differences exist, it is surprising how many parallels can be found between traditional thought and Western science (HORTON 1971).

Even a cursory examination of Greek science reveals the apparently low status attached to experiments and technological achievements compared with abstract, formal thought. BEN-DAVID tells us that within Greek society, socio-political needs were considered much more important than technological endeavours (1971: 33ff.). If one adds to this the fact that the Greek 'men of ideas' were part of a leisure class, completely freed from the production process, whose economic needs were entirely taken care by an involuntary labour force, one may perhaps more readily discover the cognitive transmission mechanism which operated in their minds. — In China, as JOSEPH NEEDHAM has so admirably demonstrated, technological inventions formed part of the general economic pattern of a home-based industry and the curious mixture between modern and traditional thought conforms well to the development of science (1954–71). In the West, with the rise of capitalism, science began to produce for the market, thereby accelerating and multiplying the market forces already in existence. This market orientation has prevailed up to this day, sometimes in form of disguise of 'applied science', sometimes in straightforward analogies, sometimes in the application of concepts that derive directly from a utilitarian ideology: 'rewards' and incentives are seen to constitute the driving motivational force in the production of science, exchange theory has it that scientists, like everybody else, exchange recognition for their ideas and

the whole enterprise is justified by the belief in unlimited growth and linear progress.

II. The circular model of scientific growth; or the return to metaphysics

Although the following presentation of another alternative approach rests exclusively on the writings of one man, I believe that the views he expresses can find support from many quarters. I take him as a representative largely because physics has played such a dominant role in the history of science as well as in the sociology of science and is still regarded as containing in its way of theorizing and methods the key to success. It may therefore come as a shock to many, that — while they are still busily engaged in attaining higher scientific prestige by imitating the methods of the natural sciences, physics (or at least some physicists) are already well on the way to a radical shift in their conception of science and the scientific method. As radical as DAVID BOHM's views may sound to some, similar statements can be heard from those who work in the field of cognitive psychology or artificial intelligence or who have espoused a 'structuralist' approach which cannot fail to have deep epistemological implications⁴.

In an article which appeared in 1970, BOHM expressed his dissatisfaction with the currently found 'fragmentation' in science which he links to a corresponding fragmentation in our general awareness, brought about by our mode of thinking and use of language (1970). In other writings, BOHM has elaborated a number of similar ideas. Thus, he holds the 'notion of order' to be the most fundamental notion that will replace currently held fundamental notions in physics (BOHM 1969). Order is common not only to physics and biology, but to all we can know and perceive. "... there is the order of events in time, the order of cause and effect, and the many topological orders that constitute the essence of what is meant by space. Without these orders ... there would be no meaning to measuring intervals of time and space, nor even to the idea of continuity or discontinuity of these intervals" (1969: 18). In BOHM's defini-

³ There is a new branch within anthropology which is devoted to the study of cognitive systems. See St. TYLER (1969), GLADWIN & STURTEVANT (1962) as well as — although following a different line of inquiry — the works of M. DOUGLAS (1973).

⁴ For the latter see especially PIAGET (1970, 1971) as well as BOURDIEU (1968).

tion, order emerges as a 'set of similar differences'. In the realm of mathematics, but also in activities like building a house, this definition can be exemplified.

A random curve is said to be one of infinite order and we learn that experiments are currently performed to distinguish between random processes and high-order processes in quantum physics, as well that a new mathematical language is being developed to convey the full richness of these notions.

More to the point of the present discussion, however, is the *metaphysical underpinning* of these ideas. In BOHM's view, metaphysics is fundamental to every branch of science. It is a set of basic assumptions about the general order and structure of existence. It is usually expressed in such linguistic clauses as 'all is X', 'X is basic', 'X is always true or never'. Of course, those who only go by what they see, also profess their metaphysical beliefs, but in a dangerous, because unconscious way which leads to an assimilation into the structure of thought of assumptions and inferences which are taken for facts and observations. Metaphysics has therefore to play an essential role in any kind of thinking: it is a metaphor which provides the user with an immediate perceptual grasp of the overall order and structure of one's thought, but it is to be used with caution, and awareness.

Under these auspices, BOHM can be very explicit about his own metaphysical assumption which he believes, perhaps, to be called for at the present stage of development of human knowledge.

His metaphysics is essentially a *metaphysics of process* indebted to field theory. He does away with 'things' (separately existing entities which appear to be only the result of our fragmented way of thinking) and abstractions of what is relatively constant in a process of movement and transformation. Forms that we see have only a relative stability. Rocks, trees, people, electrons, are only names of centres of foci of vast processes which extend ultimately over the whole universe. Each focus refers only to some aspect of the overall process and has only relative stability. While some things last only a short time, others may last longer, but nothing forever. The order in which these pro-

cesses appear can therefore be discussed on three levels:

- 1) a quasi-equilibrium process, i.e. a situation which enables one to recognize certain stable, constant features of a process. Then, as we see that these features change, we tend to explain them in terms of
- 2) a dynamic process, usually of interaction between some basic entities. Still later, we come to
- 3) the creative process, in which there are no basic objects, entities, substance, but all which is observed comes into existence as a certain order, remains relatively stable for a time and passes out of order again (as physics now explains the movement of electrons through annihilation of existing orders and creation of new orders).

In short, in the metaphysics of process creation and transformation of order become most fundamental.

The metaphysics of process is accompanied by a metaphysics of trans-functional values. Function, BOHM points out, must ultimately refer to something beyond the field of function, Physics has traditionally been a science which was supposed to be free of such trans-functional references, yet this freedom has been more apparent than real. In the last analysis, the acceptance of the Newtonian laws depend on an act of faith. In the actual development of theories of relativity, cosmology and quantum mechanics scientists seem to have been forced to make wide use of trans-functional criteria. The use of probability laws in fields such as statistical mechanics and quantum theory, has introduced the notions of 'disorder' and 'randomness', but as far as one can tell the use of the word 'disorder' means only that what actually happens to fail to harmonize with people's tacit conventions of what is supposed to constitute order.

As it is thus inevitable to have trans-functional criteria included in one's metaphysics, one might as well introduce consciously new ones (BOHM 1971). It is especially important to realize, BOHM maintains, that concepts such as length, time, mass, charge etc., which are supposed to exist

out there, have been created by man. The Cartesian division between mind and body, here and out there, has left Western scientific man in a deeply divided state, which to continue to hold seems no longer necessary. Just as the notion that there are separate existent and individual entities is an illusion, so is the separation between observer and observed. "In quantum theory, it has been found that the observed object can no longer consistently be said to exist separately and independently of the experimental conditions. Rather the form of the experimental conditions and the meaning of the experimental results have now to be one whole, in which analysis into autonomously existent elements is not relevant" (1971: 15). To think of an 'observing instrument' interacting with a separate existent 'observed particle' has no meaning. — BOHM is prepared to carry EINSTEIN's emphasis on undivided wholeness of the universe in terms of field one step further. For even that which 'observes' or 'measures' the field can no longer consistently be regarded as something that exists separately from the field. In the context of these new theoretical developments, analyzability of the whole universe in terms of 'basic building blocks' becomes utterly irrelevant.

If one does away with the separation of the observer and the observed, one is likely to end up with a world-view which is incomplete, inexhaustible, following its own order and orders of orders in a hierarchically structured way. From the total hierarchy, man can abstract certain knowledge which has partial, relative and limited validity. The abstraction is 'creative', in the sense of being part of a process of outward perception and inward perception. "In this circular movement, mankind creates its percepts, concepts, language, and so on. What has been created up to a given time provides the very terms of communication available at that time. These terms enable us to focus on some limited aspects of the vast field of what is to be perceived directly with the senses, and to treat these as 'basic', essential, significant, relevant, while other far more numerous and richer features are treated as fortuitous and irrelevant. Experience guided by these notions is then always showing us the limits of validity of the corresponding abstractions. These limits indicate the need for extending the 'circular' process to create newer ab-

stractions leading to new percepts, concepts, language etc." (1969).

It is quite evident from this that the notion of the necessary incompleteness of our knowledge runs counter to the commonly accepted tradition which sees science to progress towards some ultimate state, some goal, through a series of approximations. BOHM sees in the development of physics an indefinite and unending unfolding unto a measureless unknown, rather than a better and better covering of some limited measureable and in principle completely knowable domain.

One of the most striking examples of such a development, is modern cosmology, which has changed more radically and more often than any other theory (1971). But if there is no hope to ever find a complete theory of the universe, or of anything else, what is the use attempting to formulate theories at all? BOHM's answer to this question is to define theory in accordance with its Greek root, a form of insight, rather than a well defined and certain knowledge about reality. Theories allow one to organize the present overall knowledge and experience into a convenient, harmonizing form. But they should not be regarded as absolute truth, or as stages of a steady approach to such a truth. Such an attitude, BOHM maintains, only hinders their proper function, namely to be able to alter radically, if we learn a 'new view'.

It can therefore be said that science, like art or mathematics, helps to 'fit' our knowledge into broader aspects of the reality in which we live, first with the aid of observing instruments and eventually by seeing how it can be fitted to broader useful purposes. This action of "*fitting*" becomes the trans-functional function of science. It is important to realize that instruments are the tools through which we create the conditions in which our ideas can be put to a more precise test than could be done without instruments. Fitting refers to a wholistic, creative process in which there is no definite or final goal to be reached. Ends and means alike are contained in the action of fitting ideas to an everchanging reality. Scientific instruments and experiments are merely one kind of tool which we use to express our ideas.

So far the gospel according to DAVID BOHM. It has been cited at such length, because it opens some radically new perspectives for the study of science as well as for science. Let me try to enumerate some of them.

- 1) The linear concept of science as the growth of accumulated knowledge towards some end state of truth or total knowledge is replaced with a circular notion, of an infinite, non-repetitive kind. Increasing complexity of thought is assumed to be present in higher order forms, but the notion of 'order of orders' allows for qualitative change which can indeed give rise to new kinds of orders in a truly infinite development.

This replacement and the introduction of a circular notion of science is in itself very interesting. It comes at a time, where some maintain that the limits of progress have been reached and others start to question the linear conceptions inherent in the notion of progress, growth, and indeed, in our all-pervasive notion of time. Are we here stumbling upon a new 'world view', a new 'form of insight' which would indeed allow us to form a new coherent picture of our social, economic as well as scientific universe? These are questions which cannot be answered here. But they go to show how potent a conscious reorganization of thought might be in re-directing our attention to new forms which might emerge, because we assign new relevance to them, while at the same time, letting others disappear by assigning them to that pile of our knowledge, which we perceive as irrelevant and disorderly. (It also points into a direction in which BOHM's ideas might be tested, namely by practicing them.)

- 2) If theories are to be seen as attempts to gain and to maintain an insight, to create as coherent a view as possible, by a continuous effort of fitting it to reality (which means not only physical reality, but also other thought forms), then it can also be assumed that scientific theories are a special case of other theories or world views. Scientific thought becomes distinguished from ordinary thought only by its specific art of 'fitting'. It would therefore be advisable to look in greater detail into the criteria used in the

procedure of fitting both with regard to ideas-instrument and ideas-purpose.

- 3) These guidelines can only be meta-physical, which for BOHM means essentially, as we have seen, a prestructured set of assumptions with which to organize primary experience. As these assumptions are however based on experience, on broad criteria of what is relevant to know, the assignment of relevance is a cognitive process which goes on all the time. It is part of a necessary selection process which has to be present in all organism in those mechanisms which process information (NEISSER). Our attention focusing processes have to divide the world objects or processes, which possess relevant and non-relevant features. At the same time, the focus of attention can and must change: nothing is relevant all the time, or independent of its context.

To deny today, the impact of extra-scientific criteria ideas and ideologies on science, seems to me to be utterly untenable. This is not to say that science does not maintain its own information-processing code (its norms and the scientific method). However, this code can neither be watertight (there are wide variations between disciplines), nor immutable (procedures which were not admitted 50 years ago are admitted today etc.). These filters can be seen as a collective anticipation of 'relevance': Which product will be regarded as scientifically relevant is defined through the method of its production.

These collective filters and regulating standards are closely tied to the instruments that are available. As new thoughts beget new instruments (and methods connected with using them), the standards of validating the results are tied in a feed-back loop to new developments in scientific thought, and therefore its change. A good example to be witnessed now on a large scale are changes in methods and subsequently content which have been induced through the use of computers. One of the most fascinating properties used heuristically is that their way of organization closely resembles the organization of human information processing systems and therefore human thought. It can be predicted that experiments will loose their dominant

position to the extent that computer programs can be written which can 'demonstrate' and thus 'validate' the actual function of an idea. In addition they offer the advantage of allowing insight into the *procedure* of the mechanism involved.

- 4) The abolition of the venerated dogma of the separation of observer and observed, proposed by BOHM, points to another fundamental perceptual or information processing idea: in order to perceive at all, we have to organize stimuli information into 'patterns' which are some kinds of wholes with boundaries. It can be shown that this 'primary object formation' is dependent on further purposes for which they are to be processed. Observer and observed may have constituted such fundamental perceptual units in science for a long time. If they are now to be replaced by a notion of 'field' which is in movement, or some notion of ever-changing process, this will tend to change in quite unexpected ways the entire scientific cognitive process.

Thus, we may summarize by saying that the basic issues involved in the approaches presented so far seem to center on the fact that science develops in what appears to be an order of increasing complexity of ideas as well as by generating ever new ideas. This process has been explained by the traditional view, in terms of a linear growth model of a capitalist economy: accumulation of knowledge, leading towards an ultimate point both inherently necessary and, once a break through had been achieved, inevitable in its success. This conception has come under attack from several quarters for several reasons, as I have tried to show in the introduction, leading to the search for alternative explanations. These have comprised:

A. the evolutionary model: instead of assuming an innerdirected dynamism of growth, the evolutionary approach has tended to look for those factors in the environment which act as a regulating mechanism for the selection of ideas. In too close an analogy to the biological model of evolution, the criteria for selection involved have been sought in the survival value of ideas to adapt to the overall structure, or in an increase of fitness of the scientific community to survive in the surrounding society, its needs as well as its dominant ideology.

B. the circular model which presents itself as the most direct confrontation of the linear model. By referring to a structuralist notion of a hierarchy of orders, both inexhaustible and infinite for man to grasp, the development of scientific ideas is seen as part of a never ending creative process. The development is not entirely regulated from within, but rather the result of what could be called (with reference to PIAGET) the interplay of 'outward' and 'inward' perception. Just as the child who learns to draw, first simply moves pencil in what appears to be a random way, expressing the changing internal state of the child, by further looking at the object this internal state will be influenced by 'impressions' from the outside. The line ceases to be random and shows a vague resemblance to the object. At a certain age the child is able to notice the resemblance and also increases his attention span. The internal impression of the object is presumably sharpened and this expresses itself by an improvement in the resemblance to the object.

Both the inner state (expressed by the variations in the drawing) and the outer perceptible structures are steadily transformed.

By defining the activity of the scientist as 'fitting' his ideas into the broader aspects of the reality in which he lives (which presumably also includes the socio-economic order), it is suggested that a process similar to the PIAGETian notions of assimilation and accomodation takes place (PIAGET).

It is well worth to note the difference in the meaning of 'fitting': while the evolutionary model, true to the spirit of the 19th century, interprets 'fitting' as a passive adaptive largely involuntary process, the action of 'fitting' as proposed by BOHM and PIAGET is seen to be an active, constructive process. The environment is 'grasped' by acting on it, just as reality is transformed through the scientist's fitting of his ideas.

We shall now turn to the last alternative, represented by diverse developments in the field of cognitive psychology and artificial intelligence. Although neither method nor findings have yet been applied on a larger scale to the study of science, they appear to offer fruitful lines of investigation.

III. The information processing alternative; or scientific thought equals ordinary thought

Developments in the field of cognitive psychology have not gone unnoticed in the philosophy of science. Thus SUPPES proclaimed already in 1968: "... we are getting closer to hitting on one or two fundamental ideas needed to move rapidly forward" (SUPPES). The one or two fundamental ideas were to be taken from information processing.

The fruitfulness of such a 'fitting operation' was discussed among others by SPARKES in an article which appeared in early 1972. SPARKES although conventionalizing POPPER first takes issue with the POPPERian thesis that it is not possible to prove a theory true and contrasts it with the position taken by PEETZ, LAKATOS, KUHN, SPARKES, POLANYI, and BRAITHWAITE, that it is not in principle possible to prove a theory false either. "It looks as if the process of refuting a scientific hypothesis is too complex a matter to allow a purely formal criterion" sums up the counter-position. Evidence for it abounds: there may be total incompatibility between theories, like in the wave-particle dualism, yet they survive; within two different conceptual frameworks the same range of experience may take the shape of different evidence; and it is well known that experimental results can be explained in more than one way. But if the relationship between observational data and theoretical explanations is too complex, to confirm or to falsify according to clear cut criteria, *how do we in fact decide* between competing explanations? SPARKES' answer is outrightly cognitive: we use our *capabilities of pattern recognition* to find our way through the maze of facts and theories, and we use these capabilities in everyday life as well as in science. Thus, we recognize incomplete or distorted patterns, such as a broken letter or incomplete and distorted speech, by making use of additional information, sometimes tacitly, sometimes openly. This information may be drawn from our previous experience which also builds up our expectations, it may be drawn from the context, as when we have to decide whether a sentence is written in English or Latin, or what a word or observation is likely to mean. SPARKES leaves no doubt that the basic processes involved in pattern recognition

and scientific theorizing are very closely related: the mental processes which lead one to select theories are the same as those which enable us to acquire knowledge all the time.

How information is processed, how the sensory input is transformed, coded, elaborated, stored in memory, restructured, recovered and used, is the central theme of cognitive psychology. Today, there exists an impressive array of achievements in this area which yet has to be applied in more detail to the study of science. Work has been undertaken on the process of induction and deduction, on the recognition of pictures and construction of 'picture-grammars', on the process of understanding natural language, on various kinds of problem-solving, ranging from games to tasks like learning arithmetic, on the simulation of interactive processes as between patient and doctor and on the representation of various belief systems⁵. To varying degrees, these are processes that are all present in scientific theorizing and it can be said indeed that "cognition is involved in everything a human being might possibly do" (NEISSER). It also appears that we have no immediate access to the world and that whatever we come to know about reality is mediated by complex systems which interpret and reinterpret sensory information (HARRIS 1970). Cognitive psychology has chosen to describe some of these processes involved in this interpretation as well as strategies which are open to the processing system.

Given this task, what remains there for a sociologist of science to do, if he does not want to transform himself into a cognitive psychologist? The answer is not too difficult if one is ready to admit that the boundary between 'scientific' and non-scientific content is a flexible, if not an arbitrary one and that also a cognitive approach needs to be embedded into a social structure. The degree to which the handling of information is dependent upon the context is truly amazing, regardless whether it is language, visual stimuli information or the so-called 'higher mental processes'. Part of this context will be of a social nature, as when collective usage de-

5 The lecture notes of the NUFFIC summer course 1972, edited by G.J. DALENOORT, provide again a good overview. For the modelling of belief systems see A.P.M. COXON (1970).

finer a code, boundaries, rules of inference — in short, the surface structure of information processing. Depending on how far one wants to penetrate into the social surface structure, the information processing approach offers a number of questions to the (cognitive) sociologist, some of which will be tentatively presented here.

1. If one regards science as an information processing system to which knowledge about other information processing systems can be applied, one might ask in what specific way its *selective filter mechanisms* operate. It is well known that on the individual level, the organism possesses the ability to restrict and select the information potentially available from its surrounding space-time field. The organism must also be able to vary range and type of information it selects from its environment. Failure to do so would constitute a major defect leading to serious psychic disorders and would incapacitate the functioning of the whole organism (ORME 1969). If it is true that this is a property of the individual information processing system, is it also true for an abstract system consisting of information individuals? Certainly, not every kind of information is considered relevant and there may exist criteria that define individual as well as collective (or shared) relevance. But to what degree is this regulated collectively? Again, on the individual level, the focusing of attention is an important aspect of any cognitive process. Can it be said that an analogous process operates on the collective level and if yes, how? If certain theories are found to be 'interesting' at a certain time and place, it is not only that there are norms governing what is to be accepted and what not, but there appear to be fundamental cognitive processes involved which impose the pattern, if not the content as DAVIS has suggested (1971).

Some of these questions may sound like a revival of the DURKHEIMian notion of the collective consciousness. But while DURKHEIM had to rely on vague notions and inadequate observations, cognitive psychology puts at our disposal a set of concepts and procedures. The step from the individual as cognitive system to science as another cognitive system consisting of individuals has never appeared to be that short as now. Nor is it necessary to rely solely on the

drawing of analogies. Sufficiently is known on an empirical basis about differences in which different cognitive systems and different systems of science vary the range and type of information they allow to be processed and to which they accord different significance. The organization of these selective filters will depend on past experience and on future anticipations, which will certainly be tied to short-term and long-term uses to which knowledge will be put. In what sense and how these uses are represented in the cognitive structures of science as a system is yet to be discovered.

2. As must be evident by now, the *distinction between scientific and ordinary thought* from an information processing point of view, is practically irrelevant. Thought, in action as well as in storage (which is also active) is believed to be hierarchically ordered and scientific thought would add a new level of hierarchy and necessitate perhaps another set of subroutines for information processing. This view may not be easily acceptable for those who see a sharp demarcation line between scientific and non-scientific thought and who are convinced that it is the "Scientific Method" (at a minimum) which has been responsible for the spectacular transcendence of scientific endeavours over those of ordinary thought. But the scientific method can easily be de-mystified and represented by a set of programming rules which function in a very similar way to programming rules in a game of go or in representing algorithms for a problem-solving task. Recently, KLIMA has made an interesting attempt to incorporate various strategies for the reduction of inconsistencies into a description of scientific theorizing (1972). From a cognitive point of view, the emphasis can no longer rest on immutable or standards which govern cognitive processes as well as social ones, but must lie on different *processing strategies* available to individuals as well as to the system as a whole. These strategies are by definition flexible, as they take into account features of the context or layers of context as well as certain 'directive leads', cues which point into the direction in which one wants to move ahead. Such strategies can be socially or culturally defined, which is to be expected whenever they have been highly successful in the past or in view of certain future aims.

Strategies are also transmittable as they can be learned, but their variety is so great that they can never be pressed into a mould once and for all. If there is something like a pressure exerted from the environment and transmitted in the form of interests or needs of the society, it is most likely to manifest itself in favouring certain strategies rather than others which then in turn act as selective and directive control process.

3. Although a cognitive approach interprets scientific thought as an extension of ordinary thought it may nevertheless be of sociological interest to ask whether there may exist different kinds of systems and what are the conditions for their existence. For this purpose we may turn to anthropology. Not only have anthropologists engaged in a painstaking effort to collect as much systematized knowledge on belief systems as possible and compare them (DOUGLAS 1970), but they have also undertaken to point out similarities and differences between traditional thought and Western science (HORTON 1971). Although such an exercise, like every comparison of this kind, is one of evaluation, traditional thought equals scientific thought to an amazingly high degree. Certainly, there are also differences to be found, but many them appear more a matter of degree and can be traced if not to the same extent, yet in small doses in the practice of Western science as well. One crucial difference remains, however, which is worth to be analyzed further: we are told by R. HORTON that in traditional cultures *no developed awareness* of alternatives exists *to the established body of theory*, while such an awareness is highly developed in scientifically oriented cultures. This essential characteristic may point to a difference in the kind of systems, namely '*closed*' vs. '*open*' system. Presence or absence of alternatives are linked to the degree of internal heterogeneity the cognitive system possesses, and will lead to different mechanisms through which the system copes with the threat contained in any new incoming information as well as in constructing its own internal error-correcting devices.

The distinction between open and closed systems in this context is interesting for a number of reasons. It appears very plausible to see the conditions for the opening of a closed system in two sets of factors. One set refers to the social

communication structure: size of the community, as well as a certain degree of autonomy which comes with differentiation. Although the question of communication structure is worthwhile to be treated in greater detail, it is not possible to do this here⁶. The other set of factors is cognitive and refers to the storage capability of the system which includes its mode of organization. If GOODY and WATT are correct in their interpretation, literacy, which is a storage facility and confers storage capability, made possible for the first time a new way of confrontation with beliefs held in the past (GOODY & WATT 1962–63). One may therefore raise the question how science as a system presently organizes its storage facilities or its memory. If one is willing to infer once more from the individual's organization of his memory, it is not the storage room which limits the amount of information, but rather the way of organization, the "chunks" in which information is stored (MILLER 1956). We are today confronted with a wealth of information, which is stored hierarchically, it appears, with the help of some kinds of information processing programs. This may have far reaching implications which are yet to be investigated, but which may well lead to a decline in the experimental method and a concomitant rise of a 'constructivist' or 'artificial' method (SIMON 1969).

4. Another area which might fruitfully be reinterpreted from a cognitive point of view is the *relation between thought and instrument* or between theory and practice. As G. BÖHME et al. have also pointed out, there has been a certain reluctance to deal with the practice of science on the same level as its theoretical aspects. But pure thought would probably remain pure thought and as such nothing but a fleeting impression, if it were not tied through practice to the external world. For scientific thought practice constitutes primarily the construction and use of instruments. Among those who have searched for a pragmatic basis for scientific world views, mention should also be made of HUGO DINGLER. DINGLER explained, for instance, our commitment to EUCLIDIAN spatial relations as a consequence of the practical application procedures by which actual empirical

6 Size alone seems only to have a secondary effect on various properties of structures. These questions are treated in detail by M. SCHMUTZER (forthcoming).

shapes, surfaces etc. are identified⁷. He describes at length a 'fitting operation' through which it can be ascertained that EUCLID's geometry will be applied with complete confidence. This is so, simply because the application procedure guarantees its relevance in this case. It becomes very plausible that EUCLID's geometry will win out over its mathematical rivals as long as we identify figures, magnitudes, or relations in accordance with a certain procedure. Where other procedures have to be used, as in astrophysics or physical cosmology, EUCLID becomes correspondingly inapplicable. DINGLER also points out that the application procedure itself generates already certain regularities, especially when it consists in the construction of instruments. Results cease to be surprises and become well-founded expectations.

This 'constructivist' approach is closely paralleled in MARX's basic epistemology, notably in the notion of 'praxis' as the mediating process between cognition and its constant verification, as has recently been pointed out by ISRAEL (1972).

It would be easy to transgress further on this line of thought and inquire into *language* as another 'fitting operation' which operates in science as well as in any other realm of thought, but this cannot possibly be dealt here with the necessary care. It should be clear, however, that a cognitive approach does away with a rigid separation of content of thought, method and application procedure, whether they are seen now as instruments or wider uses. Rather, this becomes an extended dialectical process, in which thought is related to practice and practice in turn influences thought. A good example, worth to be further investigated, is the present impact of a new 'application procedure' of thought which arises in form of computer programming. Already now, it is amazing to notice to what extent this new instrument and modes of use connected with it, have changed the content of thought to be expressed with its help. In certain areas of science computer

programming promises to become a serious rival for the old and venerable experimental method and may well mark the end of an area of 'empirical science' in the traditional sense. This has nothing to do with old fashioned debates on 'instrumentalism' or 'voluntarism', but should be taken as a striking illustration of how "*choses à penser*" as LEVI-STRAUSS once said, 'things to think with', influence the very process of thinking.

The above examples should merely be taken as suggestions which illustrate the feasibility of applying a cognitive approach to the study of science. The approach itself should be seen in the light of what we set out to show: the search for alternative models of science. It should be evident by now that we cannot and do not want to offer merely the inevitability of another alternative. If we are not able or willing to transcend our previous way of thinking and still look for eternal truth or approximations to it, we will remain in the old trap of rigidly separate entities in a fragmented world. Nor do I want to claim that in observing what scientists do and in expressing my views about their activities, I could ever be, nor want to be, an independent observer. I am subject to my own cognitive structures which I apply on what I choose to see. Certainly, there are patterns which emerge, but these patterns are already the result of my information processing activity, of trying to grasp certain aspects of the broader reality around me. The various approaches which I have presented, could have been presented in a different fashion, with different emphasis and not one, but many alternatives might have been actualized. Thus, my limits are the result of the spatio-temporal organization of my own cognitive system, which extends into the past as well as into the future. I am merely operating in a vast possibility-space, trying to 'fit' observations into patterns and patterns into observations.

But what about the development of science, its 'advancement' as the technical term goes and which supposedly is the ultimate justification of such an exercise? I do not know. Science will *not develop independently of the way in which we think about it*. I have always been struck by the place which we have accorded in our thinking about science (or anything

⁷ This example has been cited by TOULMIN (1972: 432-433). DINGLER's work is not well known in the non-German speaking world. He has experienced a certain revival in the last years, especially through the efforts of P. LORENZEN and K. HOLZKAMP.

else considered worthy of scientific thought) to pre-diction and re-flection. We are used to speak about things before they have actually happened and to think about them only after they have happened. Maybe we should start to think about them before they have happened and we can then ascertain afterwards that they have in fact happened. BERTRAND RUSSELL may have anticipated such a change. In 1919, in his *Introduction to Mathematical Philosophy* he wrote that "logic is concerned with the world just as truly as zoology". In the Preface to the 1938 edition of the *Principles of Mathematics* we can read that "none of the raw material of the world has smooth logical properties, but whatever appears to have such properties is constructed artificially to have them"⁸.

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