The Knack of Scientific Revolutions*

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When reconsidering the writings of T. Kuhn (1962) on "Scientific Revolutions" one will find that Kuhn fails to explain what mechanisms come to a bearing in the process of formulating new theories. P. Forman (1971) attempts to achieve this by including external determinants in his case study. Under conditions of scientific revolutions heaps of data accumulate the interpretations of which - or even their mere handling - can not any longer be achieved by relying on the rules of "normal science". Usually there exist more models for possible interpretation than only one (Hesse, 1988). Which one will be chosen by whom and which one will win the contest among the competitors?

Paul Forman (op.cit.) tried in a heroic enterprise to demonstrate the impacts of culture and politics on the formulation of quantum physics in Weimar Germany. His results are stimulating, but still disputed (Hendry, 1980; v. Meyenn, 1994; Beller, 1999). Forman's basic proposition that German physicists "adapted the content of their science to the values of their intellectual environment" (ibid.,p.7) "to bring that (public) image (of science) back into consonance with the public's altered values"(ibid.,p.6) was amended latter. The widespread rejection of the principle of causality as a sole explanatory concept was supplemented by other motives such as pronounced individuality or an expressed creed in common sense presentations. Neither the one nor the other were served by quantum mechanics, but N. Bohr's rhetorical talents achieved to foster the desired impressions.
Forman's approach is one of an historian[1]. Hence it is not part of his intentions to come to more general conclusions, nor does his approach allow to explain why certain persons such as Schroedinger, Einstein or Planck did not adhere to the concepts proposed by the Copenhagen school. Notwithstanding the fact that Germany found itself in an extreme situation after World War I Forman does not explain what convinced the physicists of other countries such as the USA or France to accept the unorthodox propositions of the Copenhagen school in the long run.
When we remind ourselves of the writings of Duhem (1908, 1915) we will also quickly realise that the observed changes were not at all as unique as one should assume when thinking of the unique historical situation Germany found itself in. According to his point of view the trend was in a direction recognisable in France before WW I and followed a line of development existent in the UK even earlier.
To conclude these introductory remarks: I wish to achieve with this paper what P. Forman left to my understanding unfinished. Forman, T. Kuhn's former collaborator, apparently wanted to complement the former's approach to scientific revolutions by demonstrating that such revolutions and in particular their outcomes are not only results of internal processes imagined by Kuhn as "Gestaltsprung". Forman being a historian lacked a theoretical guideline, remaining hence necessarily descriptive (see footnote 1). This stance hardly permits generalisations which would allow comparative statements with regard to cases such as present day China. For doing this one would need a common denominator. It is one aim of this paper amongst other intentions to offer such an instrument.

My central concern of this paper is however to suggest a propositional response to the following question: Is it feasible to discern any guidelines for conduct or any explanatory models to which scientists will succumb probably unconsciously under rather chaotic, i.e. revolutionary conditions? I will demonstrate that in such situations of essential uncertainties people tend to return to basic experiences for guidance, which are - as Mead, Durkheim and others showed, social experiences.

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[1] It is of interest to read Kuhn's (1968) view on the difference between a "history of science" and the "philosophy of science". He stresses the fact that the aim of a historical account is to make a particular situation comprehensible (verstehen), whereas philosophers aim at the presentation of general truths.

In addition I propose however contrary to a historian's view that we may generalise these experiences and limit their number[2]. This will provide for the requested denominator.

The conveners of the Symposium on "The Interaction between Science, History and Culture in Germany" require from the participants of the conference to attempt some comparison between German and Chinese developments. This request constitutes at once a challenge and a considerable risk. One had to command not only a profound knowledge of present day China - which I do not possess -, but also of its history and its diverse cultures. In addition one has to be convinced that we know what relations shaped the links between science, culture, and politics in Germany. It would furthermore require a clear-cut terminology, which is definitely not yet agreed on.
We may however take initiative steps by employing "Cultural Theory" as done below. This would consequently permit to make transnational comparisons possible, as desired by the conveners of the Symposium, granted that sufficient data are available for attributing a given case to the employed categories.
Hence the paper intends to open up an avenue which will allow to achieve on the basis of a conceptual frame a fruitful comparison between those two nations which are normally considered to be quite distinct.

The relationship between science, society, and culture

Starting this essay by forcing complex concepts such as "science, society, culture" into the straight-jacket of a rigorous definition does not seem to be a good strategy. Although one has to concede that whoever uses these concepts has certain ideas about them, which very probably are not identical with those of his neighbour. It is even possible that there is no common ground at all. Still it I would not want to adhere to the possible solution of committing my readers to an egocentric and hence arbitrary definition.
If we subscribed for instance to the somewhat tart phrase, that "science is what scientists do" we would imply that science did not exist prior to the 19th century. In fact, neither was science recognised as a profession at that time, nor was there a creature designated a "scientist" (Murakami, 1993). Such consequences will be rejected by many with good arguments.
That the concept of "society" presents similar difficulties will become obvious by consulting a specialised dictionary of sociology (e.g. Endruweit, Trommsdorf, 1988) and the concept of "culture" suffers an analogous fate (e.g. Reckwitz, 2000; Alexander, Seidman Hg. 1990).

To discuss the relationship between entities of such vague outline is a risky undertaking, which by this very fact will have to face massive criticism from various directions. We will take this risk, encouraged by the conviction that even from a number of fuzzy sets a supporting skeleton – a crisp structure – may be constructed, which permits better comprehension of the fluctuating relationships.

A minimum amount of common understanding must of course be agreed upon if we want to enter into discussion at all. Let me use the etymology of the German word "Gesellschaft" (i.e. society) to explicate the society concept. A spatial connotation can be discerned. "Gesellschaft" derived from "Saal" indicates a population sharing a certain delimitable space. That space may be a village, a valley or a national state, to name but a few possibilities for such delimiting. For our purpose we choose the national state – or analogous entities throughout history – as our point of reference. A society thus will be understood as the population of a national state, which immediately implies that a certain structure of norms and power will be present.
In the English language the etymology of "society" does not evoke a spatial context. This provides us with a first example of a culture-specific interpretation pattern. The example can be corroborated by comparing relevant entries in popular encyclopedias. It seems significant that in contrast to the German "Neuer Brockhaus", where the entry "Gesellschaft" may be found, the "Encyclopedia Britannica" does not carry an entry "society". What we find there are "societies of ...". In this view a

[2] This approach finds additional support in another case-study of ancient Greek philosophy (see. Schmutzer, 2003b)

society is a voluntary association of people with certain characteristics, for instance the “Ornithological Society” etc. Where a German would speak of “society” the English-speaking prefer to talk about “social groups”, with the state also understood as a group of this sort. It should be obvious that these remarks do not pertain to the professional jargon of Anglo-Saxon sociologists but rather to everyday common usage. Although Anglo-Saxon social science does use the concept of “society”, its connotations run parallel to those of common usage. American Pragmatism and “Rational Choice” theories, which are cherished not only in micro-economics, are relevant examples.

T.Parsons, who together with other Anglo-Saxon sociologists is strongly influenced by German, especially Weberian, tradition, characterises the difference between his view and a view he terms “common sense” by writing
“This (his) view contrasts sharply with our common-sense notion of society being composed of concrete human individuals. Organisms and the personalities of members of the society would then be internal to the society, not part of its environment.” (Parsons, 1966, p.9).
This difference results by necessity from his understanding of society. He interprets society as a normative structure, which collectively organises the life of a population. Group membership, for which these norms are binding, must thus be defined and this in turn may be accomplished by designating a certain territory. For Parsons it is mandatory that society be in contact with an external cultural “subsystem”, which will impart legitimacy and meaning to societal norms via a value system. Society, understood as state, and culture are in Parsons’ view separate and strictly distinguished entities. The German sociologist Tönnies (1887) held analogous views, seeing society as the result of the emancipation from tradition and moral codes by the formation of states with their concomitant characteristics.

Now I do not intend to give a history of sociological concepts in this paper. The aim of the above remarks is simply to demonstrate the role of cultural preconditions, which might also be called guiding images for the concept of society[3].
There is of course a subtle irony in the fact that the American Parsons subscribes to a view which is closer to Weber and Tönnies and general German “common sense” than to the Anglo-Saxon view.
From this we see that culture should not be comprehended under a regional or national-state aspect, and that societies are not bound to a specific culture, although there are certain dominant views in every society, as exemplified by the Encyclopedia entries cited above. Also, prevalent guiding images of this sort are not eternal truths, but will change over time. They change due to shifts in the power structure and consequential shifts in the basic set of norms of a society, which are expressed in the laws passed by its political institutions.

It follows that new wielders of power will be well advised to make sure that the legitimacy of newly created norms rests on a canon of values publicly proclaimed. We need not stress that these new norms in their turn are the result of a corresponding canon of values, which, being the canon of a hitherto non-dominant culture, must still be explained and propagated publicly. All this might be understood as saying that “culture” is but a synonym for “values”. Let me make it clear, that I do not share this view, which is indeed held by some authors in cultural science. In contrast to this the thought style of “Cultural Turn” indicates a direction of research, which quite in general connects knowledge with its application to practical action. Structured patterns of knowledge are understood as schematised and habitualised patterns of meaning, which are applied in practice, and thus “culture” becomes a synonym for such ordered sets.

By means of “thick description” (Geertz,1973) these cultural patterns of meaning, also called “background knowledge” are to be empirically demonstrated. Only against this background the norms, values or interests become possible, action-relevant factors, because only now do they make sense. Furthermore these patterns of meaning and interpretation are “embodied”, that is they are stored in the body and are no longer in need of reflection. They are part of what M. Polanyi (1966) called “tacit knowledge”. The explaining factor is thus no longer to be found in atomistic objectives of actions posited by individuals, but in collectively developed systems of order, which transcend situation, space and time. From the point of view of “Cultural Turn” the origin and growth of such systems of meanings must be found by historical inquiry in each individual case. In principle this is no cause for objection, but the procedure is doubtlessly extremely time-consuming and tiresome.

[3] This will be further explained in the following.

As a consequence of all this the cognitive-symbolic organisation of reality via schematised patterns of meaning will make the difference between culture and society obsolete, knowledge itself now being part of a "social structure". Here the shadow of the skeleton mentioned at the beginning begins to take shape.

By this changed approach the concept of "knowledge" was detached from the concept of truth. "Knowledge" as a routine of action begins to come close to an algorithmic character. In other words this means that truth is generated when routines are found to be in agreement. In the sociology of knowledge or of science truth thus approaches the concept of "thought styles", to be understood as an action-relevant pattern of meaning shared with others.
The concept was introduced by L. Fleck (1935), and T.S. Kuhn (1962) renamed it "paradigm".
If orders of knowledge themselves transmute into "social structure", a one-sided cultural determination of the social situation is the result. This will furnish those social institutions, which by profession generate structured regimes of knowledge, i.e. the sciences, with an importance, which already Plato ascribed to the philosophers – the ancient variety of scientists. This is a proposal which I can accept only with profound reservations, but I concede that tendencies are at work which let such boundaries becoming blurred.

Summing up, we find that the boundaries between society and culture, between culture and science, and – not really a momentous new insight – between society and science are not clearly defined.

Sciences are cultural achievements

From the viewpoint of "Cultural Turn" the origin of systems of meaning would have to be found by empirical research in each individual case. Since empirical data cannot be understood without an underlying system of meaning, we have a clear case of the serpent biting its tail. To avoid the vicious circle we require at least a temporal delay insofar as culture-specific patterns of meaning must be assumed to already exist, against which the new data can be interpreted. This situation conforms to the ideas of L. Fleck, who speaks of the "thought-style" of existing "thought collectives".

The alternative view, which corresponds to traditional ideas about scientific progress, holds that empirical observations change culture-specific patterns of interpretation. For example: Galilei's experimental results are seen to lead to the laws of falling bodies and further to Newtonian cosmology.
This position would however not do justice to the development of the theory of science over the decades since T.S. Kuhn's work and would ignore such generally accepted maxims as the theses of incomplete determinacy of Duhem, Quine, Mary Hesse or I. Lakatos (Hesse, 1980). For example: the data of planetary motion will permit geocentrical as well as heliocentrical explanatory models. It should however not be overlooked that the change in theory had significant consequences in the societal and the cultural realm. These consequences obviously were not induced by empirical findings but by the change in the system of interpretation. In contrast to T.S. Kuhn who sees paradigm revolutions as resulting from an unbearable accumulation of anomalies, i.e. as produced science-internally, we shall, in what follows, treat them as resulting from interlocked socio-cultural change. Science is closely linked with its societal environment, and contrary to Kuhn's view, is not confined to an "ivory tower"[4] but connected to the environment by material, social and intellectual flows (Bourdieu, 1984).

We need not dwell extensively on the material flows, except to point out that the connection is not only one of financial resources, but is also, and to an important degree, established by instruments which are provided by industry and substantially define specific standards and preconditions of research. Social influences are many and varied. There are not only state subsidies but also normative directives, which for instance may eliminate certain fields of research from the agenda.
Intellectual exchange is carried out between scientists proper and through students and it involves a public of laymen of varying backgrounds representing various interests. The situation is characterised by the fact that in this public various meaning- and interpretation-patterns are current, which may not only be contradictory but also may be present in widely varying degrees, being furnished with

[4] In the introduction to Kuhn (1968) he himself tries to play down this fact.(see p. 39)

different amounts of social, political or material capital (Bourdieu, 1980). Without such resources media-presence today and thus the promotion of interpretation-patterns is impossible.
The important point here is that the public is not a closed system which is strictly distinct from science and scientists, but that scientists themselves are part of this public. Scientists are interconnected not only via certain visible or invisible "colleges", but also interact with other scientists, representing other schools of thought or other disciplines, via the media or the general public. In other words scientists like other people belong to specific cultures, which provide their corresponding interpretation-patterns and definitions of meaning. As we said above the interpretation-patterns are "embodied" and, without being reflected upon, act wherever interpretation is required. In scientific work this is the case when new data are to be integrated with an existing system of knowledge or with a system which is being newly built. The interpretation-patterns are external to science and scientists most of the time do not apply them consciously.
The question whether interpretation-patterns must be found out case by case by painstakingly detailed work or – as suggested above – if classes of patterns may be identified, will now be discussed using quantum physics as an example.

Quantum physics: Its scripts and players

Quantum physics presents a most suitable example for our purpose since its interpretation has so far not led to uniquely determined results. The empirical observations and their formal mathematical correlates permit more than one model of interpretation. N. Herbert (1987) discerns eight different "quantum realities", K. Baumann and R. Sexl (1987) discuss twelve different interpretations of quantum theory. This does not exhaust the supply, there are still other interpretations. On the other hand there is a widely shared consensus among scientists that quantum theory offers the currently best mathematical model for the physical world – as perceived through experiment – and affords the most accurate probabilistic predictions.

Quantum physics from its very beginning had a revolutionary character, since already Planck's formula of black-body radiation challenged the old dogmatic principle of "natura non saltat". The discontinuity of energy-levels of individual particles was revolutionary to such a degree, that after publication of his paper it took Planck eleven years to accept its nowadays obvious interpretation (Kuhn, 1978). Planck dismissed the radical innovation that light is made up of discrete energy packets, and tried for a long time to integrate the action-quantum into classical Maxwellian wave theory (Cohen, 1994; Simony, 1990). He tried to interpret the discontinuity as an effect of the experimental set-up, i.e. as an unintended consequence of his experimental arrangement. Einstein proposed the thesis that light is to be seen as corpuscular emission/immission of energy packets as a heuristic in 1905, that is prior to Planck's conversion to the corpuscular point of view (Cohen, 1994). Milikan's experiment of 1916 proved the particle-character of light and Comptons work of 1922 corroborated this result. In 1924 Einstein expressed the situation thus:
"One has two theories of light, both indispensable and – as must be conceded despite 20 years of strenuous efforts of theoretical physicists – without any logical connection." (Einstein, 1924, my translation).

Heisenberg's matrix-mechanics, based on the particle picture, provided a formalism which could be used to formally describe the ambivalent situation. Not much later Schroedinger presented his wave-mechanics, which is based on the wave-concept, but nevertheless also offered a mathematically equivalent solution of the problem. The situation remained ambiguous.

The two formalisms however provided an instrument which satisfied both, theoreticians and experimentalists. By consensus the physicists declared the debate closed. The solution integrating both opposing pictures actually was however rather a dictate of Niels Bohr's research group than a true international consensus. Peace, similar to a Pax Romana, was achieved through the eminence of the Danish laboratory, its magnificent resources, and not least by the bargaining skills of Niels Bohr.[5]
Bohr's dominant position resulted from his far-reaching international contacts, which partly dated back to his time as collaborator of Rutherford. He was amply funded by the Rockefeller Foundation,

[5] All this would merit a more detailed presentation which may be found in the doctoral thesis of a member of our institute at the Vienna University of Technology (Ratzer, 2003).

giving him the opportunity to attract promising young researchers from many countries to his institute. His laboratory was excellently equipped as compared with other research institutes of the time. He also had a knack of placing his pupils and collaborators in first-class universities, all of which contributed to establish the "Copenhagen interpretation" as the dominant doctrine.

Neither Einstein nor Schroedinger could compete in this respect. It should of course also be noted that neither of the two seems to have had similar ambitions. They both referred to themselves as solitary workers and were perceived as such by others (Raman, Forman 1969). It is noteworthy in this context that Einstein saw himself as dedicated to establish order in chaos (Ratzer, p.56) and that he perceived the world or the universe in the traditional way as "clockwork" (Clark, 1988, p14). Similar to Einstein Schroedinger also had a tendency to avoid teaching and frequently changed his institutional affiliation. It is remarkable that he never had a post at one of the centers of quantum physics of the time, i.e. at Copenhagen, Göttingen or Munich. De Broglie was an even greater outsider, although his work provided the basis and inspiration for Schroedinger's wave-mechanics.

While Planck held views analogous to those of the men mentioned above, he was different insofar as he came from a well-known family and himself held influential positions. He was a member of the board of the Prussian Academy of Sciences and president of the Kaiser-Wilhelm-Gesellschaft, which operated a number of research institutions and was renamed Max-Planck-Gesellschaft after the second world war. And he was president (Rektor) of Berlin University. As regards his research work he also is known as a "solitary worker", but as can be seen by the positions cited he was actively engaged in institutional matters. His basic creed is not very different from that of Einstein or Schroedinger. Deep religious faith lay at the base of his actions and his world-view[6]. Similar to Einstein he tried
"... to approach god and his world-order as the highest and eternally unattainable goal through the method of inductive science" (Planck, 1949, p.331/332, my translation).

Bohr on the other hand was at the center of an extended international network, which included persons like W. Pauli, who since his days in Munich as student of Sommerfeld had close ties with Heisenberg. Pauli, like Heisenberg was one of Bohr's "stipendiates". Other members of the network were A. Sommerfeld and M. Born, both of which made essential contributions to establishing the dominance of the Copenhagen interpretation. With these names only the most important personalities have been mentioned, but they should suffice to illustrate the difference between Bohr and Einstein.
But not only their personalities showed this difference, it also marked their basic attitude towards physics. The missing connection between the theories which Einstein decried, is still being sought today, even if the intensity and centrality of the search has lessened. Although the "Copenhagen interpretation" championed by Niels Bohr has been the dominant doctrine since the thirties of the 20th century, there still coexist acceptable rival interpretations, as for instance D. Bohm's[7] "Undivided Universe" thesis (Bohm, Hilley, 1993). Without going into further details on all these possible interpretations, we will now try to sketch the essential differences between the contrary approaches cited.

Epistemological differences

For the philosophy of science it is doubtlessly an interesting aspect to see that these differences do not concern the correctness or acceptance of experimental data, but rather their interpretation. We have obviously arrived in the realm of culture-specific systems of interpretation and meaning, which we have mentioned above. The differences of the two approaches may shortly be characterised as follows:

[6] Murakami (1993) argues that a concept of science, as we understand it today, did not exist before the 19th century. To be precise, a marketable specialist knowledge was not aimed at. According to him the aim of the previous periods' knowledge was rather an improved comprehension of God's scripts, the Holy Bible and that second book of God, nature. The leading trend then was the idea of following God's will in the best possible manner. This could be achieved by improving the capacity of reading and interpreting the two scripts. See also: Musson (1972) and Nelson et.al. (1967)

[7] Bohm could be presented as an example of the „enclave"-type of Cultural Theory, but we shall not go into this here.

The group represented by A. Einstein and E. Schroedinger, of which M. Planck may also be counted a member, postulates certain qualities of a scientific statement. Schroedinger himself expresses this in the following way:
"According to the revolutionary view (i.e. the Copenhagen Interpretation, MS) undetermined randomness is the primary, not further explainable, principle, laws will only appear statistically in mass-phenomena when a large number of random events interact. According to the conservative view (i.e. his own, or Einstein's position, MS) the constraint of law is the primary, not further explainable, principle, randomness is invoked only when a large number of interacting partial causes defy analysis. An experimental solution of the dilemma hardly seems possible, because from a logical point of view, law may be derived from randomness, as well as randomness from law, depending on how one is inclined."(Schroedinger, 1929, p.418, my translation).

Schroedinger's statement characterises a very important difference between the "conservatives" – as he calls them – and the "revolutionaries". The essence is that on the one side there is the "constraint of law" which is opposed, one might say, by the spontaneous arbitrariness of random events.
This principal difference is complemented by further positions, which to my mind are its necessary consequences. The conservatives, as the advocates of laws of nature, must also postulate a matching reality existing objectively and being knowable as such. If reality itself were not determined and knowable, the constraint of natural law would be a farce.
Thus nature is seen in fundamentally different ways, which are exclusively rooted in the cultural systems of interpretation and meaning.

In public dispute the phrase "constraint of law" is usually replaced by the concept-pair of cause and effect, or causality and determinism, or the negation thereof. The law metapher also leads to the postulate of universal validity and replicability, since laws which pertain only to a single case could not be distinguished from arbitrariness. Furthermore laws must be consistent, since contradictory laws would permit arbitrary judgments. And from all this it follows that a formalisation of these laws must obey Aristotelian logic, which prohibits the simultaneous truth of a sentence and its opposite. While this law of "tertium non datur" may seem self-evident, it cannot lay claim to universal validity. Testimony for this can be found in numerous dialectic thought-systems from Protagoras up to Hegel and Marx.
Finally I want to point out that the conservative position postulates the existence of a world independent of any observing subject and the possibility for man to apprehend objective reality in principle. This is essentially in accordance with L. Wittgenstein's view expressed in his Tractatus (1921,1922), that verbal resp. theoretical representations are more or less isomorphic mappings of reality.

The Copenhagen "revolutionaries" by contrast hold the opposite position: the central aspect of their concept of knowledge is not insight into the laws of nature, but the ability to control reality and thus to contribute to the improvement of life for man. This is a position already formulated by Francis Bacon (1623) but largely forgotten in the meantime. Since utility is the essential criterion in this view, it suffices to take theories as tools, which permit useful predictions, but are not burdened with the task of describing the interior mechanism of the "black box". All one wants is that input and output are in accordance with observed facts. Niels Bohr's sentence that there is no quantum world but only a quantum description is the classical statement of this view (Born, 1959, p.41). In this context it will not be surprising to see reality reduced to that which can be observed. Or as the Copenhagen creed proclaims: reality <u>is</u> that which can be observed. Assumptions about reality are devoid of meaning if they go beyond the observable. Heisenberg draws the conclusion thus:
"Modern atomic physics does not deal with the essence and the structure of atoms, but with processes we perceive when we observe an atom; the emphasis is always on the concept "process of observation" (Heisenberg, 1931, p.182, my translation). M. Born concurs with his statement, that it would be difficult ".. to speak about an objective world, if its state depended on what the observer does" (Born, 1959, p.41, my translation).
Altogether we find here an attitude similar to that criticised by the conservative physicist P. Duhem (1908) when, in connection with Kelvin and Maxwell, he points out that Anglo-Saxon scientists use algebraical and mechanical models for the explication of their ideas, even if these models are by themselves inconsistent. Rigor of argumentation is for them of secondary importance as compared to practical exploitability in an industrial manufacturing process.

Although this perspective of applicability in a production process is not as explicitly enunciated in the writings of the Copenhagen group as for instance by Duhem, the pragmatism of their approach is not to be overlooked. They are content to produce solutions for given science-immanent problems which are research-relevant. They shy away from descriptions of an independent reality, which ultimately might be used as reference frame for normative proclamations. The old dichotomies, such as wave vs. particle, are not resolved in favour of one or the other alternative, but are transformed into a continuum, comprising both alternatives as extremes and integrating them in a continuum. An integrative solution of this sort was already successfully employed by Sokrates in his disputations with the sophists (Schmutzer, 2003b) and is the result, but also the precondition, of an extensive bargaining process between interested and motivated partners. It is a compromise which permits all participants "to save their face".
Such an approach is of course astronomically distant from an interpretation which insists on eternal unchangeable principles and invokes God as the ultimate, all-controlling authority, as Einstein occasionally did. Einstein himself sees a similarity to Descartes' baroque world-picture, which comprehends the world and living creatures as smoothly functioning mechanisms, comparable to clockwork. In this respect he is in perfect agreement with M. Planck.

The contrasts in attitudes as well as the agreements which we have seen so far, motivate us to look at the different interpretations and at their representatives from the perspective of culture-specific meaning and interpretation, which has been sketched in the introductory paragraphs.

Society and culture

We have already mentioned in the introduction that the ideas about what society is, differ both in the realm of "common sense" represented and at the same time created in the popular encyclopedias, and in relevant science, that is in sociology. We have also seen that the differences are not regionally or geographically fixed, just like the interpretations of quantum theory which also do not heed national boundaries.
Some German physicists supported the Copenhagen interpretation and other German physicists took a negative stance and criticised it. At the same time Russian and Danish scientists became its adherents. Culture-specific analysis of the interpretation- and meaning-patterns can therefore not rely on national differences, although quantum physics would indeed provide a suitable example for the manifestation of national differences in the grasp of the problem and in the intensity of the debate. One finds that leading physicists in France for instance for some time ignored the problems raised by Planck and Einstein, and also that American scientists seemed at first little inclined to take an interest in such high-flown theories. Such regional attitudes may be explained by hegemonial dominant factors in the individual countries, which sponsor certain specific styles of thought tied to certain thought-collectives and assign funds accordingly. De Broglie for instance, who was no adherent of specific French thought-styles, was marginalised in France, although his work, as seen post hoc, was of great significance for the further development of quantum theory. After all Schroedinger's wave-mechanics was inspired by De Broglie's work.

I have already mentioned that societies, when seen as representations of national states, may comprise different cultures, which may not be regionally locatable. If our hypothesis is correct, that the different interpretations of quantum mechanics arose as results of divergent meaning- and interpretation-patterns, then the differences must result from different cultures. And if this statement is to be more than an empty phrase, we must therefore try to exhibit specific characteristics of these cultures.
Interpretation-patterns or styles of thought are embodied in thought-collectives in the sense of L. Fleck. This means that such collectives develop specific habits of thought and by necessity also put their trust in them. One must therefore take a closer look at such collectives. This approach inevitably links social characteristics with different interpretation-patterns. Since G.H. Mead (1934) we know that social relationships are of paramount importance and that they constitute the basic building blocks of human experiences. Such experiences in turn are incorporated, that is, they are no longer consciously reflected upon.

But this does not mean that they cannot be altered. Processes of change however do not occur by themselves and are not without problems. They usually take a length of time, are frequently accompanied by social marginalisation, and not infrequently appear similar to religious conversion.

E. Durkheim (1912) presented ideas similar to those of the American pragmatists, but he expressly stresses the opinion that social experiences are not only primary and formative but that their nature is coercive and that they are not freely chosen. Mead and Dewey on the other hand stress the importance of communicative action and put emphasis on subjectivity and voluntariness.
It is easy to see the connection between the different viewpoints cited above and the different pictures of society we sketched in the introduction. If society is seen as a territorial state, the idea of coercion easily enters the picture, since obviously nobody can choose his own birthplace. If on the other hand society is perceived as the voluntary association of persons in groups – the state being just such a group – emphasis is put on communicative interaction and intersubjectivity. The abstract concept of "society" is interpreted according to social experience. Other abstractions are treated analogously, because social experiences are primary and may only by an effort be brought to the level of consciousness. But if cultural interpretation-patterns result from social experiences the interdependence between society and culture is obvious. A classification of social structures would thus be desirable in order to avoid the necessity of extensive historical studies in each individual case.
Our introductory discussion of different pictures of society already suggested criteria of classification. One the one hand society-pictures differ with regard to their delimitation. A territorial picture stresses closedness and suggests a spatial image, corresponding to a container with content (see Schmutzer, 2003a). The picture of "associated groups" does not suggest boundaries of this sort but rather open networks which may develop in various directions.
Another distinguishing criterion may be derived from the coercive character of membership as exemplified by Durkheim's view versus the voluntary membership as stressed by the pragmatists.
Openness and liberalness are usually seen as connected and mutually contingent, the same seems to be the case with closedness and hierarchical structure. Closed societies or systems are therefore often assumed to be authoritarian, while open societies are assumed to be liberal. This is the point of view of classical sociological polar concepts such as "community" and "society" (Tönnies, 1887) or "mechanical" versus "organic solidarity" (Durkheim, 1893). As an alternative Mary Douglas (1970) has proposed in her "grid-group"-analysis to regard both variables – openness or closedness against the external world and the internal liberalness of the members – as independent dimensions. The resulting two-by-two table distinguishes between open authoritarian or egalitarian structures on the one hand and closed authoritarian or egalitarian structures on the other hand. M. Douglas names these types, following the sequence used above, "isolates", "markets", "hierarchies" and "clans or enclaves". In the tradition of Durkheim, or also of L. Fleck, she assigns specific "thought-styles" to these types of social structures (M. Douglas, 1996), and gives as reason for this the necessity that every social structure must legitimise itself before its members. Legitimacy is obtained via homomorphism between the social structure and other systems, which are conceived to be independent of society. Representations of such systems, for instance nature or the cosmos, are produced by certain social institutions, respectively organisations (Douglas, 1991).

If the objective of thought-styles is legitimatory this suggests that they are endowed with intentionality. But these intentions must not necessarily be conscious and purposeful. M. Douglas tries to make this plausible by citing the concept of "latent functions" of social institutions as established by the tradition of functionalism. This alone is not fully satisfactory. But if one entertains the hypothesis, that in cases where new experiences are made which are not yet linked with a cosmology, the obvious solution is to apply known and proven patterns, then the idea of purposeful manipulation may be replaced by that of "heuristic strategies". Heuristics in general start with that which is obvious and banal[8], i.e. with basal experiences. But basal experiences are social experiences, as we have already said above, and thus are experiences made together and shared by interaction. As a consequence interpretations which have originated in other cultures and relate to other, un-experienced, social structures are not only not comprehended but are rejected.

The cultures of quantum physics

[8] The original meaning of „banal" is that which is shared by persons of a certain district (Bann).

If one applies the categories of "Cultural Theory (CT)"[9] to the different interpretations of quantum theory one obtains a plausible picture. "Isolates" in the sense of CT are representatives of an open, authoritarian system. The objections which Einstein and Schroedinger made against the Copenhagen interpretation with their insistence on causality, laws of nature, determinism, and with their – especially Einstein's - reference to a transcendental being ruling the world like the divine watch-maker of absolutist, baroque physics, fit the description perfectly. The personal characteristics of Einstein and Schroedinger, as narrated by their biographers and as contained in their autobiographical sketches, confirm their solitary disposition (see above). This is also stressed by the fact that neither Einstein nor Schroedinger, in contrast to Planck or Bohr, held important positions in organisations. De Broglie shares this fate, remaining an outsider in France, Denmark, and Germany.
Max Planck, who spent long years trying to fit his revolutionary insights into the canonical frame of classical physics, shows a similar attachment to authority. In the end however he is ready to submit to a new authority created by the Copenhagen group. David Bloor (1982) would qualify this feat of Planck as characteristic behaviour in scientific hierarchies. We have seen that Planck indeed was a member and a functionary of such hierarchical organisations.
It remains for us to characterise Bohr's network. The very name tells all. Bohr and his "allies" are almost prototypical representatives of the "market" type. Not only his excellent bargaining skill but also the pragmatic solution of problems are true to type. Instead of taking sides, either for the particle-picture or for the wave-picture, both, particle and wave, are accepted. The price for this is that now there is no concrete picture at all, but since the formalism works and produces useful results, concreteness and world-explication are dispensed with.
In networks, which are based on voluntary association and thus on individual utility calculations, legitimacy of social structures is provided not by proving the necessity of the structure but by proving its usefulness. Randomness and indeterminateness are everyday social experiences in volatile networks.

Summing up, we can say that quantum mechanics and its Copenhagen interpretation replaced one cultural hegemony by another. The dispute, still a considerable conflict, was calmed in a sort of "Pax Romana". There are still skirmishes at the periphery of the realm, which shows that the competing cultures have not been eliminated. The question is, how long will the "Copenhagen interpretation" be able to defend the bastions. This will of course depend on the social environment. In the era of neo-liberalism the Copenhagen interpretation provides a cosmological symbolisation of the socially dominant paradigm and additionally serves, regardless whether its adherents intend it or not, a legitimatory purpose. This of course requires mechanisms of popularisation, since Schroedinger equations or matrix computations will not enlighten the lay public.
On the other hand there are signs of a trend reversal as well in the political realm of many states as in the natural sciences. In the sciences informatics plays an ever more central role and in the political domain there is the growth of gigantic, trans-national organisations, whose very existence will demand adherence to principles of hierarchical order. If this trend should continue we may expect to see the demise of the Copenhagen interpretation.

Resumé

We started out with the hope to be able to obtain a better grasp of the developments which determine the results of "scientific revolutions. For this the blurred concepts of culture, society, science and their overlap had to be redefined. The instrument of "Cultural Theory" seems to do the trick, by connecting meaning- and interpretation patterns with prototypical patterns of social interaction. This connection permits to understand scientific interpretations as results of the interaction of culture-specific interpretation-patterns with corresponding organisational structures, whereby individual members become representatives of thought-collectives. These social experiences mold their thought-styles and provide the necessary routines when new phenomena ought to be put into some coherent context for producing scientific forecasts.

The world of science is - as Forman (op.cit.) repeatedly stressed - no isolated domain. But at the same time it is also true that societies or nations are no uniform entities. When Forman argues that

[9] This is another name for „grid-group-analysis".

the German "Zeitgeist" of the post-World-War I era directed the thoughts of eminent German physicists one has to add that similar thoughts existed in the minds of Danish and several other nations's proponents. Particularly representatives of the Anglo-Saxon world – as Duhem rightly stressed – showed a heavy inclination to a similar, very pragmatic approach. Their basic concerns were and still are little motivated by adhering to rigid rules and theoretical consistency. Their rules of conduct require the provision of models or mechanisms applicable to concrete problems. We labelled this stance as the culture of the "market".

This should not suggest that every scientist within a particular country adheres to such new regimes. Quantum physics demonstrates this amply. But it suffices if a majority – especially of the younger generation to which the Copenhagen revolutionaries predominantly belonged[10] – exhibits inclinations towards a promising and newly imported culture. The Anglo-Saxon culture of the market which forwards a liberal political model as much as one for scientific conduct substituted during the Weimar period the toppled rigid Prussian regime. It seems more than unlikely that without the Copenhagen avenue which provided the necessary social experiences of an open and egalitarian research network, quantum mechanics could have come into existence not even in Germany.

Although I am no expert on China I feel that this country finds itself in a similar situation for the time being. It might however very well be that the clash of cultures is less one of hierarchies and markets this time, but one between the two diverse egalitarian systems. This is a proposition on my behalf only and had to be studied empirically. If this presumption should however prove to be correct no quantum mechanics shall spring from this, but a highly intensified research in the applied sciences.

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[10] As such a move opens new avenues to academic careers too.

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