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Towards a theory of scientific controversies

Our purpose in this paper is to explore an avenue for linking theory and social studies of science, and to do this in a way that can be both philosophically interesting and relevant for science policy studies. This is done by focusing on scientific controversies. Controversies in and around science, it is suggested, are a strategic and fruitful site for science studies informed by a dual consciousness — epistemological and political. The text is therefore programmatic and less a report of actual case studies, which must be left to another time.[1] Our concern lies primarily on the side of conceptual development, and we shall therefore make reference to a wider literature only insofar as it may be invoked to introduce certain ideas or sharpen a particular point. It is not our intention to review this literature, which is vast and has been written from different points of departure, both rationalist philosophical and relativist sociological.

Science is usually studied as a rational and unitary activity. In the philosophy of science, it has been analyzed on the basis of presumptions regarding its — at least in the long term — growth and progressiveness. Science develops towards something higher although one today is cautious in calling this higher quality "Truth". Such studies can proceed from Popper's falsificationism, Lakatos' idea of research programs, or Laudan's notion of research traditions. They all indicate ways of rationally reconstructing the logic and the history of the sciences, simultaneously providing guidelines for empirical analysis of the same. Traditional sociology of science also assumes rationalist consensual elements in the nature of science, which becomes especially evident in the functionalist work of e.g. Robert Merton. Where the philosophers of science presented an image of a rational but disembodied science, traditional sociologists were concerned with idealized social relations but not the cognitive contents of scientific inquiry.

During recent decades, rationalist approaches have increasingly come to be questioned from various points of view. Theoretical critique is found in the works of relativizing philosophers like Stephen Toulmin, Paul Feyerabend, Thomas Kuhn, and Mary Hesse. Here in short, rationalist assumptions are claimed to be philosophically untenable. Empirical critique, on the other hand, has been forwarded on the basis of historical case studies

which reveal non-rational dimensions within and outside the research community to be important for the growth and development of science.

But critique has also come from other empirical quarters. For one, science and its applications have increasingly given rise to negative effects in the form of pollution, atomic bombs, etc. Research seems in an ever-increasing degree to be governed by particular social interests, especially the profit demands of industry. In recent years, a combination of financial stringency within academia and increased international competitiveness has led universities and industries to form closer links with one another, prompting academic organizational innovations and structural change (Etzkowits and Peters, 1988).

Secondly, one increasingly finds conflicts emerging also within science. This is especially evident in the case of questions with significant social political import, such as nuclear reactor technology, environmental issues, hybrid-DNA, etc. Dividing lines related to different stakeholder interests in high technology also cut through the science that underpins it. Cleavages within scientific communities are generated around both factual and political issues. Where the one begins and the other ends may be difficult to determine. More recent research within the history of science has in addition tended to emphasize the existence of conflicts even under "normal" conditions, viz. conflicts without obvious extra-scientific consequences. (One example among many is the waveparticle duality within modern optics.) Allan Mazur (1979:19) has generalized this claim to say: "Just as historians used to chart the course of empires by tracing the links from one war to another, one could write a passable history of modern science by linking the great theoretical and experimental controversies".

It is also our view that controversies have not been sufficiently studied by those concerned with the history and dynamics of science. One theoretical reason for this is that rationalist theories of science traditionally have tended to picture science as autonomous. Consequently, conflicts are conceived as basically abnormal and deviant phenomena which ought (and can) be transcended with the help of rational methods and argumentation. To Karl Popper, for example, disagreement and rational critique is indeed the "motor" of science, but the purpose of critique is to disclose mistakes and to eliminate disagreement — the deviant — in order to push the frontiers of science forward. Thus scientific disputes are reconstructed to become amenable to a rationalist image of scientific development. Consensus is the point of departure and at the same time the anticipated result for rationalist philosophy of science. This is further exemplified by Imre Lakatos, whose well-known "foot-note sociology" has the same goal, i.e. to "control" controversies/deviation by placing them outside historiography proper, and by Larry Laudan's notion of an "arationality criterion" serving to separate the historiography of rational science from the misbehaviour of history. Presumably, these research strategies are connected with one of the central tasks within rationalist philosophy of science; to identify and reconstruct those aspects which may be taken to be common to all scientific theories. Historically, the rationale for this has been the hope of formulating universally valid criteria of demarcation, that is, criteria for setting up a cordon sanitaire between science and other forms of knowledge. Philosophies of science are cast in the role of meta-scientific police. Simultaneously, the ambition of finding similarities has led to a neglect or overlook of dissimilarities and controversies in science.

More recently, scholars in the rationalist genre have accommodated to the social turn in the philosophy of science to various degrees. However, they appear to have done so without wanting to accept the full implications of the historical and socially constitutive character of science that sociologists have pointed to in a number of case studies. To us, the significance lies in the need to see the socially contingent nature of the way objects of research are constituted qua "objects of research". In other words, we look for a double contingency, whereby scientific theories must be taken to have both an epistemic real world referent and a socio-historical context in which they are

postulated and implemented. This is a notion that comes close to Elkana's idea of "two tier thinking" (Elkana, 1982)

We strongly suspect, therefore, that the frequent occurrence of controversies is not a question of error or occasional deviations but rather an indicator of something else, viz.,deep-rooted tensions which go to the very heart of science, both with regard to its character and function. Discarding the assumptions traditionally made by rationalist philosophies of science, it is soon found that research has several dimensions and determinants, including social, political, economic and psychological ones. This is particularly clear in situations where scientists contend with each other, that is, in scientific controversies.

Now, of course, some modern rationalists would be ready to endorse this statement, but often the non-epistemic dimensions are still portrayed as factors and not as constitutive elements in the process of scientific knowledge production. To go further it is therefore useful to look at the works of sociologists and historians of science.[2]

The notion we are trying to articulate here receives further support, for example, from *the conflict view of intellectual change*, recently advanced by Randall Collins (1989). According to Collins, intellectual history is a conflict process in which the *negation* of the "intellectual property" of rivals is a major strategy and incentive for the generation of new ideas.

Some authors take the conflict view even further, introducing a military metaphor. Bruno Latour for example sees science as a form of political power struggle, where different actors, individuals and corporate ones, seek to enrol as many allies as they are able. According to Stephen Shapin (1988: 534) this is to take the position that "technoscience is war conducted by much the same means. Its object is domination and its methods involve the mobilization of allies, their multiplication and their drilling, their strategic and forceful juxtaposition to the enemy. This antagonistic model has, beyond doubt, picked out and stressed features of science and technology which other perspectives have missed or systematically undervalued." David Hull's new book Science as Process (1988) also lends credence to the picture of science as brutal warfare among ambitious egoists, a process that has nothing to do with rational argument or the uncovering of truth. This is a portrayal that may draw criticism from Hull's own allies amongst rationalists because it represents such far reaching accommodation to a sociologisation (cf. Kitchers review 1988: 277-8). David Edge (1989) contends that the focus in earlier scholarship on "gentlemanly" rules and consensus in science has in some cases been replaced by the opposite extreme view that exaggerates competition, as if scientific research was a sport where individual researchers race against each other and pit themselves against nature in order to outdo each other and win rewards. He points out that the broader scientific, political and financial context intervenes and mediates or channels competitiveness in various forms.

The importance of the economic and socio-political environments which support scientific infrastructures is also highlighted by Peter Weingart (1989). He argues that, to get beyond the deadlock between philosophers and cognitive sociologists of science over the primacy of contexts of justification and discovery, respectively, one should focus on the *context of relevance* of science in society. In this perspective science is seen to be an indeterminate set of meanings for which no clear boundaries can be set. Since institutionalized meanings and expectations change with socio-political environments, there must be a continual generation of sources of new controversies, sometimes with a reversal of previous standpoints. Furthermore it generates a continual need on the part of scientists, at such times, to redefine boundaries (see further below). Science thus is not only structured from within, but more so it is being restructured through its interaction with the restructuring of society, a point also brought out by other authors on the "utilization contexts" of research (Nilsson and Sunesson, 1989).

However, as a review of the literature reveals, scientific controversies as an object of research is still relatively young and undeveloped. Of course there are numerous case studies of

older and more modern controversies, but these are often isolated from each other. Despite occasional proposals for broader, more systematic research programs, no common conceptual framework or general methodology has yet been developed and accepted (e.g. Collins, 1975,1983; Social Studies of Science, Vol 11, No. 1,1981; Collins and Pinch, 1982; Nelkin, 1979,1984; Engelhart and Caplan, 1987). The most ambitious attempt to formulate a shared, "standardized" approach to controversies comes from Gerald Markle and Jarnes Petersen (1981), proposing a protocol, a kind of check-list comprising 57 issues that each scholar of controversies ideally should consider in his study. The questions relate to the shape of the controversy, historical and cultural context, the actors, organizations, various kinds of strategies, knowledge claims, value claims, economic, religious and ethical aspects, resolution. If their protocol was generally employed, we would eventually obtain a substantial data base on a broad range of controversies, facilitating comparative studies. By means of induction, we would be able to develop useful generalizations about the nature of controversies. Unfortunately, this protocol, published in 1981, does not seem to have been followed up. Generally, it seems safe to conclude that at present, there are no systematic attempts to employ controversies to explore the nature of scientific eplanation, general processes of concept development within science, or questions pertaining to the inter-relationships between science and society.

The claim that we make here — that scientific controversies constitute a useful site for elaborating a theory and sociology of science — must be seen as a working hypothesis which can be turned to advantage in the form of a research program. In this paper, we outline some elements for such a program. In other words, we shall suggest what *"controversy studies"* can be, theoretically and empirically, and how they can be fruitful.

Each science is characterized by an assembly of central concepts for sorting, classifying and analyzing its object of research, and the science of science constitutes no exception. Below, we thus suggest some concepts for the study of controversies, but here at the outset we at the same time want to emphasize that they are preliminary; probably there are other and better, alternative conceptual frameworks. Our suggestions should therefore be understood as a point of departure which may be made more sophisticated, or for that matter, rejected — in the latter case it may perhaps serve as a point of reference in relationship to which other attempts at a more coherent conceptualization can be contrasted and spurred.

Definition

First, a rough and partly stipulative definition of the phenomenon in question. *Controversus* is a latin term and means "turned in an opposite direction". More specifically, the definition often focuses on "the clash of opposing opinions; debate; disputation". Controversy creates interaction; thus it signifies unifying as well as divergent tendencies between groups of antagonists. Rough synonyms are conflict or contradiction. A characteristic feature of a controversy is that it has a certain endurance in time and space. A rapidly passing disunity will not be called controversy, nor will we use the term in cases where a dispute concerns only one single person. *In general* (although not always) a controversy exists over a longer period of time and divides groups of people; this is the case not least in modern science.

A *scientific* controversy is here taken to be primarily concerned with contending *knowledge claims*, where at least one of the parties involved has a scientific status. This means that what is overtly at issue is not primarily different courses of action or rival political measures, even if such may follow from or be implied in a scientific controversy. In a broader sense it is a question of science-based controversies in society, and an analysis of them has to take cognizance of a double contingency, one relating to knowledge claims and the other to power claims, be they overt or tacit. As Foucault has stated, in practice these two aspects are two dimensions in one and the

same process, and they are inseparable. It is only analytically that we tend to tease them out, and if our bias is non-rationalist the tendency will be to reconstruct them as mutually constitutive, one for the other. Analytically then, we bring the epistemic dimension into the foreground when we speak in the narrower sense of "scientific controversies". It is obvious also that empirically political controversies can but need not have a scientific component, and contrariwise scientific controversies can but need not have a political overlay. This much said to avoid the misunderstanding that we seek to reduce the epistemic to the sociological, or that the only controversies we are interested in are political ones.

A controversy is a *manifest* contradiction. It is something visible, and the involved parties are conscious of the fact that they are part of a controversy and act in this knowledge. (In marxist terminology one might speak of controversies as belonging to "the political scene", not the sphere of organization or structure.)

The causes of a controversy must often be sought on another, structural level, however. This means that there may exist latent tensions and contradictions which may not find expression in controversies, and contrariwise it is possible to imagine controversies that do not have a corresponding structural cause or rupture. But for the most part, controversies are manifestations, or condensations of deeper contradictions of a theoretical, social or other type — see below. In short, a controversy can be understood as a structural breaking point or rupture.

Different Types of Controversies

Scientific controversies can be typified on the basis of different kinds of conflicts, that is the kind of question around which the controversy revolves. For example, Ernan McMullin separates controversies with respect to *facts, theories,* and *principles.* Controversies of fact have to do with *what is observed,* i.e. "the observational base of science". In his self-made primitive telescope, Galileo saw mountains on the moon. This was contested by the experts of the Church (some of whom even refused to look through Galileo's scope.) With another telescope, Percival Lowell in the 1890s "saw" canals on Mars, and D.C. Miner in the years 1920-25 was able to determine for himself that the earth was moving through ether — an attempt to falsify Einstein's special theory of relativity. These are some astronomical observations which gave rise to controversies.

Theoretical controversies, however, seem to be most prevalent. Indeed, controversies regarding facts or observations presuppose theories or abstract perspectives which serve as guides for interpreting observations, or that which is "seen", in accordance with the thesis of the theory-dependence of facts. Theoretical controversies arise when two or more theories claim to explain the same phenomena. A well-known example is the controversy associated with the chemical revolution in the latter part of the 18th century. Priestley and others explained combustion with the help of the phlogiston theory, while Lavoisier introduced the concept of "oxygen" as one crucial component of a new explanatory theory. During the 1960's, attempts to explain quarks led to "charm" and "colour" as two rival models, and so forth.

Controversies of principle are still more general, involving more than fact and theory within a part of a discipline; it often concerns the foundations of large parts of science, sometimes science in its entirety. One example is the controversy regarding Heisenberg's "uncertainty principle". Pointing out the possible occurrence of "chance" in the micro-cosmos, it calls into question the time-honoured principle of universal causality. A more popular example is the ongoing controversy in the US between creationists and evolutionists regarding the emergence of humankind. (This is a "scientific" controversy by virtue of the fact that some scientists claim that Darwin's theory of natural selection is an impossibility.) Controversies of principle often involve entire perspectives and basic components of world views, pertaining to basic conceptions of man's place in the universe (e.g.the Copernican revolution), or in

natural history (e.g. Darwin's theory of evolution).

This leads over into ideologies. McMullin uses the concept "mixed" controversies in those cases where basic world pictures and value systems are prominent. Scientific, political and moral principles interact, dividing the scientific community. An example is the application of life-sustenance technologies for incurable patients in modern hospitals. In many countries disputes emerged with the transition from a heart-related to a brain-related concept of death (Brante and Hallberg, 1989). In this case the controversy involves both knowledge and action; it is not a "pure" controversy in McMullin's sense (McMullin, 1987).

Other ways of dividing controversies into types are suggested by Allan Mazur (1987), distinguishing between controversies of facts and of values; by Alasdair MacIntyre (1987), distinguishing scientific from philosophical controversies, and Alvin Weinberg (1981), distinguishing scientific from what he calls "trans-scientific" controversies. (Where the former, but not the latter, can be resolved with the help of strictly scientific criteria).

These and similar distinctions are useful, but it should be pointed out that they for the most part refer to different *focal points* in a controversy, and not really to qualitatively different kinds of contradictions or tension levels. This is because it is not possible to separate out a pure sphere of facts or observations; facts are theory- or principle-dependent, and vice versa. There are no distinct boundaries between the different types and thus it is more a question of differences of degree and focus.

An issue constituting a probable object of controversy within controversy studies is whether controversies are socially or cognitively generated, since this opposition reflects the differences between relativist and rationalistic approaches. If a controversy can be analyzed as "pure", that is, generated by scientific arguments only (facts, theories and principles), then there seems to be some basis for maintaining the thesis of the autonomy of science. And conversely, if it can be shown that purportedly "pure" controversies can be related back to social or personal contradictions, to differing economic and other interests, etc, this leads to relativistic conclusions regarding controversies. There may also be differences of opinion among students of controversies when it comes to the more exact specifications of "caused", as well as which social or cognitive aspects are seen to be generating contradictions. Furthermore there may be different views as to whether contradictions at the cognitive level presupposes disunity at the social level, and vice versa. For example, in the sociology of science it is nowadays often claimed that there is some kind of double contingency between the cognitive and the social level, between professional interests on the one hand and social affiliations on the other.

Of course it is impossible to give a *generally* valid answer to the question of social and cognitive causation, since controversies have different origins, characteristics and trajectories. Further, there are two aspects of the tension between social and cognitive levels, which should be noticed here. On the one hand, a controversy may be more or less related to factors outside the scientific community, that is, may be utterly socially and politically relevant. In some such cases the "scientific" can be seen as aspects or ingredients of larger political tensions or patterns, for instance disputes concerning the causes of inflation, pollution, and so forth. On the other hand, a controversy may also be regarded as almost entirely "internalist", that is, pertaining to differences of opinion within a scientific community only, without any extra-scientific implications. An oft cited example of the latter is the controversy about continental drift within geology. In the Engelhart/Caplan volume continental drift is dealt with as a more or less purely scientific controversy. Ronald Giere (1988:238), on the other hand, maintains that even in this case, it is possible to find evidence for very strong positive correlations between opposition to Wegener's mobility thesis and easily identifiable professional commitments to stabilism.

As these and other studies conclude, there is always a social aspect even in the most

internalist of controversies. A controversy emerges only because there are at least two groups within the scientific community holding different and rival claims, cosmologies and/or visions. These groups are situated in social and academically defined networks, conditioned by hierarchies of status, power relations and reward systems; often a zero-sum game confined by limited resources. Different groups can thus have opposing social interests, that is, there can be internal social (personal, economic, etc) reasons for internal theoretical controversies. The social level is thus not a priori less significant in the case of internal controversies.

The dividing line between internal and external, between intra-and extra-scientific factors, should not of course be seen as a sharp boundary, but rather as a continuum with two different poles; controversies may be generated to a greater or lesser extent by internal or external factors. The dividing line between internal and external in this continuum is also historically in flux, conditioned by yet other criteria (Böhme, 1977). This becomes clearer if we introduce another, related distinction, between epistemic and non-epistemic factors. A purely epistemic controversy contains only arguments that the participants in the controversy recognize as being in principle scientific (even though they may simultaneously be erroneous; all the same, they belong to the ontology of science).

The parties of the controversy often acknowledge that the arguments of their adversaries are submitted to accepted scientific standards. Hence, non-epistemic factors are arguments that are not defined as scientific at this particular point in time. Today, religious beliefs, or non-scientific influences such as social interests or political dictates of the kind found in the Lysenko affair, are typical examples of non-epistemic factors. At the time Lysenko first put forward his arguments for an alternative genetics there was a case to be made for this on rational grounds. Later, as the political side of the conflict became more central, and Stalinist dictates intervened, non epistemic factors dominated the arguments (cf Roll-Hansen, 1985).

It should be noted, then, that the distinction between epistemic and non-epistemic factors is context-dependent. What is taken as epistemic and non-epistemic by the parties involved will shift through time. How the boundary is drawn is thus an important key for the periodization of controversies. The student of scientific controversies can use such factors as instruments for defining the specific character and development of a discourse. In the dispute between the Catholic church and Galileo, the church invoked factors such as the word of God as belonging to the epistemic, while Galileo embraced a different ontology. Similarly, the debate between vitalists and mechanists involved quite different views as to what should be regarded as epistemic and non-epistemic factors. In the debates around nuclear reactor technology in various countries, some of the opponents have maintained that psychological factors such as popular fear and anxiety ought to be given epistemic status in regards to the be or not to be of nuclear reactors (Brante, 1989).

The foregoing distinctions and concepts may possibly be used to distinguish and analyze different types of controversies. They refer to the nature of controversies and their context, and are of course in need of further sophistication and articulation on the basis of theoretical and empirical work. Therewith we come to another question, viz. in what ways the student of controversies may approach his or her object of study — a question contingent upon the *purpose* of the study.

Different Perspectives

We distinguish here three different approaches to controversies. Let us call them *epistemological, descriptive* and *political.* (Naturally one might wish to distinguish further categories relating to methodological, ethical etc. controversies.) Epistemological approaches tend to be more synchronic, descriptive more diachronic, while political approaches emphasize the importance of context, of socio-political settings.

Epistemological-Synchronic Approach

The epistemological approach has as its main purpose to explore what the occurrence of controversies in science implies for concepts such as scientific objectivity, rationality, neutrality, truth. Hence the thrust is directed to drawing philosophical conclusions, while the empirical material — the actual controversies — primarily function as illustrations and background material for the more abstract discussions. The classical epistemological question: "Is valid knowledge possible?" must perhaps be understood and analyzed from a different point of view, and also familiar criteria of objectivity such as intersubjectivity, coherence, precision, etc. Does the fact that there are many controversies in science entail that we cannot speak of a universal rationality but rather have to assume several equally valid rationalities and concepts of truth? Does the existence of controversies in science demand us to draw sceptical and relativist conclusions concerning knowledge-claims? Do they provide a basis for a social epistemology, where philosophical questions have to be subsumed under the realm of empirical science?

Controversy studies promise to throw new light on such philosophical issues. We will not go into more detail here; suffice it to recall a concept that presumably will be central for further analyses — the concept of *incommensurability*. If there is incommensurability between two rival theories belonging to different paradigms, the controversy is, as Thomas Kuhn in particular has argued, insoluble from a rationalist point of view. There is no overriding rational criterion, no neutral yardstick, from which the rival theories can be assessed and weighted vis-a-vis each other. Standard examples of incommensurability are the geocentric contra the heliocentric theory, classical and relativist mechanics, the wave-particle duality in the theory of light, and, from a broader point of view, the contradiction between religious and scientific world pictures. Examples of these kinds contribute to the concretization of the ongoing relativism-objectivism debate in the theory of science. They show that controversies regarding scientific problems often involve more general epistemological principles and criteria, and even different "perceptual gestalts" for the identification of facts. Thus it is important to distinguish between incommensurable and commensurable controversies.

A recent elaboration of the concept of incommensurability is made by Ian Hacking (1983), concluding that there are three distinct features of conflict amongst researchers that may be subsumed under this term: topic-incommensurability, dissociation and meaning-incommensurability. The first of these points to a possible disagreement of focus between two theories — a later theory does not cover the same topics as an earlier theory it is meant to replace. The second type of disjunction points to the presence of conceptual schemes that are so different that anyone immersed in one of them will be unable to understand and see the world as it appears from within another conceptual framework purportedly raised over the same reality. Incommensurability in the third sense refers to the contextual change in meaning that occurs when the same term is used in two different philosophico-theoretical networks or lexical contexts (Kuhn, 1990).

A common technique of studying controversies from an epistemological point of view is to abstract and systematically compare the basic arguments of the contending parties. In this way, the argumentative structure of a controversy can be disclosed, outlined and analyzed. But a controversy is not merely an argumentative structure, it is also a *process* with a specific history.

Descriptive-Diachronic Approach

What we here call the *descriptive* approach is first and foremost historical, i.e. it details the course of development — the emergence, envelopment and termination of a controversy. Such a process can be depicted at several levels: the level of the individual actor, that of organization and institutional arrangements, or macro-levels in society (the state, economics, etc). In such cases, commonly accepted methods found in historical research,

history of science and historical sociology may be utilized. Case studies may also function as means of exploring and developing concepts, with a view to generalizing and strengthening the explanatory power of various models. Let us now suggest some concepts for a model of periodization of scientific controversies. We distinguish three overall phases: emergence, development, and termination.

1. The *emergence* of controversies can very often be understood as cases of *"boundary work"* (Gieryn, 1983), that is, the contending parties claim jurisdiction over a particular field or problem. The parties may be separate scientific disciplines, different parts of a certain discipline, or a scientific discipline versus, for instance, a profession, a political or religious movement, or the like. Socially, boundary work concerns who "has the right to speak", who is the real expert on an issue, with the adjoining claims to social rewards, status, authority etc. Social strategies can be divided into attempts to boundary maintenance and enclosure versus attempts of usurpation and expropriation. Cognitively, it is a matter of defining the nature of a problem or area of study as belonging to one's own domain of competence, simultaneously excluding other competencies. A new and potentially fruitful area of study must be possible to subsume under the discipline's conceptual framework.

The two sets of strategies have concomitant tactics for legitimating the social and cognitive demarcation of a speciality as one's own monopoly domain, or "jurisdiction". For students of controversies it is therefore useful to review contending arguments that rival parties employ to legitimate their stakes, socially and cognitively. Rhetorical analysis as it has been developed in science studies of late is of course relevant here.

Most current "social problems" of the modern welfare states are reflected in scientific controversies, for instance disputes concerning what is the nature of/who is the expert on alcoholism, drugs, homosexuality, AIDS, incest, research on the aged or gerontology, mental illness, etc. Traditional medical researchers tend to form one camp, seeking to subsume the problems in question under physiological, biomedical or clinical conceptual models, while their antagonists — perhaps with training in the softer sciences — seek to subsume the problems within the framework of social-scientific points of departure. Our most well-known historical controversies, such as between Darwin and Lamarckians, or indeed between science and religion, also exemplify how controversies emerge from territorial claims and boundary maintenance work (Gieryn, 1983).

2. The *development* of controversies may of course take a number of different routes. During controversies with major social, political and economic consequences, scientists of different persuasions typically seek alliances with various interest groups (and vice versa), that is, power blocks including various combinations of scientists, journalists, politicians, business managers and grass roots are formed around issues such as nuclear power, agricultural pesticides, genetic technology, etc. Hence, in this phase of a controversy, ordinary political theory, such as resource mobilization theory, i.e. the thesis that conflicts and power structures are functions of specific group interests and the resources these can mobilize, should be especially useful.

3. Finally, a controversy can end or be terminated in different ways. Intellectually, the most satisfactory ending is of course that the controversy is (a) resolved, that is, one of the parties succeeds in persuading its opponents with the help of what is agreed to be scientific facts and arguments, and by adhering to a common set of criteria agreed to by both sides. The controversy is resolved with solely epistemic factors, i.e.,factors are seen to be genuinely scientific. A second ending is by (b) closure, that is, something nonepistemic terminates the debate. Reference to another type of authority than "pure argument" is invoked or intervenes. Closure can assume many different forms. The state can decide to follow a particular course of action, even when scientific experts are still in disagreement. Governments can resolve questions by setting popular referenda, as in the case of the nuclear power controversy in Sweden 1980, and in Austria 1978. The parliament or its equivalent

can vote on a new concept of death, for example as occurred in Sweden, thus leading to a transition overnight from the heart-related death-concept being abandoned in favour of the brain-related death concept (Midnight Dec 31/Jan 1, 1988.) Research grants can be withdrawn, scientists can be expelled from scientific communities, etc. In all such cases, an external authority intervenes in the controversy in order to terminate it by non-epistemic means. A third possibility of ending is of course by virtue of one or several parties involved losing interest, that is, the controversy is (c) *abandoned*. One or another of the involved parties starts to get involved in other, more rewarding activities, scientists become pensioned, move to another country, etc. A fourth option, especially in regard to academic intra-disciplinary disputes, is (d) *specialization by division of labour*, i.e. two contending groups are institutionally separated; what Durkheim called the peaceful resolution of competition.

Political-Contextual Approach

The third approach, which we here refer to as the *political*, has as its purpose to locate the controversy in its wider social context, to outline the social interests and determinants which may lie behind it, and to analyze the political consequences of various solutions of types of closure. To what extent the parties involved in a scientific controversy are bound to or dependent upon external group or class interests, for example multi-national industries on the one hand or popular movements on the other, may become a central question. Can the debate on nuclear power or environmental issues be partly understood in these terms? Are scientific controversies reflections of social contradictions in society at large? American studies, especially in political science, have been devoted to many controversies of these kinds — fluoridation of drinking water, the role of experts in connection with assessment of occupational hazards and injuries and insurance, Laetrile, the construction of runways and airports, and much more. In many such cases it has been shown that apparently epistemic controversies have strong links with underlying societal interests. Indeed, one of the most distinguished controversy scholars of today, Dorothy Nelkin, argues that the contemporary proliferation of controversies involving science and technology should be accounted for politically, as a means of "negotiating social relationships and of sustaining certain values, norms, and political boundaries at a time of important scientific and technological changes, and that in most cases, scientific evidence has only limited bearing on the resolution of controversy. Accordingly, she analyses scientific and technological controversies along political value dimensions, employing the political dichotomies of efficiency versus equity, benefits versus risks, regulation versus freedom of choice, and science versus traditional values (Nelkin, 1987a).

The study of controversies involving science and technology may also form an integrated part of informal technology assessment. This has been suggested by Arie Rip (1986), who points out that some controversies sensitize us to "early warnings" about impacts of a technology or a large project. In this case the setting up of institutions to handle controversies is seen as part of a process of (social) learning and controversy studies may help make this process more self-reflexive. The context of such studies may vary — some will be to serve government agencies, feeding into policy-making in the short or longer term; others will come out of alliances with critical social movements or non governmental organizations, in order to develop alternative scenarios that differ from more established interpretations and visions of "the realm of the possible".

The political dimension is of course also present within scientific communities in the form of vested interests, as a result of research training, large scale governmental investments in crash programs to facilitate particular policies (health, energy, defence, etc), or power relations in big science. These vested interests are challenged and revealed by professional journalists in coverage of science and technology in the popular press. In her studies of technological controversies, Nelkin was "struck by the ubiquitous tendency to blame the press: scientists, engineers, and physicians

are quick to condemn the media, to criticize the quality of science reporting, and to attribute negative or naive public attitudes toward science and technology to the images conveyed in the press." In a critical study of the role of the media and science writers in particular, Nelkin has found that these in many cases, on the contrary, tend to hype up a positive image, thus contributing to the ambitions of large scale high tech projects and ventures. In modern science and particularly in relationship to scientific controversies science writers are effective brokers. Through their selection of news about science and technology they help set the agenda for public policy, and they have a key role in shaping the public consciousness, about science-related events (Nelkin, 1987b). In the political approach to the study of scientific controversies the interaction of scientific communities and the public via the media is one of several important topics. Others are the relationships between science and the state, as well as modern forms of patronage.

Integrative Approach

The three different approaches we have presented here should not be seen as mutually exclusive. An ideal type of study should strive to combine two or perhaps all three. Moreover, it is our contention that controversy studies constitute a good base for the development of a genuine *"political sociology of science"*, especially in our times, when the interaction between science on the one hand and government and private industry on the other is becoming increasingly intense, generating socially "mandated" research (Salter, 1987). Practitioners strongly connected to socially mandated science experience different pressures and are in part linked into networks that differ from those of disciplinary communities. Sometimes these communities within the realm of mandated sciences are referred to as "hybrid communites" (Elzinga, 1985; Haas, 1989), displaying characteristic reputational systems that differ from those of disciplinary academic communities. Peer review may be less prevalent than it is in academic science and there is a tension between internalist and externalist criteria for evaluating scientific research, generating an *"epistemic drift"* (Elzinga, 1988).There is an intricate dialectic between this complex political environment, changing standards and scientific controversies, and consequently it is in this context they must be approached and understood.

To sum up. In its simplest and crudest form, our suggestion for studying controversies involves that controversies can be fruitfully studied by combining diachronic and synchronic perspectives in the following manner. The progress of controversies is analytically divided into three phases. Each phase has its characteristic dynamics that can be denoted by its basic concept. During the initial phase, the *origin* of controversy, *boundary work* between representatives of different disciplines and specialities is the most characteristic feature; during the *development* of controversies, the articulation and support (alliances between groups of scientists and non-scientific power-holders) of *incommensurable positions* is the basic dynamics; and finally, the *termination* of controversies are often outcomes of external or internal *closure.* The peculiarities of each phase should of course be fleshed out on the basis of case studies and the development of further analytical concepts.

The Fruitfulness of Controversy Studies

Why study controversies? In the foregoing we have already suggested several reasons, such as focusing on controversies in order to provide an alternative to rationalistic types of research progams that have traditionally dominated the theory of science. The value of alternative approaches in its turn concerns the question of how facts are discovered within research. Theories and conceptual frameworks tend to generate "their own" facts, that is, observation is guided by anticipations, regularities and probabilities that are predicated on a certain conceptual apparatus. A point of departure with a contrasting, alternative set of concepts

—in this case "concepts relating to controversy" as opposed to the basic concepts generated by rationalist theory — in our estimation holds greater potential for alerting researchers to new and alternative facts. Paul Feyerabend (1975) has developed several arguments for this "counter-inductive" methodology.

When consensus holds sway in a group or in a society it may be difficult to find the points of departure and assumptions that underpin the reigning perceptions of reality. They are so self-evident that the basic assumptions do not appear manifestly. Rather they remain "hidden" as tacit assumptions. But if we want to understand the nature of science, it is important also to disclose just those tacit assumptions whereupon this thing called science rests; what *Vorverstandnis*, ideals of science conventions, contingencies and "lacuna" it contains.

In sociology there is a well-known method for disclosing hidden premises and norms in a social group. One investigates what situations elicit indignation; what kinds of behaviour lead to emotional outbursts and fights. If behaviour of type 1 evokes indignation, this indicates that a norm of type one is violated, if behaviour of type 2 evokes indignation, a norm of type 2, . . . etc. In this way one can map unwritten norms and rules that characterize a group. In other words, conflict situations offer good opportunities for studying norm systems, rival strategies for maintaining hegemony through claiming interpretative priority with respect to central rules and habits.

Now this method should be useful also when it comes to science, determining hidden assumptions or "norms", both epistemic and social, within science (Niiniluoto, 1990). Science in a situation of controversy, i.e. when indignation and strong feelings are present, becomes a particularly fruitful place for finding such norms, interests, etc. In certain types of controversies, epistemic criteria are articulated, and behind these we find rival ideals and images of science.

Another advantage is that the contending parties in a controversy examine each other's arguments very carefully. Thus weaknesses in arguments and counter-arguments tend to come out more clearly. This makes it possible to map out argumentative structures. Political dimensions also stand out more clearly. The characteristic feature for consensual relations — normal science in Kuhn's sense — is precisely that one does not discuss and doesn't need to bother about the foundations of one's discipline or activities. They appear as self-evident and rational. All this is called into question in controversies.

If we let go of rationalistic assumptions and problematize the autonomy of science it seems to be necessary to study science empirically, i.e. by using methods developed within the empirical sciences. There are several fields within the empirical sciences that have developed techniques and theories for analyzing conflicts, and these may with advantage be employed in the study of scientific controversies — we are thinking of conflict sociology, attribution theory in psychology, theories of contradictions in the history of ideas and historical materialism, peace and conflict research, etc.

Studies of modern controversies with important socio-political consequences also provide excellent material for throwing light on the role of scientific expertise (often; professional occupations with academic status). Of particular interest in this connection is the role of scientific experts in modern welfare states. Science and the expertise it supplies plays an ever greater role in the development of society. More and more questions are seen to be as overly technical and too complicated to be dealt with by ordinary democratic decision making processes. What does this mean for democracy? Is a technological elite taking over? Is it the case, as Habermas claims, that there is an inverse relationship between the rule of expertise and democracy? And what can be learned from disagreement between experts when it comes to these questions? (Brante, 1990).

As already mentioned, another argument for studying modern controversies is that such disciplines as the philosophy and theory of science, sociology of science, psychology and history of science, ought to take up problems with a high degree of social and political

relevance. The study of controversies in and around science provides a lever by which researchers in these fields may boot-strap themselves out of their academic ivory towers. Ideally, controversy studies would seek to find a middle road, avoiding both empiricism (data collection for its own sake) and philosophism (epistemology for its own sake), thereby paving the way for a politically informed sociology (history, psychology, philosophy) of scientific knowledge.

NOTES

1. This article belongs to a series of studies of modern scientific controversies, under a program of "Controversy studies", run by sociologists, philosophers and historians of science at the University of Gothenburg, Sweden. Studies have been conducted or are in progress on controversies about nuclear power, environmental problems of various kinds, space research, technology, child care, cholesterol, Arctic research, and more. The general ambition of the program is to attempt to construct a new conceptual apparatus for the study of modern science, based on a number of case studies in Sweden and abroad.
2. On the side of the rationalists the conflictual character of science has been taken up by several authors, among them D.T. Campbell (1986, 1990), N. Roll-Hansen (1989), P. Kitcher (1990). On the side of sociologists and historians of science, we have the advocates of the Strong Program, Harry Collins and his colleagues with their strong empiricist program (see esp. Social Studies of Science. 1981, Vol 11, No. I)

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