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Knowledge and non-knowledge

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Abstract

The polarization of knowledge and non-knowledge or ignorance has become a distinguishing feature of modernity. Nonetheless, as I will demonstrate in a sociological critique of these positions, it is theoretically and empirically unproductive to insist on an either/or, and to interpret non-knowledge as the opposite of knowledge. This contrariety only leads us into the abyss of an arbitrary, false, and also tiresome antithesis of rational and irrational, or of an unnecessary differentiation between believers and infidels. Undoubtedly, there are significant *asymmetries of knowledge* as a result of the social activity of individuals and groups. Knowledge represents a continuum. Knowledge is context-dependent. It is an anthropological constant that no one can and must know everything. The actually explosive sociological question is, therefore, how in modern society – under different basic conditions – we should approach the problems of the asymmetry of knowledge and, in particular, of knowledge deficits.[1]

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[1] Robert Avila translated my essay from a German version. I am grateful to Jason Mast for his critical reading of the text. Volker Meja offered useful editorial advice.

1 Introduction

I begin with quotations from Alfred Schütz and Georg Simmel:

> "The outstanding feature of a man's life in the modern world is his conviction that his life-world as a whole is neither fully understood by himself nor fully understandable to any of his fellow-men" (Schütz 1946: 63).

Georg Simmel in turn, emphasizes:

> "Our knowledge, as opposed to the totality of experience on which our acting is based, is marked by strange limitations and turn-offs." (1922 [1908]: 385)

My hypothesis on the presumed phenomenon non-knowledge can be summarized well in the sense of Schütz and Simmel, but still more precisely with reference to a formulation by the economist Joseph Stiglitz (2005: 133) on the *invisible hand*, ostensibly operating in the markets: Why is the invisible hand invisible? Because it doesn't exist. Why is non-knowledge difficult to grasp? Because there is no such thing as non-knowledge.

But because I don't want to capitulate already at this point, I will concentrate in this essay on observing scientific discourses, in which it is maintained that something like non-knowledge does exist. The dichotomy knowledge/non-knowledge appears in many discussions on the subject as a performative speech act, which, however, recommends only one side of that which it designates, namely knowledge. I can't sustain my restrictive cognitive interest of merely observing; from time to time, I have to deviate from it, and judge as if non-knowledge exists.

At the same time, I want to draw attention to other terms which are empirically and theoretically more productive than the naked assertion of non-knowledge. Finally, I will point to a number of fascinating, but rarely studied topics, which have to do with the question of the societal function, resp. the societal treatment of apparently insufficient knowledge.

2 Freud and Hayek

I begin with Sigmund Freud's and Friedrich von Hayek's treatment of non-knowledge. Their approach is quite representative for scientific discourse. Both Freud and Hayek recognize that there can be no such thing as a researchable subject "non-knowledge", but, unimpressed, continue in their attempt to study something which doesn't exist. This gives me the opportunity to ask why concerning oneself with the subject of non-knowledge is typical especially for the German-speaking scientific community; is it a sort of eccentricity?

Freud's theory of the dream as a psychic phenomenon, as set forth in his "Introductory Lectures on Psychoanalysis" [*Vorlesungen zur Einführung in die Psychoanalyse*], is based on the primary consideration that the "dreamer himself [should] say what his dream means" (2010 [1924]: 94). Here, a fundamental obstacle apparently stands in the way. Actually, the dreamer is, as a rule, firmly convinced that he doesn't know what his dream means: "The dreamer always says, he has no idea", according to Freud (ibid.). In this case, Freud is confronted with an apparently hopeless situation with respect to a scientific-methodological interpretation of dreams.

> "Since he [the dreamer] doesn't know anything and we [i. e., the psychoanalyst] don't know anything, and a third person can't know anything at all, there is probably no chance of finding it [the dream's meaning] out … " Freud (ibid.)

But instead of accepting these findings and giving up, Freud considers another possibility:

> "I tell you namely that it is still quite possible, even very probable, that the dreamer in reality does know what his dream means – he just doesn't know that he knows it, and therefore believes that he doesn't know it" (ibid.).

This interpretation seems to be confusing and self-contradictory. Freud even asks himself whether his hypothesis that there are "psychological things in man … which he knows without knowing that he knows them … " (ibid.), might be a *contradictio in adjecto*:

"Where, in which field should proof have been brought that there is knowledge about which a person doesn't know anything, as we want to assume of the dreamer? That would be a curious, surprising fact which would change our conception of inner life which needn't fear comparison. At the same time [it would be] a fact which abolishes itself even in its mere mention, and nonetheless wants to be something real, a contradictio in adjecto." (ibid.: 95)

It follows that one should better abandon this method of dream interpretation. But Freud doesn't. The knowledge doesn't hide after all. One only has to search persistently. Freud writes that the assumption that

"the dreamer's knowledge about his dream exists, but which is only inaccessible for him, so that he doesn't believe in it himself, isn't a pure invention … It is only a matter of making it possible for him to find his knowledge and to communicate it to us." (ibid.: 97)

Von Hayek, confronted with a similar dilemma, decides, just like Freud, to ignore it. In his essay entitled "The Creative Powers of a Free Civilization", in which the lack of knowledge is a question of the distribution of knowledge in markets, von Hayek first notes that any progress in civilization is the result of an increase of knowledge. In the real world, according to Hayek, it simultaneously holds true that "the individual profits from much more knowledge than he is conscious of" and adds,

"this basic fact of man's unavoidable ignorance of a large part of everything that the functioning of a civilization is based on, has found little attention" in science (2005 [1960]: 31).[2]

Our knowledge is far removed from being complete.

The key passage in von Hayek's analysis of the difference between what he calls the boundaries of ignorance, resp. man's unavoidable ignorance and "conscious knowledge" is:

"Our knowledge [is] a subject which is particularly difficult to discuss … We can certainly not discuss something reasonably which we know nothing about." (ibid.: 32)

Von Hayek takes recourse to a kind of "Münchhausen manoeuver":

"We at least have to be able to formulate the questions, even if we don't know the answers … Even if we can't see in the dark, we have to be able to sound out the boundaries of our ignorance." (ibid.)

Nevertheless, as von Hayek emphasizes,

"if we want to understand how society works, we have to try to determine the general nature and the extent of our ignorance" (ibid.).

3 The boom of non-knowledge

But why, in spite of the problems that Freud and von Hayek quite obviously had with the concept of *non-knowledge*, did the term nonetheless experience, in German speaking countries in particular, such resonance in the contemporary cultural and social sciences? Why is the category of non-knowledge increasingly becoming a prominent and trenchant "monetary unit" as the shady side of knowledge in the media, and in the public discourse as well?

The boom of reflection on non-knowledge certainly has to do with the essentially controversial concept of knowledge, as well as with our understanding of the modern condi-

[2] The translations of central concepts of his English essay (into German) chosen by von Hayek are of interest, and are, in my opinion, fully adequately translated as follows: "the boundaries of his ignorance" and "man's unavoidable ignorance" (Hayek 1960: 21) are translated as "Grenzen seines Unwissens" and "unvermeidliche Unkenntnis des Menschen". In other words, there is no reference to non-knowledge.

tions for the production of knowledge, with the societal role often attributed to knowledge, and with the theory of modern society as a knowledge society.

Is the difference between knowledge and non-knowledge an example of the typically static conceptual polarity of old European philosophy? Or is it basically only the widespread culture-critical complaint that the *individual* – in view of the extensive volume of, and new technical and complicated methods of access to existing and growing, objectified *knowledge* in modern societies – disposes over a minute (and probably diminishing) share of all knowledge? Are the widely-discussed findings of the political "ignorance" or "stupidity" of the average voter and the danger for democracy it poses one of the causes for the topicality of the subject of non-knowledge?

It is, on the other hand, unrealistic to assume that the average citizen, including the well-educated contemporary, has (or should have) sufficient technical knowledge in order to be able to intervene, for example, in the complex decision-making of economic questions of the goal conflict inflation/unemployment. Does the concept of non-knowledge basically merely mean the societally necessary *distribution* of knowledge? Does the concept of non-knowledge perhaps refer primarily to the future present, about which we are really only sparsely informed, or hardly know anything? Does the origin of the boom of observations on non-knowledge lie under certain circumstances in an overestimation of the societal role of allegedly unquestioned scientific knowledge and in an underestimation of the societal roles of knowledge?

At this point I would like to emphasize that there are other terms for the societal phenomena perceived as non-knowledge, and with which we can, in my view, better observe how a lack of knowledge (resp. information) manifests itself in modern societies, and how we can deal with knowledge gaps. In any case, *one* key to recognizing the myth of non-knowledge is the concept of knowledge itself, as well as the complicated question of distinguishing between information and knowledge.

4 Knowledge as a societal construct

In the discussion on the concept of non-knowledge, there is often a liberal intermingling of the terms "knowledge" and "information". I assume, on the other hand, that one should distinguish the concept of information from that of knowledge, even if this distinction is difficult to maintain in practice. A lack of information is not "non-knowledge".[3] Just exactly what knowledge is, and how knowledge differs from information, human capital, or other intellectual or cognitive characteristics, is an *essentially controversial question*. Neither the concept of knowledge, nor the manner of the production, the distribution, use, nor the consequences of knowledge are – at least for the scientific observer – foregone conclusions.

I would like to define knowledge as the *capacity for societal action* (capacity to act), as the possibility "to get something going". Knowledge therefore refers to *process* knowledge. Knowledge is a *model of reality*. In 1948 Claude Shannon published a short monograph with the title *The Mathematical Theory of Communication*. In this work, Shannon explains how words and images can be converted into characters and transmitted electronically. He thus contributed to realizing the digital

[3] Wehling (2009: 99) characterizes, for instance, the insufficient information "Does the guest arrive at 5 or 6 pm?" as a case of "non-knowledge". This example is at best vague information, as will be shown more precisely.

revolution.[4] According to Shannon, the expansion of knowledge represents a broadening of the horizon of possibilities. Whether the broadening of the possibilities for action also automatically represents an increase of the possibilities for disappointment (often also understood to be an increase of non-knowledge), has to be regarded as controversial. Insufficient knowledge on the part of an individual or a group accordingly means the inability of these actors to mobilize knowledge, in order to put something in motion.

Knowledge exercises an "active" function in the societal sequence of actions only when action isn't carried out in essentially stereotyped (Max Weber), habitual (= effortless) patterns,[5] or is otherwise regulated to a great extent, i. e., where – for which reasons whatever – leeway and the necessity for decisions make mental effort or exertion necessary.[6] The societal practices in which decisions are possible and necessary, represent the ecology of knowledge, or, more exactly, the ecology of the application of knowledge.

Every implementation of knowledge, not only of great scientific experiments, requires a control of the circumstances of action (initial conditions) through active agents, who, for example, want to carry out laboratory experiments (or a thought experiment). In other words, when

> "scientific knowledge is to be 'applied' in society, adaptation to the initial conditions prevailing there has to be made, or societal practice has to be remodelled according to the standards set by science" (Krohn and Weyer 1989: 354).[7]

5 Information and knowledge

I define information in distinction to the concept of knowledge as follows: the content of information concerns the characteristics of *products or results* (output, condition, supply), whereas the "stuff" that science is made and consists of refers primarily to the qualities of *processes or resources* (input, procedures, business enterprises), which are implemented in processes: knowledge is the capacity to act, while information

[4] Freeman Dyson describes the case of Shannon in a review in *The New York Review of Books* (March 20, 2011): "In 1945 Shannon wrote a paper, A Mathematical Theory of Cryptography, which was stamped SECRET and never saw the light of day. He published in 1948 an expurgated version of the 1945 paper with the title 'A Mathematical Theory of Communication". The version of the year 1948 appeared in the magazine *Bell System Technical Journal*, the institutional publication of the *Bell Telephone Laboratories*, and immediately became a classic: "It is the founding document for the modern science of information. After Shannon, the technology of information raced ahead, with electronic computers, digital cameras, the Internet, and the World Wide Web."

[5] A variant of these thoughts worthy of consideration and quoted by Friedrich von Hayek (2005: 31) can be found in Alfred North Whitehead's (1948: 52) *Introduction to Mathematics*: "Civilization advances by increasing the number of important operations which we can carry out without thinking. Thought processes are like a cavalry attack in a battle – they are precisely limited in umber, need fresh horses, and can only be carried forward at decisive moments".

[6] Niklas Luhmann's (1992: 136) observations on the preconditions for the possibility of making a decision possibly permit a still broader application of knowledge. "One can only decide", as he very plausibly underlines, "when and to which extent it is not certain what will happen." Under the premise that the future is highly uncertain, the lack of knowledge in decision-making processes can extend over many more societal contexts and thereby also to those which are normally characterized by routines and habitual behaviour.

[7] Hans Radder (1986: 675) arrives at a similar conclusion when he points out that material *as well as* social prerequisites have to be met in the long run for a long-term practically successful technical production: "The creation and maintenance of particular social conditions (for example, a bureaucratic and centralist administration in the case of nuclear energy) is necessary in order to be able to guarantee the permanent technological success of a project."

doesn't enable us to set anything in motion.

It is just as important to emphasize from the outset that information and knowledge have, to a limited extent, common attributes. The most important basic common denominator is that neither information nor knowledge can be understood independent of societal contexts. In daily life, as well as in the scientific discourse, the conceptual interchangeability of information and knowledge is prevalent; it is nonetheless remarkable that, in public places, like, for instance, airports, shopping centers, railroad stations, or highway roadhouses, one doesn't find knowledge, but rather information boards. It is probable that the blending of these terms will prevail further in practice, in everyday life as in science, because: who can distinguish between the information and the knowledge society?

6 Observing non-knowledge

With these observations in mind, I try to ascertain what could or could not be meant when one speaks of non-knowledge.

Our actions are guided by knowledge. Knowledge of others and self-knowledge are prerequisites for socialization. There can be no societal actors without knowledge. One is just as far from being unknowing without knowledge as one is naked without a headscarf. A society without secrets is inconceivable. Ignoring knowledge and information is sensible, even rational. A society in which there is total transparency is impossible. Knowledge is never creation out of nothing. Knowledge, or the revision of knowledge, arises out of already existing knowledge (and not out of forms of non-knowledge). The existence of a *non*-knowledge society is just as questionable as that of a speechless human society. We live in a complex society, marked by a high degree of functional differentiation, in which almost all of its members are non-knowledgeable about almost all knowledge. It is useful to ignore information and knowledge. Each individual knows that his knowledge is limited. On the other hand, we profit a great deal from knowledge we aren't acquainted with. Which indicators could we use to characterize a non-knowledge society empirically? Almost half of the American population is convinced that the earth is less than 10.000 years old. Is the American society for that reason a non-knowledge society?

Who or what is the standard of comparison when one speaks of the duality of non-knowledge and knowledge, or of the relationship of knowledge to non-knowledge (as "known unknowns")? Is it the individual, or a collective? Privileging the individual is common. Or, to put it more stringently, does the concept mean a single process, a single quality (information), or the prognosis of an occurrence? How long must (or can) non-knowledge be perceptibly recognizable, in order to be non-knowledge? Can cluelessness, for example, last only for seconds? Does one refer to individual forms of knowledge (or information) which the isolated individual (for instance, as a scientist) or a non-knowledgeable collective doesn't have, and also can not have, because one always proceeds selectively, resp. is forced to filter?

Knowledge, on the other hand, is much rather a *variable* societal phenomenon which lies on a continuum, and points to the existence of the elementary *distribution of knowledge* in complex societies. Knowledge represents a continuum, which one can not simply dissect, and not a clear-cut difference between knowledge and non-knowledge. Knowledge is a total societal phenomenon.

There is no comprehensive knowledge; nobody can know everything. Acting under conditions of uncertainty is commonplace. Knowledge of these gaps is knowledge, but knowledge of gaps doesn't belong into the category of non-knowledge, if – in case one finds this designation to be productive – it is a case of "negative knowledge". Actually, we can often close this gap quickly, because we know or can find out who might know it – see, for example, the societal role of experts. On the other hand, there are things which (almost) everyone knows, resp. about which almost everyone is *informed.*[8]

There are a number of expressions which – empirically as well as practically – are more productive than non-knowledge, and nonetheless illuminate the horizon of problems about what non-knowledge allegedly comprises. Here, I limit myself to one of these possibilities.

7 Asymmetric information/ knowledge

In an influential article "The Market for Lemons", the economist and later Nobel laureate, George Akerlof, in 1970 paved the way to a systematic analysis of *asymmetric* information through an exemplary analysis of the respective *information* of buyers *and* sellers of used cars. An asymmetric state of information is one of the fundamental characteristics of various classes of participants in the used-car market.

The owner and driver of the used car on sale knows, as a rule, much more exactly the degree of dependability or the history of the car's mechanical problems than the potential purchaser. In a credit agreement, the debtor is guided by certain intentions to repay the credit or not. The lender has, as a rule, no access to this information. The lender can also not be certain that the debtor's investment intentions will actually be profitable. Generally speaking, asymmetric information on the part of market participants should lead to market failure.

Buyers and sellers, lenders and debtors are often conscious of the fact that there is or can be a state of asymmetric information. It follows that, on the part of the buyer or lender, indicators are sought which diminish the mistrust in the information available, (resp. let it be classified) as more or less reliable. Because the conversion charges of the acquisition of relevant information might be high, the more easily accessible information on the seller's or debtor's social reputation will likely be an important indicator for the lender or buyer.

From Akerlof's deliberations and from those of other economists, the following general lesson can be derived for my analysis of the antithesis of information and knowledge: because societal knowledge is not evenly distributed, but is scattered asymmetrically, we have to assume a cognitive-societal functional differentiation in all societal institutions.[9] In science, this is not only perceived as a matter of course, but, as a rule, is also understood to be a functional characteristic of science as an institution. Not every scientist can work on just any question. And every single scientist's role cannot be classified in relation to itself, but only in relation to that of other scientists. It is therefore natural to speak of a cognitive functional differentiation in all societal institutions. In other words, it can, for that reason, only be sensible to speak of a scale of knowledge in groups of actors to asymmetrically-limited knowledge in groups of actors, and not of knowledge and non-knowledge.

[8] As, for instance, the fact that almost every human has two eyes, or that there is such a thing as weather or climate.

[9] In memory research, an extreme example of asymmetric information has recently come under study – to wit, the few people who have a "superior autobiographical memory", that is, the ability to recall every single day of their lives, resp. to remember the occurrences of every single day (cf. Parker, Cahill and McGaugh 2006).

8 On the virtues of non-knowledge

In different societal institutions non-knowledge has its own functional meaning. In an institution like science, it is a state, which has to be overcome – a condition which, in science, acts as an incentive. In a highly-stratified societal institution, for instance, in so-called "total" institutions, differing states of knowledge are a constitutive characteristic feature (a functional necessity), which is defended by all means.

Wilbert Moore and Melvin Tulmin (1949: 787), therefore, in their classical functionalist analysis of the societal functions of "ignorance", point to the widespread opinion that ignorance is the natural enemy of societal stability and of the possibility for orderly societal progress, and that every increase of knowledge automatically increases human welfare. We know that a generally positive public attitude toward new knowledge, which was widespread in the years immediately following World War II, is at present losing ground to growing scepticism with respect to new scientific and technical knowledge.

This adverse view of non-knowledge as a problem area is, however, not uncontested. There is a multitude of convincing references to the virtues/advantages of ignorance, of a lack of knowledge, or of invisibility. Among them are everyday sayings, such as, for example, "Ignorance is bliss", or "What I don't know can't hurt me". The reproach of the radically transparent ("glass") citizen belongs in this category. However, it remains an open question, whether this is a matter of mutual transparency, or primarily of the transparency of the powerless for the powerful. A society, in which complete transparency prevails, is, as Robert K. Merton, emphasized, a "diabolical" society (1965: 345). The practice of a mutually transparent, complex society is unrealistic.

Opposition against an excess of the transparency of one's own behaviour and that of other actors, as Merton (ibid.: 343) also emphasized, is a consequence of certain structural characteristics of societal groups. To these belongs, for instance, the negligence in complying with or in enforcing existing social norms,[10] which is institutionally sanctioned, but in reality also limited. To these also belongs psychologically-determined, variable opposition against a maximum transparency of behaviour (see Popitz 1968: 8). In our society, technical and legal barriers exist, in addition to these conditions for opposition, which make impossible an unlimited investigation of the behaviour and convictions of individual actors – about whom one would like to know everything. The alleged goodwill or the maliciousness of the thought police is irrelevant. For instance: new possibilities for avoiding technically-mobilized monitoring repeatedly turn up.

Heinrich Popitz, on the other hand, points in his observations "On the Preventive Effects of Non-Knowledge", to the *disencumbering* function of limited behavioural information for the system of sanctions.[11] Limiting the available or requested behavioural information –

[10] Inasmuch as the disregard and sanctioning of existing social norms by certain incumbents of societal positions of a group is known, it has to be decided whether "the basic formal structure of a group is being undermined by the observed deviations of behavior. It is in this sense that authorities can have '*excessive knowledge*' of what is actually going on, so that this becomes dysfunctional for the system of social control" Merton (1965: 343; emphasis added).

[11] In this respect, it is not uninteresting to note that the expression of non-knowledge in Popitz's treatise's title doesn't occur a single time in the text. Possibly, the publication's title is the work of the publishing house. Popitz's exposition shows that he rightly avoided the term "non-knowledge", but more guardedly wrote of limited behavioural information or limited transparency of behaviour.

which is simultaneously a relinquishment of sanctioning – is also a sort of "indeterminacy principle of social life", and

> "opens a sphere in which the system of norms and sanctions doesn't necessarily have to be taken literally, but without obviously giving up its claim to validity" (Popitz 1968: 12).

Finally, there is a further (primarily cognitive) function of insufficient knowledge. It has repeatedly been claimed that knowledge arises out of non-knowledge, or that non-knowledge can be transformed into knowledge. Just how this is supposed to happen is, however, scarcely addressed. The hypothesis of the genesis of knowledge out of non-knowledge, so to speak, out of nothing (*ex nihilo*) completely overlooks the societal genealogy of knowledge as, for example, the close interconnections or even intimate relationship between scientific and practical knowledge. The birth of a scientific discipline is no parthenogenesis. The hypothesis of the transformation of non-knowledge into knowledge favours certain knowledge, in that the origin of new knowledge is simply suppressed.

9 The societal-cognitive functional differentiation

In a modern society, with its functionally differentiated cognitive structure, it belongs to the realities taken for granted that the individual, societal groups, or societal institutions, have long since given up the wish for, or the hope of an autarky of their knowledge. Limited knowledge alleviates. Knowledge is unequally distributed. As a rule, managers don't themselves have the technical knowledge of their employed labourers, engineers, or assembly-line workers. In spite of this lack of knowledge, managers still become managers.

Knowledge gaps or incomprehensive forms of knowledge distribution, *not* non-knowledge, are constitutive for functionally differentiated societies. Asymmetrical stocks of knowledge don't lead to society's collapse. A society's ability to act competently is not a function of the knowledge and information of isolated individual actors. A competent actor, for instance, as a politically active citizen, doesn't have to be comprehensively informed as an individual.

A society without this fundamental limitation – that is, a cognitive functional differentiation – is inconceivable. No one has to know everything. This is an elementary fact, which determines society's being as it is. But alone on the basis of this fact one shouldn't conclude that non-knowledge is the opposite of knowledge. A being constantly caught up in non-knowledge can't exist. As Friedrich von Hayek (2005: 36) rightly emphasized, when collective knowledge increases,

> "the smaller the share becomes, that an individual mind can absorb. The more civilized we become, the more relatively unknowing every individual must become about the facts upon which the functioning of a civilization depends. Specifically the sharing of knowledge increases society's non-knowledge of the greatest part of knowledge." (emphasis added)

The abandonment of the possibility of an autarky of knowledge, especially the *individual* self-sufficiency of knowledge, or the conviction of fundamentally limited knowledge (*bounded knowledge*) is connected with costs as well as with benefits. But the loss of autarky – inasmuch as this condition had ever existed, even in traditional societies – is never to be understood as a form of non-knowledge. Societal innovations, such as the market, the scientific or political system, provide for the coordination of knowledge gaps.

Relevant functionally differentiated scales of knowledge[12] differ, for in-

[12] There is a parallel to the argument of the scales of knowledge, namely that of the degrees of property rights, the extent of which is calibrated according to the

stance, according to the respective epoch, the type of society, the pattern of societal inequality, the interests of the dominant worldview, etc. In modern complex societies, the knowledge scale is longer than in traditional societies. The distance to the sources of knowledge is often great. Personal acquaintance with the knowledge producer is not necessary. Only in exceptional cases the knowledge that one doesn't possess, but can obtain, includes the knowledge that was necessary for its production, legitimation, and distribution.

10 Perspectives

The current intense debate among social scientists, with its radical polarization of knowledge and non-knowledge, is like an echo from a lost world, or the wish to be able to live in this secure world. It was a world in which knowledge was reliable, objective, ontologically well-founded, truthful, realistic, uniform, and undisputed. It was a world in which scientific knowledge was unique, and the profane world of non-scientific knowledge was, to a great extent, disqualified. It was a world which favoured the acquisition of more and more knowledge – for instance, for being able to act successfully in practice (*knowledge bias*). However, the world of unquestioned knowledge is lost. Whether this is a real loss, as the talk of the divide between non-knowledge and knowledge apparently suggests, or whether it is an intellectual emancipation remains an open question.

The difference between knowledge and non-knowledge is an old European antithesis with an ancestry in premodern cultures. The old European tradition of a dichotomy of non-knowledge and knowledge makes itself felt especially in the *attribution* of persons or groups to one of these two categories. The unknowing person, or, more generally, social class, is then not only helplessly exposed to the power of knowledge, but is also a pitiable, backward social class. And inasmuch as the occurrence of non-knowledge applies to other societies and cultures, it is foreign – and not one's own – knowledge that is non-knowledge. Ludwig Fleck describes this as follows:

> "Knowledge was at all times system-compatible for the views of the respective participants, proven, applicable, evident. All foreign systems were, for them, inconsistent, unproven, inapplicable, incredible, or mystical." (1980: 34)

These traditional deliberations on the great divide between knowledge and non-knowledge, for that reason, scarcely meet the solution of the dilemma described by Niklas Luhmann:

> "Is the generally-held assumption that more communication, more reflection, more knowledge, more learning, more participation – that more of all of this would bring about something good, or, in any sense, nothing bad, at all justified?" (1992: 154)

The emerging political field of knowledge policy is dedicated to this societal dilemma of the risks of knowledge (Stehr 2003).

We should not insist on an absolute antithesis of knowledge and non-knowledge – there is only less or more knowledge, and those who know something and those who know something else. The practical problem is always to know how much or how little one knows in certain situations. A person is not either knowledgeable or unknowing. A person has more knowledge in one context than in another: a person may know much about tax regulations, but hardly anything about playing golf.

Actors (including scientists) react to complex societal forms by simplifying mental constructs of these relationships. The mental constructs are, in

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labour, need, or performance, resp. the merits of the owner (cf. Neumann 2009).

fact, incomplete, inasmuch as they don't depict reality its full complexity. These simple models change, react to the unexpected, but they are hardly non-knowledge. One of the advantages of liberal democracies is the consciousness that omniscience can be dangerous, and that safeguarding privacy has to remain a form of sanctioned ignorance.

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Conflict and consensus formation in knowledge communities

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Abstract

The evolutionary perspective of the "systems of innovation" approach meets with difficulties in accounting for new developments, such as the creation of new technological paths or technological convergence. The development of a new micro-approach to technological development and innovation is needed, which focuses on the governance of a multitude of communities involved in different arenas of the knowledge transformation process in innovation systems. Concepts such as "definition of the situation", "framing", and "image" underline the need of future innovation research to include a richer and more focused view on cognitive and collective aspects of technological governance.

1 Introduction

Concepts such as "transformative technologies" (Phillips 2007) or "converging technologies" (Roco and Bainbridge 2005) represent new challenges to the "systems of innovation" approach. The idea of a continuous, cumulative development of isolated technology strands, characteristic for this approach, does not capture the dynamics of current technological development. Instead, new aspects such as fundamental transformation, path creation, and, in particular, technological convergence, come into the foreground. The evolutionary perspective of the systems approach[1] clearly has difficulties in accounting for such new phenomena (Schienstock 2004).

Furthermore, the approach, although conceptualizing an innovation system as a social system, in which the relationships between actors have an important role to play, widely ignores conflict. This is the more astonishing, as social scientists have argued that conflict represents a key quality of social relationships (Giddens 1984, Foucault 1989, Coser 1956), can become inspiring, constructive and fruitful and can initiate technological change and systemic restructuring. But, although scholars have shown that conflict often stimulates creativity, inventiveness and innovation (Dahrendorf 1969), representatives of the systems of innovation approach have not analyzed this dimension of social relationships. Because of the fact that scholars, applying this approach are primarily interested in factors leading to successful innovations, we may characterize systems of innovation as a "consensus theory of innovation" (Boulding 1997).

Challenges of this kind make it necessary to develop a new micro-approach to innovation, which focuses on the coping of different communities with uncertainty and ambiguity within complex knowledge-transforming processes and which includes conflict as an important dimension of social relationships. Identifying efficient forms of knowledge governance then becomes a key target of innovation research. There is widespread agreement that, due to the specific character of knowledge, the governance of technological innovations cannot be based on contractual regulations and bureaucratic control; instead, future approaches in innovation need to broaden their scope to include a view on collective action and cognitive processes (Lampel 2001: 306). "Definition of the situation", "framing" and "image", developed, stabilized, and changed through communication and dialogue, represent key concepts in a new actor-centred, micro-oriented approach to innovation. These concepts can be used to overcome conflict and guiding knowledge and know-how production, to deal with sets of problems in various knowledge arenas. This article aims at contributing to the development of such a new micro-model of innovation.[2]

2 Systems of innovation as knowledge-transforming systems

Innovation, as scholars have often stressed, is not the result of a singular event or a punctual decision act, but must be understood to be a complex social process (Lundvall 1992b). In this process, a multitude of individual or collective actors is involved, who alone or together initiate, adopt, produce, or use something new. In particular, the innovation systems approach focusing on the institu-

[1] Key publications, using the system of innovation approach, are among others Lundvall (1992a), Edquist (1997), Fagerberg, Movery and Nelson (2005).

[2] We are, of course, aware of the fact that conflict has been a topic in the STS literature for quite a while (see for example Hard 1993). Here we are primarily interested in revealing conflict structures; we do not intent to analyze concrete conflict episodes, a particular focus of the STS literature.

tional embodiment of a general innovation capability of a national or regional economy underlines the importance of the interdependency between social actors and the accumulated relational capital. As no actor is self-contained, the linkages, exchange relationships, and forms of collaboration between different actors become crucial (Saviotti 1997: 180).

Many definitions of innovation focus on the development of new technical solutions and the creation, diffusion, und commercialization of new product- and process technologies (OECD 1992: 22). However, more recently, and in connection with the intensifying debate on the knowledge economy, scholars have paid "more attention to the knowledge behind or in technologies and the learning behind or in innovation" (Saviotti and Nooteboom 2000: 5). Lundvall's definition of a national innovation system demonstrates this, which, according to the author, "is constituted by elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge ..." (1992b: 2). Knowledge has not only become a core input factor to and a key output factor of innovation systems, it can also be seen as an important individual or collective resource accumulated in many innovation processes that is necessary to transform knowledge into new knowledge.

We can therefore characterize the innovation process as a knowledge-transformation process und the innovation system as a knowledge-transforming system. The basic idea of such a conceptualization is that, within innovation systems, knowledge input is transformed into knowledge output by applying internally accumulated knowledge capital. Different types of knowledge are included, such as abstract scientific knowledge, application-oriented technological knowledge, and action-oriented practical know-how and know-who. All these different types of knowledge are involved in innovation processes, but, depending on the type of innovation –, for example, whether it is an incremental or radical innovation –, one or the other type of knowledge dominates the innovation process, or at least, particular sub-processes.

3 The knowledge-transforming process and knowledge communities

In innovation research, a shift from structural to action parameters has taken place; research focuses less on technical facts, and more on technological action. Following this trend, we can characterize the innovation journey as a multi-focal process, including a multitude of knowledge-activity clusters (van Ven et al. 1999). Corresponding to this view, we can characterize the innovation system as a multi-functional system comprising a number of different knowledge fields. These fields can also be characterized as "problem domains" (Trist 1983), because each cluster of knowledge-transforming activities demands the continuous dealing with and solving of a set of interrelated problems.

In the literature, we can find different typologies of knowledge processes and functions (Rush et al. 2009); here, we differentiate between the following functions, each of them representing a problem domain within the innovation process:

- knowledge imagination and anticipation,
- knowledge creation,
- knowledge acquisition,
- knowledge diffusion,
- knowledge application,
- knowledge domestication or knowledge consumption,
- and knowledge assessment.

The knowledge transformation process is understood as a recursive process in which particular knowledge activities can be both: cause and effect, consequence and prerequisites (Asdonk et al. 1991). The process involves complicated feedback mechanisms and interactive relationships between the various knowledge activities and especially knowledge creation and knowledge application are inextricably intertwined (Edquist 1997: 1).

Knowledge fields represent ongoing patterns of relationships between a number of communities[3] occupied with developing and applying knowledge and know-how to solve emerging problems and to take advantage of new options.[4] Consequently, the term "community" refers to collectives that operate in particular problem domains. We can conclude that communities engaged in innovation activities are searching for better ways of anticipating, accumulating, applying, consuming, and assessing knowledge by striving to generate new knowledge and know-how in order to improve their contribution to the solution of field-related problems.

In the literature, different aspects are cited to characterize communities in innovation processes. For example, some scholars speak about communities of practice (Wenger 1998), others about knowledge communities (Foray 2004), and still others about communities of meaning (Yanow 2003). These are not different concepts; the various terms only highlight specific dimensions of communities. Here, we use the term "knowledge community" to grasp the emergence and expansion of new social forms, which are explicitly devoted to the production and reproduction of knowledge through decentralized and cooperative procedures to deal with an interrelated set of problems (Foray 2004: 37). Different factors can initiate the development of communities within a knowledge field, including vocational education, special expertise, methodological orientation, affiliation to "locations" within an organization, social class, or ideological orientation and world view (v. Looy et al. 201: 330).

Furthermore, the boundaries of communities are rather fuzzy; they do not always develop within a single organization; instead, they often cross boundaries and integrate members of different organizations. Particularly in the case of converging or path-breaking technologies, communities often overstep the boundaries of single organizations. For example, in the field of knowledge creation, we will probably find communities integrating scientists from different universities, private research institutes, and firms belonging to different disciplines and applying different methods. In the field of knowledge application, technologists, engineers, and production workers from different firms may form a community. On the other hand, a single community can be engaged in different knowledge fields. A scientific community, for example, can participate in know-

[3] In the literature sometimes a distinction is made between communities of practice within firms and occupational networks connecting members of different firms (Brown and Duguid 1992). The latter are less tightly linked than communities, but they still share a common knowledge reservoir and search practices, allowing some kind of dissemination of knowledge and know-how among their members. Here we will not use this distinction; instead, for us the occupation represents one factor among others that can initiate the formation of knowledge communities.

[4] In the systems of innovation literature, scholars refer to actors within an innovation system as organized entities such as universities, R&D departments, transfer institutions, or consumer associations (Lundvall 1992, Edquist 1997). But in general, whole organizations are not engaged in particular innovation processes. We therefore prefer to use the concept of communities to speak about actors in innovation systems. However, the concept of communities does not imply a particular number of members; a community can consist of a small and a large number of members and sometimes the boundaries of a community can correspond with the boundaries of formal organizations or parts of them such as departments.

ledge creation, knowledge diffusion, and even knowledge consumption activities, becoming a consultant for consumer organizations.

The various factors that underlie the formation of knowledge communities lead to the development of sets of values, beliefs, meanings, and norms that bind people together. Through a process of interaction, members of a community come to share their knowledge and search methods for using the same or similar language to talk about their ideas, thoughts, and planned actions, and to develop common practices for dealing with problems. Through group processes, these developments are reinforced, promoting internal cohesion as an identity-maker with respect to other communities. We can define a knowledge community as

> "a sustained, cohesive group of people with a common purpose, identity for members, and a common environment using shared knowledge, language, interactions, protocols, beliefs, and other factors not found in job descriptions, project documents or business processes" (Miller 1995, see also v. Looy et al. 2001: 334, Yanow 2003: 237).

The fact that communities develop their own sets of beliefs, practices, routines, and identities creates strong path dependency in various sub-processes of knowledge transformation, defining certain boundaries for knowledge development and indicating directions in which progress is possible and desirable (David 2007, Arthur 1994). Consequently, a community's basis of knowledge and know-how and related technological advantages lay the foundation for succeeding rounds of development (Foray 1997: 65).

Knowledge communities develop in knowledge fields, they cannot be established formally. Furthermore, the community concept represents a specific learning approach. A basic assumption of the community concept is that one cannot separate learning and innovation from practice; instead, learning occurs, and knowledge is created, mainly through conversations and interactions between people involved in the same knowledge-activity cluster (Brown and Duguid 1992, Easterby-Smith and Araujo 1999). Nevertheless, organizational structures and linkages, incentive systems, and skill requirements can support or hinder the development of communities. Furthermore, communities do not have a constant, formally acknowledged number of members; they constantly adapt and change membership. Through fluid membership, knowledge communities can become important sources of innovation (Brown and Duguid 1992).

Different communities confront one another in the identification of problems, the definition of questions, the development of new knowledge and know-how, and the creation of problem solutions in particular situations: "arenas". But arenas have no prior existence; they have to be enacted by members of various communities. The enactment of an arena means that conflict structures and bargaining relationships between communities become institutionalized. Here the development of knowledge and know-how takes place, which is needed to deal with a set of field-related problems. We define an "arena" as a place of continuous confrontation, cooperation, and collaboration between communities engaged in the same knowledge field. In arenas, as Strauss argues, "different subjects are debated, negotiated and the representatives of different worlds or sub-worlds confront one another ..." (1978: 124).

4 Uncertainty and ambiguity as sources of conflict in knowledge-transforming processes

Both uncertainty and ambiguity are present in innovation processes, as well as in individual knowledge arenas (Weick 1995, v. Looy et al.

2001).[5] Uncertainty is an inherent characteristic of innovation processes here, because we are dealing with expectations concerning future developments. The fundamental unknowability of the future implies that actors involved in knowledge activities have to deal with chronic information deficits.

For example, because of a lack of information, we cannot know whether research activities will result in new scientific knowledge that can trigger innovation processes. And even in the case of success, it remains uncertain whether complementary knowledge needed will be available, and can be acquired and integrated without problems. Furthermore, we do not know which technology path may yield fruit, unless plausible alternatives are explored (van de Ven et al. 1999). Generally, we can assume that the information deficit increases with the complexity of the knowledge-transforming process. We can conclude that, because of a lack of information, acting in knowledge arenas becomes a highly uncertain undertaking.

> "Portraying the innovation process as resulting from the involvement of different communities also means that ambiguity or asymmetries of interpretation enter the stage" (v. Looy et al. 2001: 334).

> "Innovation, in fact, rests upon ambiguous, confused, not wholly defined situations" (Strauss 1969: 26).

While uncertainty results from chronic information deficits, ambiguity refers to the existence of multiple and conflicting interpretations of a situation (Weick 1975). Members of different communities in a particular knowledge arena may interpret the same situation differently; they may disagree about how to make sense of confusing information, and what implications a particular observation has on their way of acting. To summarize:

> "Uncertainty relates to finding answers to well defined questions, equivocality or ambiguity implies that one is searching for the adequate questions" (v. Looy et al. 2001: 335).

Referring to these comments, we can characterize knowledge arenas within an innovation system as zones of uncertainty and ambiguity (Crozier and Friedberg 1993, Schienstock 1995, v. Looy et al. 2001).

Challenges arise from uncertainty and ambiguity, as Strauss argues (1969: 26). The situation within knowledge arenas is continuously monitored by members of the communities involved, causing them to reflect critically on themes discussed, questions asked, problems identified, and solutions found, and to question the adequacy of the knowledge and know-how reservoir, as well as the instruments, search methods, and procedures applied. Doubts may arise, whether the current constellation will foster optimal solutions for dealing with problems and whether it will allow taking advantage of emerging opportunities. Because of uncertainty and ambiguity, we can conclude, knowledge, know-how, practices, and procedures within knowledge arenas will be challenged by members of communities involved, and will therefore remain precarious. Members of different communities, developing sets of contradicting priorities, striving for conflicting goals, following different norms, and adhering to different beliefs, may have different views on how to remove the "irritation of doubt" (Laws and Rein 2003) in a knowledge arena, and may come up with different problem solutions.

One may argue that changes in the knowledge reservoir of an arena and in the set of search practices and problem-solving methods applied are caused by temporary events including occurrences determined by chance (David 1985: 332). Yet, we contend that such changes are pri-

[5] Weick and v. Looy et al. use the terms "equivocality" and "ambiguity" interchangeably.

marily the result of a continuous internal struggle and bargaining process between various communities. The concept of arenas makes it possible to analyze conflict and negotiations within particular knowledge fields, as well as the knowledge-transformation process as a whole. Striving for continuous improvement, actors can always challenge the knowledge reservoir that can be found in a particular knowledge arena, as well as the search procedures and problem-solving strategies, with the implication that practices in knowledge arenas remain problematic, and are open for continuous revision and for the integration of new and even contradicting knowledge elements; at the same time, this process is accompanied by the elimination of parts of the existing knowledge stock and search procedures. We can conclude that, within knowledge arenas, a process of continuous reproduction, challenging, and renewal of knowledge and know-how takes place.

Analyzing social relationships within knowledge arenas as sites of the articulation of conflict and differences, and as a place of social and cultural competition, we cannot focus on struggle over the optimal way of dealing with problems and taking advantage of new opportunities only. Conflict cannot be characterized exclusively as a knowledge-creating and problem-solving debate; it is also about the disposal over resources necessary to develop new knowledge for the solving of problems (Bourdieu 1977). Uncertainty and indetermination open up opportunities of reshaping the distribution of tangible and intangible resources among various communities, including for example financial or human resources. By amending their resource portfolio communities can make more significantly contributions to the knowledge transforming process.

Demands for material and immaterial resources can be understood as a concrete expression of interests. While striving for accumulating additional resources communities also aim at realizing specific interests such as increasing their esteem, prestige and status within a knowledge arena or the knowledge transformation process as a whole. This suggests focusing conflict analysis within or between knowledge arenas not only on the aspect of resources distribution, but also on the struggle over specific interests, communities aim at realizing, which are often antagonistic in their character. The interest frame can be seen as an attempt at getting away from haggling over knowledge capabilities and the distribution of scare resources (Fisher and Ury 1981: 42). Most important is that a change in the disposition over resources within a knowledge arena also effects the power relationships between involved communities. Communities are interested in amending their resource endowment, because this enables them to make credible threats and promises, which improves their chance to get their knowledge and know-how accepted as common knowledge capital and to push their envisioned solutions through. We can argue that members of the different communities aim at occupying, dominating, and exploiting knowledge arenas to increase their power and influence in further rounds of struggle and bargaining. This means that knowledge arenas are in a perpetual state of unresolved conflict (Boulding 1997: 103).

In addition, social actors have a specific identity, and they aim at acting in accordance with it. It is often the case that actors who feel their identity to be threatened defend the norms and values on which their identity is based, and forge their own sense of self in opposition to others. This means that we have to take a third type of conflict into account, the conflict over identity-forming norms and values. The issues at stake are the actors' general purposes, their mental models, and

Table 1: Examples of different types of conflict in knowledge arenas

	Type of conflict		
knowledge arena	Resource conflict	Interest conflict	Identity conflict
Knowledge creation arena	State research budget, distribution of public research finance among industries and technologies	Prioritizing of research fields, application orientation of university research, superiority of theoretical approaches	Ethical restrictions of scientific research (steam cell research)
Knowledge acquisition arena	Research expenses of different partners in supplier networks	Exploitation rights to knowledge created in co-operation	Acquisition of knowledge through offering bribes
Knowledge distribution arena	Privatization of services offered exclusively by public KIBS	Violation of patent rights	Passing of highly sensitive knowledge to foreign countries (nuclear technology)
Knowledge application arena	State direct support of product development in single firms	Fixing of environmental standards by industry (self-control)	Animal experiments to test cosmetics or new drugs
Knowledge consumption arena	Price setting for new products (overpricing)	Comprehensive labelling of products, restriction of advertising	Selling of new products with dangerous side effects
Knowledge anticipation/ assessment arena	State support of knowledge anticipation/ assessment activities	Superiority of methods and approaches in the field	role of experts, expert status of consumers

sense-making processes, their self-understanding, and self-definition. Summing up, we can distinguish between three major frames of conflict, which can be characterized as "resource conflict", "interest conflict", and "identity conflict" (Rothman and Fischer 2000: 584).[6] All three types of conflict are present in knowledge arenas. In reality, however, it is hardly possible to distinguish between them; in general, a conflict within a knowledge arena has several dimensions. The following tables gives some examples of different types of conflict in the various arenas of the knowledge transforming process.

5 Boundary-spanning as a key aspect of knowledge governance

Long-term arguing out conflicts within knowledge arenas can become dysfunctional for the performance of an innovation system; but it can also bring about disadvantages for the communities involved, and for their members. This is because communities, by pursuing their goals and interests, depend upon each other's competencies and knowledge capabilities. In particular, in the case of complex innovations merging different scientific and technology fields, single communities are not self-sufficient; instead, the knowledge as well as other tangible and

[6] There are of course other typologies of conflict, as for example those suggested by Dahrendorf (1969) or Coser (1956). Because we understand knowledge as a resource, we have not added an additional type of conflict. The more recently discussed risk conflict can partly be interpreted as identity conflict; but here more conceptual work is needed.

intangible resources needed to develop new solutions, to be able to deal with problems, and to take advantage of new opportunities, are distributed among a number of different communities. In the case of converging technologies, for example, knowledge from communities specialized in fields such as biotechnology, nanotechnology, ICT, and cognitive science is integrated to achieve scientific progress (Roco and Bainbridge 2002a, Phillips 2007).

In the literature, the main problem of developing solutions for sets of problems in a particular knowledge arena is described as enabling communication and information exchange among communities. However, cooperation between communities is "first and foremost contributing to the joint production, rather than 'exchange' …" (Lindenberg 2003: 50). Of course, information and knowledge exchange is important for the coproduction of problem solutions and related knowledge and know-how. But, if information exchange is focused exclusively improving the knowledge capabilities of a single community by broadening its knowledge base moves into the centre. Joint production of problem solutions, however, demands more: the integration and fusion of the knowledge capital and know-how of different communities into one common knowledge reservoir.

This, of course, is a very difficult undertaking. In particular, in the case of converging technologies, the risks of network-inconsistencies and network failures are high, which can hinder or even interrupt innovation processes and thus reinforcing possible breaks and ruptures between the involved communities (Ott and Papilloud 2007). "Boundary-spanning", as v. Looy et al. argue, has been a precondition for many successful knowledge-based innovations (2001). This means that successful knowledge transformation demands the spanning of boundaries within and between knowledge arenas. However, the wide distribution of knowledge, know-how, skills, and competencies among a number of different communities creates barriers for communication and collaboration, and hampers an open and constructive exchange of ideas. At the same time, specialized knowledge capabilities and competencies are used by communities to cut themselves off from interaction and cooperation with other communities, in order to pursue their own goals and interests more efficiently.

On the other hand, the interdependency between communities within knowledge arenas suggests that all parties involved aim at finding a common ground for reconciling incompatible demands and diverging interests, in order to be able to explore ways in which their concerns can be redefined in mutual terms, and integrative solutions can be forged (Rothman and Fischer 2000: 588). On the one hand, the spanning of boundaries across communities within various knowledge arenas is necessary. On the other hand, communities create significant impedance of effect that prevents and imperils boundary-spanning activities. This demonstrates the contradictoriness of this integrative undertaking (v. Looy et al. 2001: 330-331).

For the success of knowledge-transforming processes the spanning of boundaries between communities operating in different knowledge arenas may be even more important than boundary-spanning within an individual knowledge arena. For example, boundary-spanning between communities operating in the knowledge-creation arena and those operating in the knowledge-application arena becomes increasingly important. On the one hand, innovation activities can draw from technological opportunities stemming from scientific advances, while, on the other hand, technology "shapes science in the most powerful way: it plays a major role in determining the research agenda of science" (Rosenberg 1994: 16). In addition, linking knowledge-consumption communities with those operating in the knowledge-application arena has the advantage of securing consumer-oriented technology development. And integrating knowledge-assessment communities with knowledge-consumption communities can foster socially and ecologically beneficial technologies. Of course, spanning boundaries between communities operating in different knowledge arenas makes overcoming differences and contradicting orientations, belief systems, and values even more difficult.

Boundary-spanning can be seen as being at the heart of trans-community technology governance (Aichholzer et al. 2010). Of course, governance is a very vacuous term that is used confusingly to the extreme by scholars from different disciplines. While traditionally research on technological governance focuses on the system level, we apply the concept to the level of intra- and inter-organizational group relationships. Strongly influenced by transaction cost theory, the governance concept is, on this level, usually applied to contractual relations (Lindenberg 2003). The definition by Lynn et al. suggests a more inclusive concept. According to these authors

> "… governance generally refers to the means of achieving direction, control and coordination of wholly or partially autonomous individuals or organizations on behalf of interests to which they jointly contribute" (2000: 234, see also Grant 1996: 362).

This definition counts contractual regulation as just one form of governing. We therefore define governance in innovation systems as including all kinds of structural forms and processes of collaboration in the knowledge-transforming process, and of directing knowledge flows between actors, in order to enable the coproduction of knowledge.

Difficulties in homogenizing the knowledge of various communities result especially from the fact that knowledge is neither true nor false, and is also never complete; instead, the generation of knowledge and know-how to develop new problem solutions is associated with the discovery of areas of the unknown, producing further uncertainty (Stehr 1994). On the basis of the principle of truth it cannot be decided, which knowledge to integrate into a common knowledge pool within an arena. Instead, members of different communities agree on what kind of knowledge and know-how they will fuse into an arena-wide knowledge base. This suggests not to conceptualize knowledge fusion as a zero-sum conflict (Rothman and Friedman 2001: 588), where communities haggle over the value of their own particular knowledge and know-how for the arena as a whole, as well as over scarce resources, such as prestige, influence, and power.

Of course, the fusion of knowledge and know-how owned by different communities cannot be based on a formal contract, in which regulations are specified how to proceed in the generation and reproduction of a common knowledge base which is needed for finding joint problem solutions. Under conditions of uncertainty and ambiguity

> "… the view that coordination sets out the interlinking tasks and governance sees to it that people do what is expected fails when tasks cannot be well specified" (Lindenberg 2003: 50).

Knowledge production does not result from separating tasks in the workflow of knowledge operations and from establishing rules of behaviour (Pawlowsky 2001); instead, the integration of knowledge must take place in joint practices. Common experience makes it possible to identify other communities' models and to react accordingly. Because a common knowledge pool emerges out of collaboration in problem-solving processes, we have to identify those mechanisms that can explain how the knowledge and know-how of single communities becomes homogenized, and develops into the knowledge of the arena as a whole. We need to explain why different communities within a knowledge arena are motivated and prepared to act jointly and show solidarity within knowledge arenas (Lindenberg 2003: 51).

"Definition of the situation" (Thomas and Znaniecki 1927, Thomas 1969), the "image" (Boulding 1997), and "framing" (Goffman 1974) represent cognitive concepts that can be used to explain the readiness and motivation of members of communities to act collectively and to show solidarity within knowledge processes. By using these concepts, attention is drawn to the cognitive dimension of governance. The concepts can become the basis of a micro-approach to innovation drawing attention to communication, interaction, and collaboration between communities (Kesting 2008).

6 Definition of the situation, image, and framing as concepts of a micro-approach to knowledge transformation

Individual as well as collective actions depend, as Thomas (1969) argues, on the definition of the situation. Whether members of a community are prepared to collaborate with members of other communities in a particular knowledge arena depends on their subjective interpretation of elements and relationships that constitute a situation. The cognitive structuring of a situation is highly selective though; actors take only those parts of a situation into account which they interpret as relevant, based on their goals, interests, and normative orientations, while they ignore other factors as irrelevant.

In general, members of different communities are prepared to collaborate only in a crisis situation. If the perception of relevant problems evokes a consciousness of crisis, members of different communities may join together to formulate the relevant problems, identify adequate solutions, and promote them in the wider environment, including the organizations they are part of. However, it is difficult to formulate a homogeneous definition of the situation, which oversteps the boundaries of single communities, particularly when it is complex and highly dynamic. Communities therefore often aim at agreeing on very general definitions, which include a number of sub-definitions, and relate only to a single or a few aspects of the situation. They may also agree on a sequential problem-solving procedure, which means that they will continuously reflect on the situation, and will, depending on progress, revise their definition of the situation from time to time.

The concept of framing assumes that actors involved in a knowledge arena are placed in relation to a frame. Additionally, their way to act is influenced by the framing of a problem. We can define framing

> "as a particular way of representing knowledge, and as the reliance on (and development of) interpretative schemas that bound and order a chaotic situation, facilitate interpretation and provide a guide for doing and acting" (Laws and Rein 2003: 173).

Frames can be interpreted as systems of beliefs that intertwine with identity and social action (ibid.: 174).

In general, a knowledge arena includes a number of different frames that, at least to some extent, oppose one another, and can therefore paralyze a knowledge arena. However, being interested in the preconditions for the preparedness and motivation to collaborate in knowledge production, we have to shift attention from contest among conflicting frames to the integration of different beliefs, world views, and identities within a common frame, to make sense of an uncertain and ambiguous situation, which enables the coordination of actions and the coproduction of problem solutions (ibid.).

Developing a common frame is one way by which different demands within a knowledge arena can be synthesized. As long as each of the communities involved in a knowledge arena orients itself on a different frame, we cannot expect that communities adapt their behaviour, and take concerted actions. This is likely only if the different belief systems fuse, and a collective identity unifying all communities develops. Consequently, the main function of an overarching frame is to serve as a basis for discussion and joint action. The development of a common frame in each of the knowledge arenas, as, for example, a common knowledge-accumulation frame or knowledge-application frame, makes it possible to bring together and integrate the stocks of knowledge and know-how of different communities into one common knowledge reservoir. Then members of various communities can mobilize this common frame "which enables them to perceive and to understand the phenomenon they witness and to organize own action" (Flichy 2007: 81). A common frame implies that members of all communities are motivated to use their intelligent effort adaptively to advance the joint problem-solving and knowledge-creating process (Lindenberg 2003: 50). However, under no circumstances do frames determine procedures, activities, or practices. They rather provide a point of anchorage, a set of constraints which make particular activities possible, but actors can still choose freely how to act within a particular frame (Flichy 2007: 85).

Boulding's interactive theory of innovation is based on the concept of the "image" (1997). All behaviour, according to the author, can be explained not as reaction to stimuli, but to an image. Without the concept of image we cannot explain any kind of behaviour. Here, we will use Samuels' definition of an image.

> "The fundamental role of the image is to define the world. The image is the basic, final, fundamental, controlling element in all perception and thought. It largely governs our definition of reality, substantively and normatively, in part as to what is actual and what is possible." (1997: 311, quoted in Kesting 2008: 15).

It contains preferences, perceptions, as well as value judgements.

An image exists on both the individual and the collective level; we can define the image of a community as its "public image". Due to the fact that a knowledge arena consists of a multitude of communities, it will incorporate several images; in the knowledge arena, there exist in fact as many images as communities. Coproduction of knowledge within a particular arena therefore depends on the mutual modification of the images of all communities involved, and on the development of a common public image. The advantage of an image-based theory of innovation is, according to Kesting (2008: 16), that it allows for collective knowledge development through social learning.

The concepts discussed above emphasize that the development of a common view and the taking of concerted action within a knowledge arena very much depend on the establishment of a collective sense-making process which is needed to mobilize knowledge and know-how and to develop a joint problem solution. This can be achieved if communities give up their critical attitude towards problem solutions developed by others, and accept contributions of other communities to the problem-solving process as valuable, instead of stressing their limitations and risks. In addition, the creation of a climate of trust and collaboration through "attitudinal structuring"[7] makes it easier for communities to commit to the solution-seeking and

[7] The concept of "attitudinal structuring" is used by Walton and McKersie (1965) to describe a sub-process of wage-bargaining processes.

knowledge-creating process and to the outcome arrived at.

Such a commitment can be attained through a change of perspectives. Joint solutions become credible when they are evaluated from the perspective of future promises, rather than present reality.[8] By building up positive expectations concerning the joint problem-solving process and likely outcomes, it is possible to influence members of various communities in such a way that, using their predictions as a lens, they will confirm these predictions (Weick 1995). By applying such a dynamic perspective of collective sense-making, concepts such as definition of the situation, frames, and image can gain explanatory power.

7 Languaging and discursive coordination of knowledge

All concepts we have mentioned above assume that collaboration in problem-solving, knowledge creation, and know-how development is dependent on communicative action, and that new ideas emerge in dialogues and debates. Scholars either stress "the dialogical mode of communication where the exchange of arguments fulfils the creative purpose of combining knowledge to arrive at new ideas and solutions for problems" or they "highlight the more strategic use of speech acts to convince and persuade others of discoveries and initiate and push for change" (Kesting 2008: 32). The collective level of the creation of innovations is attained by a "process of the mutual modification of images, both relational and evaluational, in the course of mutual communication, discussion and discourse" (Boulding 1997: 103). Von Krough et al. argue that the production of collective knowledge is based on speech action; languaging is one of the missing links that connects knowledge bases and enables learning (1995: 95). The locus of collective learning in knowledge arenas lies in the communication among members of different communities. They have to communicate with each other about distinctions in their observations to ascribe meaning to observations, and to develop common knowledge (v. Krough et al. 1994). Communication can be seen as the means of producing and reproducing meaning over time.

Taking up the idea of the centrality of languaging for the development of collectively shared knowledge, we suggest taking "discursive coordination" as a key characteristic of the process of fusing knowledge and know-how and concerting actions (Schienstock 2004). The term makes clear that the integration of different sources of knowledge and know-how cannot be achieved without an intensive discourse about the rationale, meaning, and impact of different knowledge elements. Discursive coordination allows reconciling unorthodox or even oppositional knowledge in a novel formation, and concerting even contradicting actions.

But the aim of discursive coordination is not only to reach an understanding which may then result in the development of a common knowledge base and further collaboration in problem-solving processes. Discourse also involves a "positioning" of the participants. In such discourses, boundaries between the communities are likely to shift, or be traversed (Easterby-Smith and Araujo 1999). Learning can concern the manner of negotiating current relationships, as it can concern changing relationships. Extending the discourse over a longer period of time may result in the development of a "situated discursive identity", which enables members with different backgrounds to compare the per-

[8] This argument is borrowed from Lampel (2001). However, the author is primarily interested in relations between innovators and users, financiers, or other stakeholders, and not in relations between knowledge-developing communities.

spectives and action strategies of all communities involved. Such a discursive identity can become the basis for the fusion of single communities into a new formation spanning various boundaries.

In this respect, concepts such as "integrative power" (Boulding 1990) or "conditional power" (Galbraith 1983) become highly relevant. They describe a language-based power, which is of particular importance in the knowledge-transforming process.

> "Integrative power depends very much on the power of language and communication, especially on the power of persuasion" (Boulding 1990: 221).

> "Integrative power often rests on the ability to create images of the future and to persuade other people that these are valid." (ibid. 122)

The two concepts are closely linked to Habermas' theory of communicative action (1995); we can therefore argue that communities do not only make use of these types of power in a selfish way to achieve individual goals and to realize specific interests, but also to establish a dialogue, to reach an understanding among the participants, and to develop a common identity.

Habermas calls a dialogue "reflexive", if participants learn to understand each other's motives, underlying norms, and opinions (1995). Self-reflexivity can be defined as "the possibility for groups of actors ... to shape the course of economic evolution" (Storper 1997: 28). It means that actors do not blindly pursue the passion that moves them at the moment, or merely execute social routines. Instead, self-reflexivity characterizes the capability of actors to use their imagination, to act on different strategies (Sabel 1997), and to create new action programmes, if the external circumstances requires them to do so. Reflexivity therefore implies more than anticipating new developments, and considering them in the development of new strategies; self-reflexivity includes monitoring of the environment, critically dissociating oneself from the traditional functioning of reality, and developing alternative ways of acting (Sabel 1997).

"Reflexive discourse" means the exchange of rational arguments to deliberate about ends and means, while, at the same time in this process, the one's and the other 's preferences, goals, and interests may be changed, and a new common identity may emerge. Habermas (1995) argues that communicative rationality sets in, so that, inevitably, participants of a discourse reach an understanding. In such a reflexive discourse, participants will learn from each other and change their attitudes towards problems arising in such a way that they can develop a common solution and concert actions.

Habermas' assumption that a certain communicative rationality of speech acts which will lead to the development of creative solutions of conflicts, has often been criticized. We cannot assume that integrative power will always be consensus-oriented or inclusive (Kesting 2008: 20). Members of various communities may realize that their views, beliefs, and interpretations remain isolated, juxtaposed, non-communicating, and even conflicting. Coming to nothing has, of course, serious consequences for the knowledge-transforming process; it may lead to the breakdown of a knowledge arena and of the established patterns of arguing, negotiating and collaboration. Furthermore, language and persuasive power can also be used to manipulate others (Boulding 1990: 119), and to push solutions through, which are beneficial only to a few powerful people. Consequently, a new path developed within the knowledge transformation process will not necessarily lead to optimal solutions.

We also have to take into account that, in general, not all members of the communities involved will participate in the process of knowledge-and know-how fusion, and in concerting actions. In this process, participants are differently legitimated to act in the name of their fellows, and they may have a different standing in their community. But they all face the problem of intra-community bargaining; without the approval of the members of the communities involved, it will not be possible to create a common knowledge pool and to agree on search processes and procedures of problem-solving. This includes the preparedness of community members to undertake adaptation processes in the creation and use of knowledge, in order to stabilize inter-community relationships within a knowledge field. But it is by no means sure, whether such an approval will result from intra-community bargaining.

In the literature, trust is often mentioned as a decisive precondition for the coproduction of knowledge and for collaboration in problem-solving processes. Cumulative learning processes, to be effective, have to be embedded in social capital – the ability to work with and trust others (Lundvall 2002: 43).

> "Trust is a tacit agreement in which rather than systematically seeking out the best opportunities at every instant each agent takes a longer perspective to the transactions; as long as his traditional partner does not go beyond some mutually accepted norm." (Zuscovitch 1998 quoted in Cohendet and Joly 2001: 77)

The success of communities in building trust among each other can be explained by a high frequency and intensity of interaction leading to a strong communication culture (Cohendet and Diani 2006).

Interdependency is a key precondition for the development of trust; it prepares the ground for the development of trust between members of different communities. Of course, trusting somebody is a risky undertaking, because trust involves the willingness to entrust oneself to another person and to become vulnerable to his/her action (Sabel 1997: 162). However, continuous cooperation between various communities within a knowledge arena can transform the exchange of information and mutual adaptation into a social norm. Through reliance on a "norm of reciprocity" (Gouldner 1960), practices can be developed that create expectations which turn exchange into some kind of "collective logic". Apart from economic self-interest, strong expectations of trust and abstention from opportunism develop. Social capital contributes to the compliance of all partners to the reciprocity norm. However, the reciprocity norm is very ambivalent, as it entails the problem of balancing the obligation of exchange with the self-interest of the actors. Furthermore, some scholars have argued that trust can also have major disadvantages as it may lead to an early closure of innovation processes, which can result in ignoring promising opportunities (Oppen 2009).

8 Converging institutions: Mediating roles, creative spaces, and boundary objects

Boundary spanning activities and discursive coordination are important means to enable complex innovations. But, to open up more long-term innovation perspectives, these activities have to become institutionally embedded. Ott and Papilloud (2007) use the term „converging institutions" to point to the need of overcoming the multiple risks of networking inconsistencies and network failures in innovation processes. According to the authors, converging institutions are not only responsible for the development and application of knowledge, just as any other actor involved in innovation processes, but they also have to take up a bridging function. They have to develop into a translation instance, which enables exchange and collaboration between various actors involved in complex innovation processes. This includes relationships between communities of different technological strands as well as relationships between actors involved in different functional arenas of the knowledge transforming process.

Converging institutions not only act as stimulators of new linkages and networks, they also have to take an active role in the process of conflict resolution between communities involved in the knowledge transforming process, because these often have difficulties in integrating their diverging definitions of the situation and to develop a common frame. In doing so they can legitimize the process of homogenization and concertation and they can organize this process in a peaceful way. In the literature different forms of institutionalizing the conflict resolution process have been mentioned: the introduction of the role of the „gatekeeper",[9] providing a „creative space" and the establishment of a „boundary object". The process of institutionalization includes both forms: the evolvement out of continuous interaction between communities over time as well as the formal set up from outside. Of course, these concepts are closely linked, and they will have maximum effects, when applied jointly.

The establishment of a boundary-spanning role is often mentioned as a possible measure for dealing with conflicts within or between knowledge arenas, because it facilitates information flows (v. Looy et al. 2001). Particularly the importance of the role of the gatekeeper (Pettigrew 1973) or information broker (Burt 2004) in the innovation process has been stressed by many scholars. Tushman and Katz (1980), for example, argue that gatekeepers are able to reduce cognitive distance and mitigate the confrontation of paradigms, world views, and value systems at the intersection between scientific communities and the more practically-oriented engineering communities that prevails in the firms' daily business. But the role of the gatekeeper can also be placed at the intersection between other knowledge arenas; the holders of the role can, for example, mediate between knowledge applicants and knowledge consumers or between knowledge applicants and knowledge assessing communities. And information brokers can be placed at the boundaries between different communities within a particular knowledge arena as is the case, when different scientific communities participate in the creation of converging scientific knowledge.

Gatekeepers can be characterized as translators.

> "They must be fluent in more than one 'language', at home in more than one world, adept at playing by more than one set of 'rules'. " (Flichy 2007: 47 quoting Aitken 1976)

These translators end up in creating a new language that will be used by a multitude of communities within one or several knowledge arenas. According to Burt, the role of the broker is critical to learning and creativity because brokers translate a belief or practice to draw analogies and to synthesize, because they see new beliefs or behaviors (2004: 354).

The Nordic Innovation Centre recommends the creation of an information point for converging technologies, where the business advisors have knowledge about converging technology activities within the main regional sectors. This may serve as a key element of a regional policy. The Functional Food Science Center in Skone is given as an example in the food sector (Larson, Ahlquist and Frioriksson 2007: 36).

Here we will present the German Steinbeis Stiftung as an example for an institutional solution of the role of a gatekeeper or an information bro-

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[9] The role of the gatekeeper is often associated with particular individuals; here we associate the role with collective actors.

ker.[10] The foundation is placed at the boundaries between knowledge-creating and knowledge-applying communities and functions as translator between them. Its main task is helping to overcome the different beliefs, goals, orientations, methods and practices of communities to enable an effective and efficient co-operation between the two areas, while applying the rules of the market. The foundation has access to a network of experts from different, primarily technological fields, who can accompany problem solving processes from research and development to consulting and further training of the employees. These experts are placed at the disposal for firms in case they ask for support. The leaders of the centres, themselves mostly members of academic institutions, running them as transfer, consulting or research institutions, have great autonomy, but they have to act within centrally fixed general conditions.

An important boundary-spanning strategy is the establishment of "creative spaces" "discursive platforms" or temporal "zones of proximal development", which enable the interaction and communication between various communities, support the exchange of ideas and allow for collective problem-solving (Lowndes 2005, Vygotsky 1986). Such creative spaces can become spaces for common experimentation and learning. Their advantage is that different kinds of knowledge and a multitude of perspectives and experiences, from the different professional, social, and cultural backgrounds of the communities involved can be drawn together.

Creative spaces can fulfill their integrative function only, if each community involved accepts that no view is authoritative or true, and if none of them has a claim to a privileged position. In a creative space, trust relationships can develop, which make it more likely that members move from entrenched positions, and make concessions to concert actions. However, at the outset, such spaces are only weakly structured. Rules, methods, and functions must first be negotiated and newly agreed upon, which, at the same time, opens up a chance for improvisation and for challenging traditional models (Oppen 2009).

The establishment of discursive platforms or creative spaces within the knowledge transforming process is often seen as a core element of national and regional policy programmes in the area of converging technologies (Larson, Ahlquist and Fridriksson 2007). These platforms can be placed at boundaries of different knowledge communities within and between knowledge arenas, but they can also cover the whole knowledge transformation process.

> "… a regional converging technology platform could act as an umbrella-type of common denominator for regional exercises and create linkages between local research projects on the topic" (ibid. 35).

Furthermore, such regional platforms can initiate and enable a broad societal discourse about the benefits and risks of converging technologies, in which organized societal groups as well as the general public should take part. It could give some kind of guidance in the process of forming an opinion and accumulating knowledge and know-how. The platform could be looked after by a mediating organization, but "it should be supported by regional authorities or other public funding so that it is implemented in a sustainable manner …" (ibid 33). In addition, such a platform should closely be connected with regional foresight activities, which aim at identifying perspectives of developing converging technologies based on regional strongholds. Those foresight activities, which should identify both opportunities

[10] The focus of the Steinbeis Stiftung is not particularly on converging technologies, but the area of this technologies can be part of the foundation's activities.

and risks of converging technologies, could become an important input to the societal discourse (ibid. 31).

Other scholars have introduced the notion of boundary object to make communities cooperate and collaborate in and between knowledge arenas. According to Star and Griesemer cooperation between communities can only take place if they agree on a common boundary object.

These "are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity" (1989: 393).

The main problem is that the establishment of a boundary object should support the development of a single communities overarching identity without destroying their cohesion, which would also endanger the overall approach. The intention of establishing a boundary objects is to support communication and cooperation between communities without merging their practices. In the literature installing information artefacts such as an information system is primarily discussed in this context.

The Communicator, a "mobile systems designed to enhance group communication and overcome barriers that currently prevent people from cooperating effectively" is discussed as a collective vision of a powerful boundary object (Roco and Bainbridge 2002b: 276).

"At the heart of The Communicator will be nano/info technologies that let individuals carry with them information about themselves and their work that can be easily shared in group situations. Thus, each individual participant will have the option to add information to the common pool of knowledge, across all domains of human experience - from practical facts about a joint task, to personal feelings about the issues faced by the group, to the goal that motivate the individual's participation." (ibid. 276)

The Communicator, having the ability to tailor its personal appearance, presentation style and activities to group and individual needs, will facilitate communication between various communities.

Boundary object should enable and support communication and cooperation between different communities. However, making a technical artifact available, does not guarantee that this aim will be achieved; instead technical coordination must be accompanied by social integration. We therefore suggest the establishment of a common frame as a completion to the instalment of a boundary object. Such an overarching frame, as we have discussed above, does not just represent a compromise, but it emerges out of continuous interaction. It enables communities to set the problems, they are dealing with, in a wider context and to develop a more comprehensive understanding of them. It can provide a useful lingua franca between members of various communities and can lead to the re-evaluation and renegotiation of the knowledge, beliefs and practices of various communities. It can even result in a synthesis around a new boundary-spanning community. Within such a community, it becomes possible to find a common ground for reconciling incompatible demands and diverging interests, and to forge integrative solutions from fundamental conflicts of interests.

Here regional initiatives in different countries, which use the concept of "learning region" as boundary object, can be presented as an example.[11] Such a frame is particularly suited to be applied to the converging technology area. The concept of a learning region is a public frame of all communities involved in knowledge transformation. The aim of this concept is to initiate a process of building a collective learning capacity in a bottom up and interactive fashion. In most cases such a boundary concept is initiated by a group of interested

[11] The article by Lagendijk und Conford (2000) mentions a number of regions that use the notion of learning region as a common frame.

people who often belong to different institutions within the knowledge transformation processes that are mostly positioned in fields of technology with a high learning and innovation potential. Organizing meetings, and conferences the initiating group aims at establishing the concept of learning region as a vision of regional development.

When an initiative has reached a critical mass, more calculated measures can be taken. But again, a bottom up approach is favourable; because of intensive communication and information exchange some members of thematically connected communities may develop pilot activities, which are expected to develop in more long-term projects. Financial support from the regional state is decisive for these pilot projects , at least for start-up activities. The integrative power of the boundary concept of learning region very much depends on whether these pilot projects lead to the formation of innovation networks attracting communities from different functional arenas and technological areas and whether these networks develop into more long-term forms of co-operation and collaboration within the regional knowledge transformation process.

9 Conclusion: A community-based micro-foundation of innovation

Knowledge moves into the centre of the analysis of innovation processes. Innovation systems thus can be characterized as knowledge-transforming systems. In connection with this, a newly developed micro-approach to innovation focuses on the reduction of uncertainty and on dealing with ambiguity within knowledge arenas, which involve a multitude of communities. Uncertainty and ambiguity can give rise to a constant struggle over the optimal way of dealing with problems and taking advantage of new opportunities, in order to realize own goals, norms, and values. However, uncertainty and indetermination also open up opportunities for reshaping the distribution of influence and power, as well as of tangible and intangible resources among various communities.

Together with the growing importance of radical path-breaking innovations, the knowledge-transformation process demands the integration of different kinds of knowledge. This points to the mutual dependency of knowledge communities. Boundary-spanning therefore becomes a key dimension of innovation governance. In the case of knowledge transformation, the traditional governance forms of contractual regulation and bureaucratic steering become inadequate; instead, cognitive aspects of governance come into the foreground, and languaging and discursive coordination become key elements of knowledge governance. In particular, concepts such as definition of the situation, framing, and image represent key dimensions of cognitive governance. The role of the gatekeeper, creative spaces, and boundary objects can be seen as efficient institutional forms of cognitive governance.

To conclude, dealing with uncertainty, discontinuity, and ambiguity and related conflicts within knowledge-transforming processes will become one of the core themes in innovation research. Additionally, research will have to focus on efficient forms of knowledge governance, including cognitive aspects. So far, this is a very much under-researched area, but because of a growing importance of technological convergence and new paths to creating technologies, this gap needs to be closed. In future, innovation research must include a richer and more focused view on various forms of conflict within the knowledge transforming process as well as cognitive and collective aspects of technology governance.

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Expectations and visions in industrial practice

On the case of modern biopharmaceutics

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Abstract

Expectations and visions play an essential role in building strategic intelligence. They give orientation in the dynamics of sciences, technologies, and industries. Investigation of these frames of mind is rapidly expanding, with many important results. Pharmaceutics has always been an innovative industry. Biotechnology is identified as having an immense potential for an industrial revolution that also revolutionizes pharmaceutics. Concerning R&D, the essential problem of the recently converging pharmaceutics and biotechnology is the innovation of innovation. This means that the search for innovation itself is awaiting a Schumpeterian creative destruction. History of modern biotechnology is a steady stream of spectacular visions of repeated revolutions. But the realised profound progress in R&D in the process of convergence have not diminished the strong tension of the increased challenges and the permanent productivity crisis of pharmaceutics which has become chronic in the past twenty years.

This article first reconstructs the dynamics of pharmaceutics, with its central focus on ongoing blockbuster production, in which repeatedly radical expectations and visions are necessarily constructed, and have a key function. Among the players in the arena, advisory firms are of particular importance in providing strategic expectations and visions. This article investigates examples of advice that are based on forecasts of alleged revolutions in biopharmaceutics. In the dynamic tension of three components – first, the steady, extremely upgraded requirements the industry is constantly confronted with; second, its real continuing underperformance in meeting them; and third, the repeatedly emerging revolutionary potentials, first of all in molecular-biological research – an extremely stretched dynamics is identified, in which the visions and announcements of on duty "revolutions" in biopharmaceutics move from one self-suggestion to another.

1 Introduction

Expectation and vision-construction is integrative to any human activity. They are essential formative constituents in the various industrial practices, too.[1] We need visions, both strategic and operative, to assess how promissory technologies can realise their potentials and avoid adverse effects.

A strong research trend has been developing in the past twenty years, especially in the last decade providing a socio-cognitive interpretation for this activity (van Lente 1993, Brown and Michael 2003, Berkhout 2006, Borup et al. 2006, Kraft and Rothman 2008, Konrad 2010, Rip 2011, Bakker 2011 to name but a few authors and publications). Concerning the mechanisms of expectation dynamics, there have already been

- numerous results of reconstruction and analysis of the hype-cycle, the circulation of expectations in expectation-arenas or
- concrete analyses how guiding visions work in transition management.

The sociological approach to exploring the structural roles of expectations and visions in the abovementioned dynamics is an essential contribution. However, sometimes this is done in a sociologizing-reductionist way. Accordingly, only the sociological factors are considered when the acceptance/ rejection of an expectation/ vision is at stake. But, the dynamics of vision-making necessarily has to involve epistemological considerations. Expectations are to be made credible as reasoned narratives for scientists, entrepreneurs, governmental players. Vision-making is a socio-cognitive act, and so it is necessarily also an object of epistemological, better to say, of a socio-epistemological critique.
This article is an attempt at clarifying some sorts of expectations that have been constituent in modern biopharmaceutics in its already some decades-long history.[2] These expectations are formulated by advisory firms as visions of consecutive revolutions. The revolution-metaphor is already quasi-natural in narratives on biopharmaceutics, but is only partially correct. Obviously, there is a set of issues on the supply side which provides for a basis for narratives of revolutions, and there is a constant need for promising revolutionary solutions for problems on the demand side, namely industry. One central question is: why and how do biopharmaceutics' dynamics constantly enable and simultaneously demand devising visions of revolutions?

The article first attempts to reconstruct, at least partly, the dynamics of pharmaceutics and biotechnology (biopharmaceutics) that have been urging the conceptualisation of the future in terms of coming revolutions. Second, it turns to a specific type of players in the pharmaceutical and biotechnological arena. These are business consultancy firms such as PriceWaterhouseCoopers (PwC). As for examples, the article investigates forecasts PwC and another advisory firm, BCG, made. Third, it reflects on the narrative of science-based business (Gary Pisano's reconstruction of biotechnology) and its yield for normative requests on studying the future of biotechnology.

[1] Adam Hedgecoe and Paul Martin write in 2003: "Understanding the formation, mobilization and shape of these expectations or 'visions' is […] central to the analysis of an emerging biotechnology." (328).

[2] Most authors "abbreviate", and use the term biotechnology for red biotechnology, the utilisation of biotechnology in medicine. I prefer to use the term biopharmaceutics here, and use it only narrowly, because I do not treat medical instrument and diagnostics development. But I sometimes use the term biotechnology or biotech as equivalents.

2 On Vision-making and the Dynamics of the Biopharmaceutics Industry

Historical development of modern biopharmaceutics, starting with exploiting recombination DNA techniques and later including the utilisation of genomics for biopharmaceutics, realised numerous breakthroughs in many different respects. For a short while, successful biopharmaceutical entrepreneurs got the opportunity to gain wealth overnight (a hope that is already history, but reappears as a dream). These are important ingredients of impression-building.

Talking of revolutions, in biotechnology as a whole, or of methodological or organizational revolutions, mostly designates rapid qualitative changes, breaks with profound transformative capacities in their environment. Talking of revolutions can be made differently. The revolutionary narratives in biopharmaceutics refer to basic challenges, or to enormously growing menaces, heading for a crash, or basic changes of direction in research or doing business, or to the possibility of immense growth in performative capacity, or to the army of hindrances to overcome and the violence, which is an inevitable part of their realisation. To speak about a short time interval in which the transformation is to or has to occur is an ingredient of all of the revolutionary narratives; they speak about upheavals. It is important to see that all the revolutionary narratives I am dealing with here, are forecasting efforts.

Four stylized facts form the background for reconstructing the dynamics of expectations:

- ongoing repeated leaps in the development of most different constituents of the dynamics, a series of micro-revolutions,
- biopharmaceutics' evolutionary path,
- the continuing "productivity crisis" in pharmaceutics
- and the only half-successful organizational and business structures in biopharmaceuticals' dynamics.

The ongoing tension between repeated, even accelerating breakthroughs, bigger and bigger on the supply side, science, and the steadily deepening tension with the productivity crisis make the very basic problem to explain. In connection to this, history of biopharmaceutics is a story in which reality repeatedly lagged behind the often-extreme expectations expressed by different agents in the arena, but these expectations were an integral part of the real developments.

The dynamics of biopharmaceutics has both steadily enabled and urged strategic vision-making[3] both on the supply and on the demand side, aiming at catching sight of decisive breakthroughs.[4] In comparison with other branches of industry, beside ICT, biopharmaceutics provides an extremely fertile soil for radical vision-making. Immense potentials emerge from time to time and immense constraints repeatedly de-

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[3] I think it is important to free the term "strategic vision" from its "obligatory" connotation of "long-term". That worked well for dynamics in which long-stable processes were changed by consecutive long-stable processes. But in dynamics in constant flux, as is the case with biopharmaceuticals, "strategic" means the ability to accommodate sustainably to the series of "capricious" processes, contribute to direction changes or other nonlinearities in the environment by repeated modulating actions (Rip 2011) as quickly as possible, and keep the new direction exactly until it seems sustainable. Kraft and Rothman (2008) aptly point to Celera's repeated rapid strategic accommodations, the private genomics firm that successfully challenged the governmental human genome programme (HGP) earlier, by twice changing its profile in five years. repeatedly answering to the changing credibility of different strategic visions.

[4] Using the terms supply and demand is a simplification of the processes in an increasingly complicated networked dynamic of them.

mand exploring expected "revolutionary" potentials, taking part in producing and realizing them in an increasingly networked dynamics. These visions refer to most different content, space and time variables, and extend from overarching visions related to the industrial sector as a whole to visions of the role of new methods in development or of concrete, successful drug candidates.

Making visions workable for action presupposes road-mapping and has to find signals of progress. First successes can serve as signals for the expected bright future. Concerning their role, recognitions of signals may, for a while, provide some pseudo-certainty on how to continue or change the activity.[5] Unavoidable speculations on possible futures made by experts regularly work for science or technology management and policies, as "scientifically established rational prognoses", having the (partly alleged) authority of expertise. Advisory firms also acquired this form and level of authority.

Visions enter a "market of expectations" and acquire some perceived value pricing in negotiations over their realisability. They can assist in the acquisition of funding, or of any other resources needed. They participate in the complex processes often leading to bubbles. They can express self-confidence as at the inception of modern biotechnology, or just the opposite, be an attempt at bridging a lack of self-confidence, in extreme cases, desperation, by insisting on the existence of and pointing to the alleged certain way to the Promised Land. Sometimes, the sustained belief in the coming revolution of biopharmaceutics as a whole, the durable solution of the productivity crisis makes constrained shifts from one target to another in time, and brings about continuity in some respect: the repeated renewal of revolutionary visions pit some backbone into the activity, by preserving the faith, after consecutive failures, that looking for revolutionary solutions is the correct method to follow. Prognoses in biotechnology consecutively turn from one element of practice to another and insist on making visions that partial breakthroughs and their synergies are on the way to unify into some overarching revolution.

The serendipity factor, due to the enormous complexity of the target and in relation to it the missing knowledge, so typical for the pharmaceutical industry earlier, continues to affect its dynamics essentially in modern biopharmaceutics, but on a different level and smaller magnitude.[6]

Modern medical biotechnology reached a new level by deepening the understanding of diseases and effects of drugs on molecular level. Nevertheless, the still dominant, ontologically reductionist, genetic causal approach, by short cutting the process of catching the complexity, distorts the rationalization of the progress in drug production. It seems there is still a dominant tendency among genomics researchers to underestimate the high complexity of the tasks of understanding diseases, on three levels, the genomic, the body level and the level of the natural and social environment and their interactions. This joins the missing readiness to assess the difficulties with "unknown knowns" too. Bypassing considerations of possible "unknown unknowns" is sometimes associated with the lack of considerations of "unknown knowns",[7] as if

[5] While some of them may prove to be real signs, if only post festum, so to say, the situations in biopharmaceutics often proved to be pseudo-signs, just as lines of Sargasso did for Columbus' sailors.

[6] The earlier belt-and-braces strategy, dominant in the research based on organic chemistry, changed in research in biotech to making a smaller number of key trials.

[7] Something we know but suppress, or commit to forgetfulness is an "unknown known".

taking them into account could really be avoided.[8]

When the dynamics involve high-risk/high-benefit possibilities, actually a very high level of incalculable uncertainty, as is the case with many issues in biopharmaceutics, and some main risk problems may turn out to be solved, by breakthroughs as predictable successes of enormous and long efforts or sometimes unexpectedly, this may trigger strong hypes on sudden further breakthroughs as a result. Those agents, who believe to have been awoken in time, may hope to exploit the new situation disproportionately high. Extremely high risking may become desirable then. If multiple agents exist, their simultaneous action may result in a strong amplifying effect. But the players in the biotechnology arena seem to learn a bit as it was with the quick bursting of the genomic bubble in 2001 or is with the enduring weakening readiness to believe in sudden breakthroughs in the recent phase of history biopharmaceutics.

Signals, for selected receivers, may seem to multiply for quite a long time by progress in some expected direction. For example, the successes with one-gene-one-disease generalizations did their work, as over-generalizations for a while. And, for a while, readiness to over-generalization, encouraged by reductionist thinking, helps to sustain the idea of revolution, of the great breakthrough-in-the-making, but by referring to more resources and time needed to realise the imagined.

3 Revolving around blockbuster production

A short outline of the history of modern pharmaceutics, including its gradual convergence with modern biopharmaceutics, will promote understanding of the mechanisms in which the steadily renewing radical expectations are active constituents. These expectations are results of the interplay of urgent needs for radical improvements on the demand side and certain enabling breakthroughs on the supply side.

Pharmaceutics became an icon of innovative industry in the second half of the 20th century. First, it mostly concentrated on exploring and exploiting the organic chemical paradigm. Notwithstanding the constant and growing utilization of chemical and other scientific knowledge, this paradigm remained rather an empirical trial-and-error mode of research. It was backed by some theoretical knowledge, but finding drug candidates depended strongly on serendipity. Pharmaceutical research was not only a very uncertain undertaking, but also steadily required enormous investments along the whole value chain, the return on which took a rather long time in comparison with most other branches of industry. (The value "chain" takes 10–15 years from a research idea to drug approval.) The numerous repeated successes that made sustained growth possible needed the steady growth of financing, and the constant, even growing demand, the somehow sustained readiness of payors to pay more for new drugs made pharmaceutics one of the most

[8] I give an example of a preliminary bypassing of some "unknown-knowns" from the research problems of the so-called hydrogen economy. Envisioning the success of the hydrogen driven car is made by bypassing the problem that three ways are to try to solve the problem of storage of hydrogen in cars and all of them seems inappropriate to find an efficient solution. But the failure would be disastrous for the whole hydrogen car economy. The so-called "roadmap" of the hydrogen economy entails numerous problems of similar type. By bypassing the knowledge gap concerning "unknown knowns", the vision could acquire a preliminary rational status, because the "unknown-known" is swept under the carpet, as if we could be certain to be able to find a solution, even more, to find it when it is needed. Sometimes in history of technology a solution to such sorts of problem was suddenly fund unexpectedly.

profitable branches of industry during the second half of the 20th century.

The main reasons for its basic dependence on accidental factors, on serendipity in empirical research include the immense lack of knowledge concerning possible druggable targets (until quite recently), and of the mechanism of the drugs' (drug candidates') effects on the human organism, especially concerning adverse effects. But producing pharmaceuticals grew into a huge, sustainable growing industry essentially depending on R&D in the second half of the 20th century. Basic characteristics of its value chain are still the same: it is a sequentialized linear manner of promoting valuation and realization – now with ever stronger feedback from marketing or from the drug approval process, and so realising a half-linear development chain as a basic type of innovation of innovation.

Typical for pharmaceuticals are the very high costs, the very long term of return on revenue, the very short duration of patent protection on drugs already on the market, just some years, and the very high risks, including the highly incalculable uncertainty, of its R&D, the clinical trials, and the licensing process. It is quite natural that it has always been a central issue for Big Pharma (the largest pharmaceutical firms) to improve the prognostic ability, reduce costs, shorten the period needed for value realization, and, of course, trying to let prolong patent protection – the latter to weaken the serious menace of generics after patent expiration. One of the pharmaceutical industry's main recent activities is permanently to try to improve radically all segments of R&D and to change the linear value chain, even to transforming it profoundly through parallelisation and by realising feedbacks between the segments.

It is to stress that pharma's R&D has always been extremely risky and became even riskier with flight of time. On the other hand, there is the extraordinarily high profit, provided a firm could durably bring a blockbuster drug onto the market.[9] Notwithstanding the interaction of all those unfavourable factors mentioned above, modern pharmaceutics have been able to produce double-digit rates of revenue sustainably.

Blockbuster production made industry concentrate on drugs good enough for as many patients as possible. These drugs are typically on a mediocre level, concerning their effectivity and efficiency. To utilise the advantages of economies of scale and scope, pharmaceutical production aimed at realizing a steadily-expanding mass production in the second half of 20th century, which was combined with very aggressive marketing.[10]

The very high costs with all the uncertainties, and the long span of the time from research to bringing the product onto the market, with the menace of competitively-priced generics entering the market immediately after a patent has expired, prompted the firms to pursue a particular type of vertical integration and

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[9] A blockbuster drug is a drug generating more than $1 billion of revenue for its manufacturer each year. A mega-blockbuster generates more than $5 billion each year. They bring the "big benefit". On the other hand, any failure in the late phase of the value chain may lead to real shakes. Pfizer lost 25% of its stock value overnight when it had to withdraw Torcetrapib, a drug developed to treat elevated cholesterol levels, in early December 2006.

[10] The "one size fits all" principle is extremely problematic in mass production of drugs, first of all, because of their possible adverse effects. Probability of possible adverse effects rapidly grows with the quantity of drugs produced, with the number of patients using them. But the production of blockbusters aims at as extensive mass production as possible. Producing pharmaceutical blockbusters is a type of mass production in which extremely high quality standard requirements are set concerning exclusion of possible adverse effects.

a particular behaviour in competition – actually, pure rivalry for a long time. Large firms implemented vertical integration, including the R&D department, but more and more complemented it by some stable horizontal co-operation, realizing a growth in division of labour by outsourcing.

Quite different is the emerging new type of collaboration in joint development of the knowledge base in recent pharmaceutics, where sharing knowledge is intended. While vertically integrated large firms were in pure rivalry for a long time, a collaboration of "new best friends" has emerged by now, along the whole value chain, not only precompetitive collaboration, to be able to stand in the further strengthening globalizing competition.[11] This has much to do with acquired learning about the nature of biotechnology, in terms of renewing the business model.

The search for blockbusters is a self-inducing, under-performing, and highly uncertain dynamics. To sustain blockbuster production under quickly impeding conditions needs a permanent striving after renewal of the big firms. This adds to the explanation of the wave of mergers and acquisitions (M&As) around the turn of the century, The extraordinary strong striving after repeated renewals in very short time applies to R&D, too. While pharmaceutics was an icon of R&D-based industry already in the beginning of the second half of the 20th century, it is by now an example of an industry in constant need of the innovation of innovation too, of permanent efforts to radically renew innovation of innovation itself. The strong interaction of the abovementioned factors led to a race that constrained and enabled a special virtuous circularity as a gradually entrenched trend. It led to intensifying path dependence and a lock-in for the industrial sector as a whole. Long before a new level had been reached, this cemented dynamics demands searching for a further radical window of opportunity for sustaining, even possibly increasing the high revenue.

A rather inflexible arena was set by the permanently tense interaction of firms, the government, and regulatory agencies, etc., partly based on sustaining diametrically different attitudes. The "rules of the game" that had been constructed by the interaction of the players provided for a rather inflexible structure. The constraint to find new blockbusters in time provided for enormously growing risks for the companies. They had to try to win or had to risk disappearing from the arena in the permanently intensifying rivalry. But constructing blockbusters can only be attempted with a few candidates in the later phases of R&D, mostly because of the enormous costs and the massive uncertainty in the clinical and approval phase. There is a steady menace of loosing the whole competition in the last step, by refusal of approval, not to speak of the compelled withdrawal of an already licensed drug. [12]

This dynamics favours large concerns. As a self-inducing mechanism, searching for blockbusters requires, for the potential of a continual renewal in terms of new breakthroughs, that potential breakthroughs are already developed while the earlier blockbuster is still profitable. This process constantly presupposes having new candidates "in the pipeline" in the right time when the predecessor's patent expires. This

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[11] PwC's "Biotech reinvented" report names in 2010 some "new best friends" in pharmaceutics as ideals. (PwC 2010: 11)

[12] If you live by the blockbuster, there will be a disaster when the blockbuster fails to materialize. But developments from 2007 on show that Big Pharma is still rather locked in, and can not simply leave the path it has been following so long, even if it would be more forcefully compelled to do so as it is now.

became the first basic requirement for R&D in the growth of Big Pharma.

The pipelines started to "dry out" from the early 1990s at the latest. This happened even though, in the meantime, investments in R&D had been enormously grown. This unsuccessful attempt at solving the pipeline problem by financing the steeply-rising costs of R&D, that were felt rather unbearable by the millennium, amplified the basic problem, and sent a strong signal that, instead of simply further raising the financing, radically new means of solving it had to be found. A permanent "productivity crisis" arose in the entire branch, including drug research in medical biotechnology, because even here "the low hanging fruits had already been picked" by the end of the 20th century.

These characteristics are of fundamental importance for understanding the dynamics of the permanent need for devising radical expectations and visions on the supply side, to satisfy the radical demands. Any possible or real scientific or organizational breakthrough, such as overarching informatization, was then interrogated for its potential of causing breakthrough by solving the radical needs on the demand side of the industry. The need for innovation of innovation was widespread by the turn of the century in the meaning of profoundly transforming the way in which pharmaceutics moved and a profound turn to biotech offering arising genomics was an overarching vision.

Many industrial researchers and leaders uninterruptedly tried to catch the glimpse of the "light" from new real or expected scientific or organizational breakthroughs. One, most important enduring aspiration aimed at radically renewing the innovation chain, another, interdependently with the former, the genomization of drug research.

I jump for a second to the results. Soaring visions of promises and, especially concerning informatization and genomization, many partial breakthroughs have been realised in the last 15 years. But, concerning the problem of the solution of the productivity crisis, there has been no increase in the number of new blockbusters made yearly in the last 15 years.

The other enduring basic challenge, deriving from the reached level of the competition in pharmaceutics, can only be paradoxically solved: when one new level was reached it demanded further efforts repeatedly, in an earlier unknown measure. This characteristic irregularly periodizes the process of the growth of pharmaceutics into successive qualitative transformations, possibly requiring revolutionary breakthroughs, with every possible effort to shorten periods of equilibrium.

Big Pharma can still be defined as a group of firms which survive because they are sustainably able to successfully meet the challenge of a constant search for new blockbusters. While the costs of finding new drugs had always been rising earlier in the century, the costs of looking for blockbusters began to rise exponentially in the last decade of the 20th century. On the other hand, more and more Big Pharma firms developed connections with the new biotechnology firms. These concentrated on niche development first. Big Pharma interacted with biotech firms through different forms of cooperation in history, but especially by taking over biotech start-ups. It became increasingly clear that pharmaceutical biotechnology had to take over the task of providing new blockbuster candidates.

There seems to be a basic contradiction within Big Pharma's dynamics. From the early 60s on, it attained a decisive comparative advantage over the small firms in the drug approval regulations. This enduring advantage made them rather inflexible in many respects, but they had to adapt to the dynamics constantly in flux that they themselves partly produced.

It seems, the main present solution is still to retain the blockbuster model on the leading place but enforce the help of biopharmaceutics, more and more looking there for new candidates. The race for blockbusters has been continued, with biopharmaceuticals forging ahead. But a new PwC report made the disenchanting conclusion in 2011:

"Pharma's strategy on placing bit bets on a few molecules, promoting them heavily and turning them into blockbusters worked well for many years, but its R&D productivity has now plummeted and the environment's changing." (PwC 2011: 3)

4 Biopharmaceutics on the long way of taking the lead

Since the early 1950s, the rapidly-developing disciplines of modern biochemistry and molecular biology naturally fed a vision of a new potential to realise a most profound paradigm change in drug research. This revolution in biochemistry and molecular biology provided the emerging industry with a broad scientific overview as a starting-point for understanding the mechanisms of diseases, on the level of molecular processes. By the mid-1970s, it also led to immediately-utilizable, powerful technological instruments, first through utilizing DNA recombination, and transformed bacteria to produce the first modern biopharmaceuticals.

The radical renewal in the pharmaceutical industry's R&D based on a new, molecular-biological basis was recently made in interaction with a new long-term expectation. Genetic techniques were dominantly interpreted as promises to transform R&D into a rational method, based on the development of the theory providing predictability and powerful technological instruments of earlier far not known capability. A fantastic perspective on a possible new world could be developed and helped the imagination soar. The promise of new experimentation techniques and the subsequent theoretical development to take the world by storm could work and led to exaggerated extrapolations. This could be done, provided you abandoned the profound critique coming from different corners, for example from systems biology on one hand, or knowledge of historical breakthroughs in industry on the other. If you took the narrow, reductionist perspective, the initial techniques would provide for the first unbelievable demonstrations for extrapolations, think, as an icon, of the grows of performance of high throughput screening by six magnitudes of order and diminution of its costs also by the same measure in the last ten years.

The phase in the history of biopharmaceuticals from the mid-70s to the turn of the century more and more concentrated on exploring the possibilities for exploiting the new recombinant DNA techniques. The initial enthusiasm revolved around the general vision of a very promising future, in which a new engineering capability, developing in close connection with the new science, appeared, promising the revolutionary extension of the capabilities of the homo faber to the genetic level. As various agents in the new biotechnology recall and as Pisano (2006: X) sums it up:

"The sector seemed to have little trouble convincing others (and particularly investors) of its bright prospects." (…) "Everything we knew about business and industry performance indeed suggested a very promising future for biotechnology, not just commercially but also for its ability to transform drug therapy."

There was an enthusiasm concerning the appearance of small start ups in biotechnology.

"Biotech firms were supposed to be much more efficient at pharmaceutical R&D because they were both at the cutting edge of science and unencumbered by the bureaucracy and organizational inertia of the behemoth pharmaceutical companies" (Pisano 2006: XI).

This was a concept in which only the advantages were formed into a positive vision.

Starting a new industry is, of course, a much greater and more complicated effort than providing a new basis for research, interpretation of the research's potentials for technical applications, and providing powerful technological instruments for realizing material transformations. It is also a matter of a complex of interactions on the societal side, of economy, legal regulation, organization, management, culture, and ideology and their interaction with the scientific-technological side.[13] Emerging modern biopharmaceutics found itself confronted with a whole complex of problems. Different agents had sought and found the opportunity to meet and develop jointly a path. A learning process in which a particular complex of co-operations stabilized in the early 1980s followed and set off significant changes in numerous respects during the next 20 to 25 years.

When biopharmaceutics was established, it blazed a new trail in all of the aspects mentioned. It entered a new field of experimentation with materials and organization forms where the players were challenged to learn quickly. A working form of organization, financing, and management appropriate for the specificities of modern biopharmaceutics had to be found very quickly: the solution was the integration of biotech R&D in a bioeconomy based on the neoliberalistic economic perspective, a legal regulation adapted to it, and a new specialized policy, a neoliberal biotechnology policy.

Integration of biopharmaceutical R&D into an emerging bioeconomy required first several legal steps as a basis.[14] Concerning the organization form, small start-ups were the favoured form of organization and venture capital (VC) was used for financing. If VC was utilised as financial basis, solutions for intellectual property rights, especially patenting, were also essential[15] so that the entry for venture capitalists would be secured. Putting financing on a VC–basis unavoidably required constructing an exit for the venture capitalists because they were ready for financing for not more than around three years. Possibility of going public with the VC investment onto the public equity market provided for a solution. Entrepreneurs too, as specialized managers, able to reconcile the different "logics", for example, of research and of finance appeared in the arena.

With this factors playing the most important role in the management side of the dynamics were mentioned more or less. It was somewhat contingent that start-ups stabilized first as organization forms and VC for financing. Learning from their partly contingent interactions provided for the further stabilising path in the stabilising governance within the

[13] This can be called, mutatis mutandis, a Chandlerian problem, if we take as a Chandlerian problem the development of the economic, organizational and management side able to give way to explore and exploit new technological potentials to realise new industries. (Compare Chandler 1977)

[14] I refer to two of them. The first was the possible narrowest Supreme Court decision in 1980 allowing that genetically modified bacteria can be patented. The second was passing the Orphan Drug Act in the USA in 1983 that encouraged medical breakthroughs otherwise economically unprofitable and allowed governmental interactions to further them. This act limited the working of the free market.

[15] I want to emphasize a special type of expectations and visions. They are inherent in the patents. These are knowledge claims entrenched in the practice of legal regulation, that layer where the envisioned future is set for fixing it by proprietary claims. Besides the usual written materials and visions „inscribed" in material practice as resources for expectations, systematic investigation of patenting may add a further important resource to expectation research.

frame of a neoliberalistic perspective. Within this frame, but the rise of modern biopharmaceutics was actually a prolonged path creation through a series of improvisation.

In order to make somewhat perceptible the openness of the process leading to the stabilizing outcome, the construction of the management side of modern biotechnology and the role of agency in it, I list just a few critical turning points at which ambiguous situations were decided, with marked effects on the further course. These were important steps that greatly influenced the stabilising trajectory of the biopharmaceutics.

The first point is that Big Pharma was at first rather reluctant to embark the new course. (Exceptions were Merck and Eli Lilly.) So, setting start-ups and getting financed by venture capital was not only ambition of scientists with entrepreneurial attitude and venture capitalists, but there scarcely was any other alternative, because the readiness of the Big Pharma to participate was missing at the beginning. This attitude changed by the mid-80s. From then can we speak about the returning alternative to place the new endeavour, modern biotechnology in the "visible hand", integrating it in the hierarchical structure of the firms belonging to the Big Pharma. From then we find a repeatedly returning dancing realising cooperations with small biotech firms that left them organizational place for their creativity or, much more in number, realising annexes, acquisitions by Big Pharma, beside the independent trials to realise independent biotech firms with drug production capability.

It can not be emphasized enough that start-ups and venture capital as financing form for modern biotechnology were adopted from informatics, from a field rather different from biopharmaceutics. Venture capital worked in informatics with much smaller amounts of money in comparison to the needs of the whole biotechnology innovation biotechnology innovation chain, and, for a much shorter period of time. This is in an inherent difference to the requirements of drug development. Financing biotech R&D by VC required appropriate adjustments, and led to fragmenting the financing of the value chain and creating a stock market segment. If the results of the processes listed above had been different, we can risk the assumption that the development of biopharmaceutics would also have been quite different.

A basic turn in pharmaceutics took place in recent years. Innovation in the pharmaceutical industry is not only closely strategically linked to basic biomedical sciences and biopharmaceutics, but there is a growing convergence of biotechnology and pharmaceutics. In the meantime, it seems to be a well-founded prediction that producing biopharmaceuticals is becoming the leading trend in the development of drug production.

5 Some consulting firms repeatedly make strong prognoses that fail

There is a widespread view that experts (scientists, advisory firms) make balanced, cautious, established visions and prognoses while "laypersons", especially from the public get repeatedly, even excessively exaggerated. This idea is partially true, but is also to challenge and ask whether at least some experts behave in the same way, and if so, when. It is to cheque how at least some advisory firms behaved in our story. I can concentrate here on only one phase of vision-making. This is the phase around the turn of the millennium. I concentrate on firms specialised on economic analysis and forecasting, such as IBM, PriceWaterhouseCoopers (PwC) and the Boston Consulting Group (BCG).

This phase is important for various reasons. The productivity crisis in pharmaceutics had already been strongly perceptible and went through an ongoing deepening before 2000. But biopharmaceutics developed some very powerful new empirical research techniques by then; a few years before 2000 it was already foreseeable that, as an invaluable success, the Human Genome Project (HGP) would be soon finished (it was essentially finished by 2000). It presented the constituents of the map of the basic human genetic structure and were to set what all this would strategically mean concerning the original plan of a rational biotechnology. The questions also included whether the continuation of the obtained genomic breakthrough could be soon profoundly exploited for drug production. One main complementing issue was how to utilize, in a qualitatively different measure, the mighty possibilities the information- and communication (ICT) industry offered, both in data gathering and processing, in simulation ("in silico" research), in biopharmaceutical R&D.

It is important to follow the workings of globally-leading advisory firms, because they are important third party actors in making strategic assessments of economic changes: because of their influence, but also because of the tension in their status as allegedly neutral and precautious assessors, and their proud attitude of relying strongly on the opinions of a big number of scientific researchers, industrial experts and CEOs interrogated, involved this way into the process of the advice making.

Kornelia Konrad recently expressed the view that consulting firms play a decisive role in organizing expectations and apply a rich toolset of technologies of expectation-building.

"In parallel, a professionalization and commercialization of expectation-building has taken place with experts and 'promissory' organizations such as consultancies and other forecasting agencies playing a decisive role in organizing expectations in specific fields, and creating and serving a market for technological expectations by applying a rich 'toolset' of technologies of expectation-building."(Konrad 2010: 67)

My impression is, in contrast to this, that, numerous consulting firms have been using quite simplistic toolsets in making rather poor overarching forecasts as technological expectations that did not work. I shall assess two exemplars of them in the next two chapters. They essentially failed in their prognoses. They used their toolset for an inappropriate mode of approach, for forecasting the coming revolution in biotechnology and detailed its forecasted effects. The basic unsuitability of the forecasting approach, in relation to the peculiar nature of biopharmaceutics offers the basis for explanation of the failures.

The forecasting efforts in biopharmaceutics follow the standard way of forecasting. They try to identify durable and emerging trends in the environment. They try to find constellations of interactions determining (mostly probabilistically) what will happen. They look then for opportunities of accommodations and try to select that alternative that seems to be the best. At the end of this selection, advice can be formulated containing what the client has to do to best capitalize on the demonstrated opportunities.

In special cases forecasting can lead to law like formulations such as the so called Moore law in informatics. Forecasts can serve as self-realizing prophecies having a special organizing force in the dynamics of the interactions of actors.

It can be prognosticated under special conditions that crises in the dynamics of the demand side can led to a level that at least some of the agents identify unbearable, and a breakdown. To be able to prognosticate the possible solution also has special requirements. Prognostic efforts sometimes may lead to a claimed result in a happy coincidence. While menacing with a breakdown the prognosis makers may feel to be authorized to forecast those revolutionary opportunities that can serve to prevent the forecasted breakdown, even more to enter the revolutionary growth of the capacity to satisfy new revolutionary requirements, too. It is evident that the rightfulness of such forecasts has extraordinary preconditions.

Advisory firms committed to forecasting try to close down speculations on possible futures and try to find an as deterministic script of the future in the present action space as possible. In turbulent processes such as those of biopharmaceutics are the clients put the directed questions whether there are different possibilities of capitalizing on the remaining alternatives or is at least one and is there at least some way to catch it. They treat the issues as if they were already some triggering processes or breakthroughs as facts, and take the risk of making a short-term prognosis of their full realization.

Advisory firms give a description of the issues in which consensus views with the chosen representatives of clients is included. So, another problem is that consulting firms mostly pride themselves on including the possible largest number of working scientists and industrial experts in the development of the advice, but those mostly one-sidedly prefer coming to consensus views. In this respect, the expectations the advisory firms express may work as somewhat uncritical amplifiers of the majority opinion of these players - independently of the situation that the cooperation with them aims at forecasting. They quite rarely give weighty place for individual dissenting views.

This is connected with insisting on forecasting instead of giving more place to the more flexible scenario approach. Instead of trying to uncover the action place for the players as far as possible as a multitude of alternatives from which they have to choose, they provide for deterministic guesses as extrapolations, as far as possible, and advise the players to follow the irresistible to take possible advantage from choosing among the remaining alternatives and the timely joining.

It seems, there is a tricky interaction between numerous industrial and advisory firms. Advisory firms will get some dominating role in the interaction in a stabilized cooperation with the clients if they overtake the prognosis of the direction of overarching industrial development. They acquire and make clients believe that they have more capability of overview and help to make a choice among the remaining path and speed alternatives for their concrete clients wishing "customized" advices. They have the need for steadily improving their position. Communicating their allegedly unbiased attitude, claiming doing their work as experts in the field of "the science of the future" belongs to this strive for improving their position. In this process, self-critically admitting and uncovering mistaken prognoses does not belong to the strategy.

Around 2000, there was a dominating group of exaggerated genetic researchers and industrial CEOs, concentrating on the enormous new potentials appearing in informatization and genomization of the industrial research, claiming them to be the ways to quickly come out of the depressing productivity crisis of the industry. There were players who reasoned to resist exaggeration, too. Different sorts of counter-arguments were set and in principle, more could have been found. The decisive counter-argument was then that the ontological reductionist approach is a mistaken attitude to correctly assess both the strategic role of genomics and the expectations with short run breakthroughs, not only in science but also in industry.

But there was already a rather self-referential structure of the genomics researchers' community when setting up expectations.[16] It is an important methodological question whether advisory firms show any inclination to develop a self-referential structure when they turn to the researchers and CEOs as experts for their opinion.

In the following section, I assess two consultancies' reports. They confirm that a revolution is in the making in pharmaceutics industry as a whole. Another report bets on the informatization efforts.[17] They acquired authority in using a combination of a very rich set of partial forecasts, combining them into an overarching forecast which backs their assessment.

But there is still one more point to reflect on. When the nature of industrial revolutions is necessarily evolutionary, in the meaning of necessarily slow transition processes to qualitatively new stages, then revolutionary narratives serve for a different purpose. Nichtingale and Martin (2004) try to challenge and check the idea of a biotechnological revolution with the already available, qualitatively new evidence in 2004, and draw the conclusion that there is no real reason to speak of a biotechnological revolution in the period from the first efforts at industrial application of modern biotechnology to the early 21st century. Instead they speak of the unavoidably evolutionary dynamics of any emerging industry and dissemination of scientific knowledge. They point to the well-known historical experience and its theoretical interpretation as a historical lesson: the dissemination of breakthrough knowledge and its application in industry inevitably needs much time before the turnaround is realized.

They make the unavoidable slow evolutionary dissemination process responsible for the necessarily evolutionary characteristic of the industrial revolutions. They point to the truth of this characterization, concerning the, then around 25 years long history of biotechnology. Unfortunately, this is just a part of the whole truth. As genomics researchers recognized by 2003, genomics continued its unbelievable acceleration in finding new and new instruments, a progress that has still been continuing, but common diseases require a qualitatively different approach than rare, "orphan" diseases and this was still to start to hypothetically find and experiment with. So, it was impossible to realise a revolutionary breakthrough in solving the productivity crisis of the industry in the forecasted time period.

Revolutionary narratives may be misleading but certainly can have a role. Nichtingale and Martin (2004) draw attention to the ideological role of the revolutionary narrative: no investor would be ready to invest the needed unusually high amounts for unusually long time and in a very uncertain process, unless s/he can believe that s/he invests into something that would yield unusually significant returns within a defined time-span.

There is a special structure in the revolutionary forecasts. A normative scenario sets the requirements for a revolution on the demand side, by combining extrapolations of tendencies and knowledge whether they are still bearable at some point and there is an extrapolative forecast of the emerging processes in which revolutionary potentials offer their service. Forecasts outline the way how these alleged revolutionary potentials will

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[16] A self-referential structure means that the expectation setting dynamic works in a closed arena and opens only when strongly constrained and only thereon can enter less exaggerated players the "expectation arena" for discussion. The mentioned arena needed the basic failures first to open for discussion.

[17] A PwC report forecasted and announced in 1999 automation of the pharmaceutic R&D process by 2005, brought it into connection with overcoming the productivity crisis and devoted a whole volume to it. (PwC 1999)

lead to the solution for the recognized revolutionary needs on the demand side. Provided they got persuaded from the forecasts, most important for clients in the advice is, what, probably enormous, accomplishment they will still have to make to carry out the revolution and take their share.

To repeat it: there are numerous, ontological, epistemological and pragmatic arguments that successful forecasting has very strong preconditions and so, from the rather rich set of possible dynamics, forecasting actually has a quite narrow subset to hopefully approach. Biotechnology realises a special sort of cooperation with science, as it will be outlined a bit more detailed in the last chapter. That means that there are further arguments than usual to doubt that forecasts in biotechnology can be kept as dominant approaches. In short, biotechnology explores the human body, always to expect causing the emergence of "unknown unknowns", and tries to catch profit already from unfinished research processes. These factors together may repeatedly provide for unexpected but unavoidable and, for a while, insurmountable hurdles that make certain types of forecasts useless.

6 "Pharma 2005: An Industrial Revolution in R&D"

The first vision, I take as an exemplar, entitled as "Pharma 2005: An Industrial Revolution in R&D", was drafted by IBM Business Consultants, in affiliation with PwC, and was published in 1998. The title is interesting itself. It speaks of an industrial revolution in pharmaceutics, assessed as a fact (!), caused by the different emerging and ongoing revolutionary changes in R&D, both on the demand and the supply side. The argumentation is roughly as follows: The report concludes on the one part correctly that, on the demand side, there is an unavoidable need to revolutionize the R&D, in the meaning of carrying out a quick breakthrough. Pharmaceutics is expanding "but evolution is generally a process of slow change and the industry now faces a challenge of absolutely unprecedented scale". (IBM 1998: 3) It is impossible for the costs of R&D to grow further, a dramatic diminution of R&D costs is to be attained, while the number and quality of new drugs has to increase. To reach this goal a "total transformation of the way in which industry performs R&D" is needed, something of a systemic change within a very short time.

> "All point to the fact that the industry must learn to create affordable new drugs, and that it will only be able to do so if it totally transforms the way in which it performs R&D."

> "One thing is certain: whatever the numbers are, 'Big Pharma' will look very different by the year 2005. It has no choice but to adopt a new strategic, tactical and operational management model consistent with the fundamental drivers of this new paradigm – and to do so fast." (ibid: 10)

In the assessment of the advisory firm, this demand requires a revolutionary change within seven years – by 2005, and this can be brought into being. What "revolutionary" means is not defined, but the context refers to expecting the rise of a new paradigm. IBM "bets" for the acceleration and whole scale realization of "industralization of R&D", a running process in that time.

The report makes a "dramatic" but optimistic vision. Not only the challenge is immense and "dramatic", there are also opportunities of the same scale. These opportunities are to be transformed into a "revolution" by clever action. The report systematically assesses some of the R&D's new chances. The possible immense increase on the number of possible targets and the development of genetic screening are taken into account. The report states that there is "a revolution in the making". The rapid multiplication of new targets by orders of magnitude is one of the options with massive implications for revolutionizing the whole R&D process.

"There would be some 25000 new targets."

"And even if only a quarter of them prove to have genuine potential, this would still represent a 14-fold improvement on the current situation."

As the report assesses, scarcity in drug targets is only one of the bottlenecks that, allegedly, can come to an end by the new genomic possibilities in the estimated short period. The other bottleneck, that the fear of possible adverse effects of a possible new drug hinders their introduction can also be successfully overcome very soon. More than that medication will turn to prevention and individualized treatment.

"Moreover, apart from producing new targets, genetic screening will provide the means with which to identify genotypes and thus to predict who is at risk from what, together with the side effects of any medication. The focus of treatment will also expand from cure to the reversal of pathology in conditions such as epilepsy and Alzheimer's disease. So the industry's remit looks set to grow significantly. Where once it made pills and lotions, it will be increasingly involved in prediction, prevention and follow-up treatments."

The analysed expert material made a forecast that would realize in seven years. A rich set of most different trend extrapolations and their expected interactions are brought together in the report. Genomics will create new leads and new business areas; it will open markets for diagnostic testing, preventive medicines, follow-up treatments, and even support services such as lifestyle counselling. This is why all of this can be extrapolated seriously– according to the report. "By the year 2005, today's technologies will be mature". The report also presents exaggerated possibilities.

"However, the mechanisation of the early-stage discovery process could culminate in something much more radical, such as the development of drug discovery factories and 'tele-labs'. By the year 2005, the most successful pharmaceutical companies may be emulating some of the 'baby biotech' firms with research scientists, linked by powerful intranet facilities, working from home" (IBM Report 1998: 17).

Or further:

"Changes already on the horizon suggest that the preclinical stage will soon be a bridge nobody needs." (ibid.: 19).

"Emerging in silico techniques and technologies such as single cell differential gene expression and target searches in Expressed Sequence Tag libraries […] will enable the industry to identify targets with the ideal physiological and pathological characteristics. Pharmacophore technology, in silico lead optimisation, scale-up and preclinical trials will follow. Computer modelling will even provide the tools with which to perform in silico clinical trials, based on whole organ body models that test for everything, including side effect profiles and drug-drug interactions – although it is doubtful that the regulators will accept such evidence for some time. In short, within a few years, the industry will be able to move straight from the test tube to man (if not to the marketplace)." (ibid: 20)

It is evident by now that this forecasting as a whole was very much exaggerated, meanwhile some real progress was spectacular.

Because this vision of the future is based on this rich combination of extrapolations, integrated into an overarching forecast, we can rightfully ask: how much of it has been realized by 2005? Of course, it is difficult to assess such foggy prognoses that genomics "will open up the markets for diagnostic testing, preventative medicines". But it seems correct to observe that diagnostic testing for common diseases or preventive medicines on genomics base still were missed in 2005, and first of all, the revolutionary effects on R&D productivity were not realized. The error of method seems to be that only some very tentative, even when rich scenarios could have been formulated correctly, provided that serious epistemological prerequisites would have been accepted, not serious forecasts of short term revolutions transforming the working of the whole industry.

7 "A Revolution in R&D: How genomics and genetics are transforming the biopharmaceutical industry"

Just after the burst of the genomic bubble in 2001, The Boston Consulting Group (BCG) also published a prognosis in a volume, of which the title you find above. This is a prognosis of what will happen in biopharmaceutical and pharmaceutical R&D in the coming years. Like the IBM report the BCG report also concentrated on the radical changes that were already allegedly taking place. As BCG assesses, many had already tried to improve the development phase. In contrast, the BCG report concentrates on the research phase, and identifies promises of genomics as breakthrough possibilities for the industry.

BCG also begins by defining the challenge as a crisis. In this crisis the expectation of continuing constant double-digit yearly growth for the industry is permanently endangered. Resulting from the exclusion of any other alternative they claim that the only real way out is to increase the efficiency of the R&D process. The BCG report identifies genomics as a counterbalancing opportunity for finding the solution.

The report's message is: genomics, including genetics as the science of the distinctive genetic makeup of individuals, promises to reshaping drug R&D methods and economies radically. "Industrialised" and informatized genomic research provides more data by orders of magnitude, its processing is made already on a qualitatively higher level than earlier, and, in the end, can lead to a reduction of costs by two-thirds, and the time needed for R&D can be reduced to two years. But the process is replete with obstacles, and will first bear the costs of learning as well,

"Biopharmaceutical R&D is moving into a new era: almost every link in the value chain has the potential for tremendous boosts in efficiency or success. But these advances are not assured. Technological hurdles have yet to be overcome, particularly in the genetics wave. Moreover, because the productivity boosts are likely to be unequal and uncoordinated, the value chain itself will demand reconfiguring."…" The repercussions of genomics, in other words, are going to reach the furthest recesses of corporate constitution and culture. A true revolution, in short—and one that is already well under way." (BCG Report: 14)

As the report assures, this is already a revolution-in-the-making. But enormous hurdles are still to overcome. The BCG report makes, as a didactic example for any change it suggests, reference to a firm already benefiting from realizing the transformation it committed itself to. The mission then becomes apparent.

"It is against this background that the genomics revolution is unfolding. In their quest for improved productivity, companies should welcome the new technologies and approaches. Genomics"(…)"promises to transform how pharmaceutical research is conducted. The paradigm will shift from small-scale and serendipitous to global, industrialized, and systematic; and from methodical and compartmentalized to fluid and cross-functional. The impact on R&D economics is likely to be tremendous: in the best case, productivity could as much as double." (ibid: 59)

Made euphoric by the success of the "industrialization" of gene sequencing technology, the report paints the coming paradise onto the canvas. There is a high threshold to be crossed, but then a new world of possibilities unfolds.

"Looking beyond R&D, genomics and genetics also promise to transform the way pharmaceutical companies conduct their business in the coming years. If genetics realizes its potential, for example, treatments will become more sophisticated, markets may fragment, and the shape and value of marketing and sales organizations will change dramatically. The entire system of health care delivery, already in flux, will complete its metamorphosis." (ibid: 57)

This transformation is not merely a possibility, either, according to the report. It is already in the making, and there is no alternative to doing likewise: those who do not will lose everything, there is nowhere to hide.

> "The offer that genomics and genetics are holding out is really an offer that companies cannot refuse. Companies that fail to accept the offer adequately will find themselves not simply uncompetitive but possibly right out of contention. There is nowhere to hide, and certainly no safety in inaction. Embracing the revolution appropriately adds up to a formidable but by no means impossible task. And for companies that do it well, the rewards will be handsome. The opportunities are unprecedented. So are the challenges." (ibid.: 57).

This is a text formulating an apodictic persuasion when it speaks on the challenge, turning to the not less apodictic persuasion that the formidable future will very soon be realized, provided the needed determined commitment will be provided by the players, understanding the message.

One important element of what was actually the mission meant by "revolution" is implicitly derivable from the whole of the text in the BCG Report. It calls for determined action against the obstacles. Time is pressing, and it is impossible not to engage because this would be self-defeating. The BCG report cleverly avoids making further concrete forecasts. It only claims that there is a genomics- and genetics-revolution in the making, The process has already begun, and will continue.

Concerning the dynamics of biotechnology, the advisory firms mentioned believed to be able to recognize a revolution in the making in R&D that revolutionizes the whole industry, in a short period of time.

The BCG report is based on an extrapolation of the "industrialisation of R&D efforts" in the 90s. To assess this claim it is to see that numerous further, even more spectacular results were achieved in the first decade of the 21st century. But what is certain is that the genomics- and pharmacogenetics revolution still hasn't revolutionized the drug production even when the majority of blockbusters is already made by biotechnology.[18] Concerning the failure, it may suffice to refer to the general difficulty of prognosticating the future, perhaps refer to the inevitable slowness of diffusion even when there is an alleged revolution in the making or even a real revolution - in some part of a very complex system. But it seems even more important that the authors of the reports forgot to consider the possible role of some "unknown unknowns", in time of formulation of the reports, preventing correct forecasting. This is that the inexhaustible complexity to guess for the object of biotech research has to be repeatedly recognized through the paradox progress of research through the process of consecutive successes and failures with modelling.

One last remark: both reports address first of all those who look at the deep and ongoing productivity crisis in the industry with much anxiety, because they feel a need for a revolutionary growth in their capacity to solve the crisis. The reports simultaneously aim at tranquilizing and inspiring them by providing them with idea of the solution already unfolding as a revolution. But they also remind them on the enormous hindrances unavoidable to overcome in the process of the revolution. These clients are expected to be sensitive to the message that the radical solution

[18] Looking back onto the last decade, a summary to a new series of PwC reports, Pharma 2020, introducing the Pharma 2020 Series, states in 2011 that the golden decade of biotech has not brought a golden era in productivity of the biopharmaceutics industry. Progress has been much slower in uncovering the scientific basis than expected and the business model is not the best either. (PwC 2011: 3) The new series deals with a longer period, from 2007 to 2020, makes a detailed assessment of the changing societal and economic environment of the converging biotechnology and pharmaceutics, surveys the whole value chain, not only the R&D, but insists on forecasting what will happen by 2020 – instead of turning to foresight. A Russian proverb says: if we live to see we shall see it.

is already quickly unfolding and are reminded that they have no alternative than to follow the advice. The language of the advice has a function of reinforcing the client that s/he has to follow the message that s/he is empowered with the solution of her problems - in a prognostizable world. But all this does not really explain the setting of very courageous timing of the revolutions in the advices.

8 "Science is the business" – Looking for a better strategic connection between science-in-the - making and business

Forecasting can be successful even with high probability when the nature of the issue of which forecasting is made is known and the process under scrutiny is simple enough, so that trends can be seen dominating the dynamics. But do we know what sort of endeavour modern biotechnology is concerning its nature as business?

A leading economic analyst for biotechnology, Garry Pisano, says that in biotechnology "science is the business". He concentrates on explicating this and explaining what he points out, the relative lack of success in the financing, organization, and business of modern biotechnology. He analyses critically, how value is created and sustained in biotech R&D, claims to have found a structural failure and makes a "therapeutic" suggestion.[19]

Pisano (2006, 2007, 2011) forcefully argues that biopharmaceutics industry as a whole has permanently under-performed and that the basic problems in its development are that the players have not really recognized the nature of the new undertaking they have practiced. This undertaking is doing science and business simultaneously, a unification of two endeavours with different "logics". Players have not found the form of organization, of financing, business model, the management model best suited for supporting this sector's development. He argues that biotechnology has to be designed and function as a "science-based business", different from other industrial sectors that systematically make use of science.

I would like to express in a comprised form slightly differently what the "science-based business" means. It is, "business and industry built on co-producing and exploiting basic-science-in-the-making". Pisano introduced his term to refer to a new type of industry that is not simply based on systematically exploiting results of science, but on direct participation in the creation of new basic science, in scientific research itself. With this direct participation business got the very uncertain but very promising potential to realise a more dynamic and innovative co-operation with science than simply waiting for and utilising results of basic research.

> "Over the past century" (…) "science has played a critical role in a number of industries." "But it remained *outside* the boundaries of the business system. Science was a tool, an imprint, or a foundation for creating new products and services: it was not the business. From its inception biotechnology was different. In the biotechnology science *is* the business." (Pisano 2006: 1).

As Pisano emphasizes, by the modern biotechnology an innovation of innovation emerged by constructing a dynamic intersection of business and basic research as a new entity to develop.

A "science-based business" entails unique challenges, to which in history of modern biotechnology only myopic solutions have been found. He emphasizes that this is the central problem of history of modern biotechnology to explain.

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[19] "/T/he disappointing performance of the biotech sector reflects a fundamental and deep struggle between the conflicting objectives and requirements of the *science* of biotechnology and the *business* of biotechnology (Pisano 2006: 6).

His explanation is roughly as follows. When the nature of the problem is that science itself is the object of business, then three interdependent problems arise. The first is "profound and persistent uncertainty". Research in biotechnology is highly uncertain and so the success of its financing too. This means, first, finding scientific results needed to be able to develop technological products. This is connected with the question of technical feasibility. In other risky high-tech contexts, to make a comparison, uncertainty is a different problem. In these contexts it would be irrational to fear not to be able to solve the problem of technical feasibility at all. But this fear becomes rational when biotechnology is the topic. And it is to expect regularly that any reached new level of knowledge may lead to catch sight of new basic uncertainties and is unavoidable to face them.

"And even when one finds a 'solution' it does not necessarily have clear implications for commercial R&D; rather it may instead trigger a new round of basic research." (ibid.: 9).

In my estimation, Pisano rightfully claims to have recognized a basic new type of cooperation of science and the business.[20]

Pisano speaks of Knightian uncertainty, referring to "unknown unknowns": they represent something "you did not even know you did not know." (ibid.: 8).

He takes a Chandlerian perspective in assessing biotechnology. But solving the same task, finding the appropriate organizational form for some sorts of technologies leads to result diametrically different from the story of Chandler that deals with the 19th century. Chandler identified the emergence of the "visible hand", for example the hierarchical big firms, while Pisano has got to explain how the market-based financing, some form of the "invisible hand", the VC got dominant role in construction of biotechnology. And Pisano reaches a normative conclusion: to improve the performance of the, in its history underperforming biotechnology, an innovation of innovation should be realised, the organizational side should be profoundly innovated.

Pisano does not deny the obvious that biotechnology developed and realized a working solution for its development for a while. His concern is that the industry as a whole even lost money in this phase, as he claims to have been able to identify, and the long-term sustainability and potential of this under-performing solution, due its inborn structural errors in the organization form concerning its working for biotechnology. His problem is that a solution was implemented, in which causes of under-performance were encoded from its inception but have not been recognized.

As it was already indicated, Big Pharma was first reluctant to enter emerging biotechnology and many scientific entrepreneurs, led by simplistic ideas about the difficulties to realise successful business, started start-up firms. Pisano states that the emerging new biotechnology solved the very basic business problem it had by a sort of 'tinkering', as I call it in harmony with STS terminology, in the urging situation thirty years ago, concentrating on somehow solving one sub-problem, the financing an early part of the innovation chain, from an, each other mutually influencing group of problems. With further development in financing later phases in the innovation chain this realized a working capacity for biotechnology but proves to be unsustainable, because it didn't take all of the interrelated systemic problems into account as it became unavoidable in the long run.

Pisano identifies three interconnected basic tasks in solving the fundamental problems of development of a "science-based industry" such as biotechnology. These are, first, the management of uncertainty,

[20] Besides biotechnology he names nanotechnology and new fields in energy industry as further examples.

the risk; second, the integration of the needed heterogeneous types of knowledge which the knowledge base encompasses; and third, rapid learning.

For an optimal solution, it is necessary that all three have to be taken into account simultaneously. As he assesses, the nascent industry successfully concentrated on the problem of risk, and found a solution for it. The other two strategic tasks and the interdependence of all the three were not recognised to be of equal importance.

Concerning the question of organization, small start-ups are typical for this industrial sector.[21] It is of decisive importance to see that the start-ups, expressing the essence of the biotechnological undertaking, are start-ups realising basic research in the hope of its exploitability. They are different than the usual high-tech start-ups. They make research and produce research results, first of all. With this repeatedly appearing Knightian uncertainty is essentially embodied in the working of modern biotechnology.

Further, the actors often solve their concrete practical problems without systematic reflection on the unavoidable integration of most different types of knowledge they need. This integration is somehow unavoidable in concrete practical situations and is one of the basic possibilities to raise the capacity of biopharmaceutics, when it is made appropriately. Biotech knowledge typically emerges at the intersections of multiple bodies of science, and also different sorts of practical empirical knowledge. Breakthroughs are realised from time to time, by integrating and recombining these bodies of knowledge. Pisano emphasizes that biotechnology is a par excellence innovative endeavour in the Schumpeterian understanding of innovation as recombination of the different sorts of knowledge at their intersection. (Pisano 2011: 474) Unceasing efforts in re-integration are decisive for the success.

"The power to impact drug discovery lies in how you integrate the understanding and the tools. You have to evaluate how each new tool works in relation to all the others. You have to bring all the tools and knowledge together." (Pisano 2007: 1).

This integration was not realized systematically enough in history, and development remained fragmented.

Third, in a field where essential failures belong to the nature of the undertaking because they are unforeseeable, there is a constant basic need for rapid learning; but learning is individualized in recent practice, does not appropriately occur at the industry level, there is scarcely any possibility of learning from one another's failures. Knowledge is not accumulated, because learning is essentially remaining within the walls of the innumerable small firms that exist without interaction with each other. But sharing learning, especially of the false tracks, is decisive where failures dominate in number the attempts.

"There is a multitude of small start-ups and the result is a highly fragmented industry. This leads to the problem that *every time you launch a new firm, you start the learning cycle all over again.* This is against utilising the potentials integration and cumulative learning would secure." (Pisano 2007)

[21] The problems of solving their first financial risk problems by co-operating intensively with venture capital, the unavoidable short-term perspective of some few years, the much smaller amounts than the biotech industry needs for the whole R@D were already mentioned in this article. Pisano emphasizes that the main cause of the failure is that a solution from the info-communication sector was "indiscriminately borrowed". Epistemologically speaking this means that, in biotechnology, as sufficient reasons, positive analogies had been taken into account at the beginning of the process of adopting the model given by informatics and the negative analogies as tensions to be unavoidably faced, were not taken into account appropriately or were simply abandoned or not recognized at all.

In a highly fragmented industry "/t/here's a big opportunity lurking in one of the great inefficiencies in drug R&D, which is that most of the valuable information never gets used. When drugs fail in clinical trials – and most do – almost all the data and knowledge generated by the trials is abandoned" (…) "/N/one *of that knowledge from the failures gets shared*. Companies repeatedly make the same mistakes as their competitors in the course of the trials and aren't learning from them." (Pisano 2007, italics mine).

Pisano identifies the mechanism that leads to a continuing underperformance. His conclusion is that a new, overarching organizational, financing and management paradigm change is needed, the goal being a radical improvement of the whole management system of biotechnology, an innovation of innovation. In the view of Pisano, some mixture of cooperating big and small firms, of freeing them from the constraint of immediate profitability, looking for an appropriate mixture of cooperation of Big Pharma and VC, of hierarchy and market in the cooperation, points to the way of solution, leading to networking and knowledge-sharing efforts.[22]

This does not put an end to the defining difficulties biopharmaceutics has by its nature as science-based business but takes into account the cooperation of business and research in an appropriate way to accommodate better and better to the tension ever continuing.

In contrast to many forecasts on the future of the biopharmaceutics that try to extrapolate trends Pisano turns to understanding first the nature of the biotech, the structure of the undertaking and then, based on this knowledge, to design an appropriate mode of organization and management that is able to correctly answer the requirements of the "science-based" nature of biopharmaceutics. [23]

Whether that would allow for comprehensive reliable forecasts, to return to our basic problem with the methodologically often adventurous forecasts in biopharmaceutics, is forcefully to doubt. But it is to see that essential uncertainties reappear on new and new levels, the way of the "science-based business" is recognizing new uncertainties by stopping the old ones. Having been forced to have success by not only repeatedly exploring essential uncertainties that appear unexpectedly from the solutions reached, but even strived for such situations as source of qualitatively new knowledge, is integral to the nature of biopharmaceutics.

To come back to a central concern in this article, outlined in the fourth chapter, my claim is that the unavoidable possibility of repeated emergence of new uncertainties peculiarly limits the chances of forecasting in any science-based business. To rationalize systematic reflection on possible futures in "science-based business" including biopharmaceutics, requires a determined turn away from forecasting to the scenario method and a rethinking of the nature of advice-giving,

9 Conclusion

[22] In Europe state intervention is also imagined as a different type of hierarchical intervention. The growing problematic participation of hedge funding in financing biopharmaceutics R&D is still nowhere assessed as a problematic rationalization of managing the self-reproducing uncertainty in this field.

[23] It is unavoidable to consider the possibility of emergence of three types of „unknown unknowns" when problems of biopharmaceutics are to be solved. These originate in the ontological complexity of the object of biotechnology and systems biology can make progress here; the openness of the „science-based business, and the turbulent nature of biopharmaceutics' societal-economic-political environment". All of them call for turning to foresight exercise. The PwC Pharma 2020 series takes into account an earlier unnown richness of pieces of information and perspectives but insists on integrating them into an overarching forecast.

The development of pharmaceutics has led to a spiral of competition and a constantly raising need for new blockbusters. This produces a permanent tension on the demand side for uninterruptedly looking for radical visions. This was strengthened by the on-going and deepening productivity crisis in pharmaceutics from the early 1990s.

Among the different agents inclined to make radical visions, are large consulting firms. By presuming the effects of revolutionary changes in subsequent partial domains they repeatedly forecast different revolutions-in-the-making in biopharmaceutics as a whole, the solutions for the continuing productivity crisis. In the period of the turn of the century, the period under scrutiny, exaggerated assessments abounded in forecasts. Inclination to make exaggerated forecasts have been strongly promoted by the ongoing and surprising tension between the subsequent enormous developments in most different partial fields and their interactions and the continuing productivity crisis of the industry as a whole. Notwithstanding the long series of very quick and profound changes in concrete R&D and even on the meta-level, including innovation of innovation, falling short of expectations remained a regular issue. Converging pharmaceutics and biotechnology could not reinvent itself in the needed measure to catch up with the growing requirements.

The need for catching a sight of the coming radical solution as soon as possible to present it for the different sorts of payors (governments, venture capitalists, etc) and for self-confidence for themselves has given some special characteristics to the revolutionary forecasts. They speak about needs for revolution on the demand side and let simultaneously catch a sight of revolutionary potentials already available on the supply side. This is about the alleged repeated happy coincidence of needs for revolution and the allegedly simultaneously recognized revolutionary potential. Forecasts of revolutions in the output performance of the industry as a whole extrapolate effects of partial breakthroughs and, falsely, often claim to be able to indicate by when, according to them, the prognosticated revolution of the industry will be realised.

Modern biotechnology, from its inception, has developed as a new industrial entity, as "science-based business", with deep inherent uncertainty in its nature that repeatedly manifests itself by any level of progress achieved – as Pisano demonstrates. In its evolution, based on the analogy with ICT, modern biotechnology created a model of organization, of financing and of management that has been working. But this mode, one-sidedly concentrating on the „risk problem", has been continually underperforming, and is in need of a paradigm change, as Pisano correctly suggests.

It is not to doubt that partial forecasts with limited claim for their truthfulness are possible and important in biotechnology too. But more reliable partial forecasts could only be based on the changing entrenchment of the biotechnology in the larger societal-economical environment, in which repeatedly but irregularly returning new genuine surprises are to be expected, too, the deeper understanding of the nature of biopharmaceutics, the nature of a specific "science-based business". Due to this characteristic forecasting can only have an important but servant role in the needed strategic turn to hand over the leading role to the scenario methods as basic approaches to identify possible futures to contribute to action strategies that are really more robust, not only imagined to be, and are more flexible.

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Epistemic networks

New subjects for new forms of (scientific) knowledge production

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Abstract

The most important contribution made by some recent proposals in the philosophy of science and in the science and technology studies is the freeing from the psychical appeal made to the individual's conscience or intentions in explaining different scientific processes. This is not the same as adhering to methodological collectivism. It is not a question of reformulating the old individualism/collectivism dichotomy. Yet, is it not this community image that affirms the reality of the situation regarding collective subjects – the thought collective, the scientific community, etc. – which constitutes the alternative to methodological individualism and epistemological realism? Rather than continue in this way the aim of this paper is that of situating the alternatives in other confrontations and replacing the subjects of the old methodological individualism with new "actors", with new units of knowledge.

1 Introduction

For at least three decades now, it has been recognized that knowledge is transforming social relations and organizing another type of relations on a radically different basis (Gibbons et al. 1994/Knorr-Cetina 1999/Evers 2000). However, what kind of relations have begun to develop, and which direction such developments will take, is a question about which there is no clear consensus. What is clear, however, is that the role knowledge plays in modern societies organizes a new agenda of problems, which will mean having to rethink the basic diagnoses on which relations between science, technology, and society have to be analyzed. One of these problems is the attempt to identify the epistemic subjects, which produce and use knowledge.

There are several trends in this approach to the new problems. In the first place, the widely used term "knowledge society" (Stehr 1994) has been interpreted as interchangeable with the term "knowledge-based economy" (Cowan et al. 2002, Nonaka/Takeuchi 1995). For this perspective, the knowledge-based economy is a new term, which has been coined as a result of several related processes, such as the acceleration in the production of knowledge, the increasingly intense role of intangible capital (knowledge) in macroeconomic variables, and innovation as the dominant activity (Cowan et al. 2002). Knowledge is therefore considered here basically as a decisive factor in the "new economy" and, in consequence, the conceptual problems are oriented towards the analysis of how to transform tacit knowledge into explicit knowledge, and re-function it in areas of economic production. Approaches to knowledge management may likewise be framed in the sphere of the organizations (basically businesses), the efforts of which are oriented towards making explicit and promoting knowledge management mechanisms and organization in "learning organizations"; i. e., what is important here is the spiral of knowledge creation, in which tacit, individual knowledge is transformed into explicit, social knowledge in the frame of businesses and production systems (Nonaka/Takeuchi 1995).

A second perspective, which subordinates knowledge to economic processes, is exemplified in the widely extended discourse on national/regional innovation systems. The basic argument is that innovative businesses interact in national/regional contexts, not just with other companies (competitors, clients, and suppliers), but also with technology centers, R&D centers, various types of science- and technology-linked agencies, and political authorities. In this way, knowledge circulates more intensely and more effectively, thanks to geographical proximity, which helps to trigger the innovation processes (Lundvall 1992; Cooke 2001). One advantage of this approach is that it includes the role of the institutions and the importance of systemic relations between agents and innovation in its explanation of innovation. However, innovation (as an interactive and learning system) is still considered to be a socio-organizational process integrated in the dynamics based on technological change, organizational learning, and path dependency (Moulaert/Sekia 2003).

From a different perspective, Gibbons et al. (1994) have introduced the concept of production and distribution modes, to favor a social approach to knowledge and its circulation. Even if the metaphor of knowledge production and -distribution has an economic origin, the idea in this perspective is to make an effort to show the trends and the keys in a transition towards a new social scenario in which knowledge is produced in a multidisciplinary way in contexts of application, which include a range of actors and interests on the basis of flat, flexible, and open organizations, and where evaluation is increasingly a competency which is exogenous, rather than endogenous to knowledge-production centers (universities and other research centers).

My thesis is that, for a more complex understanding of the role of knowledge in contemporary societies, a socially distributed conception of knowledge is needed, one that considers science, technology, and innovation to be something more than a technological process associated with processes of applied science and economic value. To do this, I shall attempt to give an account of this perspective and propose a network approach for knowledge relations, in order to promote a better-structured and more complex view on the role of science and research in knowledge societies. The concept of the epistemic network is one, which – unlike individual subjects or concepts such as scientific communities or other related terms – makes it possible to criticize on the premises concerning epistemological realism and methodological individualism, the more prominent stances in the philosophical and sociological studies on the production of knowledge. How can we characterize such epistemic networks?

In the next section, I will first identify the two epistemological premises, which have underlain our controversial understanding of knowledge production in the 20th century. Next I shall consider some of the attempts, which are particularly well adapted for showing the community nature of the scientific enterprise. In the third section, before going on to propose an image of science based on non-human units of knowledge production, I shall analyze a "collectivist" approach presented recently by Hacking through an introduction to the concept of reasoning style, which stresses the decisive role played by scientific cognition putting the individual off-center. In the fourth section, I shall consider some unresolved problems in Fleck's thought collective theory, in particular, the introduction of the individual subject as a condition for structural change in thought styles. Based on the communicative practice of Fleck's collective actors, I then go on to propose, in the fifth section, the consideration of new units of knowledge, conceived as epistemic networks comprising interactions of a certain type: circulation processes of the type that will be discussed below. I shall conclude with some final considerations about some of the new challenges which that network approach introduces for the study of knowledge in contemporary societies.

2 A change in the mainstream or a change of mainstream?

The study of scientific objectivity in the analytical philosophy of science was dominated throughout the 20th century by theories which have enabled genuinely philosophical problems and issues to be commonly identified beyond the declared death of the "standard view". This would favor communication and consensus, with the conviction that the "philosophical study of real science" would give rise to theories, which are neither metaphysical nor speculative. Such is the mainstream that channeled the philosophical analysis of science in the 20th century (Kitcher 1993).

However, the emergence of the new sociology of scientific knowledge, of science studies, has triggered a branching out of mainstream philosophy into various directions. The result may appear disappointing when we observe the current fragmentation of philosophical and sociological interests, and even give rise to mutual incomprehension of what is understood by the study of science and the nature of problems and issues to be dealt with in it.

The diversity of regional contexts with very differing interests and expectations, which one would expect from this study, and which increases the fragmentation referred to above, should be added. Certain personal idiosyncrasies could also be mentioned, which hinder the continuity of traditional, sober, and suitable language for the common understanding of scientific concepts, laws, and theories.

Yet the core of the current problem in the study of (scientific) knowledge lies, in my view, ultimately in the persistence of that language – the epistemological mainstream of the 20th century – which constructs a social reality for science based on two premises which are extremely deep-rooted in our times: (i) epistemological realism (which affirms the reality of individual subjects) and (ii) methodological individualism. Something, however, seems to change at the beginning of the new century. Science studies pinpointed traditional certainties concerning categories or *a priori* rules as historically contingent; as a result, the philosophical study of science started to burden the metaphysical principle (MP hereinafter) deriving from those two premises (i)-(ii): the naïve principle that individual, intentionally-guided human actors are the makers of science, the producers of knowledge.

Indeed, has it not yet been taken into consideration – at least since the time of Kuhn (1962) – that it is the scientific communities, the collective actors, who have placed the community image of the scientific enterprise at the center of the debate, and who have ended up the old individualism. As I suggest in the following, this type of proposals does not constitute a viable alternative to the traditional mainstream with realist and individualist roots. In those proposals, it is the individual subject of the community of the group in question who ultimately gives rise to cognition, influenced by the community-institutional context. To put it bluntly: in the current mainstream, the social nature of scientific knowledge is confined to the socialization of cognition produced on an individual basis. Is that false? No, but it tells only half of the story. The other half is that which requires not only a modification in the mainstream, but also a change of the mainstream itself which may enable us to establish the fact that (scientific) knowledge – irrespective of the form in which we conceive it – constitutes its world, identifies its aims and objectives, and determines its values and norms. This must not deem acceptance of the MP, i. e., the idea of duly socialized intentions of individual subjects as determining the objectivity in science. How is this possible?

3 The discursive power of scientific social practice

Hacking has proposed a "new analytical instrument" for the philosophy and sociology of science in the study of objectivity: the "reasoning style" (Hacking 1992a, b). Although he retains certain continuity with the proposals for the analysis of scientific thought styles put forward by Fleck (1935), Crombie (1994), and other authors, Hacking nonetheless suggests focusing the study on reasoning styles in the way that object and objectivity standards are shaped in knowledge-production processes. This is a motivated focus because, in his view, reasoning – unlike thinking – is a more public than private activity; and that is why thinking is certainly required in reasoning, but also communicating, arguing, and demonstrating. Taking this analytical instrument as a basis, Hacking situates his project along the same lines as the critical project of Kantian epistemology, but with one notable difference. According to him, Kant considered scientific reason to be a historical result, but not a collective one. Hacking wants to stress the collective aspect (1992a: 4).

Thus, Hacking orients the analysis of the concept of reasoning style towards the objectual constituents and the object and objectivity standards of the discursive power of reasoning styles. Styles produce, when they prevail, extensions of cognitive areas, or new areas. They are, first and foremost, canons of objectivity; a reasoning style is a standard or model about what is reasonable regarding some matter or other. They do not only produce new principles, which were hitherto not possible, but they also delve into the domain of "positivities".

Hacking provides a list of new features, which characterize a specific style. Styles produce new types of objects-evidence sentences, new ways of being a candidate for the truth-or-falsehood laws, and new types of modality-possibility (ibid.: 23). With them, new types of classification and explanation also appear. These new features enable a reasoning style to be defined; they establish a condition deemed necessary to be able to speak of a reasoning style, insofar as each style openly and creatively introduces nearly all such new features of the type referred to above. Each style also introduces a new type of object, and the style therefore is not questionable in terms of the existence of that object or type of object – which is, in fact, possible within the framework of style. Indeed, ontological debates may be interpreted as indicators for the introduction of a new reasoning style.

However, Hacking pays special attention to what Fleck referred to as the tendency of a style to persist. This tendency is not only a constitutive element of the style, but also a more decisive one, which enables us to understand the enigmatic quasi-stability of science. In Hacking's interpretation, this relative stability of science is linked to the introduction of new ways of being a candidate for truth or falsehood through a reasoning style. In other words, the new principles are not found within the range of positivities because they clash with an extratemporal truth and, through that confrontation, attain a value of positive truth. It is rather because reasoning styles give rise to objectivity standards in accordance with which they constitute and enunciate those new positivities, i.e truths-or-falsehoods. Styles are *self-authenticating*, and it is only by virtue of that capacity for self-authentication that principles may be deemed candidates for truth or falsehood (Hacking 1992b). Principles – either true or false – of the type for which enable us to establish the value of truth, irrespective of a specific reasoning style, simply do not exist.

Rather than focusing the analysis on a study of methods and science in general, Hacking proposes researching the self-stabilizing techniques common to each style, based on the notion that reasoning styles build self-authentication strategies. He suggests that we concern ourselves with these techniques, rather than with other epistemic elements which transcend, or are not part of a reasoning style: they are the techniques which enable relative stability and robustness to be associated with new positivities introduced by the style. Taking things even further, they are the self-stabilization techniques, which constitute something like a reasoning style. The analytical tool of the reasoning style thus backs up a historical-epistemological program involving a study of the specific stabilization techniques of scientific knowledge. The self-stabilizing techniques do not become the revealers of objective truth, but rather objectivity standards (Hacking 1992a: 19).

Simple social epistemology? One more turn of the screw in our understanding of how the "social" aspect influences the individual production of knowledge? There is something else in Hacking's proposal than the understanding of how communities of scientists or laboratory cultures affect that production based on the individual subject – something more than drawing attention to how certain social (community, cultural, etc.) actors intervene in the production of knowledge. Hacking's proposal radicalizes the "social" aspect of activity involving community cognition. How is that radicalization expressed within the context of scientific cognition? What does the – doubtlessly ambiguous – expression mean that a reasoning style constitutes objects, ultimately constitutes an independent world? Likewise, is the subject also made up of style? And finally, how does a reasoning style reason, think, and know?

Like other discursive forms the reasoning style is made up of an anonymous, unintentional series of representations – of a performative nature, rather than merely specular representations or reflections of what exists – or signs located in space and time. To reduce this to a mere structure of representations would be equivalent to taking a blind alley. The style is more complex than the representations and signs deemed acceptable within the framework of a social structure. It is a *social* practice or, if one prefers, the *social* use of representations that constitute its objects and the world of which they speak. In this practice, stabilization techniques of style and objectivity standards are also formed – in other words, the conditions for making knowledge possible, expressed in a temporal and specific way. There is no place for intentional action by the individual subject in shaping the reasoning style. In a certain sense, this subject, insofar as it operates at the heart of the style, is made up of that style itself.

As in the explanation of other discursive forms, it is not easy to explain the transformations of reasoning styles, taking into account that styles can only be reduced by other styles, and that each style is self-justifiably closed. How can the style be justified, other than by that style itself? Are objectivity standards justified other than by the previously accepted objectivity standards themselves? Hacking, of course, does not attempt to offer such an explanation in his contributions on reasoning styles. Before him, Fleck had directly tackled this problem in his detailed study of the establishment of the scientific fact of syphilis.

4 The ambiguity of the disenchantment of the individual subject

In the core of Fleck's theory it is explained how change is possible in styles, which channel scientific development, and how styles can be displaced by others (Fleck 1935). To avoid circularity Fleck describes the role of the individual subject's action as a trigger of reference changes that allows one style of thought to be replaced by another. Such a replacement demands to establish elements that explain the displacement of one style by another. These elements are forms of communication between individuals who, generally speaking, take part in different thought collectives. The ambiguity of the role of the scientific individual remains, as shall be seen, unresolved in Fleck's thought collective theory. Yet this opens up a channel for us to reformulate the social dimension of scientific knowledge by considering the decisive function exercised by communication and the "circulation" of ideas in scientific cognition.

The most important contribution of Hacking's proposal is freeing the concept of style – be it thought style or reasoning style – from the psychical foundation, which appeals to the individual's consciousness or intentions. However, this is not the same as adhering to methodological collectivism. This may come as a surprise, as collectivism/holism is considered to be the alternative to methodological individualism and realism based on the principle of exhaustion ("individuals exhaust the social world in that every entity in the social realm is either an individual or a sum of such individuals", Kincaid 1994: 499). It is not a question of reformulating the old individualism/collectivism dichotomy, which was prevalent in the sixties. As I shall try to make plausible in the following section, it is more a question of situating the alternatives in other confrontations, and of replacing the subjects of the old methodological individualism with new "actors", new cognitive units conceived as some type of interaction process.

The methodological individualism affirms the "exhausted" reality made by individual actors in science. It is ubiquitous in the philosophical approaches to science, which make use of social and economic theories of science, such as those of micro-foundation and the rational actor, which reduce the collective to intentional actions by individuals (Hodgson 2007). Structuralist analyses and systemic approaches are also naturally oriented towards individualism (Giddens 1987). Similarly, the metaphysics of the individual subject prevents people, who adhere to communitarian approaches, from taking epistemological consequences (Longino 1994; Kitcher 1994). Kuhn (1962) also adopts the communitarian message, focusing on changes, which take place in the mind of the scientist. Kuhn's scientific individual is not a monadic, sovereign subject, but fits into the social processes and structures described in his theory of scientific change. Yet ultimately, it is the scientist who thinks and knows, although his/her thought is mediated by the paradigmatic context.

If individualism is ubiquitous in Kuhn's conception of scientific development (evolutionary or revolutionary), the individual subject fades in Fleck's thought style, a theory of discourse in terms of the production of facts and experience in science – significantly designated as "thought style and thought collective theory" by its author.

The central subject of science is, in Fleck's eyes, the thought collective, the "carrier" and the leading player in a thought style. Scientific facts are characterized as conceptual relations who are shaped according to thought style. The principles of science are capacities which form concepts and shape thought habits; theories are networks comprising knots of sentences; furthermore, clarity and accuracy in terms of knowledge are always relative to a thought style, in the same way that perceptions also prove to be constructs formed by style. Fleck ultimately characterizes reality as a network in a state of continuous fluctuation; the truth about principles only makes sense within the framework of this changing network (Fleck 1935: 131). In this thought-style theory, the individual subject becomes dissolved in the thought community, the new leading actor of knowledge. Knowledge is no longer conceptualized as an individual process, but rather as developing links of representations within a collective. In his view, knowledge represents the social human activity *par excellence*. Cognitive activity can not be within the individual agency. Fleck defines the thought collective through the concept of thought style. The *thought style* is not a particular manner of assembling concepts, but the specific constraint of seeing and acting in one way rather than another. Scientific facts are dependent on the thought style. All knowledge also bears the mark of a thought style in interaction between the individual, the collective, and scientific fact. The *thought collective is* defined as a community of scientists who maintain intellectual interaction involving the exchange of thoughts and ideas. The collective is not an organization made up of simple individuals – it is the "carrier" for the historical development of a field of thought, as well as for the given stock of knowledge and level of culture, i. e., of a specific thought style. "Knowing" and even "thinking" only make sense in relation to the meaning of the thought collective.

Nor is the collective the mere sum of the individual scientists who comprise it. The relationship between the collective and the individual is expressed by the relationship between the passive and active components of cognitive production. "Knowing" means mainly confirming the results imposed by certain given assumptions. Assumptions respond to *active connections*, and form the part of knowing that belongs to the *collective*. The corresponding results are equivalent to *passive connections,* and form what is perceived as objective reality. The act of affirmation is the contribution of the *individual* (ibid., 16).

However, as it was posited at the end of the previous section, the determinant question concerns the dynamics of thought styles. How can change of thought styles take place, which have been subjected to persistence strategies? How can a new thought style emerge from another? Do bridges exist between styles? How is the history of thought styles supplied with material? Significantly, in order to find an answer to such questions, Fleck identifies an element outside the thought collective and its capacity to shape style. That element is language and the deforming and even neutralizing tendency of meaning common to communication and the circulation of ideas conveyed in that language.

An individual subject does not belong to a single thought collective, but rather to several of them. Fleck thus identifies not only one type of circulation, but two: an intra-collective thought circulation, and another, inter-collective one. Neither of these two types of circulation emerges without transformation and without a remodeling taking place according to the thought style. This is a transformation, which *intra-collectively* translates into reinforcement, and *inter-collectively* into a fundamental change in the thought being conveyed (ibid.: 143).

Thoughts and concepts *circulate* from individual to individual, being modified in the course of circulation, in such a way that other individuals make a type of association, which is distinct from them. Intra-collective circulation thus gives rise to a characteristic stylistic exchange, in which hardly anything of the original content remains. The thought that continues circulating belongs to a collective, not to a specific individual. Knowledge moves within the community, and is polished, reformed, reinforced, or weakened, while at the same time influencing other thoughts and concepts.

In inter-collective thought circulation, on the other hand faces a conflict of thought styles. There is a wide-ranging spectrum of change of thought styles, compared to a small number of persistence tendencies: from small changes in terms of the tone of a style, passing through a complete change in the sense of that style, to the style's total destruction. Lastly, a new thought style may emerge, which finally subverts the existing collective thought construction.

Fleck therefore suggests a social reality of the scientific subject beyond traditional individualism: science is a community enterprise in the public domain. In his approach, the social component is not confined to a mere socialization of the individual's thinking/knowing. He convincingly affirms not only the modeling of individual knowledge via a socio-epistemic entity such as thought style (*weak thesis* regarding the social nature of knowledge), but rather, he also asserts that knowledge of the thought style takes place irrespective of the minds of scientific individuals (*strong thesis*). A thought style constitutes its objects of knowledge, epistemological values and norms, and cognitive assumptions. A thought style *knows* – irrespective of the individuals constrained by it.

Yet this collectivist image is subject to the same criticism, which had been addressed at the main driving force of methodological holism in the field of social theory: Durkheim. Parsons (1968), Giddens (1984), and others have identified the difficulty in explaining that specific entity, which acts on behalf of the collective conscience.

In Fleck's image of science this role is played by the instance, which affirms the results imposed by certain given assumptions. But it is not possible to explain who is the actor acting on behalf of the collective in the formation of these assumptions. The crux of the matter can also be found in the actor network theory, put forward by Callon, Law, and others, unfit to distinguish the individual action within the network – even in its most developed manner of identifying sub-networks within it (Nowotny 1990). Apparently, these collectivist/holist standpoints have to tackle the problem, how to treat the individual subject in a theory which pinpoints a new epistemic subject of a collective nature as central.

5 Epistemic networks as units of knowledge production

Methodological individualism does not manage to observe the autonomous social aspect of science. How can we explain the community nature of science – without risking the negation of individual action? It has already been pointed out that the prevailing epistemological realism affirms the existence of individuals as basic units of knowledge production. Alternatively, collectivism presupposes the existence of supra-individual collective entities – the collective conscience, the thought collective, etc. – as such "primitive" units of knowledge. A "third way" would give equivalent cognitive causal relevance both to the individual and to the collective level (Harré 1981; Jackson/Pettit 1992).

Our proposal situates the social reality of the subject of science beyond these approaches. It is not a question of returning to the dichotomies traditionally associated with the two premises (i) and (ii) of the principle MP, and of opting for the prevailing trends of epistemological realism and methodological individualism or their alternatives, which are equally hardly appealing. It is not a question of gauging the advisability of replacing individual subjects with supra-individual collectives. To start with, identifying the new cognitive unit means reconsidering both the understanding of individuality, and adopting an epistemology, which enables cognitive activity in general – scientific activity in particular – to be conceived as an internal construction of that cognitive unit. This means that three modifications need to be made: first, along Kantian lines, the abandonment of realism and the adoption of a constructivist strategy; second, a move away from the individual construction of the world towards social construction; and, third, identification of the unit of knowledge.[1]

Below, I will apply this strategy to a selective reconstruction of Fleck's historical epistemology, though ontologically deflated., In his realist sociological characterization he defines the thought collective as a community of scientists who maintain intellectual interaction. However, since the social nature of knowledge remains ambiguous, a characterization is problematic. As we have seen above, the assumptions of thought style constitute a response to "active" connections, and are attributed to the collective subject, whereas the confirmation of the results imposed – "passive" connections – are due to the individual. Knowledge ranges between the two subjects – collective and individual – without clarifying the ambiguity of the relationship between an *a priori* regulatory species (the thought style) and the role of the individual scientist. Fleck's relevant contribution is that of freeing the concept of thought style from scientists' individual consciences. However, its weakest aspect is the affirmation of a thought collective based on human actors – among which ideas circulate and is communicated.

The socially-reproductive nature of science only becomes visible if we adopt interactions as basic components of science. In other words: if we conceive knowledge as an essentially interactive process (Hutchins 1995), rather than situated in the mind of scientific individuals. The main problem therefore is to understand the nature of that interaction and to focus

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[1] Hacking (1998) refers to a combination of the first two as "constructionism"; Fleck would, in his view, have been the first author who had a totally "constructionist" conception.

our attention: On the elements of interaction, or on the interaction relationship itself? On the materialization of knowledge, or on what Fleck refers to as thought circulation? On the individual or on the social aspects generated in that circulation?

We shall radicalize Fleck's constructionism by also including individuals. This strategy first attempts to unify what is *a priori* the regulatory aspect (thought style) and the thought collective as a set of individuals who establish intellectual and thought-related communication. The concept of the *epistemic netw*ork favors this unification, freeing historical epistemology from its individual or supra-individual foundations.

We shall characterize the epistemic network in a relational vein (Cassirer 1910), not as a set of coercive norms regarding "seeing and acting in a specific way", but rather as a network of elementary actions which give rise to other actions. The basic elements, which make up the network are not individuals, ideas, or norms, but interactions. To be precise, they are specific forms of communication circulation of the type Fleck referred to as *circulation processes*. They are the constitutive elements of the network.[2] The epistemic network is not constituted by norms or communities of scientists, but rather by circulation processes, i. e., epistemic forms of communication. They are related to each other, forming a network, which simply produces new circulation processes. Science is made up of such circulation networks, each of which acts as guidelines for providing characteristic ways of "seeing the world and acting in it" – because the world is constituted by the networks themselves. The circulation process constitutes its own order and the world of objects in science – what Cassirer refers to as *objectual knowledge*. Individuals are also *constituted* in this process. Individuals obviously exist and create circulation processes; however, we are not referring here to the same scientific subjects which we find in the theories of the "standard view", or in the semanticist, socio-historicist, or cognitive approaches in the philosophy of science, or in science and technology studies: the individual subjects of the thesis of epistemological realism – (i) of the MP.

Does the activity of science involve human subjects, scientists? The answer is yes. Does pragmatic observation of the actions taken by these scientists challenge philosophy of science? Certainly, pragmatism today is a battlefield. A subjectivist dogma is prevailing which reduces Peirce's interpretant to an interpretative component, to a psychological individual (or set of psychological individuals) equipped with intentions (cf. Giere 2004).[3] In my reading of Peirce, however, the understanding of a representant is attained by analyzing all possible interpretations and domains of that representant. I do not claim to defend a contextualist and modal understanding, as opposed to the orthodoxy established in interpreting the pragmatic principle. However, let us recall that:

> "Pragmatism is the principle that every theoretical judgment expressible in a sentence in the indicative mood is a confused form of thought whose only meaning, if it has any, lies in its tendency to enforce a corresponding practical maxim expressible as a conditional sentence having its apodosis in the imperative mood." (Peirce 1903: CP 5.18)

Therefore, the pragmatist principle makes possible another approach to

[2] Although at first glance this claim may be familiar with Luhmann's position in his systems theory of science (cf. Luhmann 1995: 138), there are at least two basic differences between the two views. One difference deals with the resulting images of science (system *vs.* network) and the other with the different scope of the theories that must account for them. Both conceptualizations hardly can be integrated.

[3] Giere captures the activity of representing in the formula "S uses M to represent W for the purpose P".

understanding the significant behaviour of individual agents in scientific action. We can interpret the meanings of consequences as separate products, which may be distinguished from the individuals who have produced them. In this case, the object of the study is no longer that of individuals' purposes, but rather, the internal structures of the products generated.

Furthermore, individuals in epistemic networks differ in terms of an ingenious identification with their status as humans, because of their socially established reality. Individuals in science are not humans equipped with a specific psychic organization and intentions. Just as epistemological obstacles separate the "scientific spirit" of psychology from people who have had no access to science (Bachelard 1935), so do human actors in our interaction approach also have a dual identity. Individual actors from the network are constructs in the circulation processes that *socially* constitute the world of science. This constitution is clearly separated from the reality created "solipsistically" by individuals. Both forms of constitution (social/objective and subjective) are juxtaposed, although the actions leading to such constitution processes are not. Individuals are necessary in order to create circulation processes. Thus, we can attribute to individuals a role in the circulation and talk about subjects, i. e. they are necessary for forming the community of circulation processes. However, intentions and the psychical organization of individuals no longer enter into these processes. The same could be said of collective subjects.

The conspicuous function of the interactive circulation process is to organize the *immersion* of subjects – individuals and collectives – in the social (objective) constitution of the world. The immersive experience is an open interactive practice. The communication of thoughts and concepts requires, – which, in Fleck's view, a continuous modification of these "from individual to individual", in order to avoid closing the circulation system. This can be accomplished by recursive application of epistemic skills. The development of these skills in the interactive circulation process makes sense in the context of three differing components which we refer to as the "style" of the network: intervention on the part of the subject in interactions, the material content of circulation systems, and the interpretation of that content.

Circulation networks are not systems or subsystems but link agents (or nodes) in a loose coupling manner. These networks function as loose structures within them coexist strong and weak ties (circulations) between nodes. The character of lax structure favors the role of individual agency and, therefore, allows a variety of modes of agent's intervention that set up the style of the network. That style is also shaped by the content of the circulation processes that can be very different: models, concepts, lab results, …. The interpretation of that content is given by the type of circulation: there is no one single source of content production (such as science and its institutions) but multiple sources that generate asymmetrical circulation processes.

How can the structural change in – or of – epistemic networks be explained? It has already been stated that networks are self-validated units. Neither the invocation of superior "subjects" nor an appeal to the relativism of our cultural networks would seem to be suitable strategies for explaining the change. I shall merely point to another possibility. Although it has not been dealt with here, it would be a mistake to think that epistemic networks only comprise privileged collective actors – the communities of scientists. In our societies, science is a public activity, which is extraordinarily productive for innovation and social change. Yet, in the current situation of uncertainty and risk, science cannot claim to monopolize epistemic authority fully (Bechmann 2009). Collective actors, such as associations, trade unions, companies, and political institutions, etc., generate their own capacities for producing knowledge which are incorporated into epistemic networks – at times, to oppose results that have previously been obtained in them.

This gives rise to hybrid epistemic networks with heterogeneous actors who, on the other hand, form part of other networks. Coalitions of new circulation processes are thus outlined, both between scientific networks and between these and other forms of social discourse. This fragmentation cancels out the claim of the centrality of a single epistemic network for society as a whole. In accordance with the proposal put forward by Hacking, the study of the production of scientific objectivity thus could be a solution for philosophy and sociology of science, owing to the existence of multiple networks. Yet, in addition to analyzing the sanctioning and validation of the knowledge produced, the new challenge in the study of (scientific) knowledge also involves analyzing the *reliability* of cognitive production (Goldman 2003). To a certain extent, a constructivist approach makes it possible to face this challenge reasonably. If the different epistemic reticular organizations produce equally objective knowledge within different contexts, and there is no need to resort to authorities in order to assess or settle the dispute, analysis may focus its attention on the procedural elements of the flow of circulation networks, i. e. on those related to intervention, content, and interpretation. The explanation of assumptions, content, and consequences, which constitute the world of action in the epistemic network, may be accessed through them.

6 Conclusion

The issue of the subject of science remained veiled throughout the past century in the mainstream of the philosophical study of science. Scientific objectivity was an undeniable fact of science, which could be identified via logical-methodological channels and means, which could be adapted to the diverse reality of science. When the study of science is forced to introduce a social reality for science, it can nonetheless not be immunized against the reality produced by other types of discourse sustained under the prevailing premises of the epistemological realism of humans and methodological individualism. Thus, the attempt to produce in the philosophical study of science a collective image of science has been exposed to the interference caused by those premises in well-known theories of social science, economics, and sociology in particular. Despite this, the trivialization, which has undergone the analyses of these theories – above all, in Anglo-Saxon philosophy – has torn to shreds attempts to offer attractive philosophical images of the scientific collective enterprise, and of how it socially constitutes its world.

So what can we learn after half a century of the philosophical study of science? Without doubt, the introduction of subjects has proved a success in recent decades, and has influenced philosophical practice. However, the expectations of a community image of science, it has given rise to – at least since Kuhn (1962) –, have been dashed; one criterion: few sociologists would currently follow philosophers in their attempts to identify "collective subjects" of science from pre-scientific images of the prevailing human agents in philosophy.

Some authors advocate the construction of a new mainstream in the study of science. In this paper, we have situated the social reality of the subject of science in collectivity, in a network organized as a nexus of identity and action. We conclude that the community organization of science is not made up of human beings who act via intentional actions, but rather by networks of interactive processes – namely, by circulation processes of communication, which constitute the network. These networks are units of knowledge, which know and constitute their objects and their own social reality. This differs from the manner in which their members know and constitute theirs. The social constitution of science is coupled with that of the psychical constitution of its members. However, these are essentially different forms of constitution created through basically different actions. The actions of the network cannot be confined to the individual actions of its members.

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