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Nanomedicine and Space: Discursive Orders of Mediating Innovations

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Abstract. This paper examines from the perspective of discourse analysis the rhetoric of negotiation in the area of nanomedicine and compares it to the debate on genetic engineering. The following questions will be raised: what kind of symbolic space is generated by the negotiations and what role does this space play in determining the possibilities for communication regarding future nanotechnological innovations? For example, which position does the vision of the nanobot inhabit in the discourses of negotiation? Does the nanobot represent a discursive interface between the concepts of technological miniaturization and hybridization of nature and technology?

Introduction[1]

Institutions designed to support and negotiate new technologies present nanotechnology as the quintessential future technology of the 21st century. If we turn to the rhetoric used to negotiate the innovative potential of nanotechnological procedures in medicine, we happen upon the following strategy of discourse: nanotechnological developments in medicine are placed in a continuum with microtechnological innovations in minimal-invasive surgery. That means that developments in nanomedicine are negotiated like progressive miniaturizations and specifications of technical instruments in surgery.

To describe the requirements of *microsystems technology*, the joint internet presentation of the *German Federal Ministry for Education and Research* (BMBF) and the *Association of German Engineers* (VDI) uses the example of neurosurgery as follows:

> What is microsystems technology? It is as if you are standing outside the front door wanting to sew a button on a duvet in the bedroom by inserting tweezers through the keyhole. In addition, imagine the rooms full of furniture, around which you have to maneuver the tweezers. And be careful not to knock anything over!

The presentation continues that the difficulties arising on such "journeys through man's inner world" are not only "a topic in media visions" of the future. They are also "the starting point for current real problems in the development of new technologies". All solutions "to improve existing instruments, ranging from active endoscopes to models of autonomous mini-robots, which not only can observe and measure but also perform surgery" rely on "miniaturization and built-in intelligence", that is, "they depend on microsystems technology" (VDI/VDE/IT 2004).[2]

The German Ministry of Research assigns microsystems technology great significance for the future and notes its relevance for a very wide range of technological fields like communications technology, automotive technology, building services engineering, environmental technology as well as biomedical technology. In addition, the report continues, microsystems technology is important due to its character as a cross-sectional technology, since it unites the findings from a multitude of manufacturing and process technologies with information technology and bio-technology (BMBF 2000, pp. 16-29). The VDI expects that in the future a radical, innovative thrust will come from *nanotechnology* – that is, from a nanosystems technology that is expected to exceed by far all innovative developments from microsystems technology. Only through nanotechnology has it become possible to access a "scale [...] 1000 times smaller than the building elements in the micrometer sphere". This new dimension has become accessible "both by application of physical instruments and procedures and by further diminution of current microsystems as well as by using structures in animated and non-animated nature as models for the self-organizing *construction* of matter" (VDI-Nanotechnologie 2004).

According to these descriptions, nanotechnology is not only a matter of reducing the size of microtechnology. Aside from the emphasis placed on continuous 'reduction', we also find that a second aspect is emphasized, which is supposed to be specific in comparison to microsystems technology, namely the 'self-organizing construction of matter'. Giving prominence to this characteristic allows nanotechnology to be differentiated from the tradition of continuous microtechnological miniaturization. Thereby a break is marked. Nanotechnology is expected to place this mark in the sense of a 'radical' innovation within the incremental developments of medical technologies.

Presentations describing the specific characteristics of nanotechnology – as they are found in less recent specialist literature and textbooks – differentiate between two approaches: first there is a physical, technically oriented *top-down approach* that involves molding, carving and fabricating small structures 'from the top down'. This approach aims at defining small structures down to the atomic scale (0.1 nm). Next to that is a chemical, bio-molecular-oriented *bottom-up* approach that manipulates molecular and atomic components to build up structures 'from below' to arrive at the nanometric scale (Köhler 2001, pp. 1-14). In contrast, presentations in more recent literature and textbooks, place emphasis on the *hybridization* of the top-down and bottom-up approaches (that is, on combining the concepts of technological miniaturization with the self-organizing construction of matter). Today, according to a current textbook on nanotechnology, "nanosystems technology's" crucial potential lies in combining these two approaches – the technical miniaturization of existing microtechnology and the bio-molecular creation of nanostructures. According to that textbook, microsystems technology has focused until now on the top-down approach, but

> the dominant position of classical physical principles is being overcome by nanotech's arrival at atomic and molecular dimensions. Physical and chemical aspects [are becoming] equally significant factors of influence in the production and implementation of nanotechnological structures. [...] Because nature [is] not only a role model [...] for the construction of large molecules, but also makes technically interesting tools available, [...] bio-chemistry and molecular biology have taken up an important position in nanotechnology. (Köhler 2001, p. 2)

The VDI projects that by "using natural processes of self-organization" the difference between technical instruments and bio-molecular processes will be cancelled out (VDI-Nanotechnologie 2004).

In these examples of negotiation, a dual rhetoric is evident. Talk of the *miniaturization* of micro-technical instruments is one of the discursive strategies. Opposed to this is the talk of a *hybridization* of nature and technology, that is, of physical-technical instruments and chemical-bio-molecular processes. In the following sections it will be asked whether the simultaneity of these two discourses is also suggestive of their equal status in negotiating innovations. Which forms of rhetoric are applied specifically to the negotiation of nanotechnological innovations in medicine? I propose the thesis that in the presentations of nanomedical innovations, talk of hybridization is largely excluded.

1. Theoretical Approaches

In older technology debates – for example, in the debate on genetic engineering – the constitutive significance of discourses of negotiation became obvious for scientific and technological developments as well as for their socio-cultural implementation. Discourses of negotiation take place between politics, science, business, the media and the general public. They open up a symbolic *space of possibilities*. Inside the boundaries of this space it becomes possible to articulate and communicate technological – including nanotechnological – innovations. In this discursive space, plausibility and evidence are produced, which determine the way an innovation is accepted and implemented (Lösch 2001, pp. 34-38). In the following case studies, the rhetoric of negotiation in the debate on genetic engineering will be compared to the rhetoric of negotiation of nanomedical innovations. The studies are informed by the following theoretical approaches:

In the first place, I will be looking at the empirical field from the perspective of discourse analysis. This approach is oriented toward Michel Foucault's concept of discourse (Foucault 1972, Lösch *et al.* 2001). My objects of study are regularities and similarities in statements of varying origin – for instance, statements taken from the context of research, business and the mass media. I will investigate the common orders of the statements articulated in the processes of communication concerning nanomedical innovations conducted between the spheres of research, business and the media.[3]

Since this inquiry is concerned with processes of communication that produce meaning for that which is the novelty of nanotechnology, it is necessary to incorporate innovation theories such as are discussed in the area of sociology of science and technology (for example, Bijker 1995, Brown *et al.* 2000, Dierkes *et al.* 1996). The question regarding the possibility of the new has always been and continues to be raised in the areas of philosophy, in the social sciences and in cultural studies (for example, Groys 1999, Blumenberg 1996). With hindsight we can often describe the implementation of a new technology as an innovation, as a sort of recombination of 'old', tried and trusted elements, or as the transfer of concepts from one discursive context to a new context (for example, from the scientific arena to popular culture and vice versa; see Maasen *et al.* 1995, Schulz-Schaeffer 2002, Morgan *et al.* 1999). From the perspective of the sociology of knowledge, meaning for the 'new' and thus 'foreign' is produced by recourse to trusted forms of representation. This meaning arises through the reciprocal communication processes between various actors, discourses, or systems. Metaphors and images play a decisive role in the mediation and negotiation of innovations. They serve as the media of communication (for example, Bono 1990, Martin 1982, Heintz *et al.* 2001): that which is new and unfamiliar becomes communicable through the re-combination of culturally habituated concepts of nature and technology, of space and time in the representations that are used in the mediation and negotiation process.

For negotiation of innovations in the medical world, space-related metaphors (like trips through the body or body cartographies) appear to be central. They are referring to the boundaries between internal/external world, between body/environment or micro-/macrocosm. These boundaries themselves are culturally assumed to be obvious. Linking up to trusted perceptions of space seems to be an important condition for meaningfully negotiating innovations or for producing sociotechnical evidence in the medical arena (see, for example, Jones 2000, Orland 2003, Gilbert *et al.* 1996).[4] Regardless of this connection to trusted concepts, metaphorical and visual representations of nanomedicine can lead to a transformation of the perceptions of nature and technology that are typically for medical discourses. Visual images – for example, of so-called 'nanobots' – irritate the habituated perceptions of spaces within the body and of body boundaries whenever, for example, medical instruments are portrayed as spaceships within the body.

According to Bruno Latour's model of a two-fold "constitution of modernity", practices of separation ("cleaning") bring about the transformations that make it possible to both connect and break with the 'old' when negotiating innovations ("translation"; Latour 1995, pp. 22-67). An example of such a practice of cleaning is the rhetorical differentiation between the physical, technological top-down approach and the chemical, bio-molecular bottom-up approach. In the debates on genetic engineering at the end of the 1980s, to name a further example, the differentiation between genome analysis that 'discovers' nature and genetic engineering that 'constructs' nature played the dominant role. For political and judicial assessments as well as for the social implementation of new technologies in medicine, it is decisive whether these technologies are portrayed as a means of intervention in nature (in terms of medical diagnosis and therapy) or as a technological construction of nature (in terms of engineering designs). But it appears to be impossible to communicate new technologies in medicine as hybrids of nature and technology.

2. The Simultaneity of two Discursive Orders

From the viewpoint of discourse analysis, the two rhetorics of negotiating nanotechnological innovations are based on two simultaneous orders of discourse which served as the foundation of previous technology debates in the 20th century. Talk of nanotechnology as 'miniaturization' can be assigned to the discursive order of the progressive mechanization of human and non-human nature. For this order of discourse, the semantic dichotomy between nature and technology (that is, between the natural and the artificial) is seminal. Talk of the 'self-organizing construction of matter' through nanotechnology can be assigned to a discursive order of hybridization of nature and technology. This order of discourse is based on the semantics of dissolving the difference between technological intervention and biological evolution.[5]

However, their simultaneity does not imply that both orders of discourse are of equal status within the rhetoric of negotiating innovations. Instead, I will demonstrate in the following that the process of negotiating nanotechnological innovations in medicine is dominated by talk of miniaturization (that is, by the discursive order based on the separation of nature and technology). Only when nanomedical innovations are portrayed as a miniaturization of minimally invasive surgical procedures does it become possible to couple the technological discovery with familiar representations and modes of perceiving medicine. Intervening in inner bodily spaces using technical tools is among the most important images in the field of surgery.

The production of evidence for the 'new' requires, however, not only a link to already existent, familiar elements, but also the transformation of these elements in order to differentiate between 'old' and 'new'. This would be the appropriate point of entry for talk of 'the self-organizing construction of matter'. When negotiating nanomedical innovations, however, this discourse seems to remain in the background.

3. Orders of Discourse in the Debates on Genetic Engineering

In the debates on genetic engineering – more precisely, in the debates concerning human genetics – an order of discourse distinguishing nature from technology has prevailed over a discursive order of hybridization (Lösch 2001, pp. 81-161). From the viewpoint of the hybridization discourse, genetic engineering functions just like nature. In the debates on the political, judicial and social regulations of biotechnological applications in human medicine, a difference is made between 'genetic nature' and 'genetic technology'.[6] A distinction is made between techniques based on 'knowledge' of nature and others that construct nature. For example, in the debates on the prospects and risks involved in the Human Genome Project of the European Union, genetic analysis and genetic diagnostics were assessed as fundamentally different from the biotechnological interventions employed in gene therapy. Biotechnological interventions were then divided into two types: those carrying out therapeutic repairs on humans, and those using technology to shape a person's nature prior to his or her birth. Corresponding to this distinction, therapeutic interventions like somatic gene therapy were judged much differently than, for example, so-called germ line therapy. Today, adult stem-cell research is evaluated differently than research on so-called embryonic stem cells (Lösch 2001, pp. 155-161, 233-236).

As viewed from the perspective of discourse analysis, a long-term criterion of assessment is provided by the distinction between diagnostic analysis or therapeutic repair of a 'gene's nature', on the one hand, and the construction of a 'gene's nature' by applying the principles of engineering, one the other.

Space-related metaphors play a decisive role in such substantiated differentiation (Lösch 2003). During the process of negotiating biotechnological innovations, the portrayal of the Human Genome Project as a cartographic procedure was given the main function of endowing meaning (for example, Haraway 1997, Kay 2000). The cartographic descriptions support the dichotomy between knowledge or repair of 'genomic nature' on the one hand, and fundamental technological construction of 'genomic nature' on the other hand. In research programs, medical advice pamphlets, or news reports, images that directly relate the maps of the laboratory to familiar territorial maps have often been used to negotiate the meaning of genome analysis.

A German pamphlet with information on human genetics portrayed the goal of the genome project as making a complex book of very detailed maps of the human genome. It created evidence for this by comparing territorial maps with gene maps, a world map with a cell, a national map with a chromosome, a city map with a genetically mapped DNA segment, the map of a city district with a physically mapped DNA sequence, and a building's room number with a specific part of a DNA sequence. All the maps appear as partial representations of the human genetic landscape, and the comparison allows the genome project's results to resemble a world atlas (for example, Schmidtke 1997, p. 256). The comparison of laboratory maps with maps of the earth's surface allows for the negotiation of the genome project as a continuous, increasingly detailed process of exploration of natural landscapes and ever smaller regions within the human body. What is ultimately found is a specific section of an isolated DNA sequence that has the appearance of describing the location of a specific gene (see Lösch 2003, p. 10).[7]

Gene technologies that do not allow for the cartography metaphor are differentiated and assessed according to the nature-technology dichotomy, thereby excluding the notion of the hybridization of nature and technology. Somatic gene therapy thus appears like a medical means of doing repair-work at a specific site on a genome. Germ line therapies would fully re-design the cartographically recorded 'nature of man' from the bottom up. They would therefore appear like the opposite of cartographic exploration, namely as if they could construct nature on the basis of engineering principles.

4. Nanotechnological Miniaturization

In the negotiation of nanotechnological developments in medicine, the rhetoric of miniaturization dominates. As in the debates on biotechnology, this rhetoric rests on the nature-technology dichotomy. The essential medium for the production of evidence appears to be images of long-term future visions of nanomedicine in the form of so-called nanobots. Whenever, for instance, the news media, investment brochures, or specialist medical journals feature reports discussing the opportunities and risks associated with nanomedical developments, existing innovations (for instance, nano carrier systems or drug delivery technology) are often portrayed as "partial solutions" along the way to developing "self-sufficient" and "intelligent" surgical systems, that is, nanobots (for example, Jordan 2001, pp. 1074-1077; Morris 2001; Haas 2003, p. 28). As a current investment brochure regarding nanotechnology concedes, the application of "self-sufficient" nanobots capable of working in the blood vessels or of nanobots capable of "independently" adjusting to their assignments still belongs to the realm of science fiction; but the vision itself nonetheless has a great significance in that it indicates the direction in which nanotechnological development in medicine will take (Beckmann *et al.* 2002, pp. 65-66).

> At first glance the overall impression is that nanotechnology merely conveys visions [...], for instance, the 'nanorobots' or other endovascular *devices* especially for applications in medicine [...] but they appear more concrete when you look more closely and concentrate on the partial solutions and production approaches, which are already being implemented, *e.g.*, using the nanoparticles and nano carrier systems. (Jordan 2001, p. 1080)

In his contribution to the specialist medical journal *Der Onkologe* the biologist and physician Andreas Jordan reports about recent successes in treating brain tumors using ultra-small supermagnetic iron oxides (USPIO) and an external alternating magnetic field. Accompanying the text is an illustration of a nanobot maneuvering itself to locate and destroy the body's cancer cells using laser beams (Jordan 2004, p. 1074). The picture, which is located in the "Nanomedicine Art Gallery" on the homepage of the US-American *Foresight Institute* in Palo Alto, CA, is captioned as a futuristic vision of a nano carrier system (Freitas 2004). News articles also feature fictional pictures of nanobots. An example may be found in the newspaper *Frankfurter Rundschau*, where a journalist reports on the success achieved with nanoparticles in cancer therapy. The article includes an illustration of a nanobot removing debris from the arteries (Haas 2003, p. 28).

As much as the nanobots in specialist journals differ from those appearing in the newspapers, all these visions portray the nanobot as a technological instrument in the body's inner regions. In Jordan's article, for example, the nanobot resembles a space ship and in the *Frankfurter Rundschau* the nanobot looks like an excavator and industrial-size vacuum cleaner. Both hardly resemble surgical instruments, but by means of their form they indicate the dichotomy between natural space and the intervening instrument. Through such visual representations nanomedicine is negotiated and mediated as a process of miniaturization and refinement of technical instruments with which surgical interventions in the body become possible. The use of these technologies is metaphorically described as a "journey into the nanoworld" or as a "dive down into the human body" (for example, Krägenow 2002, pp. 164-165). In line with this discursive order of negotiation, future nanosystems appear as mere miniaturizations of microsystems such as the recently developed microtechnological capsule endoscope. This endoscope is a sort of "video pill". Equipped with a tiny monitor, it is expected to enable a more extensive examination of the intestinal tract of patients (for example, Krägenow 2002, pp. 164-165; CNN 2000; Wired 2000). According to this rhetoric, then, nano systems would mean a miniaturization of the video pill, so that in the future they could be sent not only through the intestinal tract but also through the blood vessels.

In the debates on genetic engineering, genetic cartography served as the main metaphorical description to suggest a form of ever more detailed knowledge of natural landscapes. Likewise, nanomedicine is represented as an ever more precise intervention in ever tinier spaces within the human body using ever smaller technical instruments. This is the prevailing order of discourse when negotiating the medical significance of nanotechnology.

It cannot be claimed that talk of the 'self-organizing construction of matter' has the same status.

5. Nanotechnological Hybridization

In some publications that are comparable to those portraying the nanobot as a long-term vision for a continuous miniaturization of microsystems, the original idea of the nanobot is attributed to the visions of Eric Drexler, one of nanotechnology's founding fathers (for example, Haas 2003, p. 29; Malinowski *et al.* 2001). When viewed from the perspective of discourse analysis, the 'figure' of the nanobot is doubled: the nanobot, which is portrayed as a miniature version of a surgical instrument, is being extended by the concept of the nanobot as self-organizing material.

In *Engines of Creation* (1982) and *Nanosystems* (1992) the "nanotech pope" Eric Drexler is said to have envisioned building small systems – so-called assemblers – directly at the atomic level. These systems would subsequently be able to self-replicate and create other materials or machines by combining atoms. The image is that of an assembler being built or building itself on a level at which physical, technological processes coincide with chemical, bio-molecular processes. The assembler is expected to function like nature, that is, to have the ability to organize itself and to self-replicate (for example, Beckmann *et al.* 2002, pp. 27-30; Jordan 2001, pp. 1073-1074; Haas 2003, p. 29).

This second nanobot concept can be classified as belonging to the discursive order of a hybridization of nature and technology. This concept does not, however, seem compatible with the body concepts currently dominant in medicine, thereby making it unsuitable for the negotiation and mediation of innovations. The nanobot visions attributed to Drexler are thus considered to be completely unrealistic. Realistic research and technology development should be carefully differentiated from them (for example, Haas 2003, p. 29; Beckmann *et al.* 2002, pp. 15-30; Meißner 2000; Pantle 2000). This act of differentiation must be viewed as a 'cleaning' strategy, considering the fact that similar statements made in other places are structured according to the discursive order of hybridization. These might concern the nanotechnological production of materials that are acceptable to the body.

To mention an example, we may look at the reports on the development by NASA researchers of a self-growing band-aid. The band-aid consists of nanostructures that replicate themselves on the model of nature (for example, Hörrlein 2003, Pfaff 2003). The replication of nanostructures seems to function according to the principle of self-developing assemblers. When considered with respect to their principles of function, *NASA*'s externally applied band-aids can hardly be distinguished from nanobots that correspond to the second conception, namely nanobots that are expected to be used on accident victims with "heavy inner bleeding" in order to support the body's own system of wound contraction or – once they have located a wound from *within* – to "incorporate themselves like a plug" (Beckmann *et al.* 2002, p. 67).

These and similar possibilities for representing nature-technology hybrids continue to be excluded from the future-oriented process of negotiating innovations in the area of nanomedicine.

6. Conclusion

In section 1, I delineated theoretical approaches for a discourse analysis of the dynamics of metaphors and images in processes of negotiating innovations. Viewed from this perspective, sociotechnical evidence for the 'new' can only be produced through linkage to familiar notions – either by recombining elements of knowledge or by transferring concepts. For this it is necessary to assume that these combinations and transferals are founded upon orders of discourse and semantics that dominate perception in the respective areas of science or technology. In the area of nanomedicine it has been shown that processes of negotiating innovations are organized along the lines of a semantic distinction between nature and technology or body and environment, which corresponds to culturally habituated, space-related bodily perceptions.

Images that present nanotechnological innovations in medicine as the progressive miniaturization of technical instruments for the reconnaissance and repair of very small spaces in the body, seem to dominate in the negotiation of innovations because they are able to connect with familiar perceptions in modern medicine (especially in surgery) and thereby produce evidence. Even today, medicine is understood to consist in the diagnosis and therapy of a naturally existing entity and hardly as a new construction according to the bottom-up approach of basic engineering. Here, the nanotechnological top-down perspective functions as a rhetorical figure. If we look comparatively at how innovations are negotiated in other areas of microsystems technology and nanotechnology, such as in materials technology or the auto industry, we might assume that here, too, an order of discourse that differentiates between nature and technology should dominate. As it turns out, however, the rhetoric of the bottom-up approach here appears to be producing the sociotechnical evidence. The obvious choice, then, in this case, is to connect this semantically to the tradition of basic engineering in construction work. When negotiating innovations in medicine as well as in the engineering sciences, the discursive order of the hybridization of nature and technology (for example, of the self-organizing construction of matter) is never central. Hybrids are emphasized only when nanotechnology is to be distinguished as a special or 'radical' innovation from the innovations in microsystems technology.

This first analysis of discursive orders in the negotiation of innovations has primarily indicated the points of connection with old and familiar forms of representation and the culturally habituated ways of perceiving. In order to investigate more completely the symbolic space of possibilities in which nanotechnological innovations become able to be articulated and communicated, the question must be raised as to whether the perspectival representations of technological innovations on various levels of negotiation – for instance, among research institutes, business firms and the mass media – result in a modified semantics of representation. Should we expect the portrayal of innovative nanotechnology to be modified by the integration of discursive orders from other technological fields? Do cross-sectional technologies like nanotechnology enable or even demand a hybridization and a recoding of transmitted, culturally habituated, medical and surgical as well as engineering concepts of nature and technology? At which points in the combination of various concepts and discursive orders can we observe 'discursive innovations'?

Notes

1 This paper is based on preliminary studies and first results of a project sponsored by the *German Research Foundation* (DFG). The project's title is "Spaces of Biomedical Microsystems Technology. A Case Study in the Sociology of Knowledge on the Negotiation and Mediation of Technological Innovations". The project and this paper are based on empirical material that consists mostly of German-language publications. My claim that the rhetoric of negotiation plays a significant role in the creation of a space that allows for the communication about nanotechnology in international publications is supported by preliminary work in the field of science and technology studies (for example, Fogelberg & Glimell 2003).

2 The quotes from German sources have been translated by A. Heede.

3 Inner-scientific forms of knowledge, procedure and communication – typical subjects of current social studies of science and of sociological laboratory studies – will not be examined in this project. Here, the objects of examination are interdiscursive interfaces or hybrid platforms of reciprocal communication among the arenas of the research lab, business and the mass media.

4 According to the historian of technology David Gugerli, "sociotechnical evidence" is generated from the specific combination of visualization techniques, pictures, and culturally cemented rules of attention in medicine (Gugerli 1999).

5 The 'classic' nature-technology dichotomy of the first order of discourse frequently functioned in modern history since the 19th century as a strategy of discourse for political and societal assessments of technological developments. These developments made the differentiation between naturalness and artificiality appear questionable in the wake of the Industrial Revolution (see, for example, Latour 1995; Foucault 1970). The second discursive order established itself in the middle of the 20th century with the rise of cybernetics, systems theory and information technology. This order of discourse is also found in certain debates on genetic engineering or concerning the immune system and bionics (for example, Haraway 1991; Hayles 1999).

6 This differentiation is not obvious. In the labs devoted to genetic engineering, unlike in the political sphere, such a differentiation does not exist. With "genetic engineering the central 'technological' entities, the tools of manipulation of a molecular-biological undertaking, even molecular tools themselves, [...] are qualitatively no longer distinguishable from the processes with which they interfere. The scissors and needles, with which genes are cut and spliced, as well as the carrier used to transport the genes, are themselves macromolecules" (Rheinberger 1997, p. 275).

7 In the laboratory, cartographic methods cannot be equated with making a world atlas. The maps in the lab serve as instruments which, when overlapped, enable investigation into such relationships as those between genetic characteristics on a chromosome and the molecular biological information of DNA sequences. Here the maps do not represent an enlargement in scale; rather, they represent maps with varying functions (*see* Lösch 2003).

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