Ingeborg Reichle

ART IN THE AGE OF TECHNOSCIENCE

Genetic Engineering, Robotics, and Artificial Life in Contemporary Art

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Art in the Age of Technoscience: Transgressing the Boundaries

The relationship between the arts and the sciences has always been both productive and characterized by tensions. There is a long history of narratives that detect a fundamental and unbridgeable divide between art and science, and an equally long history of narratives that never tire of emphasizing their consonance. For centuries art and science existed in a close relationship; it was only with the advent of modern science that the two began to grow apart. Today, in the age of technoscience, the closely guarded demarcation line between the two domains appears to be shifting again. Transgressions are taking place; however, this is not a sudden development—indeed, the signs were apparent throughout the entire twentieth century.

The last thirty years have seen increasing collaboration between artists and scientists and the reasons for this are complex and varied. One important factor is certainly the fact that technology and science have become fundamental to our modern societies. In just a few decades the effects of the ongoing technization of daily life has come to be felt in virtually all domains of life. This development has also had profound effects on the fine arts: in the 1980s a few artists started to make incursions into dedicated science contexts, such as molecular biology laboratories. At first these were isolated instances and often undertaken in ignorance of other projects by artists working in the same direction. However, over time an increasing number of artists began to work with methods and practices from fields such as genetic engineering, tissue culture, or artificial life technology, and thus these became accepted means of artistic expression.

Today there is hardly any medium, technology, or material that has not been used by artists. Many art movements attempt to intervene in social processes with subversive actions, and rarely ever reach for paint and brushes. Throughout the twentieth century, artists repeatedly posed questions about the contextuality of art and its reception. Examples are Marcel Duchamp's ready-mades and the forms of expression introduced by Dada, Bauhaus, and the Futurists to deride bourgeois reception of art or to undermine art's auraticizing role. In the 1960s and 1970s there was a widespread impulse to turn away from traditional art genres, to try out new materials and create a new repertoire of forms of expression. As the understanding of artistic materials changed, so too the position, or the relationship of the observer to the artwork changed as well for the active role of the observer has to be constantly reconstituted, including through new forms in which art is communicated. The art context in which art traditionally operated was called into question by experiments that dissolved boundaries. An almost unmanageable abundance of extensions of content and form proliferated in which multimedia, performance, happenings, interactivity, and open working situations became established as legitimate genres or modes of production. This resulted in an expanded concept of art, which ran counter to artistic positions that postulated a kind of essential nucleus of art; instead, this concept saw art more as a channel of distribution which offered the possibility to communicate certain content that was not defined a priori as artistic, but served general epistemological interest.

Artists' interest in new scientific approaches and new materials, though, was not a one-sided affair. While artists sought access to science institutions, these began to seek cooperation with artists or began to exhibit their highly impressive images in art contexts to present them to a broader public. In recent years pictures by artists have been exhibited alongside images that originated in science and were created using scientific methods and imaging techniques. At such shows, to know which exhibit was being presented as an "artwork" and which was a component of a scientific process, usually the only possibility was to read the accompanying text on the gallery wall or study the exhibition catalog. Artists have made use of science's visualization techniques for many years, not least with the objective of endowing their work with contemporary relevance. What is new, however, is that science institutions, like the German Max Planck Society or the American National Science Foundation, enhance their Websites with projects like "the picture of the month" or "the pictures of the week," and that a prestigious journal like the American magazine *Science* runs a competition with the title "Visualization Challenge" for science images, thus utilizing strategies to attract attention that were hitherto more associated with art.

The New Landscape

That scientific images are taken out of their original contexts and introduced into an art-related context is not a new phenomenon. One of the first exhibitions after World War II. in which pictures with origins in science were presented in the form of an art exhibition took place at the Massachusetts Institute of Technology in 1946. *The New Landscape (in Art and Science)* exhibition was initiated by György Kepes (1906–2001), who was then professor for visual design at MIT. Kepes sought to bring art, science, and technology together in a combined program for design. In his view, the idioms of contemporary media, such as photography, film, and television, had all contributed to establishing a language that was universally and internationally comprehensible. Because of his background with the Bauhaus and constructivism, Kepes was greatly interested in integrating the visual arts into the visual idioms of everyday life, mediated by the vocabulary of design and architecture. His position gave him the opportunity to pursue his idea of a universal vocabulary of forms in interdisciplinary working groups, which at the time were being formed at MIT. The interdisciplinary structure of these projects awakened Kepes' interest in investigating the intrinsic relationships between art, science, and technology.

In contrast to the conventional wisdom of the time—art and science are self-contained entities that cannot be mixed—Kepes was convinced that a relationship exists between them that is mediated via a common visual language, and that this relationship between art and science would become stronger through exchange of ideas and mutual contact. The perception of the surficial world that is accessible to people through the faculties of seeing, hearing, and feeling would come into contact with the hidden world that is revealed by scientific instruments: if one were to see these spheres together, then aerial views of river estuaries and road networks, feathers, ferns, blood vessels and arteries, neural ganglia, electron micrographs of crystals, and the tree-like patterns of electrical discharges seem related although they differ in location, origin, and scale. Kepes was of the opinion that the similarity of their forms was not a coincidence. As examples of the concentration and distribution of energy, for him they were similar graphs formed by similar processes.[1] In his writings he returned time and again to the notion that the form language of nature constitutes a common foundation upon which art and science can understand one another. If the task of art and science is to intervene in human experience by imposing an ordering structure upon it, then it should also be possible for art and science to reestablish balance in society, or at least make a contribution to this endeavor. Kepes pointed out that so-called image-making devices are also something art and science have in common; such devices are necessary to transfer ordering elements of experience into the realm of the visible.[2] For Kepes the many correspondences between certain paintings and photographs and the images of art and science were not coincidental; correspondences that were revealed thanks to the new optical technologies of his time, such as infrared and ultraviolet rays, microscopic and telescopic photography, x-ray and other techniques utilizing rays.

The connection between art and science was for Kepes a common quest for patterns, structures, harmonies, and—in all the order exhibited by natural phenomena—even a discernable disorder. These technologies, which had been developing since the nineteenth century, showed a completely new picture of the order of nature, which up to that point had not been visible to the human eye. Through these new media the new images represented an expansion of the horizons of perception; indeed, they opened up a new sphere of sense perception.[3]

In his writings Kepes endeavored to provide a theoretical framework for his ideas about the structure of the visual analogies that he believed to have recognized in the image worlds of art and science. He did this because he was convinced that scientists for their part were seeking new ways to describe and illustrate their experiments and increasingly abstract procedures. It was Kepes' hope that if art and science worked more closely together, it would be possible for artists to produce new imagery that would be fruitful for scientists' search for clear and descriptive models.

Half a century later it seems that the concepts of many exhibitions, which have presented pictures from the sphere of art and images produced by the scientific endeavor, have not managed to advance beyond the ideals formulated by Kepes. On the contrary: the sociopolitical impetus that still informed Kepes' undertaking—his hope that science and technology in tandem with art could restore balance to the relationship between humans and nature that had been lost through the industrial revolution—appears to have degenerated into a mere "science goes public," which is at pains to achieve the public's acceptance of new scientific techniques.

The Culture of the Laboratory

From the 1980s onward an increasing number of artists began to gain entrance to molecular biology laboratories and to work with highly controversial techniques, such as genetic engineering, which led to heated debates on such an approach to producing art. The anxieties of many contemporaries, which found expression in these debates, did not so much stem from a too limited concept of art, but had more to do with the underlying cybernetic conception of nature, which the technosciences continue to operate with today. The fact that art emerged from the laboratory made it abundantly clear that the artificiality of nature (of laboratory science) confronted the artificiality of art, and the relationship of art and nature that had existed up to that point appeared to implode. The act of transferring transgenic organisms, "epistemic objects" of molecular biology, and the simulations of artificial life research to the sphere of art clearly demonstrates to everyone that contemporary technoscientific knowledge production operates in structures that are fraught with tensions. By taking hybrids and genetically engineered organisms out of science laboratories and relocating them to the domain of art, artists showed the world that in the age of technoscience the natural sciences have long been working with a cybernetic conception of nature and are thus advancing a post-human understanding of nature the contours of which are only gradually coming into view for the majority of people. With these applications many fields of science have long since torn down their laboratory walls and made nature the object of a global experiment.

Traditional epistemological positions continue to insist on the old "humanist" connotations of nature which view nature as rather static, hard and fast, and in part endowed with inalienable properties and attributes; they are oriented on notions of the organic.[4] Postmodern critique of knowledge still focuses on the deconstruction of related classic humanist categories, but technoscience has long since ceased to operate with such a concept of nature.[5] It is not technoscience that is currently demonstrating to us how precarious the category "nature" is, but art.

Fears that the knowledge gained in the laboratory through experiments on engineered organisms and epistemic objects will be applied in the age of technoscience to organisms in general and ultimately to humans are justified. In the light of the tremendous dynamism with which the technosciences are developing and taking hold such fears are entirely understandable. In addition, because of the progressing amalgamation of technology, industry, and science today no clear distinction is made between the technical, social, economic, or political factors driving the process. The degree of present-day ubiquity of scientization and technization has led to the circumstance that technology is increasingly the constituting factor for social structures and processes—a process which potentially can lead to a fundamental rewriting of the constitutive structures of society.[6]

The implementation of new technologies in social reality proceeds only rarely without friction, and always takes place in a complex, changing, and many-facetted matrix of the balance of power between science, technology, and society. In the course of this process where the world of tomorrow is negotiated it is particularly the life sciences that are constantly designing and redesigning new general orientations for humans and intervening ever more frequently in sociopolitical debates. Yet it was precisely the exemption of the natural sciences from all questions of meaning that was an essential prerequisite for the advance of modern science and its enhanced effectiveness. Thus to functionalize modern science for a *discourse of truth* can only lead to its systematic distortion, for in this sense it is not capable of truth; on the contrary, it owes its phenomenal rise in modern times to its release *from* the discourse of truth of theology and philosophy. Focusing on answering purely instrumental questions and referring all questions concerning values, norms, and meaning to the purview of theology, philosophy, and other humanities or social science disciplines—particularly in connection with findings that potentially can be exploited commercially—was what provided the basis for the monumental rise of empirical science in the first place.[7] The delegation of ethical questions to the humanities or social sciences in favor of proceeding purely pragmatically on the basis of the "doability" and "feasibility" of theoretical approaches was one of the decisive conditions for the powerful position in society to which natural science climbed over the course of the last two hundred years.[8] This was one of the causes for the gradual differentiation that came about in the sciences and university disciplines and which ultimately led to the separation of the humanities and the natural sciences. This development resulted in the further fragmentation of a world that was already disenchanted and in which a universal concept of life and nature no longer seemed possible. And brought with it the splitting-up of the concept of nature into a multitude of fragmentary aspects.[9] Over the course of these developments it was particularly the sciences' reading of the concept of nature in technized societies that was accorded an increasingly greater power of interpretation, and in opposition to this, ideas relating to a metaphysical concept of nature were disqualified as speculative, and therefore unscientific and, moreover, nonproductive. In this way the history of *research* on nature and the history of *concepts* of nature diverged. Nonempirical concepts of nature became merely decorative, theory-oriented facets of general education in a culture that otherwise focused on the essential, use- and results-oriented, intersubjectively operating natural sciences.[10]

Techno-Science-Art

Some years ago the French art theorist Frank Popper suggested introducing a specific term for contemporary art forms that are situated within the context of science and technology.[11] Popper's term is certainly apt for certain artistic practices of our times because *techno-science-art* foregrounds *technoscience*.[12] The term *technoscience* was introduced by investigators of science such as Bruno Latour[13] and Donna Haraway[14] several years ago, after Martin Heidegger,[15] as a term that defined a new epoch and attempted to describe the complex and many-facetted transformation of knowledge production in the sciences since the beginning of the twentieth century.[16] The transformation of the natural sciences into technosciences led Haraway and Latour also to rewrite the natural sciences' concept of nature; in the light of developments the term "natural science" no longer appeared to be applicable and was replaced by "technoscience." This struggle to find adequate terminology indicates just how problematic and diffuse the concept of nature has become in our technological culture.

A central proposition of many contemporary theories is that technoscience's rapid dynamics of development and growing power to define have caused the boundaries between natural and artificial to become blurred. This could lead to the destabilization and rewriting of familiar categories and traditional dualisms of Western conceptual systems which would result in a fundamentally changed symbolic order. For some time now it has been apparent that a struggle is going on within various theoretical and technoscientific discourses over the definition of what in the future will be designated nature or culture, life or death, body or mind. This conflict can be viewed as the negotiations to draw the boundaries that will mark out the old and the new entities, as well as a dispute about which of the traditional distinctions will be stabilized, redefined, or discarded. Combined and summarized in the concept of technoscience is the diagnosed eminent importance of the technization of science, the new efficiency of industrial technology through the novel construction of the organic, the amalgamation of systemic technology with the social, the rewriting of the symbolic order by technoscientific practices and narratives, as well as the formation of a technoimaginary.

When genetic engineering made it possible to manipulate natural organisms, and when the logic of biological life was transferred to human-made technical artifacts of artificial life research and robotics, voices began to be heard that postulated the disappearance of nature, and/or the implosion of nature and culture. From this perspective Haraway posited the reinvention of nature,[17] and in his study *Science in Action*[18] and other investigations of the laboratory Latour postulated that there would be a dramatic shift in categories that had long been regarded as static. Studies on the laboratory began in the 1970s; they examined the laboratory workplace with regard to how the sciences understand processes of knowledge production and the experiment, as the basic unit of empirical research, was an object of especial scrutiny. Since then, there have been various forms of the concept of laboratory which have arisen in the course of analyzing different forms of laboratory and processes of laboratorization.[19] Notwithstanding, the laboratory is a place of scientific production that has been insufficiently explored to date. As the French sociologist Dominique Vinck puts it:

> It is still difficult to imagine that we have understood everything about how knowledge is produced with only ten or so laboratory studies. Furthermore, the laboratory is a sort of typical organization of the "knowledge society." Its ability to act on the world of objects and its dynamism arise from its capacity in terms of know-how and its *ability to reconfigure entities from the natural and social world*.[20]

In view of developments in the technosciences, and particularly considering the rapid pace of development in the life sciences, Haraway conjectures that the systematic production of knowledge within industrial practices will cause an implosion of nature and culture. She argues for a new conception of nature, which—in contrast to Latour's approach—is linked to a design for society. By postulating the implosion of these two spheres Haraway is not asserting that on principle categories like *nature* and *culture* should be abolished; rather, her argument is directed toward the shift in these categories that is apparent from the enormously accelerating developments in the technosciences. Here Haraway does not seek to level categories formerly conceived as separate, but she wishes to emphasize their insoluble connectedness, and in this way bring about the dissolution of the ideology of their separation. Implosion means for Haraway the transgression of boundaries in order to appropriate the world in a new way with a less distorted ideological framework.[21]

In her argument Haraway returns frequently to the possibility of manipulating natural organisms using genetic engineering to formulate a fundamental critique of a socially forming power that leads to the construction of certain specific organisms and environments and the exclusion of others. By referring to the construction of "nature" as a technical artifact Haraway alludes to the analysis of certain naturalizing discourses which result in a new ideologizing of nature. For many people from Western cultures, which historically cleave to notions of distinct races in nature and a clearly defined image of self, transgenic transgressions of boundaries represent a serious threat to the integrity of life. For in Western traditions the differentiation between nature and culture has always been one of the most important narratives; it forms the nucleus of many narratives of salvation/mission and their transmutations—the sagas of Western progress. In Haraway's opinion, what is at stake for adherents to this worldview is nothing less than the position of humankind in nature; the Creation and its endless recapitulation. The boundaries between the actions, causes, and effects of divine creation and those of human-made technology have not held up in the worldly borderlands of molecular genetics and biotechnology.[22]

By contrast, in his *Essay in Symmetrical Anthropology* Latour advances the proposition that in technoscientific and social practice society and nature are interwoven to an unprecedented extent, and in his actor-network theory he questions the notion of the static identity of nature and society, technical and social, and human and nonhuman actors. In a hybrid network that encompasses both science and society, according to Latour interactions take place between technical instruments, organic material, institutions, scientific communities, scientific actors, and laboratories in which human and nonhuman phenomena are on equal terms. However, for Latour contemporary production of hybrids in a historically unprecedented dimension was first made possible by vehemently holding fast to the dichotomy between the order of nature and the social order. Both Haraway and Latour view the consequences of the developments in the technosciences as an incisive caesura with irreversible effects, but they do not rekindle the controversies about breaks and continuity in contemporary debates. For the formation of a new conception of nature within practices of technoscience was not the consequence of a reversal or radical negation of the previous understanding of nature, but originated from the manifestation, or radicalization, of pivotal characteristics of modern science; a development that was a long time in the making and then took place on the terrain of contemporary science.

The Rise of Technoscience

The key characteristics of the transformation of traditional sciences into technosciences arose with the emergence of large-scale state and private research institutions at the end of the nineteenth century, which were the culmination of a long process. Already in the mid-seventeenth century the English scholar Francis Bacon (1561–1626), Lord Chancellor of England and court adviser to Elizabeth I., had described in his *Nova Atlantis* of 1627 an innovative proposal for the formal and social organization of scientific and technical research. Bacon's ideas were strongly informed by a new understanding of nature and state power; he called for closer ties between educational reform and the expansion of state powers so that knowledge production would effectively be brought under administrative control of the state, for "knowledge is power." Thus Bacon regarded control over knowledge as an essential instrument of state power.[23] Bacon's ideas in *New Atlantis* inspired the foundation of the first important scientific society: the Royal Society was formally created in 1662 in London. The late seventeenth century saw the foundation of numerous science academies and societies after the model of the Royal Society, which represented a milestone in institutionalizing modern science outside of the universities. Without the constraints of having to defer to religious, political, or other authorities, the "gentlemanly scholars" of these bodies were to a large extent free to pursue independently the experimental study of nature. There were strict rules for admitting new members. Research and production of findings was embedded in a system of social verification mechanisms whereby *true* knowledge was produced by the testimony of witnesses so its veracity could be judged.

Well into the eighteenth century amateurs and artist-scientists pursued the study of nature outside the universities, until in the early nineteenth century these universal knowledge-oriented academies were succeeded by institutions that were mainly organized in disciplines. Subsequently, scientific research shifted to the universities; a development that allowed increasing differentiation of research as well as closer linkage of research and teaching, and the resultant duality of knowledge production and teaching.

On the whole the relations between the development of science and technological innovation in the nineteenth century proceeded unsystematically and on an individual basis. This applied especially to the translation of scientific findings into new technologies as well as the demand for scientific solutions to existing technical problems. At the end of the nineteenth century, and particularly at the beginning of the twentieth century, the necessity for dynamic technical advance and scientific innovation that derived from capitalism and war led to an expansion of industrial research, the creation of institutions of applied research, and a scientization of technical education.[24] These developments resulted in the fusion and systematization of technology, science, and the state on an unprecedented scale. In the second half of the nineteenth century increasing significance had been attached to interactions between political and economic performance and the current state of scientific research. One effect of this was the coalition of science, state, and industry in large non-university research areas,[25] which were flexible enough to take on new fields of research and worked outside of the established disciplines of the universities. These developments enabled Germany to take a leading position in science by the turn of the century; however, in the early twentieth century it was clear that the USA would overtake Germany, a significant contributing factor being the immigration, persecution, and deportation particularly of Jewish scientists from Germany as of 1933 under the National Socialists. Further, the American university system was not structured so hierarchically as in Germany. Organized in departments American universities were more flexible and could branch out into new fields of research more quickly.[26]

In the 1920s and 1930s there was even closer cooperation between the state and science when some American universities, for example, Stanford University and the University of California at Berkeley, began to cooperate with partners from industry to solve problems associated, for example, with the generation and distribution of electricity or research on microwaves and radar and their industrial applications. This new form of cooperation opened up exceptional new possibilities for scientists, and attained unprecedented dimensions because of the funds available: the impacts were far-reaching, both on the forms in which scientific work was organized and on research practices.

In the course of these developments, in the second half of the twentieth century the organizational structures of certain branches of scientific research underwent systematization and achieved increased efficiency; this has been termed "industrialization of research,"[27] and it encompasses both the alignment of working methods in university research to industrial research as well as the intensified cooperation between industry and state.

As a result of the outbreak of World War II. the USA created an unparalleled complex of research, industry, and the military, in particular the Radar Project and the more famous Manhattan State Project, which had the goal of building the first atomic bomb and involved over 250,000 people. After the war ended these structures were not dismantled; they remained in existence and embarked on new large-scale projects.[28]

After World War II. there was exponential growth of the sciences.[29] This resulted in the necessity for increasingly cost-intensive technical infrastructures and, because of the onset of global interconnectedness of research, in incisive changes and dependencies within science. In turn, this led to dissolution of the clear dividing lines between the individual domains, for example, between science and technology.

The exponential growth of science is clearly illustrated, for example, in the statistics produced by scientometrics, which is the science of measuring and analyzing science. Scientometrics confirms the exponential growth of science since World War II. Post-1945 around one million people pursued scientific activities in a broad sense. Today, there are over three million researchers worldwide, one third of whom work in the USA; this means that today's generation comprises 80% of all the scientists who ever lived. A further indicator for the immense dimensions of the growth of science is the number of scientific publications: in 1750 there existed around 10 scientific journals; today there are more than 100,000. The fact that 20,000 new publications appear daily is an indicator both of the quantity of production as well as the dimensions of the new knowledge that is being generated.[30]

Over decades some branches of research have developed into large-scale projects with teams of researchers scattered all over the globe. The inauguration of such institutions has turned "little science" into "big science," to quote Derek de Solla Price.[31] The application of advanced technologies in "big science"—that is, socially important large-scale technologies of the present day[32] such as atomic physics, life sciences, information technology, and telecommunications—has subsequently become an indispensable prerequisite for the further development of cutting-edge technology and, according to the German philosopher Jürgen Mittelstraß, has led to their subsequent transformation: scientific research processes today are not only dependent upon technological knowledge and skill, they are increasingly controlled by this knowledge and skill. Technology is not only application, but also the prerequisite for science, which thus assumes technical attributes. The old scheme of things—technology which rules society, and science which rules technology—no longer applies; or at least not as far as the relationship of science to technology is concerned.[33]

Thus the transformation of "little science" into "big science" and the emergence of international large-scale research endeavors not only mean immense changes in financial or political areas, they also exert a profound influence on research as well. Due to its progressive socialization today science is often regarded as part of a "seamless web" of political and economic institutions[34] that has changed the parameters and the internal possibilities for development of science.[35] The American historian of technology Thomas P. Hughes introduced the metaphor of the "seamless web" to describe the interwoven complex consisting of society, science, technology, industry, and other areas. The amalgamation of science with other political-societal institutions and the radical technization of postindustrial societies as well as the rapid fusion and systematization of technology and science are developments that have prompted theorists and historians of science to replace the term "late modern" with "technoscience" to characterize an epoch that is marked by far-reaching shifts within the network formed by science, technology, and society.

Notes

1. See Lutz Dammbeck, *Das Netz. Die Konstruktion des Unabombers* (Hamburg: Edition Nautilus, 2005), 56.

2. Lutz Dammbeck 2005, 59.

3. Lutz Dammbeck 2005, 67.

4. Cf. Jutta Weber, *Umkämpfte Bedeutungen. Naturkonzepte im Zeitalter der Technoscience* (Frankfurt am Main: Campus, 2003), 228.

5. Jutta Weber 2003, 242.

6. Cf. Günther Ropohl, *Technologische Aufklärung. Beiträge zur Technikphilosophie* (Frankfurt am Main: Suhrkamp, 1991), 184.

7. On leaving the question of meaning out of the natural sciences see Cornelia Klinger, "Der Diskurs der modernen Wissenschaften und die gesellschaftliche Ungleichheit der Geschlechter. Eine Skizze," in *Wissenschaftlichkeit und Verantwortung. Die Wissenschaft – eine Gefahr für die Welt?* ed. Heinz Barta and Elisabeth Grabner-Niel (Vienna: WUV-Verlag, 1996), 115.

8. Jutta Weber 2003, 31.

9. Jutta Weber 2003, 35.

10. See Jürgen Mittelstraß, "Leben mit der Natur," in *Über Natur. Philosophische Beiträge zum Naturverständnis*, ed. Oswald Schwemmer (Frankfurt am Main: Klostermann, 1991), 50.

11. See Frank Popper, "Techno-Science-Art: the Next Step." *Leonardo* 20.4 (1987): 301–302; Itsuo Sakane, "The Historical Background of Science-Art and Its Potential Future Impact," in *Art@Science*, ed. Christa Sommerer and Laurent Mignonneau (New York: Springer, 1998), 227. On Frank Popper's concept of "techno-science-art" see also Joseph Nechvatal's interview with Frank Popper: "Origins of Virtualism: An Interview with Frank Popper Conducted by Joseph Nechvatal." *CAA Art Journal* 62.1 (2004): 62–77.

12. For a comprehensive description of the different aspects involved in the concept of "technoscience" see Jutta Weber 2003.

13. On the concept of "technoscience" as used by Latour see Bruno Latour, *Nous n'avons jamais été modernes. Essai d'anthropologie symétrique* (Paris: La Découverte, 1991); English version: Bruno Latour, *We Have Never Been Modern*, trans. Catherine Porter (Cambridge MA: Harvard University Press, 1993).

14. On Haraway's definition of the concept of "technoscience" see *Donna Haraway: Die Neuerfindung der Natur. Primaten, Cyborgs und Frauen*, ed. Carmen Hammer and Immanuel Stieß (Frankfurt am Main: Campus, 1995), 105ff. On the concept of "technoscience" see also Donna J. Haraway, *Primate Visions. Gender, Race, and Nature in the World of Modern Science* (New York: Routledge, 1992); Donna J. Haraway, *Simians, Cyborgs, and Women. The Reinvention of Nature* (New York: Routledge, 1991); Donna J. Haraway, *Modest_Witness@Second_Millennium.FemaleMan©_Meets_Oncomouse™* (New York: Routledge, 1997); Donna J. Haraway, *When Species Meet* (Minneapolis: University of Minnesota Press, 2008).

15. Cf. Martin Heidegger, *Die Technik und die Kehre* (Pfullingen: Neske, 1962).

16. The sociologist and science theorist Bruno Latour and the biologist and historian of science Donna Haraway must take the credit for recognizing how highly charged and problematic the production of knowledge in the technosciences is, and for clearly delineating the implications of producing technoscientific hybrids. Through the advancing hybridization and cyborgization of the human body because of the achievements of the life sciences and technosciences Haraway sees the logic of the dichotomy-driven order of the modern era being eroded with the consequence that categories which were formerly assumed to be static, like man and woman, are becoming blurred; see Donna J. Haraway, "Manifesto for Cyborgs. Science, Technology, and Socialist Feminism in the 1980s." *Socialist Review* 80 (1985): 65–108.

17. See Donna J. Haraway, "Signs of Dominance. From a Physiology to a Cybernetics of Primate Society." *Studies in History of Biology* 6 (1983): 129–219, Donna J. Haraway, "Class, Race, Sex, Scientific Objects of Knowledge. A Socialist-Feminist Perspective on the Social Construction of Productive Knowledge and Some Political Consequences," in *Women in Scientific and Engineering Professions*, ed. Violet Haas and Carolyn Perucci (Ann Arbor: University of Michigan Press, 1984), 212–229.

18. Cf. Bruno Latour, *Science in Action. How to Follow Scientists and Engineers Through Society* (Cambridge MA: Harvard University Press, 1987).

19. In this context see Bruno Latour and Steve Woolgar, *Laboratory Life. The Social Construction of Scientific Facts* (Beverly Hills: Sage Publications, 1979); Karin Knorr, "Producing and Reproducing Knowledge. Descriptive or Constructive? Toward a Model of Research Production." *Social Science Information* 16 (1977): 669–696; Karin Knorr Cetina, *The Manufacture of Knowledge. An Essay on the Constructivist and Contextual Nature of Science* (Oxford: Pergamon Press, 1981); Michael Lynch, *Art and Artifact in Laboratory Science. A Study of Shop Work and Shop Talk in a Research Laboratory* (London: Routledge, 1985); *The Development of the Laboratory. Essays on the Place of Experiment in Industrial Civilisation*, ed. Frank A.J.L. James (New York: American Institute of Physics, 1989); Andrew Pickering, *The Mangle of Practice. Time, Agency, and Science* (Chicago: University of Chicago Press, 1995).

20. Dominique Vinck, "Back to the Laboratory as a Knowledge Production Space." *Revue d'anthropologie des connaissances* 2 (2007): 159–165.

21. For a detailed discussion see Angelika Saupe, *Verlebendigung der Technik. Perspektiven im feministischen Technikdiskurs* (Bielefeld: Kleine Verlag, 2002), 266ff.

22. See Donna J. Haraway, "Anspruchsloser Zeuge@Zweites Jahrtausend. FrauMann© trifft OncoMouse™. Leviathan und die vier Jots: Die Tatsachen verdrehen," in *Vermittelte Weiblichkeit. Feministische Wissenschafts- und Gesellschaftstheorie*, ed. Elvira Scheich (Hamburg: Hamburger Edition HIS, 1996), 374–375.

23. Cf. Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996).

24. Cf. Gernot Böhme, Wolfgang van den Daele, and Wolfgang Krohn, "Die Verwissenschaftlichung von Technologie," in *Die gesellschaftliche Orientierung des wissenschaftlichen Fortschritts,* ed. Gernot Böhme et al. (Frankfurt am Main: Suhrkamp, 1978), 367.

25. On the development of large-scale research facilities see Gerhard A. Ritter, *Großforschung und Staat in Deutschland. Ein historischer Überblick* (Munich: C.H. Beck, 1992).

26. Cf. Ulrike Felt, Helga Nowotny, and Klaus Taschwer, *Wissenschaftsforschung. Eine Einführung* (Frankfurt am Main: Campus, 1995), 41–43.

27. According to Felt et al. the development of the social forms of training and organization in the sciences since the seventeenth century fall into three phases: amateur-craftsman, academic, and industrialized. Until around 1800 science, which was then still in its early stage, was done by independent or "artist" scientists outside the universities. The academic phase began with the nineteenth century and was characterized by a continuous process of institutionalization of the sciences at universities, the separation of basic and applied research, and also by increasing specialization and differentiation of scientific disciplines: see Ulrike Felt, Helga Nowotny, and Klaus Taschwer 1995, 31.

28. Cf. Wim A. Smit, "Science, Technology and the Military. Relations in Transition," in *Handbook of Science and Technology Studies*, ed. Sheila Jasanoff et al. (Thousand Oaks: Sage Publications, 1994), 598–626.

29. Derek de Solla Price is credited as being one of the founders of scientometrics, a branch of learning that is concerned with the quantitative features and characteristics of science which are studied by statistical mathematical methods; see Derek de Solla Price, *Little Science, Big Science* (New York: Columbia University Press, 1963).

30. See Ulrike Felt, Helga Nowotny, and Klaus Taschwer 1995, 44ff.

31. The rise of "big science" began towards the end of the nineteenth century because of new forms of organizing research, which received resources that were very considerable at that time for projects defined by the state, commerce, and society. In Germany the combine comprised of science, the state, and industry formed earlier than in other industrialized countries; see Gerhard A. Ritter 1992, 14ff.

32. On the situation of large-scale research at the end of the twentieth century see *Big Science. The Growth of Large-scale Research*, ed. Peter Galison and Bruce Hevly (Stanford: Stanford University Press, 1991).

33. Jürgen Mittelstraß, "Leonardo-Welt – Aspekte einer Epochenschwelle," in *Kultur und Technik im 21. Jahrhundert*, ed. Gert Kaiser, Dirk Matejovski, and Jutta Fedrowitz (Frankfurt am Main: Campus, 1993), 23.

34. Cf. Thomas P. Hughes, "The Seamless Web. Technology, Science, Etcetera; Etcetera." *Social Studies of Science* 16 (1986): 281–292.

35. As a result of the advancing technization of everyday life the perspective of recent technology research has also changed progressively. In this connection two approaches are of particular interest according to which technology is formed socially and which position this core idea at the very center of technology research: SST (Social Shaping of Technology) and SCOT (Social Construction of Technology). Unlike the approach of SST, SCOT also includes the aspect of the technological shaping of society. The socio-constructivist approach of modern technology is still characterized today by three features: first, the individual inventor as a defining category has receded into the background and has been replaced by the social interest groups involved, which represent the core of the analysis; second, they distance themselves from technological determinism, that is, from the assumption that technological development is autonomous and instead assume that social development is dominated by technology; third, in their analysis they do not differentiate between technological, social, economic, or political aspects; see Ulrike Felt, Helga Nowotny, and Klaus Taschwer 1995, 189.