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MIRRORS OF SCIENCE: IMAGE-MAKING AND THE CONSTITUTION OF SCIENTIFIC KNOWLEDGE

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Introduction

Since the rise of modern science, the role images have played in comparison to text and other formal symbolic means of knowledge representation has always been a diverse one. The following essay therefore looks at scientific images from diverse perspectives, taking into account a range of disciplines, with an emphasis on the second half of the 20th century. Images and image-making devices have always played an important role in the constitution of scieantific knowledge, but with the beginning of the 20th century a clear tendency towards the use of visual representation in the natural sciences can be observed; due to the rise of new technologies and, in later years, the rapid inception and widespread use of digital technologies and digital image-generation processes, the production of images in science reached an unsurpassed degree in the second half of the century.

Today our gaze into the heavens is guided by pictures taken by the Hubble space telescope (HST), thus allowing the general public to participate in the latest discoveries and observations in the field of astronomy and astrophysics. Commercial projects such as Google Earth and Google Maps, and recently Google Sky, provide us with access to hundreds of thousands of current satellite images of the Earth and, in combination with aerial photographs, allow us to virtually navigate around the globe with the click of a mouse. Modern medical technology provides us with ever-more detailed images of the interior of the human body; these shape our own concept of our biology and bodies more strikingly than any scientific fact can.

A variety of image-making devices give us new insights into the cosmos, the world, and our bodies, and by doing so, they not only deliver images about the world we live in, but become influential and very effective instruments for practical and theoretical action in our world. The attention and the meaning images are given in society today is to a large extent due to the immense variety of visual manifestations and representations available – they help design our vision of the world in a diverse set of ways and thus serve to shape our worldview – images of the world provide us orientation.

Nonetheless, images produced within the realm of the modern sciences are highly artificial constructs whose relation to reality cannot be explained in simple terms. Impressive in the eye of the beholder, images construct a paradoxical situation of the real and the ideal. In contrast to the spoken word or written texts, visual representations are able to convey and explain abstract and complex concepts to the observer in a single glance, but although they seem to be intuitively understandable, images – and the media in which they appear – are governed by their own logic.

Advanced systems of measurement today produce such large amounts of complex data that automated processing and visual representation as generated images are essential to make the information comprehensible to the human mind. Within the modern sciences, the computer sciences play a significant role in this development because only through the invention of evermore powerful computers will the processing and handling of such complex data continue to be possible. The complexity and dynamic of the underlying measurement processes and the resulting data structures, combined with the sheer amount of data generated, go beyond the scope of our human cognitive means and require a return to a visual presentation of the aggregate data. To a certain degree, the computer sciences have paved the way for the return of visual displays and images to science; however, most of the visualization techniques involved do not imply a revitalization of something "natural", but rather are a movement in the direction of the visual perception of constructed and complex "artifacts."

The constitutive aspects of scientific illustration and presentation have long been underestimated within the process of knowledge production and the proof of scientific facts: such illustrations and presentations have traditionally been regarded merely as silent servants. Research in the field of the history of science and laboratory studies, however, reveals that the images, instruments, and research tools play an integral part; today, it seems clear that processes and objects are transformed into epistemic objects and relevant images by specific manipulation and transformation processes in the laboratory. Instruments and devices receive their relevant meaning within these processes only through multipart adaptation and configuration by the scientists involved. Bruno Latour refers to this process as "inscription" in explaining the transformation of sparse or disparate symbols and entities into a coherent and convincing image able to convey the underlying scientific content. Which process will in the end be adopted by the scientific community within a particular field of research or discipline as an adequate standard process is often a matter of much debate and depends to a large extent on the level of consensus among the group of scientists; it is therefore always a matter of negotiation as to whether a graph, a table, a diagram or an image generated from a computer simulation process will become the ideal scientific representation.

According to Latour, inscriptions are not just innocent recoding and writing processes but integral parts of the sciences. Following the increasing complexity inherent in current research, the inscription processes and the devices used therein have also become ever more complex and elaborate. This observation by Latour could be extended to the sphere of living organisms and the transformation of organisms into epistemic objects or "biofacts": the entire range of modern life sciences are on their way to forming a new science that not only treats, dissects, processes, analyses, and modifies its materials – living organisms and parts thereof – but rather constitutes and constructs these as biofacts, which can no longer be described as being a part of a "natural nature." The term biofact was introduced by the German philosopher Nicole Karafyllis in an attempt to formulate a systematic term for technically manipulated life:
"Artifacts are artificially devised and created objects. Constructed objects were until now always in the category of objects. An artifact, referring to something man-made, serves as a collective term for such diverse, artificially created objects as buildings, art works, and machines. Artifacts generally are dead or inanimate. Biofacts are biological artifacts; that is, they are or were once alive. The categorization of the technical treatment of life is certainly not new (classical breeding!); nonetheless, there was until now no systematical term to include the technological manipulation of original natural growth. This lack of a term occurred, among other reasons, because philosophy of technology had previously focused, first of all, on systematically classifying technology and always viewed nature as 'the other' and the 'opposite' of technology, something from which one could distance one's self."[1]

Visualizations that the life sciences in particular employ range from advanced image-making technologies that offer ever more detailed views of the microstructures of the organic world, to image-based computer simulations no longer based upon a physico-biological reference system. These systems open up a new biotheoretical space, where representations such as transgenic animals, chimera, and clones become alive. With respect to this development, it may be assumed that the increasing pictorialization in natural science practices will lead to a transformation in the production of knowledge in this field and force a change of perspective from the *logic of life* to the *logic of images*, the consequences of which are yet to be determined.

Visual illustrations have always been used in the natural sciences to visualize scientific relationships or theories, or to graphically capture the results of scientific experiments. For the majority of natural scientists, the image-making devices they use are simply a resource or tool; their use represents only one of many aspects within a complex interplay of knowledge production, and the use of such tools is rarely considered from an image or media theory perspective. However, images and their mediation have their own logic and play an important role in terms of what and how we see and perceive scientific knowledge: scientific visualizations arise as part of a complex interplay of different agents. They must be *produced* as part of a labor-intensive process of production and negotiation and are to a great extent *constructed artifacts* that do not simply depict or form reality and/or the "object" of the respective investigation or experimental environment. Even photographic or other optical recording techniques do not simply record the phenomena of nature, but rather fix the state of prepared objects for the production of a visual record. Graphic representations, too, do not directly depict measured data, but rather are translated or converted into other media and visualized in diverse presentational forms that can be expressed using various representational conventions – in the form of curves, diagrams, or complex image rasters or other symbolic representations.

Visualizations in the natural sciences are never simply illustrations, but instead represent complex phenomena, which in their formulation are always bound by the conventions of representation and the reigning vocabulary of their respective period or time; they touch upon the methods and arrangements by which the respective scientific context captures knowledge in an image and ascribes to it an epistemological meaning. Visualizations and models are significantly involved in the formation of knowledge and have always been an integral component of scientific effort and a legitimate heuristic means of forming theories. Whereas theories attempt to explain concrete empirical relationships, models in the natural sciences deal much more with model-based assumptions and structural analogies. Theories can be viewed or understood as systems of evidence that attempt to adhere to assumptions about interrelationships based on strictly logical rules of reasoning and must stand up to empirical verification; models, on the other hand, reflect much more in their structure the inner relationships of a problem set.

The New York–based artist and theorist Suzanne Anker therefore looks at the representational context of the respective experimental processes and the various visual preparations – DNA, for example – which reveals more about the investigative approach of the experimenter and the circumstances of the matter than about the matter itself. Even the highly dimensional digital worlds of the sciences, as part of the molecular vision, remain forever loaded with cultural associations and values:
"Molecular vision has increasingly dominated the assumptions and methods of the biological sciences. Reducing life itself to molecules, it has displaced the visceral references that had once defined the authenticity of the body and the authority of traditional biology as a descriptive science. Despite the complexity of life, this vision implies that we are but a sequence of nucleic acids, a 'code script' of information. This transformation of biology from organism to code and/or text parallels developments in art. Artists are adapting images revealed through high technology apparatus, and their pictorial and sculptural products have shifted toward the abstract. They have recognized in genetic iconography an underlying narrative that resonates with familiar forms and issues in the history of art."[2]

Imaging Techniques in Medicine

Given the current range and diversity of image-generating diagnostic techniques and devices which put the human body into the picture, it is hard to believe that it was not until the Renaissance that the strict taboo against the opening and display of the interior of the body was overcome. The anatomist Andreas Vesalius (1514–1564) was among the first to gain his scientific insights by dissecting corpses and is still renowned as the founder of modern anatomy as well as the morphological school in medicine. He documented his knowledge in visual displays and sketches. From 1539 to 1542, Vesalius compiled his observations in a 639-page compendium *De humani corporis fabrica*, published in Basel in 1543. His drawings represented first-hand knowledge – the copperplate print on the frontispiece, for example, which programmatically places the public dissection of a female corpse in place of the formal study based on the reading of books.[3] In this period, the first anatomical theatres were founded, which offered public dissections of corpses and thereafter led to the production of anatomic atlases and depictions of the interior of the human body.[4]
Only in the 17th century did a general shift from the text-based representation of knowledge towards a visual culture in medicine begin to evolve. This shift blossomed in the 18th and 19th century, where it reached the heights of elaborate scientific visualization and modeling techniques. By means of intricate processes, high-quality images and three-dimensional models for scientific use were fabricated whose visual and material aspects yielded their own logic and offered a visual explanation other media were not able to provide: an insight that could only be gained through aesthetics or purely visual perception. The insights that images and models were able to offer could only be perceived in a visual experience; images and models thus became instruments or devices of perception – of perceiving and seeing, objects of knowledge whose strength to convey mainly derived from their materiality and visibility.

During the 19th century, many disciplines at universities, colleges, and art schools began to acquire large collections for research and teaching purposes consisting of publications, notes and dissections, and various other media, but also images and models.[5] Scientifically precise models were produced with the highest craftsmanship, thereby making the phenomenon portrayed instantly accessible by tactile and visual means. The materials used to shape the models encompassed a wide range, from wax models and *moulages* used in anatomy and dermatology to the finest glass works in zoology. In teaching natural science courses at university, models were primarily used to exemplify developmental processes and to demonstrate functional relationships. Within zoology, anatomy, and in particular in embryology, models and consecutive series of models were utilized to demonstrate to students the growth process and progressive development.

Scientific illustrations such as drawings and their graphic reproductions were rarely used to convey specific observations about the individual organism, but were rather used to communicate generalized concepts and properties of the selected organism in a visual form.
Images and models – sum of a succession of steps of abstraction, which in the final form entertained an aesthetic quite distinct from that of the original organism. It was not the depiction of the natural variable features of an animal or plant species that was of interest but the characteristic model case; the use of abstraction and schemas led to an idealized and therefore standardized concept of the selected feature. Images and models were therefore the result of a conventional modus of representation of already visually perceived forms and structures of scientifically investigated phenomena. These phenomena could not adequately be perceived and conveyed by textual representations but required visual representations. Disciplines such as comparative morphology and embryology directly taught their students visual competence in the sense of a school of seeing[6], where models formed an integral part in training the view of the scientist and in the development of the scientific visual regime.

The Body from Within

The first non-invasive images of the internals of the human body were made possible through the discovery of X-rays by the German physicist Wilhelm Conrad Röntgen (1845–1923) at the end of the 19th century. X-rays provide pictures of the skeletal structure of a living body and more recent radiography devices also offer pictures of soft tissue and the inner organs. The discovery of X-rays revolutionized, among others, the field of medical diagnostics and led to further important scientific insights, such as the discovery of radioactivity. Today, X-ray screening is still routinely employed for a wide range of medical conditions and the X-ray film, together with other symptoms and examination results, often still provides the basis for medical diagnosis.
Some twenty five years after the introduction of X-rays, ultra-sound was discovered and implemented as a technology in a similar manner as X-rays for scanning procedures. Its first relevant application was to locate German submarines in World War I. Around 1930, ultrasonic sound began to be employed in the treatment of various diseases and for diagnostic forecasting procedures. It was not until the year 1976, though, when sector-scanning devices suitable for series production and practical day-to-day usage were first introduced to the market that use of this technique in medical diagnostics became widespread. Today sonography is found in many fields in medicine and a clinical routine without its use is unthinkable.

Since the inception of computer tomography (CT), the various methods that allow us to open up a view to the interior of the human body are no longer viewed as imaging existing structures but rather as image-generating processes. They consist of and involve intricate complex and contingent pathways for aggregating complex data into a computed construction and subsequent visualization. These new technical methods and procedures have opened up pathways to previously unimaginable research and diagnostic means and techniques.[7]
Brain scans and other visualization methods for cortical structures or cortical processes have gained increased attention from a wider audience in recent years. Computer tomography (CT) and magnetic resonance imaging (MRI) are well known today as techniques for generating high-resolution images of cortical structures, as are functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) as methods for the visualization of functional relationships by means of good to very good time-resolution imaging methods that show the living brain in action. Visualizations of cerebral processes have long been regarded as a gateway for insights into the relationship of mind and brain[8] and sometimes have even been considered to offer a glimpse into the way we think and how our consciousness works.

Using MRI scans, cross-section images of the human body can be generated that allow a comparison to and an orientation along anatomic sections of the same tissue region, which in turn facilitate diagnosis of organ state and organ change as compared to a healthy state. One major advantage of the MRI technology is the greatly increased resolution of organ images compared to other image-generating technologies used in diagnostic radiology. The increase results from the ability to accurately detect slightly differing signal intensities emitted from differing soft tissues as well as from a designed variation of the parameters guiding the investigation. The measured values reported by the MRI device report underlying physical processes of atoms interacting with their environment: the translation of this physical information into physiologically and clinically relevant descriptions in an automated fashion is difficult. Reading and interpreting these data – or rather, images – therefore requires a thoroughly trained and experienced practitioner with a solid understanding of microstructural und molecular effects of pathological and physiologic processes. Functional MRI (fMRI) is a relatively recent extension of classical MRI, which enriches MRI diagnosis with a time-development analysis component. With fMRI it becomes feasible to record and visualize metabolic processes induced by metal activity; the underlying effect has been known for a long time, namely the increase in consumption of energy-rich molecules at an elevated level in regions of increased neuronal

Mapping the Brain

In the 20th century, not least due to the real needs to medically treat the large number of cortical injuries during the two world wars, a correlation between geometric position in the cortex and function of the respective locus has been inferred. This assumed correspondence between function, on the one hand, and localization and anatomy of the brain, on the other, inspired research towards a functional mapping of the brain. This mapping did not aim at a morphologically correct representation of anatomic structure but rather a functional mapping at large. In the 19th century, the German physician and anatomist Franz Joseph Gall (1758–1828), a pioneer in the study of the localization of mental functions in the brain, had already established a functional landscape of the brain, as represented in his phrenologic brain images. He developed a method to determine the personality and development of mental and moral faculties on the basis of the external shape of the skull. Although the doctrine of phrenology, with the brain at the center of all mental functions, received no further attention in science, the basic assumption behind it became the catalyst for further developments in brain science.

The idea of localization of brain function finally concluded in the desire to perform a functional mapping of the brain. In 1967, a standard system of functional neuroanatomy based on a standardized brain of a woman (Talairach and Tournoux 1988) was developed. With the aid of image-generating technologies for some selected brain functions, such as sensory sensation, speech, and memory, brain regions with close correlation could be localized experimentally and verified in repeated experiments. Brain maps such as the Talairach atlas or the Montreal Neurological Institute (MNI) brain and the Human Brain Project (HBP) have been established as influential anatomic reference systems for the analysis of structure-function relationships in the human brain – even more so since neuroanatomic and electrophysiologic studies have confirmed the specific functional meaning of cytoarchitectonical areas. Subsequently, in in vitro studies the assumption of a coherence between identifiable macroanatomic structures and cytoarchitectonical areas stimulated new in vitro experiments to investigate the relationship between structure and function. This assumption also forms the basis for the development and frequent use of stereotactic atlas systems for localization of cortical areas, which is in a classic view represented by the Talairach atlas[9]. The adoption of a unified three-dimensional standard brain is an effort to derive a complete understanding of normal and abnormal brain function – in spite of the many anatomic variations and the plasticity observed in individual brains.

The optic invasion of the human body also brings with it some problematic issues: image-generating technologies operate on huge amounts of raw data and perform highly complex and intricate transformation algorithms for image segmentation, smoothing, and noise reduction; this can result in wrong conclusions. Image-generating technologies used for the examination of the interior structure of the body also use acoustic or electromagnetic waves, which radiate inside the body. These waves are absorbed, the degree to which depending on the density of the tissue matter, or else reflected and scattered, as at boundary surfaces, for example, and are in turn registered and recorded by devices outside the body. Various mathematical algorithms are utilized to reconstruct the original three-dimensional area. The entailing graphic wave equations are then delivered to a visualization process, which comprises a sequence of process steps, including noise filtering, segmentation, interpolation, and subsequent rendering steps, leading to a reconstructed surface including high-resolution depth properties. There exists no unique standard avenue but rather a multitude of pathways depending on the technology used and the intended use of the resulting visualizations, which in turn highlights the dependency on the perspective that the researcher or practitioner chooses to employ.
These generated images take a snapshot of the body's condition and the derived inference and engrave it into one specific image, even though the body's condition is subject to change. Furthermore, these visualizations are often combined across several individual candidates for the visualization of general activation patterns, e.g., for specific cognitive activities. Many of these algorithms and methods for computing average visualizations as examples of the general underlying process rely heavily on certain preconditions such as length preservation, applicability of afine transformations or validity of landmarks as anchors for stacking 2D slices of images together to form a 3D representation. Using

these methods incurs dependence on the validity of the underlying assumptions, i.e., preconditions, which seems problematic in light of the large variability of human anatomy.

Furthermore it has to be acknowledged that the underlying physiological tissue does not always allow a meaningful discrimination according to established abstract anatomic, physiologic or functional areas. Therefore image segmentation can be difficult to achieve and is by no means always possible in an automated process, but rather requires the interaction of a human practitioner. Depending on the desired representation and goals, rendering methods are specifically selected and refined for the task at hand. Inasmuch as a multitude of tissue parameters exist that can be represented, somewhat ad hoc color codings are utilized for discrimination; at times these may display visually perceivable border lines where continuous scales of activation status would seem more appropriate. For a variety of reasons one has to conclude that there exists a rather large distance between the image and the object depicted due to the complex and abstract contingent generation processes. Thus, although these image-generating technologies visualize that which is hidden inside, the interior of the body still remains inaccessible. Digital images are also utilized for instantaneous recording of important properties of living objects; these images carry not only medical or biological—i.e., scientific meaning—but also incorporate cultural codices and consequently have a contingent technical sense of their own. Medical images of the body such as brain scans simultaneously convey cultural concepts of the human being.

The distance of the image from the imaged object, i.e., the abstract nature of the images generated by these complex transformation processes, increases with each abstraction step, each inference step, and each integration step; thus possibility of error, i.e., the possibility of image artifacts, having no physiologic counterpart, also increases. In a paradoxical reversal of facts, these visualizations and other image-generating processes, such as body mappings, which rely not only on reproduction but on processing, interpretation, and derived simulation, suggest an object view of the body and consequently a normalized portrait of the body. As always—and the more so the more complex and deductive the process chain is—there is a set of elements in the process involved that are not constitutive for the living organism; which of these elements is not only a question of the technology employed but also culturally contingent, beginning with the choice of application and the technology utilized, as in the example of image-generating technologies and visualization methods: "PET images thus seem to have a persuasive power that is out of proportion to the data they are presenting. The scans become visual truths, presenting themselves as facts about people and the world such that even their producers cannot refute them." [10]

Mapping the World

Projects like Google Earth and Google Maps seem to ideally fulfill the human desire to map the world and to create a representation of the world so precise that it is almost identical to the real physical landscape. The makers of Google Earth, an interactive program for visual navigation, have compiled and joined together hundreds of thousands of satellite and aerial photographs from various perspectives. The program makes it possible to navigate around the globe and to zoom into virtually every spot on the planet. Google Earth obtains its pictures from the American company Digital Globe, which has been providing high resolution images since 1992. Google Maps, however, suggests rather a link back to the tradition of mapping the world as established almost four centuries ago by cartographers such as Gerhard Mercator (1512–1594). In 1569 Mercator developed a world map as a plane surface representation of the spherical surface of the globe, thus beginning the age of cartographic reformation. Today maps are no longer considered as artifacts but rather as a scientific means of representation[11] inspired by the ideal of utmost precision and truth about the territory they portray.

Since the days of Mercator, there have been countless attempts to generate topographic maps of the world. As recently as 1973, the German historian and cartographer Arno Peters (1916–2002) presented a map projection in an effort to overcome the distorted Eurocentric world view. The Peters atlas was published in 1989; it was based on a special type of cylindrical projection and included maps of all national states and regions of the world at the same scale; the resulting map was thus consistently area accurate.

The representation of the spherical form of the earth on a plane surface cannot be achieved without some distortion with regard to direction, area, distance, or shape; which distortion is incurred depends on the projection method applied. Maps constitute complex social constructions and not the territories themselves: a map is a plane surface with graphical inscriptions of relations between locations, presented in the shape of a spatial and two-dimensional depiction. The notion of a transparent map as the portrayal of reality is a deceptive one, as the map is also inevitably a means of communication guided by issues of power and specific interests.

Photographic pictures of the earth were already being taken from airships in the 19th century and from 1900 onwards by airplanes. In 1915 the first automatic camera for aerial photographs was constructed that was able to take a large series of single snapshots; aerial photography is still an essential basis for the generation of maps today. The first pictures of the earth taken from outer space (still in existence today) were produced in the year 1947 as by-products of the first American space flight program. This endeavor borrowed technologies first developed by German engineers during the Third Reich. Already in the 1950s, engineers involved with the space flight program conceived of photographing and thereby creating a projection map of the complete landmass of the earth with cameras from outer space.

It is interesting to note that Google Earth and Google Maps represent two distinct modes of depicting the world. Each mode is based on a different history and uses a distinct visual language, but by superimposing the photographic aerial photographs from Google Earth onto the schematic and abstract maps of Google Maps a practical and relevant tool for orientation is generated which itself might lead to yet another "cartographic revolution." The photograph reveals every single detail and thus presents an enormous amount of information, but by eliminating information, the map offers an efficient understanding of and quick access to a territory.

Maps, however, are able to embody abstractions or information that for whatever reason may not be perceivable and convey it for human perception. Maps portray what cannot be viewed otherwise, for example, territorial borders. Maps are an instrument of visualization – ut and our interest in territories, for example, the political balance of power. The depicted information is not simply represented in a map but rather simultaneously constituted to a certain extent by the map. Inasmuch as maps – due to their air of naturalistic transparency – are considered to be a witness to something independent and precursory with respect to the map itself, they are empowered to mint the independence and precursory state according to the model of the map. The world is not simply represented by maps; rather through the means of projection an image of the world is generated. But as photographs and maps grow old – however slowly this may occur – the perfect portrayal of our world will always remain a vision.

A Question of Evidence

Within the 20th century there exists a strong interest on the part of science in visual representations, which manifests itself in conjunction with the equally strong desire to defend and save our speech from visual representations. In the same way that speech once served as a model for things to represent now the image is attributed to this purpose – even though it is still an unresolved issue as to what an image really is and in which relationship it is to be positioned with respect to speech. Nor do we know the impact of images on the observer and the world itself. Current information and communication technologies, however, synthesize abstract concepts from images. As Flusser states, "the image turns numerological." According to him, technical images attempt to betray the observer and they do this in a twofold manner. First, they suppress the fact that they are compositions of pixels and pretend to carry the same eminence as usual images. Secondly, on an elevated level of betrayal they seemingly admit they are made of pixels but only to advertise themselves as the "better" pictures by pretending to represent a fact not just on a symbolic level as conventional pictures do but "objectively," pixel by pixel.[12]

Technical images and especially computer-generated simulations create an artificial but also "natural" appearance. This is but one important element for the substitution of the natural, which has subsequently been joined by many more. The mechanisms of substitution operate substantially at the symbolic level: terms and projections of thinking find their way into computer-generated models. Thus technical images do not so much signify the world around us or parts of it but relate rather to an abstract universe of terms. Admittedly they are precise and true images, but they are only true in the sense that they strictly follow the algorithm that generated them and not the presumed concept or, in other words, the object they presumably portray.

Nonetheless, these methods and images are deeply associated with a belief in objectivity: today, scientific objectivity is not only linked to mathematical, statistical, physical, and computer science technologies but also to images. Thus highly complex and contingent artifacts influence and dominate understanding of terms such as normality, health, disease, and many derived terms and classifications, thus incurring problematic results. Due to the development from the image to simulation, Jean Baudrillard made an assumption almost three decades ago that science has become a true simulation itself, which no longer produces images but only simulacra. A simulacrum circulates within itself in a continuous closed circuit without any external reference. This implies that signs, e.g., images, are perpetually generated out of themselves and always refer back to themselves rather than something external. Baudrillard termed this circulation of signs the "Spin of the Simulacra."[13] Technical images, in whatever context they are produced, are difficult to master – to decipher, so to speak. They pretend, misleading as it were, to be self-evident, without any necessity for decoding; however, the technical image points towards the program inside the instrument, which generated it rather than at the world outside. Such images manifest imagined concepts of calculated thinking but not the real world. They constitute the attempt to make abstraction concrete; thus they seem to be not a symbol but a symptom of the real world.

NOTES

[1] See: Nicole C. Karafyllis: „Das Wesen der Biofakte". In: Nicole C. Karafyllis (ed.): Biofakte. Versuch über Menschen zwischen Artefakt und Lebewesen. Paderborn: mentis Verlag, 2003, p. 12.

[2] Suzanne Anker, Dorothy Nelkin: The Molecular Gaze. Art in the Genetic Age. New York: Cold Spring Harbor Laboratory Press, 2004, p. 19.

[3] For a separate publication and comment on the images within the complete corpus of Andreas Vesalius see: J. B. de C. M. Saunders, Charles D. O'Malley (eds.): The Illustrations From the Works of Andreas Vesalius of Brussels. With Annotations and Translations, a Discussion of the Plates and Their Background, Authorship and Influence, and a Biographical Sketch of Vesalius. New York: Dover Publications, 1973.

[4] For the history of the anatomical theatre see: Gottfried Richter: Das anatomische Theater. Berlin 1936, (Abhandlungen zur Geschichte der Medizin und der Naturwissenschaften 16).

[5] See Cornelia Weber: „Universitätssammlungen und -museen in Deutschland". In: Actes du Colloque: Le musée de sciences: dialogues franco-allemands, Wissenschaftsmuseen im deutsch-französischen Dialog (München 2003), Dijon 2004, p. 33–39. See also: database for university museums and collections in Germany: http://publicus.culture.hu-berlin.de/sammlungen/.

[6] On the topic of Rudolf Virchow's pathological Institute in Berlin as "Schule des Sehens" see: Constantin Goschler: Rudolf Virchow. Mediziner, Anthropologe, Politiker. Böhlau: Köln, Weimar, Wien 2002, p. 204–209.

[7] See: Stuart S. Blume: Insight and Industry: On the Dynamics of Technological Change in Medicine. MIT Press, Cambridge Mass. 1992.

[8] For the complex cultural context that subtends the generation, circulation, and veneration of brain images, see the American cultural anthropologist Joseph Dumit. Picturing Personhood: Brain Scans and Biomedical Identity. Princeton University Press: Princeton, 2004.

[9] Jean Talairach, Pierre Tournoux: Co-Planar Stereotaxic Atlas of the Human Brain. Thieme: Stuttgart, 1988.

[10] Joseph Dumit. Picturing Personhood: Brain Scans and Biomedical Identity. Princeton University Press: Princeton, 2004, p. 17.

[11] See: Gary Brannon: The Artistry and Science of Map-Making. In: Geographical Magazine 61, 9, p. 37–40, Ronald Rees: Historical Links between Cartography and Art. In: Geographical Review, 70, 1980, p. 60–78.

[12] Vilém Flusser: Lob der Oberflächlichkeit. Für eine Phänomenologie der Medien, second edition, Bollmann: Mannheim, 1995, p. 48.

[13] Jean Baudrillard: Die Präzession der Simulakra. In: Agonie des Realen. Merve Verlag: Berlin, 1978, p. 7–69.