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Clean by Nature. Lively Surfaces and the Holistic-Systemic Heritage of Contemporary Bionik.

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Abstract

This paper addresses questions regarding the prospering field of *Bionik* in Germany. Its starting point is the wide spread assumption that universal functional principles exist in nature and that these 'solutions' can be transferred into technological objects. Accordingly, advocates of *Bionik* herald the advent of a better world with more sustainable and efficient products of engineering. The so-called 'functional surfaces' occupy a special place within this contemporary version of biomimesis. Shark-skin-inspired swim suits, self-cleaning façade paints with lotus effect or drag reducing Dolphin-Skins for aircraft-wings are expected to improve the quality of life for everyone. It seems that skin and shell of living systems return as revenants to our technological world and live their afterlives as *lively surfaces* of everyday objects.

This paper argues however, that understanding this attention to 'natural engineering solutions' in contemporary Bionik, one needs to focus on a different kind of afterlife. For baring the historic-epistemological roots allows fathoming direct connections to two widely influential historical concepts within the history of science in the 20th century: *Biotechnik*, a very popular bio-philosophical concept from the Weimar Republic of the 1920s and *Bionics,* an in many ways similar endeavor that emerged during the second wave of Cybernetics in the USA from around 1960. Both historical concepts share a certain proximity to a distinct holistic-systemic style of thinking that emerged during the 20th century and still resonates with the movement of *Bionik* in contemporary Germany.

Based on the example of the lotus effect, I want to address three aspects of the afterlife of this holistic-systemic heritage in contemporary *Bionik*. First, the assumption that the best engineering solutions can be found in nature conceals the specific discursive and non-discursive complexity that forms the basis of all technological objects. Second, the holistic-systemic heritage of *Bionik* directly correlates with its epistemological bias towards visual evidence and its enthusiasm for 'functional surfaces'. Third, the rhetoric of Bionik paradoxically oscillates between a counter-modern demotion of human creativity and autonomy and a fascination for modern scientific instruments and practices.

Keywords

Biotechnik, Biotechnics, Cybernetics, Bionics, Bionik, Biological Computing, lotus effect, Numarete, Raoul Francé, Jack Steele, Heinz von Foerster, Wilhelm Barthlott

Cover Page Footnote

Translated from German by Clemens Ackermann. I would like to thank Thomas Brandstetter for calling my attention to Raoul Francé's biotechnics in the first place and helping me with its historical contextualization

1. Paint and Dashed Hopes

After having received countless personal inquiries from his customers and as a consequence of numerous debates with his colleagues, master painter Martin Kempf from Alzenau in Lower Franconia deemed it necessary to address a question on the website of his company in May 2003 that had worried his guild for some time past:

> It rarely ever happened that something as mundane as exterior paint would let the feelings of experts run as high, as it was the case with the promotionally effective introduction of the Lotusan paint. The industry appears to be divided into proponents and critics. On closer inspection, it is evident that the proponents are part of the faction that would make money off of this paint, and that the critics must be apportioned to the faction that unfortunately cannot offer a comparable product […] and thus see their hopes dashed. What is actually so special about this paint? And about the so-called lotus effect?[1]

A brief look at the advertising brochure for the exterior paint LOTUSAN by Sto AG[2] renders the worries of the competitors easily comprehensible and the question of the painter—"what is so special about this paint"[3]—appears more than aptly put (Figure 1). As a last consequence, Sto promises nothing less than the fact that buildings coated with LOTUSAN will never require another coat of paint. For the first time, it was allegedly successful to…

> …transfer the natural self-cleaning Lotus-Effect® of the lotus plant to exterior paint and plastering… Because, similar to the leaf

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[1] Master Painter Kempf. "Der Lotus-Effekt an der Fassade – Dichtung oder Wahrheit?" Accessed March 29, 2014. http://www.maler-kempf.de/html/thema_lotusan.html ["Es ist selten vorgekommen, dass so etwas Banales wie eine Fassadenfarbe die Emotionen der Fachwelt so hochkochen [lässt], wie die werbewirksame Einführung der Lotusan Fassadenfarbe. Die Branche [scheint] gespalten in Verfechter und Kritiker. Bei näherem Hinschauen [kann] man erkennen, dass die Verfechter zu dem Lager zählen, die mit dieser Farbe Geld verdienen, und die Kritiker dem Lager zuzurechnen [sind], die leider kein Vergleichsprodukt anbieten [können] […] und nun ihre Felle davon schwimmen [sehen]. Was ist eigentlich dran an dieser Farbe? Und an dem sogenannten Lotus-Effekt?"].

[2] Sto AG is an internationally leading manufacturer of paint, lacquer, and coating from Baden-Württemberg.

[3] Ibid. ["was dran sei"].

of the lotus plant, the paint and plastering with Lotus-Effect® have a highly water-repellent surface with a special microstructure. Dirt particles cannot adhere to this surface—as soon as it rains, they will be entrained by the rain dripping off. The result: ideal protection of the façade and the veneer remains dry and beautiful.[4]

Figure 1 – Advertisment for Sto AG's "intelligent color" LOTUSAN (http://www.lotusan.de)

Regardless of the highly controversial query among experts, whether LOTUSAN actually delivers on the manufacturer's promise, it is especially interesting regarding the question of surfaces that the maker calls its product a "trendsetter-product"[5] of a branch of engineering research, which is tremendously popular in Germany since the mid 1990s; namely, *Bionik*. According to the manufacturer, the lotus effect is a prime example for a successful transfer of a "millennia-old invention of nature" to technological applications.[6] And, since—according to their

[4] "StoLotusan. Fassadenbeschichtungen mit Lotus-Effect", advertising brochure of Sto Ges. m.b.h. 2005. ["natürlichen selbstreinigenden Lotus-Effect® der Lotuspflanze auf Fassadenfarbe und Fassadenputz zu übertragen… Denn ähnlich wie beim Lotusblatt besitzen auch Farbe und Putz mit Lotus-Effect® eine hoch wasserabweisende Oberfläche mit spezieller Mikrostruktur. Schmutzpartikel können auf dieser Oberfläche nicht anhaften – sobald es regnet, werden sie von den abperlenden Regentropfen mitgerissen. Das Ergebnis: Ein optimaler Fassadenschutz und die Fassade bleibt trocken und schön"].

[5] Ibid. ["Schrittmacherprodukt"]

[6] Ibid. ["jahrtausendalten Erfindung der Natur"]

claim—nature has often long before us discovered the most ecological and economical solutions for a specific technical problem due to "the experience of millennia",[7] one can now not only offer better, but also more sustainable exterior paint. In their advertising endeavors, the marketing department of Sto can rely on an enormous, yet constantly growing linguistic and no less visually stunning apparatus of marketing propaganda concerning *Bionik* that encompasses pretty much everything that the toolkit of contemporary business communication has to offer; viz. reaching from professional publications,[8] nonfiction and textbooks[9] to elaborately produced movies and documentaries[10] all the way to experimentation sets and board games.[11]

The so-called 'functional surfaces' occupy a special place within the binomial frenzy of enthusiasm. Be it low-friction shark skin for swim suits, anti-glare compound eyes for cell-phone displays, gecko soles with nano-hair for superglue, or the aforementioned lotus leafs for exterior paint: it seems that skin and shell of living systems return as revenants to our technological world and live their afterlives as *lively surfaces* of everyday objects.[12]

In the following, I will thus reflect upon the question of what exactly *lives on* in these products of contemporary *Bionik*. While at first glance the obvious answer would probably be, that the superiority of these artifacts can be explained

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[7] Ibid. ["Erfahrung von tausenden von Jahren"]

[8] Recent scientific publications include: Werner Nachtigall, *Bau-Bionik. Natur – Analogien – Technik* (Berlin: Springer 2013); Yoseph Bar-Cohen, *Biomimetics: nature-based innovation* (Boca Raton: CRC Press 2012); W. Nachtigall, *Bionik als Wissenschaft. Erkennen – Abstrahieren – Umsetzen* (Berlin: Springer 2010).

[9] Claus-Peter Lieckfeld, *Der Natur auf der Spur : Bionik - Herausforderung und Chance* (Waldbröl: Pro Futura/World Wildlife Fund 2012); Robert Allen and Andrea Kamphuis, *Das kugelsichere Federkleid: wie die Natur uns Technologie lehrt* (Heidelberg: Spektrum/Akademie 2011); Thea Lautenschläger, *Bionik – Experimente für die Schule: spannende Entdeckungen aus der Natur* (Berlin: Duden 2011).

[10] For example: *Bionik – Das Genie der Natur,* DVD 150 min., directed by Alfred Vendl and Steve Nicholls (ORF Universum: Vienna 2006).

[11] For example: *KOSMOS 633035 – Lotusblume Experimentierkasten*, experimentation set (Stuttgart: KOSMOS 2013) and *Bionik. Natur macht erfinderisch*, board game (Ravensburg: Ravensburger Spieleverlag 2000).

[12] By referring to these contemporary products of Bionik as 'lively' artifacts, I want to hint at the fact that they are not simply lifelike objects, understood as neutral copies of natural prototypes, but in fact independent epistemic agents that appear to be alive by showing some form of biological 'behavior'. I will go into more detail about this aspect of liveliness at a later point in this article.

by the fact that natural principles are being transferred to (and thus *live on* in) these devices, I want to focus on a different kind of afterlife. For baring the historic-epistemological roots allows fathoming direct connections to two widely influential historical concepts within the history of science in the 20th century: *Biotechnik*, a very popular bio-philosophical concept from the Weimar Republic of the 1920s and *Bionics,* a in many regards similar endeavor that emerged during the second wave of Cybernetics in the USA from around 1960. While holding a significant place in the wider context of a more general history of Biotechnology,[13] both historical concepts share a certain proximity to a distinct holistic-systemic style of thinking that emerged during the 20th century and still resonates with the movement of *Bionik* in contemporary Germany.[14]

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[13] As Robert Bud has shown, the general concept of ‘biotechnology’ understood as a combination of biology and engineering developed a rich and highly complex history in the course of the 20th century. The range of its changing connotations is very broad, many different ideologies and areas of application have gathered under its banner over the course of time. The most prominent trajectory of meaning within the history of this concept undoubtedly refers to the idea of using biological organisms for the benefit of men, ranging from such diverse (and historically contextualized) fields of application as agriculture, medicine, hygiene or eugenics to contemporary genetic engineering. In this paper however, I want to focus on the notion of ‘biotechnics’, as the attempt to emulate nature by technological means in order to create ‘environmentally friendly’ technological products in accordance with nature. Cf. Robert Bud, *The Uses of Life. A History of Biotechnology*, (Cambridge, Mass.: Cambridge University Press 1993).

[14] Historically speaking, ‘holism’ and ‘systems theory’ are evidently not the same thing. The term ‘holism’ was coined by the South African statesman and philosopher Jan Smuts in 1926, who was drawing on late 19th century biology and the popular Aristotelean idea that nature forms ‘wholes’ that are greater than the sum of its parts due to the implementation of a vital principle that is absent in inanimate things (Cf. Jan Smuts, *Holism and Evolution* (London: Macmillan 1927), 88). The introduction of a general ‘systems theory’ after WWII is usually ascribed to the Austrian biophysicist Ludwig von Bertalanffy, who wanted to overcome the prewar opposition of mechanism and vitalism by taking a new approach to understanding the ‘organizational principles’ that distinguish ‘living systems’ from other objects (Cf. Ludwig von Bertalanffy, *Problems of Life: An Evaluation of Modern and Scientific Thought* (New York: Harper 1952 [1949]). However, both concepts share an anti-reductionist and anti-mechanist worldview that focuses on the organization of a system’s parts as well as on the interaction of the whole systems with its respective environment. The so-called Second Wave of Cybernetics during the 1960s in particular drew heavily on both holistic and systemic rhetoric to explain living systems.

Subsequently, I want to show by means of the example of the lotus effect, that this holistic-systemic way of thought directly correlates with the biomimetic enthusiasm regarding surfaces. As interface between living systems and their respective environments, surfaces initially prompt thought concerning *every biotechnical endeavor* by way of the problem of natural universally valid operating principles. However, an epistemology operating on the surface—as it is the case with the example of the lotus effect from contemporary *Bionik*—can never be looked at independently of the media technologies that make epistemic things out of epidermal ones.

2. Poppy Seed Capsules and Salt Shaker

Initially, I want to consider the sober assessment that technological artifacts can be the product of a cultural technique, which purposefully imitates natural forms and functions. This mimetic demand has first been formulated as a philosophical program at the beginning of the twentieth century. Along these lines, Vienna born botanist Raoul Francé indicated, by employing the term *Biotechnik* as early as around 1920, not only the similarities between nature and technology, but he also demanded mimesis to be the highest goal of technical work.[15] Francé developed this concept in multiple monographs and numerous essays.[16] For example his

[15] Cf. Raoul H. Francé, *Die technischen Leistungen der Pflanze*, (Leipzig: Veit & Comp. 1919) & Raoul H. Francé, *Die Pflanze als Erfinder* (Stuttgart: Franckh'sche Verlagshandlung 1920).

[16] His real name being Rudolf Franze, Raoul Francé was born in Vienna on May 20, 1874. He studied analytic chemistry and microtechnology as autodidact. At the age of 16, he was the youngest member of the royal Hungarian society of the natural sciences, where he would work as vicarious editor from 1893 to 1898. Starting in 1897, Francé studied medicine for eight semesters and became a student of the Hungarian protozoa scholar Geza Entz. During this time, he accomplished 14 botanical research trips. In 1898 he was appointed vice director of the institute for the protection of plants at the agricultural academy in Hungarian-Altenburg. Here, he published his first work on natural philosophy. Subsequently, Francé was prompted to come to Munich in 1902. In 1906, Francé founded the Deutsche Mikrologische Gesellschaft and the appertaining institute, which he presided over as director. He was the editor of the societies' journal and co-founder of „Mikrokosmos" (1907). He presided over further series as editor, such as "Jahrbuch für Mikroskopiker" und die "Mikrologische Bibliothek." Also in 1906 Francé initiated the eight-volume encyclopedia *Das Leben der Pflanze* by writing the first four volumes himself (1906-1910). Alluding to the highly popular zoological reference book *Brehms Tierleben*, first published by Alfred Brehm in the 1860s, Francé's monumental work was advertised as 'Pflanzen-Brehm' by its publisher

short essay *The Plant as Inventor*, in which he describes the primal scene that allegedly lead him to the principle of biotechnics.[17]

According to Francé, he one day had to face a problem whilst conducting experiments in his laboratory in Munich. He had to evenly spread soil samples on the surface of his bench, in order to examine the microorganisms contained within them. Having tried multiple every day objects with unsatisfactory results, he had the "incidental idea […] to ask, how nature attends to dissemination."[18] He was considering specific plants and fungi, which are dependent on evenly spreading their seeds or spores; in the dried seed capsules of the poppy seed plant, he eventually found what he was looking for: "I immediately realized that nature had found a solution to my problem. All I had to do was mimic nature and I was relieved of my troubles."[19] Following the model of the dried capsules, Francé eventually applied for a patent for a new "shaker/scatterer for the household and for medical purposes." (Figure 2)[20]

Based on this primal scene, Francé subsequently developed a universal biotechnic philosophy, according to which every mechanism in the world has its necessary technical form and that this form is furthermore always already realized in nature. The crucial point with Francé is thus the substitution of men's creative effort with the originative power of nature. Or, as he put it himself: "I am […] not interested in being considered an inventor, because I am merely a wretched copyist of nature."[21] At the heart of his philosophy lies the conviction that the entire world is governed by a principle of economy, which Francé calls "the law

Kosmos, R. H. Francé et al, *Das Leben der Pflanze* (Stuttgart: Kosmos 1906-1913). Today Francé is mostly known for coining the biological term 'edaphon', cf. René Roth, "The foundation of Bionics," *Perspectives in biology and medicine* 26 (1983): 238.

[17] When using the term 'biotechnics' to translate the German term 'Biotechnik', I am following American historian and sociologist Lewis Mumford who learned about Francé's *Biotechnik* through his correspondence with the British Biologist Pattrick Geddes and introduced the term '(bio)technics' to the American discourse through the publication of his book *Technics and Civilization* in 1934, Bud, *Biotechnology*, 69.

[18] Francé, *Pflanze als Erfinder*, 5-8. ["der beiläufige Einfall ... zu fragen, wie denn die Natur das Ausstreuen besorge."]

[19] Ibid. ["Sofort sah ich ein, dass die Natur eine Lösung meines Problems gefunden (hatte). Ich brauchte sie nur nachzuahmen und war dann jeder Sorge enthoben."]

[20] Ibid. ["Streuer für Haushalt und mediz. Zwecke."]

[21] Francé, *Pflanze als Erfinder*, 5-8 ["Ich habe ... gar kein Interesse daran, als Erfinder zu gelten, denn ich bin nur ein elender Kopist der Natur."].

of least resistance and the economy of efficiency."[22] The consequence of these laws is that every mechanism "has its necessary technical form." For example: "Everything that is sought to drill or to penetrate something, has to have the form of a screw."[23] Francé even goes a step further and claims that there are no more than seven fundamental technical forms, namely, "crystal form, sphere, surface, column and brace, screw and cone" from which "all mechanisms of the world process are derived": "Nature has not brought forth anything else and the human mind may create whatever it wants, it will always only arrive at combinations and variations of these seven fundamental forms."[24] For Francé, this universal basic kit of the world is the reason, why there cannot be any form of a man-made device that would not be deducible from nature.

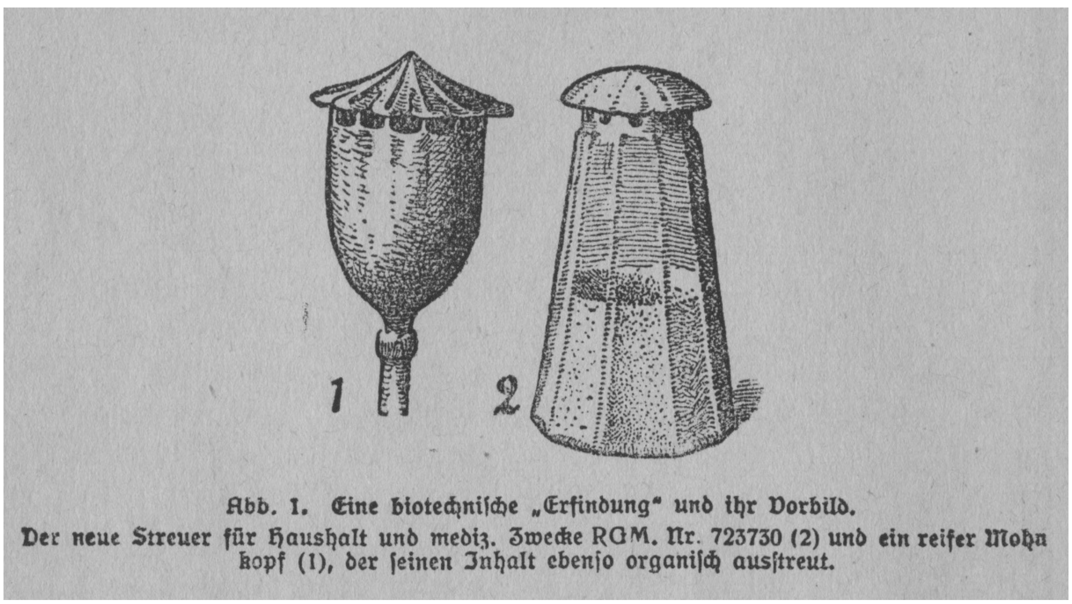

Figure 2 – Poppy Seed and Salt Shaker (Francé, *Pflanze als Erfinder* 1920, 8).

[22] Ibid., 25. ["Gesetz des geringsten Widerstandes und der Ökonomie der Leistung."].

[23] Ibid., 17. ["Alles, was bohren, durch etwas dringen soll, muss die Form der Schraube haben."]

[24] Ibid., 18. ["...Kristallform, Kugel, Fläche, Stab und Band, Schraube und Kegel ... sämtliche Prozesse des Weltprozesses ... Die Natur hat nichts anderes hervorgebracht, und der Menschengeist mag schaffen, was er will, er kommt immer nur zu Kombinationen und Varianten dieser sieben Grundformen..."]

One quickly recognizes two epistemological problems with Francé's cosmology: initially, there is a contradiction between his supposition of a universalistic principle of economy and the simultaneous call to the engineer to mimic it: why does man as part of nature not automatically choose the most economical technical solutions? The reason for this contradiction is that, despite Francé's argument for the existence of a harmonious and 'whole' cosmos, his idea of copying nature by technological means in fact presupposes a clear cut distinction between nature and culture, or to quote Katherine Hayles: "The flip side of drawing analogies is constructing boundaries. Analogy as a figure draws its force from the boundaries it leapfrogs across."[25] Secondly, there is the problem regarding the retroactive character of *biotechnics*: the starting point is always the culturally formatted search for solutions of technical problems (for example the task of evenly spreading samples of soil on a laboratory bench) and not the invention of a nature.

At this point however, I cannot extensively discuss the context of the history of science in which Francé developed his—in many respects problematic––biotechnic philosophy. It may suffice to draw attention to the fact that his approach can be classed with a whole range of popular holistic approaches from that time, which, contrary to other approaches—such as Marx or Cassirer—do *not* argue the case for autonomy of modern technic with respect to nature,[26] but instead strive for an integration of technic into a harmonically organized 'cosmos.'[27] Confronted with the disastrous ramifications of World War I, an increasing desire for "a new technology for a new age" among European intellectuals emerged. Having witnessed the catastrophic destructions caused by modern machinery and industry, an integration of biology with engineering promised to "integrate the contemporary ideal of manufacturing with visions of humanity and its environment, and a faith in the privileged view of life".[28] However, inspired by vitalist Biologists such as Hans Driesch and Lamarckian

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[25] Hayles, Katherine, *How we became posthuman: virtual bodies in cybernetics, literature, and informatics* (Chicago: University of Chicago Press 1999), 93.

[26] Marx discusses the emancipation from "organic limits." ["organischen Schranke"] Karl Marx, *Das Kapital. Erster Band* (Wien: Globus 1982), 394. Cassirer undertakes a clear separation of magical and technical worldview in his essay „Form und Technik." Ernst Cassirer, "Form und Technik", in: idem. *Symbol, Technik, Sprache* (Hamburg: Meiner 1995), 39-91: 74.

[27] In this regard Francé's Biotechnik is a typical example of what Ann Harrington labeled a 'reenchanted science', Anne Harrington, *Reenchanted Science: Holism in German Culture from Wilhelm II to Hitler* (Princeton: Princeton University Press 1999).

[28] Bud, *Biotechnology*, 51-52.

concepts of evolution, figures like Francé's must also be seen as representatives of what Jeffrey Herf has coined "reactionary modernism" in Weimar Germany; a romantic enthusiasm for technology that was accompanied by a rejection of humanist and liberal concepts.[29] Subsequently, this holistic legacy had a wide influence on all recoinings and reformulations of the biomimetic idea up until today.[30] Even the *lively surfaces* of contemporary *Bionik* such as sharkskin and self-cleaning façades ultimately also imply a counter-modern demotion of human creativity and autonomy.

Of at least equally great interest for the question of surfaces is however the fact that Francé has framed his biotechnical principle employing a rhetoric of visual evidence and immediacy. According to this, inventions of the flora could be recognized with the naked eye. And it is surely no coincidence that to this day, bionic analogies are legitimized via a mirror-imaged juxtaposition of model and copy. Nature, according to Francé, complies with the universal forms of functions "unto the very edge of visibility."[31] And yet, the fact that *Biotechnik* was the product of a fundamental shift of just this edge was not borne in mind. Because, different from what Francé's anecdote of the poppy seed shaker suggests, he developed his biotechnic philosophy of universal forms not during copious walks in the woods, but whilst sitting at the microscope, with pen and drawing paper ready at hand. Figure 3 for example shows drawings of flagellates, i.e. monads with flagella, which, according to Francé, found the "ideal solution to the problem of swimming."[32]

[29] Jeffrey Herf, *Reactionary Modernism. Technology, Culture and Politics in Weimar and the 3rd Reich* (Cambridge: Cambridge University Press 1985).

[30] Oddly enough, among the wide readership of Francés writings was the Hungarian painter, photographer and professor in the *Bauhaus School* László Moholy-Nagy. His famous *form follows function*-principle was greatly influenced by Francés cosmology, cf. Inge Baxmann, "Der labile Mensch als Kulturideal. Wahrnehmungsutopien der Moderne," in *Electric Laokoon. Zeichen und Medien, Von der Lochkarte zur Grammatologie*, ed. Michael Franz et al. (Berlin: Akademie 2007), 97-117: 110-112.

[31] Francé, *Pflanze als Erfinder* 1920, S. 14. ["bis zur letzten Grenze des Sichtbaren."]

[32] Ibid. ["optimale Lösung des Schwimmproblems"]

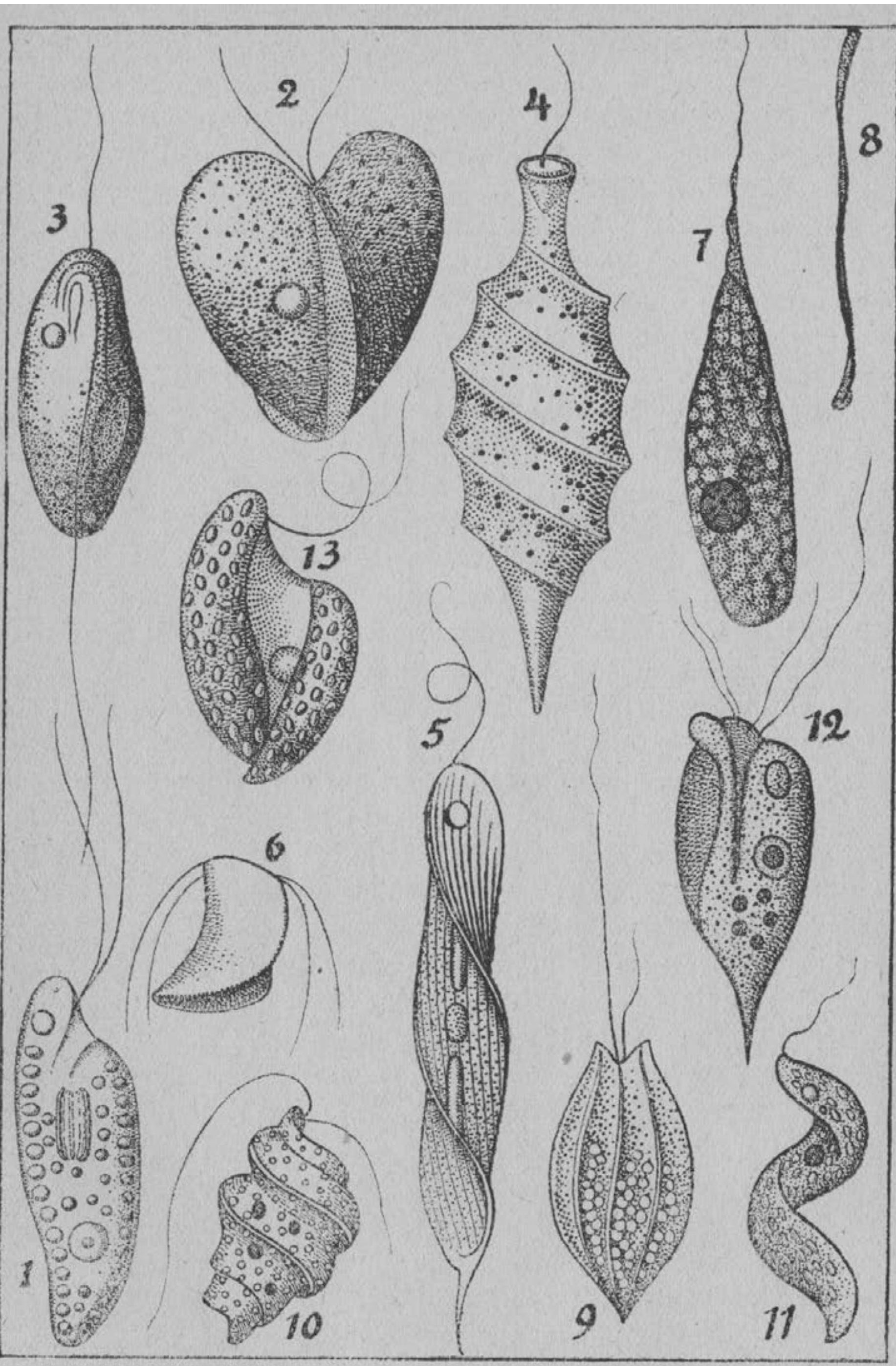

Abb. 9. Flagellatenformen. (Erklärung nebenstehend.)

Figure 3 – Flagellates drawn by Raoul Francé (Francé, *Pflanze als Erfinder* 1920, 27).

And indeed, as founder of the *German Micrological Society* and as editor of the *Yearbook for Microscopists* he found himself amidst that light microscopical wave of enthusiasm, which reached the mainstream of German speaking botanists around 1900.[33] The irony in Francé's work thus lies in the fact, that the *conditio sine qua non* of his biomimetic endeavor, was in fact a media technology that does *not* easily qualify as a biomimetic artifact. Being the product of age-long craftsmanship, purposeful experimentation and geometrical understanding, the microscope must rather be interpreted as a prime example for the discursive and non-discursive complexity that forms the basis of all technological objects.[34] That however, calling upon Kittler, the "unknown creature Hardware" walks abroad behind the back of biotechnics remains—as we shall see—a blind spot of all biomimetic ambitions.[35]

3. Frog Eyes and Biological Computer

The European holistic concept of a biologically informed technology reached the US discourse as early as in the late 1930s. Especially the idea to combine conventional engineering education with a base training in biology and medicine became increasingly popular and led to the establishment of several institutions offering a variety training and research programs.[36] In the light of this

[33] In his biography Francé mentions that, as a young man, with he tried great effort to build his first own microscope, following the descriptions of the 17th century Dutch scientist Antonie Philips Leeuwenhoek. He reports that he succeeded at building a rudimentery device that would allow him to observe the "dwellers of the swamp water ... at the size of bugs" but that he was also afraid the self-built microscope might eventually "spoil his eyes", R.R. Francé, *Der Weg zu mir. Lebenserinnerungen erster Teil*, (Leipzig: Kröner 1927), 64. ["…groß wie die Käfer krochen und huschten die sonst punktgroßen Bewohner des Sumpfwassers vor meinen entzückten Augen dahin, die man sich nun viele Stunden lang verdarb"]

[34] Note that this statement does of course not contradict Jutta Schickore's assumption of an "entwined history of microscope and the eye" from the early 19th century, understood as a *discursive* and *epistemological* entanglement of microscopy, sensory physiology and the formation of what Schickore calls "second order concerns", J. Schickore, *The Microscope and the Eye. A History of Reflections*, 1740-1870 (Chicago: University of Chicago Press 2007), 1-13.

[35] Friedrich Kittler, "Hardware. Das unbekannte Wesen", in *Medien, Computer, Realität. Wirklichkeitsvorstellungen und neue Medien*, ed. S. Krämer (Frankfurt a. M.: Suhrkamp 1998), 119-132. ["unbekannte Wesen Hardware"]

[36] The *MIT* established a combined training and research program called "biological engineering" in 1936, which was pushed forward by its Vice President and Dean of

development the idea of biotechnics was rediscovered around 1960 by the protagonists of the second wave of American cybernetics and reformulated as *Bionics.* This undertaking surely has to be initially assessed as an attempt to revive the still not successfully institutionalized universal science that was some fifteen years earlier driven forth by the now discontent protagonists of the *Macy Conferences*.[37] Other than that, the fusion of Norbert Wiener's theory of feedback as universally valid principle in the world of animals and machines alike with the old biomimetic paradigm appears to be reasonable, indeed. Ultimately, cybernetics also wants to harmonize the fragmented and specialized branches of science based on the proposition of abstract circuits and procedures. And, although there are no examples from the projects of *Bionics* research from around 1960 that would directly correlate with the initially mentioned lively surfaces, it can be established that boundaries—understood as the differentiation of a living system and its environment—are epistemically especially productive within the new field. "Functional relations", in the sense of a cause-effect relationship between form and function in Francés cosmology, were indeed put back as opposed to the problematization of modes of behavior.[38] Then again, the discourse about homeostasis, self-organization and pattern recognition moves system-boundaries and with it surfaces to the center of attention.

But one thing at a time: From 1960 to 1966, the US-Air Force research division organized four big *Bionics*-Symposia.[39] At the first meeting, the chairman of the conference, Jack Steele, explained the goal of *Bionics* as follows:

> Apparently we are going to design devices and systems, which to

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MIT School of Engineering Vannevar Bush. The University of California established a new engineering school in 1944 that offered a special program in "biotechnology", outlined by the head of the new school L.M.K. Boelter who envisioned "engineering as an unified whole", Bud, *Biotechnology*, 86-92.

[37] Ronald Kline, *Cybernetics in Crisis: Reviving and Reinventing a Postwar interdiscipline in the United States*, unpublished manuscript.

[38] Norbert Wiener, Julian Bigelow and Arturo Rosenblueth, "Behaviour, Purpose and Teleology", *Philosophy of Science* 10 (1943): 18-24. ["Funktionale Relationen"]

[39] The presented papers were published in four volumes: Joan Robinette (ed.), *Bionics Symposium. Living Prototypes. The Key To New Technology* (Dayton: WADD Technical Report 60-600 1960); Eugene E. Bernard (ed.), *Biological Prototypes and Synthetic Systems. Volume 1: Proceedings of the Second Annual Bionics Symposium*, (New York: Plenum Press 1962); Anonymous (ed.), *Bionics Symposium 1963. Contributed Paper preprints* (Ohio: WADD Technical Reports 1963); Hans Oestreicher and Darrel Moore, Darrel (ed.), *Bionics Symposium 1966: Cybernetic Problems in Bionics* (New York: Gordon and Brech Science Publishers 1966).

> the naive observer might appear to be alive. They will employ processes and techniques and accomplish functions, which hitherto have existed only in living systems.[40]

Composed of the Greek syllable "βίον" (= life form) and the English adjective ending "ic", the neologism "Bionics" was thought to signify a new universal science and finally to guide the way toward a transdisciplinary unification of biology, mathematics and engineering.[41] On the side of the military, such unification was expected to *first of all* enable a direct and productive incorporation of biology into the scientific-academic-military complex and *secondly*, to engender new 'biological' approaches to mastering the growingly complex military technologies.[42] According to Jack Steele's assessment in his closing remarks, it is crucial—in addition to the education of young engineers in the new field—to have "gadgets" available as soon as possible, which could demonstrate the potential of the new science by presenting simple solutions. As accepted products of *Bionics*, such "gadgets" were thought to generate a high degree of acceptance and support.[43]

One attendant of the first symposium was the Austrian Heinz von Foerster. The physicist had the intention to adopt the model of biological-mathematic

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[40] Jack E. Steele, "How Do We Get There?", in Robinette, *Living Prototypes*, 487-490: 487.

[41] Chris Hables Gray, "An Interview with Jack E. Steele", *The Cyborg handbook, ed. by idem* (New York: Routledge 1995), 61-69: 62.

[42] At the Symposium John E. Keto from the *Wright Air Development Division* identified two major areas of technological problems that the Air Force was currently facing and for which the new science of Bionics was expected to offer better solutions. The first area belonged to the field of information, where Keto saw "tremendous data processing problems" caused by "highly complex weapon systems" and an "extremely close coupling of man and machine". By outlining the second area of potential application Keto referred to the efficiency in nature: "Military equipment and weapon systems are plagued with major problems of size, weight and operative power requirements. These pressures increase on an exponential scale … Bionics has a tremendous potential payoff in this area when you appreciate the extreme compactness, very low comparative weight and power requirements of living prototypes", John E. Keto, "Bionics. New Frontiers of Technology through Fusion of the Bio and Physio Disciplines", Robinette, *Bionics Symposium* 1960, 7-12.

[43] "Some simply consider the task too difficult and all effort wasted. The answer is unceasing education and explanation, and gadgets, simple solutions, soon delivered. Identified as the offspring of bionics they will bring honor and support to their parent and make the greater achievements possible", ibid., 490.

research with a soldering iron in hand, for his newly founded *Biological Computer Laboratory* at the University of Illinois at Urbana Champaign.[44] Foerster understood *Bionics* to be the logical continuation and extension of the encompassing and unifying aspirations of cybernetics:

> Bionics extends a great invitation to all who are willing not to stop at the investigation of a particular function or its realization, but to go on and to seek the universal significance of these functions in living or artificial organisms.[45]

And, with the experience of five years of Bionic practice at his BCL at Illinois, he described the future perspective of the new field as follows:

> Bionics characterizes an activity – or a point of view – which insists that attempts to synthesize biomorphic functions such as habituation, adaption, perception, recognition, cognition, recall, learning abstraction, conceptualization, association, induction, ideation, appetition, awareness, consciousness, self-repair, self-reproduction, growth, evolution, self-organization, etc., etc., will not only aid the analytic studies of these functions in living organisms, but also will eventually provide us with operational definitions of these terms.[46]

Foerster conceived of this interplay of analysis and synthesis as a cybernetic control loop (Figure 4). The observation and analysis of a biological organism, the "living prototype," would thus allow for a formalization of universally valid principles that could be recorded on the technical level in the course of the construction of artificial systems. Finally, a comparison of an artificial and an organic system would in turn augment the biological analysis and thus deepen the understanding of fundamental operating principles, and so on.[47]

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[44] Albert Müller, "A Brief History of the BCL. Heinz von Foerster and the Biological Computer Laboratory", in *An Unfinished Revolution? Heinz von Foerster and the Biological Computer Laboratory BCL 1958-1976*, ed. by idem and Karl Müller, (Wien: echoraum 2007), 279-302.

[45] H. v. Foerster, "Preface: Bionics", in: Robinette, *Bionics Symposium,* 1-3.

[46] H. v. Foerster, "Bionics Principles: A summary", in: *NATO Advisory Group for Aerospace Research and Development*, edited by R.A. Williams, 1-11. Bionics Lecture Series XX Vol.1, Paris 1965.

[47] "Comparison with the living prototype may either reveal the significance of certain organizational features in the prototype – i.e., aid in the analysis of living organisms –

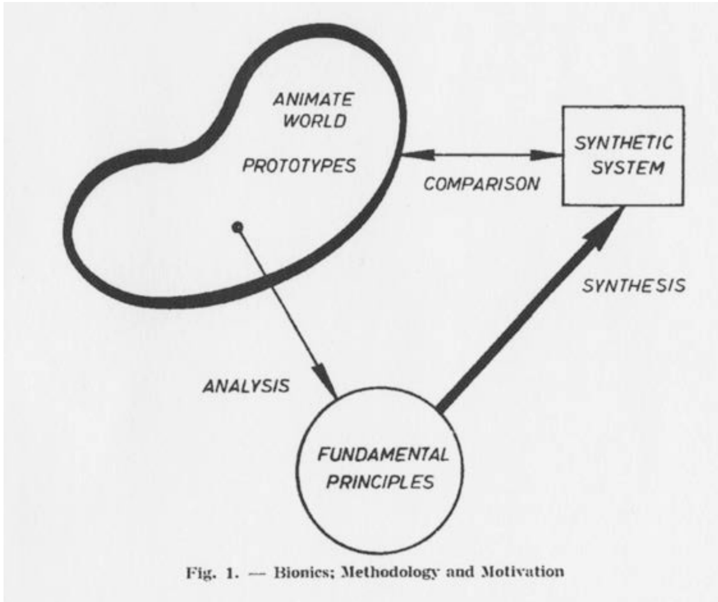

Figure 4 – Methodological Circle of Bionics (Foerster, *Bionic Principles* 1965, 2)

It is initially noticeable that the epistemologically relevant natural processes were entirely different for Foerster than they were for Raoul Francé; i.e. perception, cognition and learning, instead of spreading, screwing or cranking. And, since the military-academic-industrial complex of the 1960s would rather request information-processing systems such as radar- and computer-technologies, the research practice at the BCL would deal with *lively surfaces* very different form sharkskin and gecko feet: the *NumaRete* for example, an artificial cognition machine modeled after the retina of a frog, was thought to reproduce the 'natural' phenomenon of pattern recognition. The basis of the machine's construction plan came from the neurophysiological frog experiments by Humberto Maturana and Jerome Lettvin, who, in the late 1950s, published an essay with the central claim that for vertebrates a lateral connectivity of neurons in the retina already prompts an intelligent pre-interpretation and computation of visual stimuli before they reach the brain.[48] The frog-machine *NumaRete*, which was constructed at the BCL, would—as Foerster tirelessly pointed out—adopt the 'natural algorithm' of the faunal retina and operated according to the same, simple 'fundamental

or detect redundancies in either artifact or organism whose presence may be justified by considerations that are beyond the original task", ibid., 2.

[48] Jerome Lettvin et al, "What the Frog's Eye Tells the Frog's Brain", in: *Proceedings of the Institute of Radio Engineers* 47 (1959), 1940-1951.

principle' of retinal connectivity. Just as the frog-eye from the experiment could recognize small, agile points ('flies') and large shadows ('birds') immediately, *NumaRete* could display the number of objects sitting on its artificial retina, thus baffling the visitors on a regular basis because of this seemingly intelligent capacity (Figure 5).

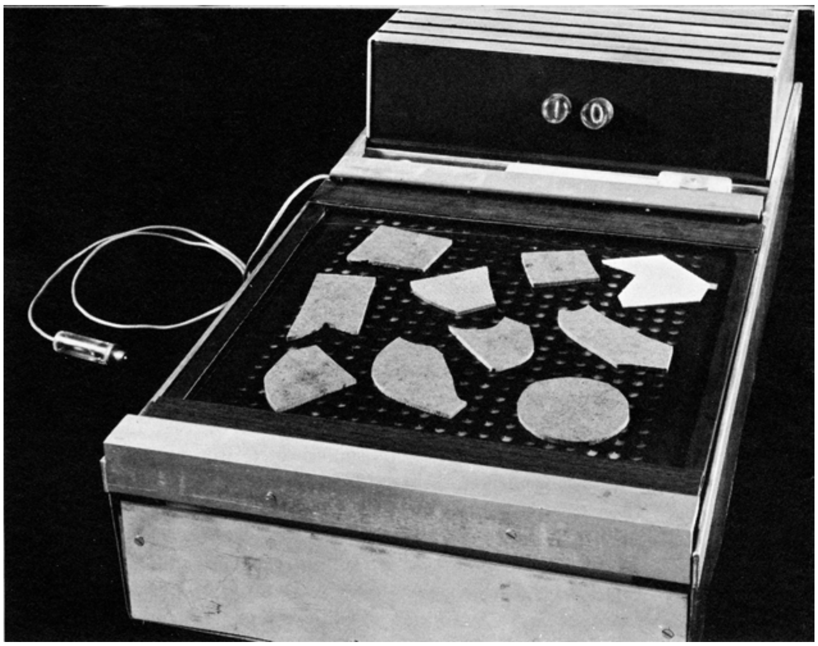

Figure 5 – *NumaRete*, an artificial retina by Paul Weston (Halacy, *Bionics* 1965, 113)

Drawing on the example of BCL's machine models,[49] I want to briefly mention two more fundamental characteristics shared by all products of *Bionics*: First, despite the holistic rhetoric regarding an immediate access to principles of natural form and function, bionic machines are screwed and soldered together by engineers, they are *constructions*. In order for the prototypes to credibly attest to the fundamental research paradigm, *Bionics*-Engineers have to improvise, explore alternative options or adapt or translate their knowledge of biology to the task at hand. Instead of simply following the 'blueprints of nature,' they always operate in an uncertain space of possibilities between improvisation and compromise, and they can only implement those solutions that are feasible regarding the

[49] For a more detailed discussion of the *NumaRete* see Jan Mueggenburg, "Lebende Prototypen und lebhafte Artefakte: Die (Un-)Gewissheiten der Bionik", *Ilinx. Berliner Beiträge zur Kulturwissenschaft* 2 (2011), 1-20.

availability of tools and materials.[50] Secondly, Bionic artifacts are in fact *lively artifacts* in the sense that they always develop their own certain epistemic dynamic beyond their characteristic as mimetic objects. Accordingly, what is meant by *lively* is the effect that creates itself mainly aesthetically and aims towards the mediation of appearance and animacy. This effect of liveliness is a function of the knowledge of the subject interacting with these artifacts. Based on this ability to create bafflement, curiosity or enthusiasm with the interacting observer, lively artifacts seem to be visual arguments *in favor of* efficiency, elegance or of the sustainability of biotechnical solutions. I.e., they stabilize the discursive formation of which they are a product and further develop it by actively advancing the process of generating discourse.[51]

4. Cacti and the self-cleaning effect

In the late 1960s funding for Cybernetics as a universal meta-discipline in the US declined, when its former military and foundational supporters started to lose interest in research under the Cybernetics label. While a few societies that were founded during this crisis continue to spread some elements of the Cybernetic heritage up until today (most prominently the *American Society of Cybernetics* and the *Society for General Systems Research*),[52] members of the second generation of cybernetic researchers such as Foerster ultimately failed to successfully institutionalize their discipline in the long term.[53] Alongside this development enthusiasm for *Bionics* in the US also started to fade away and the biomimetic approach was absorbed in specialized fields such as *Biomechatronics* or *Biomedical Engineering*.

In contrast to the decline of Cybernetics in the US, *Kybernetik* became a highly fashionable science in the Federal Republic of Germany in the 1960s and

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[50] In retrospect, Paul Weston, the maker of the NumaRete, compared his device to a Rube Goldberg-Machine, an overengineered machine that performs a comparably simple task, cf. Jan Mueggenburg, “Kybernetik in Urbana: Ein Gespräch zwischen Paul Weston, Jan Mueggenburg und James Andrew Hutchinson”, *Österreichische Zeitschrift für Geschichtswissenschaft*, 4 (2008), 126-139, 129.

[51] For the concept of *lively artifacts* see Jan Mueggenburg, “Lively Artifacts”, Feedback (Open Humanities Press 2013), accessed March 31, 2014. http://openhumanitiespress.org/feedback/science-technology/lively-artifacts/

[52] Kline, *Cybernetics in Crisis*, 20-28.

[53] A. Müller, “The End of the Biological Computer Laboratory”, in: id./Müller, *Unfinished Revolution,* 303-321.

early 1970s.[54] It was far more successful in establishing professorships, research institutes and collaborative research centers than its American mother-discipline ever was. Although it is important to note that Kybernetik in Germany has its own idiosyncratic and in parts independent genealogy, protagonists of this new boom around the 1970s adopted many of the research topics from their American colleagues. When by the end of the 1960s a search commenced in order to find a concept that would *firstly* pool the many, from an economical perspective less successful cybernetic initiatives and that would *secondly* grant further subsidies, *Bionik* was selected as an umbrella term: "Its explicit proximity to practical application permitted to expect the very economical innovative strength that cybernetics could have never offered."[55] The federal ministry for scientific research consequently initiated a large-scale development program called *Bionik* in 1969 that involved multiple institutions and that resulted in the foundation of societies, journals, and expert committees for a German *Bionik*. The implementation of the worldwide first chair for *Bionik und Evolutionstechnik* at the TU Berlin (Ingo Rechenberg, Engineer) and a course of study for "*Bionik* and technical biology" at the University of the Saarland (Werner Nachtigall, Biologist) followed. It is noticeable in this regard that the attempts to justify the old idea of biotechnics on the basis of evolutionary theory grew stronger. That is that 'natural selection' cannot only be interpreted as the further development and the emergence of new species, but also as a continuous process of optimization of technical developments and improvements. The tentative climax of the *Bionik*-movement in Germany was the implementation of the *Bionik*-network of excellence BIOKON in 2001, initially funded by the German Federal Ministry for Education and Research (BMBF) and by the German Research Foundation (DFG) since 2006. According to its website the network aggregates more than 70 academic and nonacademic national and international facilities and represents university institutes as well as private corporations. Much like its holistic-systemic predecessors it continues to nurture the hope for "sustainable and resource-conserving technologies" to this day and aims to harmonize nature, men, technology and economics (Figure 6).[56]

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[54] Philipp Aumann, *Mode und Methode: die Kybernetik in der Bundesrepublik Deutschland* (Göttingen: Wallstein 2009), 307-314.

[55] Ibid., 307. ["Ihre explizite Anwendungsnähe ließ jene wirtschaftliche Innovationskraft erwarten, die die Kybernetik nie hatte liefern können."]

[56] BIOKON – Network for the Future, last accessed June 13 2014, http://www.biokon.de/en/.

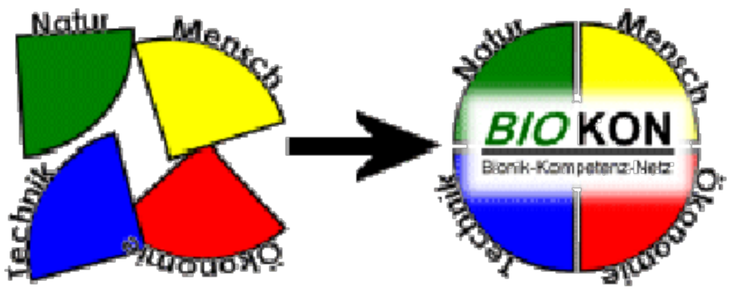

Figure 6 – Illustration from the BIOKON-Website (www.biokon.de)

Although *Bionik* was thus successfully institutionalized, and although it could revert to widely spread personal networks and generous subsidies from economy and politics, researchers in the field still tend to present their products as the result of individual discoveries. With regards to Francé's poppy seed shaker, the tale of the lotus effect for example, sounds all too familiar: It does not begin with a widespread bionic research program, but with a sole botanist and his microscope.

Wilhelm Barthlott's taking notice of the self-cleaning effect of certain phyto-surfaces in 1977 was not the result of a large-scale search, but it happened by proxy of taxonomy and systematics.[57] Barthlott was one of the first botanists, who intensively devoted himself to the scanning electron microscope (SEM) and who wanted to fathom the limits of his discipline in the nanometer-scope of the visible. As early as in his dissertation in 1972, Barthlott tried to resolve questions of taxonomy and phylogenetics by means of the new technologies in his area of expertise—viz. epiphytic cacti—by comparing and relating to each other the microscopically enlarged fine structures of their surfaces. "The scanning electron microscope," Barthlott later remembers, "revealed an almost inexhaustible and a difficult to imagine multitude of complex structures to the biologists."[58] Five years later, Barthlott chaired a project financed by the DFG, in which his method was thought to be applied to other representatives from the subsection of

[57] Wilhelm Barthlott, Nesta Ehler, *Raster-Elektronen-Mikroskopie der Epidermisoberflächen von Spermatophyten* (Wiesbaden: Steiner 1977).

[58] Zdenek Cerman, Wilhelm Barthlott and Jürgen Nieder, *Erfindungen der Natur – Was wir von Pflanzen und Tieren lernen können* (Reinbek: Rowohlt 2005), 36. ["... die Raster-Elektronenmikroskopie offenbarte den Biologen eine schier unerschöpfliche und kaum vorstellbare Vielfalt komplexer Strukturen."]

spermatophytes. A central role was assigned to "surface sculptures" of the epidermal cuticle; that thin wax film, which abuts the external wall of the epidermal cell (Fig. 7).[59]

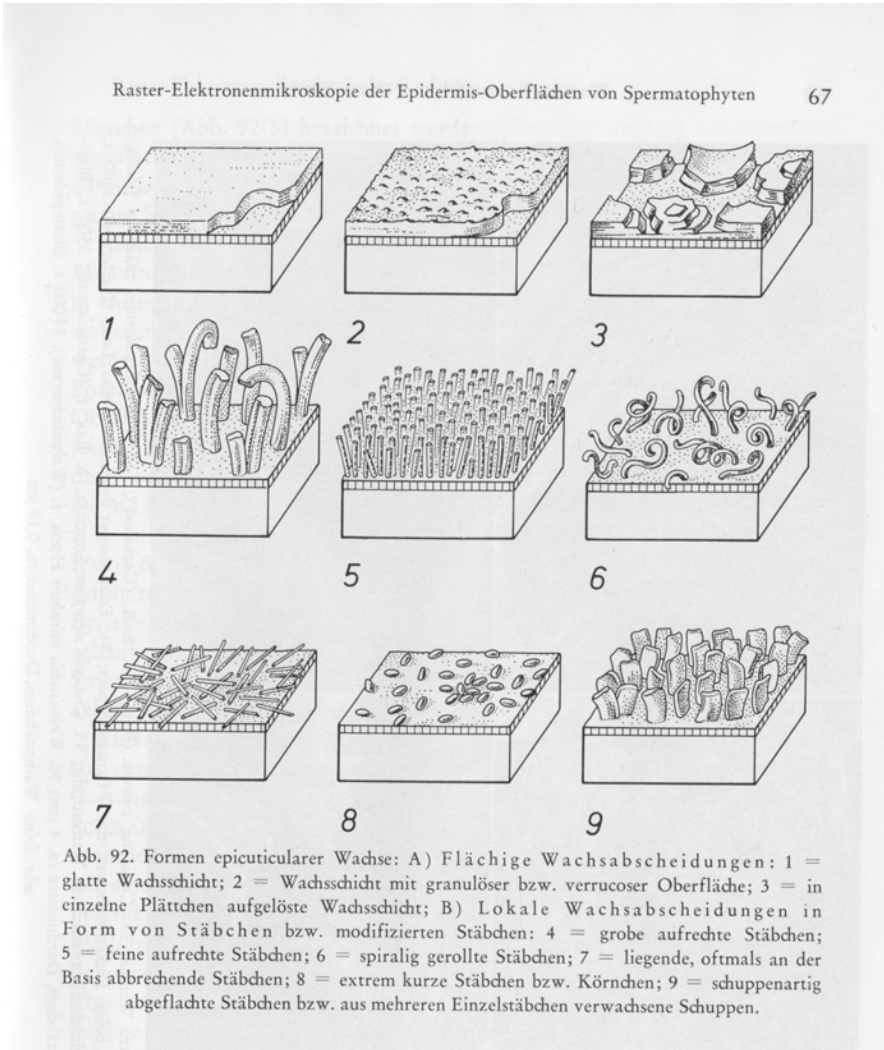

Figure 7 – Epicuticular Wax Structures (Barthlott, Epidermis-Oberflächen 1977, 67)

[59] Barthlott, *Raster-Elektronen-Mikroskopie der Epidermisoberflächen*, 1977, 35-71. ["Oberflächenskulpturen"]

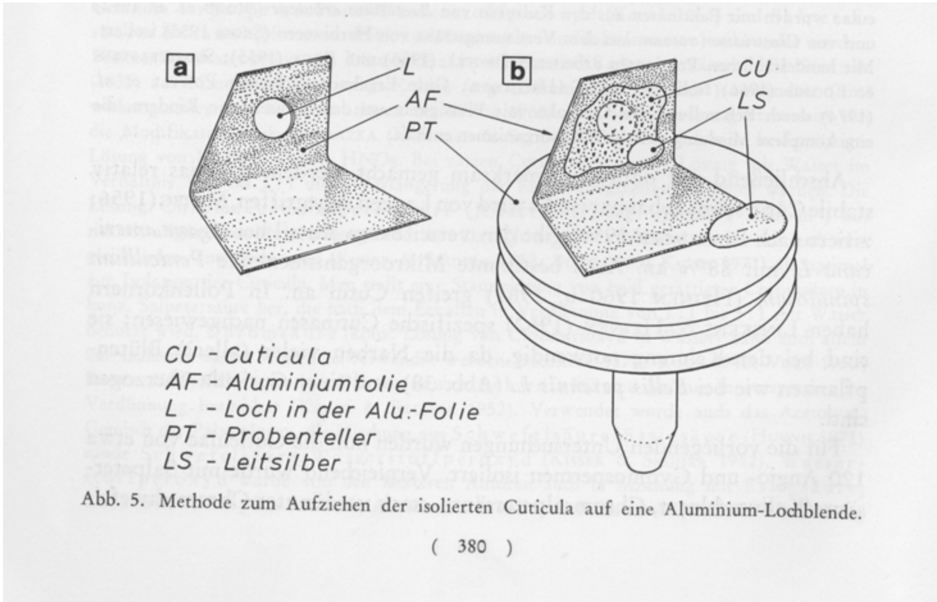

Abb. 5. Methode zum Aufziehen der isolierten Cuticula auf eine Aluminium-Lochblende.

(380)

Figure 8 – Prep. of Epidermic Samples (Barthlott, *Epidermis-Oberflächen* 1977, 18)

A first step of the elaborate preparation proceedings of epidermic samples for the SEM consisted now in cleaning the samples in an ultrasonic bath (Figure 8). And in doing so, as Barthlott reported in retrospect, he realized that some of them had apparently completed this task ‘themselves.’ Those were particularly such epidermic samples that featured especially complex folding patterns on their surface, that had highly hydrophobic surfaces based on their chemical composition and that furthermore exhibited especially complex epicuticular wax structures, such as rod cells, platelets, or granules. This combination, in conjunction with the water surface tension, lead to the ‘self-cleaning effect’ that was first named as such during the analysis in 1977. Epidermic surfaces of this kind did not only exhibit an especially low degree of “wettability”, but were also highly “unsoilable”.[60] Due to the epicuticular wax structures the contact area (and thus adhesion forces) between the epidermis and water droplets is significantly reduced so that the droplets do not spread out, but move along the surface as virtually perfect spheres even if the surface’s angle of slope is very small. If on its way across the surface, a water droplet encounters particles of dirt, the adhesion force between the particle and the droplet is higher than that between the particle and the surface and the particle simply ‘rolls off’ the leaf adhering to the droplet (Fig. 9).

[60] [“Benetzbarkeit … unbeschmutzbar”].

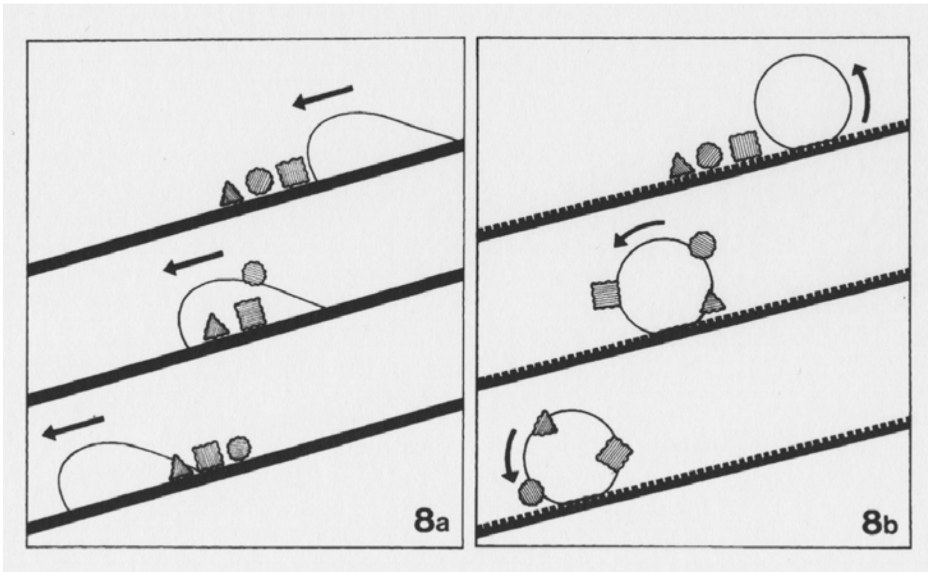

Figure 9 – "Diagram summarizing the connection between roughening and self-cleaning" (Barthlott/Neinhuis, *Sacred Lotus* 1997, 6).

Although Barthlott made his discovery of the self cleaning-effect as early as in the late 1970s, it took him ten more years before he started to think about potential applications. From 1988 on he talked to "well-respected and globally operating companies from the chemical sector", trying to convince them of the advantages the self cleaning-mechanism has against conventional methods of keeping modern surfaces clean.[61] When the industry showed little interest at first, Barthlott and his team reacted with a couple of measures: First of all, they decided to give their brainchild a new name: Whereas in the 1970s Barthlott had observed the self cleaning-effect in different kinds of cacti and plants (for example in cabbage and broccoli), he and his assistants picked the Lotus flower *Nelumbo nucifera* as their front- and figureplant to advertise what they now called the *Lotus Effect*®. Not only did the leaves of the lotus flower "afford and impressive demonstration of the effect",[62] its meaning "as a symbol for purity in Asian religions" made it the ideal choice.[63] As a next step Barthlott and his team—"even if we were

[61] Zdenek, Barthlott and Nieder, *Erfindungen der Natur,* 52. ["Renommierte und weltweit agierende Firmen aus dem chemischen Bereich"]

[62] W. Barthlott and C. Neinhuis, "Purity of the sacred lotus, or escape from contamination in biological surfaces", *Planta* 202 (1997), 1-8, 1.

[63] Zdenek, Barthlott and Nieder, *Erfindungen der Natur,* 33. ["… ein Symbol der Reinheit in asiatischen Regionen"]

Botanists"—started to build prototypes of self cleaning-surface on their own, had their 'invention' patented in Europe in 1996 and even registered the trade mark of the *Lotus Effect*®.[64] As Barthlott remembers, it was the "patent and the self developed prototypes" that finally caught the industry's attention and led to approximately 20 contracts of collaborations and a number of products; among them: Sto AG's LOTUSAN paint.[65]

5. Past Lives and Future Technologies

In his short essay on the so called telegraph plant *Desmodium gyrans*, media historian Stefan Rieger dealt with the phantasm of communicating plants and asserted, following Heidegger: "When the plant acquires a voice, a communication model speaks."[66] What Rieger means is that functionality in nature can only come into the picture in light of contemporary cultural techniques and theories. With this in mind, I want to conclude by contemplating on the question 'Who cleans a self-cleaning building?'—Or, in other words: 'What lives on in *lively surfaces*?'

Following an (admittedly bold) combination of all three perspectives of *Biotechnik*, *Bionics* and *Bionik*, the answer would probably be that in the course of evolution 'nature' has endowed certain types of plants with a 'functional' epidermis that employs an ideal solution to the problem of avoiding unwanted fungi or bacteria. The engineer can 'see' and eventually 'understand' the principle underlying this biological solution and 'transfer' it to the realm of technology. From this perspective the self-cleaning building as technological object would in fact be cleaning itself by applying this principle to the task of 'cleaning surfaces'. Consequently, to speak of an afterlife of biological systems in technological objects would be misleading. What lives in both *bios* and *techné,* according to this view, are *universal* principles that undermine the distinction between nature and technology and rather bear the implication of a whole and harmonious cosmos. The real question would then of course be, why the in*ter*vention of the engineer is necessary at all, or, to give this thought a sharper turn, why can *deficient solutions* to technological problems exist in the first place?

[64] Wilhelm Barthlott. 1996. Self-cleaning surfaces of objects and process for producing same. WO1996004123 A1, filed July 25, 1995, and issued February 15, 1996.

[65] Ibid., 54. ["Erst die Patente und unsere selbst entwickelten Prototypen weckten schließlich auch das Interesse der Industrie"]

[66] Stefan Rieger and Benjamin Bühler, *Das Wuchern der Pflanzen. Ein Florilegium des Wissen* (Frankfurt a.M.: Suhrkamp 2009), 67. ["Wenn die Pflanze spricht, dann spricht ein Kommunikationsmodell."]

However, as we have seen, biomimetic artifacts do accommodate afterlives of a very different kind. *First of all* the products of *Biotechnik*, *Bionics*, and *Bionik* involve cultural techniques such as the use of microscopes, drawing, writing and calculating. Thus, specific discursive and non-discursive factors determine what is being interpreted as 'lifelike' or 'inspired by nature' at a certain place and point of time. What lives on in *lively artifacts* is thus not the result of a clean and simple transfer from nature to technology, but rather perpetually undergoes complex processes of *translation*.

Second, all three historical manifestation of the biomimetic postulate seem to carry an epistemological bias towards visual evidence and persuasiveness. The analogy between the 'natural' and the technological solution is usually presented as a comprehensive and compelling argument, just like the juxtaposition of Francé's saltshaker next to the poppy seed capsules. In fact it can be said that *lively artifacts* are generally build for an audience, the impression of their liveliness being a function of the knowledge of the subjects observing or—for example in the case of the *NumaRete*—interacting with the artifact. It is precisely this bias towards visuality and persuasiveness that makes 'natural surfaces' like skins, coats or soles such an attractive starting point for biomimetic theory and practice.

Third, what lives on in *lively surfaces* is a *longue durée* of holistic and systemic thinking. Even if the proponents of contemporary *Bionik* occasionally name their historic predecessors such as Francé, they usually characterize them as exceptional and singular prophets while the ideological and pragmatic contexts of earlier attempts to promote the biomimetic approach are mostly neglected. On the contrary, each historical recurrence of the biomimetic postulate is presented as something new and revolutionary. As a sharp critique of modern technology and society it invokes the idea of an alternative way of harmonizing 'nature' and technology by reducing the human factor in the process of creating technological objects. However, as we have seen *Biotechnik*, *Bionics* and *Bionik* are in fact far from being actually non-modern sciences or practices. They rely on modern cultural techniques, involve human decisions and compromises and are embedded in the discursive networks of their times. In this regard, it rather seems that their proponents use the rhetoric of system theory and holism to *cleanse* their products from the 'aberrations' of modernity. Thus, what actually cleans a self-cleaning building can be called the paradoxical desire to escape modernity by modern means.

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