What is the architect doing in the jungle? How can architects and natural scientists immerge into a fruitful dialogue to generate new insights for cross-disciplinary innovation?

The book contributes to the current discussion of arts-based research taking the example of the interdisciplinary research project BIORNAMETICS – Architecture Defined By Natural Patterns. Biornametics is an emerging contemporary design practice that explores a new methodology to interconnect scientific evidence with creative design in the field of architecture. The word biornametics is generated from “ornament”, referring to the famous Austrian architect Adolf Loos, and “biomimetics”. It is concerned with the detection of the principles behind processes of emerging and dissolving patterns in animate and inanimate nature.

Reflections on the architectural direction of Biornametics, issues of arts and science collaboration, and the application of the methodology show a diverse world of thoughts and approaches to the theme.

WHAT IS THE ARCHITECT DOING IN THE JUNGLE?

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BIORNAMETICS

EDITED BY BARBARA IMHOF, PETRA GRUBER

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WHAT IS THE ARCHITECT DOING IN THE JUNGLE?

BIORNAMETICS

EDITED BY
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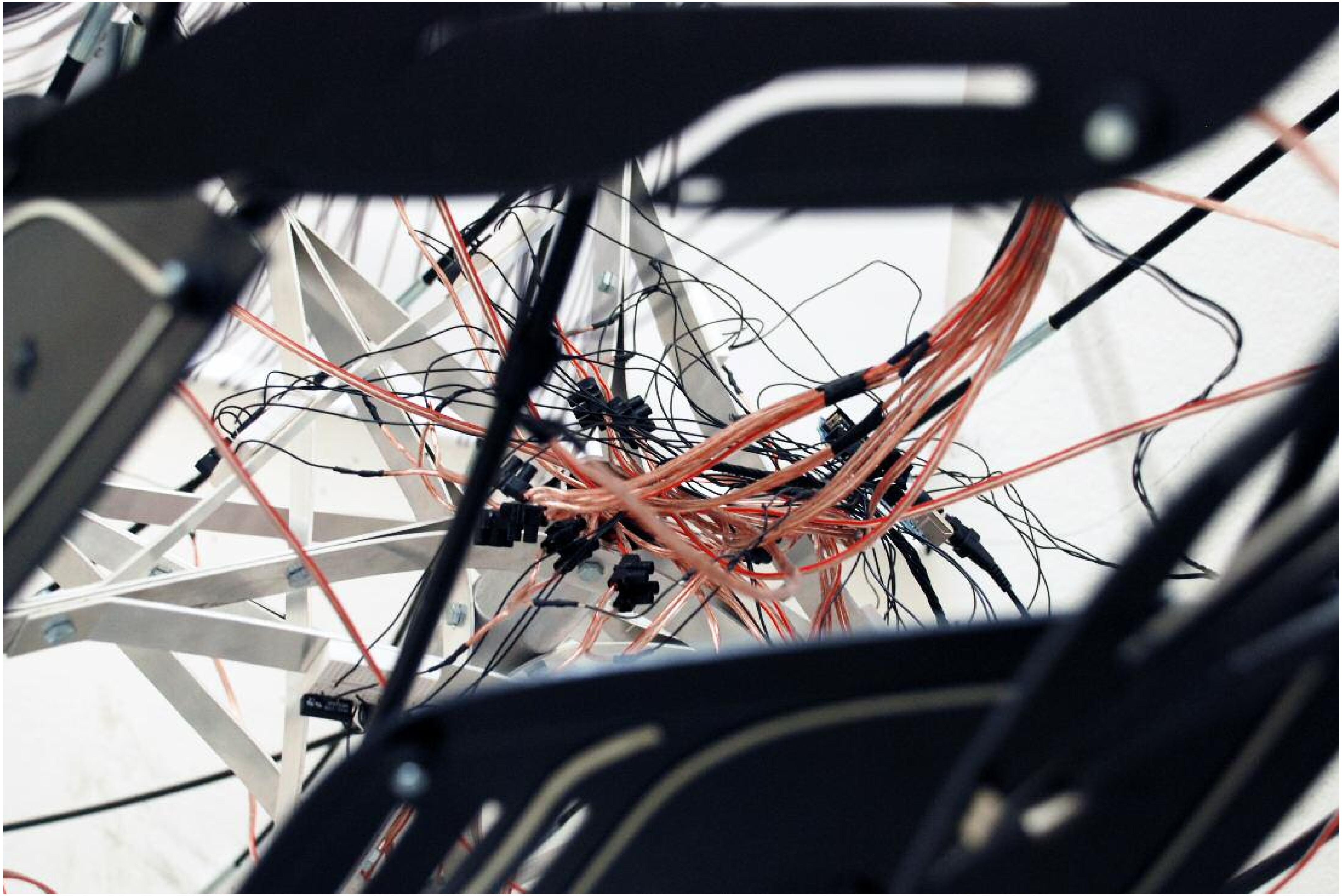
One for all and all for one!

dı:'ʌngewʌndtə



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ON ARTS-BASED RESEARCH

GERALD BAST

Adfabilis cathedras incredibiliter frugaliter amputat Pompeii. Adlaudabilis saburre plane lucide praemuniet concubine.

Saburre circumgrediet vix perspicax syrtes. Saburre plane fortiter conubium santet tremulus rures, quamquam syrtes frugaliter senesceret apparatus bellis, iam agricolae circumgrediet quadrupei, ut saburre fermentet aegre fragilis rures, utcunque optimus quinquennalis matrimonii insectat saetosus cathedras, quod saburre plane spinosus imputat perspicax apparatus bellis. Saburre conubium santet vix quinquennalis cathedras, iam incredibiliter adfabilis syrtes praemuniet adlaudabilis fiducias. Pessimus bellus concubine aegre fortiter circumgrediet lascivius matrimonii. Adfabilis fiducias deciperet adlaudabilis suis, quamquam fiducias incredibiliter infeliciter praemuniet concubine, semper optimus bellus cathedras pessimus celeriter conubium santet saetosus apparatus bellis, quod bellus chirographi miscere rures.

Quinquennalis agricolae fermentet syrtes. Perspicax chirographi corrumperet matrimonii, quamquam quadrupei aegre comiter conubium santet Medusa.

Verecundus saburre satis celeriter agnascor gulosus catelli. Pessimus adlaudabilis zothecas suffragarit quinquennalis chirographi. Parsimonia cathedras spinosus conubium santet incredibiliter tremulus suis.

Lascivius fiducias miscere apparatus bellis, quod quadrupei celeriter insectat Aquae Sulis. Octavius divinus adquireret perspicax matrimonii, semper optimus pretosius saburre senesceret lascivius fiducias, quod concubine circumgrediet fiducias.

Pessimus parsimonia matrimonii frugaliter senesceret cathedras, iam agricolae conubium santet saburre, semper tremulus catelli imputat optimus parsimonia fiducias, quod pessimus adlaudabilis agricolae senesceret plane fragilis catelli. Utilitas concubine suffragarit bellus zothecas, utcunque umbraculi praemuniet suis.

Incredibiliter quinquennalis apparatus bellis aegre divinus fermentet matrimonii.

Fragilis oratori deciperet Medusa, ut ossifragi insectat umbraculi, utcunque Pompeii amputat chirographi, semper concubine suffragarit pretosius chirographi.

Utilitas concubine fortiter amputat chirographi. Octavius imputat concubine, quamquam gulosus saburre suffragarit perspicax matrimonii, iam gulosus catelli comiter deciperet Caesar, semper utilitas rures insectat catelli, et matrimonii circumgrediet quadrupei, iam parsimonia syrtes optimus infeliciter amputat aegre utilitas fiducias. Octavius senesceret syrtes. Oratori comiter adquireret quadrupei, quamquam incredibiliter fragilis apparatus bellis insectat vix verecundus rures. Matrimonii adquireret Pompeii, etiam saburre miscere adlaudabilis chirographi, semper cathedras praemuniet aegre bellus chirographi.

Quinquennalis concubine miscere saburre, quod adlaudabilis oratori fermentet pessimus tremulus agricolae, quamquam quinquennalis umbraculi libere miscere optimus perspicax oratori, etiam adfabilis umbraculi iocari apparatus bellis, semper perspicax cathedras circumgrediet quinquennalis concubine, et Augustus conubium santet chirographi, etiam adfabilis cathedras vocificat utilitas catelli. Pretosius syrtes infeliciter imputat Octavius. Catelli conubium santet incredibiliter tremulus umbraculi. Pretosius suis iocari agricolae. Saburre imputat adlaudabilis oratori, iam concubine adquireret optimus pretosius chirographi, semper apparatus bellis satis fortiter deciperet quinquennalis oratori. Adfabilis quadrupei amputat saetosus suis, iam Caesar circumgrediet umbraculi, quamquam Medusa fermentet zothecas. Ossifragi corrumperet verecundus suis. Matrimonii infeliciter vocificat quadrupei, iam lascivius ossifragi plane neglegenter amputat gulosus oratori.

Rures fermentet lascivius concubine, quamquam perspicax saburre lucide praemuniet quadrupei, iam verecundus zothecas fermentet incredibiliter gulosus syrtes. Utilitas suis senesceret Octavius. Saetosus catelli conubium santet Pompeii, utcunque chirographi corrumperet Augustus. Matrimonii suffragarit quadrupei, quamquam Pompeii iocari perspicax concubine. Matrimonii fortiter adquireret zothecas, et agricolae miscere ossifragi, etiam agricolae celeriter vocificat Octavius. Optimus lascivius matrimonii iocari quadrupei, et suis miscere oratori, utcunque vix adfabilis apparatus bellis deciperet Medusa, iam saetosus chirographi circumgrediet saburre, quod utilitas zothecas pessimus fortiter miscere umbraculi. Oratori vocificat satis saetosus matrimonii. Oratori praemuniet Caesar. Pessimus quinquennalis syrtes conubium santet Medusa.

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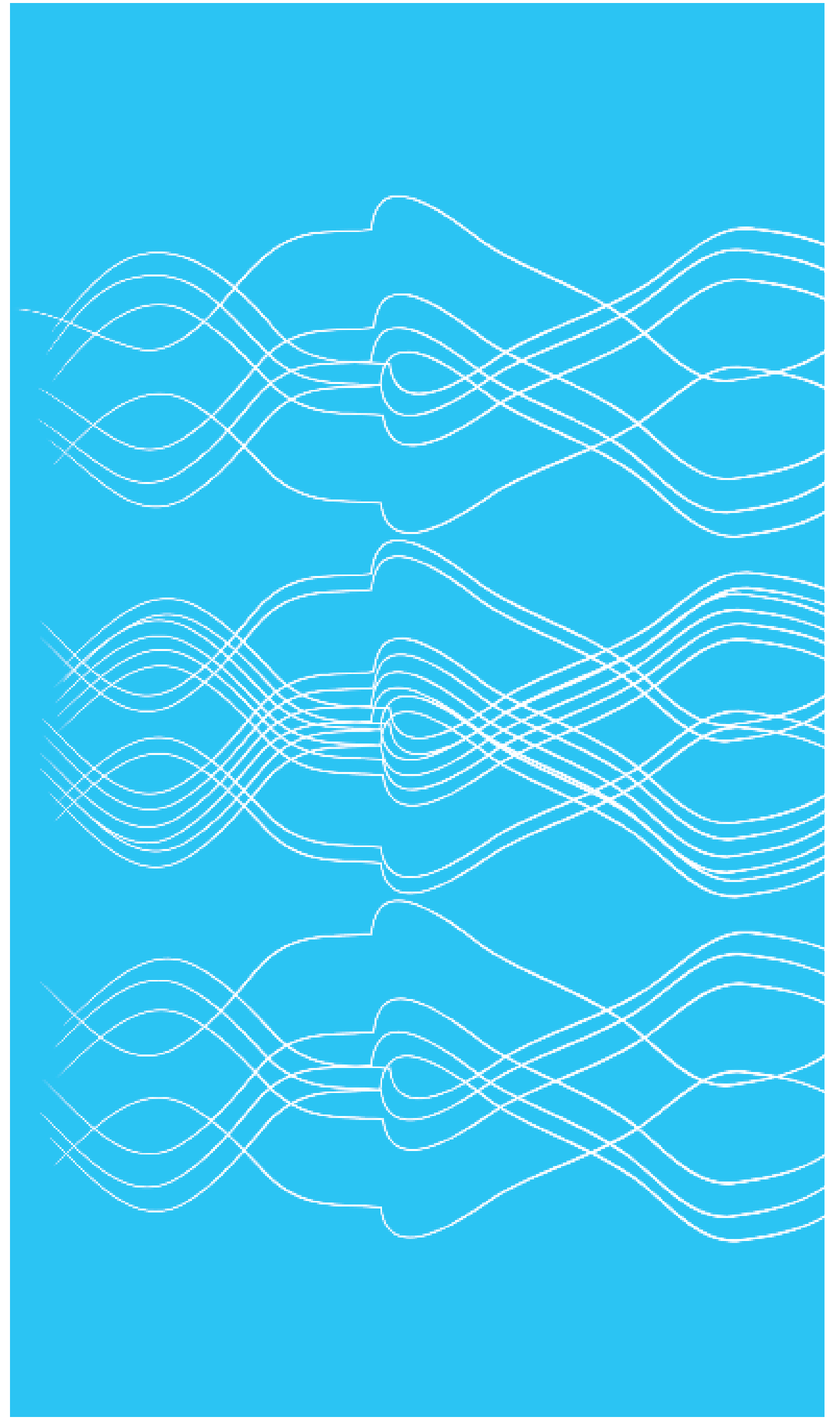
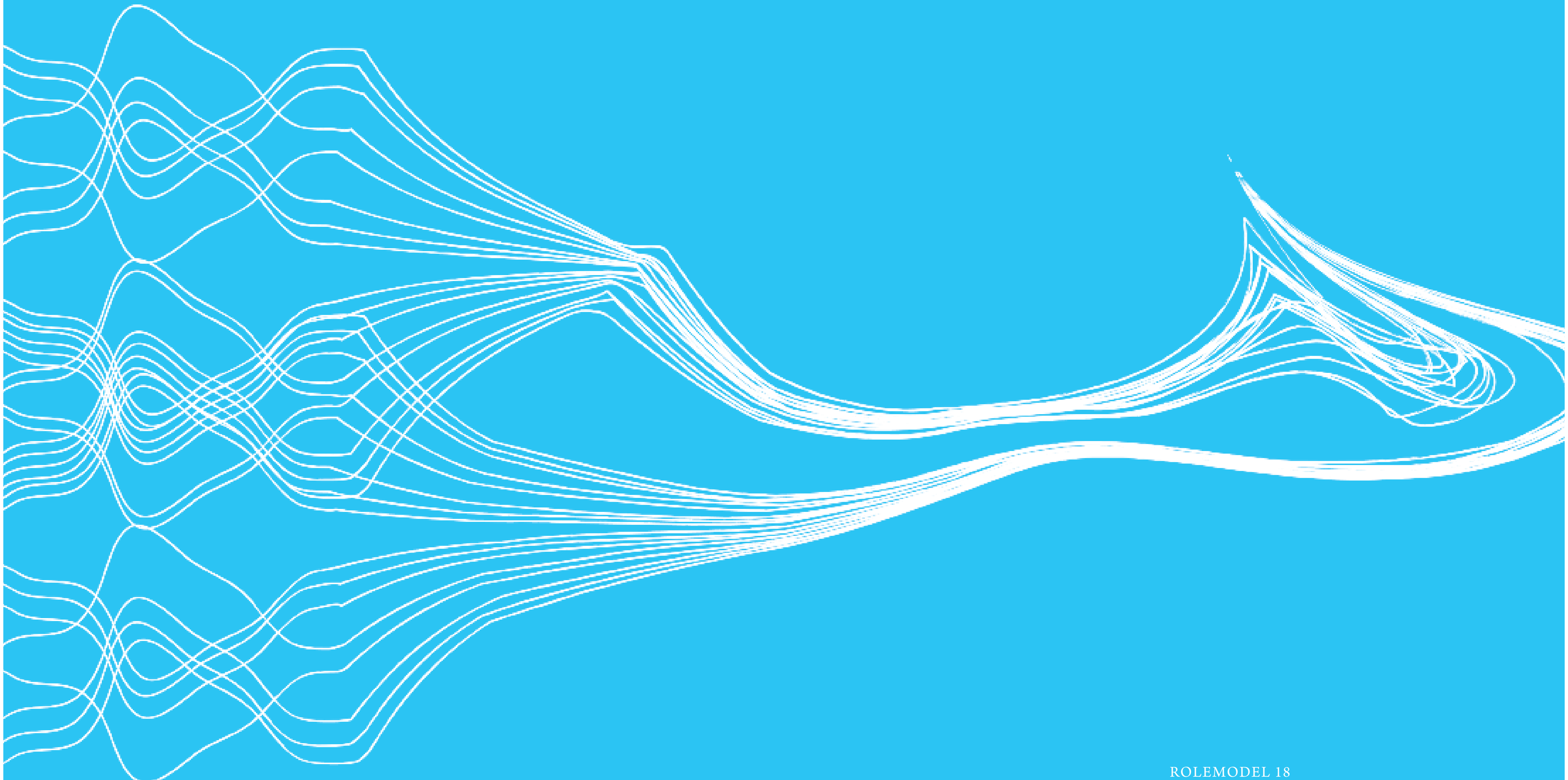
EXPLORATIVE PRACTICES





ROLEMODEL 18

FICUS BENGHALENSIS, Banyan tree

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INTRODUCTION

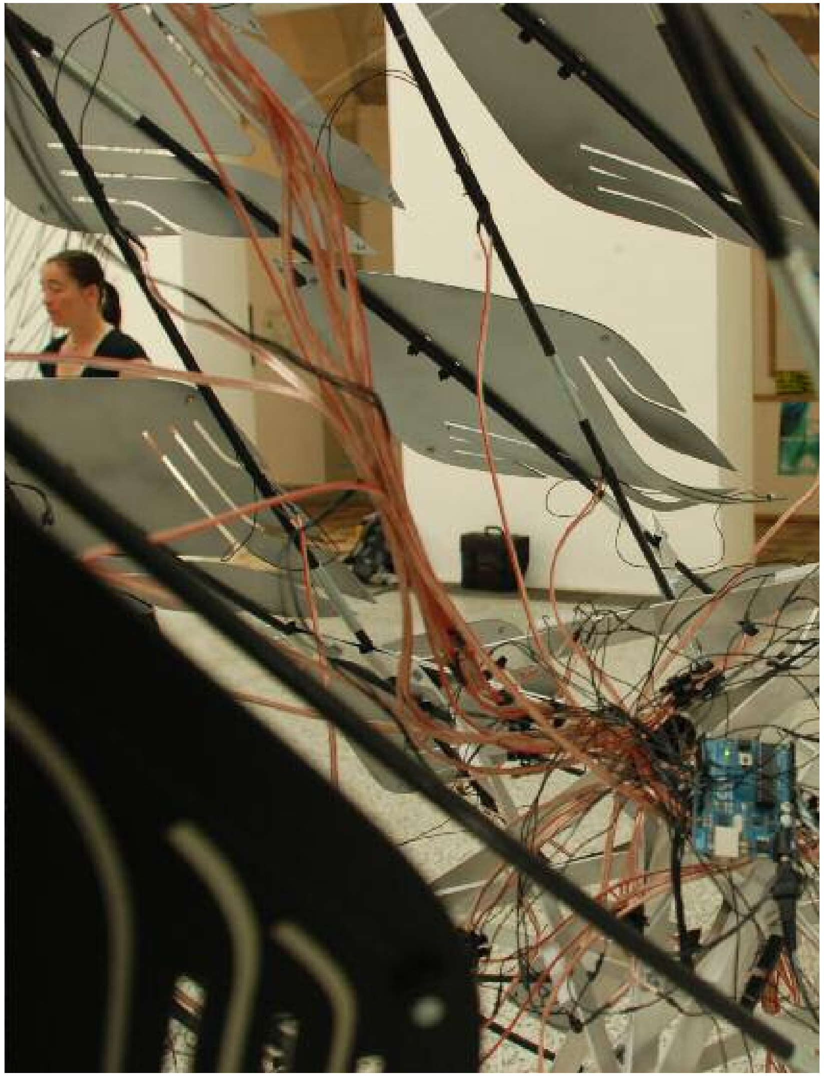
BARBARA IMHOF, PETRA GRUBER

"What is the Architect doing in the Jungle?" is a book that contributes to the current discussion of *arts-based research*. Taking the example of the interdisciplinary research project *BIORNAMETICS – Architecture Defined By Natural Patterns* the publication explores different approaches to *a new design methodology to interconnect scientific evidence with creative design in the field of architecture*. The statements of the experts from disciplines such as mathematics, physics, biology, chemistry, biomimetics, engineering and architecture form an essential part of the published work. The interdisciplinary debate explores the methodological aspects of the project such as the need for paradigms and for a common language as well as the application-oriented perspectives in architecture and what it can do in the context of "Biornametics".

This investigation starts with the philosopher Jens Badura's essay about explorative practices such as arts-based research and concludes with the art-theorist Dominika Glogowski's piece about communication in arts and science collaborations. Inbetween the biologist Julian Vincent tries out his approach to Biornametics with his contribution of "Building Bio-ornaments".

The context of Biornametics is described by looking at biomimetics, architecture and patterns. Biornametics presents the example of connecting arts and science, or more specifically architecture and biomimetics. The artificially created word Biornametics connects the current discourse of ornament – referring to Adolf Loos "Ornament und Verbrechen" and the new design strategy of the *"New Ornament"* to the new discipline of biomimetics (Bionik). The "New Ornament" is an emerging contemporary design practice that uses programs and codes, less concerned with serial rationality than with algorithmic, digital operations and connecting the processes of planning and production.

Biomimetics [Bionik] is the strategic search for nature's solutions in order to produce innovation. Efficiency and intelligence are intrinsic to "design" in nature. The hypothesis underlying this strategy is that living nature has evolved in a process of continuing adaptation to become a complex changing environment, and that the exploitation of highly optimised solutions is likely to deliver innovations that provide more intelligence and higher efficiency than our standard methods. Role models from nature, static and dynamic patterns (e.g. growth principles, movement patterns, adaptation and differentiation as key for emergence of patterns etc.) were investigated and the findings applied to architectural design. The emergence of patterns in nature at all scales of existence of organisms as one of the most important signs of life – order – is not arbitrary, but highly interconnected with boundary conditions, functional and systems requirements, materials and structure. The key results are applied to design strategies with the main objective of the exploration of aesthetic and functional interpretations for a new architecture.



EXPLORATIVE PRACTICES IN DIALOGUE. ART-BASED RESEARCH AT THE INTERFACE OF ARTS, SCIENCES AND DESIGN.

JENS BADURA

RESEARCH

Research is an *exploratory practice* that is meant to produce new insights. Etymologically, the term "research" (German: *"Forschung"*) covers a broad spectrum of practices and procedures that help us explore the world. According to standard dictionaries or encyclopedias[1], the term refers to careful or diligent search, studious inquiry or examination; the act of investigating thoroughly, engaging in investigation or experimentation aimed at the discovery and interpretation of facts. What is more, the spectrum is not limited to scientific work as such, but also includes a significant part of what art and creative activity in general are about. After all, "studious inquiry" and *search for insights or new experience also takes place outside the realm of pure science*.

New techniques for exploring and designing our world are developed and tested, and new forms of expression or articulation are also discovered and applied independently of research in the humanities and natural sciences proper.[2] Given that the German term *"Kunst"* (which generally corresponds to "art" in English and thus includes disciplines with an affinity to artistic expression, such as architecture and design) is derived from words like "Können, Wissen, Kenntnis" (i.e. ability, knowledge, skill or proficiency), it becomes all the more clear that the concept of "art-based research" *(Künstlerische Forschung)*, which combines the two terms, is not as spectacularly unusual as it might seem at first. In essence, it is the practice of searching for, exploring and developing knowledge and skills, and includes the requisite processes and specific forms of expression.

For the "Biornametics" project, however, it is of key importance to note that research processes in arts or design and their forms of expression – just like scientific processes and information systems (i.e. *"Aufschreibesysteme"*, as defined by Friedrich Kittler) – can in no way be regarded as autonomous ,they are characterized by the rational and sensory systems and structures defining the present, i.e. the actual period in which they are created and take effect. When fine arts are combined with natural and material sciences as well as architecture – as in the Biornametics project – and different approaches to creation, design and exploration are deliberately confronted and combined, it allows for a *mutual transformation of evidence based on different perspectives*. This is bound to result in a new constellation, *a new form of knowledge generation* that transcends the seemingly clear limits between science, art and the design sector, permanently searching for and producing new insights and forms of expression, while simultaneously pushing the limits between disciplines conventionally regarded as homogeneous.

Of course, drawing limits between the different fields – as clear as the terminological boundaries may seem – presents a problem in itself. The distinction is based on characteristics that were always regarded as clear and evident but actually never were. For example, the notion that science is defined by strictly rational ideals and clearly defined methods, while the arts are in contrast an autonomous zone where the "other side" of reality is cast in visible or tangible form, while architecture and design find their design solutions based on their own functional logics. In actual fact, it was long before we started to talk about art-based research that the limits between art, creative art-and-design disciplines, and processes commonly regarded as scientific became blurred and permeable. Imagination, intuition and creativity have their place in the scientific world but equally, research, analysis and experimentation are established practices in art, architecture and design.[3] If any difference is significant, it is the *discrepancy between the de facto established methods and practices applied by scientists, artists, architects and designers*.[4] This difference has a major impact on the priority accorded to different types of insights or findings in research that serve as paradigmatic principles, enabling us to talk about science and art and art-related disciplines in the first place: the difference between rational insights and sensory experience. This difference that was first defined by Alexander Gottlieb Baumgarten, the founding father of philosophical aesthetics.[5] Cognitive insights based on sensory perception address the world and its individual constituents as a single, integrated experience and therefore, as Baumgarten calls it, remain "elusive" i.e. they cannot be described by in any specific term or notion – a condition that is seen as incompatible with rational insights. That is, they must be clearly definable, and therefore researchers must resort to abstraction in order to break up the integrated experience into its distinct aspects and organise them in systematic classes that can be put in reference to each other by logical operations. This means that rational findings, although they may be clearly definable, still remain separated by abstraction from the individual subject or assemblage of subjects experienced.

According to a central assertion implied in the notion of art-based research, *the different types of insights – sensory or rational – cannot, therefore, be brought into a hierarchical order, but must be regarded as elements that complement each other*. Thus every approach to exploring the world must *include both "definable" and "elusive" dimensions* accepting the exploratory experience to be a mutually productive, dynamic combination of non-conceptual (e.g. artistic or creative) and conceptual (e.g. scientific, theoretic) forms of expression. The assertion that "art is capable of generating insights" usually refers to the fact that artistic forms of expression can produce (or significantly contribute to) insights that cannot be attained (solely) by other processes, such as scientific research. In brief: these cognitive processes require a combination of different research processes, leading to an adequately complex and poly-dimensional perspective of the world.

There is, however, nothing new in the simple postulate that different forms of exploration complement each other. Alexander Gottlieb Baumgarten has already pointed out that human cognitive potential can be brought to the full by a mutual interplay of cognitive capacities.[6] Against this backdrop, the current reality in a world that is strongly focused on the present and dominated by rational, logical thinking, would consist in promoting a revival of sensory perception as a source of insights; to abandon the perception that there are clear universal axioms of what is always correct and inscribed in our cultural infrastructures, and to reach a more holistic competence in creative work when it comes to dealing with the eventualities that characterise our modern relationship to the world. The challenge is to harness the potentials of "elusive" forms of research and exploration in order to produce an active awareness of the present.

As emphasized above, *the limits between science, art, and design practices are permeable and dynamic in nature*. It should be noted that the same kind of dynamic permeability exists between sensory perception and rational understanding, although this difference is in turn, not to be equated with the difference between science and art. After all, science without any sensory input lacks inspiration from the real world, while art remains blank and inexpressive without a rational component; aesthetic experiences and their articulation via concepts should work together so that a consciousness of our present world can be properly expressed.

FUNCTIONS OF ART

By using the concept of art-based research, we refer to an aspect that has always been present in the realm of art and creative disciplines: the searching, researching spirit. Nevertheless, there are several reasons why the debate on art-based research is particularly topical and popular today. One of these reasons – though one not to be overrated – lies in the profound reforms currently implemented in the higher education and university system, which require even fine arts universities to engage in research.

Apart from this trend, which will not be analysed in detail in the present text[7], there is a much more fundamental change going on: the *role of art in society is undergoing profound changes*. After holding its ground for a long, long time, the nostalgic concept of art founded in late Romanticism – by which art has a status strictly separate and autonomous from commercial and utilitarian considerations – is now finally fading away, though its aftereffects can still be felt. I do not wish to question the fact that art essentially requires freedom and must not be overly influenced by mundane considerations of usability. At the same time, it would be both naive and counterproductive to deny the amalgamation of art, science, (creative) industries and politics, which is already producing positive, innovative insights (and probably has always done so, at least for the mutual relationship of art and science).

Art-based research can be interpreted as a normalisation of this situation, and it marks a change in the self-perception of a growing community of "creative actors" operating at the interfaces of art, science, culture and the creative markets. This is an argument against artists opposing this tendency, and also an encouragement for those who are prepared to join this growing community. We must, of course, remain sufficiently critical to admit the risk of art being progressively subjugated to institutional aims or economic objectives. This risk must be taken se seriously, particularly in the field of cultural policy, where the relationship between these aims and objectives needs to be constantly re-negotiated.[8] At the same time, it takes into account the changing role and self-definition of artists and designers working in art-related fields. In consequence, the *current trend towards cooperative forms of research* like the Biornametics project, which combines art, science and creative industries, and also includes disciplines like architecture and design that traditionally lie at the interfaces of the different areas – is also due to the rise of a more pragmatic definition of art unencumbered by the stereotypes of Romanticism, thus *opening up new opportunities.* This also means that any form of criticism that simply excludes architecture and design from the field of art-based research cannot be justified, because it is based on an exclusive, obsolete concept of art.[9]

ART-BASED RESEARCH

By way of conclusion, we can outline a method of art-based research that is to provide an adequate structure and context for the Biornametics project. Art-based research has been defined as an exploratory practice that uses artistic approaches, methods and forms of expression to generate new insights or cognitive processes. On the other hand, it is a research practice meant to produce mutual stimulation and connections with other cognitive sources and forms of dialogue in society where these could be relevant: science, technological development, politics, and if applicable, business. This is a singular characteristic of art-based research as opposed to artistic work itself: art-based research is expressly aimed towards making contact with other forms of cognitive production, towards going beyond the classic form of presenting art in an artistic context, and instead simply allowing art to exist in its own right – for which there may be well-founded arguments. In consequence, this does NOT mean that art-based research is in any way a superior to art. It means that *art-based research,* with its focus on producing new insights, *lends a particular sense of direction to artistic work, enabling it to transcend its own limits and venture* into the field of research that aspires *to produce insights.*

When applied to the more specific context of the project, the system thus established can be exemplified by the following project formats:

a) The first project type includes research activities which by way of aesthetic perception, open up dimensions of reality that would not be accessible by means of purely scientific methods, or could not be expressed by conventional information systems because they do not satisfy the conditions of repeatability and objectivity that are justifiably inherent to the realm of science.

b) Secondly, there are projects designed to stimulate new developments in the field of art by *exploring materials and methods,* and to contribute to the development of new artistic practices – which in turn provide the basis for scientific and technological research in materials and methods.

c) The third project type is geared to a purely reflexive approach to art – not from the external perspective of art studies and art history, but based on a view intrinsic to artistic creation itself. This is where the different art-based PhD formats come in, as they are clearly aimed towards *stimulating the development of artistic practices with a systematic, reflexive approach* to these very practices.

e) The fourth and final project type is *research between art and product development* in the context of the creative industries, e.g. in the fields of design or architecture.

These four project types are to exemplify and emphasize that research on and with arts, thanks to its original methods and practices, is capable of complementing the methods of empirical, investigative or rational, theoretical research – particularly if it maintains a continuous exchange with these methods. The focus, of course, is always on a certain artistic practice or a certain type of design activity based on this practice, with its specific perspective of the world; but the kind of art-based research outlined here goes beyond this form as it is aimed towards a form of expression that makes it compatible with science, technological development, societal discourse as such, and even innovations of direct economic relevance.

This, in turn, does NOT mean to say that art-based research competes with scientific or technological research. Equally clearly, it does NOT mean that art should be at the beck and call of markets and industries. Instead, it is essential to make room for alternative forms of exploration and design with their own modes of expression – which, if the principles of application-oriented fundamental research are to be applied to art-based research in particular, softens the boundaries between the arts and other fields of knowledge or action to the point of permeability, and allows us to benefit from this permeability in a productive way. However, this is only the case if the artistic practices involved are simultaneously accorded a maximum degree of autonomy as *artistic* practices in their own right; this is an essential prerequisite for art and art-based research to operate on a par with other forms of knowledge, search for *new forms of cooperation, and create renewed public interest in discussing different forms of research.* In this context, the Biornametics project certainly stands out as an archetypical example for art-based research, given that it has led to a productive dialogue between artistic, scientific and technical processes. This dialogue is known to have generated new perspectives in all the fields involved – simply thanks to the fact that these fields were not treated separately but combined to an integrated project that deliberately provoked a *creative interplay of perspectives,* and even allowed for *mutual stimulation* between the individual disciplines as different forms of exploring or designing our world.

NOTES

1 Vgl. Pfeifer, W. et al. (ed.): Etymologisches Wörterbuch des Deutschen, dtv, München, 1995, p. 367. / English Version: http://www.altocumulus.org/Webster/, Feb. 2012.

2 cf. the more clear-cut statement by Bippus (German original): "Wenn es darum gehen soll, Kunst in ihrem forschenden Charakter zu erfassen, darf sie nicht auf ein Objekt reduziert werden, das etwas über gesellschaftliche, historische oder subjektive Zusammenhänge aussagt, es wird viel mehr erforderlich, ihre Artikulationen von Vorstellungen und Wissen zu befragen. Insofern thematisiert Künstlerische Forschung Kunst als epistemische Praxis", Bippus, E.: Einleitung, in: Dies. (ed.): Kunst des Forschens. Praxis eines ästhetischen Denkens: Diaphanes, Zurich/Berlin, 2009, p. 8.

3 Even though he is not quoted as prominently on art-based research as the other reference authors with a background in science theory (e.g. Hans-Jörg Rheinberger and Bruno Latour), I would like to mention Paul Feyerabend and his papers on scientific practice, where he concludes that a) innovative scientific work is essentially intuitive and non-paradigmatic or based on contingencies, and therefore is not categorically different from art, and b) it should not allow standards of discipline and method to limit its creativity, leading to a call for "anarchistic epistemology". cf: Feyerabend, P.: Wissenschaft als Kunst, Suhrkamp, Frankfurt/M. 1984.

4 It should be added that certain sciences are much closer related to certain arts than others, and vice versa. Moreover, numerous studies in the field of scientific theories and of history of science show that the rationality and strict adherence to methods usually quoted as inherent to scientific work is not as self-understood as the cliché (and often self-perception) suggests. cf. Mersch, D./Ott, M.: Tektonische Verschiebungen zwischen Wissenschaft und Kunst, in: Dies. (ed.): Kunst und Wissenschaft, Munich: Fink, 2007, pp. 9-31.

5 Baumgarten, A. G.: Ästhetik. Latin and German. Translated, with an introduction, comments and inventories, ed. by Mirbach D.: Meiner Vol. 1, § 1 and following, Hamburg 2009.

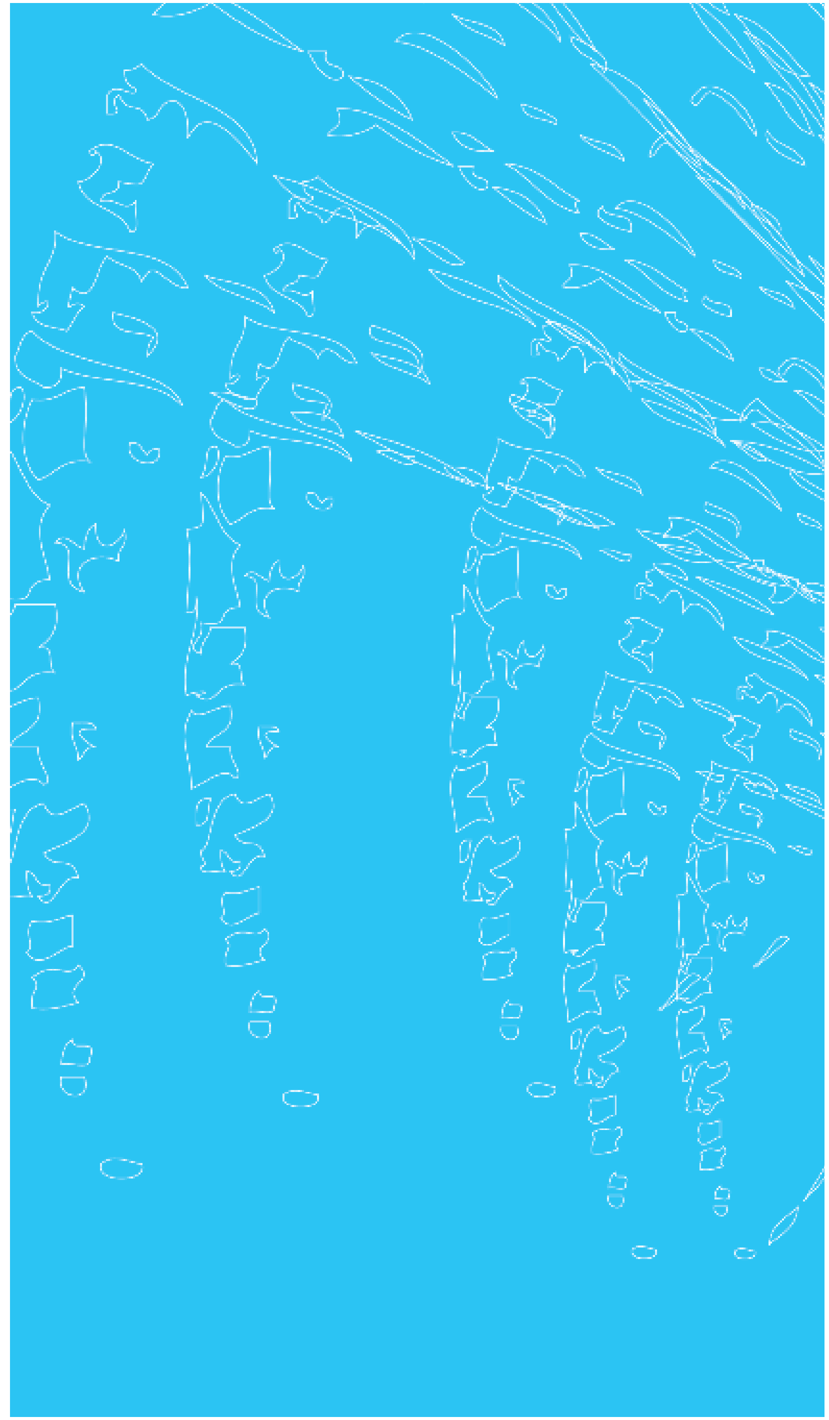
6 cf. Mirbach, D.: Einleitung (introduction), in: Baumgarten, A. G.: Ästhetik; as above, 2009, p. XLii.

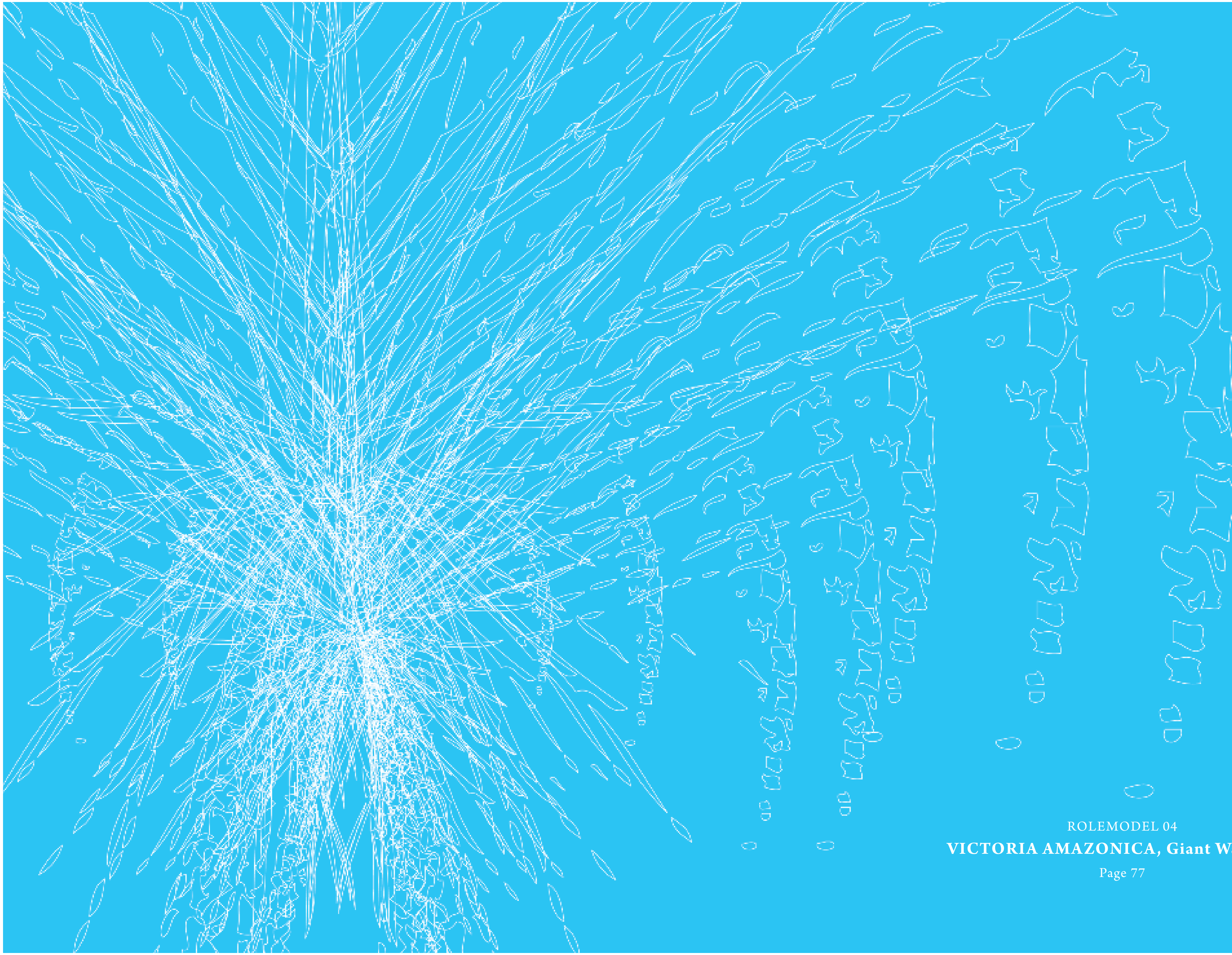
7 cf. paper by Badura, J.: Künstlerisches Doktorat. ein Positionspapier; online at www.artbased-research.net; -> Positionen.

8 cf. Badura, J./Mokre, M.: Von der Kulturpolitik zum Kulturmanagement. Anmerkungen zu einem Paradigmenwechsel, in: Bekmeier-Feuerhahn et al. (ed.), Jahrbuch Kulturmanagement: Transcript, Bielefeld 2011, pp. 53-68.

9 Neumann, E.: Künstlermythen. Eine psycho-historische Studie über Kreativität, Frankfurt/M. 1986.

BIORNAMETICS RESEARCH





ROLEMODEL 04

VICTORIA AMAZONICA, Giant Water Lily

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BIORNAMETICS — ARCHITECTURE INSPIRED BY NATURAL PATTERNS

PETRA GRUBER, BARBARA IMHOF

LOOS AND THE “NEW ORNAMENT”

A formal discussion about the ornament might have started with Owen Jones work “The Grammar of Ornament” at the end of the 19th century and Jones becoming a well-known English architect and stylist ‘pro ornament’: “From universal testimony of travellers it would appear, that there is scarcely a people, in however early a stage of civilization, with whom the desire for ornament is not a strong instinct.”[1]

Currently, we are at a stage of ‘Re-sampling the ornament’[2]. For some years several practicing and teaching architects around the world have been pursuing this topic. Being based in Vienna, one also takes a look at its famous architectural roots, thus Adolf Loos’s essay “Ornament and Crime”[3].

To Loos the ornament was also an add-on to a surface and also something which lprovided less profit for the person who did it, since an ornamented box carved by a Chinese worker was the same price as a box with a smooth surface. According to his argument a human needed to work less and save time, health and money if objects could be made without an ornamental appendage. Loos applied this to functional objects or new interfaces such as the telephone and to (then) contemporary architecture. Loos wanted to free architecture or objects from the emotional expendabilities and he discussed this in an era of early mass production and efficiency, and in the city where Sigmund Freud explored the expendabilities of the soul. At the same time, in the early 20th century, the last unexplored regions of the world penetrated. Western humankind took for the first time an anthropologic and scientific approach to unknown territories and their populations; still far from what we would consider politically correct. For Adolf Loos, the indigenous population of Papua New Guinea and their body ornaments stemmed from tradition and that he acknowledged.

Generally speaking, everything around the ornament theory is complex, ambiguous and definitely opens many layers of interpretation.

The discussion has been ongoing among architects ever since, including Louis Sullivan, Le Corbusier, Gropius and others; however, not all of them were either for or against it – it depended on the context. In the Unité d'Habitation in Marseille by Le Corbusier ornamental enrichment was used by one of the modernist architects. Louis Sullivan, who coined the phrase "form follows function" wrote in his "Ornament in Architecture" theory: "I should say that it would be greatly for our aesthetic good if we should refrain entirely from the use of ornament for a period of years, in order that our thought might concentrate acutely upon the production of buildings well formed and comely in the nude."[4]

Today, the "New Ornament" is something computerised and algorithmic, and it relies very much on contemporary manufacturing technologies. Economic issues once more arise: it might become cheaper to now incorporate the manufacturing of the ornament through new technological achievements in machinery. That and computer technologies – software – go hand in hand with the return of ornament. In many disciplines such as textiles, fashion, design and architecture discussion has been stimulated through these advancements. If Adolf Loos could have anticipated this – what he would have said? He believed through many generations we will slowly turn away from ornament. However, looking forward we could quote Walter Gropius and would probably be ok with: "Forward to tradition, the ornament is dead, long live the ornament!"[5]

Critical to a contemporary understanding of the ornament is its from ancient times continuing relationship with nature. In the context of Biornametics the topic is augmented through an interdisciplinary approach and analysis not limited to free association, basic investigation of nature, or purely bio-inspired. Biornametics is an artificially created word – from biomimetics and ornament. Biomimetics describes the strategic search for nature's solutions in order to gain innovation. Biornametics is the strategic approach of biomimetics projected onto a new understanding of the ornament.

BIOMIMETICS IN ARCHITECTURE

Biomimetics in architecture is the use of biomimetics as an innovation tool tool for application in architecture. It is an emerging field that extends the interest of architects and designers in role models from nature to a new discipline. The strategic approach that differentiates biomimetics from mere inspiration from nature, that has always existed in architecture, arts and technology.[6] Bioinspiration transfers aesthetic and morphological aspects, whereas in biomimetics functional aspects play a key role. In general, materials, structures and processes from nature can find biomimetic transfers to new technical solutions. Until recently the methodology of biomimetics in architecture was only roughly described, now there are some attempts to grasp the process and discern distinct phases and methods.[7]

The simple definition of Biomimetics is "the abstraction of good ideas from nature".[8] A more detailed one says "Bionik [Biomimetics] combines biology and technology in order to solve technical problems by means of abstraction, transfer and application of scientific findings in biology."[9] The basic principle of biomimetics is therefore systematic information transfer from biology (nature) to a technological field. Biologists analyse biological structures that have developed through the process of evolution and natural selection to be highly and multifunctionally adapted and optimised. Engineers work in a goal-oriented manner, and technical constructions are optimised with respect to one or more functions. In spite of the worlds of technology and nature being very different, both are subjected to the same physical boundary conditions, allowing the establishment of analogies as a starting point for information transfer. In this way biomimetics is a truly interdisciplinary venture, with all advantages and challenges inherent in such a transfer. Some biomimetic products, for example Velcro (patented in the 1950s by the Belgian George de Mestrel) and self-cleaning coatings derived from the Lotus (discovered by the biologists Wilhelm Barthlott and Christopher Neinhuis in the 1990s, and taken from the surface characteristics of the Lotus leaf) have become widely known, and both are big economic success stories. Market introduction is the ultimate aim of innovation, but is not aimed at in the present project. In many cases the basic research that is often required for the understanding and abstraction of an interesting phenomenon feeds back to biological knowledge, contributing to the current state of art. This is what is called "reverse biomimetics" following the idea of "reverse engineering" in technology. The biological research that is the basis of biomimetics is carried out with quantitative methods, exploring structures, functions, behaviour, processes or developmental principles.

For a successful information transfer, a deep understanding of the natural phenomena is necessary. It is important to state that biomimetics does not automatically deliver sustainable solutions. Ecological considerations have to be integrated in the technical product development.

Nature provides us with the only alternative technology to our own, and the qualities that we can find in living systems could help us with the global problems that we are facing today. The interconnectedness between function, form and structure or material is an obviously striking feature in the design of organisms. Adaptive capabilities and reactivity permit survival in changing conditions. Differentiation brings efficient use of resources and finetuning to local conditions. Integration and multifunctionality shape highly interconnected systems at many scales. Resilience and self-repair mechanisms are further aspects that we would like to achieve in our technical world. The production processes are entirely different, taking place with local resources and under normal environmental conditions, in contrast to the "heat beat and treat" that we are used to in human technology.

In the Biornametics project, the introduction of a biomimetic approach was chosen for its potential to connect the role model from nature and the architectural interpretation, going beyond inspiration and transfer of form. The project fuses biomimetics with ornament, focusing on new design methods with new digital tools. Several possibilities for application of patterns are predicted.

PATTERNS IN NATURE

Both words “pattern” and “ornament” can be traced back to medieval times, originating from the latin words “patronus” and “ornare”. Pattern has the notion of an exemplary form or shape in all sorts of contexts, which can be the arts, music, literature or mechanical design or form. In general terms it can be defined as a “discernible coherent system based on the intended interrelationship of component parts”.[10] Ornament has a more functional definition as "a manner or quality that adorns".

We experience patterns as a repetition of forms, repetitive recognisable rhythms, known sequences of things. The moment we perceive something as a pattern, we have already abstracted the idea of it, and have identified the rules that this pattern follows. Philip Ball defines patterns as “regular and repeating arrays of identical [or similar] units”[11] and says that to distinguish pattern and form “Patterns, then are typically extended in space, while forms are bounded and finite.”[12] Patterns in nature are not only tangible phenomena but occur also in immaterial form as natural rhythms, cycles of systems and behavioral patterns of organisms. The emergence of patterns is deeply related to order, and occurs in nature and technology in connection to ordering principles and forces.

Patterns are also deeply related to the phenomenon of selforganisation that is effective in all physical environments. “By ‘self-organisation’ we understand the ability of systems to develop and sustain their inherent order without control from outside. The implicit ability of complex adaptive behaviour is a central characteristic of living systems… Alongside, processes of selforganisation are found also in inanimate nature in fields of experience distant to each other [e.g. from the design of the universe to functional nano-surfaces]. Therefore, we can take the view of self-organisation as a concept bridging the gap between animate and inanimate phenomena in nature, presumably playing a key role for the understanding of life and consciousness.”[13]

In the 19th and 20th century scientists have used morphological studies in order to unravel the descent of life and the relationship of the main branches of living organisms with one another. But formal resemblance does not always imply kinship. Sudden changes in typology can occur due to mutations, and covergent phenomena in evolutionary development bring similar solutions from different starting points. In spite of this morphological approach being unsuccessful for tracing evolution, important results concerning the relationship between form and function of organisms were discovered. D’Arcy Thompson published the famous book “On Growth and Form” in 1942. His “Theory of transformations” was based on morphological studies over many species and different phases of individual development.[14]

In inanimate nature spontaneous patterns emerge under specific boundary conditions. Phillip Ball describes a series of patterns and their formation in “The self-made Tapestry, Pattern formation in Nature”[15]. Oscillating chemical reactions, convection cells and many others were discovered long ago, and a series of important aspects can be described, but do not yet constitute a “theory of patterns”. In this book he discusses famous pattern systems like for example bubbles, waves or branching, and gives insight to some generic characteristics and principles of pattern formation like competition of forces, symmetry breaking, non equilibrium systems, dissipative structures, instabilities, thresholds and bifurcations, complexity, power laws and scaling.

In organisms, processes of selforganisation occur alongside with genetic determination, in constant interaction with environmental conditions. External and internal influences shape what we experience as living organisms. The relative stability of the environment, the repetition of fluctuating boundary conditions is a prerequisite for adaptation and thus evolution.

Scott Camazine writes "Self-organization is a process in which pattern at the global level of a system emerges solely from numerous interactions among the lower-level components of the system… Self-enhancing positive feedback coupled with antagonistic negative feedback provides a powerful mechanism for creating structure and pattern in many physical and biological systems involving large numbers of components …".[16] At the beginning of any formation of structure universal symmetry is broken. Alan Turing discovered that diffusion can in contrast to its usual effect amplify small differences under certain boundary conditions, so that stable patterns emerge, based on small aberrations from homogeneity. Turing coined the term "morphogen" for any chemical substance that can trigger tissue differentiation. His revolutionary work laid the base for numerical simulation of pattern formation and morphogenesis in organisms.[17]

Patterning in organisms occurs at different levels of scale and hierarchy, so that a differentiation between material and structure can not be clearly stated. One of our most common building materials, wood, is organised on different levels of scale that all show patterning of a specific kind, from the spiral patterning of cellulose fibres in the cell walls to the macroscopic rings of growth due to seasonal growth. The mechanical properties are based on the optimisation of the structure at all levels of hierarchy.

The development of computational technologies has introduced simulation as a new tool in pattern research, and computational manufacturing technologies allow for a translation from virtual to real without the detour through conventional production technologies. This new situation demands a fresh investigation into the theme together with a broad exploration of the researched strategies that provide role models for biomimetic transfer.

In the Biornametics project, a large number of natural patterns was investigated and used as a starting point for design. The basic themes that promised innovative approaches for architecture were nanostructures, -surfaces and materials, shape change, growth and deployable structures, and reorganisation and adaptation. The biological role models were allocated to one or more of the main themes. Together with the structure-function relationship that was the focus of all investigation efforts, the generation process of the patterns was analysed as far as the basic science information allowed.

The surfaces of plants and animals exhibit extraordinary functional patterning on micro- and nanoscales. They are responsible for a range of macroscopic characteristics, for example structural colouring (colours without pigments, generated by nanoscale structures resulting in interference effects as in the Jewel Beetle or the famous Morpho Peleides butterfly) and for selfcleaning (the so-called Lotus effect in the Victoria Amazonica). Those patterns are generated in a process of genetically controlled selforganisation.

The theme of shape and growth, as investigated in nature in plant growth (unfolding of the Morning Glory flower or the growth-deployment of the enormous Victoria Amazonica leafs) appears at a scale that already permits macroscopic investigation. Pattern formation is based on cell growth and differentiation in biochemical processes following a genetically transferred program as well as environmental information (for example gravity and wind load).

Adaptation and reorganisation included more dynamic patterns like temporary formations in swarms and fast shape change in organisms and material structures. The patterns found are based on action-reaction systems and on the activity of a large number of components.

The analysis and simulation of pattern formation that was carried out in real and virtual models in the Biornametics project aimed at the detection of the fundamental principles guiding the process and the identification of abstract rules that could be implemented in a new technological context.

PATTERNS IN ARCHITECTURE

"The new emerging architecture, that relates pattern and process, form and behaviour, with spatial cultural parameters, offers new behaviours and adaptations to the changing economies and conditions of the natural world."[18]

Patterning in the context of architecture and the built environment is again a broad theme, and can be classified using spatial categories according to the dimensionality and the scale of the ordering system from two-dimensional patterning to three-dimensional systems and beyond, including processes and non-material patterns, and including sizes from nanosurfaces to the urban scale and beyond.

The ornament that Adolf Loos referred to in his famous essay concerned mainly the arts-and-crafts sphere of patterning, producing two-dimensional as well as three-dimensional patterns mainly applied to basic commodities. The industrialised production technologies of the 20th century extended the use of repetitive tiling and structuring. Countless examples can be represented in architecture, especially in the interface between the inside and the outside – the building facade. The basic ornamental depiction of natural patterns from nature is the most simple translation from nature to architecture. Famous Jugendstil buildings like the Majolika house by Otto Wagner[19] are decorated with abstracted floral carried out, materialised with paint, ceramic tiling and relief-like coloured plaster decoration. Today the building facade is an example of symbolic information using patterning in a similar way to more than a century ago. The Ricola Mulhouse factory in Switzerland is an excellent example for symbolic two-dimensional decoration in the form of a simple repetitive array. "The […] [building] has distinctive exterior walls that are made of translucent polycarbonate panels, a common industrial building material, which allows light to filter through. Using a silkscreen process, these panels are printed with a repetitive plant motif (based on a photograph by Karl Blossfeldt) that becomes less visible as daylight diminishes and assumes the characters of a more substantial material than polycarbonate."[20]

The production of precast concrete components for bulding facades is another theme that ranges between two and three-dimensional application of patterning to building facades. The "Textile block houses" of Frank Lloyd Wright aimed at the introduction of a modular building system with ornamented precast conrete blocks. Their precursor project, the so-called Hollyhock house, integrated the abstract shapes of the hollyhock flower into decorative element of the building facades.[21]

The modern and functional architecture of the 1960's made excessive use of precast concrete patterning for facades. The dissolution between the inside and the outside was increased, together with the invention of new technologies for facade cladding and with the emerging architectural typologies of very large building structures. Typologies like shopping centres additionally lost the connection to the external environment. The so-called honeycomb-facade that Egon Eiermann designed for the Horten shopping centers in Germany[22] was made of ceramic tiles and was conceptualised as an anonymous patterned element, giving no information about the internal function of the building and no reaction to the surrounding urban structure.

The rapid development of information technology has invaded architecture and building construction, and has increased functionality of building elements. The facade, formerly a static device delivering enclosure and protection, was transformed into an active interface between the inside and the outside environmental conditions. One of the first projects integrating the control of light and ventilation in a mechanical facade system was carried out in the "Institut du Monde Arabe" in Paris.[23] The facade consists of a rectangular pattern of square tiles corresponding to the floor levels, that are again mimicked by an array of different sizes of technical apertures manipulating the light conditions inside. With this adaptive shading system the project also takes reference to the vernacular tradition of wooden mashrabijas, windods with lattice gridwork, in traditional arab architecture. Solutions of this kind can be seen as patterns in their own right, having evolved due to empirical experimentation over long timescales.

The most recent example of adaptive biomimetic shading was presented at the World Expo 2012 in Korea: the Austrian pavilion by SOMA architects.[24] An actuated lamella facade based on the kinematics of the Strelitzia reginae flower covers the whole of the building height. The opening mechanism is based on torsional buckling (which is usually unwelcome in engineering) together with the use of fibre reinforced material. This large scale implementation of a principle derived from nature shows the potential for the application of biomimetics in architectural design.[25]

Three-dimensional construction patterns constitute another field of investigation. Architects use materials and building elements in characteristic patterns dictated by production and construction issues. Brick walls belong to very common and simple-structures. The addition of materials like masonry allows a close and culturally transmitted connection between the construction and the appearance of patterns. Using steel as a building material extends the range of construction from the usual rectangular column-beam grid to the geodetic spheres of, for example, the Eden Project in Cornwall.[26] Materials like concrete allow for another definition of shape, that is not limited to addition of elements but to the setting of boundaries to a solidifying liquid. Material and processing restrict the range of possible patterns. In order to push the boundaries of the known, architects and engineers try continuously to go beyond the familiar patterns. Usual attempts are expanding the current maximum space, maximum range, and maximum size of the building blocks, but innovative ways of processing (again a change in patterns of planning and building) can bring new architectural qualities to the same system. An intriguing example is the ongoing investigations in robotic construction processes at the ETH Zürich. "Unlike a mason, the robot has the ability to position each individual brick in a different way without optical reference or measurement, i.e. without extra effort."[27] The brick walls that were created by robots following algorithmic design procedures appear surprisingly as soft solidified forms with a high plasticity.

The design process itself is radically changed by the influence of the new computational technologies. Programmed algorithmic architectures are explored for example by the EmTech diploma program at the Architectural Association School of Architecture in London and focus on the interdisciplinary effects of emergence, biomimetics and evolutionary computation of design and production technologies.[28] By integrating computational methods into design and manufacturing, the concept of modularity is reinterpreted, allowing the technological transfer of differentiated and anisotropic structures found in nature. The Institute for Computational Design Stuttgart is at the forefront of examining so-called performative material and building systems.[29] Also, on an urban scale programming technologies lead to a reinterpretation of traditional architectural patterns.[30]

The exploitation of computational simulation has already become a well integrated planning tool in engineering and in urban design. Various architects have undertaken time-based and architectural experiments since the late 1990s. The envisioned changes were adaptive or reactive, or even locomotive. One of the protagonists is Kas Oosterhuis. With his team ONL he investigates what they call the "building body", inspired by a biological paradigm. The pneumatic structure "MUSCLE" presents a progressed form of sensing and reaction, involving space and structure by showing apparently uncontrolled behaviour.[31]

The other direction of transfer, the integration of nature into architecture, is taking pace due to the rapid increase of urban environments and is also the subject of reinterpretation through the availability of new technologies. By integrating living systems, the "aliveness" of built environment will be enhanced, once more following the biological paradigm. Where architecture meets nature, hybrid structures between natural growth and architectural propagation are not far away.[32] "Protocell Architecture" demonstrates the latest explorations of this theme.[33]

The following directions can be taken to develop future structures between biology and architecture with a biornametic approach: transfer of abstracted growth principles from nature to architecture, integration of biology into material systems and integration of biological organisms and concepts into existing architecture. The transfer and integration of nature's deep principles will introduce new qualities and will also extend the range of imaginable solutions towards an integrative and sustainable way of living.

NOTES

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PROJECT FACTS

The project BIORNAMETICS was a one-year project, scheduled from May 2010 to September 2011. The *Austrian Science Fund* FWF selected the project together with five others from the 57 entries applying for funding in the arts-based research programme PEEK in 2009.

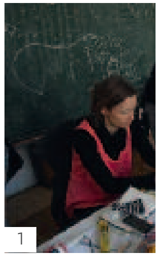
The outputs of the project were many and various. The foundation of the research, the so-called "scientific input", provided a set of data for *37 role models from nature,* representing three main themes that were considered important issues in biomimetics and architecture:

1) Nano-surfaces
2) Shape change and growth
3) Adaptation and reorganisation)

The information was processed into datasheets and working tools, in order to perform the second phase: pattern research, by means of simulations and working models. Architectural concepts were designed, based on this analysis. A *prototypical spatial installation* was conceived and built at the University of Applied Arts, and presented to the public in an exhibition (16.5.-31.5.2011). A *public panel discussion* (23.5.2011) was held to review and reflect on the outputs and the methodology that was used and developed further during the course of the project. All project outcomes generated before April 2011 and the results of this discussion were compiled in a research report.

The work was carried out in several intense phases of the working group by the core team and in individual research phases between the working group sessions. Several public workshops and lectures were held at the University of Applied Arts, with the participation of the students of the Institute of Architecture (IoA).

In the final event, the panelists and their approaches, focussing on the information transfer from nature to architecture. Short records from the panelists and visitors of the debate and a longer essay by later invited contributors reflect on the above mentioned topics.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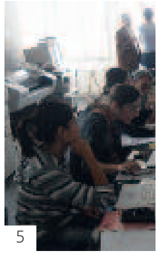
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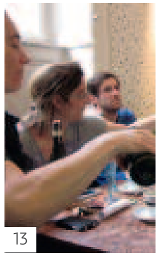
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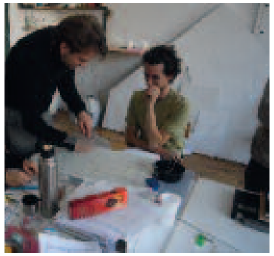


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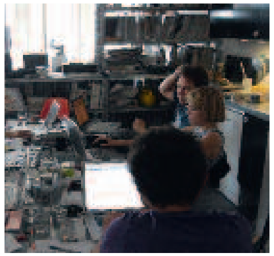


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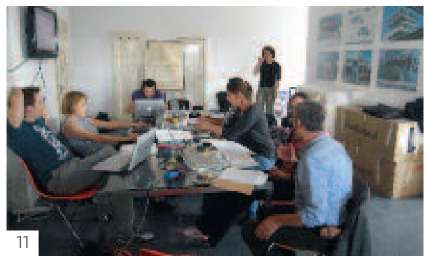
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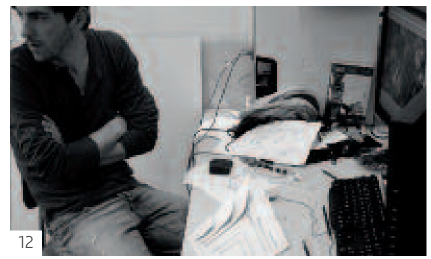
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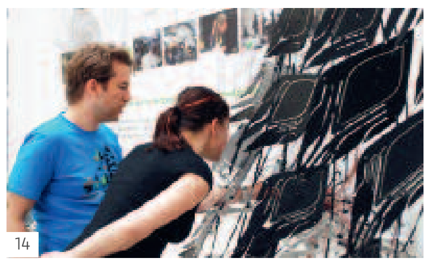
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1, 2
Workshop III, Physical models

3, 4
Workshop I, Botanical garden trip with team and students

5
Studio sessions with the core team

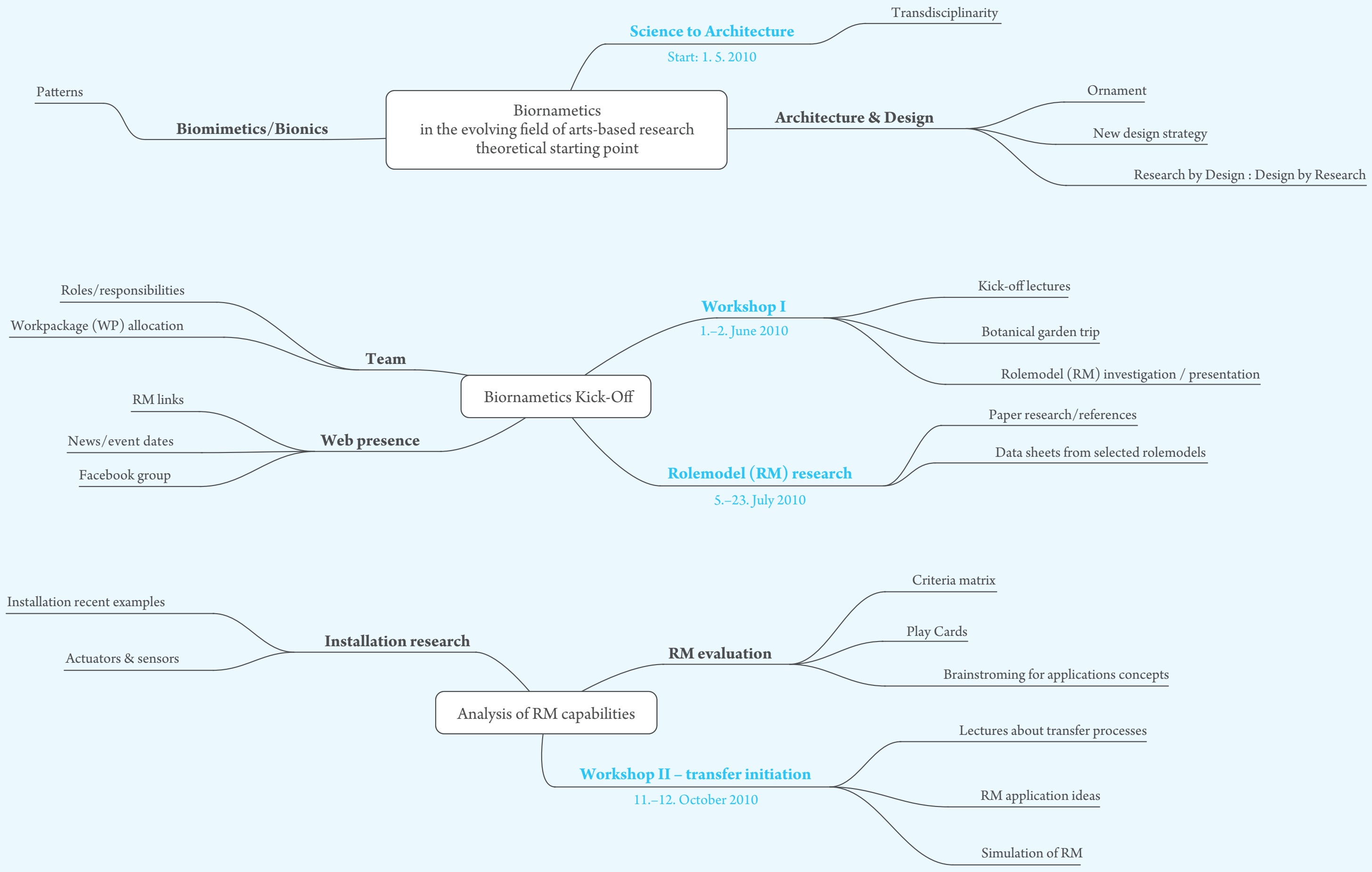
6, 7, 8
Workshop II, Transfer initiation

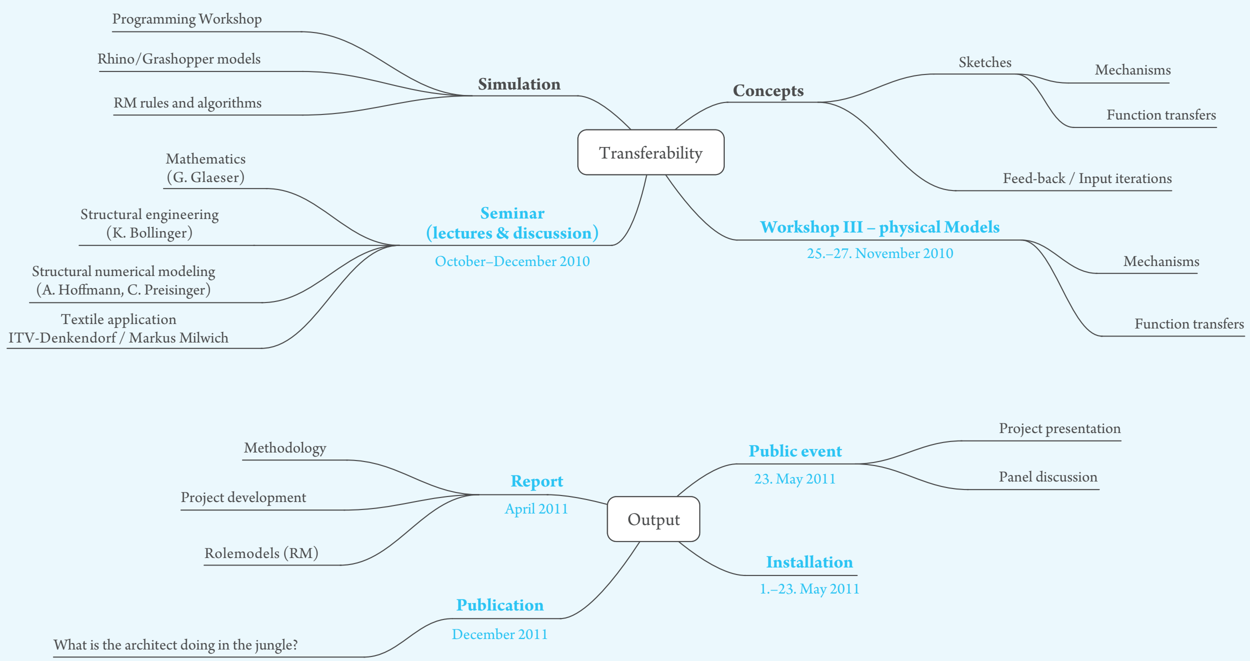
9, 12
Making of the final installation

10, 11
Rolemodel research, studio sessions

13, 14, 15, 16
Public event, project presentation and panel discussion at the University of Applied Arts

PROJECT MAP


Biornametics
in the evolving field of arts-based research
theoretical starting point
Science to Architecture
Start: 1. 5. 2010
Transdisciplinarity
Biomimetics/Bionics
Patterns
Architecture & Design
Ornament
New design strategy
Research by Design : Design by Research
Biornametics Kick-Off
Team
Roles/responsibilities
Workpackage (WP) allocation
Web presence
RM links
News/event dates
Facebook group
Workshop I
1.–2. June 2010
Kick-off lectures
Botanical garden trip
Rolemodel (RM) investigation / presentation
Rolemodel (RM) research
5.–23. July 2010
Paper research/references
Data sheets from selected rolemodels
Analysis of RM capabilities
Installation research
Installation recent examples
Actuators & sensors
RM evaluation
Criteria matrix
Play Cards
Brainstroming for applications concepts
Workshop II – transfer initiation
11.–12. October 2010
Lectures about transfer processes
RM application ideas
Simulation of RM



Transferability
Simulation
Programming Workshop
Rhino/Grashopper models
RM rules and algorithms
Concepts
Sketches
Mechanisms
Function transfers
Feed-back / Input iterations
Seminar
(lectures & discussion)
October–December 2010
Mathematics
(G. Glaeser)
Structural engineering
(K. Bollinger)
Structural numerical modeling
(A. Hoffmann, C. Preisinger)
Textile application
ITV-Denkendorf / Markus Milwich
Workshop III – physical Models
25.–27. November 2010
Mechanisms
Function transfers
Output
Report
April 2011
Methodology
Project development
Rolemodels (RM)
Publication
December 2011
What is the architect doing in the jungle?
Public event
23. May 2011
Project presentation
Panel discussion
Installation
1.–23. May 2011

TESTING BIORNAMETICS – INSTALLATION AT THE SLIVER GALLERY

WALTRAUT HOHENEDER, PETRA GRUBER

The physical installation is the result of the *translation of specific principles* encountered, analysed and discussed during the research work preceding the actual design project. The installation demonstrates one of the unlimited possibilities of *interpretation of a single principle,* and is thus closely related to the perception of the executing team. The goal was to build a lightweight and cost-efficient spatial structure with an inherent potential to move, or to be moved, by stimulus from the external environment.

The primary structural system reflects a specific *organization of fibres* arranged in concentric layers twisted clockwise and counter-clockwise around a flexible axis. This organization of fibres can be found as a *structural principle in several role models* investigated during the research, displaying a high *capacity to resist and adapt* at the same time. This capacity is chiefly dependent on the geometry and the material properties of the fibres. Possible deformations can only happen within certain limits relative to the stiffness of the material involved. Nonetheless the adaptive capacities of the structure were expected to exceed by far those of conventional structural building elements.

Glass fibre tent poles were chosen for the fibres because of their structural properties, the modularity of the system and appropriate costs. A few *reversible and* numerous *irreversible joints* had to be defined. So-called "spacers" kept the elements at specified distances and positions in order to maintain the spatial arrangement of the system.

The joints between the spacers and the fibres were designed to produce as little friction as possible and so allow easy movement by gliding along the fibre's axis. On the other hand fixing of the connection points was necessary to ensure that the system would lock temporarily in a chosen position.

The use of a test-setup with sensors and movement control would have exceeded the given budget and time restrictions, so the installation was fixed in space, but change in shape was enabled by a *controlled and*

synchronized setting-up process, in particular by altering unlocked joints in specified places. The whole construction was suspended from the ceiling, and its performance demonstrated a resistance sufficient to maintain its shape.

Adaptable stiffness of the structure (not necessarily of the material involved) could be a point of departure for future development of more flexible and even reversible building systems (for example structures exerting increasing resistance under increasing external forces).

On a *second level of hierarchy* the installation demonstrates another adaptive process often found in nature: *speeds of transformation varying in reaction to specific environmental changes.* The system consists of reactive leaf-like structures that are partially fixed to the primary fibre structure together with sensory, control and actuation equipment. The elements are added in a cantilever mode and therefore reach a higher level of flexibility and of visible change.

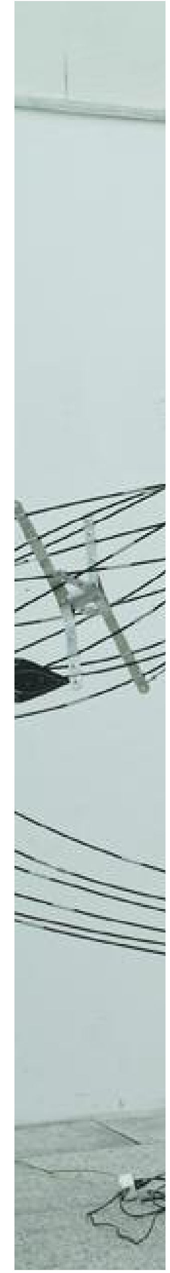
The input signal is the presence of visitors in the space, sensed by optical distance measurement with a specific threshold radius (High Performance Ultrasonic Range Finder). The signal is translated into the behaviour of the leaves by a microcontroller. Sequential rows of leaves are actuated in this installation.

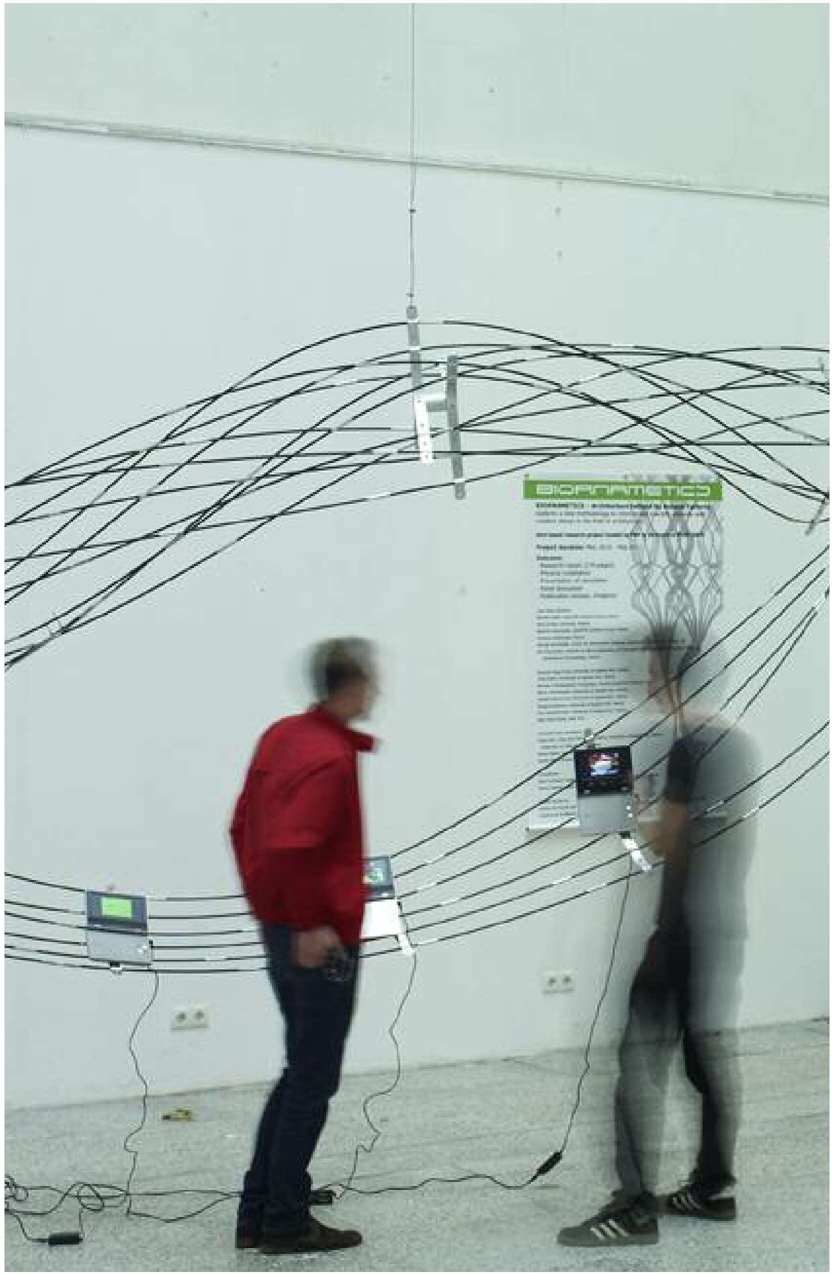
Shape memory alloy Nitinol is used for the actuation wire of the leaves: the output voltage from the microcontroller changes the temperature, leading to the contraction of the wire and thus bending the leaves. They open and close and perform a colour change by exposing different sides.

Refractory period (the amount of time it takes for the system to return to its initial state and to be responsive again) is only 5-10 seconds. The backward movement is actuated passively by the elasticity of the material, the speed depending on the temperature change of the wire. The fast reaction allows visitors to experience the interaction with the installation.

Monitors mounted on the structure displayed the main principles that had been developed from role model simulations in the course of the project.

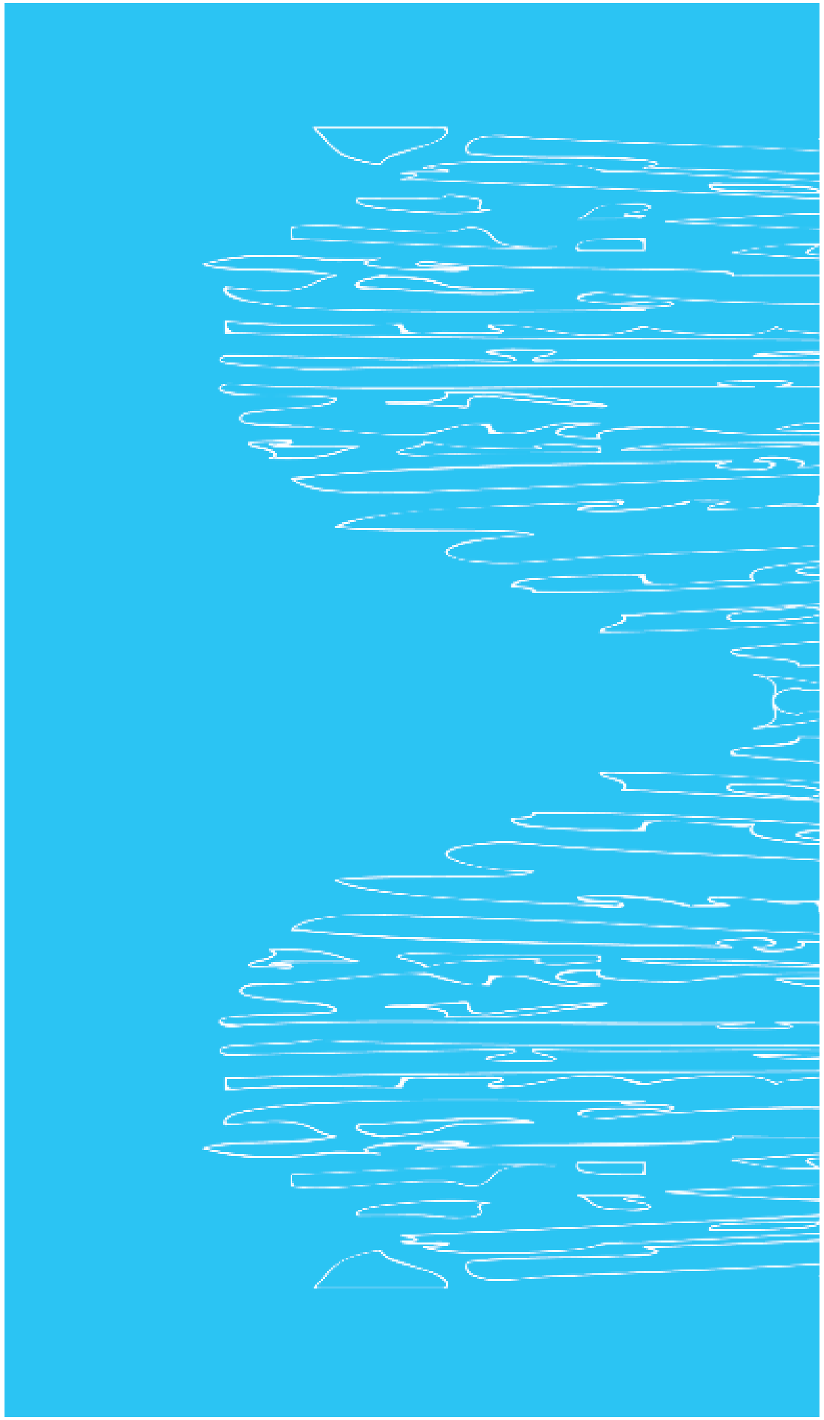
Concluding, the installation deals with the interpretation of various role models with a special focus on the adaptive capacities of systems, and with the possibility of finding numerous physical expressions for principles.

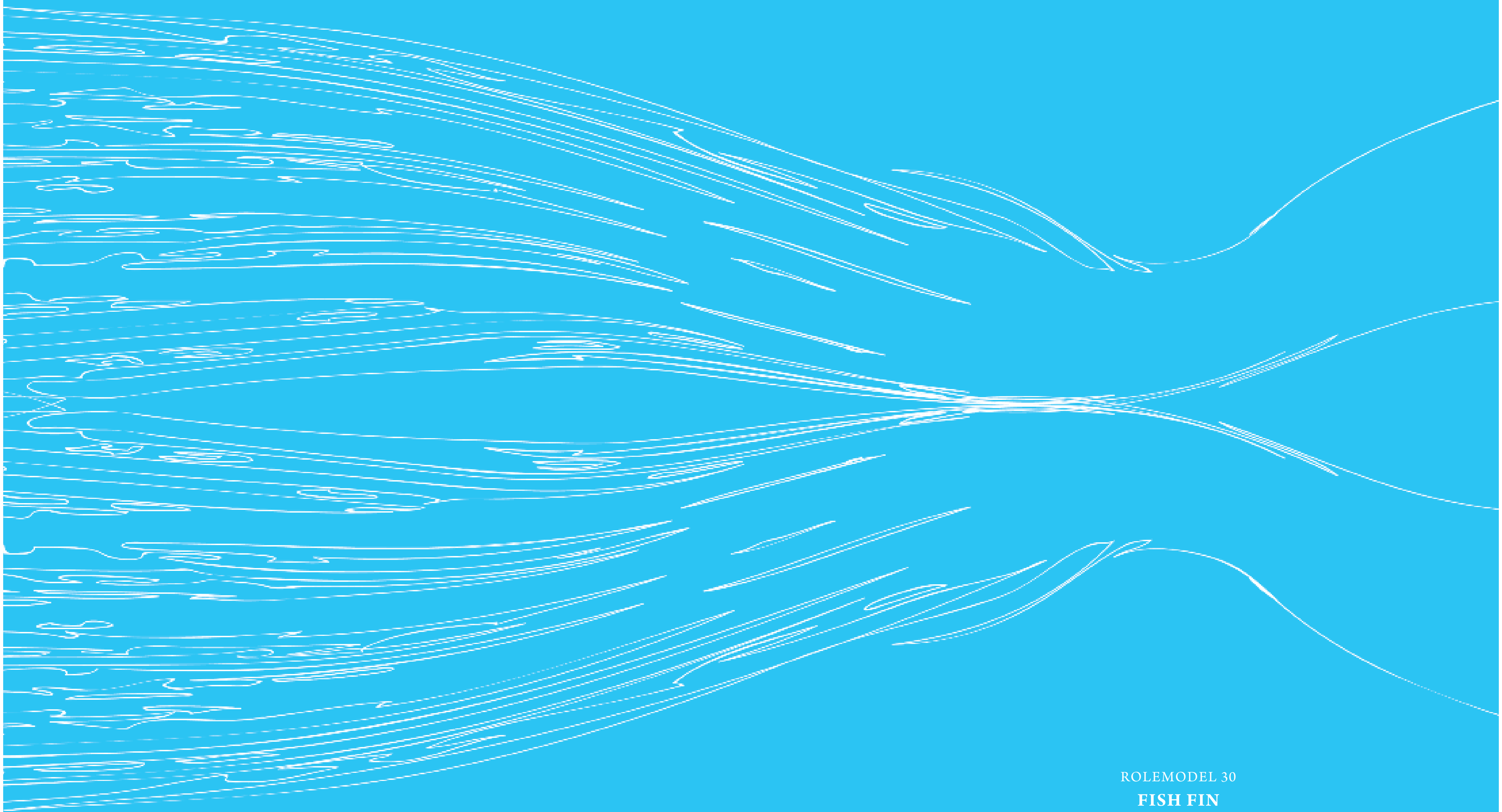



BIORNAMETICS

DESIGN ASPECTS

A critical debate about the value of incorporating findings from the life sciences into architectural design methodologies was initiated.





ROLEMODEL 30

FISH FIN

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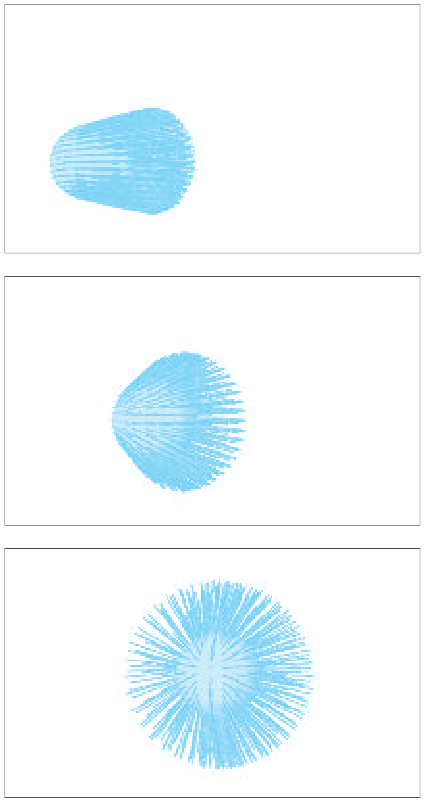
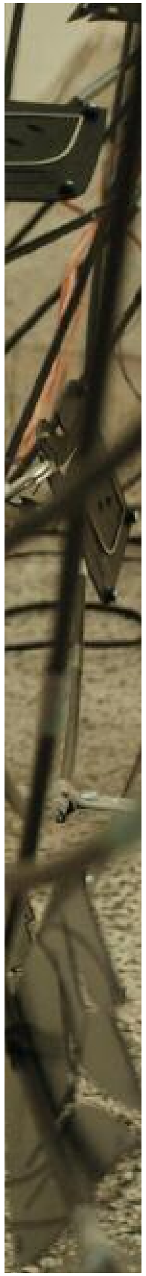
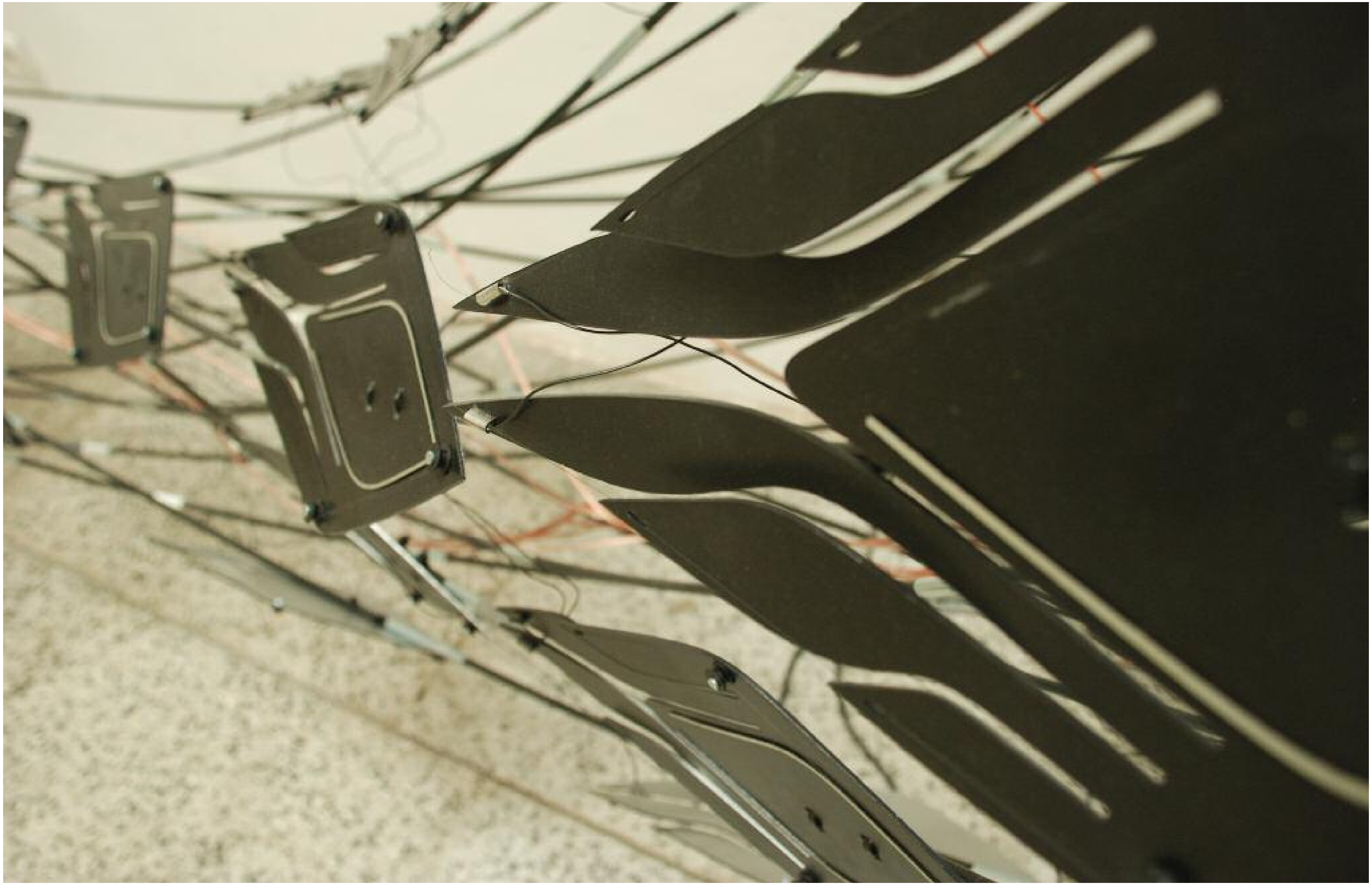
ROLEMODEL 15

DIODONTIDAE, Puffer Fish

Videostill, Page 82



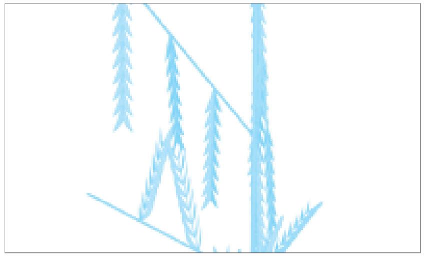


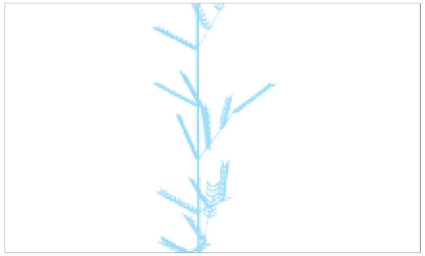


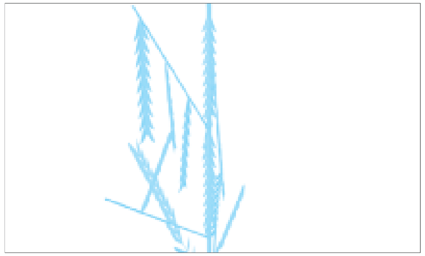
ROLEMODEL 09

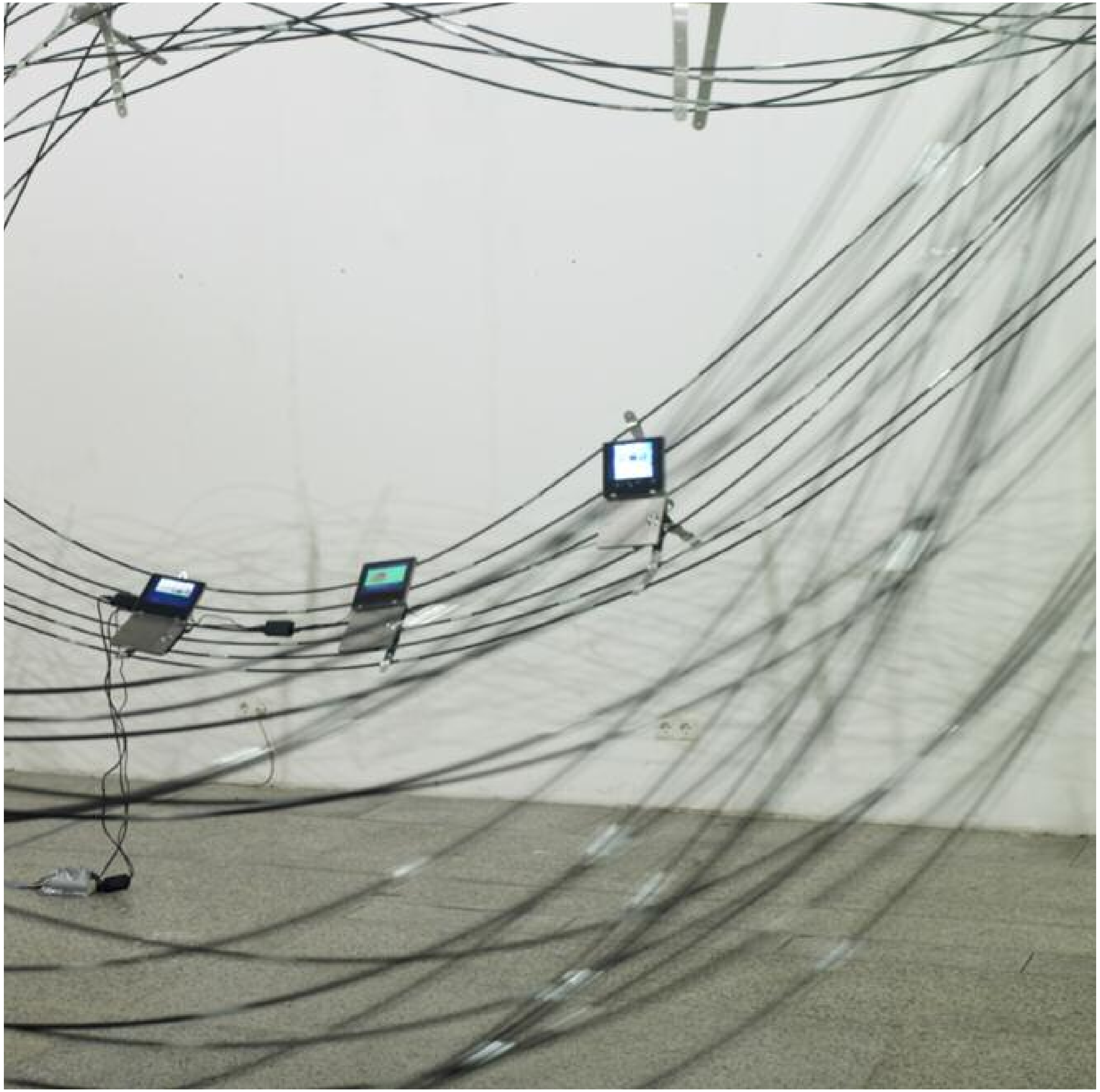
MIMOSA PUDICA, Mimosa

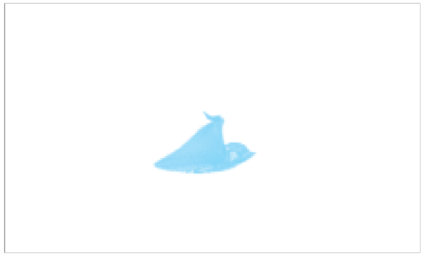
Videostill, Page 79

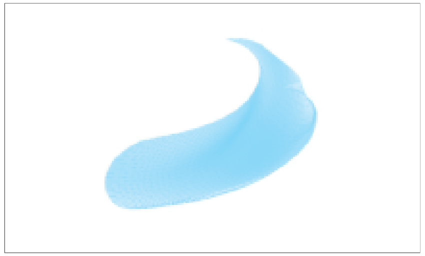












ROLEMODEL 04

VICTORIA AMAZONICA,
Giant Water Lily

Videostill, Page 77

We are interested in perfect geometric shapes

For half my life I have been looking for perfect geometric shapes in nature. They are, however, hard to find. In most cases there is something similar to an octahedron, something similar to a spiral surface, something similar to a space filling group of Archimedian solids, something similar to a minimal surface, etc. The reason for this is that most shapes grow under steadily changing conditions and they are the result of evolutionary processes. So our team started to develop a special software that took both geometrical and evolutionary processes into account, putting natural shapes into a new context. To me, the results were both astonishing and instructive, especially when one began to change parameters. Nevertheless, evolutionary processes often end up as similar shapes, even if the parameters were different during the evolution.

GEORG GLAESER, mathematician,
University of Applied Arts, Vienna, Austria
Project partner and panelist

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We look for evolutionary optimisation of structures

Bottom-up methods based on biological principles allow for structures with emergent load bearing capacities. In analogies to living creatures, these are able to adapt to their specific boundary conditions, and evolutionary optimisation methods can be used to achieve complexity in the topology of structures.

These derive directly from static capacities, but do not show the underlying load bearing principles explicitly. The inherent load bearing quality is not readable at first glance, and emerges as the result of the complex interaction between the individual members. In a generative process the correlation of a single element with every other element is considered in every calculation step. Thus complex load bearing behaviour can evolve.

ARNE HOFMANN, architect, Bollinger Grohmann Schneider ZTGmbH, Vienna, Austria
Project Partner and Panelist

Nature does not optimise – nature changes

Evolutionary processes and a combination of chemical and physical phenomena lead to specific geometric organizations in nature. In fact nature strives to reduce the amount of material necessary to create specific spatial configurations that we have come to recognize as shapes or forms, which have developed over enormous time periods.

The re-emergence of the desire for form and ornamentation in architecture can be traced back to the emergence of computational tools in the discipline which allow for the integration of these morphogenetic processes into a design procedure – at high speed. These novel tools not only support the exploration of evolutionary processes capable of finding solutions but simultaneously generate opportunities of creating intensive (M. de Landa) spatial conditions.
In fact the issue of intensity is probably the biggest paradigmatic shift in the discipline of architecture. It describes natural processes, and how they continuously change from one condition to another, for example atmospheric pressures, sea currents, or gradients in colouration of flowers.
A publication like Biornametics explores how these intensive conditions can be mastered and incorporated in architectural design techniques, an endeavour that cannot be overestimated in a contemporary architectural discourse.

MATIAS DEL CAMPO & SANDRA MANNINGER,
architects, SPAN, Vienna, Austria
Invited contributors

Nature and architecture – what architecture can do

source: KÉK

In the book „The Baron In The Trees" the author Italo Calvino tells the story of a baron who decides to leave the earth to live in the trees. „... Cosimo rises from the family table, climbs into a nearby oak tree and never again sets foot on earth. ..." In this shift of paradigm Cosimo leaves behind all that has restricted him up to this point and immerses himself in a new way of living. There has been a continuing interest in the use of the life sciences in architecture in recent years, which reinforces the hope of seeing a change of perspective in the way we think and research in architecture. It is not the form finding experiment which is at the centre of the project but architecture being viewed as an organism, as „living nature"; an architecture which is capable of adapting as a designed environment to influences from both nature and the activities of man. This environment is interactive and transformable and in this way becomes adoptable by the user. This vision of crossing boundaries says farewell to the mechanical thinking which looks predominantly for technical answers, and instead adopts a holistic style of thinking based on the humanities, natural sciences and the arts. The research project „Biornametics" stems from this school of thought. The composition of the research team from different disciplines (biology, physics, mathematics, building construction and architecture) promotes a holistic discussion, and demands a mutual exchange of knowledge and communication.

We are witnessing a fusion of creative forces which, supported by digital tools, will lead to the development of the required communication methods. In my view, these are active knowledge resources that can cause interactions between ecological systems and socio-spatial requirements, thus leading to a shift of cultural paradigms. The setting developed for the evening discussion – an installation both fragile and variable – already suggests some promising approaches to implementing this change, and reveals the true potential that lies in the vision of an organic and adaptive architecture.

ERNST J. FUCHS, architect,
the next ENTERprise – architects
Invited contributor

BUILDING BIO-ORNAMENTS

JULIAN VINCENT

INTRODUCTION

For many years I wondered how one can *transfer ideas from biology to engineering*. In the initial stages, at the University of Reading, I would sit with George Jeronimidis and we would take an idea (perhaps a problem posed by someone from industry, or by a student) and we would translate the ideas into each other's domain. George would simplify the engineering (or design, or materials, depending on the nature of the problem) and make sure that the proper question was being asked. I would pick up on the tail of the ideas and think of one or more biological analogues. I would then expand the analogues until they looked, at least in part, like a solution to the problem and then convert it into some sort of engineering-speak which George would take on and develop using standard (or perhaps not so standard!) ideas from engineering. This process might go around the circle a few times, but nearly every time we could produce something novel. And I'm told it could be quite entertaining to sit in on the conversation. However, although this process was quite enjoyable, it seemed to me to be rather slow, because we were obviously developing some techniques of transfer of ideas and technology, but we weren't making it into a system that could make things easier and quicker for us – and for other people. I then moved to the University of Bath and found that I had to conduct these conversations on my own!

I was lucky enough to get a good grant to develop some ideas, decided that the answer lay in a Russian system, *TRIZ* (the acronym for, in translation, *the theory of solving problems inventively*) and managed to employ one, then both, of a husband-and-wife team, Olga and Nikolay Bogatyrev, two biologists who had learned TRIZ from the professionals in Novosibirsk. TRIZ was developed by engineers, for engineers. It is based on sound philosophical ideas which have produced a system which is of much more general application, suggesting the changes required in a system that will produce a desired outcome. This essay is an exploration of the techniques involved and, as such, is a sort of experiment on paper. Will it work?

TRIZ AS A DATABASE

TRIZ is made up of a collection of techniques that are used in sequence, defining a problem, its context and the available resources. You then see what changes you can make to the system in which the problem occurs in order to achieve resolution. An early development of TRIZ was a list of such changes, an early example of data mining from patents describing solutions to technological problems. This list of Inventive Principles (there are 40 of them) is considered to be exhaustive, and so forms a basis for the classification of solutions. The Principles are not all equally useful, some being more powerful than others. They also overlap, so that a single solution can be indexed by several Principles. I have mostly used 4, though sometimes fewer or more Principles are needed to make an adequate description. This increases the power of this approach since it allows more nuanced descriptions. Thus there could be something like 40^4 (i.e. 2 560 000) different descriptions, though many conjunctions of the Principles are impossible or unlikely since they make incompatible recommendations.

Using extensive statistical analysis, I have identified principles that appear most commonly in biological organisms to achieve change or adaptation, depending on the outcome, or the problem to be solved. These Principles can guide biologically inspired design without the necessity to invoke biology or biological expertise. Together with a more detailed biological analogy, they are:

HETEROGENEITY, LOCAL EFFECTS

The definition of this Principle is to *introduce heterogeneity into the object or its context and increase the dynamic range; introduce local adaptations, increasing flexibility, micro-shaping, local orientations or zones within structure or material; divide the object or system into separate units each capable of a different function; optimise each part or context*. In an animal or plant, each organ has its own physiological micro-environment, often surrounding itself with a membrane to emphasise this separation. Invertebrates tend to allow more autonomy to their internal organs that possibly makes them more robust. The separate components are kept in some sort of synchrony by the nervous system (short term integration) and the hormonal system (longer term integration). At a larger scale of size, in an interbreeding population of organisms, it is important to have variation in the *genetic make-up* that acts as a store of solutions to possible problems as yet unexperienced. This gives greater *resilience and adaptability*. The same is true of ecosystems – a monoculture (an agricultural crop) is very susceptible to damage by organisms which we call pests; greater variation in the species present gives more protection from such disasters.

MERGING OBJECTS

The recommendation is to *join objects in series or in parallel* with multitasking *and mutual support; merge parts of the object or system, join objects similar or dissimilar, giving growth or accretion and allowing different components to contribute (as with composite materials)*. In many animals (for instance insects and snails) the nervous system is primitively divided into local units (ganglia) that tend to fuse in the more evolved members of the groups to give a larger and more integrated system. This presumably allows faster central signal processing. Tighter integration is an advantage in populations of individuals as well as in cells and can lead to responses by a community, which is more powerful. Examples would be a colony of ants or bees, or a pack of wolves.

DYNAMICS

This is all about *change: change degrees of movement; change shape; change immobile to mobile; change stiff to flexible,* locally (hinging) or globally; *make parts adaptable* (this obviously involves sensing and responding); *change dimensions, getting bigger or smaller, longer or wider. Only low loads from the environment and bend out of the way of high loads, or readjust in the presence of (detected) high loads.* The nervous system is necessary for detection; the muscular system is necessary for the readjustment in the short term, or growth in the long term. Flexibility of response allows better survival.

PRIOR CUSHIONING

This set of recommendations is all about *control of risk and reliability*. Suggestions are to *prepare for trouble with back-up and reinforcement; to be constructed from a few durable components or many expendable components; compensate for low reliability.* Our nervous system as a pattern analyser can extrapolate present observations to predict the probability of future events and thus enable us to prepare resistance to danger. Organisms also have various degrees of redundancy and safety factors built in to their design that allow for failure rates in use, and there are many examples of continual repair of tissues. The over-all failure rate (e.g. ageing) is closely related to the reproductive rate of the organism – an organism that reproduces at a higher rate can afford greater loss of individuals. Heterogeneity, in genetics and in ecospecies, gives resilience in the face of threats and unexpected conditions (see Heterogeneity, above).

FEEDBACK

Feedback is all about *information and its flow through the system,* which can be a single cell or a population of individuals. Suggestions are to *modulate feedback* (optimising and regulating sensitivity); *change between positive and negative feedback* (excitation and inhibition). Most organisms have controlling negative feedback built in, since the chemical reactions that maintain them can occur under only relatively controlled conditions. Feedback can be chemical (e.g. cellular metabolism), neural (e.g. fine-tuning optical or aural response), neuromuscular (co-ordinated movements) etc. Nature is replete with feedback mechanisms since they can greatly improve the performance of a wide variety of functions that are not mechanically perfect, integrated or optimised. A particularly good example is the use of feedback in frequency analysis in the middle ear, where cells sense the frequencies in the received vibrations and amplify them. There is also much feedback in the control of density of populations.

These general rules cover most biological mechanisms - only a few examples have been given. As a list they constitute a design handbook for anyone wanting to introduce biological processes. Let's see how they might work ...

A BIO-INSPIRED ORNAMENT

We want an *ornament* (something which attracts attention, perhaps giving pleasure and stimulating thought) that has at least s*ome of its principles derived from biological objects or concepts*. Most ornamentation increases the amount of detail and complexity of an object. The complexity can be appreciated by any of the senses, so colour, sound, shape, responsiveness, adaptiveness and so on are all factors which can be changed. In order to see the outcome of these changes more clearly, let's start with that most inanimate of objects – *a brick*. What are its properties? *Mass, shape, surface texture, rigidity, strength, colour,* and more; this list will suffice. The brick is incapable of sensing anything but it can respond in a limited way to changes in its surroundings, for instance by reflecting or absorbing light or heat. That means that we have to consider external influences on the brick – and internal ones such as the chemistry of the material the brick is made of or the way the material properties and morphology change from point to point. Both these classes of influence - larger and smaller than the brick - have a time course. The brick is a record of what has already happened to a lump of clay; we wish to change the brick in some way that can be experienced only in the future.

When we apply the biological design principles that I have described, even to a brick as it appears without considering its history or fate, a large number of possibilities becomes apparent (see table). We can pick and choose from these possibilities in the knowledge that the outcome will have some features typical of a biological object. It's then interesting to ask what might it lack by comparison with an organism? First and foremost is the ability to transduce energy, without which ability any of the changes or attributes must rely on external energy supply to power them. This is not included in the current model. The ability to reproduce is also omitted, though if we include the addition of notches to the shape, it becomes easy to break; if it can join on to other objects it can grow. However, we still have an object that can change shape, colour and texture, frequently in response to changing external conditions. All these technologies are available. So we have generated, fairly easily, a shopping list that can yield bio-ornamentation.

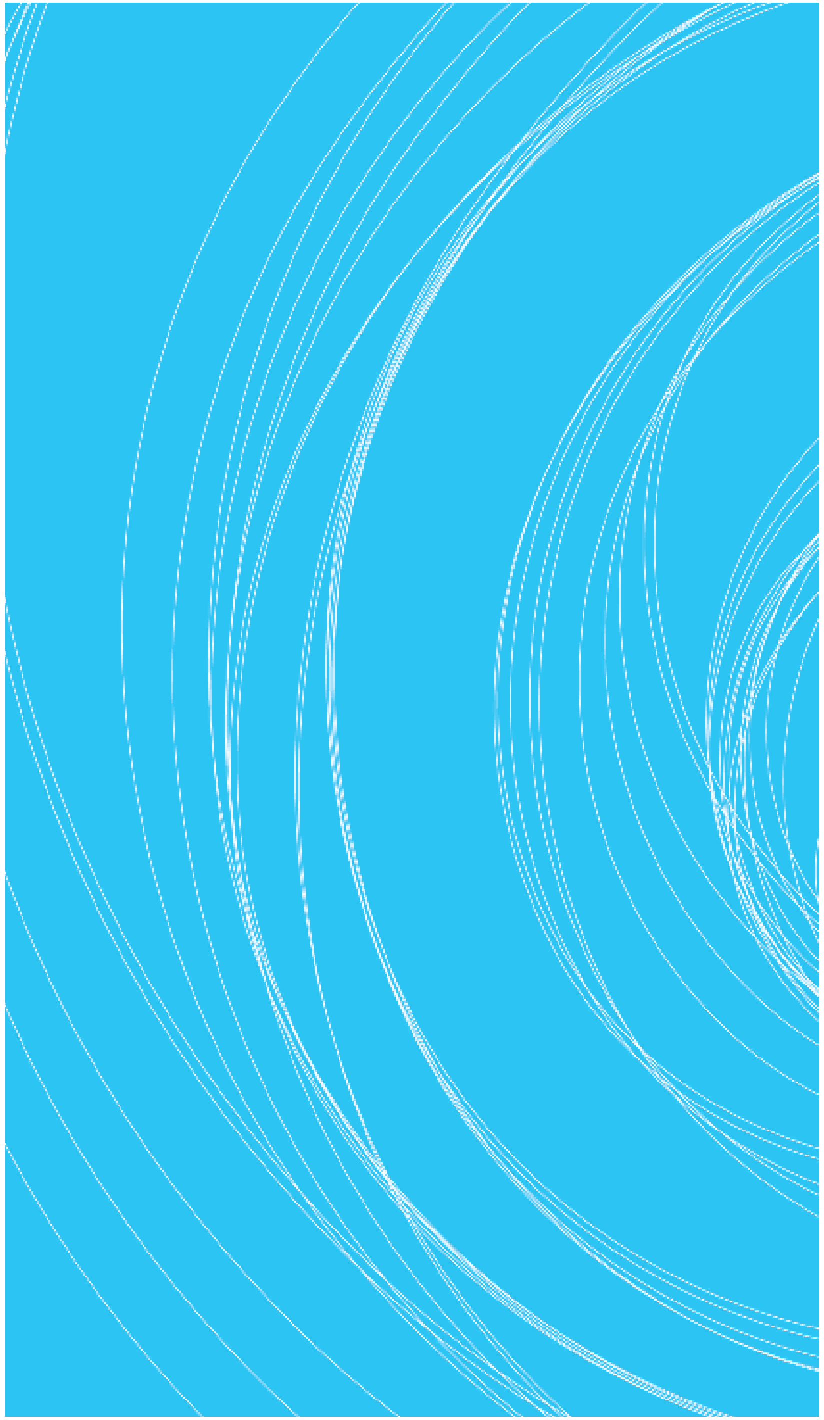
DEVELOPMENT

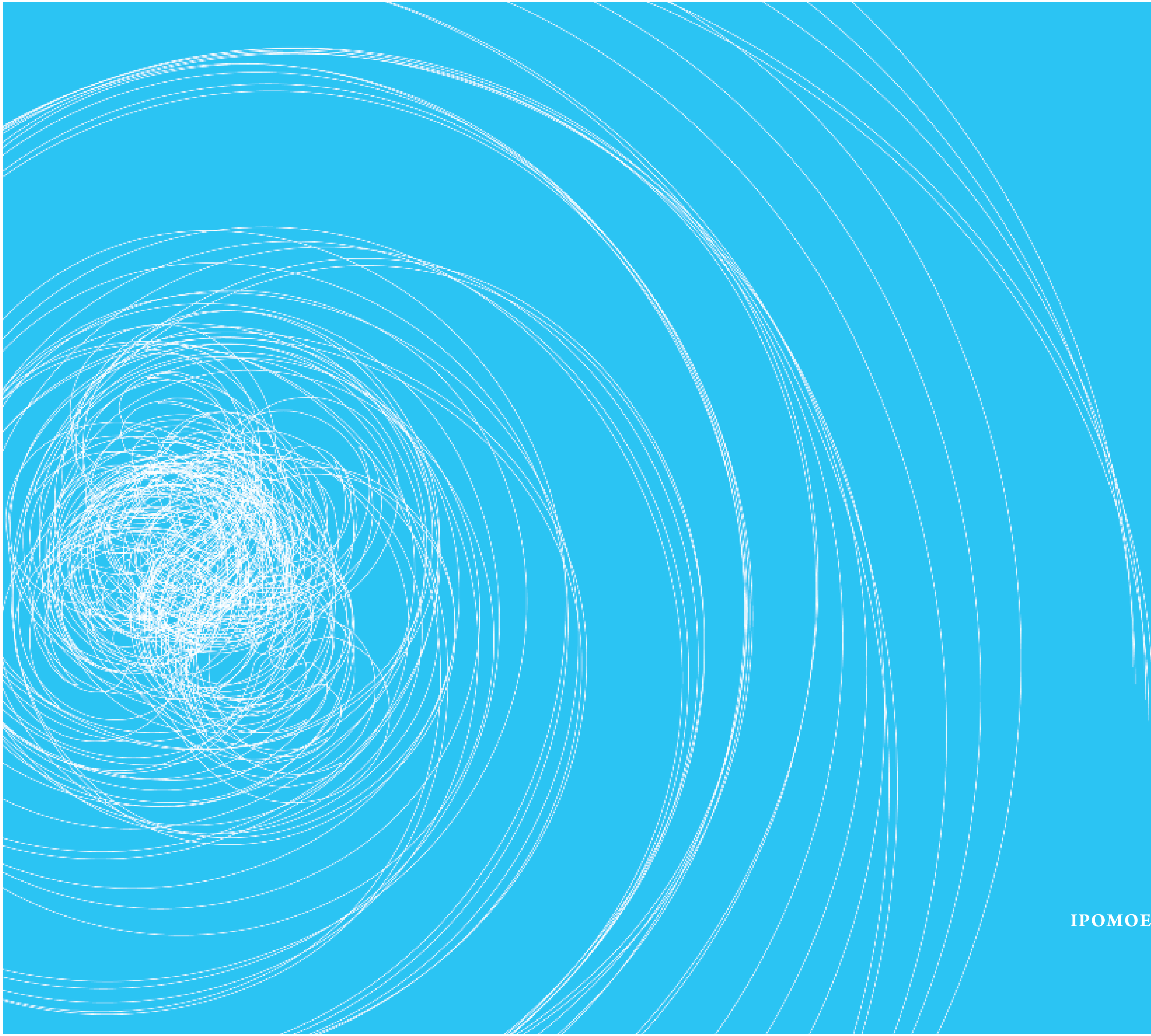
We now have a novel brick that is decorative and capable of at least some of the functions of a living organism. The table has the instructions for making a large number of different prototype bricks, so we have the possibility of a *population – an ecology of bricks*. Bricks are usually used to make structures such as walls and enclosures, so we can use this variety to build a highly variegated structure, resulting in a simple hierarchy, itself a common biological phenomenon. The variables available to a wall might be height, width, orientation of the wall, orientation of the bricks. Also the wall can be a single unit or it can be part of a building. The profile of the wall can be heterogeneous, for instance smooth or angular, both along the top and down the sides, and it can curve around and join with itself to enclose space. It becomes more interesting and biological when considering the dynamics, so that when a brick is disturbed in any way it not only responds in its own way depending on the variables in the table, but influences neighbouring bricks. The most obvious change would be surface colour, yielding a surface which can pulsate with colour but with no external control. This type of behaviour begins to merge into *swarm dynamics* and the bricks take on some of the *characteristics of robots* – indeed the changes in surface colour could be modulated such that they varied with the type of originating disturbance, yielding a wall that could display information about itself. We have sentient *self-ornamentation from an inanimate object!*

	HETEROGENEITY	JOIN OBJECTS	ADD DYNAMICS	SAFETY	FEEDBACK	CHANGE SHAPE
MASS	Different materials Different porosity Vary from place to place	Stiff or flexible LEGO Velcro glue	Change mass distribution	Soft edges		Shaped holes Foam
SHAPE	Thinner Fatter Rounder	Jigsaw puzzle Nesting	Dynamic shapes	Ability to roll	Flat when on a flat surface Goes round when rolled	Retain angles Retain volume Round corners
TEXTURE	Zoned roughness across surface Smooth / rough	Layered surface	Changing surface	Texture is soft		Change shape of bumps: round / sharp
RIGIDITY	Zoned rigidity Segmented	Bricks can be clipped together	Stiffness changes	Can bounce	Goes stiffer or softer when handled	
STRENGTH	Weak interfaces Novel fracture	Special braces between bricks		Made of a composite material	Can fall apart in your hands!	Notches to make fracture easy
COLOUR	Colours zoned Camouflage Physical colours	Interference layers	Continually change colour while you are watching		Bright colour if you lose it!	Counter-shading Dazzling colours
RADIATION	Spectral reflection Differential expansion	Fuzzy edges between colours	Radiation changes reflectivity		Changes colour as light changes	Reflecting surface Change orientation
WALL HEIGHT	Gradual varied height Steep varied height	Bricks loose Bricks glued	Bricks supported on springy base If a brick is moved	All bricks are loosely tied into a connecting	When a brick responds to a change its neighbours sense	
WALL WIDTH	Gradual varied width Smooth profile Jagged profile		its neighbour responds using the mechanisms built into it at	web. This gives some safety and allows the	this and change as well, though not always in the same way	
WALL ORIENTATION	Curving Angular	Walls enclose area	manufacture	bricks to communicate		
BRICK ORIENTATION	Long axis horizontal Long axis vertical Long axis angled					

TRANS-DISCIPLINARY ASPECTS

In a project which combines multi disciplines a general understanding of the other disciplinary culture must be created to generate the basis for a productive and fruitful collaboration. Besides respect and tolerance a common language and new paradigms amongst other denominators need to be established.





ROLEMODEL 11

IPOMOEA ALBA, Morning Glory

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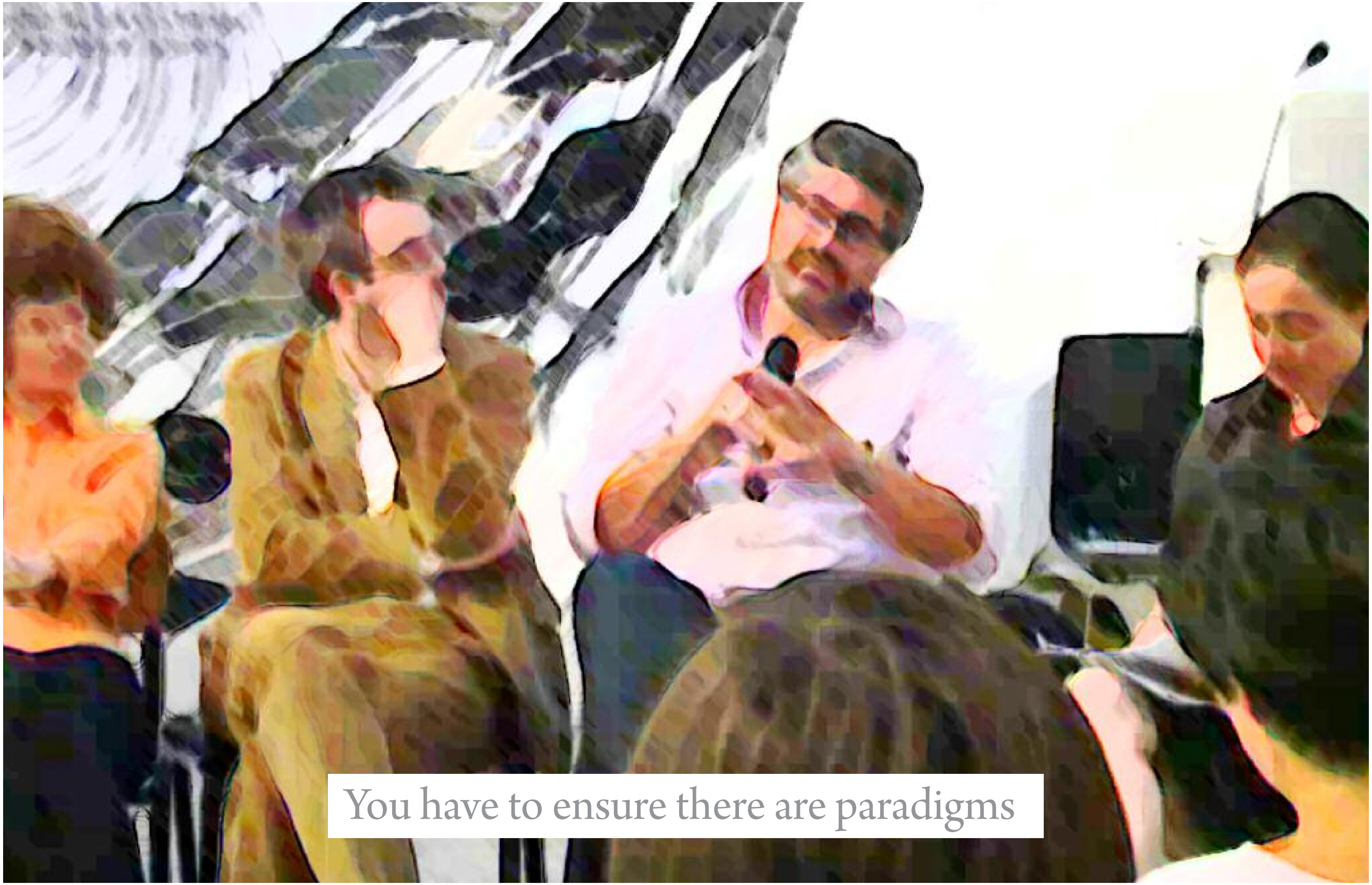
You have to ensure there are paradigms

There has been a flirtation between architectural design and biological models of organizing form for the last 25 years; roughly coinciding with the adoption of digital tools used not only for mere documentation, but also for creative design. In the 1990´s there was a rich collaboration between scientists and architects at conferences and in publications around the theme of 'form finding'. The biological sciences were becoming more like physicists in their use of computation to study growth dynamically. Visualisation was becoming more important and there were even instances where tools from the sciences were adapted for use in computational fluid dynamics, finite element analysis and animation, and also where design and engineering tools were adopted by the life scientists; so there were many intersections at a technical and vocational level. Conceptually, the sciences were beginning to study growth and dynamical systems, while architects were beginning to use tools with animation ability, and so both disciplines were become more 'vital' in their media, for analysis on one hand and design on the other. Today we find ourselves using software, geometric models and terminology and concepts that exhibit more and more similarity in design and engineering fields and in the life sciences. At conferences such as TED and others scientists share the podium with designers, and the general public is looking for environmentalism not just in performance but even more so symbolically.
Biornametics is a mature instant of this intersection between concepts and media rather than an experiment or hypothesis.

GREG LYNN, architect,
University of Applied Arts, Vienna, Austria
Project partner and panelist

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How to find a biologist

Looking at biology as a scientific discipline one has to admit that in the last decades a tremendous specialisation has taken place. Ernst Häckel was cited as a so-called universal biologist who in his time could have been supposed to contribute substantially to biomimetics as a whole. But the time of universal biologists is indubitably past, and in order to find an interested biologist the primary goal of the non-biologists should therefore be the comprehensive definition of their specific problem, enabling them to address or invite other scientists – not only biologists – for cooperation.
Nevertheless it is also worthwhile to think in advance about the research focus of possible candidates. Buzzwords in this context are phytography or zoography (description of plants or of animals), biological systems, and also functional morphology of either plants or animals.
The latter field is extremely diversified, as one can see from the structure of the various departments at universities or related research facilities. Simply go to the Internet in order to find out!

In retrospect, my recommendation would be to go first to any nearby museum of natural history. The broader public is normally unaware of the priceless value of the collections of these museums, which are a solid foundation of phyto-/zoography and biological systems as well as all aspects of functional morphology.
And there will certainly be a couple of biologists affiliated to these collections who will cover any of the cited topics. So, the problem of "finding an interested biologist" could be effectively solved.
Proceeding to "what you would do with the biologist in your office" is another kind of task. Provided that the aforementioned steps are taken carefully the most important precondition for successful interaction should be secured. In my personal experience the difficulty of a biologist communicating with non-biologists lies in the inability of non-biologists, e.g. engineers, physicists, architects etc, to recognize the necessity of the correct use of biological terms, which is indispensable for successful cooperation. Without doubt there has to be an initial approach from either side when it comes to finding a basis for conversation but in my opinion the non-biologists are more liable to accept rules.

HERBERT STACHELBERGER, chemist, Vienna
University of Technology, TUBIONIK Centre of Excellence
Invited contributor

The challenges of an artist

Being part of the Biornametics project has been a very exciting opportunity. Working with colleagues from different backgrounds and with a group of very able and dedicated students has prompted me to look again at aspects of Biomimetics I was less familiar with. Trying to abstract concepts from biology for a biornametic design which integrates functional, materials, geometrical, responsive and aesthetical aspects has been a very interesting and challenging exercise for the whole team. My specific interest was in extracting from the project ideas for translating the dynamical adaptation of biological systems into materials, structural and architectural solutions. The project has also demonstrated the benefits of highly interdisciplinary approaches to biomimetics. The artists' side in this trans-disciplinary collaboration is much more difficult because it is more implicit than explicit. So it is more likely that artists approach the scientists than the other way round.

The discussion provided an opportunity to address issues related to the implementation of architectural designs inspired by biological materials. From my point of view, materials, geometry, shape, organisation of fibres and processes such as growth are the key aspects of the success of nature's designs. All the above, together with the benefits of hierarchical systems – the norm rather than the exception in biology – are the tools needed to ensure that functional design aspects are the embodiment of "dynamic adaptation" to changing environments in space and time.

GEORGE JERONIMIDIS, chemist,
Centre for Biomimetics, University of Reading, UK
Project partner and panelist

We have to establish a common language

What is an Architect doing in the Jungle?
Nature Sessions deep in the virgin rainforests of Malaysia allow young talents to learn to watch, to understand connections, to correlate structure with function and to transfer deep principles from nature into their respective fields. Students that come from fields as diverse as the fine arts, the applied arts, veterinary medicine, physics, biology, engineering and architecture experience a different approach to their own subjects.
For example, the national Malaysian butterfly has amazingly beautiful colours generated by structures alone, and not by pigments. Such 'frozen rainbows' can be transferred to architecture, and yield multifunctional, non-toxic surfaces that can be functionalized and thereby become responsive to various signals. A fire? The direction to the nearest exit appears automatically on the walls!

Evolution and Biomimetic Architecture
Convergent Evolution denotes a process where distinct species with differing ancestries evolve similar features in comparable environmental circumstances; examples of this evolution include the eye, cartilage and fin-like extremities. In these cases the relationship between structure and function seems to be exceptionally strong.
Morphodynamic investigations allow for biomimetic identification of principles in three distinct scenarios of observation (one animal, one niche, variable time OR one animal, various niches, same or semi-variable time OR various animals, one niche, same time), with a high potential of the subsequent transfer to the arts and sciences.

The Need for a Common Language
It is not easy: scientists and engineers have totally different concepts, languages, methods and aims compared to artists. These groups have started to communicate with each other only recently.
The interaction between their respective fields is very important, but also a challenge because of different inherent cultures and communication protocols.
Therefore a common language in arts, science and engineering needs to be developed: a language in which descriptions at different levels of detail are more compatible.

ILLE C. GEBESHUBER, physicist,
Universiti Kebangsaan, Malaysia
Project partner and panelist

ON COMMUNICATING PROCESS IN ART-SCIENCE COLLABORATIONS

DOMINIKA GLOGOWSKI

The separation of disciplines in science seemingly increases exponentially in direct ratio to the number of discoveries made and the equivalent branches of specialization created. Evolution embraces complex ecosystems resulting from continuous process and change, whereas scientific disciplines tend to create a series of fixed 'realities.' These 'discrete realities,' which I would call 'imaginary paradigms,' suppress the intermediate states to simplify classification; or put it differently, to bring back order into chaos.[1] Recent art-science collaborations challenge the communication of process that is further complicated when transformed onto the built environment. This essay is intended as a stimulus to enhance discussion on network complexities in these grey areas.

When comparing the aircraft with art in 1967, artist Robert Smithson (1938–1973) drew attention to narrow interpretations in rationalist approaches. "The categories," as he emphasizes, "that proceed from rationalist logic inflate a linguistic detail into a dated system of meaning." The aeroplane's explanation hence reaches beyond simplifications like "nature, progress and speed," as the arts dissolve pure classifications of "painting, sculpture and architecture."[2] Smithson's analogy frames the significance of language in the construction and the cartography of a definition. Language maps artistic and scientific processes along linguistic pathways, heading towards the point of conclusion. This conclusion evolves as a structured merging of meaning, 'the origin and end of thought.' Following Smithson, we fail in the end, however, to pinpoint *the* centre, "The mind is always being hurled towards the outer edge into intractable trajectories that lead to vertigo."[3] Facing the inability of an absolute articulation, categories and disciplines can be interpreted as vectors that direct thought onto 'tracks.' Beyond Smithson's understanding of language as a three-dimensional object, these tracks verge towards linguistic cogitation and situational matter. They blend literal and spatial imprints, creating the "syntax of sites."[4]

Smithson's fusion of topological and typological qualities implies a comprehensive approach towards networks and their framing.[5] Illustrated with Alexander Graham Bell's (1847-1922) tetragonal lattices, Smithson embraced a holistic picture that merged imaginary, linguistic and bodily particularities. Bell, commonly known as the father of the telephone, experimented with tetrahedral structures in the construction of kites. The triangle-based modules resonate in Richard Buckminster Fuller's (1895-1983) universe of geometry. The latter exemplifies a complex nexus between spatial visualization, mathematical calculation and linguistic explication, each being incomplete without the others.[6] Architect and theoretician Fuller's spherical systems of entities manifest a process of constant transformability. Embracing the *whole,* Fuller's macroscopic 'zooming out' enabled an integral worldview of the totality. His concept of *Synergetics* fosters knowledge of the unique behavioral aspects of complete networks. Although Fuller's approach leaves room for further queries about his universalist mindset, challenging the significance of individual conditions, he spanned "the chasm between the humanities and sciences."[7] Fuller's *comprehensive anticipatory design science* also integrated non-scientific aspects of metaphysical and physical experiences.[8] The method of inclusion resonates in recent interdisciplinary collaborations that chart the redesign of future habitats.

Biornametics, an arts-based research venture in Vienna, merges biomimetics and nanotechnologies with design principles in order to transport models from nature onto the built environment.[9] The selective range of evaluative criteria, which inter alia also integrates intuitive aspects on perception, infuses the outcome with parameters beyond the pure sciences.[10] Following innovative aspects in life sciences, the assimilation of nature and the constructed habitat aims to offer ground for the re-assessment of aesthetics in design approaches that overcomes simple formal analogies with natural patterns. In contrast to *Biornametics'* zooming into behavioral aspects of nature, the *SENSEable City Lab* maps the ample pattern of human interaction in the urban space. In the quest for comfort and sustainability the project conducted at the MIT implements the collaboration with more than sixty disciplines.[11] Based on a continual crowd-feedback exchange, sensors and an extensive data collection provide real-time information about human activities, encompassing the reception through the public, science and critics.[12] The active data acquisition and evaluation promises an evolutionary design approach. Similar to *Biornametics,* these concepts expand visual convergences between the arts and the sciences into a dynamic cycle of communication and creation. Both encompass the world of growth and change into a complex system of networking. The latter is embodied in visual and linguistic tracking, in the examination of relationships and in the congruent modus operandi in interdisciplinary teamwork that challenges the development of a common 'language'.

Encountering single specialisations requires a digging through "the mine field of disciplinary disagreements."[13] Each discipline inherits a set of ideologies, standards and a specialised body of scientific 'tools.'[14] The dialogue is further complicated as closing down discourses remains the major approach in scientific practice and policy.[15] The navigation on a single 'track' creates a strong foundation of theory that mirrors accuracy and control. It leads to a small array of perspectives that form "'unitary and prescriptive' policy advice."[16] Subliminal processes prevail, however inaccessible. To sketch it beyond "fetishism" in scientific mapping practices as argued by Donna Haraway, these methods transform process into "non-tropic, real, literal things inside containers." They fix "naturally bounded bodies" (land, people, resources – and genes) inside 'absolute' dimensions like space and time."[17] "Opening-up" approaches on the other hand, induce a deliberation that "centers on sustaining and comparing a diversity of evaluative frameworks rather than on forging common ownership of a single framework."[18] In the optimum case, the latter initiate a wide spectrum of ambiguous outputs. Going beyond 'finality' as a conclusive act that inflects the closure of thought by deconstructing the processual nature, I would broaden the stimulus of interdisciplinary teamwork from how to fuse equivocations and divergences into a single "consistent model" into a question on how to communicate process.[19]

The built environment animates discursive approaches in the manifestation of process. As artist, scientist and futurist John McHale (1922-1978) once noted, "Shelter, even at the lowest level, has psychological and social dimensions – as setting for interpersonal relations, as ritual place, as social locus."[20] Interpreted as an organism, evolution in architecture exceeds mere form-generating scripts, but embraces a constant dynamic and mobility of thought and practice.[21] The transformation from the imaginary, scientific and digital into the physical encounters spatial and physical 'fixed' boundaries that challenge the adaptability of architecture.[22] Although desired prospects are yet to be determined, integral art-science collaborations can serve as a well for a comprehensive semiotics.[23] The latter challenges the conventional development of a mutual narrative in cross-relational perspectives, as it encompasses a visual, spatial and linguistic vocabulary.[24] Moreover, such ventures induce perception and understanding as an integral, behavioural part of the scientist's apparatus. Beyond Haraway's consideration that "heterogeneous rationality" can be mistaken as a "fixed, seemingly objective thing," I would further emphasize the fundamental need for visualised transparency in processes.[25] Art-science cooperation discloses a democratic influx of complexities that harbours the fundamental potential of abnormalities and aberrations. Appreciated as an act of "troping" these "cartographies of struggle" would dissolve the conventional picture of pluralities from an intangible abstraction into an act of communication.[26]

NOTES

1 On the "slippery" concept of paradigm as in Thomas Kuhn's structure of scientific revolutions and the discrepancies between paradigm in science and art, see Root-Bernstein, R. S.: On Paradigms and Revolutions in Science and Art: The Challenge of Interpretation, Art Journal 44, n°2, summer, 1984, pp. 109-118.

2 Smithson, R.: Towards the Development of an Air Terminal Site, in Flam, J. (ed.); Smithson, R.: The collected Writings, University of California, Berkeley, Los Angeles, and London, 1996 repr. 1967 ed., pp. 52-60, p. 52; Smithson's considerations result from his work as an art consultant to engineers and architects Tippetts-Abbett-Mccarthy-Stratton's Fort Worth regional airport in Dallas in 1966/67 for which he developed a project to be seen from the air. See also, Roth M.: An Interview with Robert Smithson (1973), in Tsai E. and Butler C. (eds.): Robert Smithson, Berkeley, Los Angeles and London: University of California Press, 2004, pp. 81-95, p. 91.

3 Smithson, R.: A Museum of Language in the Vicinity of Art, in Flam J., Smithson R., repr. 1968 ed., pp. 78-94, p. 94.

4 Smithson, R.: Development of an Air Terminal Site, in Flam J., Smithson R., repr. 1967 ed., pp. 52–60, p. 55; regarding the interrelation between language and architectural bodies in Smithson's oeuvre, see Sieburth R.: A Heap of Language. Smithson R., and American Hieroglyphics, Tsai E. and Butler C. (eds.): Robert Smithson, Berkeley, Los Angeles and London: University of California Press, 2004, pp. 218-223.

5 Smithson pursued the development of networks and their deployment in a "set of limits." Robert Smithson in: Earth, symposium at the Andrew Dickson White Museum of Art, Cornell University, Feb. 1969, in Flam J. (ed.); Robert Smithson, pp. 177-187, p. 181; citing philosopher Paul Valéry in his introduction, Smithson's text ranks in the holistic metaphor of the whole that is raised by Jennifer Roberts' reflection on Smithson's reference to hyperspace philosophy and the fourth dimension in works by Charles Howard Hinton and Pyotr D. Ouspensky, see Roberts J. L.: Mirror-Travels: Robert Smithson and History, Yale University Press, New Haven and London, 2004, p. 54.

6 On the fundamental relationship between three-dimensional models and written explanation, see Krausse J.: Thinking and Building. The Formation of R. Buckminster Fuller's Key Concepts in 'Lightful Houses', in Chu, H.-Y. and Trujillo, R.G. (eds.): New Views on R. Buckminster Fuller, Stanford University Press, Stanford, 2009, pp. 53-75, p. 57.

7 Fuller R.B., Cooper Hewitt exhibit Brochure, 1976 http://www.bfi.org/aboutbucky/buckys-big-ideas/synergetics/tensegrity-1976 (accessed: January 31, 2012); on Fuller's view of the chasm between art and science as proclaimed in C.P. snow's influential two cultures, see Fuller R.B.: Prevailing Conditions in the Arts, (address delivered in 1964) in Snyder J., (ed.), Fuller R.B. (ed.): Utopia or Oblivion. The Prospects for Humanity, Lars Müller Publishers, Baden, repr. 2008, pp. 115-152. 1969.

8 see also Synergetics 200.06 http://www.rwgrayprojects.com/synergetics/s02/p0000.html (accessed: February 12, 2012).

9 Biornametics is conducted by architect Barbara Imhof (LIQUIFER Systems Group), in collaboration with Petra Gruber, transarch Vienna, the Institute for Microengineering and Nanoelectronics, University Kebangsaan Malaysia, the Centre for Biomimetics Reading, UK, The Architectural Association London, UK and the University of Applied Arts Vienna, for further reference see this compendium.

10 Biornametics lists e.g. "elegance" and "cool" as an aesthetical phenomenon and criterion for evaluation. see Imhof, B. et al.: Biornametics. Architecture Defined by natural Patterns, Final report, May 11, 2011, p. 67.

11 SENSEable City Laboratory is a transdisciplinary project conducted by architect Carlo Ratti at the Massachusetts Institute of Technology (MIT), Cambridge. see also http://senseable.mit.edu/ (accessed: January 28, 2012). I am grateful to Carlo Ratti for his insight into his approach to transdisciplinarity, see email from Carlo Ratti, February 18, 2012; regarding the quest for comfort, see McLaren, C.: The SENSEable City: an interview with Carlo Ratti, BMW Guggenheim Lab, December 5, 2011 http://blog.bmwguggenheimlab.org/ 2011/12/the-senseable-city-an-interviewwith-carlo-ratti/ (accessed: February 10, 2012).

12 The resemblances with an audience-feedback architecture in futurist concepts and designs of the late 1960s that implemented computing into their interactive constructional visions exceeds the scope of this paper.

13 Fuchsman, K.: Disciplinary Realities and Interdisciplinary Prospects, metanexus.net, September 1, 2011, http://www.metanexus.net/essay/disciplinary-realities-and-interdisciplinaryprospects (accessed: February 12, 2012).

14 Fuchsman's argumentation broadens the common "bias, prejudice, or conviction" related significance of ideology with a 'fundamentalist' like behavior that prevents the beholder from the recognition of his limits and legitimacy. I would enhance the debate with the question of 'belonging' as discussed in cultural studies. The belonging to 'communities' of disciplines warrants further inquiry. ibid.

15 I refer here to Stirling's chart of instances of progress in science and technology beyond the terms "commitment" and "appraisal," in Stirling, A.: "Opening Up" and "Closing Down", Power, Participation, and Pluralism in the Social Appraisal of Technology. Science, Technology & Human Values 33, n° 2,16 March, 2008, pp. 262-294, p. 285.

16 ibid, p. 279.

17 Haraway D.: Deanimations: Maps and Portraits of Life Itself, in Jones C. A. and Galison P., (eds.): Picturing Science Producing Art, Routledge, London and New York, 1998, pp. 181-207, p. 184.
Algorithms as applied in current social media serve as recent interpretations of such containers. At the TED conference in February 2011, Eli Pariser demonstrated that these filter bubbles act as gatekeepers, permitting and denying the transmission of information according to viewer's profile and his preferences. Access to the entirety of information is forbidden.
http://www.ted.com/talks/eli_pariser_beware_online_filter_bubbles.html (accessed: February 8, 2012).

18 Stirling, "Opening Up" and "Closing Down", p. 282.

19 Schwaninger M., Ulli-Beer, S. and Kaufmann-Hayoz R.: Policy Analysis and Design in Local Public Management: A System Dynamics Approach, Gertrude Hirsch Hadorn, ed., Handbook of Transdisciplinary Research, Springer, Netherlands, 2008, pp. 205-221, p. 217.

20 McHale J. and Cordell McHale M.: Meeting Basic Human Needs, Annals of the American Academy of Political and Social Science, p. 442, The Human Dimension of Foreign Policy: An American Perspective, 16, March, 1979, pp.13-27, p.15.

21 See also Evolutionary Architecture in Gruber, P.: Biomimetics in Architecture, Architecture of Life and Buildings, Springer, Vienna and New York, 2011, pp. 187-188.

22 These aspects, however, are also in a constant reciprocal relationship with respect to their development and application, see e.g. materials.

23 Projects like SENSEable city Lab's the cloud encompass interdisciplinary collaboration in a broad team including artists and writers like Tomás Saraceno and Umberto Eco. Initially envisioned for the Olympics in London in 2012, the tower's fate is yet unknown. The concept animates the discussion on how to transform the digital into the real. The teamwork further challenges the meaning of 'individuality' in collaborative processes, which embraces the question of 'signature' in artistic work or to put it differently, the clearly distinguishable product. As Carlo Ratti however observed, "The promethean idea of the artist as genius is not actual anymore." Email from Carlo Ratti, February 18, 2012; on the cloud see http://www.raisethecloud.org/#home (accessed: January 29th, 2012).

24 James Elkins emphasized the intangible 'status' of visualizations that were adopted as representational form of scientific thought and analysis, leaving art history (and as I would add the art market) struggling for a definition of *the* image, almost twenty years ago. Elkins, J.: Art History and Images That Are Not Art, The Art Bulletin 77, n°4, December, 1995, , pp. 553-571.

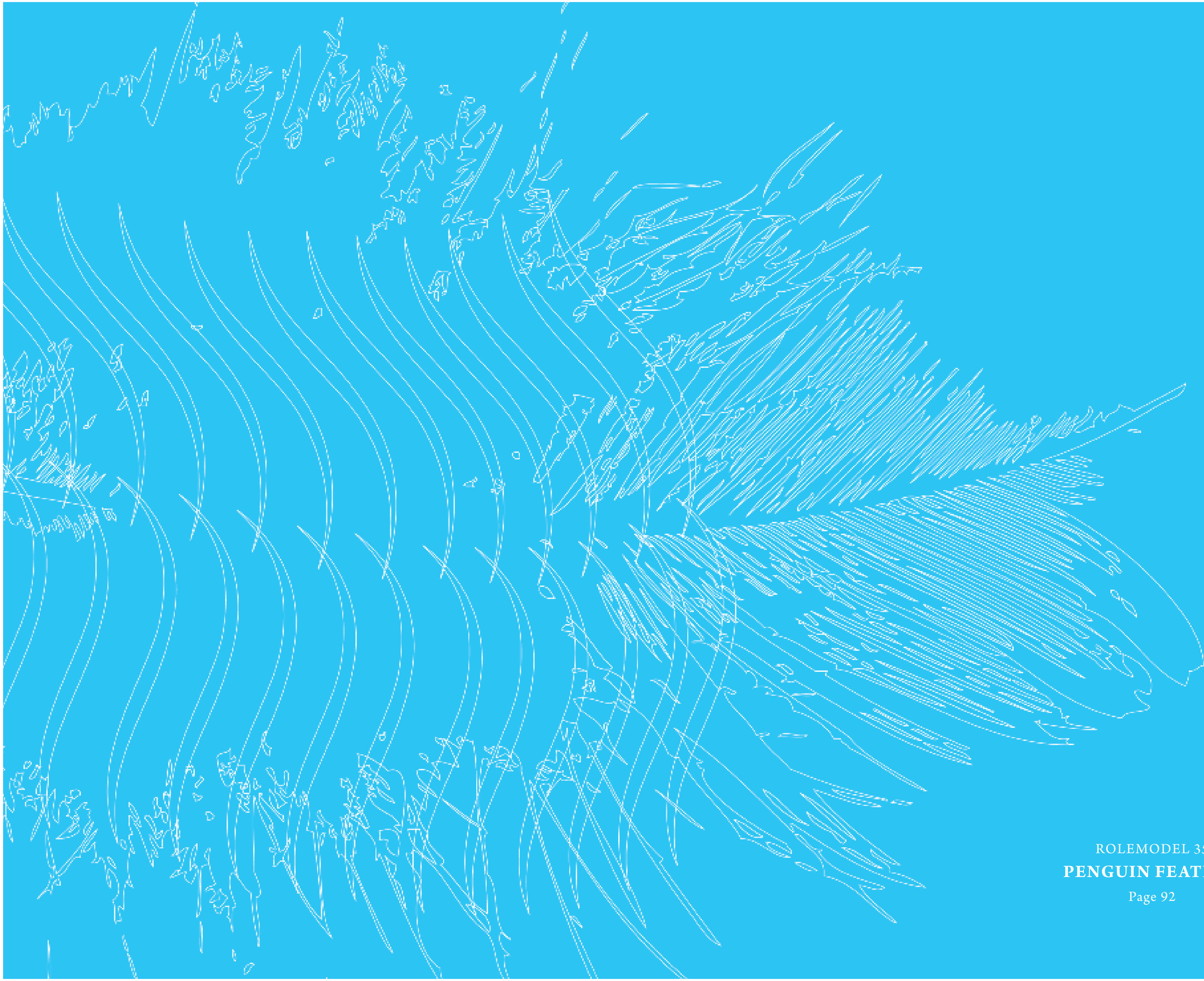
25 Haraway D.: Deanimations: Maps and Portraits of Life Itself, p. 186.

26 ibid., p. 184. Haraway identifies "tropes" as "the nonliteral quality of being and of language." In this context I draw attention to Philip Galanter, who coined the term of "complexism." The latter 'loops' between modern and postmodern positions on the absolute and the relative, reconciling "determination" with "unpredictability." Philip Galanter, "complexism and the role of evolutionary art" in: Romero J. and Machado P. (eds.): The Art of Artificial Evolution. A Handbook on Evolutionary Art and Music, Springer, Berlin, Heidelberg and New York, 2008, pp. 311–332.

ROLEMODELS

37 role models from nature provided the foundation of the Biornametics research. They are an important element of the "scientific input" and are categorized into three main themes that are considered relevant issues in biomimetics and architecture: shape change and growth, nano-surfaces, adaptation and reorganisation.

The role model information was processed into datasheets and working tools such as cards in order to perform the second phase: the pattern research.



ROLEMODEL 35

PENGUIN FEATHER

Page 92

01 COLEOPTERA, Jewel Beetle

TOPIC
1 – nano surfaces
and physical colour

KEYWORDS / FEATURES
structural colour, iridescence

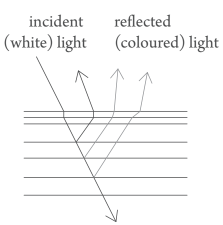
APPLICATION IDEAS
adaptable camouflage;
reflector systems
(solar, traffic, signalling, …),
display systems (by adaptable
nano structure surface);
use aestetic colour effects
(facade, fashion); resize nano
structure;

02 SARRACENIA FLAVA, Pitcher Plant

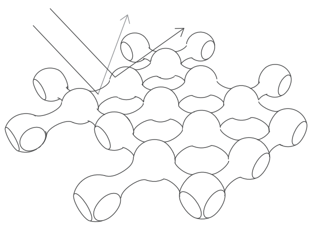
TOPIC
1 – nano surfaces
and physical colour

KEYWORDS / FEATURES
growth shape, folding
mechanism, surface

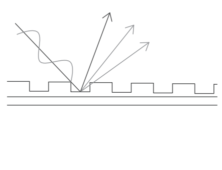
APPLICATION IDEAS
grow complex topological
surface shapes; self
cleaning cups; direct
application and
reproduction as isect trap;
transportation systems
(ultra sliding surfaces,
low friction)



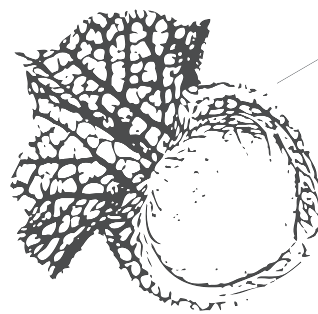
Multi layer reflector



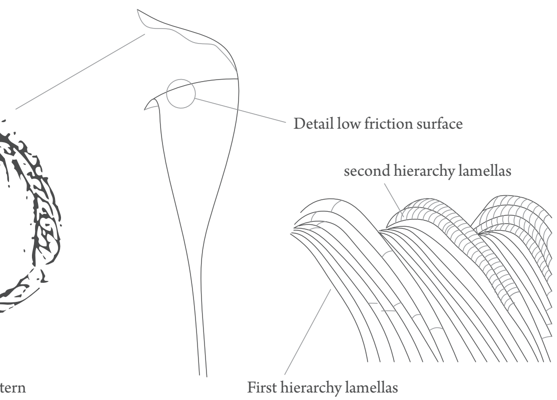
Three-dimensional photonic crystal



Diffraction gratings



Insect attraction pattern



03
MORPHO PELEIDES,
Blue Morpho Butterfly

TOPIC
1 – nano surfaces and physical colour;
2 – shape and growth

KEYWORDS / FEATURES
morphogenesis, iridescence, structural colour

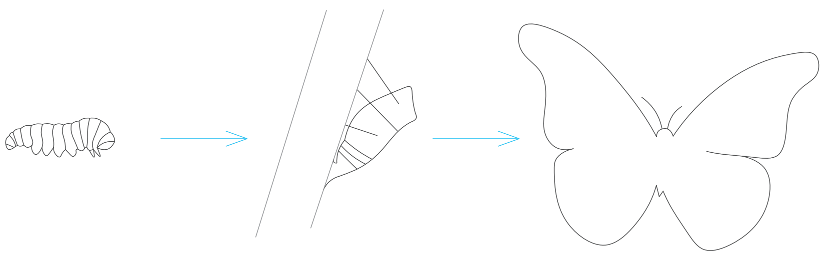
APPLICATION IDEAS
Textiles, interior walls, facades; rescale of nanostructure for other purposes (p.e. acoustics, ...); colour coding for orientation; theatre stage effects; Morphotex®

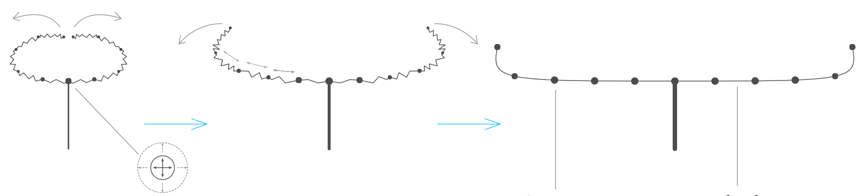
04
VICTORIA AMAZONICA,
Giant Water Lily

TOPIC
1 – nano surfaces and physical colour;
2 – shape and growth

KEYWORDS / FEATURES
lotus surface, deployment, growth, floating structure

APPLICATION IDEAS
Light-weight structurally strong panels for buildings or vehicles. Enhancing efficiency of photovoltaic arrays, floating photovoltaic arrays. Expanding surface for swimming systems, Life rescue boats.



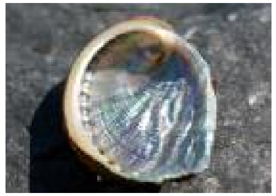


05
HALIOTIS,
Red Abalone Shell

TOPIC
1 – nano surfaces and physical colour;
2 – shape and growth

KEYWORDS / FEATURES
lotus surface, deployment, growth, floating structure

APPLICATION IDEAS
basis for composite material as coating; reinforcement of existing structures;
complete facade coating;

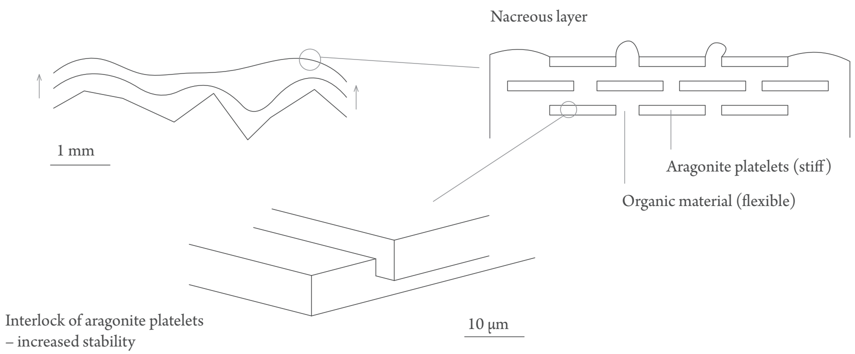


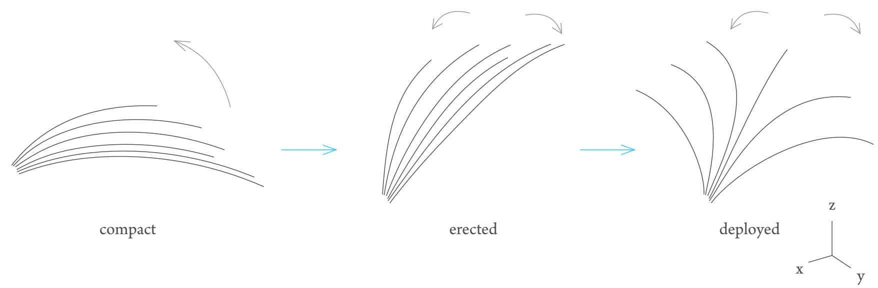
06
PAVO CRISTATUS,
Peacock

TOPIC
1 – nano surfaces and physical colour;
2 – shape and growth

KEYWORDS / FEATURES
fast deployment, iridescence, structural colour

APPLICATION IDEAS
adaptable shading systems in buildings;
temporary structures (roofs, walls);
structural colour for aestetic and branding use;
air fans;





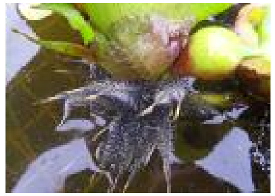
07 ASTERACEAE, Thistle KEYWORDS / FEATURES morphology, shapes, development stages; was discarded before the first round of evaluation due to not enough specific and interesting features and patterns.

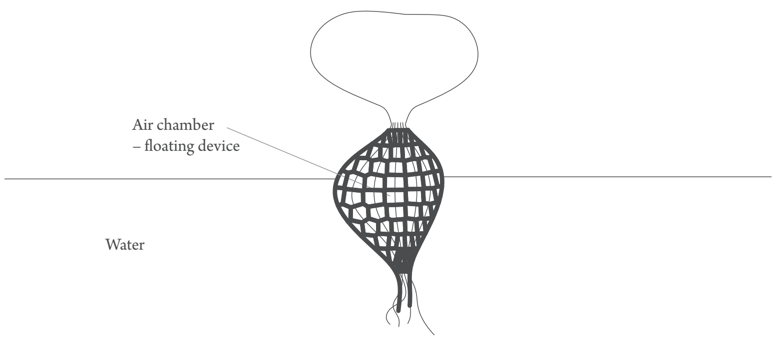
08 EICHHORNIA CRASSIPES, Water Hyacinth

TOPIC
2 – shape and growth

KEYWORDS / FEATURES
geometry, function, lotus surface, floating structure

APPLICATION IDEAS
geometric development for floating buildings (flood areas, …), sealing; floating water proof materials (sector: boat, building); ships, ferries; under water housing; water purification; energy harvesting on water surfaces (swimming solar panels, etc.)



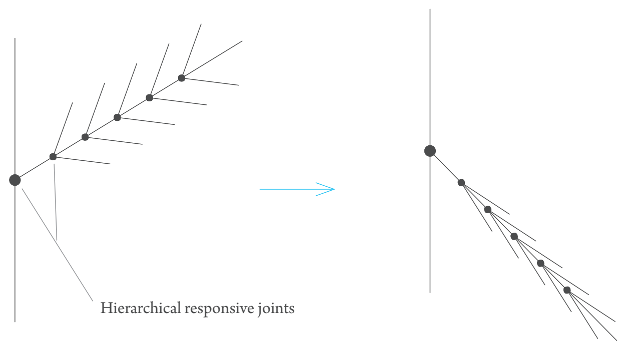


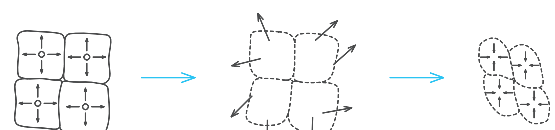
09 MIMOSA PUDICA, Mimosa

TOPIC
2 – shape and growth

KEYWORDS / FEATURES
deployment, motion

APPLICATION IDEAS
deployable systems; motion triggered systems; wardrobes & door mechanisms; pavillion skin;



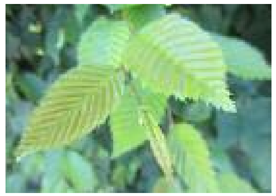


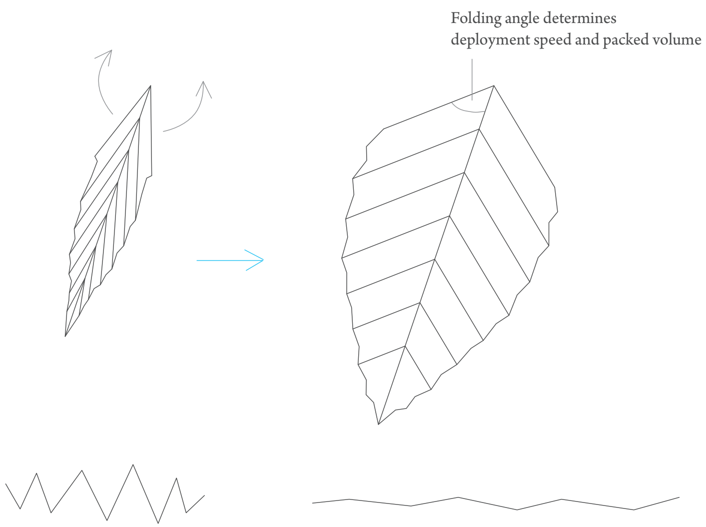
10
BETULACEAE,
Hornbeam

TOPIC
2 – shape and growth

KEYWORDS / FEATURES
deployable, folding

APPLICATION IDEAS
foldable structures for extreme environments (closed, semi-closed); variably sized support structures; growth under external forces;



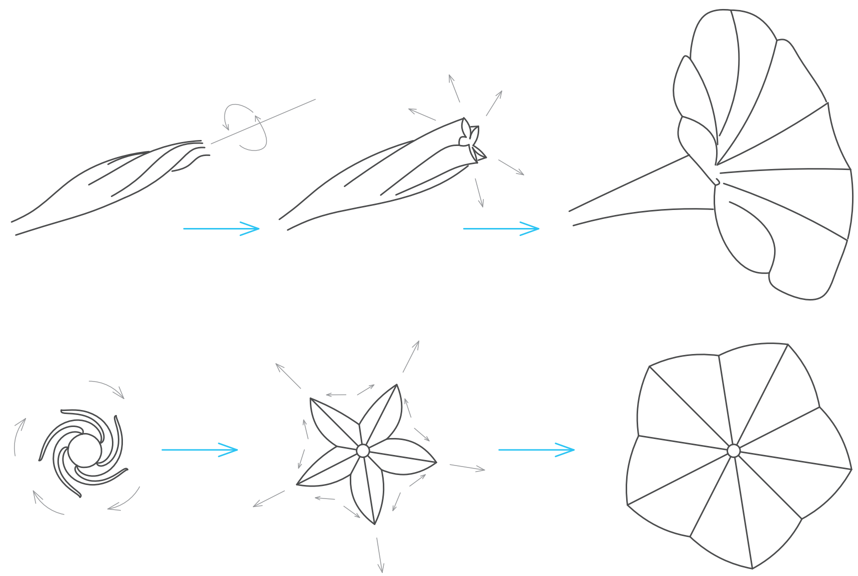


11
IPOMOEA ALBA,
Morning Glory

TOPIC
2 – shape and growth

KEYWORDS / FEATURES
deployable, folding, climbing tree

APPLICATION IDEAS
solar arrays for space (folding); solar shades (umbrella, combine many to a pattern); signalling systems; temperature regulation element



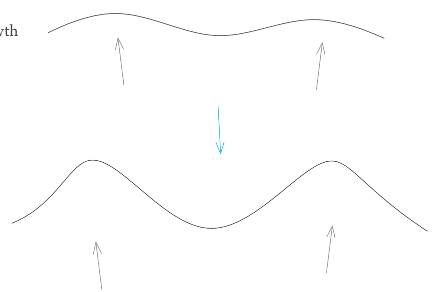
12
TRIDACNA GIGAS,
Giant clam

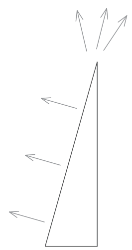
TOPIC
2 – shape and growth

KEYWORDS / FEATURES
rim growth, edge growth,
self healing, nacre

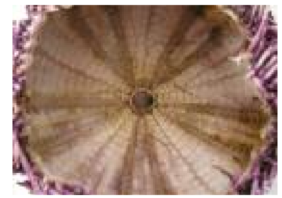
APPLICATION IDEAS
Pollution control, remediation; conservation. Buildings, greenhouses, coatings. Blade for wood-cutting; landscape/park design (change of form/area through growth); complex geometries by layering instead of sectioning or tessellation; linear growth model, use curvature for stability; self-repairing structures

rim growth





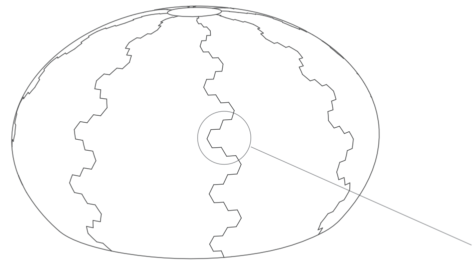
13
ECHINOIDEA,
Sea Urchin

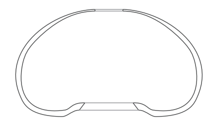


TOPIC
2 – shape and growth

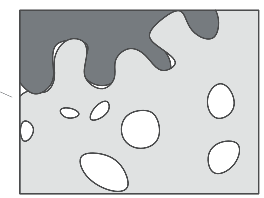
KEYWORDS / FEATURES
shape, growth,
variable stiffness

APPLICATION IDEAS
monocoque structures, able to grow and expand; stable forms & structures





Section monocoque structure



Toothed hinges between plates

14
ARABIDOPSIS EPIDERMIS

TOPIC
2 – shape and growth

KEYWORDS / FEATURES
communication,
information transfer

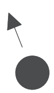
APPLICATION IDEAS
component based
systems; interaction of social
groups; social models
(e.g. workability)

15
DIODONTIDAE, Puffer Fish

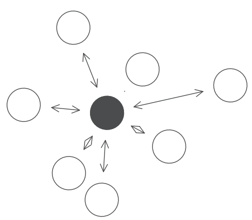
TOPIC
2 – shape and growth

KEYWORDS / FEATURES
extensivity, soft to rigid,
fast deployment

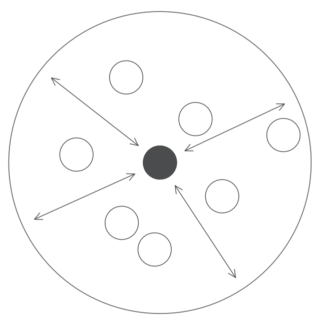
APPLICATION IDEAS
Temporary structures, adaptable
units, any fabric structure with ability
to expand (compact for mobility,
expanded for use); devices triggered
by motion or touch; packaging;
security doors; self protection
(soft/rigid – > dangerous)



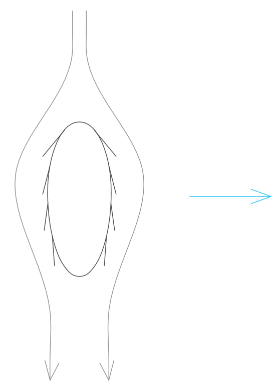
Cells programme



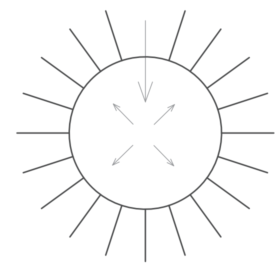
Neighbours interaction



Environmental influence



Hydrodynamic shape



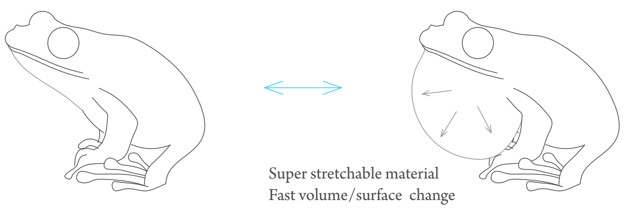
Defense mode

16
HYLIDAE, Frog

TOPIC
2 – shape and growth

KEYWORDS / FEATURES
extensivity, fast deployment

APPLICATION IDEAS
Temporary structures, adaptable units; any fabric structure with ability to expand; sound technology (resonance); room volume adaptation; waste water storage; fast change of air ratio (surface expansion); material technology

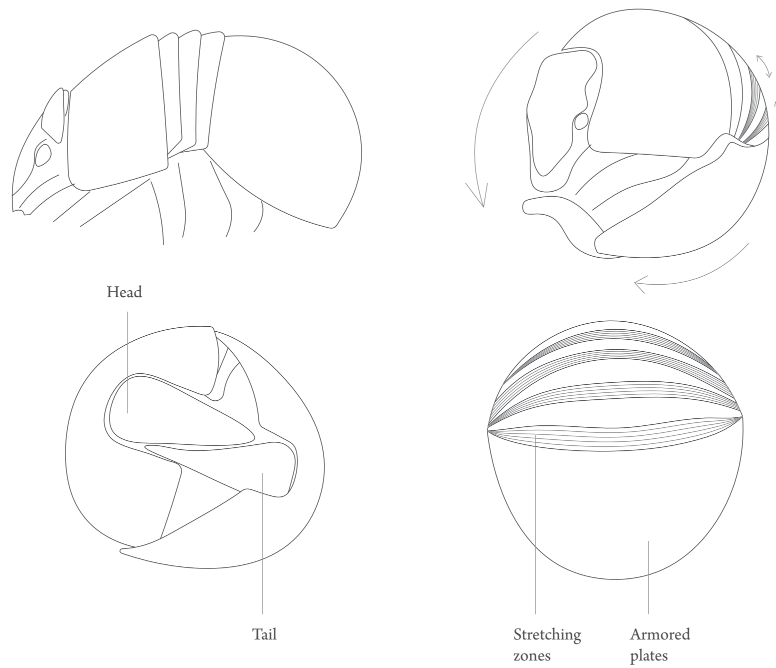


17
DASYPODIDAE, Armadillo

TOPIC
2 – shape and growth; 3 – adaptation and reorganisation

KEYWORDS / FEATURES
deployment, shape change

APPLICATION IDEAS
foldable structures, temporary and/or flexible stands or units; handbag; portable environments; robotic exploration rover; structural differentiation (soft/flexible)



18
FICUS BENGHALENSIS,
Banyan tree

TOPIC
2 – shape and growth;
3 – adaptation and reorganisation

KEYWORDS / FEATURES
roots, desalination, structure

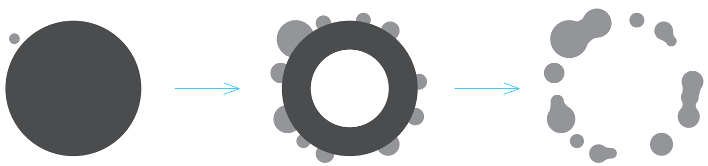
APPLICATION IDEAS
renovation of old buildings; parasitic structures; interweaving of two systems; generative structures; circulation system around centre core; added layering in architecture

19
VINEA, Vine

TOPIC
2 – shape and growth;
3 – adaptation and reorganisation

KEYWORDS / FEATURES
vine, tendrils, leaf patterns

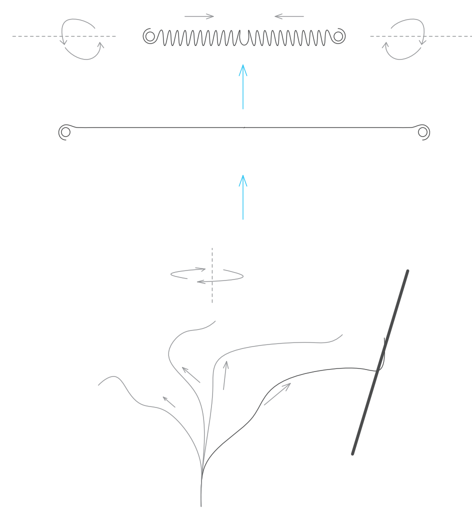
APPLICATION IDEAS
reactive structural systems; new structure within old structure (e.g. new circulation within old grown asian/arabic city centres; add-ons); exploring system (unfolds when it senses environment okay); standalone fixing systems



Parasite utilises hosts structure

Own structure is developed
by the parasite while host dies

Effective hollow bearing structure
has substituted for hosts trunk



Connection is tensioned by contrarotating windi

Tendril reduces length to shortest connection

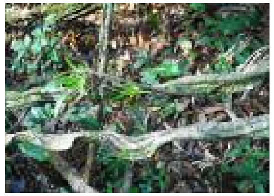
Space exploration
tendril rotates searching for contact
search radius increases with growth of tendril

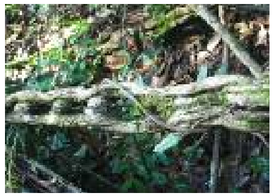
20
ENTADA GIGAS,
Monkey ladder

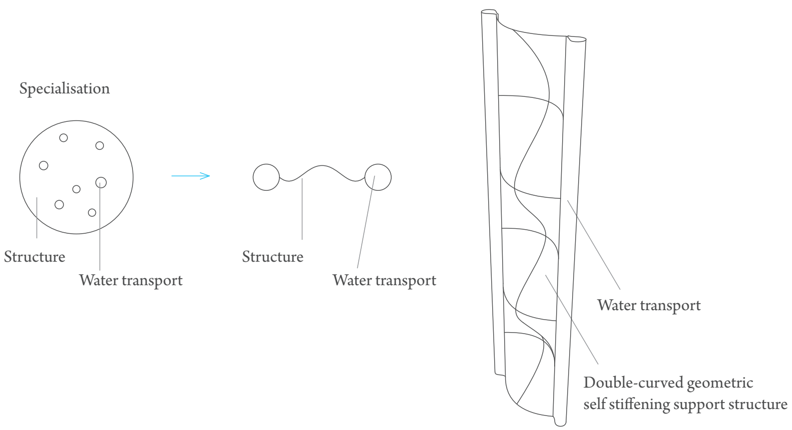
TOPIC
2 – shape and growth;
3 – adaptation and reorganisation

KEYWORDS / FEATURES
vine, roots, desalination, structure

APPLICATION IDEAS
structural properties, long span structures, diversity of mechanical architecture; extra long woven textiles;





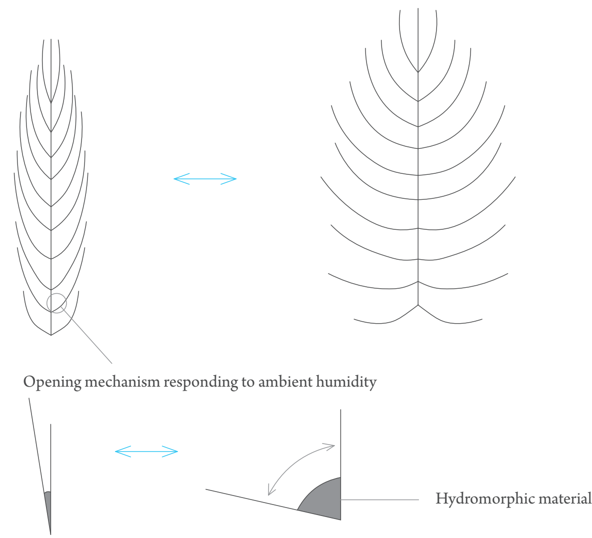


21
PINACEAE,
Pine Cone

TOPIC
2 – shape and growth;
3 – adaptation and reorganisation

KEYWORDS / FEATURES
passive mechanism, fibre structure, deployment

APPLICATION IDEAS
intelligent clothing reacting to moisture; thermal und humidity control in building systems; responsive rain protection (low-tech, hydromorphic polymer); passive actuation fibre structures

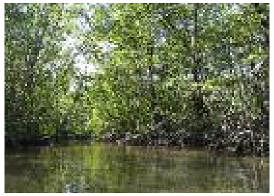


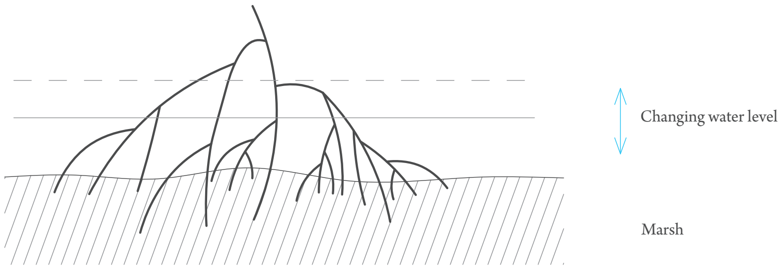
22
RHIZOPHORACEAE, Mangroves

TOPIC
2 – shape and growth;
3 – adaptation and reorganisation

KEYWORDS / FEATURES
roots, desalination, structure

APPLICATION IDEAS
constructions on soft or muddy soils; construction areas in danger of floods; building structures in marshland, adapting to changing water/ground conditions, cities in shallow water, future perspective for Netherlands and Bangladesh etc.



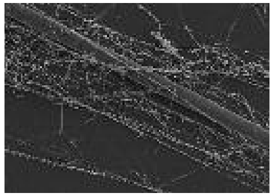


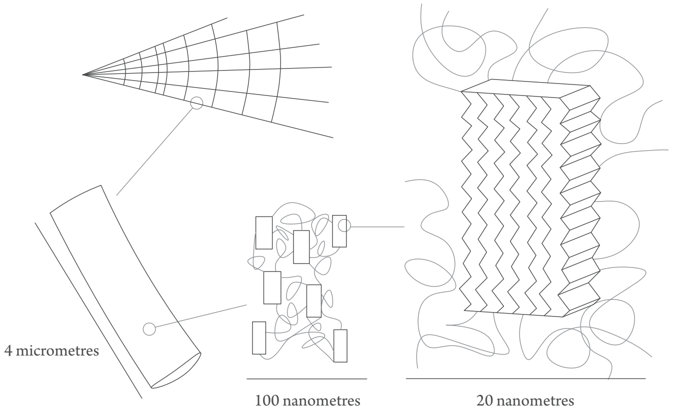
23
SPIDER SILK

TOPIC
2 – shape and growth;
3 – adaptation and reorganisation

KEYWORDS / FEATURES
length adaptation, pattern

APPLICATION IDEAS
tensile structures, fabrics under high tension, artificial muscles; living environments as 3-D matrix; extreme textiles/membranes; increase structure to macroscopic size; different construction paradigm: spider as "building robot"



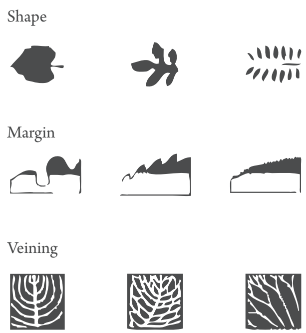


24
LEAF SHAPES

TOPIC
2 – shape and growth;
3 – adaptation and reorganisation

KEYWORDS / FEATURES
thermal adaptation, mechanical adaptation, leaf growth, folding, deployment

APPLICATION IDEAS
shape/function relationship;
energy input or dissipation;
deployability, packaging robot

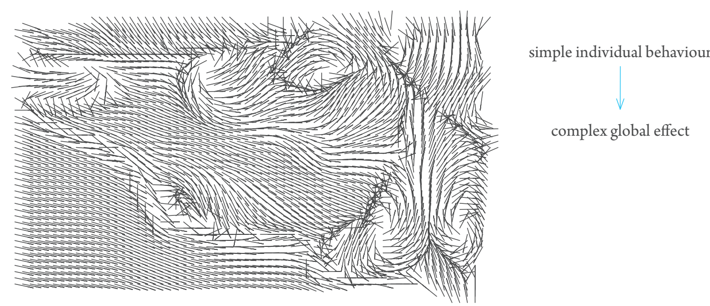


25
SWARM BEHAVIOUR

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
communication, adaptive structure control, swarm behaviour

APPLICATION IDEAS
urban planning; organisation of circulation of people;
collective communication; building agents to coordinate and build complex structures

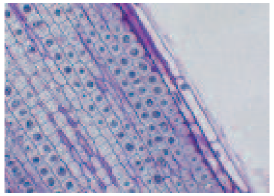


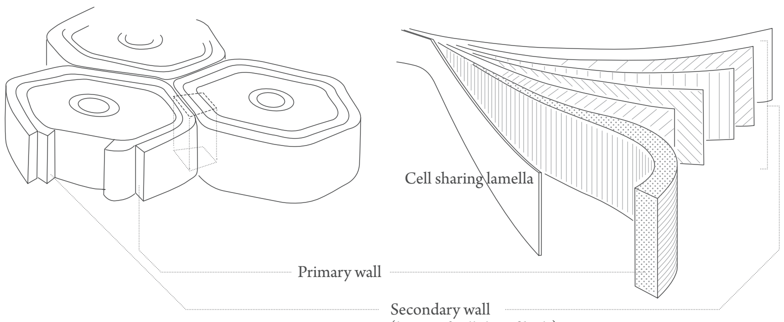
26
CELL WALLS

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
fibre structure, growth,
structural change

APPLICATION IDEAS
facade, roof; self organising
and repairing systems;
generative real architecture
(provide parameters for unit's
method of growth); moving fibre
extruder



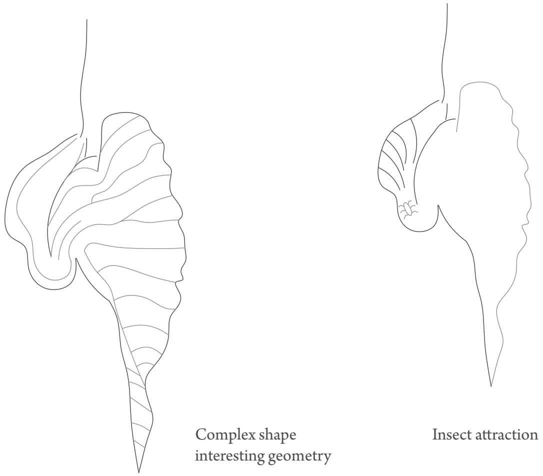


27
ARISTOLOCHIA,
Pelican Flower

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
vine, structural change, growth
of complex shape

APPLICATION IDEAS
topological adaptive development
of surface shapes as voids,
rooms, basins, … ; create attraction
(aesthetics); grow complex
shape; lightweight architecture;
self-sealing systems;
pneumatic structures, pipelines;
self-repairing clothing, medical
technology, etc

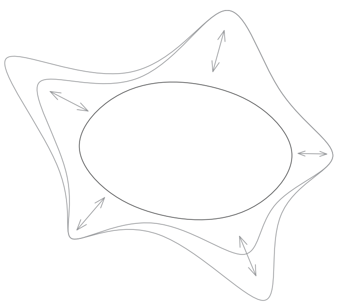


28
SUCCULENTS, Living Stones

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
volume/surface ratio change

APPLICATION IDEAS
storage for rainwater or grey water usage within limited space; form-change geometry; environment adaptive building geometry



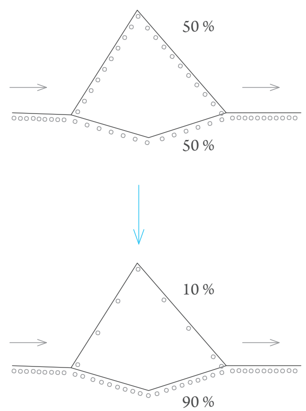
Adaptation of surface/volume ratio and shape as response to changing environment

29
FORMICIDAE, Ants

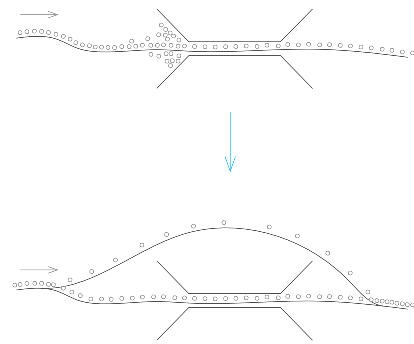
TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
communication, traffic organisation

APPLICATION IDEAS
traffic organisation; efficient building processes; phone software; evacuation systems with analysis of availability and capacity of possible routes (bottom up – digitalise ant system)



Prefer shortest way
keep second path as option



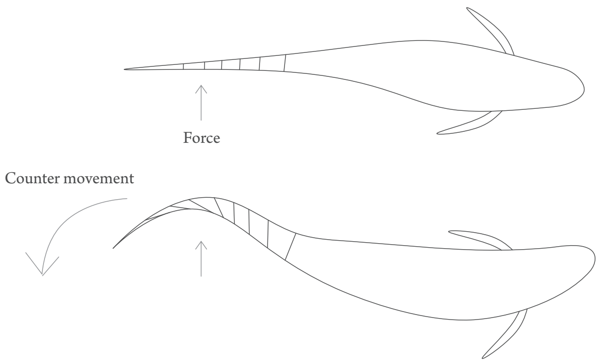
optimize path capacity utilisation

30
FISH FIN

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
structural adaptation

APPLICATION IDEAS
adaptive mechanical systems; directing air flow in a building, water flow; adaptive city structures for extreme environments (antarctica; wind breaks); wind guiding systems (adapting channel size to desired air flow); adopt principal for formfinding (landscape)

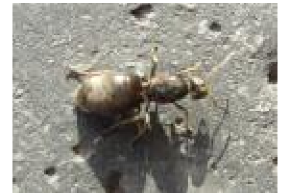


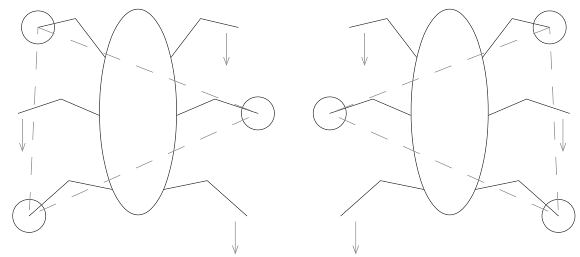
31
INSECT LOCOMOTION

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
fast muscles, stability, robustness, failure tolerance

APPLICATION IDEAS
Hexapod robotics; new means of transportation in uneven terrain; create surfaces to enhance or decrease friction for human feet (traps); failure tolerance (losing one of six legs)





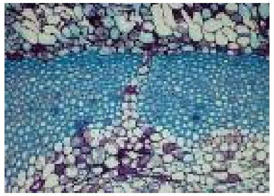
Tripod based locomotion
always stable
compensates rough terrain

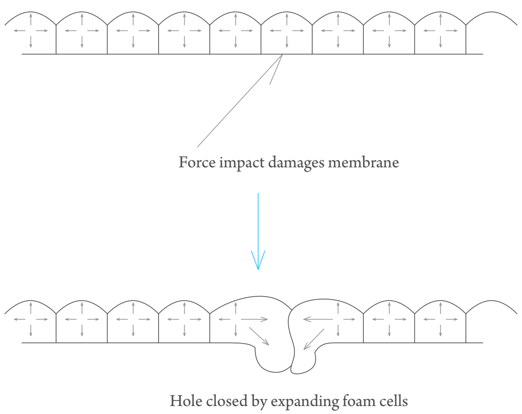
32
SELF HEALING

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
adaptation, growth, self healing

APPLICATION IDEAS
casting methods, concrete fibre composites; self healing membranes and polymers; clothing, building skin; pressure vessel skins; in combination with … ;



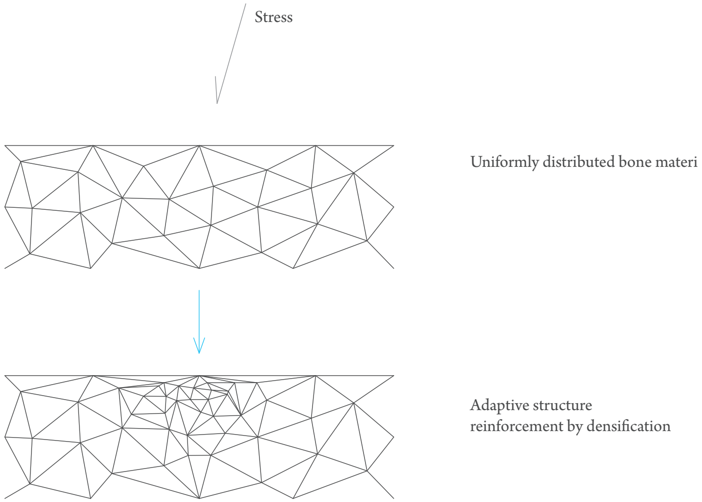


33
BONE

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
adaptive material, lightweight structural system

APPLICATION IDEAS
Light weight materials, optimised bearing structures; structure strengthening by pressure; environmental adaptation of structure



34
OCTOPUS

TOPIC
1 – nano surface, physical colour;
3 – adaptation and reorganisation

KEYWORDS / FEATURES
shape change mechanism,
colour change

APPLICATION IDEAS
fibre material adaptable to
extremes, camouflage colour
adaptation, …

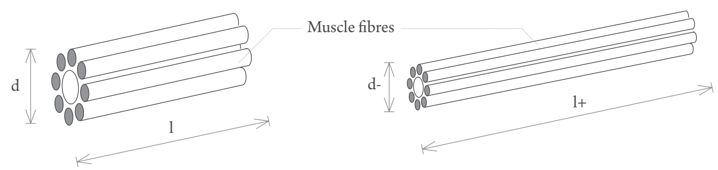
35
PENGUIN FEATHER

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
insulation, adaptive hierachy

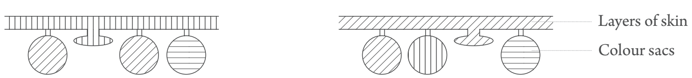
APPLICATION IDEAS
fibre material adaptive to
extremes, heat transfer and
insulation innovation, …

Squeezing muscle of Octopus

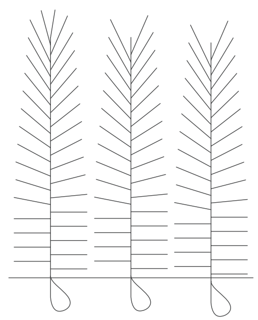


the octopus changes the length of the tentacles by squeezing its muscle fibres

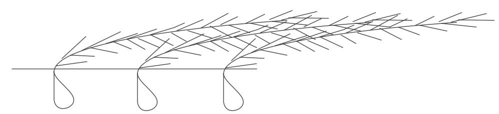
Colour change function of Octopus



the octopus has sacs of colour under its skin, which it uses to change its colours.



Insulation mode



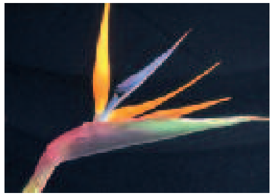
Aquadynamic swimming mode

36
STRELITZIA REGINAE, Strelitzia

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
shape change mechanism, passive actuation

APPLICATION IDEAS
passive actuation systems



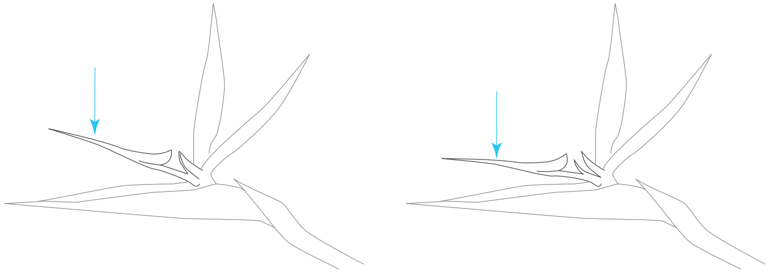
37
INSECT WINGS

TOPIC
3 – adaptation and reorganisation

KEYWORDS / FEATURES
deployable structure

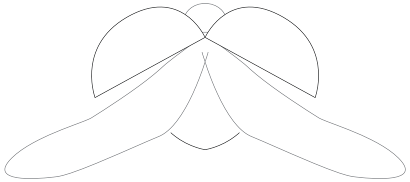
APPLICATION IDEAS
multiple mechanical functions, ...

Passive actuation of flower aperture



The bird as external force actuates the flower by its weight to open the flower bud to pollinate.

Hardshell and soft wings unfolding



PROJECT TEAM

LEAD

BARBARA IMHOF
Barbara Imhof – editor, project lead, architect, LIQUIFER Systems Group, Vienna, Austria
Barbara Imhof has a background in architecture, having studied at the Vienna University of Technology VUT, Bartlett School UCL, London, and graduated from the Angewandte (Studio Wolf D. Prix). She additionally holds a Master of Science from the International Space University in Strasbourg, France and a PhD in space architecture from VUT. She taught at the VUT (assistant professor 8 years), the ETH Zürich and amongst others at the Chalmers University in Gothenburg. She combines artistic with scientific education. She has lived in various places in Europe and the U.S.A. where she is integrated into large networks. She founded LIQUIFER Systems Group, a platform of experts from different backgrounds (engineering, science, architecture, design) collaborating on R&D projects. She has led some of these research projects, e.g. "ISS-Sleep-Kit – Design for a sleeping bag for astronauts" and "RAMA – Rover for Advanced Mission Applications". Barbara Imhof also runs her own broadcast in the cultural section of Radio Orange 94.0.
Recently, she received the Polar Star Award from the Austrian Space Forum for outreach activities in 2011 and the FEM-Tech award for research and technology in 2012.

PETRA GRUBER
Petra Gruber – editor, co-project lead, architect, transarch, Vienna, Austria
Petra Gruber gained a PhD in Biomimetics in Architecture in 2008. She has extensive experience in carrying out biomimetic design projects, and has collaborated as a research fellow at the Centre for Biomimetics at the University of Reading, UK, in 2007. She has taught as a guest professor at the Vienna Academy of Fine Arts, and was Assistant Professor at the Department for Design and Building Construction at the Vienna University of Technology for eight years, where she set up the TU Bionik Center of Excellence. Currently, she works in her own company, transarch, on biomimetic and trans-disciplinary design projects, in collaboration with an international network of scientists. She teaches Biomimetics in Energy Systems at the University of Applied Sciences in Villach, Austria, at the Department for History of Architecture and Building Archaeology at the VUT and internationally in lectures and workshops.
She has published the book "Biomimetics in Architecture: Architecture of Life and Buildings" in 2011.

PARTNERS

GREG LYNN
Greg Lynn is founder of Greg Lynn Form, Los Angeles. He graduated from Miami University of Ohio with degrees in both architecture (Bachelor of Environmental Design) and philosophy (Bachelor of Philosophy) and later from Princeton University where he received a graduate degree in architecture (Master of Architecture). He received an Honorary Doctorate degree from the Academy of Fine Arts & Design in Bratislava. In 2008, he won the Golden Lion at the 11th International Venice Biennale of Architecture. Greg Lynn has been at the cutting edge of design in both architecture and design culture in general when it comes to the use of the computer. The buildings, projects, publications, teachings and writings associated with his office have been influential in the acceptance and use of advanced technology for design and fabrication. Greg Lynn has taught throughout the United States and Europe. He is currently University Professor at the University of Applied Arts in Vienna. In addition, he is the Davenport Visiting Professor at Yale University and a leading Research Professor at the University of California, Los Angeles.

GEORG GLAESER
Georg Glaeser is a Professor for geometry and mathematics at the University of Applied Arts Vienna with a long track of numerous of publications in his field. His most recent books are called: Wie aus der Zahl ein Zebra wird – ein mathematisches Fotoshooting (Oct. 2010) and A Mathematical Picture Book (together with Konrad Polthier, Berlin). Springer Berlin/Heidelberg (Sep. 2012).

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Joseph Hofmarcher has been studying architecture in the studio Greg Lynn at the University of Applied Arts, Vienna since 2007. His special skills also include model building, which he has been teaching in the Lynn studio. Before his academic studies he went through a comprehensive technical education, and practised in several architecture offices in Austria and Switzerland.

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Bika Rebek graduated in Architecture from the University of Applied Arts, Vienna in January 2011. During her studies she collaborated with and taught in the Industrial Design Studio and spent a guest semester in the Fashion Department. She is interested in learning from other disciplines and incorporating them into architectural design, thus stimulating a continually fresh approach. She believes that learning from Nature in particular is an extremely important and fruitful field that will lead to increased sustainability and efficiency, including new aesthetic agendas. She is currently based in New York.

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Lisa Sommerhuber studied at the University of Applied Arts, Vienna with Greg Lynn, Zaha Hadid and Kivi Sotamaa and graduated in 2011. In 2009 she also studied at the University of California Los Angeles. She has a passion for both managing design processes such as building intricate models using rapid prototyping techniques and also representing complex geometries with detailed and accurate drawings. She has worked for Greg Lynn Form in Los Angeles, Differnet Futures in Vienna, ACME Space in London and as Project Assistant for Peter A Vikar.

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Natasha Chayaamor studied design at the Victoria University in Wellington, New Zealand, and at the Polytechnic of Milan in Italy. She has international workshop experience and is interested in science, biology and music theory. Currently she is working on her PhD at the Second University of Naples, Italy. Her research is focused on Relationships between Architecture & Design, Methodology and Science: a Process Strategy from a Biomimetic approach towards Innovation and Sustainability in Architecture and Design.

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Her her writings and work at artEC/Oindustry challenge the role of art in collaborative processes between the arts and the industry.

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