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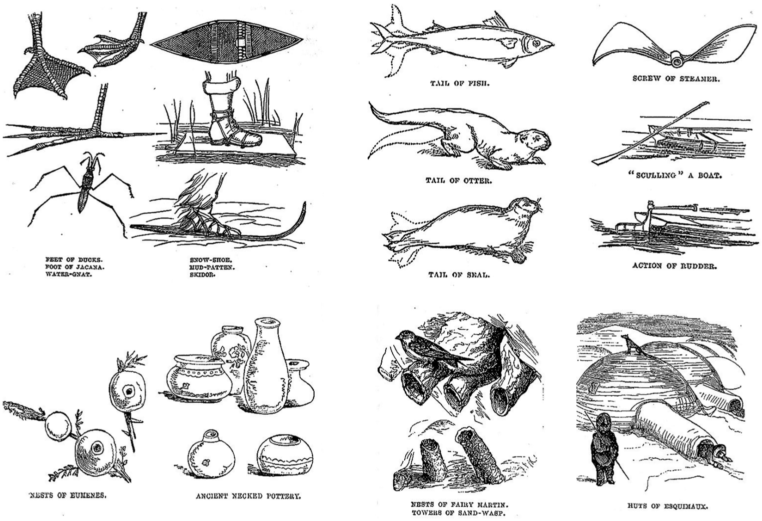

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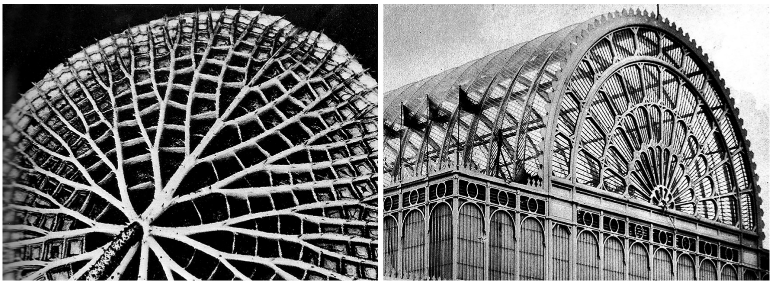

Figure 4. Comparative studies between natural and technical systems illustrated by Reverend Wood.
Figure 5. Lower structure of the water lily Vitoria Regia and gallery structure of the Crystal Palace (1851), by Joseph Paxton.

nology", and thus seek a solution to the same problem in biology and imitate it[35]. Lazlo Moholy-Nagy, artist and emblematic professor at Bauhaus, defended and disseminated R. Francé's ideas at the famous school, citing him even in his book The New Vision, referring to R. Francé as follows: is an intense study of the analogy between biology and technology, and draws on its research method and its biotechnical results"[36]. But L. Moholy-Nagy allowed an opening in the mimetic process in that, according to his view, the important thing was to follow the general principles of the methods of nature, that is, for him it was possible to conceive works "that functioned organically"[37].

Another important reference in this area is the article *On Correalism and Biotechnique* by the architect Friedrich Kiesler, published in the *Architectural Record* of 1939. According to the author, *Correalism* means the study of the relations between man and his natural and technological environment. F. Kiesler argues that "instruments and architecture are created to serve as mediators between man and the natural environment and therefore form a second and interposed, "technological environment"[38]. For this author, all utensils go through an evolution process with several states that correspond to "variations" from the "standard-type", as shown in the knife's evolution scheme *(See Figure 6)*.
But, unlike what happened with the previous authors, for F. Kiesler, biotechnology is not a simple copy of natural prototypes, but a method capable of polarizing natural forces in the direction of man's intentions. In this sense, he distinguishes between *biotechnique* and *biotechnology*, attributing the latter to Patrick Gueddes and defining it as "a method of building nature... and not man"[39]. Also, of anticipatory reference is, in the book Cities in Evolution by P. Gueddes, biologist and pioneer of urbanism, published in 1915, the introduction of the terms "biotechnology" and probably the term "biotechnical". In the same work, he also proposed the terms "paleotechnical" and "neotechnical", referring to the first rudimentary and disastrous phase of the Industrial Revolution and the second to an emerging industrial order that tended towards prosperity, beauty, and harmony with the natural environment[40].
Thus, studies in the field of biotechnology began to be formulated, which would be widely disseminated and developed in the post-war period, with the introduction of notions such as Technical Biology[41] and Bionics[42]. If, in the first, the objective is the study of formal and structural systems produced in biological systems, in the second, in addition to the analysis of natural systems, the respective synthesis is produced that allows the future application of knowledge in technical and technological systems produced by human beings. This is not a purely theoretical process, but a rigorous and scientific method of transforming organic structural and functional systems into technological systems, thus allowing their subsequent application in the project culture *(See Figure 7)*. The study and investigation of these biological and biochemical systems allows the construction of prototypes later used in the design of synthetic systems. Although naturally more developed, these post-war proposals are, however, nothing more than the "biotechnical" proposals presented, in the 1920s and 1930s, by P. Gueddes, R. Francé and F. Kiesler and which were defended as a methodology by L. Moholy-Nagy.
The proposal for the name Bionics is attributed to the major of the US Air Force, Jack E. Steele in 1958, and according to J. Steele, it means "systems science whose function is based on living systems, or which have characteristics of living systems, or that resemble them"[43], having been, however, later defined with more precision by David Offner as: "The study of living systems or assimilable by the living, tending to discover new principles, techniques and processes of application to technology. Bionics analyzes biological systems, their principles and fundamental characteristics from a qualitative point of view, to draw inspiration for the development of new orientations in the design of technical systems that have similar characteristics"[44]. Although Bionics was considered by J. Steele as a new science and was officially presented in May 1960 at the Annual Aeronautical Electronics Conference[45], that name is given by J. Steele with no knowledge that this new

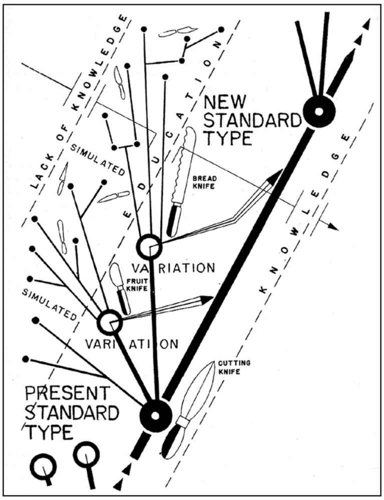

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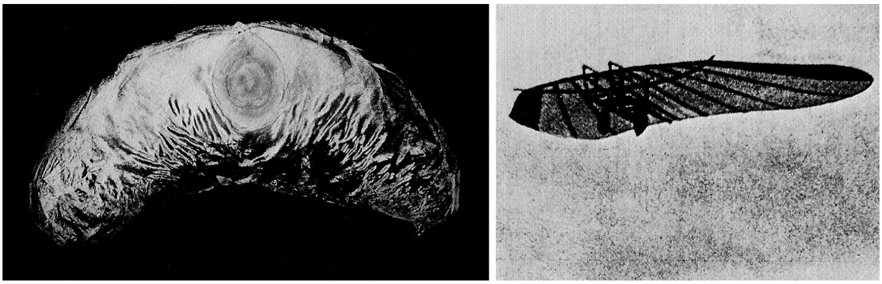
Figure 6. Diagram by F. J. Kiesler that shows the evolutionary process of the “standard type” of the knife (1939).
Figure 7. Glider seed of the Zanonia macrocarpa and Zanonia glider (1904) of the aviation pioneers Etrich and Wels.



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science already existed under the name of Biotechnics according to a proposal by P. Gueddes, from 1915, or by R. Francé, from 1920.
One of the best-known systems for the application of methodologies and processes of *biotechnological methodologies* in a widespread product is the fixation system invented in 1941 by the Swiss engineer Georges de Mestral[46], which is usually known by the name of Velcro. The name, according to its inventor, derives from the combination of the French words “velours”, which means velvet and “crochet” which means hook.
This fixation system is based on a process developed by some plants, of which Burdock seeds stand out, which, when coated with small tentacles with hooks at the end, allow their attachment to the animals’ fur, thus allowing their transport to other locations and, consequently, the spread of the plant. Sometimes these seeds, in their natural fixation process,

also adhere to clothing. This was what happened to G. de Mestral when, while walking in the mountains of the Swiss Alps, he observed that these seeds were fixed on his clothes and on his dog fur. Developed by G. de Mestral, the quick fixing system works by producing two nylon tapes, one of which is coated, on one side, by tiny hooks that in contact with the other tape, covered by tiny rings, allows anchoring the hooks in an extremely resistant way and with infinite possibilities of use *(See Figure 8)*. Patented in 1951 by its inventor, today, the Velcro brand has more than 300 registrations in about 160 countries.

One author who systematically defended the use of Bionics in design processes was Victor Papanek (1935-1998). Born in Austria, he graduated in architecture and industrial design in the USA, subsequently becoming interested in subjects such as Ethnology and Biology and, thus, creating the basis for the development of what would be called "Design for Needs"; representing a reaction to the consumer society, the author defended a design suited for real human needs. But previously, another author, Richard Buckminster Fuller, had made proposals in this regard, which culminated in his research project World Resources Inventory, developed at Southern Illinois University, which proposed a review of global resources distribution so that they could be used more efficiently[47]. Also, Richard Neutra, in 1954, published his book Survival through Design[48] that defends a worldwide strategy for non-commercial design[49]. But it would be V. Papanek with the publication of his book Design for the Real World[50], in 1971, who would assert himself as responsible for the great dissemination of the Design for Need notion, as well as the concept of Bionics. Indeed, this book has been translated into 23 languages, making it the most widely design work read in the world. With the subtitle "Human Ecology and Social Change", in this book V. Papanek's views on the ethical, social and environmental issues of design are approached in an unprecedented systematic way[51]. In that same work, the author also dedicates a chapter to Bionics, entitled "The Tree of Knowledge: Biological Prototypes in Design" in which it provides a simple definition of the term: "use of biological prototypes for the design of man-made systems"[52].

Other more contemporary proposals, mainly developed after the energy crises of 1971, 1973 and 1974, seek to create positive interfaces between technical systems and environmental systems. Among the main ones are Green Design[53] (Ecological Design), Ecodesign[54], Environmental Design[55] and Sustainable Product Design[56]. Alastair Fuad-Luke's book, The Eco-design Handbook is, in this sense, a very complete manual of products in which these concerns are thoroughly analyzed. Proposed methodologies in question are not necessarily based on Technical Biology, as they seek, fundamentally –with more or less efficiency, and through different processes and methodologies– to make products and product systems compatible considering, respectively, variables such as their production, distribution, use, destruction, recycling, reuse, that is, the factors that can be readjusted in order to reduce the environmental impact of everything that human beings produce. In this sense, these methodologies usually resort to processes such as: Life Cycle Analysis, Environmental Management, Eco-audits, or Energy Flow Management. Focusing mainly on the inside of the technical system, they will be able, through the use of Biotechnical Methodologies and Design, to have access to a new vision, external to the human technical system, which may bring unexpected and innovative information flows. It will certainly

Figure 8. Left: Suppository packaging based on the pea pod (1960s), by Victor Papanek. Right: Burdock, plant that served as inspiration for the development of Velcro, expansion of Velcro structure, Velcro system.

be part of contemporary *Biotechnical Methodologies* to use information provided by these environmental methodologies in its design process.
Biotechnical methodologies have been, in fact, an indispensable resource in the evolution of technological systems, acquiring an increasing importance in the current context of debate on environmental crises. In turn, the latter have led to the priority search for approximation solutions and greater compatibility between technological systems and biological systems. However, the potential of *biotechnological methodologies* –applied in project areas such as Design, Architecture or Engineering– has been, however, underused; although project knowledge is in a process of maturation in which Nature tends to be, increasingly, an example to follow in the 21st century.

1.2. Biomorphic Methodologies: Streamlining and Biodesign

Other methodologies that use natural systems as a reference are those that the author called as: *biomorphic methodologies*. This denomination intends to group all the methodological proposals that intend to analyze natural systems, living or non-living that, in a direct or indirect way, contribute to the aesthetic and formal evolution of objects and systems of objects produced by man. More linked to the morphological transposition of natural elements to artefacts, these have been present in material production since its beginning. As P. Steadman says: "The use of plant and animal figures in decoration is practically universal throughout the history of architecture and applied arts; in the last half of the 19th century, however, there was a special interest (...)"[58].