Zur Evolution technischer und biologischer Systeme
— *Impulsvortrag*

12. Interdisziplinäres Gespräch „Nachhaltigkeit und Technische Ökosysteme“

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Justus Schollmeyer

Robert Cummins, *Functional Analysis*, The Journal of Philosophy, 1975

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FUNCTIONAL ANALYSIS

A SURVEY of the recent philosophical literature on the nature of functional analysis and explanation, beginning with the classic essays of Hempel in 1959 and Nagel in 1961, reveals that philosophical research on this topic has almost without exception proceeded under the following assumptions: *

Grundüberlegung

- Ausgangspunkt: Erklärung einer beobachteten Regelmäßigkeit R im System S

- Dem System S wird zugeschrieben, R hervorbringen zu können;
—> dem System S wird ein Vermögen V zugeschrieben

- Aufgabe: Erklärung von V

    - Zerlegung von S in Komponenten $K_{1\text{-}m}$

    - Zerlegung von V in Teilvermögen $TV_{1\text{-}n}$

    - Wenn $TV_{1\text{-}n}$ hinreichend für die Erklärung von V sind, dann sind $TV_{1\text{-}n}$ Funktionen von $K_{1\text{-}n}$ in S

Larry Wright, *Functions*, The Philosophical Review, 1973

FUNCTIONS

THE NOTION of function is not all there is to teleology, although it is sometimes treated as though it were. Function is not even the central, or paradigm, teleological concept. But it *is* interesting *and* important; and it is still not as well understood as it should be, considering the amount of serious scholarship devoted to it during the last decade or two. Let us hope this justifies my excursion into these murky waters.

Like nearly every word in English, "function" is multilaterally ambiguous. Consider:

Grundüberlegung

- Die Funktion eines Teils T im System S ist der Effekt E, dessentwegen T „ausgewählt“ wurde.
- In biologischen Systemen erfolgt die Auswahl durch *Natural Selection*.
  - Zufällige Mutationen, blind
- In technischen Systemen wird die Auswahl von den jeweiligen UrheberInnen getroffen
  - Problemlösen, bewusst

Ernst Mayr, *Cause and Effect in Biology*, Science, 1961

Cause and Effect in Biology

Kinds of causes, predictability, and teleology are viewed by a practicing biologist.

Ernst Mayr

Being a practicing biologist I feel that I cannot attempt the kind of analysis of cause and effect in biological phenomena that a logician would undertake. I would instead like to concentrate on the special difficulties presented by the classical concept of causality in biology. From the first attempts to achieve a

tal), and Lecomte du Noüy, among the more prominent authors of the recent past. Though these authors may differ in particulars, they all agree in claiming that living beings and life processes cannot be causally explained in terms of physical and chemical phenomena. It is our task to ask whether this assertion

planation, prediction, and teleology) must be the cardinal points in any discussion of causality and were quite rightly singled out as such by Nagel (*1*). Biology can make a significant contribution to all three of them. But before I can discuss this contribution in detail, I must say a few words about biology as a science.

Biology

The word *biology* suggests a uniform and unified science. Yet recent developments have made it increasingly clear that biology is a most complex area—indeed, that the word *biology* is a label for two largely separate fields which differ greatly in method, *Fragestellung*, and basic concepts. As soon as one goes beyond the level of purely descriptive structural biology, one finds two very different areas, which may be designated functional biology and evolutionary bi-

- Zwei gängige Fragetypen in der Biologie: *Warum?* und *Wie?*
- *Warum?* im Sinne von *Wie kommt es, dass …?* (nicht im Sinne von *Wofür?*)
  - Evolutionsbiologie
  - [aitiologischer Funktionsbegriff (siehe Wright)]
- *Wie?* im Sinne von *Wie funktioniert …?*
  - Funktionelle Biologie
  - [systemischer Funktionsbegriff (siehe Cummins)]

Wie kommt es, dass … ist wie es ist?

Wie funktioniert …?

Foto aus einer Präsentation von M.V. Shankar: *Innovation Flow* (https://de.slideshare.net/shankarmv/innovation-flow-shankar-triz)

Biologie: Evolution (Mutation, Auslese)

Technik: Problemlösen

Foto aus einer Präsentation von M.V. Shankar: *Innovation Flow*
(https://de.slideshare.net/shankarmv/innovation-flow-shankar-triz)

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Review

Biomimetics: its practice and theory

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Biomimetics, a name coined by Otto Schmitt in the 1950s for the transfer of ideas and analogues from biology to technology, has produced some significant and successful devices and concepts in the past 50 years, but is still empirical. We show that TRIZ, the Russian system of problem solving, can be adapted to illuminate and manipulate this process of transfer. Analysis using TRIZ shows that there is only 12% similarity between biology and technology in the principles which solutions to problems illustrate, and while technology solves problems largely by manipulating usage of energy, biology uses information and structure, two factors largely ignored by technology.

Keywords: biomimetics; bionics; TRIZ; technology transfer; conflict; inventive principle

TRIZ Evolutionary Trends in Biology and Technology: Two Opposites

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Abstract

We examine the concept of evolution in technology and biology. It appears that most of the trends in these two domains have different meanings and development. Engineering is older than mankind, because numerous animals make tools and change the environment for their needs and requirements. The conflict of strategies in technology and biology can cause serious problems. There is a challenge for the dialectical synthesis of these two opposites. In practice it means that the technology should address its roots and see how biological functions are carried out. This can teach us a lot, because biological solutions are often more reliable, energy efficient and cleaner than conventional technology.

Proceedings of the 19th CIRP Design Conference – Competitive Design, Cranfield University, 30-31 March 2009, pp293

TRIZ Evolution Trends in Biological and Technological Design Strategies

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Abstract

The concept of evolution in technology and biology is discussed. It appears that most of the evolution trends in technology and biology result from different development strategies. This conflict has roots from the time when technology emerged to adapt *the environment* for our needs. Following that strategy to full extent is dangerous. We need also to adapt to *the environment*, but current technology neither has the mechanisms for such changes nor the knowledge of which directions to go. Therefore learning from nature is a real challenge. We suggest ten new evolution trends for strategic design to be ahead on future markets.

Keywords:
TRIZ, Evolution, Bio-Inspired Design

- TRIZ: Tausende Patente analysiert, Problemtypen und Lösungsprinzipien bzw. -schemata identifiziert

Table 1. PRIZM matrix derived from standard TRIZ matrix.

fields	substance	structure	space	time	energy	information
substance	6 10 26 27 31 40	27	14 15 29 40	3 27 38	10 12 18 19 31	3 15 22 27 29
structure	15	18 26	1 13	27 28	19 36	1 23 24
space	8 14 15 29 39 40	1 30	4 5 7–9 14 17	4 14	6 8 15 36 37	1 15–17 30
time	3 38	4 28	5 14 30 34	10 20 38	19 35 36 38	22 24 28 34
energy	8 9 18 19 31 36–38	32	12 15 19 30 36–38	6 19 35–37	14 19 21 25 36–38	2 19 22
information	3 11 22 25 28 35	30	1 4 16 17 39	9 22 25 28 34	2 6 19 22 32	2 11 12 21–23 27 33 34

- 500 biologische Phänomene, über 270 Funktionen (jeweils mindestens 3 Mal auf je unterschiedlichen Komplexitätsstufen (von Zelle bis Ökosystem))

Table 2. PRIZM matrix derived from biological effects: BioTRIZ.

fields	substance	structure	space	time	energy	information
substance	13 15 17 20 31 40	1–3 15 24 26	1 5 13 15 31	15 19 27 29 30	3 6 9 25 31 35	3 25 26
structure	1 10 15 19	1 15 19 24 34	10	1 2 4	1 2 4	1 3 4 15 19 24 25 35
space	3 14 15 25	2–5 10 15 19	4 5 36 14 17	1 19 29	1 3 4 15 19	3 15 21 24
time	1 3 15 20 25 38	1–4 6 15 17 19	1–4 7 38	2 3 11 20 26	3 9 15 20 22 25	1–3 10 19 23
energy	1 3 13 14 17 25 31	1 3 5 6 25 35 36 40	1 3 4 15 25	3 10 23 25 35	3 5 9 22 25 32 37	1 3 4 15 16 25
information	1 6 22	1 3 6 18 22 24 32 34 40	3 20 22 25 33	2 3 9 17 22	1 3 6 22 32	3 10 16 23 25

Julian F. V. Vincent, Olga A. Bogatyreva, Nikolaj R. Bogatyrev, Adrian Bowyer, Anja-Karina Pahl: Biomimetics: its practice and theory, 2006

- Nur 12 Prozent Übereinstimmung
- Ähnliche Lösungsprinzipien in Natur und Technik, für welchen Konflikttyp welches Prinzip verwendet wird, ist jedoch sehr verschieden
    - (nur in der Art Raum aufzuteilen 73% Übereinstimmung)
- a) Natur und b) Technik verfolgen gewissermaßen entgegengesetzte Strategien:
    - a) sich der Umwelt anpassen
    - b) sich die Umwelt anpassen

Julian F. V. Vincent, Olga A. Bogatyreva, Nikolaj R. Bogatyrev, Adrian Bowyer, Anja-Karina Pahl: Biomimetics: its practice and theory, 2006

At size levels of up to 1 m, where most technology is sited, the most important variable for the solution of a problem is **manipulation of energy usage** (up to 60% of the time), closely followed by **use of material** […]. Thus, faced with an engineering problem, our tendency is to achieve a solution by changing the amount or type of the material or changing (usually increasing) the energy requirement. But in biology the most important variables for the solution of problems at these scales are **information and space** […].

Julian F. V. Vincent, Olga A. Bogatyreva, Nikolaj R. Bogatyrev, Adrian Bowyer, Anja-Karina Pahl: Biomimetics: its practice and theory, 2006, 477

It appears that biological systems have developed relatively few synthetic processes at low size at which the contribution of energy is significant; but the main variety of function is achieved by **manipulations of shape and combinations of materials** at larger sizes achieved by **high levels of hierarchy**, where energy is not an issue. This is a very subtle biomimetic lesson. Instead of developing new materials each time we want new functionality, we should be adapting and combining the materials we already have.

Julian F. V. Vincent, Olga A. Bogatyreva, Nikolaj R. Bogatyrev, Adrian Bowyer, Anja-Karina Pahl: Biomimetics: its practice and theory, 2006, 478

Trends in technical evolution	Trends in biological evolution
1. Transition of the working functions from the macro- to the micro-level	
2. Increase of the degree of ideality – the more emptiness in a system the better.	
3. Systems change while they grow following S-curves	3. System ontogenesis can be expressed in S-curve
4. Systems and products evolve toward the use of higher frequency energy and use of fields: Gravitational - Mechanical – Acoustic – Chemical – Thermal - Magnetic - Electric - Electromagnetic	4. Life started as a bio-chemical phenomenon and evolved towards the active search for energy resources. Single-cellular organisms started from: Electro-Magnetic – Electrical- Chemical – Mechanical (multi-cellular organisms)- Acoustic (complex communication) in their organisation and behaviour.
5. Dynamisation, **increase** of the degree of freedom and flexibility.	5. **Decrease** of the degree of freedom in functions – species specialisation. The more primitive biological taxons are the more their universality.
6. Mono-Bi-Poly cycles , i.e. **polymerisation** of **monomerical** parts.	6. Trends in the evolution of morphology: **oligomerisation** of effectors and **metamerical** parts of the body.
7. Segmentation: **reduction** of the unit.	7. Replication, reproducing, cloning, metamerisation: **multiplication** of the units
8. **Increase** of automation and eventual exclusion of humans.	8. Increase of the role of the central control and sophistication of the nervous system. But decrease of automation, increase the role of feed-forward control.
9. "Folding-Unfolding" structural complexity.	9. Morphological degradation of parasites and other super-specialised species ("folding") is the dead-end of the evolutionary line.
10. Harmonization and coordination of the system parts (materials, shape, structure, information, rhythms and energy distribution)	10. Also true for all living systems
11. Parts of systems (sub-systems) evolve non-uniformly, creating constantly changing opportunities for innovation.	11. Species either change themselves or change each other. Misbalance in sub-systems' interactions causes ecosystem catastrophes or individual physiological stress, illness and triggers changes or death.
12. Shortening of the Energy Flow Path.	12. Energy flow paths are getting longer in the evolution of life on our planet
	13. The acceleration of evolution speed is in direct proportion to the complexity of a system (mammals evolved faster than bacteria).
14. Life span of a product is definitely shorter than the life spans of the classes of similar product and obviously shorter than the life of the whole industrial branch.	14. Life span of the ecosystem is 4-5 time larger than life spans of families, the families live 3-4 times longer than genus, genus – 3-4 time longer than species.
	15. The higher level of system complexity the more diversity of forms of such systems. Eukaryotes more complex than prokaryotes and contain 500 times more different species.
	16. Living nature evolves from short life-cycles to the long life-cycles. For example, the cycle "phototrophs →reducers→mineral substances→ phototrophs"" evolves to the cycle "phototrophs (producers) → consumers-1→consumers 2→.....→ reducers→ mineral substances →phototrophs""

N. R. Bogatyrev, O. A. Bogatyreva: TRIZ Evolution Trends in Biological and Technological Design Strategies, 2009

Vielen Dank!