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SUBSTANCE AND COGNITION OF BIOLOGICAL PHENOMENA

Biologists are not used to the term „substance"[2]. They prefer to say „a living being", „an organism", a „specimen of species *Homo sapiens*" – for instance. Chemists, on the other hand, when they say „this is a new substance" they usually mean the same Aristotle would mean – I think. The chemical meaning of the term „substance" is closest to the one I am going to discuss in this paper.

The chemical concept of substance – according to me – implies:

(a) something **limited** in its **individuality (totality, in-divisum)** and its **identity** (the kind of existence) – which means that it is **something which can be disintegrated**,

(b) the **limits** of disintegration are relatively **clear cut** – one can rather precisely measure and describe them,

(c) something which is **changeable** – i. e. which reveals (within the above mentioned limits) – in changing circumstances – a set of many interchangeable, different but characteristic properties,

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[2] We have to distinguish between a verbal absence and the mental absence of „substance" in biological sciences. A distinction between „something less essential and the most essential" cannot be eliminated neither from biology nor from any other scientific discipline. Recent paper by P. J. Hiett (1998) reviews the current controversy on the distinction between *appearance and reality* „which science must do to at least some extent, if only between better and worse appearances". Common-sense realism accepts „metaphysical realism" of a non-skeptic who believes in his capacity „to pierce through the veil of appearances to an underlying reality." „Natural science does not accept the view of common-sense realism. Mountains, tables, people, cats, dogs, etc. are not ultimately real, but merely appearances of collections of fundamental particles." One may agree that mountains and tables are collections of fundamental particles, but „people, cats, dogs" should not be too hastily classified together with mountains and tables.

(d) something which **changes in a regular pattern** – in other words – a set of structural and dynamic properties manifested within the limits of disintegration is repetitive, correlated, obviously non chaotic.

Those four conditions together constitute the so called „nature" of any concrete chemical compound. This „nature" is never evident to us or displayed at once on the phenomenal level. It takes time and it takes a lot of external changes to reveal a concrete „nature" in all diversity of its possible states and dynamisms. To know a substance, one has to accumulate and store a multitude of different forms of evidence concerning this „natural behavior". So the concept of the „nature" of a given chemical substance is necessarily very complex and it cannot result from a single sensation, or a momentary observation[3].

The biological concept of substance.

Almost every single word I have to use in my paper is loaded with potential misinterpretation. „Substance", „cognition", „phenomena", „biology", „life" ... etc., each of these words has quite a number of different meanings[4]. So how are we to get over this barrier of communication?

I will deliberately and openly restrict the object of my talk.

The first restriction – just biological entities. To reduce the sphere of possible misunderstandings I will constrict my investigation to *biological* entities alone. I don't care whether those results might have any more general meaning – a „cosmic", „universal" meaning. I don't even worry if they might or might not be relevant for the reconstruction of the past, or for the prediction of the future.

Second restriction – I will discuss only those biological entities which produce, use and regenerate organs. To me, a biological entity is **something** which

(1) builds up its organs from relatively simple chemical compounds and chaotic bits of energy,

(2) manipulates them,

[3] Rożdżeński (1997), on the basis of common sense, every-day experience argues in favor of introducing the concept of material substance back in the context of metaphysical and theological analysis of reality.

[4] On „substance" see for instance the address delivered by Ernst Mach before the anniversary meeting of the Imperial Academy of Sciences at Vienna, on May 25, 1882 – transl. by T. J. McCormack and publ. in Popular Scientific Lectures, Open Court Publ. Comp. La Salle, Ill. 1943, p. 188-213 and H. Weyl (1949) *Philosophy of Mathematics and Natural Science.* Princeton UP, p. 177-180, and D. J. O'Connor (1967) *Substance and attribute.* In: The Encyclopedia of Philosophy, ed. by P. Edwards, The Free Press, New York.

(3) produces new, single reproductive cells – (disassembling the previously made functional structures – preparing storage of the crude material – copying its DNA encoded messages).

Again, if one considers my definition of a living being not general enough, then I wish to stress that I am not studying all possible biological entities, but only those fulfilling the above mentioned conditions.

Part 1. Biological form of life means development.

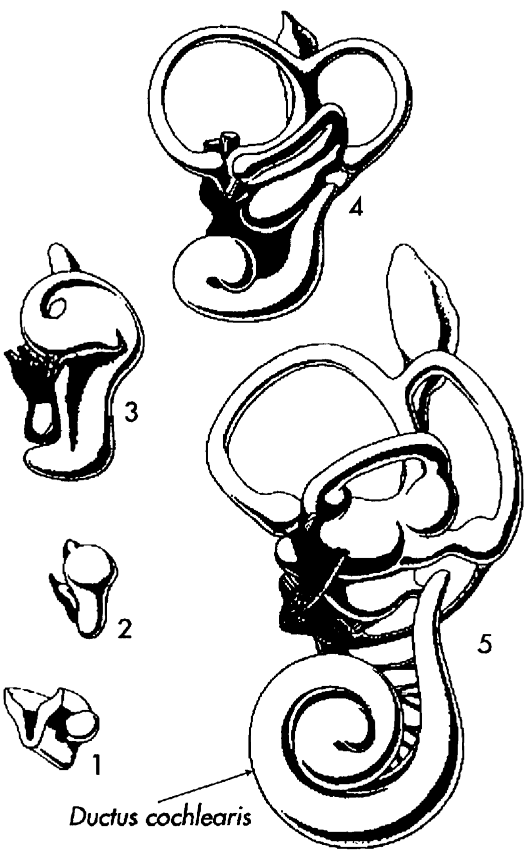

Figure 1. Some elected stages in the development of the inner ear – the last one at about 9th week of embryogenesis.

The dynamic, developmental units, the so called „life cycles", constitute the sole empirically known form of life. The life cycle starts with a single cell, equipped with the minimal set of intra-cellular organs, a minimal set of the encrypted molecular messages, and a certain amount of crude, but appropriate material and fuel. This starting stage is commonly known as „the egg".

The life cycle consists in a selective intake of the material and fuel from outside, and in the building up of specialized organs on a histological and anatomical level. When the fully developed stage (adult form) is reached, the unit produces a multiplicity of the unspecialized cells .... the eggs, which start their own life cycles.

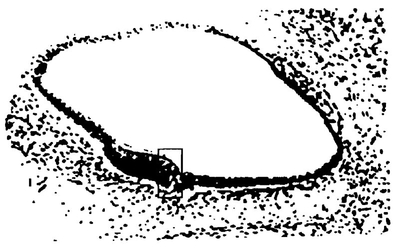

Figure 2. A section through the *ductus cochlearis* – at 11th week of embryogenesis.

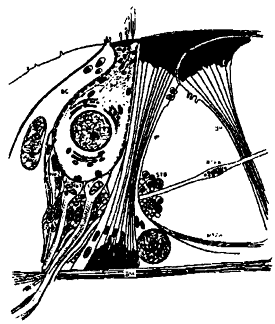

Figure 3. A section through the *ductus cochlearis* – by the end of embryogenesis.

Example A. Blue whale (*Balaenoptera musculus*). The egg cell of a whale is hardly visible. Its diameter is less than one tenth of milimetre. The adult specimen may reach over twenty metres of length. It is then 200.000 times bigger than its egg cell from which its started. To put both of them on the same picture, one had to use the logarithmic scale. The change, however, in the dimensions of the body during the life cycle are of minor importance. What is really important, is that the egg has neither muscles nor brain, while the adult specimen reveals a breath-taking complexity of the anatomical, functionally integrated structures.

Development means a correlated construction of new, complex materials and organs from the relatively simple material and relatively chaotic portions of energy.

Example B. The development of the inner ear of the man (Figs 1-3). The external shape of these structures seems almost finished after some ten weeks of pregnancy. The inner structures – responsible for registration of sound vibrations, gravity and acceleration – start developing on the eleventh week.

Example C. The proton engine of bacteria *Salmonella typhimurium* (Fig. 4). This motor rotates the spiral flagellum at about 150 revolutions per second. The rotation is thought to be driven by the flow of protons through an outer ring of proteins (the stator), which also contains the proteins responsible for switching the direction of the rotation. One turn of the engine requires the flow of about one thousand protons[5].

[5] Cfr. Alberts (1994/774) and Macnab & Parkinson (1991), fig. 1.

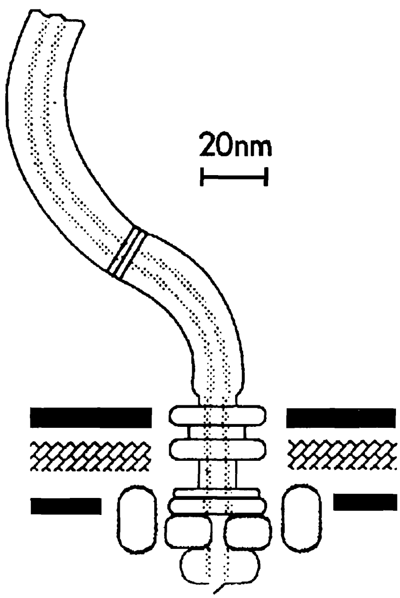

Figure 4. A schematic representation of the bacterial proton engine.

The material of about twenty different forms of protein molecules is needed to produce such an engine. Fig. 5 shows the successive stages of the building of the functional structures of the engine. Bacterial cell is able to construct six such engines within twenty minutes.
Example D. The development (biosynthesis) of the inosine molecule (Fig. 6). The inosine molecule is a precursor of such biologically important compounds as adenosine and guanine molecules. A simple bacterium has to construct at least four thousand of these molecules per second.

Through the use of labelled isotopes, the origin of each of the atoms of the two ring structure was determined – in the late fifties of our century – principally in the laboratory of J. M. Buchanan.

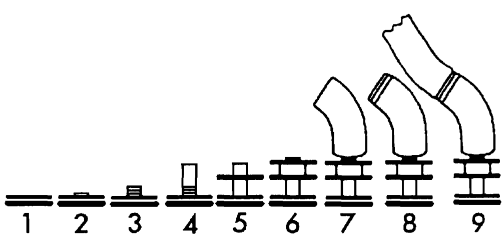

Figure 5. Some stages in the construction of the bacterial proton engine.

It was demonstrated that there is a strict, repetitive pattern of the successive steps in the biosynthesis of this molecule. On the fig. 6 the numbers 1-10 show the succession of these steps. It was also demonstrated that the material for a given step is not random, but comes from several, different, but strictly determined sources – mainly from specific, complex molecules produced by the same cell.

Then it was demonstrated that practically each step is guided by a specific enzyme molecule, which – on average – is several thousand times bigger than the small chemical group it assist. In other words these enzymes act like exquisitely precise machines which ensure that a given atom or group of atoms is positioned in the right place and in the right position.

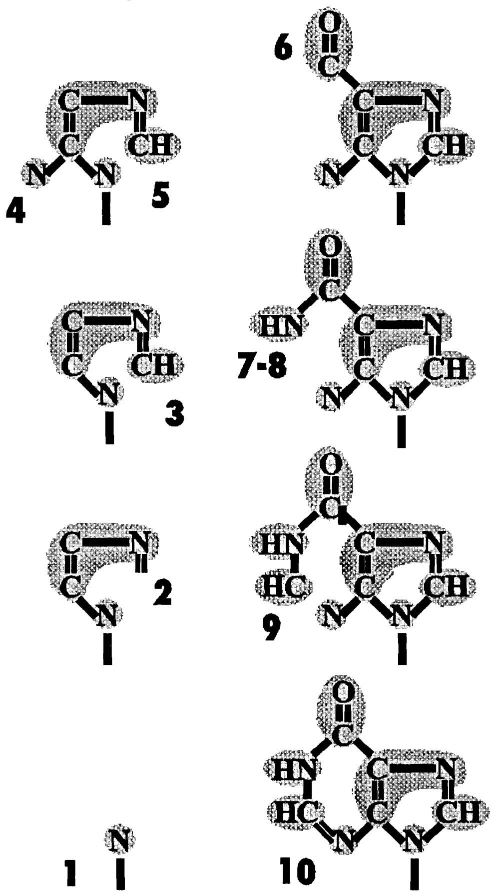

Figure 6.
Stages in the biosynthesis of inosine molecule.

Example E. The myoglobin molecule. This protein molecule was reconstructed by Kendrew and his team at the University of Cambridge, and for this they won the Nobel Prize. The myoglobin molecule consists of some two and a half thousand atoms, spaced in an absolutely exact manner. Why am I mentioning myoglobin structure instead of describing the atomic structure of an enzyme? Because most of the enzymes are at least four times bigger than this simple protein. Some of the enzymes in the bacterial cell are ten or twenty times bigger than myoglobin.

This brings me to the end of the first part of my paper. The conclusion I drew from the above is this:

There is no biological reality apart from the reality of a life cycle.

This reality means a limited, specific dynamic pattern of constructing complex, correlated set of organs.

The process of construction is multidimensional – it involves at least (in the simplest forms of life) the molecular level, the macromolecular level, the organellar level and the cytological level.

The Cartesian claim that an organism is similar to the *mechanism of a clock* is based on a serious misunderstanding. Actually a biological entity is analogous to the *process of constructing a clock.*

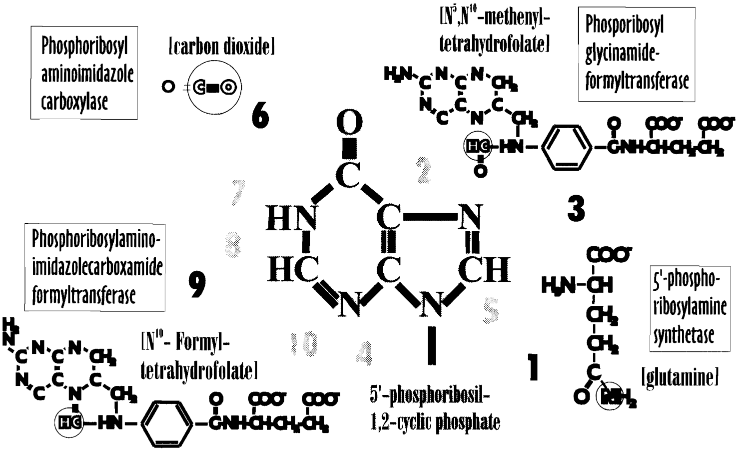

Figure 7.
More details on four selected steps in the biosynthesis of inosine molecule. Steps 1, 3, 6, and 9. (See Fig. 6). The names of the enzymes in the boxes.

Part 2. How to ruin the developmental dynamism of life?

Two methods give the best result. One consists in withholding the material and fuel (starvation), second in a destruction of the developed structures.

Let us see how the first method does work.

Example F. Stoppenbrink's observations of the starved planarians.

„The Turbellaria are able to go without food for long periods, but during starvation they grow smaller and smaller. Stoppenbrink starved *Planaria alpina*, keeping them entirely without food, while as a control he kept a similar collection supplied with food. His results are given in the table I. The measurements are in milimetres."

„This **reduction in size is accompanied by the absorption and digestion of the internal organs, which disappear in a regular order**, the animal using these as food ... *The first things to go are the eggs which are ready for laying, then follow the yolk glands and the remainder of the generative apparatus. Finally the ovaries and the testes disappear, so that the animal is reduced to sexual immaturity. Next the parenchyma, the gut and the muscles of the body wall are reduced and consumed.* The nervous system alone holds out and is not reduced so that starved planarians differ in shape from the normal forms in having a disproportionately large head end, the bulk of which is the unreduced cerebral ganglion. On feeding these **starved forms will regenerate all the lost organs and return to the normal size**, like Alice when she ate the right half of the mushroom." (Saunders J. T., 1963/196-197, – underlining by P.L).

	Fed				Starved			
Date	Largest		Smallest		Largest		Smallest	
	L.	B.	L.	B.	L.	B.	L.	B.
16. 03. 1903	13	2.0	**10**	**1.**	13	2	**10**	**1**
15. 06. 1903	17	2.5	12	1.3	10	1.5	6	0.6
15. 09. 1903	17	2.5	13	2.	7	1	4	0.5
15. 12. 1903	17	2.5	14	2.	3.5	0.5	2.3	0.3

Table I. Stoppenbrink's experiment.

The next best method of disintegration of a living body is by the destruction of its structures. Let us see how this works.

Example G. Morgan's observations of the mutilated planarians.

A whole, adult, intact planarian body can move, can search for food, and its feeding organs function perfectly.

The mutilated body – on the other hand – cannot move, cannot find food and cannot eat it. Its organs of locomotion, organs of cognition no more exist. But the damaged animal does not die. *The process of regeneration starts.* See fig. 8.

It „begins with the assembly of regeneration cells into a regeneration blastema in the region of the wound. ... The first act of regeneration is wound closure; the wound is drawn together by muscle contraction. „

„The epidermis at the edge of the wound extends over it, and the neoblasts („primitive", unspecialized, „reserve" cells – PL) come together to form a new epidermis on the outer surface" (Kühn. /421).

In a few experimental series the amputations were repeated 15 times on Dugesia, and the time required for regeneration was always the same as that in a control group operated on for the first time. The supply of neoblasts seems practically limitless. (Kühn. /422).

Epimorphosis. „The regeneration blastema grows out from the edges of the wound as a cone or ridge, according to the form and size of the wound, and it gradually replaces in outer form and inner organization the lost body parts. These events have been called *epimorphosis* by Morgan.

Morphallaxis. In addition to the new construction around the edge of the wound, however, other important changes take place in the intact remainder of the body, and these changes are called, collectively, *morphallaxis*. If the form of a little piece is so changed that the normal proportions must be recreated on a smaller scale, some organs that are normally far apart must be crowded together; organ parts or whole organ complexes, such as the reproductive apparatus, are dismantled if they are now disproportionately large. They are then formed anew.

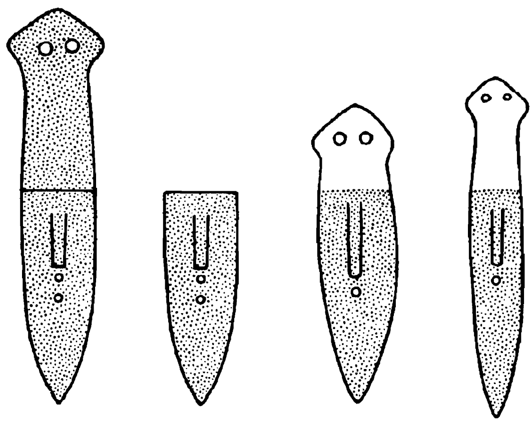

Figure 8. Morgan's experiment.

The quantitative relationship between epimorphosis and morphallaxis depends, of course, on the proportions of the body which must be regenerated; it also depends on the species. Epimorphosis can predominate, or morphallaxis can restore the typical organization by itself, practically, without the formation of a regeneration blastema. Generally, though, epimorphosis and morphallaxis work hand in hand." (Kühn. /422).

Example H. Lehn's observations on the mutilated hydras (Fig. 10).

„In an aggregate of 30-60 hydra *(Pelmatohydra oligactis)* fragments, clumped together by centrifugation, randomly oriented fragments join primarily at their endodermal surfaces and fuse. [...] In the course of 7-10 hours the gastral cavity forms, swells up and flattens again, expelling all the [useless] tissue remnants. The regenerant becomes smaller, and after two or three days new tentacles sprout" ... (Kühn, 1971/4-11). Gierer et al., 1972 have confirmed Lehn's observations, but in their experiment the hydra's body was fragmented in a much more destructive way. The regeneration process took some six days. Afterwards the reconstructed organism was able to prey and feed on *Artemia* arthropods.

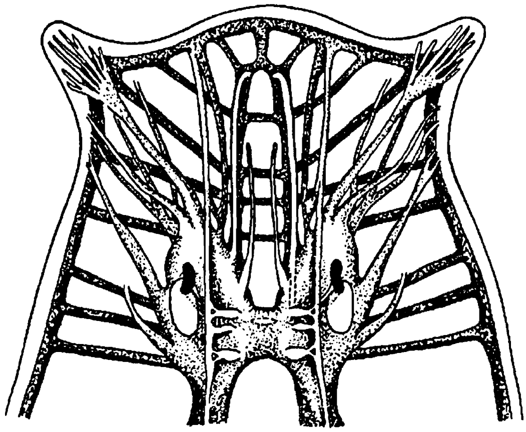

Figure 9. The brain and sensory neural endings of the planarian head.

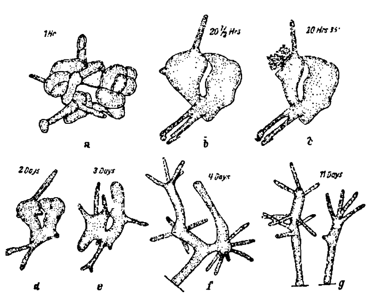

Figure 10. Lehn's experiment.

Example I. Silber's and Hamburger's (1939) observations on the planarian monsters (Fig. 11).

In *Euplanaria tigrina*, a sagittal cut **(A)** is made from just in front of the pharynx to the tip of the tail and then the head is cut off **(B)**, so that the two halves of the body are connected only tenuously. ... The pharynx is removed, and the two halves of the body are prevented from rejoining. ... Where the two body halves are joined, one head regenerates forward and another backward. ... a two-headed animal arises, which is reminiscent of the so-called *„duplicitas cruciata"* seen in vertebrates. ... This peculiar inner organization of the two-headed animal, and in particular the mutual independence of the brains, leads to the persistent efforts of each head

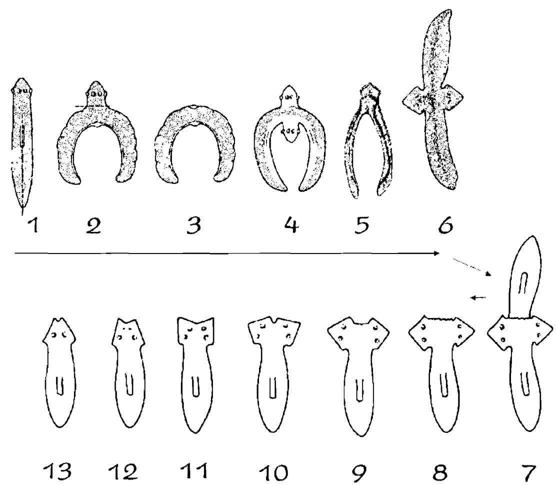

Figure 11. Silber's and Hamburger's experiment on *Euplanaria tigrina*.

to go its own way. This results in twistings and turnings which extended to the very ends of the body. (Kühn /425-7). The Buridan's donkey didn't eat because two equally attractive objects paralyzed its possible decision to follow just one of them, here in the Lehn's experiment, the animal is paralyzed because of the opposite tendencies of its body-parts.

But this is not the whole story – just the first part of it.

Regeneration – a strictly limited dynamism

„In any event, the reorganizing region as a whole is responsible for constructing and maintaining the stable structure out of an abnormal situation. This is seen in the resorption of supernumerary body parts when the normal balance of abnormal structures is destroyed. If a lateral part of the *duplicitas crotchety* is cut off, the wound closes, and the two heads draw together and ultimately fuse. The two eyes which are now in a median position are also resorbed, and thus morphallaxis gradually results in a single head." (Kühn /427).

That is the end of the second part of my talk. The conclusions are these:

(a) A limited destruction of the developed structures does not stop developmental activity. **Biological dynamism consists in developmental activity, and is, within certain limits, independent of the already developed structures.**

(b) The quantity and, to a certain extent, the quality of **the accessible material influences the scale of the developmental activity but not its inner complexity.**

Part 3. Why does the concept of a „substance" seem necessary for a proper account of the biological reality?

It is obvious that a scientific description of every „life cycle" requires quite a number of distinct concrete concepts to do justice to the structural and dynamic reality of these phenomena. The number of these distinct concepts increases with the progress of more detailed observations. So biologists need a separate mental „data base" to keep this information together. Such data-base-like concepts are subconsciously created in our mind from our boyhood (on frogs, beetles, girls ... and so on).

The data-base concept does not seem sufficient to describe the reality of a „life-cycle". The tendency to construct the proper organs, to repair or replace them has to be included in the complete description of life.

Two elements come together here.

I. **Material and fuel.** One is the absolutely necessary material and fuel. It cannot be *any* material or *any* fuel. Each kind of „life-cycle" has its own requirements. Some organisms require the energy of light, whilst other rely on chemical sources of energy. Similarly – within the same „life cycle" – the material for a caterpillar is quite different to that for a butterfly.

Because of these specific requirements this selective material and energy – within structures of a given life cycle – share a character of „substance" (in the chemical sense of the word). They can be disintegrated. This – of course – would spoil any chance of survival of a given „life cycle".

So the concept of a proper material and proper energy source seems to enter into the idea of a living being. This is not enough however.

II. **An active agency.** An active, immanent agency capable to drive and to correlate the production of different new, „biological" materials and the further construction of organs seems absolutely necessary condition for the regular pattern of the life cycle. Biologists – who are usually ignorant of the new trends in philosophy – are well aware of this necessity. They use to call this real principle of biological activity the „genetic information". Many of them believe the set of the encrypted messages „written" along the DNA biopolymer is identical with this „genetic (developmental) information". Many others, and their number increases every year, do realize how chaotic, limited and generally fragmentary is this set of molecular messages[6]. In fact the DNA

[6] „It is commonly stated that the genome incorporates a Bauplan, an architectural plan

reminds us of a „crib" (ger. Schwindelzettel) *utilized* by the Ruling Principle of the Development rather, than the Main Organizing Control Agency.

The last controversy does not enter into my subject. I just want to say, that the constantly improved scientific knowledge of living being is very complex and within this knowledge at least four different mental notions are present:

(1) a numerous set of different but intrinsically *homogenous, abstract concepts* (like weight, shape, color, mass, ... etc.),
(2) a single *data-base cumulative concept* in which some regular patterns, typical for a given kind of the animal, or plant can be recognized,
(3) a concept of the necessary *material and energy* resources,
(4) a concept of an *integrated, active, informing agency,* which explains the extremely selective and repetitive pattern of the developmental and regenerative phenomena[7].

The last two concepts seem to be close to the aristotelian idea of „substance".

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or blueprint of the body. Actually, this is not the case; the genome is not a sketch or design of the finished body. The informational capacity of DNA is simply too low to store blueprints of the very complex final pattern of an organism. For example, a detailed design of the one hundred trillion to one quadrillion synaptic contacts in our brain alone would greatly exceed the capacity of the genomic memory. [...] **We do not yet understand [...] how a developing organism is created on the basis of such minimal information, or how many organisms are able to regenerate lost structures**". (Müller, W., 1996 – underlined by PL).

[7] „Embryos are integrated systems with the whole having overall control of the parts. [...] the newly regenerating whole is controlling what happens in its parts. [...] That last statement reflects a truly extraordinary biological phenomenon. Let us consider some of the implications. **A planarian when cut begins to regenerate and stops when its body is complete. What stops this regeneration?** Why does it not continue as a cancerous growth forever? **Each fragment must have the complete information on „How to make a whole planarian" and also a mechanism to shut off regeneration when the complete body has been formed**. In the case of planarians the marvel is not only that the lost part is restored but that each fragment is totally reformed. The entire structure is altered in each fragment so that at the end of regeneration a perfect, though small, palanarian is the result. (There is no feeding or growth during this period.)" (Moore, J.A. , 1987, 563-564)

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SUBSTANCJA I POZNAWANIE ZJAWISK BIOLOGICZNYCH

Streszczenie

W biologii współczesnej termin substancja został porzucony. W chemii natomiast ma on praktycznie takie samo znaczenie, jakie mu nadawał Arystoteles. „Substancja" jest to coś ograniczonego w swej całościowości (niepodzielności) i identyczności (swoistości istnienia). Ograniczenia konkretnej substancji są wyraźne, można je stosunkowo precyzyjnie mierzyć i opisywać. Substancja jest czymś, co posiada jakby otoczkę sfery zmiennych przejawów strukturalnych i dynamicznych, które w znacznej mierze podlegają wpływom otoczenia. Ta zmienna otoczka ujawnia jednak pewne charakterystyczne dla danej substancji prawidłowości. Gdy wpływy zewnętrzne przekroczą wspomniane wyżej ograniczenia, wtedy substancja ulega dezintegracji, choć nie jest to anihilacja, lecz przemiana w inny rodzaj substancji.

Poznawanie substancji chemicznej nie może zatem dokonać się *in instanti.* Potrzeba na to wielu obserwacji, prób i eksperymentów prowokujących substancję do ujawnienia swych prawidłowości i ograniczeń.

Gdy od chemii przechodzimy do biologii, wtedy praktycznie każdy termin nabiera wielu znaczeń i rodzi nieporozumienia. Dlatego, by mówić o substancji biologicznej, ograniczyłem się do omawiania tylko tych bytów, które wykazują zdolność do konstruowania organów, posługiwania się nimi oraz regenerowania organów uszkodzonych. Proces konstruowania organów zachodzi w tzw. cyklu życiowym. W tym „cyklu" komórka z selektywnie pobieranego prostego materiału organicznego i selektywnie pobieranych porcji określonej formy energii buduje kolejne piętra hierarchii struktur funcjonalnych, biochemicznych, cytologicznych i ewentualnie anatomicznych. Nie istnieją zjawiska biologiczne poza kontekstem „cyklu życiowego".

Te stwierdzenia zostały zilustrowane przykładami całości cyklu (wieloryb), rozwoju struktur ucha wewnętrznego (Fig. 1, 2, 3), konstrukcji silniczka protonowego bakterii *Salmonella typhimurium* (Fig. 4, 5),

biosyntezy cząsteczki inozyny (Fig. 6, 7), oraz danymi na temat cząsteczki myoglobiny.

Zatem utrwalony od czasów Kartezjusza pogląd, jakoby dynamika biologiczna przypominała dynamikę zegara, jest fundamentalnie błędny. W rzeczywistości dynamika organizmu przypomina *konstruowanie* zegara z bezkształtnego materiału.

Czy da się zniszczyć tę „substancjalną" dynamikę rozwoju i regeneracji? Biolodzy stosowali tu dwie metody. Jedna polega na pozbawieniu organizmu pokarmu (materiału i ulubionego „paliwa"). Druga polega na bardziej lub mniej rozległym niszczeniu struktur wytwarzanych podczas „cyklu życiowego".

Badania nad głodzeniem organizmów rzędu wypławków (Triclada) wykazały, że taki organizm w pierwszej fazie głodu zmniejsza rozmiary swoich organów, a w drugiej karmi się tymi organami, które w sytuacji braku pożywienia są bezużyteczne (np. organy rozrodcze, przewód pokarmowy, mięśnie; por. Tabela I). Gdy po wielomiesięcznej głodówce takie zredukowane strukturalnie organizmy otrzymały pokarm, wtedy odbudowały kolejno wszystkie zjedzone przez siebie organy. Zatem niszczenie dynamiki rozwojowej poprzez głodzenie nie jest łatwe i musi przekroczyć pewien limit charakterystyczny dla konkretnej „substancji" żywej.

Niszczenie struktur wytworzonych w cyklu życiowym też nie musi prowadzić do śmierci (zatrzymania procesów rozwoju), lecz często prowadzi do regeneracji utraconych części dzięki zmiejszeniu rozmiarów ciała i zaoszczędzeniu w ten sposób materiału oraz energii, których organizm uszkodzony nie jest chwilowo w stanie zdobywać (por. Fig. 8, 9, 11).

W jaki sposób przytoczone wyżej fakty wpływają na teorię poznawania zjawisk biologicznych? Teoria, która nie ignoruje opisanych wyżej faktów, wymaga uznania obiektywnej wartości paru pojęć nie mających odpowiednika wśród pojęć opisujących zjawiska przyrody nieożywionej. Jedno, to pojęcie *cyklu życiowego*. Nie jest to pojęcie *sensu stricto* abstrakcyjne, bowiem stanowi ono rodzaj bazy danych odnoszących się do różnorodnych etapów tego cyklu i do rozmaitych poziomów hierarchicznej złożoności powstających struktur. Drugie, to pojęcie *materiału i paliwa*, czyli takich struktur chemicznych i takich form energii, jakich do istnienia wymaga *de facto* dany typ organizmu. Wreszcie proces poznawania dynamiki biologicznej nie może ignorować oczywistej konieczności *czynnika integrującego* procesy rozwojowe. Obojętne, czy będzie on rozumiany jako struktura chemiczna zaszyfrowanego polimeru DNA, czy traktowany jako osobna, „niematериałowa" forma istnienia, pojęcie tego czynnika musi obejmować element integracji, immanentnej aktywności i pewnej, elementarnej orientacji w otoczeniu.

Pierwsze z tych trzech pojęć – cykl życiowy – ma charakter opisowy, a nie wyjaśniający. Pojęcie materiału i paliwa nie zawiera w sobie wewnętrznej determinacji do takich czy innych struktur lub dynamizmów. Jest to więc pojęcie podporządkowane pojęciu „informacji genetycznej". Czy można ją utożsamić ze strukturą chemiczną DNA? Coraz to nowe odkrycia biologii molekularnej wskazują na informacyjnie fragmentaryczny, bierny i stosunkowo chaotyczny – z punktu widzenia organizacji przestrzennej – charakter „genów" (czytaj sekwencji polimeru DNA). Z drugiej strony wewnętrzna dynamika cyklu życiowego i jego perfekcyjna całościowość nadal czekają na uznanie i wyjaśnienie przyczynowe. Pojęcie „substancji" biologicznej jest na razie podsumowaniem pewnego poznawczego *status quo* oraz wyzwaniem wobec ludzkiego intelektu.