Serial Endosymbiotic Theory (SET): The biosemiotic update 2005

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ABSTRACT - The Serial Endosymbiotic Theory (SET) explains the origin of nucleated organisms by a merging of archaebacterial and eubacterial cells in anaerobic symbiosis, historically followed by acquisition of mitochondria or plastids. The paradigmatic change vis-à-vis former evolutionary theories is that the driving force behind evolution is not ramification but merging.

Lynn Margulis describes the symbiogenetic processes in the language of mechanistic biology in terms such as “merging”, “fusion”, “incorporation”. As *biosemiotics* has proved, all cell-cell-interactions are (*rule-governed) sign-mediated* interactions (rsi’s) i.e., communication processes. Rsi’s between and within cells and cell societies can be described better in terms of a *biology as an understanding social science*, than in terms of mechanistic biology. The difference between natural laws and semiotic rules is that every living being underlies natural laws in a strict sense, semiotic rules, on the other hand, may be followed or not, may be changed or not, may be generated or not. Thus, living beings have a relationship of following or following-not to rsi’s but not to natural laws.

The change from mechanistic biology to a *biology as an understanding social science* may also be a change from the 3rd person perspective (external observer) to a 1st/2nd person perspective (*performative participant*). It leaves behind the subject-object dichotomy and integrates the Umwelt-concept (J.v.Uexkuell) into a Mitwelt-concept, in which *all* living beings are participants in a universal community of communicating life.

***Keywords**: endosymbiosis, multilevel communicative competence, pragmatic turn, 3-levelled semiotics*

SET - Serial Endosymbiotic Theory

The SET is so revolutionary because it reversed the evolution vector from ramification to merging. Eukaryotic cells, according to Margulis, are the result of merging several different ancestor genomes (Margulis 1996, 1999, 2004, Margulis et al. 2000, Margulis and Sagan 2002).

The important factor is the sequence of merging in symbiogenesis, i.e. the serial evolution. The first merger involved (1) thermoplasmic archaebacteria with motile spirochaeta-like eubacteria that (2) were able to swim, to the nucleocytoplasm. These forms were still anaerobic. This was followed by a merging with (3) aerobic organisms. This enabled them to survive the increasing oxygen concentrations. The final step was the merging with (4) photosynthetic bacteria. With this approach, the SET contradicts traditional theories of evolution, all of which firmly held that the direction lay in ramification and not in merging.

Cilia, the rods in the retina, the tail of sperm cells, sensory hairs and many similar appendages of nucleated cells arose during the original merging of archaebacteria and a swimming bacterium. The bodies they contain so-called “centriole-kinetosomes” arose through this archaic merger. There is also a genetic relationship between cilia and microtubules at the surface of nuclei of plants, and between microtubules and the mitotic spindles responsible for chromosome movement during cell division. Baluska et al. (2004: 17) have convincingly reconstructed this in their *cell body*-theory. According to Margulis, the Spirochaeta are the modern, free-living relatives of these symbiogenetically merged centriole-kinetosomes.

One integrated genome was sufficient in the merger of archae- and eubacterium, in the Proctista 2 integrated genomes were necessary, in the fungi 3, in animals at least 4, and in the plant kingdom (400 million years ago) at least 5, perhaps even 7 (Margulis 1996). Thus, the plant genome is the epitome of symbiogenetic evolution processes and represents the most complex integration process. Considering that the evolution of flowering plants took place only about 150 million years ago, and that their seeds and fruits provided the foundation for higher animals, then these revolutionary symbiogenetic processes are relatively young compared with evolutionary history as such (Margulis and Schwartz 1988).

The SET also supports her assumption by pointing out that most of the DNA found in the cytoplasm of animals, fungi, plants and protoctists comes from genes of bacteria that became organelles, and not from genetic drift or mutations. Eukaryotic genes that participate in information processing (translation, transcription etc.) show a close relationship to eubacteria. Genetic factors that control metabolic processes, however, more closely resemble those of archaebacteria.

Another advantage of the merging paradigm of the SET is that DNA elongation (from bacterium to humans: 1 – 1000 mm) need not be attributed to chance, which would be highly improbable (Vollmert 1985), but rather to a merging of entire gene-blocks. This demonstrates that complex genomic make-ups can be passed on directly and that the step-by-step development via chance mutations is outdated.

Merging? – Communication!

Lynn Margulis uses in the SET the classic language of mechanistic biology to describe the highly complex interactions of a symbiosis and, subsequently, symbiogenesis: “merging” “fusion”, “incorporation” are imprecise physicalistic descriptions.

In fact, a multi-levelled, generative communication process rather than “fusion” is involved. Its success, however, depends on whether the necessary sign processes proceed according to rules or whether they fail. Moreover, the integration of genetic components into available genomes and therefore the creation of a new individual does not involve “incorporation”, but rather a communication process between cells and cell components.

The pragmatic philosophy of biology (Witzany 1993, 2000) and the young science of biosemiotics (Kull 2005) demonstrate that life functions are *always* related to sign processes.[1] More precisely: sign processes *regulate and constitute* life functions. If these sign processes are faulty, then life processes are compromised or terminated. These sign processes regulate life processes on different levels *simultaneously*: intracellularly, within the cell (DNA, RNA activities, messenger substances, etc.), and intercellularly as cell-cell communication. This is the intraorganismic level. In parallel, each organism also conducts (species-specific) interorganismic and (transspecific) metaorganismic communication processes.

Should the symbiosis lead to a symbiogenesis, to the development of a new species and thus to the disappearance of the formerly independent individuals, then the result is generative DNA-text processing in which genetically different gene pools are combined into *one* DNA text. This requires a recombination that assimilates the foreign data set, converting the external into the internal. Which genome editing competences are able to integrate an endosymbiontic genome in a host genome in respect to the former existing genome architecture. Manfred Eigen would ask how to think a correct rearrangement of the molecular genome grammar.

Symbiogenesis by communicating organisms

Over the last 25 years, tens of thousands of papers have been published in the field of molecular biology, genetics, biochemestry, epigenetics and similar disciplines. They outline

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[1] Sign processes follow three levels of rules in principle: *Syntactic* rules regulate the relationship between the signs itself, *semantic* rules regulate the relationship between signs and designated object/something, *pragmatic* rules regulate the relationship between sign-user/interpreter und signs.

in great detail the intracellular processes of recombinant DNA, splicing, RNA-editing, coding, copying, major and fine repairs, transcription, translation, RNA processing, insertion, the role of introns and exons in “reading” processes, the complementary roles of DNAs and RNAs, even the significance and indispensable structural function of non-coding DNA (Cavalier-Smith and Beaton 1999, Sternberg 2002, Jaenisch and Bird 2003, Baluska et al. a/b 2004, Shapiro and Sternberg 2004, Schmitt and Paro 2004, True et al. 2004, Wang et al. 2004).

Successful DNA/RNA processing requires numerous, specifically tailored enzyme proteins. *In all cases, text-processing enzyme proteins and also interacting RNAs are involved in very precisely conducting these varied DNA - processing steps. Any mistakes here typically have grave and often lethal consequences for the organism.*

Today there are strong reasons, that this text processing on protein-coding DNA is overruled by the genome processing abilities of DNA coding not for proteins but for active micro-RNAs (Mattick 2001, Mattick and Gagen 2001, Spotswood and Turner 2002, Turner 2002, Mattick 2003, Mattick 2005, Shapiro and Sternberg 2005). Especially the recombination of two different genomes into one as happened in early symbiogenesis we can imagine through the text processing competences of active micro RNAs.

Active micro-RNAs control and integrate large-scale structures of the chromosome**.** The number of different micro-RNAs is estimated to exceed several 10 000. Some of the discovered tasks of these micro-RNAs are co-suppression, suppression of transposition, position effect variegation, start-stop signals, RNA interference, imprinting, chromosomal methylation, transvection, transscriptional and posttransscriptional gene silencing along with numerous other RNA-DNA, RNA-RNA (trans-acting RNAs), RNA-protein interactions. These active RNAs are as competent as proteins in catalysing, signaling and switching.

Cellular differentiation and phenotypic variation results primarily from variations in this high order regulation, not in the proteins themselves or in their mutations. The phenotypic variation in complex organisms is the result of a *different use of a set of protein-coding core components* The higher order regulation in non-protein-coding genome architecture is able to manage a larger genetic data set in its phenotypic range. As far as evolutionary processes are concerned, it is naturally much simpler to change or expand a number of very small control sequences than to duplicate an entire network of protein-coding DNA. Variations of this higher order regulation can create an enormous spectrum of different protein expression profiles and we can understand why one and the same gene can be used for multiple protein meanings.

Plant multilevel communication competence

Plant scientists formerly thought of plants also in terms of mechanistic biology as automatons. Meanwhile research into the multilevel communication of plants revealed activities like learning, memory, individuality and plasticity as an expression of so-called “plant intelligence” (Trewavas 2003, 2004). Plant research in the past 5 years has also revealed that the old dichotomy of chemical versus neuronal-electric communication was a misinterpretation. Today we know that 99% of neuronal communication is based on chemical messenger substances, and that electric action potentials serve merely to maintain the transport of messenger substances along long neural tracts (Trewavas 2003). Therefore, the catchword for this congress is “plant neurobiology”, not “plant physiology”.

Plants represent a major success story in evolution and are the most recent organismic kingdom. Higher plants make up 99% of the eukaryotic biomass on our planet. At the same time, this success story also reflects the success of *multilevel communicative actions* by plants in their intra-, inter- and metaorganismic stages: it represents a crucial dependency on successful communication with microbial communities (Walker et al. 2003, Bais et al. 2004), with fungi (especially in the rhizosphere), with animals (especially with insects), and, in parallel, the multilevel brain-like communication processes in and between cells, tissues and the whole body (Trewavas 2003).

The communication between plant tissue and the plant cells is exceptionally complex and encompasses nucleic acids, oligonucleotides, proteins and peptides, minerals, oxidative signals, gases, hydraulic and mechanical signals, electric signals, fatty acids, oligosaccharides, growth regulators, amino acids, numerous secondary products, simple sugars, and many other as yet unstudied aspects.

Language and communication: from *linguistic turn* to *pragmatic turn*

For more than 10 years, most biological disciplines have increasingly been referring to "communication" and "language" in describing and explaining interactions in and between cells, between tissues and organs, whole bodies, organisms, species-specific and trans-species interactions. The influence of a linguistic vocabulary is omnipresent and has become irreplaceable. This calls for an up-to-date definition of "language" and "communication" if we are to avoid using these terms in an uncritical, unreflected or merely metaphorical manner.

In referring to the language of life, to codes, and to communication in linguistic terminology in order to describe essential life processes, we can rely on an unspoken and uncritical pre-understanding of language and communication, i.e. on metaphysical and/or reductionistic prerequisites: We can say that (1.) we are working in standardized experimental setups and that theoretical preconditions are not very interesting. We can say that (a) we refer to the world of objects in the language of exact natural science whose validity claim is founded on the laws of the physical world. We might assume that (b) observed things have a direct empirical significance that need not be further questioned because the laws of physics correspond 1:1 with the material foundations of the linguistically constructive human brain (universal syntax). We might also assume (c) an overlying meta-system in which human populations represent one of the subsystems that communicates within itself and with co-systems in an information-theoretical framework (Witzany 1995, 1998, 2002).

This suddenly leaves us directly in the midst a 60-year-long theory of science discussion that extended from approximately 1920 to 1980. It consisted of two phases, and its first result was (a) the *linguistic turn*, the second result being (b) the *pragmatic turn*.

(a) The linguistic turn was the result of an attempt to delimit the *logic of science* from philosophy and other "unscientific" cognitive methods. In the aftermath of Wittgenstein's "Tractatus logico philosophicus", the "Wiener Kreis" around Carnap, Neurath, Feigl, Waismann, Kraft, Frank, Menger, Gödel, Hahn and in further developmental stages also Russel and Tarski held that no subjective phenomenology, philosophy or similar discipline provided a suitable logic for an exact natural science; rather, only protocol propositions of observations that are reproducible in experimental setups are capable of depicting reality on a 1:1 basis; this is also valid for propositions of a language of theory, that would have to be brought into agreement with these protocol propositions.

What is required is a language that can be formalized, f.e. logical calculations, algorithms. This language would represent a universal syntax that would be universally valid (a) in the things of the external world, (b) in the physicalistic laws and (c) in the material reality of the brain of humans speaking in formalizable propositions (Witzany 1995)[2].

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[2] The history of science clearly documents the course of this discussion. Logical empiricism had to abandon its effort to achieve the ultimate validity claim of a physicalistic universal language. Concepts such as empirical significance, initial and marginal conditions, verification und falsification, but above all the disposition terms, could not be adequately derived. Even the concept of "natural law" was justifiable only under the assumption of an arbitrary experimental design that presupposed a free will. Thus, the strongest, centuries-long argument against free will – the determinism of the material world – principally needed autonomous researchers if it was to be used in the natural sciences (Witzany 1995).

The conviction of the possibility of an *exact language of science* was so deeply imbedded - and this might serve as an example for the valuation of emotions in purportedly emotion-free objectivit - that, while it was refuted and ultimately rejected in the theory-of-science

Communication processes – rule-governed sign-mediated interactions

In fact, the transition from the *linguistic turn* to the *pragmatic turn* was already emerging in Wittgenstein's "Philosophical Investigations" and in his analysis of rule obeyance:
"Is what we call 'obeying a rule' something that it would be possible for only *one* man to do, and to do only *once* in his life? (…) It is not possible that there should have been only one occasion on which someone obeyed a rule. It is not possible that there should have been only one occasion on which a report was made, an order given or understood, and so on – To obey a rule, to make a report, to give an order, to play a game of chess, are customs (uses, institutions). To understand a sentence means to understand a language. To understand a language means to be master of a technique." (Wittgenstein 1972: 80e)

In his analysis of the expression "to obey a rule", Wittgenstein provides proof that the identity of meanings logically depends on the ability to follow *intersubjectively valid rules with at least one additional* subject; there can be no *identical meanings* for the lone and lonesome subject. Speaking is a form of social action.

(b) Following Wittgenstein's analysis of rules, the theory-of-science discourse derived and justified scientific statements based on an *intersubjective-communicative* language and communication concept. At the same time, it replaced the solipsistic subject of knowledge of subjectivism and objectivism with the "ultimate opinion" of an "indefinite community of investigators" of Ch.S. Peirce. The axis Wittgenstein 2, Austin, Searle, Apel, and Habermas founded the intersubjective-communicative character of thought, experience and research and was therefore able to avoid the omnipresent subject-object dichotomy and its unavoidable consequences, solipsism and objectivism.

Preconditions of understanding

Before we can resolve the terms "language" and "communication", we must understand the language that we use to discuss these terms.

We understand sentences in a language in which we are linguistically competent; we understand sentences in which the speaker presents propositions interconnected with validity claims. We do not understand *ontology*, i.e. natural phenomena, empirical observations, physiological processes, physical principles, but rather sentences and actions that underlie grammatical, semantic and pragmatic rules *that we share with the members of a linguistic community*. A prerequisite for understanding is therefore a *historically evolved* social lifeworld, which provides the basis for the historical development of the commonly shared language (Witzany 2005).

This, however, means that problems with understanding can arise if we are unaware of the grammatical, semantic or pragmatic rules that an uttering individual is following.[3]

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discourse and in the history of science, it was and continues to be considered valid in many standard sciences, curricula, underlying convictions.

[3] In order to reach an understanding with another speaker and establish an interrelationship, four validity claims must be fulfilled: (1.) An utterance must be *understandable*. If the partner cannot understand the utterance, then he or she cannot answer (respond) appropriately. (2.) The utterance must be *correct*, i.e. the expressions used must be the correct ones to express the situation (normative rightness). (3.) It must be *true* – the expressed situation must correspond with reality (propositional truth), (4.) It must be *sincere*, i.e. be meant in the manner in which it was expressed.

The understanding of intersubjective acts of human communication is directed at three levels, on that of (a) linguistic utterances, (b) actions, and (c) body-embedded expressions. Linguistic utterances have an evident (locutionary) communicatory aspect. Depending on the intention, they can use this grammatically clearly visible structure to mean something different: This represents their not-immediately-evident (illocutionary) force, which prompts those who are addressed to react in one way or another *to one and the same grammatical structure* of an expression. And they are part of an (perlocutionary) action; perlocutionary acts are performed with the intention of producing a further effect.

We do not need third-person observations and experimental studies to understand how understanding functions. We can analyze the ordinary language that we ourselves use, in the 1st or 2nd person, i.e. as a participant; here, we can find all the elements of linguistic and communicative action. In a first step, we can determine that utterances such as requests, orders, questions, insinuations, accusations, approval, declarations, fabrications, etc. are regulative, imperative, expressive, objectifying, innovative, etc. actions with the intention of (a)

3-levelled semiotics and classical variations of the "abstractive fallacy"

The *pragmatic turn* founded the intersubjective-communicative character of thought, experience and research and was therefore able to avoid the omnipresent subject-object dichotomy and its unavoidable consequences, solipsism and objectivism or how Thomas McCarthy characterized the monological observer perspective:" "The monological approach preordained certain ways of posing the basic problems of thought and action: subject versus object, reason versus sense, reason versus desire, mind versus body, self versus other, and so on." As opposed to the linguistic turn, the pragmatic turn enables an understanding of human language and communication that is coherent with our communicative experience *and* with our subjective life. Such an understanding of language and communication should allow us to describe the *intersubjective-communicative character of thought, experience and research* in a non-reductionistic manner, as well as to describe the everyday prerequisites for successful communication, i.e.:

- the simultaneous understanding of identical meanings in two interacting partners, as expressed in successfully coordinated activity
- the differentiation between deep and superficial grammar of a statement along with differentiation between locutionary, illocutionary and perlocutionary speech acts with which the statements are made
- the differentiation between communication-oriented action and strategic manipulation of the communicating partners
- the critical judgment of the validity being claimed when making a particular statement

Only with such an *universal-pragmatic* concept of language and communication (Habermas 1979), one which is neither subjectivistic nor objectivistic-naturalistic, can we sensibly determine whether similar structural features exist in the non-human realm.

It therefore makes little sense to refer to sign use in the communication processes of plant or bacterial lifeworlds, all the while presupposing an objectivistic language and communication concept, and using an empirical methodological ideal to explain the evolution of communicative interactions from the amoeba to humans. This would lead to the dead-end of the solipsistic subject of knowledge and hopeless entanglement in the subject-object dichotomy of objectivism/ physicalism/ naturalism.

The reverse pathway is correct, beginning with humans, and human self-understanding, which must be coherent with the used concepts of "language" and "communication".

The semiotics of Ch.S. Peirce is helpful in this respect. It can provide the irreducible conditions for the appropriate analyses of sign-usage and linguistic communication via a 3-levelled semiotics.[4]

According to Peirce, a sign (1) designates something (2) to an interpreter (3). Semiotics is therefore an irreducible 3-levelled relation of syntactic, semantic and pragmatic rules. *Each of the 3 elements of the sign function already presupposes in its function the other two*. According to Peirce, all those who reduce this principally irreducible 3-levelled relation to 2

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establishing a commonly held understanding *about something* and (b) establishing an *intersubjective relationship of action that enables a common, coordinated* action or appropriate division of labor (Witzany 2005).

[4] The decisive change versus Kant's solus-ipse subject of knowledge (and subsequently the objectivism in logical empiricism) is the "community of interpretation" in the "community of investigators". *Scientific knowledge does not exist for a solipsistic cognitive subject, but only for members of a community of interpreters.* With this, Peirce adheres to the intersubjective-communicative character of thought, experience and research. (This is coherent with Wittgenstein's analyses of "obeying a rule".)

Intersubjective validity of scientific knowledge requires therefore linguistic communication of meaning and consensus formation via statements. Those who apriori neglect or feel they can negate the intersubjective character of linguistic communication (and it presupposes a *historically evolved and reconstructable linguistic community*) will fall victim to an *abstractive fallacy* (Apel 1974).

or 1 level, have fallen victim to an abstractive fallacy. The most common of these are (Apel 1974):

- Linguistic platonism of scientific models. Signs (1) without the corresponding reality (2) and without sign interpreter (3): Abstraction from the (apriori of the) linguistic community. The *logic of science* in the linguistic turn: the linguistic expressions or the explanatory model are the reality.
- Idealism of consciousness. (3) without (1) and without (2): Abstraction from the linguistic community; Descartes, Kant, Fichte, Hegel, Husserl: subjective/objective reason is the reality. Language is only a secondary means.
- Pansemiotics, metaphysical semioticism. (3) and (1) without (2): Semiotic idealism: signs and sign interpreters are reality. Everything is sign.
- Realism, materialism, pre-Kantian metaphysics. (2) without (1) and without (3): Reality is solely the physical-chemical laws of the material world. Sign use and sign interpretation are pre-scientific constructions.
- Positivism of the sensory data. (2) and (3) without (1): Leibniz, Locke, Berkeley, Hume, Popper. The material function of the sensory organs adheres to a universal syntax that is identical to the laws of physics and chemistry.
- Solipsism, realism, ontosemantics, constructivism, systems theory. (2) and (1) without (3): Subjectless, syntactic-semantic phase of the *logic of science* in Wittgenstein 1, Carnap, Russel, Tarski: Abstraction from (apriori of) the linguistic community.

Pragmatic philosophy of biology: Biologists as performative participants

As opposed to the above, the pragmatic philosophy of biology integrates the irreducible 3-levelled semiotics; it also integrates the formal-pragmatic conditions for the possibility of successful, rule-governed sign-mediated interactions, developed in line with Wittgenstein 2, Austin, Searle, Apel and Habermas.

This approach avoids the abstractive fallacy and allows us to understand linguistically and communicatively structured and organized living nature in a non-solipsistic, non-objectivistic manner. It can therefore methodologically anchor *biology as an understanding social science* whose descriptions are not in a 3rd person perspective but rather in the perspective of *performative participants* (1st/2nd perspective) of a planetary communicating community of living nature (Mitwelt).

The pragmatic philosophy of biology enables a clear distinction between life and the non-living. The unbridgable gap between a mechanistic and the communicative concept is that rsi's are restricted to living individuals (-in-populations) and do not primarily involve natural laws, such as those that are fundamental preconditions for metabolism. The decisive difference between natural laws and semiotic rules is that every living being underlies natural laws in a strict sense. Semiotic rules may be followed or not, may be changed or not, may be generated or not. The fundamental difference between living nature and non-living nature is the difference between rsi's and natural laws (Witzany 2005).

Invitation to cooperative research: understanding communicative competences of plants

If we deal with “language” and “communication” in multilevel communication processes of plants we could try - and this project can take place in a transdisciplinary form - to describe sign-use, to extract the semiotic (syntactic, semantic and pragmatic) rules that sign use follows. Perhaps we can even find some rules by identifying the non-following of rules and its consequences. The semiotic rules we will find in describing sign-use within plants will differ from those found in describing sign-use between plants of the same species, or those between different plant species. These semiotic rules of sign-use will be different from sign-use between plants and (a) bacteria, (b) protoctists, (c) animals and (d) fungae.

But, step-by step, we will be able to discover the true nature of rule-governed sign-mediated interaction in plants, i.e. the *communicative competences* of plants. This is the correct way to understand the plant kingdom: not as an (quasi-extraterrestrial) 3rd person observer, but as *performative participants* in the global community of communicating nature, i.e. the *Mitwelt* that all living beings share.

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