Comparing the Long-Term Evolution of "Cognitive Invariances" in Physics with a Dynamics in States of Consciousness

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Abstract

It is shown that the evolution of physics can in several regards be described by elements of "regression", i.e., that within a certain tradition of ideas one begins with the construction of most "plausible" statements (axioms) at hand, and then "works onself backwards" with respect to developmental terms. As a consequence of this strategy, the further work proceeds along such a "regressive" path, the more one arrives at concepts and relationships which are unexpected or even counter-intuitive in terms of our everyday experiences.

However, a comparable phenomenology is well known from studies on states of consciousness. In particular, the evolutionary logic of the constructions of major "cognitive invariances" in physics, which is in part due to ever increasing rates of data processing, is mirrored in a logic of states of consciousness which deviate from a "normal" state of daily routine along increasing levels of central nervous arousal.

Examples are given from the evolution of physics, and future perspectives are briefly outlined on the basis thereof.

(Keywords: physics, evolutionary logic, arousal, states of consciousness, constructions of invariances)

Introduction

> ...Sometimes I have the impression as if there had developed a relation between research and discovery similar to the one between a drug addict and the drug he consumes.
>
> Very peculiar. Then the whole modern change of the world would be ...
>
> ...the result thereof; and is, moreover, another aspect thereof ... velocity, overstimulation of the senses.
>
> Paul Valéry, *L'Idée fixe*

The fundamental laws of physics are expressed in the form of so-called "variational principles", or as "symmetry principles", for example. However, in all cases do these basic laws refer to something which is "conserved" or held at an "extremum" (i.e., a maximum or a minimum). In other words, the most fundamental axioms in physics, from which all further consequences can be deduced, constitute expressions on some observed invariant behavior, which one can therefore also identify as "cognitive invariances". (Grössing 1993)

However, like in cognition, which is essentially characterized by references to invariances and recursive variations of, or deviations from, such "canonical" references, one can observe very similar processes in the history of physics: said "invariances" often do not remain invariant over longer periods of time. For example, in the physics of fundamental particles and forces, the twentieth century has repeatedly seen formulations of "symmetry principles" (equivalent to "conservation laws" for some "quantum numbers"), which eventually have been found to be "broken". Thus, more encompassing symmetry principles had to be constructed (equivalent to more complex conservation laws for a larger set of quantum numbers), which eventually turned out again to be "broken" at very high "resolutions" (i.e., at very high energies). Thus, although the fundamental laws are always characterized by "cognitive invariances" that are thoroughly investigated, they eventually demand refinements. In other words, the evolution of high energy physics is always characterized by *recursive variations* of statements on *invariances*. This pertains also to all other areas of fundamental physics.

Interestingly, on a formal level, such developments seem to be related to the dynamics of increased data processing, something which has been studied also in the context of individual persons and their corresponding states of consciousness. In this paper, I shall first highlight some results of this latter research and then try to translate some of the findings into the transpersonal regime of information processing. In particular, I shall then focus on long-term developments in physics. What I basically want to outline here is that an intrinsic logic in the evolution of physics is paralleled by, if not identical to, a logic in the dynamics of "states of consciousness", due to a comparable logic of complex information processing in both domains.

1. A Cartography of States of Consciousness

In his seminal 1971 paper in *Science* (Fischer 1971), and in many subsequent ones, the US-American psycho-pharmacologist Roland Fischer has presented a cartography of states of consciousness, which – to my knowledge – until today has remained the only attempt to do so within a scientific approach. Various states of consciousness are thereby mapped on a perception-hallucination continuum of increasing excitation or "hyper-arousal" (on the left hand side of Fig. 1), and on a perception-meditation continuum of increasing central tranquilization or "hypo-arousal" (on the right hand side of Fig. 1).

On the perception-hallucination continuum of increasing arousal of the sympathetic nervous system ("ergotropic arousal"), a person cortically interprets changes (drug-induced, or by sensory overstimulation, and the like) in his/her subcortical activity as creative, psychotic, and ecstatic experiences:

"These states are marked by a gradual turning inward toward a mental dimension at the expense of the physical. The normal state of daily routine, our point of departure, is followed by an aroused, creative state, which can be characterized by an increase in both data content ... and rate of data processing ... . However, in the next aroused state on the continuum, the acute schizophrenic [or rather, 'hyperphrenic'...] state, a further increase in data content may not be matched by a corresponding increase in the rate of data processing. While the creative state is conducive to the evolution of novel relations and new meaning, the psychotic 'jammed computer' state interferes with the individual's creative interpretation of the activity of his central nervous system (CNS). At the peak of ecstatic rapture, the outside (physical) world 'retreats to the fringe of consciousness', and the individual reflects himself in his own 'program'." (Fischer 1971)

As there exists a mutually exclusive relationship between the sympathetic and the parasympathetic nervous systems, or the "ergotropic" and the "trophotropic" systems, respectively, it is justified to introduce a separate perception-meditation continuum of increasing trophotropic arousal ("hypoarousal") that complements the perception-hallucination continuum (Fig. 1). Starting again from the "normal" state of daily routine, deviations from it along the tranquil perception-meditation continuum, i.e., gradually increasing hypoarousal, may symbolically be interpreted via Far-Eastern interpretational patterns as Zazen, Dharna, Dhyan, and, ultimately, Samadhi. (Fischer 1971, 1995) Particularly with regard to arriving at Samadhi in Kundalini Yoga, but also in some "Western" contexts, one can show that regression towards the "Self" re-enacts neuronal patterns which originally derive from perinatal structures. (See the recently added innermost circle of Fig. 1 and its discussion in Grössing 1997.)

Fischer points at the intrinsic emergence of "self-programmed invariances" during a person's development, a genuinely constructivist feature which I intend to compare lateron with the self-organized invariances emerging throughout the evolution of physics: "Although the newborn infant's only reality, in the beginning, is his CNS activity, he soon learns, by bumping into things, to erect a corresponding model 'out there.' (...) This gradually learned and projected model, then, is the re-presentation of a world ordered and stabilized by self-programmed invariances." (Ibid.)

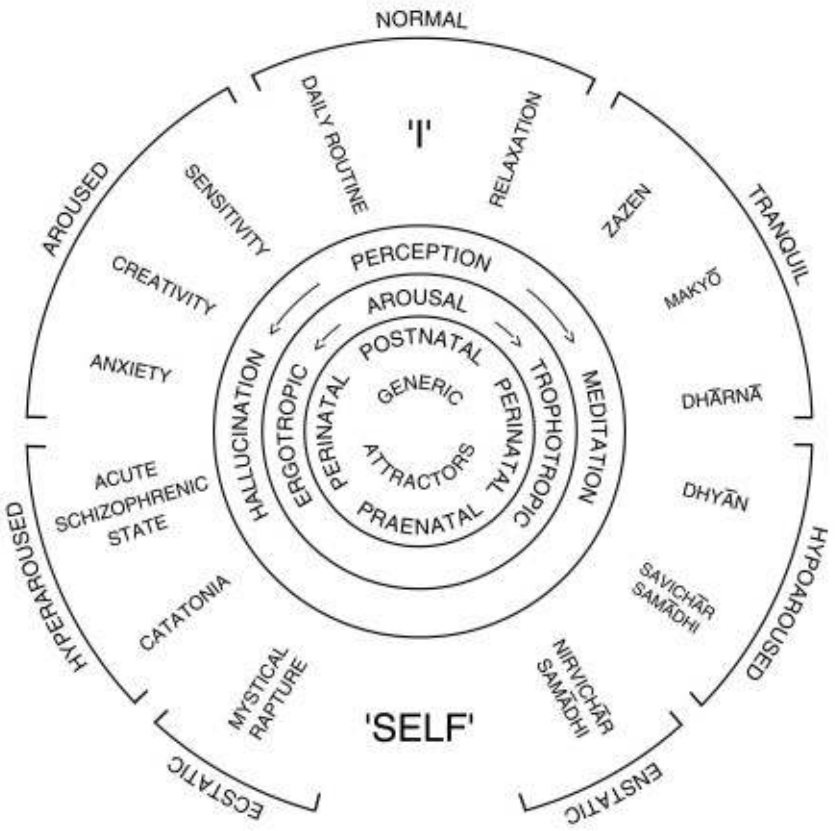

Fig. 1: The "Fischer spectrum" of states of consciousness – the arousal-state-bound setting in which constructions of cognitive invariances emerge. It is mapped on a perception-hallucination continuum of increasing central hyper-arousal or excitation (on the left hand side), and a perception-meditation continuum of increasing central tranquilization or hypo-arousal (on the right hand side).
Each night while asleep we repeatedly travel through revolving excited (rapid eye movement or REM) and a tranquil (delta or slow-wave EEG) series of sleep stages, experiencing creative as well as stereotyped dialogues between the socially programmed "I" and the biologically programmed "Self". Note that the upper third of the Fischer spectrum depicts cognitive states of consciousness, whereas the lower two thirds refer to states of consciousness that do not necessarily depend on (rational) cognition. Increasing arousal on both continua is paralleled by increasing sensory over (voluntary) motor ratios. (After Fischer 1971, 1975/76, 1995.)
The additional innermost circle refers to hypothesized neuronal systems first activated around birth and thereby developing into "attractor basins" for neuronal phase space which can be re-enacted throughout life, like, for example, through the practice of Kundalini Yoga. (Grössing 1997)

Fischer has demonstrated in his numerous papers that, and how, the constancy of the "I" of daily routine (a symbolic or perceptual-behavioral (cortical) interpretation, or metaprogram, of subcortical activity) is interfered with as one moves along the perception-hallucination continuum from the "I" of the objectified physical world to the "Self" of personal experience. Analogously, the perception-meditation continuum also involves such a departure from the "I" to the "Self", so that both continua might also be called "I-Self" continua. Moreover, Fischer argues in the sense of constructivism that "I"-"Self" communication is the creative source of art, science, literature, and religion.

The separateness of constructed objects and subjects is in this framework a reflection of the relative independence of cortical interpretation from subcortical activity. However, when departing along either continuum from the "I" toward the "Self",

> "the separateness of object and subject gradually disappears and their interaction becomes the principal content of the experience. This interaction, again, is a reflection of the gradually increasing integration of cortical and subcortical activity. In this state of Unity, the separateness of subject and object that is implicit in dualistic, Aristotelian logic and language becomes meaningless; only a symbolic logic and language can convey the experience of intense meaning. Apparently, then, *meaning is "meaningful" only at that level of arousal at which it is experienced, and every experience has its state-bound meaning*.
>
> During the "Self"-state of highest levels of hyper- or hypoarousal, this meaning can no longer be expressed in dualistic terms, since the experience of unity is born from the integration of interpretive (cortical) and interpreted (subcortical) structures. Since this intense meaning is devoid of specificities, the only way to communicate its intensity is the metaphor; hence, only through the transformation of objective sign into subjective symbol in art, literature, and religion can the increasing integration of cortical and subcortical activity be communicated." (Ibid., my emphasis)

As Fischer notes, the "Self" along the perception-hallucination continuum and the one along the perception-meditation continuum are one and the same. Moreover, levels of arousal still higher than those associated with mystical rapture result in epileptic seizures and may culminate in death:

> "The closeness of ecstatic (orgasmic) experiences to epileptic seizures and death is evident in the French expression *le petit mort* for orgasm. ... With the erotic smile of St. Teresa (on the statue in S. Maria della Vittoria, Rome) and Lemaitre's photograph of 'Ramakrishna in samadhi' in mind, ecstatic states seem to represent the ultimate meaning through self-creation of oneness with a Universe, that is oneself." (Fischer 1995)

A whole range of empirically testable predictions supports the validity of the Fischer spectrum, like an increasing sensory-to-motor ratio with increasing arousal, for example, which thus also serves as a measure of hallucinatory intensity. Moreover, the electroencephalogram (EEG) displays *desynchronization*, i. e., a functional independence of neuronal elements, along the perception-hallucination continuum of increasing arousal, whereas on the perception-meditation continuum of decreasing arousal the EEG shows *synchronization*, i. e., a homogeneous time domain that is obtained during rhythmic experiences (of chanting the same words, for example). Fischer concludes:

> "Mystical tradition shows that 'knowledge' is expressed here in culturally conditioned specific forms that are both true and limited, as is the human condition, in general. The Buddhist 'Void' experience - or consciousness without content - is a sophisticated way of a-voiding pre-programmed genetic and social 'learning'." (Ibid.)

Arousal-State-Bound Invariances Emerge in Cognition as well as in Physics

Now, what does all this have to do with the evolution of physics? To answer this question, we first note that already the earliest forms of "natural history", or the pre-scientific exploration of nature (like in alchemy, for example), has been characterized by a tendency to increase amounts of "data" as well as the "data processing rate". (See, for example, Mircea Eliade (1980), who describes the aimed at "acceleration of time" of the alchemists. See also Grössing 1993.)

This tendency has been maintained, and more: it has lead to continually accelerated data processing, up to the present-day "data explosion" in world wide media. However, what does it mean when we speak of steadily increased data amounts or processing rates at a neuronal level (of a single person)? With Roland Fischer we can give an answer by pointing at the corresponding increased arousal of the central nervous system. Such an increase corresponds to a movement in the Fischer spectrum from the normal "I" state of daily routine towards hyper-arousal along the perception-hallucination continuum as discussed above.

If we thus imagine (merely metaphorically!) humanity's knowledge about the world (or only a small fraction of it dealing with, say, physics) as if it accumulated in *one* big brain, then the most conspicuous characteristic of this accumulation process would be, if averaged over sufficiently long periods of time, a steady increase in ergotropic arousal. Of course, this is by no means to say that physicists are - individually - on a path towards ecstasy, or the like, but merely that they employ domains of neuronal organization which in the course of their innovative phases do include such a path: While Galileo, for example, studied the behavior of a stone that was dropped from the top of a ship's mast, with the ship moving across the sea with constant speed, Einstein considered the behavior of the observer himself being enclosed in a freely falling elevator, and Wheeler later enquired what would happen to an astronaut falling into a black hole. Evidently, the problems and metaphors chosen illustrate a development away from ordinary day-to-day experiences towards ever more "remote" areas. In other words, as one moves towards increasing arousal, new "invariances" emerge, both in constructions during the cognition of an individual, and in the evolution of physics, thus pointing at a possible relationship between the two phenomena. However, let us now look at the presumed relationship in more detail.

2. An Intrinsic Logic in the Evolution of "Cognitive Invariances" in Physics, and its Relation to States of Consciousness

The primary categories which are the warp and woof of any discussion on the foundations of theoretical physics, are those of space, time, and causality. The conceptions of space (and later of space-time) at any time in history have been based on the prevailing standards of geometry. Historically, the first formal type of geometry has been the *metric* geometry of classical Greece, i.e., Euclidean geometry. Already implied by the latter, but explicitely worked out only in the seventeenth century, was the second type, i.e., *projective* geometry. Then, in the nineteenth century, *topological* geometry was developed. In comparing these three types of geometry, it turns out that topology is the most basic type, from which both Euclidean and projective geometry can be deduced: topology encompasses the two other types of geometry.

Now, Jean Piaget (1970) has posed the question, "whether during the development of a child's thinking geometry follows the historical or the theoretical order. Or, more precisely: will we find that at first Euclidean intuitions and operations will develop, and only later topological intuitions and operations? Or will we find the reverse order of succession?" (Ibid.) One might be tempted to assume a repetition of Haeckel's "biogenetic principle", i.e., that the child's "ontogenetic" developments of geometric conceptions are repeated "phylogenetically" within the evolution of science, that is, that also children first become acquainted with Euclidean geometry before being able to make decisions based on topology. However, it turned out that the opposite holds: "Indeed we find that the first intuitions are topological ones. Also the first operations – division of space, ordering within space – are very much closer to topological operations than to Euclidean or metric ones." (Ibid.) For example, children under four years old in their drawings "do not maintain Euclidean distinctions, the different Euclidean forms, but topological distinctions... . Closed forms are drawn as closed ones, open forms as open ones." (Ibid.) These children are further capable of maintaining the relations of "inside", "outside", or "at the border".

This experimentally established fact also confirms, among other things, an important distinction of the semiotician W. A. Koch between *genesis* and *metagenesis*. Metagenesis manifests itself in scientific (but also in poetic) reconstructions of genesis, where the developmental state closest to the present functions as the point of departure:

> "The rudiments of cognitive adventures, conscious thought, the more elaborated forms of scientific reflection, all seem to follow a special path of dynamic heuristics. In the successive and continuous unravelling of cognitive mysteries, in the 'methodical' (re)construction of cognitive maps of the world, or of parts of it, man's modelling and analogizing capacities seem invariably to obey, in some form or other, the law of the metagenetic pathway. It exacts that man starts out from the structure 'near at hand' in order to arrive, via various strategies of 'transposition' of structures, at the 'farthest possible edge' of the continuum of a special cognitive map. The 'near at hand' may vary according to the evolutionary status of a particular train of thought; it will be characterized by the first terms of the following constellations: 'the most familiar structure in everyday life' vs. 'the least familiar', 'the least complicated structure' vs. 'the most complicated structure', 'the most recent phenomenon – from the point of view of conscious or unconscious

> evolution' vs. 'the most distant phenomenon – as to evolutionary emergence'. There seems to be a certain kind of irreversibility in the ordering of steps taken on this metagenetic pathway." (Koch 1983, p. 483)

One can therefore say that the developmental history of geometry proceeds along a metagenetic path: the perceptually/genetically more "at hand" is Euclidean geometry, while the more general and encompassing field of topology is arrived at along a "regressive path". Koch's representation of scientific progress in terms of both "progressive and regressive integration" manifests itself also in the *simultaneous differentiation and generalization* of a specific field: the new, "more fundamental" field must include the old one as its part. One can thus say that fundamental laws of nature are products of metagenetical regression with a broad potential for applications due to its complexification. In other words, while physics at any time in its history has made use of the *formal* constructions of "cognitive invariances", their *contents* have changed due to the dynamics of progression and regression.

However, progressive and regressive, differentiating and generalizing integration also circumscribes the different functional characteristics of left and right hemispheres of the brain, respectively. As mentioned in the previous chapter, increasing hyper-arousal corresponds to desynchronization of EEG amplitudes, while increasing hypo-arousal is characterized by their synchronization. As a consequence, progressive and regressive integration are obtained through a permanent alteration between hyper- and hypo-aroused states during a movement away from the "normal" state of daily routine. Such alterations are known from psychopathology and –pharmacology as "rebounds", which guarantee (in the healthy person) that a person will not get "stuck" in a particular arousal state. In this regard it is also interesting to observe that along with increasing (de)synchronization of hemispheric differences in EEG amplitudes, also the dynamics of temporal judgements becomes understandable. While the right hemisphere always acts in arousal-state-bound "real time" (Ivanov 1983), the left hemisphere acts as descriptive, controlling unit performing "symbolic operations", including procedures to measure or estimate passing time. As measured spatial units neuronally reduce to relations between oscillations, so that *operationally* it is the *temporal* processes which govern our cognition of space and time (although *symbolically*, or *descriptively*, time is considered in terms of the spatial categories of order and length), one can say that *the metric geometry of space and time is primarily dealt with by the left hemisphere.* (My use of the terms "operational" and "symbolic" is identical to the one in Varela 1979.)

Let us now assume an electrochemical (or simply "neuronal") network, which is divided into two different halves, each characterized by its functional characteristic of a differentiating and an integrating type, respectively, and with both halves connected via some "bridge" for mutual information transfer. What happens in such a system, which is also assumed to proceed according to the temporal characteristics as described above, if one increases its "arousal", or data volume and processing rate, respectively? At first, the differences in the "time scales" of both halves will become manifest: the left half will have more and more difficulties to cope analytically with the flood of data from the right half, i.e., *operational* and *symbolic* processing velocities will increasingly diverge. Extrapolating such a scenario to its extreme, sooner or later a point will be reached which can be characterized by the appearance of an unsurmountable "limiting velocity": the different processing velocities of electromagnetic and molecular transmission will finally diverge so drastically, that the latter can be ignored in comparison to the former. One can therefore postulate that the decoupling of electromagnetic and chemical transmission will thus lead to a state "without geometry", characterized by the operational dominance of the right hemisphere.

[Note that there also exists a similar, more basic argument, that does not refer to hemispheric differences, but to the brain's information processing in general: Walter Freeman (1990) distinguishes between high-velocity long-distance transmissions based on an "oscillatory common carrier wave with minimal phase dispersion" on one hand, and much slower "local wave transmission" on the other hand. Concerning the latter, Freeman's data "suggest that the cortical mantle can be likened to a *relativistic medium*, in which there is a *limit on the rate of transmission of information* within it" (my emphasis).]

Such a scenario is actually confirmed for the cartography of states of consciousness in the Fischer spectrum: if one increases arousal along the perception-hallucination continuum, a narrowing of the visual horizon is reported, with a consecutive "contraction of space and time" (Fischer 1971, Grössing 1993), which may be described mathematically by transformational systems as they are known from non-Euclidean geometry. We thus arrive at a very intriguing *analogy* to the theory of relativity in

physics: the more one approaches an operational limiting velocity, the more space and time become contracted (compare: Lorentz contraction and time dilation in the special theory of relativity), until finally, in "ecstatic states" the limiting velocity is reached and the categories of space and time become irrelevant. A particularly impressive example for this latter "disappearance of geometry" is known from the physics of black holes in the general theory of relativity, where the space-time geometry beyond an "event horizon" (sic!) loses any meaning. Note that we are dealing with an *analogy* here, which in no way is to be understood as causal link. My point exclusively aims at a *comparable evolutionary logic* in the two fields, because of basic systemic similarities, where, however, the two fields need not have anything to do with each other in a *causal* sense.

If in our information processing ("neuronal") system such an unsurmountable limit is reached, then an observer's attention may eventually turn towards other processes, i.e., processes which are not concerned with the symbolical descriptions of operational processes in one hemisphere by the other hemisphere, but processes concerning the symbolical description of the interaction between both halves, i.e., a metalevel description: symbolical description now has to deal with processes occuring, more or less "synchronously", in both halves. As a consequence, during such an integration of right and left hemispheres a new form of causality emerges: *linear causality*, as it was typical for the description of one half by the other, now is substituted or extended on the metalevel by a *circular causality* describing their mutual influences. (For a discussion of circular causality and its role in the constructions of observers, see H. von Foerster 1985, for example.)

We can thus reconstruct an *evolutionary logic in the understanding of space, time, and matter*. The alchemistic picture of nature, as well as the one of Aristotelian physics, is a vitalistic, subjectivistic one: "A stone ... 'opposes' the attempts of a horse to drag it away, and ... this resistance can be 'overcome', if the tie force is transferred via a system of rollers." (Prigogine and Stengers 1981) In Aristotle's general theory on movement, *any* movement is caused by a mover, and not only a forced one. (Feyerabend 1977) One can easily recognize a state of symmetry here: as the movement of a person requires an inner impulse, so does the movement of matter. However, in Newton's physics, the absolute categories of space and time, which exist *per se* and are of divine origin, determine the behavior of matter through their laws. Mach and Einstein later pointed at the corresponding asymmetry in Newton's physics: while space and time act on matter, the reverse does not hold. In the special theory of relativity, the first step is made towards the integration of said reverse option into the description of nature: the measurable quantities of space and time are not absolute any more, but depend on the standpoint of the observer, i.e., on a reference frame which is tied to the presence of matter. In the general theory of relativity, then, this presence becomes the central issue. It causes the curvature of space-time, and, in turn, the trajectories of matter are determined by Riemannian space-time geometry. One can thus observe a *logic of evolution* (Koch 1983, Grössing 1993) in the developments of our views of nature: i) symmetric/subjectivistic scheme in Aristotelian physics and alchemy ® ii) asymmetry in Newtonian physics between space and time on one hand, and matter on the other ® iii) integration via mutual influences of space-time and matter in the general theory of relativity. (See Table 1.)

Here we can also continue by observing an evolutionary logic in the *development of the concepts of causality* (see also Table 1), which – for the time being – ends up in circular relations, not only in general relativity, but also in quantum theory (Grössing 2000): i) subjectivistic "foundation" by a personification of nature (i.e., as Mother, Demon, God, etc.) ® ii) linear description of nature (i.e., of planet trajectories in Newtonian physics, independently from the observer's frame of reference) ® iii) circular, holistic causality (like, e.g., the relation between space-time and matter, or between a quantum and its context as defined by an experiment's apparatus).

In what I call an "echology" (Grössing 1993 and 1997) of comparative developmental studies, one focuses on the "echoes" between different systems of knowledge, as they are created by the *repetitions of specific kinds of (structural or organizational) change.* In the examples given here, we note the evolutionary logic in the uses of historically varying "neuronal" repertoires: first Euclidean geometry, then non-Euclidean (Minkowskian and Riemannian) geometry; first the space-time contractions in the special theory of relativity, then the "extreme" physics of black holes or "cosmic wormholes" in the general theory of relativity; first classical, linear causality, then circular causality (which one may also describe as "holistic" – in the sense of "based on a network of mutually interdependent feedback loops"). *All these developments are accompanied by corresponding physical developments of new neuronal connections (or forms of organization, respectively) according to a general increase in neuronal processing activity.*

This constitutes the evolutionary logic of some of the major cognitive invariances in the sciences of the twentieth century, which one may also associate with what Gerald Holton termed "themata" (Holton 1988). It may be described by echoes, which one could also find in conditions of industrial production, communication technology, or in art styles. In general, no single one of these manifestations will have a historical priority: the echoes result from processes of self-organization; as such, they cannot be described by the "old", linear causality, but can be understood only in a holistic context, where the developmental processes in the various domains of knowledge "stabilize each other", so to speak, and create what one might also call the *zeitgeist*.

Conclusion and Outlook: Towards New "Resolutions"

The long-term development of some of the major "cognitive invariances" in physics has been shown to follow an intrinsic, evolutionary logic. If one tries to project this logic into the future, a few themata can be guessed, which may become relevant. Let us consider one "direction" in the evolution of physics from (static, linear) "being" – as reflected in time-reversible "universal laws" - to (complex, dynamical, nonlinear) "becoming" in time-irreversible processes (Prigogine 1980). In this case, one starts from linear mappings between two domains of "being" (like the right and left hemispheres) and thus projects the "being", and later the "becoming", onto a static background: the "being" of the ahistoric and universal tools of science. Consequently, one may expect as a next step one of the *projection of the "becoming" in nature onto the "becoming" of the tools of science*. (Table 1)

	symmetry	**asymmetry**	**integration**
matter in space and time	subjectivistic (Aristotle, alchemy)	Newtonian physics	general theory of relativity
causality	personalized	linear	circular, holistic
theory of science	*being* being	*becoming* being	*becoming* becoming

Table 1: Manifestations of a *logic of evolution* in the developments of physical themata. Under "theory of science", the development of the relation between the *description of nature* (italics) and the *description of the used neuronal, semiotic, or socio-cultural "tools"* (below) is indicated. (Grössing 1993)

One example for such a projection is the study of the relation between the description of nature and the basic "tools" for this description (like thinking, language, computation, etc.). In a very recent paper, for example, such a relation has been addressed with regard to quantum theory, logic, and computation: see D. Deutsch *et al.* (1999). The development "from being to becoming" usually occurs before the background of a being, namely the "being of science", as it is often assumed to represent universal, unchangable truths. Only the recognition of the *historicity of any scientific practice*, which itself has an intrinsic logic, too, leads to questions of an *echology*: what are the relations between the *becoming* of our understanding of nature and the *becoming* of its neuronal, semiotic, or socio-cultural "tools" and preconditions?

Finally, what is the relevance of such "echological" questions to constructivism, and *vice versa*? Ernst von Glasersfeld (1988) interprets a quotation by Jean Piaget as the "fundamental constructivist principle", namely, "that the human mind [Verstand] organizes reality by organizing itself." (J. Piaget 1937; for a critique of v. Glasersfeld's interpretation, see G. Grössing in E. v. Glasersfeld 1998.) However, from what has been discussed here, it is legitimate to ask again with respect to constructivism: who constructs? I have tried to stress in this paper that there exists a logic of evolution in the sciences, which is definitely bound to transpersonal regimes. "The human mind", in other words, is never the mind of an "individuum" – this holds even for a single living person (compare R. Fischer 1990) –, or, as Gotthard Günther (1980) has worked out so thoroughly, the history-pervading concept of a single ("universal") mind is flawed from the outset on logical grounds. Günther's multi-valued logic is exactly based on this insight that there is not one "mind" facing "the universe", but that there exist many minds constructing their universes according to their points of view, and producing networks via these constructions. In this light, then, science in general must be seen as such an intersubjective network, which is, however, highly self-referential: science is a "subjectual" organization that iteratively constructs and modifies its descriptions of reality. Thereby, self-organized invariances emerge that

intimately relate to the major "themata" of science, which in turn undergo developmental stages as I have tried to indicate them here for physics.

Said development is presently characterized by ever higher "resolutions" of scientifically studied objects as well as of the investigators' "I"-states. With the scientific pictures and models of the latter today becoming more and more "dissolved" in the state of a "Self", we have clearly arrived at a qualitatively new phase of development. This makes it possible also to throw a new light on Heinz von Foerster's famous dictum: "The laws of physics, the so-called `natural laws´, can be written by us. The laws of brain functions, or – more generally – the laws of biology must write themselves." (H. v. Foerster 1985, p. 67, my translation) Von Foerster argues that a theory of the brain *T(B)* would have to be developed, which explicitely is a function of a brain: *B(T),* and, as a consequence, such a theory would write itself: *T(B(T)).* As a result of the foregoing investigations, I propose to substitute the "one brain" *B* by science's connectionist network *N* of brains (and computers, etc.), and to include the temporal aspect of theory formation. Thus, one arrives at science's self-referential ("subjectual") nature with a developmental logic of its own. As this refers to science generally, and not only to biology, it even applies to physics. In other words, also the laws of physics must write themselves.

What may change if physics will be regarded as a subjectually based constructivist-biased discipline? Along with ever increasing automatization and networking, I would expect the emergence of a growing independence from the "unconscious in physics" as we have it today, i.e., from the constraints given by implicit cognitive routines, or, even more radically, by what it means to be a human person.

Which direction such a development may take, is certainly an open question. Possible, though often very naively-utopian, scenarios include a development towards "spiritual" machines (see W. Gibson 1988, or R. Kurzweil 1998, for example), or towards overcoming evolution-based human nature in new bio-technological "solutions" (as in M. Houellebecq 1998, or P. Sloterdijk 1999). Any physics constructed by the corresponding would-be subjectuals will yet have to be imagined.

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