

# Actio non est Reactio

An Extension of the Concept of Causality towards Phenomena of Information

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**Abstract:** The goal of this article is to subsume the concept of information under a more general heading. One basic notion which can be generally applied is the term "causality". This concept is used in everyday language, in mythological thinking, and in scientific languages as well. Therefore there exists some chance to adapt it to the context of information, to extend it towards our needs, and to explicate it more precisely. We think it promising to look for information under this perspective, and to work out the differences, similarities, and the particularities of causality of information processes compared to purely physical ones. The advantage of this perspective is the unfolding of a larger range of analysis than is opened by physics. It allows for the inclusion of different causal relations which cannot be viewed by classical physics.

Key Words: causality, determinism, mechanism, information

## 1. Causality in Physical Processes

Let us sketch the main argument. For human beings it is essential to be able to understand the world; the reason for understanding is the need to control the world, the reason for controlling is the necessity for survival (although one should not reduce human activity to this general goal). According to Kant, the principle of causality is the a priori of how we talk about this possibility of control (although we have to modify its precise content). Cassirer taught us that the content of this principle is not only applicable in physics, but in everyday modern (and, as we see it, postmodern) and mythological thinking as well. Nevertheless, the understanding of the principle has changed considerably over time. Here we will deal with the variations of the content of causality during the history of physics, and we will look for the difference between the physical and informational processes, and the implications of the causal principle.

Let us present a first, very general, definition of causality. Causality is the direct, concrete, and fundamental mediation of the connection between objects and processes, where one process (the cause) produces the other one (the effect) (Hürz: 208). In this definition, causality is seen by Hürz as a property of the outer world, a property of things and objects, of objective reality. It is not restricted to the physical world. It may be applied to a mythical understanding of the world as well, or to events of everyday life. Example: sorcery by analogy is a causal relationship. If one offers some cereals as a sacrifice to a god, and the god replies as wished by sending rain, the god's act is the cause of the rain. There is a cause (the sacrifice) and an effect (it is raining).

## 1.1. Causality in Classical Physics

Newton's (1643-1727) mechanical perception of the world was based on three principles (Vogel, 13):

1. The principle of inertia: a body on which no forces are exerted moves constantly in a straight line.
2. The principle of action: If a force  $F$  is exerted on a body of mass  $m$  and velocity  $v$ , the impulse of the body,  $mv$ , is changed, such that
$$\frac{d}{dt}(mv) = F$$
From  $F = 0$  follows the above principle of inertia.

3. The principle of reaction: If the force  $F$  which is acting on a body has its origin in another body, exactly the opposite force  $-F$  is acting on the latter.

Newton's classical mechanics used the concept of causality in an elementary way. If a force is acting on a body, by the principle of action the velocity of the body is changed in a unique way. The body is accelerated proportionately to the force exerted.

These principles - well-known by the Latin shortcut "actio est reactio" - imply the unique determination of the effect on the basis of a known cause. Newton's writings became the prototype for scientific reasoning in the future. Newton's axioms nourished Laplace's (1749-1827) fantasy about the omniscient scientist expressed by his "daemon": A daemon who has the complete knowledge of the state of the world at any single moment would be able to compute all future and past states. The astronomers mind of the 18th century represents an approximation of Laplace's daemon.

Newton had intuitively felt the limitations of the mechanical paradigm. He thought that God ultimately had to act directly on the solar system to keep it in order. This way of interpretation was common for many scholars of those times. Leibniz, Newton's competitor in being first in developing differential calculus, looked for other philosophical concepts to explain everyday phenomena, in particular human beings, mind, soul and creativity. In his main work "La Monadologie" the monads, related to Aristotle's "Entelechie", represent sensitive substances, furnished with wholeness and uniqueness, indivisible, connected to a body, and created by God (with God as the only exception). By this construction Leibniz tried to escape the reductionist view of contemporary science. His motive was less the need for a unified scientific perspective than the feeling that the mechanical view offered by Newton or by John Locke (who died in 1704) would belittle the glory of the creator, his creation, and his creatures. The young physics was not able to offer an explanation for the whole wealth of phenomena but restricted itself to the measurable; this was the basis for its overwhelming success later on. Nevertheless, in Newton's times physics offered an ideal of complete knowledge about the natural world which science could approach and approximate over time, while Laplace and others extended this ideal to an actual possibility and belief (Cassirer 1994, 143).

History of science has taught us that the law of causality has changed its content over time in important ways. Although at any time it meant a definite connection between events, and their division into the class of "causes" and the class of "effects", it was nevertheless strongly influenced by the corresponding views of

- \* what an event is,
- \* what is meant by reality, and
- \* what kind of determination brings the effect to the fore.

Cassirer characterizes Leibniz's view as "metaphysical mathematicism" (144). Nature has to obey the same laws and rules as mathematics without libilism. If this were not so, mathematics could not be applied to the physical world. Leibniz's causality means the conviction that mathematics and nature are identical. God has thought of his creation, and by thinking he has produced it. God's thoughts are determined by mathematical terms, by size, number, and measure. These notions do not represent mirrored reality but are its essential prototypes or archetypes. Thinking and being meet each other at the moment of creation. Human beings are able to think according to the thoughts of God and therefore are able to understand nature. But nature is a realm of derived, not basic forces; behind the causal relations of the physical world there is one basic cause, one simple substance, a primitive force, a "Monad". Leibniz's world is governed by them. Monads are able to self-develop and to self-unfold. Their utmost law is a law to change. A Monad conserves itself within this change.

Opposed to Leibniz' thoughts, David Hume no longer referred to simple substances. Reality is constructed by simple perception. If we look for a justification of the law of causality, we have to look at the realm of perception. But immediately we see that in this realm there is no hint of a general law of causality. Whatever we observe is the simultaneity of two events; usually we call them cause and effect, because from force of habit we call the link between them a causal link. "Objects have no discoverable connexion

together" (Hume, D., Treatise of human nature, Book I, Part III, Sect. VIII, quote. After Cassirer: 150). The explanation of causality cannot be found on another level than the psychological one, there is no a priori, metaphysical explanation available any longer.

Immanuel Kant found a deeper insight into the problem of causality. Like Hume he stated: "Denn man kann von einem Gegenstand und dessen Dasein auf das Dasein des anderen oder seine Art zu existieren durch bloße Begriffe dieser Dinge gar nicht kommen, man mag denselben zergliedern wie man wolle. Was blieb nun übrig? Die Möglichkeit der Erfahrung als einer Erkenntnis, darin uns alle Gegenstände zuletzt müssen gegeben werden können, wenn ihre Vorstellung für uns objektive Realität haben soll." (One cannot go from one object and its existence to another object and its existence or way of existing simply with terminology, however it is divided up. What else was left? The possibility of experience as recognition, in which all objects have to be included if our image of it is to have objective reality for us). (Kant, I., Kritik der reinen Vernunft, 2. Auflage, Ausgabe Cassirer, III, 193f, quote. From Cassirer: 152).

Kant shifted the question of causality from the ontological level to the level of our knowledge, to the realm of the principles of how notions are created and linked to each other. No longer is it possible to speak of the causal law as related to real objects or events, but of conditions for our perception and thinking.

## 1.2. Modifications of the Causal Principle

Before we continue to discuss the consequences of Kant's shift towards the transcendental, we take a look to the history of science to see how the causal principle has been modified over time. In his "Philosophiae naturalis principia mathematica" Newton gave the logical prototype of how nature could be explained, in his version, by a reduction to mechanical principles only, in a mathematical-like way of definitions and axioms, and by the (astonishing at that time) metaphysical assumption of forces which can act not only locally, but over large distance. The forces are defined as the accelerations they exert on a mass concentrated on one point. By the knowledge of a few variables, the physical system is defined, and its future and past can be derived by mathematical methods. The principle "actio est reactio" has up to now been used in the analysis of mechanical problems. It offers a kind of trick to break the problem down into manageable and operational terms, and to construct systems of equations to be solved by straight forward algorithms.

A new view of causality came into existence in physics when the interest in mechanical problems faded away and the electromagnetic field became a focus of investigation. At first the starting point of the new theory was expressed in old forms; Coulomb's Law was constructed like Newton's Law of Gravity. Newton's two masses were replaced by two electric charges; still their distance to the power of  $(-2)$  defines the strength of the force between them. But Maxwell's equations of the electromagnetic field brought back the older belief that causal relations are possible at the same location only. The electromagnetic field and its related forces can be described locally in the static case, and it represents a wave propagating through space at the speed of light in the dynamic case. The reversal of view was possible by the change in the definition of the elements of the theory. No longer can masses concentrated at certain points in space represent the objects of the theory but extended entities, the fields. Cause and effect is taking place at one point in space and time again. No longer are hypotheses on distant causality needed.

One can see from this adaptation of physical theory that the elements and the laws can change, while the basic causal principle is still in place. Nevertheless, the interplay of elements, laws, and the basic principle is modified. Later on we will use this property to adopt causality to the realm of information.

## 1.3. Causality in Modern Physics

Although Immanuel Kant moved the perspective from the laws between objects to the laws of thinking, he did not follow his own ideas with sufficient consequence. In a rational way he tried to construct the natural world by means of two sets of assumptions, firstly on the axioms of classical mechanics, secondly on the classical laws of logic. He identified the rational approach with Newton's Laws and with Euclidian geometry, both - unfortunately, as we know today - only approximations of a more general picture which was brought up by Albert Einstein. By his Special and General Theory of Relativity, Einstein (because of the empirical finding of a constant velocity of light in vacuum irrespective of the movement of the observer) did not only change the way we have to add velocities, he interpreted the notion of mass in a new way, and he put an end to the former separation of content and container, by showing the interplay between masses and energy, gravity and inertia in space-time and the geometry of the universe. Causality not only linked the events of the physical world, but also showed a causal effect of mass on geometry and vice-versa. The geometry of the space-time exerts forces on the bodies in the universe. Still Einstein believed in a strictly deterministic universe: "Gott würfelt nicht!" (God doesn't throw dice!).

From a completely different perspective, this belief was questioned first by Sadi Carnot, who had looked at heat and its ability to perform work. Clausius created the notion of entropy. Entropy shed new light on mechanical processes by dividing them into reversible and irreversible ones, a difference not seen before. It sharpened the awareness that physical processes show some preference. Boltzmann was one of the first who was able to integrate this strange finding about nature into the body of physics. His kinetic theory of gases allows for a new way of interpretation of matter by statistics and probability. By these notions, no longer was only a strictly deterministic possibility available for material entities by laws of nature, no longer was its behavior a necessity; now a more flexible way of describing the future was being developed. This change became possible by looking at two levels of matter at once: the particle and at the ensemble level. While it was still possible to speak of a unique determination of the ensemble, at the same time it became impossible to forecast the path of a single particle. From then on the interest in the interplay between necessity and chance moved into the center of physics. Mechanical determinism on the micro level could be transformed into probabilities for certain parameters of the ensemble on the macro level.

A new stage of development was reached by the Quantum Theory. The discrete nature of energetic states of elementary particles was revealed, and Heisenberg's Uncertainty Relation led to a revision of the traditional perception of reality. Location and impulse cannot be determined with infinite precision at the same moment. Therefore it is no longer possible to link causality to the particles described by space-time. Causality and space-time description are now seen as complementary on the level of the particle. Fortunately the probabilities for the occurrence of the particles themselves are strictly deterministic. Causality is preserved on the level of the absolute amount of the wave function,  $\psi^*\psi$ . Thus one could argue that the meaning of the term "reality" for physics has to be moved away from the particle level to the wave function. A single particle cannot be observed with necessary precision, thus it is not "real" within the realm of physics.

Let us summarize the result of the above discussion on the history of physics with other words. It showed the causal law as a principle guiding our experience. If new experiences can be had, the content of the causal law changes in parallel. Nevertheless, the causal law was seen as a selective category, maybe a kind of definition of the range of the realm of physics. If causality could no longer be found, the realm of physics was no longer applicable.

Still, one has to question the notion of causality, in particular with respect to the notions of necessity and chance. Can one speak of cause if there is a radioactive decay of one atom? Or should we reserve the causal law for uniquely determined processes? It seems possible to preserve the causal law for the process of radioactive decay for the ensemble; the decay of a particular element is only one moment in the realization of the causal law of the ensemble. In this way one could deal with chance without breaking the link to causality (Hörz 1971).

From another point of view, laws of nature can be seen as statements about the possibilities of qualitative change, in particular the Laws of Conservation (of energy, impulse, mass etc.), in quantitative terms. For example, the Law of the Conservation of Energy states the possibility of transformation of one kind of energy into another (radiation into solid matter and vice versa, or potential energy to kinetic energy and vice versa).

#### 1.4. Ambiguities in Physical Causality

If we want to expand scientific thought continuously to other phenomena of the world, we have to extend the causal principle once more. There are several natural ways in physics itself. One runs along the ambiguity of solutions of mathematical equations incorporating causal relationships. The breaking of a stick described by classical mechanics is possible via different mechanical oscillations. In basic mode (the wavelength of the oscillation is twice the length of the stick) and of its overtones (the doubled length of the stick is equal to an integer greater than one times the wavelength of the oscillation). They are characterized by eigenvalues of the basic equation. It depends on chance which of the solutions will occur.

Another possibility consists of the well-known effects of deterministic chaos. Small changes in the initial conditions result in large changes in the trajectory. Although we can derive a unique solution on the same computer with a fixed precision for numerical operations, the effects does not remain constant if we switch to another computer or if we change the initial conditions by a small amount. This is the reason for the limitation of our ability to forecast the weather, or to predict what will happen in such a well-defined mechanical system of more than three bodies. In fact, we know now that in the case of three bodies, the resulting motion cannot be derived mathematically in a unique way except in a few special cases.

A third source which can be seen in physics is radioactive decay, or the behavior of single particles in quantum mechanics. Once again the predictive power of the Schroedinger Equation is not applicable at the

level of individual particles, but only to the behavior of the ensemble.

## 2. Physical and Informational Processes Compared

Now, to gain some insight into the specific features of causality in information processes, let us compare information processes with mechanical ones. We see differences on three levels: symbolic representativity, the lack of any Law of Conservation, ambiguity, and even unpredictability. Let us give a typical example of human informational interaction. A woman is greeted by her neighbor and - because she is a polite lady - she answers the greeting with a friendly word. What is the difference from an event described by physics? In our everyday understanding of causality, we can say that there is a cause and an effect as in a physical experiment. We can identify the utterance of a greeting word as the cause and the answer as the effect.

### 2.1. Symbolic Representativity

But here arises the first essential difference to physics: although the spoken word could be measured by physical units (decibel) it need not be the important feature in this interaction. In this respect it may not make any difference if the word was spoken forte or piano, with a high pitch or a low one. The important feature is the symbol of a greeting, transferred to another person. It must be interpreted by the receiver, and its meaning should be understood by the sender. In physics, the physical unit cannot be exchanged, it is fixed once and for all. Information can be represented in different ways; there is no unique link between an object of the world and its representation by any word or gesture etc.

### 2.2. Lack of Laws of Conservation

In physics, reactions happen under a certain, well-defined framework of side conditions. One very important case is the particular Law of Conservation (of energy, of impulse, or of solid matter). The Laws of physics offer a set of possibilities for the objects or processes to behave. Stated by differential equations the future behavior in space is dependent on the set of initial conditions. If a particular set is fixed, the future behavior is well-defined. So, one could state that the cause of the movement of a body is its initial conditions, e.g. a certain acceleration in a gravitational field. Because of the conservation of energy, the body will move along this or that trajectory. Energy is a general measure for qualitatively different states of the body. There exists a tertium comparationis, a common rod to measure states of different quality, such as potential and kinetic energy; the first is measured proportionally to the location of the body relatively to the source of the gravitation field, while the second is measured proportionally to the square of velocity of the body. The energy units may be applied to both different types of energy.

While in physical processes there is a Law of Conservation, this is not necessarily so for the information process itself. Usually in a physical event, the energy balance before and after the exertion of the cause remains the same. In an information process this need not be the case. For example, in electronics one can control the grid of an electronic valve or the basis of a field effect transistor by applying a small voltage. The effect of such an amplifier will be large compared with the small cause. Of course, the Law of Conservation is not violated, because there has to be an external source of energy, (like a battery or a plug to an electric power network) but this is not the interesting point here. In this case, the "cause" in the information process is the small signal at the grid or the base, the "effect" is the change in voltage at the anode or the collector. In fact, such amplifying processes are characterized by the gain, the multiple of the size of the output compared with the input signal. In the realm of information, there is not necessarily a common denominator between cause and effect. Not even measuring units need to exist on both sides of the causal relationship. The connection between input and output is not a physical one, but rather a symbolic one. It depends on the interpretation of the input and output by the partners of the communication process, in order to see the link between the two. This link may be defined (or created) on a subjective basis only.

### 2.3. Creative Power

The most important information processes are those which result in output which is completely different the input. The reaction of the other person is not determined in a unique way. A lot of usual and predictable answers are possible (hi, hello, good morning etc.), but it is also possible that the person will react with a completely unpredictable, and thus unpredicted, answer. The person could react by a gesture, or by a sentence you could never have expected etc. It could be possible as well that the greeting person cannot

see any connection between his/her greeting and the reaction (although there may be one, but only understood by the answering person).

Two different cases are possible:

\* Case 1 (Ambiguity): The output is an element of a well defined set of alternatives. The surprise consists in this case merely in the selection of the respective element. This first case is very similar in both the physical and the informational worlds.

\* Case 2 (Novelty): This case is the more interesting. In this case any forecast is impossible, because we do not even know the resulting set of possible outputs. This is the case if a new theory is created, or if a completely new technical device is developed, or a totally unexpected behavior of an animal or a person can be observed. "New" could be new to the person in interaction, or it could be new to humankind in general. A scientific innovation like Einstein's theory of general relativity was at the time of creation of the latter type; the answer in a foreign language unknown to the other person would be an example of the former. Of course, the adjective "new" to an event has to be exchanged by "known" after its first appearance. This astonishing fact of creativity became the cause of Leibniz's consideration of inborn ideas which were put into the individual by God, or for Augustine belief in the existence of a realm of Platonic ideas. This position can again be found in modern discussions (Penrose, Nørretranders 1994). In our opinion, they do not take into account the potential of the human brain to produce genuine new ideas, therefore they have to shift the solution to external powers. Still, they had to answer the question for the origin of these Platonic realms.

### 3. Informationality as an Emergent Property of Physical Systems

These three features of information processes (symbolic function, lack of laws of conservation, creative power) make clear that the causality principle of the type used in classical physics cannot be applied to this kind of phenomena. Its universal claim has to be replaced. The alternative is either to accept perforations in the overarching determinacy of our universe (through which supernatural powers may interfere, if blind chance may not invade), or to realize that nature itself is capable of spontaneously producing events which are symbolically mediated, not conserving, ambiguous, or even novel. The latter gives no room for non-causal events. It admits, however, that there are more flexible connections in the real world, too, and that strict determinacy is but a special case of causality.

Today there is a paradigm shift from classical physics towards self-organization theories, and from the mechanistic world view which originally laid the foundations for classical physics, towards a view which allows for processes that produce emergent properties, relations and entities (see KANITSCHIEDER 1993, COVENEY/HIGHFIELD 1990, GOERNER 1994, ) From this viewpoint, the historical development of the physical as well as the philosophical concept of causality may be looked upon as step-by-step efforts to overcome the limits of mechanism (see MAINZER 1994). Leibniz was among the first, but not the last, to oppose the philosophical mechanistic principle, which was then propagated in the aftermath of Descartes. Political, economic, social and ideological circumstances in the dawning age of industrialism impeded those efforts which focussed on integration, unification and synthesis (rather than differentiation, particularization and analysis). Only today, in the face of global challenges to the survival of humanity, does the fragmented way of thinking seem to be obsolete.

In terms of system-theoretical considerations, the old version of the principle of causality can be described as follows.

Given a system, inputs and outputs are related in such a way that each input is related to one, and only one, output. The system transforms the input into the output by way of a mechanism which can be conceived of as a bijection. If you call the input "cause", and the output "effect", you may state that equal causes have equal effects and distinct causes have distinct effects (see HEYLIGHEN 1990). In this sense *causa aequat effectum*, or - as Newton's dictum may be interpreted - *actio est reactio*. Due to the mathematical function, a tool is provided by which calculable results seem to be guaranteed. But, as science has unravelled the natural world, this holds for systems at or near at thermodynamic/chemical equilibrium only. This does not hold for systems exposed to fields in which the uneven distribution of energy density exceeds a critical level. Such field potentials force energy to flow in non-linear and interdependent ways. And here the systems are showing self-organization, that is the build-up of order out of fluctuations via dissipation of entropy.

In this case, causality must be described as follows:

Inputs and outputs are not related in a way which can be plotted as bijective mapping. Different inputs may lead to the same output, and the same input may lead to different outputs. So causes and effects are not coupled unambiguously. Causes may give rise to novel effects. Little causes may have big effects. Similar

causes may have dissimilar effects. Thus *causa non aequat effectum, actio non est reactio*. Due to mathematical short cuts not being applicable, emergent phenomena cannot be predicted in detail. There is no mechanistic transformation which turns the cause into the effect. There is an activity of the system itself which selects one of the several possible ways of reacting. There remains a gap in quality between cause and effect which cannot be bridged.

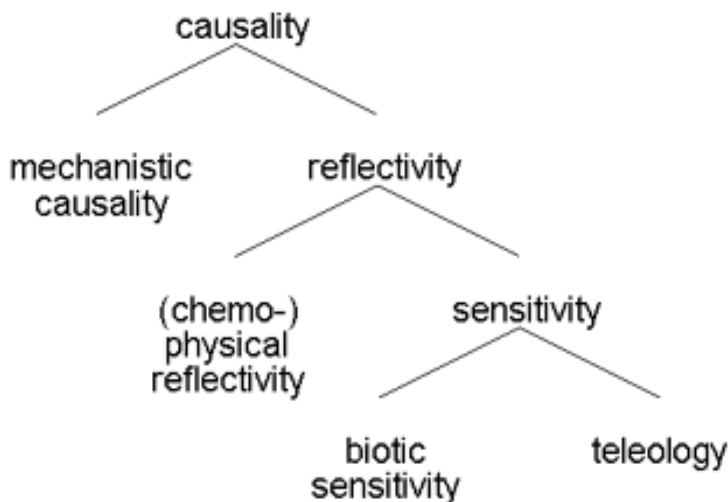
Because of the fact that far-from-equilibrium systems show "symbolic", non-conserving, ambiguous or novel interactions, the notion of complex or evolutionary systems is appropriate for describing information-processing systems in one of these.

Now that we have introduced the distinction between mechanistic causation on the one hand, and self-organized causation on the other (which also holds for information processes), we may distinguish the non-linear interdependent cause-effect-relations even further (see FENZL/HOFKIRCHNER 1996). The common feature of all non-mechanical causation is that the cause is an event which plays the role of a mere trigger of processes, which themselves depend on the nature of the system, at least inasmuch as they are dependent on the influence from the system's environment, and that the effect is an event in which this very self-organization process finally ends. The next distinction is between simple self-organized causations and more complex self-organized causations.

Examples of the first type are Bènard-cells or the Laser. In this case of physical morphogenesis, of self-(re)structuring, we discover a rudimentary kind of information process going on: insofar as the qualitatively new structure/state/behavior of the system reflects in a unique manner changes in the control parameter (thus changes in the outside), we may speak of a "reflex" as an individual way of reflection of outside conditions.

Biotic processes belong to a more sophisticated, second type of self-organized causality. So-called autopoietic systems are a special category of dissipative systems which arose from the first simple non-biotic dissipative systems. They exhibit division into a sensorium and an effectorium, which involves two cycles of self-organisation, one on the top of the other. The self-organised structure, which represents a change in the outer world of living systems, undergoes a further step and becomes understandable and behaviorally relevant to the system. Representations appear as new kinds of informational relations. Representations mediate between stimuli (causes) and responses (effects). The sphere of influence shows (due to the presence of representations) better adaptability of the systems to their environment. They are in a position to take advantage of the environment to such an extent that they can reproduce themselves. But again we can distinguish between simple stimulus-response-relationships and more complex ones. Social systems which form another special category of autopoietic systems exhibit even greater adaptability: they alter their environment to suit themselves. That is to say, their field of influence is characterized by a feedback loop, through which the systems can create the conditions necessary for their reproduction. They are, so to say, "re-creative" systems, because they make a degree of freedom for themselves due to further differentiation of the self-organisation cycles. The behavioral decisions are no longer identical to the representations, but are now only supplied with knowledge via a phase transition. Evaluations emerge. An inner model of the relationship with the environment enables the systems to anticipate (to some degree) the results of their actions, and to formulate goals. So, a more differentiated information process has come into being, which mediates perceived problems (causes) and tried solutions (effects).

The following tables show the differentiation of cause-effect-relations and the respective informational relations.



**Table 1: Types of Causality**

Table 1 shows the hierarchy of causality types according to what evolution has brought about. There is no non-causal relationship to be postulated. All self-organizing systems exhibit some sort of reflection, all life forms are sensitive, and subjects on the human level act in pursuing chosen goals under given social circumstances. Following the ladder down to teleological systems, cause and effect are increasingly decoupled, and increasingly mediated via self-organizing processes.

stage of self-organization	stage of information generation (symbolization, intentionality)
self-restructuration	reflection
self-reproduction	reflection + interpretation = representation
self-re-creation	representation + evaluation = anticipation

**Table 2: Types of Informationality**

Table 2 shows the quality of information processes of which self-organizing systems are capable. Table 3 shows the typical products which are processed on the different levels. In simple reflective systems, the reflecting change of structure/state/behavior (see Table 2) - i.e. the emerging pattern (see Table 3) - plays the role of an as-yet-undifferentiated (proto-)symbol and (proto-)intention. Only the adding of interpretation in sensitive systems (see Table 2) leads to an unfolding of sign and meaning (see Table 3). Eventually, in teleological systems representations are transformed into anticipation by the appearance of evaluation (see table 2), which requires differentiation in data, knowledge and decisions (see table 3).

pattern		
sign		meaning
data	knowledge	decision

**Table 3: Types of informational products**

Summing up, we may postulate the following as a working hypothesis: mechanical cause-and-effect systems have only material, not informational, aspects. Only self-organizing systems have material aspects as well as informational. There is no self-organization without generation of information. Properties of information processes go beyond the limits of simple material processes, that is they are emergent properties. Nevertheless they can be dealt with within the framework of causality.

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