The Self-Organization of Matter

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Matter and substance in dialectical materialism

Fredrick Engels formulated some theses of a dialectical philosophy of nature that remain very topical today:

- "The real unity of the world consists in its materiality" (1987a, 41).
- "The basic forms of all being are space and time, and being out of time is just as gross an absurdity as being out of space" (1987a, 48–49).
- *"Motion is the mode of existence of matter*. . . . Matter without motion is just as inconceivable as motion without matter. Motion is therefore as uncreatable and indestructible as matter itself. . . . Motion therefore cannot be created; it can only be transferred" (1987a, 55–56).
- The human mind is the highest product of organic matter (1987b, 335; 1990, 369).
- "Nature does not just *exist,* but *comes into being and passes away"* (1987b, 324); it "has its existence in eternal coming into being and passing away, in ceaseless flux, in unresting motion and change" (327).
- Matter is "eternally changing, eternally moving, . . . we have the certainty that matter remains eternally the same in all its transformations, that none of its attributes can ever be lost, and therefore, also, that with the same iron necessity that it

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will exterminate on the earth its highest creation, the thinking mind, it must somewhere else and at another time again produce it" (1987b, 335).

- Nature forms a system, an interconnected totality of bodies that react on one another; this mutual reaction constitutes motion (1987b, 363).
- "The basic form of all motion is approximation and separation, contraction and expansion—in short, the old polar opposites of *attraction* and *repulsion*" (1987, 364). This can today be interpreted in such a way that all forms of matter are in continual motion; they produce chaos, and they also produce order from chaos, and hence higher levels of organization. The dialectic of attraction and repulsion is a description of dynamic movement that produces emergent qualities on higher levels of organization.
- "Matter is nothing but the totality of material things from which this concept is abstracted. . . . Words like matter and motion are nothing but *abbreviations*,[1] in which we comprehend many different, sensuously perceptible things according to their common properties" (1987b, 515). Matter is an abstraction in the sense that we abstract from the qualitative differences of things and combine them as physically existing in the concept of matter (533–34).

Matter is the totality of objects that constitute reality and is itself constituted in space and time by an interconnected totality of bodies that react on one another (motion)—that is, they repulse and attract each other. Motion is the mode of existence of matter in space-time. Matter is an eternal process of becoming and passing away, a ceaseless flux; it is uncreatable and indestructible. Matter is the totality of objective, really existing systems that are interconnected and subject to different physical laws. Matter develops dialectically, and this development produces various forms of matter that have emergent qualities that distinguish these different forms. Matter can exist independently of human consciousness. Consciousness is not a necessary result of the development of matter, but it has historically emerged from it. As an activity of the thinking brain and as part of the human being, it thus forms part of a specific organizational level

of matter that we can term the level of human beings. The material unity of the world means that the motion of matter results in a natural hierarchy of relatively autonomous forms of movement of matter, where each level has new, emergent qualities that cannot be reduced to lower levels or an assumed primary form. Time is an expression of the irreversible changing state of matter. Movement in time means movement in space and vice versa. Both space and time express the permanence of change that is a fundamental property of matter. Matter permanently organizes itself and produces an irreversible sequence of states.

Attraction and repulsion are the essence of matter (Hegel 1973, §§97f); as polar opposites they are "determined by the mutual action of the two opposite poles on one another, . . . the separation and opposition of these poles exists only within their unity and inter-connection, and, conversely, . . . their inter-connection exists only in their separation and their unity only in their opposition" (Engels 1886a, 357).

Energy is the measure of the capacity of a physical system to undergo change (Marquit 1980); it is an attribute of matter. Energy is not something external to matter, but is inherent in matter. Physical conceptions, such as Heisenberg's conception of the field as the source of particles, the assumption of quarks as elementary particles, etc., show that the source of existing forms of matter is itself material and that the unity of the world is its materiality (Hörz 1976).[2] In contrast to dialectical materialism, mechanical materialism has been invalidated by modern physics. Dialectical materialism's assertion that the world is in constant flux and process is continually borne out. The basic hypotheses of Marx and Engels about the dialectics of matter still remain topical. Complementarity does not mean a dualistic, but a dialectical, relationship of wave and particle.

Energy and information do not exist outside of, nor are they external to, matter; they are specific aspects of the movement and development of matter and as such are integral aspects of the world.

The Middle Ages were dominated by a religious conception that considered matter as a creation of God. This was questioned

by pantheistic conceptions such as that of Giordano Bruno, who considered God as an eternal force immanent in nature. The Newtonian worldview was characterized by its belief in the absolute immutability of nature and a reductionist methodology. Nature was considered as a conservative system that remains stable from its beginning until its end. Organic matter was reduced to mechanics. French materialism of the eighteenth century (La Mettrie, Holbach, Diderot, Helvétius, Condillac, d'Alembert, Condorcet, Bonnet, Robinet, Laplace) as well as the "mechanical" materialists (Engels 1990, 369) of the nineteenth century (Moleschott, Büchner, Vogt) were influenced by this worldview. The human being was considered a machine, and the universe was not comprehended *"*as a as matter undergoing uninterrupted historical development" (390). Relatively autonomous objective systems with higher forms of motion were reduced to mechanical ones.

Marx and Engels, as well as Hegel (the latter remained trapped in irrational thinking, although he revolutionized philosophical methodology), were highly critical of the Newtonian worldview. They emphasized interconnection and processes instead of singularities and reduction. Hegel criticized atomistic philosophies by saying that they fix the One as One, "the Absolute is formulated as Being-for-self, as One, and many ones." They do not see that the One and the Many are dialectically connected: the One is being-for-itself and related to itself, but this relationship only exists in relationship to others (being-for-another), and hence it is one of the Many and repulses itself. "But the Many are one the same as another: each is One, or even one of the Many; they are consequently one and the same. . . . [A]s those to which the One is related in its act of repulsion are ones, it is in them thrown into relation with itself. The repulsion therefore has an equal right to be called **Attraction**; and the exclusive One, or Being-for-self, suppresses itself" (Hegel 1973, §§ 97–98).

Marx and Engels, in criticizing Max Stirner's reductionism and individualism, put forward the notion of the individual as a social being that is estranged in capitalism and can only become a well-rounded individual in communism (1976, 117–427). Engels criticized the reductionism and individualism of "metaphysical thinkers":

> To the metaphysician, things and their mental reflexes, ideas, are isolated, are to be considered one after the other and apart from each other, are objects of investigation fixed, rigid, given once for all. He thinks in absolutely irreconcilable antitheses. "His communication is 'yea, yea; nay, nay,' for whatsoever is more than these cometh of evil" [Matthew 5:37—Ed.]. For him a thing either exists or does not exist; a thing cannot at the same time be itself and something else. Positive and negative absolutely exclude one another, cause and effect stand in a rigid antithesis one to the other. (1976a, 22)

> HARD AND FAST LINES are incompatible with the theory of evolution. . . . For a stage in the outlook on nature where all differences become merged in intermediate steps, and all opposites pass into one another through intermediate links, the old metaphysical method of thought no longer suffices. Dialectics, which likewise knows no HARD AND FAST LINES, no unconditional, universally valid "either—or" and which bridges the fixed metaphysical differences, and besides "either—or" recognizes also in the right place "both this—and that" and reconciles the opposites, is the sole method of thought appropriate in the highest degree to this stage. (1976b, 493–94)

Self-organization theory today also stresses the interconnectedness and process-structure of the world and criticizes reductionism. Ilya Prigogine and Isabelle Stengers, the founders of dissipative systems theory, stress that Hegel, Marx, and Engels are important process-thinkers in this regard: "The Hegelian philosophy of nature systematically incorporates all that is denied by Newtonian science. In particular, it rests on the qualitative difference between the simple behavior described by mechanics and the behavior of more complex entities such as living beings. It denies the possibility of reducing those levels, rejecting the idea that differences are merely apparent and that nature is basically homogeneous and simple" (1984, 89). "The idea of a history of nature as an integral part of materialism was asserted by Marx and, in greater detail, by Engels. Contemporary developments

in physics, the discovery of the constructive role played by irreversibility, have thus raised within the natural sciences a question that has long been asked by materialists. For them, understanding nature meant understanding it as being capable of producing man and his societies" (252).

Marx and Engels opposed the idea of substance (an everlasting, changeless carrier of changing qualities[3]) as primary matter because they considered such a position as mechanical and undialectical, and argued that it neglected the fact that matter is always in motion, and develops higher levels of organization in the dialectical process of becoming. In the history of dialectical materialism, one finds an animosity toward the notion of substance. Lenin, for example, wrote: "The recognition of immutable elements, 'of the immutable substance of things,' and so forth, is not materialism, but metaphysical, i.e., anti-dialectical, materialism" (1962, 261). Herbert Hörz, one of the main philosophers of the German Democratic Republic, argued that owing to the physics of fields, the discovery of radioactivity, relativity theory, and quantum theory, the notion of substance has become untenable (1976, 222–25). Modern physics has shown that elementary particles are transformed into one another; particles arise and continue to exist only in qualitative relationships to others. Hence the idea of an unchangeable carrier of qualities seems no longer to be valid. "Whereas the substance concept presupposes an unchanging carrier, . . . modern physics conceives material events primarily as change and interaction, and searches for the structural laws of this change" (225). The notion of substance would not be able to show the dialectical relationship of particle and field that was introduced by quantum theory. Fields and elementary particles cannot be substance because they are subject to change.

Hegel opposed the notion of substance for other reasons: Spinoza sees substance as *causa sui*—it is its own reason. Hegel says that such an assumption would exclude the creation of the world by God, which he believed in. "A deeper insight into nature reveals God as creating the world out of nothing. And that teaches two things. On the one hand it enunciates that matter,

as such, has no independent subsistence, and on the other that the form does not supervene upon matter from without, but as a totality involves the principle of matter in itself" (1973, §128; see also §§150–51).

Modern physics repudiates the mechanistic and reductionist conception of substance. Nonetheless, there seems to be an alternative conception of substance immanent in Engels's works on nature: The substance of the world—that which exists permanently and endlessly—is the process-structure of matter. Matter is without pause in permanent motion, in ceaseless flux, and is a self-producing entity. In its dialectical movement it produces different levels of organization that have higher, emergent qualities that cannot be reduced to earlier qualities. Engels stressed that matter is a producing entity, and through its permanent flux and motion "remains eternally the same in all its transformations" (1976b, 335).

The Marxist philosopher Ernst Bloch worked out an alternative conception of substance and matter within the framework of dialectical materialism (for details, see, for example, Zeilinger 2003). In opposition to mechanical materialism, Bloch argues that matter is process-like; it is not a "dead block, moved only by pressure and push and remaining itself all the time" (1963, 230), but nonetheless he does not give up the notion of substance.[4] Matter for Bloch is fermenting and process-like (203); it is a process-being, being-in-possibility (1963, 207) and has a historical-dialectical character (209). Bloch's concept of matter anticipated the modern theories of self-organization that also stress the productivity of matter resulting in different organizational forms and hierarchical levels of matter and the self-reproduction and recreativity of self-organizing units.

Nature is for Bloch a producing subject; he says it is forming itself, forming out of itself (234). In this context Bloch takes up Spinoza's concept of *natura naturans* in order to stress that nature is not only passively produced, but is also itself an actively producing system. The relationship of tendency and latency in matter also reappears as a dialectic of chance and necessity in self-organization theory (the concepts of relative chance by Kolmogorow and Chaitin and of incomplete determinism). What

Bloch calls a *novum* is called emergent qualities in the sciences of complexity. Bloch used the term *emergence* himself by stressing that all gestalt figures *emerge* from the dialectical process and from matter as developing, producing (*ausgebären*[5]) substance immanently as well as speculatively (Bloch 1975, 165). For Bloch matter is a dialectically developing, producing substance. Substance for Bloch is *process-substance* (1975, 246); it opens up possibilities, is fermenting, and actively producing.

Self-organization and dialectics

Saying the substance of the world is the permanent dialectical movement of matter and its self-productivity corresponds to saying that matter organizes itself and that nature is a self-organizing system. Wolfgang Hofkirchner has stressed that the new results of scientific research have been anticipated by Marx and Engels, and that the concept of dialectical development reenters science with self-organization theory (1993; see also Hofkirchner 1998).

The theory of self-organization has led to a change of scientific paradigms—from the Newtonian paradigm to the approaches of complexity. There is a shift from predictability to nonpredictability; from order and stability to instability, chaos, and dynamics; from certainty and determination to risk, ambiguity, and uncertainty; from control and steering to the self-organization of systems; from linearity to complexity and multidimensional causality; from reductionism to emergentism; from being to becoming; and from fragmentation to interdisciplinarity. This has been interpreted as a shift from modern to postmodern knowledge (Best and Kellner 1997).

Concepts of physical self-organization have been put forward in Ilya Prigogine's theory of dissipative systems (Nicolis and Prigogine 1989; Prigogine 1980), Hermann Haken's synergetics (1978, 1983), and Manfred Eigen's hypercycle theory (Eigen and Schuster 1979).

The principles of physical self-organization[6] are (see Fuchs 2001, Ebeling and Feistel 1994, and Arshinov and Fuchs 2003):

1. *Control parameters*: A set of parameters influences the state and behavior of the system.

2. *Critical values*: If certain critical values of the control parameters are reached, structural change takes place and the system enters a phase of instability/criticality.
3. *Fluctuation and intensification*: Small disturbances from inside the system intensify themselves and initiate the formation of order.
4. *Feedback loops, circular causality*: Feedback loops occur within a self-organizing system; circular causality involves a number of processes $p_1, p_2, \ldots, p_n$ ($n \geq 1$), and p_1 results in p_2, p_2 in $p_3, \ldots, p_{n-1}$ in p_n and p_n in p_1.
5. *Nonlinearity*: In a critical phase of a self-organizing system, causes and effects cannot be mapped linearly: similar causes can have different effects and different causes similar effects; small changes of causes can have large effects, whereas large changes can also result in only small effects (but nonetheless it can also be the case that small causes have small effects and large causes, large effects).
6. *Bifurcation points*: Once a fluctuation intensifies itself, the system enters a critical phase where its development is relatively open, certain possible paths of development emerge, and the system has to make a choice. This means a dialectic of necessity and chance. Bifurcation means a phase transition from stability to instability.
7. *Selection*: In a critical phase that can also be called point of bifurcation, a selection is made between one of several alternative paths of development.
8. *Emergence of order*: In a critical phase, new qualities of a self-organizing system emerge; this principle is also called *order from chaos* or *order through fluctuation*. A self-organizing system is more than the sum of its parts. The qualities that result from temporal and spatial differentiation of a system are not reducible to the properties of the components of the systems; interactions between the components result in new properties of the system that cannot be fully predicted and cannot be found in the qualities of the components. Microscopic interactions result in new qualities on the macroscopic level of the system. Checkland defines an emergent quality in

similar terms "as a whole entity which derives from its component activities and their structure, but cannot be reduced to them" (1981, 314). The emergence of order includes both (a) bottom-up-emergence (a perturbation causes the system's parts to interact synergetically in such a way that at least one new quality on a higher level emerges) and (b) downward causation (once new qualities of a system have emerged they, along with the other structural macro aspects of the system, influence—that is, enable and constrain—the behavior of the system's parts). This process can be described as top-down-emergence if new qualities of certain parts (seen as wholes or systems themselves) show up.

9. *Information production*: Information is a relationship between specific organizational units of matter. Reflection means reaction to influences from the outside of a system in the form of inner-systemic structural changes. A causal relationship exists between the result of reflection and the reflected. The reflected causes structural changes, but does not mechanically determine them. The system has a certain relative autonomy that can be described as a degree of freedom from perturbations. On the different organizational levels of matter, we find different degrees of freedom. The degree increases along with complexity if we go up the hierarchy from physical-chemical to living systems, and finally to social systems. The causal relationship between the reflected and the result of reflection is based on a dialectical relationship of freedom and necessity. Information is an objective relationship between the reflected, the result of reflection inside the system's structure, and the realization of functions of the system within the reflected environment of the system (see Hörz and Röseberg 1981, 273–96). This means that information is a relationship of creative and active reflection between a system and its environment—to be more precise, between units of organized matter. Stimuli and fluctuations cause inner-systemic structural change; fluctuations are actively reflected within the system. Information is not a structure given in advance; it is produced

within material relationships. "Information is a physical structure and at the same time a structure which dominates the physical forces. . . . Information is not a physical substance; it is instead temporarily 'attached' to it. Information must be understood as a specific effect and as a relationship" (Fuchs-Kittowski 1997, 559–60).

10. *Fault tolerance*: Outside a critical phase, the structure of the system is relatively stable concerning local disturbances and a change of boundary conditions.
11. *Openness*: Self-organization can only take place if the system imports entropy that is transformed; as a result, energy is exported, or, as Prigogine says, dissipated.
12. *Symmetry breaking:* The emerging structures have less symmetry than the foundational laws of the system.
13. *Inner conditionality*: Self-organizing systems are influenced by their inner conditions and the boundary conditions from their environment.
14. *Relative chance*: There is a dialectic of chance and necessity in self-organizing systems; certain aspects are determined, whereas others are relatively open and subject to chance.
15. *Complexity*: Self-organizing systems are complex systems. The term *complexity* has three levels of meaning: (1) There is self-organization and emergence in complex systems (Edmonds 1999). (2) Complex systems are not organized centrally, but in a distributed manner; there are many connections between the system's parts (Kauffman 1993, Edmonds 1999). (3) It is difficult to model complex systems and to predict their behavior even if one knows to a large extent the parts of such systems and the connections between the parts (Heylighen 1996, 1999; Edmonds 1999). The complexity of a system depends on the number of its elements and the connections between the elements (the system's structure). According to this assumption, Kauffman defines complexity as the "number of conflicting constraints" in a system (1993). Heylighen says that complexity can be characterized by a lack of symmetry (symmetry breaking), which means that "no part or aspect of a

complex entity can provide sufficient information to actually or statistically predict the properties of the others parts" (1996), and Edmonds defines complexity as "that property of a language expression that makes it difficult to formulate its overall behavior, even when given almost complete information about its atomic components and their interrelations" (1999). Aspects of complexity are things, people, number of elements, number of relations, nonlinearity, broken symmetry, nonholonic constraints, hierarchy, and emergence (Flood and Carson 1993).

16. *Cohesion:* Cohesion means the closure of the causal relations among the dynamical parts of a dynamical particular that determine its resistance to external and internal fluctuations that might disrupt its integrity (Collier 2003, 2004). It is a "dividing glue" of dynamic entities (Collier 2004).
17. *Systemness:* Self-organization takes place in a system—in a coherent whole that has parts, interactions, structural relationships, behavior, state, and a border that delimits it from its environment.
18. *Hierarchy:* The self-organization of complex systems produces a hierarchy in two distinctive senses: (1) The level of emergence is a hierarchically higher level—that is, it has additional, new emergent qualities that cannot be found on the lower level that contains the components. The upper level is a sublation of the lower level. (2) Self-organization results in an evolutionary hierarchy of different system types; these types are hierarchically ordered in the sense that upper levels are more complex and have additional emergent qualities.
19. *Globalization and localization:* Bottom-up-emergence means the globalizing sublation of local entities; downward causation means the localization of more global qualities (Fuchs 2003c).
20. *Unity in plurality (generality and specificity)*: The organizing system is characterized by a number of distinctive qualities that distinguish it from other self-organizing systems. On the other hand, each type of self-organizing system also shares general principles and qualities with all other types of

self-organizing systems. Both generality/unity and specificity/plurality are characteristic of self-organizing systems.

The concept of emergence is the central notion of self-organization concepts. Aspects of emergence are:

- *Synergism:* Emergence is due to the productive interaction between entities. Synergy is a very general concept that refers "to combined or 'co-operative' effects—literally, the effects produced by things that 'operate together' (parts, elements or individuals)" (Corning 1998, 136). Synergy takes place and shapes systems on all organizational levels of matter; it is a fundamental quality of matter. Synergies between interacting entities are the cause of the evolution and persistence of emergent systems.
- *Novelty:* On a systemic level different from the level of the synergetically interacting entities, new qualities show up. Emergent qualities are qualities that have not been previously observed and have not previously existed in a complex system ("a whole is more than the sum of its parts").
- *Irreducibility*: The newly produced qualities are not reducible to, or derivable from, the level of the producing, interacting entities.
- *Unpredictability*: The form of the emergent result and the point of emergence cannot be fully predicted.
- *Coherence/correlation*: Complex systems with emergent qualities have some coherent behavior for a certain period of time. This coherence spans and correlates the level of the producing entities into a unity on the level of emergence (Goldstein 1999).
- *Historicity:* Emergent qualities are not given a priori, but are the result of the dynamical development of complex systems.

One example of physical self-organization is the Bénard cells: A special liquid is heated at a certain temperature t_2 from beneath and cooled down to a certain temperature t_1 from above. The temperature difference $\Delta t = t_2 - t_1$ becomes control parameter of the system (principle 1). At $\Delta t = 0$ the system is in equilibrium, the temperature gradient rises, and, at a certain critical

value (principle 2), a new pattern emerges in the liquid that looks like honeycombs (principles 8 and 9). The liquid particles are located in layers; lower layers result from their temperature being warmer than upper ones; they expand and their density decreases. At the beginning of the critical phase, a first small fluctuation occurs, which means that a particle is displaced from its position in a certain layer and enters an upper or lower layer (principle 3). The layer in which this fluctuation will occur is not predetermined. Fluctuations only take place if a certain threshold of the control parameter Δt is crossed. The fluctuation intensifies itself (principle 3); more and more liquid particles are detached from their stationary position; disorder, chaos, and motion appear (principle 6). The liquid particles arrange themselves in cells that have different forms (round, square, broad, thin, large, small, etc.). These forms are dependent on the elementary modes of motion. Several types of cells exist simultaneously. Finally, one type can assert itself and become a dominant form due to a selection process within the system (principle 7). As a result of the superimposition of many cells of the same form, a pattern emerges that looks like a honeycomb (principles 8 and 9). So from an initial chaos of particles, order has emerged. At a certain value of the temperature gradient, this order disappears. In this process, order will definitely emerge, initial fluctuations will spread out, and one of several types of roles will be selected. But it is not determined in which layer the fluctuation will occur, exactly how the cell-types will look, and which one will be selected (principle 14). This experiment will only be successful if energy in the form of a temperature difference is applied to the system (principle 11).

A laser is another example that is frequently used to explain self-organization (see Haken 1987). A laser consists of an active medium that is situated between two mirrors. This medium is either a gas that is radiating due to the discharge caused by the entry of current or a crystal that is pumped by a flash lamp (e.g., a ruby with chrome ions). The flashes stimulate the crystal, and an electron changes its trajectory, jumping from an inner trajectory to an outer one, absorbing energy from the flash lamp. It

spontaneously returns to its former trajectory and emits energy in the form of a light wave. Therefore, the atoms emit light waves because of their stimulation by the flash lamp. The two mirrors continually reflect the light. First there is a chaos of light waves. A light wave can hit other atoms and force an increase in the light intensity. By such processes, the light waves reach certain amplitudes. Haken says that one light wave "enslaves" the others; this means that it becomes dominant and orders the system. As a result, an ordered light wave—the laser beam—emerges. From a chaos of light waves, an ordered pattern emerges (principles 8 and 9). The decisive control parameter is the current supply (principles 1 and 11). The system can only enter criticality if the current reaches a certain threshold (principle 2). A light wave is caused by a fluctuation—that is, an electron returns to its inner trajectory and emits energy; a light wave can intensify itself by "enslaving" electrons (principle 3). Such an intensification always means circular causality, because one entity causes the behavior of another entity, and this behavior results in a transformation of the first entity (principle 4). Due to such intensifications, the system enters a state of chaos/instability/bifurcation (principles 5 and 6). A certain light wave is selected (principle 7) and determines the emergence of the laser beam (principles 8 and 9). It is determined that a laser beam will emerge, that fluctuations and intensification will result; but not determined is exactly how this will take place and which light wave will order the system (principle 14).

According to Hegel's outline, the purpose of dialectics is "to study things in their own being and movement and thus to demonstrate the finitude of the partial categories of understanding" (1973, note to §81). Self-organization refers to the forms of movement of matter and hence is connected to dialectics. What are called control parameters, critical values, bifurcation points, phase transitions, nonlinearity, selection, fluctuation, and intensification in self-organization theory (principles 1, 2, 3, 5, 6, 7) correspond to the dialectical principle of transition from quantity to quality. This corrresponds to what Hegel discussed as *Measure* (1973, §§107–11):

Measure is the qualitative quantum—quantum is the existence of quantity.

> The identity between quantity and quality, which is found in Measure, is at first only implicit, and not yet explicitly realized. In other words, these two categories, which unite in Measure, each claim an independent authority. On the one hand, the quantitative features of existence may be altered, without affecting its quality. On the other hand, this increase and diminution, immaterial though it be, has its limit, by exceeding which the quality suffers change. . . .
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> . . . But if the quantity present in measure exceeds a certain limit, the quality corresponding to it is also put in abeyance. This however is not a negation of quality altogether, but only of this definite quality, the place of which is at once occupied by another. This process of measure, which appears alternately as a mere change in quantity, and then as a sudden revulsion of quantity into quality, may be envisaged under the figure of a nodal (knotted) line. (§§108–9)

What is called emergence of order, production of information or symmetry breaking in self-organization theory (principles 8, 9, 12) corresponds to Hegel's notions of sublation and negation of the negation. Something is only what it is in its relationship to another, but by the negation of the negation this something incorporates the other into itself. The dialectical movement involves two moments that negate each other, a somewhat and an another. As a result of the negation of the negation, "something becomes an other; this other is itself somewhat; therefore it likewise becomes an other, and so on *ad infinitum*" (Hegel 1973, §93). Being-for-self or the negation of the negation means that somewhat becomes an other, but this again is a new somewhat that is opposed to an other and as a synthesis results again in an other and therefore it follows that something in its passage into other only joins with itself; it is *self-related* (§95). In becoming, there are two moments (Hegel 1969, 176–79): coming-to-be and ceasing-to-be: by sublation—being passes over into nothing; it ceases to be, but something new shows up, is coming to be. What is sublated on the one hand ceases to be and is put to an end, but on

the other hand, it is preserved and maintained (185). In dialectics, a totality transforms itself; it is self-related. This corresponds to the notions of self-production and circular causality. The negation of the negation has positive results—that is, in a self-organizing system, the negation of elements results in positive new qualities.

The two examples mentioned here in fact are examples of the dialectical development of matter. Hegel says that when the control parameters reach a certain threshold, a point of bifurcation, or criticality, a nodal-line arises. The quantities that are increased and transform into quality are the temperature gradient and electric current. The emergence of the honeycomb pattern or the laser beam means sublation and negation of the negation. The old states of the systems are eliminated, but nonetheless preserved in new qualities. New qualities arise and the systems thereby reach a higher level.

The principle of relative chance that is typical for self-organizing systems had already been considered as a dialectic of chance and necessity by Hegel, Marx, and Engels (Hegel 1973, §§144–49; Engels 1987b, 497–501). Engels stressed that the dialectic of attraction and repulsion is an aspect of matter and its movement. Both elements are also described by self-organization theory: chaos, noise, or instability is described as disordered movement of the elements of a complex system. One can also say that the elements are repelling each other. But this repulsion is one that turns into attraction, because the elements interact, there are processes of ordering and selection—attraction takes place as the emergence of a coherent whole and new qualities.

As an example of the transition from quantity to quality, Engels mentions the homologous series of carbon compounds:

> Here therefore we have a whole series of qualitatively different bodies, formed by the simple quantitative addition of elements, and in fact always in the same proportion. This is most clearly evident in cases where the quantity of all the elements of the compound changes in the same proportion. Thus, in the normal paraffins C_nH_{2n+2}, the lowest is methane, CH_4, a gas; the highest known, hexadecane, $C_{16}H_{34}$, is a solid body forming colourless crystals which melts at 21°

> and boils only at 278°. Each new member of both series comes into existence through the addition of CH_2, one atom of carbon and two atoms of hydrogen, to the molecular formula of the preceding member, and this quantitative change in the molecular formula produces each time a qualitatively different body. (Engels 1987a, 118)

Nodal lines or the transition from quantity to quality is today also studied in self-organization theory. The theory of self-organized criticality (SOC) (Bak 1996) especially focuses on this. It studies phenomena where perturbations that normally have small effects have large effects in a critical situation and push the system into chaos. A frequently mentioned example is a pile of sand. Dropping grains of sand onto each other will result in a pyramid. When the pile reaches a certain critical point, there is the possibility that just one additional grain results in the avalanching collapse of the whole pile. In a phase of SOC, the effects of one additional element vary from small to large, either pushing the system into chaotic behavior or locking it into a fixed behavior. The system is on the "edge of chaos." One feature that characterises SOC systems is a power-law distribution of the characteristic events such as avalanches, quakes, crashes, etc. The average frequency of the event is inversely proportional to some power of its size: log (F) = –log (M). The log of the frequency of events is a linear function of the log of their magnitudes. The theory of SOC assumes that SOC patterns can be found, for example, in wars, wildfires, stock prices, traffic jams, international conflicts, and the collapse of society (Brunk 2002).

Almost everywhere in chemistry one can find examples of the transition from quantity to quality. Therefore Engels speaks of chemistry as the "science of the qualitative changes of bodies as a result of changed quantitative composition" (1987b, 359). This transition is what today in self-organization theory is called emergence.[7] In a self-organizing system, a certain threshold of a control parameter is crossed and order emerges. What is today called a point of bifurcation, instability, or criticality, Engels refers to as "Hegelian nodal line of measure relations—in which quantitative change suddenly passes at certain points into qualitative transformation" (Engels 1987a, 117), or

even directly anticipating the modern terminology, he speaks of "critical point" (Engels 187b, 359). As other examples of nodal lines, Engels mentions a certain current strength that is required to cause the platinum wire of an electric incandescent lamp to glow, the temperatures of incandescence and fusion of metals, the freezing and boiling points of liquids, the critical point at which a gas can be liquefied by pressure and cooling (1987b, 359). The transition from quantity to quality that occurs, for example in the homologous series of carbon compounds when certain atoms are added can also be termed the emergence of a qualitatively different body.

Other examples that Engels mentioned for the transition from quantity to quality, and that could equally be described as the emergence of new qualities in a critical situation after a threshold of a certain control parameter has been crossed, include:

- Change of form of motion and energy:

> All qualitative differences in nature rest on differences of chemical composition or on different quantities or forms of motion (energy) or, as is almost always the case, on both. Hence it is impossible to alter the quality of a body without addition or subtraction of matter or motion, i.e. without quantitative alteration of the body concerned. . . .
>
> . . . Change of form of motion is always a process that takes place between at least two bodies, of which one loses a definite quantity of motion of one quality (e.g., heat), while the other gains a corresponding quantity of motion of another quality (mechanical motion, electricity, chemical decomposition). Here, therefore, quantity and quality mutually correspond to each other. (1987b, 357)

- Engels's citation of Hegel's example of the states of aggregation of water (Engels 1987b, 359):

> Thus the temperature of water is, in the first place, a point of no consequence in respect to its liquidity: still with the increase of diminution of the temperature of the liquid water, there comes a point where this state of cohesion

> suffers a qualitative change, and the water is converted into steam or ice. (Hegel 1973, §108)

As other examples, Hegel mentions that a point is reached where a single additional grain makes a heap of wheat; or where a bald tail is produced by plucking a single hair from a horses tail.

For Engels, "the negation of the negation" is "an extremely general . . . law of development of nature, history, and thought; a law which, as we have seen, holds good in the animal and plant kingdoms, in geology, in mathematics, in history and in philosophy" (1987a, 131). As an example from nature, he mentions the development process of a grain of barley:

> Billions of such grains of barley are milled, boiled and brewed and then consumed. But if such a grain of barley meets with conditions which are normal for it, if it falls on suitable soil, then under the influence of heat and moisture it undergoes a specific change, it germinates; the grain as such ceases to exist, it is negated, and in its place appears the plant which has arisen from it, the negation of the grain. But what is the normal life-process of this plant? It grows, flowers, is fertilised and finally once more produces grains of barley, and as soon as these have ripened the stalk dies, is in its turn negated. As a result of this negation of the negation we have once again the original grain of barley, but not as a single unit, but ten-, twenty- or thirtyfold. (126)

As similar examples, he mentions the development process of insects, geology as a series of negated negations, a series of successive shatterings of old and deposits of new rock formations, differential and integral calculus, the development of philosophy and society. These development processes can also be described in terms of physical self-organization: the control parameters that influence the development of the grain are time and natural conditions such as heat and moisture. During this development, new seeds will show up. At a certain time, a critical point is reached and the grain ceases to exist. But at the same time, new grains emerge.

Dialectical processes and negation of the negation mean not only just the emergence of other, new qualities. Dialectical development also includes development process that results in higher qualities and other structural levels. Dialectical development is not just change or self-transformation and self-reproduction; it is also the emergence of higher levels of organization (Hörz 1976, 311–24). Hence dialectical thinking assumes an immanent hierarchy in nature and evolutionary leaps. This was also pointed out by Engels:

> The transition from one form of motion to another always remains a leap, a decisive change. This is true of the transition from the mechanics of celestial bodies to that of smaller masses on a particular celestial body; it is equally true of the transition from the mechanics of masses to the mechanics of molecules—including the forms of motion investigated in physics proper: heat, light, electricity, magnetism. In the same way, the transition from the physics of molecules to the physics of atoms—chemistry—in turn involves a decided leap; and this is even more clearly the case in the transition from ordinary chemical action to the chemism of albumen [proteins] which we call life. Then within the sphere of life the leaps become ever more infrequent and imperceptible. (1987a, 61–62)

Self-organization theory is also dialectical in the respect that it frequently considers self-organization as emergent evolution. This means that there are different hierarchical organizational levels of self-organization that differ in complexity and where new qualities of organization emerge on upper levels. In self-organization theory, Ervin Laszlo, for example, argues that evolution does not take place continuously, but in sudden, discontinuous leaps (1987). After a phase of stability, a system enters a phase instability, fluctuations intensify and spread out. In this chaotic state, the development of the system is not determined; what is determined is only that one of several possible alternatives will be realized. Laszlo says that evolution takes place in such a way that new organizational levels emerge, constituting the successive steps of evolution. Not all scientists who speak

about self-organization include the development of higher qualities into their concepts. Hence, in this respect, dialectical materialism can be considered as a broader evolutionary concept than self-organization.

In his *Anti-Dühring* and his *Dialectics of Nature*, Engels pointed out the problem of defining life and intuitively anticipated the theory of autopoiesis. Of course today we know much more about life than Engels did, especially since the discovery of the double helix. But what is important is that Engels anticipated the idea of autopoiesis. He said that life exists in the "constant self-renewal of [its own] chemical constituents"; life is a "self-implementing process" (77). Proteins not only continually undergo decomposition, but also continually produce themselves from their components (1987b, 576–77).

Science, materialism, and religion

As Engels implicitly pointed out, the substance of the world is its process character, the continual dialectical movement of matter, and the productivity of matter that results in self-reproduction and the emergence of new, higher qualities and organizational forms of matter. This corresponds to saying that the substance of the world is the continual self-organization of matter. As has been shown, processes of physical self-organization can be described in dialectical terms. Control parameters, critical values, bifurcation points, phase transitions, nonlinearity, selection, fluctuation, and intensification in self-organization theory correspond to the dialectical principle of transition from quantity to quality. What is called emergence of order, production of information, or symmetry breaking in self-organization theory corresponds to Hegel's notions of sublation and negation of the negation. The concept of emergent evolution corresponds to the principle of dialectical development, the dialectics of chance and necessity, as well as of attraction and repulsion that have been described by Hegel, Engels, and Marx are constitutive for processes of self-organization. Conversely, the examples Engels gave for the dialectics of nature can also be seen as examples of the self-organization of matter.

Self-organization theory shows that Engels's *Dialectics of Nature* is still very topical and that dialectical materialism, contrary to mechanical materialism, has not been invalidated; rather, it confirms that dialectics is the general principle of nature and society. Self-organization theory supports Engels's assumptions that the real unity of the world consists in its materiality, that matter is process-like and in constant flux, that it is a producing entity that is uncreateable and indestructible. That the substance of the world is self-organization of matter, which results in higher forms of organization of matter—the highest form of organization of matter thus far being human society—means that God does not exist, that there is no *creatio-ex-nihilo* and no first mover that is not itself moved. Hence religion and esoteric thinking are mere ideology and false consciousness. Dialectical materialism seems to be confirmed by modern science, whereas serious problems arise for idealist worldviews. "The conceptions of self-organization, the conceptions that assign a determining role to the activity of inner factors instead of outer, are new scientific affirmations of the old dialectical theses, as well as the conceptions of the general connection of all things and appearances" (Steigerwald 2000). Self-organization theory is indeed a dialectical-materialist theory, but unfortunately its representatives all too often do not realize this and do not acknowledge the dialectical tradition and heritage of the philosophy of nature in the line of Frederick Engels and Karl Marx.

The natural sciences that emerged during the last century, such as quantum theory, quantum mechanics, first- and second-order cybernetics, general system theory, nonequiblibrium thermodynamics, synergetics, dissipative systems theory, autopoietic systems theory, catastrophe theory, punctuated equilibrium theory, hypercycle theory, string theory, loop theory, etc. deal with the ontology of the material world. Hence there seems to be scientific evidence that nature is a self-organizing totality and is its own cause. This seems to confirm the materialist notion that matter is uncreateable and indestructible.

Twentieth-century science indicates that dialectical development is a universal law of nature and that dialectical materialism

is correct, but that human consciousness frequently lags behind the progress of science, technology, and society. Linked to the current crisis of the capitalist world system is a tendency to spread mysticism and irrationalism in society. This tendency also affects the scientific community.

It is quite common today in idealistic thinking to interpret the big bang as the creation of the world by God, where nothing turns into something. But if before the big bang there was nothing except God, what is the foundation of God? There has never been scientific evidence that God could really exist as an eternal substance outside of material existence and that God is his or her own reason, whereas modern science has produced evidence that matter is *causa sui*, organizes itself and has not been created by an external first mover out of nothing. It is not reasonable to assume that the world has been created out of nothing by God and that God really exists. In such arguments, a causal principle is applied to matter, but the same causal principle is declared as not holding for God. There are no rational reasons why this should be the case. Talking about God and the origin of the world means talking about universality. It is unreasonable to apply a form of universal causality to one universal phenomenon, but simply ignore it for another one.

Philosophy deals with explanations of how single aspects of the world and single sciences are connected. It is the science of universality. Philosophy is the thinking study of material reality and the things that comprise reality. Philosophy works out notions and categories in order to describe and explain the total world process on a general level. Various idealistic, religious, and esoteric theories explain the world as being created by God as an external first mover who is not moved himself. This violates fundamental philosophical theorems such as Occam's Razor: if the material world can be explained as its own reason, as can be done by philosophically generalizing theories of self-organization, reference to an external creator is an unnecessary over-specification and multiplication. The theorem of foundation holds that everything that is or can be has some foundation or ground. With physics serving as the starting point for the history of the cosmos, matter can be

conceived as its own reason and as the self-referential foundation of the world. Philosophy actually must explain the development of the universe, and must start from physics as the fundamental natural science; idealistic conceptions that stress spirit will fail to find a sufficient ground of the universe (Zimmermann 1999).[8] If Spirit and God are conceived as eternal entities that are their own reason, irrational categories are simply defined tautologically and without reference to the really existing, material world that can be rationally explained by the natural and social sciences. Idealism cannot provide a reasonable foundation of the world.

While we have no scientific proof for the existence of God, we have every reason to assume that matter is organizing itself and that this is a universal phenomenon. Manfred Eigen's hypercycle theory provides an explanation of the origin of life and the human being that requires no argument assuming divine creation, because it explains the emergence of life as a qualitative leap in the self-organization of matter that results in a new level of organization within an evolutionary hierarchy. Life is the result of a cross-catalysis between autocreative nucleic acids and proteins. "There is no need for a miracle, for a divine, supernatural act to explain biological development. The only possibility of avoiding this conclusion would be the statement that the laws ruling it have been created together with the world by an extrahuman force. But then reasonable arguments for the possibility and necessity of this extranatural power must be found, and that cannot be established by scientific means" (Steigerwald 2000). The existence of life is due to self-reproducing molecules; there is no scientific evidence for a creation of life and human beings by God.

In one of its versions, idealism is based on a dualism of mind and matter; in another, matter is reduced to mind. Examination of the history of the division of labor shows that this division resulted in a widening separation between manual and mental labor. The emergence of this separation coincides with the emergence of class-based society. Idealism received a boost from the emergence of classes and heteronomous societies; conversely, it is an ideology that justifies and is helpful in upholding such societies.[9]

With the breakdown of Fordist capitalism in the sixties, the capitalist world system entered a permanent crisis, and global problems have quickly worsened since then. A new post-Fordist mode of capitalist development emerged and individualization has shown up as a new phenomenon that serves dominating interests and results in the erosion of collective institutions that formerly seemed to give sense to the human being. Such institutions are traditional religions, unions, associations, families, etc. Capitalism is now based on a deregularized and flexible institutional setting (flexible regime of accumulation, neoliberal mode of regulation), and people throughout the world are faced with the dangers of precariousness and extinction due to the development of the internal antagonisms of the capitalist world system. With the breakdown of the Soviet Union, an ideological vacancy appeared, and the former Eastern European states have been fully included into the global capitalist dynamics.

In ideology and science, the emptiness and helplessness felt by many due to the antagonisms of the capitalist world system have resulted in a search for new transcendental and mystical explanations and salvations. As a result, there is a boom of various forms of mysticism, esotericism, and spiritualism. People are looking for irrational guidelines, instead of looking for the foundations of problems and developments within the real world. The new irrationalism is a result of the increased complexity of the world with which people cannot cope.

These irrational tendencies can also be found within the self-organization paradigm that has been interpreted by some as holistic spiritualism (for example, Capra 1982; Jantsch 1975, 1992).

In such mystical views, the universe is seen as one large living totality that consists of a network of equal parts. There is no hierarchy in nature in such conceptions and hence also no qualitative differences between systems. They are all considered as an expression of spirit. Based on the Gaia hypothesis, biologistic and ecofascistic arguments are frequently employed. In such new mystifications and irrational understandings of science, God is not necessarily considered as an eternal creator, but an eternal principle exists external to matter.

Philosophy is not an area of religious belief; religion is not a part of science and philosophy. Values and norms are part of ethics, which comprises one part of philosophy. The other parts are ontology (what is the world and all being like?) and epistemology (how do we perceive the world?). Philosophy is not an area where "anything goes" in the sense of a radical constructivist or anarchistic epistemology of science as put forward, for example, by Paul Feyerabend. Philosophy, instead, tries to connect, to generalize, and to unify single sciences. It produces interrelationships between single sciences on a more general metalevel. Hence it is based on the natural and social sciences; philosophical categories are related to the single sciences; categories like reason, love, human being are related to the humanities; categories like nature, space, time, matter are related to physics, etc.

Categories like God and Spirit that are conceived as the Absolute, as something infinite and unquestionable and as absolute truth, are not at all connected to the single sciences. This results in isolated doctrines that cannot be analyzed, questioned, and examined scientifically. For example, there is no proof for the claim that humans occupy some lower steps in a universal field where God means the Absolute. The realm of religion, mysticism, spiritualism, and esotericism is where science ends and pure ideology starts.

Hegel said that "what is reasonable is actual and what is actual is reasonable." Actuality means materiality, hence turning Hegel right side up means that only material reality can be reasonable, and that something that is conceived as existing prior or external to matter is unreasonable. Areas such as religion and esotericism are unscientific and irrational; they proclaim absolute truths that cannot be researched or contested. Irrational arguments avoid objectivity, exactness, logic, verifiability, and falsifiability. Pseudosciences use strategies of immunization in order to avoid criticism. If pseudosciences like creationism, spiritualism, mysticism, parapsychology, and astrology were right, this would mean that the modern sciences are all wrong. Hence isolationism is typical for such areas of thinking.

Religion and other irrationalisms have no scientific grounds. Religions might include some elements that are interesting for

science and philosophy, but one should deal with these topics scientifically, not religiously and in terms of absolute truths. Religion and esoterics are a "universal basis of consolation and justification. . . . Religious distress is at the same time the *expression* of real distress and also the *protest* against real distress. Religion is the sigh of the oppressed creature, the heart of a heartless world, just as it is the spirit of spiritless conditions. It is the *opium* of the people" (Marx 1975, 175).

There is no need to refer to mystic forces for explaining the self-organization of the universe and society. New properties simply emerge due to the complex interactions of the parts of a system, not because some external holistic force is at play. The founders of the philosophy of emergentism, Conwy Llord Morgan and Samuel Alexander, saw emergence as something mystic, and so they introduced spiritual forces (known as "Nisus") as the driving principle. To posit such forces shows a lack of understanding of the dialectical relationship of quality and quantity and the whole and its parts. The emergence of order need not be explained metaphysically, because new qualities of the whole are solely constituted by interactions of its parts. The philosophical mistake of overspecification that is grasped by Occam's razor is made by holistic thinkers such as Jantsch and Capra. This opens the way for irrationalism and esotericism, which belong to the scope of ideology rather than to (critical) *science.*

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NOTES

1. For Hegel also, matter is an abstraction. He defines the Thing as the determined and concrete unity of Ground and Existence. It consists of matters or materials, which are themselves partly things, which in that way may be once

more reduced to more abstract matters. Numerous diverse matters coalesce into the one Matter.

> Thus Matter is the mere abstract or indeterminate reflection-into-something-else, or reflection-into-self at the same time as determinate; it is consequently Thinghood which then and there is—the subsistence of the thing. By this means the thing has on the part of the matters its reflection-into-self . . . ; it subsists not on its own part, but consists of the matters, and is only a superficial association between them, an external combination of them. (1973, §127)

2. "The process of continual change which characterizes the world at the subatomic level is a striking confirmation of the fact that dialectics is not just a subjective invention of the mind, but actually corresponds to objective processes taking place in nature. This process has gone on uninterruptedly for all eternity. It is a correct demonstration of the indestructibility of matter—precisely the opposite of what it was meant to prove" (Woods and Grant 2002, 105).

3. In the eighteenth century, Kant, too, assumed a permanence of substance and said that "throughout all changes in the world *substance* remains, and that only the *accidents* change" (1933, 214).

4. Bloch says that mechanical materialism has a concept of matter that is only analytical and static; it does not know history, perspective, and horizons of transformation (Bloch 1963, 208).

5. The German term used by Bloch is *ausgebären,* which corresponds on the one hand to "bearing," and not only points at an active production, but also refers to a developing process.

6. Due to the fact that the physical principles are the most fundamental ones, they can also be considered as general principles of self-organization. Self-organization in other systems like biological or social ones is based on these fundamental qualities, but also shows additional emergent qualities. For a detailed discussion of principles of social self-organization see Fuchs 2002a, 2002b, 2000c, 2003a, 2003b, 2003c, 2003d, 2003e, 2004; Fuchs and Hofkirchner 2003.

7. Geoffrey Hodgson points out that the concept *emergence* was anticipated by the philosophies of Hegel, Marx, and Engels: "The terms 'emergence' and 'emergent property' date from the last quarter of the nineteenth century. However, the general idea behind these terms is older. It is redolent, for example, of the 'law of the transformation of quantity into quality' laid down by G. W. F. Hegel in his *Logic* and subsequently taken up by Karl Marx and Frederick Engels" (2000, 65).

8. Law of Ground:

> Ground, like the other determinations of reflection, has been expressed in the form of a law; everything has its sufficient ground. This means in general nothing else but: what *is*, is not to be regarded as a merely *affirmative immediate* but as something *posited*; we must not stop at immediate determinate being or determinateness as such, but must go back from this into its ground, in which reflection it is a sublated being and is in and for itself. In the law of ground, therefore, the essential character of reflection into into-self in contrast to mere being is expressed. To add that the

> ground must be *sufficient* is really quite superfluous for it is self-evident; that for which the ground is not sufficient would not have a ground, but everything is supposed to have a ground. (Hegel 1969, 446)

9. "Essentially, philosophical idealism is a product of the extreme division between mental and manual labor which has existed from the dawn of written history down to the present day" (Woods and Grant 2002, 36).

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