

Systemic versus Genetic Determination

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► **Purpose** – Reflecting on the propensity of our culture to think in local linear causality such as “genetic determination” by examining (living) systems and their operation.

► **Findings** – The existence of a system is operational, and a system exists as such only as long as the operational conditions that constitute it prevail. As the observer distinguishes a system, he or she specifies with his or her operation of distinction the conditions that constitute the system. Since the adaptation between living systems and medium is invariant, all that happens in their history must happen as a flow of structural congruent changes conserving their organization and adaptation. Therefore, the ontogenic phenotype is not genetically determined but arises in the process of epigenesis, i.e., along a path of interactions starting from the initial structure of both system and medium, along the conservation of its living. ► **Implications** – Natural selection should not be considered as a directing pressure causing the differential survival of living systems but as its result.

► **Key words** – Causality, structural determinism, systems, existence, adaptation, epigenesis, Lamarck, natural selection.

One of our main difficulties in understanding historical phenomena in general, and biological and human phenomena in particular, is our cultural manner of thinking in local, linear causal terms. Thus, our usual form of arguing is that “A” causes “B,” as if “A” determined “B” by itself. And we are frequently unaware that what we call a causal relation is an abstraction of some local regularity of the structural dynamics of a larger system that we have not distinguished as such in our attempt to understand, in local linear terms, the situation that we want to explain. In other words, we frequently do not see or are not fully aware of the system with which we are dealing at any instant, and as we attend to the linear local relations that constitute the particular situation under our view, we do not grasp the systemic structural coherences to which it belongs.

Causality is an a priori explanatory notion used by the observer to deal with the regularities of the linear flow of his or her experiences. As such, causality is highly appealing in a culture centered on control, such as our patriarchal culture, because its application, if properly handled, seems to offer endless possibilities for the management and control of human life, including human relations with the biosphere. In contrast to the notion of

causality, the notion of *structural determinism* is not an a priori explanatory notion, but rather an abstraction from the coherences of the operation of the observer in his or her domain of experiences with which he or she connotes the operational coherences of the domain of existence and operation of living beings. Structural determinism, then, is not

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an explanatory argument but our condition of existence. The notion of structural determinism is not so appealing in a patriarchal culture because its application demands sensitivity to and awareness of the systemic coherences of the domain of living of the observer and leads to cooperation, not to domination and control.

Another aspect of our difficulty in seeing as well as in understanding systems is that the distinction of a system and the understanding of the flow of its operation as a totality requires the observer to be aware that systems exist in two non-intersecting operational domains; namely, in the domain of the operation of their components and in the domain in which they operate as totalities. That is, to understand a system requires: (1) seeing it operating as a totality in its domain of existence as a totality; (2) seeing it as a composite entity by seeing its components as they compose it as a network of interconnected pro-

cesses; and (3) seeing a non-causal generative relation between these two domains that gives origin to the system as a totality in the larger context in which it exists as such. Moreover, because we usually analyze systems in terms of local linear causal relations between their components, we do not easily see and understand the interrelated structural dynamics entailed in the simultaneous origin of a system and its domain of existence, nor do we see the coherent structural changes of the system and its circumstances while the system is conserved.

Because I think that we have to understand systems in their constitution and relational operation in order to understand both humanness now and the origin of humanness in the history of living beings to which they belong, I shall now make some remarks about systems and their operation.

Systems

A network of processes realized by interacting elements that through their preferential interactions and relations establish an operational boundary that separates them as a whole from other elements with which they may also interact is a *system*. Therefore a system is a totality and operates as a totality in the domain in which it arises as a totality. The elements that participate at any instant in the network of processes that constitutes the system at that instant are its *components*. That is, the elements that compose a system are its components only as they participate in the operations that compose it, and when they stop doing so, they stop being components of the system. Therefore, the existence of a system is operational, and a system exists as such only as long as the operational conditions that constitute it prevail. Accordingly, a cell, a family, a political party, an organism, a factory, or a country, exist as systems (totalities) only as long as the internal and external dynamic relations that constitute each of them, and realize in each of them their particular different extensions, are conserved through their

operation. And any of the elements, molecules, persons, communities, institutions, and so forth that constitute these different systems integrate them as systems only as long as they participate in their composition. The elements with which the components of a system interact that are not components of it constitute the *medium* in which the system exists.

In these circumstances, a system arises abruptly and spontaneously in the moment in which an operational boundary is produced that separates a collection of interacting elements, that thus become its components, from other elements with which these may also

interact and that become its medium or domain of existence as a composite unity because they are not its components. A system always appears to an observer as arising from chaos or from nothing, even if afterwards he or she may imagine a generative mechanism or process to explain its origin. This is so because the processes that give origin to a system and the processes in which the system participates as a totality once it is constituted take place in different and necessarily non-intersecting operational domains. The boundaries of a system are operational and arise in the terms just described. Similarly, and according to what I have already said, the components of a system are operational, and any element becomes a component of a system only as it participates in its composition and remains a component only while it does so.

As the observer distinguishes a system, he or she specifies with his or her operation of distinction the conditions that constitute it. So a system is brought forth in the observer's domain of existence by the operation of distinction that he or she performs, and does not exist or preexist in it by itself as an independent entity, although once it is distinguished it can be treated as if it indeed existed by itself. What occurs is that as the observer distinguishes a system, he or she realizes with his or her behavior, in a domain of structural determinism that is thus specified, a set of operations that will result in the appearance of the system whenever they happen in that domain. Moreover, as the observer distinguishes a sys-

tem, he or she specifies an operational domain in which such a system will arise regardless of whether those operations take place spontaneously or as a consequence of the doings of some other system. I call the set of operations that brings forth a particular system the *operation of distinction*.

A system does not preexist in the domain of existence of the observer prior to the realization of the operation of distinction that will bring it forth. Existence is a cognitive

A system is brought forth by the observer's operation of distinction and does not preexist as such as an independent entity

claim, in the same way as reality, and as such it pertains to the domain of operation of the observer as a living system in language. In these circumstances, because language happens in the domain of

the observer's doings in the recursive flow of consensual coordinations of consensual coordinations of behaviors,¹ the claim of existence as a cognitive claim gives rise to that which is claimed to exist in the operational concreteness of the structural domain in which this cognitive claim is made. It is because existence is a cognitive claim that a system exists only as an observer claims, or can claim, its existence through actually performing or stipulating the operation of distinction that will bring it forth in a particular domain of operational coherences of his or her living. What I say then, is that when an observer speaks of existence and of the medium in which the system distinguished exists, he or she refers to the domain of interactions in which it operates and in which it arises with the operation of distinction that brings it forth. Moreover, all this is valid for the existence of the observer, too.

We belong to a culture that operates in terms of considering that we human beings exist immersed in an independent reality. This attitude is what makes us speak as if we human beings were physical entities existing in a physical space, and it is this attitude that leads us to give to the science of physics the epistemological preponderance that it now holds. But the understanding of living systems and of human beings shows that living systems are systemic entities and that cognition is a manner of relating, and not a way of

referring to an independent reality that cannot be known or even talked about. This understanding shows that knowing is a manner of living in language doing things together, and that the epistemological grounding of human knowledge is human operation as a living system. Yes, for epistemological reasons as we explain living systems we need a substratum that makes them possible as living systems, yet we cannot talk about it, because as we do so we talk not about it but rather about what we do. In these circumstances existence is what we do, and something is there as the conditions of our actual or possible doings are fulfilled. In these circumstances also, the cosmos that we human beings generate in our explanations of our experiences as if it existed independently of our doings, arises in our doings immersed in a substratum that we cannot characterize, not even to claim that there is any resemblance between it and the cosmos that we describe and explain. According to me, this is not a limitation, it is our condition of existence, and it is our awareness of this that makes us human beings now totally responsible for how we live.

Conservation of adaptation

In modern evolutionary explanations, adaptation, the operational relation of dynamic congruence between a living system and the

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medium in which it exists, is usually treated as a variable. Following this view, adaptation is usually spoken of as an attribute of an organism (and also by implication as an attribute of systems

in general) as if living systems could be more or less adapted to the medium in which they exist. With this manner of thinking, biologists also frequently use the word "adaptation" to refer to the manner of operational congruence with the medium that a living system exhibits in its living (or its operation), and as they do so, they treat the operational congruence between living system and medium as something obtained in the process of adaptation. I think differently. I think that the operational congruence between living system and

medium is not a variable because it is for them (as for all systems) a condition of existence. That living systems are alive only as long as their relation of operational congruence with the medium is conserved is obviously apparent to all biologists at the moment in which they reflect on what actually happens in the realization of the living of an organism. What occurs is that as one looks at a living system one may think that it would survive better in another environment, and one treats that opinion as a revelation of what happens with the living system. But that reflection reveals only the imagination of the observer. Therefore, what I say is that adaptation as a relation of operational congruence between living system and medium is necessarily an invariant.

In my view, then, a living system lives only as long as its organization and its adaptation are conserved, and all structural changes takes place in it around the conservation of both its organization and its adaptation in the continuous flow of its living, or it disintegrates. So conservation of organization and adaptation are two basic operational conditions of existence for any system, and all that has happened and happens in the history of living systems has happened and must happen as a flow of structural changes under the conservation of organization and adaptation of the living systems in a process in which living system and medium change together congruently.

Systems as totalities

A system does not exist as a totality by itself in solitude. A system exists in a medium in recursive interactions that trigger structural changes in it, and it conserves its identity as a system of a particular kind only as long as the organization that defines and constitutes it as a system of that kind is conserved through those recursive interactions. That is, a system can exist only in a medium that triggers in it those recursive structural changes through which its identity and adaptation are conserved. Therefore, the identity of a system is not determined in its components, and the kind of entity that a system is as a totality at any moment is constituted in the dynamics of interactions in which it is realized as such through the continuous flow of its structural changes in the conservation of organization and adaptation. At the same time, the actual

realization of a system in its recursive interactions in a medium continuously brings forth the medium in which it is realized while the structure of a system and the structure of the medium change together congruently along the flow of their recursive interactions, or the system disintegrates. The notion of *structural coupling* refers to this. I will now summarize and expand on some of what I have said about systems:

1. A system exists in interactions with the elements of a medium that arise together with it as it becomes a system in its cleavage from the medium: system and medium arise together. Prior to this cleavage, the elements that will constitute the system and the medium are not separable because there is neither system nor medium, and any attempt to identify those elements before this arises in its distinction is an operation that can be performed by the observer only after he or she has conceived the system through his or her imagination. A system interacts through the operation of the elements that compose it, and the interactions trigger in it structural changes that are determined at any moment by its structure at that moment. Moreover, a system remains a system of a particular kind only as long as the organization that defines its class identity is conserved through the structural changes that take place in it both through its internal dynamics and through those structural changes triggered in it by its interactions in the medium.

2. The medium in which a system exists arises together with the system, and all that applies to the system as such, applies as well to the larger system that forms its medium. In these circumstances, a system exists in the conservation of its organization through its structural changes while interacting in a medium that changes congruently with it only as long as the changes in the medium make the realization of the system possible. Therefore, a system exists and conserves its identity only while its realization in its recursive interactions with the medium results in the appearance in the medium of those conditions that make possible the conservation of the system – and vice versa. In other words,

the conservation of the identity of a system through a continuous structural drift in structural coupling is a systemic phenomenon.

3. The systemic conservation of the identity of a system is a feature of its spontaneous constitution as a structure-determined entity, not the result of a design or a purpose. A system arises spontaneously when the structural conditions that make it possible prevail in the background in which it appears, and it is conserved for as long as the dynamic conditions

The background in which a system appears is a domain of chaos or nothingness, about which the observer can say nothing before the appearance of the system

of interaction in the medium that arises with it and make its conservation possible are there. The background in which a system appears is indeed a domain of chaos or nothingness, a domain of structural coherences about which the observer

can say nothing before the appearance of the system. Chaos and nothingness are cognitive relations. After the system appears, the background changes its character and becomes knowable through the system itself as this is used as an indicator of the characteristics of the background in which it arose. Accordingly, a system arises and is conserved only in the systemic structural dynamics that makes its spontaneous appearance possible in the conservation of the organization that constitutes it. I call this process, “spontaneous organization from chaos or nothingness”: all systems arise spontaneously from chaos or nothingness, and the chaos or nothingness from which a system arises stops being chaos or nothingness and becomes a medium whose structural coherences become visible as they are revealed by the operation of the system and are used by the observer to explain the origin of the system.

4. The systemic conservation of the identity of a system in its recursive interactions with the medium opens a space for all those features of the structure of the system, and of the relations of the system with the medium that are not involved in the conservation of its identity, to change. In general terms, when in a collection of elements some configuration of relations between them begins to be conserved, a space is open for all else to change around what is conserved. In particular, when in the systemic realization of a system some

relations begin to be conserved in addition to the relations of the organization of the system, all else becomes open to change. Similarly, when in the interactions between two or more systems some of their relations begin to be systemically conserved together with the organizations of the systems involved, all else becomes open to change around what is conserved.

Epigenetic process

The development of a living system and, in more specific terms, the life history of an organism (its ontogeny) occur in a systemic form as a history of structural changes around the conservation of the manner of living that defines the organism as a living system of a particular kind. In biology this phenomenon is called *epigenesis*, a term that refers to the systemic transformations that an organism undergoes in its life history through the interactions of its initial structure and the medium along the conservation of its living.²

Due to the systemic dynamics of the epigenetic process, the initial genetic (DNA) and somatic (cytoplasmic) constitution of an organism do not determine the structural and relational changes that it will undergo along the course of its living. The genetic and somatic initial structure of a living system (its *total initial structure*) determines the domain of the different epigenetic courses that it may follow in its life history as a concrete field of possibilities, but only one of these will be realized in its actual living. In other words, the genetic constitution of a living system does not determine the features that this develops along its life, and, therefore, it is inadequate to speak of genetic determination of the characters or features that arise in the life of an organism. It is due to the systemic nature of all biological phenomena that, strictly speaking, there is no genetic determination of the characteristics of an organism as such in its domain of existence. I repeat, the total initial structure with which a living system begins its life only determines the field of possible epigenetic courses that it may follow. The epigenetic course that, in fact, happens in the

ontogeny of a living system arises in the actual circumstances of its living as it encounters the medium as if the medium existed as an independent system. But, at the same time, the place in the medium in which a living system normally begins its living through the reproduction of its progenitors is not just any; it is a particular one that has also arisen in the systemic dynamic history to which the progenitor living system belongs and in which living system and medium have changed together congruently. Human history is not different.

Cellular epigenesis

The structural dynamics of a single cell – its dynamics of molecular transformations and productions – also occurs as an epigenetic process. That is, the course followed by the molecular changes of a cell along its individual ontogeny arises moment by moment in

the interplay between the molecular changes triggered in the cell by its interactions with the medium and those that arise in it in the course of its own internal dynamics. The overall consequence of this process is that the *total genetic constitution* of a cell (that is, the structural and the dynamic configuration of its nuclear DNA, and the structural and dynamic configuration of its cytoplasm) changes along its life history in such a way that when the cell reproduces it does so with a total genetic constitution different from the one that it had at its birth. As a result, the offspring of such a cell may give rise to the realization of a cellular manner of living or ontogenic phenotype different from the parental one. This phenomenon occurs, for example, in the course of the cellular differentiation that takes place during embryonic development when the different cellular lineages (the different types of cells) that compose the organism arise through a shift of the total genetic constitution conserved through reproduction in a manner that involves nuclear DNA and cytoplasm. In

this context, two different systemic processes can take place through cellular reproduction in an organism, which will give rise to tissue and cellular differentiation. These are:

1. the systemic conservation in the offspring of the total genetic constitution of the parental cell in an epigenetic manner that conserves the original cellular ontogenic phenotype;
2. an epigenetic change in the structural dynamics of the parental cell that gives rise to a change in the total genetic constitution of the offspring that is epigenetically conserved in the realization of a new cellular ontogenic phenotype.

The processes of tissue and cell differentiation that take place during embryogenesis are not usually seen or remarked on as processes of displacement of the ontogenic phenotype realized and conserved in the epigenetic constitution of different cellular lineages. I think that this is so because of two circumstances: (1) because the attention of the observer is usually oriented nowadays to the molecular processes that seem to secure the regular repetition of the standard molecular and cellular dynamics according to an expected or known norm; and (2) because we usually assume that the reproductive stability of the DNA is due basically to its molecular structure and not to systemic conditions in its synthesis.

The epigenetic change of the total genetic constitution of a cell (in a way that may include its DNA) according to the particularities of its life history is not a phenomenon of inheritance of acquired characters in the terms usually understood as Lamarckian inheritance. Lamarck seems to have proposed that the characteristics that an organism acquired in the course of the life that it happened to live could be directly inherited and appear in the offspring. Such a

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proposition, of course, is in conflict with our present view that associates inheritance with DNA. Lamarck, of course, could not have thought about heredity as we do now in terms of hereditary molecules, but he was concerned with how the life history of the parents could participate in the life history of their offspring. I think that this theme can be

reconsidered. As already stated, I claim that heredity is a systemic and not a molecular phenomenon, and that it occurs as a systemic reproductive conservation of a manner of living in a process in which both organism and medium participate through the conservation of the organization of the organism and its adaptation to the medium. The DNA plus all the other cellular components determine what epigenetic courses are possible for an organism at the beginning of its life, but the actual epigenetic course that the organism follows in its particular life history arises in a systemic dynamics of recursive interaction with the medium in which it lives. So, a manner of living is conserved through reproduction only if the systemic dynamics that results in the repetition of a particular epigenesis is conserved, and such a conservation is a systemic process that entails that the organism and the medium undergo coherent structural changes.

Accordingly, although the ontogenic phenotype that an organism lives is not determined genetically (only by its DNA), it is made possible by its genetic constitution

and it can be and is conserved systemically in the organism–medium relation when it is conserved through reproduction. In these circumstances, then, the epigenetic change of the total genetic constitution of a cell or of a multicellular organism during its ontogeny is a phenomenon through which the course of the individual life history of a cell or of an organism has hereditary consequences through systemic processes involved in the phenomenon of reproduction.

Lineages

When a manner of living (an ontogenic phenotype) begins to be conserved generation after generation through reproduction, a lineage arises. As I have said, the conservation of a manner of living through reproduction is not genetically determined, even though the genetic constitution of the organism makes such conservation possible. The reproductive conservation of a manner of living is a systemic epigenetic process. In the epigenesis the structure of an organism and the structure of the medium change together congruently,

and, as a result, when reproduction takes place the new organism is deposited in a place determined by the living of the progenitors. As a result of this process, some of the peculiar features acquired along the life of the progenitors can be systemically repeated in the epigenesis of the offspring, giving rise to the possibility of the establishment of a new lineage.

As the latter happens, an observer sees the reproductive inheritance of the manner of living (ontogenic phenotype) systemically conserved in the lineage as if it were the result of a genetically determined process. But the manner of living is systemically inherited, not genetically determined, and heredity is not a genetically determined process. The systemically conserved ontogenic phenotype arises anew in the epigenesis of the new generation through the systemic conservation of the genetic and cytoplasmic structure that makes it possible, and the systemic conservation of

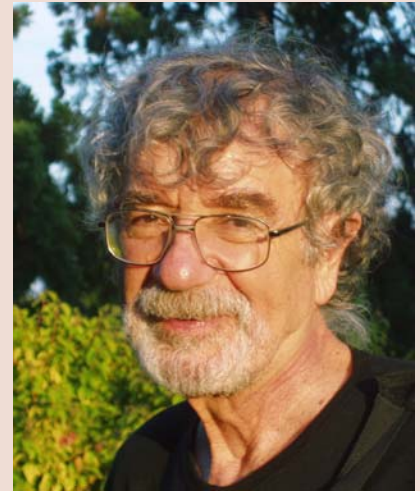
the structure of the medium in which it can be realized.

Since the initiation and conservation of a lineage occurs as a systemic process, and the ontogenic

phenotype or manner of living conserved in a lineage is not genetically determined, any manner of living that can be systemically conserved from one generation to the next can give rise to a lineage. When this happens, the genetic (DNA) constitution of the members of the new lineage is opened to change in any way that does not interfere with the realization of the manner of living of that lineage and begins to drift in a course contained within operational boundaries defined by the epigenetic realization of the systemically conserved ontogenic phenotype. As a result, in the succession of generations of a lineage all genetic changes become co-opted in a trend that facilitates the manner of living (ontogenic phenotype) conserved in the lineage, or the lineage changes, or it comes to an end. What is conserved, in fact, in the constitution of a lineage, is an *ontogenic phenotype–medium* relation.

The history of living systems on earth is the history of the configuration of a biosphere as an immense system of interwoven congruent epigenesis that is continuously arising systemically as a matter of course according to the spontaneous structural coherences of all the systems involved. In this process every liv-

ABOUT THE AUTHOR



Humberto Maturana was born in Santiago Chile in 1928. Starting with biological research on perception, he has developed the Biology of Cognition and the Biology of Love. Several threads are intertwined through the development of his body of work. For one, he notes that in any relation where something, including an explanation, is offered it is the person who accepts who determines the truth, value, or adequacy of the offering. Maturana retains an awareness throughout his work that it is the observer who determines the validity of what he or she accepts as valid. In his works he shows that we do not know, and constitutively cannot ever know, if what we live as valid at any instant is something that we shall later treat as a mistake or an illusion. In noting that we live our lives trusting the repetitiveness of the manner in which things appear to operate, he developed the notion of structural determinism. As we too are structure determined systems so that external agents do not specify what happens in us, then nothing external can tell us anything about itself. Thus instead of asking how things are, he began following a path of asking for the processes that gave rise to them, and for the criteria used to accept the answers he considered valid. Thus in all his writings one may find the proposition of generative mechanism that give rise to the phenomena he explains, along with the criteria he uses to claim that something is as he says it is.

ing system is part of the medium of the others in a network of recursive interactions in which each living system and its medium change together congruently. Ecological coherences reveal in the present such a history of systemic conservation of coexistence in a field of changing genetic constitutions co-opted by the manners of living that are conserved in a manner that facilitates their occurrence. Or, in other words, ecological coherences in the constitution of a biosphere are a necessary result of the systemic coevolution of living systems on the earth.

From all that I have already said, it is evident that habits and preferences, whether

behavioral, developmental, or metabolic become incorporated in the features that define a lineage if they are conserved systematically through reproduction (*systemic reproduction*). It is also evident that such a phenomenon gives evolution both a structural and a temporal plasticity much greater than that expected from mutations and gene recombinations only. It is also evident that all structural and all relational processes involved in the realization of the living of a living system can participate in the process of systemic conservation of an ontogenic phenotype. In these circumstances, a lineage may thus arise through the conservation of

habits or preferences, whether relational or organic.

Biologists have frequently spoken of natural selection as if this were, acting as a directing pressure, the mechanism that generates differential survival of living systems through progressive adaptation to the medium in their evolutionary history. I think differently. I think that natural selection is the result of the differential survival of the living systems, and not its origin. In fact I maintain that the generative mechanism of evolution in living systems is a spontaneous ontogenic and phylogenetic structural drift that results in differential survival.

Notes

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1. Organisms coordinate their behavior either as a result of their development in manners that do not depend on and are not formed in their individual histories of interactions, which we can call instinctive, or in manners which depend on and are formed in their individual histories of interactions and which we can call consensual.

Consensual coordinations of behavior can involve any form of interaction. When consensual coordinations of behavior become recursive, that is, when consensual coordinations of behaviour coordinate consensual coordinations of behavior, a new domain of doings appears that can be expanded through further consensual coordinations of behaviors and recursions in consensual coordinations of behaviors in which infinite kinds of new of consensual doings are possible, and which we live as languaging. Indeed, I claim that humanness arose when living in language begun to be conserved from one generation to the next as the manner of living that defined our lineage, some three million

years ago, in the learning of the children at the arising of our ancestral family in some branch of bipedal primates.

2. The notion of epigenesis was introduced by the embryologist Caspar Friedrich Wolff in 1759 as he refuted preformationism and replaced it by epigenesis as the progression from simpler to more complex through a cumulative development. It is here used as its meaning implies, development (genesis) on top of (epi) a prior configuration that itself arose on top of that which pre-existed it.

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