A note on information, order, stability and adaptability

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Abstract

This brief essay explores some of the subtler ramifications of the notion of order or information. It starts out by arguing that and why a system's information or order must be one of the central determinants of its power and productivity, hence of its capacity to survive. Furthermore, such information must also underlie a system's stability and adaptability. And this again leads us to what may well be one of the main laws or non-linear relationships underlying the growth of information or order: an increase in a system's information or order is more likely as its initial level of order is already higher.

Keywords: Information; Order; Adaptability; Stability; Non-linearity; Social systems

1. Information, order and work

In the last century or so, the notion of information or order seems to have been growing into one of the central unifying notions of all science. It originated in 19th-century thermodynamics, in which a material system's level of information appeared to determine the amount of usable energy which it contains, and also the amount of work it is able to perform. It next made its appearance in the theory of communication. Shannon and Weaver, in particular, saw that the information carried by a message was a matter of its internal organization (Shannon and Weaver, 1959), although, somewhat unfortunately, they identified a message's 'information' content rather as its uncertainty or entropy (see Stonier, 1990, pp. 54 ff.). Nowadays, it is becoming ever clearer that biological, theoretical, human, cultural, and social systems, too, function by virtue of the information or order which they hold. Apparently, then, the notion refers to a crucial characteristic of our universe (See for instance, Brillouin, 1962; Jantsch, 1980; Campbell, 1982; Haken, 1984; Brooks and Wiley, 1986; Prigogine and Stengers, 1986; De Vree, 1990, 1994; Stonier, 1990).

That the concept has become known by the name of 'information' essentially represents an incident of intellectual history, which is unfortunate because it may occasionally cause misunderstandings. For in ordinary life, 'information' tends to refer to what we know, something which, on the face of it at least, differs quite considerably from a conception in which the notion basically stands for a system's order or organization. However, the two conceptions may well differ by less than what might appear at first sight.

Thus, there are strong reasons to believe that common, intellectual information cannot just be everything we know, but that it also must be a
matter of insight into how things hang together, that is, of the measure of order or organization in what we seem to know. After all, a disparate collection of ‘facts’ or bits and pieces of knowledge is just that: a meaningless jumble, of which it is impossible to make head or tail, and which is quite useless both in our practical behavior and in the production of more insight. It is meaningless precisely because it lacks order or coherent organization. Conversely, one of the basic reasons for the use of the thermodynamic notion of information was precisely that information renders a system more predictable, i.e. that it provides us, the observers, with information in the everyday meaning of that term.

As intimated already, information may be defined as a system’s, any system’s, measure of coherent order or organization. It denotes the degree to which the system’s several components are well-aligned or coordinated with each other in the sense that what any single one of them does or produces enhances the effect or efficiency of what the others do or produce, and that, conversely, it prevents or inhibits those actions that have a deleterious effect on such productivity or efficiency. In other words, a system’s order or information is the source of the synergy that forms such a prominent and essential feature of the natural world, human as well as non-human (see Haken, 1978; Corning, 1983; Freeland, 1984; Bushev, 1994). As a consequence, the system as a whole will be able to produce a joint effect exceeding that of which its individual components would be capable of. Information or order, then, is what makes the whole more than the sum of its parts, as the saying goes. And a lack of it means that the likelihood that the system’s components interfere with each other or that they even stimulate such actions as inhibit each other’s productivity, is higher, and that the productivity of the whole will be lower.

Thus, a common magnet works by virtue of the neat alignment of the elementary magnets of which it consists. A modern automobile or steam engine is a much more efficient engine than its predecessors because, briefly, its many parts are so much better attuned to each other. Thus, it is the deductive coherence among its component propositions that gives scientific theories such a high level of (intellectual) order or information, and which makes them such excellent instruments for producing more of it. It is the rich and coherent organization of our ideas, notions, preferences, and values which allows us to act more or less efficiently, and to maintain our balance in the face of the vicissitudes of life. It is its organization and discipline which makes a business enterprise such a productive, and an army such a destructive (though not self-destructive) social system. It is a comparatively high measure of information or order, which underlies both the peace and security, and the power and productivity of a well-ordered society. Conversely, it is the relative absence of order and information which makes international systems so unpleasantly destructive and unproductive.

Unfortunately, however, a state of disorder or entropy is also a system’s most probable state or, put a bit more generally, the probability of a system having a higher level of order or information must be lower than that of its having less of it. This derives ultimately from the second law of thermodynamics, according to which everything is subject to continuous decay so that the creation or maintenance of order or information costs effort or work. And if this is not forthcoming, the system will inevitably return to a state of complete disorder or entropy.

In that condition, a system’s components typically behave just randomly, and enjoy the greatest measure of freedom to behave or move how best pleases them. So, when in a state of high entropy, the system’s components are least constrained by each other, and the number of possible (micro)states accessible by them is accordingly largest. Conversely, as a system contains more order or information, the degree to which its several components constrain or determine each other’s state, movement, or behavior is greater, too. In other words, more order also means that a commensurately smaller number of a system’s components will determine the state, etc. of the rest, that is, of the system as a whole. This means that as a system possesses more order or information, its state or behavior will be commensurately easier to predict, i.e. it makes it easier for us to cull any (intellectual) information from it.
2. Information, stability and adaptability

In practice, all real systems, with the possible exception of the universe as a whole, are open systems in that they interact with an environment with which they exchange all sorts of matter or energy. This applies especially to a biological and human social or behavioral system which exists and survives by virtue of a more or less continuous exchange of matter or material resources with their social and physical environment. In a way, such systems are even ‘designed' precisely for such exchange.

To assume, then, that a system functions better or more efficiently if it contains a higher level of order or information, would also commit us to saying that more of such information also implies that it will be better able to profit from its interaction with its social or physical environment so as to maintain or even strengthen itself — and, of course, to withstand what might harm it.

Yet, this environment typically changes, and subjects the system to all sorts of fluctuations, disturbances and perturbations. So to say that a system’s capacity to process, use, or withstand what its social or physical environment presents it with, must be proportional to its level of order or information, and must also be taken to imply that it will be able to do so with respect to a greater range of more varied stimuli or exchanges. In other words, as a system possesses more order or information it will be better able to use or withstand a greater variety of environmental stimuli so as to maintain or strengthen itself, i.e. its own measure of order or information.

But this means that the order or information notion must also cover a system’s capacity to adapt its own internal structure so as to preserve or enhance its own measure of order in the face of a larger range of environmental stimuli, fluctuations, or changes. In brief, the notion of order quite naturally also appears to imply a system’s adaptability to environmental change and variation.

But the notion of adaptability is but a generalization of that of stability. And as a consequence, the above reasoning would also commit us to say that as a system becomes more highly ordered, it will also become more stable.

In the most simple case, a system is called stable if, after being disturbed, it manages to return to its previous state. And, conversely, a system is called unstable to the degree that an initial disturbance is being magnified to ever greater proportions. Generalizing this notion just a little bit, we might call a system stable to the degree that it is able to more quickly or easily correct a wider range of (larger) disturbances.

In view of the ubiquity of change and development, however, this conception of stability will often be of but very limited relevance to empirical inquiry. That is, we will often not even be interested in a return to a status quo ante, the system’s initial state, to begin with. In many cases, we will have to accept the system’s change or development as inevitable, and a return to its previous state or condition as utterly impossible. In such cases, we will, rather, be interested in how precisely the system responds to the perturbations to which it is being subjected, specifically, whether it will do so in a peaceful or violent way, whether it will maintain its productivity or power in the process, or whether it will evolve and strengthen its structure so as to make it better able to cope with (larger) perturbations in the future.

This conduces us to a considerable generalization of the simple stability notion discussed above. That is to say, we shall call a system stable to the degree that it responds to (larger) disturbances or perturbations in such a way as to maintain or even strengthen its own power or inner organization, and of which the simple stability notion just discussed represents but a degenerate case. But this stability notion is basically equivalent to that of adaptability. Accordingly, we may conclude that a system’s stability, too, must be proportional to its order or information.

In all, then, we arrive at the following tentative ‘scale', linking the notion of information to those of stability, adaptability, productivity and synergy:

very low level of information or order ('disorder'): System is highly unstable, virtually incapable of adapting to even small changes in its environment, unproductive or even self-destructive, and poorly able to maintain itself. Synergetic effects are almost lacking.
low level of information or order: System is stable in, and capable of minor adjustments to a narrow range of environmental conditions, in which it is barely able to survive. It is not very productive or powerful, and exhibits but little synergy.

moderate level of information or order: System is stable in, and capable of adjustments to relatively small environmental fluctuations within a moderate range of conditions. Its chances of survival are moderately good, and it is moderately productive or powerful, while exhibiting moderate synergetic effects.

high level of information or order: System is highly stable in, and adaptable to larger environmental fluctuations and changes. It is highly productive or powerful, exhibits marked synergetic effects, and is able to survive in a broad range of conditions.

very high level of information or order: System is exceedingly stable in, and adaptable to a very broad range of environmental conditions and changes. It is very powerful or productive, and capable of systematically improving its own performance. It exhibits very strong synergetic effects, and is able to survive in very different and highly changeable environmental conditions.

Of course, in all probability, neither a system’s information or order, nor its stability or adaptability will ever be absolute. That is to say, these notions are defined in relation to a certain range of environmental conditions, fluctuations and changes. But it may always happen that the environment confronts a system with such events, stimuli, impulses, or inputs of matter or energy, as fall outside the range of things which the system is initially ‘designed’ to process, and to which the system may not be able to adapt in time. In fact, what makes an occurrence into a ‘shock’ for any particular system might well be defined as something which deviates from what that system is normally built to process.

For instance, a piece of dynamite will blow up only in case the energy fed to it by means of a detonating fuse exceeds a certain level, but it is quite invulnerable to anything below it. Thus, too, the human body is admirably suited to profitably use moderate amounts of a limited range of foodstuffs, and to cope with such temperatures and temperature changes as we meet in most climates on Earth. But it is plainly incapable of thus using the energy of the bullet or shell fired at it, and it will be destroyed by the heat of a blast-furnace. Similarly, whereas a few West European countries, as well as the United States and Japan, managed to adapt themselves in a relatively smooth, peaceful, and productive fashion to the shock of the Industrial Revolution, quite a few others succumbed to the strain. And in the relatively disordered European system as a whole, this same shock led to considerable destruction and bloodshed.

Yet, it should also be recognized that highly ordered systems will typically also be quite delicate things — with respect, that is, to such stimuli or perturbations as lie outside the range for which they have been ‘built’. For the structure of such systems will typically be very dense in that their components will be tightly connected by a great number of mutual, direct and indirect relationships. As a consequence, disturbances that change the state of some of those components will be transmitted commensurately rapidly throughout the whole system. Characteristically, too, many of the relationships underlying such systems will be of a non-linear nature. As a consequence, initially relatively small perturbations may easily grow to ever larger proportions as they are being transmitted through the system, eventually throwing it into disarray or perhaps even destroying it altogether.

3. Order, flexibility, and the limits of information

To say that a (very) high level of information or order must also imply a system’s adaptability, makes the notion into a far more subtle thing than we may sometimes be inclined to take it for. This becomes clearly visible in the sphere of human social systems. Thus, a firmly established, strong government or institutional structure appears to be essential to the higher levels of societal order. Yet, one may not simply turn this around. For, as the Communist experiment everywhere shows us, a very strong state and a very high level of institutional, specifically bureaucratic development may well prevent society from attaining the higher levels of order required for adaptation to environmental change.

Indeed, the development of the contemporary West European welfare states may well be moving in the same direction. In particular, too, the enormous production of ever new and changing laws
and decrees, and the proliferation of bureaucracies which is so characteristic of these very strong states, may be making them into sources of societal disorder and uncertainty rather than of order. And, of course, a neatly organized social hierarchy or even dictatorship does not necessarily produce more real order in society than does a democracy. In fact, to judge from historical experience, it would seem to be precisely the other way around.

Surely, order or information is most easily recognizable in its less developed forms, characteristic, for instance, of the simpler material systems we find in nature. In such cases, it consists in a neat, rigid, and transparent arrangement of parts or components, in which every such component occupies a definite position and fulfills a fixed role or function. And it is precisely these properties which we tend to associate with the notion of order, properties that seem to typify the ideal of the bureaucrat and which we commonly seek to realize in the institutional arrangements and governmental policies we devise.

We find it much harder to recognize order in the more highly developed and complex, not to say messy, forms characteristic of, in particular, living and adaptable systems. Surely, their growth or adaptation to changing circumstances typically calls for a very highly coordinated development, i.e. for information or order. For system growth, development, or adaptation requires that the system finds ways of making the behavior or functioning of, in principle all, its several components change in response to the possibly spontaneous change in some of them. But it must do so in such a way as maintains or raises the productivity of, in principle, all its components and their contribution to that of the others. And, of course, it must be able to recognize, prevent or neutralize such spontaneous or induced changes in any of its components as may have a deleterious effect on the others. All this has nothing at all to do with the entropy or randomness which is sometimes equated with creativity.

In adaptable systems, then, order or information cannot assume the form of a neat, rigid and transparent arrangement of their components. Growth, development and adaptation definitely call for a considerable measure of flexibility, freedom, and creativity in the system’s components, for qualities, that is, which we tend to see as the obverse of order or information. Accordingly, it is interesting to see that more advanced research into what are called (hyper)-complex systems brings to light that system development and adaptation typically takes place at the ‘edge between order and chaos’, as both a fully rigid order and a total lack of it preclude any such development or adaptation (see for instance Waldrop, 1992; Lewin, 1993; Kaufman, 1993). Indeed, the more adaptable, comparatively very highly ordered, systems we find in living nature and in human society typically stimulate inventiveness, creativity, and experimentation.

To define the notion of order or information in a quantitative fashion, also raises the question as to whether it is possible to identify any bounds to it. To begin with, we will conceive disorder and instability as very low levels of order and stability, respectively, rather than as their negation or obverse. For the latter interpretation would imply that a system in a state of disorder or high entropy would be uniformly self-destructive, and that an unstable system would invariably blow up in response to each and every disturbance to which it would be subjected. Such systems cannot exist, however. In other words, we will stipulate zero to be the absolutely lowest level of any system’s measure of order or stability.

Moreover, order or information underlies the form and functioning of every observable system. Accordingly, its complete absence would also mean the disappearance of the system concerned as a recognizable and functioning entity. This forms a very good reason indeed for the somewhat stronger assumption that order must always be positive. Note, too, that the total destruction of order in a system would also have to imply that of the order in the system’s components, and of that in the components of these components, etc. (see also Stonier, 1990, pp. 38 ff.).

On the other hand, there does not seem to exist a maximum to the order or information which a system may contain. For such complete order or information would have to imply that the state or behavior of each and every system component or
member were completely determined by that of the others. But this would obviously preclude the freedom and creativity which must form such important features of the higher levels of information. Complete order or information would render all growth, development or adaptation impossible, and it would freeze a system forever in its current state. Interestingly, as far as our insight, i.e. intellectual information, is concerned, epistemological considerations alone also lead to the conclusion that complete information is impossible. Gödel's (1906–1976) famous mathematical theorems similarly show us that virtually no non-trivial theory can ever be complete either, results which, far from testifying to the limitations of the human mind, actually guarantee that our theories may always be developed further, thus raising the level of information which they contain.

4. The emergence of order and the basic law which governs it

The explanation of how order or information emerges has always represented one of the most baffling problems of all the sciences. This is not just because of the sheer intellectual difficulty of the issue, but also because it requires us to overcome our own deeply ingrained, broadly anthropocentric attitude towards the world. For it is probably no exaggeration to say that we tend to approach the world first and foremost as makers and doers who are continually searching for ways, means, and opportunities for bending reality to our will — as, indeed, we must, if we are to survive. But this same attitude also means that in everything which happens we will first of all be interested in who or what can be held responsible for it, as it is such knowledge which does indeed allow us to bring forth what we like and to prevent what we dislike. And it leads us to assume, almost as a matter of course that everything which exists is indeed made, produced or caused by some definite, identifiable human or non-human agency or intelligence.

Conversely, we tend to find it extremely hard to even imagine that it could be otherwise, that things could emerge or evolve all by themselves as it were, as the products or by-products of blind forces, guided neither by any purposeful agency, nor by any premeditated intentions or goals. The things which we do find in the world so very often exhibit such an exquisitely beautiful and exceedingly intricate design which is so admirably matched to the purposes it is to serve. Such things, we are almost automatically inclined to believe, simply cannot be due to 'blind chance'.

In the realm of human affairs, this difficulty is compounded by the fact that so many things do indeed seem to be made by us. Constitutions, laws, treaties, governmental institutions, peace and war: they are all devised, designed, and made by identifiable people or agencies. That these people or agencies are themselves part of the very processes which they seek to control, is usually ignored. Moreover, the belief that social, political, and economic life are under our control, and can be manipulated to suit any such purposes as we may jointly have, is deeply embedded in the institutions of the typically large and powerful contemporary state.

It is, then, not really surprising that it took so very long before a rather more satisfactory conception of the emergence and evolution of order or ordered systems began to arise. Apart from such isolated precursors as Lucretius (first century B.C.), it was basically only in the 17th and 18th centuries that such philosophers as Spinoza (1632–1677), Bernard de Mandeville (1670–1733), Adam Ferguson (1723–1816), David Hume (1711–1776) and Adam Smith (1723–1790) began to see that the evolution of ordered systems in human social life represented the unintended outcome of the social processes occurring within such systems rather than of any agency's design. In the 19th century, Herbert Spencer (1820–1903) devised a very comprehensive theory in which he explained the emergence of order generally, including that in human society, as the result of blind evolutionary processes. And, of course, Charles Darwin's (1809–1882) theory of biological evolution still represents the prime example of a theory in which the emergence of highly ordered (living) systems is explained as the result of purely natural processes unguided by any purpose or conscious design.
Nowadays, it is, especially in biology, the natural sciences and, indeed, mathematics that the greatest advances in the explanation of ordered systems as the autonomous results of natural dynamical processes have been and are being made. Research in these areas has revealed that the emergence and evolution of order or information are typically non-linear phenomena, involving various self-reinforcing or autocatalytic (feedback) relationships. But it also appears to apply to the evolution of human behavior and of social or cultural systems, where we find that the further growth of an individual's intellectual information, of science and technology, and of the level of order in social, political or economic systems all depend on the initial level of information or order of the system concerned (see De Vree, 1984, 1990, 1991, 1994; Dagevos, 1994).

Indeed, the present analysis itself implies as much. For it naturally leads to what may well be the central law underlying the emergence of ordered systems generally, to wit, that the likelihood that a system's level of formation or order will grow, and that it will adapt to a wider range of new circumstances, must be proportional to that system's initial level of order or information. So when a system's level of order is as yet but low, the probability that it will get bogged down at that level must be commensurately high. And, conversely, the likelihood that a system will be able to raise its level of order will be higher if it already possesses more of it.

On the face of it, this would seem to imply the possibility, or even likelihood, of indefinite, exponential growth to ever higher levels of order, even more so as it has already appeared that order or information cannot have a maximum value. In practice, however, systems evolve so as to be able to survive in a specific kind of physical or social environment. As soon as this environment stabilizes, the 'motivation', so to speak, for further growth will accordingly become weaker or will even vanish altogether. After all, growth and adaptation usually cost a lot of effort or energy, which may not even be available in the first place. And, of course, while a system might perhaps learn to eventually adapt to such environmental changes as do occur, it will often not be given the time to actually do so.

References