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Models and Change

- adapting models to the natural world of complex systems-

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Abstract

Sometimes the problematic difference between physical and theoretical systems, with large undefined gaps between them, can be made very useful. Natural physical systems that arise in open environments are complex, necessarily remain undefined, and continually change. Theoretical models depicting them are necessarily self-contained in their definitions that don't change, and can't realistically operate as physical systems do in our environments. The relation is like the loose fit between the weather and weather forecasts. For cultural and economic systems which science has even fewer certainties about, the relation is even more tenuous. Some few physical certainties for all complex systems can be found, though, and made good use of. Models of regular changing scale such as of growth or decay have no limits of scale. Physical processes of regular changing scale, however, represent stable complex systems certain to be temporary due to natural limits of scale. Anticipating approaching change in such physical systems, and the need to be ready to change model assumptions accordingly, forces inquiry into scales of physical system organization beyond the information encoded in models. Methodology helps generate various useful focused questions about what will change and suggest where to look for how. Experience helps develop foresight into the choices for both steering and adapting to such systems and the models designed for assisting with that. Though physical systems remain substantially undefined as a whole, this diagnostic approach uses models to pose well defined questions for exploring them for critical information. It builds a new bridge of methodology between theoretical and natural physical systems, introducing a new kind of empirical research and another way for models to become adaptive.

A mid-course correction in the assumptions of economic models is implied, calling for timely response before growth leads to diminishing returns.

Keywords:

scientific method, mathematical modeling, physical systems, change, adaptation, foresight.

1. Introduction

The subject of how natural systems embedded in open environments change form continually has been limited by representing them with theoretical models that do not. Using models one may adopt an inadvertent strategy of pushing systems to failure as the way of obtaining information about where the points of failure are, simply because models based on prior normal conditions omit that information and the principle that physical systems break when pushed too far is also missing. All physical systems break when pushed too far. Much better strategies are available. Some are simple, but not known because the differences between physical and theoretical systems are often glossed over by the use of language that refers to both with the same terms, as with the word "apple" referring to both our information about it and the physical thing having features beyond our information.. The approach to modeling proposed here is to create adaptive models to raise questions about that difference and about timely needs to change assumptions. That helps to turn the apparently vague and changing forms of nature into successively clearer features and allow our fixed rules and definitions to fit them more responsively. It is not always useful to take that approach, but it generally exposes productive questions that would not be asked otherwise. The particular strategy to be proposed is a way to represent divergent processes as having different boundary conditions at their beginning and end, prompting focused questions about the changing directions of change in their complex interior and exterior environments.

What models and explanations do for us, where we get them to work, is represent one scale or aspect of organization, assuming the regularities of others are constant. That helps predict what those regularities would result in, but is valid only as long as those assumed constant properties remain so. That assumption is always highly uninformed, is the key, a matter of faith. Due to the natural complexity of physical things most of what is assumed constant is completely unknown. For example, if you have a simple computable model of ocean waves, changing the scale of the variables does not change the behavior of the model. Increasing the scale of actual waves leads to a point where they break, though, due to physical system scales not represented in the model. That difference in behavior due to scales of organization that models contain no information about is predicable. It also helping predict the emergence of new realities and lead to discovering them, whether the circumstance concerned is familiar or not.

The usual aim of modeling is to finding what regularities can be relied on. The interest here is somewhat the opposite. The object here is to exploit common regularities certain to be temporary to point to what parts of a system will change for reasons beyond your information. For natural systems that is an ongoing process. Because models would never change, the differences can help locate where change is or will occur, and raise good questions about the missing information needed. The learning isn't over when a good set of regularities and a useful model are found, but really just begun. Learning how to use models to help closely follow natural systems as they change, even without being quite able to explain or predict them, would teach a great deal about how to adapt to or avoid conflict with them. It would show display some of the hair raising complications of our trying to ever increasingly control them too.

The issues are framed in a conversational style both for wider audiences and because the real subject is a new scientific method for raising unanswered questions, a hypothesis generator as it were. One needs to go slow and revisit issues from various perspectives because the method does not initially produce equations, but rather better questions about when and why nature will soon stop following the equations we have. After discussing the main conceptual problems, some features of natural complex system development, and describing the method, a conceptual application offers insight into the what constitutes timely decision making about how to approach natural limits of development.

2. Distinguishing between information and things

It also takes time to understand how it can be meaningful to discuss physical systems as existing beyond our information, having their own organization embodied in their own structures, and independent of the logic and patterns we see in them. If one attempts to refer to features of natural systems beyond what are visible, the question is if they are not visible how do you then refer to them at all. What is used to connect these apparently separated worlds of mental and physical systems, and resolve the subject/object problem their duality presents, is learning. Learning is a heuristic mental process that directs attention beyond the knowledge of the learner toward the experience of things in the physical world from which you learn.

Others have considered that any "subject" is necessarily limited to our available information, so any "object" needs to be reduced to information for it to be referred to and meaningfully exist. This is one way of stating the Copenhagen interpretation of physics and Heisenberg's uncertainty principle, to say "if you don't know about it you can't talk about it". The approach here is the opposite, to consider the subject of science as studying things of the physical world beyond our information, by raising good questions about them. We get our questions from the information we have, from its incompleteness, and by searching for paths of discovery. That treats the features of the physical world our information implies to exist, beyond our knowledge, as the real subject of science. Rather than excluding the physical world from our concerns, information is used for referring to it with our questions and following the paths of inquiry we find productive. That way the 'real world' of scientific information (about a virtual physical reality), and the 'real world' of physical phenomena (our virtual information constructs of it describe) become connected. Both then can be considered 'real', alternately looking with one for the other. Questions may abound, but it seems this dual use of the words is also much more in keeping with normal usage than either one. People who consider only their theories or beliefs as "real" treat the physical world 'virtual', while others tend to do the opposite, and most people seem to go back and forth.

This tension between our incomplete information and understanding the physical systems we are part of that have organization well beyond our information is also complicated by the two often being confused. It's a common habit to represent physical systems as being the models and explanations we have deduced from our information about them. We sometimes have little other way to refer to them. The phenomenon of light seems to be a well proven reality, but is only known by deduction from other things, for example. We use our explanation as a "stand-in" for it in our minds, a way to fill in information about the phenomenon wherever that missing information is needed. Though the phenomenon of light may not change, lots of other things we treat the same way do, and that becomes a problem of functional fixation (blind spot) if our information does not change with them. Substituting explanations for features of human cultures and environmental relationships is similarly common and useful, but blocks the learning process by hiding the open questions that might be important to ask as environments change. To keep explanations from being mistaken for their subjects would call for use them to separately refer to the open questions that remain as well as to what we think we know, as by looking through one at the other. Otherwise there's a likelihood of confusing the two, substituting simple but wrong explanations precisely where physical systems have their most dense organization and unexpected features. Table 1 lists major worlds of human information and ideas with their corresponding physical subject, each representing a learning process about organizational processes, the understanding and the doing or things.

Explanatory Systems (information worlds)	Physical Systems (behavioral worlds)
Perception, Reasoning & Belief	• individual learning and experience
Physics	• forces, fields, mass, energy, forms of complexity & change
Economics	• economies, businesses, human behavior
Biology	• organisms
Ecology & Geology	• relations between animate and inanimate parts of environments
Sociology & Anthropology	• human relationships and cultures
Medicine	• practice of health care
Engineering, Architecture, Technology	• practice of design

The Arts	• practice of crafts
Culture, Business, Government	• practice of organization

Table 1. Short list of mental disciplines with corresponding physical subjects

Mistaking mental and physical systems might be less of a problem if the two kinds of organization, mental and physical, were similar in kind. Mental models and physical systems are remarkably different, though, such as one being scale dependent and the other not. It is also interestingly difficult, for example, to determine if what happens inside natural systems is deterministic as it sometimes appears, or if parts act in a way that is truly opportunistic as it also sometimes appears, or a mixture. The more information we have the more it appears we can determine, as if projecting a state of having limitless information would mean being able to determine everything. It is also precisely the interior designs and behaviors of complex systems that are most opaque to study, and for which so very little can be determined, that do appear to represent individuals truly behaving opportunistically. It's as if the interiors of the more complex natural systems are distinct holes in an information world made like Swiss Cheeze, where natural system organization is most densely concentrated in what look like voids. If true, the substitution of simple deterministic explanations to fill these voids of understanding, about self-organizing and self-animating things, would result in a particularly large misrepresentation.

In either case correcting the error of letting your own information become confused with the subject it is about then allows some comparison, and making the differences between them useful. Failing to do so makes explanations self-referencing and become just a collection of conventions instead of information about any other thing at all. If in addition systems that were opportunistic are then represented as deterministic what is lost is even the concept of their having their own original behavior and reactions, learning and internal world. Keeping them mentally separate, our dual physical and information worlds, may not be automatic or easy but considering the information as an overlay, is then just a matter of shifting attention when needed to the unanswered questions underneath.

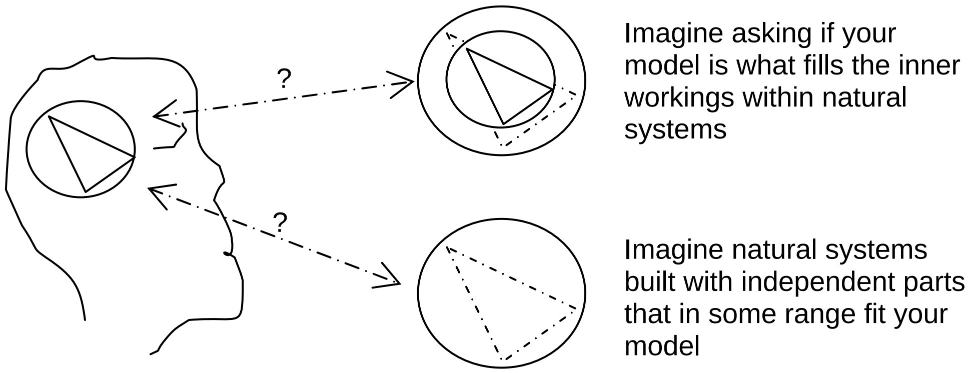


Fig. 1 Are our models what nature uses to operate? If not, does keeping the two separate help or hinder? Does using models to fill voids in our understanding of nature hide anything that turning them into questions would illuminate?

2.1 Why physical things remain undefined

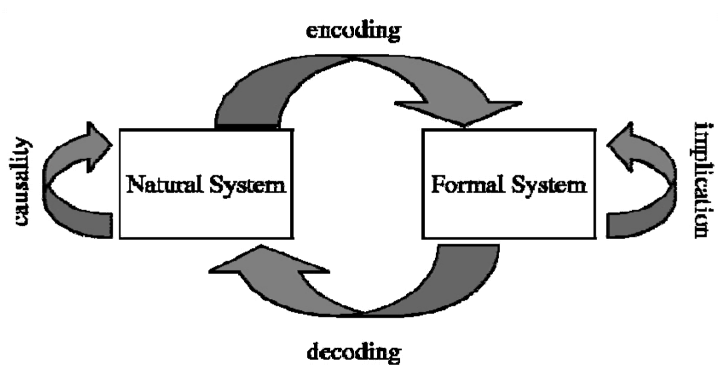
Natural systems, like storms, organisms or cultures, take care of themselves and work by processes seemingly inside themselves that remain largely invisible. but One great difference from our theories is that these and many other kinds of natural systems appear to be significantly opportunistic in their behavior, as if probing their environments to seek out new directions to develop. How that might occur is hidden within their complex and changing forms, making any line between opportunistic and deterministic behavior unclear. Having it hard to see how they work does not keep one from watching for warning signs for when they will change direction though, or find a few reliable regularities. Watching them change direction helps locate where they are too, and then some of our considerable native understanding of them that is part of natural language can be used. The subject of natural systems actually seems to be the main subject of natural language, one or another way. There's hardly any topic of conversation that doesn't concern one or another kind of leaderless network of relationships, with real properties and consequences for us personally. Many common words refer to them and their general properties. Natural systems are the subject of anything one might refer to as "established" or "on track" or "off track" or "coming to a head". It also refers to natural systems to discuss most anything as having "relationships" or as "growing" or "developing".

Natural systems tend to be cohesive, but among the many reasons it is quite hard to follow how they work is that, like in your body, the activity and parts of such networks of connection are changing everywhere all the time. That means that wherever you look nearly all the real action is located somewhere you're not looking. Still, with many kinds of complex natural systems the closer you look you don't find chaos. You more often find more scales of exquisitely organized processes arranged in leaderless networks, with similarly distributed changing parts. The individuality of natural systems is another aspect of them that is stubbornly resistant to explanation, the appearance that no two physical things are ever made alike. That what theoretical constructs are based on is exact and completely unvarying replication, rigid rules of logic, points to another basic difference between them.

A number of other scientists studying the relation between systems of equations and physical systems have also reached the conclusion that natural systems actually can not be validly modeled, or if they were their models would be 'incomputable'. Walter Elsasser (1987) found that the persistence of diversity in natural form (heterogeneity) would conflict with the assumption of statistical causation that underlies mathematical science. Robert Rosen (1991) showed that modeling systems would at minimum require infinite regressions that no machine could perform and so nature could not be a machine or modeled by one. Rosen (1996) also observed that living systems seem to incorporate divergent series of changes and scientific models can only be usefully defined using convergent mathematical sequences. In addition various systems scientists such as John Sterman (2002) have observed that "All models are wrong" for a combination of causes ranging from natural human failings, to the deep complexity and profound lack of information about most kinds of complex systems of interest. These all point to modeling failures as being largely for natural causes, a difference between the subject and our information.

These observations on the fundamental problems of why models fail were essentially cautionary, though, rather than providing improvements on any method for modeling complex systems. Not to diminish the value of any of the extensive efforts of others in finding regularities that a mathematical model could be reliably be built around, the approach here is to identify predictable irregularities, identifying where models are about to need to change. It could be seen as an application of Rosen's later observation, that nature is full of what appear to be divergent sequences of development, for which useful equations can't be defined. Looking at what nature can do that math cannot do, and for what math can do that nature cannot, provides a way to connect them through the questions about how they differ, and use each to learn about the other. The method introduced in section 3. uses a family of implied violations of the conservation laws that physical systems are subject to but mathematical systems are not. They generate very useful questions about when modeling will need to go beyond the available information to discover what new assumptions will be needed.

2.2 Connections between natural systems and formal systems.



Presented world	Learning to coordinate systems different in kind	Re-presented world

Fig. 2 – Natural & Formal Systems - Robert Rosen 1991 with added notes

Fig. 2 is Robert Rosen's diagram of the relation between natural and formal systems, how the theoretical world is assembled (encoding) and used to guide us (decoding) in navigating the physical world . In addition to the difficulties of making good models that Sterman and others identify, there are some very odd features of physical causality that models could never be made to emulate. Natural systems are all individually different and continually changing everywhere at once, with each part changing differently. Any model that did that would not compute. Our ability to describe physical things requires using general categories and statistical uncertainty, but physical subjects are not composed of categories, and also appear to be completely particular in every detail, apparently having no ambiguous feature of any kind except for the ambiguity faced by an observer in how to describe or explain them. Natural systems also have multiple scales of differently organized parts. Their multi-scale networks of separately changing parts are held together by interacting through and with their environments, and so are not at all self-contained or self-consistent in design. Information about any part will very predictably omit relevant information about the other scales of organization around and within it.

Mathematical models rely on fixed definitions and complete information, though, having none of those odd features of nature. Mathematical models need to be self-contained and self-consistent because they have nothing to hold them together but logic and the abstract definitions the logic connects. Models rely on natural regularities of unknown origin, but there's a flaw in relying on them if we don't understand something about where and when they might change.

In the process of observing and formalizing natural systems people reduce nature to information. We record information by counting individual physical events and the results of periodic measures grouped in defined categories, using a mix of fairly narrow as well as broad and loose definitions. Sometimes we keep track of whether the measures we use are of conserved change in accumulative processes or non-accumulating indicators, and sometimes not, and represent changes in one as factors for the other. Our information categories are not naturally connected, in general, other than how we use them.. Consequently it can be quite unclear what we are measuring and what it is information about except the conventions of normal practice. We also may not think that our categories change, for example, but nature may fill them with all kinds of changing things, even if we use the exact same procedure for collecting data for them over and over. For a simple hypothetical example, you may ask a standard interview question one year, and find that the words have changed meaning the next, or try to track the price of a standard "market basket of goods" to find later that no one buys those things anymore. That nature is not as confused as the arrangement of our information is sometimes only evident in what Elsasser described as "persistent heterogeneity" or Rosen as "life", the evident continuities displayed in our separate categories of information that seem associated with the continuity of entire systems beyond our description. A great many of the natural systems displaying real continuity that concern people are full of independently learning and responding parts, like economies and ecologies, that are both highly complex and evidently take care of themselves. Reading those continuities, as evidence of implied natural systems, and their systematically diverging relationships as evidence of approaching change helps point to where and how it will occur, and the need for connected formal explanations, whatever their arrangement is, to adapt.

Having signs of when they will change would be a way to study how natural systems are so very effective in taking of themselves, without controls, clearly displaying methods of very efficient cooperation in many ways. There is a strong similarity between how neatly the parts of many kinds of natural systems fit together and provide complementary services to each other. The wastes and inadequacies of one part often serve as resources and opportunities to develop for others. If the parts of natural systems were actually opportunistic, that could well explain that odd feature. Opportunistic systems would use what they find free to take, fill in where there are gaps, avoid conflict as a waste of energy. It would also explain the coincidental similarity between how economic markets link complementary talents and businesses and the way natural environments are similarly assembled from complementary parts and functions, if nature's main method of creating systems were similar to the way people make their livings. If so it would provide a new diverse group of physical models of more successful kinds of economies that don't build to collapse, for studing how .

2.3 Reading beyond one's information

That learning pushes you find ways to read beyond one's information, and relate to physical things and relationships that may remain partly out of view, takes also being cautious to not jump to conclusions. Hypotheses need some testable foundation. A "hypothesis" is itself a cautious reading beyond one's data in search of evidence. Even representing nature with equations, for example, is by itself a leap of faith in representing complex physical things with a symbolic construct and implies a “reading beyond the available data” that we choose to rely on. Identifying progressions that will be certain to upset the system of relations they are part of is then just another kind of valuable information about things presently hidden, an open question with a solid foundation. Discovering evident gaps in explanations, such as energy densities implied to approach infinity or zero has led to numerous discoveries of physics. The discovery of atoms and atomic particles partly resulted from trying to explain how to avoid unlimited electric field densities.

Still, referring to things that have yet to be discovered, and are known mainly by something clearly being missing from view, can easily be confusing. Common language has a way to do it, by just pointing to undefined physical things with names, For many of the unusual forms of natural systems and their organization there are as yet no names, nor a good way to point. What seems clear is that our own very limited logical constructs for them are clearly organized in a rather different way. I will propose some terms and uses, but those who prefer to be cautious might continue to begin from the presumption that individual physical systems are always undefined and actually contain nothing to directly inform us themselves. Some others, perhaps the “agnostics” may then wish to follow that by a ? mark, asking that statement as a question. At the very least I think it’s it appropriate to always continue to refer to the physical organization of natural systems hypothetically. What people find inside the workings of natural systems, say looking inside a human body or trying to understand what water is, continues to fill books of facts and remain inexplicable. If what we see from the outside of any locus of organization has some predictable regularity, we still generally don’t know quite where it comes from and so may never quite know when it will change.

That we have a natural way of pointing to natural systems without specifying exactly what is being pointed to at is a start can be improved on. The existence of their interior designs of many kinds of natural systems is evident from how they change everywhere at once, using multiple nested scales of organization, changing scale and form at the same time with no apparent communication from elsewhere. Something holds together their great networks of separately developing and adapting parts, interacting with others through environments with undefined boundaries. Equations of controlled variables can't do that and asking why real and formal systems differe is a way asking productive questions. If one of the main features of natural systems is their inexplicably complex and smooth operating interior designs, one place to start is observing that to us they seem organized around a "wilderness of unknowns", definite realities that remain "undefined and unexplored". Thinking of the "envelope" of all that is possible to explain, individual natural systems each represent significant holes..

Nature is an exemplary organizer and builder of vaguely machine-like systems. The numerous systematic growth processes that smoothly develop exceptionally complex things with only the process and an environment of loose parts to account for it is a primary example. That is so very different from how logically defined and controlled systems operate that the problem may not be that we have not yet found how natural systems are organized, but that they may not actually have any of our kind of definable organization at all. It may not then "explain" them, but just be very helpful for making models we can trust to be able to tell when natural systems are changing form and new assumptions for our models will be needed. The object here is then to define some limited ways to predict when and how our models will become undefined, and point to learning paths for finding new assumptions to make and accommodate the natural changes taking place.

2.3 Raising questions of change

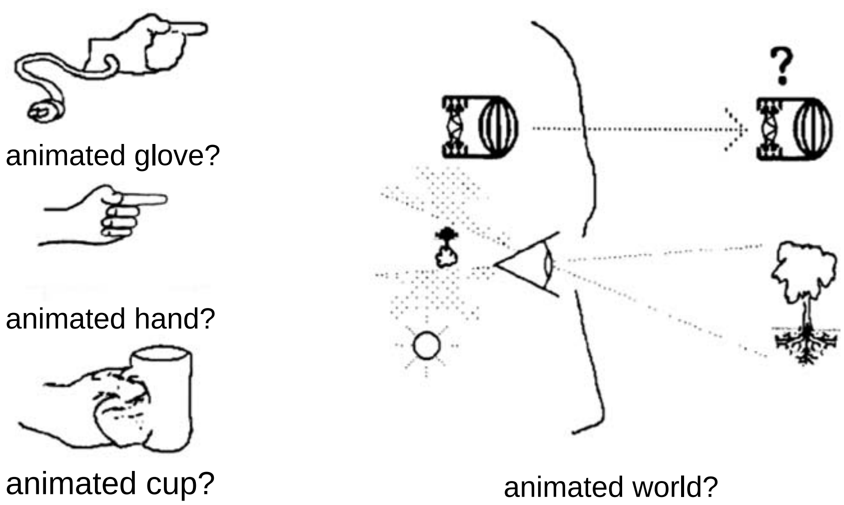


Fig 3 Which wholes does one choose to model?

The “null hypothesis” here is that trustworthy theories reflect some regularity of the complex physical world beyond their information *and so do not contain information about the range of their own validity*. For questions about the limits of their validity someone would need to look into the gaps in their information. So in order for models to imitate natural systems and adapt to their environments as natural systems do, models would need their makers and users to do the learning needed and change them. What requires the learning is not that modelers are not proficient in emulating any form of behavior that can be specified. It’s that we cannot specify behavior beyond our information, particularly if it concerns natural systems which themselves may be learning processes or self-animating. If you consider a model (fig. 3) as an animated glove, designed to emulate the animated hand of nature,it may not contain information about whether or not the fingers in the glove or the cup held by the hand are connected.

If the regularities of the physical system taken to be constant were to change, or “come alive” as it were, then the assumptions of the model would become invalid leaving the model and perhaps the purpose it was designed for undefined. Technology change frequently presents this kind of problem of basic changes in relationships that were once assumed constant and unexpectedly redefine the meaning of the questions people have. The changing scale of our economic footprint on the earth does as well, forcing a general rethinking of the purpose of development and our relationship with the earth. If you know that’s coming it has the effect of turning the “=” signs into “?” marks, in time to learn how to change the model before it fails..

For example, the usual way models of growth and climax are defined, say in maximizing the use of a limited resource, is with a logistic curve. That approximates the transition from positive feedback in seed growth followed by negative feedback in responding to limits with one continuous equation. Clearly in nature those are often two separate and distinct processes operating by two very different kinds of systems of response. In particular, the constraints of natural limits do not begin with the first use of a seed resource. As a seed resource is uses systems are self-limited as they develop their ability to use what is plentiful , but as the demands of the growing system exceed it’s available resources and force it change what it is responding to. That means that in nature there is a break in the middle of the sequence where the responses of the physical system to one thing end and to another thing begin, a discontinuity. That means it's possible that any logistic curve mistakenly represents a succession of different systems as a single system, and skips over the organizational discontinuity between them. In that case the inflection point in the response curve from growth to climax possibly needs to be read as a question mark ( = ?) about what physical system change the missing discontinuity in the equation represents. The system starts with quite different boundary conditions than it ends with.

Logically, of course, a system can't have information about its end before its beginning, any more than a car fender would be starting to bend for the tree it will hit as soon as the car heads toward it. So there must be at least two periods of regularities with different equations,not one, with new information needed about what will change to define the transition. What is then clearly missing from logistic curves is the point or period of time in which changes to the assumed regularities of the system beyond the information of the model occur and begin following new boundary conditions.. Therefore some system changing event occurs, due to change in features of the physical system beyond the information of the model. They might be either within the system or its parts or in the environment in which it operates, or both.

Examples abound of natural systems that begin with unconstrained growth brought to an end by some internal change rather than some external bound. Organisms generally mature to some optimal size for their life ahead rather than being limited by exhausting their environments. Air currents and drips of water are also self-limiting in how they develop, coming to points of development where they separate from their sources rather than continuing to develop to the exhaustion of their sources. Externally limited processes are common as well too, as well as systems that exhibit a combination of internal responses to external limits, such as animals foraging and searching for food as they also seek to avoid danger, or crystal formation or bee hive designs based on modular elements that are replicated to consume other natural limits.

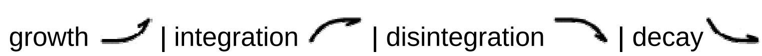
Often times one can tell from a model that the development of a system will be limited, though the model won't say how exactly. If the change in boundary conditions and behavior in switching from growth to climax in natural systems takes place due to a combination of internal and external forces, many of which could involve complex behavioral systems on other scales, what is happening is more complicated than an equation. You then have one complex process coming to an end and setting the stage for the next. What determines how the change will occur is made by interactions between elements within and around the originating system that are unprecedented. Studying a model for where these are implied to take place as if inserting question marks into the models for "what's happening here ?" then helps locate and discover them. It's "raw science" not "finished science", and intended as a way to extend either beginning or advanced research into any field by raising new kinds of focused questions about changing environments. It's also a way to open our minds and learn how to follow nature's actual processes.

At first the ability to follow successions for system states takes time to develop, but we also all have somewhat highly develoed skills for it in areas of personal experience. Many of the same kinds of questions about when developmental stages will be changing apply very broadly. Raising children, for example, exposes you to a succession of natural stages of development that are temporarily stable. As change from one to the next approaches it exposes threads of new questions and issues that both parent and child need to follow to be able to make the successions from one world of relationships to the next. Sometimes such changes catch either parent or child off guard as circumstances race ahead of preparation for them. Sometimes they're prepared for long ahead. The same would apply in not an entirely dissimilar way to the issues surrounding the maturation of lots of other kinds of growth systems, a business, a whole civilization, or single projects that start from scratch like a group of kids learning a school play. Each of these are of different kinds and on different scales but of the sequence of developments has many things in common.

3. The basic method

If one can identify systems that are naturally temporary it raises the question of how they begin and end. Beginnings like either the germination of a seed, a handshake between people or the tipping of an environmental balance, are events on other scales of organization than the processes that develop from them. Process ending events are similarly different from the processes they end. They include the slight jerk that occurs as breaks bring a vehicle to a stop, the death of an organism, the completion of a task, and a circuit burning out from increasing load. They are organizational events on other scales than the subject process as beginning events are. As you learn to look for them you recognize the kinds of processes that begin and end with them, and it develops foresight for what to expect and what processes are naturally temporary because of it. Processes that are necessarily temporary include regular positive feedback systems. They begin somehow (with smaller scale processes) and lead to conditions that make them end somehow (with smaller scale processes). Watching for them leads one's questions beyond the information available to unexplained but connected processes and relationships, and so to a path of inquiry where you can be sure of there being information to find. The ability to predict them helps you to find them and serves to expose other scales of system organization to view. Simple temporary processes include the four types of systems of regular proportional change,which are usually present where you find evidence of regular proportional change (Fig. 4).

Fig. 4



For example, in studying plants you discover they come from the germination of seeds, and that the end of their explosive seed growth is when they use up their seed resource and switch to growing responsively to their environments to begin their maturation. One needs to validate that any curve that looks like regular proportional change represents a system of proportional change to use this approach, of course. There are a variety of mathematical tests to help verify the apparent systemicity of apparent developmental processes as part of that (Henshaw 1999, 2007). As with any search what you find depends on the combination of what is there and how resourceful in looking for it one is.

As with testing a hypothesis, the validity of each question is then to be confirmed by having it lead to useful discoveries about the system producing the evidence. Because feedback networks that are dominant enough to show in measures of accumulative change tend to be system-wide, finding them also tends to clearly localize the boundaries of individual system networks that are acting as a whole and that is often a useful way to validate the original question about them. The powerful question is asking how each kind of sustem of proportional change begins and how its own development will lead to its own end. As such it is also a new way of considering time, organized as a one-way ladder of accumulative change by locating some of the rungs.

If a system model itself implies either continual growth or decay for a physical system, or an inflection from growth to decay, learning to read those as a question about the implied behavioral changes in physical system is the task. In each case once you've identified the likely behavioral change approaching then that would probably lead to changing the model at some point to correspond. Though the physical system features hidden from view one looks for remain quite undefinable, this exploratory approach still leads you to more and more details of how they are organized and discovering better and better questions about them.

Chained together as they commonly occur in nature, the four temporary systems of regular proportional change become a general map of "how things come and go" and "a typical life story" of developmental processes and their punctuating smaller scale events. Fig. 5.

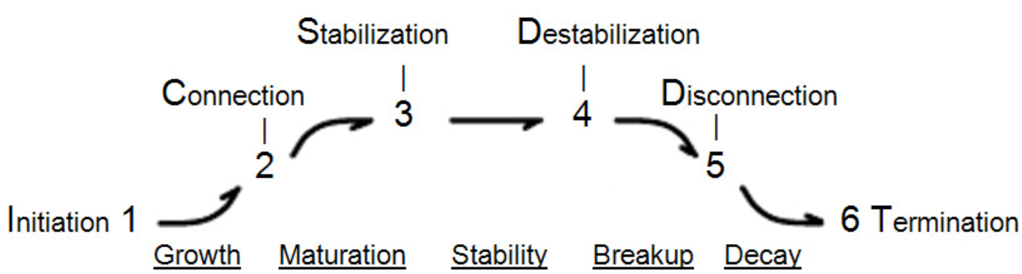


Fig 5. A Model of Change, six punctuating smaller scale events and five periods of regular proportional change. Showing one possible naming convention for the natural sequence of developmental processes (Henshaw 1985, Salthe 1993)

In any case of either a model or an observed physical process exhibiting the character of any place on the model of change prompts the questions about how the physical system would be connected to the other parts and where in the model to replace the "=" signs with "?" marks.

4 Conceptual application & discussion

Keeping with the conversational format the example application is discussed in relation to the following diagram of alternative paths for a system making a switch from growth to maturation, either early or late. The change symbolized is from having a limitless environment and changing in proportion to itself to having a limited environment and changing in proportion to its distance from its limit, fig. 6. The equation is the same for each, with only a different point in time for the switch from responding to the past to responding to the future. It is almost self-explanatory that delayed response results in disruptive change and timely response in smooth change, but it helps to see it visually too.

Arbitrary units are used and the response rate of 10% is used before and after. An arbitrary point of failure (the Cap = 75) is set at 2.5 times the arbitrary stable limit set at 30, as well as to to keep the graph small enough for the page. What varies is the time when switching from multiplying to limiting accumulation occurs.

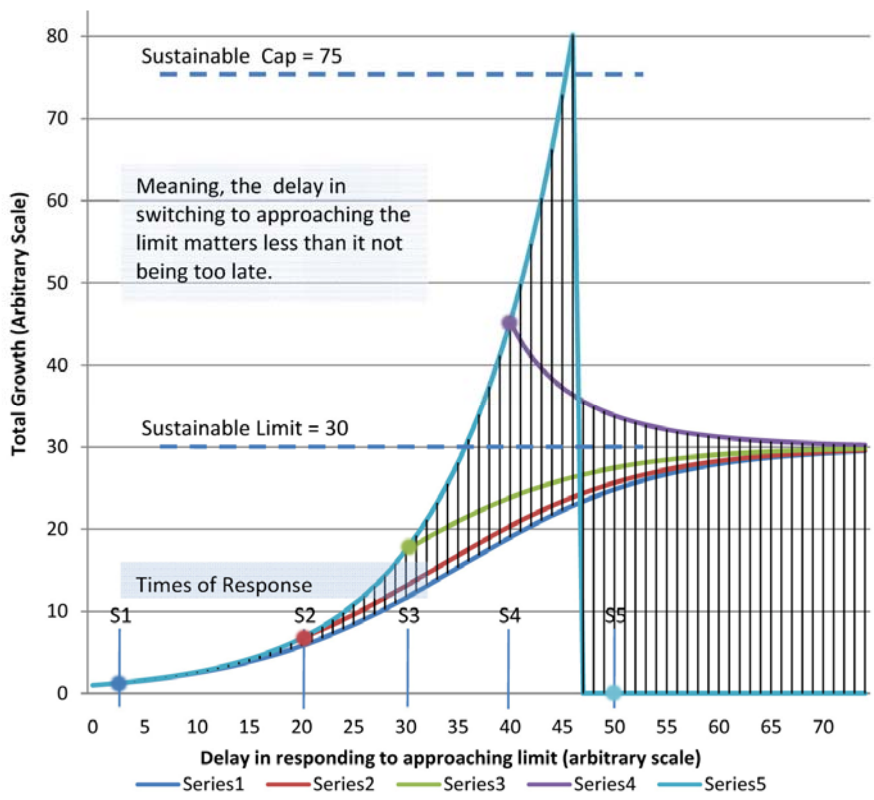


Fig. 6 - Growth toward a limit with delay in recognizing the limit:
IFY0<cap,Y1=Y0*(1+RateConst*(1Y0*(IFBefore=0,else=1/limit)))

The model represents any growth system as it changes from its independent seed growth, and then switches to integrating with its environment, as in maturation. The question asked is how does it affect the system if the switch in response occurs early or late, with the time of the change marked for each series. The clear implication is that switching early has little effect on the future and switching late has a very large effect.

One need not know anything more to acknowledge the general principle displayed, that in environments presenting a need to respond to new conditions the window of opportunity for responding gets shorter and shorter. The important recognition is that system response problems are all about the fact that systems start without the information that a responses will become needed. The practical opportunity is that the simple information that the starting process will end does provide the information that responding to the end will be needed. The model shows generally how the timing of beginning that response determines whether it will be made gracefully. The key is contradiction implied, that systems growing independent of their future constraints need to “encode and decode” information about a world of relationships they have no information about, before they make contact. If systems don’t have information about the future, how do so many seem to demonstrate exceptionally graceful self-limiting development. The hypothesis here is that it is by the growth system itself becoming increasingly sensitive to disturbance as the progression of the whole pushes its unseen parts beyond their organizational limits, producing instability of the whole.

Once a system is sensitized to the need for change, brought on by its own internal instability, the continuity of the process requires time for change. For people involved in steering growth system responses to environmental limits the difficulty is that the momentum of institutional habits from the past seems to necessitate going well beyond the point where changing directions of development cannot be made gracefully. That is the default case for when the sensitivity to the need to respond did not come early enough. That’s where the inherent temporary nature of systematic change needs to be the information needed for drawing the conclusion that you need to prepare to turn already, long before any contact with natural limits is made. Many kinds of natural systems that gracefully respond to limits seem to do just that.

The trick seems to be needing to start to turn before you really need to, otherwise the time needed to adapt to new conditions would make a system unable to or to not do so smoothly. For example, as in paddling a canoe on a winding river (or generally for any craft of steering) you quickly discover that taking the last possible opportunity to turn risks capsizing and spoiling the trip. So the earliest opportunity that is not premature is the one you choose. That means being very sensitive to the need to steer. You'd take the earliest opportunity to think of how to turn and then focus attention on determining the optimal time to do so, ready to turn before the need to turn, and particularly before the turning point is determined by external forces. In the real world we have a choice just like that, the need to steer our economic system with it's practice of adding to things by %'s built into the culture, practice, projections and needs of society. It's not even yet discussed in public whether there is a question of needing to end the institutions of growth somehow, let alone have a ready response for doing it. In responding to the limits of growth the question of delay seems to be in how late we are in seeing the need to turn at all. We seem likely to be following a path like series 3, 4 or 5. Series 1 or 2 would have made the most graceful turns, but the noticeable resource strains and series of major growth disruption crisis for systemic causes suggests the system has already gone past the period of unfettered growth it is thus already too late to climax smoothly.

For people, understanding how to respond to limits is complicated by how the limits themselves always seem moveable, allowing us to use our creativity to make successive delays in dealing with it. The need to learn how to turn doesn't go away, but can be successively ignored, making the question one of whether to respond to "soft signals" or waiting for "hard signals". With increasing effort and creativity it starts off being fairly easy to disguise the mounting difficulty in moving natural limits. That ends in approaching back breaking resistance from nature, though, and then much too late to gracefully respond. One can see a possible "Darwinian" cause for why nature is so full of systems that are highly responsive to soft signals, then. Organisms and weather systems and lots of other things do, though, seem to have a way to respond to the approach of limits by completing their development rather than extending their development to points of failure. The rarity of complex systems that delay their responses to the last opportunity might be because they tend to not survive. It's certainly true in business and personal relationships, that the people insensitive to emerging lines of conflict and the need to adapt to change around them don't tend to prosper. Perhaps that's also why what we mostly see in nature are kinds of systems that respond to real limits at their earliest opportunity. The implied principle for modeling is that for models to sensitize us to the need to change assumptions in the future, models should include leading questions for when to look for information beyond the model.

For our present situation the standing world plan for economic growth to multiply wealth forever includes the design of all our institutions being organized for that, rather than sensitized to steer away from that. If, say, this is the first moment the real necessity of that is being noticed, the rational response would then be to first ask how and when, and the observation that it seems we are already too late to do it smoothly. Those are things you can know without knowing very much, is the point. These questions naturally deserve longer discussion than is possible here. One way to begin exploring the physical system for answers is to ask what new conditions it's parts will run into, and look for the things that would disrupt its positive feedback mechanisms. Those mechanisms will be partly identified by anything that increases by %'s. Without even knowing what they are, one can conclude as you identify them that the question is how it would be best to have them end. Using energy to multiply our uses of energy and using money to multiply our uses of money to keep track of what we do with energy both display the basic features of positive feedback mechanisms and so pose the question of how to end them. Responsive steering would mean being prepared to end them in a constructive way at the right time, to avoid having them end disruptively.

5. Conclusion

Learning much better how to also shape our way of thinking to fit nature's, relying less on increasingly controlling nature to fit our own logics and values, seems to be a necessary part of successfully responding to even our own designs on earth. Perhaps the time has come when people can finally understand the formal value of maintaining two explanatory worlds in our minds, one of connections within our information and one of questions about things beyond our information. We have actually lived with those two worlds in our minds all along, of course, while often confusing things by treating them as one. One gives us our cultural world of meanings that occupies most of our thoughts mentally, and the other is made of our questions pointing to a physical world of natural systems we live in physically. Learning to separate them provides a possible way to understand their connection, having a use for a world beyond our real understanding supporting an awareness of how separate that reality is from our own explanations of things. Science would seem to clearly need both, at least, and the difference in perception might also be of use to the other parts our own personal and cultural worlds of arts, values and relationships

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Supplemental Resources

1. An appendix of general interest perspectives cut from the final edit. http://www.synapse9.com/pub/ModChangeSupp.pdf

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