An Ecological Economics of Growth:
Learning from nature when to turn

Note: This is a 95% progress draft of an essay, released now to circulate the substantial content 5/13/20 JLH

Jessie Henshaw, HDS natural systems design science - sy@synapse9.com

Abstract

All kinds of organized human and natural systems develop by a process of growth, with a beginning, middle, and end. Examples range from the growth of organisms, cultures, and ecologies to the growth of businesses, social movements, weather systems, even personal and social relationships, and many more. Close observation reveals organizational growth to be a progressive building process of self-organization. It typically follows a recurrent six-stage continuity of developmental stages, that offers a window on their varied internal and external working designs, recognizable as developing by a series of milestones along an "S" curve assembly line. Studying that common model allows comparison of all kinds of emerging natural and human-designed systems, enabling a diagnostic as opposed to deterministic view, keeping what "ought to be" in close association with "what is." Discussed are the historical roots of the field, a set of pattern recognition tools, three brief pedagogical case studies, and an eco-economy view of the human world.

Electronic supplementary material

Figures Slide set:

http://synapse9.com/_pub/EcoEconOfGrowth-figs.pdf (Preliminary)

Keywords:

natural growth, development stages, eco-economy, natural succession, emergent systems, organizational continuity, points of change, when to turn.

How highly organized complex building-blocks of life develop and operate is the general subject here; a general systems/ecological/economic perspective on ecologies, cultures, organisms, communities, businesses, industries, social networks, movements, relationships, and teamwork, and also various organized energy systems such as convection, weather, storms, and climate. What they all have in common is developing their functional organizations by an individual observable self-organized growth process. Many others have studied the rich diversity of designs produce by growth, such as Brian Goodwin (1982) and D'Arcy Thompson (1942), whose studies of organism design did help inspire this work. The general nature of the physical process of growth seems to have attracted less attention.

The focus here, though, is more on the patterns of the system building process, one can observe both in natural growth and in all kinds of work processes (Henshaw 2018). The aim is to develop useful systems biomimicry for system transformation strategies large and small. So instead of primarily studying the end designs produced by growth, the study is of the process problems nature confronts, such as from nature's 'madness' in creating the perfection of each design for life one individual at a time. That natural systems emerge from their environments by an individual development process presents a problem for modeling.

There are also many other features of the self-organization processes of life that resist mathematical definition, such as the growth stages of germination and maturation, which present individuals interacting with environments. Self-organization is also found to develop locally, further inhibiting mathematical modeling and calling for empirical pattern search and recognition, rather than deterministic modeling. So the general model to be presented here is of growth systems displaying properties of both ecologies and economies. The following topics for each section introduce the subject:

1) Discussion of general questions about growth
2) Research method and overview of growth studies literature
3) Simple models of growth to aid in case studies
4) Three outline case studies to illustrate the method
5) The ecological economy of growth systems
6) Complications of the global eco-economy and
7) When to turn growth from upward to forward
8) General findings and discussion.

General Questions About Growth

Growth is a lively process, seeming to be both responsive and opportunistic, found in every lively thing throughout nature, as well as in every kind of work people do. That is an observation offered to prompt the reader to question it for themselves, as are all the observations suggested here. Growth in nature appears to adjust over and over from start to finish, as people do in the course of doing work of any kind (ibid.). It seems to be the continuity of those adjustments that corresponds to the organization-building process of growth, generally in plain sight, but often hidden from human eyes for lack of interest and perspective. The very general pattern fits a three-part development cycle, much like any life story, of beginning, middle, and end. The story has two immature stages, first branching out then narrowing down to when the story's mature life begins.

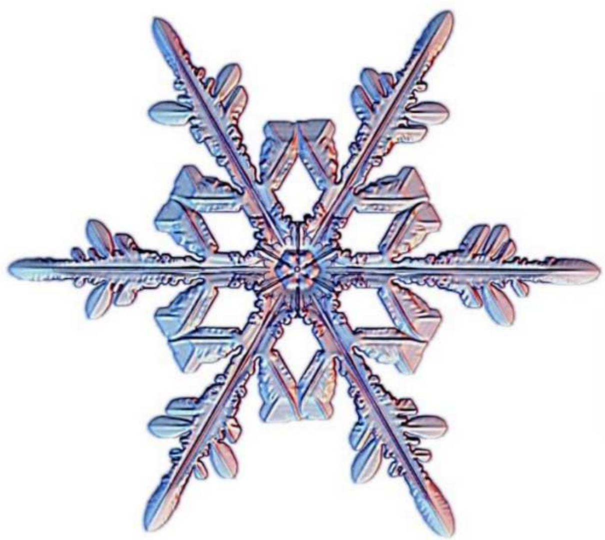
Like most strategies and histories, early growth is immature in design, and gains strength and resolves challenges step by step as it confronts new environments and matures. One of the main findings of this study is that looked at carefully; the three phases of growth are really six, three longer periods each begun with a short change-in-kind and new direction.

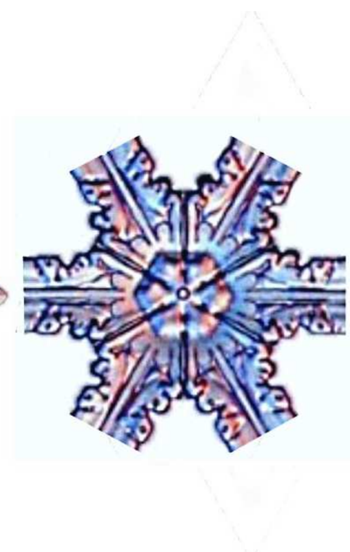
Perhaps the most useful viewpoint is of growth as a continuity of organizational stages, like a series of milestones along an "S" curve assembly line, first stage rough design, second stage refined design, third stage the systems service life. That makes it somewhat like the stages the Panarchy model (Holling & Gunderson 2002) but observed as going from start to finish as a one-way process of organization, not in an endless loop. We can also observe that the six-stage model of growth as a process of emerging organization does not fit very well with models of "cause and effect." The six-stages of growth roughly correspond to the internal animation that drives its opportunistic building process, and "cause and effect" more corresponds to its external limitations.

Another remarkable feature of growth is its usual climax at a state approaching perfection in every part. That applies to the growth of animals, but also businesses, communities, relationships, and snowflakes. It also applies to the design of houses and garments and most any other work people do. That addition of perfecting detail as the second phase comes from infilling the frameworks of design established in the first phase, a period of positive then negative feedback, as the design first diverges in kind, then converges on a finished end, to then live out its mature life. What prompts growth to begin may be very different in each case. However, the general pattern is so common that it serves as a very useful model for comparison to any individual case. We can most closely study it in the most familiar processes of creative system-building, like examining the steps of making a successful dinner, getting an office project to work, or developing a new personal relationship or community negotiation.

Perhaps the most puzzling feature of growth systems is how they seem to invisibly emerge from small beginnings with a contagious pattern of system-building. Examples are 1) the moment when two people notice each other that begins a relationship, 2) the flash of insight leading to the "napkin sketch" that an architect develops into a graceful building, or 3) the joining of sperm and egg, leading to the growth of a new human being. It is also quite mysterious how so many growth systems first expand with a burst of acceleration, to then get some sort of signal to switch in mid-stream to slowing down for taking the building process to its natural finished end.

Sometimes there is an easily identified reason for the turn forward. The genes of a person, for example, somehow coordinate the growth of all the parts then end in perfection all at the same time. That shift from ever-faster expansion to slower and slower perfection of the design of organisma seems to occur at their birth, ending explosive growth in the womb to begin a long process of slowly preparing for adult life. For a home builder, it is the limited fee he will get that assures he will perfect the work in time. Both the builder and client will work like “the genes” of the building process, making sure all the needed parts fit together. For the office project, that change tends to come with a degree of team panic as the need to finish what they started becomes clear. Another clue to what is happening is that explanations for these stages of system design seem always to lack the “requisite variety” (Ashby 1991) for what happens, how such apparently simple signals produce such complex and individually perfected. Clearly, something happens, but it seems hard to explain using ideas of cause and effect, growth seeming to behave as an organized whole.





Snowflake details — Central kernel

Fig 1. A Snowflake and its Central Kernel: The design builds up from a tiny central crystal. The smallest visible hexagonally differentiated shape is still quite simple, with the next rings of shapes quite complex. The six spines that emerge develop nearly identical filigree as if organizationally “entangled” in that first crystal core.

We can see the same thing in more varied forms in business growth. Some businesses take growth only far enough to make a steady profit and satisfy family needs. Among other strategies, some will develop a small business only far enough to sell it and leverage its wealth to start something bigger, climbing a ladder of start-ups, risking everything on each one. The growth of a snowflake (Fig 1) also shows both the beginning and finishing stages. Growth starts with the tiny dot at the center, a speck of ice condensing on a dust particle in the super-cooled humid air. Adding layer upon layer, it differentiates into its final form, build a symmetrical jeweled crown of ice crystals that is individually unique.

Context of Growth Studies

Methods

The original field research from which this research method developed was a two year instrumented field study of the microclimates of homes. Recordings of numerous temperature and airflow sensors over 24 hr periods, mostly in passive solar homes, coupled with the study of smoke tracers, allowed a study of how successive indoor circulation patterns developed (Henshaw 1978). That study of the systemic reorganization of the thermal environments expanded into a study of other kinds of system change, and the start of learning to read the shapes of growth curves for information on the organizational changes taking place. The pattern of swelling then subsiding stages of development proved to apply particularly widely, as a universal pattern of organizational development (Henshaw 1979, 1985a 1985b). In the late 1980s and 90s, the focus of research switched to developing data-driven mathematical pattern recognition methods for growth systems, applied to time-series data from published sources for ecological, astronomical, environmental, and economic systems (Henshaw 1995, 1999, 2007). General theory papers followed, focusing increasingly on the active learning exhibited by whole ecological and economic growth systems (Henshaw 2008, 2010a, 2010b, 2011, 2015, 2018).

Over the years, the research method that developed was to use the universal patterns of organizational development as models of the norm, such as shown in Fig 4 and 5, to sharpen by contrast the observations of of individual cases. Comparing particular cases with typical cases frames the way particular growth systems uniquely emerge, differentiate, and develop. Understanding individual cases then helped methods of exploring their roles in ecological domains, displaying their coevolving internal and external systems of relationships (Henshaw 2015). The comparison of empirical and model behavior helps generate well-grounded hypotheses and tests for individual cases, making a seemingly successful observational diagnostic method. The reading recorded growth curves as a history of rapid organizational development also helps create a storyline into which to insert detailed observations to find how to connect (Henshaw 2018).

Literature

Many other scientists have also noticed growth as a fundamental phenomenon of nature that needed study. It seems, however, since instances of growth vary so much, are so complex, dynamically transient and generally not determined by external forces, the commonalities displayed were slow to be recognized. Scientists who took an interest in growth and helped lay the groundwork included Malthus (1809), Jevons (1877, 1885), Alan Turing (1952), Ken Boulding (1953), Albert Bartlett (2004), Walter Elsasser (1987), Robert Rosen (1991, 1993), and Stewart Kauffman (2008).

Malthus was surely not the first observer to notice the natural instability and urgent need look ahead on the curves of compound growth, an awareness of things erupting seemingly essential for the success of any shepherd, farmer, cook, leader, or banker. However, Malthus did succeed in tying the mechanics of unconstrained growth in a new way to the social trap of unresponsive cultural desires. Even today, though, the problem persists, and our cultures seem unable to accept that 'innocent' human desires can produce a traumatized world.

Malthus's famous observation that compound growth is inherently self-limiting was incomplete, however. He failed to include that compound growth is also the beginning of many essential things in life, and did not ask, in those cases, how growth becomes self-limiting without causing chaos. That question of "When to turn?" to make growth a great success rather than a failure is still one we need to ask. People are, of course, remarkably skillful in responding to natural limits of all sorts, whenever they see a "practical" response, but then quite inept and confused if that response conflicts with their values.

Jevons' famous so-called "paradox," that industrial efficiency most often increases rather than decreases industrial resource consumption (1885) illustrates the paradox of human confusion about growth systems in another way. No one is hiding the fact that the use of efficiency in business is for expanding output and increase profits. Virtually worldwide, though, people expect efficiency to reduce resource use, even as the global data is remarkably clear that the opposite is happening[1]. That makes it seem the popular faith in efficiency for solving economic problems is really for improving business and raising profits, what efficiency actually promotes. The increase in unit efficiency is what lowers the price and allows a business to multiply the units produced and its income.

A less well known but equally important contribution of Jevons was his earlier work on describing the scientific method (1887). His view was that the progress of science rests first on recognizing the natural phenomena of interest to study, driving scientific progress by asking the right questions. That defines science as being nature-centered, relying on:

> "…a rare property of mind which consists in penetrating the disguise of variety and seizing the common elements of sameness [..] which furnishes the true measure of intellect." (Jevons 1877, p5 The Powers of Mind concerned in the Creation of Science)

Jevons' view rests the progress of science squarely on forming hypotheses that illuminate nature. That differs considerably from Popper's (2002) general view that the progress of science rests the rigor of formal data analysis. Most working scientists would want to have both, of course. The inability of science to define nature, however, appears to have forced a philosophy of science separating them. Relying on abstraction for defining scientific theory seems to steer science first away from the need for science to illuminate nature and then toward using abstract science to define nature. The study of growth as nature's perennial cauldron of invention would become a natural casualty, simply defined out of existence.

Among the relatively rare studies considering growth as an instrumental natural phenomenon were those of H. S. Reed (1924) and Ken Boulding (1953). They both recognized growth as a progression that had very

---

[1] Evidence of Decoupling Still Zero, Henshaw research notes: https://synapse9.com/signals/2018/06/18/evidence-decoupling-still-zero/

different structural and quantitative dimensions and emphasized how representing growth mathematically differed fundamentally from characterizing the emergence of its working designs and structures. Reed's observations, such as the following, seem to represent particularly forward thinking and usefulness:

a) the irreversibility of growth,
b) the flowing continuity of growth and development,
c) the conservation of energy regulating growth processes,
d) the frequently evident self-regulation and autonomy of growth systems, and that
e) the continuity and regularity of growth were often independent of adverse conditions.

For that last observation (e), he speculated that a natural mechanism could give growth the power of homeostatic negation of outside influences. That would have distinct limits for many things, but it is how mammals regulate their temperatures, in opposition to exterior thermal pressures by varying internal heating and cooling.

Boulding's observations on the study of growth (1953) include remarking on how mathematical growth laws were not very useful due to growth system behaviors arising from their internal structures. That defect becomes an advantage, however, as he quotes Dr. S. A. Courtis pointing out:

> "an empirical growth law which fits many cases has at least the virtue that it calls attention to possible unknown sources of disturbance in cases where it does not fit - just as the law of gravity led to the discovery of the outer planets." (quoted in Boulding, 1953)

That diagnostic use of general theory to highlight local departures for further study is indeed a valuable tool for both research and practical use. It is central to this present work, the use of general patterns to aid the discovery of how the parts of some particular case fit together.

Boulding also developed several general principles restated here for structural growth:

1) Nucleation principle: The observation that a nucleus must form to initiate growth. Boulding offers two useful examples, first, how a dust spec is needed to initiate condensation for forming raindrops, and second, how students are unable to retain information on new subjects until some insight nucleates in their minds.
2) Non-proportional scales principle: Changes of different properties tend not to have different scales, such as for differences in length, surface area, and volume, also presenting interrelated limits to growth determined by the laws of scale for each dimension of the system.
3) D'Arcy Thompson principle: that form results from its patterns of growth (what grows is what becomes), resulting in various laws of proportionality for both organisms and organizations, and at the limit, that whatever grows the fastest takes over the environment.
4) The Carpenter Principle: that growth exhibits unexplained coordination of the whole as if a carpenter is in charge of making the parts fit and steering the whole toward an original

vision as the ultimate goal. System assembly cannot rely on predetermined parts but must, therefore, have adaptive parts that seek to fit globally. He also gave the example of how a student's first recognition that language has grammar transforms their ability to improvise.

5) Principle of Equal Advantage: (corollary to the carpenter principle) Positing that systems have parts that fit together by all seeking their highest potential or most productive fit in an organization.
6) Principle of natural pace: The possibility of temporary equilibrium rates of growth in an organism or system such that higher (or lower) growth rates may seriously disturb the functioning of the system even to the point of its collapse.

Alan Turing's paper on morphogenesis (1952), offers theoretical equations for the spontaneous emergence of new forms of organization, using a biosystem model. Relatively recent efforts demonstrate Turing's model for the patterning of animal markings and other organic geometries, such as the leopard's spots and sand ripples on dunes (Ball 2015) but not the general case. There are various observable conditions to study to understand better what Turing was trying to explain. Cases of growth's apparent spontaneous emergence from a protected location and state of calm "before the storm" are common.

In a protective environment, the fragile beginnings of things get an undisturbed chance to develop. Not only do actual storms arise from a summer calms, but business start-ups need their period of early protection to get organized. New lives also emerge from the protected conditions within seeds and in the womb, as fresh ideas frequently occur in a calm mind, all examples affirming both Boulding's and Tourings' intuitions. Of course, all those kinds of examples also serve to contest the formerly trusted assumption that such beginnings were the result of random external disturbances instead of delicate internal developments.

Walter Elsasser was a noted physicist who then studied biosystems and Stuart Kauffman a noted theoretical biologist both of whom were suspicious of the random theory of evolution. Elsasser (1987) found that if there were only random variations, it would be impossible to explain persistent order in the universe, the odds of any persistent order being on the order of one in as many chances as the total number of sub-atomic particles in the universe. Kauffman (1993) struggled with the same problem; only he saw it as a need for evolution to have a way of restraining mutation. In either case, they concluded that the statistical laws of physics, however useful for engineering, could not have been how the complex designs of nature developed.

The answer may be in plain sight given that life and nature are processes of accumulative change, built layer on layer, with past events the necessary precedent for following ones. That would also seem to make time itself a developmental process, not a stochastic one, represented stochastically to approximate the undefined complexity of nature. Not every growth process displays it as clearly as the rings of a tree trunk with the core of the tree persisting unchanged as new layers are added one at a time. Every case of growth seems to follow the same rule, however.

Theoretical biologist Robert Rosen (1993) seems to have started his critique of the standard scientific model of nature by observing that natural processes generally follow improper rules without predetermined ends, quite unlike scientific equations. Science for centuries had modeled nature using only deterministic equations.

That life processes are both accumulative and adaptive makes them opportunistic as well, reduces the applicability of scientific models to controlled, rather than to natural, conditions. Modern complexity science has responded with accumulative and adaptive computer models, using deterministic statistical rules. That has generated lots of applications for complex controlled outcomes, robotics, and artificial intelligence (Henshaw 2018) without seeming to have found ways to emulate the emergence of novel properties of natural system organization or natural growth (Pines 2014).

Rosen's most significant contribution may have been turning the light of biological reasoning on the process of science itself, studying the accumulative design process by which science itself works, illustrated in Fig 2. The figure shows science as an accumulative loop of knowledge, or a rising spiral if one likes. Science, as a practice, starts with observations for "encoding" in the language of science and then made part of the formal system of scientific implications. That is followed by "decoding" the scientific implications in the language of nature, as test applications of theory, to see if nature's language of causation matches the scientific language of implication, and then take those observations and repeat the cycle.

That same alternating cycle of exploratory engagement and adaptation is also central to most human endeavors, with alternating work and evaluation taken from start to finish as a natural practice of "action research" that brings work started to completion (Henshaw 2018). One can observe the same general kind of exploratory engagement by other species, and other kinds of exploratory growth systems, taking the directions that produce the most advantage, whether that is intended or not. Those cases are not applying human values, of course, but if watched for some time displaying similar practices of opportunistic exploration that result in accumulative learning (Henshaw 2008). The same pattern seems evident in economic cycles, as alternating periods dominated by one paradigm of production followed by a period of retooling to create the next paradigm. So, with some care, one can use the Rosen model as a guide to the designs of natural growth systems.

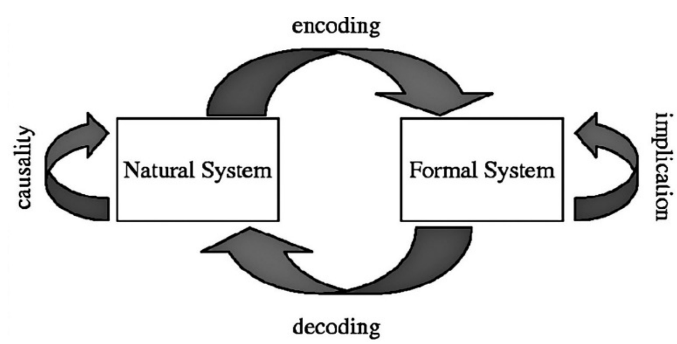


Fig 2. Robert Rosen's Heuristic Model of Scientific Learning: A cycle of *observing causality* in nature for *encoding* in the scientific language of *implications, to* then *decode* as applications for testing, repeating the cycle with further *observation and testing.*

Human interest in this level of granular detail in the development of natural systems may have been on the fringe of scientific thinking for a long time, of course, given how broadly these learning patterns seem to apply. The subject seems even traceable to the ancient Greek word that eventually became 'physics,' the

Greek word 'Φύσς', pronounced "phúsis" (Wikipedia)[2] a term that initially referred to growth and the productivity of nature in giving birth to new things. How the meaning of that ancient Greek term for the creativity of nature turned into our present meaning for "physics" referring to the invariable laws of nature (Merriam Webster: physics)[3] might surely have come about in many ways. One plausible way, applying Boulding's principle of advantage, would be the natural tendency for scientific studies resulting in economic success then to predominate. Indeed the search for predictive certainty that physics became so known for also dominated the scientific culture for being so economically profitable. That singular focus on deterministic rules would then slowly altered the original meaning of the word for creative processes, going from a focus on the creativity of nature to one on controlling nature.

Growth Models for Case Studies

The case studies section demonstrates the use of simple growth models for diagnostic study, to give a hands-on feel for the research method.

Three Growth Models to use for Studying Growth System Designs

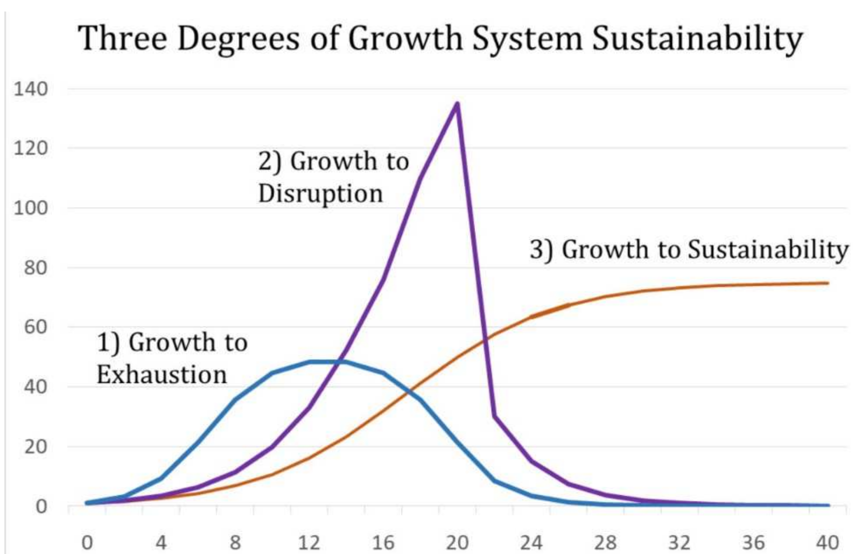


Fig 3. Three degrees of endurance for growth systems: 1) Consuming available resources without building a system for finding more. 2) Building a system for only growing its access to resources. 3) Using the start-up period of to build a system and a finish-up period to make it sustainable.

There is much to learn from what one might call 'failing' growth strategies. Growth paths 1 & 2 in Fig 3 show generic shapes of the development curves for two types of system-building that fail to go to completion

[2] (Wiktionary: Φύσς) Translated "gro.sis" and pronounced "fi.sis. https://en.wiktionary.org/wiki/%CF%86%CF%8D%CF%83%CE%B9%CF%82

[3] (Merriam Webster: physics; History and Etymology) https://www.merriam-webster.com/dictionary/physics

and die prematurely. The first, 1) “Growth to Exhaustion,” depicts a growth system that consumes its starting resource without building access to additional resources. Examples are a seedling that fails to put down roots, a match that flairs its phosphorus head and goes out, or a business that just consumes its seed money without attracting a market. The second, 2) “growth to disruption,” represents a system that succeeds in building ever-expanding access to resources, but fails to become sustainable. As it expands ever faster, its acceleration disrupts its own operation. Examples are (a) the common gardening problem of seedlings that shoot up till they fall over, (b) businesses that grow too fast and collapse due to fatal errors, or (c) economies that become top-heavy with overhead costs but push growth till the imbalance causes their collapse.

The third growth pattern, 3) “Growth to sustainability,” is for systems that build secure access to resources and then change strategies to secure longevity. A Type 3 growth system responds internal or external strains and instead of multiplying its parts to maximize its growing power as a sole purpose, begins to use more and more of its investment resources for building resilience instead. That change of purpose is what causes the Type 3 growth system to stabilize, repurposing its surpluses to climax its growth at a peak of vitality rather than a peak of exhaustion or disruption. With lots of easy mistakes for entrepreneurs to make, learning may come mostly from multiple failures, every attempt a trial by fire. That gives entrepreneurship a strategy of “try, try again,” a strategy of maturing while surviving multiple failures.

It is very reasonable to ask what ecologists have said on the subject. H. T. Odum (2007 p.283) similarly illustrates growth systems, showing six trajectories, including the three in Fig 3. For each, he diagrams a computer model and equations. The organizational processes are not themselves numerical, though, so the organizational designs and how they change from one growth stage to the next are not discussed.

What is often the most recognizable feature of growth systems is how is the “S” curve shapes they trace, shown in Fig 4 along with the minimal stages of organizational progression, such as for the growth of organisms, ecologies, cultures, and relationships (Fig 4). We also see the “S” curve pattern of growth that stabilizes in the development of industries, communities, and organizations of all kinds. Perhaps the model we can learn the most from, though, is the personally familiar office or home project, for reorganizing the office, creating a new deliverable for a client, and building an addition. From our personal experience with them, we gain a detailed view of the start-up phase of creative decision-making and how it connects to the finish up phase, leading to the release of the finished product. Any such project starts with some inspiration, a fresh idea “catching on,” serving as the “nucleation” of combined interests that get the work started. What follows are stages of clarifying the whole idea, identifying its requirements, and then organizing the team and their tasks. Once the final framework of the project set, the team can turn to filling in the details, then perfecting the design and preparing for its delivery.

Other familiar creative work efforts follow roughly the same stages, getting it together then getting it done. It is part of everything we do, like making lunch or dinner, making friends, gardening and building design, and organizing neighborhood groups. So one can learn from the examples of system development that are most familiar. They all start with a fresh idea that catches on, starting with exploring the idea, organizing the work, putting it all together, then adding finishing touches for delivery. That “S” curve of building things is a universal pattern that mimics natural growth in producing finished products (Henshaw 2018).

Life Stages of Growth Timeline

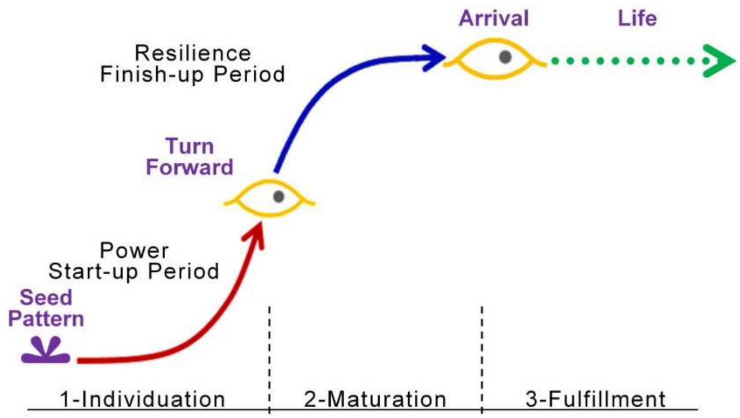


Fig 4. The six stages of natural growth alternate between events of organizational change and developmental periods. [4]

1) the **seed event,** , followed by 2) **start-up growth period** (red)]─***Individuation***

2) the **turn forward event,** , and **finish-up growth period** (blue)]─***Maturation***

3) the **arrival event,** , and **Climax life period** (green)]─***Fulfillment***

Simple Organization Plan for an Ecological Economy

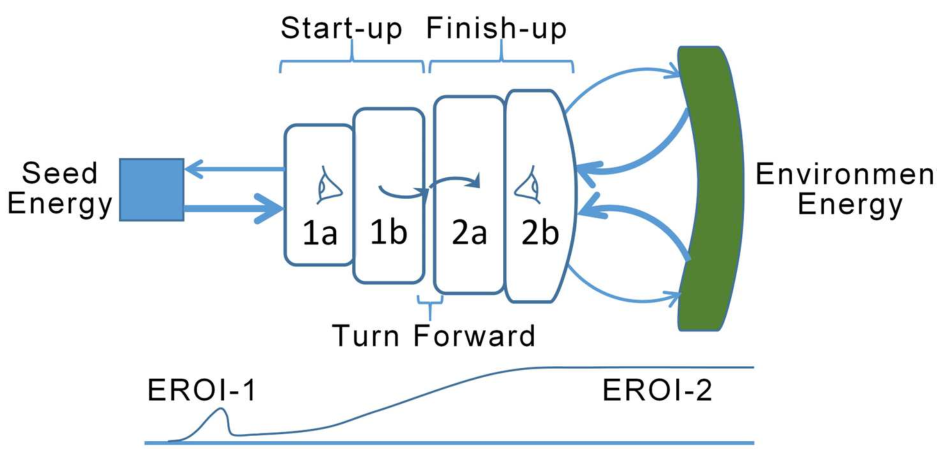


Fig 5. Economic systems need energy returns greater than societal energy costs (SEROI) to balance its energy budget. Its first energy source, EROI-1, is usually consumed as the system develops more lasting sources, EROI-2, perhaps depleting several on the way.

[4] For alternate terminology to use see Appendix I. below and Henshaw (2018 Sec IV)

Fig 5, like Fig 4, also depicts the start-up and growth periods of an emerging system, but shown as a phased building process, like adding sections to an expanding business as its operations increase rather than as a graph of increasing scale. The first building section is 1a, developed using the finite seed energy resource at the left. Subsequent building sections are parts 1b, 2a, and 2b, each using increasing amounts of the lasting environmental energy at the right, the first two sections corresponding to the beginning and end of the start-up period, and the last two sections to the beginning and end of the finish-up period. To use Fig 4 and 5 as guides, one studies a growth system to find features that seem to correspond to the parts or phases of growth shown in the figures. Then one makes a judgment of how well, or poorly, the general model fits the subject of study as a way to start making a new model that better fits the observations, making sure to keep the continuity and needed sequences in the new model.

For example, often not visible in the commotion of a working business is the handshake that marked the new business partners settling on a plan of action. That is the model and seed design for the business from which all that follows would come, generally passing on those original ideas and values unless something disruptive happens, as the general idea of "how it works." So when studying a business culture, one might ask about the seed idea that started it to understand better what ways of harmonizing or departing from it might be possible.

The "missing origin" is also observed in plant or animal reproduction. It is science that tells us that fertilization and germination must have occurred, though one cannot observe those events. The same is true for that moment when two people suddenly take an interest in each other. That fleeting 'spark' is the start of everything but later hidden from view. Of course, it is often not possible to discover the influence of hidden turning points of life. The principle that it takes nucleation to begin any growth system still does open the questioning to a search for pervasive patterns that might have come on from the system's origin. A similar diagnostic approach would apply to finding out about any other surprising or missing part of the history of any growth system and its downstream effects.

3 Case Studies

The three case studies below demonstrate the use of the general diagnostic signs of natural growth (Fig 4 and 5) to suggest useful questions for interpreting recorded growth system timelines. The exercise teaches a kind of guided exploratory guesswork, stepping stones, for illuminating behaviors behind the data, suggesting new hypotheses to test, offering a better grasp of real-world problems, and better decision-making. The life stories of natural systems are much more varied of course, so starting asking whether the models fit at all is an needed first step. For example, the familiar graphs of coronavirus contagion all start with explosive growth, but then do not build any organized system. Explosions that do not build things are shown in Fig 3 as type 1

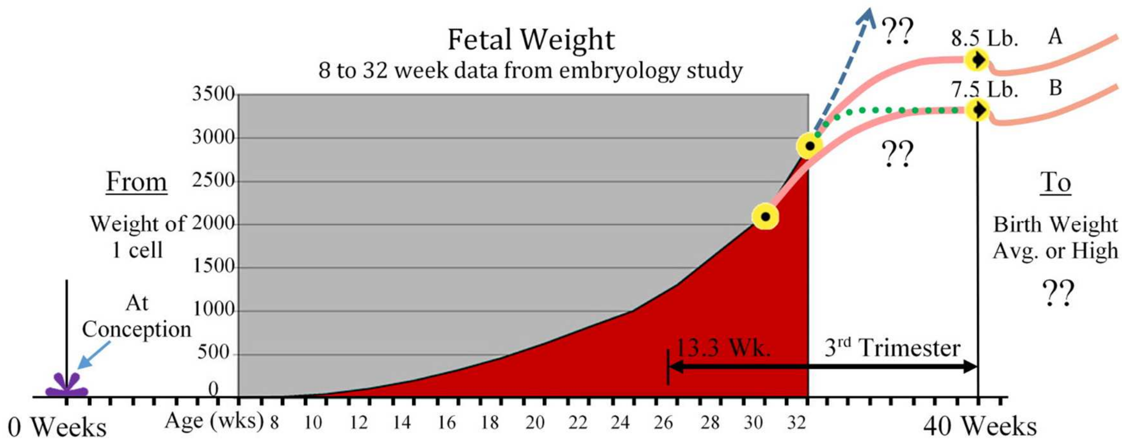


Fig 6. Case Study I. Human Gestation based on partial data on fetal weight.

Case Study I Human Gestation

Phase	Observations
0 Context	The data shows only 26 weeks, redrawn to 40 weeks. The maternal environment is a protected and nourishing place for the descending unfertilized egg.
1 Seed	Fertilization marks “Week 0,” the blastocyst (~200 cells) implanted in about ~5 days.
2 Start-up	The growing embryo’s weight does not register until “Week 8” but has been doubling in size about every 5 ½ days, some 40 times in the next 32 weeks. [5]
3 Turn Forward	We test the Turn Forward at both Week 31 ( ) & Week 33 ( ). *Do you see why? Is there a better guess?* To be at Week 31 the last data point needs to be a little high.
4 Finish-up	One option is the **dashed blue line** extending the data trend, toward a birth weight of ~1000 lbs! So there *must* be a Turn Forward. The **dotted green line** levels off abruptly to hit the avg birth weight of 7.5 lb. The lower and upper **pink curves** ( ) show weight gain smoothly birth weights of either 7.5 or 8.5 lb. *Which 3rd Trimester growth curve seems most natural,* **A** or **B**? Does pregnancy end gradually, **B**, of fast, **A**? *Which is more likely, that the birth weight is near 8.5 lb or that the last data point is a little high?*
5 Arrival	Birth at 40 weeks ( ) leaves a newborn stressed and needing to recover, a dip in the curve.
6 Life	*How does weight gain during infancy and childhood proceed? In big spurts? Might physical growth be slowing the whole time, explaining why it takes 20 years?*[6]
7 New Context	Leaving home for a bustling world and further developing skills for Life.

- The study shows a method of expanding the timeline of partial data to compare challenges ahead, 1) looking at all six stages of growth as a whole, 2) seeing a necessary turn forward and possible sharp turns ahead, and 3) compare the smoother paths for which to prepare. The primary constraint for all the options is to maintain the continuity (smooth shapes) of the transitions while connecting the options available.

[5] Data source- Univ of New South Wales Embryology Study - https://embryology.med.unsw.edu.au/embryology/index.php/2009_Lecture_22

[6] Mayo Clinic “Pregnancy week by week” https://www.mayoclinic.org/healthy-lifestyle/pregnancy-week-by-week/in-depth/fetal-development/art-20045997

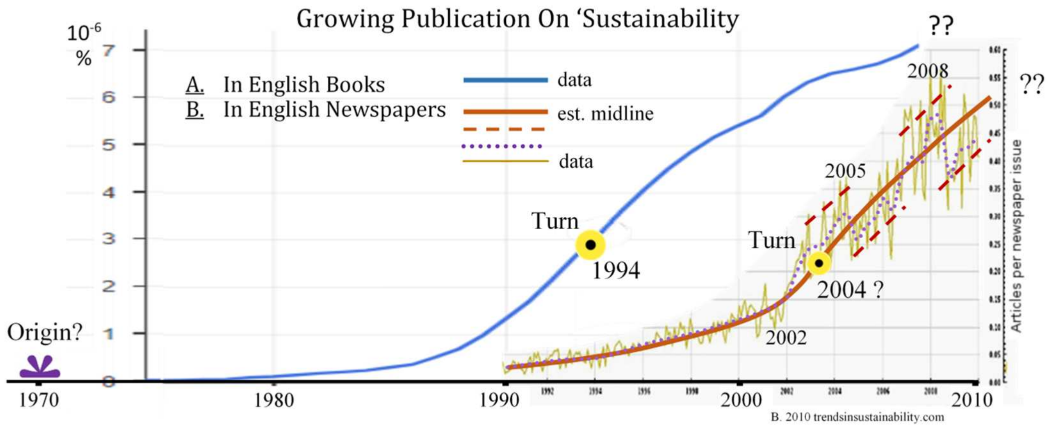


Fig 7. Case Study II. Data on book and newspaper publishing on 'sustainability.'

Case Study II The Growth of Publishing on Sustainability [7 8]

0 Context	Concern with growing environmental impacts began long ago, becoming a mainstream interest in the 1980s and 90s, at different rates for publishing in books and newspapers.
1 Seed	Curve A traces of the rise of "sustainability" in books, first appeared in the 1940s but its growth starting in 1970. Curve B might have had a long gestation period too.
2 Start-up	Growth of Curve A is about ten years ahead of Curve B. *Did sustainability start as a matter of private debate before becoming a public debate. Was it that reporters were not reading books? Why else would treating it as news be delayed?*
3 Turn Forward	The 1994 and 2004 marks for Curves A and B locate the start of climaxing for the book audience's maturation and the for the newspaper audience's shift from steady growth to wild fluctuation. *What caused the big flurries in newspaper interest? How would you tell if the turning points marked either a new seriousness or the exhaustion of the subject?*
4 Finish-up	Curve B after 2004 was estimated first by tracing the midpoints of the data's largest fluctuations (••••) then the extremes of the data's largest fluctuations (– – –) and then interpolating the smooth curve (▬) through the first two. Neither data source is available after 2010. *Does your understanding of sustainability culture help you guess where the trends have gone? Are the issues headed for resolution yet?*
5 Arrival	The resolution of the sustainability issues would mark our arrival at a model for living in the future. *When might that occur? If not directly ahead, what is in the way? Is it possible the discussion is still searching for direction, or is it resolving?*
6 Life	As in life, a healthy maturity is a highly eventful steady state. *In that sense, what is needed for the discussions of sustainability to reach maturity?*

- The study shows how an enriching exploratory narrative can be developed even without clear evidence of most of the milestones. All that is needed is some evidence of development to start the development of a narrative for discussing it as beginning middle and end. The last section of the 2018 paper "Reading Life Stories" (Henshaw 2018) discusses methods of interpreting change with life story arcs.

---

[7] Google "Ngram" for Sustainability - https://books.google.com/ngrams/graph?content=sustainability

[8] Global Sherpa.org http://globalsherpa.org/news-trends-sustainability-development-issues/ publishing research by trendsinsustainability.com

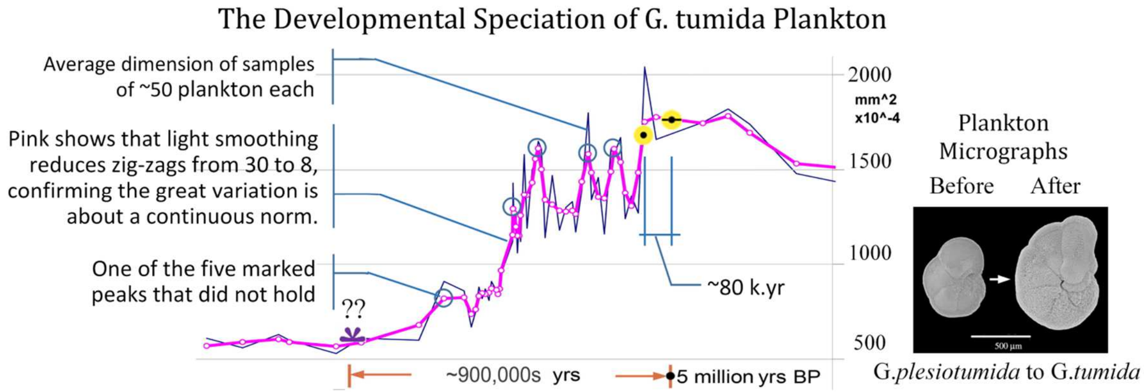


Fig 8. G.tumida plankton 900 k.yr punctuated evolution of showing repeated bursts of regular increase in species size, that do not hold, until after almost 900,000 yrs one does.

Case Study III An evolutionary case of "try, try, again."[9]

0 Context	The jittery data points trace a nominal 900 k.yr evolutionary transition from one species of open ocean plankton to another (Henshaw 2007). Statistical tests show the data is not random, and light smoothing approximates the trend, showing several periods of very rare continuity in evolutionary change.
1 Seed	The initiating seed event ( ) for the G.*tumida* transition places the estimated earliest point when the species genome instability might have begun.
2 Start-up	After five failures to sustain spurts of growth that then collapse ( ), "try, try again" seems to be the growth rule followed. *What are examples of similar patterns of persistent attempts and failures? Why do they occur?*
3 Turn Forward	After the five growth peaks that did not hold ( ), the final and highest growth surge falls back to a Turn Forward ( ) in the trend curve, after some ~820,000 yr. *What are examples of systems following a "try, try again" growth path that succeed. Is the smoothed storyline easier to read? How do you tell the story to reflect the raw data?*
4 Finish-up	The end of the long struggle resolution seems to come relatively quickly, lasting only an estimated 80 k.yr from the Turn Forward to the estimated point of Arrival.
5 Arrival	After the estimated point of Arrival ( ), the trend line returns to the kind of lazy drifting as before the long wild transformation struggle began.
6 Life	*What is life for a species?* It's hard to say without a lot more understanding of how tripling the size of this common ocean species changes its ecology. *Could changes in the species' role in its environment be reflected in its repeated growth failures?*

- Think about "try, try, again" patterns, and what drives them in personal, business, and political struggles. Natural systems do not have human motives, of course. However, they might have fixations with similar effects, as for a self-organizing system repeatedly disrupted by some innovation that persists. So for that period, the system would be trapped by struggles between its own new and old orders. *Are all great struggles like that, facing issues that come back again and again until finally resolved? Can human fixations be informed by other long struggles, like the evolution of G.tumida appears to display?*

[9] Ocean core data collected by Bjorn Malmgren (1983), Further analysis by Henshaw (2007)

Eco-Economics of Growth

"Try, try again" is also a way to describe the growth model of our world economy, with people making every effort to sustain maximum rates of compound growth until that repeatedly runs into trouble producing another crash. Historically, it seems clear the consideration of "when to turn" the driving forces of perpetual growth simply never comes up. To better understand that pattern of challenges not faced, it will help to look at the world economy as being an ecology too, picking out the following partial list of the observed features both have in common:

1. Ecologies and economies both need energy for all their parts, each part balancing its energy budget with positive returns on investment similar to balancing financial budgets with positive returns.
2. To do that, both rely on working designs that combine different specializations into units that work as a whole and have emergent productivity along and other unique properties.
3. Both have living parts that rely on exploratory learning to establish environmental niches as individual home bases for their ways of living and their connection with the whole.
4. Both also thrive on moderate disruptive innovation, causing "creative destruction" when new kinds of organization disrupt the old, triggering system adaptation and a reshuffling of relationships.

To frequently remind us of these and other granular details of ecological design in economies it is useful to call them eco-economies for short.

Assumption four, above, explains how growth in eco-economies can become both highly refined and smoothly flowing as a developing system continually adapts as a whole to the emergence of adaptive forms develop within it. For human eco-economies, it is fairly easy to imagine the active learning and innovation of new parts, using individual creativity to explore and exploit opportunities, develop new designs and establish new niches for them. It also appears to imply that wherever one sees growth that innovative systems learning is also taking place.

It is perhaps the signature behavior of all living systems to actively explore their environments, the active behavior of all animal species we most often see. That, of course, applies to humans as well, using exploration and creative adaptation as a way of living, finding food, safety, and usually community too (Henshaw 2008). Think of the complex world of a freshwater pond, becoming a great center for interweaving the niches of numerous species by how their members arrange the economy of their homes. In a healthy pond, the small fish can dart into the reeds and shallows when big fish come around, both learning to survive, with each community securing a niche for itself while serving each other (Forbes 1887).

These granular details of how eco-economies smoothly develop and grow, relying on organized environmental relations, are part of the needed mechanics of growth. They are also a source of the limits to growth and the risks of collapse when those organizations experience excessive demands. That may be when chains of connections stretch to their breaking point, as when stretching a bucket brigade till it breaks. A good example is the financial crisis of 2008, which came partly from out-of-control speculation stretching the obligations of insecure homeowners until their cascading collapse then triggered a global collapse.

All growth-driven eco-economies have that built-in tendency to fail, organized as an expanding assembly of "bucket brigades," that continually accelerate. Business people are generally good at coordinating the new parts and changing environments, but only to a point. The approach of the unavoidable breaking point is usually signaled long in advance, too, as increasingly costly internal and external resistance develops throughout the system. That results in diminishing marginal rates of return on increasing investment, marking the time when driven growth systems start to compound their own struggles, often ignored as "externalities," but that any effective response will have to take into account. Increased congestion, distressed environments, and distressed communities produce unproductive increases in complexity and costs of regulation. Deferred maintenance, planning, and research, like all excessive efficiencies, make systems unable to adapt as pressures to adapt multiply. Those self-inflicted difficulties add to the hazard of systemic failure, both because they whittle down margins of safety, increasingly distract people from the long view, and assure crises will break out where no one is paying attention. As with the Coronavirus, once it is clear that systemic crises are out of control, it is people who immediately listen to the environment and foster a politics that unifies the society that succeed in minimizing impacts and guiding the community to safety.

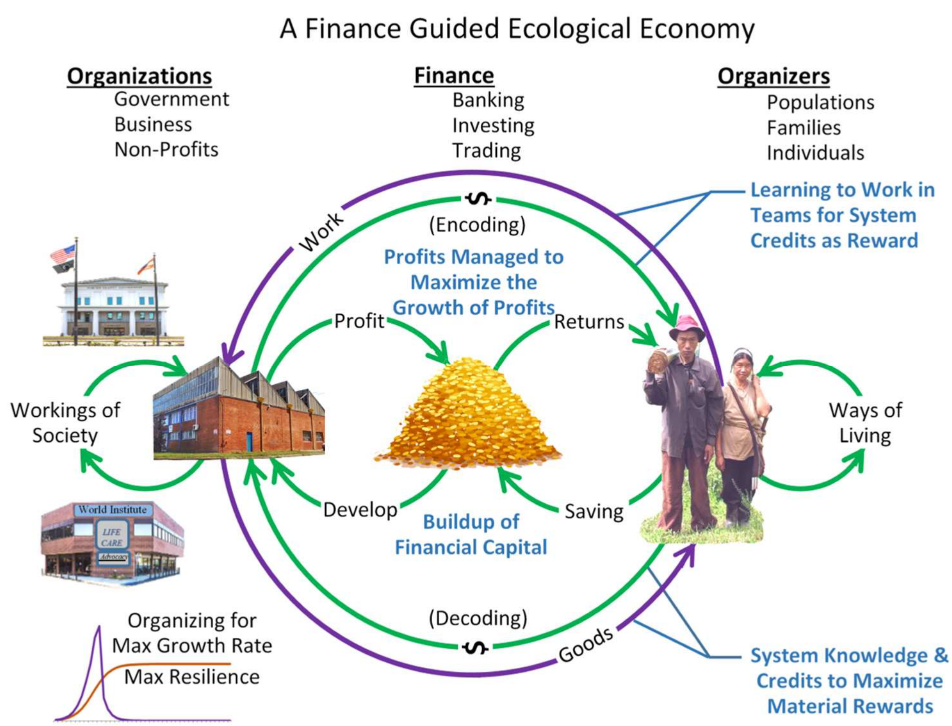


Fig 9. Decision-Making in a Finance Guided Eco-Economy: Business and Investor choices set future directions of development to maximize their growing profits. Consumer choices reward the most attractive products. Government and Non-Profit choices respond to societal values and needs, with most costly "externalities" of growth not counted.

The centers of decision making that steer the world eco-economy into the future are the subject of Fig 9. In the center is the pool of accumulated investment funds, represented as a pile of gold, used to fund growth and new directions. A key detail not shown, of interest to many, is how the money supply expands and contracts. Money is regulated to represent a share of the wealth of the whole economy. In normal conditions, fiat currency expands and contracts with the creditworthiness of borrowers. The value of currency also varies with central bank efforts to stabilize inflation and government fiscal efforts to drive expansion, and of course, with the creativity of the whole system itself. The profits of the eco-economy come from the systems of production, creating value greater than their costs, a surplus-value produced by the organization of the parts, allowing them to work as wholes. The main centers of eco-economy productivity shown in Fig 9 are listed below, from left to right in the diagram, as:

1) the organized foundations of human society and cultures
2) the matching of the talents of people with technologies making work valuable, and
3) the public services of government and non-profits,
4) the profit-making businesses, industries, and service networks,
5) the financial industry's management of investment funds,
6) the ways of living of individuals, families, and social and occupational circles.

All sectors combine differing specializations to create emergent productivities that work together to produce growing profits from creative organization. The system as a whole has two general outcomes, shown in the lower-left corner of Fig 9, either maximizing the growth rate to collapse or turning forward to maximize long term resilience instead.

7) The principle distinction being perhaps only whether the six centers of decision-making respond to the whole system's diminishing returns and related exponentially growing threats.

Given the increasingly hazardous directions the world is now taking[10,111213] there appears to be a need for a dramatic whole-system change in direction. To do that all six decision-making sectors would need to work together, each playing its part, not at odds with each other as at present. Numerous examples show how

[10] 2019 WEF Global Risks Report http://www3.weforum.org/docs/WEF_Global_Risks_Report_2019.pdf
"Global Risks out of Control - Is the world sleepwalking into a crisis? Global risks are intensifying but the collective will to tackle them appears to be lacking. Instead, divisions are hardening. The world's move into a new phase of state-centred politics, noted in last year's Global Risks Report, continued throughout 2018. The idea of "taking back control"—whether domestically from political rivals or externally from multilateral or supranational organizations—resonates across many countries and many issues. The energy now being expended on consolidating or recovering national control risks weakening collective responses to emerging global challenges. We are drifting deeper into global problems from which we will struggle to extricate ourselves".

[11] 2019 UN Global Assessment Report on Disaster Risk - https://gar.unisdr.org/ Conclusion: - "Disaster risks emanate from development pathways, manifesting from the trade-offs inherent in development processes. In some ways, this has always been well recognized. What is new in today's increasingly interconnected society is the diversity and complexity of threats and hazards, and the complex interaction among them, which result in "an unprecedented global creation of risks, often due to previous socioeconomic development trends interacting with existing and new development dynamics and emerging global threats." P 418

[12] Experimental list of The Top 100 Disruptive World Crises Growing with Growth (Henshaw 2020): https://www.synapse9.com/_r3ref/100CrisesTable.pdf

[13] Living Planet Index http://www.livingplanetindex.org/projects?main_page_project=LivingPlanetReport&home_flag=1

completely investors ignore systemic costs, until this spring being managed to accelerate the worst of climate change with atmospheric CO2 growing has a sustained high exponential rates.[14].

Steering the Eco-Economy

Money is an information commodity, a traded unit of credit any holder can exchange for shares in any investment or for any material thing or service the eco-economy can and deliver. That gives financial choices the power to guide the work and development of the eco-economy as a whole, represented in Fig 9 by the large circle of trade in one direction and money in the reverse. Non-financial choices and roles also shape the eco-economy. How people learn to serve others helps steer the eco-economy, too, such as by how competing for sources of income motivates people and organizations to offer useful services. Perhaps the Coronavirus experience will have taught the world enough about growth systems to recognize the huge impact of making choices in time.

Individuals: Some patterns of influential financial choices are generally hidden from view, such as the private choices that investors make about their investments. People do make many kinds of investment choices for varied reasons, with more people investing philanthropically in recent times. With that premise, individual voices can have lasting impacts on the world directly, as well as through their roles in family, work, and society. Individual choices on what goods and services to consume may make much more influence through letting their voices be heard than on directly reducing environmental impacts. Research shows that one's individual environmental impacts depend much more on how much money they have than on what they spend on (Henshaw 2011), and so what helps make one's life meaningful is probably both the most rewarding choice as well as the most impactful choice.

Government and Non-Profit Sector: The role of government is to inspire and convey the true vision of its constituents at each scale of society. It needs to provide essential services, ensure civil and legal rights, maintain infrastructure, regulate business and finance, support scientific research, provide for the common defense, and national and international relations. Non-Profits, like service organizations and schools, convey their inspiration, and guide their constituencies. All those roles influence society, share their vision, and enable or inhibit the eco-economy's ability to make good choices. That is particularly important at present when the long-standing societal organization around maximizing growth seems to be in self-conflict. Given the societal steering challenge that "normal" has become "abnormal," perhaps the most important role for government is to explore what a "new normal" might be in order to get everyone thinking. Just forging ahead because change is difficult, as in Hardin's Tragedy of the Commons (1968), is the opposite of "being safe."

Business Development: The direct way business creates the future eco-economy is by investing in development, setting new directions for the eco-economy. Existing businesses often use their own profits to fund expansion or new ventures, or they may use investment funds from others through finance. What businesses develop are usually innovations responding to emerging culture change that promise to be

[14] Scripps Atmospheric CO2 data https://scrippsco2.ucsd.edu/data/atmospheric_co2/icecore_merged_products.html

profitable, and so also support current directions of societal evolution. They may also steer the economy by creating artificial market demand, with advertising, often creating needs where none exists, such as to make consumption more glamorous. Where it becomes unethical is when selling products that poison the user or hide damaging impacts on the environment. Creating artificial demand is also compelled by competition and by investor and self-interest pressure to maximize the growth of profits, and hide its growing side effects.

Lots of small businesses, the kind that become anchors of neighborhoods and communities, do not do use their profits to grow faster except at first. As they mature, they grow more like trees, growing linearly rather than exponentially, adding a layer every year to live long as part of a healthy environment. The explosive growth period of a tree may last only a couple days, till they have their first two little leaves and start putting down roots, signaling their using up the ‘fossil fuel’ in their seed to relying on ‘environmental’ resources.

Finance, and Investing: If considered globally, the main role of finance is to move money to wherever it can reliably grow the most profits the fastest while disinvesting in everything else. That is also the source of the “growth imperative,” which forces all kinds of businesses exposed to global competition, and both local and global eco-economies too, to grow or die. That rule of profit maximization typically delivers the most financial support to wherever the eco-economy is growing the fastest. The financial practice at the heart of it is ‘compounding’, the reinvestment of profits to multiply investments. That 1) gives the most support to the most disruptive innovation, forcing a rapid turnover, whether needed or not, and 2) maximizes financial returns while not taking into account non-financial costs like the exhaustion, disruption, and degradation of the earth.

The question is, what will determine the future of our growth-driven eco-economy (Fig 9 lower left figure, Fig 3 and Fig 4)? Will it maximize its growth rate until it fails or switch to maximizing its resilience in time to emulate the natural climax of living systems? Will it be our ability to recognize that the fast-growing environmental costs to our future take precedence over short-range financial interests? Will we try to take the whole economy on the turn forward, or just let the unstable parts fail? Will the ever-growing threats we face be persuasive, or will there be a more subtle cultural shift to pave the way?

In the current literature, the two economic transformation models most like the approach discussed here are Kate Raworth’s “Doughnut Economics” (2017) and the ‘r3.0’[15] plan for redesign, resilience, and regeneration. Both models propose a transformation journey to eco-economy of sufficiency that is equitable and distributive and avoids a spectrum of planetary boundaries. Those regenerative economic principles are compatible with the ones outlined here, for a soft landing to climax our growth-driven eco-economy, retaining much of the prior growth-driven economy’s creativity and profitability, just losing its exponential driver. The

[15] https://www.r3-0.org/about-us/ r3.0 promotes Redesign for Resilience and Regeneration. As a global common good not-for-profit platform, r3.0 crowdsources open recommendations for necessary transformations across diverse fields and sectors, in response to the ecological and social collapses humanity is experiencing, in order to achieve a thriving, regenerative and distributive economy and society.

effect would be similar to the recognition of the natural fiduciary duty of business and financial decision-makers to making decisions about everyone's future in the interests of the world commons.

When to Turn?

The best examples to learn from are the familiar ones, like when to turn from starting to finishing a home or office project. Both start with a build-up of experiments and turn on the need to complete and deliver a satisfying product. For services to an office client the turn forward comes when the team can agree on the main elements of what to deliver. That design decision makes it possible to plan the work ahead to complete before the money runs out, that becomes more and more risky if delayed (Fig 10). If one waits until after the money runs out to decide what product to deliver, of course, there is no more time left to do the work.

What to focus on is the familiar pivot from widening start-up thinking to narrowing finish-up thinking. One also sees the same pivot in the efforts to starting and finishing homework, in starting and finishing preparations for dinner, or in bringing in the harvest in time, or any other creative effort (Henshaw 2018). In each case and the rules and roles of engagement may differ, such as for judging the turn forward of a developing personal relationship, of a growing business, of a whole growing eco-economy, or an observed growing ecological transformation. The reorientation of the process, from starting up something to completing it is much the same though. The turn forward focuses on the work left to do, shaped by the values and opportunities of participants and the time and resources available.

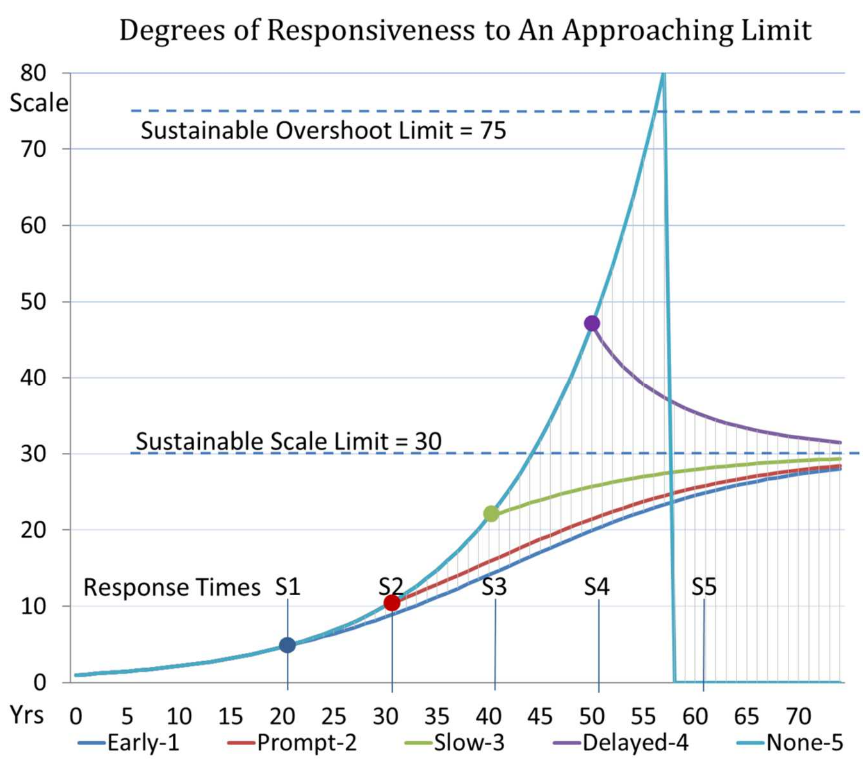


Fig 10. Early and Delayed Responses to Sustainable Limits: Increasing delay in response results in increasingly disruptive responses. The growth rate of all five curves is +7 %/yr. After

each response, its rate of approach to the limit is -7 %/yr. Both reflect the assumed maximum reorganization rate of the growth system. (Henshaw 2008)

So, the most general rule for "when to turn" is "before it is too late." Judging from Fig 10 "too late" sneaks up rather suddenly, and "too early" carries little cost, though the scales depend entirely on the immediate circumstance. The first clear sign might be of diminishing returns on ever-growing investment, read as a "canary in the coal mine," calling for a proactive response. Lots of familiar personal experiences of involve being alert to "going too far" too, whether in developing personal relations or judging how to steer a perfect curve, when skiing, sailing, or canoeing. Perhaps the clearest signal for investment in the world eco-economy to turn forward is the wide array of environmental crises that emerged in the 1950s to 70s. Those include ever-growing financial inequity, information overload, unmanageable complexity, habitat loss, longlived pollutants, land, water, soil, and other resource depletion, along with a long list of others (Henshaw 2020b). Together they represent a clear sign of mounting environmental resistance. The exponential encroachment of the economy on the natural world was evident well before, too, as indicated by the creation of the US National Park system, dedicated to protecting large parks but setting no global limits. Lists of more general signs of approaching environmental limits are in Appendix II and III.

To help guide a turn forward for the world eco-economy, one could make a list of guiding values, such as the UN did for the SDGs. The SDGs focus mainly on desired economic benefits, so various guiding principles for good economic health, a new eco-economic constitution, is needed. Three systemic health factors others might leave out are:

1) sustaining the system's healthy creativity, especially as it approaches an end to growth,
2) internalizing *all* externality costs in investment impact accounting, and
3) reversing any decline of net available energy, balancing energy supply and demand.

To fund entrepreneurs sustainably, once the turn forward is underway, the total pool of investment funds would need to climax smoothly along with the whole eco-economy, and not allow the continued compound growth of finance and its demands.

a biomimicry "reset" for the world eco-economy to resolve its increasingly vulnerable and increasingly disruptive "try, try, again" cycle

Perhaps by a regulated distribution of profits to limit the compound investment of unearned income,

Perhaps using an assets tax on savings from unearned income, waved for unearned income invested in the common good.

Key Observations

1) Growth as a non-linear accelerating and then decelerating building process,
   a. nature's primary way of building organized systems individually
   b. a rising then falling momentum of things falling together,

   c. that will also, at some later point, fall apart.

2) Close observation reveals distinctive stages of growth exposing their organizational process,
   a. seen in time series data as an "S" curve (Fig 4)
   b. as the lively succession of six main stages
   c. Seed, Start-Up, Turn-Forward, Finish-Up, Arrival, Life
   d. Nucleation, Individuation, Pivot, Maturation, Fulfillment
   e. Divergence - Convergence
   f. the stages proceeding from immature beginnings to mature ends,
   g. organization emerging first with functional differentiation then articulation,
   h. at non-linear rates, of first bigger then smaller adaptive layers,
   i. sometimes flowing smoothly, sometimes by exploratory learning processes
3) Growth systems also recognized by their,
   a. individual organization found within boundaries between internal and external relationships,
   b. various growth trajectories (Fig 3), growth to exhaustion, disruption, or resilience.
4) Case studies highlighting
   a. how to fit the model of the six stages of growth to partial data on individual cases of growth
   b. special cases (case study III) repeated growth to disruption called "try, try, again."
5) The eco-economy and growth
   a. Features that ecologies and economies have in common, suggesting levels of granular details of living systems to keep in mind:
      i. all parts access to energy,
      ii. productive working units combining different specializations,
      iii. learning, adaptive and homemaking parts,
      iv. thriving on sustainable disruptive innovation,
      v. strains relieved by surpluses or spread globally by shortage.
   b. Main Centers of productivity: cultural and societal, people and technology in organizations as the basic units, government and non-profit services, profit making business and industry organization, business and financial profit maximization.
   c. The steering centers of the world eco-economy, individual choices, government and non-profit services, business choices, finance and investor choices, and how they respond to disruptive innovation, environmental distress, and diminishing whole system returns.
   d. Alternative sustainability models, for individual organizations
   e. When to turn:
      i. Once aware of any limits to growth a turn forward for investment to end growth early hardly slows the path to the limit
         1. Delayed response quickly becomes extremely dangerous
      ii. a biomimicry "reset" for the world eco-economy to resolve its increasingly vulnerable and increasingly disruptive "try, try, again" cycle

1. Perhaps by a regulated distribution of profits to limit the compound investment of unearned income,
2. Perhaps using an assets tax on savings from unearned income, waved for unearned income invested in the common good.

Discussion

- Edit in process below -

Disc That so many kinds of systems can change from fluidly maximizing their growing power to fluidly stabilizing their designs indicates that the phenomenon can either be part of the original design, or not, and can be brought about intentionally or not. It suggests there is sure to be a smooth way to transition from growth capitalism to climax capitalism, too, if we could tell when to turn and how to let it happen. There is also little doubt that if we could make that turn before the global growth economy becomes even more unstable and overshoots our ability to manage it, the future would be far more profitable. It is something we would have to do intentionally, however. So for a large community of people to understand the process, they would need to study some of the familiar transitions.

Disc The question, of course, is also how adaptive humans can be, and how to make soft decisions that leave room for real progress and adaptive design. We have centuries of habits to re-explore and change. We indeed do have a long-standing growth maximizing eco-economy. It is not clear that it could discover that it is also an ecology too. It is only theoretical at this point that its common interests in limiting the growing pains from the growing demands on all its parts.

Disc Nature makes the task look simple. At the very steepest part of the growth curve is the time change from ever upward to ever forward acceleration. There would need to be innovation in science combined with societal pressure on both governments and wealth holders to set new rules stabilizing the eco-economy and making good on the world we started building. There are lots of real questions that need to be answered in time, most importantly, how to know when to do it, to know "when to turn."

Disc There would be many ways to manage the limits on finance. For a simple example there might be an increase in capital gains taxes to help persuade wealthy investors to use their profits for non-profit public interest purposes, such as the SDGs. Having a wealth tax limited to the retention of unearned income is another way. It is how the accumulation of profits multiplies without limit that most directly drives the growth imperative and extremes of financial inequality. Since any solution would need to start locally and apply globally, it would be critical for it to seem practical and, on balance, profitable for all sectors, and to make the eco-economy purpose-driven, distributive and regenerative on the whole. The resulting stable eco-economy and its pool of investment funds would then provide successive generations of creative inventors and entrepreneurs the resources needed to remake the economy again and again, for a thousand-million years or more, of living well while continually reinventing itself.

It appears that businesses and investors are not yet obligated to act in the public interest, only to act as financial fiduciaries to their shareholders or clients. According to Lynn Stout[16] they can make any decision about what to invest in and whether to reinvest profits to maximize investment growth and concentration of financial power without limit, as long as they have a "good business reason" for it, such as maximizing profit. It is also a common practice for "good business reasons" to include ignoring long term societal costs. That also appears to include creating risks to the financial system, the interests of others, or of the eco-economy as a whole. Global warming is as clear an example as one could want that forms of suicidal behavior are OK if they are profitable in the short term.

Given the long studied boom and bust cycles of growth driven eco-economies (Tainter 1988, Diamond 2005, Odum 2007) there is something wrong with humanity's learning. It appears we are on a fatalistic course of "try, try again" as discussed in Case Study III, suggesting the blind efforts to achieve the impossible do sometimes resolve with substantial gains, and not always trigger collapse as in Fig 3. Of course, you might point out that there are tremendous differences between an oceanic plankton eco-economy and the global eco-economy of human civilization. That the same behavior appears in systems so many worlds apart does indeed call for being careful in making the comparison. That there are also familiar cases of start-up businesses and personal relationships eventually resolving in success after repeated unbalanced growth attempts suggests the pattern is more universal than anecdotal, though. In fact we also quite endlessly need to take care not to push new efforts or relationships too far or too fast. So for curing the world eco-economy of that misguided habit might not be so impossible at all, more a matter of raising consciousness.

In ecological terms the question in then how humans started as a K-selected species (surviving on efficiency, developing skills of a top predator with small population) and then became an r-selected species (surviving on productivity, maximizing population as a prey species to survive) (Pianka 1970, Livingston 1995). Humans, on the other hand, have evolved to do both use their skills to multiply their productivity and efficiency, tuned for maximum rates of growth, producing ever more disruptive change for both human societies and the niches of the natural world.

Again, in ecological terms, it appears we need to use our genius to go back to being a K-selected sustainable species, using our genius to stop being overrun by our own productivity. In nature r-type species, that maximize their population growth, serve as prey populating the bottom of the global food chains, their productivity supporting the rest of the food chain. K-type species consist of expert predators that minimize the time they need to spend feeding and maximize their time engaged in other things. Are we at a point where we open a discussion of which way we'd want to go, to turn forward or not? We clearly seem to have the genius to do it, but are we responsible enough to treat it in a practical rather than a political way? That "turn forward" in our cultural norms seems to have to come first.

[16] NY Times Apr 16 2015 "Corporations Don't Have to Maximize Profits" Lynn Stout, distinguished professor of corporate and business law at Cornell Law School, author of "The Shareholder Value Myth: How Putting Shareholders First Harms Investors, Corporations, and the Public." https://www.nytimes.com/roomfordebate/2015/04/16/what-are-corporations-obligations-to-shareholders/corporations-dont-have-to-maximize-profits

These kinds of observations are part of an exploratory method of identifying patterns and testing them on the way to build up to informative narratives and testable hypotheses. Having to do with development processes and their continuities the search goes back and forth between identifying continuities that seem to tell a story and then checking the departures, to see if they are "exceptions that help prove the rule" rather than "exceptions that invalidate the rule." That makes it unavoidable to carefully study each "bump on the curves" to extract the useful information about the organizational transformations reflected.

Appendix

I - Alternate terms for the phases and turning points of natural growth

Table 1. Organizational shifts (1, 3, 5) to begin growth periods

1	3	5
Seed	Turn Forward	Arrival
Awaken	Inflection	Completion
Germ	Transformation	Release
Innovation	Purpose	Delivery
Outbreak	Reaction	Finishing touch
Bloom	Fertilization	Fruit
Nucleation	Transformation	Integration
Fertilization	Birth	Freedom

Table 2. Names for minimal growth periods (2, 4, 6) and origins for successful growth

0	2	4	6
Environment	Start-up	Finish-up	Fulfillment
Context	Takeoff	Landing	Service
Climate	Gestation	Maturation	Life
Situation Etc.	Sprout	Youth	Adult
	Feedback	Feedforward	Homeostasis
	Develop	Refine	Deliver
	Elaboration	Integration	Maturity
	Individuation	Actualization	Performance

II Experimental list of research topics

Eight signs of systemic distress

1) Crowding, Overload, Congestion, Imbalance, Unmanageability
2) Misunderstanding, Information Overload, Misread & Changing Signals
3) Increasing Solution Failures
4) Economic And Social Disruption
5) Environmental Disruption
6) Human Resource Depletion And Degradation
7) Natural Resource Depletion And Degradation 8) Rising Societal Overhead costs

Twelve Signs of Approaching Systemic Limits of Strain or Organization

1. **Growth:** Is itself an accelerating systemic instability, harmless or highly creative if its development brought to a conclusion in time, but often ignored until too late.
2. **Increased Rigidity:** Pressing limits of response; The balloon only pops after its surface stretches to the point of rigidity
3. **Strains and deformities:** Destructive wearing; Distributed threats; Divergent growth rates a sign of growing strains; Scattered spots of new intrusions, chattering or shuddering
4. **Loss of resilience:** Slower or recovery time; Loss of cushions, tolerance, generosity
5. **Sacrificing standards:** Living on debt, ignoring infrastructure, pressed into making mud bricks without straw, the appearance of demigods in place of politicians
6. **Abnormal interruptions:** Increasing downtime, people finding they have multiplying responsibilities
7. **Abnormal behavior:** Mice jumping ship and birds going silent; declining responsiveness; shakes or unfamiliar tremors. Divided interests in times of crisis needing common effort.
8. **Silence as a messenger:** When the canary in the mine dies. Silent Spring, when there are no more birds or insects, silent and vanishing without warning.
9. **Unusual silence:** Nature 'abhors a vacuum' and emerging systems initially need an orderly calm to develop. Like kids getting into mischief may be signaled by an unexpected calm, or the calms before a local storm.
10. **Increasing overhead costs:** Approaching systemic bankruptcy, rising resource costs and diminishing returns EROI, rising environmental costs, societal budget inflation
11. **Growing systemic conflict:** waves of crises of all kinds, a systemic "plague of plagues" like the whole world coming unglued.
12. **Top 100 Disruptive World Crises**: Experimental list of research topics (Henashaw 2020), categorizing the disruptive anthropic pressures on nature and society growing with growth.

References

Ashby, W. R. (1991). Requisite variety and its implications for the control of complex systems. In *Facets of systems science* (pp. 405-417). Springer, Boston, MA.

Ball, P. (2015) Forging patterns and making waves from biology to geology: a commentary on Turing (1952) The chemical basis of morphogenesis. Philosophical Transactions of the Royal Society B, 19 April 2015. Accessed 2020 - https://royalsocietypublishing.org/doi/10.1098/rstb.2014.0218, Online lecture - https://www.youtube.com/watch?v=6ed54_95kP4

Boulding, K. E. (1953) Toward a General Theory of Growth. The Canadian Journal of Economics and Political Science / Revue Canadienne d'Economique et de Science Politique, Vol. 19, No. 3 (Aug., 1953), pp. 326-340. Accessed 2020 - https://www.jstor.org/stable/138345?seq=1

Courtis, S. A. (1937). What is a growth cycle?. Growth, 1, 155-174.

Diamond, J. (2005). *Collapse: How societies choose to fail or succeed*. Penguin.

Elsasser, W.,(1987) Reflections on a Theory of Organisms - Holism in Biology, Johns Hopkins.

Forbes, S. A. (1887). The lake as a microcosm. Bulletin of the Scientific Association, Peoria, IL 1887 77-87. Reprinted from the original 25 February 1887 meeting of the Peoria Scientific Association. Accessed 2020 - http://people.wku.edu/charles.smith/biogeog/FORB1887.htm

Fullerton, J. (2015). Regenerative capitalism. *Capital Institute: Greenwich, CT, USA*.

Goodwin, B. C. (1982). Development and evolution. *Journal of Theoretical Biology*, *97*(1), 43-55.

Hardin, G. 1968 The tragedy of the commons. Science 162, 1243– 1244.

Henshaw, P. (1978) Natural Orders in Convection, and Direct Observation Skills for Natural Climate Design.

Henshaw, P. (1979). An Unhidden Pattern of Events, in self-published book of the same name, 1979. Accessed 2020 - https://synapse9.com/pub/1979_UnhidPatt-uhp.pdf

Henshaw, P. (1985a). Directed Opportunity, Directed Impetus: New tools for investigating autonomous causation. Proceedings of Society for General Systems Research, Louisville KY. ISBN 0-914-10536-1. Accessed 2020: http://www.synapse9.com/pub/1985_DirOpp.pdf

Henshaw, P. (1985b). Unconditional Positive feedback in the economstagesic system, *Proceedings,* Society for General Systems Research, Louisville KY. Accessed 2020 - https://synapse9.com/pub/1985_PosFeedbackSys.pdf

Henshaw, P. (1995) Reconstructing the Physical Continuity of Events, internal author research report on analytical methods. Accessed 2020 https://synapse9.com/pub/ContPrinciple95.pdf

Henshaw, P (2007) Flowing processes in a punctuated species change, G. *pleisotumida* to G. *tumida*, displaying feedback driven evolution, pending resubmission. https://www.synapse9.com/pub/GTRevis-2007.pdf

Henshaw, P. (2008). Life's Hidden Resources for Learning, Cosmos & History: The Journal of Natural and Social Philosophy, vol. 4, nos. 1-2, 2008, 2008 issue on "What is Life." *ISSN* 1832-9101. Accessed 2017: http://www.cosmosandhistory.org/index.php/journal/article/view/102/203

Henshaw, P. (2010a). Models Learning Change. Cosmos and History, *ISSN* 1832-9101, 6(1). - http://www.cosmosandhistory.org/index.php/journal/article/view/176/295

Henshaw, P. (2010b) The Energy Physics of Continuity in Change. Self-published review of 1995 general theorem on why divergent & convergent organization are required for continuity in change. https://www.synapse9.com/pub/2010_drtheo.pdf

Henshaw, P., King, C. & Zarnikau, J. (2011). System Energy Assessment (SEA), Defining a Standard Measure of EROI for Energy Businesses as Whole Systems. Sustainability 2011, 3(10), 1908-1943; doi:10.3390/su3101908 ISSN 2071-1050.

Henshaw, J. (2015). Guiding Patterns of Naturally Occurring Design: Elements, in Proceedings PURPLSOC 2015 "Pursuit of Pattern Languages for Societal Change," July 3-5 2015 Krems, Austria. ISBN 9-646-73066. Retrieved from - https://www.synapse9.com/pub/2019%20Henshaw-GuidingPatterns'Elements'. pdf

Henshaw, J. (2018) Systems-thinking for Systems-making: Joining systems thought and action. in Systemic Practice and Action Research, 32(1), 63-91. DOI: 10.1007/s11213-018-9450-2, Accessed - https://rdcu.be/LdlR

Henshaw, J. (2020a) Growth Constant Fingerprints of Economically Driven Climate Change: From 1780 origin to post-WWII great acceleration. Climatic Change. - https://synapse9.com/drafts/2019_12-GrowthConstFingerprintsOfCC-preprint.pdf - In revision

Henshaw, J. (2020b) Top 100 Disruptive World Crises Growing with Growth. Experimental list of research topics https://www.synapse9.com/_r3ref/100CrisesTable.pdf

Hill, M. (2020) Fetal Development. *UNSW Embryology* ISBN: 978 0 7334 2609 4 - UNSW CRICOS Provider Code No. 00098G. Retrieved From https://embryology.med.unsw.edu.au/embryology/index.php/Fetal_Development

Holling, C. S., & Gunderson, L. H. (2002). *Panarchy: understanding transformations in human and natural systems*. Washington, DC: Island Press.

Jevons, W. S. (1885). The Coal Question: An Inquiry Concerning the Progress of the Nations. MacMillan.

Kauffman, S. A. (1993). The origins of order: Self-organization and selection in evolution. OUP USA.

Kauffman, S. A. (1995). At Home In The Universe: The search for the laws of Self-Organization and Complexity. Oxford Univ. Press, ISBN 0-19-511130-3

Livingston, J. A. (1995). Rogue Primate an Exploration of Human Domestication.

Malmgren, B. A., Berggren, W. A., and Lohmann, G. P. (1983). Evidence for punctuated gradualism in the Late Neogene Globorotalia *tumida* lineage of planktonic foraminifera. Paleobiology 9:377-389

Malthus, T. R. (1809). An essay on the principle of population, as it affects the future improvement of society (Vol. 2).

Odum, H. T. (2007). *Environment, power, and society for the twenty-first century: the hierarchy of energy*. Columbia University Press.

Pianka, E. R. (1970). On r- and K-selection. *The American Naturalist*, *104*(940), 592-597.

Pines, D. (2014) Emergence: A unifying theme for 21st century science. SFI Foundations & Frontiers of Complexity. Medium. Online: https://medium.com/sfi-30-foundations-frontiers/emergence-a-unifying-theme-for-21st-century-science-4324ac0f951e

Popper, K. (2002). *Popper: The logic of scientific discovery*. New York, NY: Routledge Classics.

Porter, M.E. (1980) Competitive Strategy. The Free Press, New York

Raworth, K. (2017). *Doughnut economics: seven ways to think like a 21st-century economist*. Chelsea Green Publishing.

Reed, H. S. (1924). The nature of growth. The American Naturalist, 58(657), 337-349. https://www.journals.uchicago.edu/doi/pdfplus/10.1086/279986

Rosen, R., Life Itself, Columbia Univ. Press, 1991.

Rosen, R. (1993) On The Limitations Of Scientific Knowledge, in J. L. Casli (ed.) *On The Limits To Scientific Knowledge*, Perseus Books, 1993.

Thompson, D. W. (1942). On growth and form. *On growth and form.*

Tainter, J. (1988). *The collapse of complex societies*. Cambridge university press.

Turing, A. M. (1952) The Chemical Basis Of Morphogenesis. Philosophical Transactions of the Royal Society of London B. Vol 237, No 641 (Aug. 14, 1952), 37-72. Online http://www.dna.caltech.edu/courses/cs191/paperscs191/turing.pdf