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 5/20/20 JLH

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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

Supplementary topics:

http://synapse9.com/_pub/EcoEconOfGrowth-Supl.pdf

Figures Slide set:

http://synapse9.com/_pub/EcoEconOfGrowth-figs.pdf

Keywords:

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

This paper offers a new empirical view of the processes by which individual natural and human growth systems develop and operate, generally observed to be:

1) accumulative, and self-organizing, with
2) adaptive and effectively opportunistic responsiveness, with
3) different systems of internal and environmental relationships.

Examples include ecologies, plants and animals, cultures, communities, businesses, industries, societies, movements, families, and relationships. Many kinds of non-living energy systems also display periods of accumulative self-organizing growth, too, such as convection, weather, fluid flows, and crystallization. The most familiar examples are probably our own accumulative "give and take" work methods, with each step adaptively building toward a discovered result (Henshaw 2018). One can watch it as it happens. Tasks like cooking, design, labor, and others, typically proceed by accumulatively larger starting steps that lead to successively smaller finishing steps, with the design occurring during the process. It is a universal pattern for self-organization on any scale. We can also observe these examples of growth as having

4) energetic rising, then falling action
5) continuity and momentum of connecting steps
6) individually produced new designs,
7) a three-stage differentiation of beginning, middle, and end, and
8) display high degrees of multi-level design.

These patterns and properties are generally observable wherever we or nature is doing something new. The rising and falling action of growth also allows its time-series measures and records of events to be a useful proxy for its rates of organizational change, highlighting what to study. The individuality of each process of self-organization and the result produced are among the features of growth that resist mathematical definition. Other observable features that resist mathematical definition include the growth stages of germination (nucleation), differentiation, and maturation. Those have to do with properties we can only describe as qualitative, having to do with organizational development, not numerical, concerning relationships between whole individual systems and their environments.

Familiar studies taking somewhat similar approaches, focused on the recurring patterns of growth, are those by Brian Goodwin (1982) and D'Arcy Thompson (1942). Equations for growth are relatively simple, but they are also generally too simplistic to describe the multi-level, qualitative, and organizational developments that underly emerging growth. So the this study is built upon recognizing recurring and connecting patterns, which sometimes yield useful numerical diagnostic indicators. One of the most useful observations (#5 above) is that growth appears to exhibit mathematical-like derivative continuity. That appears to be a natural result of the necessary physical continuity of natural processes and produces smoothly graduated scales of change for smoothly building up in order to build down again. Those graduated adjustments of increasing then decreasing the scales of change create the recurrent three-part narrative pattern of beginning, middle, and end to reach a new finished form (Henshaw 1995 1999).

Context of Growth Studies

Methods

The original field research that began this study was a two year instrumented field study of the microclimates of homes. Recordings of numerous temperature and airflow sensors over 24 hr periods combined with using smoke tracers to help watch individual air currents develop exposed how whole systems of airflow grew and faded successively throughout the day (Henshaw 1978). That study, and learning from it how to read the shapes of swelling and subsiding dynamic rates of change for information on organizational change expanded into studies of many other kinds of growth systems, 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 evidence of 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 most observable universal patterns of growth as models of the norm for all, such as shown in Fig 4 and 5. Those baseline patterns would then, by contrast, expose the unusual details distinguishing individual cases. That method exposed more and more of how particular growth systems uniquely emerge, differentiate, and develop, helping to generate well-grounded hypotheses and tests for individual cases, making a seemingly successful observational diagnostic method. Understanding individual cases then helped clarify the common patterns, as a learning feedback loop, leading to reporting on a great many more common elements (Henshaw 2015). The practice of reading recorded growth curves as a history of organizational development also helped create useful lifecycle storylines for helping find how detailed observations connect (Henshaw 2018).

Literature

Many other scientists have also noticed growth as a fundamental phenomenon of nature that needed study. It seems, however, that 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 the study of growth, and helped lay the groundwork for this work, including 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 to where growth curves would climax. That awareness of 'things erupting' seems essential for the success of any shepherd, farmer, cook, entrepreneur, leader, banker, or any parent too. However, Malthus did find a new way to connect the mechanics of unconstrained growth with the social trap of overpopulation. The problem persists too, now for having boundless growing wealth for still-growing population, as if that made any material difference. Malthus's observation that compound growth is inherently self-limiting was incomplete, however. It fails to recognize that compound growth is also the beginning of all stable systems too. In those cases, growth becomes self-limiting without causing chaos, what we need to learn about now. When one looks, one finds people remarkably skillful in responding to natural limits of all sorts, whenever they see a "practical" response.

Jevons' famous so-called "paradox" that industrial efficiency most often increases rather than decreases industrial resource consumption (1885) illustrates how humans are confusion by growth systems in another way. No one is hiding the fact that the use of efficiency in business is for expanding output and increasing 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 the popular faith in using efficiency for solving economic problems misplaced, what it actually does is improve business profits. 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 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, exemplified by modern physics, that the progress of science rests the rigor of formal data analysis. Most working scientists would want to have both, of course.

Among the relatively rare studies considering growth as a universal natural phenomenon were those of H. S. Reed (1924) and Ken Boulding (1953). They both recognized growth as a progression that had very different structural and quantitative dimensions and emphasized how representing growth mathematically differed fundamentally from characterizing the emergence of its working designs and structures. Particularly forward thinking and useful are Reed's following observations of:

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

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.

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: Boulding offers three useful examples of a nucleus serving to initiate growth. First is how a dust spec is needed to initiate the condensation of raindrops. The second and third are how students are unable to retain information on new subjects until some insight nucleates in their minds and how student ability to improvise transforms when they recognize that language has grammar.
2) Non-proportional scales principle: Changes of different properties tend to have different scales, as for differences in length, surface area, and volume.
3) D'Arcy Thompson principle: that form results from 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.
4) The Carpenter Principle: that growth exhibits unexplained coordination of the whole as if a carpenter is in charge of making the parts fit. Assembly cannot rely on predetermined parts but must, therefore, have an adaptive means to fit globally.
5) Principle of Equal Advantage: Hypothesizing that systems have parts that fit together by all seeking their role in an organization with the highest potential. (corollary to the carpenter principle)
6) Principle of natural pace: Natural equilibrium rates of growth in an organism or system such that higher (or lower) growth rates may 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 advocated by Turing. Observable conditions seen to illustrate better what Turing was trying to explain. In many cases, growth appears to spontaneously emerge from in a protected location where delicate parts can develop undisturbed, like a state of calm "before the storm," or how species develop by punctuated equilibrium (Gould 2009). Not only do new species and storms arise from quiet places, but so do new lives emerge from the protected conditions within the womb, as fresh ideas frequently occur in a calm mind, all examples affirming both Boulding's and Tourings' intuitions. These examples also seem to differ with the formerly trusted assumption that such beginnings from random external disturbances if the absence of such disturbance is a primary indicator.

Walter Elsasser was a noted physicist who then studied biosystems, and Stuart Kauffman, a noted theoretical biologist. Both 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 anywhere in the universe, smaller than one chance is the estimated total number of 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, with past events necessary foundations for following ones. 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 change is open-ended and accumulative, unlike how science defines equations to have predetermined answers. That life processes are both accumulative and adaptive makes them opportunistic as well, and reducing the applicability of scientific models. Modern complexity science has responded with accumulative and adaptive computer models; however, still using deterministic statistical rules. That has generated lots of applications for complex deterministic outcomes, robotics, and artificial intelligence without seeming to explain the emergent properties of organization in natural systems or to replicate them (Pines 2014).

Rosen may have made his most significant contribution by turning the light of biological reasoning on the process of science itself, depicting the accumulating adaptive design process by which science itself works (Fig 2). The figure shows science as a loop of knowledge formation and testing, a rising spiral if one likes. The systematic process we see in science today starts with observations of nature and "encoding" them in the formal language of science and studied for their implications. That is followed by "decoding" the implications to test their application in nature, to see if natural causation matches, then using those observations to repeat the cycle.

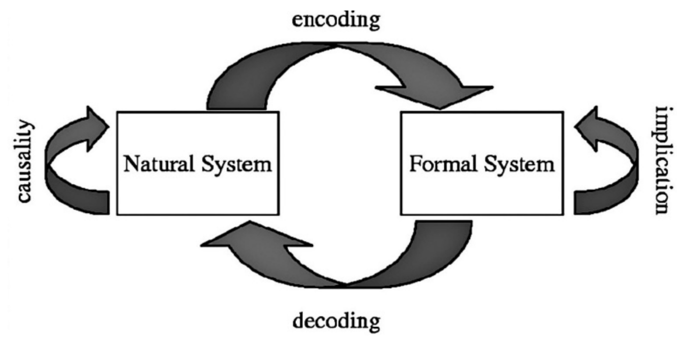


Fig 1. Robert Rosen's Heuristic Model of Scientific Learning: A cycle of *observing causality* in nature for *encoding* in the scientific language of *implications, to* then *decode* as applications for testing, repeating the cycle with further *observation and testing.*

Similar alternating cycles of exploratory adaptation are also central to most human endeavors. Almost all work involves alternating work and evaluation, taken from start to finish. A standard model names the process "action research" (Henshaw 2018). One can observe the same general kind of exploratory engagement in animal behavior of all kinds, as repeated observation and reaction, adjusting the directions to produce the most advantage. Those cases are not applying human values, of course, but do display similar opportunistic exploration that gives the impression of intelligence and results 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, organically setting the direction of history. So, taking some care, of course, it seems one can use the Rosen model as a general guide to the exploratory learning process of natural growth systems of other kinds too.

Interest in this kind of granular detail of natural systems may have been on the fringe of scientific thinking for a long time, of course. The occasional poetry and wisdom of many scientists suggests it. To curious observers, it would also seem hard not to be struck by how coordinated the interactions of most natural systems seems to be. 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" as a study of the invariable laws of nature (Merriam Webster: physics) [3] is the puzzle. One way, applying Boulding's "principle of advantage," would be if scientific studies bringing economic success were to dominate, and be imitated, changing the meaning of the craft as it followed its paths of success. A singular focus on deterministic rules could have emerged from that, and while interest in the creative processes of nature diminished.

[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

Growth Models for Case Studies

Simple growth models used for diagnostic study give a hands-on feel for the research method.

Three Growth Models to use for Studying Growth System Designs

In Fig 3 growth paths 1 & 2 show generic shapes of the development curves for two types of system-building that fail to go to completion 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 makes itself unstable, expanding ever faster until its rate of acceleration disrupts its 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 in confusion[4], or c) growth driven economies that do not respond to signs of diminishing rates of return.

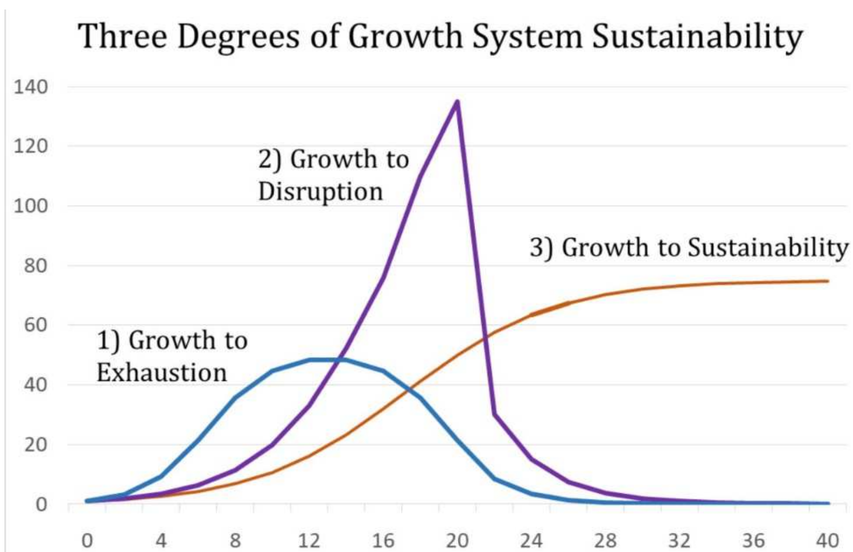


Fig 2. Three degrees of endurance: 1) Consuming available resources without a system for finding more. 2) Building a system while ignoring its limits of internal coordination. 3) Using the start-up period to build a system to then stabilize for long life.

The third growth pattern, 3) "Growth to sustainability," is for growth systems that are responsive to internal or external strains, instead of using its surplus resources just for growing its power, as strains emerge it instead shifts its surplus 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, a strategy shown in more detail in Fig 3. With lots of easy mistakes for

[4] 8 Dangers of Growing Your Business Too Fast https://www.inc.com/cox-business/eight-dangers-of-growing-your-business-too-fast.html

growth systems to make, success may come as a result of multiple failures, with every attempt a trial by fire, a strategy of "try, try again" possible for systems that mature while surviving multiple failures.

Life Stages of Growth Timeline

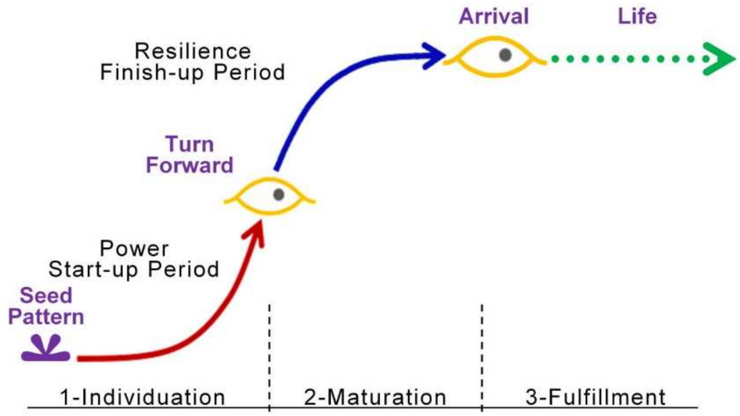


Fig 3. The six stages of natural growth alternate between events of organizational change and developmental periods.[5]

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

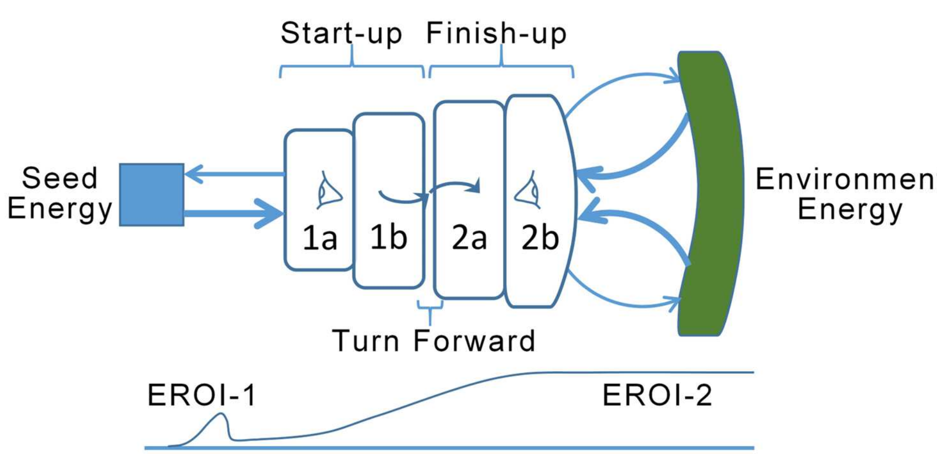


Fig 4. An economic system needs energy supplies greater than its operating energy costs to balance its energy budget. Its first energy source, EROI-1, is usually consumed as the system develops more lasting energy resources, EROI-2.

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

For an ecologist's view of the same issues, H. T. Odum (2007 p.283) similarly illustrates growth paths that reflect different types of growth systems, showing six alternatives that include the three in Fig 2. He also represents each with diagrams and equations for computer models. His analysis does reflect the systems being responsive or not but treats the systemic differences as resulting from external environmental pressures, not internal options, as would be needed for a business or an economy.

A more detailed view of growth to longevity (Fig 2.3) is shown in Fig 3 as an "S" curve with the names for six organizational stages of growth, three developmental events followed by developmental periods. Not all "S" curves that trace change over time show patterns of organizational development, so that has to be verified. The converse is generally true, that organization has to develop, such as for the growth of industries, communities, and organizations of all kinds and for organisms, ecologies, cultures, and relationships.

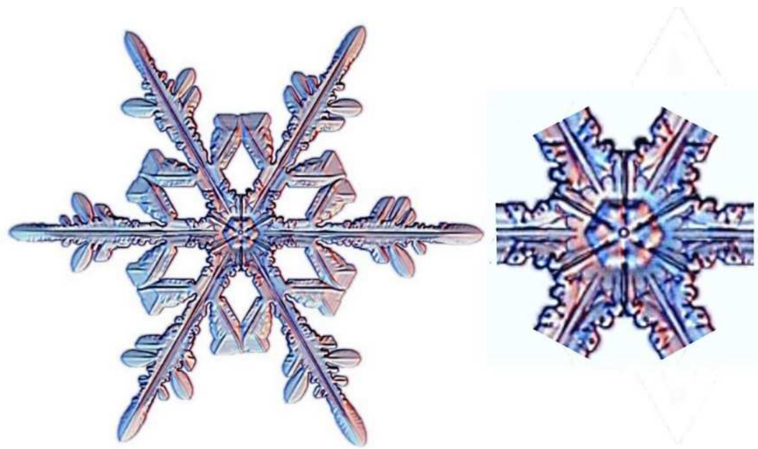
Perhaps the model growth we can learn the most from, though, is the personally familiar creative work of a home or office project, or even more simply. For familiar projects, that might be for reorganizing the living room or office, creating a new deliverable for a client, starting a business or doing a renovation. The accumulative effort invested in any of them will first build-up and then level-off as they are completed, tracing an "S" curve. 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. Our personal experience with them lets us compare the creative decision-making at each phase that finally leads to the release of the finished product.

The same succession of creative development stages 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, Fig 2).

Fig 4, like Fig 3, also depicts the start-up and growth periods of an emerging system, but as an abstract organism adding layer upon layer (1a to 2b), like adding sections to an expanding business operation, not a time-series "S" curve. The first building section, 1a, is 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 source at the right. The first two sections corresponding to the beginning and end of the start-up period, the last two sections, the beginning, and the end of the finish-up period.

To use Fig 3 and 4 as guides, one studies features of a growth system that might correspond to the typical stages of sections of development. As illustrated in the three Case Studies below, one tries to arrange the evidence available to fit the two models, Fig 3 and Fig 4, and look for more information where there are gaps, to understand better the context in which the implied changes in direction have or will occur. For example, often not visible in the commotion of a working business is the handshake that marks the new business partners settling on a plan of action. That "seed" contains a general idea of "how it works" that gets passed on as the business develops, reflecting its original ideas and values. So if studying ways to change a business, understanding the seed understanding from which it grew might suggest better ways changes could either harmonize or depart from it.

Whether called it a "seed," "spark," "germ," or "nucleation" that initiates a growth process, an observer is likely not to find direct evidence of it. For the snowflake below (Fig 5), we can see a tiny dot in the center where the crystallization began, but not the molecular pattern that propagates its complex six-pointed geometry. What we have to rely on is our ability to trace the pattern back toward its origin.



Snowflake details   Central kernel

Fig 5. A Snowflake and its Central Kernel: The crystal design builds up from a tiny central dot. The smallest visible hexagonal shape is still quite simple, and next rings increasingly complex, as if the filigree design was "entangled" within that crystal core.

So the origin of its growth pattern is partly presumption and partly an accumulation of observations that reifies the science, though still relying on verification too. 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 that follows but later hidden from view.

3 Case Studies

The three case studies below demonstrate the use of the general natural growth models (Fig 3 and 4) to suggest useful questions for interpreting recorded growth system timelines. The exercise teaches a kind of guided exploratory guesswork, like stepping stones, for illuminating behaviors behind the data, suggesting new hypotheses to test, offering a better grasp of real-world problems. The life stories of natural systems are much more varied, of course, so starting to ask whether the models fit at all is a needed first step.

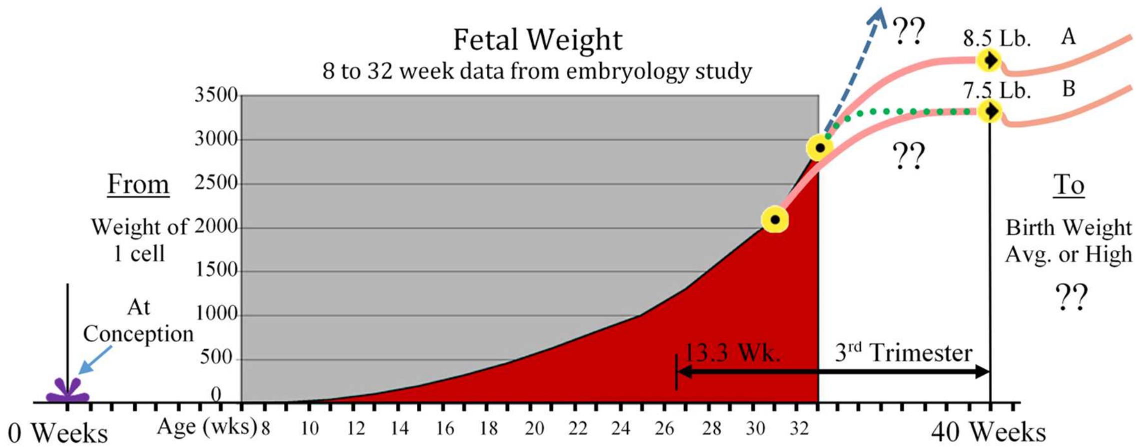


Fig 6. Case Study I. Human Gestation based on partial data on fetal weight.

Case Study I Human Gestation

Stage	Observations
0 Context	The data shows only 26 weeks, on an expanded 40 week scale. 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 42 times, by week 33 [6]
3 Turn Forward	We test the Turn Forward at both Week 31 ( ) & Week 33 ( ). *Do you see why? Is there a better guess?* At Week 31 it assumes the last data point is a little high, first tried to allow a smooth curve to the average birth weight at 40 weeks.
4 Finish-up	Is the final birth weight the **dashed blue line,** extending the data trend to a birth weight of ~1000 lbs? NO. Is it the **dotted green line** leveling off suddenly to hit the avg birth weight of 7.5 lb? NO. Is it either the lower and upper **pink curves** ( ) showing weight gain curving smoothly toward either 7.5 or 8.5 lb? OK *Which 3rd Trimester growth curve seems most natural,* **A** or **B**? *Which is more likely birth weight 7.5 or 8.5 lb*
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?*[7]
7 New Context	Leaving home for a bustling world and further developing skills for Life.

- The study shows expanding the interpretation beyond the limited data, expanding the timeline to try to determine the final growth shape to birth. The primary constraint for all the options is to maintain the natural shape of the growth curves (the continuity).

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

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

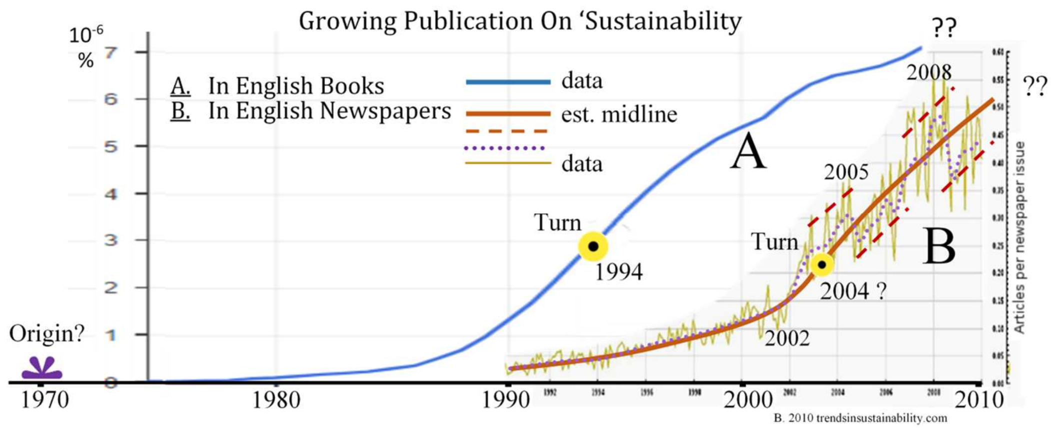


Fig 7. Case Study II. Data on book and newspaper publishing on 'sustainability.'

Case Study II The Growth of Publishing on Sustainability [8 9]

0 Context	Concern with growing environmental harm began long ago, seen in the use of the term "sustainability" in the 1980s and 90s, at first for publishing in books, then newspapers.
1 Seed	Curve A (in books) traces of the rise of "sustainability" appearing in the 1940s but its growth began in 1970. Curve B (in papers) might have had a long gestation too.
2 Start-up	Growth of Curve A is about ten years ahead of Curve B. Why? *Did sustainability start as a matter of private debate before becoming a matter or public debate? Was it that reporters were not reading books? Why else would treating it as news be delayed?*
3 Turn Forward	Curve A turns from curving upward to forward in 1994, marking the maturation of the book audience. For curve B it is less clear, marked as 2004? The newspaper audience shifts from smooth growth to wild fluctuation. *What might have caused the large swings of newspaper interest? If not to resolution what might the turning points really measure?*
4 Finish-up	Curve A after 1994 shows steady maturation. Curve B after 2004 was hard to estimate. First the midpoints of the data's largest fluctuations (····) were traced. Then the extremes of the data's largest fluctuations (- - -) shown. Finally, the smooth trend curve (▬) through the first two. Neither data source is available after 2010. *Does an understanding of sustainability culture help predict where the trends have gone since 2010? 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 the discussion still searching for direction? What has become clear?*
6 Life	As in life, maturity is still a very eventful kind of steady-state. *In that sense, what is needed for the discussions of sustainability to reach maturity?*

- The study shows how departures from the model can start a useful narrative. All that is needed is some evidence hints of beginning middle and end.

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

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

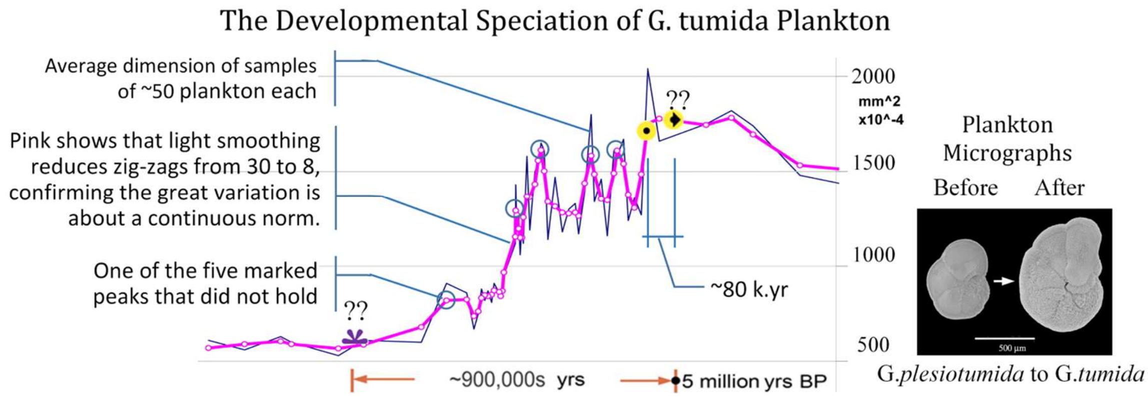


Fig 8. G.tumida plankton punctuated evolution over 900 k.yrs, showing repeated bursts of increase in species size, that then fall back until finally, one holds (◆).

Case Study III An evolutionary case of "try, try, again."[10]

0 Context	The jittery data line (blue) and more regular running average line (pink) trace a 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, revealing several periods of rare continuity in evolutionary change.
1 Seed	The initiating seed event (??) for the G.*tumida* transition places the estimated earliest point when instability in the species genome might have developed.
2 Start-up	Five spurts of growth then collapse (○) establishing a "try, try again" development path. *Why might the evolutionary spurts have collapsed?* *Might study of similar patterns of repeated failure help?* *Have you experienced this kind of struggle?*
3 Turn Forward	After the highest growth peak of all the trend Turns Forward (•), after some ~820,000 yr. *What are examples of "try, try again" efforts that that finally succeed? In personal or business relations. In cultural struggles?*
4 Finish-up	At the end of the long struggle how it resolved is unclear, except that resolution came 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 new species?* Here it is hard to say without a lot more understanding of how tripling the size of this common open ocean plankton changes its ecology.

- 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 without being accepted might produce this kind of pattern. During such a period the system would be trapped by struggles between its own new and old orders. *Are perhaps **all** great struggles like that, facing issues that come back again and again until finally resolved?* *Can the resolution of today's human fixations be informed by other long struggles, like the evolution of G.tumida appears to display?*

[10] 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 every effort devoted sustaining maximum rates of compound growth until large parts become unstable, producing another crash. The consideration of "when to turn" the driving forces of perpetual growth to secure the gains never seems to 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.

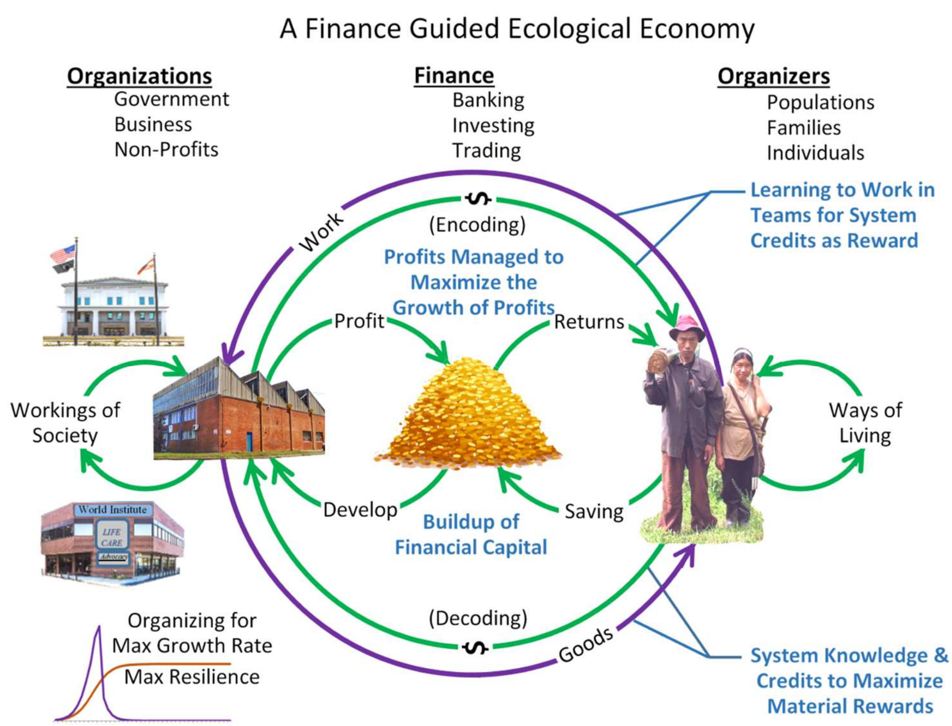


Fig 9. Decision-Making in a Finance Guided Eco-Economy: Business and Investor choices set future directions of development to maximize their growing profits. Consumer choices reward the most attractive products. Government and Non-Profit choices respond to societal values and needs, with most costly "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[11,12][13][14] 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

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[11] 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".

[12] 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

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

[14] 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.[15].

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

[15] 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'[16] 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

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[16] 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.

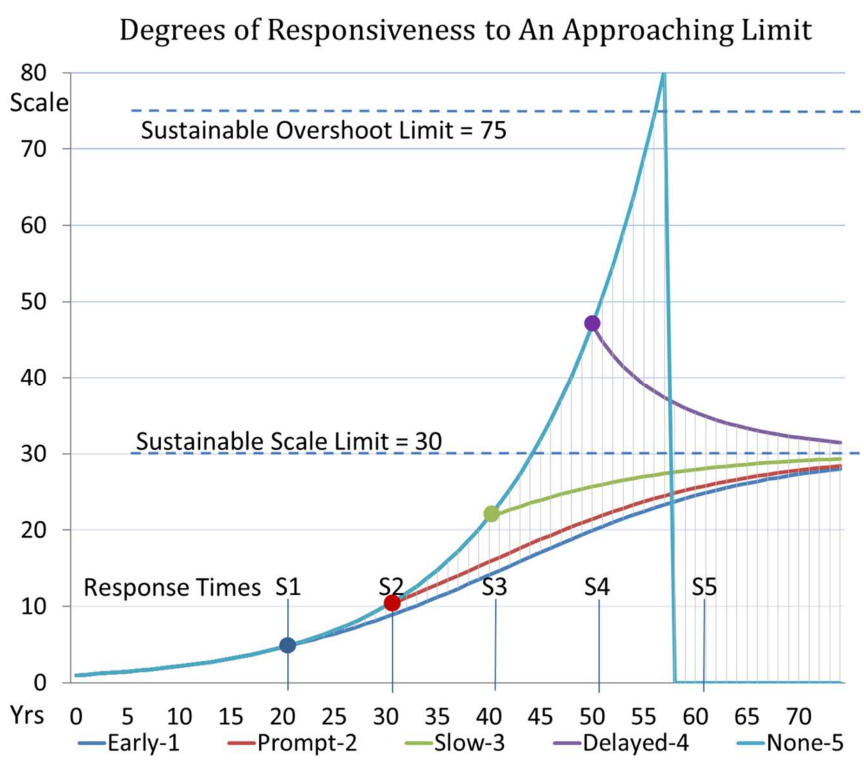

Fig 10. Early and Delayed Responses to Sustainable Limits: Increasing delay in response results in increasingly disruptive responses. The growth rate of all five curves is +7 %/yr. After each

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, long-lived 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.

Acknowledgments

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.

Gould, S. J., & Gould, S. J. (2009). *Punctuated equilibrium*. Harvard University Press.

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. (1999). Features of derivative continuity in shape, International Journal of Pattern Recognition and Artificial Intelligence (IJPRAI link to article), for a special issue on invariants in pattern recognition, V13 No 8 1999 1181-1199. Online - http://www. synapse9. com/fdcs-ph99-1. 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

Keynes, J. M. (1935). The General Theory of Employment, Interest, and Money. First Harbinger Edition 1964 reprinting of the 1935 original. (Ch16-III). Harcourt Brace Jovanovich, New York. Accessed 2019, from http://synapse9.com/ref/Keynes-ebook-TheGeneralTheory.pdf

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