# Evolutionary and archaeological perspectives on estimating the likelihood of civilization collapse

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The likelihood that modern civilization will collapse has been estimated many times for many reasons. From evolutionary and archaeological perspectives, the repeated disintegration of ancient civilizations (none have survived more than a few millennia) is unsurprising. Can we expect modern civilization to also collapse? This is likely in the absence of proactive, self-preserving methods, which may be informed by survival strategies known to evolutionary biology. Such methods include deployment of technologies to realize the current potential of modern civilization (and the modern genomes we select to protect) to be the Earth's longest-lived complex adaptive system. I suggest some of these methods, which include the use of technology to spread humanity from Earth to other solar system habitats.

## 1. Estimating the likelihood of civilization collapse

Ramsden (2016) reviews the literature of largely 20th-century predictions of the likelihood of civilization collapse ($p$),[1] finding a wide variety of methods used to estimate this parameter. While some compelling arguments are made—based on the common variables of planetary resources and resource consumption rates—Ramsden notes that, as a whole, such estimates remain unconvincing because of "the severity of the assumptions" built into the predictive models.[2] From the perspective of anthropology and archaeology, which over the past century have capably described (if not explained) human evolution and the development of civilization, this result is not surprising. Attempts in these fields to identify larger patterns that we might learn from for our own benefit (thus requiring applicability to modern, global civilization) have also been on occasion compelling, but overall remain a sterile quest, in large part because of a theoretical fragmentation that allows little communication between practitioners and little, if any, universal consensus on such fundamentals as the modes and tempo of culture change.

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1 Ramsden, J.J. Doomsday scenarios: an appraisal. *Nanotechnology Perceptions* **12** (2016) 35–46.

2 Ref. 1, p. 38.

*Nanotechnology Perceptions* **13** (2017) 116–122

*Received* 27 February 2017; *accepted* 15 April 2017
doi: 10.4024/N09SM17A.ntp.13.02

Nevertheless I propose that even a purely descriptive (rather than explanatory) comprehension of the human past can furnish us with useful information on the likelihood of civilization collapse. Figure 1 displays chronologies for the eight major ancient civilization complexes. Stars indicate significant collapses, better termed *disintegrations* to reflect nonfunctioning of a previously-integrated socio-economic system.[3] While the reasons for collapse are many, and sometimes debated,[5] one pattern is clear: in each civilization complex there have been multiple disintegrations. The observation that all prior civilization systems, across the globe and spanning several millennia, have collapsed suggests that it reasonable to generalize that $p$ approaches 1.0.[6] This is unsurprising from an evolutionary perspective: Raup (1992) has pointed out, and quantified, that in the geological record we see a roughly 99% extinction rate for any observable lineage.[7] Figure 2 illustrates that for a sample of over 17 000 marine genera, duration in the fossil record has rarely been over ca. 20 million years,[8] and elsewhere he has estimated the duration of a generic mammalian species at roughly two million years, one of several estimates in this range.

Both in the extensive fossil and archaeological records, then, the clear pattern is that known Earth-based life lineages—what Hull has collectively referred to as called "replicator interactor lineages",[9, 10] and others have referred to as "complex adaptive systems" (e.g.,[11, 12])—normally become extinct. For practical purposes, estimating $p$ at 1.0 is warranted.

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3 Civilizations are well-understood in archaeology (e.g., Trigger, 2003[4]) and are here defined as socio-economic and political organizations featuring nonfood production specialization, urbanization, taxation, vassal tribute, agricultural subsistence base, monumental architecture, state religious tradition, hierarchical and centralized authority, social and economic ranking, durable record-keeping, mathematics, long-distance trade, standardized measures, standing armies and territorial sovereignty. Other forms of sociopolitical organization, such as the chiefdoms of Polynesia or subSaharan Africa, may feature some of these traits but typically not all of them; they were also smaller in population and typically less politically stable, with limited polity size compared to civilizations.

4 Trigger, B. *Understanding Early Civilization*. Cambridge: University Press (2003).

5 Tainter, J. *The Collapse of Complex Societies*. Cambridge: University Press (1990).

6 I counter the argument that modern civilization is too integrated to collapse and thus is incomparable to ancient civilizations (in this way) with the argument that in the larger picture, all civilizations have had the same essential framework,[4] and that modern civilization's reliance on distant interconnexions is arguably as much a weakness as a strength; should the agricultural system fail, all other higher-order activities, such as precision manufacture and data processing—which are required to maintain today's civilization features—would come to a halt because individuals would be obliged to focus on food production.

7 Raup, D. *Extinction: Bad Genes or Bad Luck?* New York: W.W. Norton (1992).

8 Raup, D. The role of extinction in evolution. *Proceedings of the National Academy of Sciences of the USA* **91** (1994) 6758–6763.

9 Hull, D.L. 1981. Units of evolution: A metaphysical essay. In: *The Philosophy of Evolution* (eds U.J. Jensen and R. Harré), pp. 23–44. Brighton: Harvester Press (1981).

10 Taylor, D. and Bryson, J.J. Replicators, lineages and interactors. *Behavioral and Brain Sciences* **37** (2014) 276–277.

11 Buckley, W. Society as a complex adaptive system. In: *Modern Systems Research for the Behavioral Scientist* (ed. W. Buckley), pp. 490–513. Chicago: Aldine Publishing Co. (1968).

12 Abel, T. Complex adaptive aystems, evolutionism and ecology within anthropology: Interdisciplinary research for understanding cultural and ecological dynamics. *Georgia Journal of Ecological Anthropology* **2** (1998) 6–29.

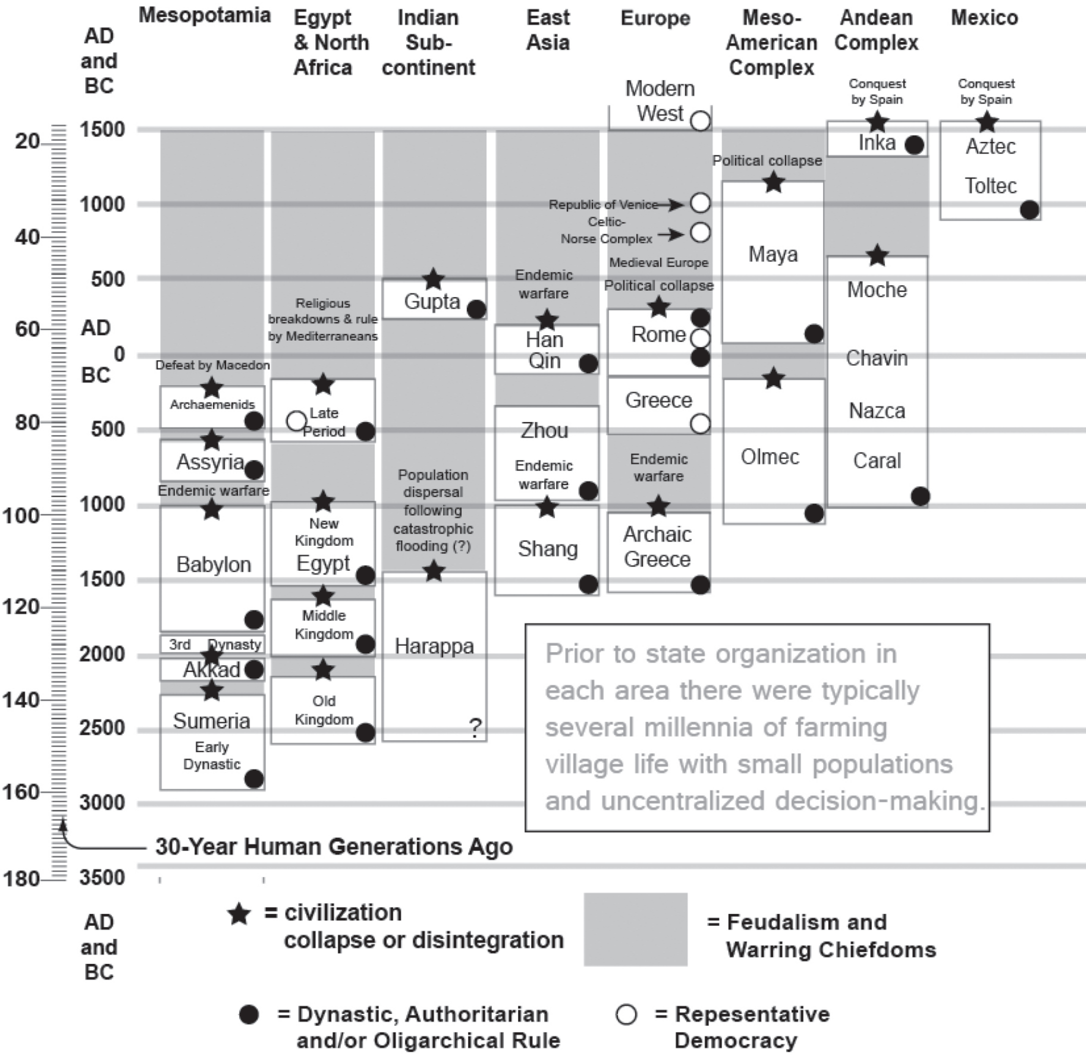


Figure 1. Durations of the eight main ancient civilization complexes.

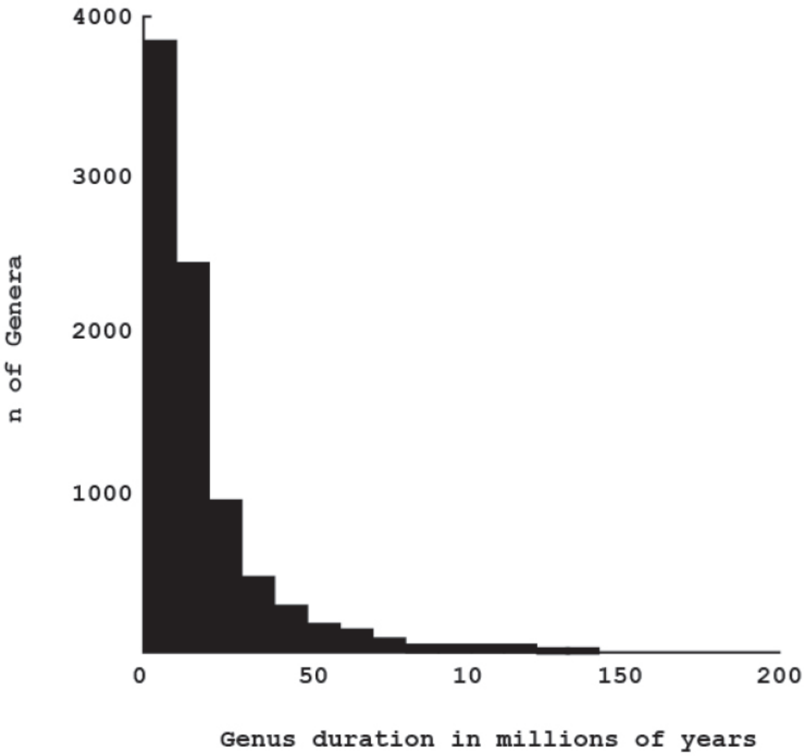


Figure 2. Duration of 17 500 fossil marine genera. After Raup.[8]

## 2. Complex adaptive system collapse and adaptive survival strategies

There are many reasons for extinction (see, e.g., Smith, 1989[13]) or the collapse of complex adaptive systems (including cultures and genetic lineages), but ultimately extinction reflects the adaptive system's inability to accommodate change in the *selective environment*, here defined as the totality of factors that condition the likelihood that one will replicate; biological replication in the genetic inheritance system and cultural replication in the cultural inheritance system. This is because, aside from in the case of humanity, adaptation is a *reactive* phenomenon lacking foresight and centralized decision-making. When selective pressures and environments change, life forms simply either possess (and express) sufficient variability in their phenotypes and/or behavioural repertoires to endure the change (and then pass on the genes for the better-fitted individuals to future generations), or they do not. If they do, they survive to be "evaluated" in the next moment. If they do not, extinction is imminent, which is common.

There is a significant exception in one life-form: modern humanity. Central to modern cognition (dating to about 100,000 years ago) is the awareness of distant space and time, and the

[13] Smith, J.M. The causes of extinction. *Philosophical Transactions of the Royal Society B* **325** (1989) 241–252.

ability to model distant space and time in the mind, allowing adaptive *proaction*. The chimpanzee mind, with many similarities to our own, is incapable of mentally modeling the result of a comet impact with Earth at some future time as that mind has only short-time and small-space awareness (an "episodic" consciousness in terms of the evolution of the modern mind.[14] However intelligent or aware any other forms of Earth life are, there is no evidence that any other than human kind possess the cognitive capacity to proactively adapt to immediate, distant and even theoretical threats to cultural and genetic equillibrium. This capacity is one of humanity's unique characteristics and furnishes our biocultural lineage with the potential to escape the apparent fate of all known Earth adaptive systems or lineages, namely extinction.

How can humanity fulfil this potential for effectively indefinite survival? One way is to learn from the natural world.[15] Many lineages do survive long spans and Vermeij (2008) has identified the most evident survival tactics in the history of Earth life;[16] recall that "tactic" imputes a consciousness or intent to the evolutionary process that is not evident in nonhuman life forms.[17] These tactics include (a) tolerance of threats by passive resistance, (b) active engagement to eliminate threats with force, (c) increase of intelligence to make threats more predictable, (d) increasing unpredictable behavior to avoid threats, (e) isolation and starvation of threat and (f) use of modular design to prevent catastrophe (Table 1 defines and provides examples of these features). Each of these methods are observed in the natural world, have pros and cons, and may be employed by humanity in both behaviour and technology on multiple scales, from policy to design and action, in order to increase the survivability of our lineage.

## 3. The evolutionary role of technology in long-term human survival

The evolutionary survival strategies outlined in Table 1 can all be advanced and implemented with some variety of technology to increase the likelihood of the long-term survival of our species and civilization. However, the Earth will always be a selective environment that could rapidly change beyond our capacity to predict or our range to react, as in the case of supervolcanism or Earth impact by substantial and unexpected space debris and a variety of other "civilization killers" reviewed elsewhere. I argue that even these methods, carried out only on Earth, will not guarantee long-term survival; that can only be advanced by focusing on strategies 4 ("Increase unpredictable behaviour to avoid prediction—that is, get out of the potentially threatening environment, in this case, Earth) and 6, "Use of redundancy and modular design to prevent catastrophe"—that is, replicate our genome, those of our domestic creatures, and humanity's information archives) beyond Earth. These are the evolutionary

[14] Donald, M. *Origins of the Modern Mind: Three Stages in the Evolution of Culture and Cognition*. Cambridge Mass.: Harvard University Press (1993).

[15] We must be careful to avoid the *naturalistic fallacy*, in which one suggests that anything found in Nature is good (and therefore, in this case, worthy of imitation) simply because it is natural; this falls when we consider that the Ebola virus is natural, but not good for humanity overall.

[16] Vermeij, G.J. Security, unpredictability and evolution. In: *Natural Security: a Darwinian Approach to a Dangerous World* (eds R.D. Sagarinm and T. Taylor), pp. 25–41. Berkeley: University of California Press (2008).

[17] Ref. 18, pp. 21–22.

[18] Smith, C.M. *The Fact of Evolution*. New York: Prometheus / Random House (2011).

Table 1. Six adaptive strategies noted in Nature and applied by humanity. Expanded after Vermeij.[16]

| Strategy | In Nature | Among humanity | Pros | Cons |
|---|---|---|---|---|
| **Tolerance of threat via passive resistance** | Tardigrade (microscopic "water bear") dessicates / hibernates in absence of water. | Apollo spacecraft's "passive thermal control" maintained temperatures inside by continuously "rolling" on way to moon, warming side facing sun and cooling side away from sun; a simple solution that requires minimal energy and no extra cooling / warming hardware. | Low energetic cost; easy solution to stable conditions. | Low capacity to react to change (unstable conditions). |
| **Active engagement to eliminate threat with force** | *Homo* (defensive structures) and/or offensive behaviours. | Use of tools and social organization by early humans to confront and drive off predators or competitors. | Highly specific; can be tailored for certain threats. | High energetic cost; requires innovation structure / behaviour. |
| **Increase intelligence to make threat more predictable** | Evolution of neural networks (brains) with increasingly capable sense organs; the two, together, increase capacity to both perceive (sense organs) and predict (neural net) threat behaviour. | Essentially same as Nature, but more elaborate, over time using cave art and other external memory storage devices to archive effectively limitless information about the natural world, increasing understanding and capacity to make predictions for self-benefit and preservation. | Many; accurate predictions allow great proactive flexibility. | Must continuously update intelligence as conditions change. |
| **Increase unpredictable behaviour to avoid prediction** | Rapid, unpredictable "flitting" behaviour of prey species thwarts many predator attacks. | Capacity to move away from predictable threats; e.g., Earth destruction by space debris. | Single solution might apply to many potential threats. | High energetic / strategic cost. |
| **Isolate and starve threat of resources** | Antibody "absorbs" foreign element, shutting down its capacity to act in tandem with others, and eventually shutting down its metabolic processes. | Use of fishing net to capture individuals or multiples from larger schools; other traps of many kinds. | Direct, immediate action; need not be directly offensive. | Requires specific methods and perhaps resources. |
| **Use of redundancy and modular design to prevent catastrophe** | Starfish losing limb grows new limb due to modular genetic controllers. | Use of multiple watertight bulkheads in submarines, or Mars habitat not a single dome, but having multiple, self-sufficient nodes, any of which could survive disasters such as rapid depressurization or disease by sealing off damaged or quarantined areas. | Decentralized redundancy prevents large-scale catastrophe. | High initial cost for redundant element resources. |

reasons for the long-considered concept of settling space beyond Earth and evolutionary reasons to develop enabling technologies including nanotechnology, already identified by many space agencies as significant for extending human action to space beyond Earth.[15, 19]

## 4. Communicating the life-affirming, evolutionary nature of technology for human survival

When the larger picture of human evolution and even the evolution of Earth life are invoked, the use of technology for survival can be given a new identity. Often vilified in broad statements, "technology" is actually what humanity has relied upon for at least a million years as its chief adaptive means, even over genetics; we survive not because of our biology, but despite it, by supplementing it with technology. Technologists can present their work in ways that centralize long-term human survival and marginalize the technocracy that many focus on in their vilification. I argue, based on my own experience, that this elevates discussions, taking them from daily concerns to contemplation of revolutionary, inspirational, radical actions by our species for the benefit of all.[20]

Seen from such an evolutionary perspective the old term "space colonization" is archaic and loaded with industrial connotations. I have advocated communicating the evolutionary significance of extending our lineage beyond Earth, partly by devising new phrases to use in public communication and even in our own thinking.[22] I encourage nanotechnologists to highlight the evolutionary issues mentioned in this paper in their communication with the general public, when the inevitable questions arise regarding the use of nanotechnology.[23]

[19] For example, see https://science.nasa.gov/science-news/science-at-nasa/2005/27jul_nanotech

[20] Similar concerns are explored by Ramsden (2005).[21]

[21] Ramsden, J.J. The music of the nanospheres.*Nanotechnology Perceptions* **1** (2005) 53–64.

[22] Smith, C.M. An adaptive paradigm for human space settlement. *Acta Astronautica* **119** (2016) 207–217.

[23] While I agree with Ramsden that technology has historically been used to control and in some cases dominate Nature, I don't feel this is the whole story. Many technologies are used to harvest energy without domination, including solar power generation.