### Title

Hill Climbing and Darwinian Evolution: A Response to John Langrish




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# Correspondence: Incremental Radical Innovation

**John Z. Langrish**

A Response to Donald A. Norman and Roberto Verganti's "Incremental and Radical Innovation: Design Research vs. Technology and Meaning Change," *Design Issues* 30, no. 1 (Winter 2014): 78–96.

I found the article, "Incremental and Radical Innovation," by Norman & Verganti (Winter 2014, 78-96) to be very interesting but also puzzling. Why do the authors make no reference to the concept of local maxima as it occurs in evolutionary biology?

The basic idea is that in searching for better ways of existing and propagating, entities can climb up a hill of gradual improvement until they reach the top where further small changes will only move downward. The hilltop is called a local maximum because there may be other peaks that are higher; but, how can you reach these other peaks?

This idea has been around for more than 100 years and is not just limited to the academic literature. Richard Dawkins' book, *Climbing Mount Improbable*, provides a popular account in which there is a mount with a steep cliff face, almost impossible to climb.[1] Out of sight, however, is a sloping path that reaches the top in gradual steps.

The idea of local maxima in human design cropped up in 1862 when Eilert Sundt (1817–1875), a Norwegian sociologist, visited England and was impressed by Charles Darwin. He wrote a paper giving a Darwinian model of gradual technical change involving accidental changes, perceived improvements, choice, etc. In his account of shipbuilding, he concludes with the idea of experiments, "when the idea of new and improved forms had first been aroused, then a long series of prudent experiments, each involving extremely small changes, could lead to the happy result that from the boat constructor's shed there emerged a boat whose like all would desire."

This gradual series of changes comes to a stop when, "Each kind of improvement has progressed to the point where further developments would entail defects that would more than offset the advantage.[2]

The problem of getting stuck on a point had to be tackled by evolutionary theorists, and maybe the reason for the authors ignoring their ideas is that they came to different conclusions.

Norman & Verganti claim that radical innovation needs a different mechanism from the gradual climbing of a slope but Darwinian theorists don't agree. In 'Origin', Darwin wrote, "If it could be demonstrated that any complex organ existed which could not possibly have been formed by numerous successive, slight modifications my theory would absolutely break down."[3]

You can't be much clearer than that. For "complex organ," substitute "complex system" or "radical innovation" and it becomes obvious that Darwinians have to find a way out of being stuck on a peak. In fact, there are many ways out.

- The ridge. Something that seems to be a peak when viewed from one side may actually be connected to another apparent peak by a "ridge," allowing movement from one peak to another.
- Symbiosis. Entities that have climbed different peaks may find a ridge that enables them to get together; this is what philosopher Daniel Dennett calls the improvement of an entity through joining with something "designed elsewhere" (i.e., it has climbed up a different slope).
- Twin peaks. Entities climbing up a slope of improvement may find that further advances lead in different directions so that they end up on different peaks. This is how evolutionary biology proceeds with one species dividing into two or many new species. Common ancestry can also be found in technological change. An entity stuck on a peak may be overtaken by a "cousin" climbing a different and higher peak.
- Change in the landscape. Changes in the "rules" of competition can be visualized as a geographic upheaval. At one time the major upward direction for aircraft was speed. Concorde got stuck at the top of this peak. It was the fastest but not the "best." The landscape had changed with cost per

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passenger being the dominating peak. Major upheavals can be compared with the arrival of a new volcanic island emerging out of the sea. Steam engines and the internal combustion engine were new to the scene, but they emerged slowly and developed many ridges to existing peaks.

- Any new form of living entity or artifact arrives via a series of small steps. In the real world, there are many more dimensions than in the simple geological metaphor. More dimensions increase the probability of connections between peaks.[4]
- I am aware that the size of technological change is important, and in 1970 I devised a scale for the size of a technological innovation. This was a five-point scale based on the change required in a standard technical textbook. Size five represented the need for a new book and size four meant a new chapter in the textbook. From a study of British innovations that had gained the Queen's Award for Industrial Innovation, I obtained evidence that sizes four and five seemed to happen in different ways from those with smaller changes.[5] However, even these large changes had gradually climbed up their own historical peaks and continued to climb once they had combined with other things.

George Basalla's classic study, The Evolution of Technology, attempts to demonstrate the continuity of all technology right back to the use of the first stones and flints, "every new artefact is based to some degree upon a related existing artefact." Even the transistor climbed out of earlier solid-state amplifiers, used in the "crystal" radio sets.[6] As Norman & Verganti rightly state, "a completely novel innovation is impossible. All ideas have predecessors and are always based on previous work - sometimes through refinement, sometimes through a novel combination of several pre-existing ideas."

This being so, where then is radical innovation and how is it different from hill climbing in a rugged terrain with many peaks connected by ridges? Perhaps it is a matter of semantics with radical—not meaning very radical—or perhaps it is a reluctance to follow the Darwinian path up the hill of explanations of innovation.

By seeming to support the idea that some innovations are not obtained by gradual hill climbing, they are in danger of giving support to the so-called intelligent design movement. This offshoot of the creationists seeks to show the impossibility of some biological innovations being the result of Darwinian gradual change. "What is the use of half a wing?" etc. (The fossil record shows that both "wings" and feathers existed before they were used for flight; birds' bodies are covered in feathers, not just their wings.) Many apparently radical innovations in both biology and in technology can be shown to make use of previously existing systems that were used for a different purpose.

Given Norman & Verganti's claim that "a completely novel innovation is impossible," why don't they stick with Darwin? They claim, "All ideas have predecessors" and ideas can form the basis of a Darwinian approach to design. Ideas can be thought of as memes—imperfect replicators—existing as electro-chemical neuronal patterns in the brain. A previous paper in this journal shows that different types of memes can be used in discussing Darwinian design. Norman & Verganti's two dimensions of technology and meaning can be thought of as two kinds of memes: recipemes—ideas about how to do things, and selectemes—ideas about what sort of things you want to do. The desire to travel faster is a selecteme; the idea of supersonic transport is a recipeme.[7]

I don't believe that Norman & Verganti are closet creationists, and I don't believe that they are ignorant of biological ideas of local maxima. So why do they omit any mention of biological maxima, and why do they want to insist that radical innovations don't arrive through a series of small changes?

1 Richard Dawkins, *Climbing Mount Improbable* (Harmondsworth, Middlesex, England: Penguin, 1996).

2 Eilert Sundt, paper in Norwegian, 1862, translated in Jon Elster, *Explaining Technical Change* (Cambridge University Press, 1983), 136–37.

3 Charles Darwin, *The Origin of Species By Means of Natural Selection* 6th edition, (London: J Murray, 1859), 58, 137.

4 Sergey Gavrilets, *Fitness Landscapes and the Origin of Species* (Princeton University Press, 2004).

5 John Langrish et al., *Wealth from Knowledge: Studies of Industrial Innovation*, Part Two (London: Macmillan, 1972).

6 George Basalla, *The Evolution of Technology* (Cambridge University Press, 1988).

7 John Z. Langrish, "Darwinian Design: The Memetic Evolution of Design Ideas," *Design Issues* 20, no. 4 (Autumn 2004). See also J. Z. Langrish, "Different Types of Memes: Recipemes, Selectemes and Explanemes," *Journal of Memetics* 3, (1999). http://cfpm.org/jom-emit/1999/vol3/langrish_jz.html (accessed February 2, 2014).

**Donald A. Norman and Roberto Verganti**

## Hill Climbing and Darwinian Evolution: A Response to John Langrish

We find John Langrish's argument to be puzzling. We wrote a paper on product evolution and he chides us for failure to cite the literature in evolutionary biology.

The issue is our discussion of optimization through small, local iterations—each iteration moving in the direction that yields an improvement, stopping when all further changes lead to a decrement. This is a well-known technique, widely understood and discussed in a wide variety of disciplines. The mathematics are well studied. There are numerous variants of this method, such as gradient descent and ascent, hill climbing, and simulated annealing. For the purpose of this response, let us call them all "hill climbing." All these methods lead to local optimization but are incapable of finding a global optimization. This is an indisputable fact of mathematics, very widely-known, and in our opinion so well known that they are not necessary to cite nor are they open to discussion.

As Langrish properly points out, Darwin considered evolution to be a kind of local optimization process. Moreover, he was aware of the difficulty of reaching a global optimum. So how does evolution work? Langrish seems to think that Darwin assumed that this method had to work, else his theory "would absolutely break down." Langrish cites this as evidence that we are wrong in our assessment of the imitation of hill-climbing optimization. Langrish's quotation of Darwin's statement was a hope not a proof.

The problem of reaching global optimization has been well-studied, once again, in many disciplines. A simple solution is to use different starting points, and if the space of possible starting points is well-covered, then one is likely to lead to a global optimization. This is precisely what we said in our paper. We stated that by starting at a different point in space, driven either through new technological possibilities or meaning change, the new starting point can lead to a superior solution. Indeed, this is what Langrish himself partially suggests in his list of possible candidates for solving the dilemma. Multiple entities climbing at the same time but taking different routes (his suggestion 3) are examples of different starting points. His suggestion of changes in the landscape (his suggestion 4), is what we mean by new technological innovations or changes in meaning.

But many of his suggestions are rather bizarre, perhaps because he is not aware of the underlying mathematics. Suggestions 1 and 2, that a ridge might connect local peaks, do not solve the problem of having to descend (de-optimize) in order to traverse the ridge, unless there is a path across the ridge that does not require a descent. Hill climbing methods fail if the ridge requires any decrease in value, but they will succeed if the ridge never entails a decrease. Note that it is possible to traverse ridges that require some de-optimization through any one of a number of stochastic optimization methods. These are also well–studied in the literature on optimization, but these are not the methods we discuss in our paper because we did not believe they would apply to the normal process of invention and improvement.

Langrish's suggestion 5 is correct but irrelevant. We assume the full space of possibilities, namely the space existing in the world. That is, we do not assume a simple-minded geological metaphor. Actually, adding dimensions also increases the likelihood of multiple local maxima: more places to get stuck.

We stated that all radical innovations do come from pre-existing ideas and innovations. So how do they combine if not by local incremental

optimization? By novel combinations, that's how. We proposed that these novel combinations are done through tinkering, through systematic trial and error, through accidents, through a deliberate design act, or through whatever events transpire. New technologies and new meanings provide new starting points as well as novel combinations. The formation of these combinations does not arise through hill climbing nor optimization mechanisms. Once the combination is assembled, then a hill-climbing process begins to determine if the new combination will survive or not, and then whether it can climb the hill to an optimization point. (This is precisely how genetic algorithms work: they randomly combine features of winning organisms, creating new novel transformation.) Some proposals for the mechanisms of biological evolution are similar. In addition, biological mechanisms probably are stochastic because of the existence of "noise" and probably follow optimization processes, whether through noise (stochastic processes), the mixing of genes (as in genetic algorithms), multiple starting points (as Langrish points out), or any one of the multitude of well-known ways of modifying simple hill climbing techniques.

Unfortunately, Langrish does not clarify his perspective for optimization: who is surviving, who is succeeding? Optimization from the perspective of the species may not lead to optimization for the world. Optimization from the perspective of the world probably leads to species that get stuck in local maxima and therefore die, or in Langrish's words, are "overtaken by a 'cousin' climbing a different and higher peak." We look from the perspective of the individual entity, for example, an organization or a firm. Of course the socio-economic system evolves and survives, but individual firms and organizations that get stuck in an old pattern of local maxima disappear (consider Olivetti, Polaroid, Digital Equipment Corporation, etc.), overtaken by organizations that abandon the path-climbing process of their industry and find new combinations. Although, in this Schumpeterian mechanism of creative destruction, new organizations may come from the ashes of previous ones, the old entity is definitely not happy to disappear.

In the published literature on the economics and business of innovation and technological change, the concepts of local maxima and path dependence are well studied and the importance of disruption as a strategy for success is a well-known mechanism. We refer to this body of literature in our citations of studies of radical innovation (see our notes 15 and 16—in particular, the work of Clayton Christensen), and then when we acknowledge Giovanni Dosi, a well-known evolutionary economist (note 26). We connect these theories to our discussion of design research in relation to drivers of change such as technology and meaning.

We thank Langrish for his interest in our paper, but similar issues have been faced in many disciplines. As we have demonstrated, his attempts to map biological mechanisms to our approach are either already accounted for (his suggestions 3 and 4) or are inappropriate (his suggestions 1, 2, and 5). We see no reason why we should have cited every field that has thought about problems of local versus global optimization; and, we see no reason to modify our suggestions based upon his analyses.

We are accused of being creationists. We plead guilty. That's what the field of design is all about: all-seeing, overarching designers who look over their creations and go in and change them. Designers have that luxury. Release a product and call it back for revision. Or completely change the next release, keeping the stuff that worked and deleting the stuff that didn't. Or completely repurpose it for some other usage that had not been considered at first. None of this incremental creep that evolution must suffer through: designers get rid of the appendix when it is no long needed. Designers are creators.

Radical innovation in the field of design does not come from hill climbing. It comes from putting together things that never before were thought to belong together. It comes from the heart and mind of the designer. Yes, as designers we are creationists. We teach it, practice it, and take delight in it.