WHY WE SHOULD EXPECT THE VARIATION IN EVOLUTION TO BE NON-RANDOM

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The version of evolution taught in high school science class usually includes a story about how Charles Darwin was on an expedition to the Galapagos and was inspired by the specialized beaks of many different species of finches to realize that natural selection could stack up small "random" variations in species over time to evolve into new niches. In this paper we argue that natural selection can also stack up "non-random" variations, and explore the evidence and implications of this possibility.

Basics of natural selection: Variation-Competition-Reproduction

The classic story begins with Darwin documenting many unique but closely related species of finches and observing how they fit into their environment:

a. There are many similar finch species specialized to take advantage of different niches (one with curved beaks for reaching inside flowers, one with sharp beaks for breaking into seeds, and so on)
b. Baby finches have similar beaks to their parents
c. Finch species compete and within each niche specialized beaks dominate
d. Large differences between two distantly related finch species can be broken down into many small changes across a string of intermediate finch species

These observations helped inspire Darwin to describe the process of Natural Selection and observe that the incredible variety of animals on earth result from Natural Selection occurring over many millions of generations. At its core natural selection has three basic steps:

- Variation – Small changes are introduced to an initial design
- Competition – Multiple variations compete, with more resources going to the winners
- Reproduction – The most successful variations have better access to resources and are able to reproduce more, slowly moving the population towards the most successful changes

Natural Selection with non-random variations: Corporations

The most basic description of Natural Selection states that changes in the "variation" step occur "randomly". This is certainly one possibility, but it is not the only possibility. Variation-Competition-Reproduction is a process which can start with any source of variations (random or not) and then double down on the higher fitness variations and abandon the lower fitness ones.

To help give you an intuition for how VCR can work with non-random variations consider the example of a modern capitalist economy. Individual companies are roughly analogous for animals in evolution and they similarly experience VCR:

- Variation – New companies start using business models of previous generations, but with small changes
- Competition – Companies compete for resources, with more going to the winners
- Reproduction – The most successful companies grow large and become the models for future generations

From 30,000 feet, you can make a lot of the same observations about companies that Darwin made about the finches:

a. There are many similar companies specialized to take advantage of different niches
b. New companies reuse ideas from earlier successful companies
c. Companies compete and within each niche specialized companies dominate
d. Big changes in business models usually take place as an accumulation of small changes instead of springing into existence fully formed

At 30,000 feet, if you couldn't look at the internal machinery of the companies you could easily think that companies experience "random variations" generation to generation. But of course, you know that in reality the people inside the companies are trying very hard to make the companies successful and the variations they experience are carefully chosen after a great deal of thought and analysis to try and maximize the company's chances of success. Despite the best efforts of the leadership teams, there are still plenty of bad variations and that is where the macro forces of competition and natural selection step in to cull the bad variations and reproduce the good ones. Hopefully this gives you a sense of how "optimized variations" and natural selection can co-exist.

<u>Why to expect "optimized variations" in nature?</u>

Early life may not have been very sophisticated and it may have just dealt with random variations that resulted from cosmic radiation. However, modern mammals are incredibly sophisticated in almost everything they do. Sexual reproduction, for example, is a highly complex system that exists to allow the next generation to combine favorable mutations from their entire tree of ancestors instead of being an exact copy of just one parent. Combining genetic material from multiple parents is a massive advantage which allows the next generation to – stay with me here - have a much better chance of including favorable variations relative to the previous generation than random chance alone. We see similar levels of sophistication all sorts of places: from our powerful yet flexible brains to the tightly choreographed army of different cells that make up our immune system.

Evolving more control over the variations passed down to subsequent generations would confer a significant advantage on a species - allowing it to adapt and take advantage of changes in the environment much faster than species which only had "random variations".

Knowing that Variation-Competition-Reproduction can have “optimized variations” and knowing that “optimized variations” are a huge advantage, it seems likely that advanced organisms would have evolved systems to optimize what variations are passed down to the next generation. Even if we haven’t yet discovered all the mechanisms by which that occurs, we have all the pieces to hypothesize that mechanisms are likely to exist.

What form could optimized variations take?

It seems likely there are many different mechanisms by which biology optimizes variation, many of which we don’t fully understand yet. Here are a handful of plausible mechanisms going from well understood through active research areas to entirely hypothetical:

A. Sexual Reproduction (discussed above)
B. Children and grandchildren of parents who lived through famine inherit epigenetic markers that make them better able to survive food scarcity. This is not a random variation but a direct response to the challenges their parents faced. We are just starting to learn how this mechanism works [1]
C. Genes which are risky to change experience less change than ones which can be mutated without harming the organism.[2]
D. We might see gradient descent of traits where, for example, children and grandchildren of parents who use their arms a lot are genetically predisposed to have stronger arms.
E. Populations might have more variation between generations during times of plenty, when there is less risk to a bad variation and less variations when the population is under pressure and cannot afford to take risks.
F. Genetic encoding might intelligently reuse design patterns from one part of the body in another part of the body.

Takeaway

The takeaway from this discussion is that we shouldn’t assume the process of Variation-Competition-Reproduction necessarily means variations are “random”. It is equally possible that there are some mechanisms steering the variations in more evolutionarily promising directions and good reasons for those mechanisms to have evolved. This gives us interesting hypotheses for further research which are firmly rooted in first principles of evolutionary theory.

Referenced Papers

1. Human transgenerational responses to early-life experience (2014), Journal of Medical Genetics - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4157403/
2. Evidence of non-random mutation rates suggests an evolutionary risk management strategy (2012), Nature - https://www.nature.com/articles/nature10995