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Causation, State Spaces, Evolvability, and Creativity

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An intuition

Evolution – whether we think about outcomes of selection or of evolvability – is often taken to be about movement through **state spaces**

An intuition

Two literatures (at least) talk extensively about what happens when we **innovate** in those kinds of state spaces:

1. **evolvability**
2. **evolutionary novelty** or **creativity**

An intuition

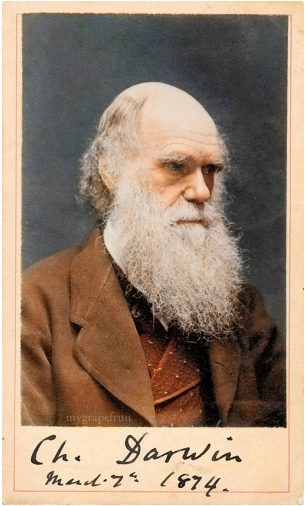
My goal for today: The literature on evolutionary creativity is **much older** than the literature on evolvability. Can we learn anything from the structure of those debates that we think might translate?

My tentative proposal: Keeping this distinction in mind can help us think about how we decide to build conceptual models of evolvability. It *might* even help us to understand some of the diversity of ways people have thought about the concept.

Creativity and evolution

> Claims to the effect that natural selection is creative and counterclaims that, no, mutation is the creative agent, are not just hyperbole or rhetorical flourish. They reflect interestingly different, empirically contested views about how evolution by natural selection proceeds. In particular, they have to do with the *initiation* and *direction* of evolution by natural selection… (Beatty 2019)

Darwin



Darwin

Let an architect be compelled to build an edifice with uncut stones, fallen from a precipice. The shape of each fragment may be called accidental; yet the shape of each has been determined by the force of gravity, the nature of the rock, and the slope of the precipice, – events and circumstances, all of which depend on natural laws; but there is no relation between these laws and the purpose for which each fragment is used by the builder. In the same manner the variations of each creature are determined by fixed and immutable laws; but these bear no relation to the living structure which is slowly built up through the power of selection, whether this be natural or artificial selection. (Darwin 1868)

Darwin

Although Darwin does not explicitly refer to “creativity” here, he does compare evolution by natural selection to a creative process, and aspects of this comparison figure centrally in the subsequent creativity debates, especially with regard to the role of selection in initiating evolutionary change. (Beatty 2016)

Morgan

Morgan

> The origin of these types – the real creative steps – not the preservation of certain of them after they have appeared, might rather be regarded as the essential phenomenon of evolution. If so, “the struggle for existence” and “the survival of the fittest” may express only a sort of truism or metaphor, and have nothing to do with the origination of new types out of antecedent ones. (Morgan 1935)

The early “creativity” fight

1. Darwin: natural selection never needs to **wait** on variation, because there is a vast amount of variation already available. Natural selection **initiates** the process of evolution, it is thus the **creative** force.
2. “Mendelians” or “mutationists”: natural selection works on variations that are **already** available in the population; if those variations aren’t around, it needs to **wait** for them to appear. The **creative** force is mutation.

A second aspect

> Thus, a central difference between the Darwinians and the mutationists was that according to the former, selection brings about directional change all the while *shifting and preserving* a wide range of selectable variation. Whereas according to the mutationists, directional evolution takes place at the expense of selectable variation: natural selection *reduces* the range of variation that it can act upon. (Beatty 2016)

The middle “creativity” fight

1. Darwinians: natural selection never needs to wait on variation, because it can **shift the mean in the population** for a character for an essentially unlimited time, without reducing population variance. It is thus the **creative** force.
2. Mendelians: natural selection, if operating in the same direction for enough time, **eliminates** variation around a given (classic, Mendelian) character; any **creativity** thus remains with mutation.

An interpretive move

The Darwinian side in this debate seems to think of natural selection as operating within a **single, well-defined space** of genes and gene combinations.

The Mendelian-mutationist side seems to think of mutation as **creating novel possibilities** that were not previously open to natural selection.

An interpretive move

An important part of what was going on in this case, then, was how people were understanding the conceptual background against which evolutionary creativity takes place.

Should we think just about **reaching new areas** of the space of outcomes available to natural selection, or rather about **changing the outcomes** available to natural selection?

The end of the story

From the Modern Synthesis perspective, there is general agreement that there is significant standing variation in most populations, but there's *also* the thought that most evolutionary change results from novel gene **combinations** rather than novel **genes.**

The end of the story

But creativity is only **apparent:** it's the result of natural selection "pulling up" recessive variation already present in the population that would otherwise have gone entirely unnoticed.

(Things get more complicated when we talk about the neutral theory of evolution or about recent work on directed mutation; not for today.)

Evolvability: Static spaces

I argue that evolvability is an abstract and robust dispositional property of populations whose physical basis is the many non–selection-based features of populations (such as mutation rate, developmental constraint, and population structure) that can influence the **parts of phenotypic space populations are able to access** over evolutionary time. (Brown 2014)

Evolvability: Static spaces

We can see this interest reflected in our case study. Young et al. ([2010]) are concerned with explaining why the ape lineage has moved from a part of ‘morphological space’ with low limb length ratio diversity to one of higher diversity, while the monkey lineage (and indeed most tetrapods) have made no such move… (Brown 2014)

Evolvability: Static spaces

> One of the most significant is that [the two-legged goat case] shows that **pre-existing genetic and developmental possibilities** allow physiological adaptations that could never have been selected in the past. (Jablonka 2006)

Evolvability: Changing spaces

These all seem to be accounts of evolvability that take us to be **moving within** a space of morphologies, phenotypes, or adaptations.

There doesn't seem to be anyone who's argued for a **changing-space** account of evolvability (at least in a survey of the thirty or forty papers I have on my hard drive that mention the concept).

Evolvability: Changing spaces

But! We've spent a **lot** of time yesterday and today talking in terms that sound like "creating possibilities" or "opening up possibilities."

It seems like the natural way to cash this out is with "changing-space" talk, **but** it seems like very few people actually talk this way in print!

What gives? What account of biological possibility do people have in mind?

What kind of space?

- populations or lineages
- characters or traits
- adaptations
- genotypes
- phenotypes
- designs

What kind of space?

> The distinction between evolutionarily relevant mutations and the class of all possible mutations is also helpful to emphasize that rare dramatic mutations found in nature and generated in the laboratory may unfairly represent the kinds of mutations that are allowed to persist in natural populations. (Stern 2000)

What kind of space?

> Yet a simple consideration of microevolutionary morphological patterns suggests which networks and network modules might be most profitably explored. This number is considerably smaller than the totality of possibilities. (Wilkins 2007)

Why does this matter?

One possibility: **it doesn't**

This is all just semantic gloss over the same kinds of change in the same kinds of systems; formalize models of possibility however you want, it doesn't even much matter *epistemically*

Why does this matter?

Second possibility: **it mostly doesn't**

These are questions about our *representational devices* for evolutionary change, which are interesting and maybe relevant around the edges – if you have a better representation you could think more effectively, maybe? – but don't say anything about the world

Why does this matter?

Third possibility: here are a few reasons that **it might, actually**

- modal inferences in natural selection and evolvability (or, e.g., in synthetic biology; Ijäs and Koskinen 2021)
- characteristics of dispositional properties like fitness or evolvability
- questions of the causal force of fitness or evolvability

Why does this matter?

> Considering how important the notion of possibility is, there is surprisingly little discussion that explicitly aims to tackle biological possibility. Several research areas in biology do deal with modal statements related to possibility, either directly, as in the case of evolutionary contingency, or indirectly, as in the case of constraint and convergence. However, the concept of biological possibility itself has received relatively little attention in the philosophy of science. (Ijäs and Koskinen 2021)

Questions?

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