Causation, State Spaces, Evolvability, and Creativity

Institute of Philosophy, Leibniz University Hannover, 2023-12-05

Charles H. Pence

@pence@scholar.social

UCLouvain

isp INSTITUT SUPÉRIEUR DE PHILOSOPHIE

LIBST LOUVAIN INSTITUTE OF BIOMOLECULAR SCIENCE AND TECHNOLOGY

ACADÉMIE ROYALE DE BELGIQUE 1772

Cambridge Elements

The Philosophy of Biology

The Causal Structure of Natural Selection

The Causal Structure of Natural

PENCE

Outline

1. A causal structure for natural selection
2. The problem of multi-level probabilistic causal systems
3. Creativity, evolvability, possibility, and modality
   - 3.1 The history of creativity in evolution
   - 3.2 Evolvability and possibility

The take-home: Questions of innovation and creativity in natural selection turn on unappreciated causal details.

A Causal Structure for Natural Selection

Individuals live and die, give birth, mate, eat, and so on.

Fitter individual organisms are more likely to succeed than the less fit.

Populations are likely to change over time in the direction of increased fitness.

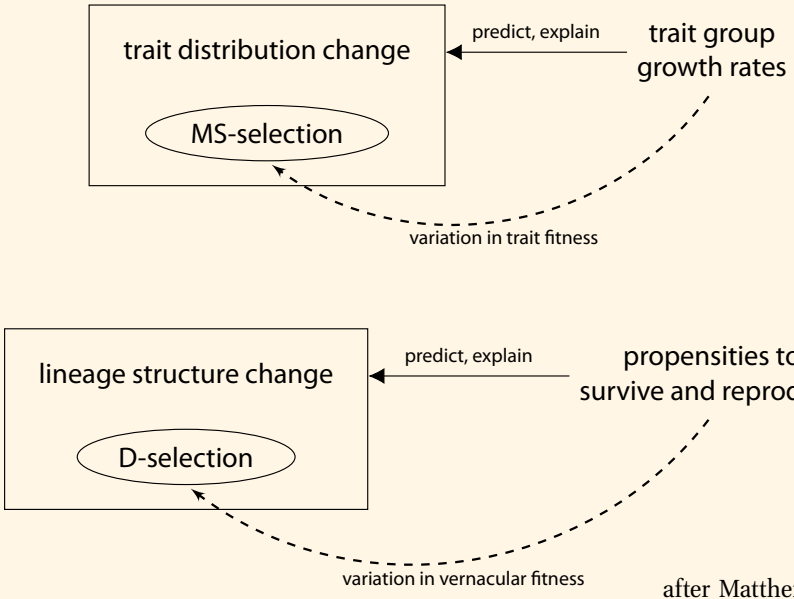
Where, or what, exactly, is natural selection?

Where, or what, exactly, is natural selection?

More precisely, is there an account of those three (classes of) facts on which natural selection is *causing* something, or is natural selection merely a *label* or a *summary* of those facts?

There is a healthy (viz. massive) debate concerning this question.

How can we generalize it so that we can fruitfully put it in contact with other literatures – in the metaphysics of science, the study of causation, the philosophy of physics, the philosophy of psychology, etc., etc.?

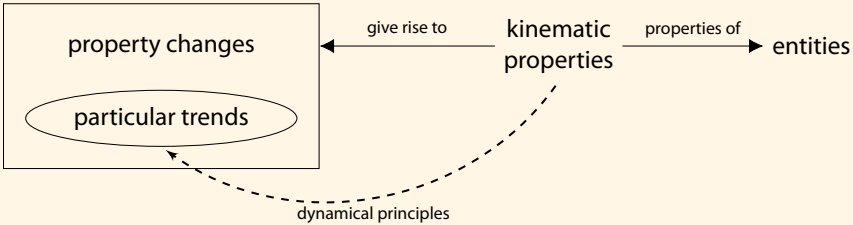


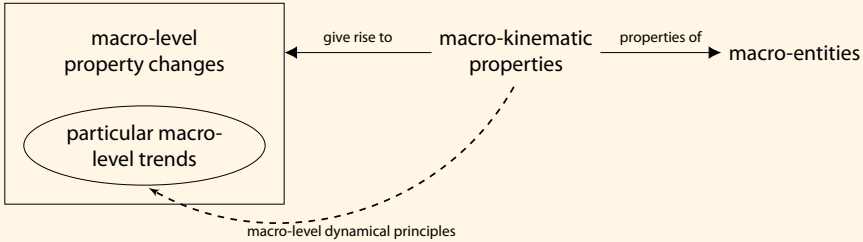
after Matthen and Ariew (2002)

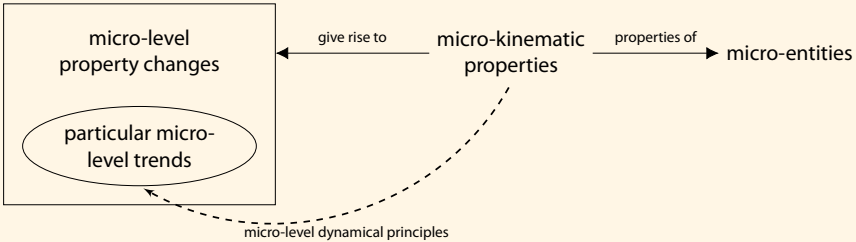
Their goal: argue that, simply, these are **two quite different processes,** employing two very different kinds of explanation.

Their goal: argue that, simply, these are **two quite different processes,** employing two very different kinds of explanation.

Perhaps! But: there's two important things missing from their picture.


property changes
particular trends
give rise to
kinematic properties
properties of
entities
dynamical principles


macro-level
property changes
particular macro-
level trends
give rise to
macro-kinematic
properties
properties of
macro-entities
macro-level dynamical principles


micro-level
property changes
particular micro-
level trends
give rise to
micro-kinematic
properties
properties of
micro-entities
micro-level dynamical principles

What does that let us do?

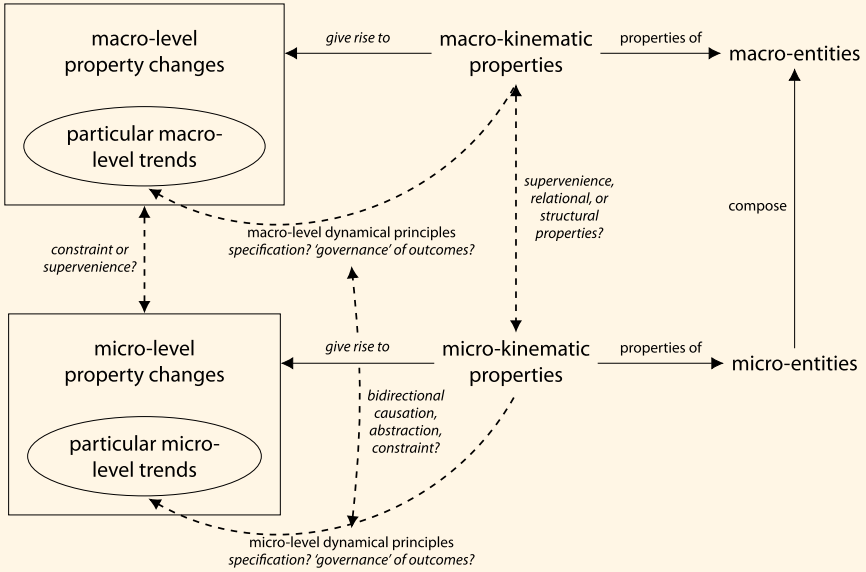
1. It lets us see the role of the **underlying entities** in these explanations
2. It lets us look at **inter-level relations** – and we already know, at the very least, that composition is involved!

Multi-Level Probabilistic Causal Systems

What kinds of questions could we ask?

What kinds of questions could we ask?

...too many.


macro-level
property changes
particular macro-
level trends
give rise to
macro-kinematic
properties
properties of
macro-entities
supervenience,
relational, or
structural
properties?
compose
macro-level dynamical principles
specification? 'governance' of outcomes?
constraint or
supervenience?
micro-level
property changes
particular micro-
level trends
give rise to
micro-kinematic
properties
properties of
micro-entities
bidirectional
causation,
abstraction,
constraint?
micro-level dynamical principles
specification? 'governance' of outcomes?

State Spaces and Evolvability

Looking for Help

This multi-level causal system approach demands that we know something about that **state space of possible property changes** on the left-hand side of the diagram

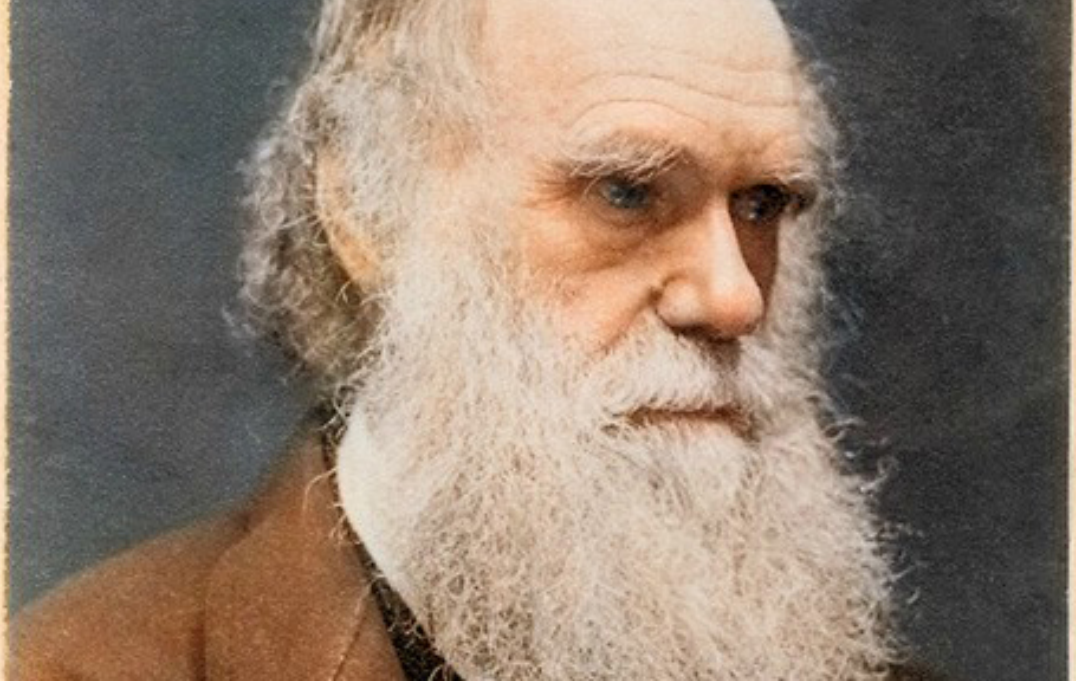
Looking for Help

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

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

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

> 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)

T.H. 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 space of possible property changes in a multi-level causal system.

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?

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: Dynamic 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: Dynamic Spaces

But! A **lot** of the evolvability literature talks in terms like "creating" or "opening up" possibilities.

It seems like the natural way to cash this out would be with a "changing-space" model, **but** it seems like very few people actually talk this way in print! What account of biological possibility do they have in mind?

A Metaphysical Point

Normally, in literature on modality in science, we don't talk about "adding" or "changing" possibilities, because this is **too unconstrained to be helpful.** Instead, we talk about adding further **necessities** to our models, which then **change which states in the state space are possible.**

A Metaphysical Point

Normally, in literature on modality in science, we don't talk about "adding" or "changing" possibilities, because this is **too unconstrained to be helpful.** Instead, we talk about adding further **necessities** to our models, which then **change which states in the state space are possible.**

Is this equivalent to the kind of "dynamic state space" approach I've sketched here? I don't know yet.

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 matter, 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?

charles@charlespence.net
https://pencelab.be
@pence@scholar.social

PENCE LAB

fnrs
LA LIBERTÉ DE CHERCHER