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[4] Evolution by Natural Selection

0. Outline

1. Recap
2. Evolution by natural selection: the general idea

1. Recap

- In the previous couple of lectures, we made some general methodological points…
- We pointed out, in the context of evaluating the hypothesis that current organisms were the product of chance processes, that even if it did turn out that it is ok to accept/reject hypotheses on the basis of their relative posteriors, it still isn't ok to reject hypotheses on the sole basis of their having low absolute likelihoods, as nothing follows regarding their absolute posteriors (or indeed their relative posteriors).
- In addition to the likelihood of the hypothesis under consideration, we would need values for its prior, as well as the priors and likelihoods of competing hypotheses.

1. Recap

- We also noted that in the absence of good epistemic reasons for assigning particular values to the priors, some people appeal to PI and assign equal priors to the hypotheses under consideration: the ordering of likelihoods would then suffice to determine the ordering of posteriors.
- One quick last point before we move on…
- Elliott Sober [2004], who also worries about lacking epistemic grounds to settle on specific values for the priors (for *completely* different reasons), points out the following:

  > Whatever we are entitled to say about the prior/posterior probabilities, we can, on the sole basis of epistemically well-motivated values for the likelihoods, make the weaker claim that our evidence *favours* one hypothesis over another (or not).

1. Recap

- E.g. of evidential favouring: the fact that I prefer tea to coffee favours the hypothesis that I will drink tea over the hypothesis that I will drink coffee (although not the hypothesis that I will drink tea over the hypothesis that I will drink water).
- Why do we only need likelihoods for this?
- According to the so-called '*Law of Likelihood*':

  LL: evidence E favours rival hypothesis H_1 over hypothesis H_2 iff $\Pr(E|H_1) > \Pr(E|H_2)$
- Whilst there are a number of alternative accounts of the notion of evidential favouring on the market, there are *very good* reasons to prefer the account given in LL.

1. Recap

- First of all it accords pretty much with our intuitions about evidential favouring is:

  It turns out that what LL says is that (on the assumption that $H_1 \models \neg H_2$) E favours H_1 over H_2 iff it raises the probability of H_1 on the assumption that $H_1 \vee H_2$ is true (the equivalence is trivial to prove mathematically)

  Example: my preferring tea to coffee raises the probability of my drinking tea, conditional on only tea and coffee being on offer and my not going thirsty, as required by LL.
- There are other advantages.
- For instance, one can rigorously prove that the only kind of information worth paying for is evidence that favours some hypothesis over another according to LL.

1. Recap

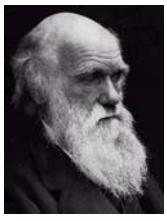
- In what follows, I will avoid the issue of the prior values of CH and its competitors (*as everybody else does*, incidentally) and follow Sober in restricting myself to a comparison of their likelihoods.
- This isn't totally satisfactory but a likelihood comparison will nevertheless:
  - tell us which hypothesis our evidence favours, pending something more sensible to say about the priors.
  - if some version or other of PI is well motivated, give us posterior probabilities, in the absence of epistemic grounds for settling the priors.

2. Evolution by natural selection: the general idea

- Science's current best alternative to the 'chance alone' hypothesis:

  > Current populations of organisms have evolved, under the influence of natural selection and in a series of small, cumulative steps, from a single population of primitive self-replicating organisms.

- This view, of course, traces back to Darwin's *The Origin of Species* (1859).
- Some of the component ideas do predate Darwin however…



2. Evolution by natural selection: the general idea

- Lamarck's *Recherches sur l'Organisation des Corps Vivans* (1802) also defended the view that current populations of organisms had evolved from populations of more primitive organisms.
- However, Lamarck's views on the major driving forces behind evolution differed from Darwin's.

- He had envisaged two core mechanisms:

  (i) A '*complexifying force*', gradually driving lineages of organisms to increasing complexification over time (with each organism producing ever more complex offspring), as well as more famously…

2. Evolution by natural selection: the general idea

(ii) A mechanism of *inheritance of acquired characteristics*, whereby organisms pass on to their offspring traits acquired during the course of their lifetime (e.g. sharpened reflexes, increased musculature, etc.).

- Darwin scrapped the first altogether and relegated the second to a peripheral role, placing natural selection center-stage in the explanation of biological evolution.
- This is just as well: neither (i) nor (ii) have been subsequently empirically vindicated.
- So what *is* evolution by natural selection?
- A precise treatment would be mathematically hard-going but the *very rough* idea is easy to grasp (if a little frustratingly vague)…

2. Evolution by natural selection: the general idea

- In informal presentations of evolutionary theory, three necessary and sufficient conditions are generally cited for a population of organisms sharing a common environment to be subject to natural selection:

  [1] *Variation in traits* (i.e. properties) amongst population members.

  [2] *Variation in degree of organism/environment fit* ('fitness') resulting from this variation in traits.

  Note: fitness is in the first instance a property of organisms. When biologists speak of the fitness of a *trait*, they mean the average fitness of the bearers of that trait.

  [3] *Heritability* of (roughly: tendency of offspring to resemble parents with regards to) the varying traits.

2. Evolution by natural selection: the general idea

- If these conditions hold and no other relevant forces are at play the structure of the population will tend to change over time…
- At each generation, the fitter organisms are more likely to survive and reproduce fecundly than their less fit counterparts.
- Because the offspring will tend to qualitatively resemble their parents, the fitter traits in the population are likely to increase in proportion (however slightly).
- Over enough generations, the fittest traits will, in all likelihood, eventually reach 'fixation' (i.e. frequency of 100%).

  Note: there are noteworthy exceptions to this picture, such as cases in which traits with comparatively lower fitnesses can be kept at a stable frequency in the population due to the specifics of the mating system (heterozygote superiority).

2. Evolution by natural selection: the general idea

- Of course, another important force in biological evolution is germline *mutation* (i.e. alteration of the genetic material in the germ cells – i.e. sperm and eggs), which is one of the main sources of the variation required for natural selection to act.
- Under the influence of mutation, at each reproductive cycle, there is a certain probability of small modifications being made to the designs already in circulation.
- This opens up the opportunity of yet fitter trait combinations being generated, traits whose frequency will in turn tend to increase in the population.
- Over a surprisingly short timespan, natural selection + mutation can produce fairly dramatic adaptive change.

2. Evolution by natural selection: the general idea

- To get an idea of the difference between the picture painted by contemporary Darwinism and the picture painted by the 'chance hypothesis', consider the following analogy (borrowed, with modifications, from Dawkins' *The Blind Watchmaker*):
  - Consider the string of characters COMPLEXADAPTATION.
  - Now consider two procedures:
    - **P1**: Pick a sequence of 17 characters at random; repeat.
    - **P2**: **(i)** Pick one character at random, if this character is 'C', keep it and go to (ii), if it isn't, repeat.

      (ii) Pick a second character at random, if this character is 'O', keep it and go to (iii), if it isn't, repeat.

      (iii) …

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P1	P2
ACTJSKEOWMSNWIGMP	T
SKNRJFPKSAUHZMWUR	S
…	…
IUHIUJWTQGNXAJIIW	C
NEJHQOAMRUVPANQUZ	C
NDUHSPUEMXLAIEMAQ	C
…	…
MEIWHHQBXTEPANEUA	CO
MCNEWIAOXMEPLANTO	CO
EASTILLNOTTHEREQT	COM

2. Evolution by natural selection: the general idea

- The analogy:
  - P1 represents the process of generating a population of complex organisms at random from scratch (what we called the 'chance hypothesis').
  - P2 represents the process of evolving a population of complex organisms by cumulative selection from a population of simple organisms (the letter 'C') generated at random from scratch:
    - At each step, the population is subject to chance mutation (generating a new letter at random).
    - If the mutation (new letter) leads to a fitter form (string that better matches ADAPTIVECOMPLEXITY), this form supplants the previous one, before itself being subject to another round of mutation, etc.

2. Evolution by natural selection: the general idea

- It should be obvious (and can be demonstrated) that even after fairly small number of steps, it becomes the case that:

  probability of having produced COMPLEXADAPTATION given the use of procedure P2 >> probability of having produced the same string given the use of procedure P1.

- The analogy isn't perfect, but it should get the following point across:

  A population of highly complex organisms can have a better-than-chance probability of being produced if it can be connected to a population of simple organisms via a chain of not-to-improbable mutations such that each successive mutation would bring about an even slight gain in fitness to its bearer.

2. Evolution by natural selection: the general idea

- Dawkins puts the point in characteristically slick prose:

  '[Darwin's] way is a gradual, incremental improvement starting from very simple beginnings and working up step by tiny incremental step to more complexity, more elegance, more adaptive perfection. Each step is not too improbable for us to countenance, but when you add them up cumulatively over millions of years, you get these monsters of improbability.' (Dawkins [2006])

- The importance of the possibility of evolving complex characters via a chain of small incremental steps of increasing fitness was stressed by Darwin himself:

  'If it could be demonstrated that any complex organism existed which could not possibly have been formed by numerous, slight modifications, my theory would absolutely break down' (Darwin *The Origin of Species* Ch 6)

2. Evolution by natural selection: the general idea

- This is overly pessimistic on Darwin's part: the result would be solely to lower the likelihood (in the technical sense) of the Darwinian hypothesis.
- As we will shortly see, the issue of the possibility of cumulative evolution of complex adaptations has been the object of much attention recent in the creationist camp.
- But before we move on to these guys, a couple of important clarifications concerning evolutionary theory…

Reference

- Dawkins, R. [2006]: 'God vs. Science', interview in *Time Magazine* Sun, Nov. 05, 2006.
- Sober, E. [2004]: 'The Design Argument', in W. Mann (ed.) *The Blackwell Guide to Philosophy of Religion*, Oxford: Blackwell.

Next lecture: ‘Evolution By Natural Selection (ctd.)’

- Reading: finish off the Sober reading.