Evolutionary Theory and Empirical Content

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Abstract. There is a category of objections against the theory of evolution by natural selection that is of particular interest to philosophy (of science), namely attempting to show that evolutionary theory is empty of empirical content (or unfalsifiable), and thus not a science. In particular, opponents of evolutionary theory often claim that: 1) the theory makes no testable predictions, 2) that it makes *too many* predictions, i.e. it can easily be rendered all-explanatory, and 3) that it is trivially true, or tautologous. In this paper, said objections are identified, analysed in some detail, and refuted.

I N what follows I attempt to systematise and criticise a category of arguments against the theory of evolution by natural selection that aim to undermine its scientific status. Three such arguments are discussed: 1) that the theory makes no testable predictions, 2) that it makes *too many* predictions, and 3) that it is trivially true, or tautologous. I argue that all of these arguments, as applied to evolution by natural selection, fail under scrutiny.

The theory of evolution has faced and continues to face a number of objections, of varying degrees of scientific and philosophical competence. Among them, the potentially most dangerous are attempts to show that evolutionary theory is not a science at all; that it is more akin to a religion or an ideology. The strategy of this approach is a simple one, namely to identify a property that all scientific theories must necessarily possess and proceed to demonstrate that evolutionary theory lacks it. In the cases that interest me here the property in question is that of testability, or of having empirical content, where by empirical content I understand the set of observable implications of a theory, i.e. statements inferable from the theory, whose truth value is decidable by observation and/or experience. To say that a theory has empirical content is to say that this set is not empty. This seems an uncontroversial and universally accepted necessary condition for the scientific status of any theory.

There are, it seems, three general ways in which a theory, or a system of statements, can be empty of empirical content.

1. When it has no observational consequences, or makes no testable predictions.[8] Various statements of metaphysics traditionally belong to this category.

2. When it can be tweaked to yield *any* observational consequence, because then observational consequences cannot inform us about the truth or falsity the theory - the theory is compatible with every possible observation and thus unfalsifiable.

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[8]I am using these terms interchangeably

3. When it is trivially true or tautologous, as tautologies are, by definition, immune to empirical testing.

All of these charges have been raised against the theory of evolution by natural selection. They are quite closely interconnected and overlap partially - for instance, 3 is a subset of 1, as tautologies make no observable predictions, but a statement does not have to be a tautology to be empty of empirical content. However, since each objection follows a discernibly different line of argument, it makes sense to disarm them separately. But before we disarm them, we need a basic understanding of what evolution by natural selection is.

In bare essential, Darwinism and neo-Darwinism postulate a mechanism for evolutionary change - natural selection. Natural selection occurs when three necessary and sufficient conditions are met in a population of organisms, namely:

1. There exists variation of traits in the population.

2. Some of the variable traits are heritable.

3. Some of the heritable traits are responsible for differential fitness.

Organisms with traits conferring high relative fitness will tend to have high relative reproductive success, leading to the spread of the fitness-conferring trait. Thus evolution by natural selection occurs. In other words, the fittest will reproduce more, increasing the frequency of the trait responsible for their fitness. We will call this 'the principle of natural selection.' It is at the very core of evolution by natural selection.

In light of this, the first of our objections is that the principle of natural selection, as it stands, entails no observational consequences, and hence cannot be tested empirically. Imagine that, armed with the principle alone, you are asked to predict the traits exhibited by Australian fauna, having heard nothing of the continent before.

I, for one, would be very surprised if you came up with marsupials. The principle of natural selection alone does not allow you to predict anything, and certainly not anything specific enough to be of any practical value to science.

However, this objection is methodologically misguided, because no scientific theory can issue predictions on its own.[9] Theories are tested in bundles, for only in bundles can they entail observational consequences. In particular, a theory needs so-called auxiliary hypotheses to produce a prediction. A simple example will demonstrate this: Newtonian mechanics (the laws of motion plus the law of gravitation) on its own predicts nothing whatever unless supplemented by a hypothesis regarding forces operational in the system being tested at the time of testing. The fact that the apple will fall is not an observational consequence of Newton's theory alone, but of Newton's theory in conjunction with hypothesised forces acting on the apple.

It follows that the objection that evolutionary theory on its own has no observational consequences is bogus - we should not expect predictive power from the bare theory in the first place. What we can legitimately expect is that the theory of evolution coupled with relevant auxiliary hypotheses will produce testable predictions. Examples of such evolutionary auxiliaries might include:

- Initial environmental conditions of the population

- Selection pressures acting on the population

- Adaptability of traits

These, together with the principle of natural selection, serve to form so-called Darwinian histories - a kind of historical narrative that describes and explain evolutionary changes of a species over time. Darwinian histories constitute the main explanatory tool of evolutionary theory.

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[9]As demonstrated in Duhem (1906).

Observational consequences of evolutionary theory, yielded by particular Darwinian histories, can broadly be grouped into two kinds - predictive and retrodictive. In other words, we can test the theory of evolution with regard to what we expect to *happen*, as well as with regard to what we expect to *find* has happened already. These two modes of testing differ only methodologically, not logically, because logically speaking both predictions and retrodictions constitute observational statements inferable from the theory.

Since evolutionary processes normally happen over extensive periods of time, it is often difficult to test evolutionary theory for its predictive success. Perhaps the most famous example is Kettlewell's experiments with moths (Biston betularia).[10] In a very crude outline: hypothesising that better camouflaged moths have a selective advantage over their more visible counterparts due to vulnerability to predation, Kettlewell predicted that in industrial areas melanic moths will enjoy greater reproductive success than speckled variants, as industrial pollutants darken tree trunks (where moths rest), exposing the latter to predators. This was confirmed by relative incidence of both variants in areas of varying degree of industrialisation, as well as experimentally by releasing and recapturing marked individuals in these areas. Kettlewell was also able to experimentally discount factors other than selective advantage due to camouflage in accounting for his results.

Other examples of this kind include predictions regarding the development of resistance to medication in bacteria and viruses - predictions that have serious medical consequences (for example regarding the minimal length of effective antibiotic treatments, or in epidemiology) and fuel the pharmaceutical industry. These predictions use as their auxiliaries independently testable assumptions regarding the ability of bacterial and viral genomes to develop advantageous mutations in relatively short periods of time.

Retrodictive successes of evolutionary theory are no less impressive. First of all palaeontologists consistently rely on (as well as

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[10]Kettlewell (1973)

independently, and invariably, confirm) what kinds of fossils Darwinian histories predict to be found in particular layers of strata, and the body of evidence corroborating the theory thus amassed is overwhelming. In an analogous way, Darwinian histories can be used to retrodict facts about living organisms. One of the most spectacular retrodictions of this kind was made by Darwin and Wallace themselves. Confronted with *Angraecum sesquipedale*, an orchid from Madagascar with tubular nectaries over 11 inches long, both men hypothesizing about symbiotic relationship of plants and insects, and in particular about the amazing ability of many orchids to target a specific species of insects in the evolution of their reproductive organs (thus greatly increasing the chances of successful pollination) predicted that a moth will be found with proboscis long enough to pollinate *A. sesquipedale*. Wallace wrote:

> That such a moth exists in Madagascar may be safely predicted; and naturalists who visit that island should search for it with as much confidence as astronomers searched for the planet Neptune - and they will be equally successful![11]

The moth was discovered in 1903 and aptly named *Xanthopan morgani praedicta*. It is difficult to think of a more compelling example of retrodictive success, and Wallace's comparison to the discovery of Neptune is very telling.

We have established that the theory of evolution by natural selection can only produce predictions by invoking auxiliary hypotheses. This potentially exposes a new vulnerability of the theory. Some have argued that the repository of potential auxiliaries at the disposal of evolutionary theorists is so large as to render them capable of explaining anything. If this were true, any observation actually made could be subsumed under evolutionary theory and made into its "observational consequence." For example, if kangaroos are found in Australia, a suitable Darwinian history can be found to account

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[11]Wallace (1871)

for this fact. But if - counterfactually - kangaroos had gone extinct in Australia, then a different Darwinian history with a different set of auxiliaries could have been found that yielded that result.

It is pointless to empirically test such theories, because the test will come out positive no matter what - the theory is unfalsifiable, and therefore scientifically useless.(this insight is due to Popper, who famously raised similar objections in regard to Marxism and Freudian psychoanalysis). Therefore the worry here is that Darwinism is too cavalier in picking its auxiliary hypotheses, and that this condition is endemic to evolutionary theory.

This worry is unsubstantiated because there is no reason why the theory should not invoke auxiliaries that are testable independently, i.e. without having to assume the truth of Darwinism. Some of such auxiliaries were mentioned in the previous section, and others are not difficult to find. If a Darwinian history explaining a particular pattern of distribution of some family of animals hypothesises continental drift, the hypothesis is checked by findings in geology. An evolutionary explanation which requires a specific rate of mutation on a particular chromosomal locus is subject to scrutiny from biochemistry and genetics. Most of all, a great many evolutionary auxiliaries are checkable by direct observation, e.g. anatomical claims, behavioural claims, etc. Further, different Darwinian histories must cohere with each other in that they do not invoke mutually contradictory auxiliary hypotheses, so the theory has internal checks as well.

The final attempt to undermine the testability of evolutionary theory concerns its purported tautological status. As tautologies are, by definition, immune to empirical testing, this approach attempts to show that evolutionary theory is in principle not empirical, whereas the previous two merely claimed that its empirical basis was too poor to qualify as scientific. The source of the alleged tautological status of the theory lies in its notion of fitness. As we have discussed, at the core of evolution by natural selection is the claim that organisms with higher relative fitness have more offspring than their less fit counterparts, thus spreading the characteristics re-

sponsible for their fitness. Now, It has not been uncommon, even in professional writings, to define fitness as actual reproductive success, that is, the actual number of offspring (Waddington, for example, defines the fittest organisms as those "most effective in leaving gametes to the next generation"[12]) Clearly, if we define fitness as the actual number of offspring, then what the principle of natural selection seems to be saying is that organisms that have more offspring have more offspring, or that those that reproduce more reproduce more. This is a tautological statement with no empirical import. This would seem to undercut the empirical underpinnings of evolution by natural selection.

That this objection is bogus can be demonstrated in two ways. Firstly, appealing as it might be for computational reasons, the statistical concept of fitness (that is, measuring fitness by the actual number of offspring) allows sheer luck to be a factor in how fit an organism is, and this is obviously undesirable. At the very minimal level, two organisms with identical genomes living in identical environments should be considered identically fit from an evolutionary standpoint. The fact that one gets eaten before it has a chance to reproduce and the other goes on to mate promiscuously means that the former was unlucky, not unfit. Clearly, fitness ought to be construed as a dispositional trait, referring to the likelihood of having offspring, rather than actual offspring had; expected reproductive success in place of actual reproductive success. Then our alleged tautology becomes "organisms expected (or likely) to leave more offspring will leave more offspring," which can be false, as illustrated by our prematurely devoured hypothetical organism, and so is no longer a tautology.

Second of all the tautology objection makes the egregious mistake of reducing the theory of evolution to the principle of natural selection alone. Natural selection provides the primary engine for evolutionary change, but alone carries no explanatory power unless fuelled by specific, independently testable hypotheses regarding se-

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[12]See Waddington (1968)

lective advantages conferred by the traits it is invoked to explain (which takes us back to objection 1 above). For example, concerning evolutionary modifications of the shape of the beak in a bird species, the evolutionary biologist would postulate *specific* selection pressures acting on the species' ancestral population due to, say, changing availability of food due to a change of climate. These hypotheses can be tested independently by climatology and botanics (if the species in question is herbivorous). Natural selection works through exerting selective pressures on organisms, and it is discerning what these pressures are, how they achieve their results, and how they amalgamate in the web of life, that evolutionary biology is concerned with. The simple pronouncement that something is a result of *some* selection pressures is just as non-explanatory as the opponents of the theory of evolution declare it to be, but it is never made in evolutionary biology.[13]

In conclusion, as has been demonstrated by Duhem, no theory taken in isolation is capable of issuing predictions, therefore attempts to show that the theory of evolution is unscientific for this reason are misguided from the very beginning. As soon as we realize that auxiliary hypotheses are necessary to give any theory its predictive power, and that the theory of evolution thus augmented proves to be quite powerful indeed, the first of the above objections fails. The second quickly follows, once we learn that the theory's power is not unlimited, and held in constant check by independent sciences that supply the auxiliaries, as well as by the requirement of internal coherence. And when we make sure that no tautology is lurking behind the entire edifice, all attempts to divorce Darwinism from its empirical underpinnings collapse. Not only is the theory of evolution by natural selection testable and as empirical as can be demanded of any science; it is also the only currently available account of the development of living forms that explains complexity without having to assume it first.

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[13]Kitcher (1982) provides a comprehensive rebuttal of the tautology objection; my analysis is based on his remarks.

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