

Cryptic designs on the peppered moth

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Received 10-X-2001. Corrected 07-IX-2001. Accepted 20-IX-2001.

In a provocative recent book, Jonathan Wells (2000) decries what he discerns as a systematic pattern in how introductory biology textbooks “blatantly misrepresent” ten routinely cited examples offered as evidence for evolution. Each of these examples, according to Wells, is fraught with interpretive problems and, as such, textbooks that continue to use them should at the very least be accompanied by warning labels. The following essay critiques his reasoning with reference to one of these examples, the phenomenon of industrial melanism. After criticizing Wells’s specific argument, the essay draws several conclusions about the nature of science lost in his account.

In Icons of evolution science or myth? Why much of what we teach about evolution is wrong, Jonathan Wells calls into question whether ten examples of evolutionary change routinely cited by biology textbooks (his so called “icons of evolution”) are as well understood as textbook writers would have us believe. Drawing attention to longstanding published criticisms of each, Wells disputes that they are indeed evidence for evolutionary theory. Indeed, Wells explicitly suggests in the face of these shortcomings that evolutionary theory lacks any evidence in favor of it—it is more akin to myth than the well established scientific theory elitists would have us believe. Importantly, Wells emphasizes that not all biologists are complicit in this blatant misrepresentation of the “facts” in favor of evolution. Most do not conduct research within evolutionary biology and have been indoctrinated to believe these standard examples. Among those biologists who do research in evolutionary biology, awareness of the weaknesses associat-

ed with an example in one’s chosen subdomain of inquiry has curiously not led to recognize similar flaws associated with other examples routinely offered by textbooks in favor of evolutionary theory. Hence the specific task of Wells’s book: to call attention to the consistent “pattern of distortions” (both unconscious and deliberate) of the evidence for evolution in the hope of educating students and the public at large (p. xii).

Wells’s book represents the latest in a series of attempts by creationists¹ to discredit evolutionary theory in favor of an allegedly equally scientific alternative, intelligent design theory (for which Wells, like other authors of this genre, provides no positive evidence).² While most readers of this journal might be inclined to dismiss the book without comment as representing a view best ignored, this essay will comment on Wells’s “argument” because if left unchallenged it might have the appearance of having genuine merit and because of the danger Wells’s book (and works like it)

represent to scientific literacy. The critique that follows will clarify where Wells goes wrong before drawing several morals about the nature of science that apparently have been lost on Wells and those seduced by his presentation. I write primarily with reference to his discussion of the work of H.B.D. Kettlewell, whose work I have studied for the past six years, but (as I hope will be clear to the reader) the morals to be drawn outstrip this particular example.

THE PEPPERED MOTH STORY

Chapter 7 of Wells's book is devoted to the most well known example of natural selection, the phenomenon of industrial melanism as illustrated in the peppered moth, *Biston betularia*, which he pointedly refers to as "the peppered moth story". The strategy of the chapter is to contrast what biology textbooks state about the phenomenon with what is actually known both to underscore how poorly understood the phenomenon actually is and to raise questions about why biology textbooks continue to portray it as a particularly well understood example of natural selection when it is not.

The chapter begins by emphasizing the importance of the peppered moth story as the first direct evidence of natural selection in the wild, aside from Hermon Bumpus's well known (1898) statistical analysis of a fortuitous finding of English sparrows collected after a severe snowstorm. (This claim is, as readers of this journal are undoubtedly aware, historically inaccurate—see Dobzhansky (1951) for a review of several studies documenting natural selection prior to Kettlewell's work on the subject.) The chapter makes reference only once to other studies of natural selection, John Endler's (1986) *Natural selection in the wild*, and does so only to point out that the peppered moth story was mistakenly included in the book by Endler (who when writing was unaware of problems associated with the peppered moth story) as "one of the few cases in which the cause of natural selection was known." (p. 155).

Wells initially recounts the peppered moth story (in which he mistakenly identifies Kettlewell as working with a theory associated with J.W. Tutt³) as follows: "Most peppered moths were light-colored in the early part of the nineteenth century, but during the industrial revolution in Britain the moth populations near heavily polluted cities became predominantly 'melanic' or dark colored. The phenomenon was called 'industrial melanism', but its causes remained a matter of speculation until the early 1950's, when British physician and biologist Bernard Kettlewell performed some experiments which made him famous. Kettlewell's experiments suggested that predatory birds ate light-colored moths when they became more conspicuous on pollution darkened tree trunks, leaving the dark-colored variety to survive and reproduce. Industrial melanism in peppered moths appeared to be a case of natural selection." (p. 138).⁴ The account is juxtaposed by *drawings* of the two forms of the peppered moth on soot darkened and lichen covered trunks in the polluted and rural settings—both of which are fairly easily picked out, despite Wells's caption's assurance that the drawings are intended to illustrate the striking differences in camouflage in the two settings.⁵

Wells then reviews the empirical evidence in favor of Tutt's explanation which consists according to Wells of three field experiments conducted by Kettlewell in the early 1950's and several field studies conducted from the late 1950's to the 1970's that documented a predictable decline of the melanic form of the moth following the advent of clean air legislation. While acknowledging additional research has been done by Kettlewell and others, Wells interprets subsequent work as uncovering a series of insurmountable interpretive problems associated with Kettlewell's original investigations. One has only to examine the text of the articles Wells cites (*e.g.* Grant 1999) to know much more research has been done on the phenomenon of industrial melanism than he indicates, much of it affirming Kettlewell's basic explanation (see Majerus 1998).

What are the problems scientists have uncovered regarding Kettlewell's original investigations? According to Wells, they fall into three categories. First, the actual distribution of the dark form of the moth is not confined to areas near (downwind) of manufacturing centers. Second, there are interpretive problems associated with the precise role of the lichen cover. And third, peppered moths are known not to rest on tree trunks. For each type of problem, Wells deftly shows that there are studies that throw doubt on this part of Kettlewell's explanation and further that there are pointed disagreements among scientists about the merits of the evidence. While acknowledging that almost all of the participants still believe that, on the whole, the evidence supports the basic story we associate with Kettlewell, Wells clearly suggests that this belief is held on to dogmatically more as a matter of faith in Darwinian evolution than a careful and unbiased examination of the evidence in question.

CRITIQUE

Specific problems with Wells's analysis

Wells is correct in pointing out that the phenomenon of industrial melanism has proven to be more complicated than textbooks would have us believe. The reason why the explanation is turning out to be complicated, however, is *not* that an evolutionary explanation in terms of natural selection is not applicable. Rather, it is because the phenomenon itself has turned out to be more complicated, as revealed by numerous additional investigations conducted by Kettlewell and other researchers since. For instance, with regard to Wells's first concern about a few anomalous populations where the frequency of *carbonaria* is relatively high in the absence of pollution, it is fairly clear (as Kettlewell was well aware) that the environment of the moths can become darkened by factors other than soot (Kettlewell 1973). We have good reasons to believe the

phenomenon of melanism has been a recurring pattern in nature in many animal groups and for a variety of reasons. Smoke from volcanoes in the past in all likelihood had a very similar effect to industrial pollutants in darkening the environment downwind from the source. Moreover, when one considers that the environment can become dark due to other factors (*e.g.* increased humidity), and further that melanic coloration might have other effects on the health of the moth (*e.g.* thermoregulation), it becomes possible to understand how an "anomalous" population in a rural area might have a high frequency of melanic forms as a result of differential bird predation even in the absence of pollution.

Discrepancies in peppered moth distribution might also be the result of the fact that the *carbonaria* gene conferring dark coloration may have other effects on the physiology of the moth, such as making it more tolerant to other components of the pollutants in question, such as sulfur dioxide emissions (Cook *et al.* 1999). The exact role of migration between individual populations of peppered moths needs further attention as well (Cook 2000). The important thing to note is that these interpretive difficulties underscore the fact that a single explanation of the phenomenon of industrial melanism might not fit each and every population within which it occurs—much hinges on details associated with each individual population (Majerus 1998, 1999). Disagreements among scientists regarding the precise role of each of these factors with reference to a particular population is a typical situation in biology, and indeed symptomatic of an active area of investigation. The fact that the oversimplified explanation recounted in textbooks does not fit every population within which the phenomenon has been found to occur is entirely predicably given the unique and contingent nature of biological phenomena.⁶

Well's second concern, his argument concerning the role of lichen in the phenomenon, (like other parts of his book) rests crucially on either a woeful misrepresentation of the scientific work he does cite (*e.g.* Majerus 1998) or a

blatant neglect of work bearing specifically on the question at hand (*e.g.* Grant *et al.* 1996). For instance, while it is the case that Bruce Grant has raised concerns about the emphasis placed on lichen cover associated with the classic account of the phenomenon of industrial melanism, Wells misleadingly suggests Grant interprets these concerns as calling into question the role of camouflage—despite Grant’s published statements pointing out that the light form of the peppered moth is quite effectively camouflaged even in the absence of lichen (Grant 1999, p. 983). Again, Wells’s portrayal of debates among investigators on this topic relies on a distorted view of the nature of science that invites readers to interpret arguments over details of a particular phenomenon as disputes calling into question the fundamental tenets of evolutionary biology.

Wells’s most serious concern about the peppered moth story is that the photographs that accompany textbook accounts were staged, and continue to be used despite the fact that evidence has been accumulating since the 1980’s that “peppered moths do not normally rest on tree trunks” (p. 149).⁷ Wells is correct in pointing out that some studies have suggested that the moth might spend most of the day higher in the canopy and/or underneath the boughs of trees and if they did not spend the day on tree trunks this would seriously undermine the basis of Kettlewell’s experiments. However, it is an overstatement to suggest, as he repeatedly does, that it is *known* that peppered moths do not rest on tree trunks—it is still the object of ongoing observation and experiment. Nevertheless, Wells does raise an interesting question about whether textbooks should continue to use staged photographs of peppered moths resting on tree trunks when there is serious cause for doubting that this is the case. I’m inclined to think it isn’t a particularly serious problem in the context of a biology textbook when the photographs are used to clarify a particularly lucid illustration of the concept of natural selection. Heuristic considerations associated with clarifying an important and difficult biological concept such as

natural selection may at times justify the use of examples teachers recognize are not completely accurate. We do this all the time in physics classes when, for instance, we teach Newtonian mechanics in full recognition of the fact that it is technically false. But why not, after having introduced the concept of natural selection by means of the phenomenon of industrial melanism, use this problem regarding the exact resting location of the moths as a vehicle for discussing the process of science and nature of science issues more generally?⁸ It is simply disingenuous on Wells’s part to suggest that textbooks intended for children and adults with limited backgrounds in biology should introduce science in all its complexity.

*More general problems
with Wells’s analysis*

After reading Wells’s chapter on the peppered moth, the careful reader would be wise to reflect upon what Wells has in fact accomplished and how this fits into the overall argument of the book. Two interpretations suggest themselves. First, the title of Wells’s work and also page 6 of his introductory chapter suggest Wells views the peppered moth story as proffered evidence for Darwinian evolution. From this perspective, the goal of the chapter, should be to clarify why contemporary research on the peppered moth casts doubt on the claim that it indeed is an example of evolutionary change. Since the peppered moth story on Wells’s own account does not involve the creation of new species, the task before him, presumably is that of disputing that the phenomenon of industrial melanism is indeed an example of microevolutionary change. Wells pointedly does *not* accomplish this task, and indeed not only acknowledges that the dark form of the moth is inherited (p. 141) but that we also have records documenting changes in the relative frequencies of different forms of the moth over time (p. 140-143). Thus, even by his own account, the peppered moth story is a well documented example of evolutionary change.

Of course, in common with other critics of evolutionary theory, Wells disputes that change over time (aka microevolution) represents evidence in favor of evolutionary theory. “No rational person denies the reality of change...If evolution meant only this, it would be utterly uncontroversial” (p. 5). Other creationists would be inclined to dismiss the peppered moth story as evidence for evolutionary theory, restricted to “the theory that all living things are modified descendants of a single common ancestor that lived in the distant past” (p. 4) because it does not involve the creation of new species. Wells in contrast recognizes that it is often cited as evidence of Darwin’s chief mechanism of evolutionary change, namely natural selection. These considerations point to a second interpretation for the goal of Well’s discussion of the peppered moth story, namely disputing that it is indeed an example of natural selection.

To begin with, let’s remind ourselves of Darwin’s theory of natural selection with reference to the phenomenon of industrial melanism:

1. If the peppered moth has both dark and light forms, and if these differences are correlated with survival differences in different environments; and,
2. If the dark and light forms are heritable; and,
3. If there is a competition in nature for resources, owing to the fact that the moths reproduce far in excess of those that can possibly survive;
4. It follows that the form of the moth that is correlated with an increased chance of surviving in an environment will increase in frequency in the population inhabiting that environment over time (if it is not already in equilibrium).

The reader should notice immediately that the theory need not be stated with reference to the specific survival advantage associated with dark coloration in polluted environments or pale coloration in unpolluted locals. As such, even in the absence of *any* reliable evidence on precisely what effect of the *carbonaria* gene is

responsible for increased survival in areas downwind of industrial sites, the phenomenon of industrial melanism still constitutes an example of natural selection.

In this light, Wells’s discussion boils down to the worry that textbooks suggest that there is a consensus among investigators regarding the precise selective mechanism responsible for the phenomenon of industrial melanism when there is none. Even here, he misrepresents the controversy among biologists who work on the phenomenon, because he suggests that investigators disagree much more strongly about the evidence than is in fact the case.

On evidence

One of the curious aspects of Wells’s discussion (in common with other creationist writings) is his dogmatic insistence on an extremely narrow and unadvised view of what constitutes evidence in science (see Pennock 1999). Evidence for a theory, according to Wells, is restricted to considerations of empirical adequacy—namely how well the predictions of the theory mesh with what we observe. Certainly scientific theories are judged in part by the extent to which they accord with the results of experiments and observations, but this is only part of the story, particularly when, as is the case with evolutionary theory, the phenomena in question may range over the space of continents and hundreds of millions of years. In lieu of direct evidence, scientists often rely on other criteria. In the case of Darwin’s theory of common descent, for instance, it was the explanatory power of the theory and its ability to unite what were otherwise disparate but tantalizingly related biological phenomena that led to its initial adoption by scientists. With reference to his theory of natural selection, Darwin had a host of direct evidence that each of the conditions postulated on his theory did exist in nature (within a population organisms vary from one another, some of these variations are correlated with survival and reproductive success, organisms in every species reproduce far in excess of those that could possibly survive). What Darwin

lacked was direct evidence of the predictable and probabilistic consequences of these conditions in nature. Here he gestured in the direction of the results of domestic breeders, which provided an important source of indirect evidence for the mechanism. But we should recognize that Darwin's situation is not at all unique—scientists in all fields regularly make and substantiate claims about entities and processes they cannot or have not observed in nature with reference to indirect evidence. This includes claims about solar systems we've never visited, the discovery of atoms, and historical claims about the past.

CONCLUSIONS

Critics would have us believe that the scientific standing of evolutionary theory rests on ten examples routinely cited in textbooks. From this perspective, one can see the rationale behind taking pot shots at the poster children of evolution in the hope the entire edifice will come crumbling down. The situation is not this dire—the evidence we currently have in favor of evolutionary theory is overwhelming. The curious point lost on Wells is that Darwin and his contemporaries were compelled to believe in the fact of evolution in the absence not only of contemporary evidence, but also most of the icons Wells frets over.

Wells's discussion begins and ends with textbooks and how he says they are used to systematically "indoctrinate" students into believing the truth of evolutionary theory. What Wells has actually shown is that a comparison between journal articles written by professional evolutionary biologists and short entries written for introductory biology texts illustrates there are differences between the two accounts. Nobody needed Wells to tell us that.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the insightful comments of Bruce Grant, Joel

Hagen, Eric Howe and Rob Pennock on an earlier version of this manuscript.

NOTES

- 1 Pointing out that Wells has an implicit agenda in this context (Coyne 2001) is *not* an argument *ad hominem*. Just as readers of an article that disputes the carcinogenic effects of nicotine should be informed as to whether the research has been funded by the tobacco industry when evaluating its merits, so too a reader of a book disputing evolutionary theory written by someone without a strong background in evolution should be made aware of the possibility that his interpretation has been colored by considerations other than a careful appraisal of the evidence.
- 2 See Pennock 1999 for a recent critical review of this literature.
- 3 James William Tutt (1890) is generally recognized as the first to publish an explanation of the phenomenon of industrial melanism solely in terms of the selective value of melanic coloration in soot darkened environments. Although often portrayed as a test of Tutt's theory, Kettlewell (1955, 1956, 1958) clearly indicates he worked under a model of the phenomenon of industrial melanism developed by E.B. Ford, his mentor at Oxford, that proposed that the phenomenon was the result of *two* selective forces, of which selection for color was initially indicated as the less important (see Rudge 1999).
- 4 Note the rhetorical importance for Wells of stressing that the phenomenon is a "matter of speculation" until its causes are understood. Note also that the key point of the explanation, that the phenomenon occurs *downwind* of industrial centers, as a consequence of the accumulation of soot *carried by wind*, is lost when described as simply occurring "near" heavily polluted cities. The word "become" is also objectionable in this context, as it suggests the moths undergo some sort of transformation upon alighting on tree trunks, which contrasts with how biologists would describe the situation—namely that the dark form *is* inconspicuous when it rests on a soot darkened trunk, whereas the pale form on the same trunk *is* conspicuous. Throughout the chapter Wells incorrectly discusses the phenomenon (and work on it) as if it only occurred in Britain, with only one isolated mention to work done in the U.S.—despite recognition by each of the researchers he cites that it is a much more general phenomenon.
- 5 Wells's choice to depict the contrast by means of drawings, rather than photographs, seems deliberately made to undercut the plausibility of Kettlewell's explanation—a comparison of these drawings with photographs from any standard biology text will clarify that the moths on their correct (matching)

backgrounds are much more difficult to locate than the drawing suggests.

- 6 See Grant 1999 for a technical review of the import of contemporary research on our current understanding of the phenomenon of industrial melanism.
- 7 See Rudge "The role of photographs and films in Kettlewell's popularizations of the phenomenon on industrial melanism" (manuscript submitted to *Science and Education*) for a discussion of Kettlewell's use of these photographs.
- 8 See Rudge 2000 for a more extended treatment of this argument.

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