

## PEPPERED MOTHS

### THE STORY OF THE PEPPERED MOTH

Industrial melanism in peppered moths is one of the most frequently used examples of natural selection in action. This is largely because of its pedagogical simplicity — it is a straightforward example that is visual and dynamic — and its copious documentation. Industrial melanism refers to the darkening of color that occurred in a number of species of insects following the Industrial Revolution. This change appears to be related to the increase in pollutants in the environment. Before the Industrial Revolution, individuals of the moth species *Biston betularia* (commonly called the “peppered moth”) were predominantly white with black speckles. By the end of the 1800s, they were predominantly charcoal grey. This change was well documented and led Tutt (1896) to hypothesize that this change was a result of pollution-stained trees’ affecting the camouflage potential of the moths. This change was termed “industrial melanism.” In the 1950s, Bernard Kettlewell decided to test the hypothesis that natural selection was working on the differential camouflage of the moths. In order to do this, he released marked light and dark moths into polluted and non-polluted forests. He found that birds appear to prey selectively on light moths in polluted forests and on dark moths in non-polluted forests and so documented the idea of natural selection of these color patterns in moths by birds. After anti-pollution laws took effect and the bark lightened, the moth populations in formerly polluted areas returned to previous color distributions.

### HOW MANY MOTHS CAN DANCE ON THE TRUNK OF A TREE? DISTRACTION BY IRRELEVANT DATA

Wells disagrees with the results of the research on industrial melanism in the peppered moth, and manipulates the literature and the data to fit his views. He points out that the “problem” of the peppered moths is far from simple. His discussion centers on three points where he believes textbooks are in error, alleging that (1) the daytime resting places of peppered moths invalidates Kettlewell’s experimental results; (2) the photos of the moths are “staged”; and (3) the recovery patterns of populations dominated by light moths after the levels of pollution were reduced do not fit the “model,” although he is unclear as to what the “model” is. All three of these objections are spurious. They are distractions from the general accuracy of the story and its value in showing the effects of natural selection on genetic variability in natural populations.

First, Wells argues that the story is seriously flawed because “peppered moths in the wild don’t even rest on tree trunks” (Wells, 2000:138). He repeats this point throughout the chapter. However, it is both false and irrelevant, and only serves as a distraction to lead the reader away from the actual story of the moths. Contrary to Wells’s assertions, data given by Majerus (1998:123) indicate that the moths do indeed rest on the trunks of trees 25% of the time. The rest of the time moths rest in branches (25%) or at branch-trunk junctions (50%). The facts have been pointed out repeatedly to Wells; his response has been mostly to claim that moths don’t rest on “exposed” tree trunks (Wells, 2002 [www.discovery.org/viewDB/index.php3?program=CRSC&command=view&id=1144](http://www.discovery.org/viewDB/index.php3?program=CRSC&command=view&id=1144)). But this is *not* what he said in the text of *Icons*, which

remains flatly wrong. Moths are found all over trees, which is not a surprise (Clarke et al., 1994) and it is mentioned in the references that Wells cites.

To clear up any confusion, no researcher doubts that the peppered moth rests in trees (Clarke et al. 1994; Majerus 1998), which means that the resting substrate is bark. *Entire* trees are stained by pollution — the leaves, twigs, branches, trunks, and the surrounding ground (Kettlewell, 1973) — and so the colors of the moths are relevant no matter where on the tree they rest — trunks, trunk-branch junctions, branches, twigs, and even the leaves. Wells's argument implies that predatory birds can only see moths that are on *exposed trunks*. By making this argument, however, Wells shows an apparent ignorance of the ecology of birds and woodland ecosystems. If you walk into any forest, you can see that the birds fly from tree to tree, branch to branch, and hunt at all levels of the forest. Woodland species of birds that prey on moths and other insects live and hunt *in* the canopy (the leafy part of the trees). These birds are not hunting from outside, soaring above the trees like hawks, as Wells's argument would require.

In the scientific literature, there is extensive discussion of the hunting behavior of birds, including those that hunt peppered moths. Ornithologists have shown the woodland ecosystem to be vertically stratified by competition between different bird species. This zonation means that there are skilled predators patrolling all levels of the forest: the trunks, trunk-branch joints, branches, and higher canopy (Colquhoun and Morley, 1943; Hartley, 1953). Further, birds learn to distinguish their prey against various backgrounds and preferentially hunt prey in locations where they have found it in the past and that birds selectively prey on the more visible moths (Pietrewitz and Kamil, 1977, 1981). In other

words, birds hunt the prey they can see and hunt it where it *is*, not where it isn't. Therefore, no matter where the moth rests in the tree, it is visible to predatory birds, and thus its differential camouflage is important.

The purpose of Wells's distraction is to put the actual experiments into question and make it sound as if the textbook authors are either mistaken, or intentionally trying to fool students. The insinuation is that because Kettlewell released the moths during the day, they did not find "normal" resting places. Whether or not this is so, the release and capture experiments took place over a number of days, so the moths were able to take up positions of their choosing, even if the first day was not perfectly "natural" (Kettlewell, 1955, 1956, 1973). Kettlewell's experiments were not perfect — few field experiments are — and they may have magnified the degree of selection, but all serious researchers in the field agree that they were certainly not so flawed as to invalidate his conclusion.

In his second objection, Wells ties the Kettlewell experiments to textbooks by constantly repeating the statement that the illustrative photos were "staged" (Wells, 2000:150); the important issue here is not how the photos were made, but rather their intent. Wells implies that the photos purport to show a "life-like" condition to prove that moths rest on trunks. This is not the case. The photos are meant to demonstrate the visibility of the different forms of the moth on polluted and unpolluted trees. It is absurd to expect a photographer to just sit around and wait until two differently colored moths happen to alight side by side. Further, how the photos were produced does not change the *actual* data. Birds eat moths and they eat the ones that they see more easily first. The textbook photos never claim to depict a real-life situation, and it is improper to imply otherwise.

The third criticism, and the only scientific one that Wells levels, deals with the recovery of the light form of the moth following the institution of pollution control laws. The main thrust of his argument is that because the recovery of light-colored lichens does not correlate with the recovery of the light form of the moths, the entire story is incorrect. Wells exploits the fact that the original researchers thought that the camouflage of the light moths depended on the presence of lichen. However, the light forms recovered before the lichens did; therefore, Wells concludes, natural selection has nothing to do with the story. Although it is true that the moths are well-camouflaged against lichens, and lichens are destroyed by pollution, nevertheless the camouflage of the moths ultimately depends upon the color of the trees, which reflect the amount of soot staining the trees. Although lichens play a role in camouflage, they are not *necessary*. This is what happened: pollution was reduced, the trees got lighter, then the moths got lighter. Further, in all areas, the light moths have recovered, as predicted by the hypothesis. This is clearly stated in the literature (e.g., Grant et al., 1998), but it does not fit Wells's story, and he just ignores it.

#### TEXTBOOK TREATMENT OF THE PEPPERED MOTHS

All but one of the textbooks (Campbell, Reese, and Mitchell) reviewed in *Icons* cover the peppered moths and present the basic story correctly. Again, however, the coverage is limited to only a couple of paragraphs (Figure 15), varying from 117 to over 500 words. Miller and Levine devote more than a page to the story, and even discuss some of its complexity, suggesting that the story is not as simple as it seems.

#### GREY AREA GRADES

Like the grading schemes for the other “icons,” this one is stacked against the textbooks as well. Even books that have more extensive discussions of the problems and details (such as Miller and Levine) can at best earn a D. Like the grading schemes for Miller-Urey and Haeckel's embryos, it is based largely on the presence or absence of pictures (Figure 15). Explaining the peppered moth story without photos (as in Biggs et al.), garners a peculiar X grade. In order to get an A or B, a book must contain pictures of moths in “natural” resting places. Given Wells's explanation that these are unknown, presenting those would be impossible. How can textbooks be expected to do that? A C would be awarded to a textbook that (1) used “misleading” pictures, but (2) referred to them as “staged,” and (3) stated that the results of the experiment are in doubt. Any standard textbook discussion of the issue, *even if* it mentions that the story is more complicated, is given a D. So as usual, this is a “no win” situation. This falls into Wells's pattern of requiring the books to “criticize” their examples, although the criticisms he insists on are largely fallacious.

#### WHY WE CAN STILL TEACH PEPPERED MOTHS AS AN EXAMPLE OF NATURAL SELECTION

Although there will always be details of the peppered moth story that we do not fully understand, its status as an example of natural selection is not even remotely in doubt. There is a clear correlation between pollution levels and moth color. Even if bird predation may not be the only factor involved in the selection of one color over another, observations show that bird predation and substrate color play the major roles in natural selection of the color of peppered moths. There are many areas in science where our knowledge is

Book	Peppered Moths		
	#pages	#words	Wells's grade
Schraer, W. D. and H. J. Stolze. 1999. <i>Biology: The Study of Life</i> , seventh edition. Prentice-Hall, Upper Saddle River, NJ. 944p.	1.5	440	F
Johnson, G. B. 1998. <i>Biology: Visualizing Life</i> . Holt, Rinehart & Winston, Orlando. 895p.	1	245	F
Biggs, A., C. Kapinka, and L. Lundgren. 1998. <i>Dynamics of life</i> . Glencoe/McGraw Hill, Westerville, OH. 1119p.	1/3	117	X
Miller, K. R. and J. Levine. 2000. <i>Biology</i> , fifth edition. Prentice-Hall Upper Saddle River, NJ. 1114p.	1.5	500	F
Starr, C. and R. Taggart. 1998. <i>Biology: The Unity and Diversity of Life</i> , eighth edition. Wadsworth Publishing Company, Belmont CA. 920p.	3/4	346	F
Guttman, B. S. 1999. <i>Biology</i> . WCB/McGraw-Hill, Boston. 1175p.	3/4	299	F
Mader, S. 1998. <i>Biology</i> , sixth edition. WCB/McGraw-Hill, Boston. 944p.	1 + 1/2	364 + 80	F
Raven, P. H. and G. B. Johnson. 1999. <i>Biology</i> , fifth edition. WCB/McGraw-Hill Boston. 1284p.	2	>500	D <sup>1</sup>
Campbell, N. A., J. B. Reese, and M. G. Mitchell. 1999. <i>Biology</i> , fifth edition. Benjamin Cummings, Menlo Park, CA. 1175p.	-	-	N/A
Futuyma, D. 1998. <i>Evolutionary Biology</i> . Sinauer Associates, Sunderland, MA. 761p.	1/4	121	D <sup>2</sup>

1. While the text does not call the photos "staged," it does mention the questions surrounding the daytime resting places of the moths, and it discusses the possibility of "other" selective factors. A "C" would be a more appropriate grade.

2. Futuyma clearly states that the photos are staged, but does not say that moths do not rest on trunks. A "C" may be a more appropriate grade.

### Figure 15. Wells's grades for textbooks' treatments of peppered moths.

incomplete, but that does not mean we should not teach about them. There are things we still do not know about gravity, but no one is demanding that examples of gravity in action be removed from textbooks.

### HOW TEXTBOOKS COULD IMPROVE THEIR PRESENTATIONS OF PEPPERED MOTHS

For the most part, textbook coverage of the peppered moth story is adequate. As always, expanding the discussion would improve the coverage in the textbooks that cover it briefly. Textbooks could qualify the captions with a statement that the pictures illustrate differential camouflage in order to clear up any misunderstanding (however unlikely) as to the meaning of the photos. A better way for books to improve the topic is by adding other examples of natural selection act-

ing on genetic variation. Some books already cover sickle-cell anemia in humans (Figure 15). Other possible examples include antibiotic resistance in bacteria and myxomatosis virus in rabbits in Australia. The key here is to expand the exposure of students to the many examples of natural selection-driven evolutionary change (e.g., Endler, 1986). What is curious about Wells's criticism of the peppered moth is that he says in *Icons* that he accepts "microevolution." The peppered moths are an example of "microevolution," so why does he have a problem with teaching it?

## References

- Clarke, C. A., B. S. Grant, F. M. M. Clarke, and T. Asami. 1994. A long term assessment of *Biston betularia* (L.) in one UK locality (Caldy Common near West Kirby, Wirral), 1959-1993, and glimpses elsewhere. *Linnean* 10:18–26.
- Colquhoun, M. K., and A. Morley. 1943. Vertical zonation in woodland bird communities. *Journal of Animal Ecology* 12:75–81.
- Endler, J. AL. 1986. *Natural Selection in the Wild. Monographs in Population Biology* 21. Princeton University Press, Princeton, 336p.
- Grant, B.S., A.D. Cook, C.A. Clarke, and D.F. Owen. 1998. Geographic and temporal variation in the incidence of melanism in peppered moth populations in America and Britain. *Journal of Heredity* 89:465–471.
- Hartley, P. H. T. 1953. An ecological study of the feeding habits of the English titmice. *Journal of Animal Ecology* 22:261–288.
- Kettlewell, H. B. D. 1955. Selection experiments on industrial melanism in the Lepidoptera. *Heredity* 9:323–342.
- Kettlewell, H. B. D. 1956. Further selection experiments on industrial melanism in the Lepidoptera. *Heredity* 10:287–301.
- Kettlewell, H. B. D. 1973. *The evolution of melanism: the study of a recurring necessity; with special reference to industrial melanism in the Lepidoptera*. Clarendon Press, Oxford. 423p.
- Majerus, M. E. N. 1998. *Melanism: evolution in action*. Oxford University Press, New York. 338p.
- Pietrewicz, A. T. and A. C. Kamil. 1977. Visual detection of cryptic prey by blue jays *Cyanocitta cristata*. *Science* 195:580–582.
- Pietrewitz, A. T., and A. C. Kamil. 1981. Search image and the detecting of cryptic prey: an operant approach. In A. C. Kamil and T. D. Sargent eds. *Foraging behavior. Ecological, ethological and psychological approaches*. Garland Press, New York, p. 311–331.
- Tutt, J. W. 1896. *British Moths*. George Routledge, London 368p.
- Wells, J. 2000. *Icons of evolution: science or myth?: why much of what we teach about evolution is wrong*. Regnery, Washington DC, 338p.