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| **Gapless Explanation -for the educator**Big IdeasBernard Kettlewell’s 1950 study of peppered moths observed that the sooty bark of the local trees resulted in increases of the darker form of the peppered moth and decreases of the lighter form. This resulted in the hypothesis that the population change was due to the process of natural selection driven by bird predation. | Gapless Explanation KeyLeft column = Researching the topicRight column = Connections to the Next Generation Science Standards Red = ESS3.C Human Impacts on Earth Systems Purple = LS3A Inheritance of TraitsOrange = LS3.B Variations of TraitsBlack = LS4.B Natural SelectionBlue = LS4.C AdaptationGreen = Nature of Science Appendix F |
| Supporting research (Majerus, 2009)* Biological evolution may be defined as a change in the frequency of an allele through time.
* The carbonaria (dark) form of the peppered moth differs from f. *betularia* (light form) with respect to the alleles of a single gene. (There is also an in-between form)
* The frequency of the carbonaria allele did increase during the nineteenth and first half of the twentieth centuries, and is now declining as less soot is present on forest trees.
* “This is irrefutable evidence of biological evolution.” (Majerus)

Essential QuestionHow is the Peppered Moths Phenomena a model of Natural Selection?Explanation Scenario of the Peppered Moths -educator level* Economic changes known as the Industrial Revolution began in the nineteenth century.
* In England during this time, coal-burning factories spewed tons of coal dust into the surrounding area, causing a sooty deposit on the bark of local trees.
* In 1848, a dark-colored phase of the peppered moth, Biston *bistualla,* was first recoded.
* In 1896, the Lepidopterist, J.W. Tutt, hypothesized that the increase in carbonaria, was the result of differential bird predation in polluted regions.
* Bernard Kettlewell obtained evidence in support of this hypothesis in the 1950s, with his predation experiments in polluted and unpolluted woodlands.
* Kettlewell concluded that this peppered moth phenomenon was evidence of the process of Natural Selection. ([www.biologycorner.com/worksheets/peppered moth.html](http://www.biologycorner.com/worksheets/peppered%20moth.html))
* There was a variation of color phase in the peppered moth population.
* While resting during the day against the bark of the sooty trees, darker peppered moths were more camouflaged and less likely to be eaten by predator birds.
* Surviving moths were able to mate and reproduce more dark moth offspring than light moths.
* Over moth generations, more of the peppered moth population had the darker coloration trait than the light coloration trait.
* When pollution was abated in this area, more light phase moths were observed.
* Later studies conducted by Majeras confirm that the peppered moth can be considered an example of a case of natural selection driven by bird predation.(Cook, L.M., Grant, I.J. Saccheri, J. Mallet. 2012. Selective bird predation on the peppered moth: the last experiment of Michael Majerus. *Biol. Lett.* DOI: 10.1098/rsbl.2011.1136)
* In 2006, the gene location for the peppered moths’ dark color phase was identified.
* The industrial melanism mutation in British peppered moths is a transposable element. (van’t Hof, A. et al. 2016. Nature 534:102-105)
* The initial study and later re-examination of Kettlewell’s findings is a clear example of the application of the Nature of Science (NGSS Appendix H)

Additional information.* No moth lives for over a year.
* This phenomenon was observed across both sides of the Atlantic Ocean.
 | Disciplinary Core Ideas from NGSSESS3.C Human Impacts on Earth Systems Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth’s environments can have different impacts (negative and positive) for different living things.LS3.A Inheritance of Traits Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits.Variations of inherited traits between parent and offspring arise from genetic differences that result from the sub-set of chromosomes (and therefore genes) inherited. (MS-LS3-2)  LS2A Interdependent Relationships in Ecosystems(Similarly,),) predatory interactions may reduce the number of organisms or eliminate whole populations of organisms.LS3.B Variations of TraitsIn sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two alleles of each gene, one acquired from each parent. (MS-LS3-2)In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others are harmful, and some are neutral to the organism.LS4.B Natural SelectionNatural Selection leads to the predominance of certain traits in a population, and the suppression of others. (MS-LSS-4)LS4.C AdaptationAdaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. (MS-LS4-6)Excerpts of the Understandings about the Nature of Science associated with Practices* Science knowledge is based on empirical evidence Science Knowledge is based upon logical and conceptual connections between evidence and explanations.
* Scientific knowledge is open to revision in light of new evidence
* Science findings are frequently revised and/or reinterpreted based on new evidence.
* Science models, laws, mechanisms, and theories explain natural phenomena
* Science theories are explanations for observable phenomena
* A hypothesis is used by scientists as an idea that may contribute important new knowledge for the evaluation of a scientific theory.
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