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Nature of Science and Common Core Math Practices
Course: Methods of STEM Education Secondary

Article: "The Vampire Birds of the Galápagos Have Fascinating Inner Lives: Yes, there is such a thing as a vampire finch," by Joshua Sokol, Published June 8th, 2019, The New York Times.

Rationale: This article represents a phenomenon that is relatively simple to model: vampire finches eating blood from Nazca Booby birds when other food sources are scarce. Underlying this simplicity are questions of adaptation and evolutionary history. Many students at the secondary level are familiar with the finches on the Galapagos Islands as evidence of divergent evolution by the principle of Natural Selection as described by Charles Darwin. The article also introduces the possibility of convergent evolution of gut bacteria amongst blood eating animals in various places in order to be able to digest blood. Although not explicitly mentioned in the article, parasitism is also described. Ideally, a phenomenon allows students to connect many disciplines of science: in this example, genetics, microbiology, evolution and ecology are connected.

Part A: Nature of Science

1) **Scientific knowledge assumes an order and consistency in natural systems**
   High School level understanding: Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future. (Appendix H, 2013)

The Theory of Evolution by Natural Selection postulates that organisms with similar characteristics share a recent common ancestry. This common ancestry was first demonstrated by morphological similarities and with the advent of genomic testing, it is now possible to show common ancestry through sharing similar DNA/RNA. In this article, one of the original studies was referenced. This study by Alice, et al., sequenced an rRNA sequence and it was found that almost all of the species of finch share similar gut biota,

> We characterized the microbial community associated with 12 species of Darwin's finches using high-throughput 16S rRNA sequencing of fecal samples from 114 individuals across nine islands, including the unusual blood-feeding vampire finch (*Geospiza septentrionalis*) from Darwin and Wolf Islands. The phylum-level core gut microbiome for Darwin's finches included the Firmicutes, Gammaproteobacteria, and Actinobacteria, with members of the Bacteroidetes at conspicuously low abundance. The gut microbiome was surprisingly well

> conserved across the diversity of finch species, with one exception—the vampire finch—which harbored bacteria that were either absent or extremely rare in other finches, including *Fusobacterium*, *Cetobacterium*, *Ureaplasma*, *Mucispirillum*, *Campylobacter*, and various members of the Clostridia—bacteria known from the guts of carnivorous birds and reptiles. (Alice, 2018)

This article clearly shows how common ancestry and similar genetic sequences are a function of evolution.

2) **Science is a human endeavor**
High school level understanding: Individuals and teams from many nations and cultures have contributed to science and to advances in engineering (Appendix H, 2013).

In the study of complex phenomena and collecting supporting data from multiple disciplines of science, scientists must cooperate. Scientists must specialize out of necessity but in order to make connections between their fields, they rely on each other for both ideas and logistical support. In this article, the original researcher Song has studied vampire bats in Central and South America and she also wants access to the feces of vampire finches in the Galapagos in order to compare genetic sequences of the bacteria found in the feces,

> Dr. Song already had collected data on vampire bats. But to compare these animals to the birds, she had to turn to colleagues working in the Galápagos, who collected samples of vampire-finch poop (Sokol, 2019)

Travel is expensive and scientists who work in a particular locale are able to collect specimens much more easily than a scientist who has never worked in a locale. The Internet has also facilitated the sharing of information through platforms such as E.O. Wilson's Encyclopedia of Life where taxonomists and biologists from all over the world upload information. This allows scientists from all over the world to have access to the findings and use the information of their colleagues.

3) Scientific knowledge is open to revision in light of new evidence
High school level Understanding: Scientific explanations can be probabilistic (Appendix H, 2013).

This New York Times article and the two supporting research articles that are referenced pose some interesting questions. As Song states in her abstract, "Animal microbiomes play an important role in dietary adaptation, yet the extent to which microbiome changes exhibit parallel evolution is unclear (Song, 2019). Scientists have established how evolution proceeds at the organismal level but they are unsure of how symbiotic gut biota might evolve as well. In addition to looking at bacteria as evidence of convergent evolution amongst blood-drinking animals, other scientists are planning to research other biochemical adaptations present,

> Back on the Galápagos, Dr. Song's co-authors, Jaime Chaves, of the University of San Francisco de Quito, in Ecuador, and Daniel Baldassare, a fellow biologist, are testing whether the finches have also evolved any of the pain-numbing or anti-clotting proteins that vampire bats use on their victims (Sokol, 2019).

There is a probability that animals with certain functionality will also have similar biochemistry. This exemplifies how new evidence leads to new hypotheses.

B) Common Core Mathematics Practices

Context and science teacher bias: It was so hard for me to connect directly to the article at first. In fact, the first mathematics practice that came to mind was the third one, "Construct viable arguments and critique the reasoning of others." And then I read this in Appendix L,

> About CCSSM practice standard MP.3: None of the connections boxes include a link to CCSSM practice standard MP.3, which reads, "Make viable arguments and critique the reasoning of others." The lack of a connection to MP.3 might appear surprising, given that science too involves making arguments and critiquing them. However, there is a difference between mathematical arguments and scientific arguments—a difference so fundamental that it would be misleading to connect to MP.3 here. The difference is that scientific arguments are always based on evidence, whereas mathematical arguments never are. It is this difference that renders the findings of science provisional and the findings of mathematics eternal..." Blurring the distinction between mathematical and scientific arguments leads to a misunderstanding of what science is about. (Appendix L, 2013)

1) **Reason quantitatively and abstractly**
   High School level understanding: Make inferences and justify conclusions from sample surveys, experiments, and observational studies

   CCSS.MATH.CONTENT.HSS.IC.B.4
   Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

   In the collection of samples of feces of the vampire finches, only a sample of birds were part of the study, and then these results are extrapolated to the vampire finch population in general.

   2. Model with mathematics
   High school level understanding: Modeling

The use of both descriptive and analytical models such as graphs allow complex data to be represented in a way that creates meaning. Another aspect of modeling that is found in the way this study was conducted was the methodology used by the researchers. The Common Core Math Practices describes a modeling process,

> The basic modeling cycle is summarized in the diagram. It involves (1) identifying variables in the situation and selecting those that represent essential features, (2) formulating a model by creating and selecting geometric, graphical, tabular, algebraic, or statistical representations that describe relationships between the variables, (3) analyzing and performing operations on these relationships to draw conclusions, (4) interpreting the results of the mathematics in terms of the original situation, (5) validating the conclusions by comparing them with the situation, and then either improving the model or, if it is acceptable, (6) reporting on the conclusions and the reasoning behind them (High School Modeling).

This process shows the reasoning inherent in creating and explaining a model.

3) Use appropriate tools strategically
High school level understanding: Summarize, represent, and interpret data on a single count or measurement variable

CCSS.MATH.CONTENT.HSS.ID.A.1
Represent data with plots on the real number line (dot plots, histograms, and box plots).

Technology is broadly interpreted in the context of this practice to mean any tool that can be used to understand the phenomena. This definition includes paper and pencil, graphs, software, etc. For this study quoted in the article is was necessary to represent large amounts of data in a small space and the scientists used the tool of a graph to do this. The article by Alice, shows the composition of gut microbiota in the different species,

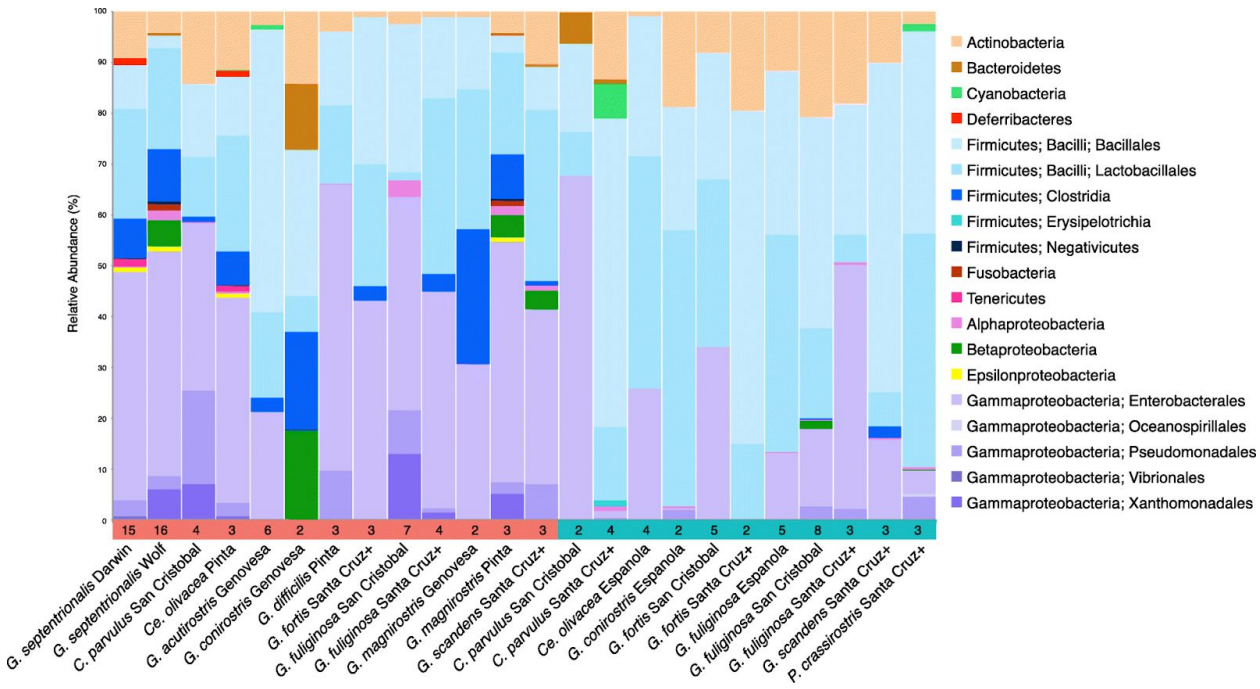

Fig. 2
Average taxonomic composition of gut microbial communities of Darwin's finches, from Illumina 16S rRNA gene surveys, based on OTU clustering at 97% identity trimmed to at least 1% relative abundance in at least one finch. Data is grouped by season, island, and species. The colored bar at the bottom, which also shows sample sizes, distinguishes finch samples from the dry (red) and wet (blue) seasons (Note that for this analysis, Santa Cruz, and neighboring islands Santa Fé, and North Seymour are grouped together as "Santa Cruz +"). An average of 25,382 reads per finch, comprised of 297 unique OTUs (clustered at 97% similarity level), was recovered at greater than 1% relative abundance in at least one finch across the dataset (Alice, 2019).

Citations:

Alice J. Michel, Lewis M. Ward, Shana K. Goffredi, Katherine S. Dawson, Daniel T. Baldassarre, Alec Brenner, Kiyoko M. Gotanda, John E. McCormack, Sean W. Mullin, Ariel O'Neill, Gabrielle S. Tender, J. Albert C. Uy, Kristie Yu, Victoria J. Orphan, and Jaime A. Chaves. "The gut of the finch: Uniqueness of the gut microbiome of the Galápagos vampire finch." Microbiome. 19 Sept. 2018. BioMed Central. 09 June 2019 <https://microbiomejournal.biomedcentral.com/articles/10.1186/s40168-018-0555-8>.

"APPENDIX H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards." Www.nextgenscience.org. Apr. 2013. 09 June 2019 <https://www.nextgenscience.org/sites/default/files/Appendix%20H%20-%20The%20Nature%20of%20Science%20in%20the%20Next%20Generation%20Science%20Standards%204.15.13.pdf>.

"APPENDIX L – Connections to the Common Core State Standards for Mathematics." Www.nextgenscience.org. 2013. 09 June 2019 <https://www.nextgenscience.org/sites/default/files/Appendix-L_CCSS%20Math%20Connections%2006_03_13.pdf>.

"High School: Modeling." High School: Modeling | Common Core State Standards Initiative. 10 June 2019 <http://www.corestandards.org/Math/Content/HSM/>.

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