Teacher Resource for:

Ongoing drought-induced uplift in the western United States.

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GENERAL USE OF *Science* in the Classroom

Student Learning Goals:

"One fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge."[1]

The U.S. National Academy of Sciences defines science as: "Any new finding requires independent testing before it is accepted as scientific knowledge; a scientist is therefore required to honestly and openly report results so that they can readily be repeated, challenged, and built upon by other scientists. Proceeding in this way over centuries, the community effort that we call science has developed an increasingly accurate understanding of how the world works. To do so, it has had to reject all dogmatic claims based on authority, insisting instead that there be reproducible evidence for any scientific claim."

An important student learning goal, central to any understanding of "the nature of scientific knowledge," is to give each student an appreciation of how science is done.

This includes knowing why:

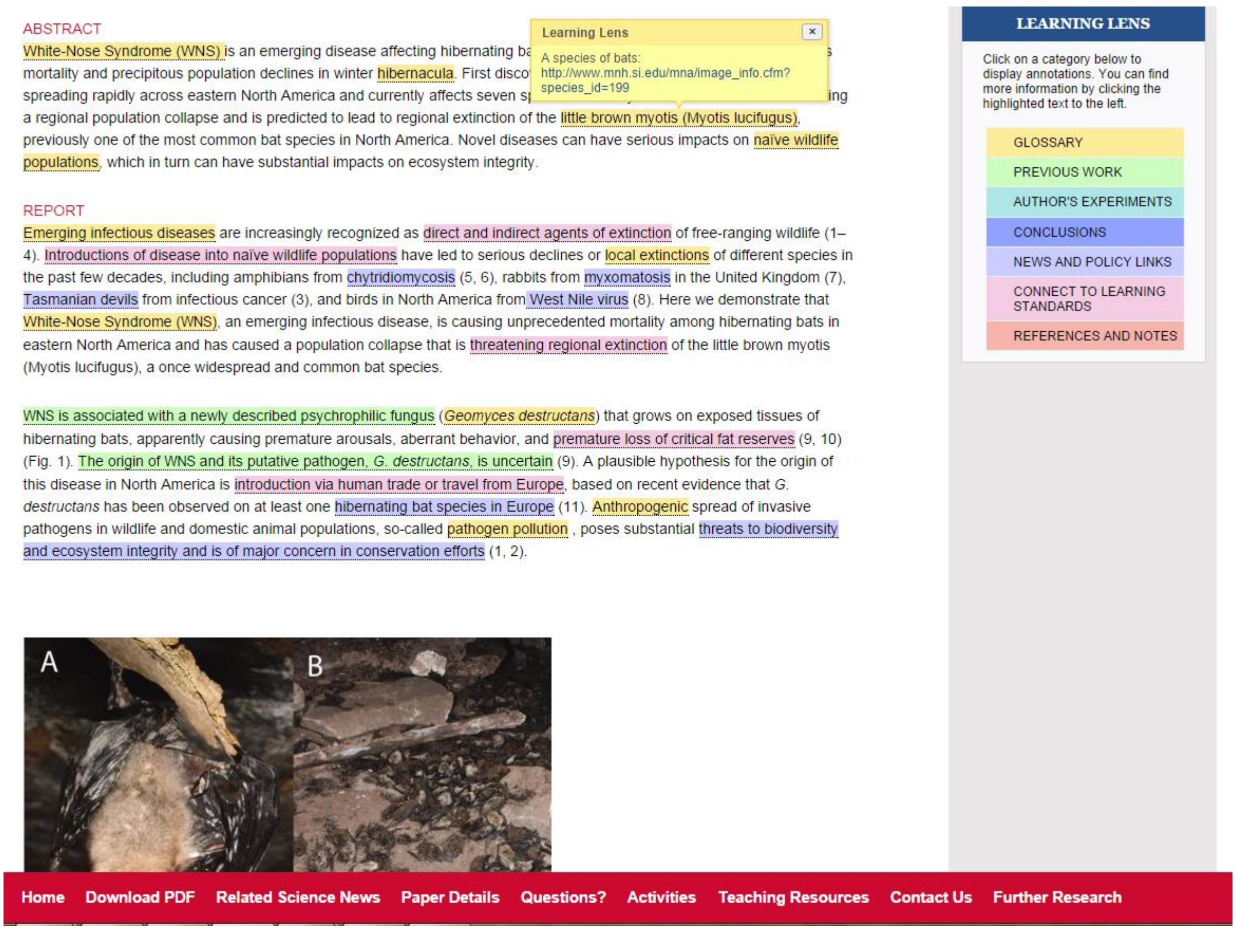
- Scientists must be independent thinkers, who are free to dissent from what the majority believes.
- Science can deal only with issues for which testable evidence can be obtained.
- All scientific understandings are built on previous work
- It is to be expected that one scientist's conclusions will sometimes contradict the conclusions of other scientists.
- Science is a never-ending venture, as the results from one study always lead to more questions to investigate.

[1] *A Framework for K-12 Science Education*, National Research Council, 2012

Using This Resource

Learning Lens:

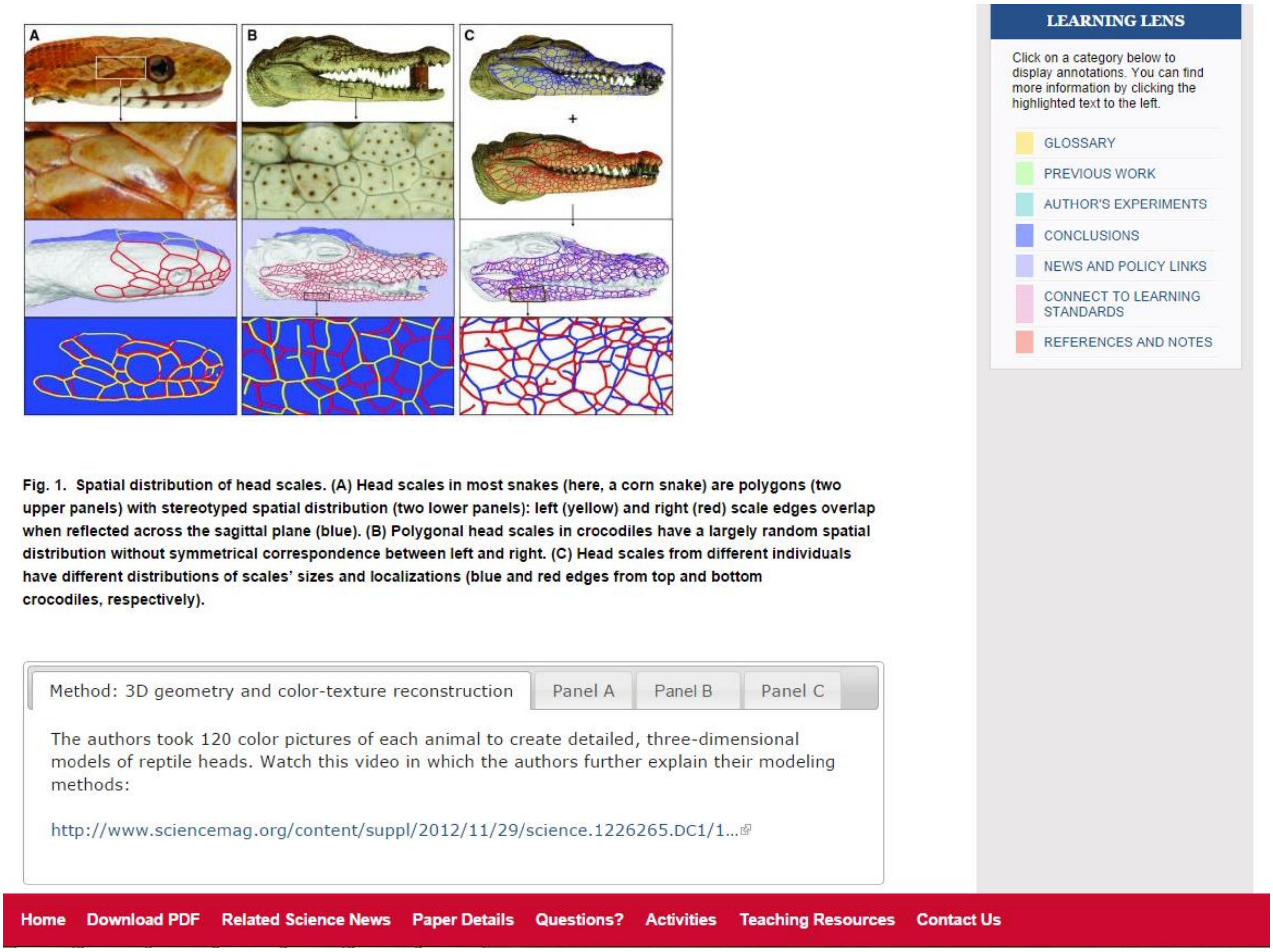
The Learning Lens tool can be found on the right sidebar of each resource and is the source of annotations. Click on the headings to highlight portions of the text of the corresponding research article. A subsequent click on the highlighted text will produce a text box containing more information about that particular piece of text. Below is an example of the Glossary function of the Learning Lens.



An example of the resource with the Glossary, Previous Work, Author's Experiments, News and Policy Links, and References and Notes tools turned on. The Glossary tool is in use.

Learning Notes:

Learning Notes accompany each figure and are designed to help students deconstruct the methods and data analysis contained within each figure.



References:

The Reference section of each resource is annotated with a short statement about how or why each reference relates to the current research study.

6. L. Lewejohann, B. Zipser, N. Sachser, “Personality” in laboratory mice used for biomedical research: A way of understanding variability? Dev. Psychobiol. 53, 624 (2011).
7. G. Kempermann, The neurogenic reserve hypothesis: What is adult hippocampal neurogenesis good for? Trends Neurosci. 31, 163 (2008).
8. Lewejohann et al., Behavioral phenotyping of a murine model of Alzheimer's disease in a seminaturalistic environment using RFID tracking. Behav. Res. Methods 41, 850 (2009).
9. B. Steineret al., Differential regulation of gliogenesis in the context of adult hippocampal neurogenesis in mice. Glia 46, 41 (2004).
10. Garthe, J. Behr, G. Kempermann, Ad flexible use of spatially precise learning strategies. PLoS ONE 4, e54
11. G. Kempermann, New neurons for ‘su 27 (2012).
12. G. Kempermannet al., Why and how brain plasticity. Front Neurosci 4, 189 (2010).
13. K. Fabelet al., Additive effects of physical exercise and environmental enrichment on adult hippocampal neurogenesis in mice. Front. Neurosci. 3, 50 (2009).
14. Amrein, H. P. Lipp, Adult hippocampal neurogenesis of mammals: Evolution and life history. Biol. Lett. 5, 141 (2009).
15. G. Kempermann, Why new neurons? Possible functions for adult hippocampal neurogenesis. J. Neurosci. 22, 635 (2002).
16. C. Crabbe, D. Wahlsten, B. C. Dudek, Genetics of mouse behavior: Interactions with laboratory environment. Science 284, 1670 (1999).
17. Lewejohann et al., Environmental bias? Effects of housing conditions, laboratory environment and experimenter on behavioral tests. Genes Brain Behav. 5, 64 (2006).
18. D. W. Bailey, How pure are inbred strains of mice? Immunol. Today 3, 210 (1982).
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22. P. B. Baltes, J. R. Nesselroade, S. W. Cornelius, Multivariate antecedents of structural change in development: A simulation of cumulative environmental patterns. Multivariate Behav. Res. 13, 127 (1978).
23. M.E. Raijmakers, P. C. Molenaar, Modeling developmental transitions in adaptive resonance theory. Dev. Sci. 7, 149 (2004).
24. K. Friston, M. Breakspear, G. Deco, Perception and self-organized instability. Front. Comput. Neurosci. 6, 44 (2012).
25. Van de Weerd et al., Effects of environmental enrichment for mice: Variation in experimental results. J. Appl. Anim. Welf. Sci. 5, 87 (2002).
26. D. P. Wolferet al., Laboratory animal welfare: Cage enrichment and mouse behaviour. Nature 432, 821 (2004).
27. K. Lewin, Dynamic Theory of Personality (McGraw-Hill, New York, 1935).
28. K. L. Jang, R. R. McCrae, A. Angleitner, R. Riemann, W. J. Livesley, Heritability of facet-level traits in a cross-cultural twin

Learning Lens

This paper showed that while both physical activity, like running, and living in an enriched environment can result in the generation of new hippocampal neurons in mice, a combination of the two activities leads to even greater rates of neurogenesis.

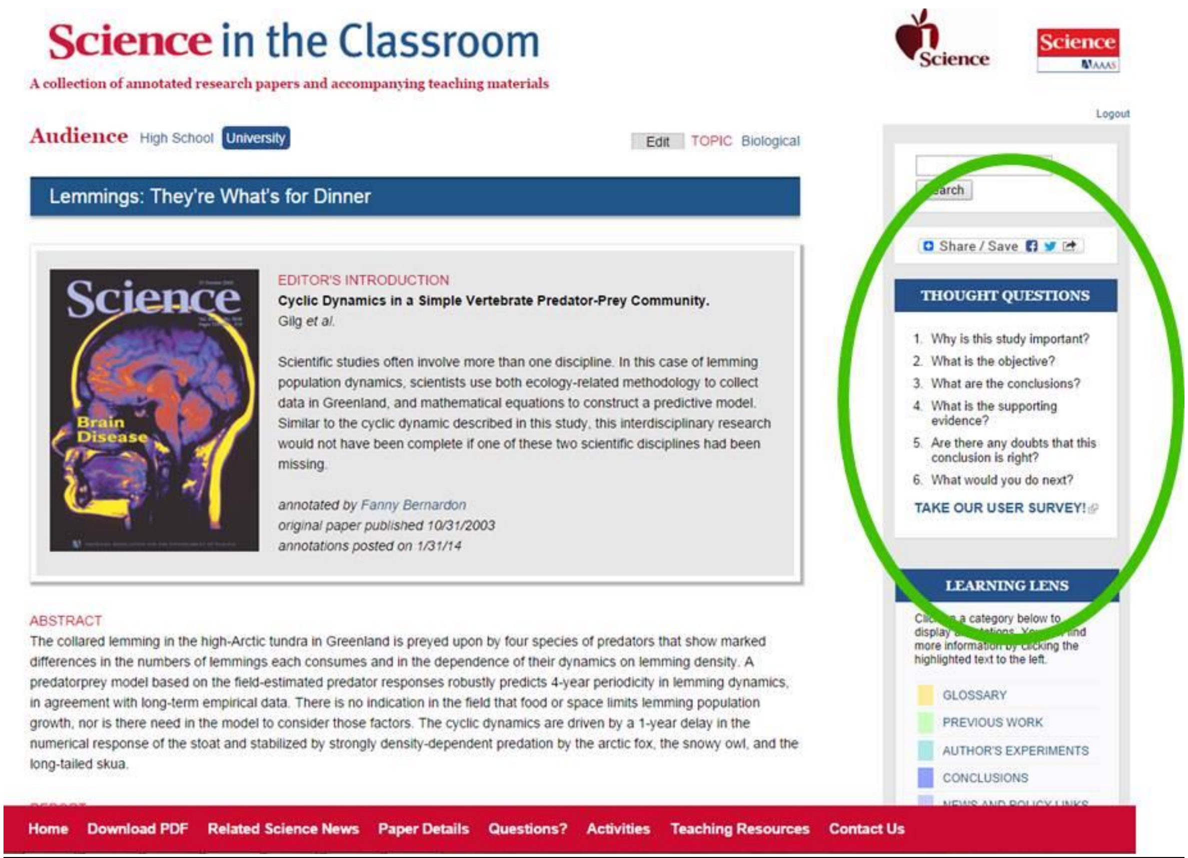
LEARNING LENS

Click on a category below to display annotations. You can find more information by clicking the highlighted text to the left.

- GLOSSARY
- PREVIOUS WORK
- AUTHOR'S EXPERIMENTS
- CONCLUSIONS
- NEWS AND POLICY LINKS
- CONNECT TO LEARNING STANDARDS
- REFERENCES AND NOTES

Thought Questions

Thought Questions are located above the Learning Lens in the right sidebar of each resource. These questions were written to be universal and applicable to any primary research paper. Thought questions do not have a single answer, or a correct answer for that matter, and can be used to stimulate discussion among students.



Suggestions for Classroom Use:

In addition to the thought questions discussed above, other resources are provided for use in the classroom. These can be found toward the end of the teacher guides associated with each specific article and include:

1. Discussion questions specific to the article, related to the standards, and/or associated with the figures.

2. Activities tied to the articles.

Some ways to use the *Science* in the Classroom articles:

1. Assign to student groups to read and discuss during class.

2. Assign small sections of the article to student groups to read and discuss during class, with the expectation that they will present or use jigsaw to teach the entire class what is in their part of the article.

3. Assign to individual students to complete during class or as homework.

4. Assign reading as an extra credit project.

Some ideas for interactive student engagement after reading the article:

1. Students write answers to discussion questions (for example, those linked to the standards or those linked to the diagrams).

2. Go over the abstract, as well as information about the purpose and structure of an abstract, and have students write their own abstracts for the articles in language that could be understood by their peers.

3. Have students edit the article, or parts of the article, to a simpler reading level.

4. Have students, alone or in small groups, use the annotated list of references to explain how the scientists who wrote this article built on the published work of at least one independent group of scientists in making their discoveries. In the process, did they produce data that supports the findings of the earlier publication that they have cited in the text? In what way does this article support the statement that scientific knowledge is built up as a “community effort”?

5. Use the article and discussion questions linked to the standards and the diagrams for a teacher-led classroom discussion. The discussion can focus on the nature of science and scientific research, as well as on the science in the article itself.

6. Have students give a classroom presentation about the article, parts of the article, or their answers to discussion questions.

ARTICLE-SPECIFIC MATERIALS

Connections to the nature of science from the article

- How can we monitor groundwater loss at a regional scale?
- What are some ways we can use GPS stations to learn about ground movement?
- How can water loss effect stress and strain?
- How do scientists present data and use statistics?

The importance of this scientific research

- GPS stations can be used to monitor groundwater loss at regional scales, and, in the future, may be used to monitor long-term effects of regional climate change.

The actual science involved

- Geology (elastic rebound)
- Hydrology
- Statistics

Connect to Learning Standards:

The AP Environmental Science Standards
http://media.collegeboard.com/digitalServices/pdf/ap/10b_2727_AP_Biology_CF_WEB_110128.pdf

- I. Earth Systems and Resources. C. Global Water Resources and Use (Fresh water/salt water; ocean circulation; agricultural, industrial, and domestic use; surface and groundwater issues; global problems; conservation)

The Science and Engineering Practices contained in the Next Generation Science Standards
http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

- Practice 3: Planning and carrying out investigations
- Practice 5: Using mathematics and computational thinking
- Practice 7: Engaging in argument from evidence

The AP Statistics Standards

http://media.collegeboard.com/digitalServices/pdf/ap/ap-statistics-course-description.pdf

- I. Exploratory analysis of data makes use of graphical and numerical techniques to study patterns and departures from patterns
- *II. Data must be collected according to a well-developed plan if valid information is to be obtained.*

The Common Core English and Language Arts Standards
http://www.corestandards.org/ELA-Literacy/RST/11-12/

- Integration of Knowledge and Ideas: CCSS.ELA-Literacy.RST.11.12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical test, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

<u>Summary of the Article for the Teacher:</u>

It is recommended that this not be used by students in place of reading the article.

General Overview:

Groundwater is a large source of fresh water for most of the western United States. Being, of course, beneath the surface can make it quite a challenge to monitor, especially at the regional scale. However, ways we can keep track of changes in this most valuable resource are evolving. A series of GPS stations known as PBO have been placed across the western United States to measure plate movement. These stations have been used in the past to measure ground motion along faults and track magma movement beneath volcanoes. What if we could use these same stations to measure regional changes in the most valuable of resources: groundwater. Scientists now are presenting these stations as way to monitor regional and global scale climate change.

Topics Covered:

- Statistical analysis and inference
- Time series analysis (including trend removal)
- Loading effects
- Inversion modeling
- Drought
- Remote sensing

Why this Research is Important:

This research presents a novel method to measure surface deformation related to interannual hydrological changes. The method uses GPS stations, which can provide smaller scale (local) measurements on otherwise difficult to measure parts of the hydrological system. They demonstrate the method's effectiveness by applying it to the recent drought in the western United States.

Methods used in the Research:

- Secular trend removal
- Seasonal trend loss method
- Data selection
- Statistical analysis
- Inversion and modeling
- Error analysis (statistical and checkerboard tests)
- Stress calculations

Conclusions:

- There is an area-integrated water deficit in the western United States of 240 gigatons (as of March 2014).
- The amount of stress change caused by water loss is not enough to affect seismicity.
- GPS stations can measure loading changes in wet and dry conditions at interannual scales
- GPS provides a method to measure water loss at a finer scale than other methods such as satellite measurements (GRACE). However, combining GPS and satellite data together should produce good measurements of terrestrial water storage at local, regional, and global scales.

Areas of Further Study:

- What can we learn about the hydrological observing network by adding GPS stations to existing measurements?
- What are the long-term effects of regional climate change?

Resources for Interactive Engagement:

Discussion questions associated with background information

1. When groundwater is depleted, why does the ground rise up instead of subside?
2. Do you think GPS stations used in this study have more vertical or horizontal motion?
3. What other geologic processes cause the earth to have vertical displacement?
4. Why are droughts so common in the western United States, and why might the most recent (2013) drought be one of the worst so far?

Discussion questions associated with methods

1. Do you think the GPS stations the authors excluded from their analysis are valid? Why or why not?
2. How do the authors go from having a series of data points at each station to an estimation of the total water loss?
3. How do the authors remove information about seasonal rainfall variations?

Discussion questions associated with analysis

1. Why is it important the authors prove that GPS can measure surface loading in dry and wet conditions?
2. What is the smallest scale in which the GPS stations can resolve loading differences?
3. What might be some methods to get even higher resolution data?

Discussion questions related to conclusions and future research

1. Why is this research so exciting; what new things does this article bring to science?
2. How does using both GPS and satellite data improve our understanding of the hydrologic system in the United States?

Discussion questions associated with the figures

Fig. 1: Would the data show more or less variability if the thin red lines (standard deviation) were farther apart?

Fig. 2: What trend does this figure show from 2011 to 2014?

Fig. 3: Which areas have experienced the most loading deficit? The least? How does this compare to Fig. 4?

Fig.4: Do your own comparison of rainfall and vertical displacement patterns from 2011 to 2014. Do you agree or disagree with the authors' interpretation?