Teacher Resource for:

Sunlight controls water column processing of carbon in arctic fresh waters.

Table of Contents:

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.

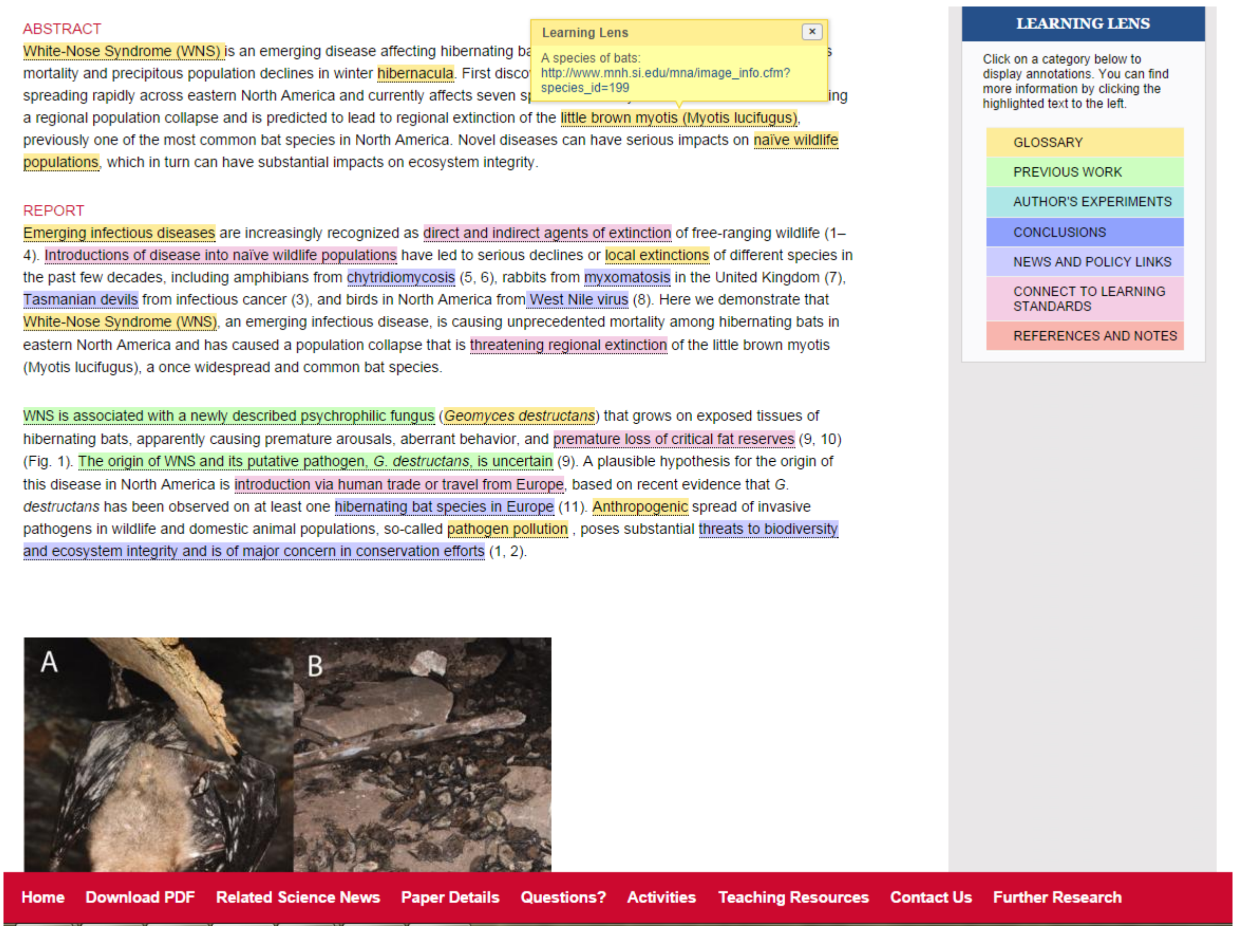
---

[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.

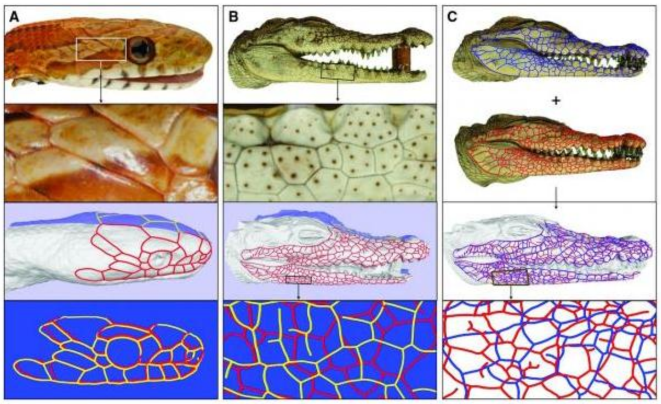


Fig. 1. Spatial distribution of head scales. (A) Head scales in most snakes (here, a corn snake) are polygons (two upper panels) with stereotyped spatial distribution (two lower panels): left (yellow) and right (red) scale edges overlap when reflected across the sagittal plane (blue). (B) Polygonal head scales in crocodiles have a largely random spatial distribution without symmetrical correspondence between left and right. (C) Head scales from different individuals have different distributions of scales' sizes and localizations (blue and red edges from top and bottom crocodiles, respectively).

Method: 3D geometry and color-texture reconstruction | Panel A | Panel B | Panel C

The authors took 120 color pictures of each animal to create detailed, three-dimensional models of reptile heads. Watch this video in which the authors further explain their modeling methods:

http://www.sciencemag.org/content/suppl/2012/11/29/science.1226265.DC1/1...

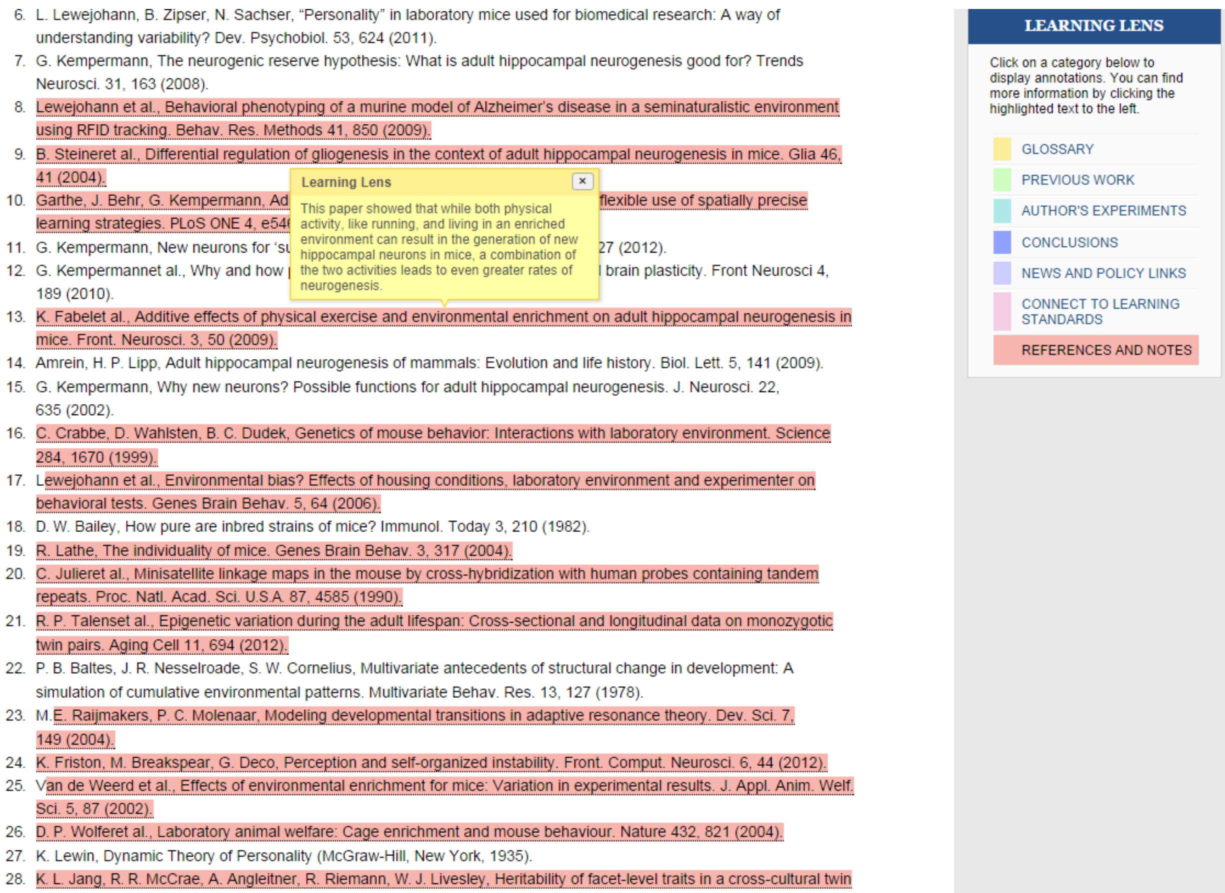
LEARNING LENS

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

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).
19. R. Lathe, The individuality of mice. Genes Brain Behav. 3, 317 (2004).
20. C. Julieret al., Minisatellite linkage maps in the mouse by cross-hybridization with human probes containing tandem repeats. Proc. Natl. Acad. Sci. U.S.A. 87, 4585 (1990).
21. R. P. Talenset al., Epigenetic variation during the adult lifespan: Cross-sectional and longitudinal data on monozygotic twin pairs. Aging Cell 11, 694 (2012).
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.

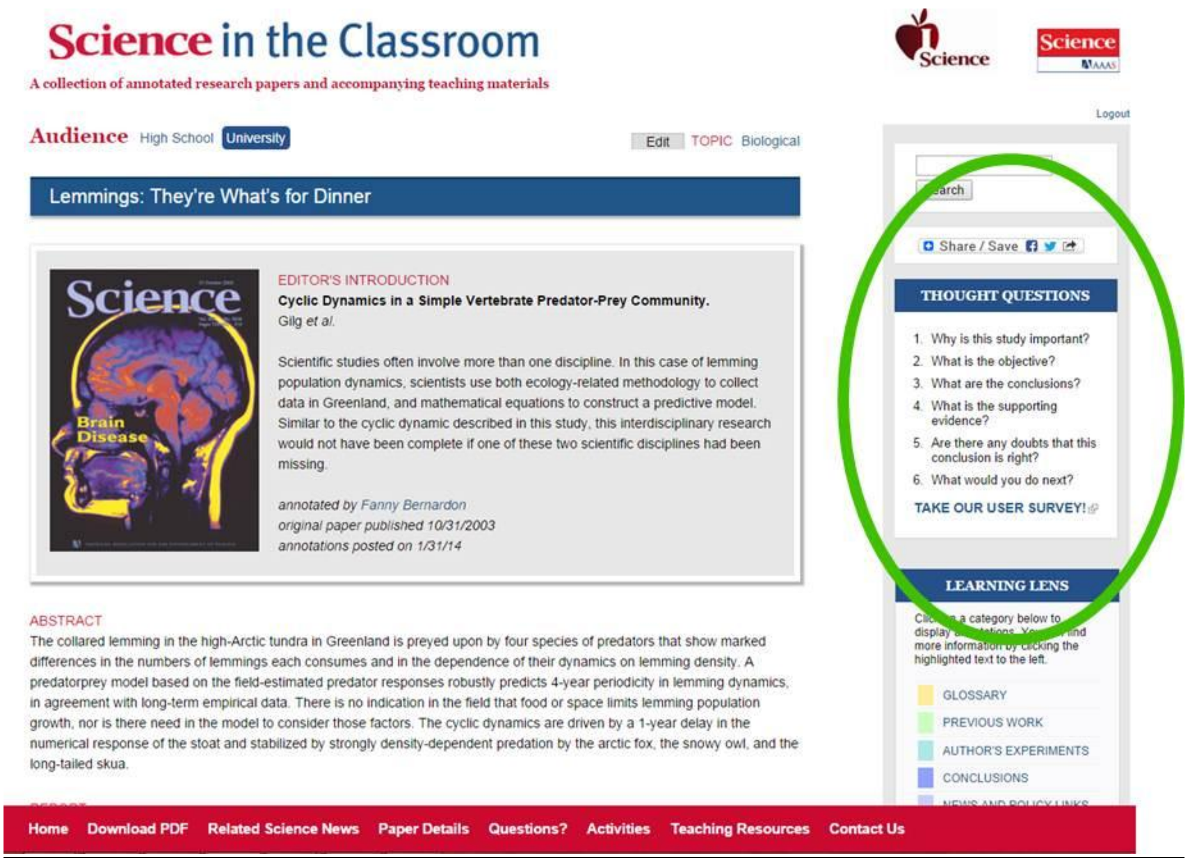
LEARNING LENS

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

- Why are scientists studying carbon from melting permafrost in the arctic?
- This paper includes experiments that cover a wide range of sizes–from molecular interactions to adding up all of the carbon dioxide (CO2) release in a large land area.
    - Why do the authors need to care about results at different scale?
    - Why couldn't all of their experiments be field scale or all just about molecular interactions?

The importance of this scientific research

- Melting permafrost has the potential to release large amounts of CO_2 into the atmosphere. It is important to understand how that process works so we can predict how fast the CO_2 will be released and how much there will be.

The actual science involved

- Photochemistry of DOC
- Microbial respiration
- Areal rate calculations

Connect to Learning Standards:

NGSS 8 practices for science and engineering
http://www.nap.edu/openbook.php?record_id=13165&page=42

- Practice 2: Developing and using models
- Practice 7: Engaging in argument from evidence

Science practices for AP Biology
https://advancesinap.collegeboard.org/stem/science-practices

- Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.
- Practice 7: The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

English Language Arts Standards Science & Technical Subjects, Grade 11-12
http://www.corestandards.org/ELA-Literacy/RST/11-12/

- 11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
- 11-12.9: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

Vision and Change Core Competencies and Disciplinary Practice
http://visionandchange.org/files/2011/02/Vision-and-Change-low-res.pdf (page 35)

- Competency 3: Ability to use modeling and simulation
- Competency 4: Ability to tap into the interdisciplinary nature of science
- Competency 6: Ability to understand the relationship between science and society

Common Core: Statistics & Probability
http://www.corestandards.org/Math/Content/HSS/introduction/

- Make inferences and justify conclusions from sample surveys, experiments, and observational studies

Summary of the Article for the Teacher:

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

General Overview:

In the Arctic, there is a layer of soil underground that stays permanently frozen; summers are not long enough or warm enough for it to melt. However, because of climate change, soil that has been frozen for many years is beginning to thaw. One of the many consequences of this is that organic carbon that has been trapped in the frozen ground is now able to move in the environment. Much of the newly released organic carbon ends up dissolved in the water flowing into arctic streams, rivers, and lakes. In this paper, the authors study the importance of sunlight in breaking down dissolved organic carbon (DOC) into carbon dioxide (CO2) in arctic surface waters by taking water samples and measuring rates of DOC degradation driven by sunlight and driven by bacteria. The authors then use their results to model the amount of CO2 released from different types of DOC degradation for the entire study area on the North Slope of Alaska. The results show that sunlight-driven DOC degradation is an important process in the Arctic.

Topics Covered:

- Permafrost thawing
- Carbon cycling
- DOC photochemistry
- Microbial respiration
- Areal rates
- Climate change

Why this research is important:

CO_2 in the atmosphere is a major cause of climate change. The Intergovernmental Panel on Climate Change has set a target amount for how much CO_2 can be released before we reach the critical limit of $2^{o}C$ above preindustrial global temperatures (the "carbon budget"). It is important to account for any CO_2 released by melting permafrost, as the amount may be a significant portion of the carbon budget. This research works on identifying processes that convert carbon from permafrost to CO_2 and determining which ones are important enough to consider in global climate models. Sunlight has not previously been identified as an important driver of CO_2 production from permafrost carbon.

Methods used in the Research:

- Field sampling of various water bodies
- Measurement of light attenuation
- Photodegradation assays
- Dark culture of bacteria from water samples
- Calculations of areal rates

Note: Although this publication has many fine qualities, it is *not* a methods driven paper. There is very little methods information in the main text, and even the supplemental information contains several references to other publications rather than a full explanation of the methods used. Although some method details are provided in the annotations, there is still minimal information included about how measurements were made,what instruments were used, and specific analytical techniques.

Conclusions:

- In the Kuparik River Basin, 55% of DOC in surface water is converted to CO_2 and 45% is partially oxidized and remains in the DOC pool downstream.

- 55% of the CO_2 released from DOC was processed by light. 75% of total DOC processing (including partial oxidation) is driven by light.

- Light-driven DOC degradation is more important in shallow streams and rivers and less important in lakes.

- Light driven DOC degradation is more important for DOC that has recently been dissolved from permafrost than for older DOC.

Areas of Further Study:

- Benthic respiration, or break down of DOC caused by microorganisms living at the bottom of streams, lakes, and rivers, could be even more important that sunlight-driven DOC processing.

- CO_2 release from sunlight-driven degradation of DOC should be incorporated into global climate models.

Discussion Questions:

1. What was the goal of this study?

2. Why is this study important?

3. The remains of a decayed leaf have been frozen in the soil next to a stream for many years. The soil thaws one summer and the remains of the leaf are dissolved and swept into the stream.

    a. What are the different ways that the remains of the leaf could be converted to CO_2? What else could happen to the remains of the leaf?
        i. Once the remains of the leaf are dissolved, they become DOC. DOC can be converted to CO_2 by sunlight (photo-oxidation) or bacterial respiration, or a combination of the two (photostimulated bacteria respiration). DOC can also be partially degraded/oxidized by sunlight or not degraded at all. In these cases, the remaining DOC is transported downstream to larger bodies of water.

    b. What properties of the stream might affect what happens to the leaf?
        i. Possible answers include: stream depth, stream size, whether the stream is in the shade, how much bacteria is in the stream

    c. How did the results of the paper inform your answers to parts a and b?
        i. The results of the paper show that sunlight-driven degradation of DOC is more likely to occur in streams than bacterial respiration, but that both can happen. If the DOC is transported to a lake, the paper results show that bacterial respiration becomes more likely.

4. This paper includes experiments that cover a wide range of sizes—from molecular interactions to adding up all of the CO_2 release in a large land area.
    a. Why do the authors need to care about results at different scale?

    b. Why couldn't all of their experiments be field scale or all just about molecular interactions?

    c. How do the authors relate the different scales?