

Teacher Resource for:
Radio Jets Clearing the Way Through a Galaxy:
Watching Feedback in Action.

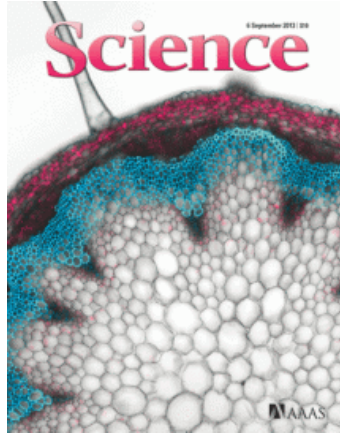


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GENERAL USE OF Science in the Classroom

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.

ABSTRACT

White-Nose Syndrome (WNS) is an emerging disease affecting hibernating bat mortality and precipitous population declines in winter hibernacula. First discovered spreading rapidly across eastern North America and currently affects seven species, WNS is a regional population collapse and is predicted to lead to regional extinction of the little brown myotis (Myotis lucifugus), previously one of the most common bat species in North America. Novel diseases can have serious impacts on naïve wildlife populations, which in turn can have substantial impacts on ecosystem integrity.

REPORT

Emerging infectious diseases are increasingly recognized as direct and indirect agents of extinction of free-ranging wildlife (1–4). Introductions of disease into naïve wildlife populations have led to serious declines or local extinctions of different species in the past few decades, including amphibians from chytridiomycosis (5, 6), rabbits from myxomatosis in the United Kingdom (7), Tasmanian devils from infectious cancer (3), and birds in North America from West Nile virus (8). Here we demonstrate that White-Nose Syndrome (WNS), an emerging infectious disease, is causing unprecedented mortality among hibernating bats in eastern North America and has caused a population collapse that is threatening regional extinction of the little brown myotis (*Myotis lucifugus*), a once widespread and common bat species.

WNS is associated with a newly described psychrophilic fungus (Geomyces destructans) that grows on exposed tissues of hibernating bats, apparently causing premature arousals, aberrant behavior, and premature loss of critical fat reserves (9, 10) (Fig. 1). The origin of WNS and its putative pathogen, G. destructans, is uncertain (9). A plausible hypothesis for the origin of this disease in North America is introduction via human trade or travel from Europe, based on recent evidence that *G. destructans* has been observed on at least one hibernating bat species in Europe (11). Anthropogenic spread of invasive pathogens in wildlife and domestic animal populations, so-called pathogen pollution, poses substantial threats to biodiversity and ecosystem integrity and is of major concern in conservation efforts (1, 2).

A



B



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

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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.

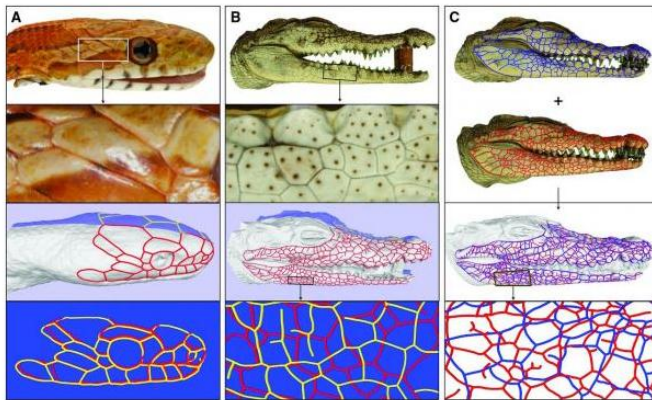


Fig. 1. Spatial distribution of head scales. (A) Head scales in most snakes (here, a corn snake) are polygons (two upper panels) with stereotyped spatial distribution (two lower panels): left (yellow) and right (red) scale edges overlap when reflected across the sagittal plane (blue). **(B)** Polygonal 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...>

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- 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.

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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

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

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.

flexible use of spatially precise

brain plasticity. *Front Neurosci* 4,

Thought Questions

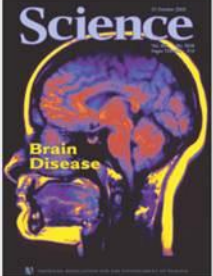
Thought Questions are located above the Learning Lens in the right sidebar of each resource. These questions were written to be universal and applicable to any primary research paper. Thought questions do not have a single answer, or a correct answer for that matter, and can be used to stimulate discussion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

Science in the Classroom

A collection of annotated research papers and accompanying teaching materials

Audience High School **University** **Edit** TOPIC Biological

Lemmings: They're What's for Dinner



EDITOR'S INTRODUCTION
Cyclic Dynamics in a Simple Vertebrate Predator-Prey Community.
Gilg et al.

Scientific studies often involve more than one discipline. In this case of lemming population dynamics, scientists use both ecology-related methodology to collect data in Greenland, and mathematical equations to construct a predictive model. Similar to the cyclic dynamic described in this study, this interdisciplinary research would not have been complete if one of these two scientific disciplines had been missing.

annotated by Fanny Bernardon
original paper published 10/31/2003
annotations posted on 1/31/14

ABSTRACT
The collared lemming in the high-Arctic tundra in Greenland is preyed upon by four species of predators that show marked differences in the numbers of lemmings each consumes and in the dependence of their dynamics on lemming density. A predator-prey model based on the field-estimated predator responses robustly predicts 4-year periodicity in lemming dynamics, in agreement with long-term empirical data. There is no indication in the field that food or space limits lemming population growth, nor is there need in the model to consider those factors. The cyclic dynamics are driven by a 1-year delay in the numerical response of the stoat and stabilized by strongly density-dependent predation by the arctic fox, the snowy owl, and the long-tailed skua.

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THOUGHT QUESTIONS

1. Why is this study important?
2. What is the objective?
3. What are the conclusions?
4. What is the supporting evidence?
5. Are there any doubts that this conclusion is right?
6. What would you do next?

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LEARNING LENS

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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

Student Learning Goals:

Connections to the nature of science from the article

- How is it different to "do an experiment" when studying galaxies versus other types of science that can be performed on a benchtop?
- What big questions can be answered by studying the universe?
- What impacts might technology used in observations of the universe have on other aspects of our society?

The importance of this scientific research

- Since one cannot do experiments on test galaxies to see how they evolve, it is essential to use telescopes to look at distant objects and deduce their evolutionary paths from these observations. Fortunately, the universe is vast so it is likely that snapshots of galaxies at different evolutionary stages are visible. All galaxies have a black hole at their center and a correlation between the mass of this black hole and the mass of the overall galaxy had been observed, but the connection between these two masses was unclear. This work suggests one possible mechanism for coupling of the mass of a galaxy and its central black hole using state-of-the-art high-resolution observations.

The actual science involved

- A large, multinational radio interferometer was used to image gas flowing out from the galaxy 4C12.50, which is at a distance of roughly 1.5 billion light years from earth. These observations were then compared to radio emissions, which reveal that the gas is being pushed out of the galaxy by radio emissions coming from the central black hole.

Connect to Learning Standards:

AP Physics:

<http://media.collegeboard.com/digitalServices/pdf/ap/ap-physics-1-2-course-and-exam-description.pdf>

- Essential Knowledge 3.C.1: gravitational force (page 49)
- Essential Knowledge 6.F.1: types of electromagnetic radiation are characterized by their wavelengths (page 106)
- Essential Knowledge 6.A.1 kinematics (page 42)
- Essential Knowledge 1.A.4: discrete energy state transitions lead to spectra (page 19)
- Essential Knowledge 1.E.1: matter has a property called density (page 27)
- Essential Knowledge 1.C.2: gravitational Mass (page 23)

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:

Supermassive black holes exist at the center of galaxies, often weighing more than one billion times as much as the sun. What forces could connect the mass of a galaxy to the mass of its central black hole? One possibility is the light emitted from the disc of material being drawn towards the black hole. This active galactic nucleus shoots jets of light away from the black hole out through the surrounding galaxy. These jets of light can interact with material in the host galaxy as they pass by and eject this material from the galaxy. In this way, the mass of the black hole influences the brightness of the jet, which then shoots more material out of the galaxy, providing a compelling explanation for how the mass of a galaxy could be coupled to the mass of its central black hole.

Why this Research is Important:

Since one cannot do experiments on test galaxies to see how they evolve, it is essential to use telescopes to look at distant objects and deduce their evolutionary paths from these observations. Fortunately, the universe is vast so it is likely that snapshots of galaxies at different evolutionary stages are visible. All galaxies have a black hole at their center and a correlation between the mass of this black hole and the mass of the overall galaxy had been observed, but the connection between these two masses was unclear. This work suggests one possible mechanism for coupling of the mass of a galaxy and its central black hole using state-of-the-art high-resolution observations.

Methods used in the Research:

- Radio interferometry
- computer analysis

Conclusions:

Hydrogen gas is being pushed out of the galaxy 4C12.50 by radio emissions from its central black hole, influencing the rate of star formation in the galaxy and providing an explanation for the correlation between the mass of a galaxy and the mass of its central black hole.

Areas of Further Study:

- Locate similar objects and image them
- conduct additional computer simulations to connect these observations to theory
- explore multiple stages of interactions between the central black hole and outflowing matter.

Resources for Interactive Engagement:

1. Discussion Questions

What other forces contribute to the evolution of galaxies besides radio jets?

What other methods could be used to study the forces governing galaxy evolution?

What implications does the huge size of the universe have in terms of observation of cosmological objects?