Teacher Resource for:
Hippocampal Neurogenesis Regulates Forgetting During Adulthood and Infancy.

Using This Teacher Resource

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GENERAL USE OF Science in the Classroom

**Student Learning Goals:**
Current views of science education emphasize that “one fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge.” (From *A Framework for K-12 Science Education*, National Research Council, 2012).

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.”

A very 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.
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. Clicking on any of the headings will result in corresponding text of the research article being highlighted. A second 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 in use.

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.
Suggestions for Classroom Use:

Four alternative ways to use the SitC reading, questions, and activities:

1. Assign to small groups to complete during class

2. Assign different sections of the article to small groups to complete during class. Use class presentations or jigsaw to teach the entire class what is in the article.

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

4. Assign as an extra credit project.

Interactive student engagement ideas for use after reading the article:

1. Have 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 best understood by their peers.

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

4. Have students, working 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*

- When conducting research, it is important to ask the same question in multiple different ways (i.e. using both running and Memantine to increase neurogenesis). This ensures that your result is not caused by the design of one specific experiment, but is what is actually happening.

- When proving causation it is important to demonstrate that the cause is both necessary and sufficient for producing the effect.

*The importance of this scientific research*

- Enhances understanding of memory and how it works and develops.

- Enhances understanding of the concept of the trade-off between plasticity and stability (just increasing neurogenesis is not always the answer!).

- Potential Implications for understanding and/or treating memory diseases/disorders such as Alzheimer’s (too much memory loss) or Post-Traumatic Stress Disorder (want to induce forgetting).

*The actual science involved*

Researchers manipulated the level of neurogenesis to determine the effect of neurogenesis on memory stability. Infant mice, adult mice, guinea pigs, and degus were used as model systems.
Connect to Learning Standards:

Next Generation Science Standards 8 Practices for Scientists and Engineers:

http://www.nap.edu/openbook.php?record_id=13165&page=42

Practice 2: Developing and using models

Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

AP Biology Essential Knowledge


Essential Knowledge 3.D.2 (page 69):
Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.

Essential Knowledge 1.B.1 (page 14):
Organisms share many conserved core processes and features that evolved and are widely distributed among organisms today.
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:
Why do we have so much trouble remembering our own infancy? This phenomenon, known as infantile amnesia, occurs in humans as well as many animal species. Does the synthesis of new neurons (neurogenesis), especially as our brain is developing, affect memory formation? The rate of neurogenesis is significantly higher in infancy than later in life. Is this increase related to our difficulties in forming memories during the same time period? By manipulating the rate of neurogenesis in several animal models, scientists may now have an answer to the question of forgetfulness.

Topics Covered:
- Neurogenesis and natural ways to increase it.
- Function and organization of the hippocampus (Dentate Gyrus and CA3 region).
- Synapses, synaptic connectivity, synaptic development, synaptic remodeling.
- Development of an organism in terms of memory stability.

Methods used in the Research:
- GFP labeling
- Immunohistochemistry
- Animal Behavior Tests
  - Context Fear Conditioning
  - Incidental Context Learning Paradigm
  - Water Maze
- Transgenic Mice (TK+ and iKO-p53 mouse lines)
- Drug treatment (Memantine, Temozolomide)

Conclusions:
- High levels of neurogenesis disrupt established, hippocampus-dependent memories.
  - Increasing neurogenesis in adult mice disrupts memory stability.
  - Decreasing neurogenesis in infant mice enhances memory stability.
  - Animals with low levels of neurogenesis at birth do not exhibit infantile amnesia, but increasing neurogenesis can induce infantile amnesia.
Areas of Further Study:

Do these concepts translate to primates and humans?

How are memories ultimately retrieved and what is different about the memories that we retain and the ones that we forget? How does synaptic remodeling due to high levels of neurogenesis impact this system?
Resources for Interactive Engagement:

Discussion Questions

1. Taken from the text of the article:

*Increasing Neurogenesis Promotes Forgetting in Adult Mice*

To determine if levels of neurogenesis and memory persistence are causally related, we tested whether increasing hippocampal neurogenesis after learning promotes forgetting in adult mice.

Question: What do you predict will happen in this experimental set up if the authors’ hypothesis is true?

2. Taken from the text of the article:

As voluntary running induces several neural and physiological changes apart from increasing hippocampal neurogenesis (29), forgetting might alternatively be mediated by these non-neurogenic changes. Therefore, we first examined the impact of running before (rather than after) training (Fig. 2I).

Question: Can you think of any other components of this experiment that the authors should consider before they can claim that increasing neurogenesis decreases memory? For example, is it clear that it is increased neurogenesis and not increased spine density that causes decreased memory? How did the authors address this question in their next experiments?

3. Taken from the text of the article:

*Third, nonrunning interventions that increase neurogenesis might similarly induce forgetting of established memories. Administering the proneurogenic drugs memantine (MEM) (31) ([Fig. 3, D to F](#)), and fig. S10) or fluoxetine (32) (fig. S11) after training induced forgetting*

Question: The remaining experiments in this paper support either the conclusion that neurogenesis is necessary or sufficient for inducing forgetting to support the overall conclusion that increased neurogenesis causes forgetting (In science in order to prove causation you must first prove that a specific event is necessary and sufficient to cause another). Which of the remaining experiments support each of these conclusions?
4. Taken from the text of the article:

Through a series of studies, we showed that high levels of neurogenesis disrupt established hippocampus-dependent memories. As such, our findings reveal a novel role for neurogenesis in forgetting or memory clearance, in line with theoretical predictions (12, 14–16).

Question: Do you think this research is relevant and interesting? Can you think of a human disorder/disease that this may eventually be applicable for? What question would you want to answer next to continue this research?
Activities connecting to the data shown in the Article

The Activities are linked to in the red tool bar running along the bottom of the page. Activities linked to this particular resource contain raw data from the authors that the students will be able to work with directly.