How flexible is your brain?

Educator guide

PAPER DETAILS

Original title: Neurotransmitter plasticity at the molecular level

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Authors: IB Black, JE Adler, CF Dreyfus, GM Jonakait, DM Katz, EF LaGamma, KM Markey

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DISCUSSION QUESTIONS

	LEARNING STANDARDS
1. The authors tested neuroplasticity in different brain regions to test their hypothesis. Why was it necessary to test in several brain regions?	LS1.B Patterns EK2.E.2 VC1
2. What are the depolarizing agents used in the paper? Can you identify other depolarizing agents not used in this paper? To address the same question, what might an experiment with these alternative depolarizing agents look like? What would be the limitations in this alternative approach?	SEP3 Cause and effect RST.11-12.1 SP3 SP4 EK3.E.2
3. Scientists often use animal models to learn about scientific processes. What evidence is there that rats were a good model for this experiment? What are the animal models used to test this hypothesis?	Systems and system models EK3.D.2 VC1
4. This paper was published in 1984. What advances in neurological techniques would you implement to improve on the design presented in this paper? What would you change and what would stay the same?	SEP3 Cause and effect SP4 VC1 NS3
5. The field of plasticity has grown over several decades. Using this iBiology video of Dr. Eric Kandel, define the terms *synaptic plasticity*, *long-term potentiation*, and *long-term depression*.	LS1.B RST.11-12.2 SP6
6. What is the evolutionary advantage of the brain being a plastic organ?	LS1.B RST.11-12.9 SP3 EK3.E.2 VC1

ACTIVITIES FOR INTERACTIVE ENGAGEMENT

	LEARNING STANDARDS
Writing an abstract Students write a new abstract for the article at a grade-appropriate reading level.	**RST.9-10.2** **RST.11-12.2** **VC1**
Locating this study in the larger field Students use the annotated list of references to explain how this research builds on the published work of at least one other independent group of scientists. Students will evaluate whether data from this research supports or contradicts previous conclusions, and reflect on the statement that scientific knowledge is a "community effort."	**RST.9-10.8** **RST.11-12.8** **NS3**
Science in the news Students explore news stories in the Related Resources tab and evaluate the stories for tone, accuracy, missing information, etc. They may then write their own news stories on the article.	**RST.9-10.5** **RST.11-12.5** **RST.9-10.6** **RST.11-12.6** **RST.9-10.8** **RST.11-12.8**
Building blocks Students identify a paper or papers from a different group of scientists that have built their work based on this 1984 paper. How did they use and incorporate the main findings from this paper into their own work? What are the similarities and differences in their approach? Determine how their findings added to the current study of neurotransmitter plasticity.	**LS1.B** **Patterns** **SP6** **NS3**
Results and conclusions Students diagram each of the experiments presented in the study (divided up by figure, if appropriate). They then consider the results depicted in each figure, and how these results support the conclusions of the study.	**SEP3** **Cause and effect** **RST.11-12.4**
The next steps Students design a follow-on experiment to this study that either addresses flaws or unanswered questions in the research at hand or builds on it to explore a new question.	**SEP3** **LS1.B** **Systems and system models** **SP4** **NS3**

ARTICLE OVERVIEW

Article summary (recommended for educator-use only)

The brain is a malleable organ that performs diverse functions with the help of neurotransmitters and communication between brain cells called neurons. With the advent of new neurotransmitters being identified, our understanding of the brain's complexity is expanding. Several studies postulated that the transmitters can change their expression levels in response to environmental conditions. In this paper, researchers identified that the change in transmitter status can happen in both developmental and mature neurons. In particular, the midbrain region can cause an increase in the level of tyrosine hydrolase (an enzyme responsible for DOPA synthesis, a precursor to many neurotransmitters) in response to depolarization. Future research will focus on identifying the mechanisms responsible for this transmitter expression.

Importance of this research

The adaptability of the nervous system and the phenomenon of transmitter expression was a novel discovery as the results questioned the traditional understanding of neurotransmitters. Previous work in the field had focused on the peripheral nervous system (PNS). Evidence from the PNS suggests that the transmitter expression can be changed in response to environmental conditions. The authors wanted to test whether such adaptability occurs in the brain as well. The results in this study paved the way for the understanding of the molecular mechanisms behind this effect, which will, in turn, help improve the understanding of the dynamics and flexibility of transmitter plasticity.

Experimental methods

- Explant cultures: A region of the midbrain called the locus ceruleus was dissected from the rat brain and placed in a nutrient medium. The cultures were maintained in this medium.
- Depolarization manipulation: Pharmacological drugs, including veratridine, tetrodotoxin, and potassium, were used to manipulate the sodium influx and depolarization of cell membranes.
- Statistical analysis: Researchers used one-way ANOVA and Student's *t*-test.

Conclusions

- Young cultures show a significant increase in tyrosine hydrolase activity when exposed to veratridine for 7 days. The effect of veratridine is blocked by tetrodotoxin, a sodium channel blocker.
- Exposure to potassium also shows a significant increase in tyrosine hydrolase activity in young cultures. The effect is similar to the effect observed in the presence of veratridine.
- Similar to young cultures, 2-week old explant cultures also show an increase in tyrosine hydrolase activity suggesting that developing and mature locus ceruleus neurons exhibit plastic responses to depolarization.

LEARNING STANDARDS ALIGNMENT

The following tables provide an overview of the learning standards covered by this article, including the A Framework for K-12 Science Education (Framework), Common Core State Standards English Language Arts-Literacy (CCSS ELA), Common Core State Standards Statistics and Probability (CCSS HSS), AP Science Practices, and Vision and Change for Undergraduate Education. Where applicable, activities and information will be marked with specific standards to which they are linked.

A Framework for K-12 Science Education		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Planning and Carrying Out Investigations (SEP3) Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.	**LS1.B: Growth and Development of Organisms** In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successfully to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosomal pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.	**Patterns** Observed patterns of forms and events guide organization and classification, and prompt questions about relationships and the factors that influence them. **Cause and Effect** Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts. **Systems and System Models** Models (e.g. physical, mathematical, computed) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Common Core State Standards English Language Arts-Literacy		
Key Ideas and Details	**Craft and Structure**	**Integration of Knowledge and Ideas**
RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.	**RST.9-10.4** 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 9-10 texts and topics.	**RST.9-10.8** Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
RST.9-10.2 Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.	**RST.9-10.5** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).	**RST.9-10.9** Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.
RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.	**RST.9-10.6** Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.	**RST.11-12.8** Evaluate the hypotheses, data, analyses, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.	**RST.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.	**RST.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.
	RST.11-12.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas.	
	RST.11-12.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.	

AP Science Standards	
AP Science Practices	AP Biology Content Standards
Science Practice 3 (SP3) The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course. **Science Practice 4 (SP4)** The student can plan and implement data collection strategies in relation to a particular question. **Science Practice 6 (SP6)** The student can work with scientific explanations and theories.	**Essential Knowledge 2.E.2 (EK2.E.2)** Timing and coordination of physiological events are regulated by multiple mechanisms. **Essential Knowledge 3.D.2 (EK3.D.2)** Cell communication processes share common features that reflect a shared evolutionary history. **Essential Knowledge 3.E.2 (EK3.E.2)** Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.

Connections to the Nature of Science	
Vision and Change for Undergraduate Biology Education Core Competencies and Disciplinary Practices	A Framework for K-12 Science Education Understandings About the Nature of Science
Ability to apply the process of science (VC1) Understand the process of science and how scientists construct new knowledge by formulating hypotheses and then testing them against experimental and observational data.	**Scientific knowledge is open to revision in light of new evidence (NS3)** Scientific argumentation is a mode of logical discourse used to clarify the results of relationships between ideas and evidence that may result in revision of an explanation.