WHAT'S A PREPRINT?

KEY TERMS
- Peer review
- Preprint
- Scientific journal article
- Scientific method

KEY SKILLS
- Active reading
- Critical thinking
- Reading primary scientific literature

GRADE LEVEL
High school AP, IB, and concurrent enrollment

NGSS CONNECTIONS
Practices: obtaining, evaluating, and communicating information

ESTIMATED TIME
Two 45-minute class periods

MATERIALS
- Class set of the "Sharing a Scientific Discovery" scenario (print or upload to LMS)
- Class set of the "Visualizing the Scientific Method" activity guide (print or upload to LMS)
- Class set of one annotated preprint (print or upload to LMS)
- Poster boards (~18 x 24 in.) and markers

SUMMARY

In this lesson, students will learn about preprint articles ("preprints") and the information these articles typically contain. While there are different types of preprints, this lesson focuses on those that report findings from a scientific study.

LEARNING OBJECTIVES

By the end of this lesson, students will be able to:

1. Explain what a preprint is
2. Describe key elements of the scientific method included in a preprint, such as a question, hypothesis, materials and methods, results, discussion, etc.

PRIOR KNOWLEDGE

Ideally, students will have some experience reading primary scientific literature (i.e., journal articles) or a general understanding of how science reports are structured.

BACKGROUND INFORMATION

Professional scientists often communicate their research by publishing in **peer-reviewed journals**, which are scientific periodicals that have other scientists from the same field (**peers**) review the research before it is published. While the style and content guidelines for a **manuscript** (submitted article) vary between journals, the general steps to **publishing** are the same: a researcher or group submits a manuscript to a journal and the editor decides if it aligns with the journal's scope. If it does, the manuscript is sent for **peer review**. Peer review is integral to the **publication process** because these fellow experts evaluate whether the research is ethical, original, and scientifically sound – in short, whether the content is ready to be published. Based on the feedback from the peer reviewers, the author(s) may revise their manuscript or submit to a different journal altogether (i.e., if the peer reviewers **reject** it). However, just because a published scientific journal article is peer-reviewed does not mean it is perfect. Although peer review serves as useful and necessary quality control, it's important to remember that authors, reviewers, and editors alike all bring their own biases.

The lengthy peer review process can take several months to a year, sometimes delaying communication of new scientific knowledge. Paywalls, subscriptions, and other barriers can also restrict public access to these articles. This is exactly where preprint articles ("preprints") come into play. A **preprint** is a scientific manuscript that has been posted online on a **preprint server** but has not gone through the formal peer review publishing process. However, preprints are more than just a draft or informal report of findings, since preprints can eventually evolve into peer-reviewed publications. In fact, some journals now require manuscripts to be posted as a preprint before they are published. Researchers start by uploading their preprint to an **open-access server** or online platform, making it publicly available within days. Unlike a published journal article, preprints don't receive peer review prior to being publicly posted. Instead, other scientists and community members can access the publicly posted preprint and provide direct, real-time feedback. There is even a growing trend to provide structured peer reviews to preprints with organizations like PreReview.

Believe it or not, preprints have been around for several decades! The first preprint server was founded in the 1990s by physicist Paul Ginsparg to improve communication within the physics community. Preprints became more popular during the COVID-19 pandemic when the urgency to share knowledge made the traditional publishing timeline impractical. Since then, preprints have become increasingly common across various scientific fields. Although they have some drawbacks - such as the lack of formal peer review - preprints represent an exciting shift in how scientists communicate and share their scientific knowledge.

See References for more information

MATERIAL PREPARATION

Finding Preprints

We recommend the following preprint servers to find a preprint that is relevant to your class:

- eiRxiv for manuscripts written by middle and high school students across many scientific fields
- arXiv for physics, mathematics, computer science, economics, and related fields
- bioRxiv for biology
- ChemRxiv for chemistry
- SocArXiv for social sciences

You can search for a preprint broadly by subject area or use an advanced search option to filter by terms and keywords or date posted. Keywords and the Abstract can be used to connect the preprint to subject-specific NGSS standards.

For this lesson plan, use a preprint that reports new results from an experiment rather than a commentary or review paper. The Abstract will often describe the type of preprint, for example:

- "We conducted a systematic review to find..." indicates a review preprint.
- "We investigated the effects of... on ..." indicates the preprint describes an experiment.

Annotating Preprints

Before class, read the preprint and prepare it for students by:

1. Highlighting key sections (e.g., Introduction, Methods, Results, Discussion) and sentences that illustrate the scientific method (e.g., "In this study, we asked the following research questions..." or "We hypothesized that...")
2. Adding brief comments in the margins to define technical terms in the highlighted sections, pointing out elements of the scientific method, or connecting to concepts students already know
3. Minimizing dense detail by deleting pages or greying out text, especially in the Methods section

Highlight, circle, or star any visible indication that the article is a preprint. Look for a note or disclaimer stating the article has not yet been peer-reviewed. Then, write a comment in the margin for students such as: *"Peer review means a scientific report has been read and evaluated by other expert scientists in a similar field. Peer reviewers check that the experiment was done correctly, the results make sense, and the ideas are new."*

CLASS ONE PROCEDURES

Small Group Discussion - "Sharing a Scientific Discovery" Scenario (15 minutes)

1. Distribute the "Sharing a Scientific Discovery" Scenario Handout (found at the end of this lesson) and read the following scenario to your class: *Imagine a team of scientists who spend several years collecting and analyzing data to study the role of DNA mutations in cancer development. They make an exciting discovery that helps answer a big question in their field: are most cancers caused by new mutations that occur during one's life, or are they inherited? Eager to share their findings with other scientists, the team writes a detailed report and submits it to a scientific journal for publication as a scientific journal article. They hope their work will lead to better ways to identify and treat different types of cancer.*

To support various learning styles and needs, students can also read along with the printed or digital scenario, popcorn read, read individually, or read in small groups.

Before the report can be published, it must go through peer review, a process where other expert scientists in a similar field read the report and provide feedback. The first round of peer review takes more than three months, and the reviewers ask for clarification on the experimental design and suggest changes to the writing style. The scientists see this feedback as a chance to improve the report. However, it takes over a month to make the revisions because the scientists are busy with other lab work; they're investigating new questions about the role of mutations in cancer.

For a real scenario about the lengthy publishing process, read this News Feature published in 2016 in *Nature* (written by Kendall Powell).

After submitting the revised report to the journal again, the team learns that one of the original peer reviewers is no longer available, so a new reviewer is assigned. After two more months, the new reviewer requests additional changes. So, the team must revise the report again. By this point, six months have passed since the report was first submitted. It will be several more months before it's finally published and shared with the scientific community.

(**Discussion Questions** are on the following page)

2. Have students discuss the following questions in small groups:

- The scientists value peer review because they believe it will help improve their report. How has feedback helped you on assignments or projects?
- Can you think of a time in school or in an extracurricular activity when you had to wait a long time to get feedback? How did that make you feel?
- How might the scientists feel in this scenario, believing that their discovery is important but having to wait over six months to share it with others?
- What are the pros and cons of the peer review process referenced in this scenario?
- What are some other ways the scientists could formally communicate their discovery with the scientific community while waiting for peer review?

3. Students will revisit this scenario at the end of the lesson once they have learned what a preprint is.

Individual Activity - Skimming a Preprint (30 minutes)

1. Give each student a copy of the annotated preprint or have them access it digitally through your LMS.

2. Explain what a preprint is: *a scientific report that has been shared publicly before other scientists have peer-reviewed it. A preprint is not considered a published scientific journal article.* Then, ask students to locate where in the preprint it states that it has *not yet been peer-reviewed.*

3. Have students skim the preprint, first identifying the main sections (e.g., Introduction, Methods, Results, and Discussion). Then, students should read your annotated notes in the margins and highlighted sentences in the main text. Emphasize that they do not need to read the entire preprint.

For a 45-minute class period, end the lesson here. If you have a 90-minute block, proceed to the next activity.

Many text-to-speech apps read PDFs of primary scientific literature. To limit what text these apps read, consider redacting non-essential text from the PDF before sharing it with students (i.e., headers and footers, figure and table captions).

CLASS TWO PROCEDURES

Small Group Activity - Visualizing the Scientific Method (20 minutes)

1. Divide the class into small groups (2-3 students per group), and give each group a poster board and some markers.

2. Each group will create a diagram that outlines the structure of the preprint and highlights key elements of the scientific method - such as background information, research questions, hypotheses, materials and methods, results, discussion, limitations, and references.

- Encourage students to use arrows or lines to show connections between sections. For example, a hypothesis might be stated in the Introduction and referenced in the Discussion (e.g., was it supported or not?).
- The diagram should go beyond simply listing the section headers. Students should include specific details, using your annotated notes and highlighted text as support.

While the scientific method is often depicted as a linear, step-by-step process, in reality, science is more complex.

Nonetheless, scientific reports such as preprints are typically structured in a standardized format (i.e., Introduction → Methods → Results → Discussion) to clearly organize and communicate the research.

Class Discussion (15 minutes)

1. Lead a class discussion by asking the following questions:

- What key elements of the scientific method did you notice in the preprint? Were any elements missing or unclear?
- Does the organization of the preprint make the research easier or harder to understand?
- How is the structure of the preprint similar to or different from other types of scientific writing you've seen?
- The preprint included a statement that it had not yet been peer-reviewed. Do you think it was clear enough that this was a preprint and not a final, peer-reviewed scientific journal article?
- Based on what you have learned so far, how would you define a preprint?

Video and Quick Write (10 minutes)

1. Show the video "What are preprints?" (4:00 minutes) created by the organization, *Accelerating Science and Publication in biology* (ASAPbio). This video provides a brief comparison between peer-reviewed scientific journal articles (publications) and preprints. Although biology preprints have become more common since this video was posted in 2016, the content and comparison in the video remains relevant today.

ASAPbio is a nonprofit organization committed to open publishing for the life sciences. For more information about preprints and resources you can use, visit asapbio.org.

2. After the video, assign students a quick write with these prompts:

- Define a preprint now that you have learned about them.
- Consider the earlier scenario with the scientists. How could the scientists have used preprints to share their discovery? Do you think they should share their findings as a preprint?

EXTENSIONS

- Ask students to read the full preprint from class, including the sections that were removed or not annotated. Then, have them add detail to their diagrams.
- Give students another preprint but have them annotate it themselves (i.e., main sections and key words). How does the new preprint compare to the one they reviewed in class? In what ways is the structure similar and/or different?

ASSESSMENTS

The following prompts offer different ways for students to reflect on and apply what they have learned:

- Create a diagram that compares a preprint to a peer-reviewed scientific journal article. Include a brief definition for each type of scientific report and identify at least five similarities and differences. Consider the report's structure, intended audience, review process, etc.
- Identify some potential benefits and downsides of using preprints to share scientific findings before peer review. Find evidence (such as blogs, news articles, podcasts, videos) to support your claims.
- Write a short blog post (about 500 words) or create a 1-2 minute video introducing preprints to other high school students who may not be familiar with them. Using what you learned in class, explain what they are and make specific connections between the structure of a preprint and the scientific method.

REFERENCES

This lesson plan draws on resources and information provided by the organizations listed below:

- Accelerating Science and Publication in biology (ASAPbio) - asapbio.org
- Emerging Investigators Preprint Server (eiRxiv) - eirxiv.org
- Journal of Emerging Investigators (JEI) - emerginginvestigators.org
- PreReview - prereview.org

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At eiRxiv and JEI, we are committed to providing the tools, mentorship, and community necessary for any middle or high school student to publish and share their research with other students and the broader scientific community. Visit us at eiRxiv.org and emerginginvestigators.org.

SHARING A SCIENTIFIC DISCOVERY SCENARIO

1. Read the following scenario:

Imagine a team of scientists who spend several years collecting and analyzing data to study the role of DNA mutations in cancer development. They make an exciting discovery that helps answer a big question in their field: are most cancers caused by new mutations that occur during one's life, or are they inherited? Eager to share their findings with other scientists, the team writes a detailed report and submits it to a scientific journal for publication as a ***scientific journal article.*** *They hope their work will lead to better ways to identify and treat different types of cancer.*

Before the report can be published, it must go through ***peer review****, a process where other expert scientists in a similar field read the report and provide feedback. The first round of peer review takes more than three months, and the reviewers ask for clarification on the experimental design and suggest changes to the writing style. The scientists see this feedback as a chance to improve the report. However, it takes over a month to make the revisions because the scientists are busy with other lab work; they're investigating new questions about the role of mutations in cancer.*

After submitting the revised report to the journal again, the team learns that one of the original peer reviewers is no longer available, so a new reviewer is assigned. After two more months, the new reviewer requests additional changes. So, the team must revise the report again. By this point, six months have passed since the report was first submitted. It will be several more months before it's finally published and shared with the scientific community.

2. In your small group, discuss the following questions:

- The scientists value peer review because they believe it will help improve their report. How has feedback helped you on assignments or projects?
- Can you think of a time in school or in an extracurricular activity when you had to wait a long time to get feedback? How did that make you feel?
- How might the scientists feel in this scenario, believing that their discovery is important but having to wait over six months to share it with others?
- What are the pros and cons of the peer review process referenced in this scenario?
- What are some other ways the scientists could formally communicate their discovery with the scientific community while waiting for peer review?

VISUALIZING THE SCIENTIFIC METHOD

STEP 1: Create a diagram

Now that you've skimmed a **preprint** to identify its main sections and get a general idea of the study design, it's time to dive deeper! With your group, create a diagram that shows how the preprint is organized and how it connects to the scientific method. While making your diagram, think about what key elements of the **scientific method** the preprint includes. For example, does it have a research question, hypothesis, and methods? Do the authors present their data (results), how do they discuss these results, and what are their final conclusions?

There is no one "right" way to make your diagram, so get creative! Use text, symbols, and colors to express your ideas. Your diagram should include more than just the section titles: add details, evidence, and ideas you find in the preprint. Although we think of science as a step-by-step, linear progression, the parts of the scientific process are all tightly woven together. Use your diagram to show how different sections connect – for example, a hypothesis might be introduced in the Introduction and discussed again in the Discussion.

If you have time left after making your diagram, review the questions in Step Two (below) with your group members. You'll then discuss these questions as a class.

STEP 2: Class discussion

- What key elements of the scientific method did you notice in the preprint? Were any elements missing or unclear?
- Does the preprint's structure and organization make the research easier or harder to understand?
- How is the preprint's structure similar to or different from other types of scientific writing you've seen?
- The preprint included a statement that it had "not yet been peer-reviewed." Do you think most readers would be able to clearly see this was a preprint and not a final, peer-reviewed scientific journal article?
- Based on what you have learned so far, how would you define a preprint?