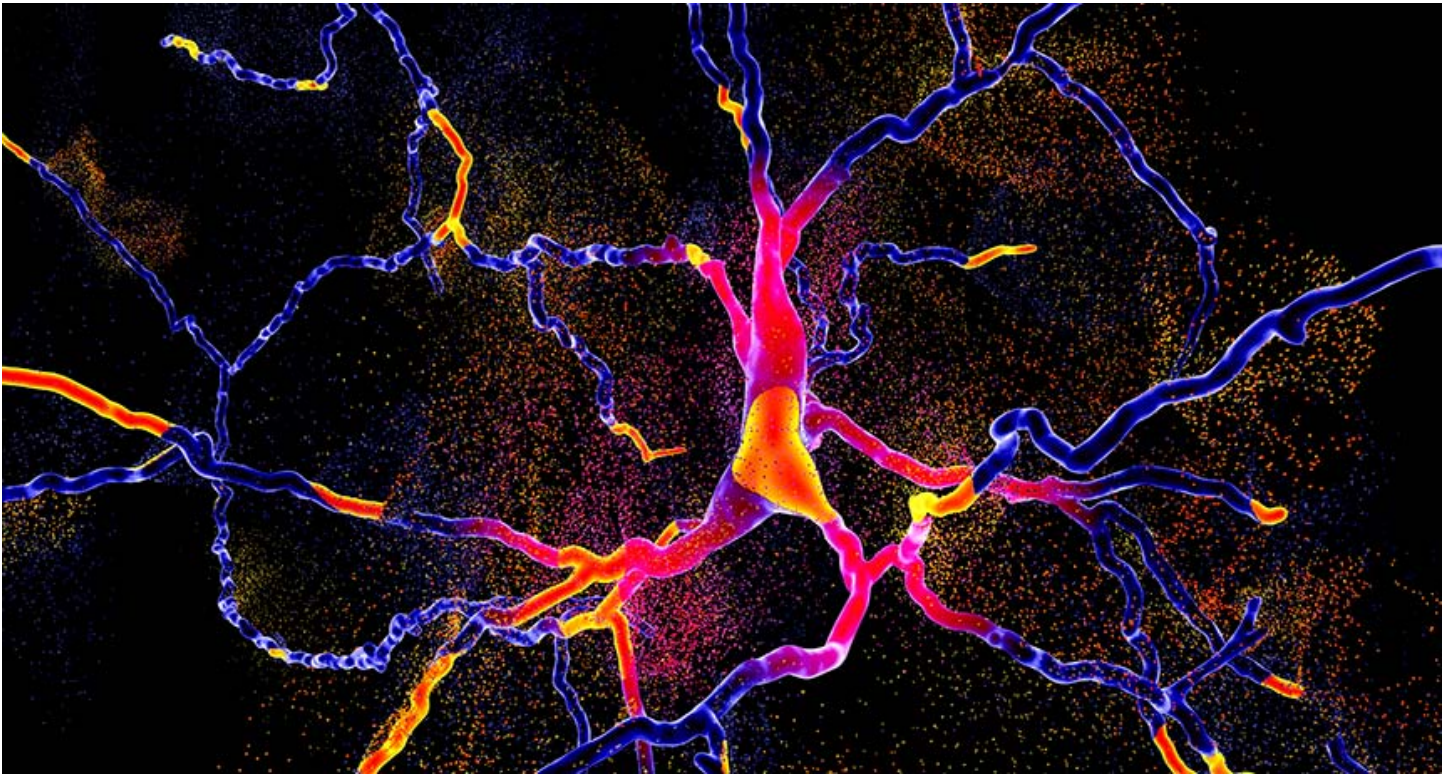


ScienceNews

IN HIGH SCHOOLS | EDUCATOR GUIDE



DR_MICROBE/ISTOCK.COM

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Parkinson's Pathways

About this Guide

Use this Guide to help students learn about Parkinson's disease through the *Science News* article "[Parkinson's pathways](#)." The article reports on recent research exploring the role that the gastrointestinal tract may play in the disease. **Readability score: 12.0**

This Guide includes:

Article-based observations: Q&A — Reading comprehension questions and answers on "[Parkinson's pathways](#)."

Key topics covered: Neuroscience, biochemistry, microbiology

Article-based observations, questions only — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular connections: Q&A

Defining terms relating to the article — Ask students to define key science terms related to neuroscience, biochemistry and microbiology. Students can consult outside resources if necessary.

Discussion beyond the article — Students will use resources beyond the article to answer more detailed questions on neuroscience, biochemistry and microbiology.

Cross-curricular connections, questions only — These definition and discussion questions are formatted so it's easy to print them out as a worksheet.

Analyze this! Q&A — Questions and answers about the graph "Parkinson's risk is lower in patients with a cut vagus nerve." The graph shows that patients who have had surgery to cut this nerve connecting the gastrointestinal tract and brain have a lower risk of developing Parkinson's disease over time than people with an intact vagus nerve.

Analyze this! Questions only — These questions are formatted so it's easy to print them out as a worksheet.

Other related articles and media — *Science News* and *Science News for Students* articles and videos on similar topics that you can use in your teaching.

Standards

Next Generation Science DCI	Common Core ELA
From Molecules to Organisms: Structures and Processes: HS-LS1-1 , HS-LS1-2 , HS-LS1-3	Reading Informational Text (RI): 1, 2, 4, 5, 7
Ecosystems: Interactions, Energy, and Dynamics: HS-LS2-3 , HS-LS2-6	Writing (W): 1, 2, 3, 4, 6, 7, 8, 9
Heredity: HS-LS3-1 , HS-LS3-2	Speaking and Listening (SL): 1, 2, 4, 5, 6
Engineering Design: HS-ETS1-1 , HS-ETS1-2 , HS-ETS1-3	Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 3, 4, 5, 7, 8, 9
	Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 4, 7, 8, 9

Article-Based Observation: Q&A

These questions are based on the *Science News* article "[Parkinson's pathways](#)." Students should read the article introduction and answer related questions (Introduction to "Parkinson's pathways"). Students can then form groups to read and answer questions about the sections of the article that you assign. The story sections are: Gut feeling, Neural highway, Belly bacteria, Microbial forces and Head for a cure. Note that Belly bacteria and Microbial forces should be assigned together. Once groups are finished, they can present the information they learned to the rest of the class. Finally, allow students to individually answer the final questions in the section titled, Summarize ideas and think critically.

Introduction to "Parkinson's pathways"**1. What is Parkinson's disease and what causes it?**

Possible student response: Parkinson's disease is a progressive, incurable disease in which nerve cells in a brain region involved in muscle control die. The cause of the disease is unknown, but abnormally clumped and misfolded proteins are the prime suspect. Some theories suggest that head trauma or exposure to environmental pollutants such as heavy metals, pesticides or air pollution might play a role.

2. Why are Parkinson's researchers interested in the gut and nose?

Possible student response: People with Parkinson's disease commonly lose their sense of smell and have digestive issues. Since the early 2000s, scientists have been gathering evidence that the malformed proteins in the brains of Parkinson's patients might first appear in the gut or nose.

3. Describe a recent study that provides evidence for a link between the gut and Parkinson's disease.

Possible student response: Scientists in Sweden reported that people who had their appendix removed had a lower risk of developing Parkinson's disease years later. The appendix, attached to the colon, may play a role in intestinal health.

Gut feeling**4. Describe an early connection made between the gastrointestinal tract and Parkinson's disease?**

Possible student response: London physician James Parkinson, for whom Parkinson's disease is named, wrote that some of his first patients with the disease had digestive problems. He treated two patients with a laxative and noted that their tremors subsided.

5. What is alpha-synuclein and what is known about its role in Parkinson's disease?

Possible student response: In patients with Parkinson's disease, the protein alpha-synuclein is abnormal and can become bundled with other proteins into Lewy bodies, which collect in the substantia nigra, a brain region that helps control movement.

6. What evidence did neuroanatomists Heiko Braak and Kelly Del Tredici and their collaborators find that suggested Parkinson's might not arise in the brain?

Possible student response: The researchers tested for Lewy bodies and unbundled alpha-synuclein in deceased Parkinson's patients. Based on comparisons with people without Parkinson's, the team found signs that Lewy bodies had started to form in the nasal passages and intestines of Parkinson's patients before showing up in the brain.

7. What is the standard treatment for Parkinson's disease?

Possible student response: Parkinson's disease kills nerve cells that produce the chemical messenger dopamine. Levodopa, a synthetic replacement for dopamine, can alleviate some symptoms. But the drug does not prevent the disease from progressing.

Neural highway

8. How might proteins associated with Parkinson's disease travel from the gastrointestinal tract to the brain? What have experiments in mice found?

Possible student response: Proteins might travel from the gut to the brain via the vagus nerve. In one study in mice, alpha-synuclein migrated from the intestine to the brain via the vagus nerve. In other studies, mice that ate and inhaled the pesticide rotenone developed Parkinson's symptoms.

9. What results were found in patients who had their vagus nerve severed right above the stomach?

Possible student response: For people who had their vagus nerve cut, the risk of developing Parkinson's began dropping five years after surgery, eventually reaching a difference of about 50 percent compared with people who had an intact vagus nerve.

10. What is *LRKK2* and how does it relate to Parkinson's disease and the gut?

Possible student response: *LRKK2* is a gene involved in the immune system. Variations of the gene appear to increase the risk for developing inflammatory bowel disease and Parkinson's.

11. What further links were found between inflammatory bowel disease and Parkinson's disease?

Possible student response: In one analysis, patients with inflammatory bowel disease were about 30 percent more likely to develop Parkinson's than people without the disease. And inflammatory bowel disease patients who took antitumor necrosis factor were 78 percent less likely to develop Parkinson's than similar patients who did not take that drug.

Belly bacteria and Microbial forces

12. What results were found in mice that were genetically engineered to overproduce the alpha-synuclein protein?

Possible student response: If engineered mice were raised without any microorganisms in their insides, they did not develop Parkinson's symptoms. If the mice were given microbes from healthy people, the mice developed some Parkinson's symptoms. Mice given microbes from Parkinson's patients developed severe Parkinson's symptoms. The scientists suspect that something in the microbiome triggers the misfolding of alpha-synuclein.

13. What happened in one study when rats' gut bacteria became stressed and produced their own amyloids? What does this suggest about a gut-brain connection?

Possible student response: When *E. coli* bacteria in rats' intestines were stressed and produced amyloids — fibers of tightly stacked proteins — alpha-synuclein in the rats' brains also formed amyloid clumps. The finding suggests that the immune system's reaction to amyloid in the gut might somehow be involved in triggering amyloid formation in the brain.

Head for a cure

14. What do observational studies of Parkinson's patients' microbiomes find? What does the finding mean for our understanding of Parkinson's disease?

Possible student response: Many Parkinson's patients report serious gastrointestinal problems, and observational studies find differences in gut bacteria between Parkinson's and non-Parkinson's patients. But it's too early to know how those differences might matter for the development of the disease.

15. How might microbiome research help Parkinson's patients?

Possible student response: Doctors might be able to test for changes in the microbiome that put people at higher risk for developing Parkinson's and restore healthy microbe populations through diet or some other means to delay or prevent the disease. Drugs may one day be developed that could stop the spread of abnormal alpha-synuclein from cell to cell.

16. Who is Martha Carlin and what is she doing to help promote further research of the microbiome and Parkinson's?

Possible student response: Martha Carlin is a woman whose husband, John Carlin, was diagnosed with Parkinson's disease. She founded a company that collects microbial samples from Parkinson's patients for researchers to study.

17. Who is John Carlin and what is he doing to help people who are diagnosed with Parkinson's?

Possible student response: John Carlin is a man who was diagnosed with Parkinson's disease at age 44. He operates biking programs for people with Parkinson's disease in order to stay active.

Summarize ideas and think critically

18. What is the central idea of the article?

Possible student response: Parkinson's disease kills nerve cells that send signals from the brain to muscles, leading to uncontrolled movement. Recent evidence suggests that there might be a relationship between Parkinson's and the gut, although the details are still not understood.

19. If the gut turns out to have an important role, what approaches could you imagine that might eventually treat Parkinson's disease?

Possible student response: Detecting abnormal alpha-synuclein or other markers of Parkinson's disease in the gastrointestinal tract or nose to potentially diagnose and begin treating Parkinson's patients earlier. Using strong antibiotics to kill all of the potentially bad gut bacteria in Parkinson's patients, then repopulating patients' gastrointestinal tracts with bacteria from healthy people. Using drugs and/or surgery to stop potentially harmful proteins from moving from the gastrointestinal tract to the brain.

Article-Based Observation: Q

Directions: Read the introduction of the *Science News* article "[Parkinson's pathways](#)" and answer the related Introduction to Parkinson's disease questions. Then in a group, read the article section assigned to you by your teacher and answer the related questions. The sections are: Gut feeling, Neural highway, Belly bacteria, Microbial forces and Head for cure. Once your group is finished, prepare and present a short summary of your article section to the class. Finally, individually answer the two questions in the last section titled, Summarize ideas and think critically.

Introduction to "Parkinson's pathways"

1. What is Parkinson's disease and what causes it?

2. Why are Parkinson's researchers interested in the gut and nose?

3. Describe a recent study that provides evidence for a link between the gut and Parkinson's disease.

Gut feeling

- 4. Describe an early connection made between the gastrointestinal tract and Parkinson's disease?**
- 5. What is alpha-synuclein and what is known about its role in Parkinson's disease?**
- 6. What evidence did neuroanatomists Heiko Braak and Kelly Del Tredici and their collaborators find that suggested Parkinson's might not arise in the brain?**
- 7. What is the standard treatment for Parkinson's disease?**

Neural highway

- 8. How might proteins associated with Parkinson's disease travel from the gastrointestinal tract to the brain? What have experiments in mice found?**
- 9. What results were found in patients who had their vagus nerve severed right above the stomach?**
- 10. What is *LRKK2* and how does it relate to Parkinson's disease and the gut?**
- 11. What further links were found between inflammatory bowel disease and Parkinson's disease?**

Belly bacteria and Microbial forces

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Head for a cure

14. What do observational studies of Parkinson's patients' microbiomes find? What does the finding mean for our understanding of Parkinson's disease?

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Summarize ideas and think critically

18. What is the central idea of the article?

19. If the gut turns out to have an important role, what approaches could you imagine that might eventually treat Parkinson's disease?

Cross-Curricular Connections: Q&A

Directions: Define key science terms relating to topics in neuroscience, biochemistry and microbiology using contextual clues from "[Parkinson's pathways](#)." Students can use resources beyond the article to find more information if necessary.

Definitions relating to the article:

What is Parkinson's disease?

Parkinson's disease is an incurable brain and nervous system disease in which nerve cells die off in the substantia nigra, a brain region involved in muscle control, causing tremors and affecting movement, memory and mood.

What is Alzheimer's disease?

Alzheimer's disease is an incurable brain disease characterized by nerve cell death resulting in progressive memory loss and dementia. The causes of Alzheimer's are not well understood, but a very visible effect in the brain is tangles or plaques of clumped proteins.

What are neurotransmitters?

Neurotransmitters are chemical signals that nerve cells in the brain use to communicate with each other. Different types of nerve cells in different brain regions produce different neurotransmitters.

What is alpha-synuclein and what role does it play in the body?

Alpha-synuclein is a protein mainly found in nerve cells and its normal role is not well understood. Misfolded alpha-synuclein can form clumps and hinder communication between cells.

What are Lewy bodies? What role do Lewy bodies play in Parkinson's disease?

Lewy bodies are large clumps of alpha-synuclein and other proteins that accumulate in the brains of people with Parkinson's disease and Lewy body dementia.

What is amyloid? Name a disease which is closely associated with amyloid buildup.

Amyloids are clumps of proteins that form when proteins misfold and become tangled together. Various proteins can form amyloids, which can build up in the brain to form plaques — a hallmark of Alzheimer's disease.

What is the human microbiome? Name a common bacteria that lives in the human body and describe its function.

The human microbiome is the population of bacteria and other microorganisms that live on and inside a person. One type of bacteria commonly found in the human microbiome is *Escherichia coli*. In the gut, *E. coli* can help prevent pathogenic bacteria from taking hold. But some strains of *E. coli* can also cause gut inflammation.

What is a biofilm? Give an example of a biofilm that exists in/on the human body.

A biofilm is a population of microorganisms that stick together by producing a "film" or extracellular matrix of sugars, proteins and fats. Biofilms strongly adhere to surfaces and can be

very difficult to remove. An example of a biofilm is dental plaque, which is formed by bacteria on teeth.

What are prions? Name a disease caused by a prion.

Prions are misfolded proteins that can cause disease. Prions can form clumps in the brain and cause memory impairment, affect movement and personality. An example of a prion disease is bovine spongiform encephalopathy, or mad cow disease.

Discussion beyond the article:

What is a current treatment for Parkinson's disease?

Current treatments focus on controlling symptoms. The drug Levodopa is a chemical that once in the brain converts into the neurotransmitter dopamine. Other drugs that activate nerve cells' dopamine docking stations can also be given. Deep brain stimulation is a surgical treatment in which electrodes are implanted in a specific brain region to help control movement.

What is amyotrophic lateral sclerosis (ALS)?

In ALS, motor neurons in the brain's muscle control region and spinal cord die. Early symptoms include muscle stiffness, weakness, twitching, cramps and atrophy. As the disease progresses, patients gradually lose the ability to move, speak, swallow and breathe. The causes of ALS are not well understood.

What is chronic traumatic encephalopathy (CTE)?

CTE is a disorder diagnosed after death that's associated with memory loss, emotional outbursts, depression and dementia. The disorder appears to be initiated by repeated head injuries, such as those received by some athletes or soldiers. Over many years after the initiating events, nerve cells in the brain become progressively damaged and die. The mechanisms by which CTE develops are not well understood. However, one apparent hallmark is that tau proteins begin to form tangles, often seen in other degenerative brain diseases.

What are tau proteins?

Tau proteins, mainly found in nerve cells in the brain, help stabilize scaffolds that give cells their proper shape and help cells move. If a tau protein becomes misfolded, it can form clumps and alter brain function.

What are tumor necrosis factors (TNFs) and antitumor necrosis factors?

Tumor necrosis factors are signals that trigger inflammatory reactions in cells in response to an injury or infection. Antitumor necrosis factors are anti-inflammatory drugs that interfere with TNF signaling between cells. Such drugs can reduce inflammation or prevent undesirable responses from the immune system.

What are stomach ulcers?

Ulcers are sores that occur in the lining of the stomach and small intestine. Many stomach ulcers are caused by the bacteria *Helicobacter pylori* and can be cured with antibiotics.

What is Crohn's disease?

Crohn's disease is an inflammatory bowel disease that causes tissue damage in the gastrointestinal tract. The exact cause of Crohn's disease is unknown, but a number of factors such as heredity, a malfunctioning immune system and even the gut microbiome likely play a role in the disease's development. Crohn's disease can be treated with steroids and immunosuppressant drugs.

Cross-Curricular Connections: Q

Directions: Define key science terms relating to topics in neuroscience, biochemistry and microbiology using contextual clues from "[Parkinson's pathways](#)." Use resources beyond the article to find more information if necessary.

Definitions relating to the article:

What is Parkinson's disease?

What is Alzheimer's disease?

What are neurotransmitters?

What is alpha-synuclein and what role does it play in the body?

What are Lewy bodies? What role do Lewy bodies play in Parkinson's disease?

What is amyloid? Name a disease which is closely associated with amyloid buildup.

What is the human microbiome? Name a common bacteria that lives in the human body and describe its function.

What is a biofilm? Give an example of a biofilm that exists in/on the human body.

What are prions? Name a disease caused by a prion.

Discussion beyond the article:

What is a current treatment for Parkinson's disease?

What is amyotrophic lateral sclerosis (ALS)?

What is chronic traumatic encephalopathy (CTE)?

What are tau proteins?

What are tumor necrosis factors (TNFs) and antitumor necrosis factors?

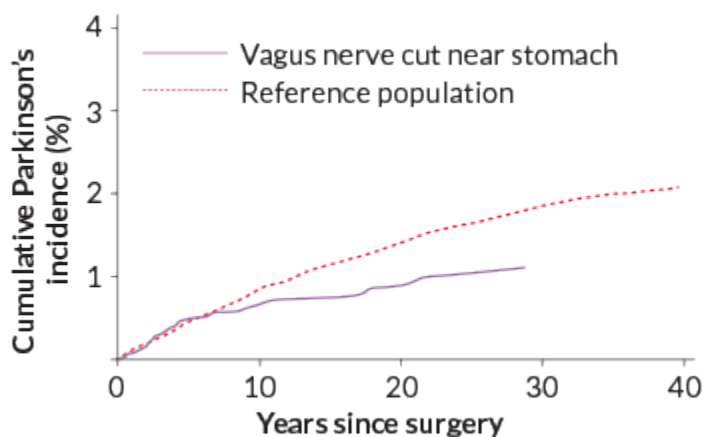
What are stomach ulcers?

What is Crohn's disease?

Analyze This! Q&A

Directions: Study the graph “Parkinson’s risk is lower in patients with a cut vagus nerve” in the *Science News* article “[Parkinson’s pathways](#)” and answer the following questions.

Read the figure: Parkinson’s risk is lower in patients with a cut vagus nerve



Radical protection Because the vagus nerve is a route to the brain, scientists wondered if a severed vagus nerve helped protect against Parkinson’s. In one study, patients who had undergone one type of vagotomy had lower disease incidence starting five years later than people who did not have the surgery. Source: B. Liu et al/*Neurology* 2017

1. What variable is plotted on the x-axis of the graph? Make sure to include the unit of measurement for the variable.

Possible student response: The time in years since surgery to cut the vagus nerve.

2. What variable is plotted on the y-axis of the graph? Make sure to include the unit of measurement for the variable.

Possible student response: The cumulative incidence of Parkinson’s disease, as a percentage of each population.

3. What do the lines represent?

Possible student response: The dotted red line represents the population in the study that did not undergo vagus nerve surgery. The solid purple line represents the population in the study that underwent the vagus nerve surgery.

Interpret the graph:

4. According to the graph, what benefit is associated with the cut vagus nerve?

Possible student response: The population with the cut vagus nerve had a lower risk of developing Parkinson's disease. At just shy of 30 years after surgery, the risk was a little less than 50 percent lower for those who had had surgery compared with people who had not had the surgery.

5. How long does it take for the cut vagus nerve to make an apparent difference in the cumulative Parkinson's incidence?

Possible student response: The curve for people with a cut vagus nerve starts to diverge from the curve for people with an intact vagus nerve roughly seven years after surgery.

Connect the graph to the article:

6. What relationships might be further investigated based on the data given in the graph?

Possible student response: The data suggest an interesting link between a cut vagus nerve and Parkinson's risk. It would make sense to further investigate this potential connection to see how the two may be connected. However, other factors probably also contribute to the development of Parkinson's disease because the risk was not eliminated.

7. How does this figure support the general ideas in "Parkinson's pathways?"

Possible student response: The graph shows an example that connections between the gastrointestinal tract and the brain could be involved in the development of Parkinson's disease.

Analyze beyond the article:

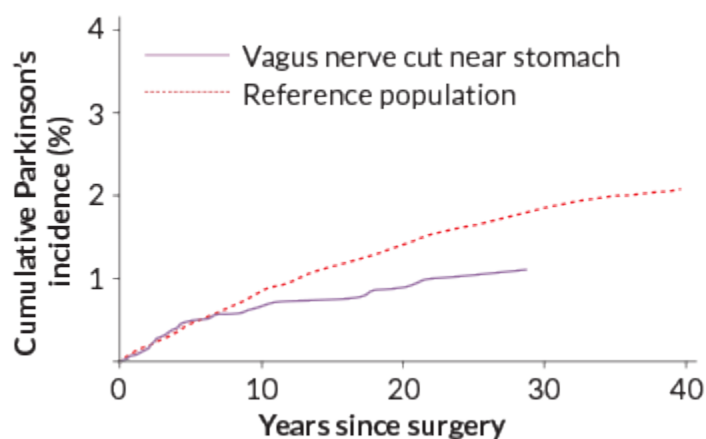
8. What other observational study could you run in an attempt to understand Parkinson's risk in relation to the gut?

Possible student response: I would like to compare how surgery or removal of different parts of the gastrointestinal tract, such as the appendix, affects Parkinson's risk over time.

Analyze This! Q

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Other Related Articles and Media

Science News

Article: "[The appendix is implicated in Parkinson's disease](#)"

Article: "[Constipation might signal Parkinson's](#)"

Science News for Students

Article: "[Belly bacteria can shape mood and behavior](#)"

Readability score: 7.0



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