What's normal? The scoop on poop

Educator guide

PAPER DETAILS

Original title: Population-level analysis of gut microbiome variation

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DISCUSSION QUESTIONS

	LEARNING STANDARDS
1. Why is it important to account for confounding variables? How might these variables affect the authors' conclusions?	SEP3 Cause and effect SP4 EK4.A.5
2. Why do the authors care about comparing only healthy individuals in the same population? What information can they gather that is different from previous studies, like the U.S. National Institutes of Health's Human Genome Project?	SEP1 Scale, proportion, and quantity
3. Could the authors have found this information using other techniques? What techniques might they have used? How could they verify their results?	SEP3 LS1.C
4. The authors mention that there may be some intrinsic microbial ecological processes that are unexplained in their study. Are there any other processes that they could account for in future studies to explain more of the variation?	SP4 EK4.A.5 Nature of Science
5. Early life events were found not to affect adult microbiota composition. Why did the researchers highlight this evidence?	LS2.C Nature of Science
6. The researchers conclude that there exists a core microbiota. What genera are included? What might account for differences in core microbiota, both on a population and individual scale?	LS2.C Patterns EK4.A.5

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** **Nature of Science**
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."	**Patterns** **RST.9-10.8** **RST.11-12.8** **Nature of Science**
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.	**SEP1** **RST.11-12.5** **RST.11-12.6** **RST.11-12.8**
Microbiome study comparisons Compare the results of this paper with another microbiome study. What variables do they account for that are similar and what are different? How might you determine and compare the quality of two studies on similar topics?	**SEP3** **LS2.C** **Cause and effect** **EK4.A.5**
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.	**LS1.C** **Scale, proportion, and quantity** **SP4**
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.	**SEP1** **SEP3** **RST.11-12.5** **Nature of Science**

ARTICLE OVERVIEW

Article summary (recommended for educator-use only)

This study identified the composition and abundance of the fecal microbiome in healthy individuals from Western Europe through 16S rRNA sequencing. The found that there were 14 genera that were present in 95% of all samples. Integrating clinical and questionnaire data, they found that stool consistency, as measured by the Bristol Stool Scale, had the largest predictive effect on microbiome composition. Moreover, they showed that there were associations between some variables and certain genera that were proposed to be markers for disease. However, because they identified certain medical interventions affected the outcome of the association studies, they believe that future research in drug-microbiome association studies need to be done to carefully to account for potentially confounding effects of medication.

Importance of this research

This study is important because it provides a list of core microbiome genera that gives us new insights into the inheritance and evolution of microbes. This work is one of the many recent genome-wide studies that have revealed new insights into the relationship between our gut microbiome and human health. Many studies have since used this data to study the impact of fecal transplants in patients infected with *Clostridium difficile*, a bacterium that causes severe intestinal conditions.

Experimental methods

- 16S rRNA: A sequencing technique that can be used to identify and compare bacteria in a sample without needing to culture them first
- Unconstrained canonical correspondence analysis: A statistical method that finds linear combinations of variables that have the most correlation with each other
- Principle coordinate analysis: A statistical technique used to visualize similarity between variables by representing the variance in reduced dimensions
- Stepwise redundancy analysis: A statistical technique used to describe linear relationships between components of dependent variables that can be explained by a set of independent variables
- Bioclustering: A statistical technique that clusters groups with similar properties given a specific set of conditions

Conclusions

- There exists a global human core microbiota comprised of 14 genera.
- Bristol stool scale and stool consistency has the strongest effect on microbiota variation.
- There are correlations between certain bacteria genera and disease.
- Medication has some correlation with microbiota variation but may also be a potential confounding factor in clinical studies.
- Early life events do not significantly affect the adult microbiome composition.

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
Asking Questions and Defining Problems (SEP1) Evaluate questions and challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. **Planning and Carrying Out Investigations (SEP3)** Plan and conduct an investigation to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitation of the precision of data.	**LS1.C: Organization for Matter and Energy Flow in Organisms** As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products. **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e. the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.	**Patterns** Observed patterns of forms and events guide organization and classification, and they 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. **Scale, Proportion, and Quantity** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

Science in the Classroom AAAS

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.9-10.2** 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.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.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.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.9-10.5** Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy). **RST.9-10.6** 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.11-12.4** 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.11-12.5** 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.	**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.9-10.9** 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.11-12.8** 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.11-12.9** 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.

AP Science Standards	
AP Science Practices	AP Biology Content Standards
Science Practice 4 (SP4) The student can plan and implement data collection strategies in relation to a particular scientific question. (Note: Data can be collected from many different sources, e.g., investigations, scientific observations, the findings of others, historic reconstruction and/or archived data).	**Essential knowledge 4.A.5 (EK4.A.5)** Communities are composed of populations of organisms that interact in complex ways. For example, the structure of a community is measured and described in terms of species composition and species diversity.

Science in the Classroom AAAS

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 use quantitative reasoning Apply quantitative analysis to interpret biological data: developing and interpreting graphs, applying statistical methods to diverse data, mathematical modeling, managing and analyzing large data sets. **Ability to understand the relationship between science and society** Identify the historical and social dimensions of biology practice: evaluating the relevance of social contexts to biological problems, developing biological applications to solve societal problems, evaluating ethical implications of biological research.	**Science is a human endeavor** Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. Technological advances have influenced the progress of science and science has influenced advances in technology.