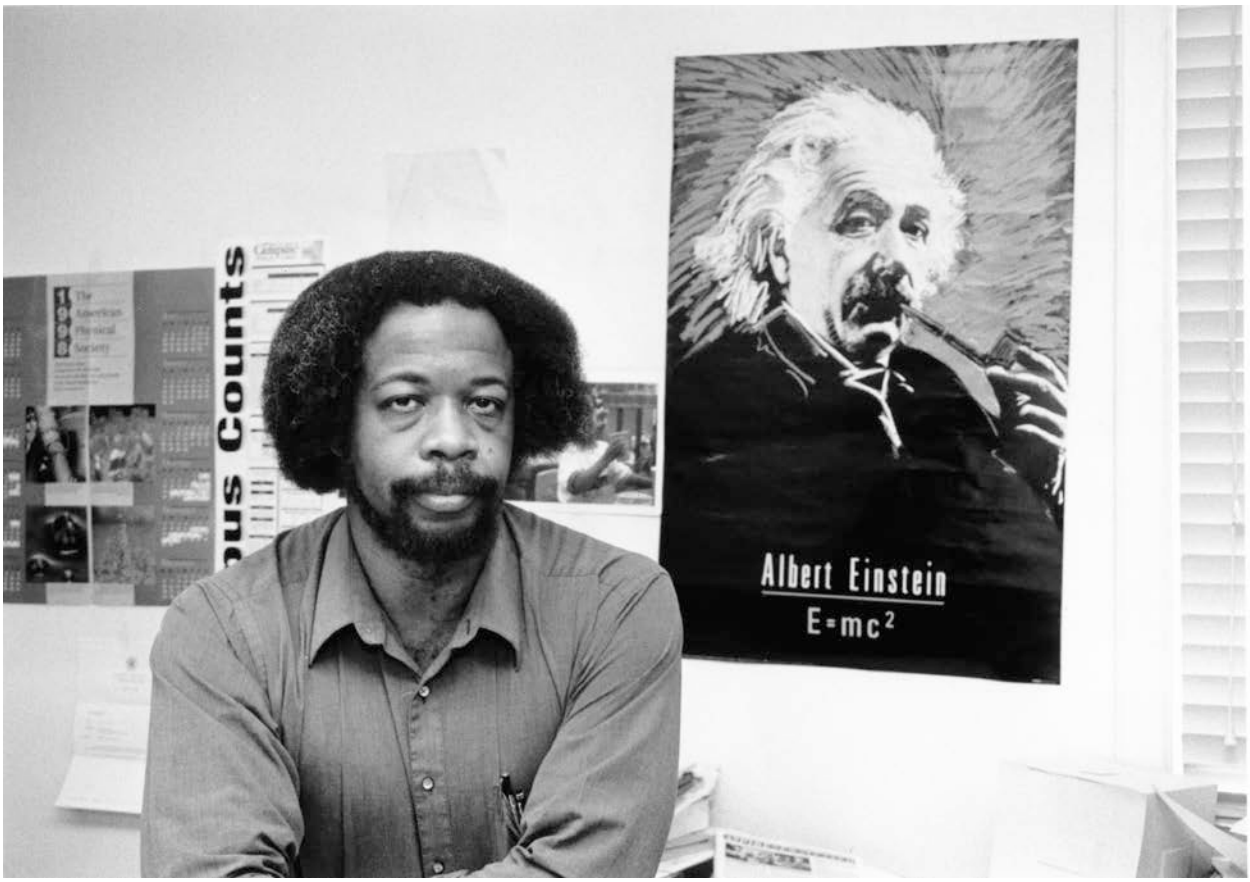
Lesson Plan
Dr. Gates and the Nature of the Universe



Dr. Sylvester James Gates, Jr.,
Image courtesy AIP Emilio Segré Visual Archives, Ronald E. Mickens Collection.

Grade Level(s): 9-12	**Subject(s): History, Physics, Contemporary**

In-Class Time: 60-80 min	**Prep Time: 15-20 min**

Materials

Part One: Dr. James Gates' Life

- Downloads or access to certain videos on the HistoryMakers website (via a free account – see Required/Recommended Resources)

Part Two: What is String Theory?

- A set of nesting Russian dolls or a set of nesting boxes
- Printouts of NOVA: The Elegant Universe "Viewpoints on String Theory: Jim Gates" and other credible research resources (see Required/Recommended Resources)

Objective

In this two-part lesson plan, students will learn about the life of theoretical physicist Dr. Sylvester James Gates, Jr. and string theory, his field of research. The activities in this guide are designed to help students better understand some of the basic concepts underlying particle physics and string theory.

Introduction

Sylvester James Gates, Jr. was born in 1950 in Tampa, Florida. Gates' father had a 24-year career in the military, so the family moved often when Gates was young. His parents always encouraged him to learn and when he was eight, his father bought him an *Encyclopedia Brittanica* set which sparked his interest in science. He recalls being fascinated by books about space and planets that his father brought home and had an early interest in comic books, fantasy, and science fiction which continued to fuel his passion for science.

When he was in sixth grade, Gates went for the first time to a segregated school. He and a classmate started a chess club at school. They competed mostly against all-white schools, which were often surprised by Gates' club's winning record. In eleventh grade, Gates took his first class in physics and he knew immediately it was for him. He had always thought of math as a game with certain rules -- but here was a way to apply it to real life. Gates almost didn't apply to college. Although he was a good student he felt sure he would be rejected anyway. His father and step-mother (a teacher) coaxed him to rethink the decision, and he applied and was accepted to MIT. He earned a B.S. degree in mathematics and physics in 1973 and earned his Ph.D. from MIT in 1977. His doctoral thesis was the first at MIT to discuss supersymmetry.

After receiving his degree, he did more physics research at Harvard and the California Institute of Technology. He served as a physics professor at Howard University for three years before joining the faculty at University of Maryland, College Park, where he has remained since 1994. Gates is an expert at explaining complex physics to a non-physics audience and has been featured in many documentaries and videos about string theory. In 2013, Dr. Gates was awarded the National Medal of Science.

Throughout his career, Gates has focused on string theory, an extremely mathematical view of physics, joining relativity and quantum mechanics. While general relativity applies to huge objects in the universe like planets, stars, and black holes, quantum physics applies to the world of the very miniscule – subatomic particles. String theory attempts to reconcile contradictions between Einstein's theory of general relativity and quantum physics and explain the nature of the universe. According to string theory, all the objects in our universe are composed of tiny, vibrating strings and membranes of energy. Strings are theorized to make up even the smallest subatomic particles. In this lesson plan, students will learn about string theory and its potential to revolutionize our understanding of how nature works.

AIP Center for History of Physics

Instructions/Activities

Part One: Learn about Dr. Sylvester James Gates, Jr.

Engage: 5-10 Minutes

In order to get students thinking about the lesson, ask them what the smallest thing they can think of is. Eventually students should get down to atoms, and you can point out that even these are made up of other particles. You can then segue this into a discussion about how someone would go about answering these questions, and who they think would be doing that.	
What is the teacher doing? Ask the students what the smallest thing they can think of in. Continue eliciting responses and ask if the thing they name is made up of anything else. For instance, once students get down to atoms, you can say that they are made up of different particles, which in turn are made of even smaller things. Ask them if they think it's possible all the things they have named are actually different parts of a single thing. Then ask how someone would go about figuring this out. You can also ask who are the people they think would be working on these questions. Based on their responses, you may surprise them by introducing Jim Gates, a scientist who grew up in the segregated South and is now at the forefront of the science of string theory.	**What are the students doing?** Students should be sharing out responses to the question and thinking about the scale at which the building blocks of matter operate. They should also be considering this question and how to learn more about it.

Explore: 10-20 Minutes

Students will now have the chance to learn more about Sylvester "Jim" Gates. They should be given the discussion questions and links to the interviews. Divide the class into small groups of students, and ask them to summarize the interview and Dr. Gates' life. If desired, each group can watch one of the interviews and summarize it for the rest of the class.	
What is the teacher doing? The teacher should hand out printed materials or make sure the students have access to the online materials. Assist students with problems accessing the videos and answer any questions they have about the assignment.	**What are the students doing?** Students should be reading the interviews and watching the assigned videos (links are posted in the Required/Recommended Readings and Resources). They should take notes and create a summary of the interview and Gates' life.

Explain: 5-10 Minutes

Now the students will share out what they have gathered from reading and working with their partners. This sharing of information will become a discussion based around the social and historical events that Jim Gates experienced and his views of science.	
What is the teacher doing? The teacher should guide the discussion based on themes students see in Gates' life. Important points are the ways in which racist assumptions	**What are the students doing?** Students should summarize some of the facts they learned from the interviews and their views of Gates. They should also make sure any

pervaded his life, but how he overcame other people's limited expectations of him. A set of sample discussion questions are provided later in the lesson. These discussion questions can be answered verbally by students or on the provided handouts (see supplementary materials).	assigned handout questions have been completed.

Elaborate: Included in Explain

The elaboration comes naturally during the explanation portion of this lesson. While students are discussing ideas and answering discussion questions, the teacher can interject with more information, clarification, or historical context to help ideas become clearer.	
What is the teacher doing? The teacher will lead discussion and clarify any troubling spots that come up.	**What are the students doing?** Students will be participating in the discussion that is described in the Explain section. Students should ask for clarification on any ideas or concepts that they do not immediately understand.

Evaluate:

The teacher can evaluate the students' summaries. If answers to discussion questions are written down, the teacher can collect and evaluate these. In addition, students' participation in the group discussion can be evaluated.

Part Two: What is String Theory?

Adapted from Physics for the 21st Century Unit 4: String Theory and Extra Dimensions, https://www.learner.org/courses/physics/courseguide/FG_Unit4.pdf.

Now that students know who Dr. Gates is, introduce them to his area of study: string theory. String theory attempts to reconcile the contradictions between general relativity and quantum physics and explain the nature of the universe. In this activity, students will learn about what strings are and about how string theory fits with other branches of physics.

Engage: 5 Minutes

In order to understand string theory a little better, explain how it fits into physics using the Russian nesting dolls. Students should be able to stop and ask questions to complete their understanding.	
What is the teacher doing? Take out the nesting dolls or boxes. Explain to the class that the largest one represents classical physics – the world of Isaac Newton. That box/doll represents the theories of what would happen if you threw a ball into the air – where it would land, how long it would take to get there, etc. But it turns out there are deeper levels of physics that we ignore when we study classical mechanics. Hidden inside classical mechanics is the world of atomic physics. Open the first nesting doll to reveal the second doll. In atomic physics, we study the structure of the atom, its energy states, and how it interacts with particles and fields. To do classical physics, we don't need to know anything about atomic physics. The next doll represents nuclear physics, which focuses on the nucleus of the atom. Nuclear physicists focus on understanding matter composed of things like quarks and gluons and try to explain how the different elements of the universe were formed. The next nesting doll represents particle physics. This branch of physics focuses on the properties, relationships, and interactions of subatomic particles. The smallest nesting doll represents string theory. In order to do atomic or nuclear physics, we don't need to know all the details about subatomic particles and to do particle physics, we don't need to know much about	**What are the students doing?** Students should be listening to the teacher's explanation and asking questions about the meaning of the dolls/boxes. They should write down any questions this explanation brings up.

strings. The physics at deeper and deeper levels survive as only a small set of parameters in the higher levels. General relativity describes the stretching and bending of space and time by gravity. One could also imagine an even larger box representing general relativity, which would contain all the smaller boxes. How big are strings? Well, imagine a yard stick and divide it into 10 pieces and throw away 9. Then, do the same thing again – cut the remaining piece into 10 pieces and throw away 9. If you did this 10 more times, you would reach the size of the atom. If you did it a total of 35 times, you would reach the size of a string.	

Explore: 20 Minutes

Students will now have the chance to learn more about string theory from Dr. Gates himself. Have them read the Nova article about Dr. Gates and string theory. If desired, have them also watch the explanation of string theory he presents on the HistoryMakers website (via a free account – see Required/Recommended Resources)	
What is the teacher doing? The teacher should hand out copies of the Nova article. If desired, the teacher can also show the video of Dr. Gates explaining string theory to the whole class. If possible, show the video listed in Part Two of the Required Sources.	**What are the students doing?** Students should be reading the Nova article "Viewpoints on String Theory." They should take notes and ask any questions about confusing ideas.

Explain: 5-10 Minutes

Have a discussion about the work of Jim Gates and string theory in general.	
What is the teacher doing? The teacher should be leading a discussion of the readings and asking/answering student questions. A set of sample discussion questions are provided later in the lesson. These discussion questions can be answered verbally by students or on the provided handouts (see supplementary materials).	**What are the students doing?** Students should be participating in the group discussion. They should be answering the questions from the teacher and asking further questions about Dr. Gates and string theory. They should also make sure any assigned handout questions have been completed.

Elaborate: 5 Minutes

Encourage the students to think about both how science is done and who does the science. Point out that even though Dr. Gates faced many obstacles, he was still able to make important scientific contributions. Similarly, even though string theory has not been verified by experiment, it has stimulated a great deal of excitement and research among the scientific community.

What is the teacher doing?	What are the students doing?
Wrap up the lesson by encouraging students to learn more about string theory and the many kinds of scientists who are working at the forefront of science. One possibility is to point them to the Nova documentary *The Elegant Universe* (see additional resources) and other resources about African American physicists in the AIP Teacher's Guides on Women and Minorities in the Physical Sciences.	Students should be thinking about further questions they have about string theory and the scientists who made it. They should take notes of resources for further research.

Evaluate:

Answers and participation in discussion can be used to evaluate student performance. Students can also turn in their answers to the discussion questions handout for evaluation. The short presentations in the elaborate section can also be evaluated by the teacher.

Required/Recommended Reading and Resources

Part One: Learn about Dr. Sylvester James Gates, Jr.

- HistoryMakers ScienceMakers Interview with Sylvester James Gates, Jr., (Requires free Makers account) http://www.thehistorymakers.com/biography/sylvester-james-gates-jr.
- Gates' Early Education (6:40): http://smdigital.thehistorymakers.com/iCoreClient.html#/&i=17938
- The racial climate of his upbringing (4:00): http://smdigital.thehistorymakers.com/iCoreClient.html#/&i=17946
- Gates talks about his choices during cultural shifts of the 1960s while he attended college (3:30): http://smdigital.thehistorymakers.com/iCoreClient.html#/&i=17952
- Gates' view of science (2:30): http://smdigital.thehistorymakers.com/iCoreClient.html#/&i=17964

Part Two: What is String Theory?

- Jim Gates, "Viewpoints on String Theory," NOVA: The Elegant Universe (PBS), http://www.pbs.org/wgbh/nova/elegant/view-gates.html.
- Gates explains string theory: http://smdigital.thehistorymakers.com/iCoreClient.html#/&i=17962

Discussion Questions

Discussion Questions can be found as a Handout with a corresponding Answer Key in the Supplemental Materials to this lesson plan.

Part One: Learn about Dr. Sylvester James Gates, Jr.

1. What was happening in the country when Dr. Gates was a young child? How about when he was a teenager?
2. How did Dr. Gates become interested in physics?
3. What challenges did Gates face to becoming a theoretical physicist?
4. How did Gates respond to assumptions other people made of him based on his race?

Part Two: What is String Theory

1. What role does imagination play in doing physics?
2. String theory is still fairly controversial and not accepted by some physicists. Why is that?
3. How does string theory fit with other fields of physics?
4. What is supersymmetry?
5. What are the four forces of nature? Why did physicists such as Einstein and Gates pursue a "unified field theory"?
6. What is the potential of string theory to fulfill Einstein's quest for a unified theory?

Further Reading and Additional Resources

Part One: Learn about Dr. Sylvester James Gates, Jr.

- Clarence G. Williams (ed.), Oral History Interview with Sylvester James Gates, Jr. in *Technology and the Dream: Reflections on the Black Experience at MIT, 1941-1999* (Cambridge, MA: The MIT Press, 2001), 782-805.
- Kristine Krapp, ed., *Notable Black American Scientists* (Gale: Detroit, 1999).
- James H. Kessler, *Distinguished African American Scientists of the 20th Century*, (Phoenix, Ariz: Oryx Press, 1996).
- "The Secret Life of Scientists & Engineers: Jim Gates," NOVA, http://www.pbs.org/wgbh/nova/blogs/secretlife/physical-science/jim-gates/.

Part Two: What is String Theory?

- Patricia Schwarz, "The Official String Theory Web Site," http://www.superstringtheory.com/. This website contains basic and advanced explanations of many of the concepts behind string theory. It also includes a section on the history of string theory.
- Ernie Tretkoff, "Einstein's quest for a unified theory," APS Physics This Month in Physics History (December 2005), http://www.aps.org/publications/apsnews/200512/history.cfm.
- *The Elegant Universe* is a three-part documentary series which explores string theory with author-physicist Brian Greene. All three parts are available online at http://www.pbs.org/wgbh/nova/physics/elegant-universe.html. The series is also accompanied by a teacher's guide available at http://www-tc.pbs.org/wgbh/nova/education/activities/pdf/3012_elegant.pdf.

Extensions

Symbols of Power: Adinkras and the Nature of Reality – James Gates talks about Adinkras, symbols created by West African peoples to represent a concept or aphorism. Gates and his students have figured out how to represent equations with drawings they call Adinkras, and use them to manipulate equations pictorially.
http://www.onbeing.org/program/uncovering-codes-reality/feature/symbols-power-adinkras-and-nature-reality/1460

Related AIP Teacher's Guides on Women and Minorities in the Physical Sciences:

- African Americans in Astronomy and Astrophysics
- The National Society of Black Physicists
- Physical Sciences at HBCUs

Common Core Standards

For more information on Common Core Standards, visit http://www.corestandards.org/.

Speaking & Listening	
CCSS.ELA-LITERACY.SL.9-10.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
CCSS.ELA-LITERACY.SL.9-10.3	Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, identifying any fallacious reasoning or exaggerated or distorted evidence.
CCSS.ELA-LITERACY.SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
CCSS.ELA-LITERACY.SL.11-12.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
CCSS.ELA-LITERACY.SL.11-12.3	Evaluate a speaker's point of view, reasoning, and use of evidence and rhetoric, assessing the stance, premises, links among ideas, word choice, points of emphasis, and tone used.
CCSS.ELA-LITERACY.SL.11-12.4	Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.
History/Social Studies	
CCSS.ELA-LITERACY.RH.9-10.1	Cite specific textual evidence to support analysis of primary and secondary sources, attending to such features as the date and origin of the information.
CCSS.ELA-LITERACY.RH.9-10.2	Determine the central ideas or information of a primary or secondary source; provide an accurate summary of how key events or ideas develop over the course of the text.
CCSS.ELA-LITERACY.RH.9-10.4	Determine the meaning of words and phrases as they are used in a text, including vocabulary describing political, social, or economic aspects of history/social science.
CCSS.ELA-LITERACY.RH.11-12.1	Cite specific textual evidence to support analysis of primary and secondary sources, connecting insights gained from specific details to an understanding of the text as a whole.
CCSS.ELA-LITERACY.RH.11-12.2	Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas.

CCSS.ELA-LITERACY.RH.11-12.4	Determine the meaning of words and phrases as they are used in a text, including analyzing how an author uses and refines the meaning of a key term over the course of a text (e.g., how Madison defines *faction* in *Federalist* No. 10).
Science & Technical Subjects	
CCSS.ELA-LITERACY.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.
CCSS.ELA-LITERACY.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.
CCSS.ELA-LITERACY.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*.
CCSS.ELA-LITERACY.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*).
CCSS.ELA-LITERACY.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.
CCSS.ELA-LITERACY.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.
CCSS.ELA-LITERACY.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*.

Next Generation Science Standards

For more information on the Next Generation Science Standards, visit http://www.nextgenscience.org/.

Dimension One: Practices	1. Asking questions (for science) and defining problems (for engineering) 2. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information
Dimension Two: Crosscutting Concepts	1. Patterns 2. Scale, proportion, and quantity
Dimension Three: Disciplinary Core Ideas	Core Idea PS1: Matter and Its Interactions Core Idea PS2: Motion and Stability: Forces and Interactions Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer